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ELECTROMAGNETIC COMPATIBILITY TEST REPORT

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American Association for Laboratory Accreditation Certificate Number: 3657.02

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Applicable Test Standards:	FCC Title 47 CFR Part 15: Subpart B FCC Title 47 CFR Part 15: Subpart C - § 15.247 RSS-247 Issue 2, RSS-Gen Issue 5, ICES-003 Issue 6

Equipment Tested	Smart Swimming Goggles Device
Model Number:	FSG1
FCC ID:	2ASL3-FSG100
IC Certification Number:	24807-FSG100
Manufacturer:	FORM Athletica

REVISION HISTORY

Date	Report Number	Rev #	Details	Author
May 14, 2019	E11022-1801_FORMAthletica-SSG_Rev	1.3	Removed photos	MK
May 8, 2019	E11022-1801_FORMAthletica-SSG_Rev	1.2	Update HVIN, Cal. dates	MK
May 3, 2019	E11022-1801_FORMAthletica-SSG_Rev	1.1	Added: 6dB BW, RE 18-26 GHz.	MK
April 25, 2019	E11022-1801_FORMAthletica-SSG_Rev	1.0	Final Release	MK
March 14, 2019	E11022-1801_FORMAthletica-SSG_Rev	0.0	Initial Release	MK
All previous versions of this report have been superseded by the latest dated revision as listed in the above table. Please dispose of all previous electronic and paper printed revisions accordingly.				

REPORT AUTHORIZATION

The data documented in this report is for the test equipment provided by Six Guys Labs Tests were conducted on the sample equipment as requested by FORM Athletica Inc. for the purpose of demonstrating compliance with FCC Title 47 CFR Part 15: Subpart B, FCC Title 47 CFR Part 15: Subpart C - § 15.247, RSS-247 Issue 2, RSS-Gen Issue 5 & ICES-003 Issue 6 as agreed upon by FORM Athletica as per Quote 18SH08303R1.

FORM Athletica is responsible for the tested product configuration, continued product compliance, and for the appropriate auditing of subsequent products as required. This report may comprise partial list of tests that are required for FCC & IC Declaration of Conformity and can only be produced by the manufacturer.

This is to certify that the following report is true and correct to the best of our knowledge.

Radio Testing by Bruce Balston,
Senior RF/EMC Test Engineer

Emissions Testing by Maryam Kashi,
RF/EMC Test Engineer

Report by Maryam Kashi,
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Approved by Parminder Singh,
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QAI FACILITIES

Founded in 1994 by a group of experienced certification and testing experts, QAI is an independent third-party testing, inspection and certification organization which serves the building industry, government and individuals with cost effective solutions through our in-house capabilities / services, and an established world-wide network of qualified affiliates. To help get your product to market, trust the provider that many leading global manufacturers do: QAI.

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QAI EMC ACCREDITATION

QAI EMC is your one-stop regulatory compliance partner for electromagnetic compatibility (EMC) and electromagnetic interference (EMI). Products are tested to the latest and applicable EMC/EMI requirements for domestic and international markets. QAI EMC goes above and beyond being a testing facility—we are your regulatory compliance partner. QAI EMC has the capability to perform RF Emissions and Immunity for all types of electronics manufacturing including Industrial, Scientific, Medical, Information Technology, Telecom, Wireless, Automotive, Marine and Avionics.

EMC Laboratory Location	FCC Designation (3m SAC)	IC Registration (3m SAC)	A2LA Certificate
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Headquarters & EMC Laboratory in Burnaby, BC

TABLE OF CONTENTS

REVISION HISTORY 2
REPORT AUTHORIZATION 2
QAI FACILITIES 3
QAI EMC ACCREDITATION 3
TABLE OF CONTENTS 4
Section I: EXECUTIVE SUMMARY 5
1.1 Purpose 5
1.2 Scope 5
1.3 Summary of Results 6
Section II: GENERAL INFORMATION 7
2.1 Product Description 7
2.2 Environmental Conditions 7
2.3 Measurement Uncertainty 8
2.4 Worst Test Case 8
2.5 Sample Calculations of Emissions Data 8
2.6 Test Equipment List 9
Section III: TEST RESULTS 10
3.1 Antenna Requirements 10
3.2 Duty Cycle Correction Factor Calculation 11
3.3 RF Conducted Peak Output Power 12
3.4 Power Spectral Density (PSD) 13
3.5 6-dB Bandwidth 17
3.6 99% Bandwidth 21
3.7 2.4 GHz Bandedge and Out-of-Band Emissions 22
3.8 Spurious Emissions 24
3.9 Harmonic Emissions 31
3.10 Unintentional Radiated Emissions – Receiver Mode 35
3.11 AC Mains Conducted Emissions 38
3.12 Frequency Stability 40
3.13 RF Exposure Evaluation 43
Appendix A: TEST SETUP PHOTOS – available upon request 44
Appendix B: ABBREVIATIONS 44
End Of Report 45

