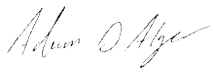
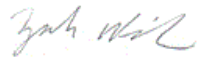
Test Report # 3538 A

Equipment Under Test:	Radio Apparatus
Test Date(s):	November 22-24 and December 20, 2021
Prepared for:	Vermeer Manufacturing Company Attn: Ty Gross 1716 Vermeer Rd East Pella, IA 50219

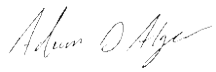
Report Issued by: Adam Alger, Laboratory Manager

Signature:  Date: 8/8/2022

Report Reviewed by: Zach Wilson, EMC Engineer

Signature:  Date: 12/21/2021

Report Constructed by: Adam Alger, Laboratory Manager

Signature:  Date: 12/01/2021

CONTENTS

Laird Connectivity Test Services in Review

The Laird Connectivity LLC laboratory located at W66 N220 Commerce Court Cedarburg, Wisconsin, 53012 USA is recognized through the following organizations:

A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025:2017 with Electrical (EMC) Scope

A2LA Certificate Number: 1255.01

Scope of accreditation includes all test methods listed herein unless otherwise noted

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Federal Communications Commission (FCC) – USA

Accredited Test Firm Registration Number: 953492

Recognition of two 3 meter Semi-Anechoic Chambers

Government of Canada

Innovation, Science and Economic Development Canada

Accredited U.S. Identification Number: US0218

Recognition of two 3 meter Semi-Anechoic Chambers

1 TEST REPORT SUMMARY

During **November 22-24 and December 20, 2021** the Equipment Under Test (EUT), **RADIO APPARATUS**, as provided by **Vermeer Manufacturing Company** was tested to the following requirements:

Requirement	Description	Specification	Method	Result
FCC: 15.247 (a)(1) IC: RSS-247 5.1	Channel Separation, Number of Hopping frequencies, Time of Occupancy	FHSS	ANSI C63.10	Compliant
FCC: 2.1049 IC: RSS-GEN 6.7	Occupied Bandwidth	Reported	ANSI C63.10	Reported
FCC: 15.247 (b)(1) IC: RSS-247 5.4 (b)	Maximum Conducted Output Power	21 dBm	ANSI C63.10	Compliant
FCC: 15.247 (d) IC: RSS-247 5.5	RF Spurious Emissions at the Transmitter Antenna Terminal	20 dBc	ANSI C63.10	Compliant
FCC: 15.247 (d) IC: RSS-GEN 8.10	Spurious Radiated Emissions in Restricted Bands	FCC 15.209 RSS-GEN 8.9	ANSI C63.10	Compliant
FCC: 2.1055 (d) IC: RSS-GEN 6.11	Frequency Stability	Reported	ANSI C63.10	Compliant
FCC: 15.207 IC: RSS-GEN 8.8	Conducted AC Mains Emissions	Class B	ANSI C63.10	Compliant

Notice:

The results relate only to the item tested as configured and described in this report. Any additional configurations, modes of operation, or modifications made to the equipment under test after the specified test date(s) are at the decision of the client and may not apply to the data seen in this test report.

The decision rule for Pass / Fail assessment to the specification or standard listed in this test report has been agreed upon by the client and laboratory to be as follows:

Measurement Type	Rule
Emissions – Amplitude	Below specified limit
Emissions – Frequency	1% less than the specification
Immunity	Tested at specified level

2 CLIENT INFORMATION

Company Name	Vermeer Corporation
Contact Person	Ty Gross
Address	1716 Vermeer Rd East Pella, IA 50219

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	RADIO APPARATUS
Model Number	VERMEER2
Serial Number	Engineering Sample
FCC/ISED ID:	FCC ID: 2AXF5-VERMEER2 IC: 26431-VERMEER2

2.2 Product Description

The Radio Apparatus is a 2.4 GHz Frequency Hopping Spread Spectrum (FHSS) Wireless Module used in OEM Host applications.

2.3 Modifications Incorporated for Compliance

None noted at time of test

2.4 Deviations and Exclusions from Test Specifications

None noted at time of test

2.5 Additional Information

The EUT is a module facilitated using a devkit (model: DVK-RM024-FCC) powered by 120 VAC, 60 Hz. The Radio Apparatus houses a proprietary frequency hopping 2.4 GHz radio that operates from 2404 – 2466.9 MHz. Unit tested in the low mid, and high channels as shown below, and in the hopping mode as required for each test. Unit tested with a set of channels comprising 43 channels with 280kHz and 500 kHz data rates.

Low – 2404 MHz
Mid – 2435.5 MHz
High – 2466.9 MHz

2.6 Antenna Information

This EUT was tested with a cabinet radiation method assuming a worst-case antenna gain of 9.0 dBi in accordance with FCC guidance.

Vermeer Part #	Manufacturer	MFG Part #	Type/Description	Gain dBi
296575415	L-COM	HG2409Y-NF	Yagi	9.0
296575413	L-COM	HG2409P-NF	Flat Patch	8.0
296575414	L-COM	HG2408P-NF	Round Patch	8.0
296541293	Pulse / Larsen	SLPT2400NMOHF	Shadow	5.1
296575379	Nearson	S151TC-2450	Dipole	5.0
296541296	Pulse / Larsen	SLPT2400DMN	Shadow	4.8
163722969	Laird	TRA6927M3PB-001	Phantom	4.6
296272382	PCTEL	PCTCN24005	Open Coil Colinear	4.5
296541297	Laird Connectivity	TRAB24003P	Phantom	3.0
296541408	Molex	146153 100mm	Balance Flex	3.0
296589356	Laird Connectivity	TRAB24003NP	Phantom	3.0
296304935	Pulse / Larsen	SPDA172400	Dipole	2.0
296521447	Laird Technologies	MAF94045	PCB Trace	2.0
296541344	Nearson	S181FL-5(178)-PX-2450(S)	Dipole	2.0
296541409	Molex	146153 150mm	Balance Flex	2.0
296575378	Nearson	S181TC-2450	Dipole	2.0
296575416	Nearson	S181FL-6-PX-2450S	Dipole	2.0
296575417	Laird Technologies	001-0014	FlexPIFA	2.0

2.7 Cabinet Radiation Method

Per FCC tracking number 557901 the conducted measurement and cabinet radiation method of KDB 558074 and ANSI C63.10 is acceptable for FHSS devices with multiple antenna options.

3 REFERENCES

Publication	Edition	Date	AMD 1
FCC Title 47	-	2022	-
ANSI C63.10	-	2013	-
RSS-247	2	2017	-
RSS-GEN	5	2014	2019

4 UNCERTAINTY SUMMARY

Using the guidance of the following publications the calculated measurement uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k = 2.

References	Version / Date
CISPR 16-4-1	Ed. 2 (2009-02)
CISPR 16-4-2	Ed. 2 (2011-06)
CISPR 32	Ed. 1 (2012-01)
ANSI C63.23	2012
A2LA P103	February 4, 2016
A2LA P103c	August 10, 2015
ETSI TR 100-028	V1.3.1 (2001-03)

Measurement Type	Configuration	Uncertainty ±
Radiated Emissions	Biconical Antenna	5.0 dB
Radiated Emissions	Log Periodic Antenna	5.3 dB
Radiated Emissions	Horn Antenna	4.7 dB
AC Line Conducted Emissions	Artificial Mains Network	3.4 dB
Telecom Conducted Emissions	Asymmetric Artificial Network	4.9 dB
Disturbance Power Emissions	Absorbing Clamp	4.1 dB
Radiated Immunity	3 Volts/meter	2.2 dB
Conducted Immunity	CDN/EM/BCI	2.4/3.5/3.4 dB
EFT Burst/Surge	Peak pulse voltage	164 volts
ESD Immunity	15 kV level	1377 Volts

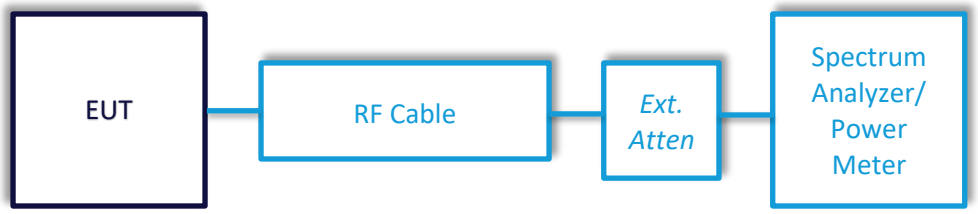
Parameter	ETSI U.C. ±	U.C. ±
Radio Frequency, from F0	$1x10^{-7}$	$0.55x10^{-7}$
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
Supply voltages	3 %	1 %

5 TEST DATA

5.1 Antenna Port Conducted Emissions

Description of Measurement	The direct measurement of emissions at the antenna port of the EUT is achieved by use of a RF connection to a spectrum analyzer or power meter. The cable and attenuator factors are loaded into the analyzer or power meter allowing for direct measurement readings without the need for further corrections.
Example Calculations	Measurement (dBm) + Cable factor (dB) + External Attenuator (dB) = Corrected Reading (dBm) Peak Corrected Reading (dBm) - Duty cycle correction factor (dB) + Ground Reflection factor (dB, if applicable) = Average Corrected Reading (dBm) Margin (dB) = Limit (dBm) – Corrected Reading (dBm)

Block Diagram



5.1.1 Antenna Port Conducted Emissions

Operator	Ivan Alvarez, Anthony Smith, Adam Alger	**QA**	Adam Alger
Temperature	20.2° C	**R.H. %**	22.40
Test Date	11/22,23,24 & 12/20 2021	**Location**	Conducted RF Bench
Requirement	FCC Part 15.247 / RSS-247	**Method**	ANSI C63.10 Sections 6.8, 6.9, 7.8.2, 7.8.3, 7.8.4, 7.8.5, 7.8.6, 7.8.8

Limits:

Frequency Separation	Number of Hopping Channels	Maximum Occupancy Time
>25 kHz or 20 dB Bandwidth	>15	0.4 seconds in 0.4 seconds * number of hopping channels (43) = 17.2 second period

Maximum Conducted Output Power (mW)	Maximum Conducted Output Power (dBm)
125	21

RF Spurious Limit
20 dBc

Test Parameters

Frequency	30-25000 MHz	**Setup**	EUT connected to Spectrum Analyzer via SMA cable, attenuator, and u.fl to SMA adapter

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
AA 960143	Cable	Gore	EKD01D01048.0	5546519	2/3/2021	2/3/2022	Active Verification
EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/28/2021	7/28/2022	Active Calibration

EUT Parameters

Input Power	5 VDC (7.5 VDC via external adapter for frequency stability)	**Mode**	Modulated Tx Mode Hopping Mode
Frequency	2404.0 MHz 2435.5 MHz 2466.9 MHz	**Channel**	Low Mid High
Notes	EUT tested at both 280 kHz and 500 kHz data rates		

Data

20 dB and 99% BW

280k		
Channel	**20 dB BW (kHz)**	**99% BW (kHz)**
Low	863.9	838.8
Mid	858.7	835.2
High	879.0	877.7
500k		
Channel	**20 dB BW (kHz)**	**99% BW (kHz)**
Low	1182.0	1074.7
Mid	1198.0	1113.4
High	1358.0	1219.2

