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

2/22/2024
Tractian Technologies Inc.
1389 Peachtree St NE
Atlanta, GA 30309
USA

Dear Jorge Sousa,

Enclosed is the EMC Wireless test report for compliance testing of the Tractian Technologies Inc. Smart Receiver Ultra as tested to the requirements of FCC Part 15.247 and RSS-247 Issue 3 for Intentional Radiators. This test report pertains specifically to the 915MHz ISM transmitter onboard which operates in the 902MHz – 928MHz band.

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: WIRA130598 - FCC15.247-RSS247_R1

915MHz ISM Test Report

for the

Tractian Technologies Inc.
Smart Receiver Ultra

Tested under
FCC Part 15.247 and RSS-247 Issue 3
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
∅	2/21/2024	Initial Issue.
1	2/22/2024	Corrected antenna gain

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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 Smart Receiver Ultra, with the requirements of FCC Part 15.247 and RSS-247 Issue 3. Tractian Technologies Inc. should retain a copy of this document which should be kept on file for at least two years after the manufacturing of the Smart Receiver Ultra, 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 and RSS-247 Issue 3, in accordance with Tractian Technologies Inc. purchase order number SRU-FCC-008. 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	**Compliant**
Title 47 of the CFR, Part 15 §15.247(a)(2)	RSS-247 (5.2)	6dB Occupied Bandwidth	**Compliant**
---	RSS-GEN(6.7)	99% Occupied Bandwidth	**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

II. Equipment Configuration

A. Overview

Eurofins MET Labs was contracted by Tractian Technologies Inc. to perform testing on the Smart Receiver Ultra, under Tractian Technologies Inc.'s purchase order number SRU-FCC-008.

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform compliance testing of the Smart Receiver Ultra.

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

Product Name:	Smart Receiver Ultra	
Model(s) Tested:	Smart Receiver Ultra	
Serial Number or Sample Number:	CER4F01 and CERF03	
EUT Specifications:	Primary Power: 100-250VAC, 50/60Hz	
	Type of Modulations:	O-QPSK
	Equipment Code:	DTS
	Peak RF Output Power:	19.89dBm
	EUT Frequency Ranges:	915MHz – 925MHz
	Antenna Gain[1]:	1.1dBi
Analysis:	The results obtained relate only to the item(s) tested.	
Environmental Test Conditions:	Temperature: 15-35° C	
	Relative Humidity: 30-60%	
	Barometric Pressure: 860-1060 mbar	
Evaluated by:	Bryan Taylor	
Report Date(s):	2/5/2024 through 2/19/2024	

Table 2. EUT Summary Table

[1] The antenna gain information was provided by Tractian Technologies Inc. and may affect compliance.

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 3, August 2023	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 3. 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 4. Uncertainty Calculations Summary

E. Description of Test Sample

The Smart Receiver Ultra is a Gateway that collects data from Tractian's IOT sensors and sent to the Tractian platform using LTE networks or Wi-Fi. The LTE and WiFi radios are preapproved modules (FCCID: 2AJYU-8PYA007 and FCCID: 2AC7Z-ESP32WROVERE).

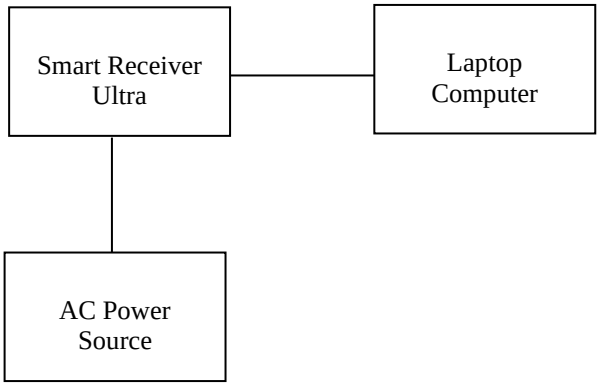


Figure 1. Block Diagram of Test Configuration

F. Equipment Configuration

The EUT was set up as outlined in Figure 1 above. The laptop computer was used to send test commands to force the transmitters to operate in the appropriate test mode.

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	Laptop Computer	Lenovo	ThinkPad	None

Table 5. Support Equipment

H. Ports and Cabling Information

Port Name on EUT	Qty	Length as tested (m)	Shielded? (Y/N)	Termination Box ID & Port Name
AC Power Cable	1	2m	None	AC Power Source

Table 6. Ports and Cabling Information

I. Mode of Operation

User controlled Software is provided to enable the EUT to achieve 100% duty cycle during EMC testing on low, mid, and high channels. The support laptop 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	Modulation	Channel Frequencies Tested	Test Tool Power Setting[2]
902 – 928MHz	O-QPSK	915MHz / 921MHz / 925MHz	Product Default (20dBm)

Table 7. Test Channels Utilized

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 Tractian Technologies Inc. upon completion of testing.

[2] Note, the test tool power setting does not necessarily correspond to a power in dBm or Watts.

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 and it uses a unique coupling.

Test Engineer(s): Bryan Taylor

Test Date(s): 2/5/2024

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

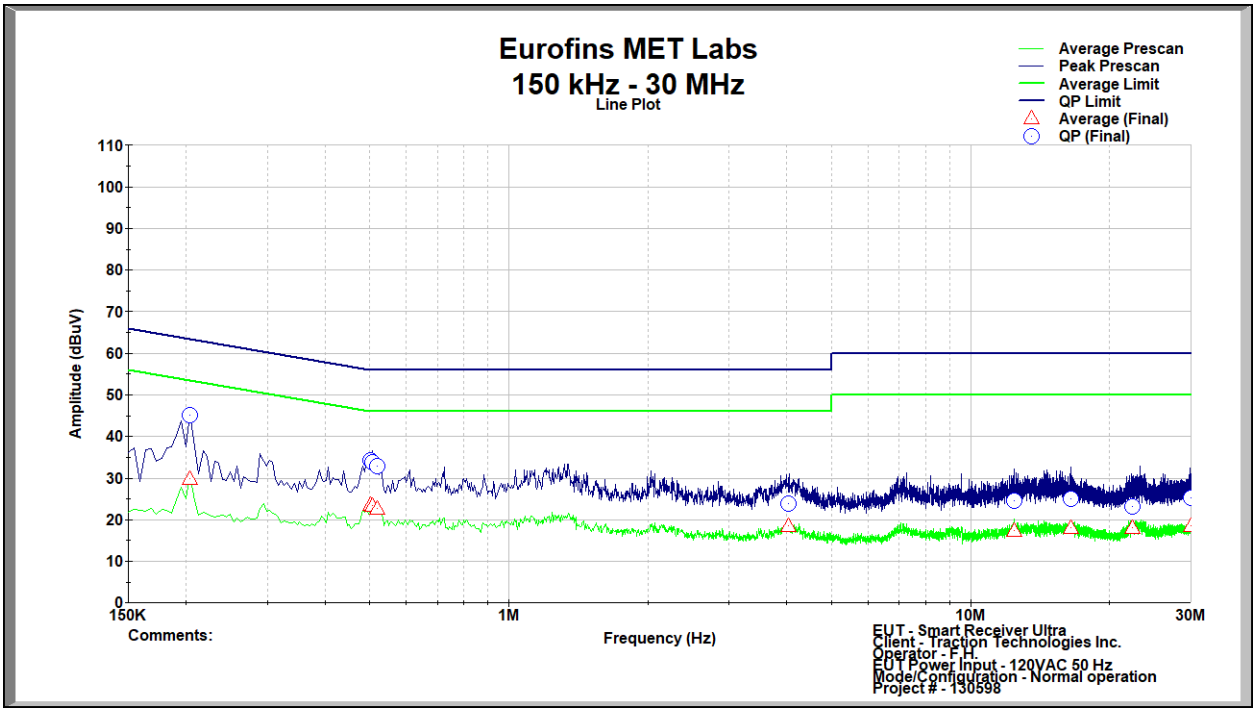
Test Procedure: The EUT was placed on a 0.8 m-high wooden table. The EUT was situated such that the back of the EUT was 0.4 m from one wall of the vertical ground plane, and the remaining sides of the EUT were no closer than 0.8 m from any other conductive surface. The EUT was powered from a 50 Ω/50 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: The EUT was compliant with this requirement. During these tests the Smart Receiver Ultra was connected to a D2-PS-120 AC/DC power adapter.

