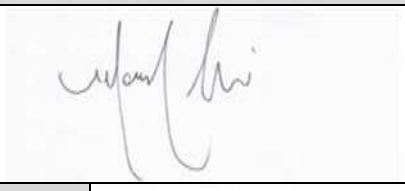
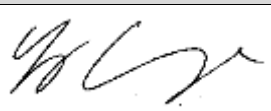
CERTIFICATION TEST REPORT

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

&

RSS-247 Issue 2: Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices

Equipment under test:	WIT2420
Model:	WIT2420
Company Name:	Murata Electronics North America, Inc.
FCC ID:	HSW-2420
IC:	4492A-2420
Date of Test(s):	May 18 - 28, 2021 June 1 - 29, 2021
Date of Issue:	July 1, 2021
UST Project Number:	21-0174
Total Pages:	64

Test report completed by:		**Test report approval by:**	
			
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3505 Francis Circle Alpharetta, GA 30004
PH: 770-740-0717 Fax: 770-740-1508
www.ustech-lab.com

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

US TECH (Agent Responsible For Test):

By: Alan Ghasiani

Name: 

Title: Compliance Engineer – President

Date: July 1, 2021

NVLAP LAB CODE 200162-0

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MEASUREMENT TECHNICAL REPORT

Company Name:	Murata Electronics North America, Inc.
Address:	2200 Lake Park Drive Smyrna, GA 30080-7604
Model:	WIT2420
FCC ID:	HSW-2420
IC:	4492A-2420
Date:	July 1, 2021

This report concerns (check one): ☒ Original ☐ Class II Permissive Change

Equipment type: 2.4 GHz ISM Radio Transceiver

Technical Information:

Radio Technology:	FHSS
Frequency of Operation (MHz):	2401.6896 – 2469.888
Rated Output Power (dBm):	17 – 18
Type of Modulation:	GFSK
Data/Bit Rate (kbps):	460
Number of Channels:	75
Antenna Gain (dBi):	Refer to Tables 5 and 6
Software used to program EUT:	WinCom 3.11
EUT firmware:	WIT2420 v5.59
Measured Power Level:	17.23 dBm

Report prepared by:

US Tech

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Theory of Operation	Sample Label
IC Cross Reference	ISED Application Forms
ISED Agency Agreement	Canadian Representative Letter

1 General Information

1.1 Purpose of this Report

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

1.2 Characterization of Test Sample

The sample used for testing was received by US Tech on May 13, 2021 in good operating condition.

1.3 Product Description

The Equipment under Test (EUT) is the Murata, Model: WIT2420. The EUT is a frequency hopping, wireless transceiver designed for industrial monitoring and control applications.

1.4 Configuration of Tested System

The Test Sample was tested per *ANSI C63.10:2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices* for the intentional radiator aspect of the device and *ANSI C63.4:2014, Methods of Measurement of Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz (2014)* for the unintentional radiator aspect of the device as well as FCC subpart B and C of Part 15 and per FCC KDB Publication number 558074 v05r02 for Digital Transmission Systems Operating Under section 15.247.

Digital RF conducted and radiated verification emissions data (FCC 15.107 and 109) below 1 GHz were taken with the measuring receiver (or spectrum analyzer's) resolution bandwidth adjusted to 9 kHz and 120 kHz, respectively. All measurements performed above 1 GHz were made with a RBW of 1 MHz. All measurements are peak unless stated otherwise. The video filter associated with the spectrum analyzer was set to 3 times the RBW or as required per the standard throughout the evaluation process.

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

1.5 Test Facility

Testing was performed at US Tech's measurement facility at 3505 Francis Circle, Alpharetta, GA 30004. This site has been fully described and registered with the FCC. Its designation number is 186022. Additionally, this site has also been fully described and submitted to Industry Canada (IC), and has been approved under file number 9900A-1.

1.6 Related Submittal(s)/Grant(s)

The EUT is subject to the following FCC Equipment Authorizations:

a) Certification under section 15.207 and 15.209 as a transmitter.

b) SDoC under 15.101 as a digital device. The results of this test are provided in a separate report; US Tech report number 21-0173.

Table 1. EUT and Peripherals

EUT/ MANUFACTURER	MODEL NUMBER	SERIAL NUMBER	FCC ID / IC	CABLES P/D
EUT/ Murata	WIT2420	10AA40190060042	Pending FCC ID: HSW-2420 IC: 4492A-2420	P/D
PERIPHERAL/ MANUFACTURER	**MODEL NUMBER**	**SERIAL NUMBER**	**FCC ID / IC**	**CABLES P/D**
Laptop/ Dell		Engineering Sample	N/A	P
Antenna See antenna details	--	--	--	--

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

Table 2. Details of Cables Attached to EUT

DESCRIPTION OF CABLE	DETAILS OF CABLE			CABLE LENGTH
USB-A to USB-B	**Manufacturer**		**Part Number**	2.0 m
	Generic		Various	
	Shield Type	**Shield Termination**	**Back-shell**	
	N/A	N/A	N/A	

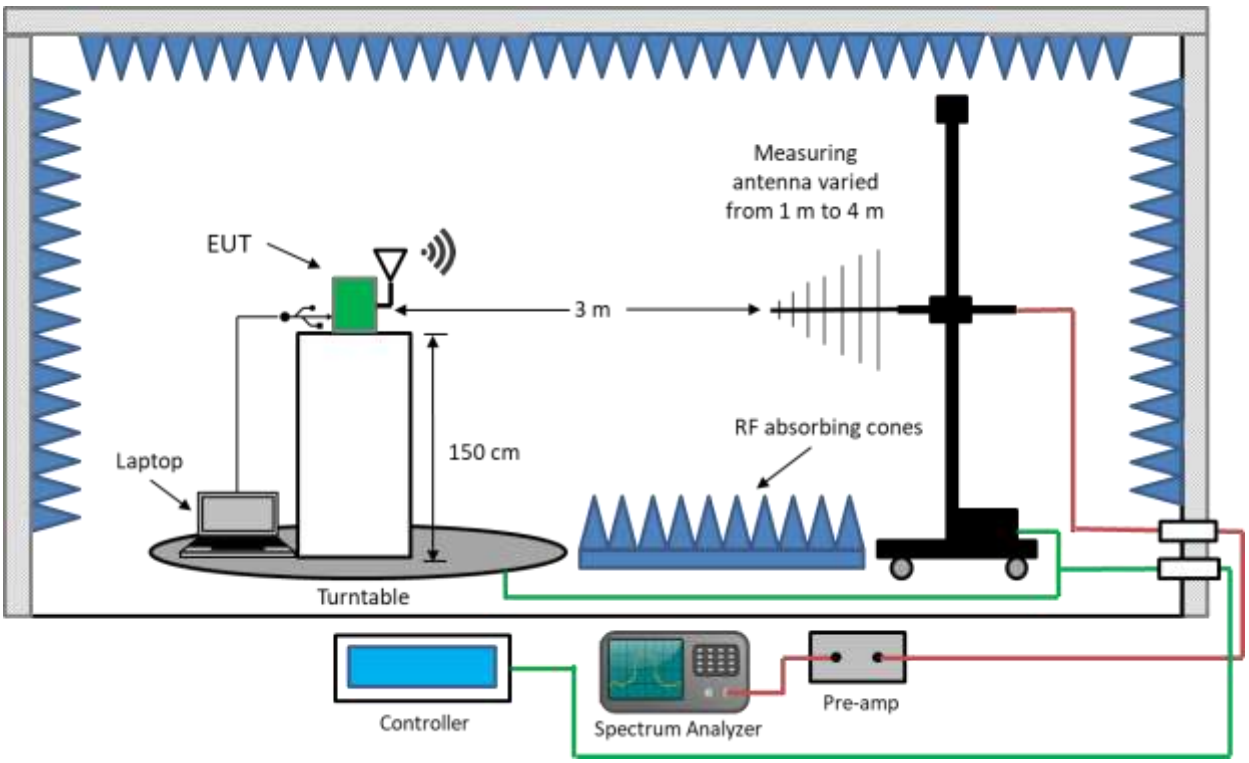


Figure 1. EUT Test Configuration Diagram

2 Tests and Measurements

2.1 Test Equipment

The table below lists test equipment used to evaluate this product.

Table 3. Test Instruments

TEST INSTRUMENT	MODEL NUMBER	MANUFACTURER	SERIAL NUMBER	CALIBRATION DUE DATE
SPECTRUM ANALYZER	E4407B	AGILENT	US41442935	9/02/2022 2 yr.
SPECTRUM ANALYZER	U3772	ADVANTEST	1806001039	7/28/2021
RF PREAMP 100 kHz to 1.3 GHz	8447D	HEWLETT-PACKARD	1937A02980	6/9/2022
PREAMP 1.0 GHz to 26.0 GHz	8449B	HEWLETT-PACKARD	3008A00480	6/25/2022
LOOP ANTENNA	SAS-200/562	A. H. Systems	142	4/06/2022 2 yr.
BICONICAL ANTENNA	3110B	EMCO	9307-1431	11/11/2022 2 yr.
LOG PERIODIC ANTENNA	3146	EMCO	9305-3600	6/3/2023 2 yr
HORN ANTENNA	3115	EMCO	9107-3723	2/3/2023 2 yr
HIGH PASS FILTER	H3R020G2	MICROWAVE CIRCUITS	001DC9528	8/11/2021 Extended

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

2.2 Modifications to EUT Hardware

No modifications were made by US Tech to bring the EUT into compliance with FCC Part 15.247 requirements.

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

Measurements of intentional radiators or receivers shall be performed and reported for each band in which the device can be operated, with the device operating at the number of frequencies in each band specified in Table 3 as follows:

Table 4. Number of Test Frequencies for Intentional Radiators

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

Because the EUT operates over 2401.6896 MHz to 2469.888 MHz, three test frequencies were used.

2.4 Frequency Range of Radiated Measurements (CFR 15.33)

2.4.1 Intentional Radiator

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

2.4.2 Unintentional Radiator

For the digital device, an unintentional radiator, the frequency range shall be 30 MHz to 1000 MHz, or to the range specified in 2.4.1 above, whichever is the higher range of investigation.

2.5 Measurement Detector Function and Bandwidth (CFR 15.35)

The radiated and conducted emissions limits shown herein are based on the parameters listed in the following sections.

2.5.1 Detector Function and Associated Bandwidth

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

2.5.2 Corresponding Peak and Average Requirements

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

2.5.3 Pulsed Transmitter Averaging

When the radiated emissions limit is expressed as an average value, and the transmitter is pulsed, the measured field strength shall be determined by applying a Duty Cycle Correction Factor based upon dividing the total ON time during the first 100 ms period by 100 ms (or by the period if less than 100 ms). The duty cycle may also be expressed logarithmically in dB. In this case, the Duty Cycle Correction Factor was determined from the manufacturer's claim. This data is presented in paragraph 2.6 and Figure 2 below.

2.6 Transmitter Duty Cycle (Part 15.35(c))

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

The maximum time a WIT2420 can transmit on a single channel is:

280 bytes * 8 bits/byte * (1/460.8 Kbps) = 4.86 ms

A WIT2420 (in any configuration or operating condition) can never transmit more than 4.86 ms during a single hop. The minimum hop duration (time on a given channel) for this maximum transmit time is 6.94 ms. Given that we have 75 channels in our hop set, it takes 521 ms to go through the entire hop table and repeat a transmission on the same channel. Therefore, the WIT2420 can only transmit for 4.86 ms on any given channel over a 100 ms period.

The transmission duty cycle correction factor is then calculated as:

20* log (4.86ms/100ms) = -26.3 dB.

2.7 Restricted Bands of Operation (Part 15.205)

Only spurious emissions can fall in the frequency bands of CFR 15.205. The field strength of these emissions cannot exceed the limits of 15.209. Radiated harmonics and other spurious emissions are examined for this requirement see paragraph 2.10.

2.8 EUT Antenna Requirements (CFR 15.203)

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. Following are the antenna details:

Type	Manufacturer	Model	Gain (dBi)	Connector
Patch	Murata	PA2400	+6.0	MMCX
Corner Reflector	Mobilemark	SCR9-2400-WHT	+9.0	Reverse N Type
Dipole	Nearson	S181XX-2450S	+2.0	Reverse SMA

2.9 Maximum Peak Conducted Output Power (CFR 15.247(b)(3))

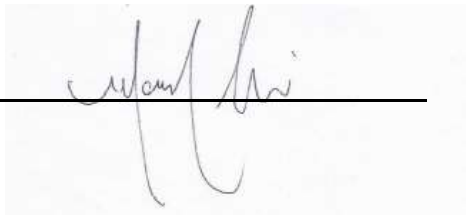
The EUT was programmed to operate at a normal operating output power across the bandwidth. A short RF, coaxial cable was connected between the antenna port of the EUT and RF input port of the spectrum analyzer. A 20 dB attenuator was used to help protect the test measurement equipment. This attenuator factor has been accounted for in the analyzer's settings.

Peak power within the band 2401.6896 MHz to 2469.8880 MHz was measured per FCC KDB Publication 558074v05r02 and ANSI C63.10-2013. Antenna-port RF conducted output power test was performed.

Table 5. Peak Antenna Conducted Output Power per Part 15.247 (b)(3)

Frequency of Fundamental (MHz)	P_{Cond} (dBm)	P_{Cond} (W)	FCC Limit (W Maximum)
2401.6896	15.95	0.039	0.125
2435.7888	17.23	0.053	0.125
2469.8880	17.18	0.052	0.125

