TEST REPORT

Report Number: 105267899MPK-002
Project Numbers: G105267899
July 14, 2023

Testing performed on the
String Optimizer
Model Number: I50

To

FCC Part 15 Subpart C (15.247)
ISED RSS-247 Issue 2

For

Ampt, LLC

Test Performed by:	Test Authorized by:
Intertek	Ampt, LLC
1365 Adams Court	4850 Innovation Drive
Menlo Park, CA 94025 USA	Fort Collins, CO 80525 USA

Prepared by: Kenneth Roque **Date:** July 14, 2023

Kenneth Roque

Reviewed by: **Date:** July 14, 2023

Anderson Soungpanya

Report No. 105267899MPK-002	
Equipment Under Test:	String Optimizer
Model Number(s):	I50
Applicant:	Ampt, LLC
Contact:	Robin Richardson
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Country:	USA
Tel. Number:	1 (970) 372-6960
Email:	robin.richardson@ampt.com
Applicable Regulation:	FCC Part 15 Subpart C (15.247) ISED RSS-247 Issue 2
Date of Test:	May 8 – July 10, 2023

We attest to the accuracy of this report:

Kenneth Roque
EMC Project Engineer

Anderson Soungpanya
EMC Team Leader

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1.0 Summary of Tests

TEST	Reference FCC	Reference ISED	RESULTS
RF Output Power	15.247(b)	RSS-247, 5.4.b)	Complies
20-dB Bandwidth	15.247(a)(1)	RSS-247, 5.1.a)	Complies
Channel Separation	15.247(a)(1)	RSS-247, 5.1.b)	Complies
Number of Hopping Channels	15.247(a)(1)	RSS-247, 5.1.d)	Complies
Average Channel Occupancy Time	15.247(a)(1)	RSS-247, 5.1.d)	Complies
Out-of-Band Antenna Conducted Emission	15.247(d)	RSS-247, 5.5	Complies
Transmitter Radiated Emissions	15.247(d), 15.209, 15.205	RSS-GEN	Complies
AC Line Conducted Emissions	15.207	RSS-GEN	Complies
Antenna Requirement	15.203	RSS-GEN	Complies (Internal Antenna)

EUT receive date: May 1, 2023

EUT receive condition: The pre-production version of the EUT was received in good condition with no apparent damage. As declared by the Applicant, it is identical to the production units.

Test start date: May 8, 2023

Test completion date: July 10, 2023

The test results in this report pertain only to the item tested.

2.0 General Description

2.1 Product Description

Ampt, LLC supplied the following description of the EUT:

The Ampt String Optimizers are DC/DC converters that are used to lower the cost and improve performance of new PV systems, upgrade existing systems to produce more energy, enable low-cost DC-coupled solar & storage systems, and provide string-level data for improved O&M.

For more information, see user's manual provided by the manufacturer.

This test report covers only the 2.4GHz FHSS radio.

Information about the 2.4 GHz radio is presented below:

Applicant	Ampt, LLC
Model No.	I50
Type of Transmission	Frequency Hopping Spread Spectrum
Rated RF Output	2.65 dBm
Antenna(s) & Gain*	Internal Antenna, Gain: 4.0 dBi
Frequency Range	2410 – 2474.5 MHz
Number of Channel(s)	255 (only 25 used at any given time)
Modulation Type	FSK
Applicant Name & Address	Ampt, LLC 4850 Innovation Drive Fort Collins, CO 80525 USA

*as provided by the client. Intertek takes no responsibility for the accuracy of this information.

2.2 Related Submittal(s) Grants

None.

2.3 Test Methodology

Antenna conducted measurements were performed according to the FCC documents “Guidance for Performing Compliance Measurement on Digital Transmission Systems, Frequency Hopping Spread Spectrum System, and Hybrid System devices Operating under §15.247” (KDB 558074 D01 15.247 Meas Guidance v05r02), RSS-247 Issue 2, ANSI C63.10: 2013 and RSS-GEN Issue 5.

Radiated emissions and AC mains conducted emissions measurements were performed according to the procedures in ANSI C63.10: 2013. Radiated tests were performed at an antenna to EUT distance of 3 meters, unless stated otherwise in the "Data Sheet" of this report.

All other measurements were made in accordance with the procedures in part 2 of CFR 47.

Following is the channel test plan:

Channels in 2.4 GHz band			
Test Channel		**Frequency, MHz**	**Tested**
Low	0	2410	√
Middle	127	2442	√
High	255	2474.5	√
Hopping Mode		2410 - 2474.5	√

2.4 Test Facility

The test site used to is located at 1365 Adams Court, Menlo Park, California, 94025. This test facility and site measurement data have been fully placed on file with the FCC, IC and A2LA accredited.

3.0 System Test Configuration

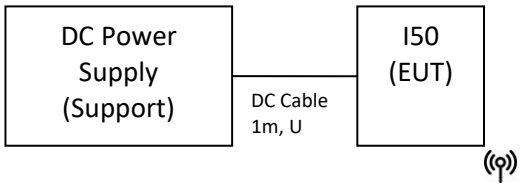
3.1 Support Equipment

Description	Manufacturer	Model Number
DC Power Supply	Tekpower	TP12001X
Laptop	Dell	Latitude 13
Ethernet Switch	D-Link	DGS-2208
PoE Injector	EnGenius	EPE-5818af
Control Unit	Ampt, LLC	31570025

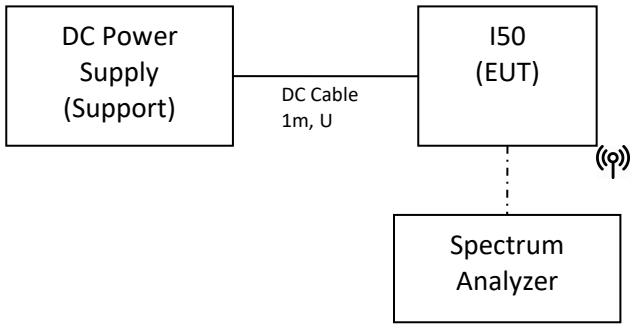
3.2 Block Diagram of Test Setup

Equipment Under Test			
Description	**Manufacturer**	**Model Number**	**Serial Number**
Conducted Unit	Ampt, LLC	I50	33070042 D 4722T000907
Radiated Unit	Ampt, LLC	I50	31570040-00 B 4722T000908

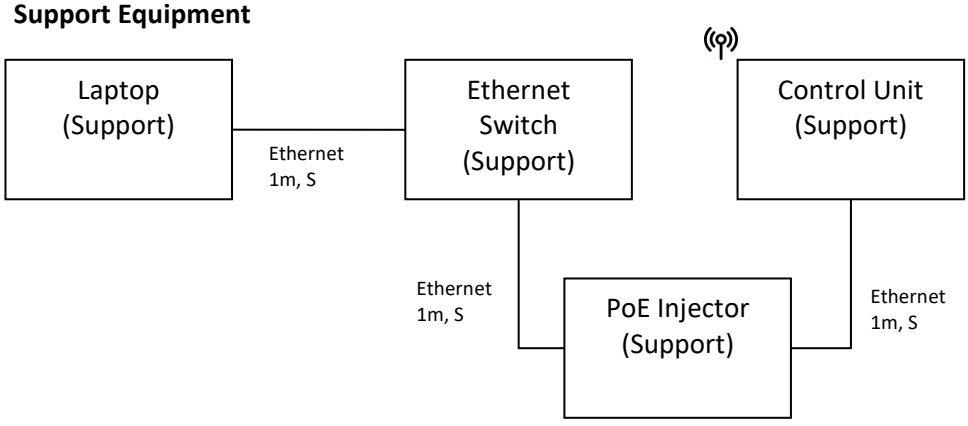
Radiated Unit



Conducted Unit



Support Equipment



Antenna was removed and co-axial connector was installed for Conducted Measurements.

S = Shielded **U** = Unshielded	**F** = With Ferrite **m** = Length in Meters

3.3 Justification

For radiated emission measurements the EUT is placed on a non-conductive table.

3.4 Mode of Operation During Test

During transmitter testing, the transmitter was setup to transmit continuously at maximum RF power on the low channel, middle channel, high channel and with hopping channels enabled.

3.5 Modifications Required for Compliance

Intertek installed no modifications during compliance testing in order to bring the product into compliance.

3.6 Additions, Deviations and Exclusions from Standards

No additions, deviations or exclusions from the standard were made.

4.0 Emissions Measurement Results

4.1 20dB Bandwidth, and 99% Occupied Bandwidth
FCC Rule 15.247(a)(1)

4.1.1 Procedure

The Procedure described in the FCC Publication 558074 D01 Meas Guidance v05r02 & Section 7.8.7 of ANSI C63.10:2013 for Frequency Hopping Spread Spectrum Systems was used to determine the 20dB bandwidth.

- Span = Approximately 2 to 3 times the 20 dB bandwidth, centered on a hopping channel
- RBW = 1% of the 20 dB bandwidth
- VBW = 3 x RBW
- Sweep = Auto
- Detector function = Peak
- Trace = Max hold

The EUT should be transmitting at its maximum data rate. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. Use the marker delta function to measure 20 dB down one side of the emission. Reset the marker-delta function, and move the marker to the other side of the emission, until it is (as close as possible to) even with the reference marker level. The marker-delta reading at this point is the 20 dB bandwidth of the emission. If this value varies with different modes of operation (e.g., data rate, modulation format, etc.), repeat this test for each variation. The limit is specified in one of the subparagraphs of this Section. Submit this plot(s).

For 99% power bandwidth measurement, the bandwidth was determined by using the built-in 99% occupied bandwidth function of the spectrum analyzer.

The antenna port of the EUT was connected to the input of a spectrum analyzer (SA). For each RF output channel investigated, the spectrum analyzer center frequency was set to the channel carrier. A Peak output reading was taken, a Display line was drawn for 20dB lower than Peak level. The 20dB bandwidth was determined from where the channel output spectrum intersected the display line.

Tested By	Test Date
Kenneth Roque	July 10, 2023

4.1.2 Test Result

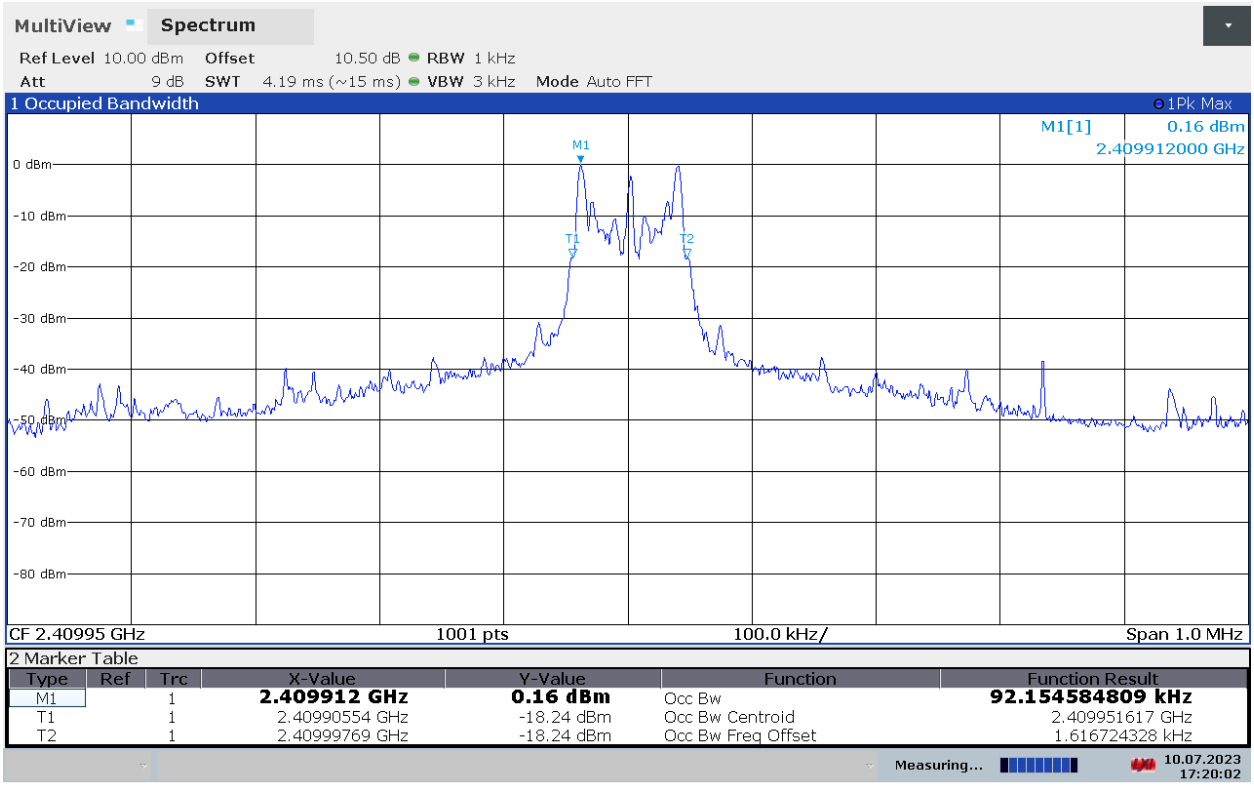
Frequency MHz	20 dB FCC Bandwidth, kHz	99% Bandwidth, kHz	Plot #
2410	111.400	---	1.1
	---	92.155	1.2
2442	112.900	---	1.3
	---	92.172	1.4
2474.5	112.900	---	1.5
	---	93.414	1.6

Results	Complies

Plot 1.1 – 20dB Bandwidth, 2410 MHz

03:08:25 17.05.2023

Plot 1.2 – 99% Bandwidth, 2410 MHz



17:20:03 10.07.2023

Plot 1.3 – 20dB Bandwidth, 2442 MHz

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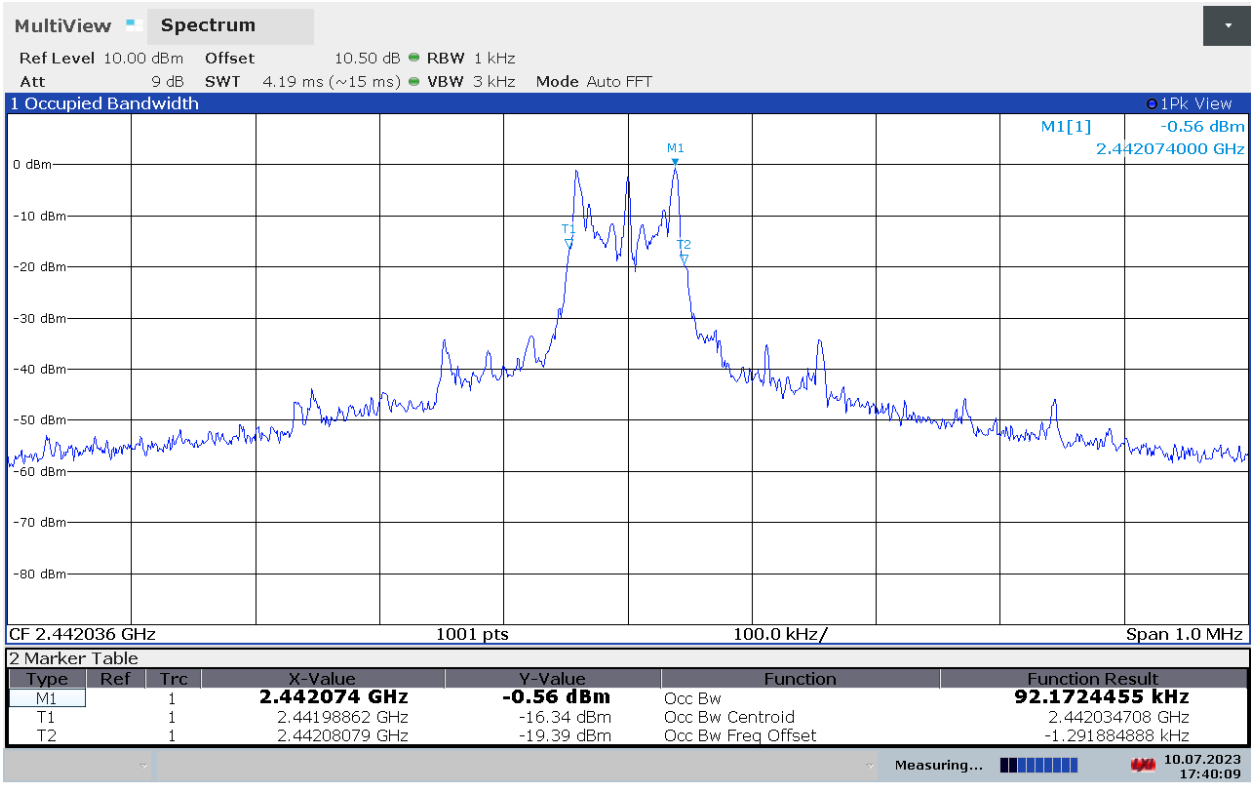
Plot 1.4 – 99% Bandwidth, 2442 MHz