Test Engineer(s): Frank Hernandez

Test Date(s): 2/5/2024

15.207(a) Conducted Emissions Test Results

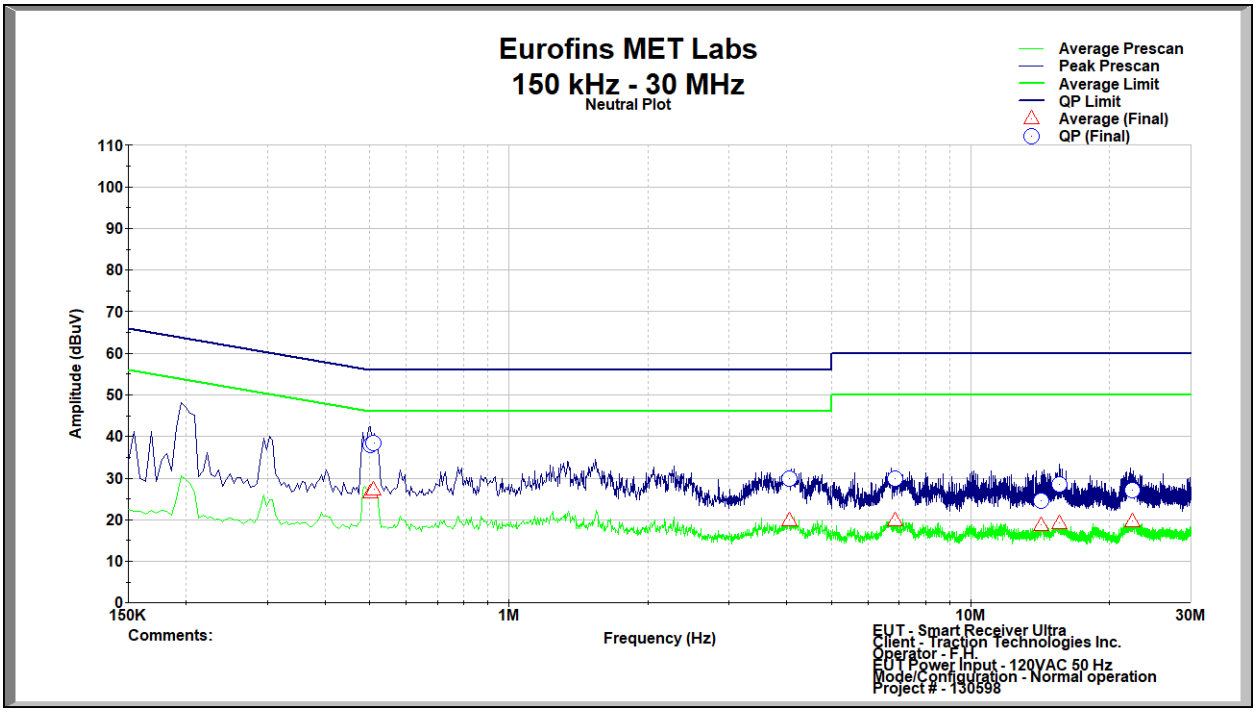


Conducted Emissions, 15.207(a), Phase

Frequency (MHz)	Quasi-Peak (dBµV/m)	Quasi-Peak Limit (dBµV/m)	Quasi-Peak Margin (dB)	Average (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)
0.204	45.19	64.457	19.267	29.802	54.457	24.655
0.501	34.148	56	21.852	23.518	46	22.482
0.505	33.795	56	22.205	23.396	46	22.604
0.519	32.825	56	23.175	22.699	46	23.301
4.04	23.822	56	32.178	18.561	46	27.439
12.445	24.476	60	35.524	17.46	50	32.54
16.488	25.016	60	34.984	18.033	50	31.967
22.386	23.137	60	36.863	17.978	50	32.022
29.967	25.185	60	34.815	18.598	50	31.402

Table 9. Conducted Emissions, 15.207(a), Phase, Test Results

15.207(a) Conducted Emissions Test Results



Conducted Emissions, 15.207(a), Neutral

Frequency (MHz)	Quasi-Peak (dBµV/m)	Quasi-Peak Limit (dBµV/m)	Quasi-Peak Margin (dB)	Average (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)
0.501	37.911	56	18.089	26.591	46	19.409
0.51	38.38	56	17.62	27.31	46	18.69
4.044	29.795	56	26.205	20.023	46	25.977
6.845	29.946	60	30.054	19.913	50	30.087
14.214	24.448	60	35.552	18.794	50	31.206
15.556	28.534	60	31.466	19.181	50	30.819
22.399	27.195	60	32.805	19.69	50	30.31

Table 10. Conducted Emissions, 15.207(a), Neutral, Test Results

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(a)(2) 6 dB Bandwidth

Test Requirements: **§ 15.247(a)(2):** 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. The minimum 6dB bandwidth shall be at least 500 kHz.

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 6 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)(2).

The 6 dB Bandwidth was determined from the plots on the following pages.

Test Engineer(s): Bryan Taylor

Test Date(s): 2/6/2024

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): 2/6/2024

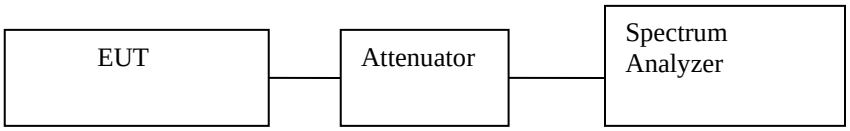
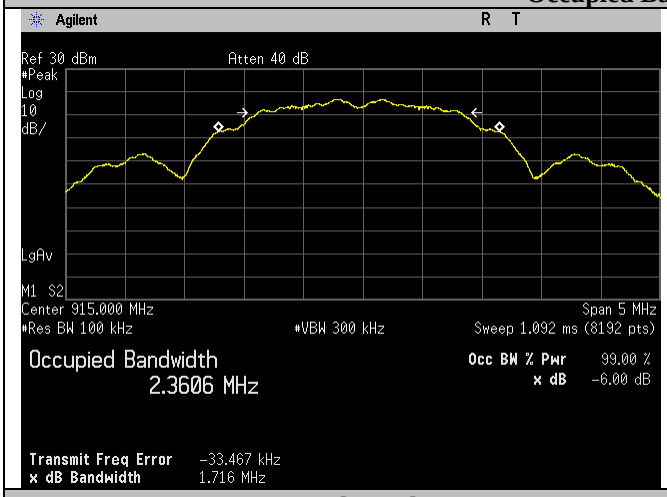


Figure 2. Block Diagram, Occupied Bandwidth Test Setup

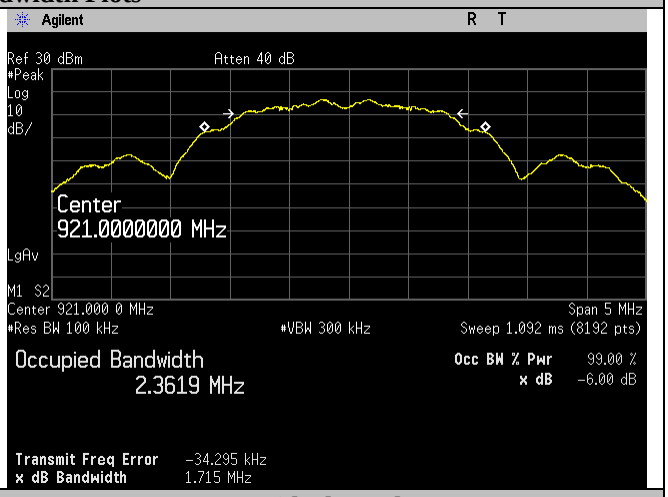
Channel	Frequency (MHz)	6dB Bandwidth (MHz)	6dB Bandwidth Limit (MHz)	99% Bandwidth (MHz)	Result
Low	915MHz	1.716MHz	0.5MHz	2.361MHz	Pass
Middle	921MHz	1.715MHz	0.5MHz	2.362MHz	Pass
High	925MHz	1.716MHz	0.5MHz	2.364MHz	Pass

Table 11. 99% and 6 dB Occupied Bandwidth, Test Results

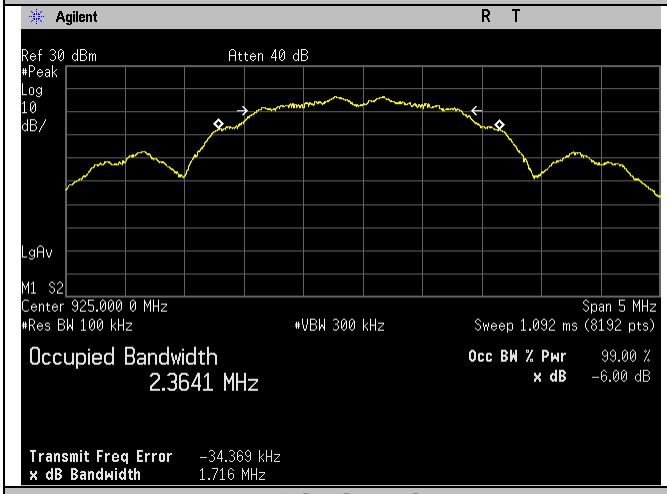
Occupied Bandwidth Plots



Low Channel



Mid Channel



High Channel

Intentionally Blank

Figure 3. 6dB and 99% Bandwidth Plots

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(b) Peak Power Output

Test Requirements: **§15.247(b):** The maximum peak output power of the intentional radiator shall not exceed the following:

Digital Transmission Systems (MHz)	Output Limit (Watts)
902-928	1.000
2400–2483.5	1.000
5725– 5850	1.000

Table 12. Output Power Requirements from §15.247(b)

§15.247(c): if transmitting antennas of directional gain greater than 6 dBi are used the peak output power from the intentional radiator shall be reduced below the stated values in the Table 12, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Systems operating in the 2400 – 2483.5 MHz band and using a point to point application may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

Systems operating in the 5725 – 5850 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi without any corresponding reduction in transmitter peak output power.