Test Date: June 21, 2021

Tested By
Signature:  Name: Mark Afroozi

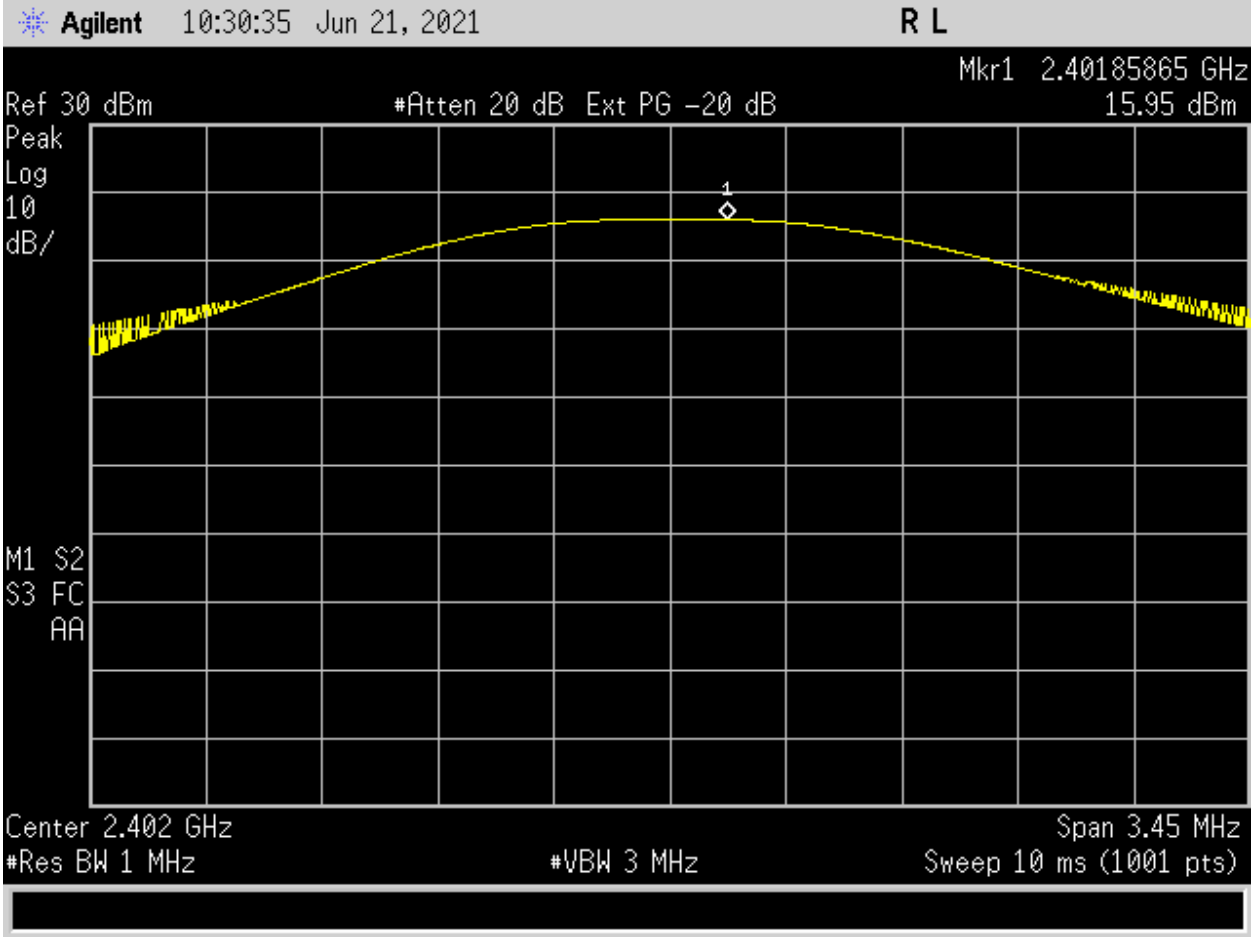


Figure 2. Peak Antenna Port Conducted RF Output Power – Low Channel

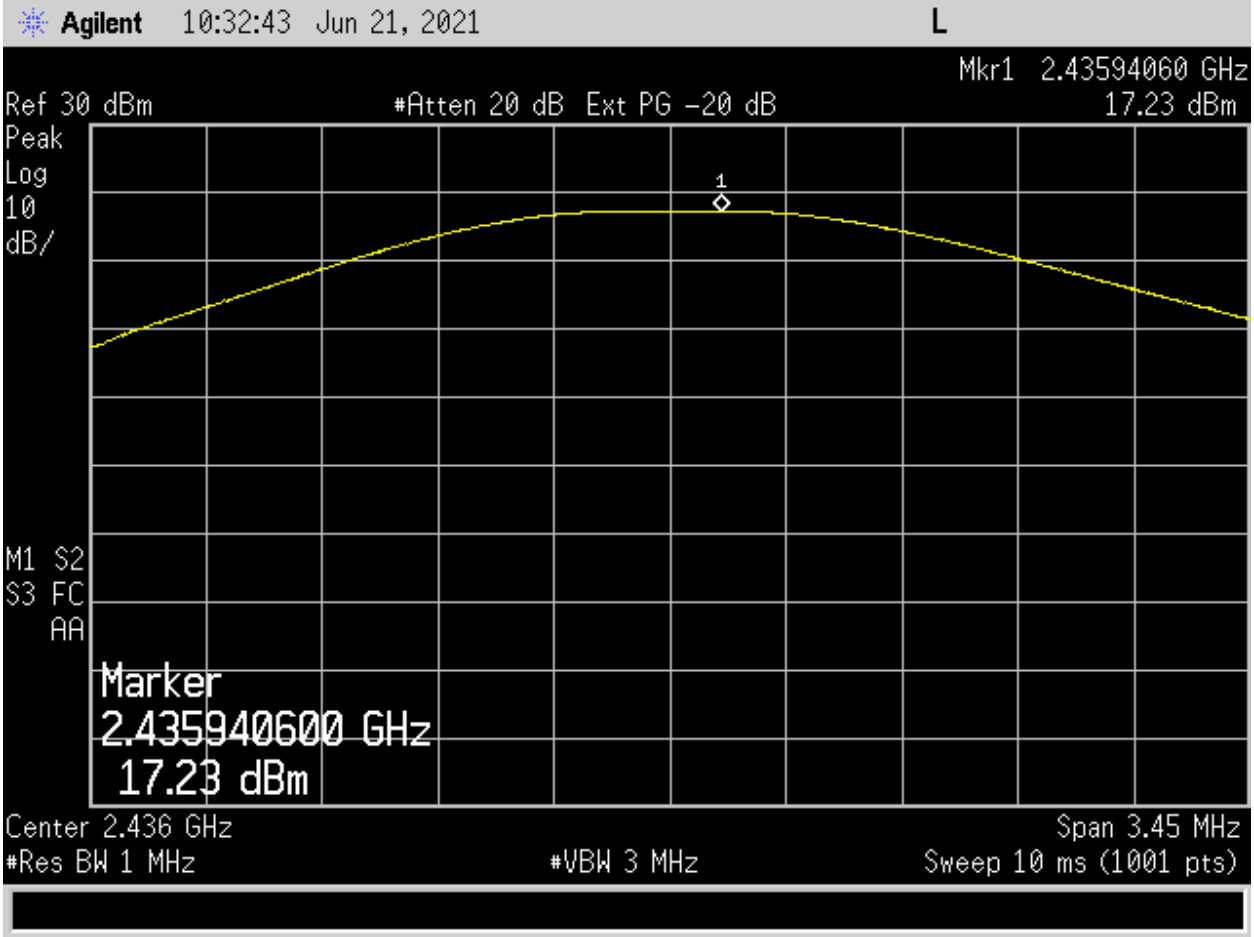


Figure 3. Peak Antenna Port Conducted RF Output Power – Mid Channel

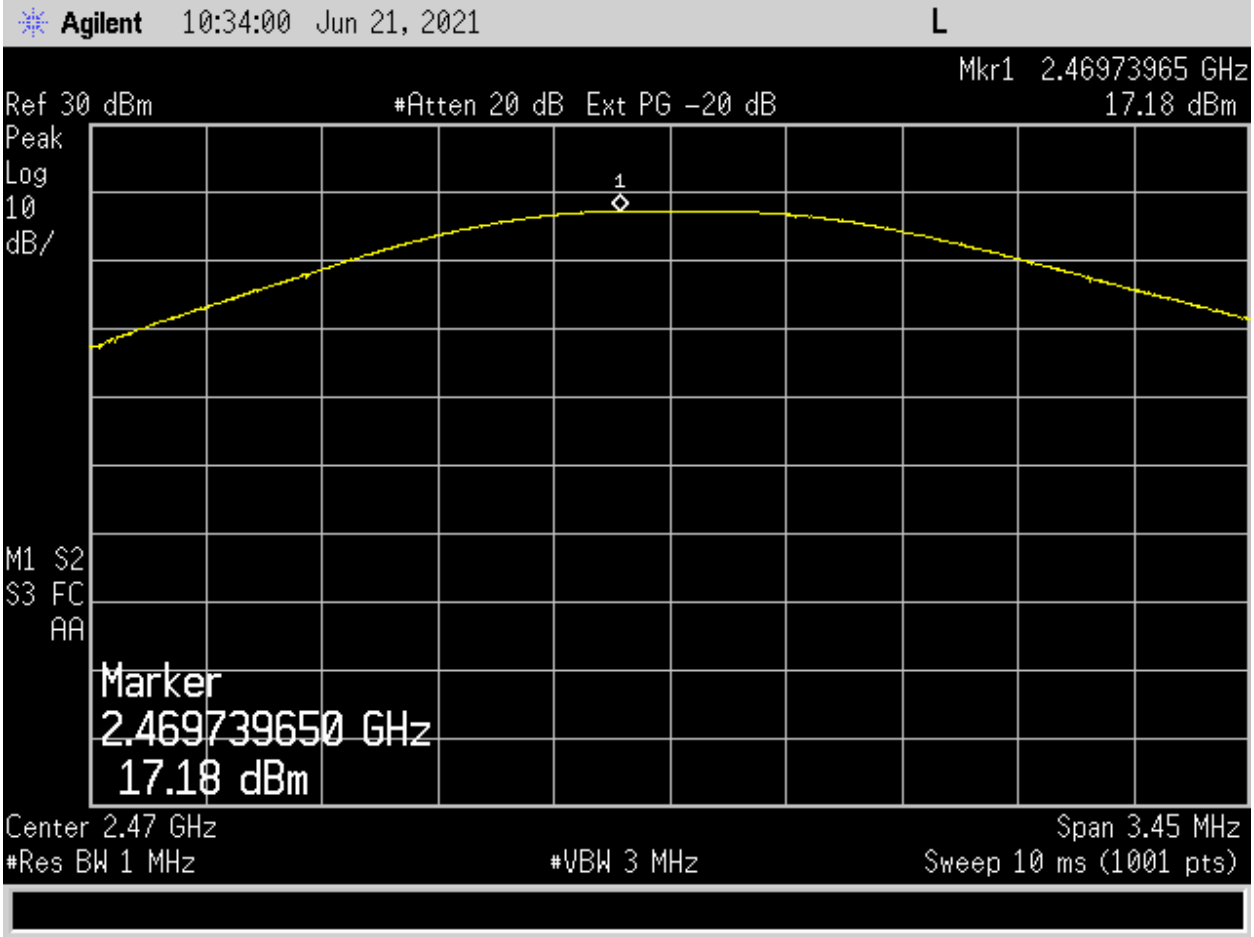


Figure 4. Peak Antenna Port Conducted RF Output Power – High Channel

2.10 Antenna Conducted Intentional and Spurious Emissions (CFR 15.209, 15.247(d)) (RSS-247 (5.5), RSS-Gen 8.9)

The EUT was put into a continuous-transmit mode of operation and tested per FCC KDB Publication 558074v05r02 for conducted out of band emissions radiating from the antenna port over the frequency range of 30 MHz to ten times the highest clock frequency generated or used in this case, 25 GHz. A conducted scan was performed on the EUT to identify and record spurious signals that were related to the transmitter. Antenna conducted emissions of a significant magnitude that fell within restricted bands were then measured as radiated emissions in the semi-anechoic chamber. The conducted emissions graphs are found in figures below. All spurious emissions must be at least 20 dB below the fundamental signal.

For RF antenna conducted tests, the RBW was set to 1 MHz, video bandwidth (VBW)> RBW, scan up through the 10^{th} harmonic of the fundamental frequency. All harmonics/spurs must be at least 20 dB down from the highest emission level within the authorized band. Plots of the spurious emissions that were recorded are presented in the following figures. The display line in each of the plots represents 20 dB below the peak output power of the fundamental frequency.

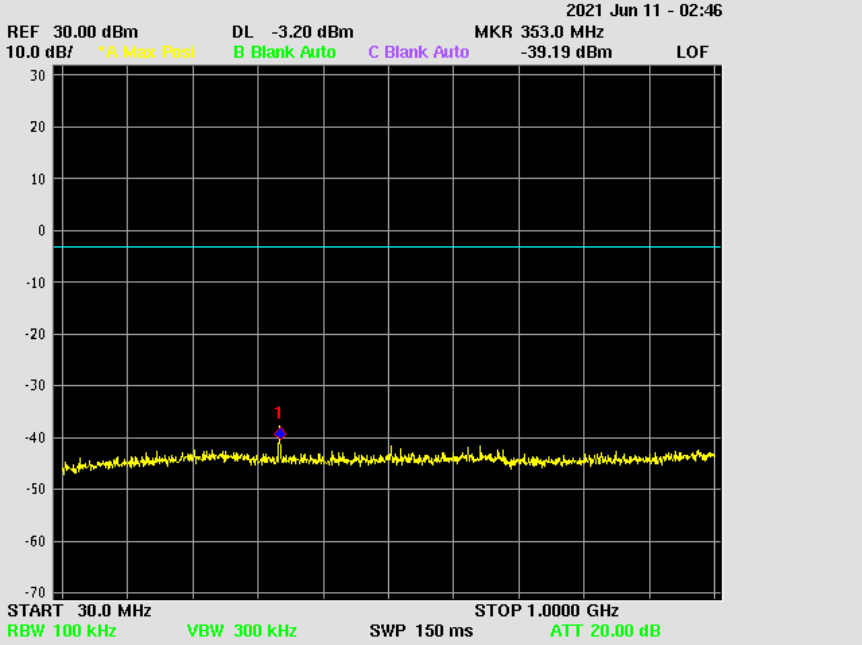


Figure 5. Conducted Spurious Emissions: High Channel, 30 MHz – 1 GHz

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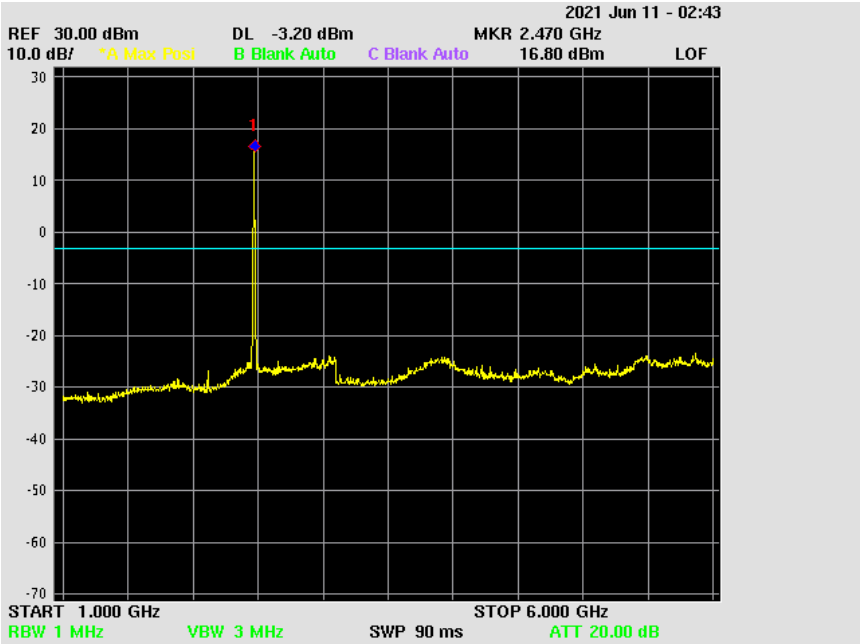

Figure 6. Conducted Spurious Emissions: High Channel, 1 – 6 GHz

Large Signal shown is fundamental frequency

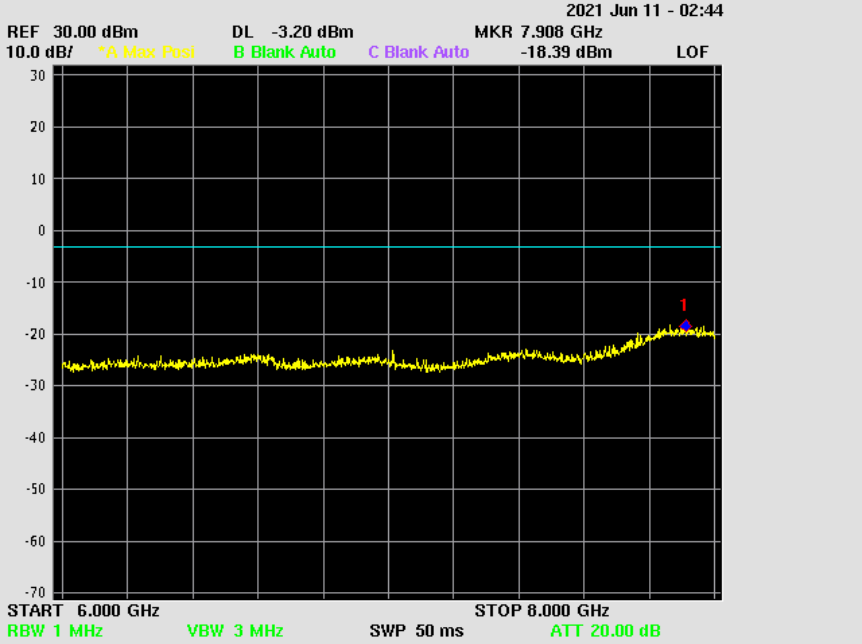

Figure 7. Conducted Spurious Emissions: High Channel, 6 – 8 GHz

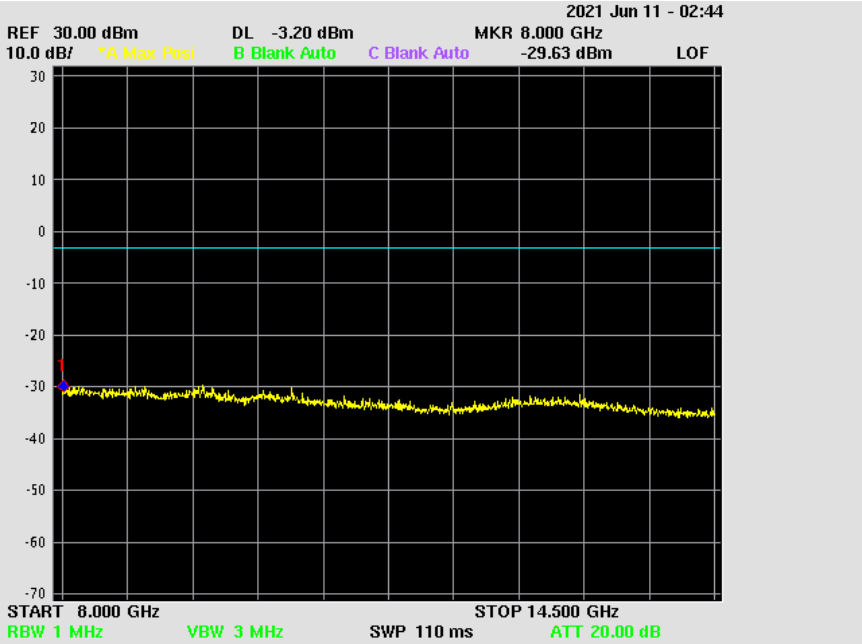

Figure 8. Conducted Spurious Emissions: High Channel, 8 – 14.5 GHz,

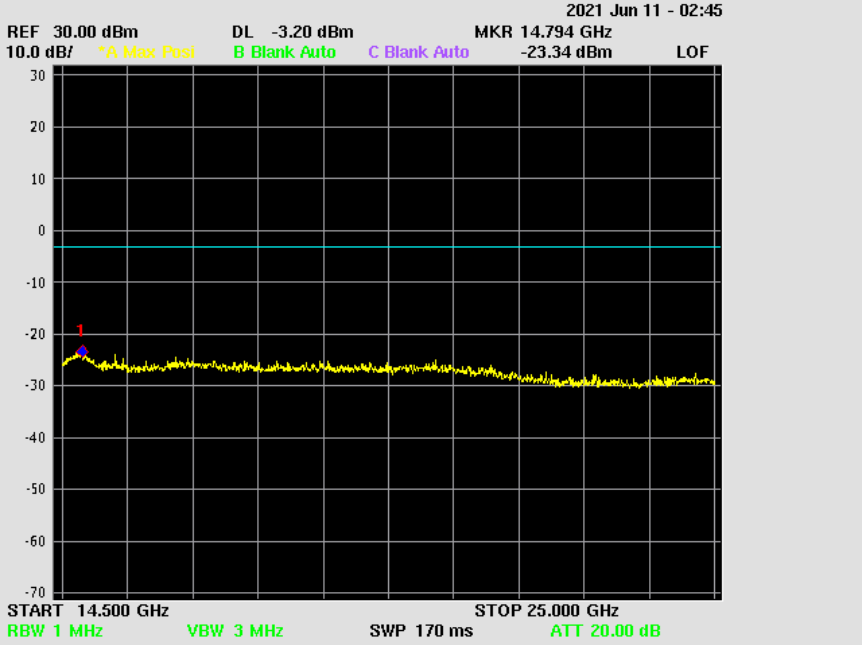

Figure 9. Conducted Spurious Emissions: High Channel, 14.5 – 25 GHz

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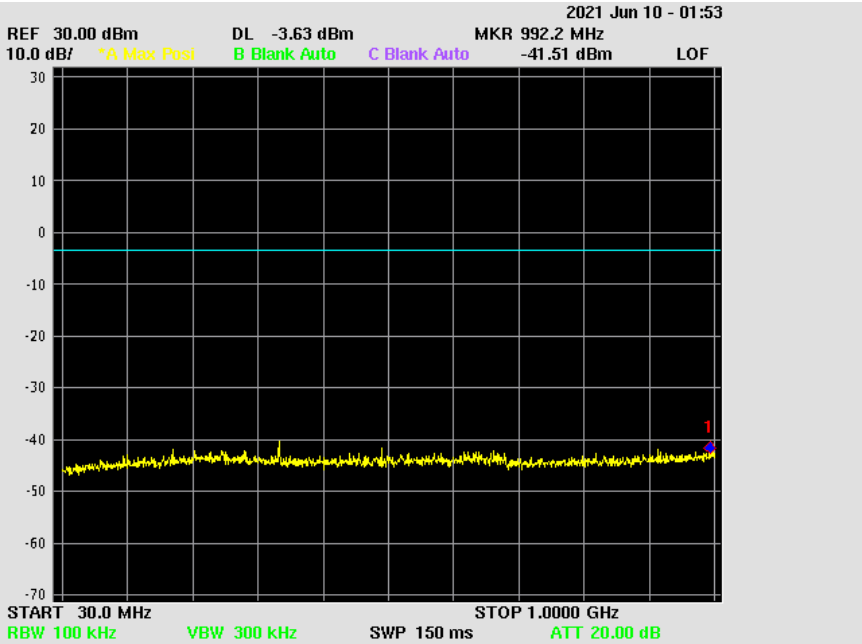

Figure 10. Conducted Spurious Emissions: Mid Channel, 30 MHz - 1 GHz

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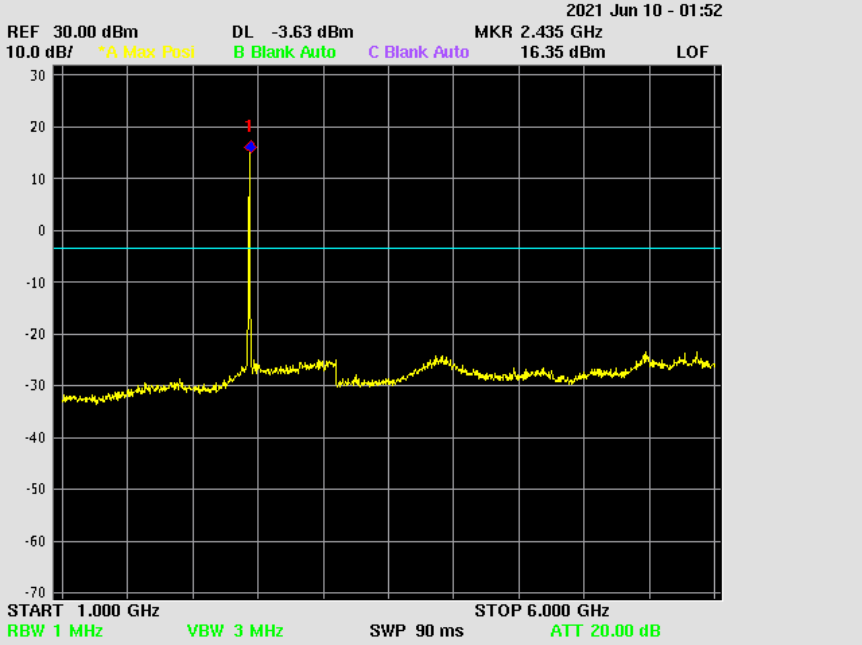

Figure 11. Conducted Spurious Emissions: Mid Channel, 1 – 6 GHz

Large Signal shown is fundamental frequency

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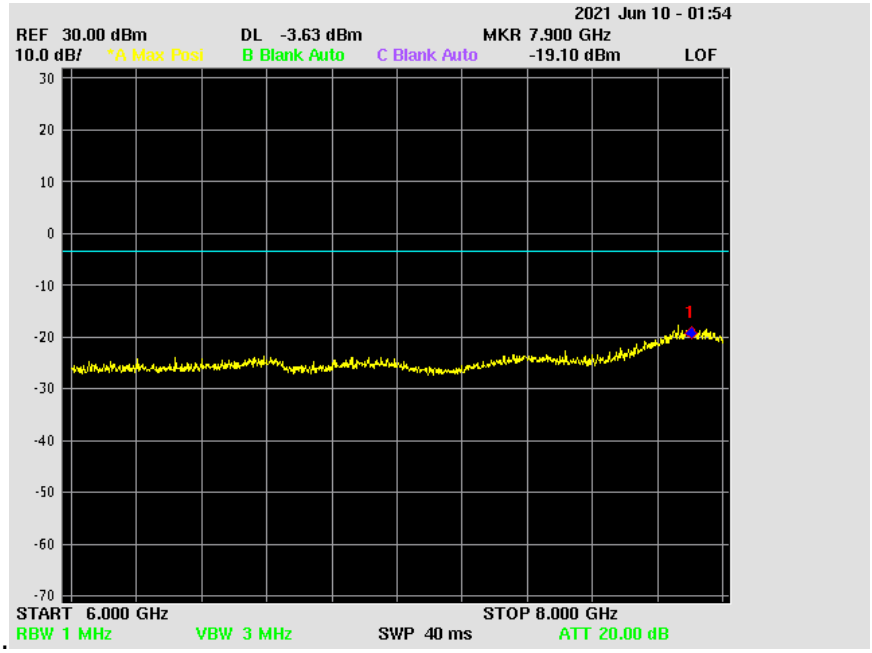