Section I: EXECUTIVE SUMMARY

1.1 Purpose

The purpose of this report is to demonstrate and document the compliance of Smart Swimming Goggles as per Sections 1.2 & 1.3.

1.2 Scope

The information documented in this report is based on the test methods and levels as per Quote 18SH08303R1:

FCC Title 47 Part 15 - Radio Frequency Devices, Subpart C – Intentional Radiators.
15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz.

CFR Title 47 FCC Part 15 - Radio Frequency Devices, Subpart B – Unintentional Radiators.

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

RSS-Gen Issue 5 – General Requirements and Information for the Certification of Radio Apparatus

ICES-003 Issue 6 – Information Technology Equipment (Including Digital Apparatus) – Limits and Methods of Measurement

The tests documented in this report were performed in accordance with ANSI C63.4-2014, ANSI C63.10-2013, and FCC KDB 558074 D01 DTS Meas Guidance v05.

1.3 Summary of Results

The following tests were performed pursuant to the FCC/IC Unintentional Radiated Emissions, Intentional Radiated Emissions, and Radio Testing Standards:

No.	Test Description	Standard Clause	Result
1	Antenna Requirement	FCC 47 CFR Part 15.203 IC RSS-Gen Issue 5 Section 7.1.2	Complies
2	Duty Cycle Corrction	FCC Title 47 CFR Part 15: Subpart C - §15.247 (b)(1) RSS-247 Issue 2	Complies
3	RF Conducted Peak Output Power	FCC Title 47 CFR Part 15: Subpart C - §15.247 (b)(1) RSS-247 Issue 2	Complies
4	Power Spectral Density	FCC Title 47 CFR Part 15: Subpart C §15.247 (e), RSS-247 Issue 2: 5.2 (2)	Complies
5	6-dB Bandwidth	FCC Subpart C §15.247 (a) (2), RSS-247 Issue 2 §5.2	Complies
6	99% Bandwidth	RSS-247-Issue 2, RSS-Gen Issue 5 FCC Subpart C §15.247	Complies
7	Bandesge and Out-of-Band Emissions	FCC Title 47 CFR Part 15: Subpart C - §15.247 (d) RSS-247-Issue 2	Complies
8	Spurious Emissions	RSS-247-Issue 2, RSS-Gen Issue 5 FCC Subpart C §15.205, §15.209 & §15.247	Complies
9	Harmonnic Emissions	FCC Title 47 CFR Part 15: Subpart C - §15.247 (d) RSS-247-Issue 2	Complies
10	Unintentional Radiated emissions - Receiver Mode	FCC Title 47 CFR Part 15: Subpart B - §15.109 ICES-003 Issue 6	Complies
11	AC Mains Conducted Emissions	FCC Title 47 CFR Part 15: Subpart B - §15.109 ICES-003 Issue 6	Complies
12	Frequency Stability	FCC Title 47 CFR Part 15: Subpart C §15.247, 2.1055, RSS-247 Issue 2	Complies
13	RF Exposure Evaluation	FCC 47 CFR §1.1310: RSS-102 Section 2.5.2	Complies

Section II: GENERAL INFORMATION

2.1 Product Description

The information provided in this section is for the Equipment Under Test (EUT) and the corresponding Auxiliary Equipment needed to perform the tests as a complete system.