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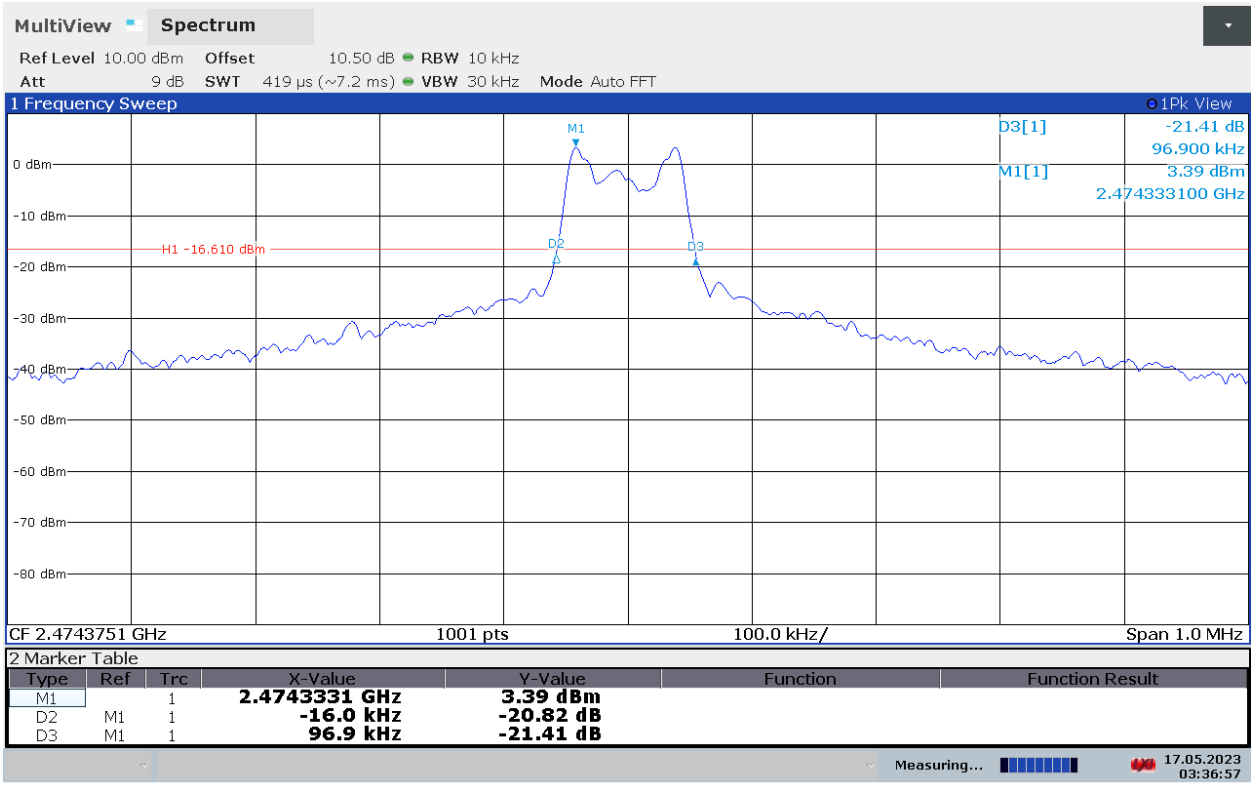
Plot 1.5 – 20dB Bandwidth, 2474.5 MHz



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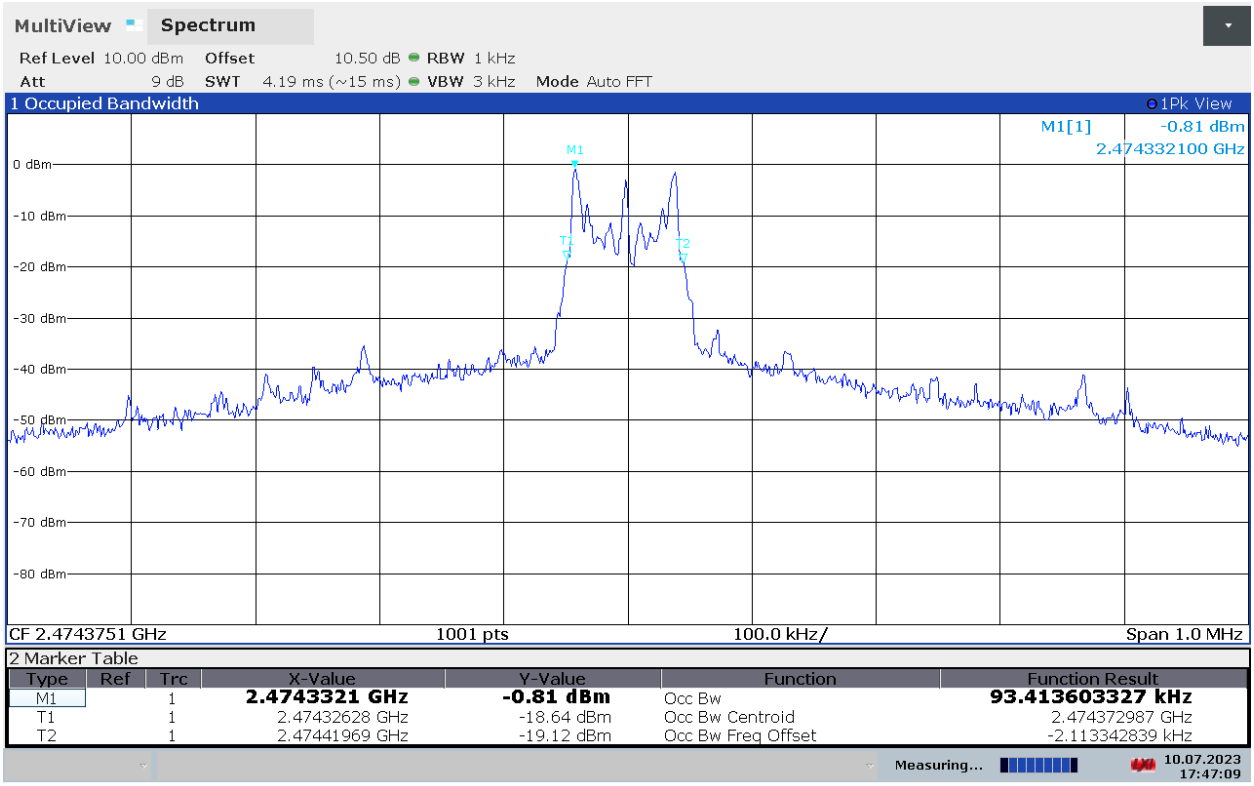
Plot 1.6 – 99% Bandwidth, 2474.5 MHz



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4.2 Conducted Output Power at Antenna Terminals
FCC Rule 15.247(b)(1)

4.2.1 Requirement

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

4.2.2 Procedure

The procedure described in FCC Publication 558074 D01 Meas Guidance v05r02 was used. Specifically, Section 7.8.5 of ANSI C63.10:2013 for Frequency Hopping Spread Spectrum Systems was used to determine the RF Output Power.

- Span = approximately 5 times the 20 dB bandwidth, centered on a hopping channel
- RBW > the 20 dB bandwidth of the emission being measured
- VBW = 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. The indicated level is the peak output power (see the NOTE above regarding external attenuation and cable loss). The limit is specified in one of the subparagraphs of this Section. Submit this plot.

The antenna port of the EUT was connected to the input of a spectrum analyzer. Power was read directly from the spectrum analyzer and cable loss correction was added to the reading to obtain the power at the antenna terminals.

Tested By	Test Date
Kenneth Roque	May 17, 2023

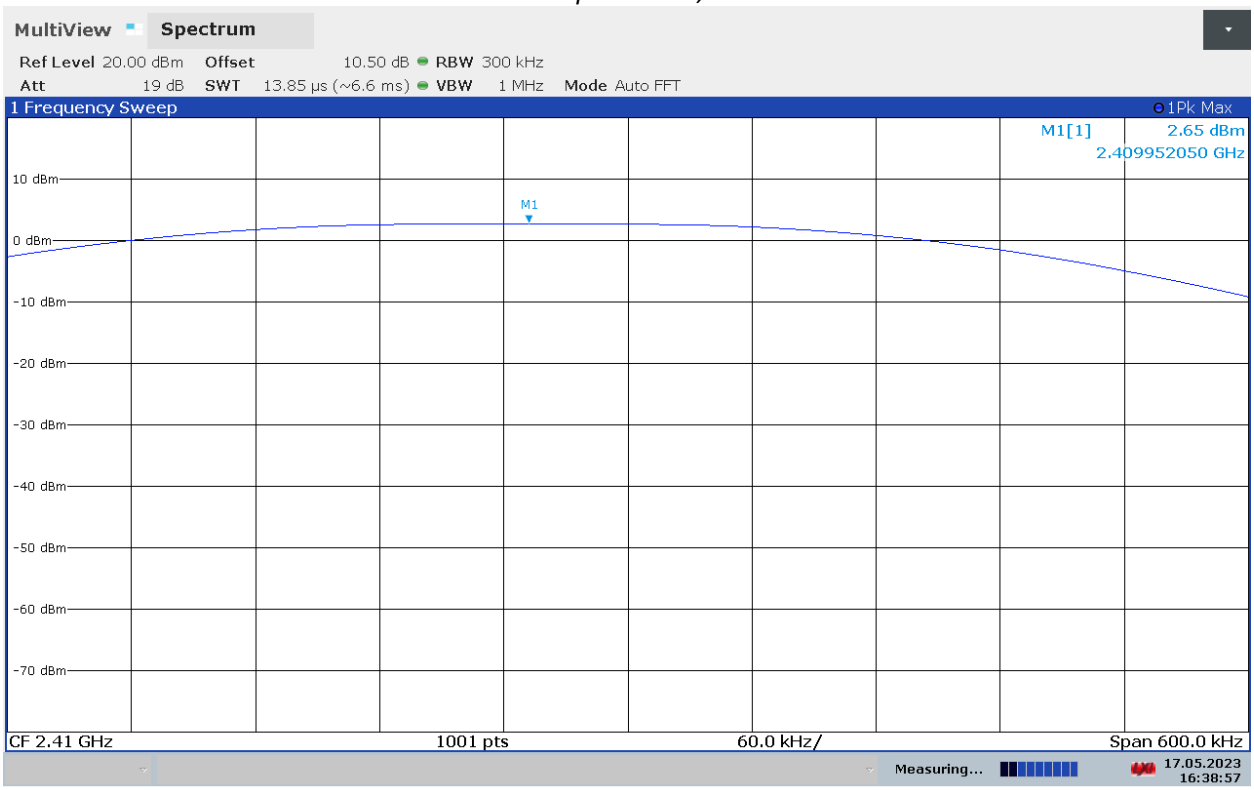
4.2.3 Test Result

Refer to the following plots for the test result:

Frequency MHz	Conducted Peak Power dBm	Conducted Peak Power mW	Plot #
2410	2.65	1.84	2.1
2442	2.35	1.72	2.2
2474.5	2.08	1.61	2.3

Results	Complies

Plot 2.1– Output Power, 2410 MHz



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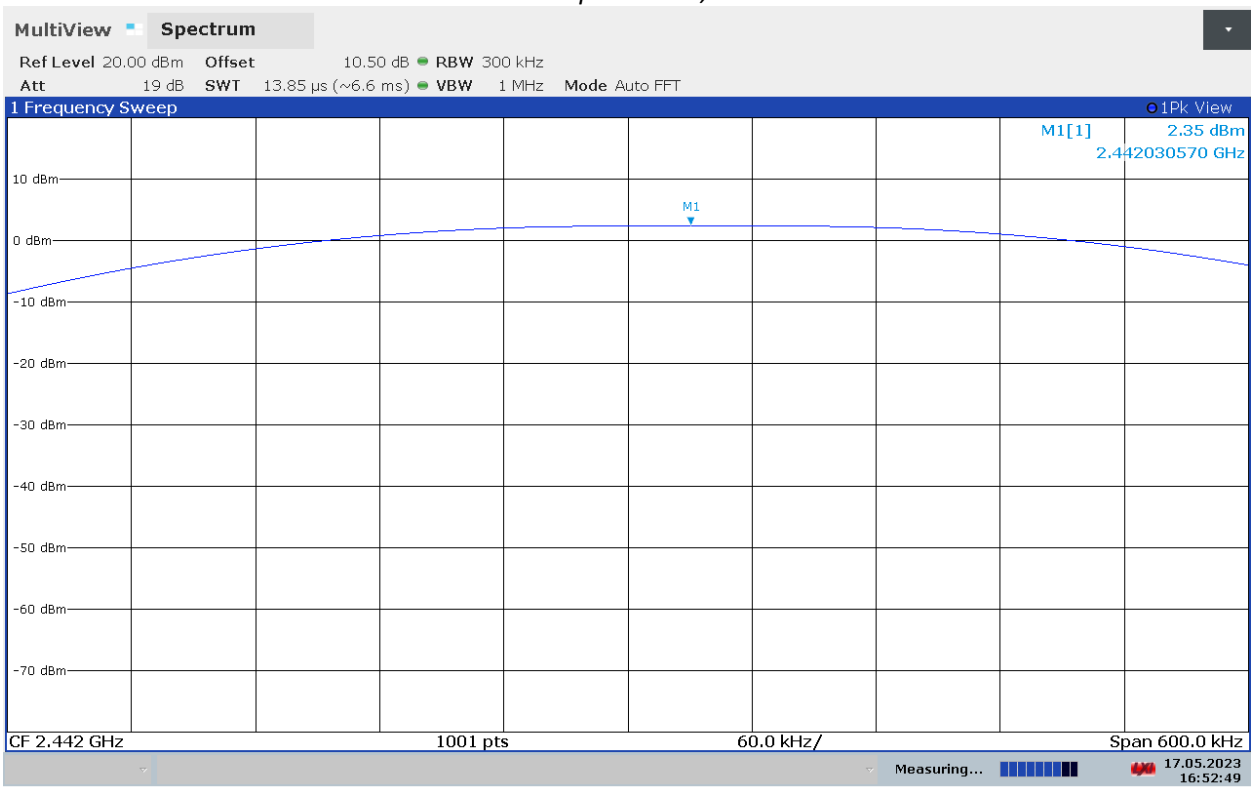
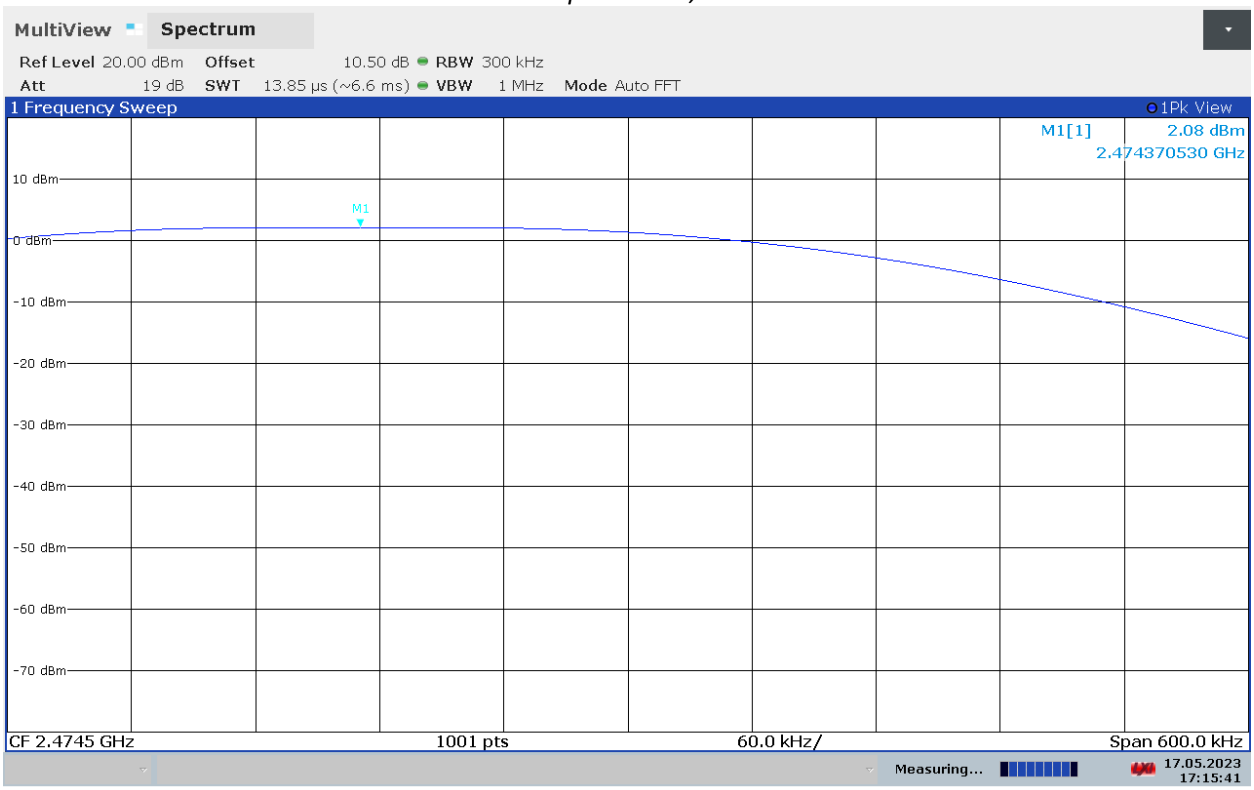
Plot 2.2 – Output Power, 2442 MHz



16:52:50 17.05.2023

Plot 2.3 – Output Power, 2474.5 MHz



17:15:42 17.05.2023

4.3 Carrier Frequency Separation
FCC 15.247 (a)(1)

4.3.1 Requirement

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.