Peak Output Power

Rate	Channel	Frequency (MHz)	Conducted Output Power Level (dBm)	Conducted Output Power Limit(dBm)	Margin (dB)
280	Low	2403.8	19.5	21.0	1.5
280	Mid	2435.3	19.5	21.0	1.5
280	High	2466.9	19.6	21.0	1.4
500	High	2466.9	19.6	21.0	1.4
500	Mid	2435.4	19.5	21.0	1.4
500	Low	2403.9	19.5	21.0	1.5

Frequency Stability

	Channel	6.4 VDC Freq. (Hz)	7.5 VDC Freq. (Hz)	8.6 VDC Freq. (Hz)	Deviation (Hz)
280	Low	2403986592	2403986757	2403986703	165
	Mid	2435445626	2435445622	2435444829	797
	High	2466903406	2466904367	2466903904	961
	Channel	**6.4 VDC Freq. (Hz)**	**7.5 VDC Freq. (Hz)**	**8.6 VDC Freq. (Hz)**	**Deviation (Hz)**
500	Low	2403986071	2403986032	2403986003	68
	Mid	2435445231	2435445039	2435444432	799
	High	2466904495	2466903729	2466904203	766

100 kHz Reference Level

Rate	Frequency (MHz)	Ref level (dBm)	Limit (dBm)	Channel
280	2404.1	19.2	-0.8	Low
	2435.5	19.2	-0.8	Mid
	2466.8	19.2	-0.8	High
500	2467.0	19.4	-0.6	High
	2435.5	19.3	-0.7	Mid
	2404.1	19.1	-0.9	Low

Spurious Emissions

Rate	Frequency (MHz)	Peak Measurement (dBm)	Limit (dBm)	Margin (dB)	Channel
280	2399.5	-31.6	-0.8	30.8	Low
280	2311.0	-37.4	-0.8	36.6	High
500	2399.1	-32.1	-0.9	31.2	Low
500	2310.9	-38.7	-0.6	38.1	High

Spurious Emissions Hopping

Rate	Frequency (MHz)	Measurement (dBm)	Limit (dBm)	Margin (dB)	Channel
280	2400.0	-30.5	-0.8	29.7	Hopping
280	2561.5	-33.9	-0.8	33.1	Hopping
500	2399.8	-31.0	-0.6	30.4	Hopping
500	2559.9	-33.6	-0.6	33.0	Hopping

Hopping

Rate	Occupancy Time (µs)	Number of Transmissions in 17.2s period	Occupancy time in 17.2s (ms)	Limit (ms)	Margin (ms)
280	638.8	30.0	19.2	400.0	380.8
500	422.7	30.0	12.7	400.0	387.3

43 Channels > 15 minimum

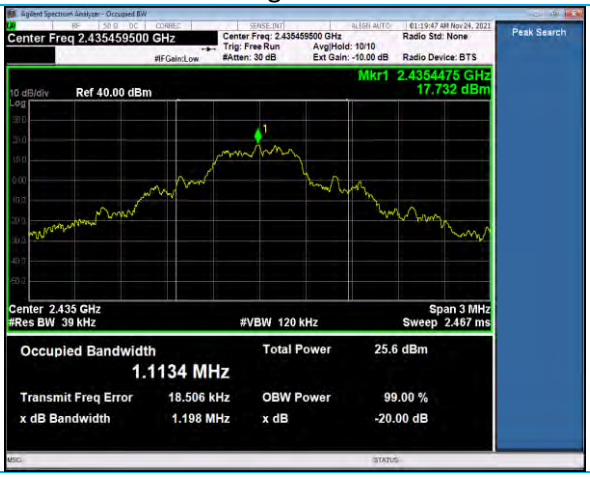
Separation 1.5 MHz > 20 dB BW

280k Low Ch. – BW

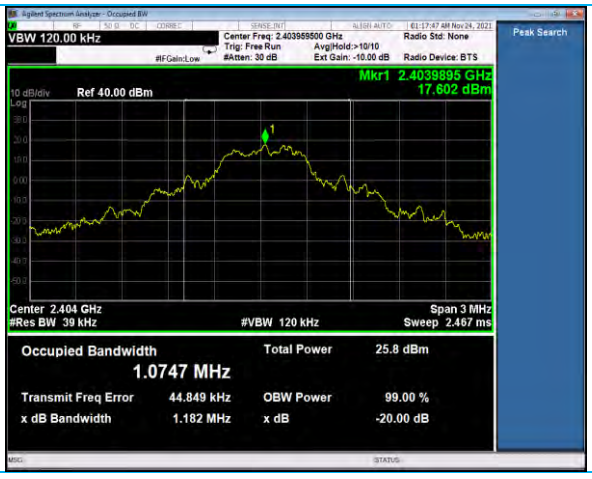
280k Mid Ch. – BW

280k High Ch. – BW

500k Low Ch. – BW



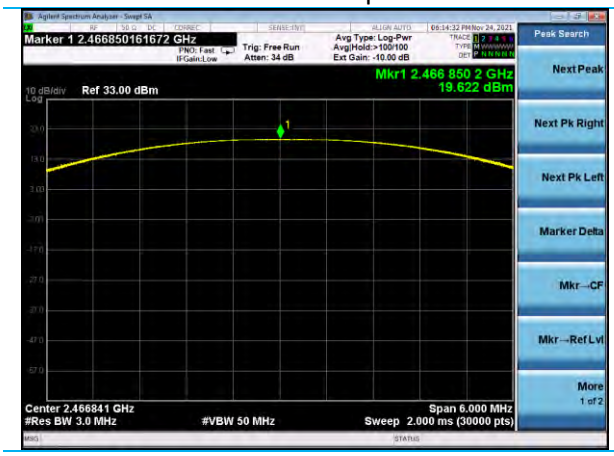
500k Mid Ch. – BW



500k High Ch. – BW

280k Low Ch – Output Power

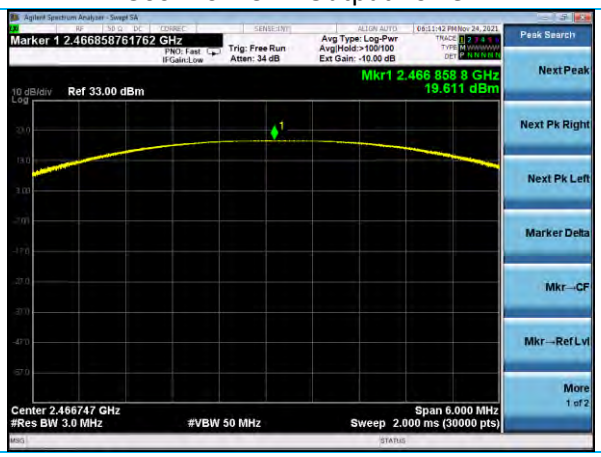
280k Mid Ch – Output Power



280k High Ch – Output Power

500k Low Ch – Output Power

500k Mid Ch – Output Power



500k High Ch – Output Power

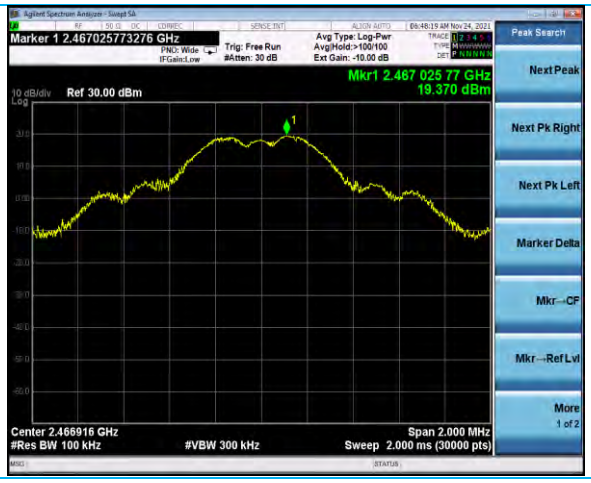
280k Reference Level – Low Ch

280k Reference Level – Mid Ch

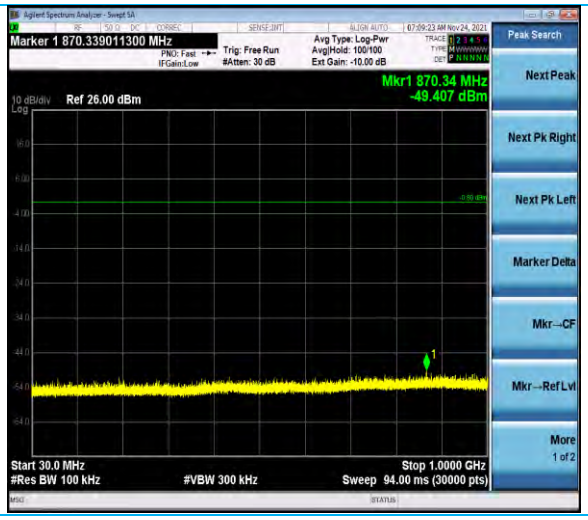
280k Reference Level – High Ch

500k Reference Level – Low Ch

500k Reference Level – Mid Ch



500k Reference Level – High Ch



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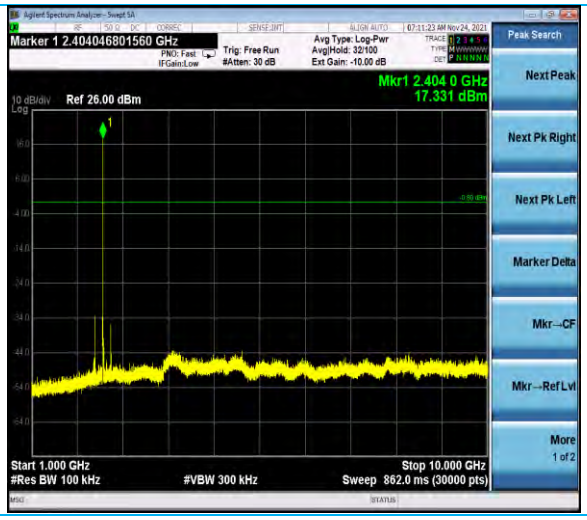

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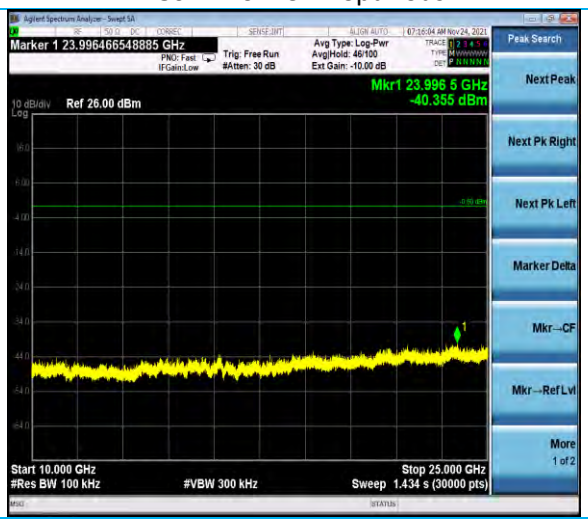

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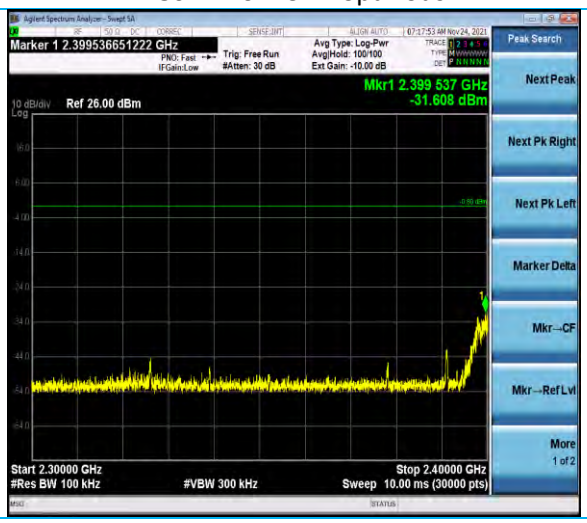

