HEADQUARTERS: 914 WEST PATAPSCO AVENUE • BALTIMORE, MARYLAND 21230 • PHONE (410) 354-3300 • FAX (410) 354-3313

6/12/2023

Mikado Model Helicopters GmbH (MIK3)
Edward Eckstein
Graf-von-Schwerin-Str. 40
Potsdam, 14469
Germany

Dear Edward Eckstein,

Enclosed is the EMC Wireless test report for compliance testing of the Mikado Model Helicopters GmbH (MIK3) VBar EVO as tested to the requirements of FCC Part 15.247, RSS-247 Issue 2 for Intentional Radiators.

Thank you for using the services of Eurofins MET Labs. If you have any questions regarding these results or if MET can be of further service to you, please feel free to contact me.

Sincerely yours,
EUROFINS MET LABS

Nancy LaBrecque
Documentation Department

Reference: WIRA125540_15.247_RSS247_R1

FHSS Test Report

for the

Mikado Model Helicopters GmbH (MIK3)
VBar EVO

Tested under
FCC Part 15.247, RSS-247 Issue 2
For Intentional Radiators

Bryan Taylor, Wireless Team Lead
Electromagnetic Compatibility Lab

Nancy LaBrecque
Documentation Department

Engineering Statement: The measurements shown in this report were made in accordance with the procedures indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurements made, the equipment tested is capable of operation in accordance with the requirements of the FCC Rules Part 15.247 under normal use and maintenance.

Matthew Hinojosa
EMC Manager, Austin Electromagnetic Compatibility Lab

Report Status Sheet

Revision	Report Date	Reason for Revision
∅	4/25/2023	Initial Issue.
1	6/12/2023	Implemented changes from TCB review

Table of Contents

List of Tables

List of Figures

List of Terms and Abbreviations

AC	**A**lternating **C**urrent
ACF	**A**ntenna **C**orrection **F**actor
Cal	**Cal**ibration
d	**M**easurement **D**istance
dB	**D**eci**b**els
dBµA	**D**eci**b**els above one **micro**amp
dBµV	**D**eci**b**els above one **micro**volt
dBµA/m	**D**eci**b**els above one **micro**amp **per m**eter
dBµV/m	**D**eci**b**els above one **micro**volt **per m**eter
DC	**D**irect **C**urrent
E	**E**lectric Field
DSL	**D**igital **S**ubscriber **L**ine
ESD	**E**lectro**s**tatic **D**ischarge
EUT	**E**quipment **U**nder **T**est
f	**F**requency
FCC	**F**ederal **C**ommunications **C**ommission
GRP	**G**round **R**eference **P**lane
H	Magnetic Field
HCP	**H**orizontal **C**oupling **P**lane
Hz	**H**ert**z**
IEC	**I**nternational **E**lectrotechnical **C**ommission
kHz	**k**ilo**h**ert**z**
kPa	**k**ilo**pa**scal
kV	**k**ilo**v**olt
LISN	**L**ine **I**mpedance **S**tabilization **N**etwork
MHz	**M**ega**h**ertz
µH	**microh**enry
µ	**microf**arad
µs	**micros**econds
NEBS	**N**etwork **E**quipment-**B**uilding **S**ystem
PRF	**P**ulse **R**epetition **F**requency
RF	**R**adio **F**requency
RMS	**R**oot-**M**ean-**S**quare
TWT	**T**raveling **W**ave **T**ube
V/m	**V**olts **per m**eter
VCP	**V**ertical **C**oupling **P**lane

I. Executive Summary

A. Purpose of Test

An EMC evaluation was performed to determine compliance of the Mikado Model Helicopters GmbH (MIK3) VBar EVO, with the requirements of FCC Part 15.247, RSS-247 Issue 2. Mikado Model Helicopters GmbH (MIK3) should retain a copy of this document which should be kept on file for at least two years after the manufacturing of the VBar EVO, has been **permanently** discontinued.

B. Executive Summary

The following tests were conducted on a sample of the equipment for the purpose of demonstrating compliance with FCC Part 15.247, RSS-247 Issue 2, in accordance with Mikado Model Helicopters GmbH (MIK3) purchase order number 428234. All tests were conducted using measurement procedures ANSI C63.4-2014 and ANSI C63.10-2013.

FCC Reference 47 CFR Part 15.247:2005	IC Reference RSS-247 Issue 2: 2017; RSS-GEN Issue 5: 2018	Description	Compliance
Title 47 of the CFR, Part 15 §15.203	---	Antenna Requirement	Compliant
Title 47 of the CFR, Part 15 §15.207(a)	RSS-GEN(8.8)	Conducted Emission Limits	Not Applicable[1]
Title 47 of the CFR, Part 15 §15.247(a)(1)	RSS-247 (5.1)	20dB Occupied Bandwidth	Compliant
---	RSS-GEN(6.7)	99% Occupied Bandwidth	Compliant
Title 47 of the CFR, Part 15 §15.247(a)(1)	RSS-247 (5.1)	Average Time of Occupancy (Dwell Time)	Compliant
Title 47 of the CFR, Part 15 §15.247(a)(1)	RSS-247 (5.1)	Number of RF Channels	Compliant
Title 47 of the CFR, Part 15 §15.247(a)(1)	RSS-247 (5.1)	RF Channel Separation	Compliant
Title 47 of the CFR, Part 15 §15.247(b)	RSS-247(5.4)	Peak Power Output	Compliant
Title 47 of the CFR, Part 15 §15.247(d); §15.209; §15.205	RSS-GEN (6.13), (8.9), & (8.10)	Radiated Spurious Emissions Requirements	Compliant
Title 47 of the CFR, Part 15 §15.247(d)	RSS-247(5.5)	RF Conducted Spurious Emissions Requirements	Compliant
Title 47 of the CFR, Part 15; §15.247(e)	RSS-247(5.2)	Peak Power Spectral Density	Compliant

Table 1. Executive Summary

[1] This test was not applicable since the VBar EVO was exclusively battery powered and had no connections to the AC mains.

II. Equipment Configuration

A. Overview

Eurofins MET Labs was contracted by Mikado Model Helicopters GmbH (MIK3) to perform testing on the VBar EVO, under Mikado Model Helicopters GmbH (MIK3) purchase order number 428234.

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform compliance testing of the Mikado Model Helicopters GmbH (MIK3) VBar EVO.

The results obtained relate only to the item(s) tested.

Model(s) Tested:	VBar EVO	
Model(s) Covered:	VBar EVO	
EUT Specifications:	Primary Power: 4.8VDC	
	Type of Modulations:	MSK
	Equipment Code:	DSS
	Peak RF Output Power (Conducted):	16.74dBm
	EUT Frequency Ranges:	2401MHz - 2481MHz
	Supported Channels:	A maximum of 80 channels will be supported by any single VBar EVO unit. Each VBar EVO will be pre-programmed at the factory to operate exclusively on networks 1, 2 or 3 with a maximum of 80 channels on any one network. The complete list of channels for networks 1, 2, and 3 is shown in the following tables.
	Antenna Gain[2]:	2dBi
Analysis:	The results obtained relate only to the item(s) tested.	
Environmental Test Conditions:	Temperature: 15-35º C	
	Relative Humidity: 30-60%	
	Barometric Pressure: 860-1060 mbar	
Evaluated by:	Bryan Taylor and Sergio Gutierrez	
Report Date(s):	3/10/2023 through 3/31/2023	

Table 2. EUT Summary Table

[2] The antenna gain information was provided by Mikado Model Helicopters GmbH (MIK3).

Channel	Frequency (MHz)	Network
1	2401.064	1
2	2401.398	2
3	2401.731	3
4	2402.064	1
5	2402.397	2
6	2402.731	3
7	2403.064	1
8	2403.397	2
9	2403.730	3
10	2404.064	1
11	2404.397	2
12	2404.730	3
13	2405.063	1
14	2405.397	2
15	2405.730	3
16	2406.063	1
17	2406.396	2
18	2406.730	3
19	2407.063	1
20	2407.396	2
21	2407.729	3
22	2408.063	1
23	2408.396	2
24	2408.729	3
25	2409.062	1
26	2409.396	2
27	2409.729	3
28	2410.062	1
29	2410.396	2
30	2410.729	3
31	2411.062	1
32	2411.395	2
33	2411.729	3
34	2412.062	1
35	2412.395	2
36	2412.728	3
37	2413.062	1
38	2413.395	2
39	2413.728	3
40	2414.061	1
41	2414.395	2
42	2414.728	3
43	2415.061	1
44	2415.394	2
45	2415.728	3
46	2416.061	1
47	2416.394	2
48	2416.727	3
49	2417.061	1
50	2417.394	2
51	2417.727	3
52	2418.060	1
53	2418.394	2
54	2418.727	3
55	2419.060	1
56	2419.393	2
57	2419.727	3
58	2420.060	1
59	2420.393	2
60	2420.726	3

Channel	Frequency (MHz)	Network
61	2421.060	1
62	2421.393	2
63	2421.726	3
64	2422.059	1
65	2422.393	2
66	2422.726	3
67	2423.059	1
68	2423.392	2
69	2423.726	3
70	2424.059	1
71	2424.392	2
72	2424.725	3
73	2425.059	1
74	2425.392	2
75	2425.725	3
76	2426.058	1
77	2426.392	2
78	2426.725	3
79	2427.058	1
80	2427.391	2
81	2427.725	3
82	2428.058	1
83	2428.391	2
84	2428.724	3
85	2429.058	1
86	2429.391	2
87	2429.724	3
88	2430.057	1
89	2430.391	2
90	2430.724	3
91	2431.057	1
92	2431.390	2
93	2431.724	3
94	2432.057	1
95	2432.390	2
96	2432.723	3
97	2433.057	1
98	2433.390	2
99	2433.723	3
100	2434.056	1
101	2434.390	2
102	2434.723	3
103	2435.056	1
104	2435.389	2
105	2435.723	3
106	2436.056	1
107	2436.389	2
108	2436.722	3
109	2437.056	1
110	2437.389	2
111	2437.722	3
112	2438.055	1
113	2438.389	2
114	2438.722	3
115	2439.055	1
116	2439.388	2
117	2439.722	3
118	2440.055	1
119	2440.388	2
120	2440.721	3

Table 3. Supported Channel List

Channel	Frequency (MHz)	Network
121	2441.055	1
122	2441.388	2
123	2441.721	3
124	2442.054	1
125	2442.388	2
126	2442.721	3
127	2443.054	1
128	2443.387	2
129	2443.721	3
130	2444.054	1
131	2444.387	2
132	2444.720	3
133	2445.054	1
134	2445.387	2
135	2445.720	3
136	2446.053	1
137	2446.387	2
138	2446.720	3
139	2447.053	1
140	2447.386	2
141	2447.720	3
142	2448.053	1
143	2448.386	2
144	2448.719	3
145	2449.053	1
146	2449.386	2
147	2449.719	3
148	2450.052	1
149	2450.386	2
150	2450.719	3
151	2451.052	1
152	2451.385	2
153	2451.719	3
154	2452.052	1
155	2452.385	2
156	2452.719	3
157	2453.052	1
158	2453.385	2
159	2453.718	3
160	2454.052	1
161	2454.385	2
162	2454.718	3
163	2455.051	1
164	2455.385	2
165	2455.718	3
166	2456.051	1
167	2456.384	2
168	2456.718	3
169	2457.051	1
170	2457.384	2
171	2457.717	3
172	2458.051	1
173	2458.384	2
174	2458.717	3
175	2459.050	1
176	2459.384	2
177	2459.717	3
178	2460.050	1
179	2460.383	2
180	2460.717	3

Channel	Frequency (MHz)	Network
181	2461.050	1
182	2461.383	2
183	2461.716	3
184	2462.050	1
185	2462.383	2
186	2462.716	3
187	2463.049	1
188	2463.383	2
189	2463.716	3
190	2464.049	1
191	2464.382	2
192	2464.716	3
193	2465.049	1
194	2465.382	2
195	2465.715	3
196	2466.049	1
197	2466.382	2
198	2466.715	3
199	2467.048	1
200	2467.382	2
201	2467.715	3
202	2468.048	1
203	2468.381	2
204	2468.715	3
205	2469.048	1
206	2469.381	2
207	2469.714	3
208	2470.048	1
209	2470.381	2
210	2470.714	3
211	2471.047	1
212	2471.381	2
213	2471.714	3
214	2472.047	1
215	2472.380	2
216	2472.714	3
217	2473.047	1
218	2473.380	2
219	2473.713	3
220	2474.047	1
221	2474.380	2
222	2474.713	3
223	2475.046	1
224	2475.380	2
225	2475.713	3
226	2476.046	1
227	2476.379	2
228	2476.713	3
229	2477.046	1
230	2477.379	2
231	2477.712	3
232	2478.046	1
233	2478.379	2
234	2478.712	3
235	2479.045	1
236	2479.379	2
237	2479.712	3
238	2480.045	1
239	2480.378	2
240	2480.712	3

Table 4. Supported Channel List (Continued)

B. References

CFR 47, Part 15, Subpart C	Federal Communication Commission, Code of Federal Regulations, Title 47, Part 15: General Rules and Regulations, Allocation, Assignment, and Use of Radio Frequencies
RSS-247, Issue 2, February 2017	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
RSS-GEN, Issue 5, March 2019	General Requirements and Information for the Certification of Radio Apparatus
ANSI C63.4:2014	Methods and Measurements of Radio-Noise Emissions from Low-Voltage Electrical And Electronic Equipment in the Range of 9 kHz to 40 GHz
ISO/IEC 17025:2017	General Requirements for the Competence of Testing and Calibration Laboratories
ANSI C63.10-2013	American National Standard for Testing Unlicensed Wireless Devices

Table 5. References

C. Test Site

All testing was performed at Eurofins MET Labs, 13501 McCallen Pass, Austin, TX 78753. All equipment used in making physical determinations is accurate and bears recent traceability to the National Institute of Standards and Technology.

Radiated Emissions measurements were performed in a 10 meter semi-anechoic chamber (equivalent to an Open Area Test Site). In accordance with §2.948(a)(3), a complete site description is contained at MET Laboratories.