4.3.2 Procedure

The procedure described in FCC Publication 558074 D01 Meas Guidance v05r02 was used. Specifically, Section 7.8.2 of ANSI C63.10:2013 for Frequency Hopping Spread Spectrum Systems was used to determine the Carrier Frequency Separation.

- The EUT must have its hopping function enabled
- Span = wide enough to capture the peaks of two adjacent channels
- Resolution (or IF) Bandwidth (RBW) = 1% of the span
- Video (or Average) Bandwidth (VBW) = 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

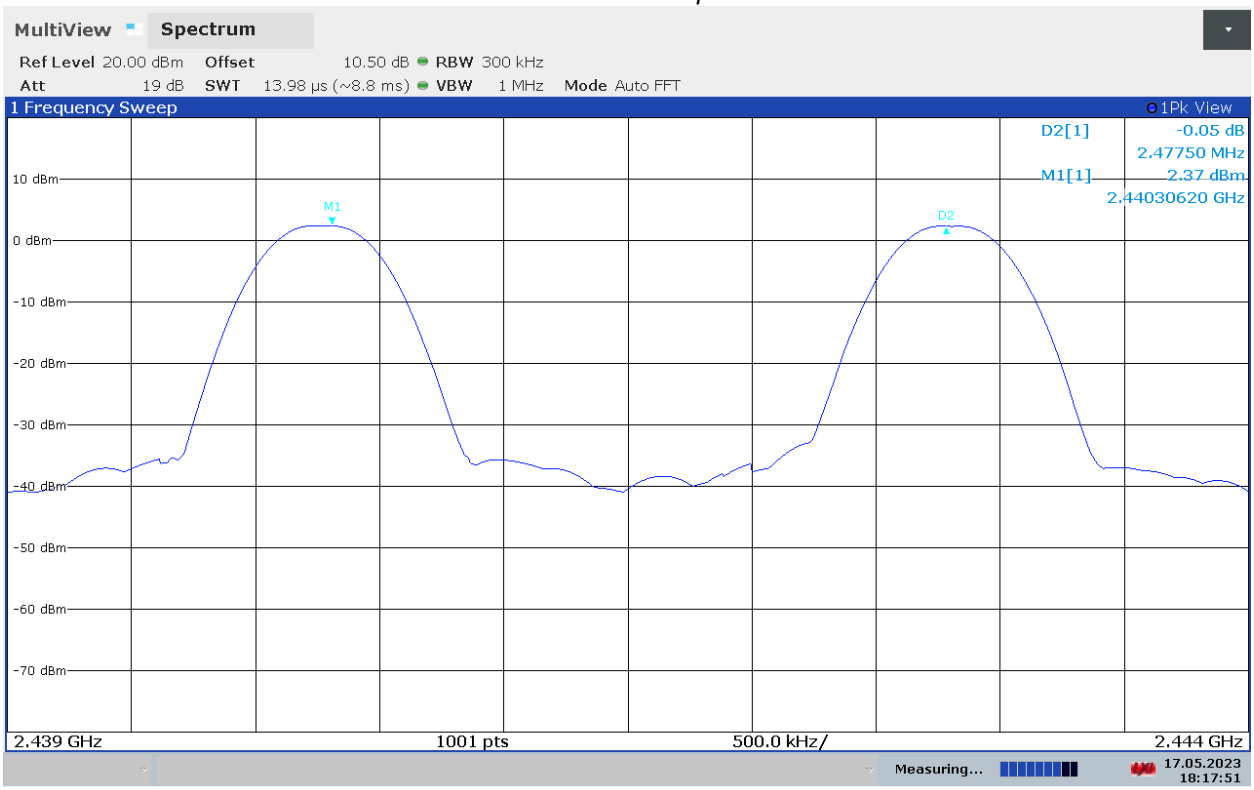
Allow the trace to stabilize. Use the marker-delta function to determine the separation between the peaks of the adjacent channels.

Tested By	Test Date
Kenneth Roque	May 17, 2023

4.3.3 Test Result

The highest measured 20dB Bandwidth is 106.196 kHz, therefore the minimum Carrier Frequency Separation shall be greater than two thirds of the 20dB bandwidth; 70.797 kHz. The measured channel separation is 2.47750 MHz. Carrier Frequency Separation meets the minimum requirement. Please refer to spectrum analyzer Plot 3.1 below for the test result.

Plot 3.1– Channel Separation



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Results	Complies

4.4 Number of Channels
FCC 15.247 (a)(1)(iii)

4.4.1 Requirement

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.

Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

4.4.2 Procedure

The procedure described in FCC Publication 558074 D01 Meas Guidance v05r02 was used. Specifically, Section 7.8.3 of ANSI C63.10:2013 for Frequency Hopping Spread Spectrum Systems was used to determine the Number of Channels.

- The EUT must have its hopping function enabled.
- Span = the frequency band of operation
- RBW = 1% of the span
- VBW = 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

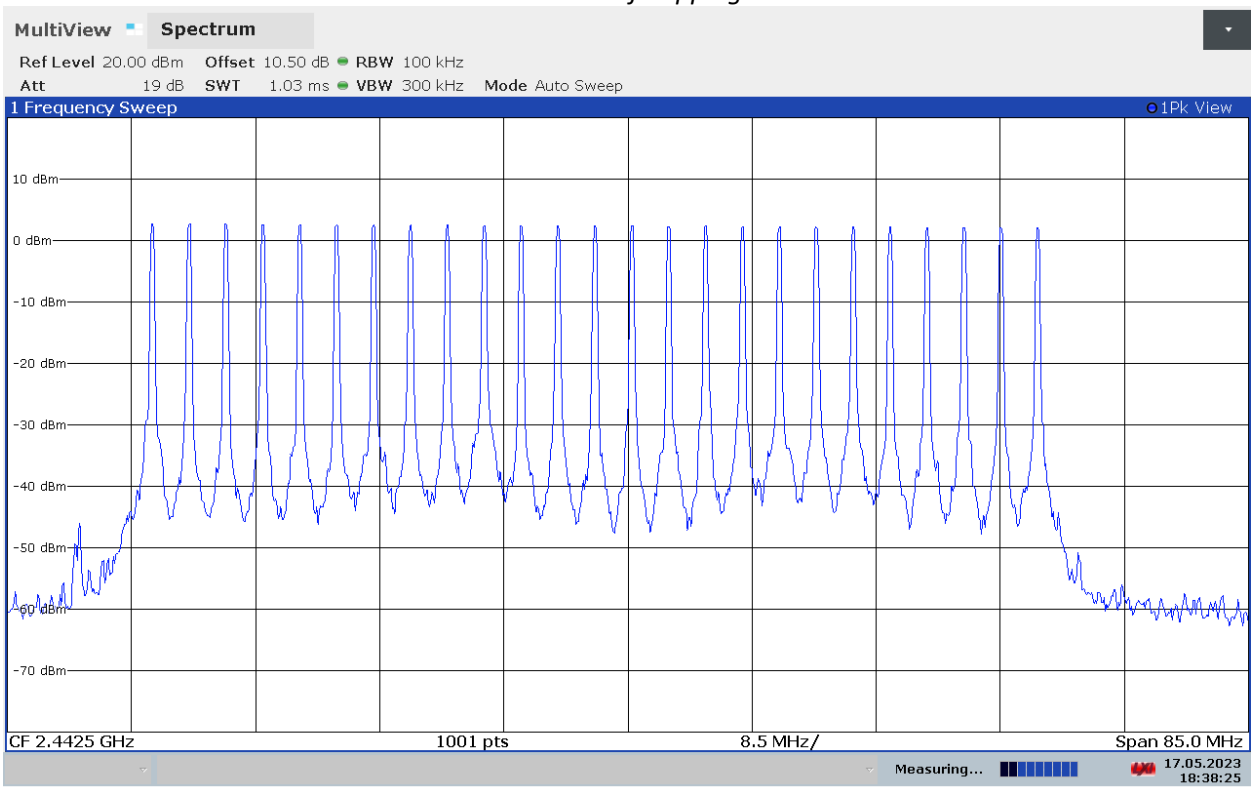
Allow the trace to stabilize. It may prove necessary to break the span up to sections, in order to clearly show all of the hopping frequencies.

With the analyzer set to MAX HOLD, readings were taken once channels were filled in. The channel peaks were recorded and compared to the minimum number of channels required in the regulation.

Tested By	Test Date
Kenneth Roque	May 17, 2023

4.4.3 Test Result

Plot 4.1 - Number of hopping channels



Results	Complies, 25 Channels

4.5 Average Channel Occupancy Time
FCC 15.247(a)(1)

4.5.1 Requirement

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.

Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

4.5.2 Procedure

The procedure described in FCC Publication 558074 D01 Meas Guidance v05r02 was used. Specifically, Section 7.8.4 of ANSI C63.10:2013 for Frequency Hopping Spread Spectrum Systems was used to determine the Average Channel Occupancy Time.

- The EUT must have its hopping function enabled.
- Span = zero span, centered on a hopping channel
- RBW = 1 MHz
- VBW = 3 x RBW
- Sweep = as necessary to capture the entire dwell time per hopping channel
- Detector function = peak
- Trace = max hold

If possible, use the marker-delta function to determine the dwell time. If this value varies with different modes of operation (e.g., data rate, modulation format, etc.), repeat this test for each variation. The limit is specified in one of the subparagraphs of this Section. An oscilloscope may be used instead of a spectrum analyzer.

The spectrum analyzer center frequency was set to one of the known hopping channels, the SPAN was set to ZERO SPANS, and the TRIGGER was set to VIDEO. The time duration of the transmission so captured was measured with the MARKER DELTA function.

Tested By	Test Date
Kenneth Roque	May 17, 2023

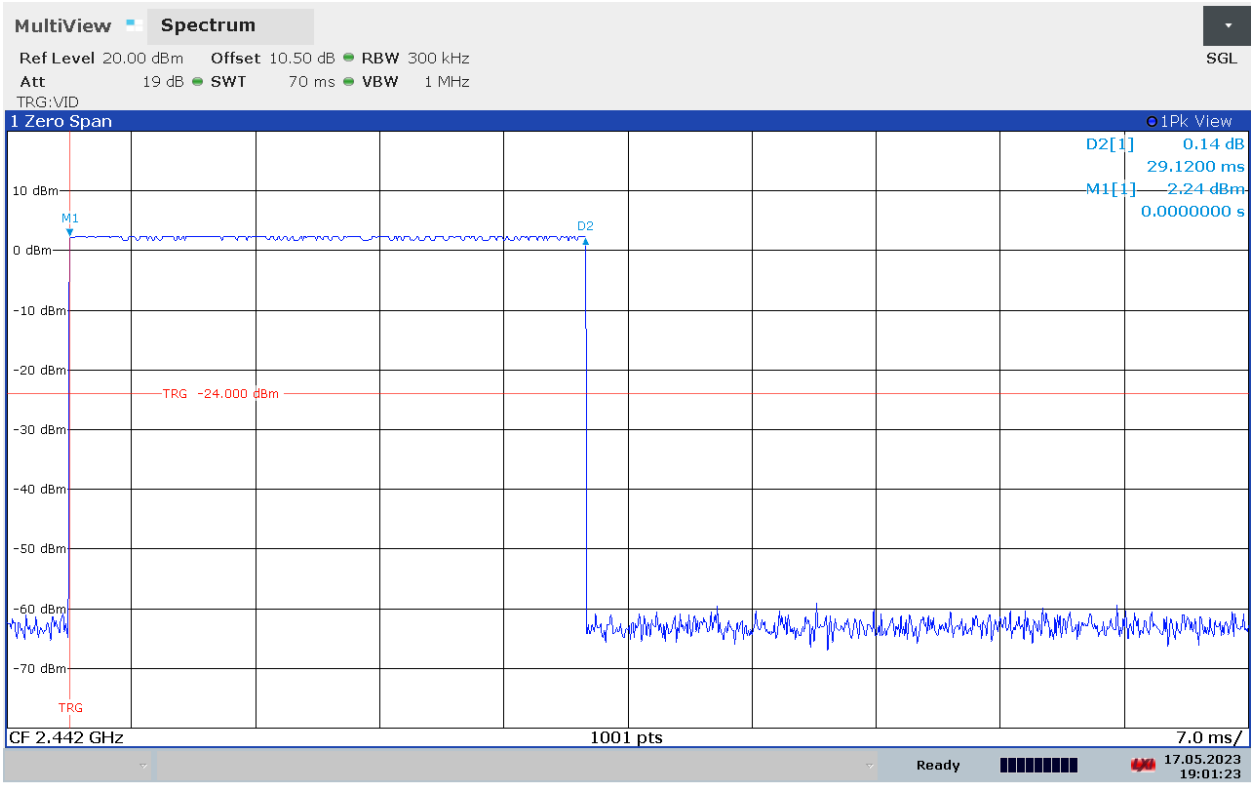
4.5.3 Test Results

Burst On Time (ms)	No. of Burst in 10 seconds	Dwell Time (ms) (Burst Time * No. of Burst * 10)	Dwell Time limit (ms)
29.120	1	29.120	400

The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a period of the number of channels (25) multiplied by 0.4 second (10 seconds).

Results	Complies

Burst Time



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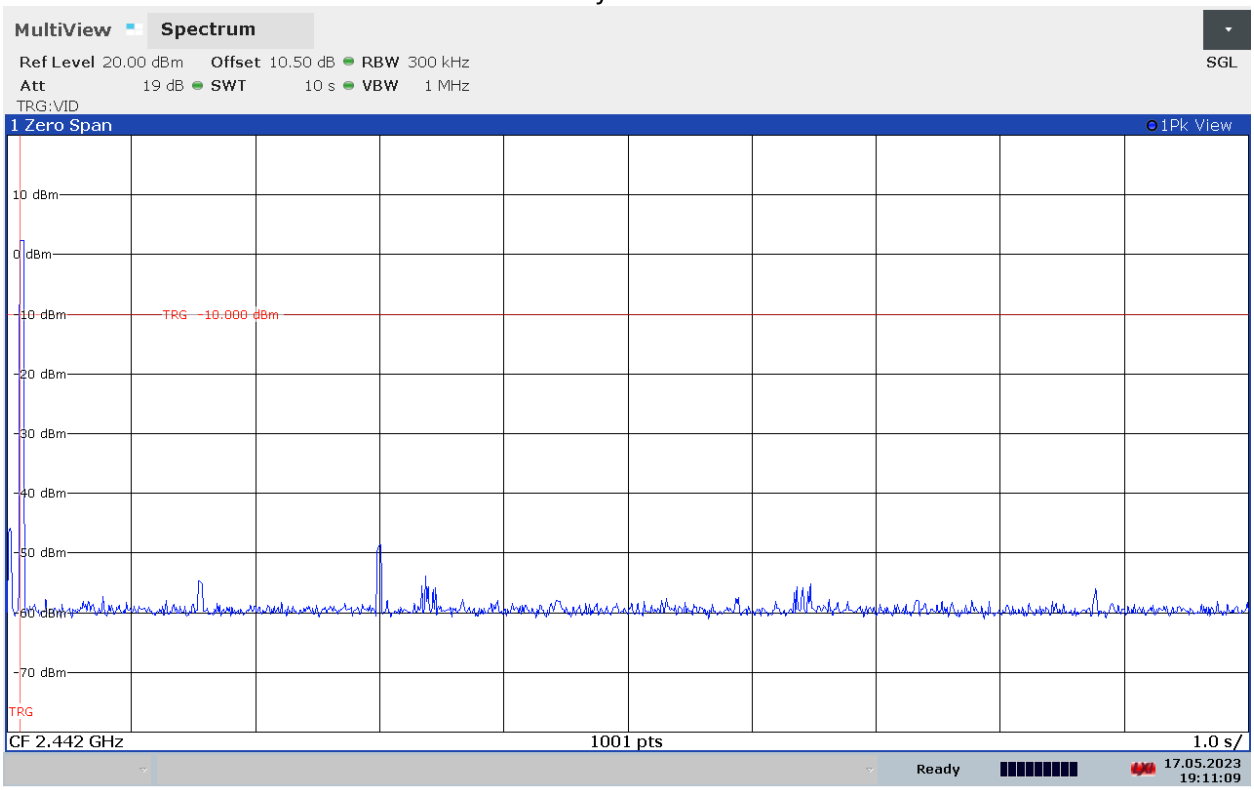
Number of Bursts in 10 s



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4.6 Out-of-Band Conducted Emissions
FCC 15.247(d)

4.6.1 Requirement

In any 100 kHz bandwidths outside the EUT pass-band, the RF power shall be at least 20dB (peak) or 30 dB (average) below that of the maximum in-band 100 kHz emissions.

4.6.2 Procedure

The procedure described in FCC Publication 558074 D01 Meas Guidance v05r02 was used. Specifically, Section 7.8.8 of ANSI C63.10:2013 for Frequency Hopping Spread Spectrum Systems was used to determine the Out-of-Band Conducted Emissions.

- Span = wide enough to capture the peak level of the in-band emission and all spurious emissions (e.g., harmonics) from the lowest frequency generated in the EUT up through the 10th harmonic.
- RBW = 100 kHz
- VBW = 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

Allow the trace to stabilize. Set the marker on the peak of any spurious emission recorded. The level displayed must comply with the limit specified in this Section.

A spectrum analyzer was connected to the antenna port of the transmitter. Analyzer Resolution Bandwidth was set to 100 kHz. For each channel investigated, the in-band and out-of-band emission measurements were performed. The out-of-band emissions were measured from 30 MHz to 26 GHz.