Figure 12. Conducted Spurious Emissions: Mid Channel, 6 – 8 GHz

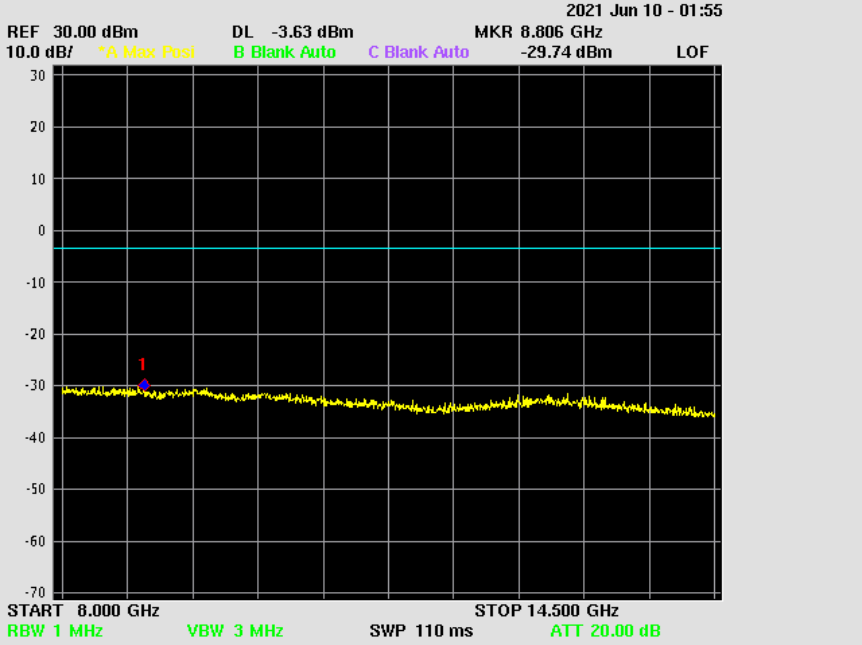


Figure 13. Conducted Spurious Emissions: Mid Channel, 8 – 14.5 GHz

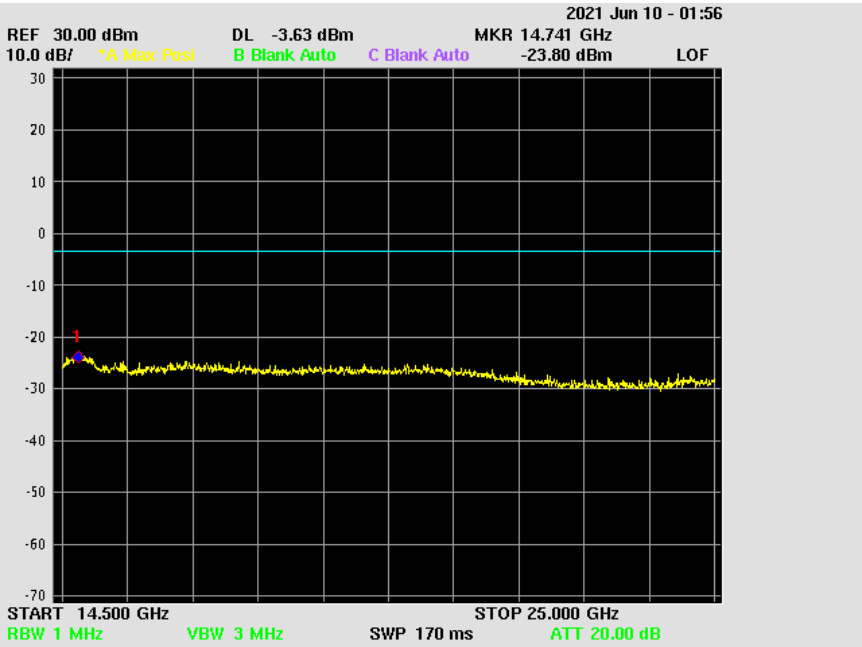


Figure 14. Conducted Spurious Emissions: Mid Channel, 14.5 – 25 GHz

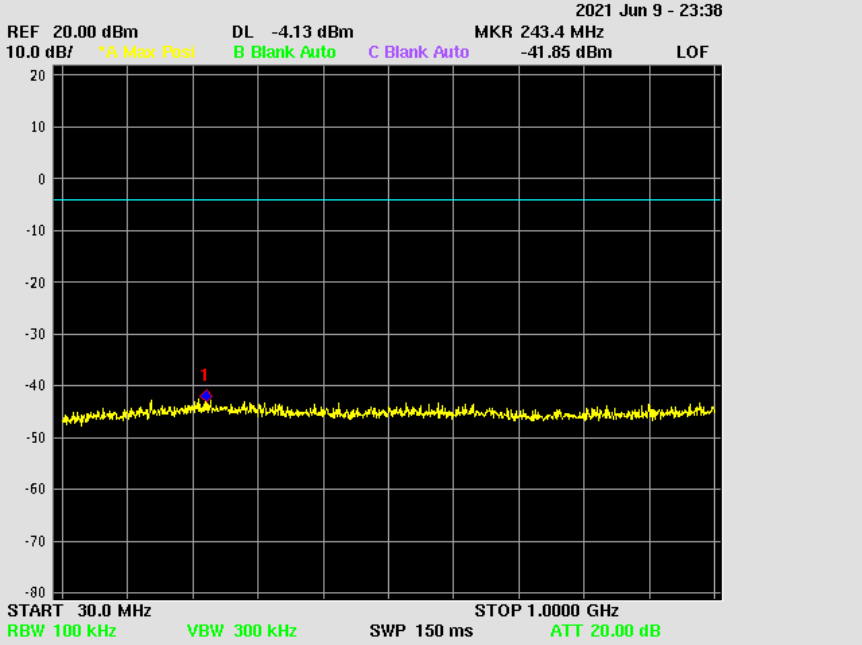


Figure 15. Conducted Spurious Emissions: Low Channel, 30 MHz – 1 GHz

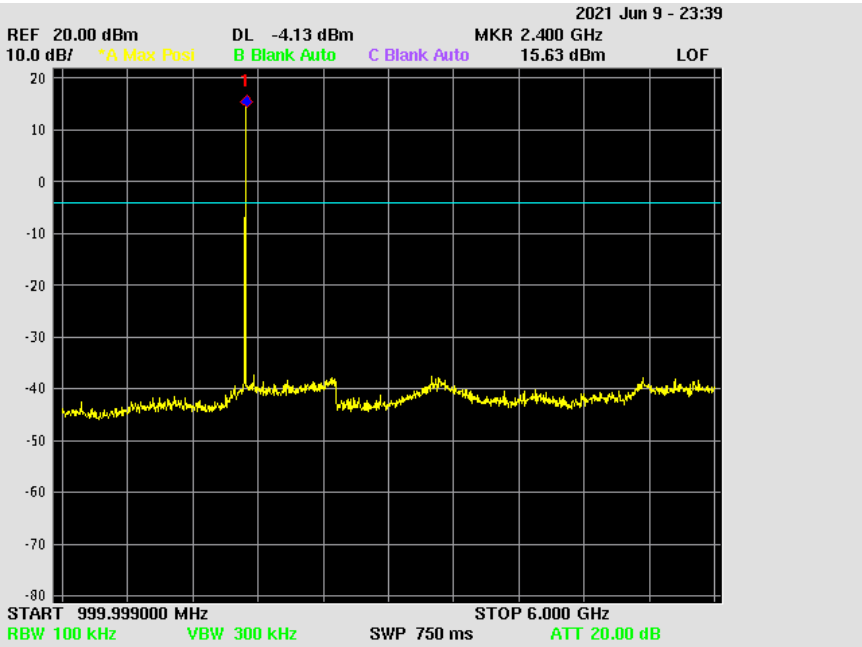


Figure 16. Conducted Spurious Emissions: Low Channel, 1 – 6 GHz

Large Signal shown is fundamental frequency

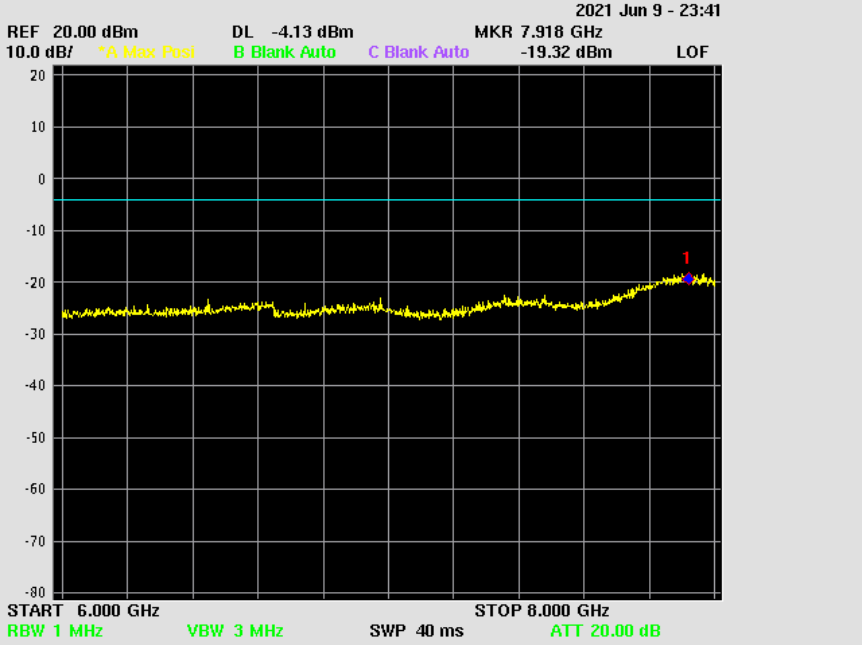


Figure 17. Conducted Spurious Emissions: Low Channel, 6 – 8 GHz

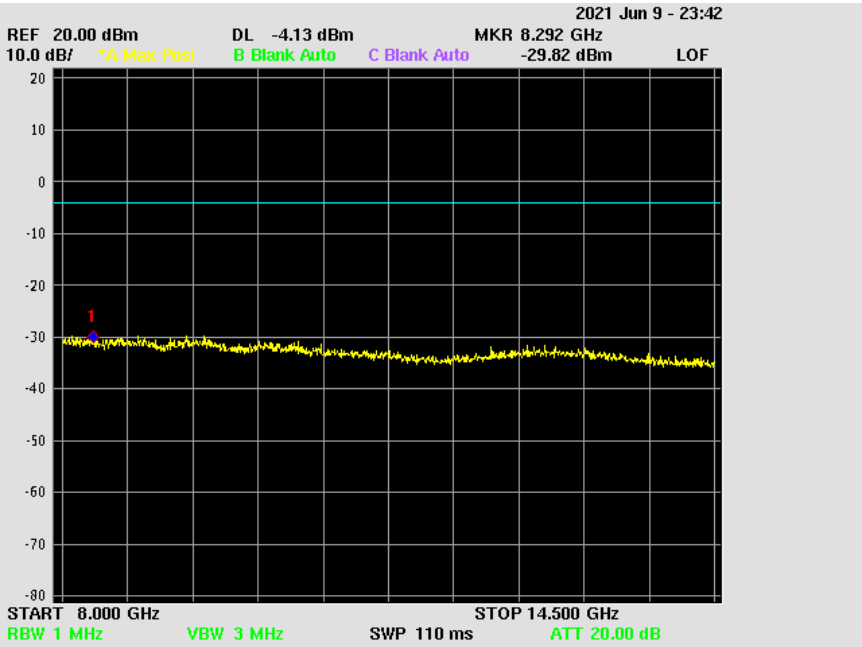


Figure 18. Conducted Spurious Emissions: Low Channel, 8 – 14.5 GHz

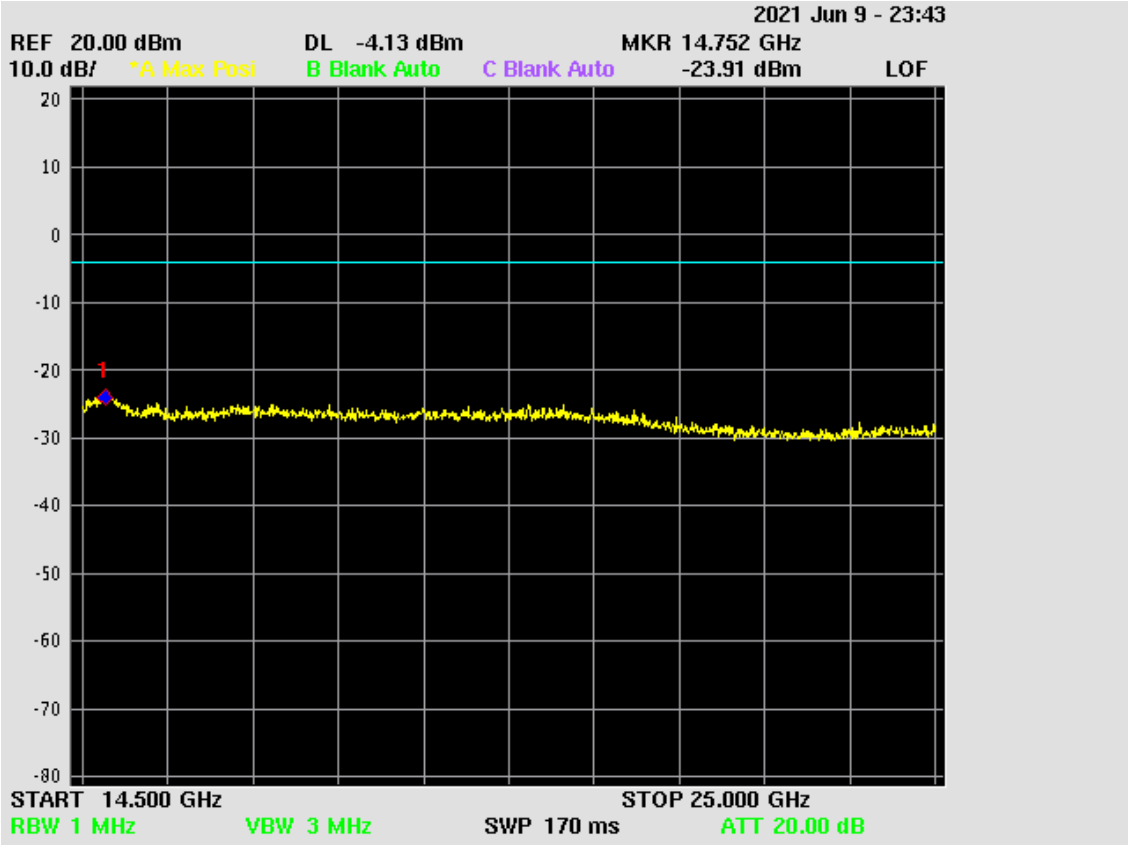


Figure 19. Conducted Spurious Emissions: Low Channel, 14.5 – 25 GHz

2.11 Intentional Radiator, Radiated Emissions (CFR 15.209, 15.247(d))

Inside the semi-anechoic test chamber, the EUT was placed on top of a non-conductive table, 150 cm above the floor, positioned along the X axis with its back side in parallel with the floor. The front of the EUT faced the measurement antenna located 3 meters away. Each signal measured was maximized by raising and lowering the receive antenna between 1 and 4 meters in height while monitoring the ever changing spectrum analyzer display (with channel A in the Clear-Write mode and channel B in the Max-Hold mode) for the largest signal visible. That exact antenna height where the signal was maximized was recorded for reproducibility purposes. Also, the EUT was rotated about its Y-axis while monitoring the Spectrum Analyzer display for maximum. The EUT azimuth was recorded for reproducibility purposes. The EUT was measured when both maxima were simultaneously satisfied.

For radiated measurements, the EUT was set into a continuous transmission mode. Below 1 GHz, the RBW of the measuring instrument was set equal to 120 kHz. Peak measurements above 1 GHz were measured using a RBW = 1 MHz, with a VBW ≥ 3 x RBW. The results of peak radiated spurious emissions falling within restricted bands are given in Table 5 below. For average measurements above 1 GHz, the emissions were measured using an average detector.

Table 6. Radiated Fundamental and Harmonics: EUT (X-position) with Corner Antenna (Y position)

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarity	Margin (dB)	Detector
Low Channel								
2401.69	83.04	--	28.83	111.87	--	3.0m./HOR	--	**PK**
4803.38	51.85	--	3.55	55.40	74.0	3.0m./HOR	18.6	**PK**
4803.38	35.11		3.55	38.66	54.0	3.0m./HOR	15.3	**AVG**
7204.59*	57.22	-9.50	3.92	51.64	54.0*	1.0m./VERT	2.4*	**PK**
9604.25*	50.87	-9.50	2.61	43.98	54.0*	1.0m./VERT	10.0*	**PK**
Note 1	--	--	--	--	--	--	--	--
Middle Channel								
2435.79	82.15	--	28.98	111.13	--	3.0m./HOR	--	**PK**
4871.58	50.78	--	3.61	54.39	--	3.0m./HOR	--	**PK**
4871.58	34.88		3.61	38.49	54.0	3.0m./HOR	15.5	**AVG**
7306.81*	54.43	-9.50	4.66	49.59	54.0*	1.0m./HOR	4.4*	**PK**
Note 1	--	--	--	--	--	--	--	--
High Channel								
2469.89	86.18	--	31.47	117.65	--	3.0m./VERT	--	**PK**
4939.78	51.09		4.30	55.39	74.0	3.0m./HOR	18.6	**PK**
4939.776	29.72		4.30	34.02	54.0	3.0m./HOR	20.0	**AVG**
7409.26*	55.65	-9.50	4.96	51.11	54.0*	1.0m./HOR	2.9*	**PK**
Note 1	--	--	--	--	--	--	--	--

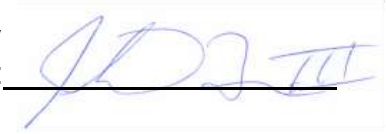
Notes:

1. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic
2. A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.
3. (*) = Peak Measurement compared to Average limits.

Sample Calculation at 2401.6896 MHz:

Magnitude of Measured Frequency	83.04	dBuV
+Additional Factor (Duty Cycle Correction)	0.00	dB
+Antenna Factor + Cable Loss - Amplifier Gain	28.83	dB/m
Corrected Result	111.87	dBuV/m

Test Date: May 18, 2021

Tested By
Signature:  Name: John Freeman

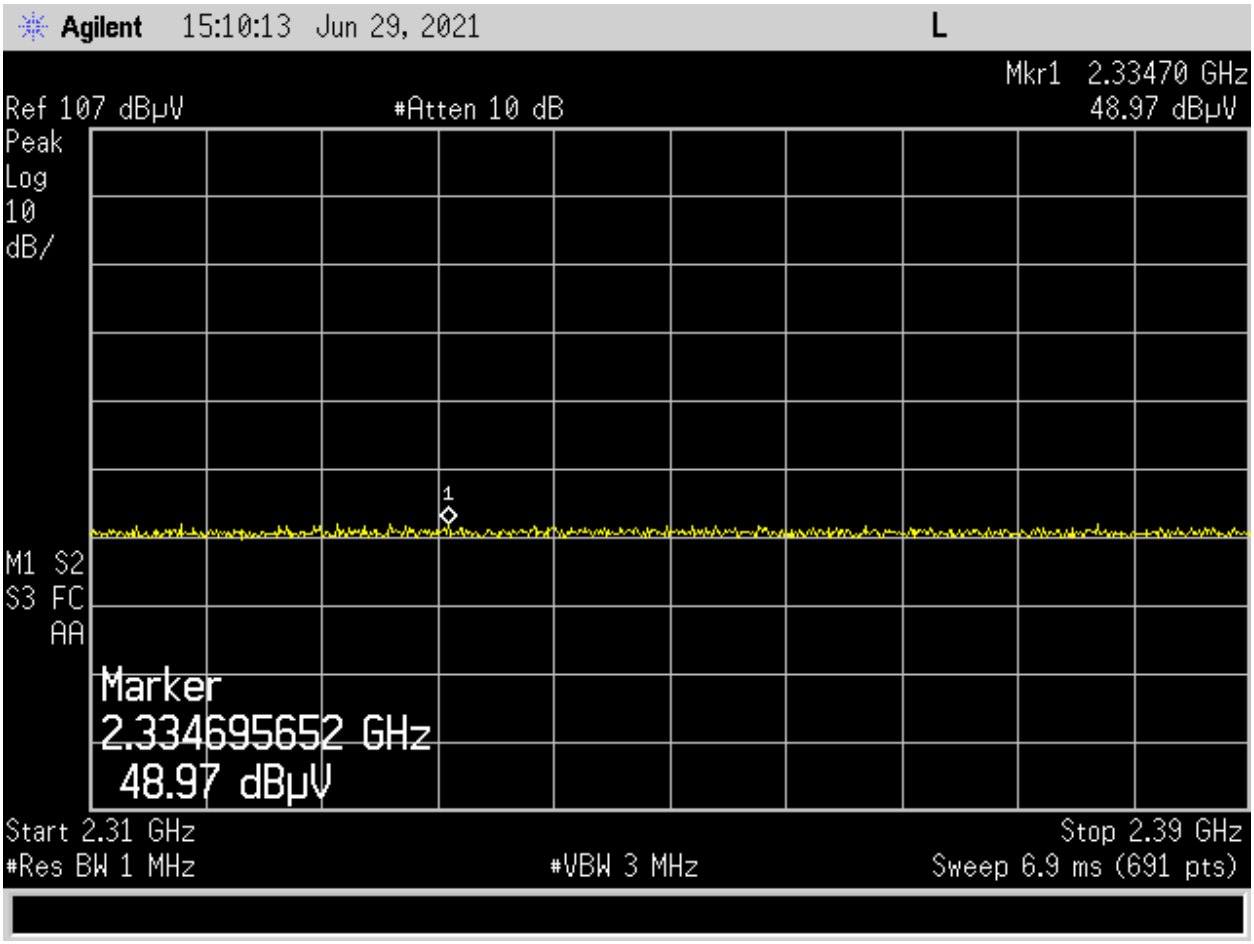


Figure 20. Lower Restricted Band Edge – EUT with Corner Antenna (Peak)