Equipment Under Test (EUT) Information

EUT	Smart Swimming Goggles - BLE
Description	Swimming goggles with heads-up display w/ BLE capability.
FCC ID	2ASL3-FSG100
IC Number	IC: 24807-FSG100
Manufacturer	Form Athletica
Model No.	FSG1
Serial No.	J0141800064
Operating Frequency	2402 MHz to 2483.5 MHz
Transmit Power	6 dBm
Modulation Type	GFSK
Test Channels	2402, 2440 and 2480 MHz
Data Rate	<= 1Mb/s
Antenna Type	IFA
Antenna Gain	2.3 dBi
Input Power	AC/DC adaptor
Charging Cable	Model No. FCH1, USB Type A – Custom pogo pins

Auxiliary Equipment Information

Manufacturer	Product Description	Model No.
Apple	AC/DC Power Adapter	A1385
Polar	OH1 - Heart Rate Sensor	2L

2.2 Environmental Conditions

The equipment under test was operated and tested under the following environmental conditions:

Parameter	Conditions
Location	Indoors
Temperature	22-28ºC
Relative Humidity	39.7 - 54.4%

2.3 Measurement Uncertainty

Parameter	Uncertainty
Radiated Emissions, 30MHz-1GHz	± 2.40 dB
Radiated Emissions, 1GHz-40GHz	± 2.48 dB
Radio Frequency	±1.5 x 10-5 MHz
Total RF Power Conducted	±1.36 dB
Spurious Emissions Conducted	±1.36 dB
RF Power Density Conducted	±1.36 dB
Temperature	±1ºC
Humidity	±5 %
DC and low frequency voltages	±3 %

2.4 Worst Test Case

Worst-case orientation was determined during the preliminary testing. The final radiated emissions were performed in the worst-case orientation.

2.5 Sample Calculations of Emissions Data

Radiated and conducted emissions were performed using EMC32 software developed by Rohdes & Schwarz. Transducer factors like Antenna factors, Cable Losses and Amplifier gains were stored in the test templates which are used to perform the emissions measurements. After test is finished, data is generated from the EMC32 consisting of product details, emission plots and final data tables as shown below.

Frequency (MHz)	QPeak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Ant. Ht. (cm)	Pol	Turntable position (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
42.663900	33.0	1000.000	120.000	100.0	H	70.0	13.2	7.5	40.5

Quasi Peak reading shown in the table above is already corrected by the software using correction factor shown in column “Corr.” The correction factor listed under “Corr.” table calculated as:

Corr.(dB) = Antenna factor + Cable loss

Or

Corr.(dB) = Antenna factor + Cable Loss - Amp gain (if pre-amplifier was used)

The final Quasi peak reading shown in the data is calculated by the software using following equation:

Corrected Quasi Peak(dBµV/m) = Raw Quasi Peak Reading + Antenna factor + Cable loss

To obtain the final Quasi-Peak or Average reading during power line conducted emissions, transducer factors are included in the final measurement as shown below.

Frequency (MHz)	QPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150	44.3	1000.000	9.000	GND	0.6	21.7	66.0

Frequency (MHz)	QPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150	27.2	1000.000	9.000	GND	0.6	28.8	56.0

Quasi Peak or Average reading shown in above table is already corrected by the software using the correction factor shown in column “Corr.” The correction factor listed under “Corr.” table calculated as:

Corr.(dB) = Antenna factor + Cable loss

The final Quasi peak or Average reading shown in the data is calculated by the software using following equation:

Corr. Quasi Peak/Average Reading (dBµV) = Raw Quasi Peak/Average Reading + Antenna factor + Cable loss

The allowable margin from the limits, as per the standards, were calculated for both radiated and conducted emissions:

Margin(dB) = Limit – Quasi-Peak or Average reading

2.6 Test Equipment List

The tables below contain all the equipment used by QAI Laboratories in conducting all tests on the Equipment Under Test (EUT) as per Section 1.3.

Emissions Test Equipment

Manufacturer	Model	Description	Serial No.	Last Calibration Date	Calibration Due Date
ETS Lindgren	S201	5-meter Semi-Anechoic Chamber	1030	N/A	N/A
Sunol Sciences	SM46C	Turntable	051204-2	N/A	N/A
Sunol Sciences	TWR95	Mast	TREML0001	N/A	N/A
Sunol Sciences	JB3	Biconilog Antenna 30MHz – 3GHz	A120106	2017-Sep-24	2020-Sep-24
ETS Lindgren	DRH 3117	Horn Antenna 1GHz-18GHz	75944	2017-Aug-29	2020-Aug-29
Rohde & Schwarz	ESU40	EMI Receiver	100011	2017-Nov-20	2020-Nov-20
EMCO	3825/2	LISN (150kHz-30MHz)	9002-1601	2017-Aug-25	2020-Aug-25
EMCO	6502	Loop Antenna	6502	2017-Nov-13	2020-Nov-13
EMCO	3160-09	Horn Antenna 18-26.5GHz	9701-1071	13-Sep-17	2020-Sep-13

The following components and equipment are calibrated as a complete signal path.