Fixed, point-to-point operation excludes the use of point-to-multipoint systems, Omni-directional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

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): 2/6/2024

Figure 4. Peak Power Output Test Setup

Peak Power Output Test Results

Channel	Frequency (MHz)	Peak Power (dBm)	Peak Power Limit (dBm)	Result
Low	915MHz	19.89dBm	30	Pass
Middle	921MHz	19.69dBm	30	Pass
High	925MHz	19.59dBm	30	Pass

Table 13. Peak Power Output, Test Results

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(e) Peak Power Spectral Density

Test Requirements: **§15.247(e):** For digitally modulated systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8dBm in any 3 kHz band during any time interval of continuous transmission.

Test Procedure: 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 between 3kHz and 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.

Test Results: The EUT was compliant with the peak power spectral density limits of **§ 15.247 (e)**.

The peak power spectral density was determined from plots on the following page(s).

Test Engineer: Bryan Taylor

Test Date: 2/6/2024

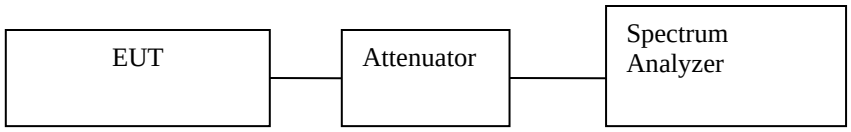


Figure 5. Block Diagram, Peak Power Spectral Density Test Setup

Channel	Frequency (MHz)	Peak Power Spectral Density (dBm / 8kHz)	Peak Power Spectral Density Limit (dBm / 8kHz)	Result
Low	915MHz	2.19	8	Pass
Middle	921MHz	3.00	8	Pass
High	925MHz	2.88	8	Pass

Table 14. Peak Power Spectral Density, Test Results

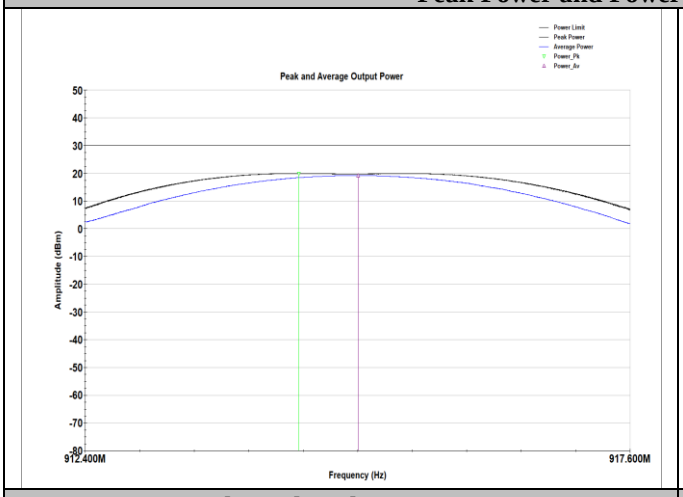
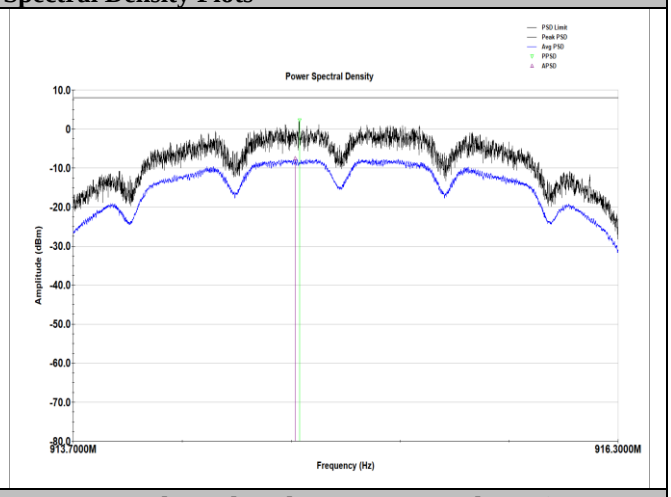
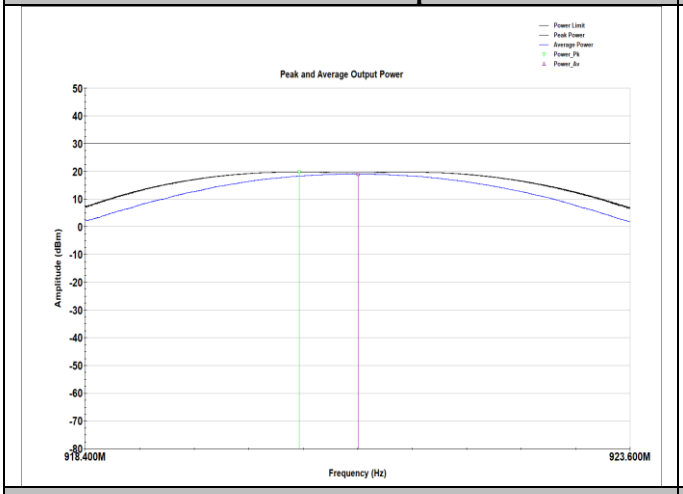
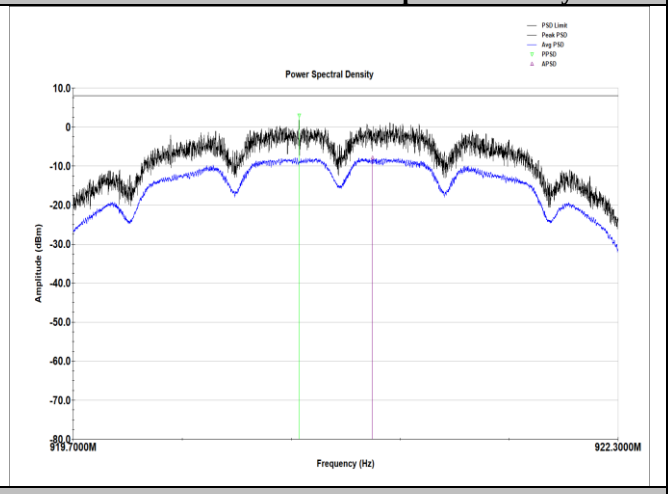
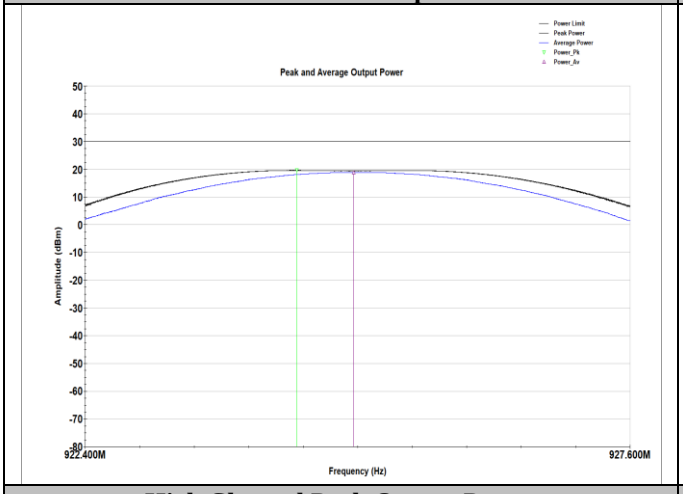
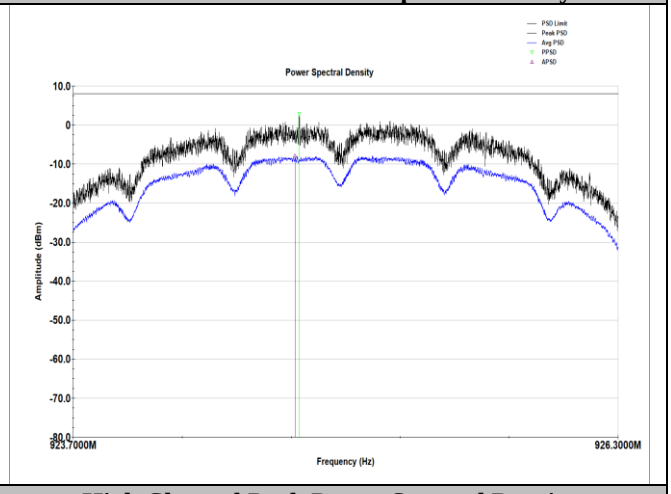
Peak Power and Power Spectral Density Plots	
	