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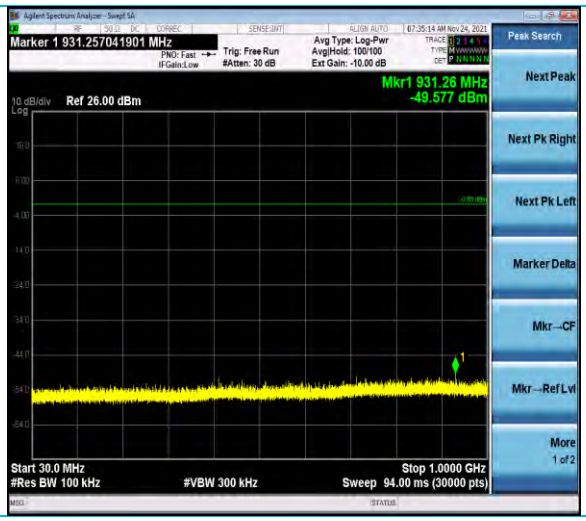
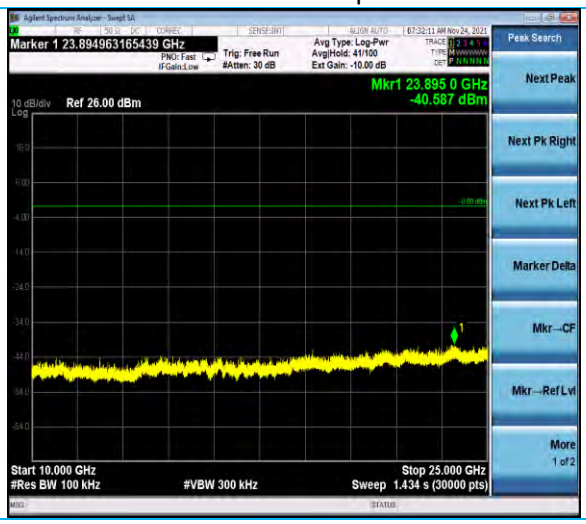


280k – Mid Ch – Spurious

280k – Mid Ch – Spurious



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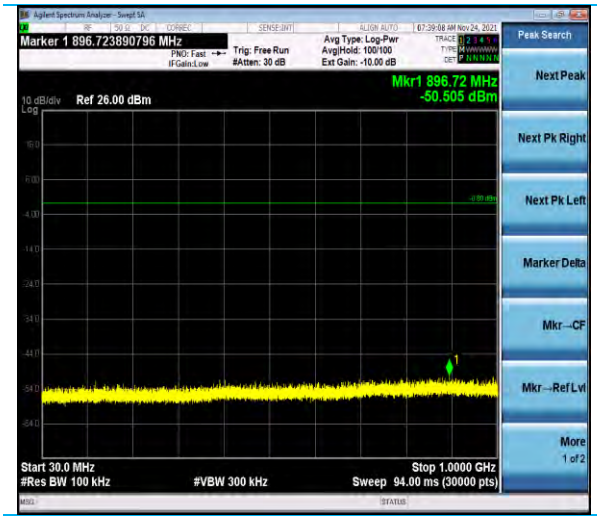

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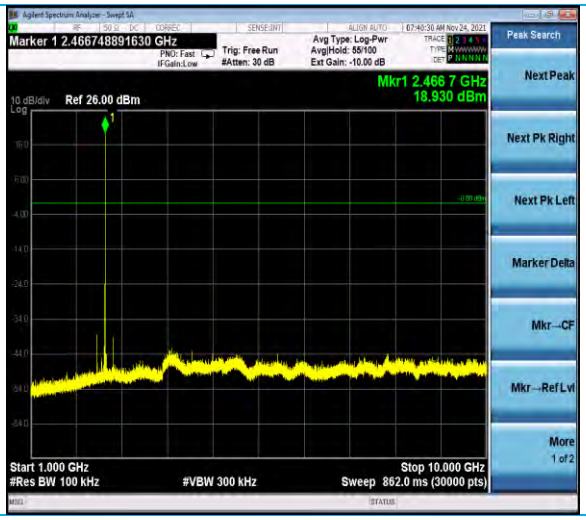

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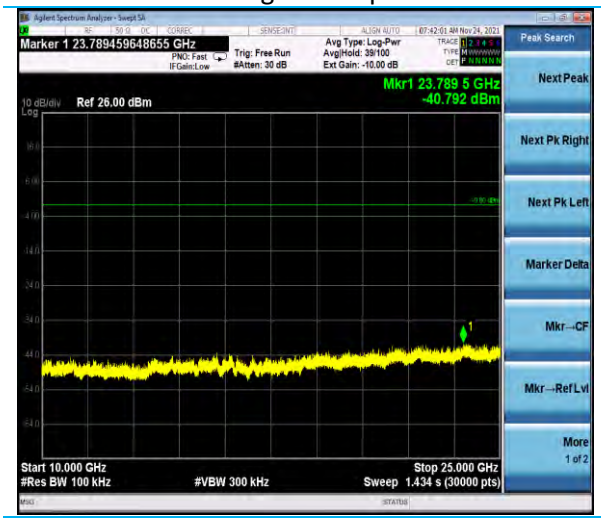

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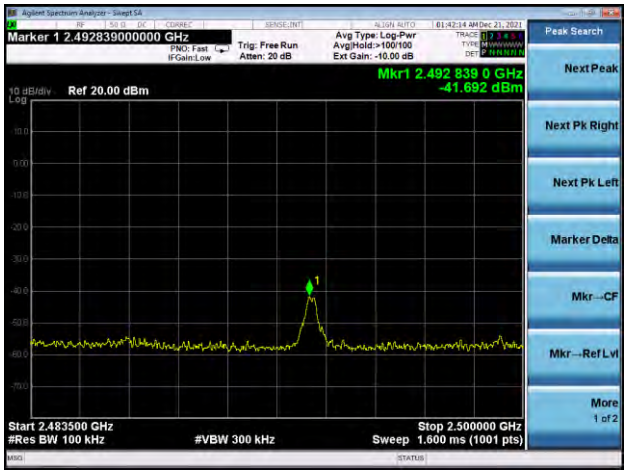

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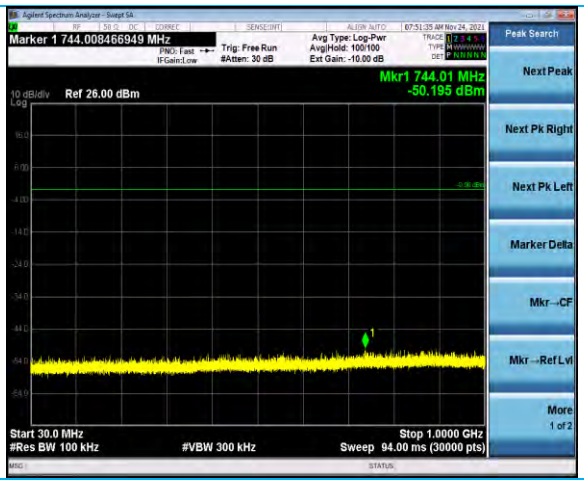

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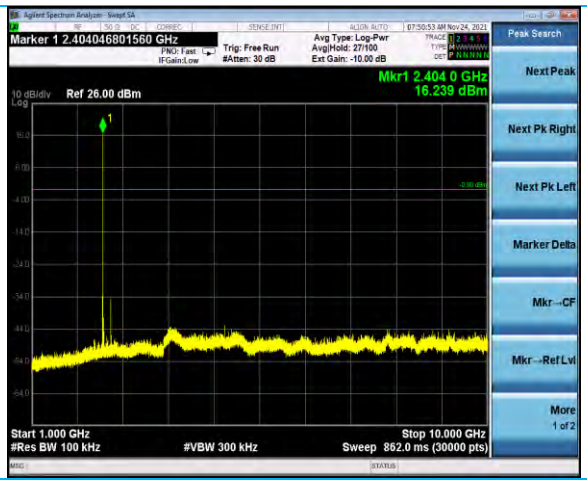

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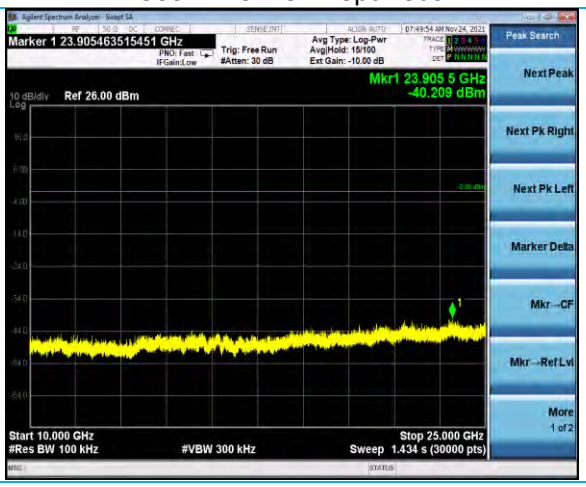

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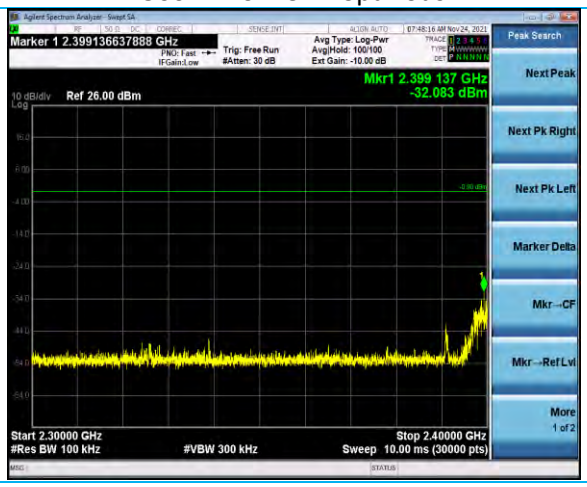

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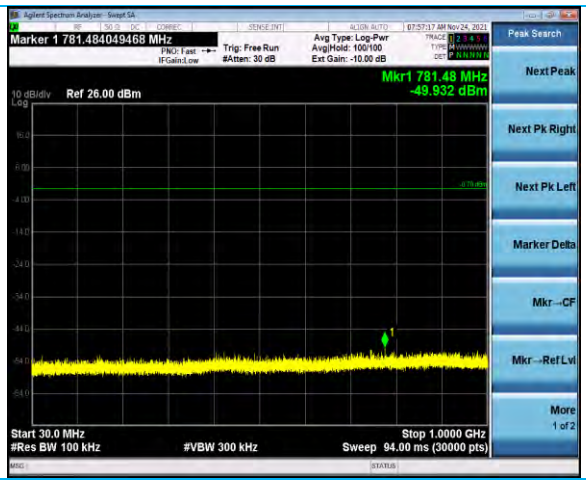
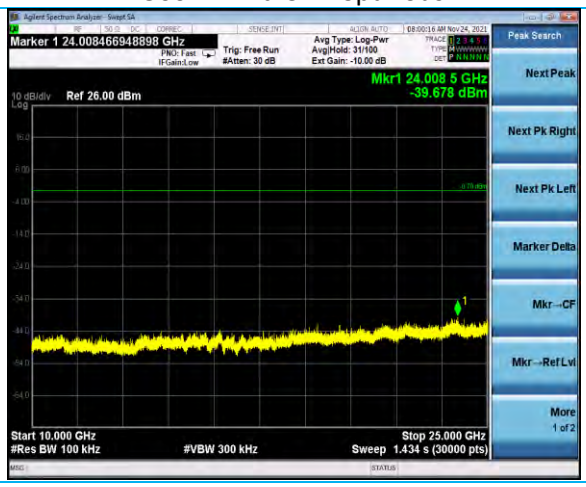