Manufacturer	Model	Description	Serial No.	Last Calibration Date	Calibration Due Date
AH Systems	PAM118	Amplifier 10KHz-18GHz	189	January 1, 2019	January 1, 2020
Insulated Wire Inc.	SPS-1753-1140-SPS	Yellow cable, 3m	102395		
Insulated Wire Inc.	SPS-1753-2400-SPS	Yellow cable, 6m	091096		
WEINSCHEL ENGINEERING	44	6db attenuator	665		
A.H.Systems	PAM-1840VH	Preamplifier 18-40GHz	152	January 1, 2019	January 1, 2020
A.H.Systems	2649-03	Green short input cable	395		
A.H.Systems	2649-225	Green short output cable	396		

Measurement Software List

Manufacturer	Model	Version	Description
Rohde & Schwarz	EMC 32	6.20.0	Emissions Test Software

Section III: TEST RESULTS

NOTE:
All three channels were tested for each section. Unless a frequency is reported as the worst case, results proved equivalent across all three channels.

3.1 Antenna Requirements

Date Performed:

January 8, 2019

Test Standard:

FCC 47 CFR Part 15.203 and IC RSS-Gen Issue 5 Section 7.1.2

Applicable Regulation:

The purpose of this requirement is to make certain that no other antenna, except for that provided by the responsible party, shall be used with the Equipment-Under-Test (EUT) as defined in FCC CFR 47 Part 15.203 & RSS-Gen Issue 5:

> "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 the user can replace a broken antenna, but the use of a standard antenna jack or electrical connector is prohibited." … "the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this Part are not exceeded."

Modifications:

No modification was required to comply for this test.

Result:

An integrated antenna is used on this product and it is not field replaceable.

Antenna Description (from antenna datasheet):

Manufacturer: Molex
2.4 GHz Ceramic SMT Antenna (Series 203006)

BLE

Polarization	Linear
RF Power	2 Watts
Compact Size	3.20(L) by 1.60(W) by 1.10(H) mm
Antenna Type	IFA
Return Loss	<-10 dB
RoHS	Yes
Frequency Range	2.4 GHz
Peak Gain	2.3 dBi
Impedance	50 Ohms
Total Efficiency	>70 %

3.2 Duty Cycle Correction Factor Calculation

Date Performed:

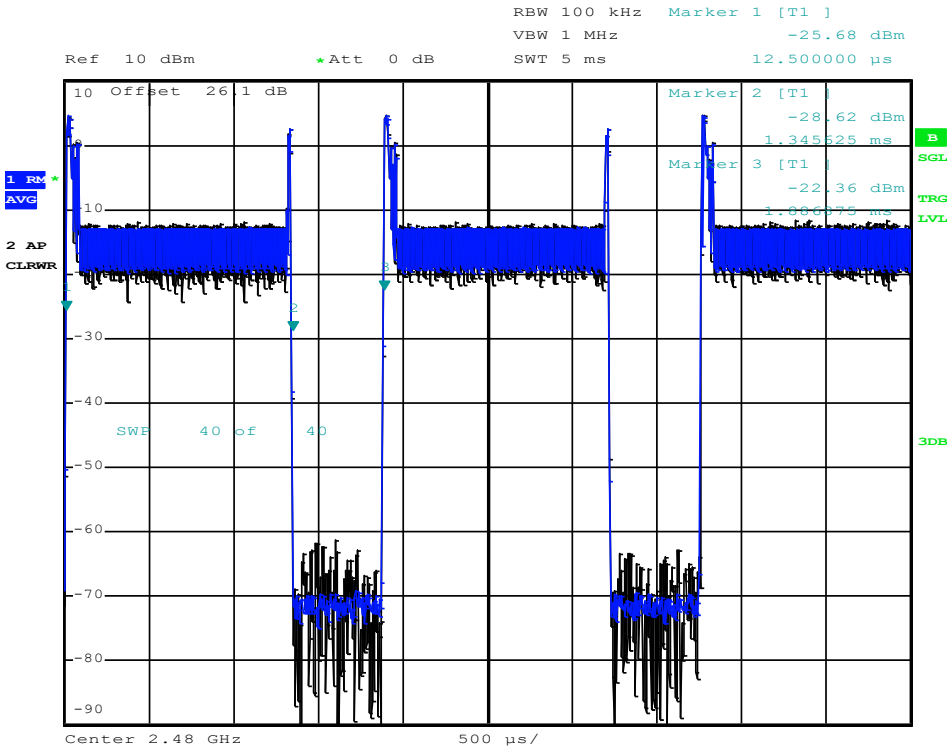
March 26, 2019

Requirement(s):

- *§ 15.35(c)* - Unless otherwise specified, e.g. § 15.255(b), when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds. As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted with any application for certification or shall be retained in the measurement data file for equipment subject to notification or verification.

Method of Measurement:

- As called in the ANSI C63.10-2013 standard.



Duty Cycle Correction Factor Calculation

Data Transmissions		Number of pulses
Pulse Train Duration	1.873 ms	~53 in 100 ms
ON Time Duration	1.333 ms	
ON Time within 100 msec	~53 x 1.333 ms = 70.65 ms	
Duty Cycle Correction Factor	**20log (70.65/100) = -3.02 dB**	

3.3 RF Conducted Peak Output Power

Date Performed: January 30, 2019

Test Standard: FCC Title 47 CFR Part 15: Subpart C - §15.247 (b)(3), RSS-247 Issue 2

Test Method: FCC KDB 558074 D01 DTS Meas Guidance v05

Test Requirement: For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt.

Result: The EUT complies with the applicable standard.

Measurement Data:

Channel	Frequency MHz	Power-meter rms measurement (dBm)	Duty Cycle Correction Factor	RF Peak Output Power (dBm)	Limit (dBm)	Results
Low	2402	2.14	3.02	5.16	30	PASS
Mid	2426	1.99	3.02	5.01	30	PASS
High	2480	1.92	3.02	4.94	30	PASS

Average Power (rms) = Peak Power + Duty Cycle Correction Factor (DCCF)

Peak Power (dBm) = Average Power (rms) (dBm) + 3.02 dB

3.4 Power Spectral Density (PSD)

Date Performed: January 30, 2019

Test Standard: FCC Title 47 CFR Part 15: Subpart C §15.247 (e), RSS-247 Issue 2: 5.2 (2)

Test Method: FCC KDB 558074 D01 DTS Meas Guidance v05

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

Modifications:
No modification was required to comply for this test.

Result:
The EUT complies with the applicable standard.

Measurements:

Channel	Frequency (MHz)	System Loss/SA Offset (dB)	PSD (100 kHz RBW) (dBm)	RBW Correction Factor (dB)	PSD (3 kHz RBW) (dBm)	Limit (dBm)	Results
Low	2402	23.8	1.02	-15.23	-14.21	8	PASS
Mid	2440	23.8	0.3	-15.23	-14.93	8	PASS
High	2480	23.8	1.7	-15.23	-13.53	8	PASS

RBW Correction Factor = 10Log(BW1/BW2) = 10Log (3 kHz/100 kHz) = -15.23 dB

PSD (3 kHz RBW) (dBm) = PSD (100 kHz RBW) (dBm) + (-15.23) (dB)