Tested By	Test Date
Kenneth Roque	May 17, 2023

4.6.3 Test Result

Refer to the following plots and out-of-band conducted spurious emissions at the Band-Edge, Table 4.1 & 4.2 for the test results:

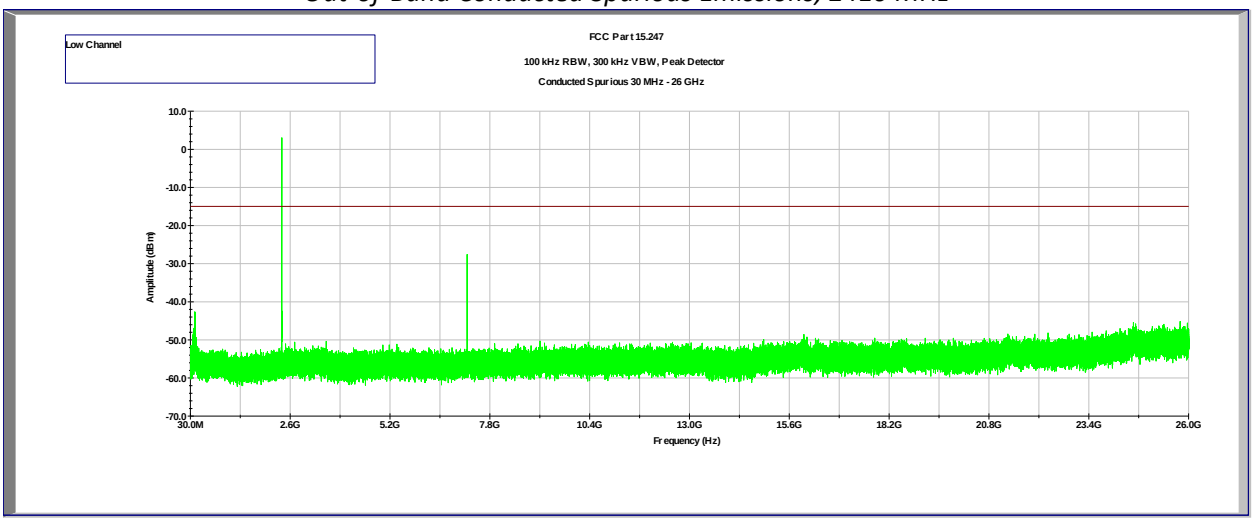
Out-of-Band Conducted Spurious Emissions

Frequency MHz	Description	Results
2410	Scan 30 MHz – 26 GHz	Complies, Greater than 20dB
2442	Scan 30 MHz – 26 GHz	Complies, Greater than 20dB
2474.5	Scan 30 MHz – 26 GHz	Complies, Greater than 20dB

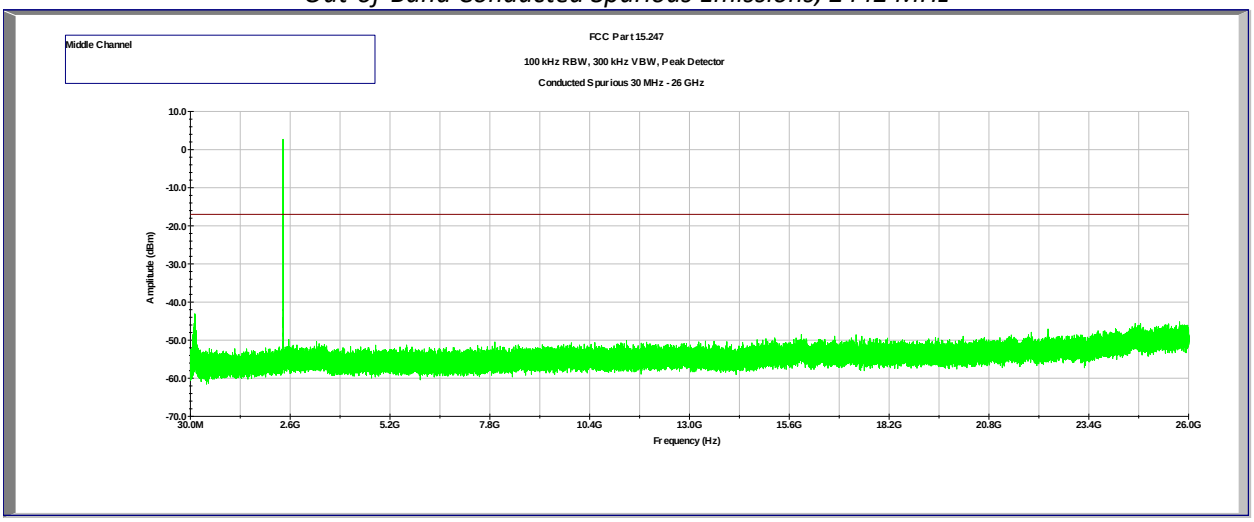
Out-of-Band Conducted Spurious Emissions at the Band-Edge:

Channel	Frequency MHz	Results
0	2410	Complies, Greater than 20dB
Hopping	Low Band Edge	Complies, Greater than 20dB
255	2474.5	Complies, Greater than 20dB
Hopping	High Band Edge	Complies, Greater than 20dB

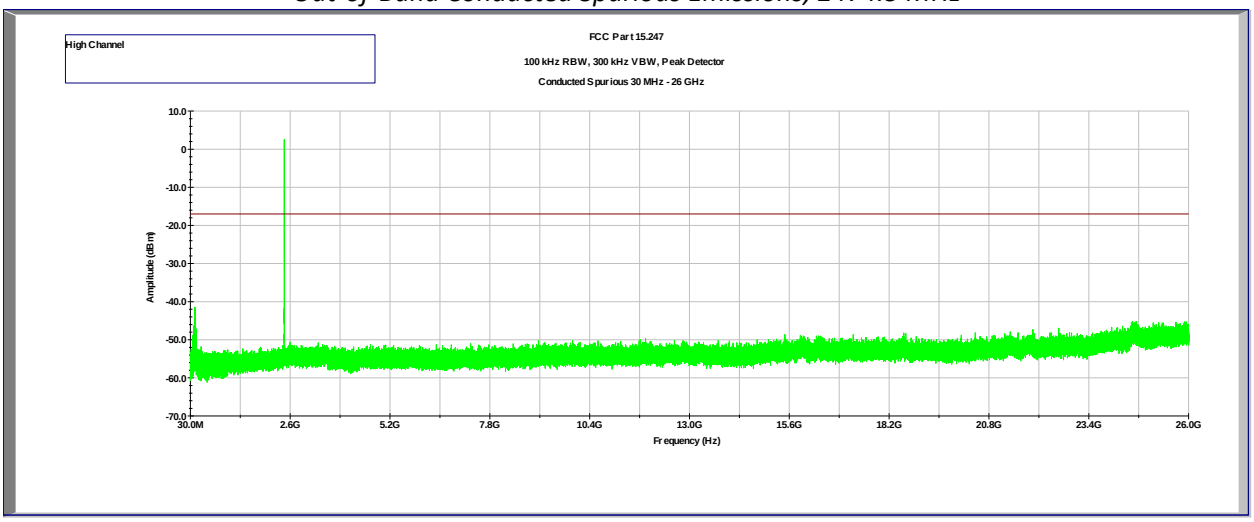
Out-of-Band Conducted Spurious Emissions, 2410 MHz



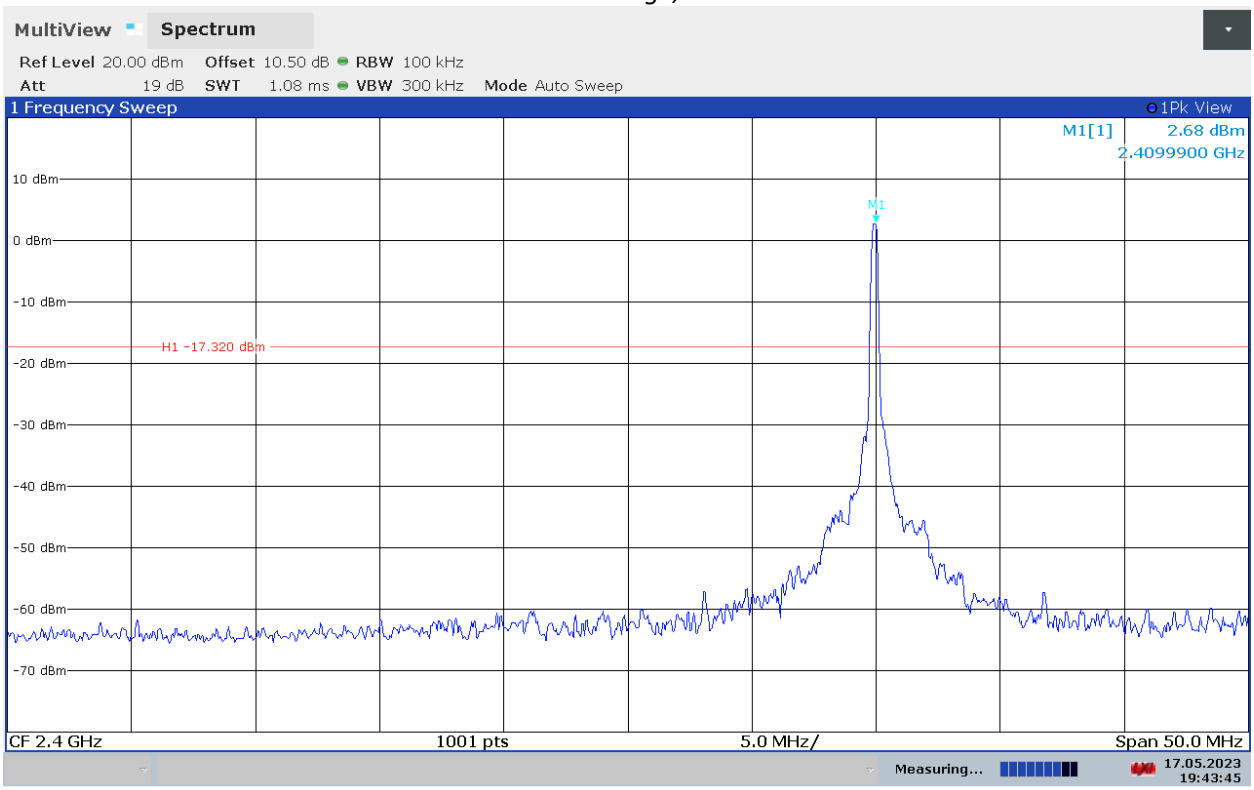
Out-of-Band Conducted Spurious Emissions, 2442 MHz



Out-of-Band Conducted Spurious Emissions, 2474.5 MHz



Out-of-Band Conducted Spurious
Conducted Band Edge, Low Channel



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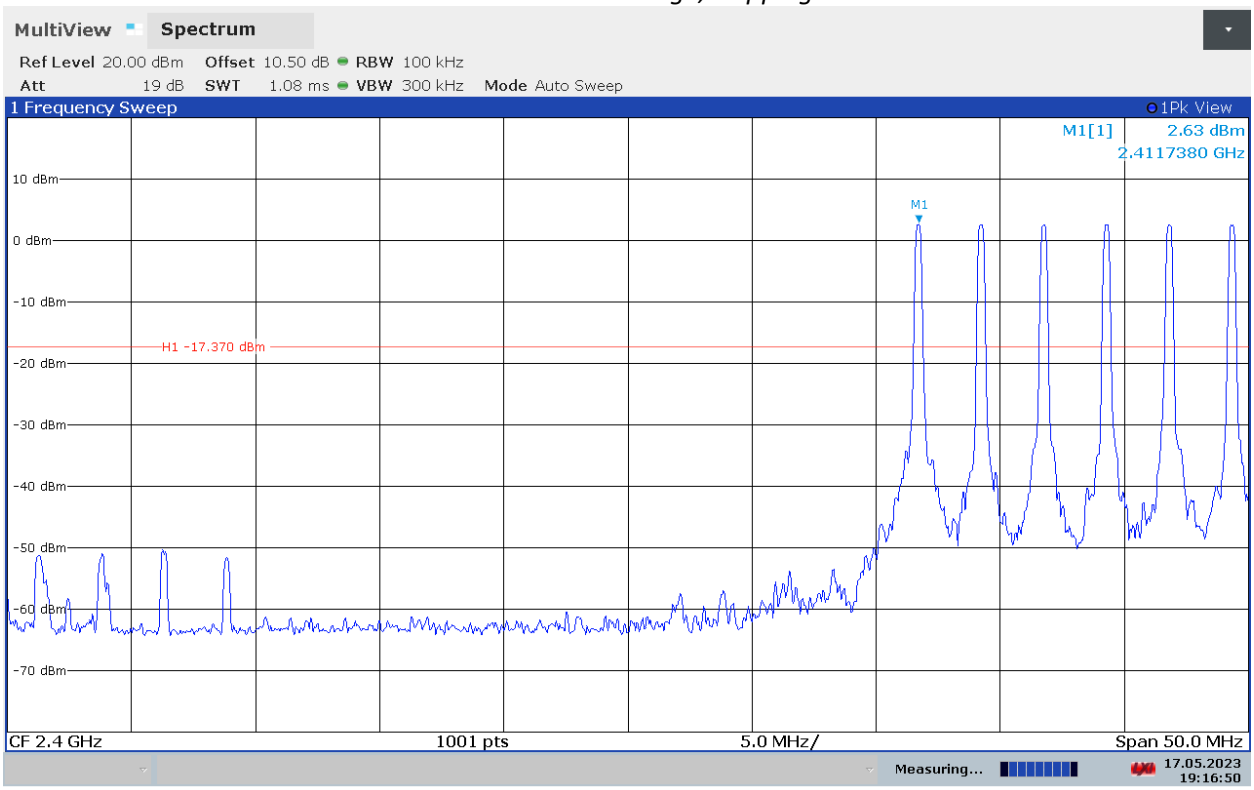
Out-of-Band Conducted Spurious
Conducted Band Edge, Hopping



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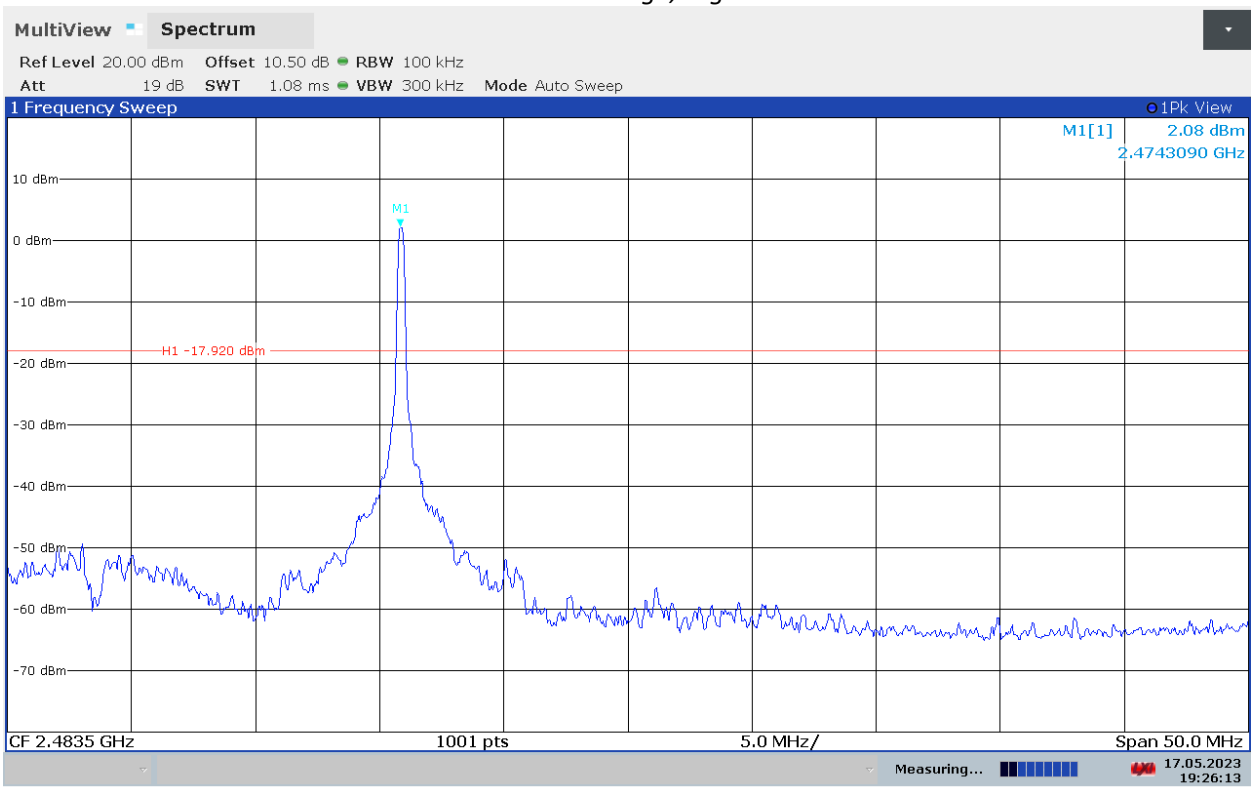
Out-of-Band Conducted Spurious
Conducted Band Edge, High Channel