Low Channel Peak Output Power	**Low Channel Peak Power Spectral Density**
	
Mid Channel Peak Output Power	**Mid Channel Peak Power Spectral Density**
	
High Channel Peak Output Power	**High Channel Peak Power Spectral Density**

Figure 6. Peak Power and Power Spectral Density Plots

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): 2/6/2024

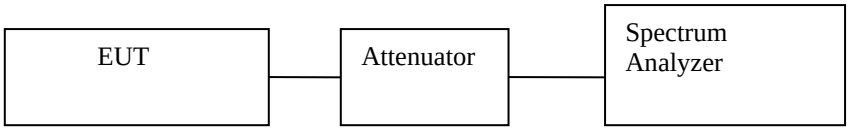


Figure 7. Block Diagram, Conducted Spurious Emissions Test Setup

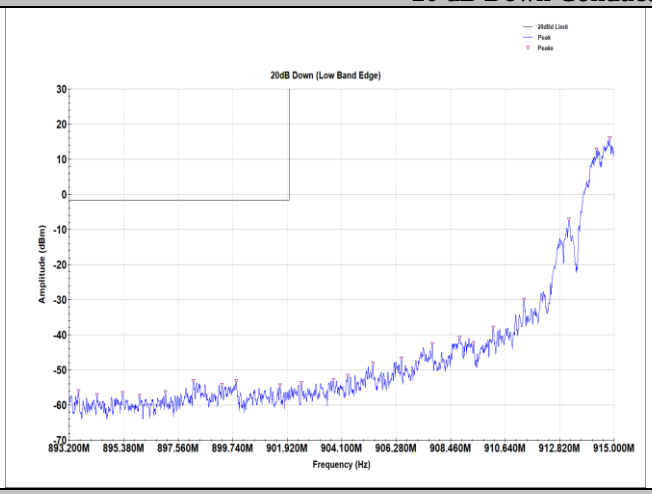
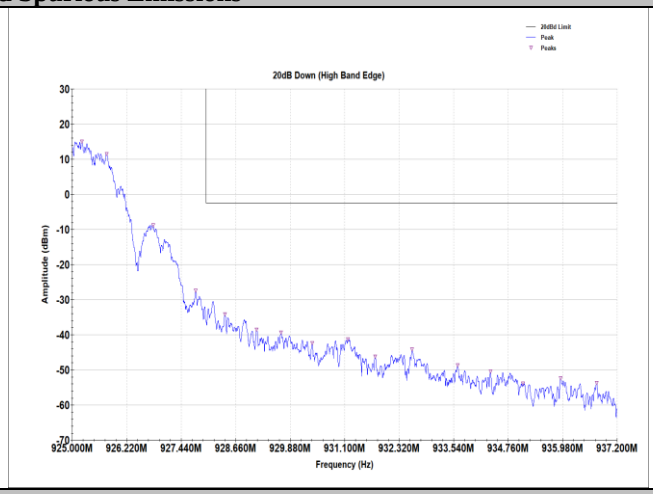
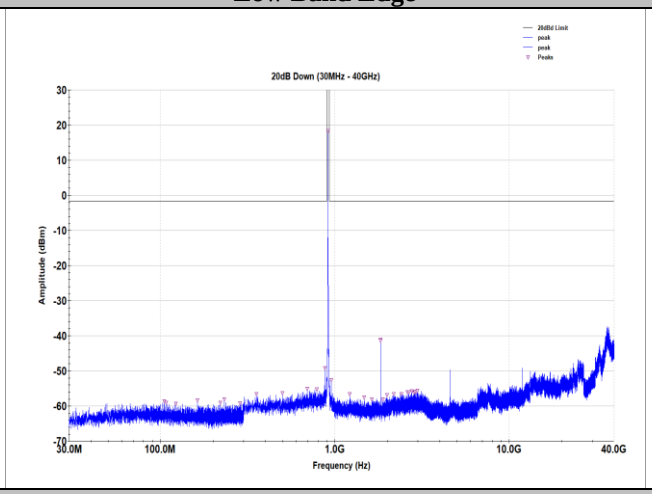
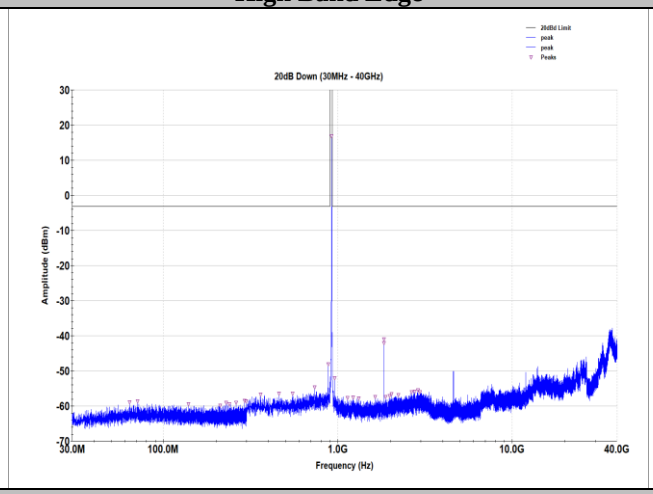
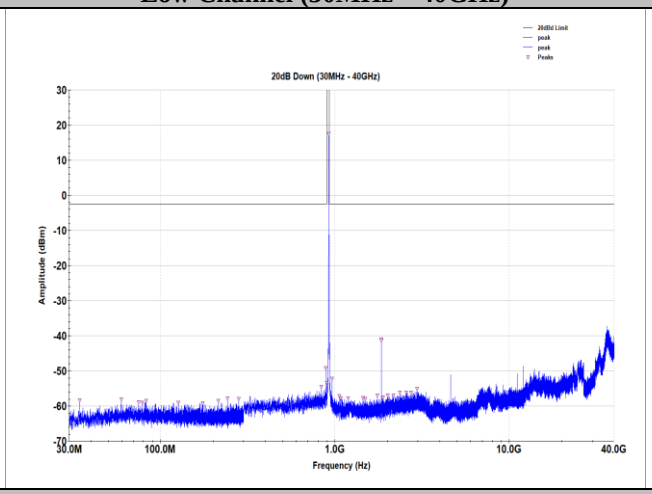
20 dB Down Conducted Spurious Emissions	
	
Low Band Edge	High Band Edge
	
Low Channel (30MHz – 40GHz)	Mid Channel (30MHz – 40GHz)
	
High Channel (30MHz – 40GHz)	Intentionally Blank

Figure 8. 20dB Down Conducted Spurious Emissions

Spurious Frequency (MHz)	Peak Amplitude (dBm)	-20dBd Limit (dBm)	Margin (dB)	Result
893.565	-55.97	-1.59	54.38	Pass
894.306	-57.11	-1.59	55.52	Pass
895.336	-56.58	-1.59	54.99	Pass
896.007	-57.44	-1.59	55.85	Pass
897.053	-56.36	-1.59	54.77	Pass
898.17	-53.15	-1.59	51.56	Pass
899.312	-54.21	-1.59	52.62	Pass
899.884	-53.11	-1.59	51.52	Pass
901.626	-54.37	-1.59	52.78	Pass

Figure 9. Low Channel 20dB Down Emissions, Low Band Edge

Spurious Frequency (MHz)	Peak Amplitude (dBm)	-20dBd Limit (dBm)	Margin (dB)	Result
928.419	-34.12	-2.49	31.63	Pass
929.131	-38.51	-2.49	36.02	Pass
929.674	-39.33	-2.49	36.84	Pass
930.37	-42.29	-2.49	39.8	Pass
931.176	-41.23	-2.49	38.74	Pass
931.782	-46.14	-2.49	43.65	Pass
932.611	-44.08	-2.49	41.59	Pass
933.627	-48.6	-2.49	46.11	Pass
934.362	-50.36	-2.49	47.87	Pass
935.094	-53.85	-2.49	51.36	Pass
935.937	-52.33	-2.49	49.84	Pass
936.739	-53.7	-2.49	51.21	Pass