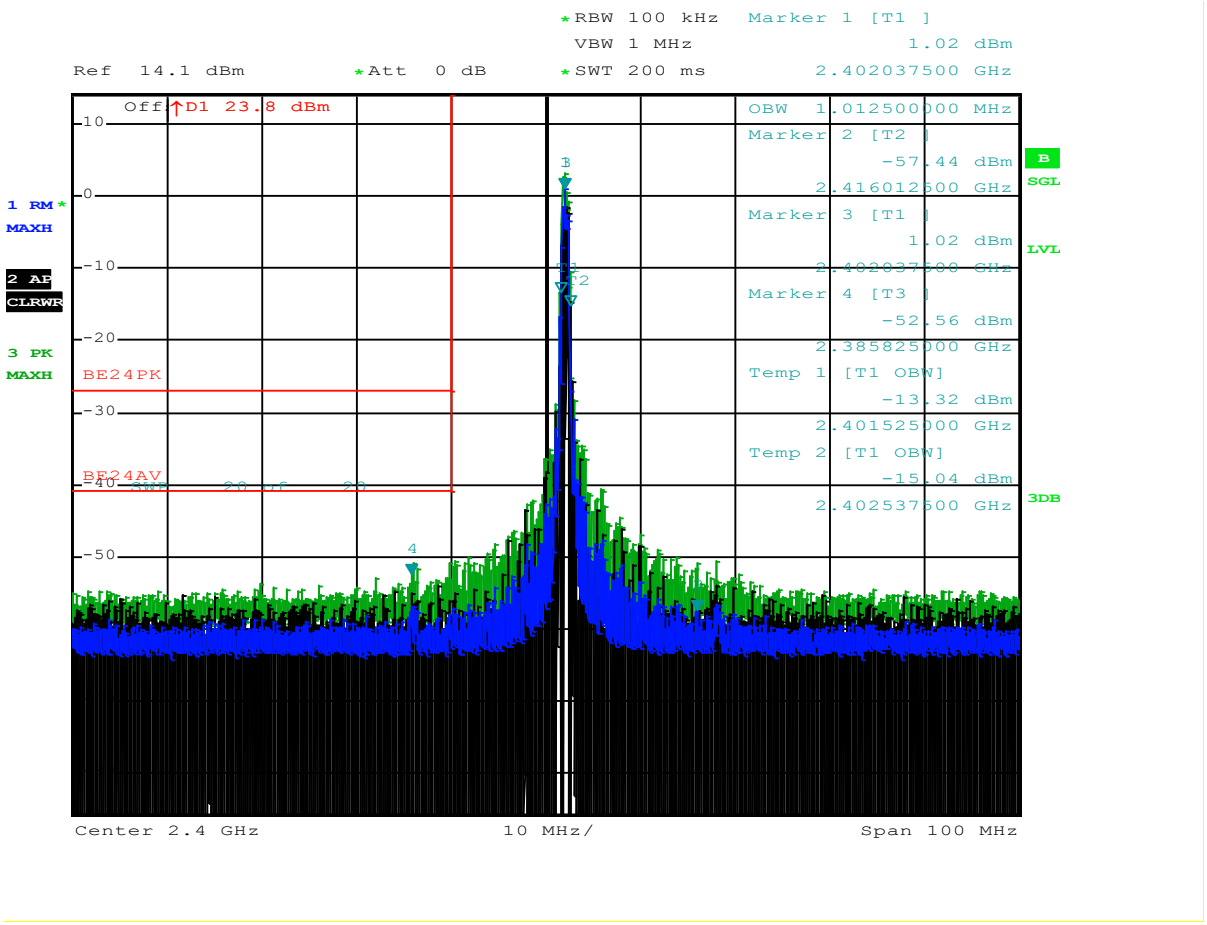


Figure1. Low Channel (2402 MHz)