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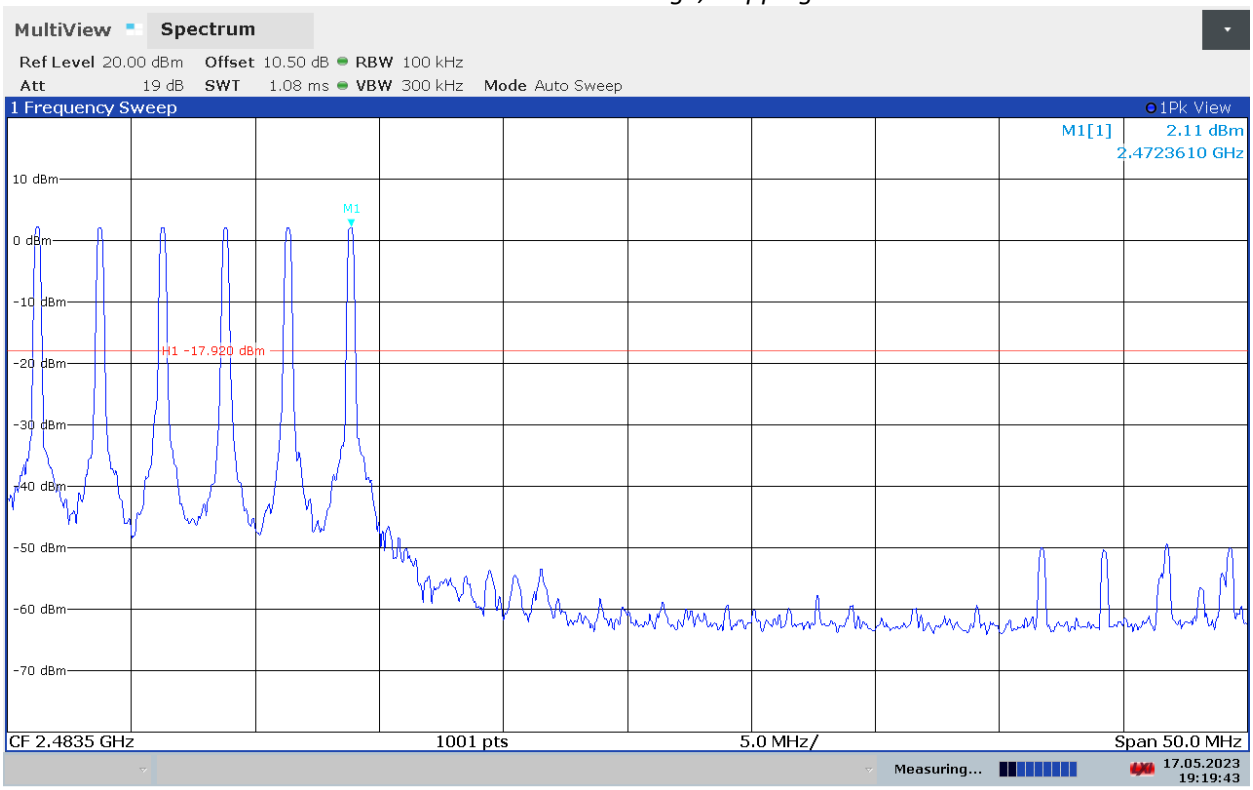
Out-of-Band Conducted Spurious
Conducted Band Edge, Hopping



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4.7 Transmitter Radiated Emissions
FCC Rule 15.247(d), 15.209, 15.205

4.7.1 Requirement

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)).

For out of band radiated emissions (except for frequencies in restricted bands), in any 100 kHz bandwidths outside the EUT pass-band, the RF power shall be at least 20dB (peak) or 30 dB (average) below that of the maximum in-band 100 kHz emissions.

4.7.2 Procedure

Radiated emission measurements were performed from 9kHz to 25GHz. Spectrum Analyzer Resolution Bandwidth is 100 kHz or greater for frequencies 30 MHz to 1000 MHz, 1 MHz for frequencies above 1000 MHz.

If the EUT attaches to peripherals, they are connected and operational (as typical as possible). During testing, all cables were manipulated to produce worst-case emissions. The signal is maximized through rotation. The antenna height and polarization are varied during the search for maximum signal level. The antenna height is varied from 1 to 4 meters.

Radiated emissions are taken at 3 meters for frequencies above 1 GHz and at 10 meters for frequencies below 1 GHz.

Spurious measurements are made with a preamp from 9kHz MHz to 25 GHz.

Measurements may be made with a Peak Detector and compared to QP limits for 9kHz – 1 GHz and Average limits for 1 GHz – 25 GHz.

Correlation measurements were performed below 30MHz between 10m ALSE and Open Field site according to FCC KDB 414788 D01 Radiated Test Site v01r01 section 2. All readings were within the acceptable tolerance.

Data is included of the worst-case configuration (the configuration which resulted in the highest emission levels).

4.7.3 Field Strength Calculation

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

FS = RA + AF + CF – AG; if measurement is performed at a distance other than specified in the rule, a Distance Correction Factor (DCF) shall be added.

Where FS = Field Strength in dB(μV/m)
RA = Receiver Amplitude (including preamplifier) in dB(μV); AF = Antenna Factor in dB(1/m)
CF = Cable Attenuation Factor in dB; AG = Amplifier Gain in dB

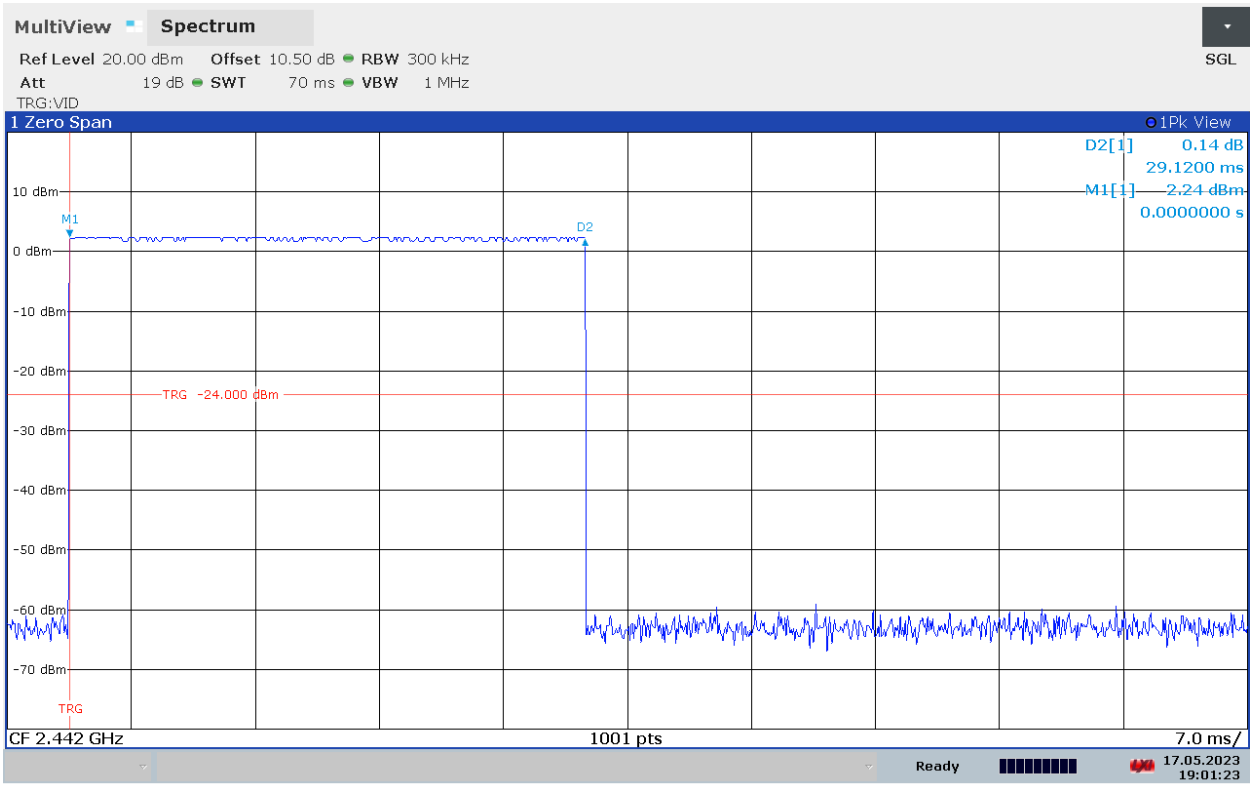
Assume a receiver reading of 52.0 dB(μV) is obtained. The antennas factor of 7.4 dB(1/m) and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving field strength of 32 dB(μV/m). This value in dB(μV/m) was converted to its corresponding level in μV/m.
RA = 52.0 dB(μV)
AF = 7.4 dB(1/m)
CF = 1.6 dB
AG = 29.0 dB
FS = 52.0+7.4+1.6-29.0 = 32 dB(μV/m).
Level in μV/m = Common Antilogarithm [(32 dBμV/m)/20] = 39.8 μV/m.

4.7.2.1 Duty Cycle Correction Factor (DCCF)

Per 558074 D01 15.247 Meas Guidance, the use of a duty cycle correction factor (DCCF) is permitted for calculating average radiated field strength emission levels for an FHSS device in 15.247. This DCCF can be applied when the unwanted emission limit is subject to an average field strength limit (*e.g.*, within a Government Restricted band) and the conditions specified in Section 15.35(c) can be satisfied. The average radiated field strength is calculated by subtracting the DCCF from the maximum radiated field strength level as determined through measurement. The maximum radiated field strength level represents the worst-case (maximum amplitude) RMS measurement of the emission(s) during continuous transmission (*i.e.*, not including any time intervals during which the transmitter is off or is transmitting at a reduced power level). It is also acceptable to apply the DCCF to a measurement performed with a peak detector instead of the specified RMS power averaging detector. Note that Section 15.35(c) specifies that the DCCF shall represent the worst-case (greatest duty cycle) over any 100 msec transmission period.

Duty Cycle Correction Factor Calculation
Subclause 7.5 of ANSI C63.10 was used to determine the DCCF.

DCCF = 20*log(29.12/100) = -10.71



19:01:23 17.05.2023

4.7.4 Antenna-port conducted measurements

Antenna-port conducted measurements may also be used as an alternative to radiated measurements for demonstrating compliance in the restricted frequency bands. If conducted measurements are performed, then proper impedance matching must be ensured and an additional radiated test for cabinet/case spurious emissions is required.

4.7.5 General Procedure for conducted measurements in restricted bands

a) Measure the conducted output power (in dBm) using the detector specified for determining quasi-peak, peak, and average conducted output power, respectively.

b) Add the maximum transmit antenna gain (in dBi) to the measured output power level to determine the EIRP level (see 12.2.5 for guidance on determining the applicable antenna gain)

c) Add the appropriate maximum ground reflection factor to the EIRP level (6 dB for frequencies ≤ 30 MHz, 4.7 dB for frequencies between 30 MHz and 1000 MHz, inclusive and 0 dB for frequencies > 1000 MHz).

d) For devices with multiple antenna-ports, measure the power of each individual chain and sum the EIRP of all chains in linear terms (*e.g.*, Watts, mW).

e) Convert the resultant EIRP level to an equivalent electric field strength using the following relationship:
E = EIRP – 20log D + 104.8+DCF (DCF for Average measurements)
where:
E = electric field strength in dBµV/m,
EIRP = equivalent isotropic radiated power in dBm
D = specified measurement distance in meters.
DCF = Duty Cycle Correction Factor
f) Compare the resultant electric field strength level to the applicable limit.
g) Perform radiated spurious emission test

4.7.6 Test Results

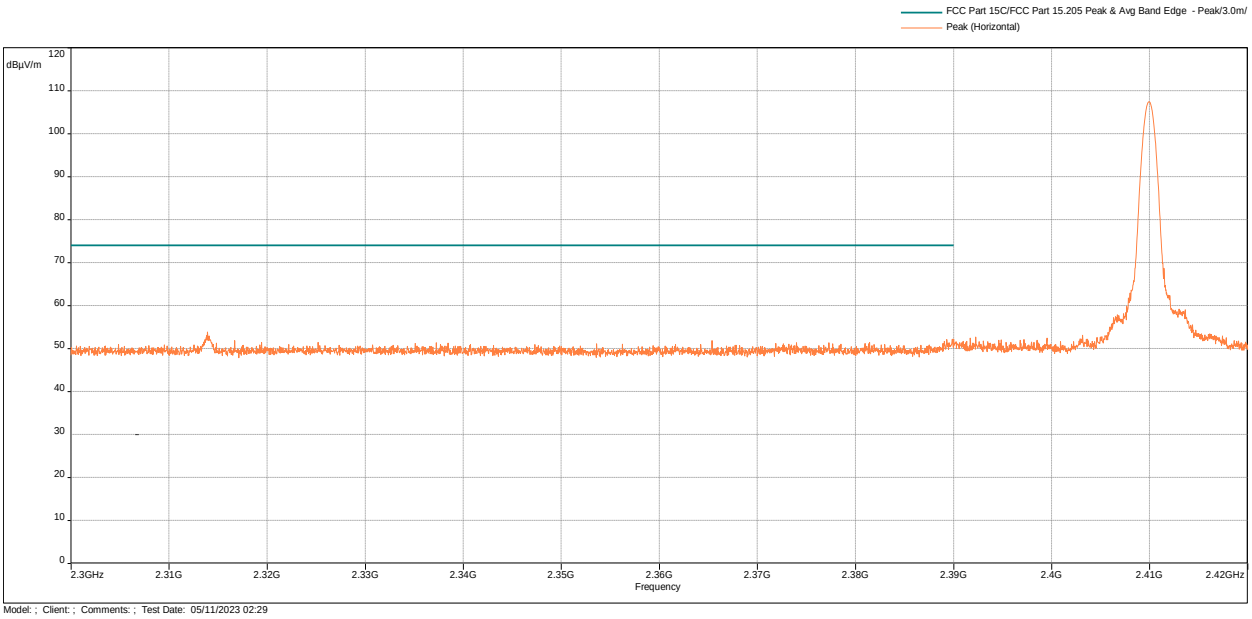
Tested By	Test Date
Kenneth Roque	May 8 – May 26, 2023

These measurements were performed with antenna in place.

4.7.6 Test Results (Continued)

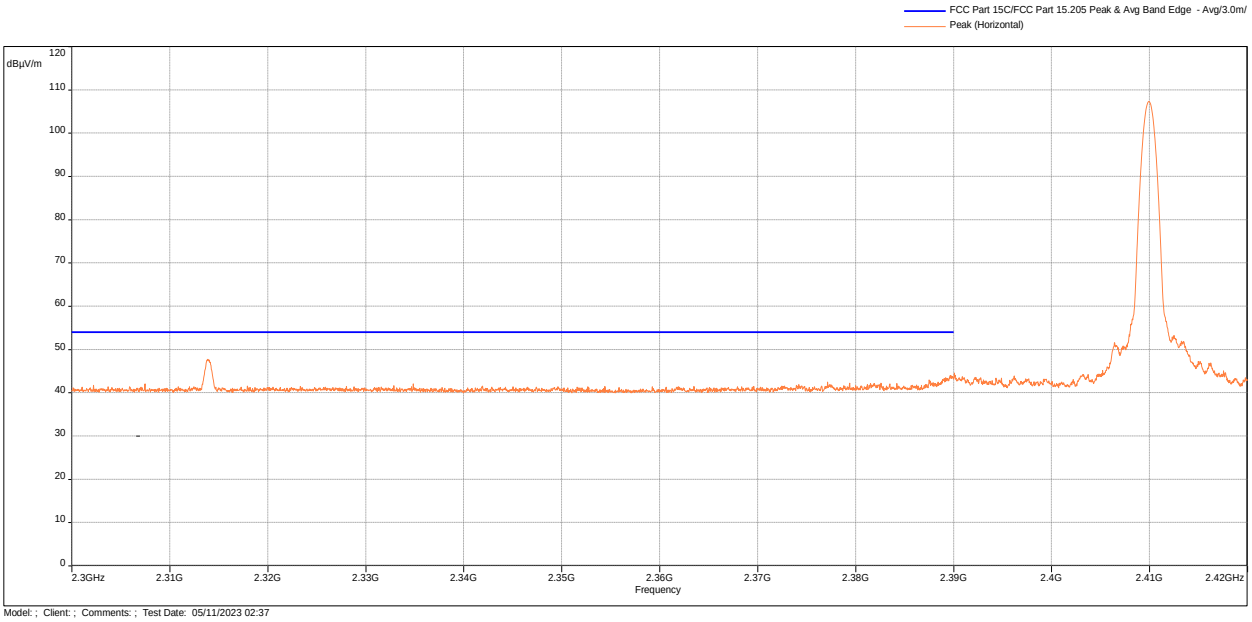
Test Results: 15.209/15.205 Radiated Restricted Band Emissions