Lower Restricted Band Edge – Peak								
2334.70	48.97	-9.50	28.91	68.38	74.0	1.0m./HOR	5.6	**PK**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

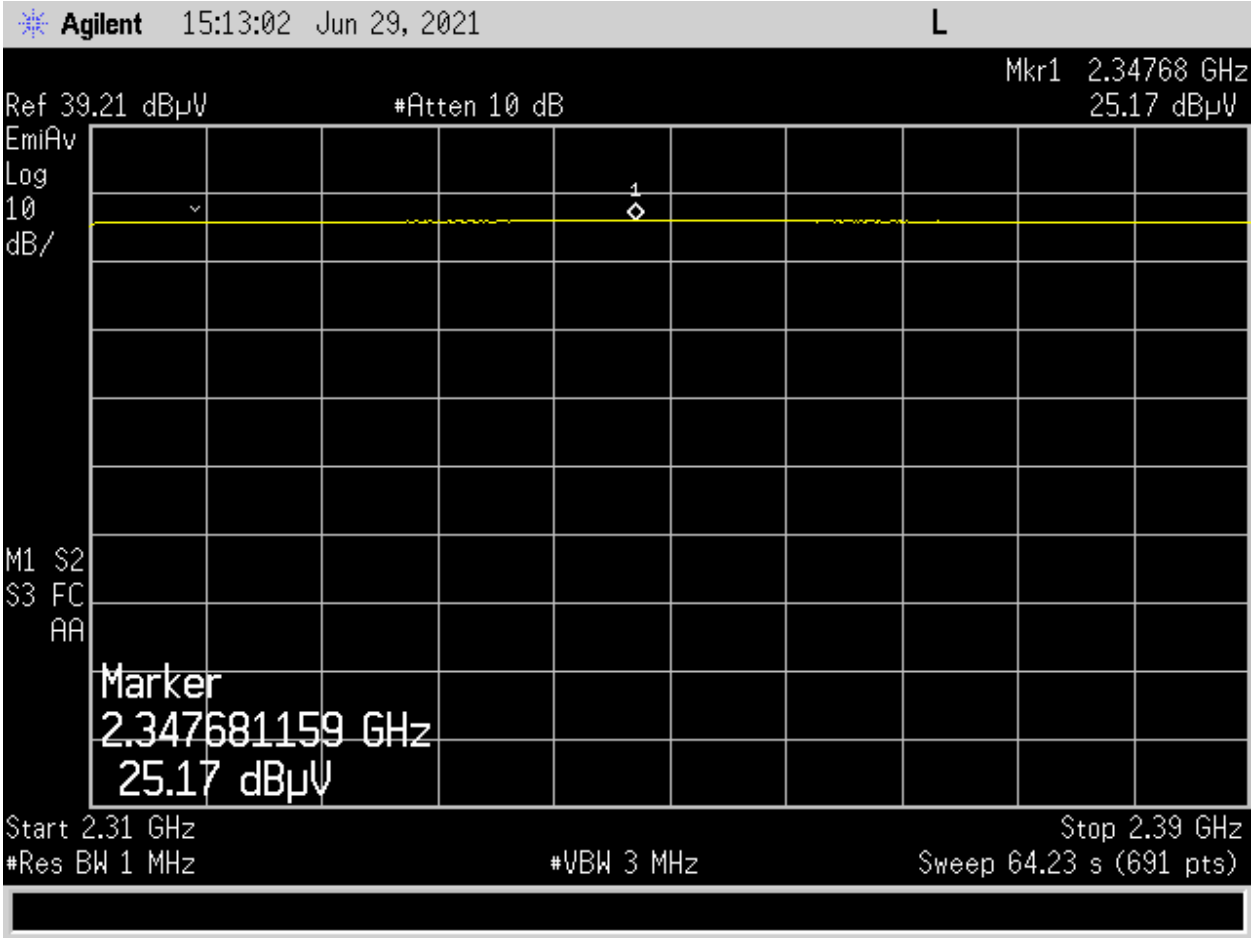


Figure 21. Lower Restricted Band Edge - Corner Antenna (Average)

Lower Restricted Band Edge – Average								
2347.68	25.17	-9.50	28.91	44.58	54.0	1.0m./HOR	9.4	**AVG**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

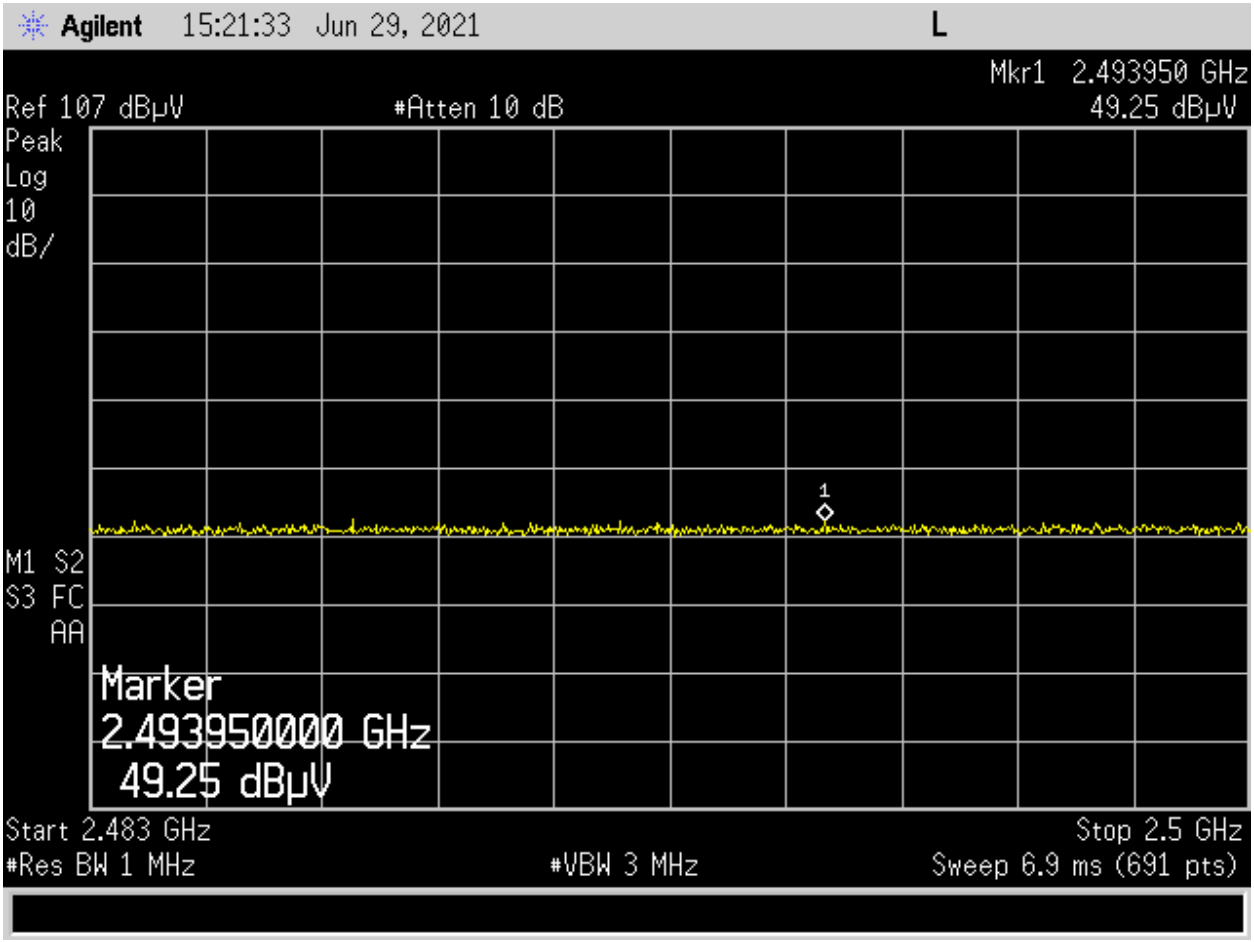


Figure 22. Upper Restricted Band Edge – EUT with Corner Antenna (Peak)

Upper Restricted Band Edge – Peak								
2493.95	49.25	-9.50	29.37	69.12	74.0	1.0m./HOR	4.9	**PK**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

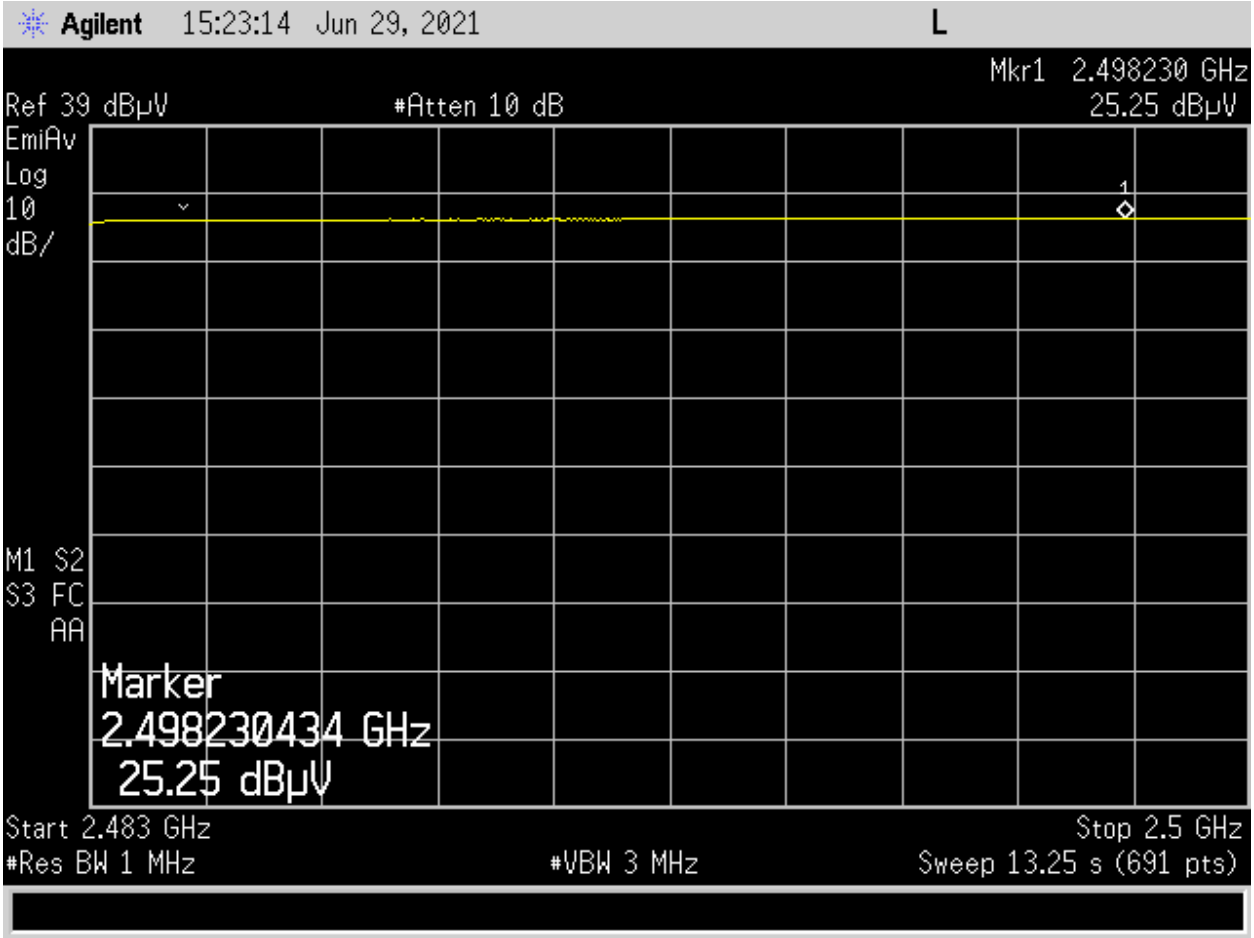


Figure 23. Upper Restricted Band Edge - Corner Antenna (Average)

Upper Restricted Band Edge – Average								
2498.23	25.25	-9.50	29.37	45.12	54.0	1.0m./HOR	8.9	**AVG**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

Table 7. Radiated Fundamental, Harmonics & Restricted Band Edges: EUT (Y-position) with Dipole Antenna (Y-position)

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarity	Margin (dB)	Detector
Low Channel								
2401.69	80.64	--	26.47	107.11	--	3.0m./VERT	--	**PK**
4803.38*	50.42	--	-0.05	50.37	54.0*	3.0m./VERT	3.6*	**PK**
7205.10*	54.50	-9.50	3.92	48.92	54.0*	1.0m./VERT	5.1*	**PK**
9606.14*	51.31	-9.50	2.61	44.42	54.0*	1.0m./VERT	9.6*	**PK**
Note 1	--	--	--	--	--	--	--	--
Middle Channel								
2435.79	82.62	--	26.58	109.20	--	3.0m./VERT	--	**PK**
4872.48*	50.70	--	0.13	50.83	54.0*	3.0m./HOR	3.2*	**PK**
7307.87*	53.04	-9.50	4.64	48.18	54.0*	1.0m./VERT	5.8*	**PK**
Note 1	--	--	--	--	--	--	--	--
High Channel								
2469.89	81.97	--	26.49	108.46	--	3.0m./VERT	--	**PK**
4940.80*	49.86	--	0.76	50.62	54.0*	3.0m./VERT	3.4	**PK**
7409.33*	53.86	-9.50	4.91	49.27	54.0*	1.0m./VERT	4.7*	**PK**
Note 1	--	--	--	--	--	--	--	--

Notes:

1. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic
2. A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.
3. (*) = Peak Measurement compared to Average limits.

Sample Calculation at 2401.6896 MHz:

Magnitude of Measured Frequency	83.04	dBuV
+Additional Factor (Duty Cycle Correction)	0.00	dB
+Antenna Factor + Cable Loss - Amplifier Gain	28.83	dB/m
Corrected Result	111.87	dBuV/m

Test Date: May 18, 2021

Tested By
Signature: 

Name: John Freeman

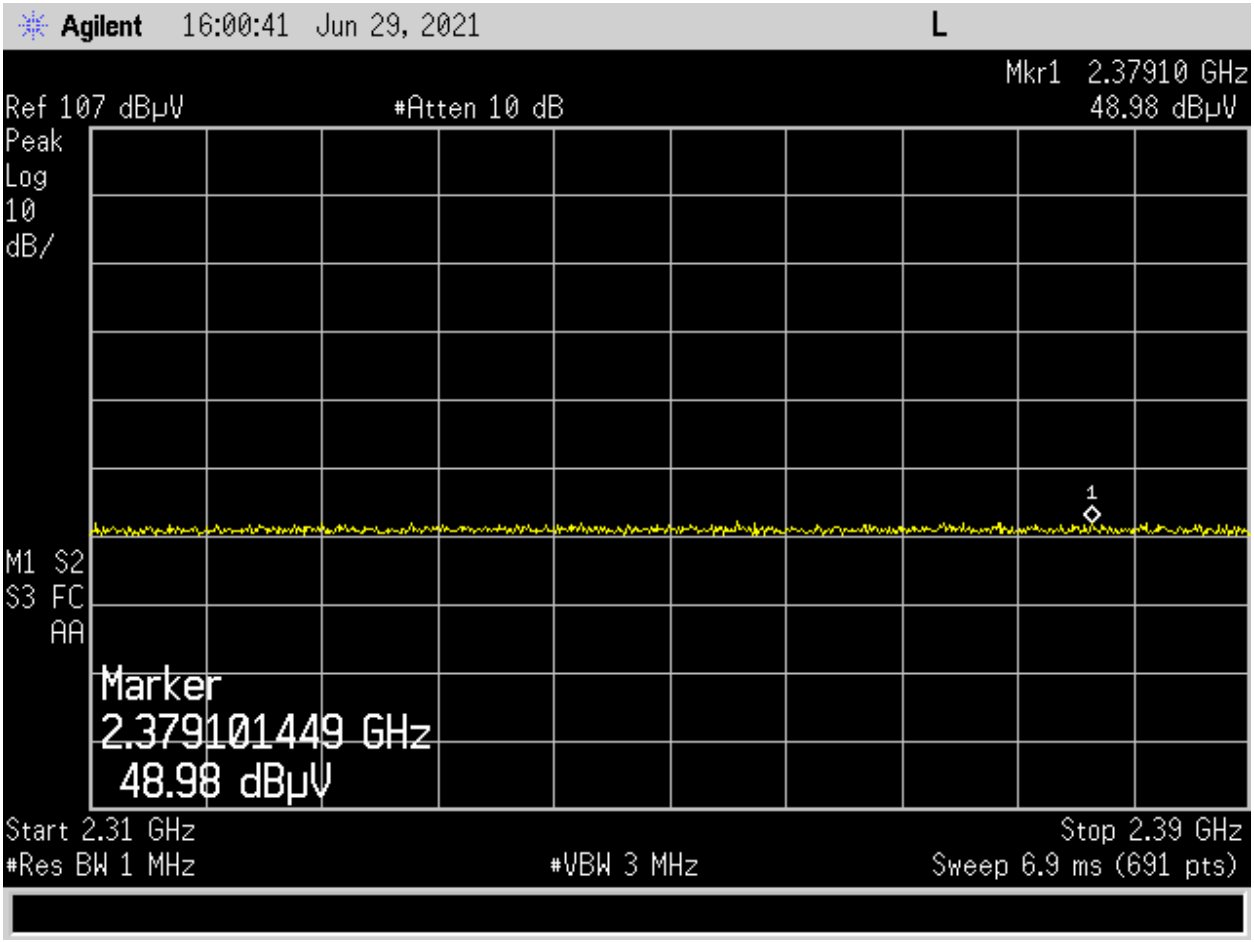


Figure 24. Lower Restricted Band Edge – EUT with Dipole Antenna (Peak)

Lower Restricted Band Edge – Peak								
2379.10	48.98	-9.50	29.11	68.59	74.0	1.0m./HOR	5.4	**PK**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

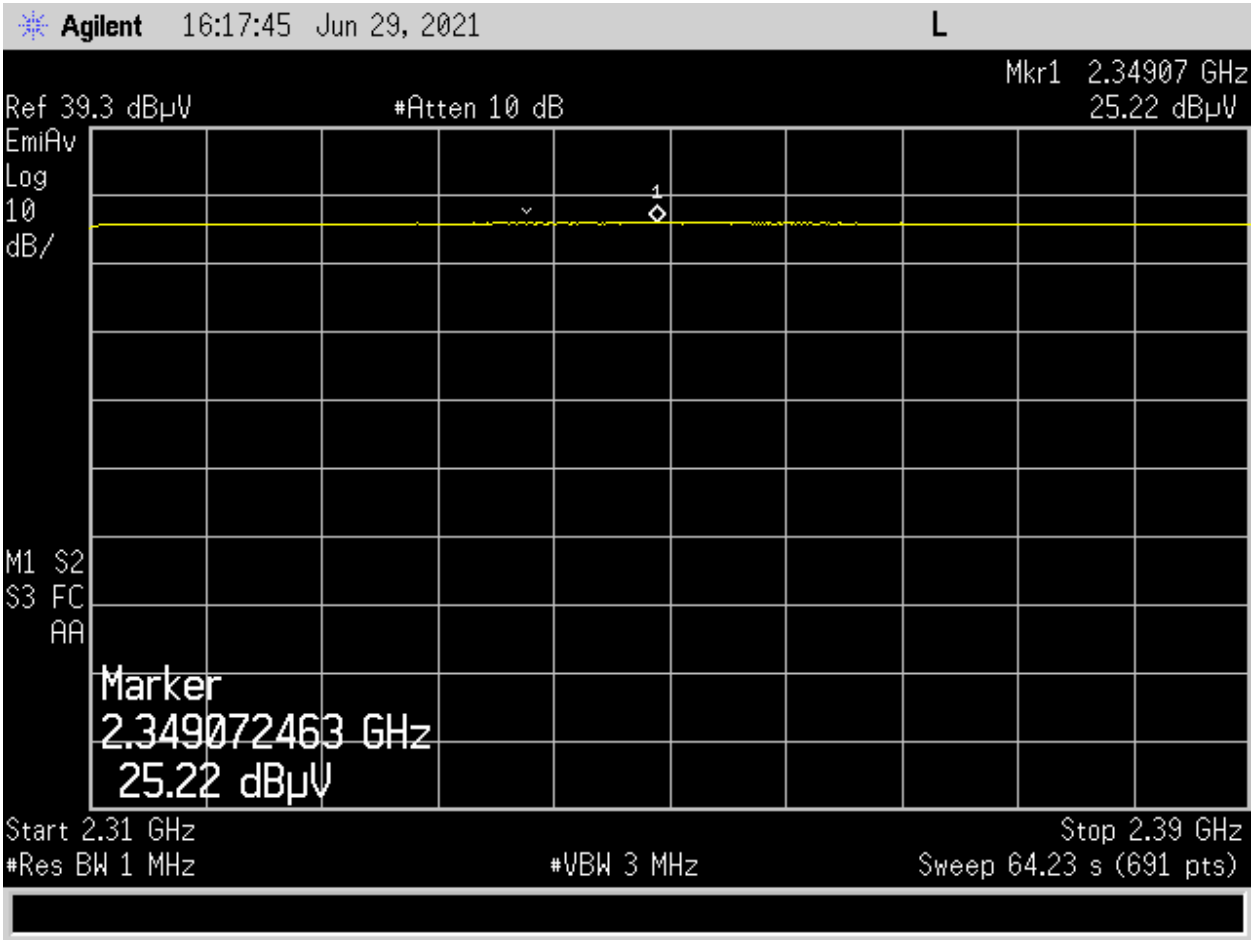


Figure 25. Lower Restricted Band Edge - Dipole Antenna (Average)