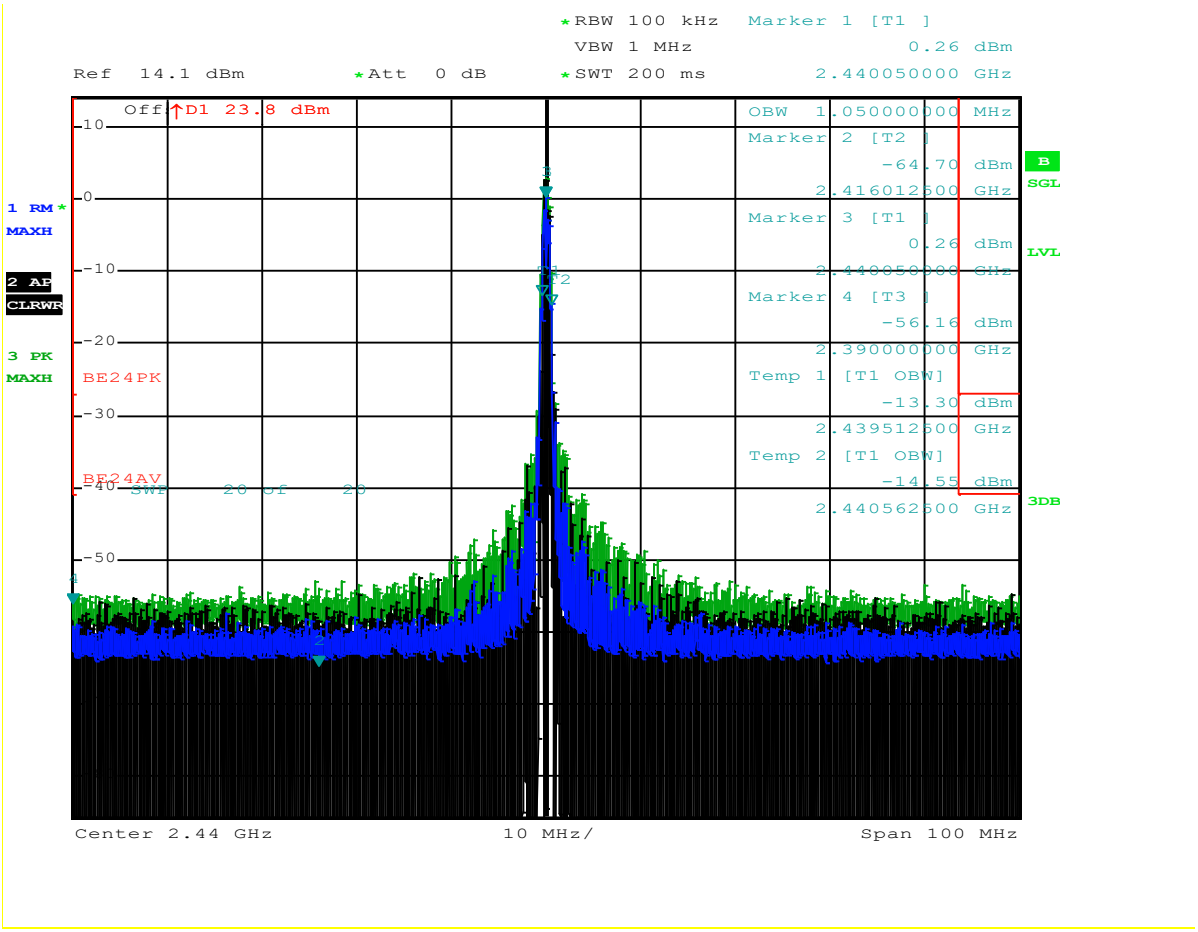


Figure 2. Mid Channel (2440 MHz)