500k – Mid Ch – Spurious

500k – Mid Ch – Spurious



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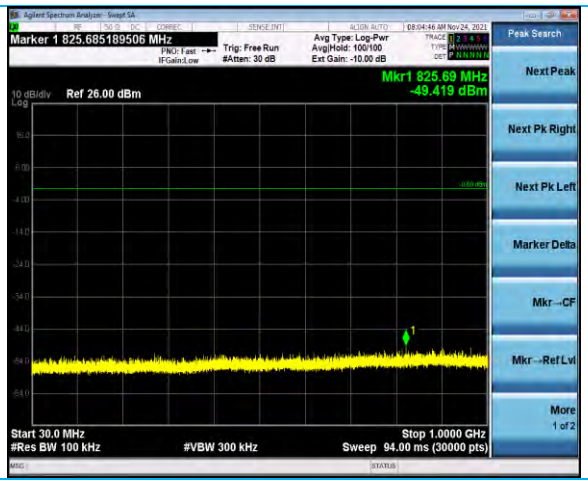

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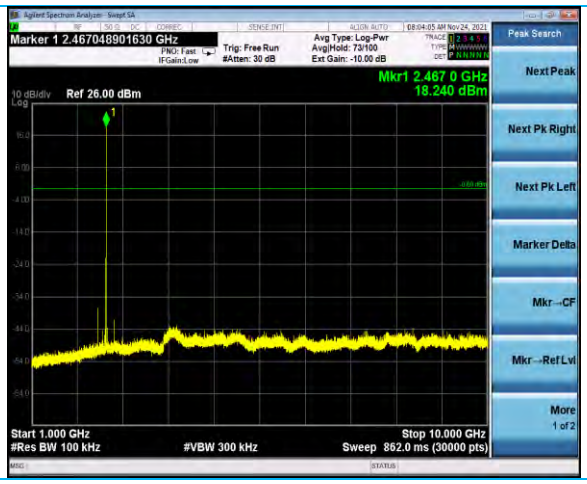

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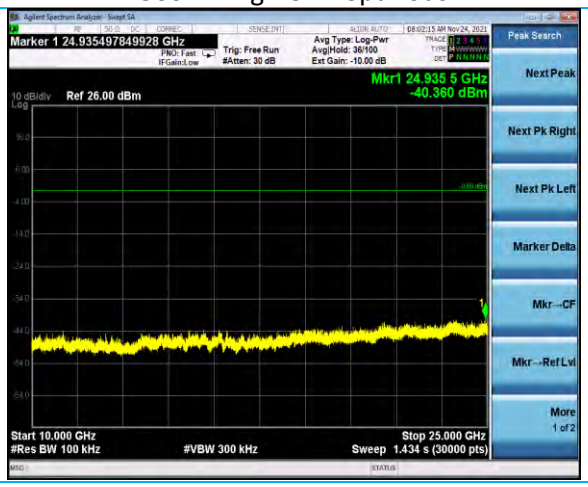

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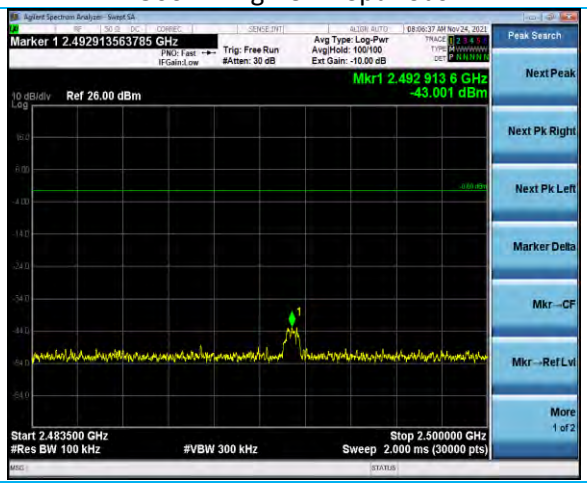
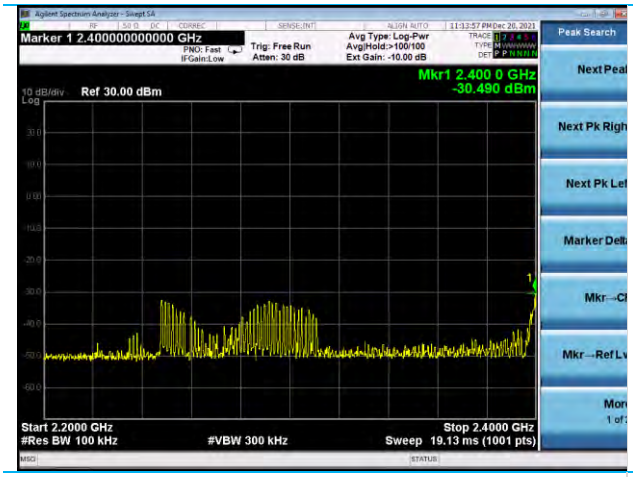
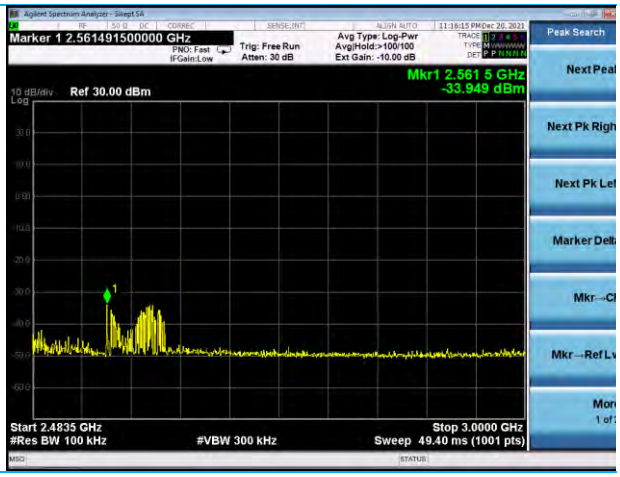


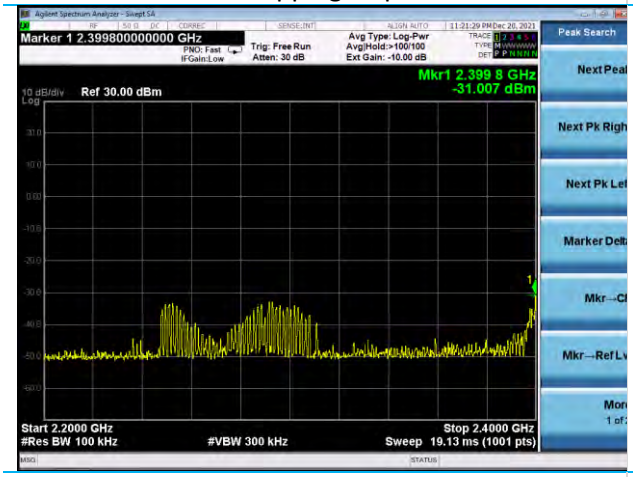
500k – High Ch – Spurious



280k – Hopping – Spurious



280k – Hopping – Spurious

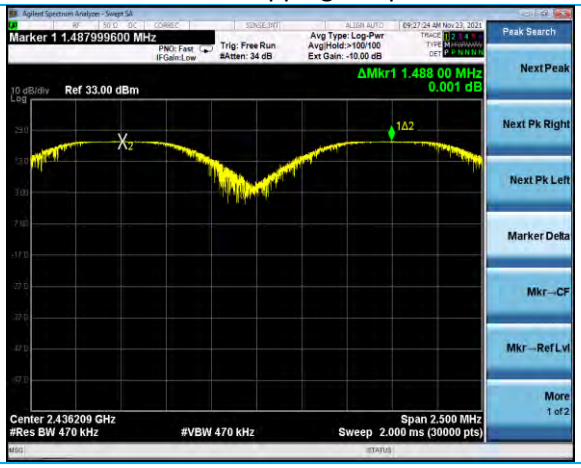


500k – Hopping – Spurious

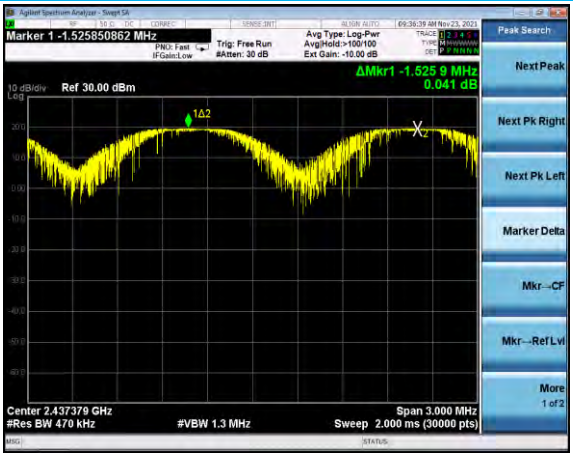
500k – Hopping – Spurious

280k Number of hopping Frequencies = 43

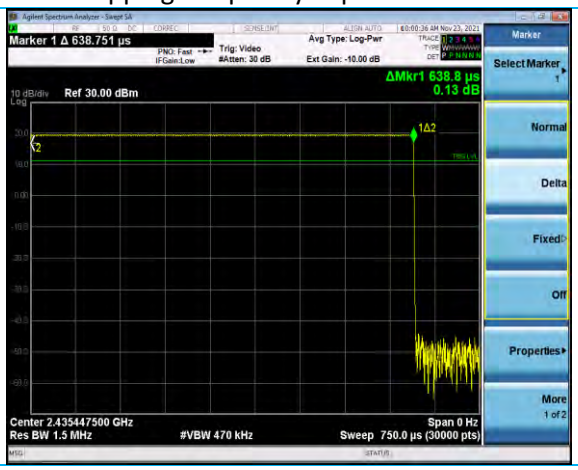
500k Number of hopping Frequencies = 43



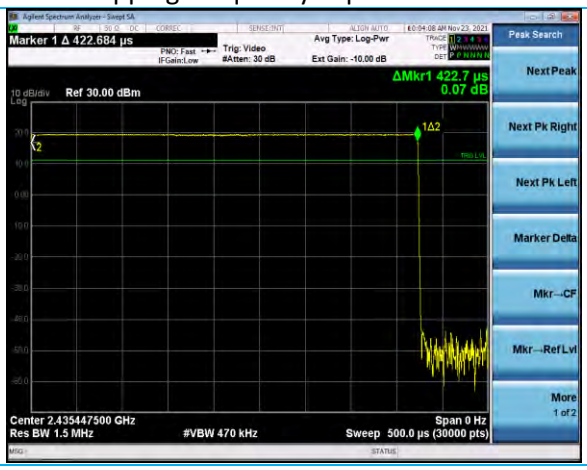
280k Hopping Frequency Separation = 1.5 MHz