Figure 10. High Channel 20dB Down Emissions, High Band Edge

Spurious Frequency (MHz)	Peak Amplitude (dBm)	-20dBd Limit (dBm)	Margin (dB)	Result
105.195	-58.64	-1.59	57.05	Pass
107.76	-59.06	-1.59	57.47	Pass
122.374	-59.27	-1.59	57.68	Pass
163.245	-58.39	-1.59	56.8	Pass
220.654	-59.02	-1.59	57.43	Pass
232.669	-58.14	-1.59	56.55	Pass
285.251	-59.17	-1.59	57.58	Pass
355.012	-56.52	-1.59	54.93	Pass
501.15	-56.37	-1.59	54.78	Pass
694.875	-55	-1.59	53.41	Pass
791.4	-55.27	-1.59	53.68	Pass
875.775	-49.2	-1.59	47.61	Pass
953.063	-52.6	-1.59	51.01	Pass
1214.963	-56.54	-1.59	54.95	Pass
1476.188	-57.5	-1.59	55.91	Pass
1633.463	-58.11	-1.59	56.52	Pass
1828.875	-41.06	-1.59	39.47	Pass
1830.9	-41.33	-1.59	39.74	Pass
1885.575	-58.11	-1.59	56.52	Pass
1989.525	-56.83	-1.59	55.24	Pass
2178.188	-56.62	-1.59	55.03	Pass
2414.775	-56.6	-1.59	55.01	Pass
2615.925	-55.99	-1.59	54.4	Pass
2667.9	-56.07	-1.59	54.48	Pass
2761.725	-55.78	-1.59	54.19	Pass
2860.95	-56.19	-1.59	54.6	Pass
2880.863	-56	-1.59	54.41	Pass
2928.787	-55.84	-1.59	54.25	Pass
2977.05	-55.66	-1.59	54.07	Pass

Figure 11. Low Channel 20 dB Down Emissions

Spurious Frequency (MHz)	Peak Amplitude (dBm)	-20dBd Limit (dBm)	Margin (dB)	Result
64.054	-58.96	-3.16	55.8	Pass
71.175	-58.58	-3.16	55.42	Pass
138.979	-59.4	-3.16	56.24	Pass
210.934	-59.88	-3.16	56.72	Pass
229.024	-59.03	-3.16	55.87	Pass
239.115	-59.4	-3.16	56.24	Pass
261.525	-59.1	-3.16	55.94	Pass
292.204	-58.46	-3.16	55.3	Pass
298.245	-58.59	-3.16	55.43	Pass
360.075	-56.73	-3.16	53.57	Pass
460.65	-56.41	-3.16	53.25	Pass
550.425	-56.43	-3.16	53.27	Pass
738.075	-54.61	-3.16	51.45	Pass
882.862	-48.09	-3.16	44.93	Pass
960.15	-52.01	-3.16	48.85	Pass
1137.675	-57.69	-3.16	54.53	Pass
1224.75	-57.61	-3.16	54.45	Pass
1315.875	-57.77	-3.16	54.61	Pass
1640.213	-57.39	-3.16	54.23	Pass
1841.025	-40.99	-3.16	37.83	Pass
1843.05	-42.12	-3.16	38.96	Pass
1882.875	-57.38	-3.16	54.22	Pass
1985.475	-57.14	-3.16	53.98	Pass
2034.75	-56.61	-3.16	53.45	Pass
2221.05	-56.91	-3.16	53.75	Pass
2654.4	-55.97	-3.16	52.81	Pass
2759.025	-55.89	-3.16	52.73	Pass
2879.512	-55.48	-3.16	52.32	Pass
2958.488	-56.04	-3.16	52.88	Pass

Figure 12. Mid Channel 20 dB Down Emissions

Spurious Frequency (MHz)	Peak Amplitude (dBm)	-20dBd Limit (dBm)	Margin (dB)	Result
34.455	-58.39	-2.49	55.9	Pass
59.801	-58.02	-2.49	55.53	Pass
75.09	-58.92	-2.49	56.43	Pass
78.735	-59	-2.49	56.51	Pass
82.819	-58.46	-2.49	55.97	Pass
126.896	-59	-2.49	56.51	Pass
174.99	-59.16	-2.49	56.67	Pass
214.815	-58.43	-2.49	55.94	Pass
243.097	-57.86	-2.49	55.37	Pass
281.438	-57.98	-2.49	55.49	Pass
837.975	-54.57	-2.49	52.08	Pass
886.237	-49.21	-2.49	46.72	Pass
899.4	-53.48	-2.49	50.99	Pass
964.875	-52.25	-2.49	49.76	Pass
1063.763	-57.12	-2.49	54.63	Pass
1086.375	-57.79	-2.49	55.3	Pass
1190.662	-57.77	-2.49	55.28	Pass
1448.85	-57.68	-2.49	55.19	Pass
1500.825	-58	-2.49	55.51	Pass
1757.662	-56.99	-2.49	54.5	Pass
1848.787	-40.92	-2.49	38.43	Pass
1851.15	-41.44	-2.49	38.95	Pass
1889.287	-57.53	-2.49	55.04	Pass
2012.813	-56.97	-2.49	54.48	Pass
2170.088	-56.98	-2.49	54.49	Pass
2364.15	-56.2	-2.49	53.71	Pass
2574.075	-56.11	-2.49	53.62	Pass
2741.813	-56.16	-2.49	53.67	Pass
2962.537	-55.09	-2.49	52.6	Pass

Figure 13. High Channel 20 dB Down Emissions

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 15. 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 16.

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

Test Procedures: The conducted methodology referenced in ANSI C63.10: 2013 Section 11.12.1 was utilized in order to assess the unwanted emissions in the restricted bands.

Additionally, in order to assess the emissions emanating from the cabinet, a radiated scan was performed with the antenna of proper impedance installed per ANSI C63.10 Section 11.12.2.7. 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)**.