D. Measurement Uncertainty

Test Method	Typical Expanded Uncertainty	K	Confidence Level
RF Frequencies	±4.52 Hz	2	95%
RF Power Conducted Emissions	±2.97 dB	2	95%
RF Power Radiated Emissions	±2.95 dB	2	95%

Table 6. Uncertainty Calculations Summary

E. Description of Test Sample

The Mikado Model Helicopters GmbH (MIK3) VBar EVO is a small device that is placed inside a model helicopter. It receives data from the transmitter and dispatches it to the connected servos with standard PWM signals. Additionally, it manages received telemetry data like currents and voltages, and sends it back to the Transmitter device, where it is shown on the display.

The Device is powered by an external battery. It powers the servos directly from this battery.

VBar EVO only works in combination with a VBar Control Radio. It is bound together once at installation time, and from then on will only work in this combination.

F. Equipment Configuration

The VBar EVO was set up as shown below.

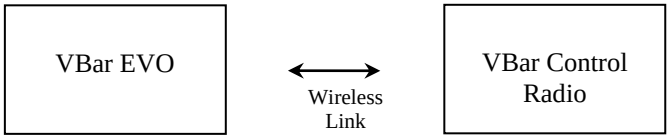


Figure 1. Block Diagram of Test Configuration

G. Support Equipment

Support equipment necessary for the operation and testing of the EUT is included in the following list.

Ref. ID	Name / Description	Manufacturer	Model Number	Customer Supplied Calibration Data
None	VBar Control	Mikado Model Helicopters GmbH (MIK3)	VBar Control	None

Table 7. Support Equipment

H. Ports and Cabling Information

Ref. Id	Port Name on EUT	Qty	Length as tested (m)	Shielded? (Y/N)	Termination Box ID & Port Name
No cables were connected to the test sample during the testing.					

Table 8. Ports and Cabling Information

I. Mode of Operation

The support VBar controller provided a direct means of controlling transmitter parameters. Unless otherwise stated or shown, all tests were performed at worst-case modulation and data rates on the following channels.

Transmit Band	Operating Mode	Channel Frequencies Tested	Test Tool Power Setting
2400 – 2483.5MHz	MSK	2401.06MHz / 2440.7MHz / 2480.7MHz	Maximum

Table 9. Test Channels Utilized

Additionally, some tests required the test sample to operate in its normal frequency hopping mode.

J. Method of Monitoring EUT Operation

A spectrum analyzer was used to confirm proper transmitter operation.

K. Modifications

a) Modifications to EUT

No modifications were made to the EUT.

b) Modifications to Test Standard

No modifications were made to the test standard.

L. Disposition of EUT

The test sample including all support equipment submitted to the Electro-Magnetic Compatibility Lab for testing was returned to Mikado Model Helicopters GmbH (MIK3) upon completion of testing.

III. Electromagnetic Compatibility Criteria for Intentional Radiators

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.203 Antenna Requirement

Test Requirement: **§ 15.203:** An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited.

The structure and application of the EUT were analyzed to determine compliance with Section 15.203 of the Rules. Section 15.203 states that the subject device must meet at least one of the following criteria:

a.) Antenna must be permanently attached to the unit.

b.) Antenna must use a unique type of connector to attach to the EUT.

c.) Unit must be professionally installed. Installer shall be responsible for verifying that the correct antenna is employed with the unit.

Results: The EUT as tested is compliant the criteria of §15.203. The TX antenna is not accessible by the end user.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.207(a) Conducted Emissions Limits

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

Frequency range (MHz)	§ 15.207(a), Conducted Limit (dBμV)	
	Quasi-Peak	Average
0.15-0.5	66 - 56	56 - 46
0.5-5	56	46
5-30	60	50

Table 10. Conducted Limits for Intentional Radiators from FCC Part 15 § 15.207(a)

Test Procedure: The EUT was placed on a 0.8 m-high wooden table. The EUT was situated such that the back of the EUT was 0.4 m from one wall of the vertical ground plane, and the remaining sides of the EUT were no closer than 0.8 m from any other conductive surface. The EUT was powered from a 50 Ω/50 μH Line Impedance Stabilization Network (LISN). The EMC receiver scanned the frequency range from 150 kHz to 30 MHz. Conducted Emissions measurements were made in accordance with *ANSI C63.4-2014 "Methods and Measurements of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9kHz to 40 GHz"*. The measurements were performed using a 50 Ω/50 μH LISN as the input transducer to an EMI receiver. For the purpose of this testing, the transmitter was turned on.

Test Results: This test was not applicable since the VBar EVO is exclusively battery powered with no connections to the AC mains.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(a)(1) 20 dB Bandwidth

Test Requirements: **§ 15.247(a):** Operation under the provisions of this section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:

For systems using digital modulation techniques, the EUT may operate in the 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz bands. For DTS, the minimum 6 dB bandwidth shall be at least 500 kHz. For frequency hopping systems, the EUT 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.

Test Procedure: The transmitter was on and transmitting at the highest output power. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using a RBW approximately 1% of the total emission bandwidth, and the VBW > RBW. The 20 dB Bandwidth was measured and recorded. The measurements were performed on the low, mid and high channels.

Test Results The EUT was compliant with § 15.247 (a)(1).

The 20 dB Bandwidth was determined from the plots on the following pages.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

Electromagnetic Compatibility Criteria for Intentional Radiators

RSS-GEN (6.7) 99% Bandwidth

Test Requirements: The occupied bandwidth or the "99% emission bandwidth" is defined as the frequency rang between two points, one above and the other blow the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained. The occupied bandwidth shall be reported for all equipment in addition to the specified bandwidth required in the applicable RSSs.

Test Procedure: The transmitter was connected to the spectrum analyzer through an attenuator. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using a RBW approximately equal to 1% of the total emission bandwidth, and the VBW > RBW. The 99% Bandwidth was measured and recorded.

Test Results The 99% Bandwidth determined from the plots on the following pages.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

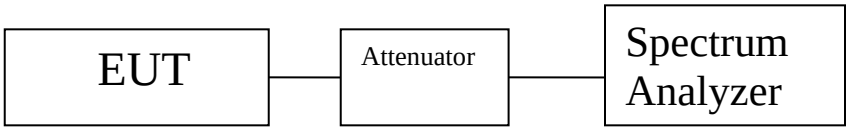


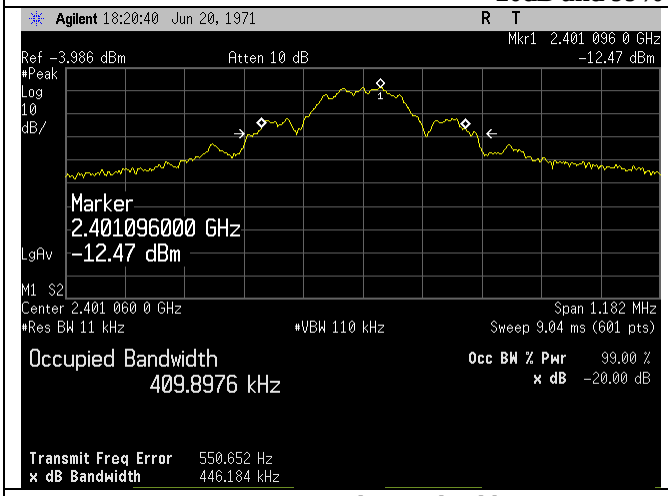
Figure 2. Block Diagram, Occupied Bandwidth Test Setup

Test Mode	20dB Bandwidth (kHz)	99% Bandwidth (kHz)
2401.06MHz	446.18	421.83
2440.7MHz	417.34	420.46
2480.06MHz	415.09	402.34

Table 11. 99% and 20 dB Occupied Bandwidth, Test Results

Occupied Bandwidth Test Results

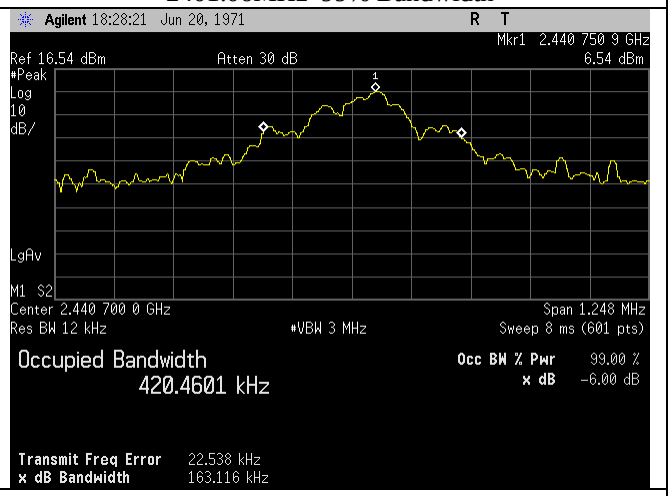
20dB and 99% Bandwidth Plots



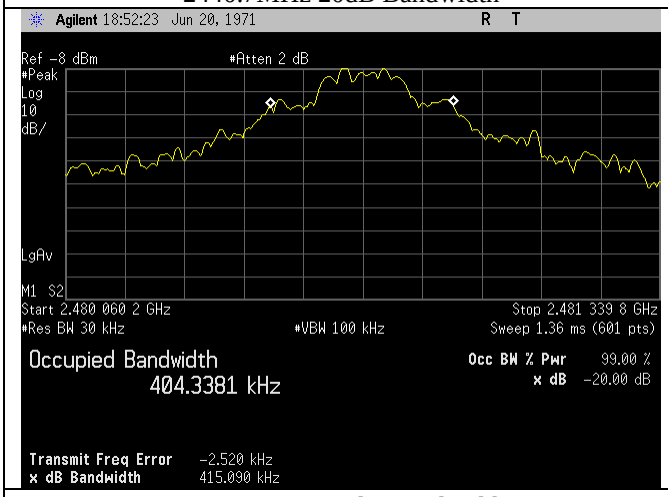
2401.06MHz 20dB Bandwidth

2401.06MHz 99% Bandwidth

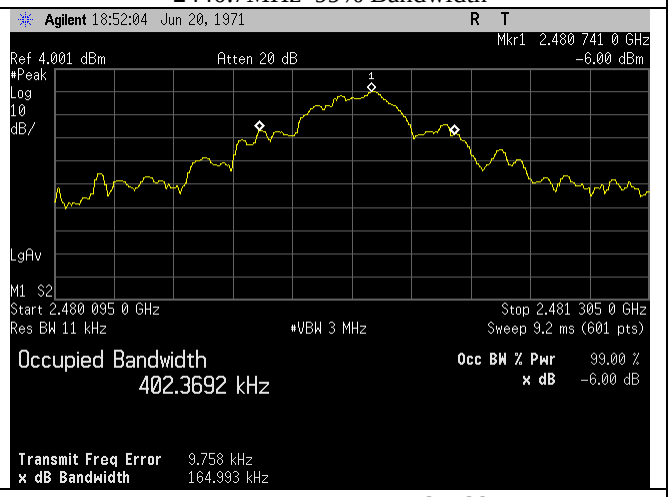
2440.7MHz 20dB Bandwidth



2440.7MHz 99% Bandwidth



2480.06MHz 20dB Bandwidth



2480.06MHz 99% Bandwidth

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(a)(1) Average Time of Occupancy (Dwell Time)

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

Test Results: The average time of occupancy is less than the 0.4 seconds over an observation period of 0.4 multiplied by the number of hopping channels employed.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

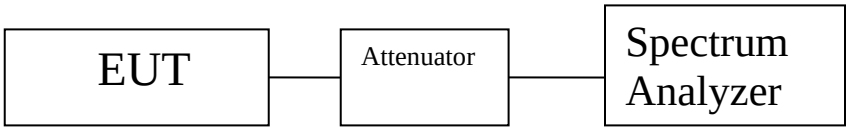
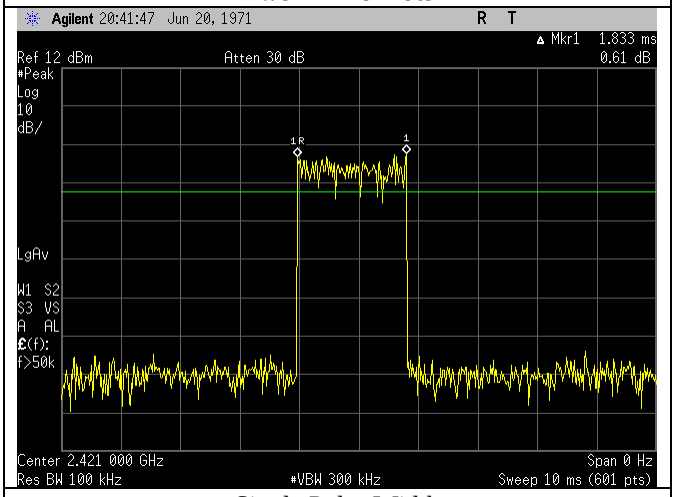


Figure 3. Block Diagram, Average Time of Occupancy Test Setup

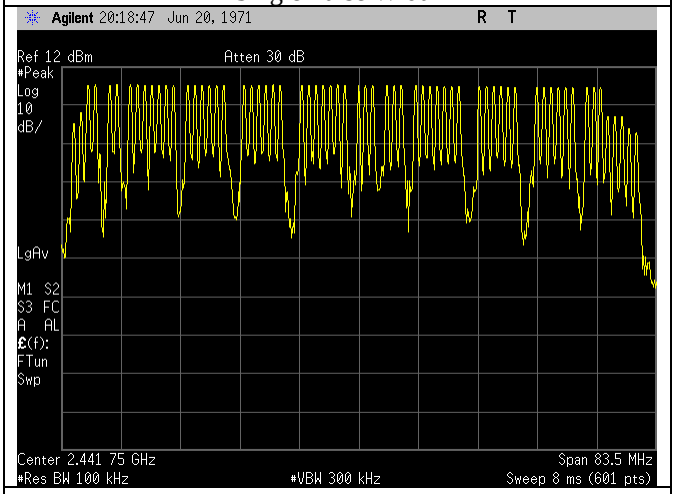
Number of Hopping Channels	Observation Period (0.4sec X 65 Channels)	Single Hop Pulse Width (msec)	Number of Pulses in 10 sec	Number of Pulses in 26 Second Observation Period (2.6 x pulses in 10 sec)	Average Time of Occupancy in Observation Period (msec)	Limit (msec)	Margin (msec)
65	26 sec	1.833	12	31.2	33.033	400	366.967