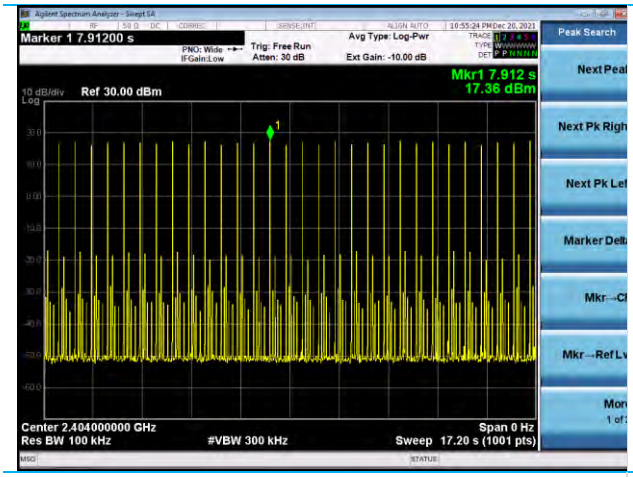
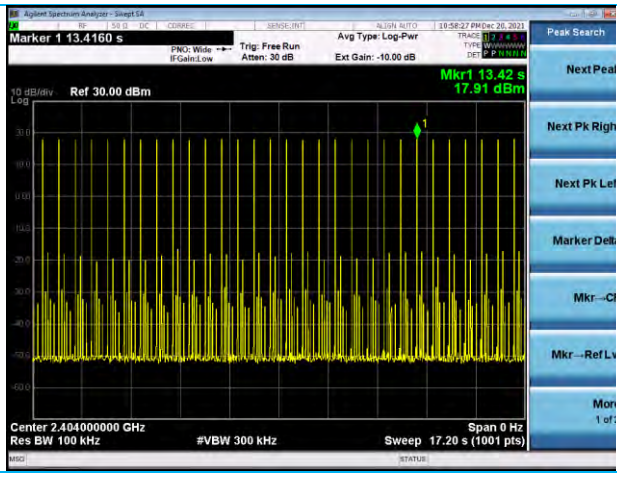
500k Hopping Frequency Separation = 1.5 MHz



280k dwell time = 639 µS



500k dwell time = 423 µS

	
280k Hops per period = 30 per 17.2 seconds	500k Hops per period = 30 per 17.2 seconds

5.1.2 Conducted RF Emissions – Cabinet Radiation

Operator	Ivan Alvarez, Anthony Smith, Adam Alger	**QA**	Adam Alger
Temperature	20.2° C	**R.H. %**	22.40
Test Date	11/22,23,24 & 12/20 2021	**Location**	Conducted RF Bench
Requirement	FCC 15.247	**Method**	ANSI C63.10

Limits:

Frequency (MHz)	Field Strength (dBµV/m) at 3 meters	Measurement Detector Type
30-88	40.0	Quasi-Peak
88-216	43.5	
216-960	46.0	
Above 960	54.0	
Above 1000	54.0	Average
Above 1000	74.0	Peak

Test Parameters

Frequency	30 – 25000 MHz	**Setup**	EUT connected to Spectrum Analyzer with an SMA cable
RBW	100 kHz (< 1 GHz) 1 MHz (> 1 GHz)	**VBW**	300 kHz (< 1 GHz) 3 MHz (> 1 GHz)
Detector(s)	Peak, calculated average based on DCCF	**Note**	-
Note	Measurement in dBm corrected to limit unit dBµV/m by adding 95.2 dB (as well as applicable antenna gain and ground plane correction factor) Peak – 17.7 dB DCCF = Calculated Average		

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
AA 960143	Cable	Gore	EKD01D01048.0	5546519	2/3/2021	2/3/2022	Active Verification
EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/28/2021	7/28/2022	Active Calibration

EUT Parameters

Input Power	5V via USB	**Mode**	Modulated Tx
Frequency	2404 - 2466.9 MHz	**Channel**	Low, Mid, High Channels Hopping (All Channels)
Settings	280, 500k data rates.		

Data

30-1000 MHz

Channel	Frequency (MHz)	Peak Measured (dBm)	Antenna Gain (dBi)	Ground Plance Reflection Factor (dB)	Corrected Peak Measurement (dBµV/m)	Quasi-Peak Limit (dBµV/m)	Margin (dB)
Low	823.6	-72.2	9.0	4.7	36.7	46.0	9.3
Mid	900.8	-78.8	9.0	4.7	30.1	46.0	15.9
High	314.7	-78.7	9.0	4.7	30.2	46.0	15.8

Peak		1000MHz - 2310MHz, 4000MHz - 25000MHz				
		Conducted Tx Spurious				
Frequency (MHz)	**Measured (dBm)**	**Antenna Gain (dBi)**	**Measurement (dBµV/m)**	**Limit (dBµV/m)**	**Margin (dB)**	**Channel**
2304.9	-40.0	9.0	64.2	74.0	9.8	Low
4807.8	-42.7	9.0	61.5	74.0	12.5	High

Average		1000MHz - 2310MHz, 4000MHz - 25000MHz				
		Conducted Tx Spurious				
Frequency (MHz)	**Measured (dBm)**	**Antenna Gain (dBi)**	**Measurement (dBµV/m)**	**Limit (dBµV/m)**	**Margin (dB)**	**Channel**
2304.9	-40.0	9.0	46.5	54.0	7.5	Low
4807.8	-42.7	9.0	43.8	54.0	10.2	High

Peak			2310MHz - 2390MHz, 2483.5MHz - 2500MHz				
			Conducted Tx Spurious				
	Frequency (MHz)	Measured (dBm)	Antenna Gain (dBi)	Measurement (dBµV/m)	Limit (dBµV/m)	Margin (dBm)	Channel
280kBps	2326.0	-37.5	9.0	66.7	74.0	7.3	Low
	2357.5	-40.8	9.0	63.4	74.0	10.6	Mid
	2310.6	-34.3	9.0	69.9	74.0	4.1	High
	2492.9	-39.8	9.0	64.4	74.0	9.6	High
	2499.8	-44.2	9.0	60.0	74.0	14.0	Mid
	2488.5	-39.5	9.0	64.7	74.0	9.3	Low

Average			2310MHz - 2390MHz, 2483.5MHz - 2500MHz				
			Conducted Tx Spurious				
	Frequency (MHz)	Measured (dBm)	Antenna Gain (dBi)	Measurement (dBµV/m)	Limit (dBµV/m)	Margin (dBm)	Channel
280kBps	2326.0	-37.5	9.0	49.0	54.0	5.0	Low
	2357.5	-40.8	9.0	45.7	54.0	8.3	Mid
	2310.6	-34.3	9.0	52.2	54.0	1.8	High
	2492.9	-39.8	9.0	46.7	54.0	7.3	High
	2499.8	-44.2	9.0	42.3	54.0	11.7	Mid
	2488.5	-39.5	9.0	47.0	54.0	7.0	Low

Peak			2310MHz - 2390MHz, 2483.5MHz - 2500MHz				
			Conducted Tx Spurious				
	Frequency (MHz)	Measured (dBm)	Antenna Gain (dBi)	Measurement (dBµV/m)	Limit (dBµV/m)	Margin (dBm)	Channel
500kBps	2310.8	-34.4	9.0	69.8	74.0	4.2	High
	2357.8	-40.0	9.0	64.2	74.0	9.8	Mid
	2325.9	-37.6	9.0	66.6	74.0	7.4	Low
	2493.0	-40.2	9.0	64.0	74.0	10.0	High
	2499.9	-44.7	9.0	59.5	74.0	14.5	Mid
	2489.0	-39.3	9.0	64.9	74.0	9.1	Low

Average			2310MHz - 2390MHz, 2483.5MHz - 2500MHz				
			Conducted Tx Spurious				
	Frequency (MHz)	Measured (dBm)	Antenna Gain (dBi)	Measurement (dBµV/m)	Limit (dBµV/m)	Margin (dBm)	Channel
500kBps	2310.8	-34.4	9.0	52.1	54.0	1.9	High
	2357.8	-40.0	9.0	46.5	54.0	7.5	Mid
	2325.9	-37.6	9.0	48.9	54.0	5.1	Low
	2493.0	-40.2	9.0	46.3	54.0	7.7	High
	2499.9	-44.7	9.0	41.8	54.0	12.2	Mid
	2489.0	-39.3	9.0	47.2	54.0	6.8	Low

Hopping Mode

Peak

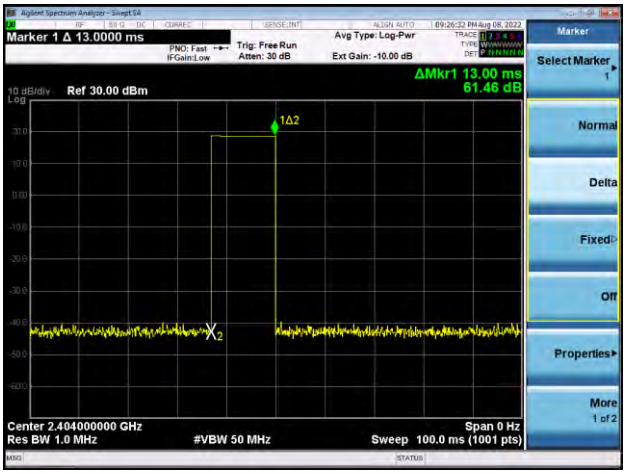
Rate	Frequency (MHz)	Measured (dBm)	Antenna Gain (dBi)	Measurement (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Channel
280k	2310.6	-35.7	9.0	68.5	74.0	5.5	Hopping
	2489.4	-36.8	9.0	67.4	74.0	6.6	Hopping
500k	2375.7	-37.1	9.0	67.1	74.0	6.9	Hopping
	2485.0	-36.5	9.0	67.7	74.0	6.3	Hopping

Average

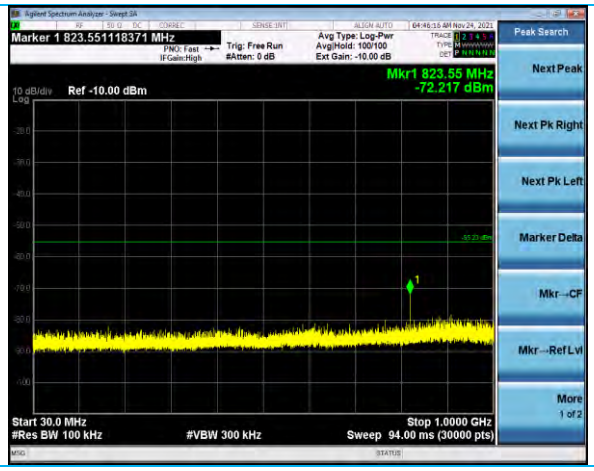
Rate	Frequency (MHz)	Measured (dBm)	Antenna Gain (dBi)	Measurement (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Channel
280k	2310.6	-35.7	9.0	50.8	54.0	3.2	Hopping
	2489.4	-36.8	9.0	49.7	54.0	4.3	Hopping
500k	2375.7	-37.1	9.0	49.4	54.0	4.6	Hopping
	2485.0	-36.5	9.0	50.0	54.0	4.0	Hopping