Lower Restricted Band Edge – Average								
2349.07	25.22	-9.50	28.91	44.63	54.0	1.0m./HOR	9.4	**AVG**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

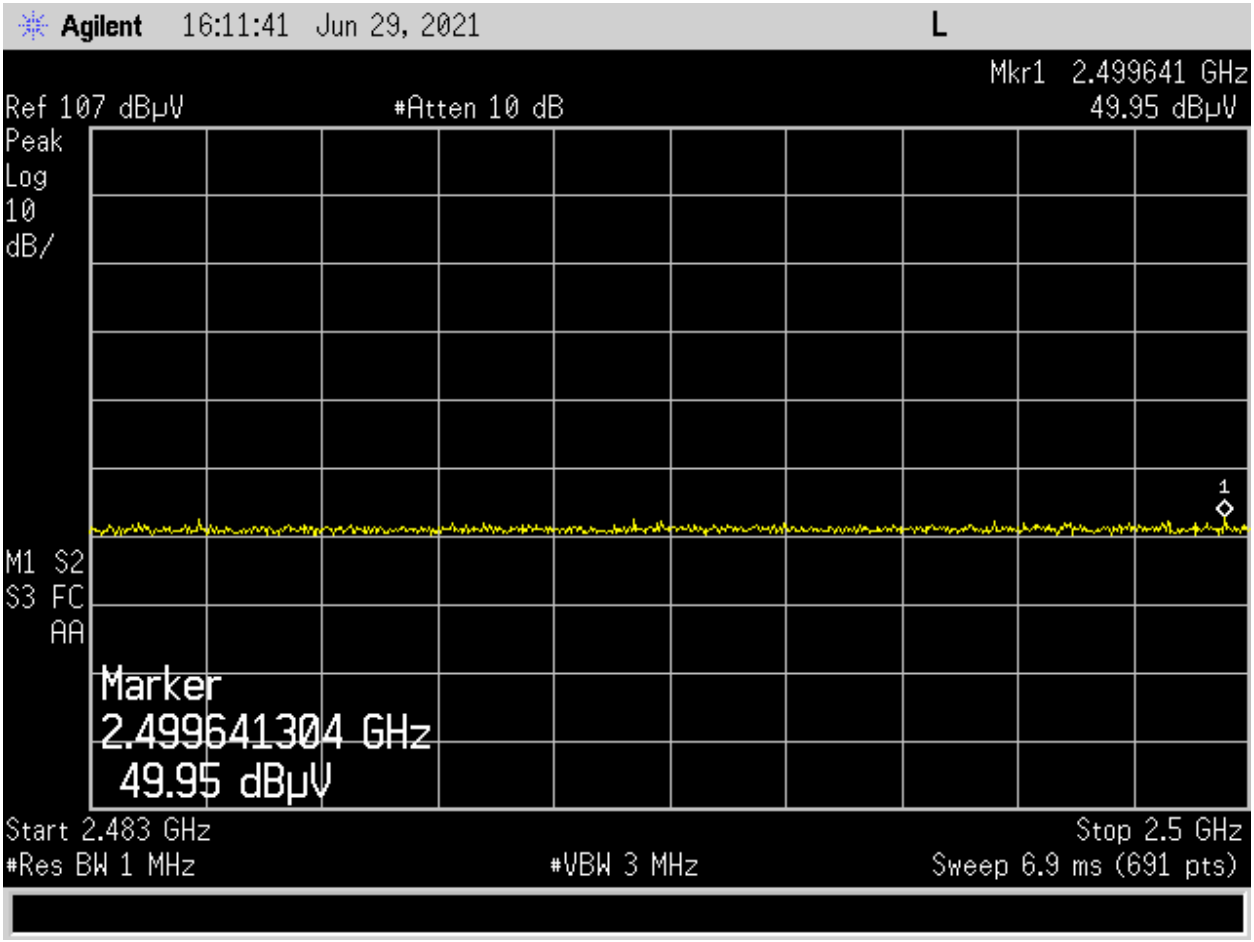


Figure 26. Upper Restricted Band Edge – EUT with Dipole Antenna (Peak)

Upper Restricted Band Edge – Peak								
2499.64	49.95	-9.50	29.37	69.82	74.0	1.0m./HOR	4.2	**PK**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

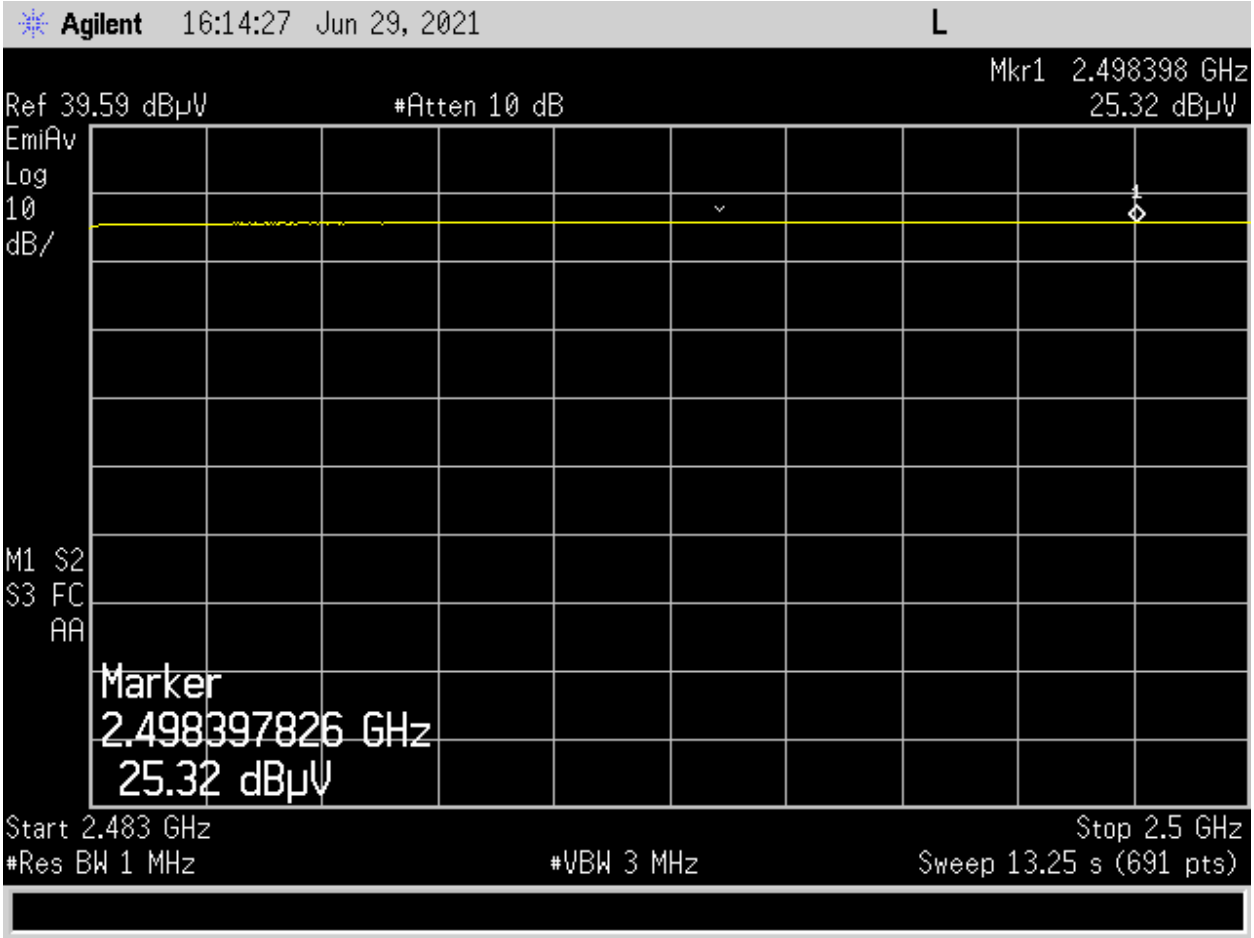


Figure 27. Upper Restricted Band Edge - Dipole Antenna (Average)

Upper Restricted Band Edge – Average								
2498.40	25.32	-9.50	29.37	45.19	54.0	1.0m./HOR	8.8	**AVG**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

Table 8. Radiated Fundamental, Harmonics & Restricted Band Edges, EUT (X-position) with Patch Antenna (Z-position)

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarity	Margin (dB)	Detector
Low Channel								
2401.69	81.61	--	28.83	110.44	--	3.0m./HORZ	--	**PK**
4803.38	50.52	--	3.55	54.07	74.0	3.0m./HORZ	19.9	**PK**
4803.38	29.57	--	3.55	33.12	54.0	3.0m./HORZ	20.9	**AVG**
7205.24*	55.82	-9.50	3.98	50.30	54.0*	1.0m./VERT	3.7	**PK**
9607.43*	50.30	-9.50	2.61	43.41	54.0*	1.0m./VERT	10.6	**PK**
Note 1	--	--	--	--	--	--	--	--
Middle Channel								
2435.84	84.14	--	26.63	110.77	--	3.0m./HORZ	--	**PK**
4871.30*	50.70	--	-0.02	50.68	54.0*	3.0m./VERT	3.3	**PK**
7307.87*	52.65	-9.50	4.64	47.79	54.0*	1.0m./VERT	6.2	**PK**
Note 1	--	--	--	--	--	--	--	--
High Channel								
2469.89	81.65	--	28.99	110.64	--	3.0m./HORZ	--	**PK**
4939.78	50.79	--	4.18	54.97	74.0	3.0m./VERT	19.0	**PK**
4939.78	30.98	--	4.18	35.16	54.0	3.0m./VERT	18.8	**AVG**
7409.33*	51.38	-9.50	4.91	46.79	54.0*	1.0m./VERT	7.2	**PK**
Note 1	--	--	--	--	--	--	--	--

Notes:

1. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic
2. A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.
3. (*) = Peak Measurement compared to Average limits.

Sample Calculation at 2401.6896 MHz:

Magnitude of Measured Frequency	81.61	dBuV
+Additional Factor (Duty Cycle Correction)	0.00	dB
+Antenna Factor + Cable Loss - Amplifier Gain	28.83	dB/m
Corrected Result	110.44	dBuV/m

Test Date: May 18, 2021

Tested By
Signature: 

Name: John Freeman

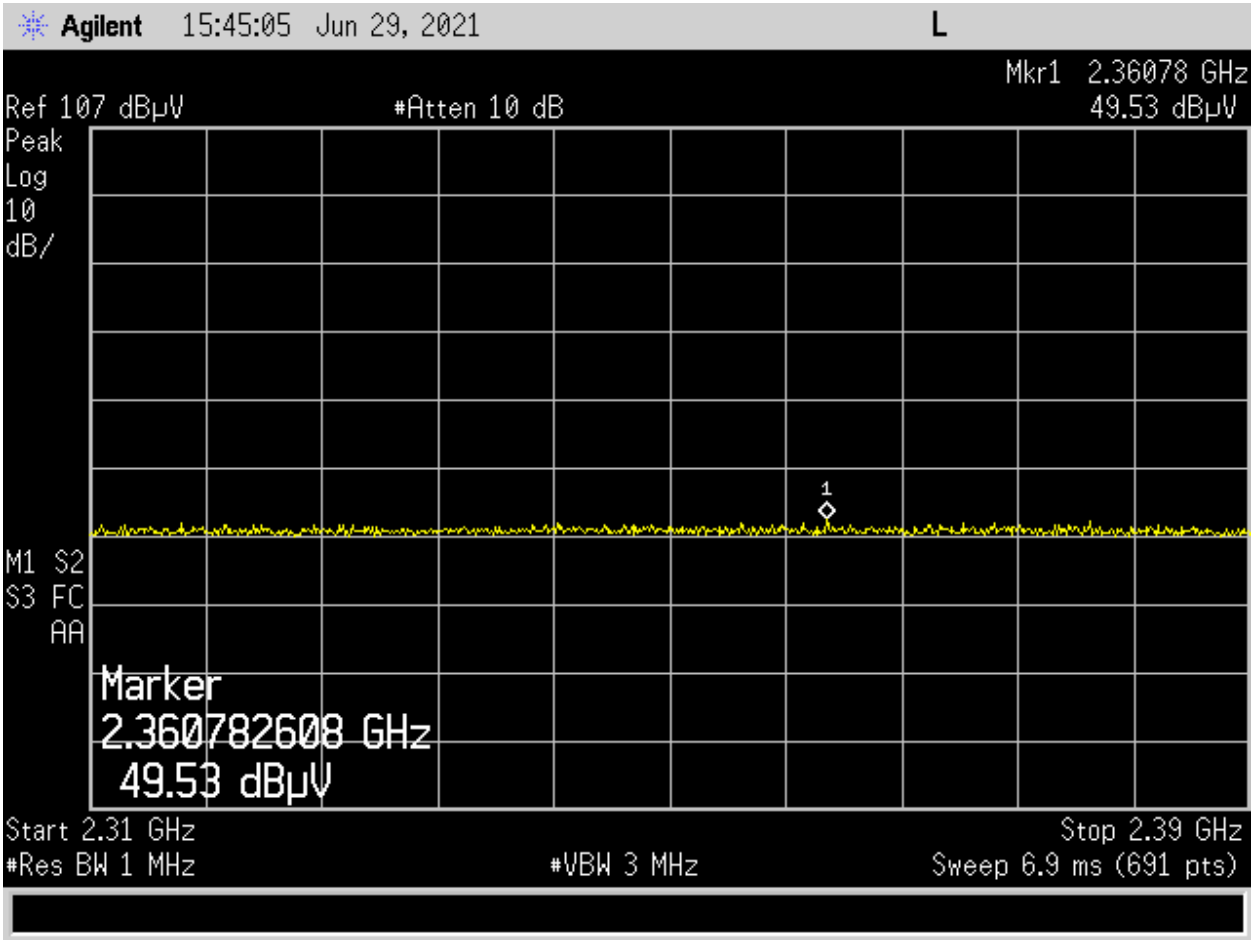


Figure 28. Lower Restricted Band Edge – EUT with Patch Antenna (Peak)

Lower Restricted Band Edge – Peak								
2360.78	49.53	-9.50	29.11	69.14	74.0	1.0m./HOR	4.9	**PK**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

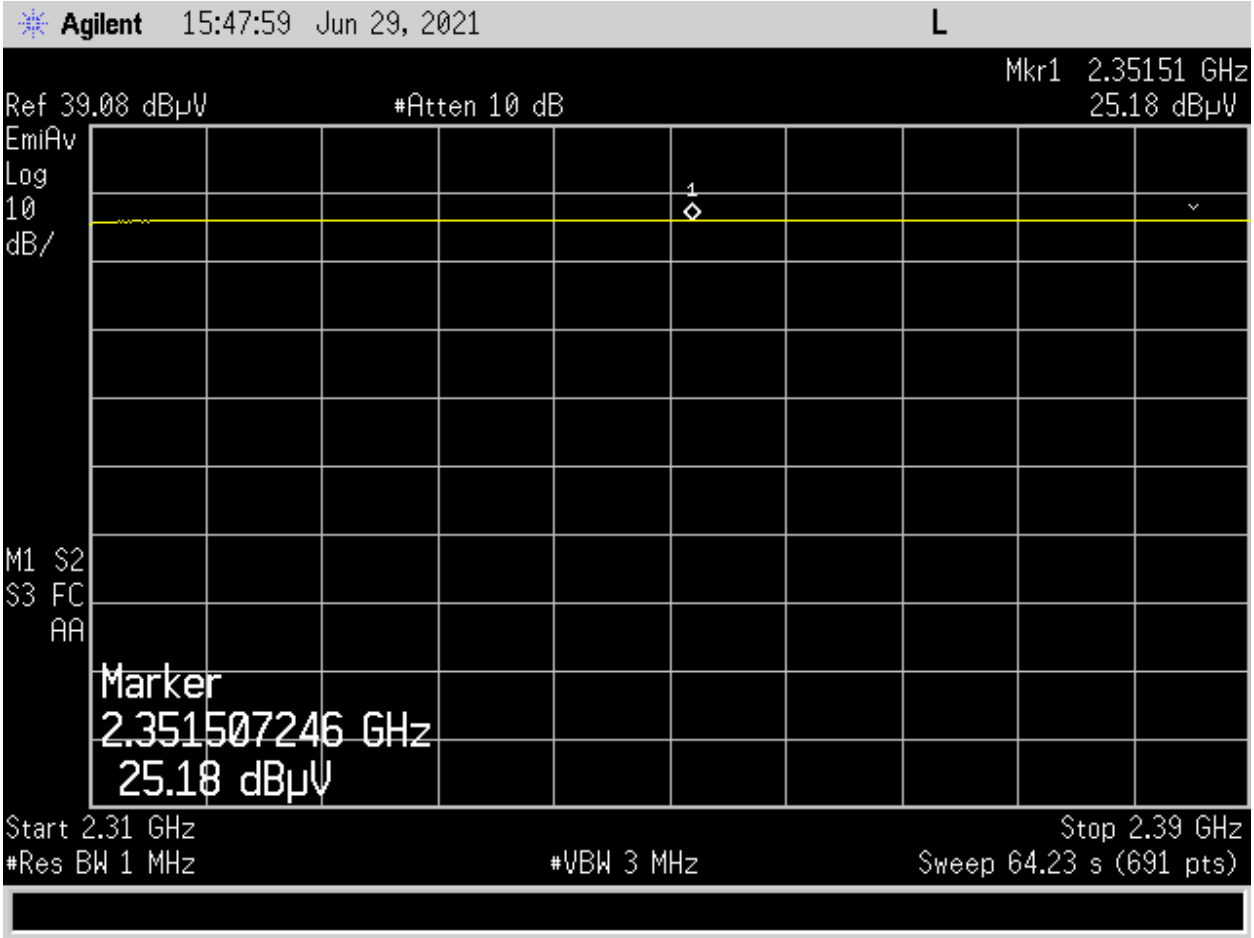


Figure 29. Lower Restricted Band Edge - Patch Antenna (Average)

Lower Restricted Band Edge – Average								
2351.51	25.18	-9.50	29.11	44.79	54.0	1.0m./HOR	9.2	**AVG**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

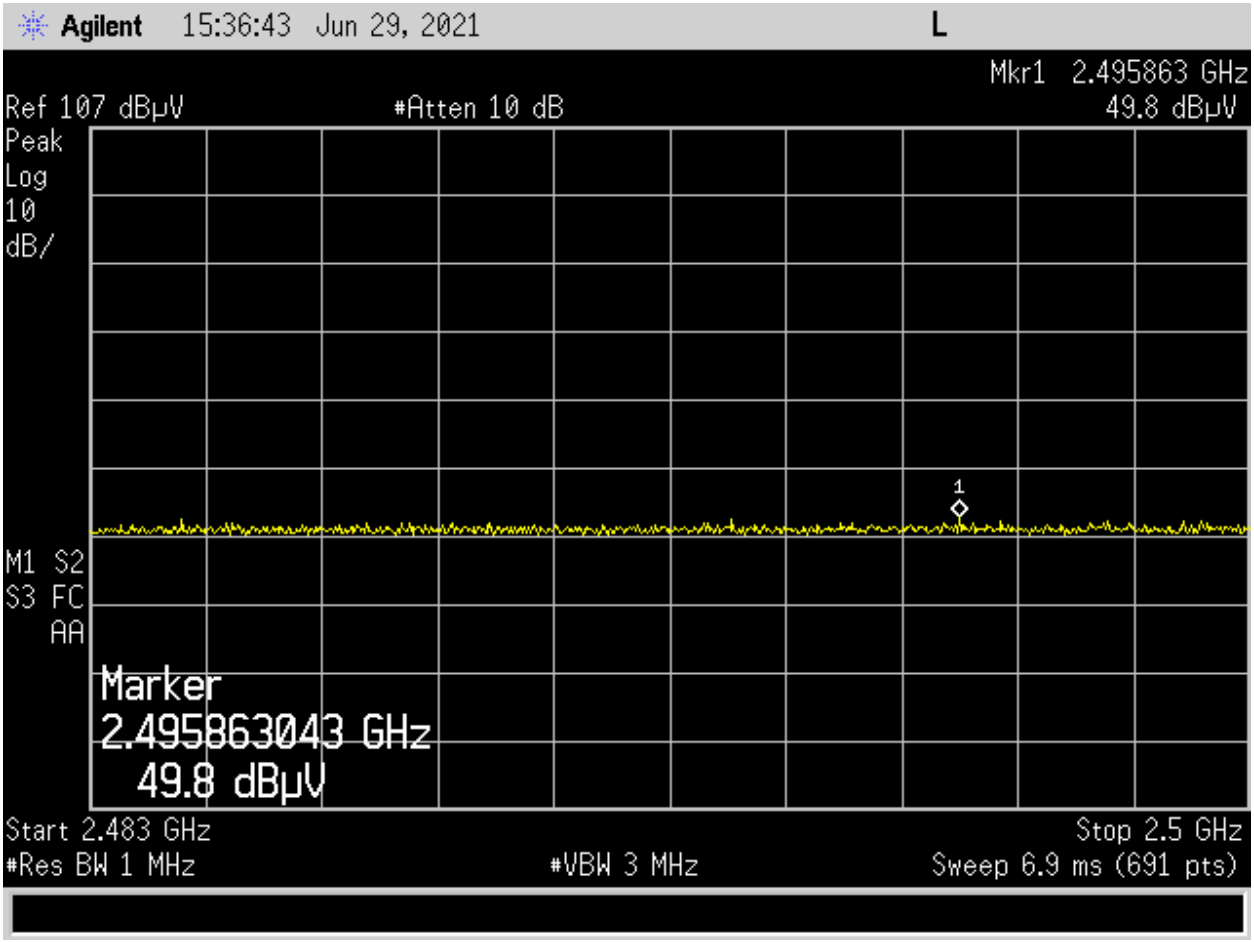


Figure 30. Upper Restricted Band Edge – EUT with Patch Antenna (Peak)

Upper Restricted Band Edge – Peak								
2495.86	49.80	-9.50	29.37	69.67	74.0	1.0m./HOR	4.3	**PK**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m.