Test Engineer(s): Bryan Taylor, Sergio Gutierrez

Test Date(s): 2/6/2024 – 2/19/2024

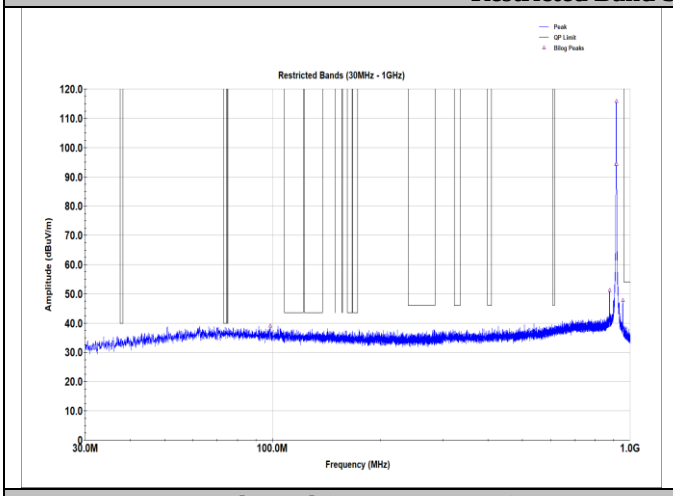
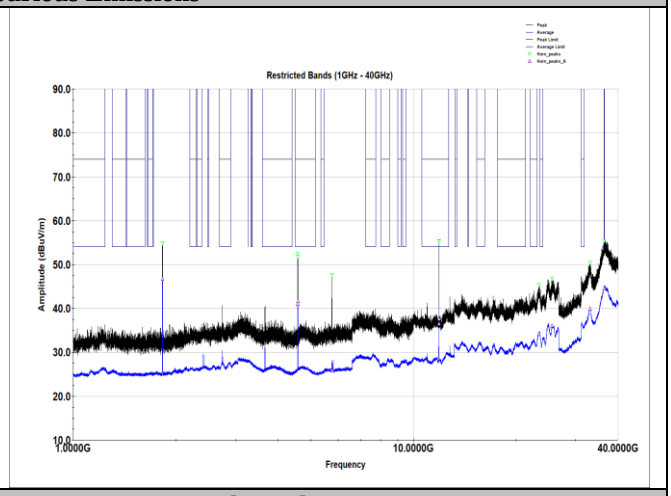
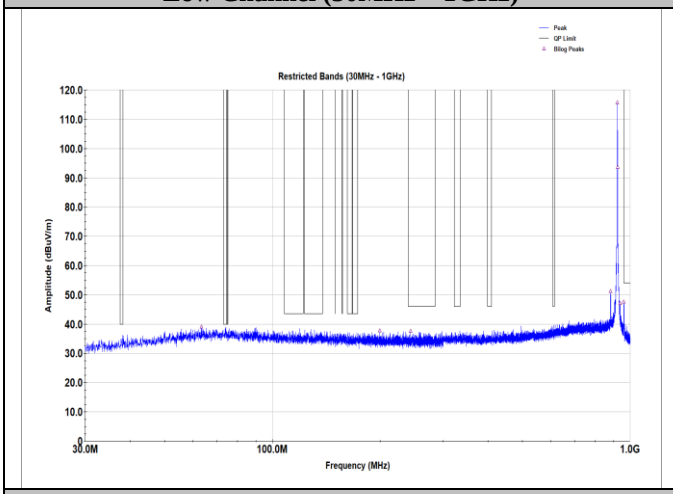
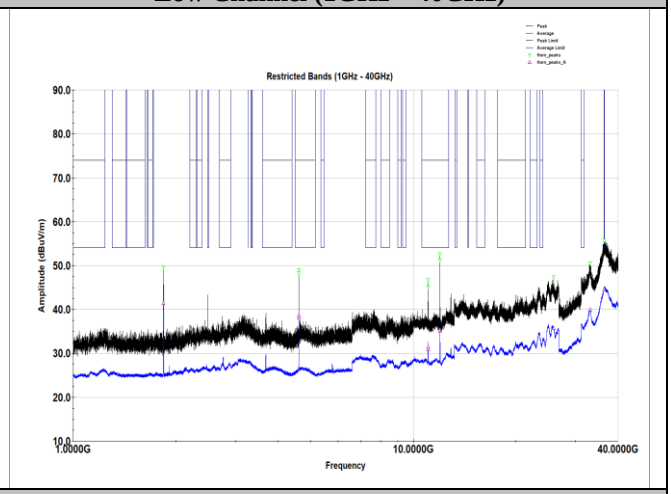
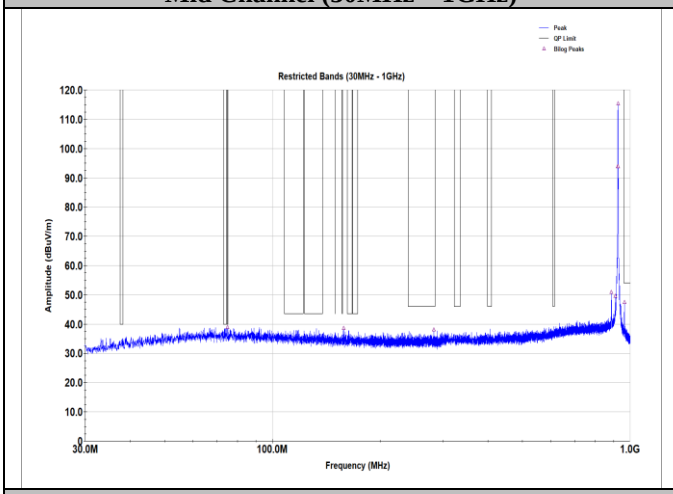
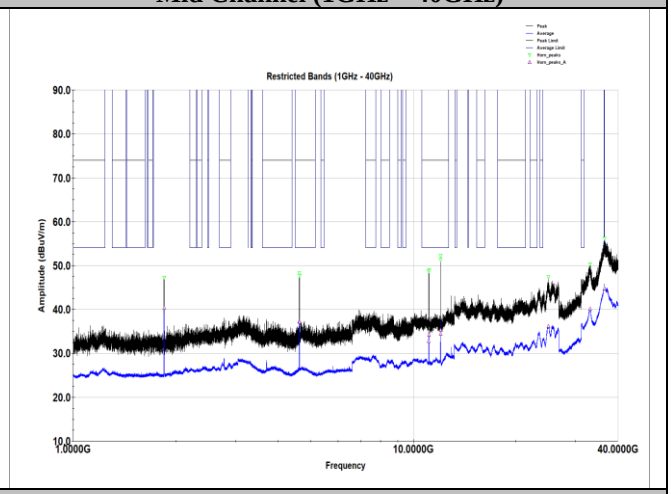
Restricted Band Spurious Emissions	
	
Low Channel (30MHz – 1GHz)	Low Channel (1GHz – 40GHz)
	
Mid Channel (30MHz – 1GHz)	Mid Channel (1GHz – 40GHz)
	
High Channel (30MHz – 1GHz)	High Channel (1GHz – 40GHz)

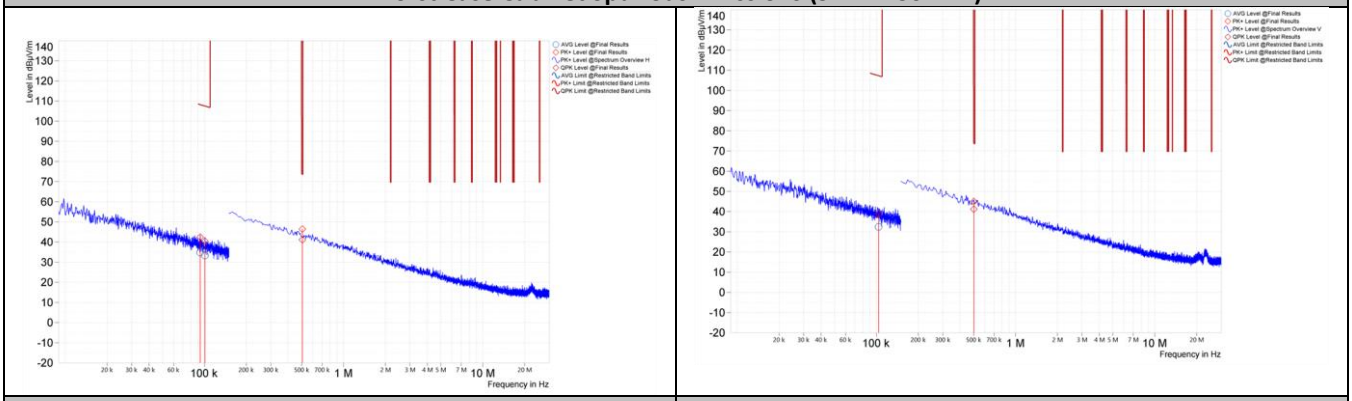
Figure 14. 30MHz – 40GHz Restricted Band Spurious Emissions

Transmit Channel	Frequency (GHz)	Peak Reading (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)	Avg Reading (dBuV/m)	Avg Limit (dBuV/m)	Avg Margin (dBuV/m)	Result
Low	4.572	52.42	74.00	21.58	41.05	54.00	12.95	Pass
	4.577	51.79	74.00	22.21	41.72	54.00	12.28	Pass
	11.888	55.36	74.00	18.64	36.52	54.00	17.48	Pass
	11.902	55.24	74.00	18.76	37.59	54.00	16.41	Pass
Mid	4.602	49.03	74.00	24.97	38.19	54.00	15.81	Pass
	4.607	48.26	74.00	25.74	38.75	54.00	15.25	Pass
	11.045	45.01	74.00	28.99	30.88	54.00	23.12	Pass
	11.058	46.7	74.00	27.3	31.53	54.00	22.47	Pass
	11.965	52.6	74.00	21.4	35.1	54.00	18.9	Pass
	11.98	51.23	74.00	22.77	35.1	54.00	18.9	Pass
High	4.622	48.25	74.00	25.75	37.25	54.00	16.75	Pass
	4.628	47.7	74.00	26.3	37.13	54.00	16.87	Pass
	11.094	48.67	74.00	25.33	32.75	54.00	21.25	Pass
	11.105	49.07	74.00	24.93	34.18	54.00	19.82	Pass
	12.017	51.36	74.00	22.64	34.41	54.00	19.59	Pass
	12.032	52.24	74.00	21.76	35.36	54.00	18.64	Pass
	36.454	56.09	74.00	17.91	44.78	54.00	9.22	Pass