Duty Cycle Correction

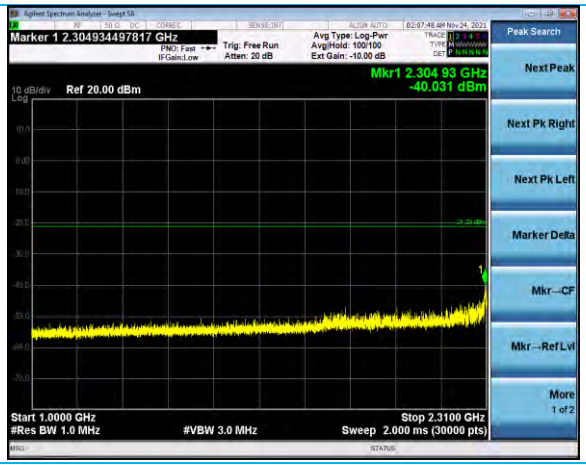
20*log(13/100) = 17.7 dB



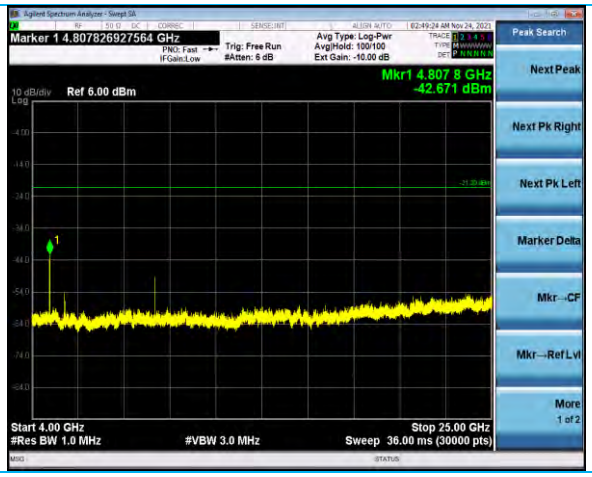
30-1000 MHz (280k worst case)



30-1000 MHz



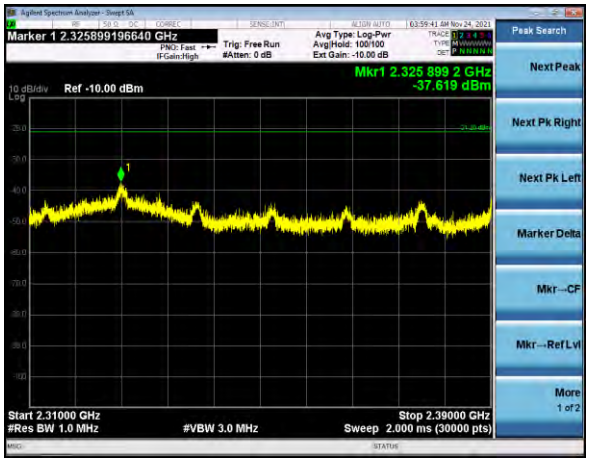
1-2.31 GHz



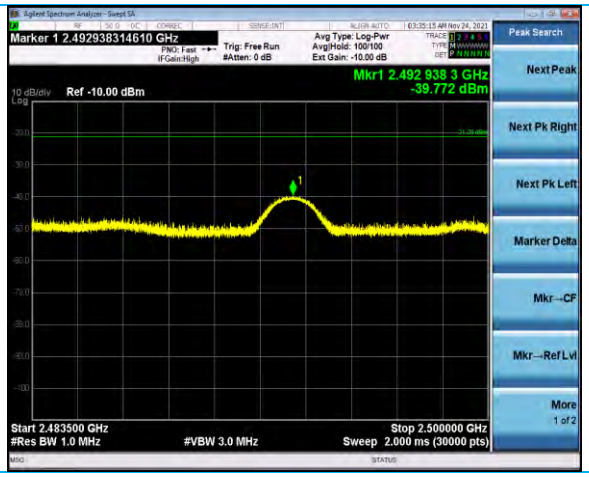
4-25 GHz

Restricted Band-Edges (2310-2390 & 2483.5-2500 MHz)

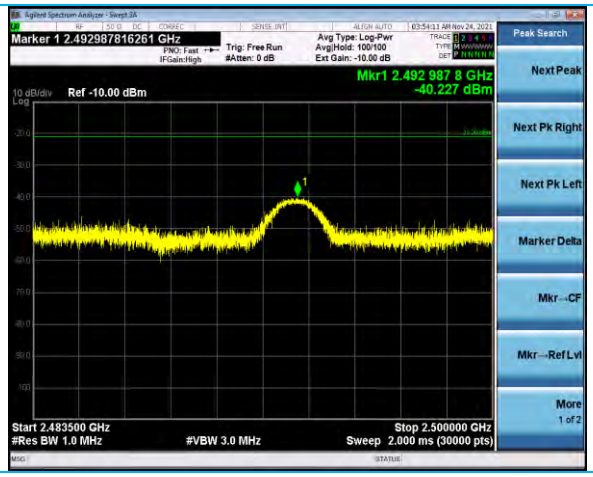
280k Low Ch



500k Low Ch

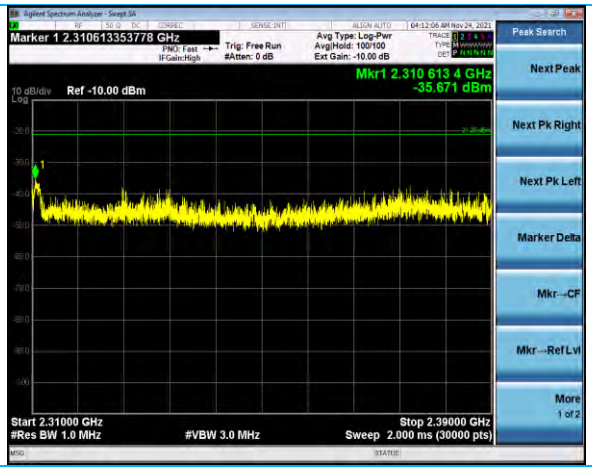


280k High Ch

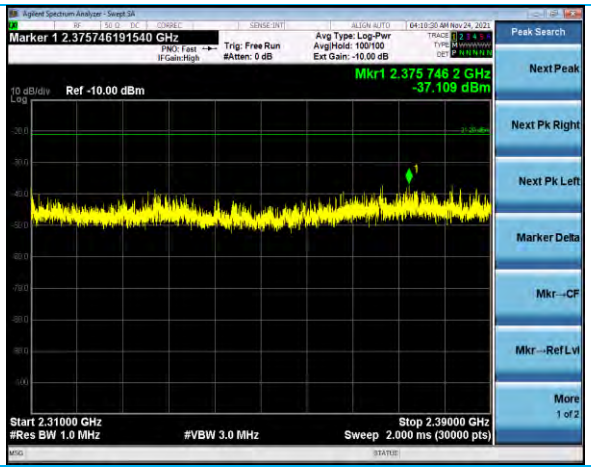


500k High Ch

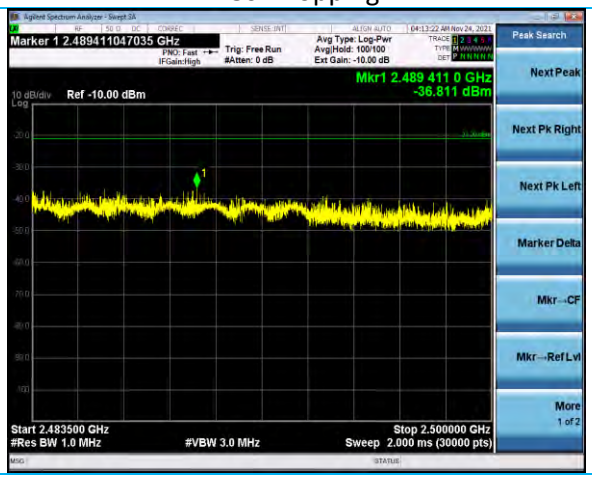
Restricted Band-Edges (2310-2390 & 2483.5-2500 MHz) – Hopping



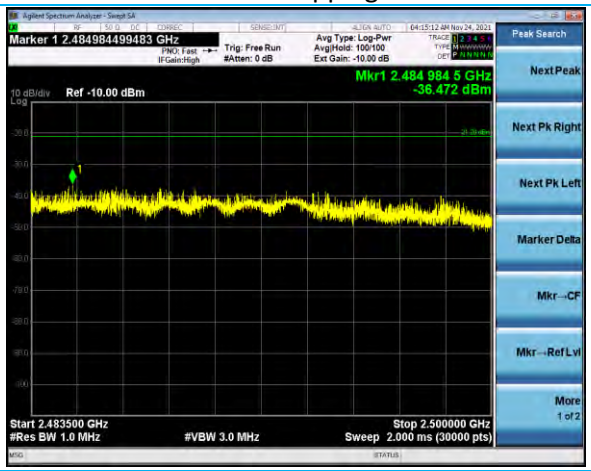
280k Hopping



500k Hopping



280k Hopping

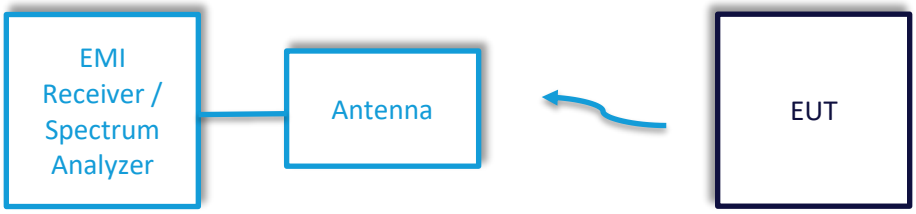


500k Hopping

5.2 Radiated Emissions

Description of Measurement	The frequency spectrum is investigated for intentional and / or unintentional signals emanating from the EUT by use of a standardized test site and measurement antenna. The antenna, cable, pre-amp, and other necessary measurement system correction factors are loaded onto the EMI receiver / spectrum analyzer when the measurements are performed allowing the data to be gathered and reported as corrected values. The maximum emissions from the EUT are determined by turn-table azimuth rotation (360°) and scanning of the measurement antenna. Maximized levels are noted at degree values of azimuth, measurement antenna height, and measurement antenna polarity.
Example Calculations	Measurement (dBµV) + Cable factor (dB) + Other (dB) + Antenna Factor (dB/m) = Corrected Reading (dBµV/m) Margin (dB) = Limit (dBµV/m) - Corrected Reading (dBµV/m) Example at 4000 MHz: Reading = 40 dBµV + 3.4 dB + 0.9 dB + 6.5 dB/m = 50.8 dBµV/m Average Limit = 20 log (500) = 54 dBµV/m Margin = 54 dBµV/m - 50.8 dBµV/m = 3.2 dB

Block Diagram



5.2.1 Radiated Emissions

Operator	Jon Dilley	**QA**	Adam Alger
Temperature	21°C	**R.H. %**	35%
Test Date	11/22-24/2021	**Location**	Chamber 3 > 1 GHz Chamber 5 < 1 GHz
Requirement	FCC Part 15.247, RSS-247	**Method**	ANSI C63.10

Limits:

Frequency (MHz)	Field Strength (dBµV/m) at 3 meters	Measurement Detector Type
30-88	40.0	Quasi-Peak
88-216	43.5	
216-960	46.0	
Above 960	54.0	
Above 1000	54.0	Average
Above 1000	74.0	Peak

Test Parameters

Frequency	30-1000 MHz, 1-25 GHz	**Distance**	3m
Detector(s)	Quasi-Peak (Under 1 GHz); Average, Peak (Above 1 GHz)	**Table height**	80 cm (Under 1 GHz); 150 cm (Above 1 GHz)
RBW	120 kHz (Under 1 GHz); 1 MHz (Above 1 GHz)	**VBW**	1.2 MHz (Below 1 GHz) 3 MHz (Above 1 GHz);
Notes	VBW reduced for screenshots above 1 GHz		

EUT Parameters

Input Power	120 VAC 60 Hz	**Mode**	Modulated Tx Mode
EUT	Low, Mid, High Channel	**EUT**	Worst-Case Reported
Notes	43 Channel Hopset used with 280 and 500 kHz data rates. Cabinet Radiation method used. DCCF of 17.7 dB used (Peak – DCCF = Calculated Average) Emissions below 1 GHz were investigated are not a function of the Tx.		