Radiated Band Edge at the Restricted Band – Tx @ Low Channel, Peak



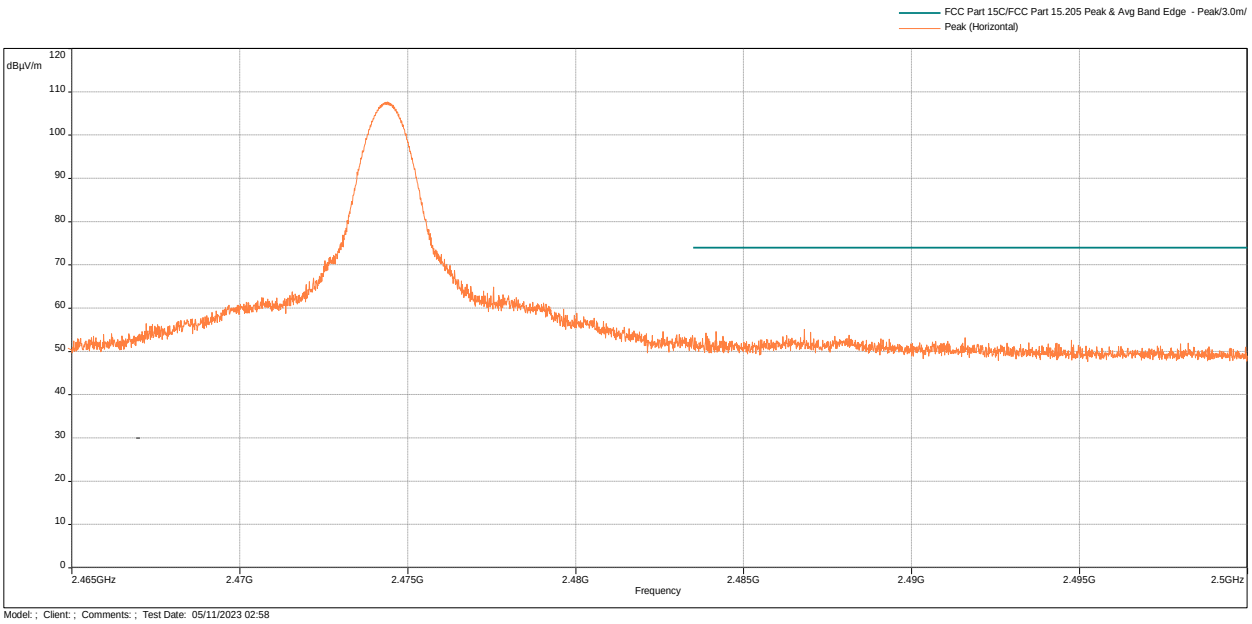
Frequency (MHz)	Peak (dBµV/m)	Lim. Peak (dBµV/m)	Peak-Lim (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
2390.000	49.40	74.00	-24.6	1.50	356.00	Horizontal	31.44

Radiated Band Edge at the Restricted Band – Tx @ Low Channel, Average



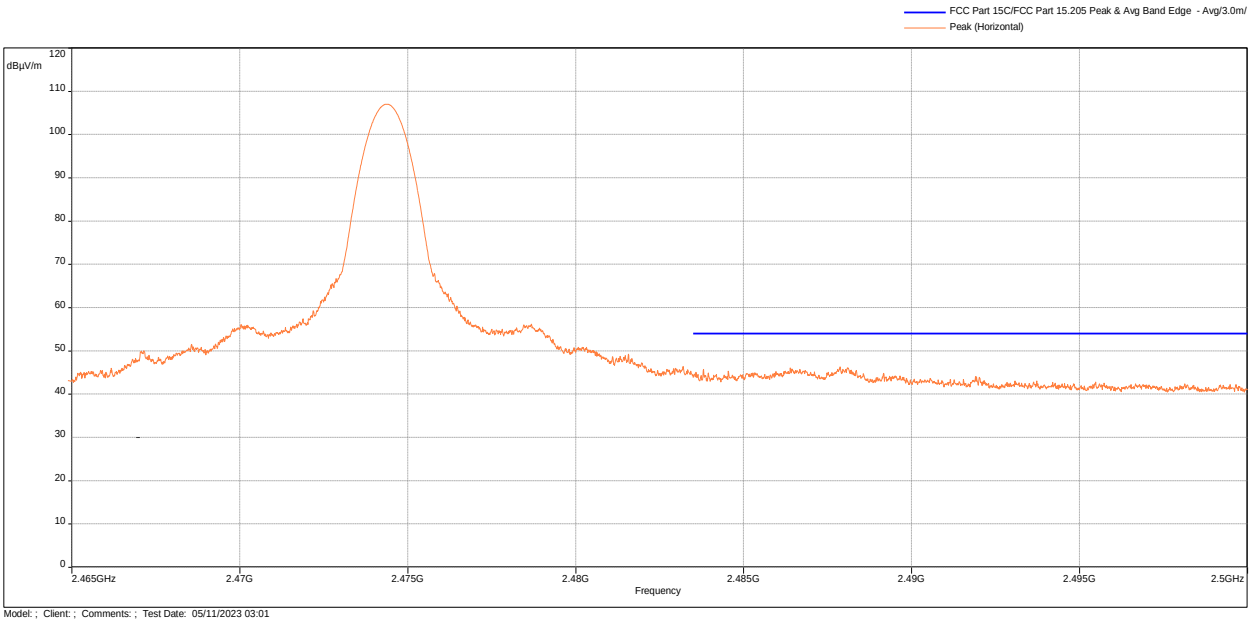
Frequency (MHz)	Peak (dBµV/m)	Lim. Avg (dBµV/m)	Peak-Lim (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
2313.913	47.68	54.00	-6.32	1.50	311.75	Horizontal	31.76
2390.000	43.06	54.00	-10.94	1.50	311.75	Horizontal	31.44

Radiated Band Edge at the Restricted Band – Tx @ High Channel, Peak



Frequency (MHz)	Peak (dBµV/m)	Lim. Peak (dBµV/m)	Peak-Lim (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
2483.500	52.03	74	-21.97	1.50	317.25	Horizontal	31.76

Radiated Band Edge at the Restricted Band – Tx @ High Channel, Average



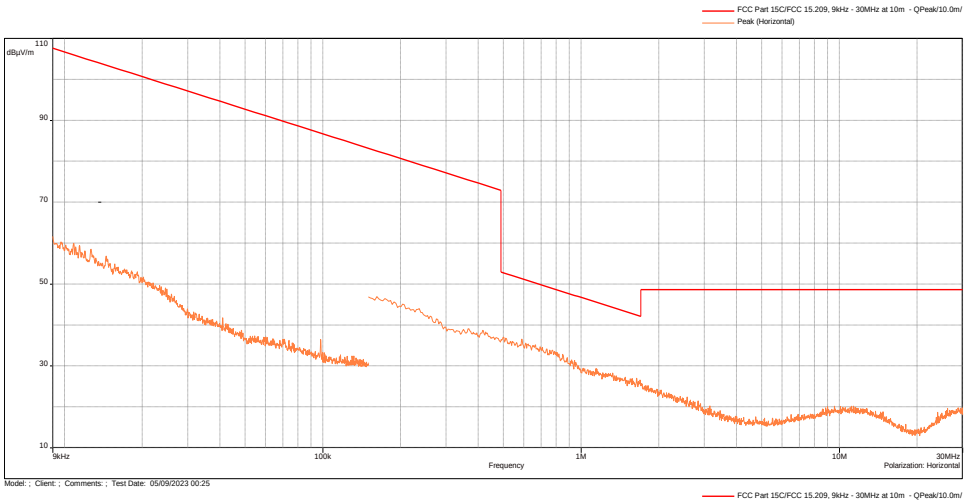
Frequency (MHz)	Peak (dBµV/m)	Lim. Avg (dBµV/m)	Peak-Lim (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
2483.500	43.90	54.00	-10.10	1.50	312.00	Horizontal	31.76

Out-of-Band Radiated Spurious Emissions

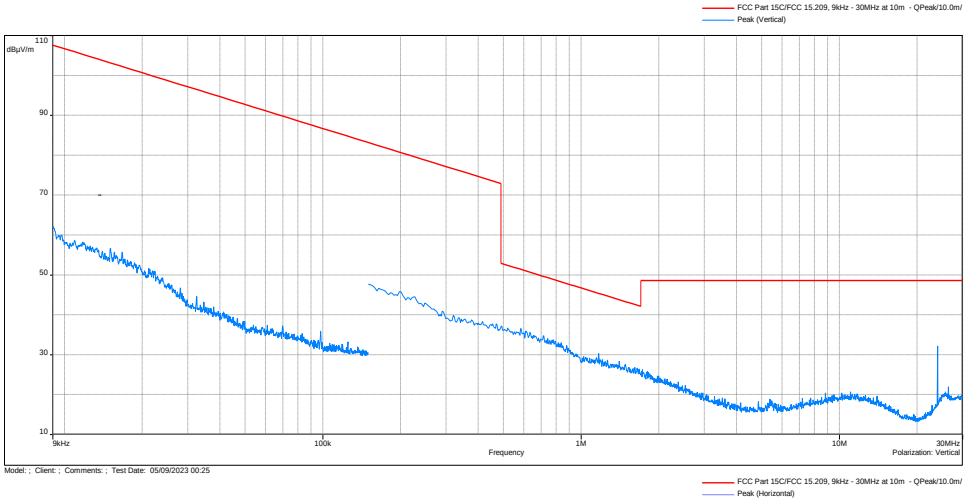
Test Results: 15.209 Radiated Spurious Emissions

Radiated Spurious Emissions 9 kHz to 30 MHz, Peak Scan vs QP Limit

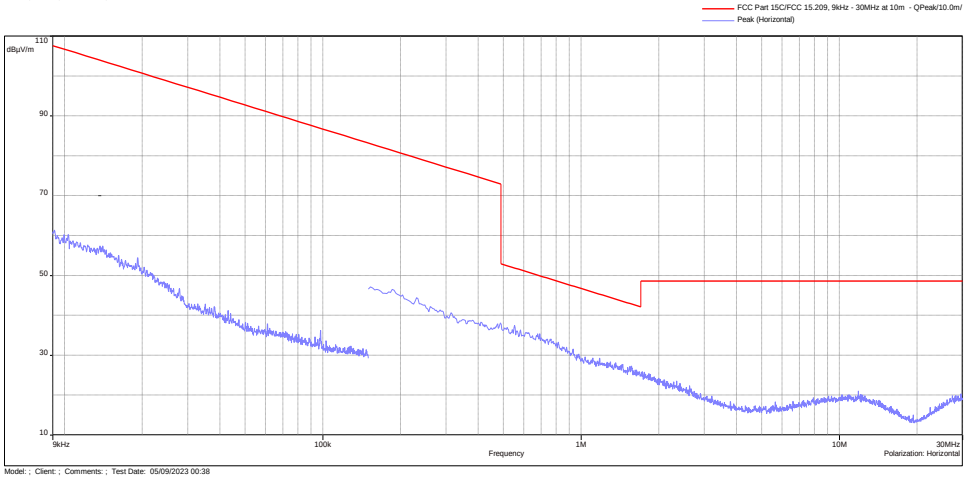
Antenna Position - Coaxial



Antenna Position - Coplanar

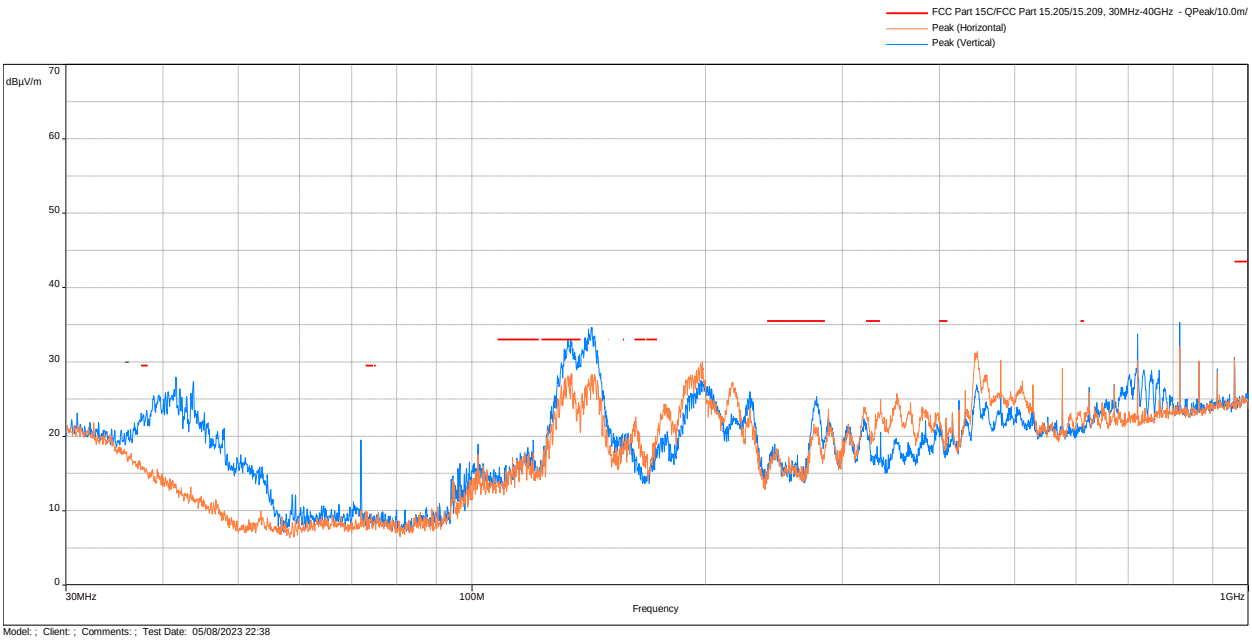


Antenna Position - Horizontal



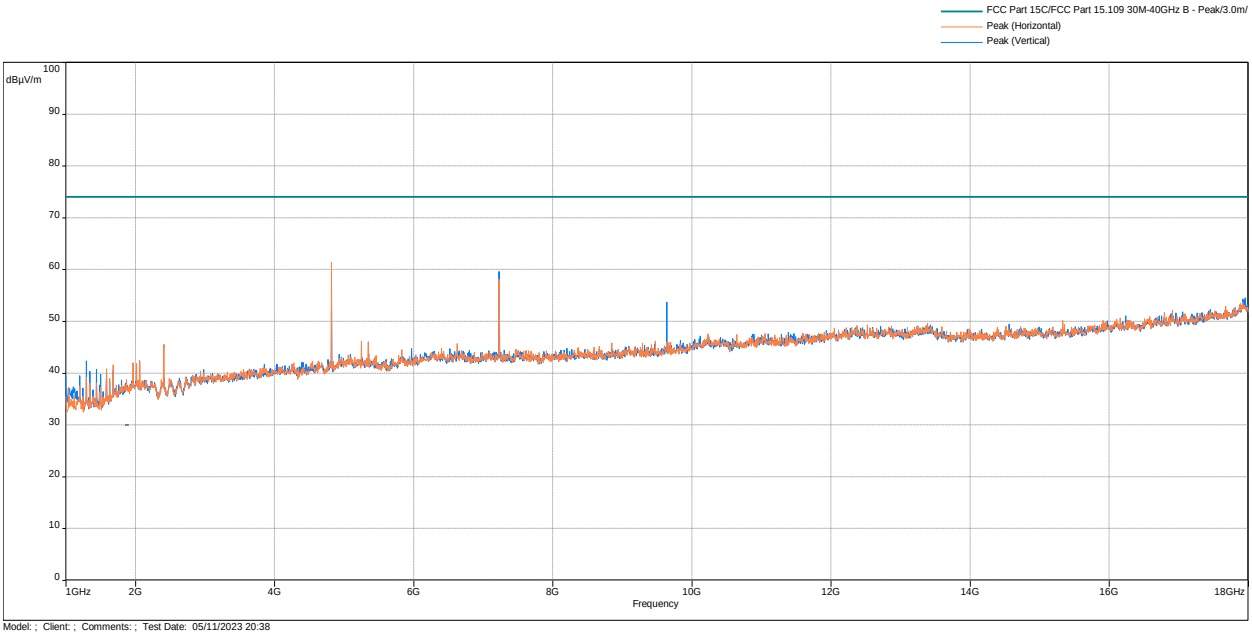
Test Results: Test Results: 15.209 Radiated Spurious Emissions, Tx at 2410 MHz

Out-of-Band Radiated Spurious Emissions - 30 MHz to 1000 MHz



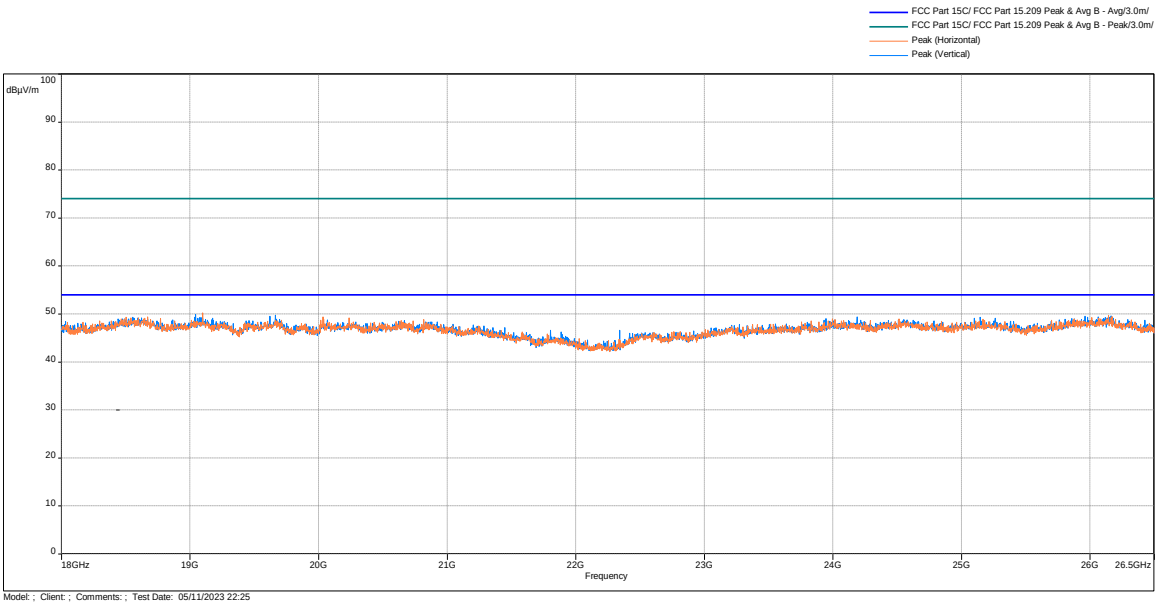
Model: ; Client: ; Comments: ; Test Date: 05/08/2023 22:38