Figure 15. Worst Case Restricted Band Spurious Emissions

Worst Case Cabinet Spurious Emissions

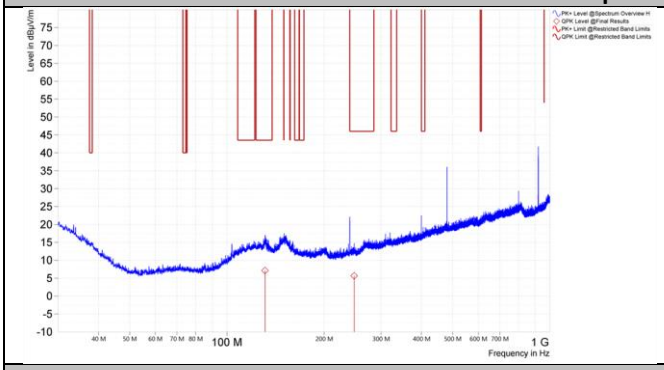
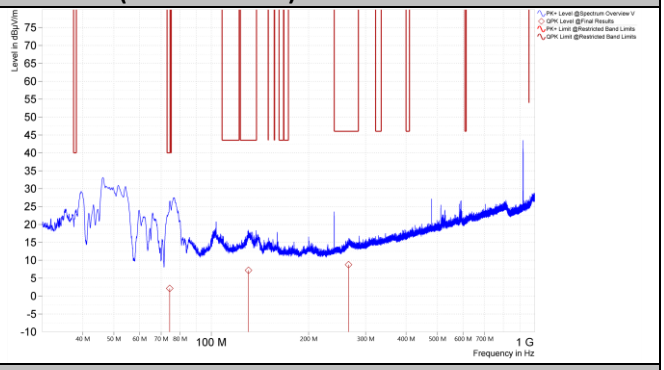
Worst Case Cabinet Spurious Emissions (9kHz – 30MHz)



9kHz – 30MHz (Horizontal) | 9kHz – 30MHz (Vertical)

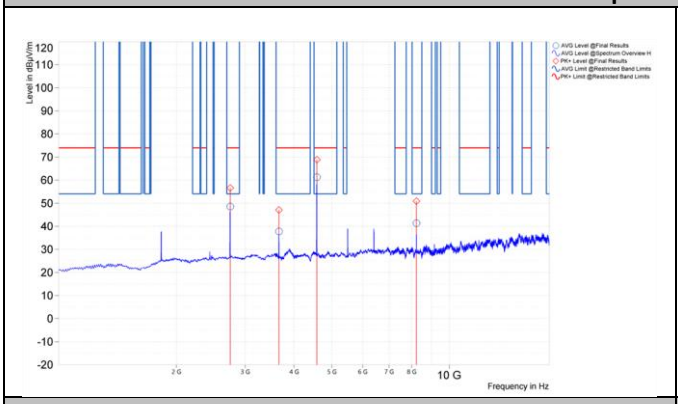
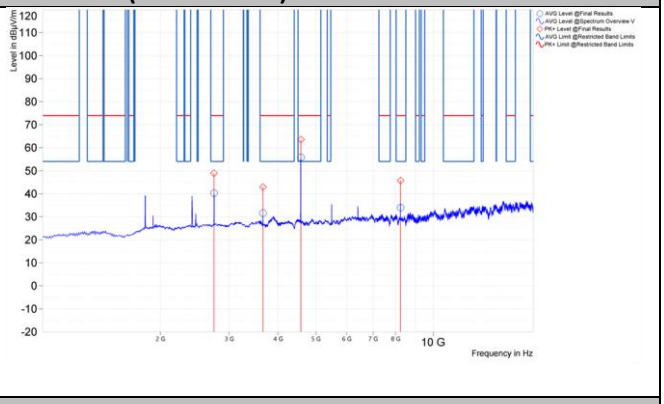
Fequency [MHz]	Level [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Detector	Correction [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Meas. BW [kHz]	Result
0.093	42.44	108.20	65.75	PK	11.57	H	157.8	1	0.200	Pass
0.101	40.44	107.52	67.08	PK	11.27	H	211	1	0.200	Pass
0.104	38.94	107.28	68.34	PK	11.31	V	141.7	1	0.200	Pass
0.501	45.03	73.69	28.66	PK	11.27	V	77.8	1	9.000	Pass
0.506	46.42	73.62	27.19	PK	11.31	H	318.4	1	9.000	Pass

Figure 16. Worst Case Cabinet Radiation, Below 30MHz (representative of low, mid, and high channels)

Worst Case Cabinet Spurious Emissions (30MHz – 1GHz)	
	
30MHz – 1GHz (Horizontal)	30MHz – 1GHz (Vertical)

Frequency [MHz]	Level [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Detector	Correction [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Meas. BW [kHz]	Result
74.370	2.14	40.00	37.86	QP	-12.21	V	147.1	3.99	120.000	Pass
130.260	7.20	43.52	36.32	QP	-6.91	V	152	1.8	120.000	Pass
131.160	7.11	43.52	36.41	QP	-6.45	H	124.7	3.52	120.000	Pass
247.650	5.65	46.02	40.37	QP	-7.64	H	82.7	1.26	120.000	Pass
265.710	8.78	46.02	37.24	QP	-6.19	V	316.4	1.26	120.000	Pass

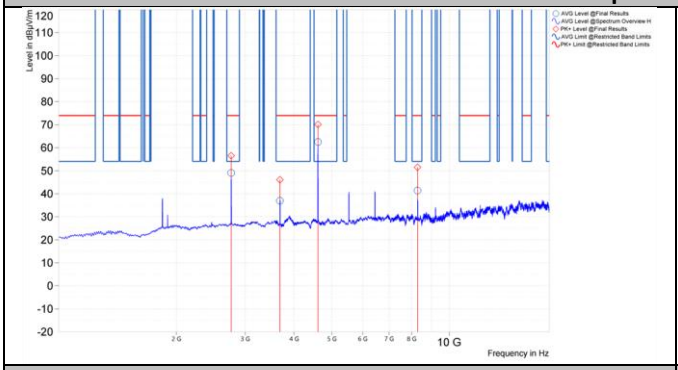
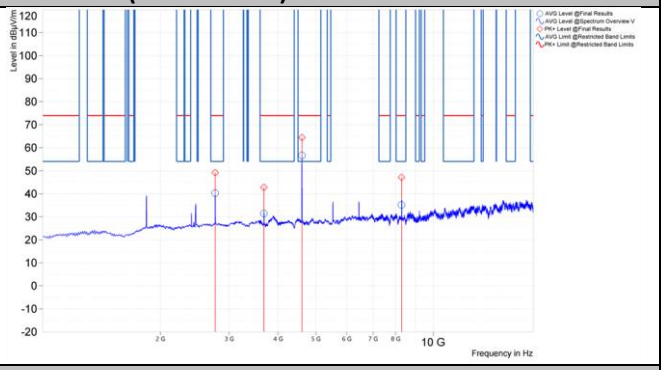
Figure 17. Worst Case Cabinet Radiation, 30MHz – 1GHz (representative of low, mid, and high channels)

Worst Case Cabinet Spurious Emissions (1GHz -18GHz)	
	
1GHz – 18GHz (Horizontal)	1GHz – 18GHz (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]	DCF [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Result
2,743.500	48.96	74.00	25.04	40.26	54.00	13.74	-2.74	NA	V	211.8	2	Pass
2,746.500	56.58	74.00	17.42	48.55	54.00	5.45	-2.74	NA	H	327.5	1.63	Pass
3,662.000	47.06	74.00	26.94	37.79	54.00	16.21	-3.69	NA	H	53.2	3.16	Pass
3,662.000	42.88	74.00	31.12	31.62	54.00	22.38	-3.69	NA	V	350.6	3.44	Pass
4,577.500	68.83	74.00	5.17	40.97	54.00	13.03	-3.82	-20.28*	H	300.1	1.88	Pass
4,577.500	63.55	74.00	10.45	35.52	54.00	18.48	-3.82	-20.28*	V	148.5	2.99	Pass
8,230.000	50.91	74.00	23.09	41.36	54.00	12.64	-3.10	NA	H	289.3	3.09	Pass
8,239.500	45.74	74.00	28.26	33.95	54.00	20.05	-3.21	NA	V	297.9	3.45	Pass

* A duty cycle correction factor was applied to the tabular data in order to arrive at an average measurement per ANSI C63.10 Section 7.5. The plots above do not include the duty cycle correction factor.