Table 12. Dwell Time Test Results

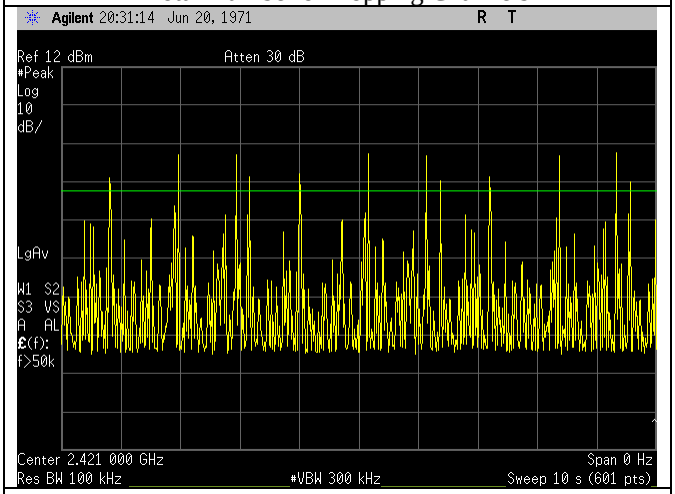
Dwell Time Plots



Single Pulse Width



Total Number of Hopping Channels



Number of Hops Over 10 Seconds

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(a)(1) Number of Hopping Channels

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

Test Results: The number of hopping channels observed is 65 which is more than the 15 channel minimum requirement.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

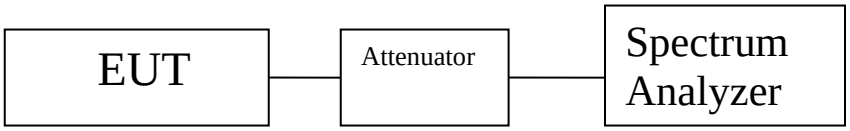


Figure 4. Block Diagram, Number of Hopping Channels

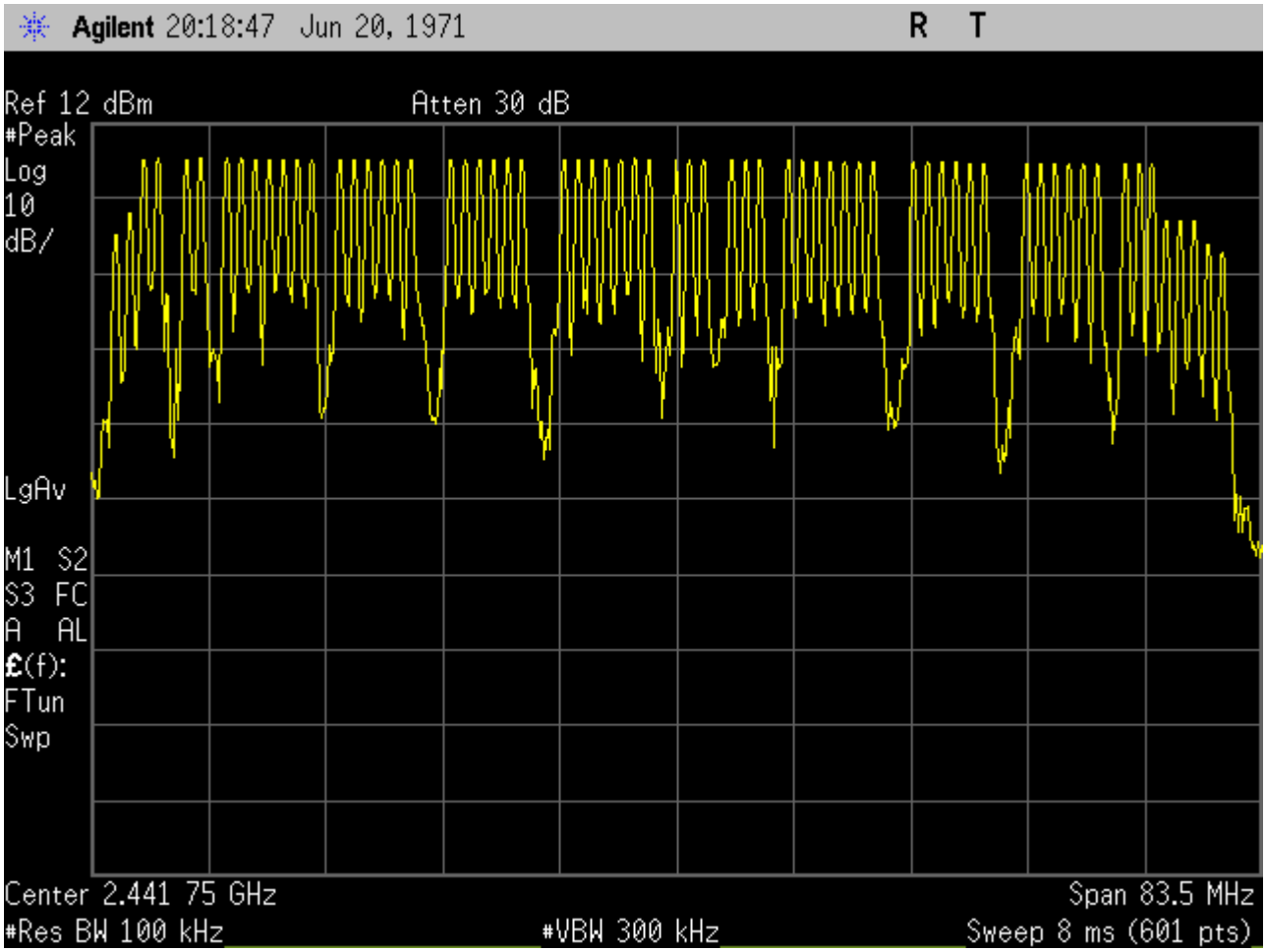


Figure 5. 65 Hopping Channels

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(a)(1) RF Channel Separation

Requirement: Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400–2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

Test Results: The VBar EVO operates below 125mW (20dBm) and the hoping channels are separated by more than two thirds of the -20dB Bandwidth.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

Figure 6. Block Diagram, Number of Hopping Channels

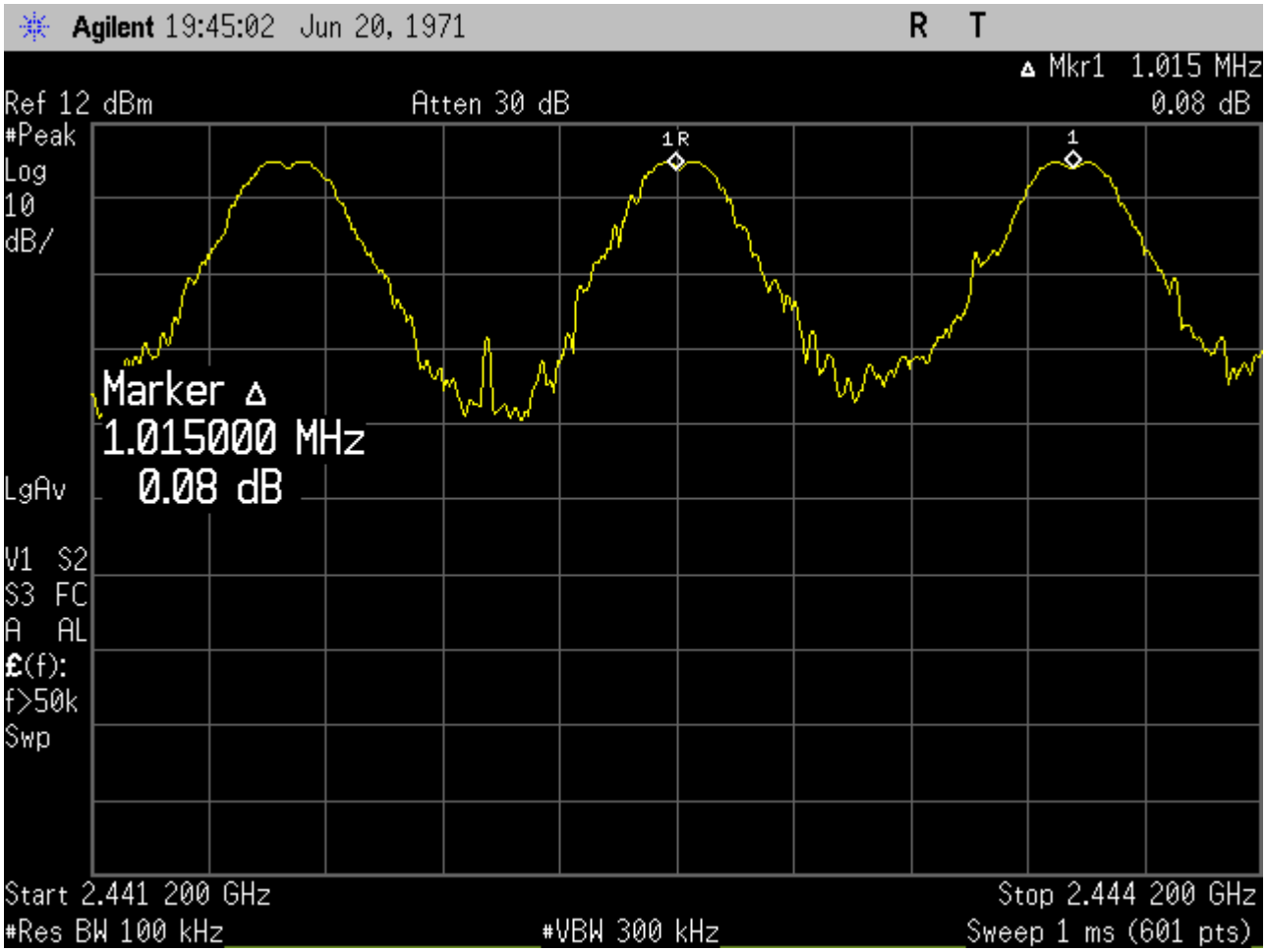


Figure 7. Channel Separation = 1.015MHz

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(b) Peak Power Output

Test Requirements: **§15.247(b)(1):** For frequency hopping systems operating in the 2400–2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725–5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400–2483.5 MHz band: 0.125 watts.

Test Procedure: The transmitter was connected to a calibrated spectrum analyzer. The analyzer reference level was offset by cable loss connecting to the test sample. The peak power was measured at the low, mid and high channels of each band at the maximum power level.

Test Results: The EUT was compliant with the Peak Power Output limits of **§15.247(b)**.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

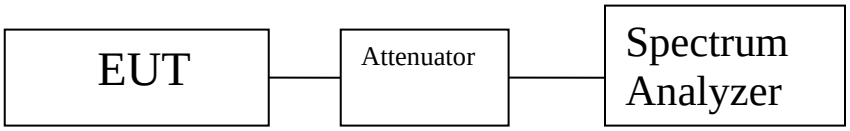


Figure 8. Peak Power Output Test Setup

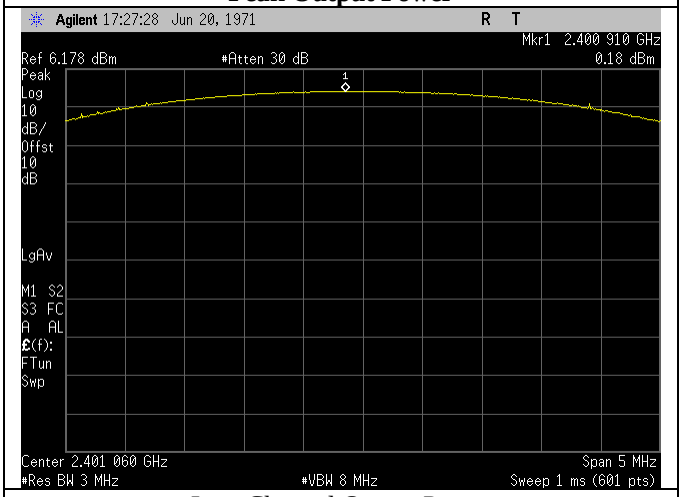
Peak Power Output Test Results

Test Mode	Peak Power (dBm)	Limit (mW)	Limit (dBm)	Margin (dB)
2401.06MHz	0.18	125mW	20.96911	20.78911
2440.7MHz	16.74	125mW	20.96911	4.22911
2480.7MHz	4.53	125mW	20.96911	16.43911

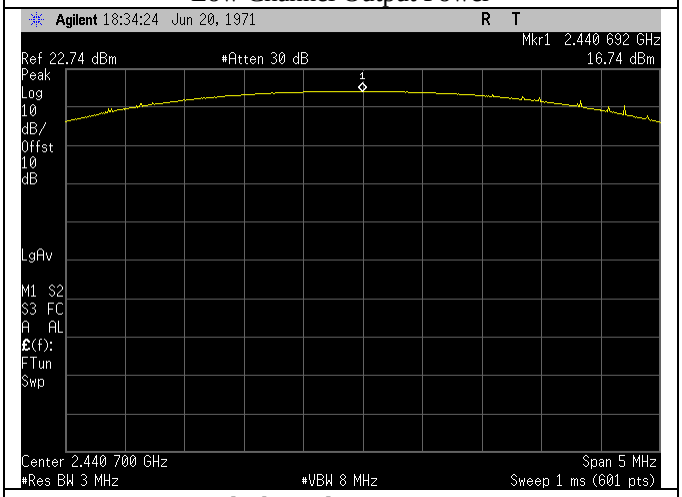
Table 13. Peak Power Output, Test Results

Peak Power Output Test Results

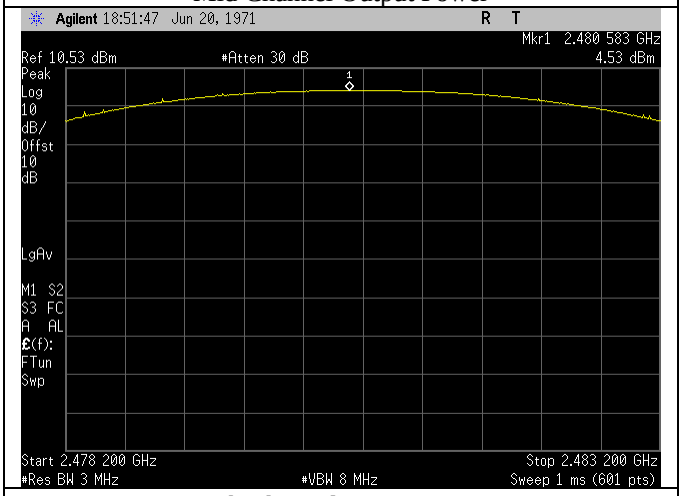
Peak Output Power



Low Channel Output Power



Mid Channel Output Power



High Channel Output Power

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(d) Radiated Spurious Emissions Requirements and Band Edge

Test Requirements: **§15.247(d); §15.205:** Emissions outside the frequency band.