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
AA 960154	Filter - High Pass 2.4 GHz	KWM	HPF-L-14186	7272-02	4/21/2021	4/21/2022	Active Calibration
AA 960158	Antenna - Double Ridge Horn	ETS Lindgren	3117	109300	9/27/2021	9/27/2022	Active Calibration
AA 960171	Cable	A.H. Systems, Inc.	SAC-26G-6	386	2/3/2021	2/3/2022	Active Verification
AA 960174	Antenna - Small Horn	ETS Lindgren	3116C-PA	00206880	9/1/2021	9/1/2022	Active Calibration
AA 960194	Antenna - Biconical	A.H. Systems, Inc.	SAS-540	780	9/2/2021	9/2/2022	Active Calibration
AA 960195	Antenna - Log Periodic	A.H. Systems, Inc.	SAS-512-2	557	8/17/2021	8/17/2022	Active Calibration
AA 960211	Antenna - Low Noise Amplifier	Mini-Circuits	ZVA-213X-S+	97711030	9/27/2021	9/27/2022	Active Calibration
EE 960085	Analyzer - EMI Receiver	Agilent	N9038A	MY51210148	4/20/2021	4/20/2022	Active Calibration
EE 960203	Analyzer - EMI Receiver	Keysight	N9038A	MY56400072	4/20/2021	4/20/2022	Active Calibration
LSC-300	Cable	Chamber 3 Emissions	-	-	4/15/2021	4/15/2022	Active Verification
LSC-500	Cable	Chamber 5 Emissions	-	-	9/14/2021	9/14/2022	Active Verification

Table

Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Quasi-Peak Reading (dBµV/m)	Quasi-Peak Limit (dBµV/m)	Margin (dB)
97.2	Vertical	Vertical	100	0	17.9	43.5	25.6
101.3	Vertical	Vertical	100	0	18.1	43.5	25.4
91.4	Vertical	Vertical	100	0	17.4	43.5	26.1
179.1	Vertical	Horizontal	100	0	23.2	43.5	20.3
998.9	Vertical	Horizontal	100	0	30.8	54.0	23.2
838.5	Vertical	Vertical	100	0	29.5	46.0	16.5

Band-Edge

Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Peak Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Calculated Average (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)	Note
2492.1	Vertical	Horizontal	153	281	50.9	74.0	23.1	33.2	54.0	20.8	High (280k)
2382.4	Vertical	Horizontal	250	263	51.2	74.0	22.8	33.5	54.0	20.5	Low (280k)
2487.2	Vertical	Horizontal	203	251	50.9	74.0	23.1	33.2	54.0	20.8	Hopping (280k)
2348.3	Vertical	Horizontal	203	251	49.9	74.0	24.1	32.2	54.0	21.8	Hopping (280k)
2499.5	Vertical	Horizontal	150	263	50.4	74.0	23.6	32.7	54.0	21.3	High (500k)
2385.0	Vertical	Horizontal	158	265	50.8	74.0	23.2	33.1	54.0	20.9	Low (500k)
2490.9	Vertical	Horizontal	150	264	51.4	74.0	22.6	33.7	54.0	20.3	Hopping (500k)
2313.3	Vertical	Horizontal	150	264	50.4	74.0	23.6	32.7	54.0	21.3	Hopping (500k)

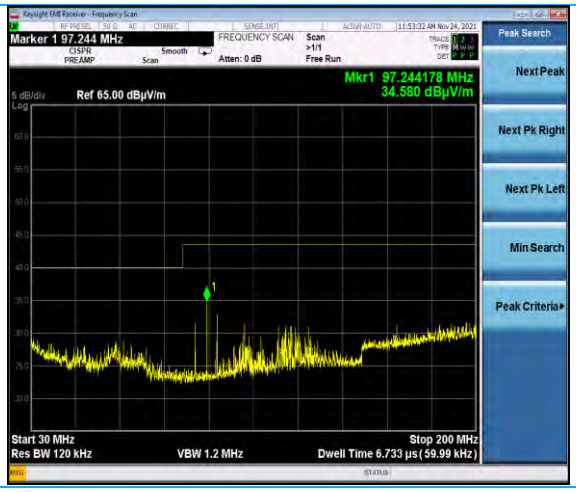
Harmonics in Restricted Bands (280k worst case)

Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Calcualted Average (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)	Peak Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Note
4871.0	Vertical	Horizontal	269	0	28.4	54.0	25.6	46.1	74.0	27.9	Mid
4871.0	Vertical	Vertical	273	0	24.9	54.0	29.1	42.6	74.0	31.4	Mid
4871.0	Horizontal	Vertical	250	333	28.3	54.0	25.7	46.0	74.0	28.0	Mid
4871.0	Horizontal	Horizontal	204	332	25.8	54.0	28.2	43.5	74.0	30.5	Mid
4871.0	Flat	Horizontal	264	58	23.9	54.0	30.1	41.6	74.0	32.4	Mid
4871.0	Flat	Vertical	250	24	24.4	54.0	29.6	42.1	74.0	31.9	Mid
4933.8	Horizontal	Vertical	224	332	29.9	54.0	24.1	47.6	74.0	26.4	High
4808.0	Horizontal	Vertical	250	330	28.8	54.0	25.2	46.5	74.0	27.5	Low

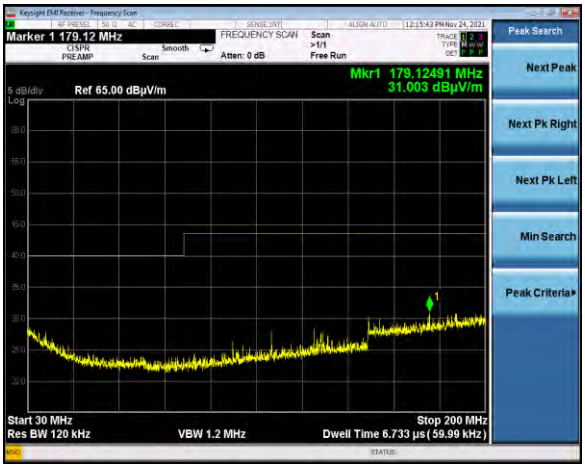
Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Calculated Average (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)	Peak Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Note
7306.4	Vertical	Horizontal	100	320	29.4	54.0	24.6	47.1	74.0	26.9	Mid
7306.4	Vertical	Vertical	100	42	32.5	54.0	21.5	50.2	74.0	23.8	Mid
7306.4	Horizontal	Vertical	240	44	31.0	54.0	23.0	48.7	74.0	25.3	Mid
7306.4	Horizontal	Horizontal	222	316	34.5	54.0	19.5	52.2	74.0	21.8	Mid
7306.4	Flat	Horizontal	250	79	32.1	54.0	21.9	49.8	74.0	24.2	Mid
7306.4	Flat	Vertical	250	324	30.3	54.0	23.7	48.0	74.0	26.0	Mid
7400.8	Horizontal	Horizontal	230	309	35.9	54.0	18.1	53.6	74.0	20.4	High

Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Caluclated Average (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)	Peak Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Note
12177.3	Vertical	Horizontal	250	347	21.4	54.0	32.6	59.6	74.0	14.4	Mid
12177.3	Vertical	Vertical	250	340	20.6	54.0	33.4	58.8	74.0	15.2	Mid
12177.3	Horizontal	Vertical	165	352	21.5	54.0	32.5	59.7	74.0	14.3	Mid
12177.3	Horizontal	Horizontal	182	321	20.6	54.0	33.4	58.8	74.0	15.2	Mid
12177.3	Flat	Horizontal	250	320	18.9	54.0	35.1	57.1	74.0	16.9	Mid
12177.3	Flat	Vertical	233	228	21.9	54.0	32.1	60.1	74.0	13.9	Mid
12334.6	Flat	Vertical	222	225	21.1	54.0	32.9	59.3	74.0	14.7	High
12020.0	Flat	Vertical	224	219	21.3	54.0	32.7	59.5	74.0	14.5	Low