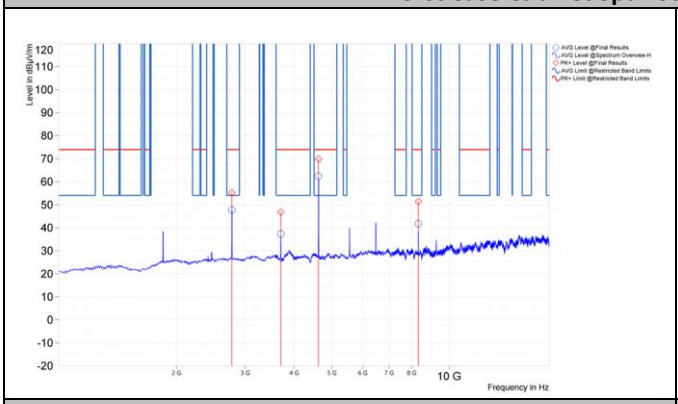
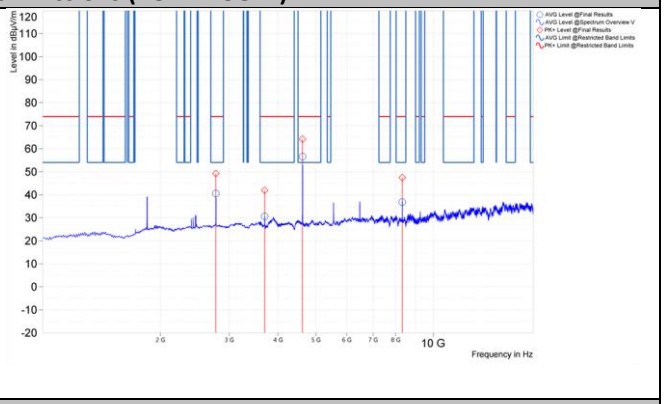
Figure 18. Worst Case Cabinet Radiation, Above 1GHz (Low Channel)

Worst Case Cabinet Spurious Emissions (1GHz -18GHz)	
	
1GHz – 18GHz (Horizontal)	1GHz – 18GHz (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]	DCF [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Result
2,761.500	56.55	74.00	17.45	49.07	54.00	4.93	-2.76	NA	H	326.5	1.61	Pass
2,761.500	49.19	74.00	24.81	40.28	54.00	13.72	-2.76	NA	V	212.9	1.96	Pass
3,682.000	46.10	74.00	27.90	37.00	54.00	17.00	-3.96	NA	H	218.3	1.84	Pass
3,682.000	42.77	74.00	31.23	31.41	54.00	22.59	-3.96	NA	V	356	3.42	Pass
4,607.500	70.12	74.00	3.88	42.25	54.00	11.75	-4.13	-20.28*	H	297.3	2.5	Pass
4,607.500	64.48	74.00	9.52	36.34	54.00	17.66	-4.13	-20.28*	V	155.4	3.44	Pass
8,284.000	51.51	74.00	22.49	41.43	54.00	12.57	-3.86	NA	H	274.4	3.33	Pass
8,284.000	47.13	74.00	26.87	35.16	54.00	18.84	-3.86	NA	V	358.2	3.07	Pass

* A duty cycle correction factor was applied to the tabular data in order to arrive at an average measurement per ANSI C63.10 Section 7.5. The plots above do not include the duty cycle correction factor.

Figure 19. Worst Case Cabinet Radiation, Above 1GHz (Mid Channel)

Worst Case Cabinet Spurious Emissions (1GHz -18GHz)	
	
1GHz – 18GHz (Horizontal)	1GHz – 18GHz (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]	DCF [dB]	Polarization	Azimuth [deg]	Antenna Height [m]	Result
2,773.500	55.25	74.00	18.75	47.77	54.00	6.23	-2.78	NA	H	326	1.99	Pass
2,773.500	49.21	74.00	24.79	40.56	54.00	13.44	-2.78	NA	V	200.9	1.76	Pass
3,698.000	41.92	74.00	32.08	30.56	54.00	23.44	-4.17	NA	V	232.4	2.01	Pass
3,702.000	46.79	74.00	27.21	37.30	54.00	16.70	-4.16	NA	H	25.5	2.03	Pass
4,622.000	69.88	74.00	4.12	42.21	54.00	11.79	-4.22	-20.28*	H	286.4	2.5	Pass
4,622.000	64.19	74.00	9.81	36.28	54.00	17.72	-4.22	-20.28*	V	171.6	3.13	Pass
8,320.000	47.48	74.00	26.52	36.78	54.00	17.22	-3.88	NA	V	359.8	3.42	Pass
8,329.500	51.34	74.00	22.66	41.78	54.00	12.22	-3.81	NA	H	274.8	3.32	Pass

* A duty cycle correction factor was applied to the tabular data in order to arrive at an average measurement per ANSI C63.10 Section 7.5. The plots above do not include the duty cycle correction factor.

Figure 20. Worst Case Cabinet Radiation, Above 1GHz (High Channel)

Electromagnetic Compatibility Criteria for Intentional Radiators

§ ANSI C63.10 Duty Cycle Correction Factor

Test Procedure: In order to obtain the average value of pulsed emissions ANSI C63.10 Section allows the use of a duty cycle correction factor defined as follows:

DCF(dB) = 20log(Δ) where:

DCF = the duty cycle correction factor in dB
Δ = the duty cycle in decimal form over 100mS

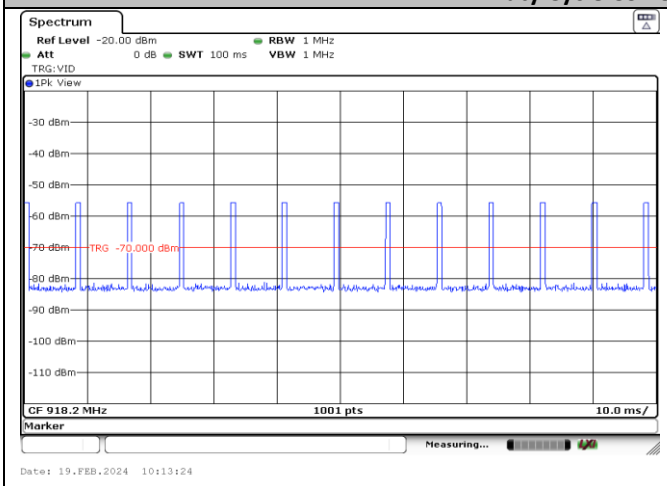
The Smart Receiver Ultra in normal operation will transmit a pulsed signal requiring the use of the duty cycle correction factor in order to achieve a true average value. In order to determine the duty cycle correction factor, the test sample was configured to transmit its worst-case pulse train. The duty cycle over 100mS was measured by setting a spectrum analyzer to zero span mode and capturing the number of pulses over 100mS. The on time of all pulses in this 100mS window was measured and divided by 100mS in order to arrive at the duty cycle. This duty cycle was then used to calculate the duty cycle correction factor via the formula above. When necessary, the duty cycle correction factor was applied to emissions where comparison to an average limit was required. When the DCF is utilized, a note will appear in the tabular data alongside the measurement.

Results: The duty cycle correction factor was determined to be -20.28dB.

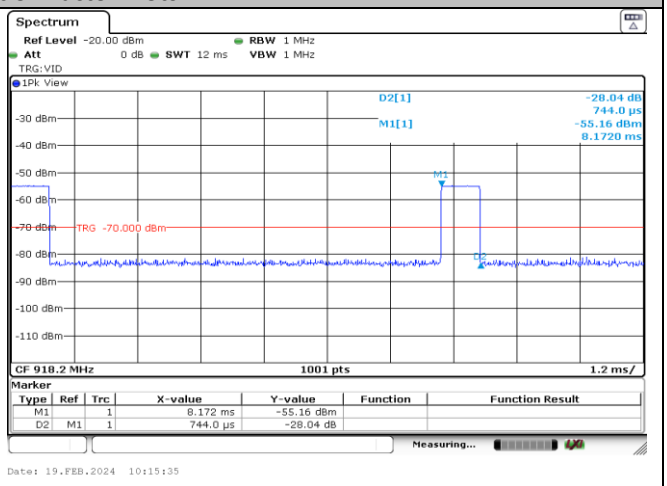
Test Engineer(s): Sergio Gutierrez

Test Date(s): 2/19/2024

Duty Cycle Correction Factor Plots



13 Pulses in 100mS



"On Time" of a single Pulse = 0.744mS

Duty Cycle Correction Factor = 20log([0.744 x 13]/100) = -20.28dB

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
MY46180897	Spectrum Analyzer	Keysight	E4448A	7/27/2023	7/27/2024
1A1083	Receiver	Rohde & Schwarz	ESU40	11/20/2023	11/20/2024
1A1176	Active Loop Antenna (9KHz-30MHz)	ETS-Lindgren	6502	7/13/2023	7/13/2024
1A1147	Bi-Log Antenna	Suno Sciences Corp	JB3	04/06/2023	4/06/2025
1A1047	Horn Antenna	ETS - Lindgren	3117	06/16/2022	6/16/2024
1A1065	EMI Receiver	Rohde & Schwarz	ESCI	8/4/2023	8/4/2024
1A1122	LISN	Teseq	NNB 51	9/19/2023	9/19/2024
1A1123	LISN	Teseq	NNB 51	12/20/2023	12/20/2024
1A1149	DC Milliohm Meter	GW Instek	GOM-802	9/20/2023	9/20/2024
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 17. Test Equipment List

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

End of Report