§15.247(d): In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in § 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in § 15.205(a), must also comply with the radiated emission limits specified in § 15.209(a).

§15.205(a): Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090–0.110----------	16.42–16.423	399.9–410	4.5–5.15
[1] 0.495–0.505----------	16.69475–16.69525	608–614	5.35–5.46
2.1735–2.1905----------	16.80425–16.80475	960–1240	7.25–7.75
4.125–4.128----------	25.5–25.67	1300–1427	8.025–8.5
4.17725–4.17775----------	37.5–38.25	1435–1626.5	9.0–9.2
4.20725–4.20775----------	73–74.6	1645.5–1646.5	9.3–9.5
6.215–6.218----------	74.8–75.2	1660–1710	10.6–12.7
6.26775–6.26825----------	108–121.94	1718.8–1722.2	13.25–13.4
6.31175–6.31225----------	123–138	2200–2300	14.47–14.5
8.291–8.294----------	149.9–150.05	2310–2390	15.35–16.2
8.362–8.366----------	156.52475–156.52525	2483.5–2500	17.7–21.4
8.37625–8.38675----------	156.7–156.9	2655–2900	22.01–23.12
8.41425–8.41475----------	162.0125–167.17	3260–3267	23.6–24.0
12.29–12.293----------	167.72–173.2	3332–3339	31.2–31.8
12.51975–12.52025----------	240–285	3345.8–3358 36.	43–36.5
12.57675–12.57725----------	322–335.4	3600–4400	([2])

Table 14. Restricted Bands of Operation

[1] Until February 1, 1999, this restricted band shall be 0.490 – 0.510 MHz.
[2] Above 38.6

Test Requirement(s): **§ 15.209 (a):** Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in Table 15.

Frequency (MHz)	§ 15.209(a),Radiated Emission Limits (dBµV) @ 3m
30 - 88	40.00
88 - 216	43.50
216 - 960	46.00
Above 960	54.00

Table 15. Radiated Emissions Limits Calculated from FCC Part 15, § 15.209 (a)

Test Procedures: The antenna-port methodology form ANSI C63.10: 2013 Section 11.12.2 was utilized as an alternative to radiated emissions in the restricted bands.

The transmitter was connected directly to a Spectrum Analyzer through an attenuator. The power level was set to the maximum level. For frequencies below 1GHz, the RBW was set to 100 kHz and the VBW was set to 3x the RBW. For frequencies above 1GHz the RBW was set to 1MHz and the VBW was set to 3x the RBW. The spectrum analyzer was set to an auto sweep time and a peak detector was used. The maximum antenna gain was added to the measurement trace as was the appropriate maximum ground reflection factor as outlined in section 11.12.2 of ANSI C63.10. The resultant EIRP was then converted to an equivalent electric field strength which is shown on the graphical plots which follow. Measurements were carried out at the low, mid and high channels.

In order to assess the cabinet radiated spurious emissions, a radiated scan was performed with the antenna of proper impedance installed. The transmitter was turned on. Measurements were performed of the low, mid and high Channels. The EUT was rotated orthogonally through all three axes if multiple mounting orientations are supported. Plots shown are corrected for both antenna correction factor and distance and compared to a 3 m limit line.

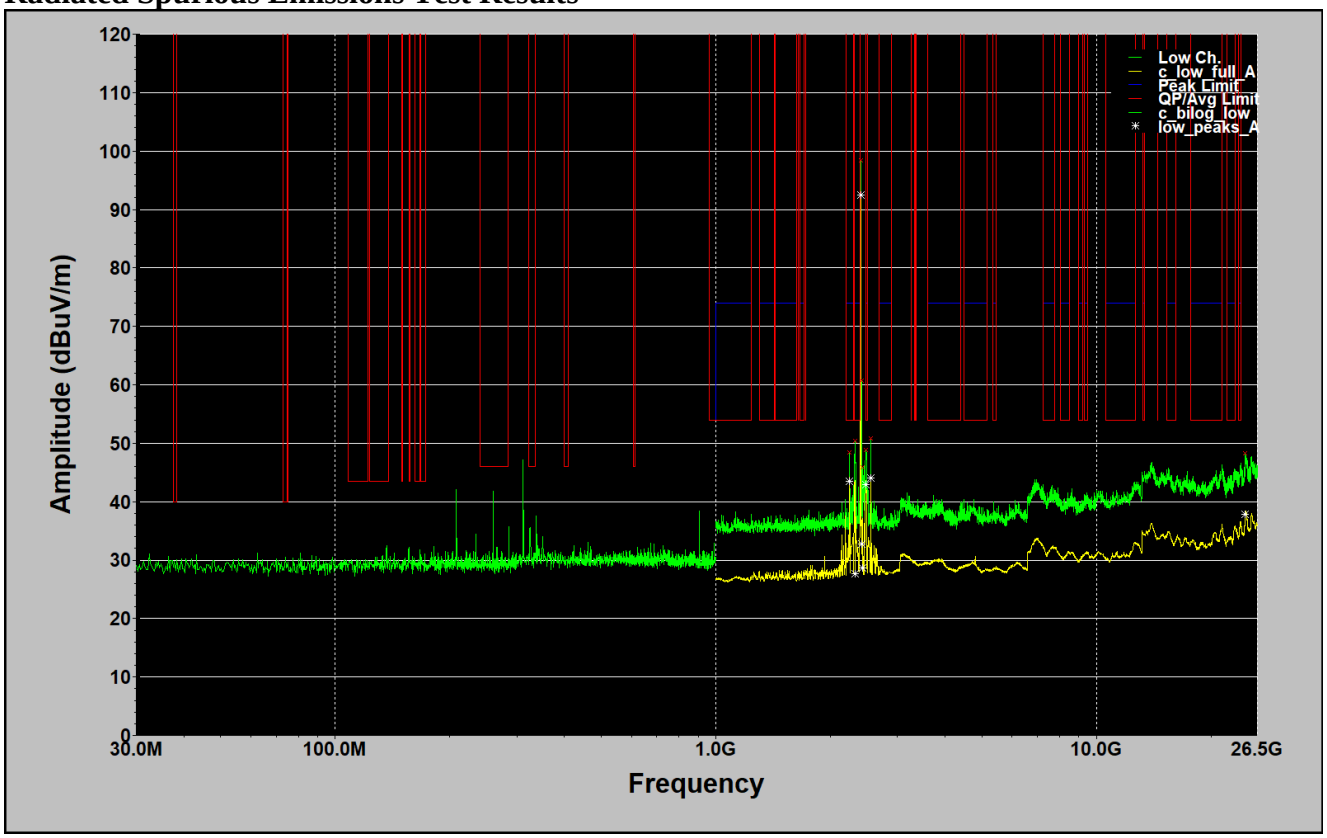
Radiated measurements below 30MHz were performed in a semi-anechoic chamber that has been correlated to an open area site.

Test Results: The EUT was compliant with the Radiated Spurious Emission limits of **§ 15.247(d)**. Emissions outside of the restricted bands were assessed against the 20dB down criteria in the next section of the report.

Test Engineer(s): Bryan Taylor and Sergio Gutierrez

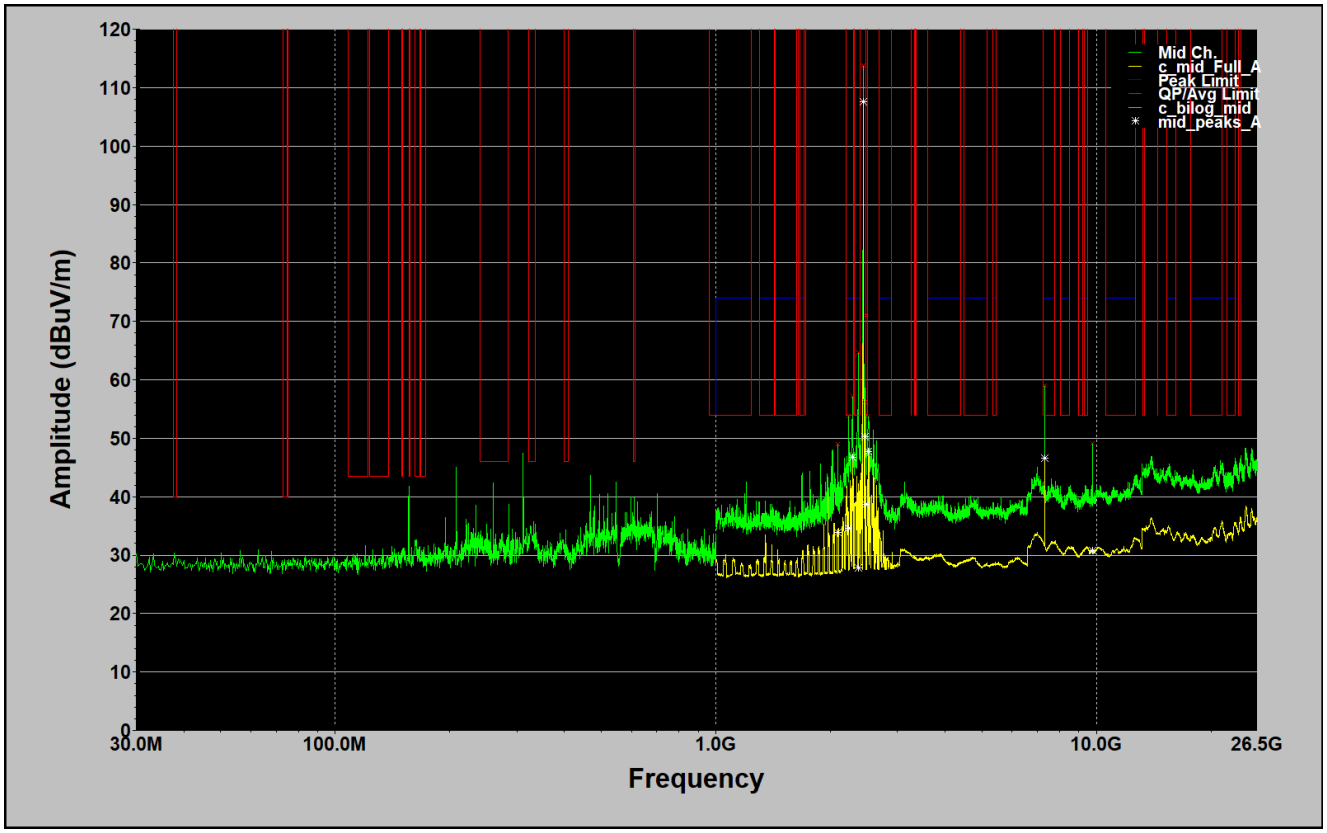
Test Date(s): 3/10/2023 to 3/31/2023

Radiated Spurious Emissions Test Results



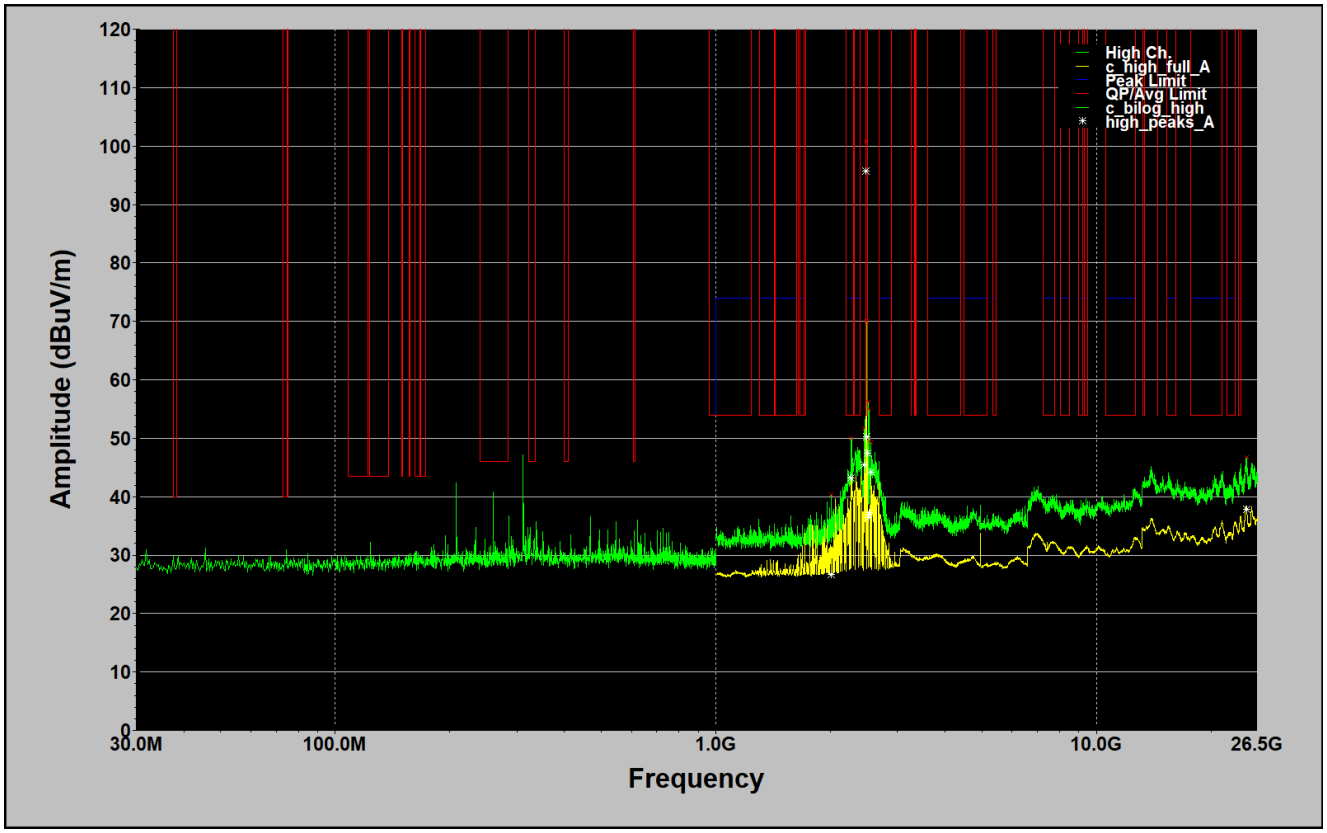
Frequency (MHz)	Peak Amplitude (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)	Avg Amplitude (dBuV/m)	Limit (dBuV/m)	Avg Margin (dB)
0.260	41.845	46.02	4.175			
2.246	48.382	74	25.618	43.428	54	10.572
2.324	50.428	74	23.572	27.611	54	26.389
2.485	48.903	74	25.097	42.927	54	11.073