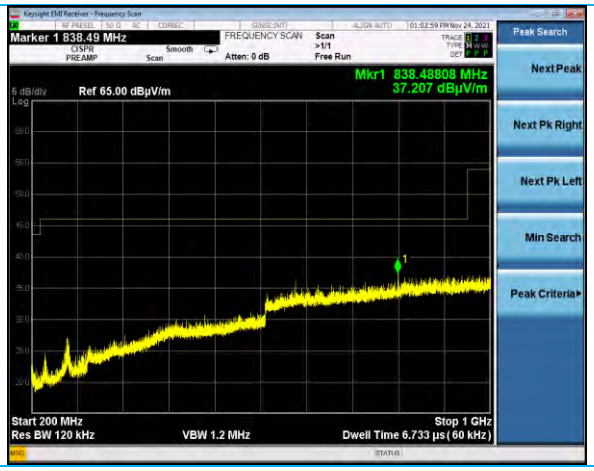
Plots



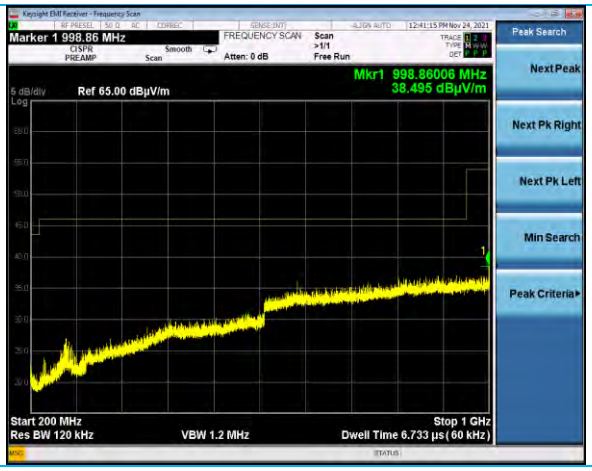
30-200 MHz Vertical



30-200 MHz Horizontal



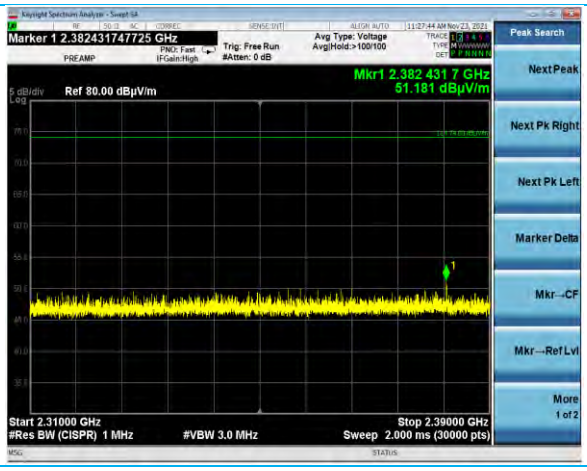
200-1000 MHz Vertical



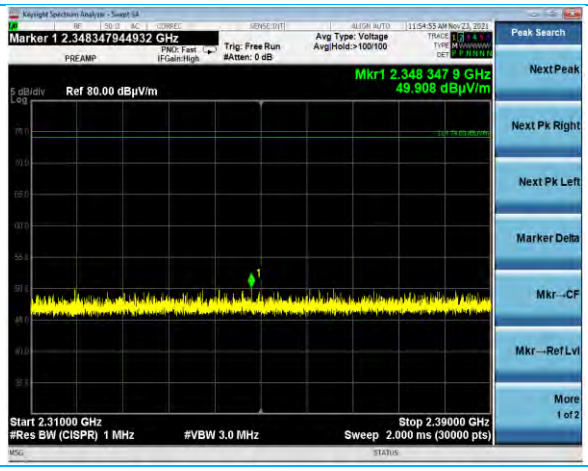
200-1000 MHz Horizontal

1000-2310 MHz Vertical

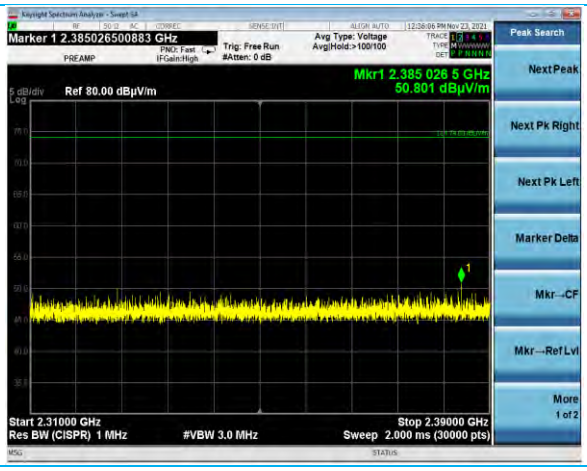
1000-2310 MHz Horizontal



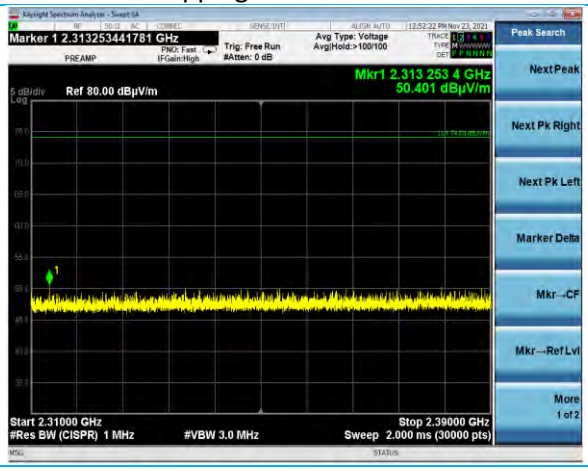
280k Low Ch 2310-2390 MHz Peak



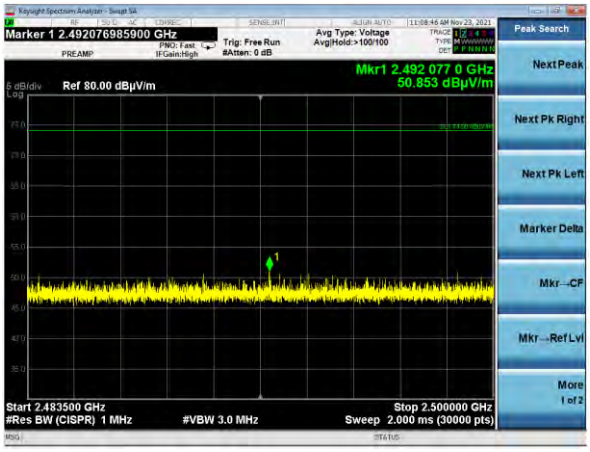
280k Hopping 2310-2390 MHz Peak



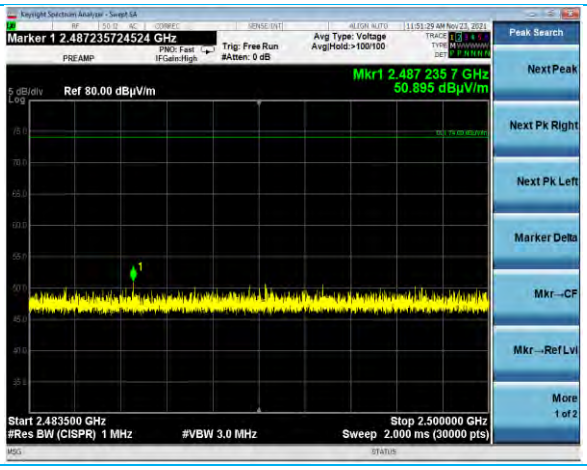
500k Low Ch 2310-2390 MHz Peak



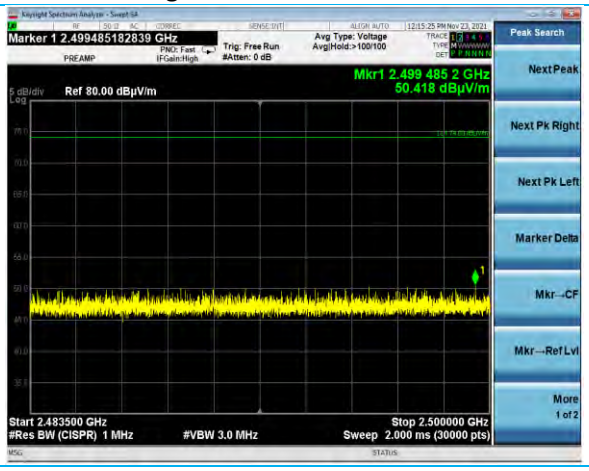
500k Hopping 2310-2390 MHz Peak



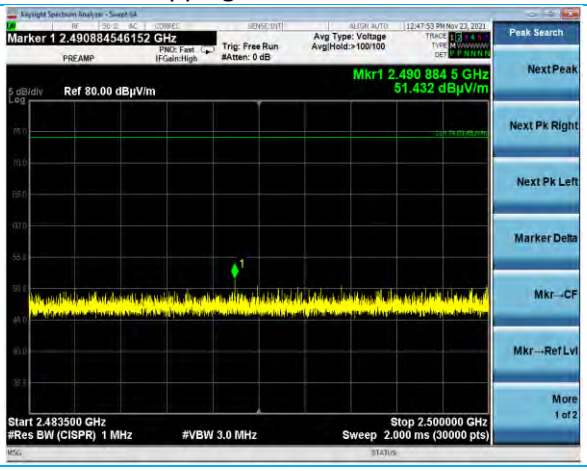
280k High Ch 2483.5-2500 MHz Peak



280k Hopping 2483.5-2500 MHz Peak



500k High Ch 2483.5-2500 MHz Peak



500k Hopping 2483.5-2500 MHz Peak

2500-4000 MHz Vertical

2500-4000 MHz Horizontal

280k 4000-18000 MHz Vertical

280k 4000-18000 MHz Horizontal

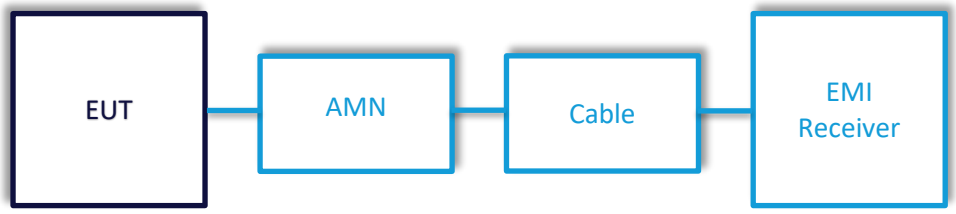
280k 18000-25000 MHz Vertical

280k 18000-25000 MHz Horizontal

5.3 AC Mains Conducted Emissions

	A line impedance stabilization network (LISN) or artificial mains network (AMN) allows the emissions of the power supply conductors to be measured while isolating the EUT from the supply mains.
Description of Measurement	The AMN, cable, and other necessary measurement system correction factors are loaded onto the EMI receiver when the measurements are performed. The data is gathered and reported as the corrected values. Maximum emissions are determined with a peak max hold trace then measurements at a selection of the highest points are made with quasi-peak and average detectors. Results are recorded and compared to limit for each line. (e.g. line and neutral)
Example Calculations	Measurement (dBµV) + Cable factor (dB) + Other (dB) = Corrected Reading (dBµV) Margin (dB) = Limit (dBµV) - Corrected Reading (dBµV)

Block Diagram



5.3.1 AC Mains Conducted Emissions

Operator	Braden Smith	**QA**	Adam Alger
Temperature	20.7° C	**R.H. %**	33.20%
Test Date	11/23/2021	**Location**	Conducted Bench Area
Requirement	15.207	**Method**	ANSI C63.10 Section 6.2

Limits:

Frequency (MHz)	Conducted Limit (dBµV)	
	Quasi-Peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

*Decreases logarithmically with frequency

Test Parameters

Frequency	0.15 - 30.0 MHz	**Distance**	80 cm from LISN, 40 cm from wall
Detector(s)	Quasi-Peak, Average	**Table height**	80 cm
RBW	9 kHz	**VBW**	90 kHz

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
EE 960088	Analyzer - EMI Receiver	Agilent	N9038A	MY51210138	4/21/2021	4/21/2022	Active Calibration
EE 960162	LISN	COM-POWER	LI-215A	191969	4/19/2021	4/19/2022	Active Calibration
LSC-200	Cable	Micro-Coax	UFB311A-0-1440-70U70U	64639 224071-003	4/15/2021	4/15/2022	Active Verification

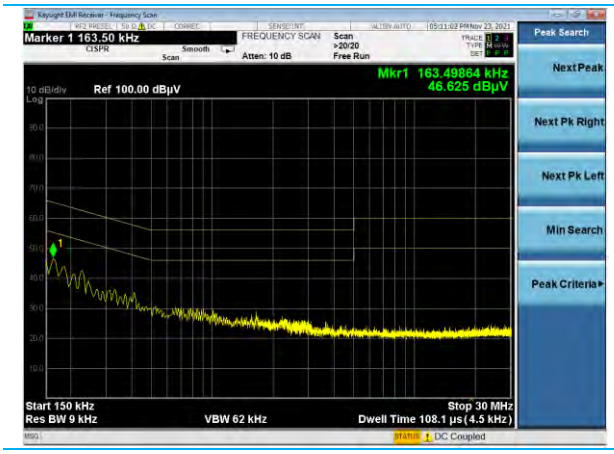
EUT Parameters

Input Power	120 VAC, 60 Hz	**Mode**	Modulated Tx Mode
EUT	Low, Mid, High Channel	**EUT**	Worst-Case Reported
Notes	43 Channel Hopset used with 280 data rate.		

Table

Line	Frequency (MHz)	Quasi-Peak Reading (dBµV)	Quasi-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
1	0.164	42.2	65.3	23.1	31.7	55.3	23.6
1	0.150	37.8	66.0	28.2	29.5	56.0	26.5
1	0.227	35.6	62.6	27.0	26.6	52.6	26.0
2	0.164	42.2	65.3	23.1	31.4	55.3	23.9
2	0.150	37.8	66.0	28.2	29.5	56.0	26.5
2	0.411	33.7	57.6	23.9	29.4	47.6	18.2

Plots



Line 1

Line 2

6 REVISION HISTORY

Version	Date	Notes	Person
0	12/1/2021	Initial Draft	Adam Alger
1	5/20/2022	Final	Adam Alger
2	8/8/2022	TCB Comments	Adam Alger

END OF REPORT