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit



Model: ; Client: ; Comments: ; Test Date: 05/11/2023 20:38

Radiated Spurious Emissions 18000 - 26000 MHz, Peak Scan vs Peak & Avg Limit



Frequency (MHz)	QP@10m (dBµV/m)	Limit@10m (dB(uV/m))	Margin (dB)	Height (m)	Azimuth (deg)	Polarity	Correction (dB)
133.035	31.69	33.00	-1.31	1.13	81.00	Vertical	-15.62
134.517	31.25	33.00	-1.75	1.86	36.75	Vertical	-15.73

Note: Correction = AF + CF – Preamp

Frequency (MHz)	Peak@3m (dBµV/m)	Duty Cycle Correction Factor	Final Field Strength (dBµV/m)	Limits (dBµV/m)	Margin (dB)	Height (m)	Azimuth (deg)	Polarity	Detection	Correction (dB)
4819.333	61.34	0.00	61.34	74.00	-12.66	2.26	267.75	H	Pk	-7.22
4819.333	61.34	-10.71	50.63	54.00	-3.37	2.26	267.75	H	Avg	-7.22
7229.933	59.62	0.00	59.62	74.00	-14.38	1.26	213.25	V	Pk	-4.20
7229.933	59.62	-10.71	48.91	54.00	-5.09	1.26	213.25	V	Avg	-4.20
7229.933	58.06	0.00	58.06	74.00	-15.94	3.24	182.00	H	Pk	-4.20
7229.933	58.06	-10.71	47.35	54.00	-6.65	3.24	182.00	H	Avg	-4.20
4819.900	54.34	0.00	54.34	74.00	-19.66	2.24	349.25	V	Pk	-7.22
4819.900	54.34	-10.71	43.63	54.00	-10.37	2.24	349.25	V	Avg	-7.22
9639.967	53.72	0.00	53.72	74.00	-20.28	3.24	342.25	V	Pk	-1.74
9639.967	53.72	-10.71	43.01	54.00	-10.99	3.24	342.25	V	Avg	-1.74

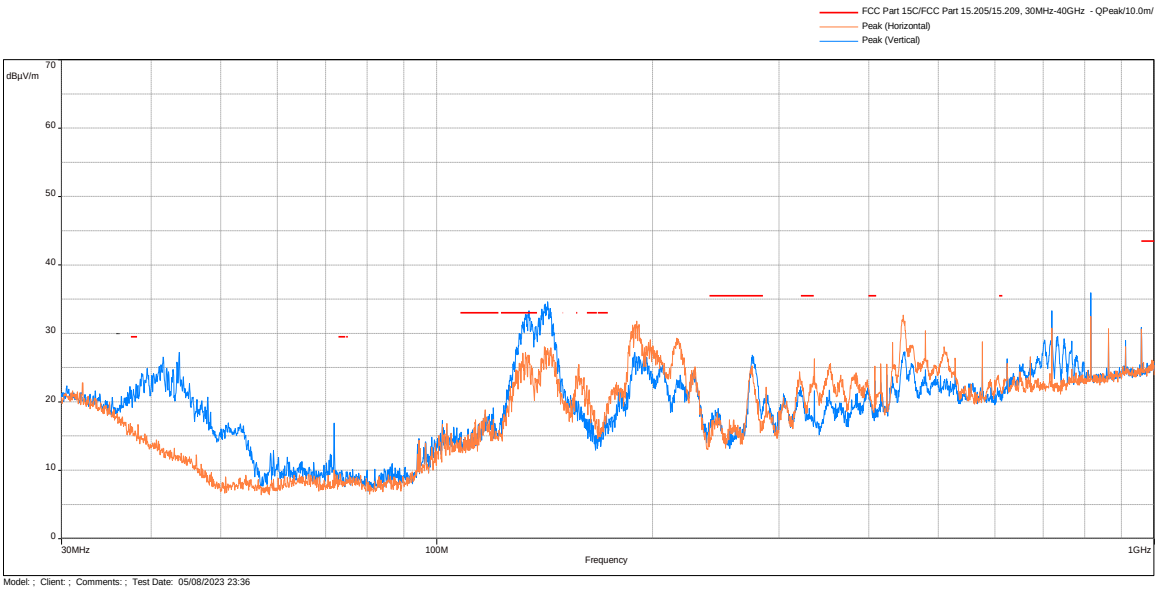
Note: Correction = AF + CF - Preamp

Results	Complies

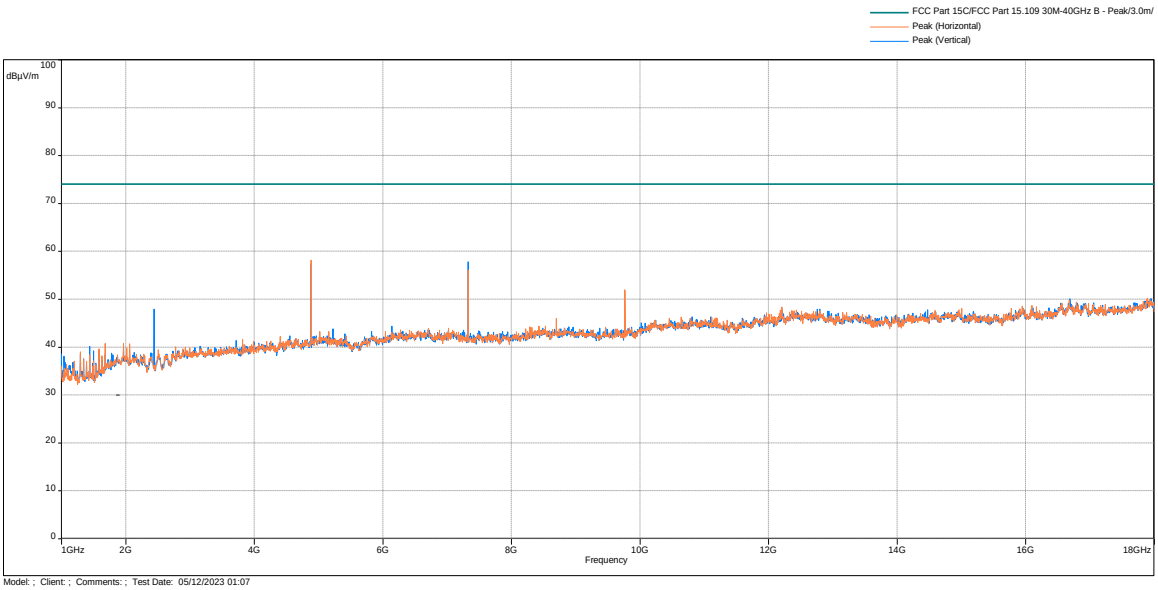
Note: Radiated emission measurements were performed up to from 9kHz to 26GHz.

Test Results: Test Results: 15.209 Radiated Spurious Emissions, Tx at 2442MHz

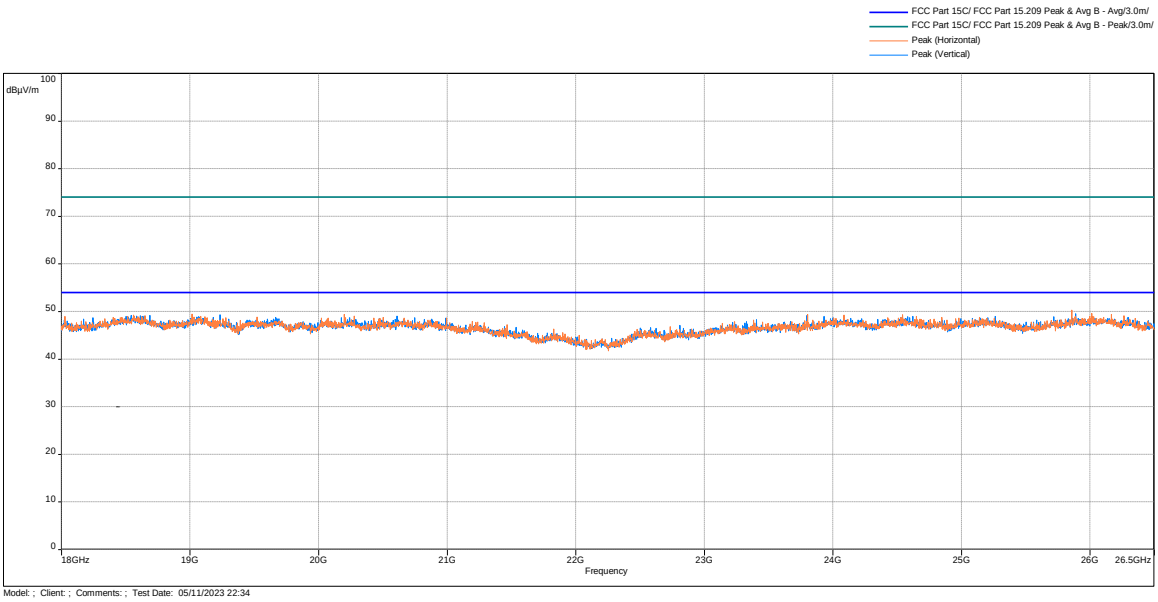
Out-of-Band Radiated Spurious Emissions - 30 MHz to 1000 MHz



Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit



Radiated Spurious Emissions 18000 - 26000 MHz, Peak Scan vs Peak & Avg Limit



Frequency (MHz)	QP@10m (dBµV/m)	Limit@10m (dB(uV/m))	Margin (dB)	Height (m)	Azimuth (deg)	Polarity	Correction (dB)
133.012	31.80	33.00	-1.20	1.16	360.00	Vertical	-15.62
134.471	31.69	33.00	-1.31	1.16	66.25	Vertical	-15.73

Note: Correction = AF + CF – Preamp

Frequency (MHz)	Peak@3m (dBµV/m)	Duty Cycle Correction Factor	Final Field Strength (dBµV/m)	Limits (dBµV/m)	Margin (dB)	Height (m)	Azimuth (deg)	Polarity	Detection	Correction (dB)
4883.933	58.18	0.00	58.18	74.00	-15.82	3.24	10.00	H	Pk	-7.00
4883.933	58.18	-10.71	47.47	54.00	-6.53	3.24	10.00	H	Avg	-7.00
7326.267	57.82	0.00	57.82	74.00	-16.18	3.24	129.50	V	Pk	-4.12
7326.267	57.82	-10.71	47.11	54.00	-6.89	3.24	129.50	V	Avg	-4.12
4883.933	57.32	0.00	57.32	74.00	-16.68	2.26	355.75	V	Pk	-7.00
4883.933	57.32	-10.71	46.61	54.00	-7.39	2.26	355.75	V	Avg	-7.00
7325.700	56.06	0.00	56.06	74.00	-17.94	2.24	200.00	H	Pk	-4.12
7325.700	56.06	-10.71	45.35	54.00	-8.65	2.24	200.00	H	Avg	-4.12
9768.033	51.94	0.00	51.94	74.00	-22.06	2.24	308.25	H	Pk	-1.49
9768.033	51.94	-10.71	41.23	54.00	-12.77	2.24	308.25	H	Avg	-1.49

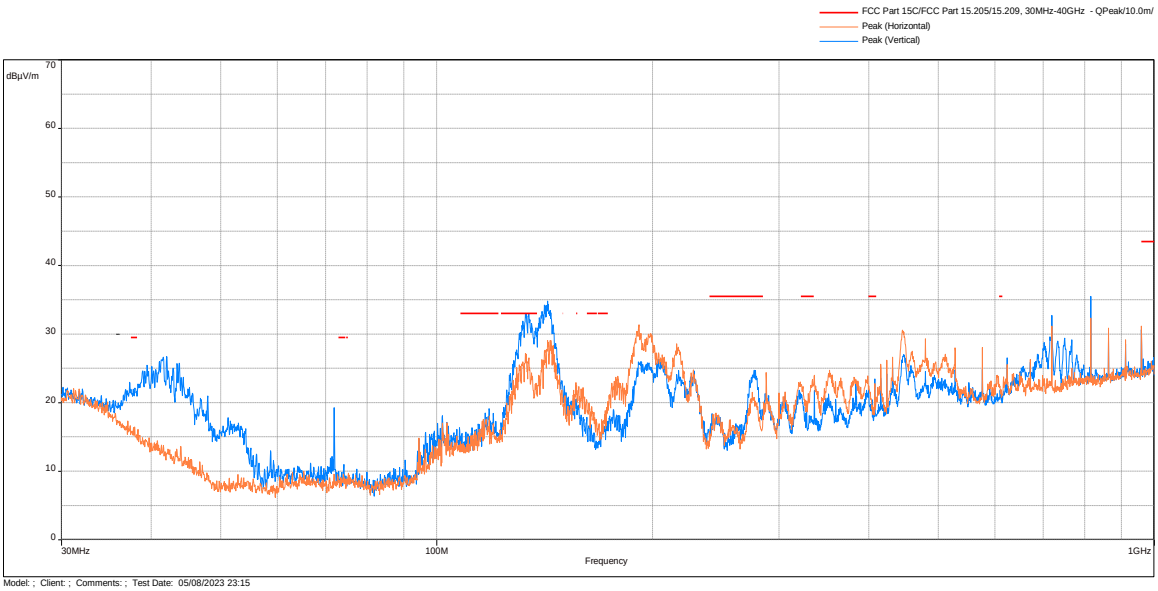
Note: Correction = AF + CF – Preamp

Results	Complies

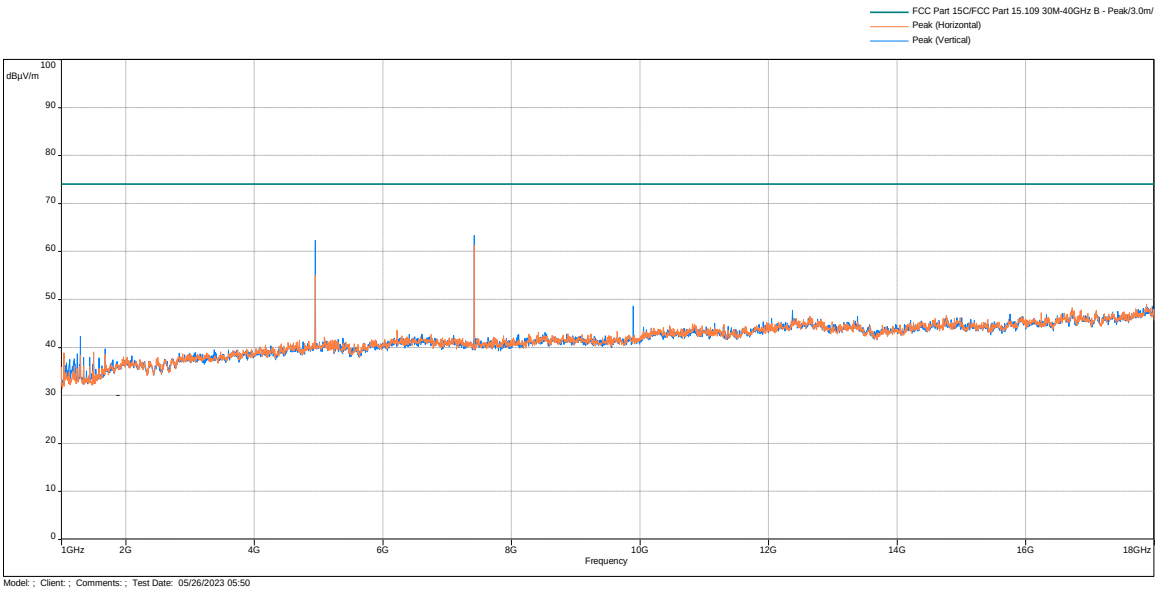
Note: Radiated emission measurements were performed up to from 9kHz to 26GHz.