Figure 9. Low Channel Restricted Band Emissions (Peak and Average)



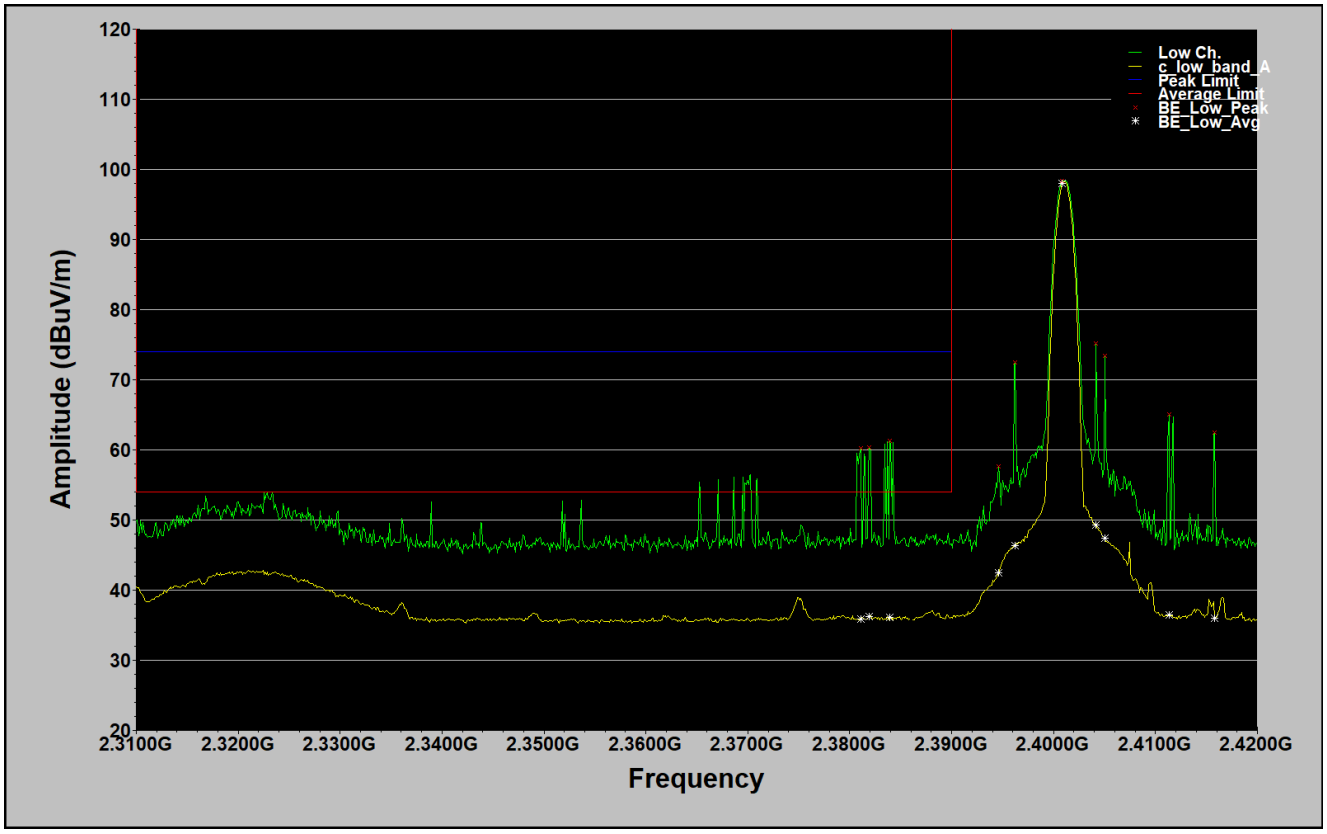
Frequency (MHz)	Peak Amplitude (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)	Avg Amplitude (dBuV/m)	Limit (dBuV/m)	Avg Margin (dB)
0.260	42.359	46.02	3.661			
2.232	53.811	74	20.189	34.618	54	19.382
2.284	57.228	74	16.772	46.698	54	7.302
2.371	64.624	74	9.376	27.781	54	26.219
7.321	59.05	74	14.95	46.551	54	7.449

Figure 10. Mid Channel Restricted Band Emissions (Peak and Average)



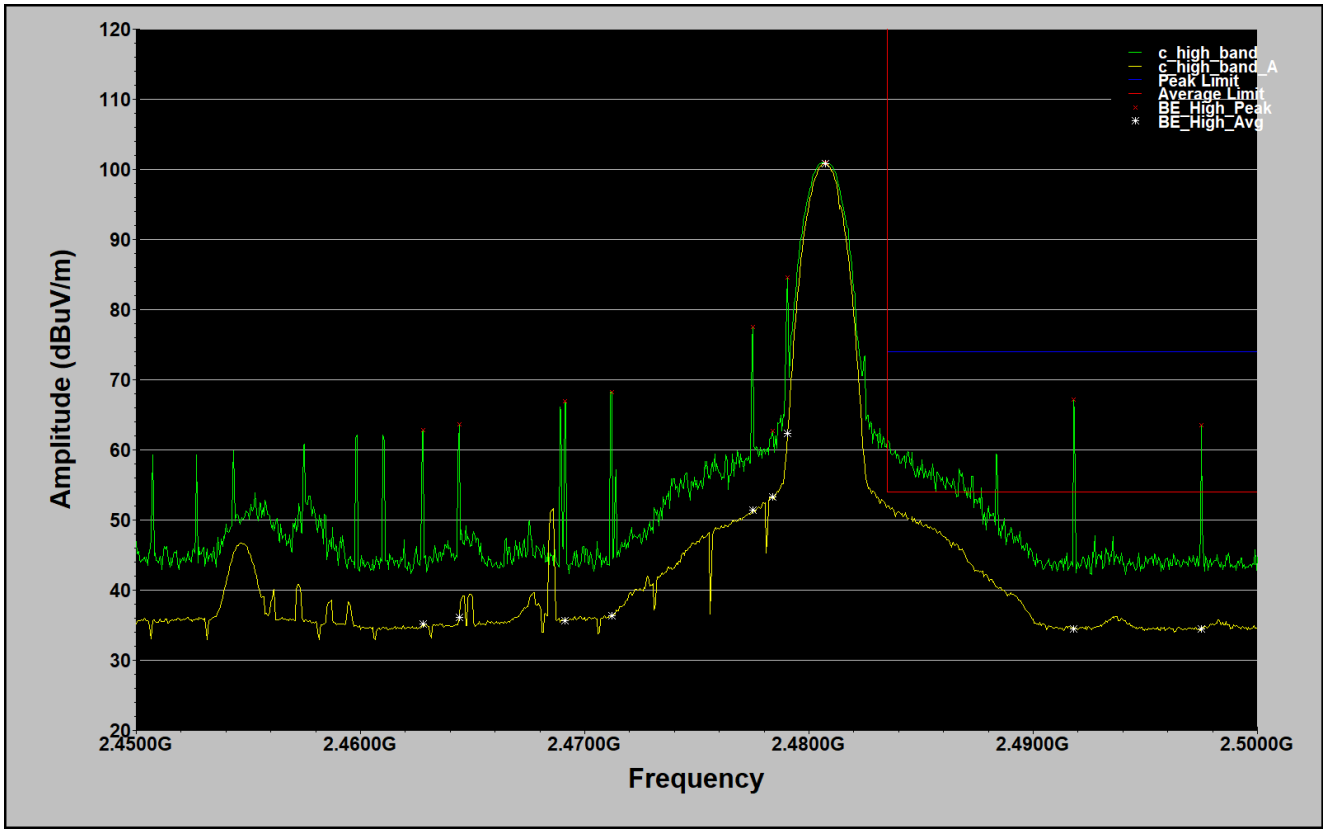
Frequency (MHz)	Peak Amplitude (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)	Avg Amplitude (dBuV/m)	Limit (dBuV/m)	Avg Margin (dB)
0.260	40.829	46.02	5.191			
2.271	50.016	74	23.984	43.157	54	10.843
2.488	70.051	74	3.949	50.185	54	3.815

Figure 11. High Channel Restricted Band Emissions (Peak and Average)



Frequency (MHz)	Peak Amplitude (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)	Avg Amplitude (dBuV/m)	Limit (dBuV/m)	Avg Margin (dB)
2381.06	60.18	74	13.82	35.858	54	18.142
2381.94	60.303	74	13.697	36.204	54	17.796
2383.92	61.338	74	12.662	36.12	54	17.88

Figure 12. Low Band Edge (Peak and Average)



Frequency (MHz)	Peak Amplitude (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)	Avg Amplitude (dBuV/m)	Limit (dBuV/m)	Avg Margin (dB)
2491.8	67.174	74	6.826	34.462	54	19.538
2497.5	63.584	74	10.416	34.441	54	19.559

Figure 13. High Band Edge (Peak and Average)

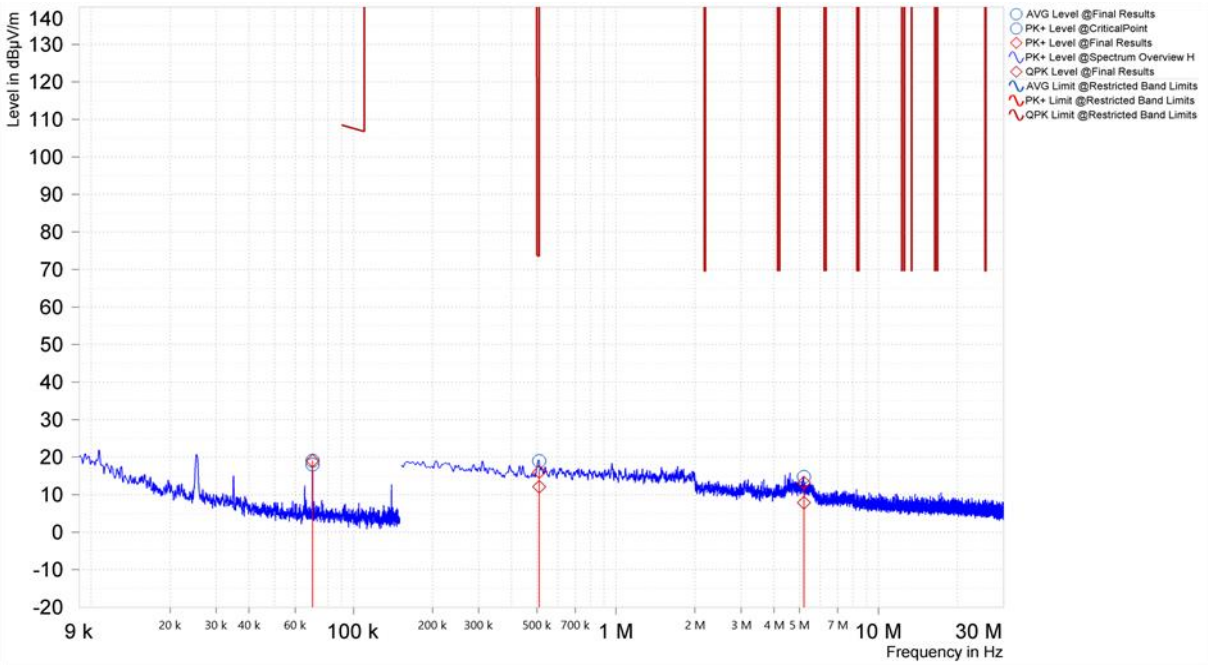


Figure 14. 9kHz – 30MHz Cabinet Radiation (Coplanar Loop)

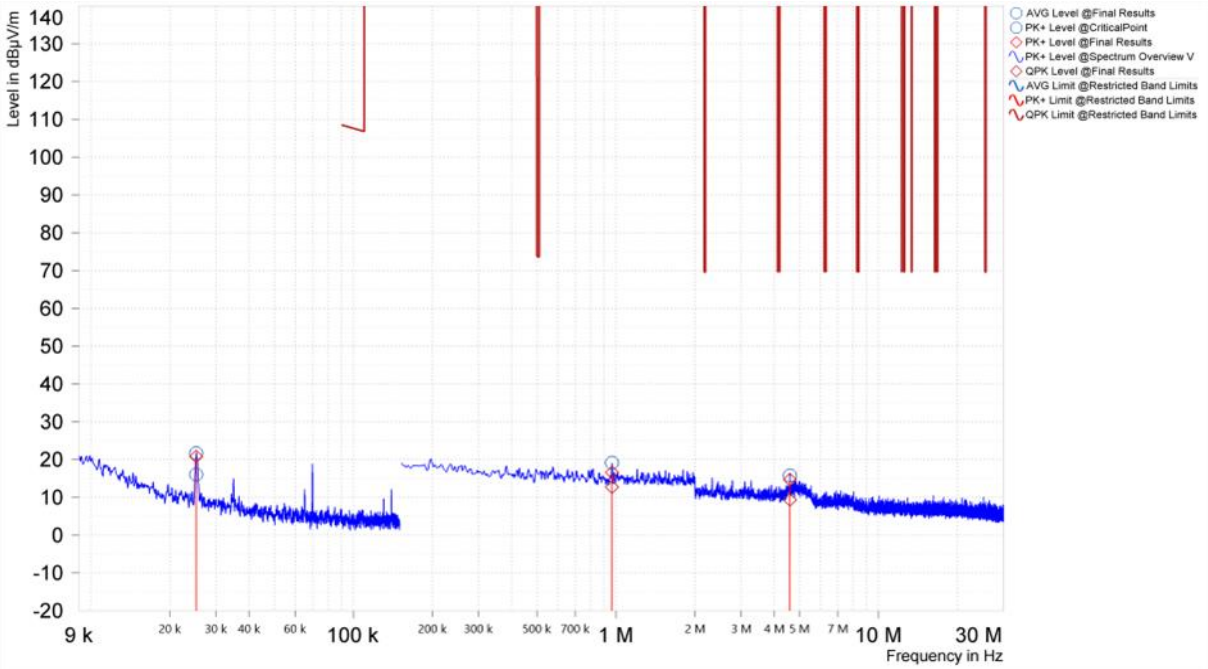


Figure 15. 9kHz – 30MHz Cabinet Radiation (Coaxial Loop)