Test Date: June 29, 2021

Tested By
Signature: _____ Name: Mark Afroozi

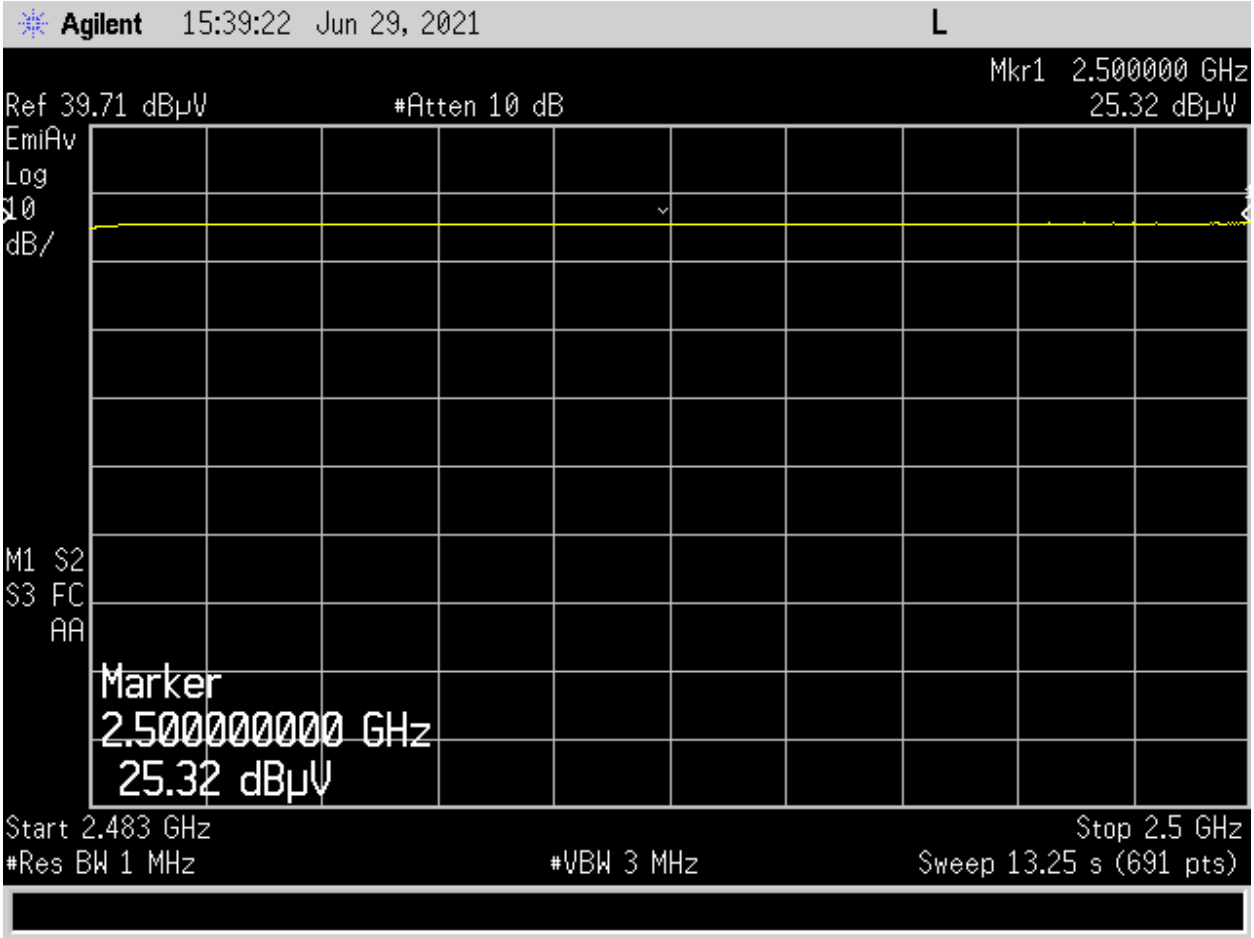


Figure 31. Upper Restricted Band Edge - Patch Antenna (Average)

Upper Restricted Band-edge – Average								
2500.00	25.32	-9.50	28.24	44.06	54.0	1.0m./HOR	9.9	**AVG**

A correction factor of -9.5 dB was applied to measurements made at a distance of 1 m

Test Date: June 29, 2021

Tested By
Signature: 

Name: Mark Afroozi

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

Band Edge measurements are made following the guidelines in FCC KDB Publication No. 558074 v05r02 with the EUT initially operating on the Lowest Channel and then operating on the Highest Channel within its band of operation. Antenna port conducted measurements are performed to demonstrate compliance with the requirement of 15.247(d) that all emissions outside of the band edges be attenuated by at least 20 dB when compared to its highest in-band value (contained in a 100 kHz band).

To capture the band edge, set the Spectrum Analyzer frequency span large enough (usually around 10 MHz) to capture the peak level of the emission operating on the channel closest to the band edge as well as any modulation products falling outside of the authorized band of operation. Conducted measurements are performed with RBW ≥1% of the frequency span. In all cases, the VBW is set ≥3 x RBW. See figures and calculations below for more detail.

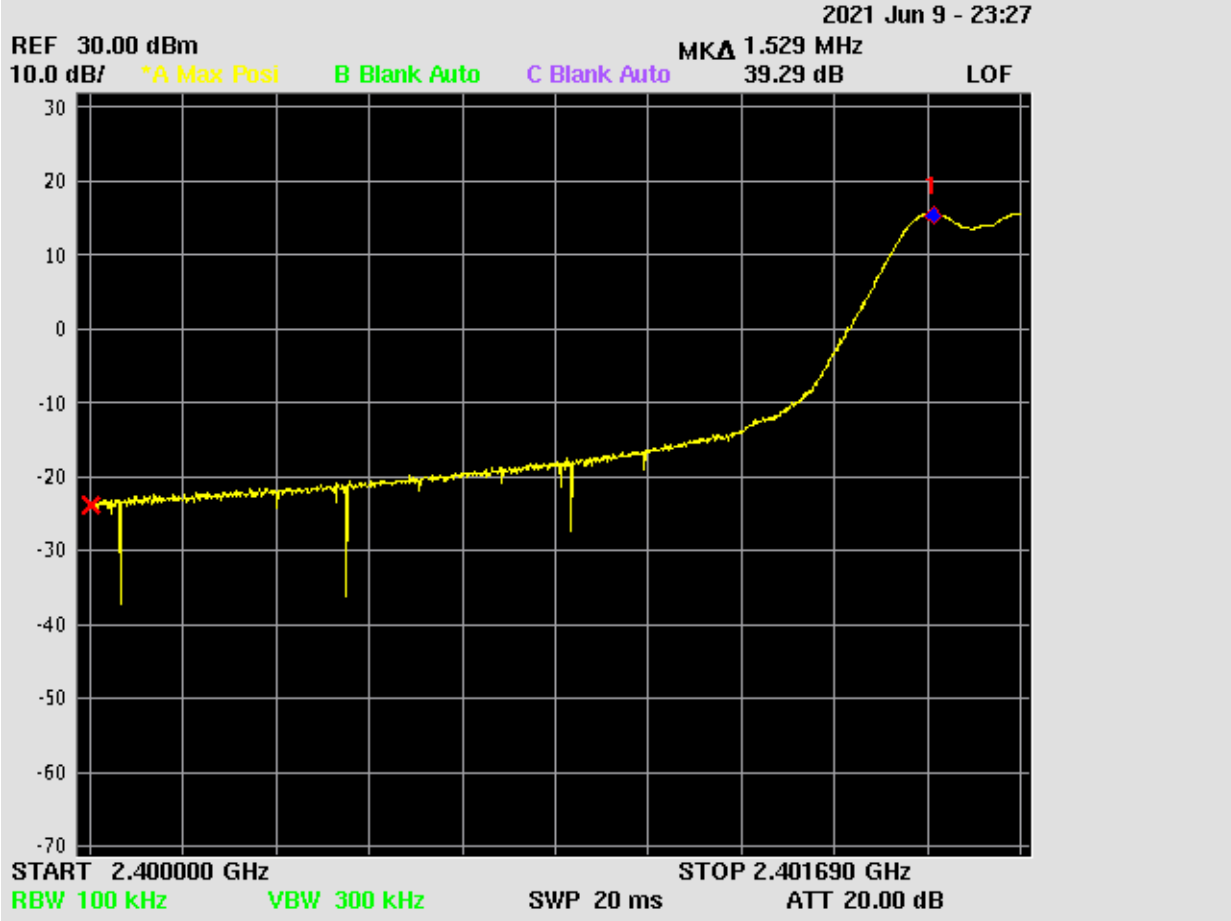


Figure 32. Band Edge Compliance: Low Channel

Lower band edge must be 20 dB below the peak of the fundamental frequency. This requirement is met.

Measured Result	39.29	dB
Band Edge Limit	20.00	dB
Band Edge Margin	19.29	dB

Test Date: June 9, 2021

Tested By
Signature: _____ Name: Mark Afroozi

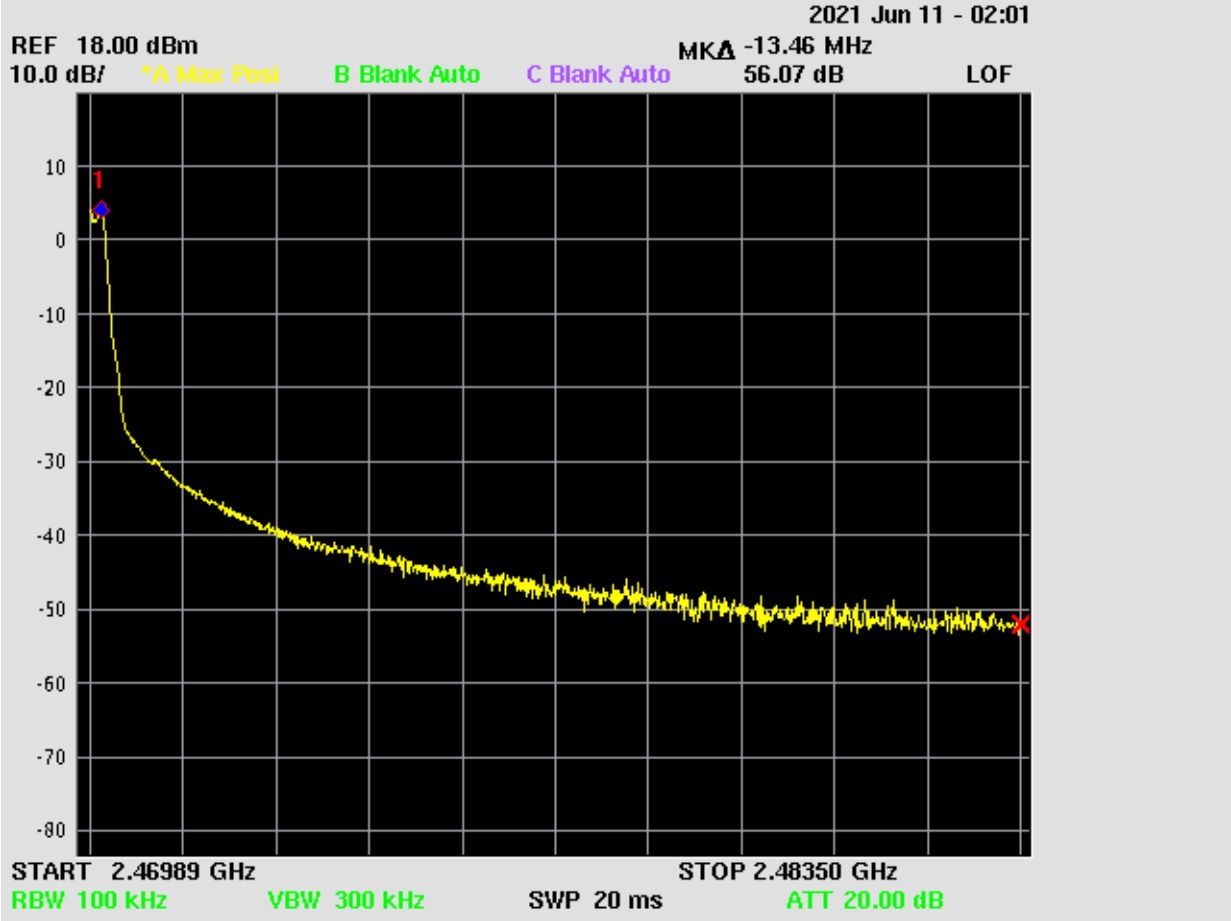


Figure 33. Band Edge Compliance: High Channel

Higher band edge must be 20 dB below the peak of the fundamental frequency. This requirement is met.

Measured Result	56.07	dB
Band Edge Limit	20.00	dB
Band Edge Margin	36.07	dB

Test Date: June 11, 2021

Tested By
Signature: _____ Name: Mark Afroozi

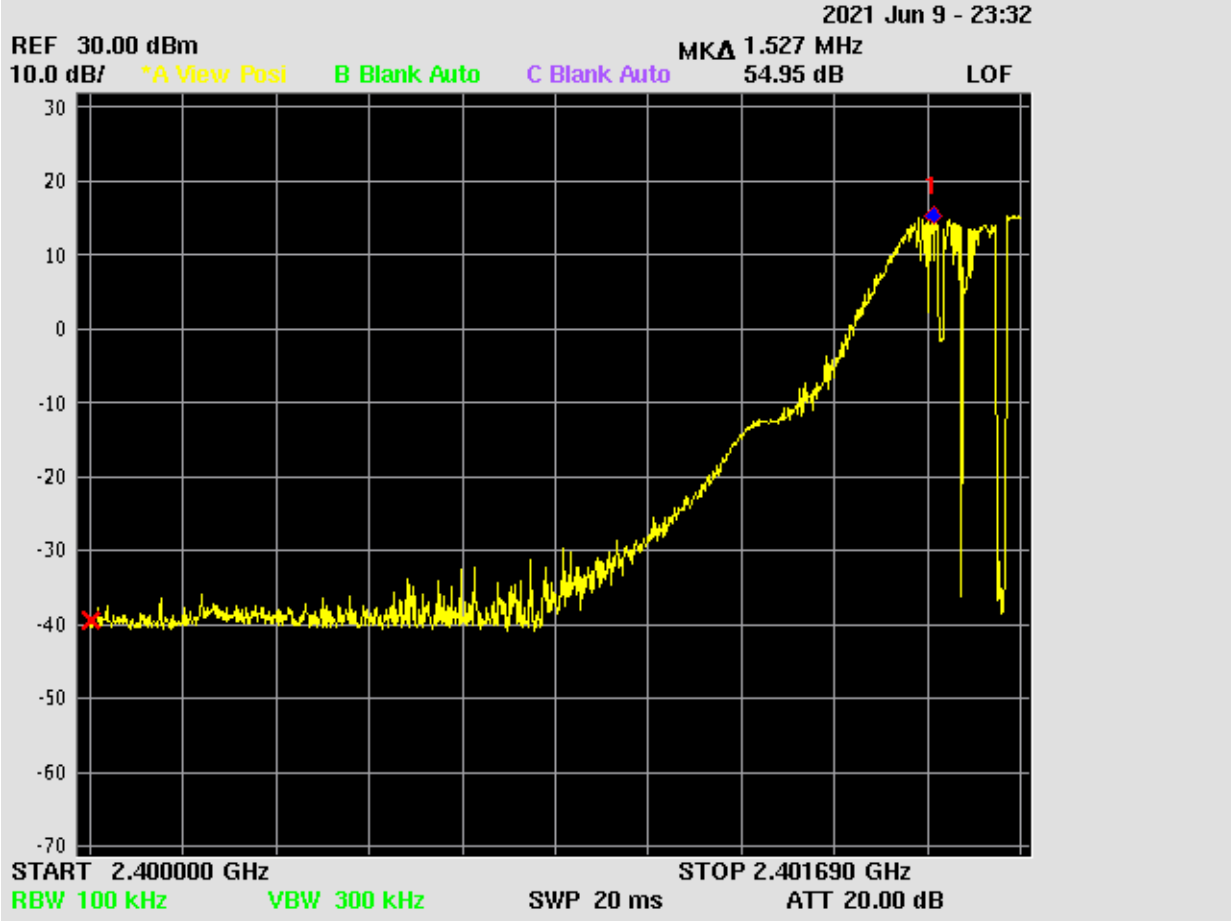


Figure 34. Band Edge Compliance with Hopping Mode Enabled: Low Channel

Lower band edge must be 20 dB below the peak of the fundamental frequency. This requirement is met.

.