Test Results: Test Results: 15.209 Radiated Spurious Emissions, Tx at 2474.5MHz

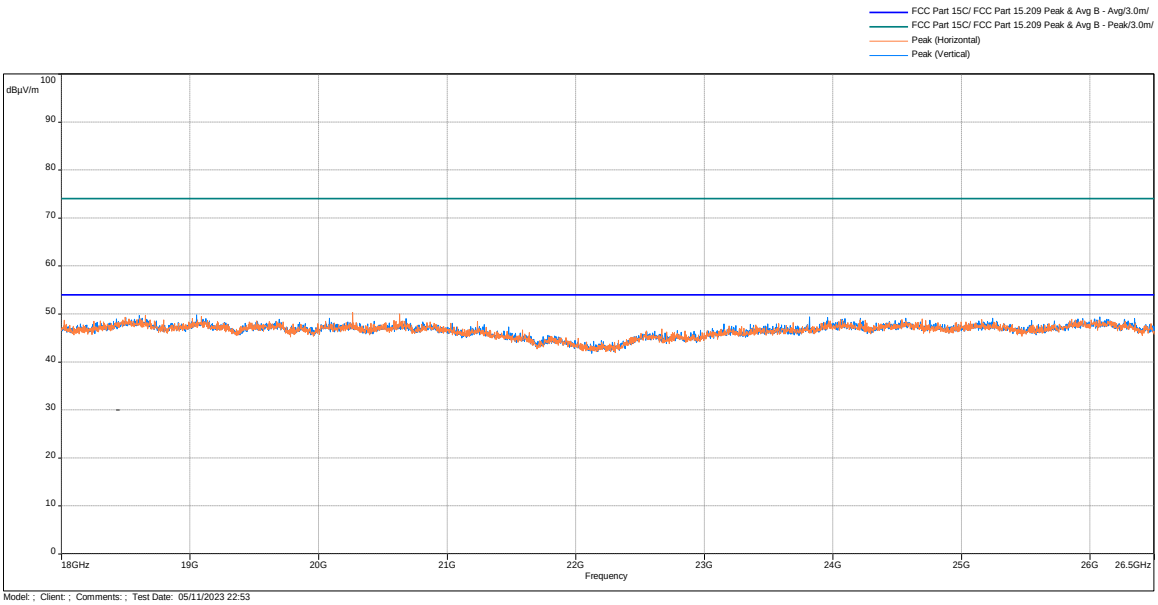
Out-of-Band Radiated Spurious Emissions - 30 MHz to 1000 MHz



Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit



Radiated Spurious Emissions 18000 - 26000 MHz, Peak Scan vs Peak & Avg Limit



Frequency (MHz)	QP@10m (dBµV/m)	Limit@10m (dB(uV/m))	Margin (dB)	Height (m)	Azimuth (deg)	Polarity	Correction (dB)
133.002	31.81	33.00	-1.19	1.12	63.25	Vertical	-15.62
134.494	31.95	33.00	-1.05	1.60	59.50	Vertical	-15.73

Note: Correction = AF + CF – Preamp

Frequency (MHz)	Peak@3m (dBµV/m)	Duty Cycle Correction Factor	Final Field Strength (dBµV/m)	Limits (dBµV/m)	Margin (dB)	Height (m)	Azimuth (deg)	Polarity	Detection	Correction (dB)
7423.167	63.33	0.00	63.33	74.00	-10.67	2.26	359.75	V	Pk	-3.80
7423.167	63.33	-10.71	52.62	54.00	-1.38	2.26	359.75	V	Avg	-3.80
4948.533	62.27	0.00	62.27	74.00	-11.73	2.26	192.50	V	Pk	-6.71
4948.533	62.27	-10.71	51.56	54.00	-2.44	2.26	192.50	V	Avg	-6.71
7423.167	61.23	0.00	61.23	74.00	-12.77	3.24	320.25	H	Pk	-3.80
7423.167	61.23	-10.71	50.52	54.00	-3.48	3.24	320.25	H	Avg	-3.80
4948.533	55.11	0.00	55.11	74.00	-18.89	1.26	205.00	H	Pk	-6.71
4948.533	55.11	-10.71	44.40	54.00	-9.60	1.26	205.00	H	Avg	-6.71
9897.233	48.63	0.00	48.63	74.00	-25.37	2.26	286.25	V	Pk	-1.33
9897.233	48.63	-10.71	37.92	54.00	-16.08	2.26	286.25	V	Avg	-1.33

Note: Correction = AF + CF – Preamp

Results	Complies

Note: Radiated emission measurements were performed up to from 9kHz to 26GHz.

4.8 AC Line Conducted Emission
FCC: 15.207; RSS-GEN;

4.8.1 Requirement

Frequency Band MHz	Class B Limit dB(μV)		Class A Limit dB(μV)	
	Quasi-Peak	Average	Quasi-Peak	Average
0.15-0.50	66 to 56 *	56 to 46 *	79	66
0.50-5.00	56	46	73	60
5.00-30.00	60	50	73	60

*Note: *Decreases linearly with the logarithm of the frequency. At the transition frequency the lower limit applies.*

4.8.2 Procedure

Measurements are carried out using quasi-peak and average detector receivers in accordance with CISPR 16. An AMN is required to provide a defined impedance at high frequencies across the power feed at the point of measurement of terminal voltage and also to provide isolation of the circuit under test from the ambient noise on the power lines. An AMN as defined in CISPR 16 shall be used.

The EUT is located so that the distance between the boundary of the EUT and the closest surface of the AMN is 0.8m.

Where a flexible mains cord is provided by the manufacturer, this shall be 1m long or if in excess of 1m, the excess cable is folded back and forth as far as possible so as to form a bundle not exceeding 0.4m in length.

The EUT is arranged and connected with cables terminated in accordance with the product specification.

Conducted disturbance is measured between the phase lead and the reference ground, and between the neutral lead and the reference ground. Both measured values are reported.

The EUT, where intended for tabletop use, is placed on a table whose top is 0.8m above the ground plane. A vertical, metal reference plane is placed 0.4m from the EUT. The vertical metal reference-plane is at least 2m by 2m. The EUT shall be kept at least 0.8m from any other metal surface or other ground plane not being part of the EUT. The table is constructed of non-conductive materials. Its dimensions are 1m by 1.5m, but may be extended for larger EUT.

Floor standing EUT are placed on a horizontal metal ground plane and isolated from the ground plane by resting on an insulating material. The metal ground plane extends at least 0.5m beyond the boundaries of the EUT and has minimum dimensions of 2m by 2m.

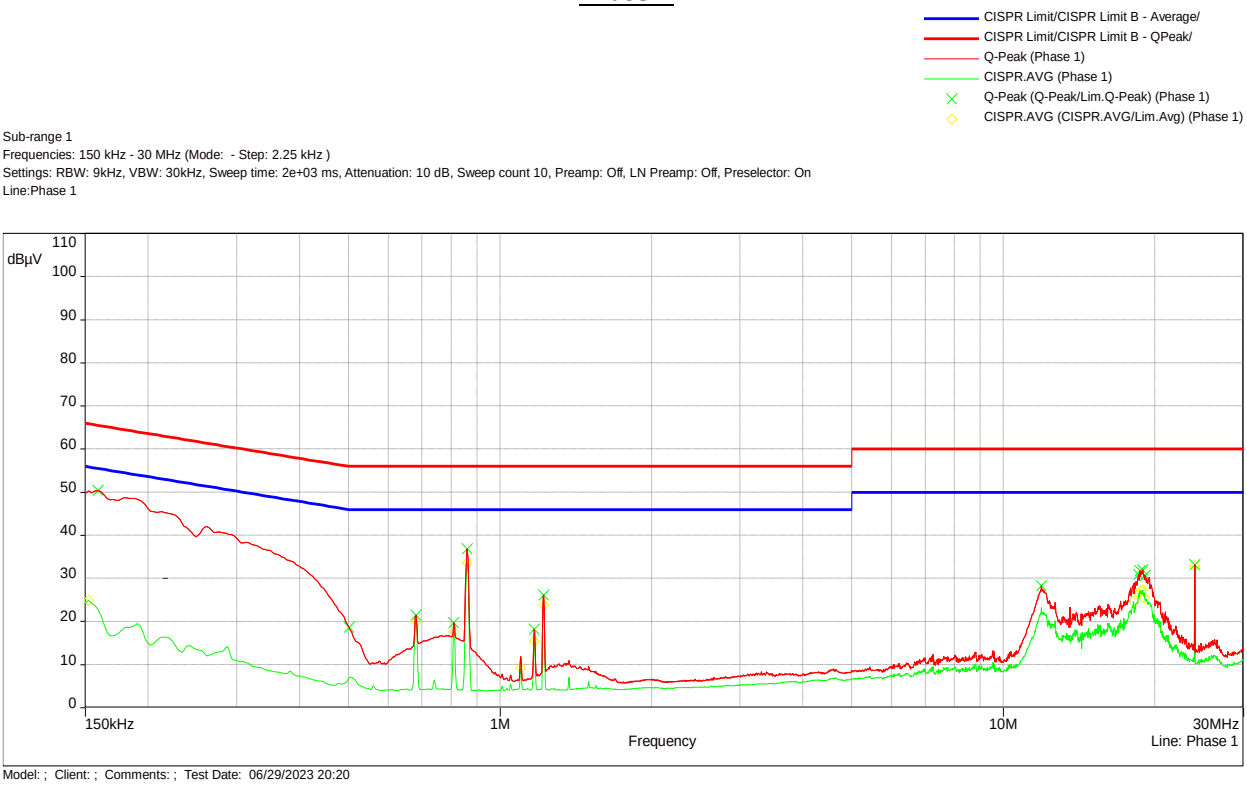
Equipment setup for conducted disturbance tests followed the guidelines of ANSI C63.10-2013.

Tested By / Supervised By	Test Date	Results
Bryce Toma / Minh Ly	June 29, 2023	Complies

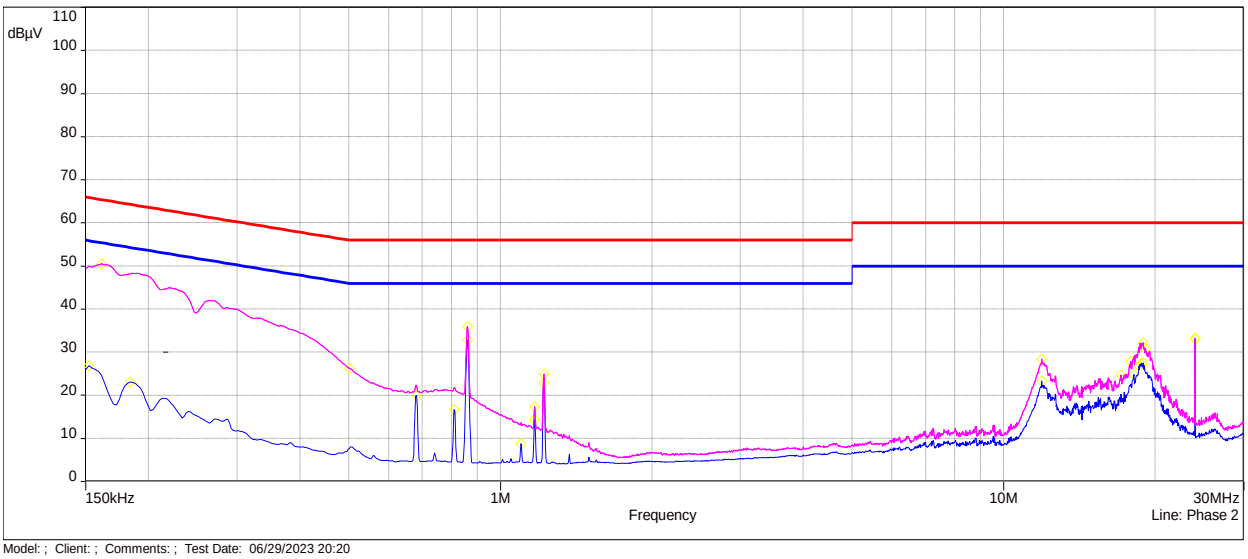
4.8.3 Test Result

15.207: Conducted Emissions 120VAC 60Hz

Phase 1



Phase 2



Sub-range 2
Frequencies: 150 kHz - 30 MHz (Mode: - Step: 2.25 kHz)
Settings: RBW: 9kHz, VBW: 30kHz, Sweep time: 2e+03 ms, Attenuation: 10 dB, Sweep count 10, Preamp: Off, LN Preamp: Off, Preselector: On
Line:Phase 2

Model: ; Client: ; Comments: ; Test Date: 06/29/2023 20:20

4.8.3 Test Results (Continued)

Frequency (MHz)	Q-Peak (dBµV)	Limit Q-Peak (dBµV)	Margin Q-Peak (dB)	Line	Correction (dB)
0.16125	50.53	65.40	-14.87	Phase 2	10.53
0.15900	50.35	65.52	-15.16	Phase 1	10.53
0.86100	36.82	56.00	-19.18	Phase 1	10.57
0.86100	35.97	56.00	-20.03	Phase 2	10.57
24.00000	33.28	60.00	-26.72	Phase 2	11.04
24.00000	33.15	60.00	-26.85	Phase 1	11.04
18.90150	32.23	60.00	-27.77	Phase 2	10.98
18.90150	31.96	60.00	-28.04	Phase 1	10.98
18.66750	31.77	60.00	-28.23	Phase 1	10.97
18.56400	30.89	60.00	-29.11	Phase 1	10.97
19.11075	30.86	60.00	-29.14	Phase 2	10.98
19.11300	30.63	60.00	-29.37	Phase 1	10.98
0.50100	26.28	56.00	-29.72	Phase 2	10.55
1.22100	26.17	56.00	-29.83	Phase 1	10.58
1.22100	24.91	56.00	-31.09	Phase 2	10.58
11.89950	28.39	60.00	-31.61	Phase 2	10.87
11.90175	28.34	60.00	-31.66	Phase 1	10.87
17.87325	27.91	60.00	-32.09	Phase 2	10.96
0.68100	21.46	56.00	-34.54	Phase 1	10.56
17.10150	24.71	60.00	-35.29	Phase 2	10.95
0.80925	19.68	56.00	-36.32	Phase 1	10.56
0.50100	18.66	56.00	-37.34	Phase 1	10.55
1.16925	18.18	56.00	-37.82	Phase 1	10.58

Frequency (MHz)	CISPR AVG (dBµV)	Limit Avg (dBµV)	Margin Avg (dB)	Line	Correction (dB)
0.861	33.59	46.00	-12.41	Phase 1	10.57
0.861	32.84	46.00	-13.16	Phase 2	10.57
24.000	33.09	50.00	-16.91	Phase 2	11.04
24.000	32.97	50.00	-17.03	Phase 1	11.04
1.221	23.84	46.00	-22.16	Phase 1	10.58
18.899	27.49	50.00	-22.51	Phase 2	10.98
18.760	27.39	50.00	-22.61	Phase 2	10.98
18.899	27.31	50.00	-22.69	Phase 1	10.98
18.760	27.17	50.00	-22.83	Phase 1	10.98
1.221	22.88	46.00	-23.12	Phase 2	10.58
18.564	26.73	50.00	-23.27	Phase 2	10.97
18.562	26.47	50.00	-23.53	Phase 1	10.97
19.075	25.50	50.00	-24.50	Phase 1	10.98
18.128	24.82	50.00	-25.18	Phase 2	10.97
18.128	24.62	50.00	-25.38	Phase 1	10.97
0.681	20.08	46.00	-25.92	Phase 1	10.56
0.681	19.96	46.00	-26.04	Phase 2	10.56
11.897	23.26	50.00	-26.74	Phase 2	10.87
0.809	17.64	46.00	-28.36	Phase 1	10.56
0.152	26.86	55.88	-29.01	Phase 2	10.53
0.809	16.69	46.00	-29.31	Phase 2	10.56
1.169	15.38	46.00	-30.62	Phase 1	10.58
0.152	24.89	55.88	-30.99	Phase 1	10.53
0.184	23.07	54.31	-31.25	Phase 2	10.53
1.169	14.43	46.00	-31.57	Phase 2	10.58
1.100	9.26	46.00	-36.74	Phase 1	10.58
1.100	8.84	46.00	-37.16	Phase 2	10.58

Results	**Complies** by 12.41 dB

5.0 List of Test Equipment

Measurement equipment used for emission compliance testing utilized the equipment on the following list:

Equipment	Manufacturer	Model/Type	Asset #	Cal Int	Cal Due
EMI Receiver	Rohde and Schwarz	ESU40	ITS 00961	12	03/14/24
Horn Antenna	ETS Lindgren	3117PA	ITS 01325	12	11/19/23
Horn Antenna	ETS-Lindgren	3115	ITS 00982	12	05/11/23
Spectrum Analyzer	Rohde and Schwarz	FSW	ITS 01818	12	07/19/23
Loop Antenna	ETS Lindgren	6512	ITS 01573	12	11/21/24
BI-Log Antenna	SunAR RF Motion	JB1	ITS 01577	12	02/20/24
Pre-Amplifier	Sonoma Instrument	310	ITS 00942	12	04/21/24
18-40 GHz Preamplifier	uComp Nordic	MCNS-50-18004000335P	ITS 01799	12	03/15/24
Horn Antenna	EMCO	3160-09	ITS 00571	#	#
Notch Filter	MICRO-TRONICS	BRM50702	ITS 01166	12	06/24/23
LISN	COM-POWER	LIN-115A	ITS 01290	12	08/01/23
10m Semi-Anechoic	Panashield	10m Chamber	ITS 00984	36	07/29/23

Software used for emission compliance testing utilized the following:

Name	Manufacturer	Version	Template/Profile
Tile	Quantum Change	3.4.K.22	Conducted Spurious_30M-26GHz Conducted Emissions
BAT-EMC	Nexio	3.20.0.23	Ampt – 05-08-23.bpp

6.0 Document History

Revision/ Job Number	Writer Initials	Reviewers Initials	Date	Change
1.0 / G105267899	KRQ	AS	July 14, 2023	Original Document

END OF REPORT