Frequency [MHz]	QPK Level [dBµV/m]	QPK Limit [dBµV/m]	QPK Margin [dB]	Correction [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Meas. BW [kHz]	Comment
0.510	12.08	73.54	61.46	11.49	Coplanar Loop	45	1	9.000	Pass

Figure 16. Worst Case Emissions 9kHz – 30MHz Cabinet Radiation

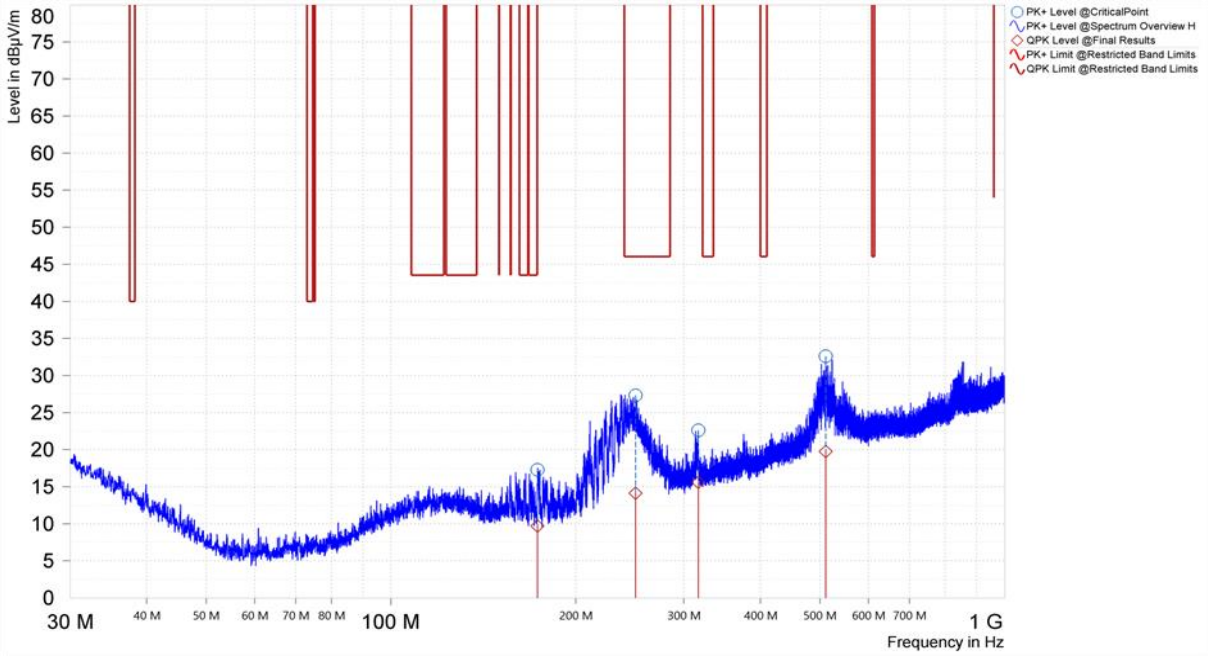


Figure 17. 30MHz – 1GHz Cabinet Radiation (Horizontal)

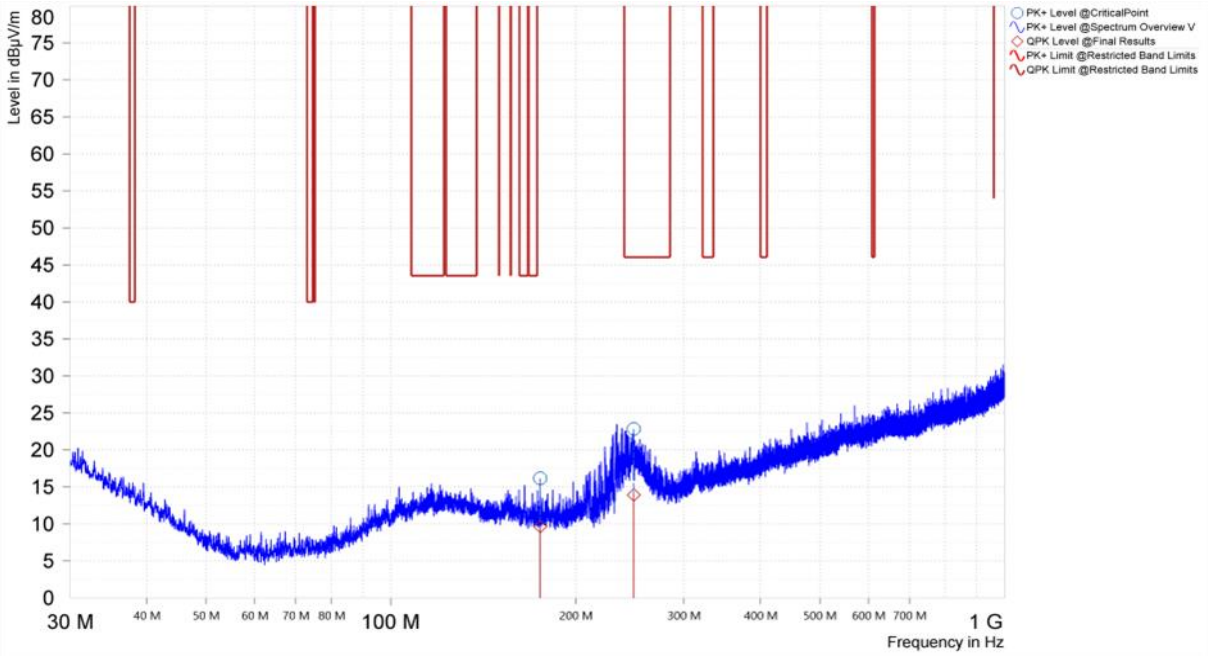


Figure 18. 30MHz – 1GHz Cabinet Radiation (Vertical)

Frequency [MHz]	QPK Level [dBµV/m]	QPK Limit [dBµV/m]	QPK Margin [dB]	Correction [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Meas. BW [kHz]	Comment
248.730	13.93	46.02	32.09	-6.60	V	255	3.5	120.000	Pass
250.380	14.13	46.02	31.89	-6.44	H	45	2.74	120.000	Pass

Figure 19. Worst Case Emissions 30MHz – 1GHz Cabinet Radiation

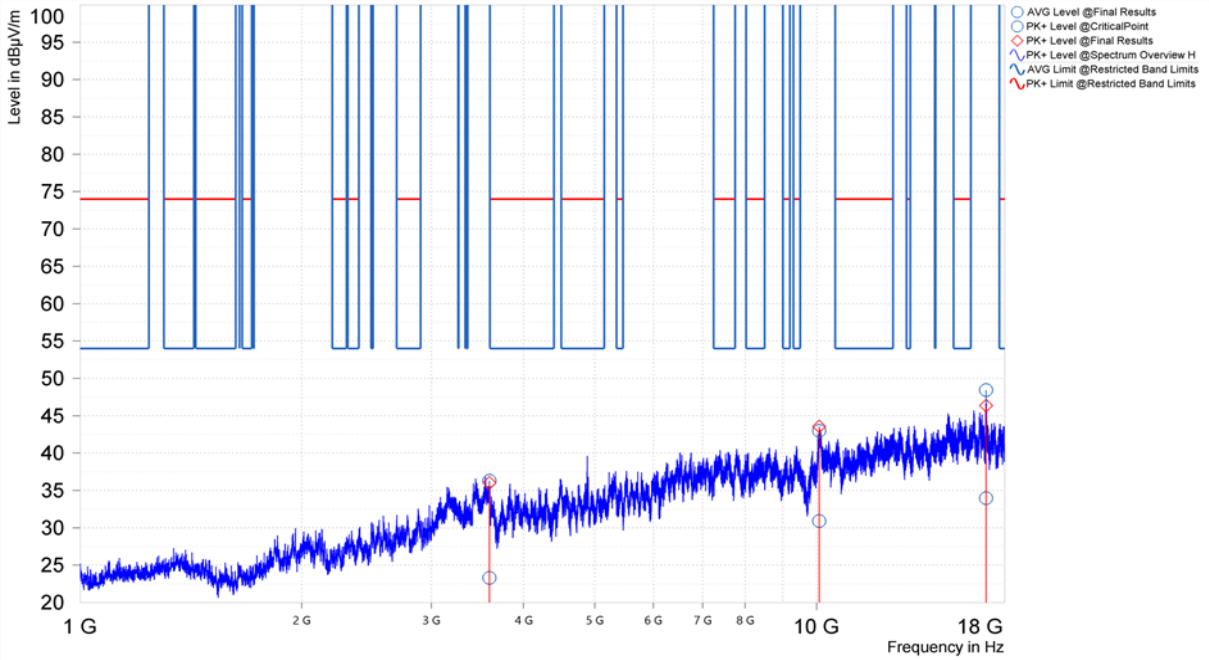


Figure 20. 1GHz – 18GHz Cabinet Radiation (Horizontal)

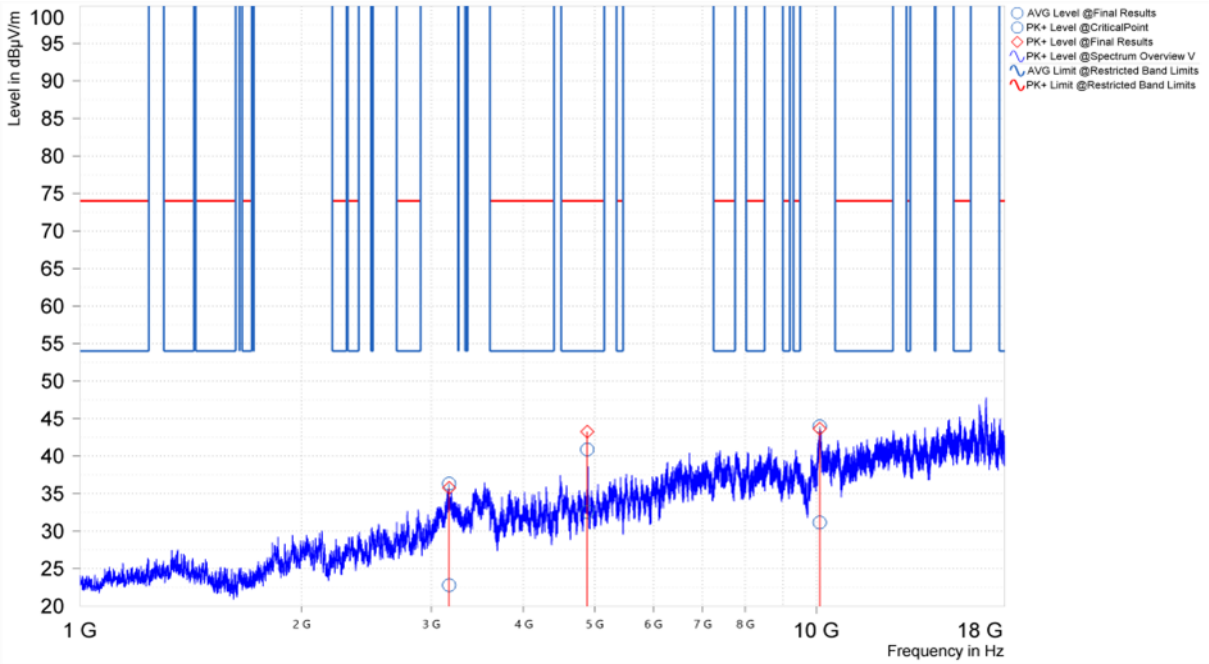


Figure 21. 1GHz – 18GHz Cabinet Radiation (Vertical)

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AVG Level [dBµV/m]	AVG Limit [dBµV/m]	AVG Margin [dB]	Correction [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Results
4,882.000	43.26	74.00	30.74	32.57	54.00	21.43	-3.31	V	25	1.66	Pass

Figure 22. Worst Case Emissions 1GHz – 18GHz Cabinet Radiation

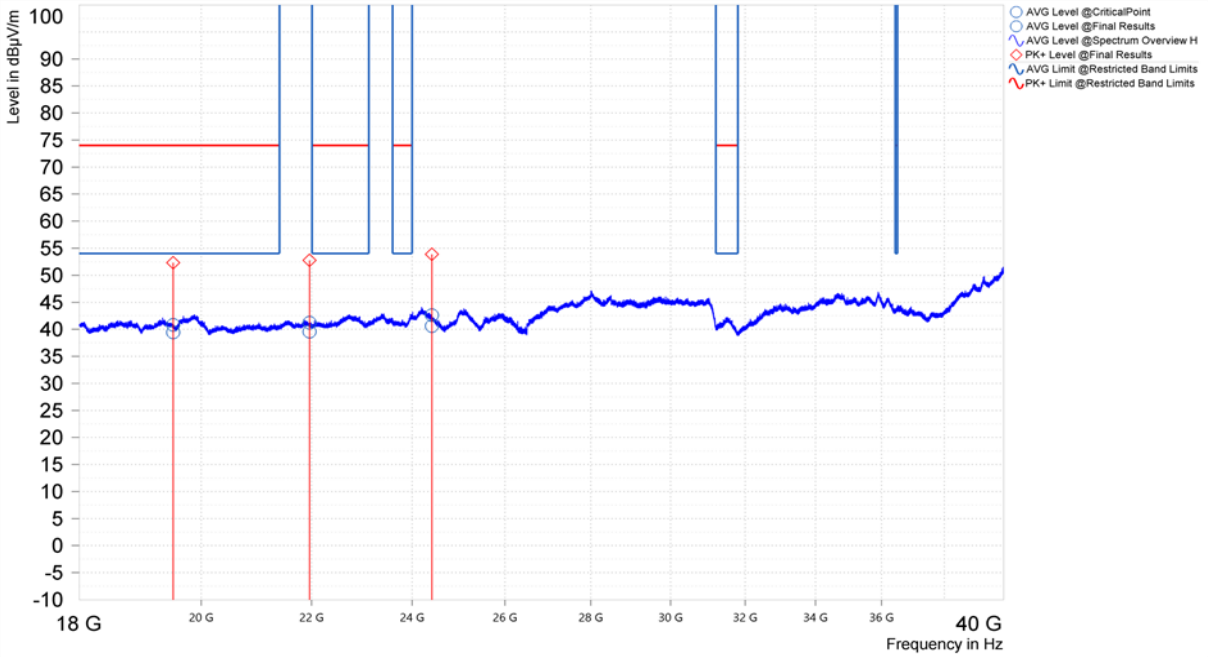


Figure 23. 18GHz – 40GHz Cabinet Radiation (Horizontal)