Measured Result	54.95	dB
Band Edge Limit	20.00	dB
Band Edge Margin	34.95	dB

Test Date: June 9, 2021

Tested By
Signature: _____ Name: Mark Afroozi

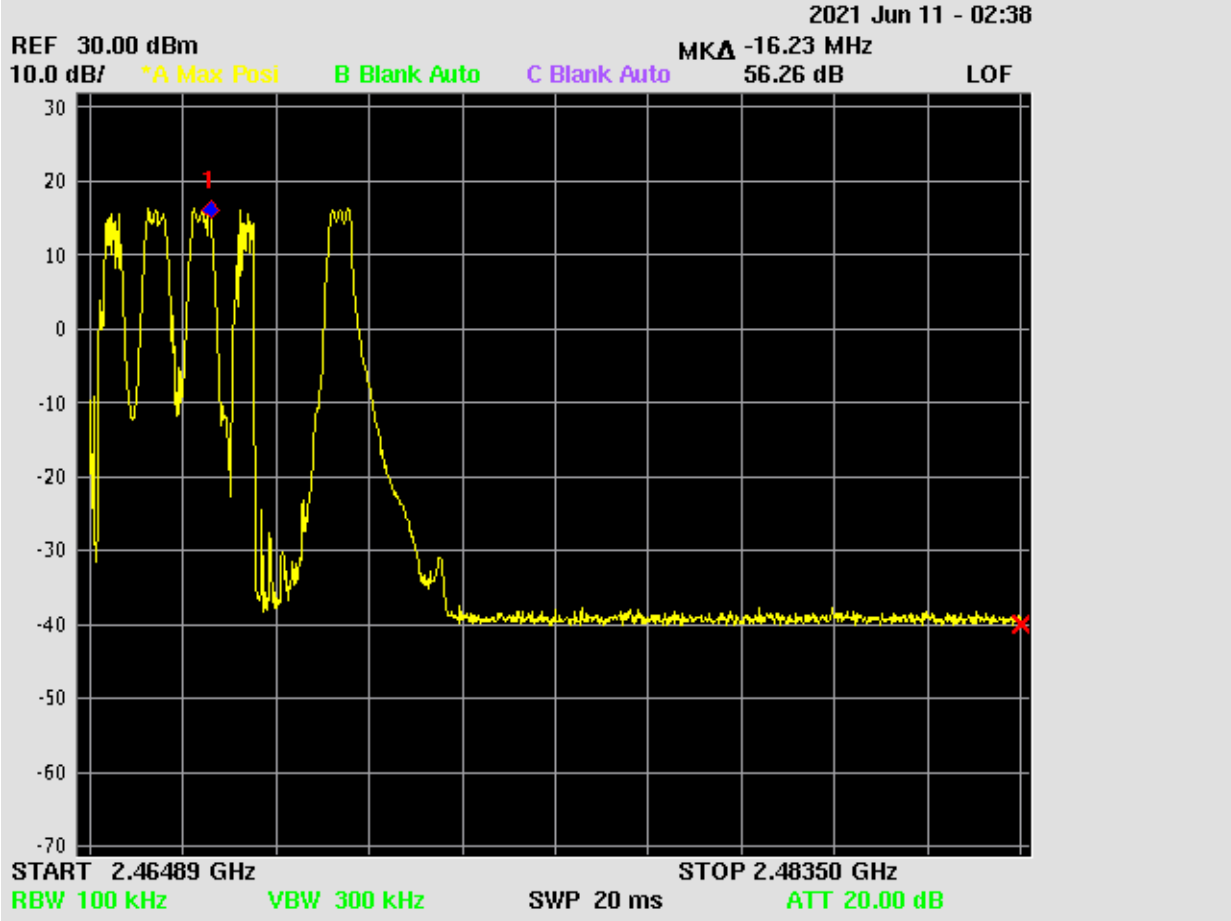


Figure 35. Band Edge Compliance with Hopping Mode Enabled: High Channel

Higher band edge must be 20 dB below the peak of the fundamental frequency. This requirement is met.

Measured Result	56.26	dB
Band Edge Limit	20.00	dB
Band Edge Margin	36.26	dB

Test Date: June 11, 2021

Tested By
Signature: Name: Mark Afroozi

2.13 20 dB and 99% Occupied Bandwidth (RSS-Gen, 6.7 and RSS-247, 5.1 (b))

The EUT antenna port was connected to a spectrum analyzer having a 50 Ω input impedance. Measurements were performed similar to the method of FCC, KDB Publication No. 558074 v05r02 and ANSI C63.10-2013 Option 1. The RBW was set to 100 kHz and the VBW was set to ≥ [3 X RBW]. The detector was set to PEAK and trace was Max Hold. The measurement was taken at 20 dB down from the peak fundamental emission. The results of this test are given in the table and figures below.

Table 9. 20 dB and 99% Occupied Bandwidth

Frequency (MHz)	20 dB Bandwidth (kHz)	99% Occupied Bandwidth (kHz)
2401.6896	675	615
2435.7888	690	615
2469.8880	690	615

Test Date: June 9 & 11, 2021

Tested By
Signature:  Name: Mark Afroozi

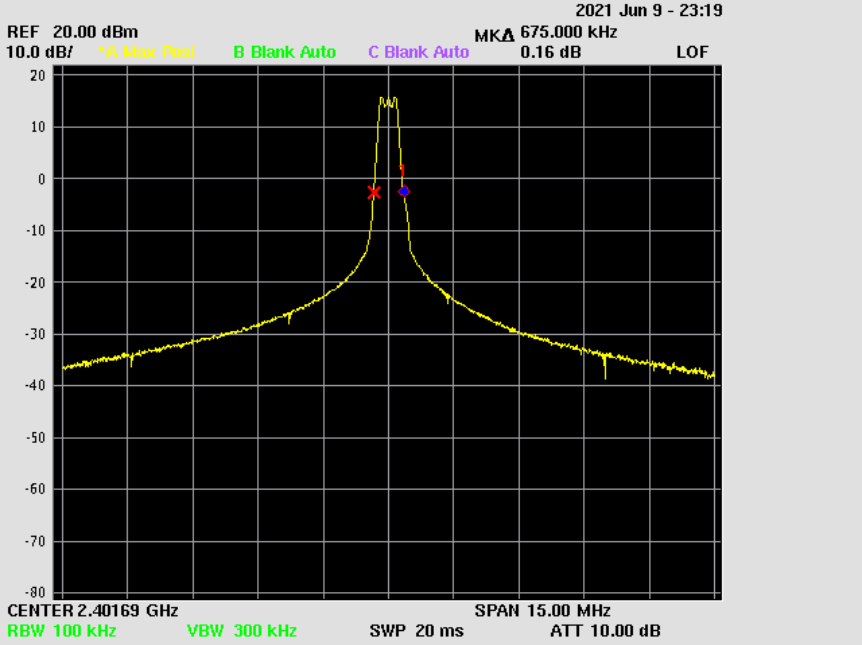


Figure 36. 20 dB Bandwidth – Low Channel

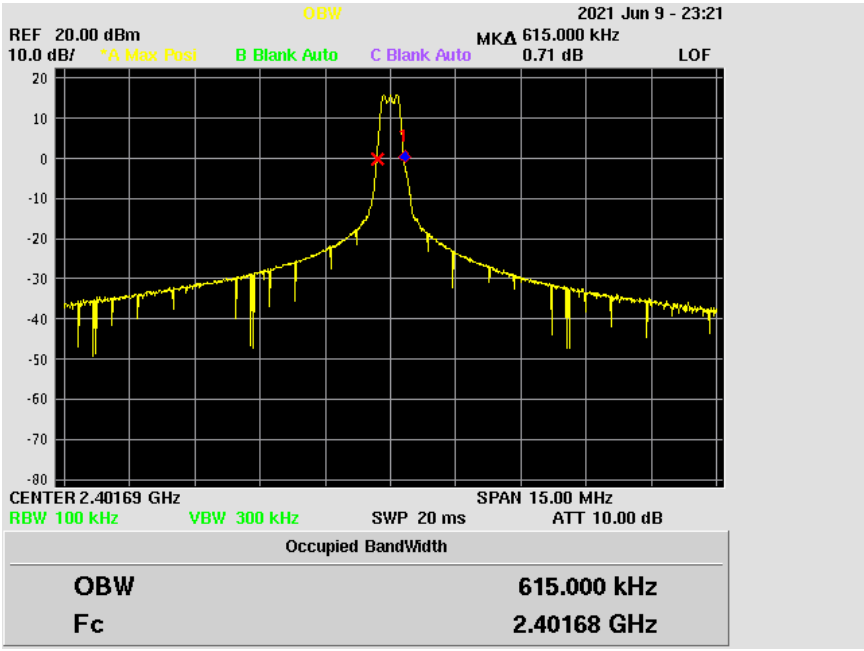


Figure 37. 99% Occupied Bandwidth – Low Channel

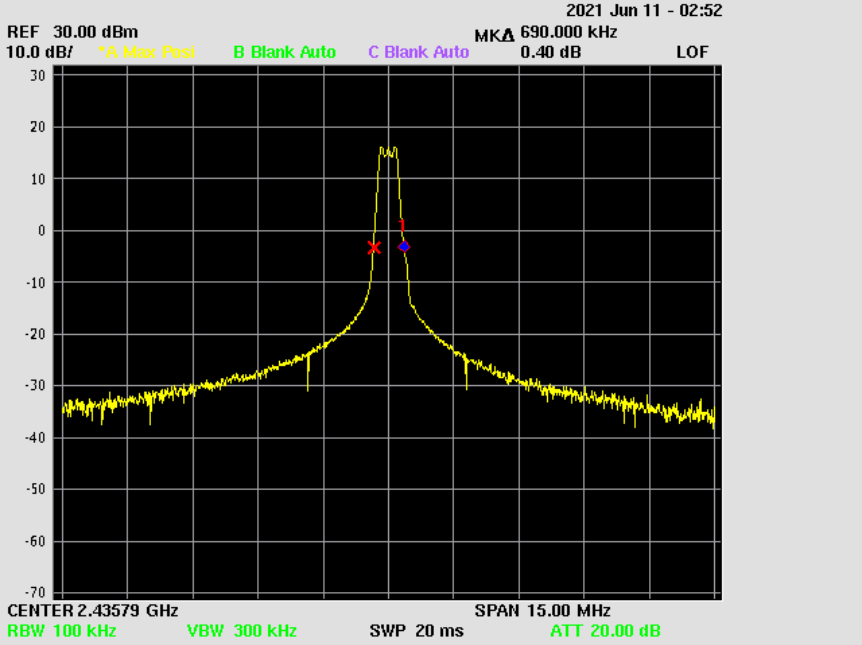


Figure 38. 20 dB Bandwidth – Mid Channel

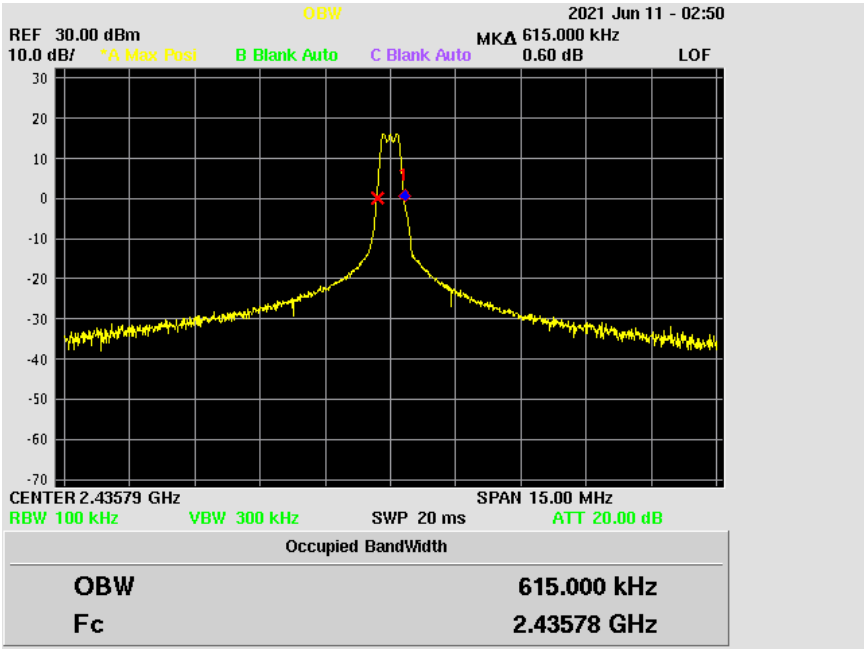


Figure 39. 99% Occupied Bandwidth – Mid Channel

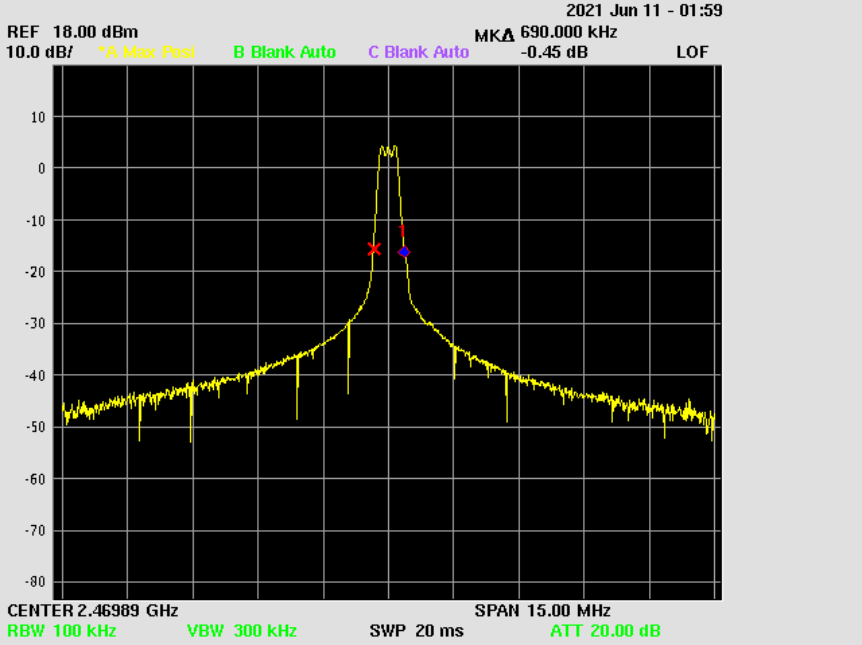


Figure 40. 20 dB Bandwidth – High Channel

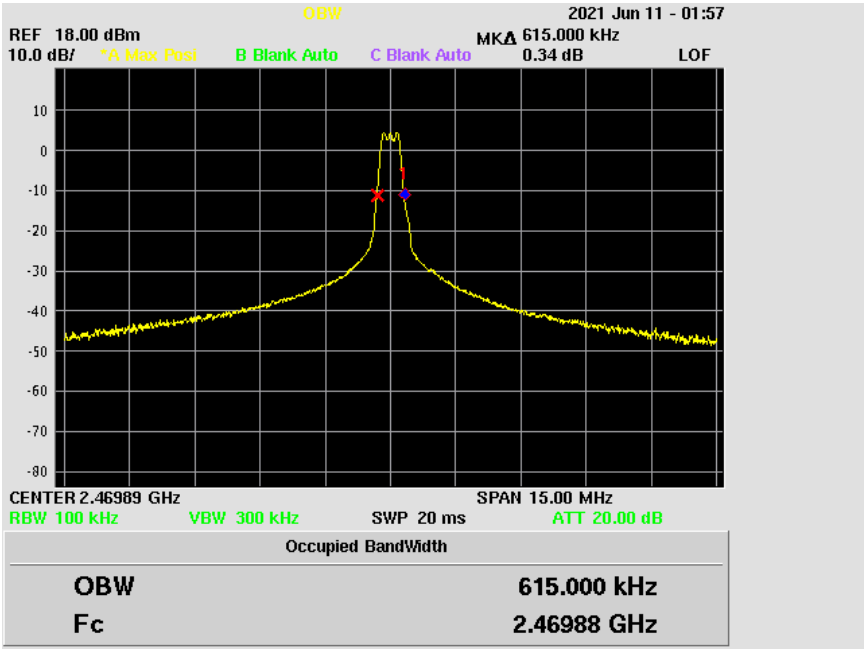


Figure 41. 99% Occupied Bandwidth – High Channel

2.14 Channel Carrier Frequency Separation (CFR 15.247 (1), RSS-247 5.1(b))

FHSs shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The EUT was programmed to operate on channel 1 and channel 2. The delta between the peaks of each channel was measured using the marker-delta method to determine the separation value.

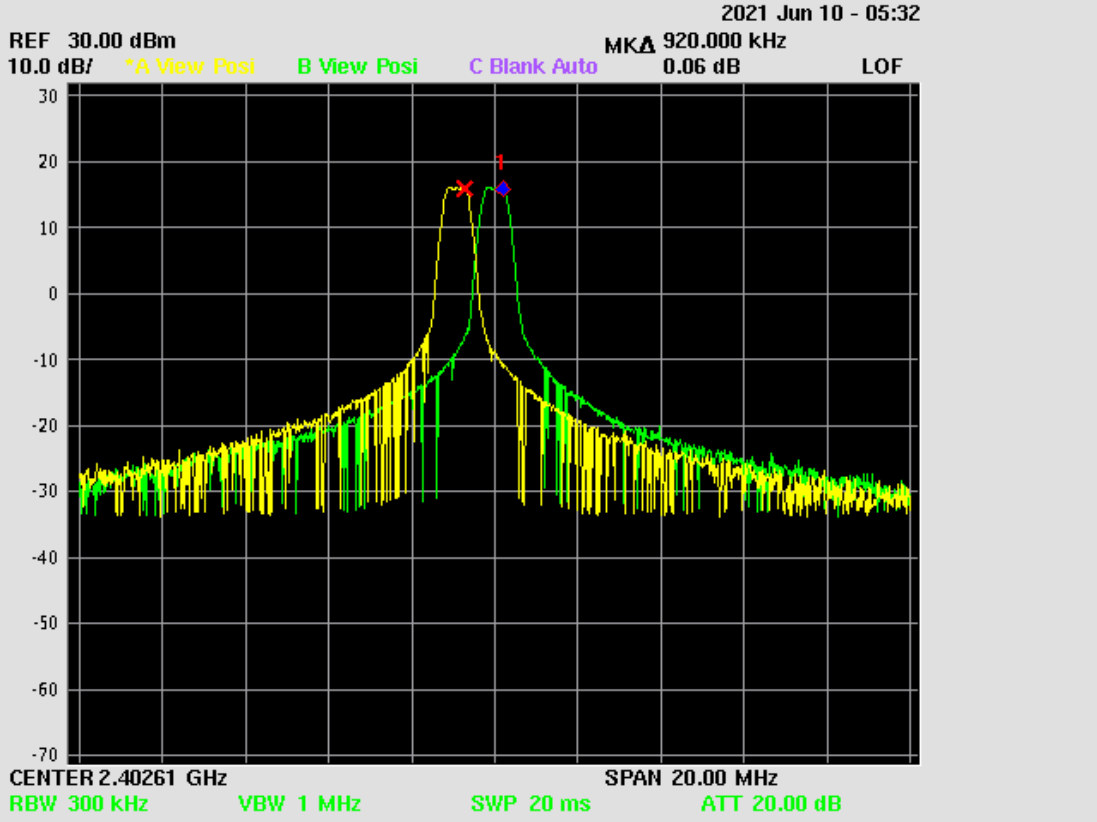


Figure 42. Frequency Separation (CH 1 and CH 2)

Minimum separation requirement = 20 dB bandwidth = 675 kHz (see Figure 37)

Measured frequency separation = 920 kHz

2.15 Hopping Channels and Time of Occupancy (CFR 15.247 (1)(iii), RSS-247 5.1(d))

The EUT employs 75 hopping channels with a maximum channel occupancy time of 21.6 ms. Plots displaying time of occupancy measurements and hopping channels are presented in the figures below.