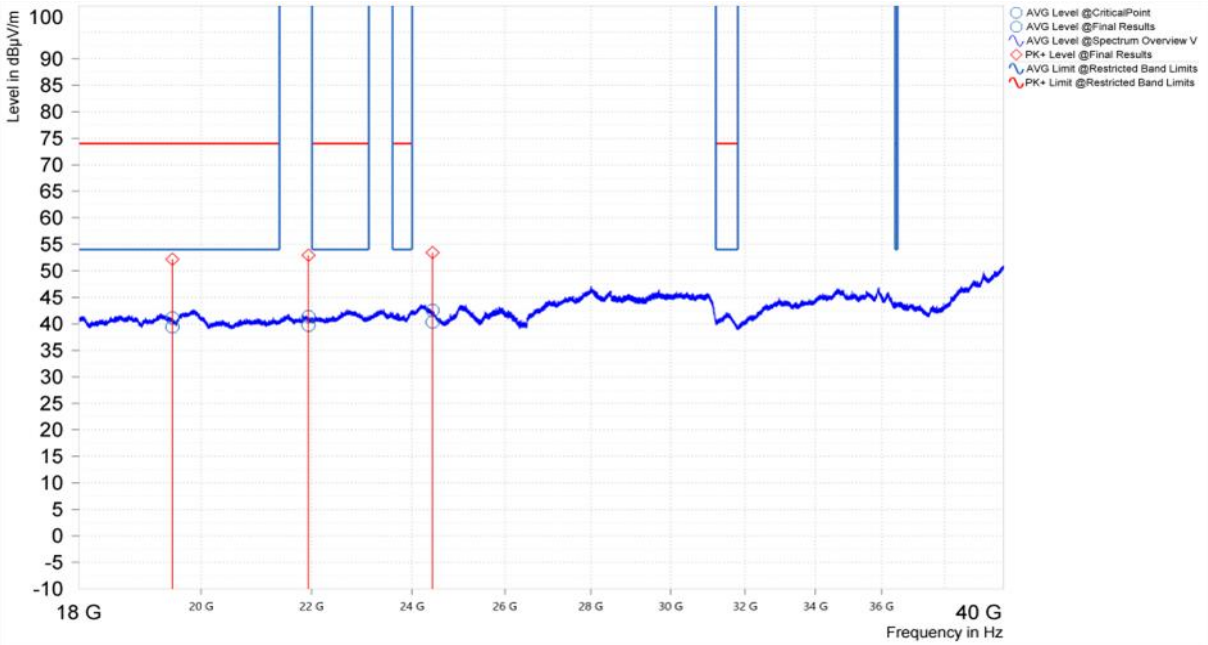


Figure 24. 18GHz – 40GHz Cabinet Radiation (Vertical)

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AVG Level [dBµV/m]	AVG Limit [dBµV/m]	AVG Margin [dB]	Correction [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Results
19,513.000	52.20	74.00	21.80	39.45	54.00	14.55	15.18	V	22	3.9	Pass
19,524.500	52.32	74.00	21.68	39.41	54.00	14.59	15.18	H	352	2.34	Pass

Figure 25. Worst Case Emissions 18GHz – 40GHz Cabinet Radiation

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(d) RF Conducted Spurious Emissions Requirements

Test Requirement: **15.247(d)** In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

Test Procedure: For intentional radiators with a digital device portion which operates below 10 GHz, the spectrum was investigated as per §15.33(a)(1) and §15.33(a)(4); i.e., the lowest RF signal generated or used in the device up to the 10th harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

The transmitter was connected directly to a Spectrum Analyzer through an attenuator. The power level was set to the maximum level. The RBW was set to 100 kHz. The VBW was set to 3x the RBW. The spectrum analyzer was set to an auto sweep time and a peak detector was used. Measurements were carried out at the low, mid and high channels.

See following pages for detailed test results with RF Conducted Spurious Emissions.

Test Results: The EUT was compliant with the Conducted Spurious Emission limits of **§15.247(d)**.

Test Engineer(s): Bryan Taylor

Test Date(s): 3/10/2023 to 3/31/2023

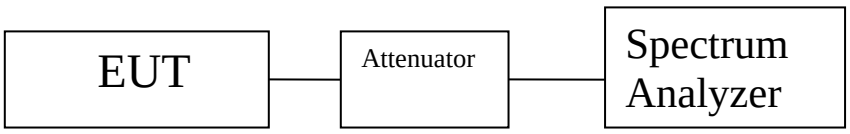


Figure 26. Block Diagram, Conducted Spurious Emissions Test Setup

Conducted Spurious Emissions Test Results

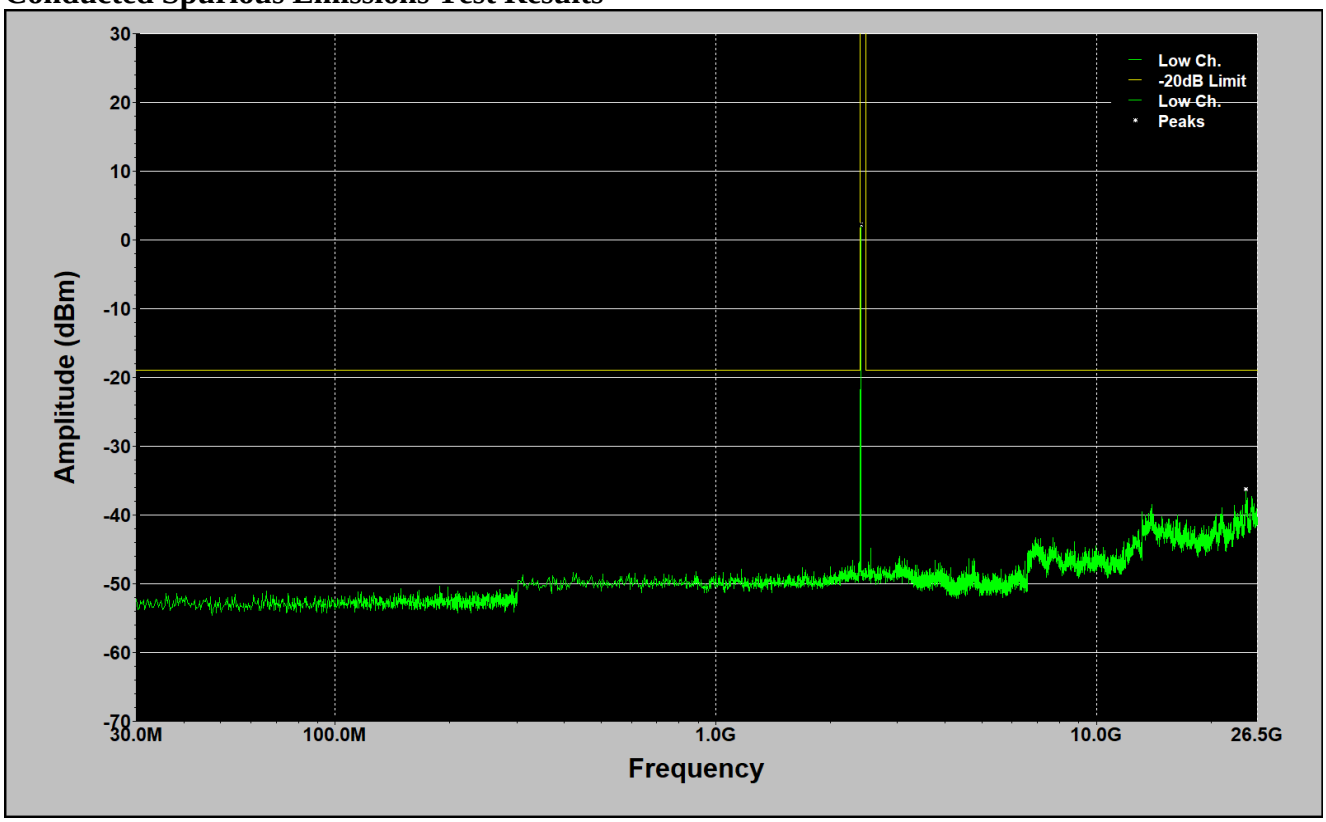


Figure 27. -20dBc Emissions, Low Channel (Peak Detection)

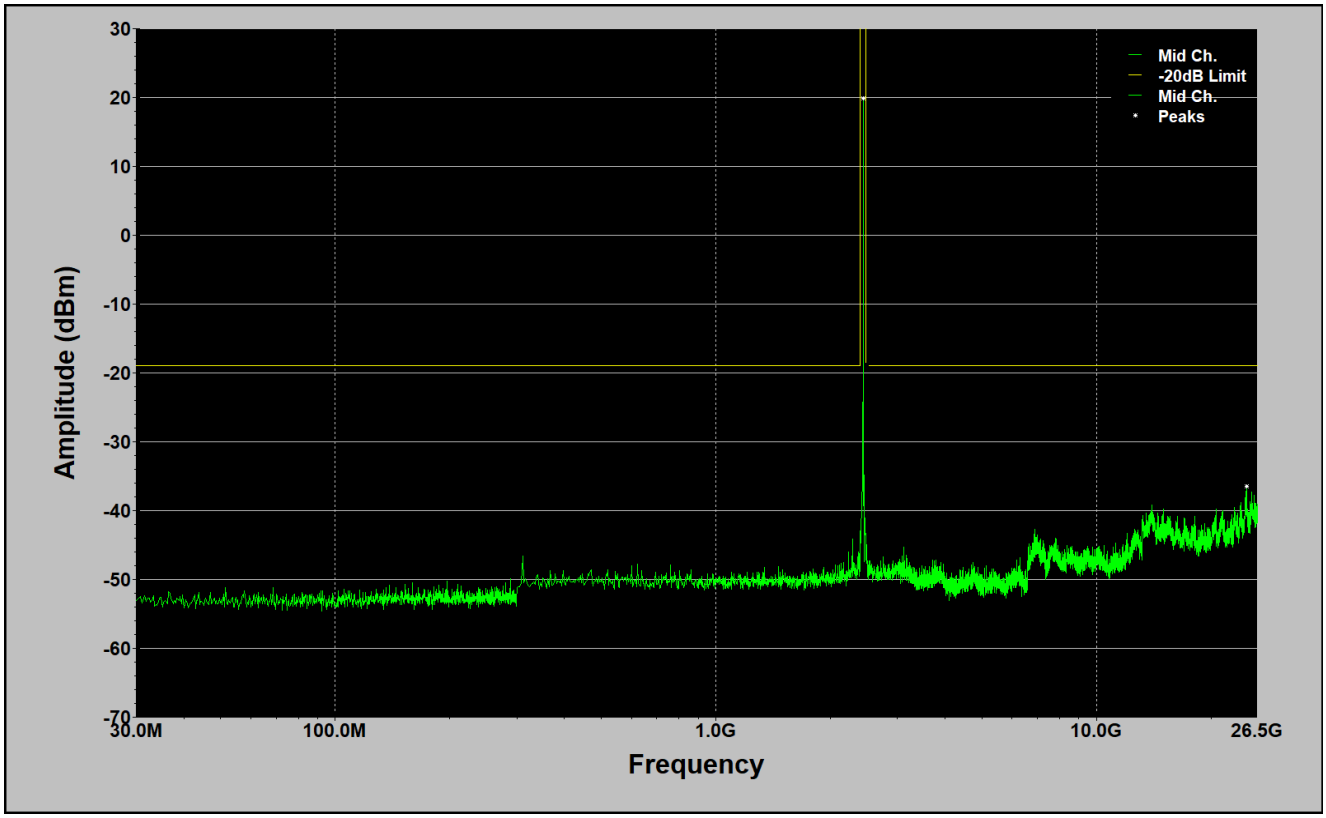


Figure 28. -20dBc Emissions, Mid Channel (Peak Detection)

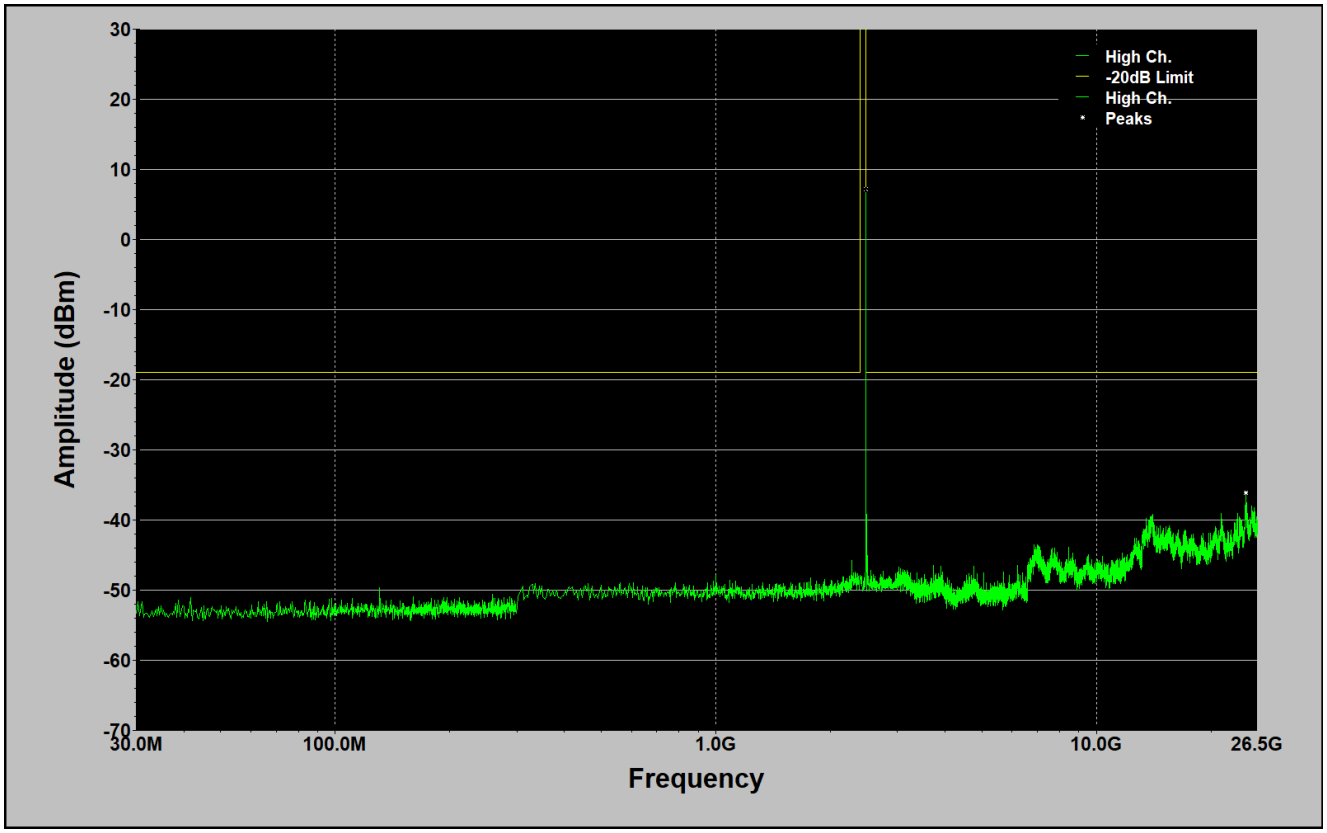


Figure 29. -20dBc Emissions, High Channel (Peak Detection)

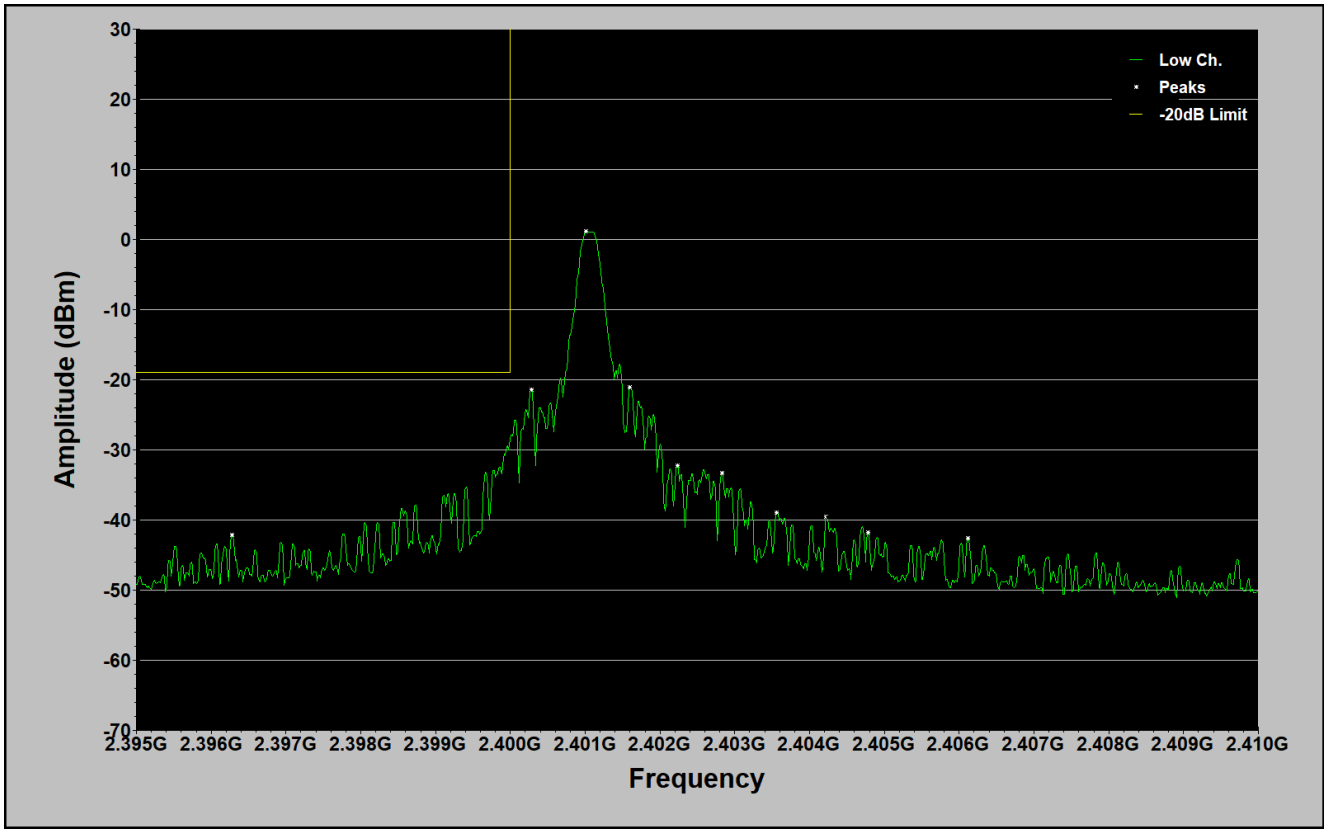


Figure 30. -20dBc Emissions, Low Band Edge

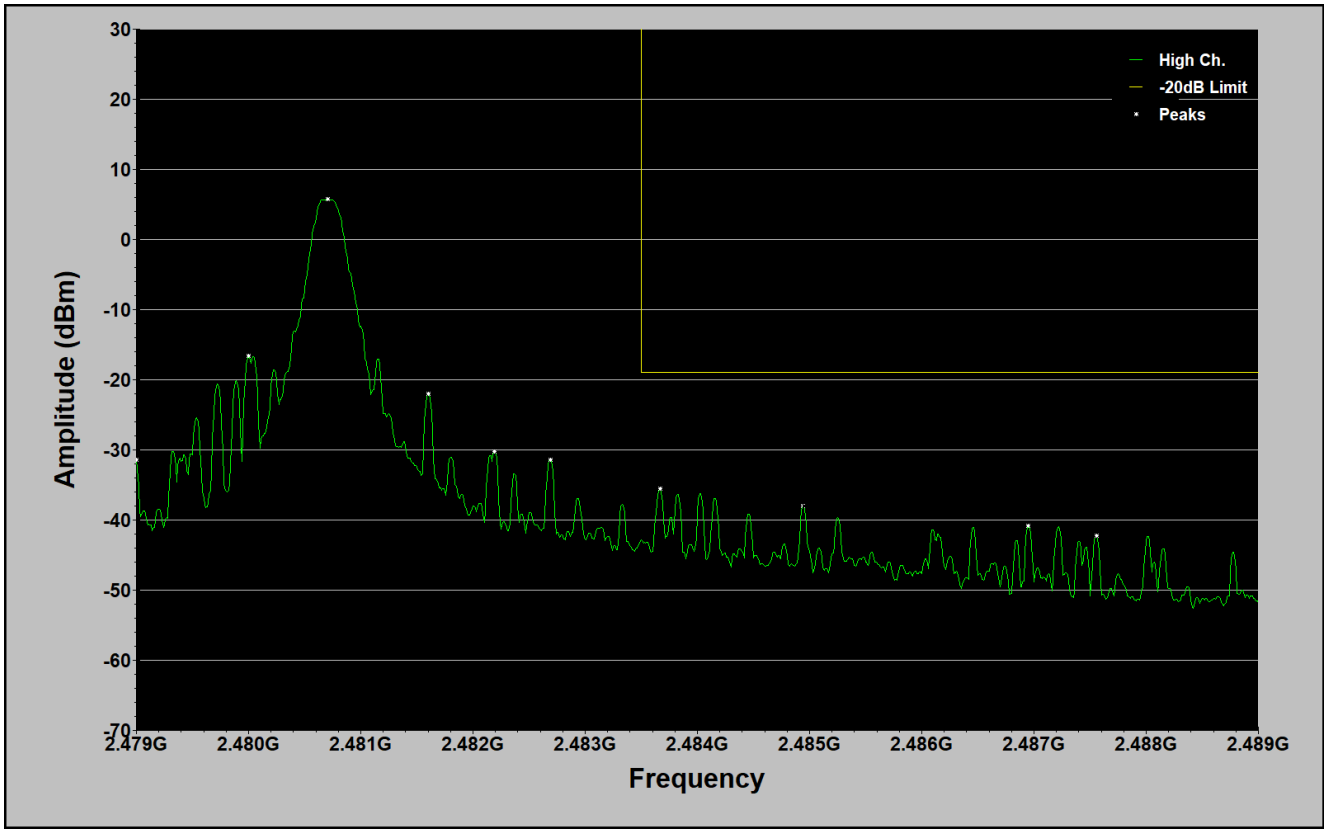


Figure 31. -20dBc Emissions, High Band Edge

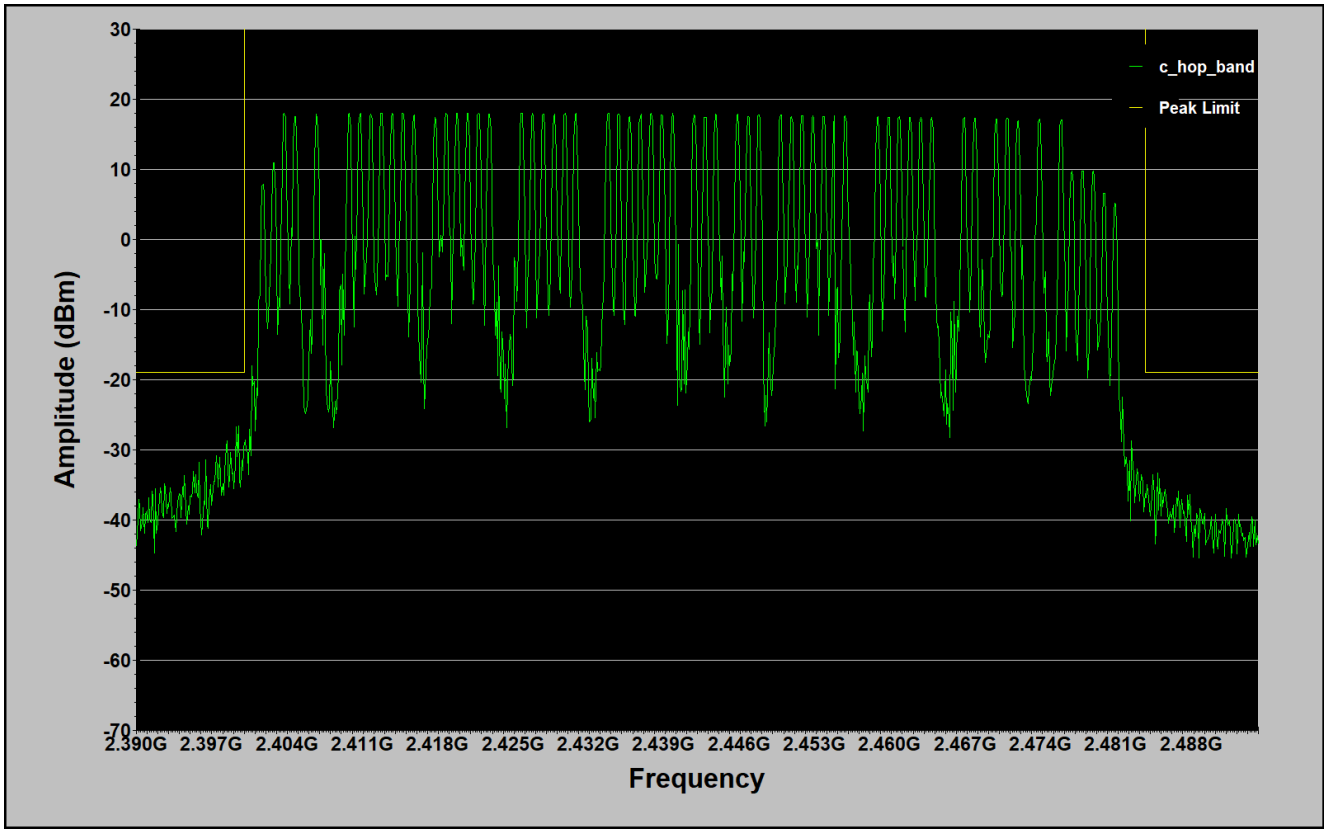


Figure 32. -20dBc Emissions, Hopping Mode

IV. Test Equipment

Test Equipment

Calibrated test equipment utilized during testing was maintained in a current state of calibration per the requirements of ISO/IEC 17025:2017.

MET Asset #	Description	Manufacturer	Model	Last Cal Date	Cal Due Date
1T4771	Spectrum Analyzer	Keysight	E4446A	4/25/2022	10/26/2023
1A1083	Receiver	Rohde & Schwarz	ESU40	10/14/2022	10/14/2023
1A1176	Active Loop Antenna (9KHz-30MHz)	ETS-Lindgren	6502	6/16/2022	6/16/2023
1A1050	Bilog Antenna (30MHz – 1GHz)	Schaffner	CBL 6112D	1/24/2023	1/24/2024
1A1183	Horn Antenna (1GHz – 18GHz)	ETS Lindgren	3117	1/4/2023	1/4/2024
1A1161	Horn Antenna (18GHz – 40GHz)	ETS Lindgren	3116C	7/15/2022	7/15/2023
1A1065	EMI Receiver	Rohde & Schwarz	ESCI	8/4/2022	8/4/2023
1A1087	Pulse Limiter	Rohde & Schwarz	ESH3Z2	6/24/2022	6/24/2023
1A1122	LISN	Teseq	NNB 51	9/19/2022	9/19/2023
1A1123	LISN	Teseq	NNB 51	12/20/2022	12/20/2023
1A1149	DC Milliohm Meter	GW Instek	GOM-802	9/20/2022	9/20/2023
1A1099	Generator	Com-Power	CGO-51000	See Note	
1A1088	Preamplifier	Rohde & Schwarz	TS-PR1	See Note	
1A1044	Generator	Com-Power	CG-520	See Note	
1A1073	Multi Device Controller	ETS	2090	See Note	
1A1074	System Controller	Panasonic	WV-CU101	See Note	
1A1080	Multi-Device	ETS	2090	See Note	
1A1180	Preamplifier	Miteq	AMF-7D-01001800-22-10P	See Note	

Table 16. Test Equipment List

Note: Functionally tested equipment is verified using calibrated instrumentation at the time of testing.

End of Report