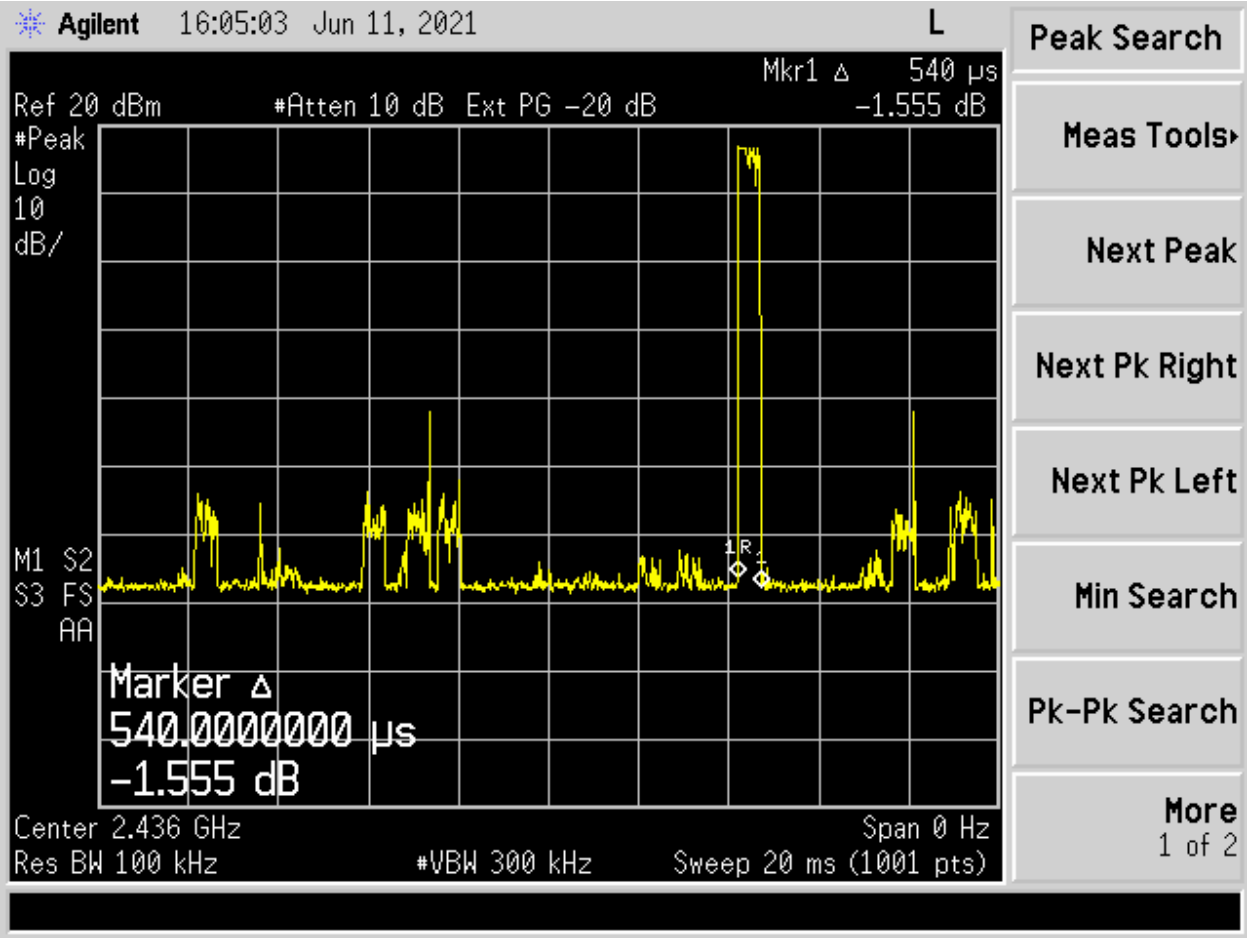


Figure 43. Time of Occupancy: Pulse duration = 540 us

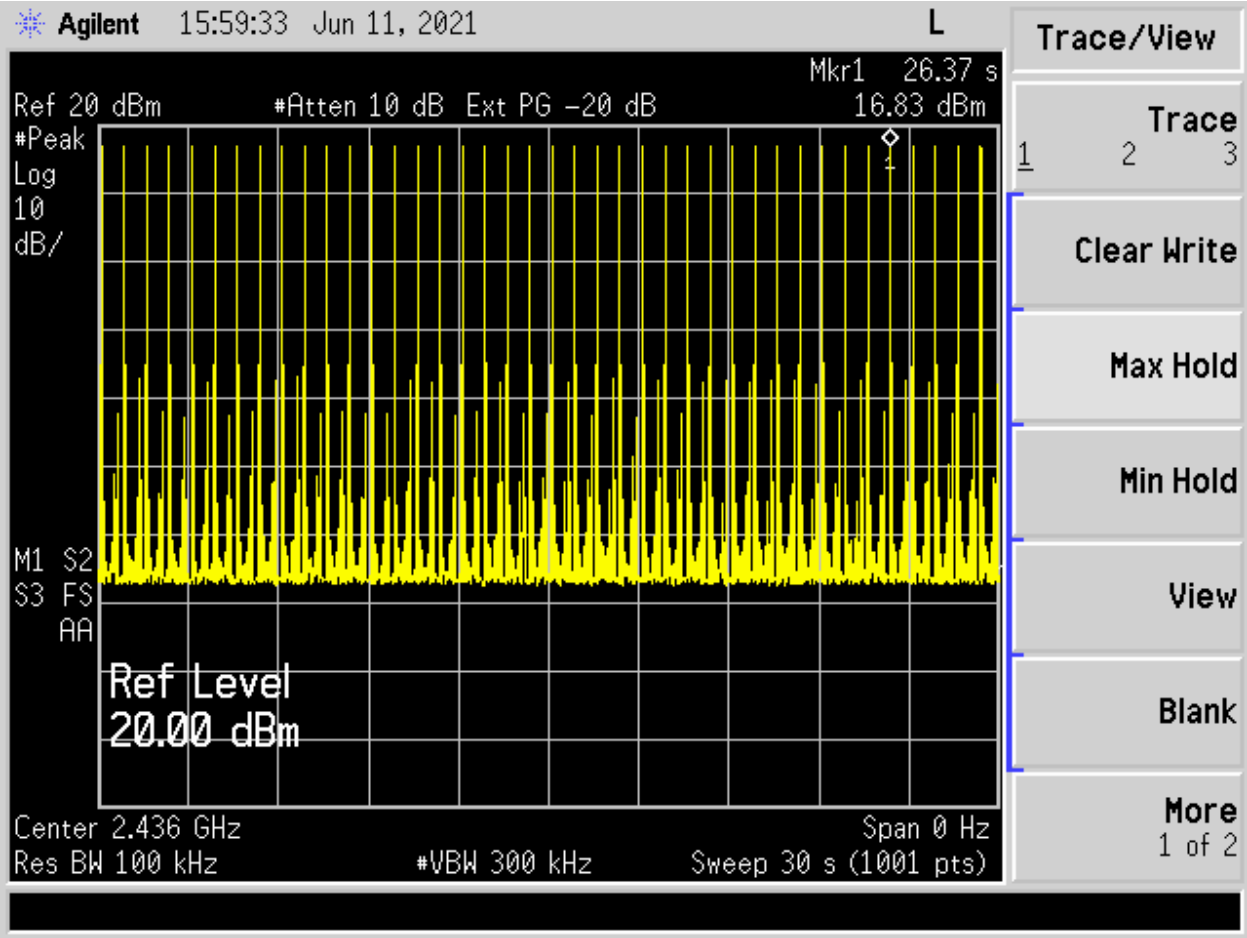


Figure 44. Time of Occupancy Dwell Time

75 (number of hopping channels) * 400 ms = 30 s (observation time)
Limit = 400 ms (Max Occupancy Time)
Measured Occupancy Time = 540 us (Figure 44) * 40 (number of pulses) = 21.6 ms

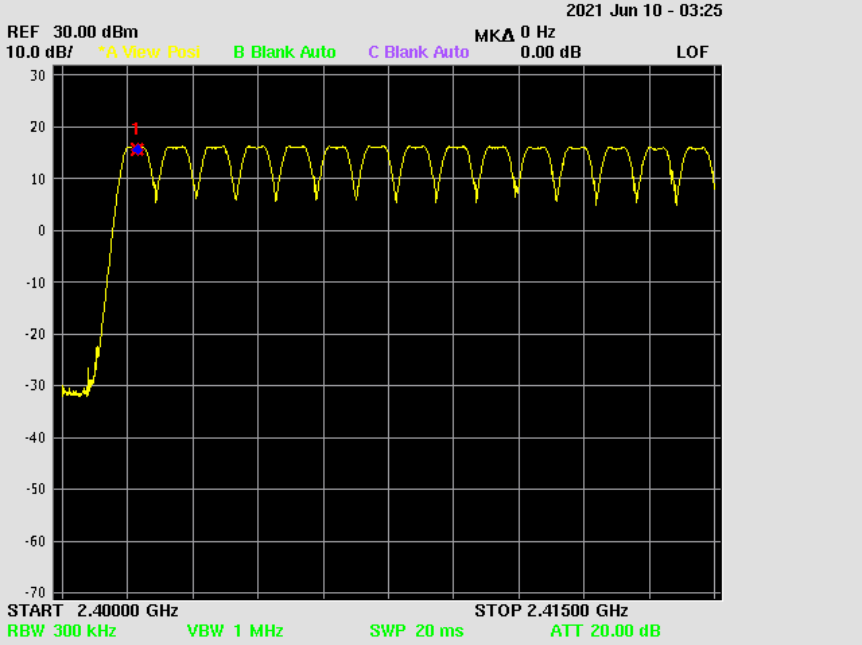


Figure 45. CH 1 - 15

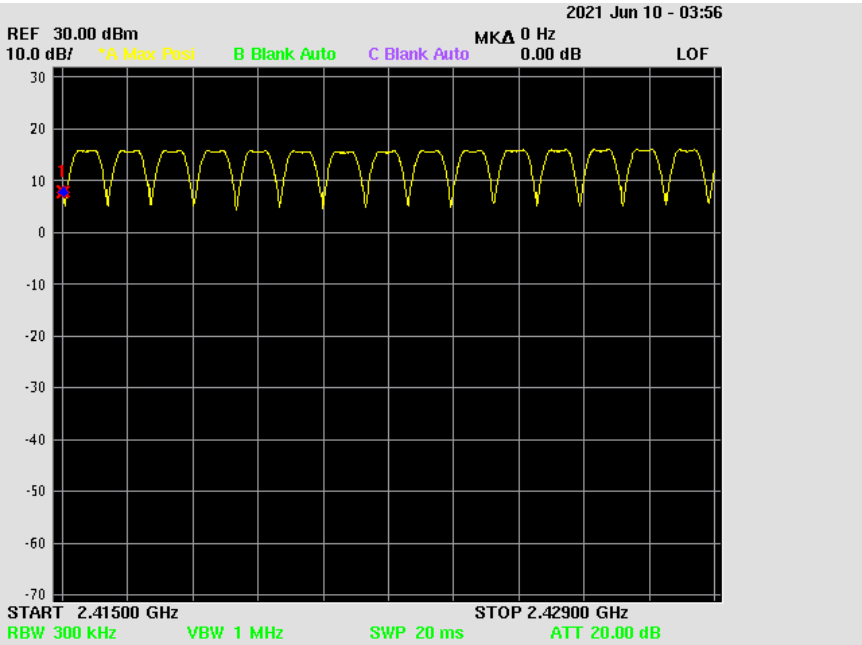


Figure 46. CH 15 – 30

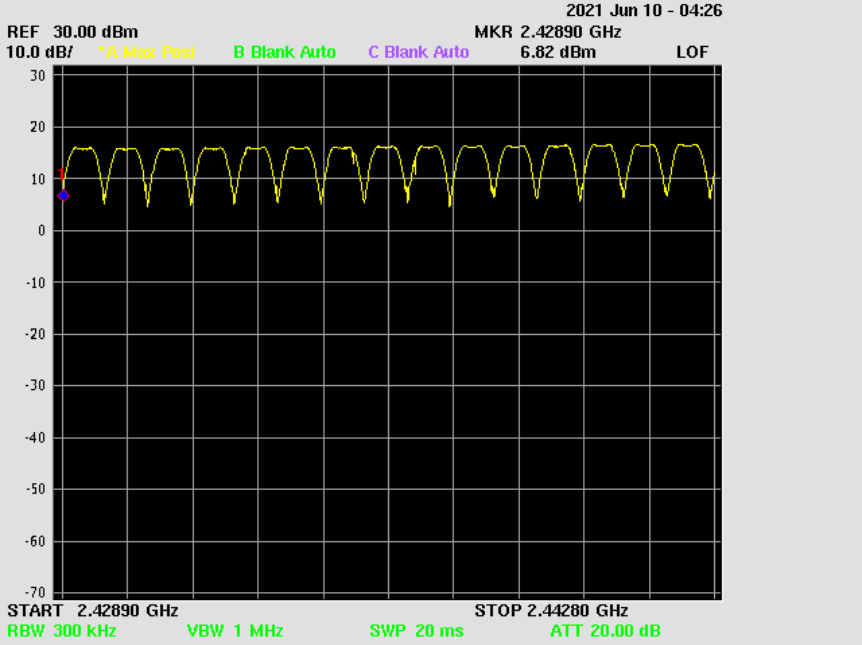


Figure 47. CH 31 - 45

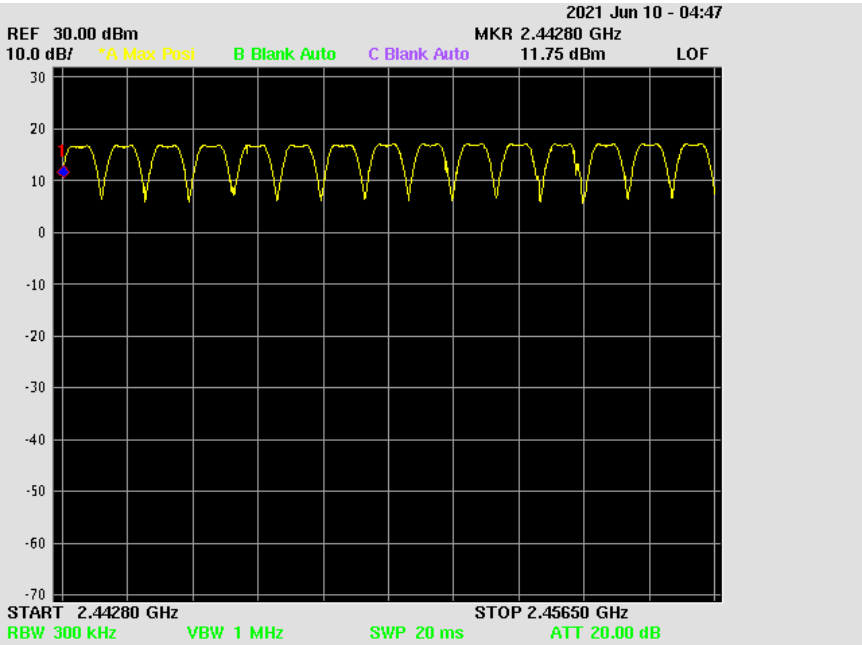


Figure 48. CH 46 – 60

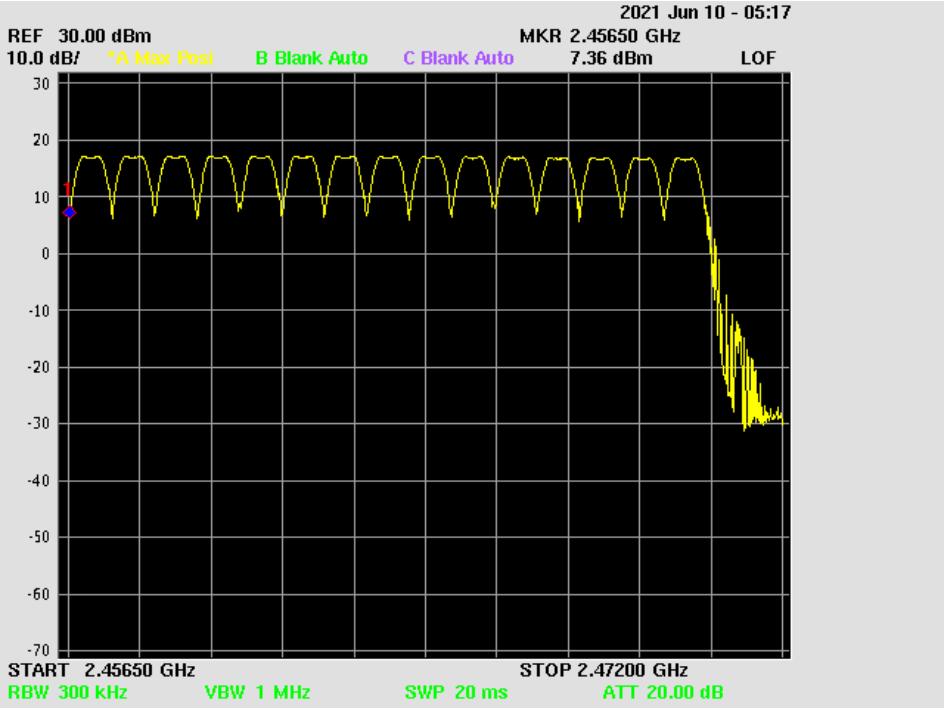


Figure 49. CH 61 – 75

2.16 Intentional Radiator Power Line Conducted Emissions (CFR 15.207)

The power line conducted voltage emission measurements have been carried out in accordance with CFR 15.207, per ANSI C63.10:2013, Clause 6.2, with a spectrum analyzer connected to a LISN and the EUT placed into a continuous mode of transmission. The worst-case results for conducted emissions were determined to be produced when the EUT was operating under continuous transmission.

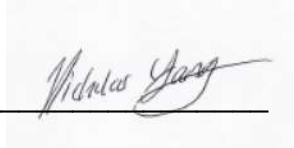
Table 10. Power Line Conducted Emissions 150 kHz to 30 MHz

Frequency (MHz)	Test Data (dBuV)	LISN+CL (dB)	Corrected Results (dBuV)	Limits (dBuV)	Margin (dB)	Detector
Phase @ 120 Vac/60Hz						
0.1540	40.38	0.08	40.46	55.8	15.5	**AVG**
0.6783	35.98	0.23	36.21	46.0	9.8	**PK**
1.4466	34.60	0.34	34.94	46.0	11.1	**PK**
5.4917	32.29	0.23	32.52	50.0	17.5	**PK**
14.5000	31.30	0.83	32.13	50.0	17.9	**PK**
25.0500	24.36	1.26	25.62	50.0	24.4	**PK**
Neutral @ 120 Vac/60Hz						
0.1500	34.23	0.13	34.36	56.0	21.6	**AVG**
0.5375	33.85	0.51	34.36	46.0	11.6	**PK**
1.2266	32.85	0.51	33.36	46.0	12.6	**PK**
5.8166	28.88	0.45	29.33	50.0	20.7	**PK**
14.3833	32.29	1.13	33.42	50.0	16.6	**PK**
23.6330	25.21	1.58	26.79	50.0	23.2	**PK**

Sample Calculation at 0.1540 MHz:

Magnitude of Measured Frequency	40.38	dBuV
+ LISN + Cable Loss	0.08	dB
Corrected Result	40.46	dBuV/m

Test Date: June 14, 2021

Tested By
Signature: 

Name: Nick Yang

2.17 Radiated Emissions of the Intentional Radiator, (CFR 15.209)

The test data provided herein is to support the verification requirement for radiated emissions coming from the EUT in a transmitting state per 15.209 and were investigated from 9kHz or the lowest operating clock frequency to 25 GHz and tested as detailed in ANSI C63.10:2013, Clause 6.4-6.6.

Radiated emissions within the band of 9 kHz to 30 MHz were investigated using a calibrated loop antenna and per the requirements of ANSI C63.10:2013.

The spectrum analyzer's resolution bandwidth was set to 120 kHz for measurements made between 30 MHz and 1 GHz. For measurements made above 1 GHz, the resolution bandwidth was set to 1 MHz. The video bandwidth was set to three times the resolution bandwidth (1 MHz RBW and 3 MHz VBW). The magnitude of each emission was maximized by rotating the turntable 360 degrees clockwise and counterclockwise then raising and lowering the receiving antenna between 1 to 4 meters in height as part of the measurement procedure. The test data is presented in the tables below.

Table 11. Spurious Radiated Emissions (9 kHz – 30 MHz)

Test: Radiated Emissions per FCC Part 15.209								
Frequency (MHz)	**Test Data (dBuV)**	**Additional Factor**	**AF+CL-PA (dB/m)**	**Corrected Results (dBuV/m)**	**Limits (dBuV/m)**	**Distance / Polarity**	**Margin (dB)**	**Detector**
All spurious emissions were lower than 20 dB below the applicable limit.								

Test Date: June 1, 2021

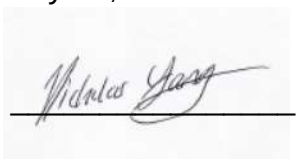
Tested By
Signature: 

Name: Nick Yang

Table 12. Spurious Radiated Emissions (30 MHz – 1 GHz)

Test: Radiated Emissions per FCC Part 15.209								
Frequency (MHz)	**Test Data (dBuV)**	**Additional Factors**	**AF+CL-PA (dB/m)**	**Corrected Results (dBuV/m)**	**Limits (dBuV/m)**	**Distance / Polarity**	**Margin (dB)**	**Detector**
316.17	48.28	--	-9.82	36.46	46.0	3m./HORZ	9.5	**PK**
30.00	38.42	--	-11.90	26.52	40.0	3m./HORZ	13.5	**PK**
44.34	44.93	--	-14.76	30.17	40.0	3m./HORZ	9.8	**PK**
96.01	43.97	--	-16.94	27.03	43.5	3m./HORZ	16.5	**PK**
All other spurious emissions were lower than 20 dB below the limit.								

Test Date: May 28, 2021

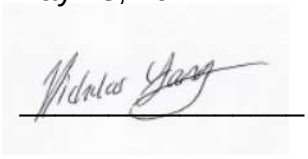
Tested By
Signature: 

Name: Nick Yang

Table 13. Spurious Radiated Emissions (1 – 25 GHz)

Test: Radiated Emissions per FCC Part 15.209								
Frequency (MHz)	**Test Data (dBuV)**	**Additional Factor**	**AF+CL-PA (dB/m)**	**Corrected Results (dBuV/m)**	**Limits (dBuV/m)**	**Distance / Polarization**	**Margin (dB)**	**Detector**
All spurious emissions were lower than 20 dB below the applicable limit.								

Test Date: May 28, 2021

Tested By
Signature: 

Name: Nick Yang

2.18 Measurement Uncertainty

The measurement uncertainties given were calculated using the method detailed in CISPR 16-4-2:2011. A coverage factor of k=2 was used to give a level of confidence of approximately 95%.

2.18.1 Conducted Emissions Measurement Uncertainty

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

2.18.2 Radiated Emissions Measurement Uncertainty

For a measurement distance of 3 m the measurement uncertainty (with a 95% confidence level) for this test using a Biconical Antenna (30 MHz to 200 MHz) is ±5.3 dB. This value includes all elements of measurement.

The measurement uncertainty (with a 95% confidence level) for this test using a Log Periodic Antenna (200 MHz to 1000 MHz) is ±5.1 dB.

The measurement uncertainty (with a 95% confidence level) for this test using a Horn Antenna (Above 1000 MHz) is ±5.1 dB.

3 Test Results

The EUT is deemed to have met the requirements of the standards cited within the test report when tested as detailed in the test report.