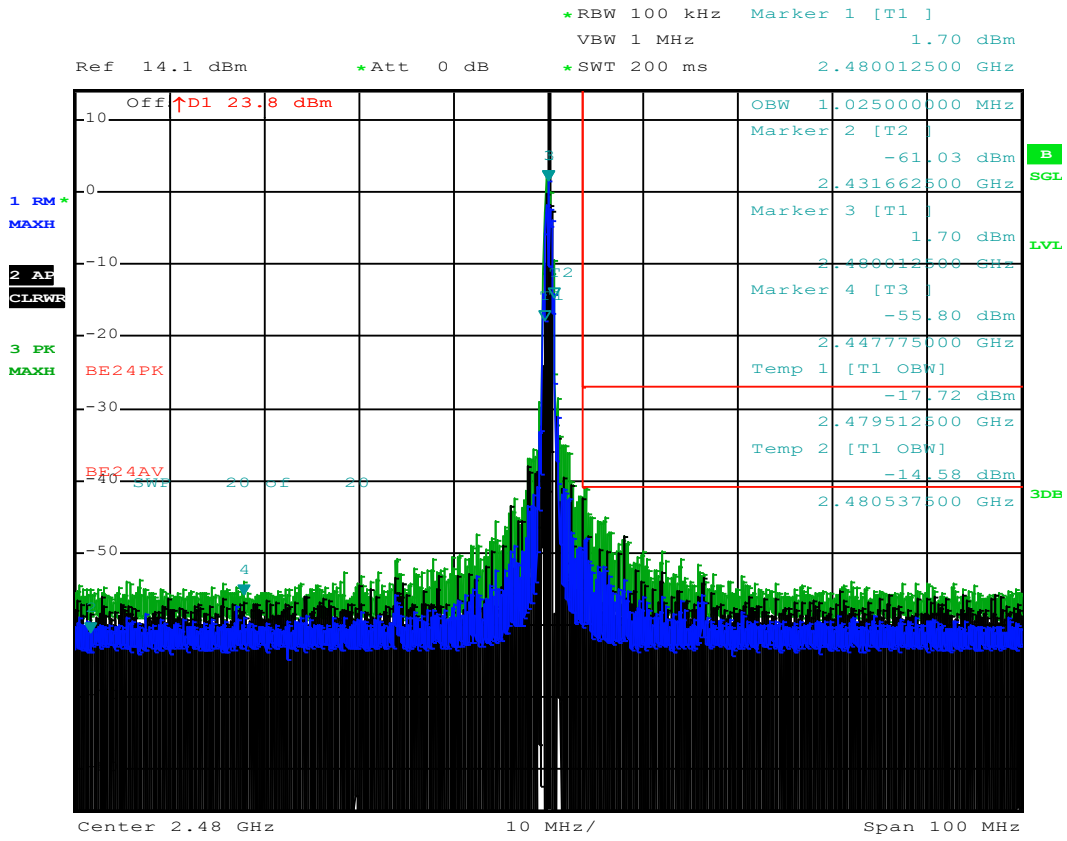


Figure 3. High Chnnel (2480 MHz)

3.5 6-dB Bandwidth

Date Performed: May 3, 2019

Test Standard: FCC Subpart C §15.247 (a) (2), RSS-247 Issue 2 §5.2

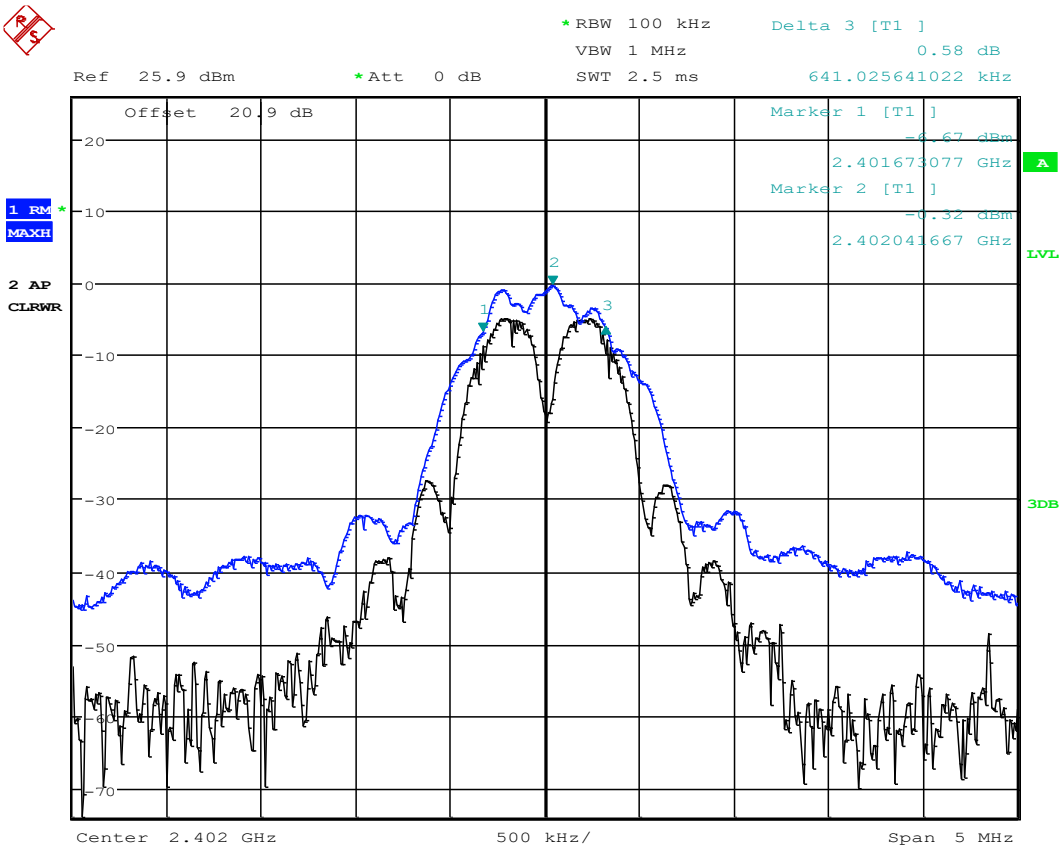
Test Method: ANSI C63.10:2013

Test Requirement: Systems using digital modulation techniques may operate in the 902–928MHz, 2400–2483.5 MHz, and 5725–5850MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

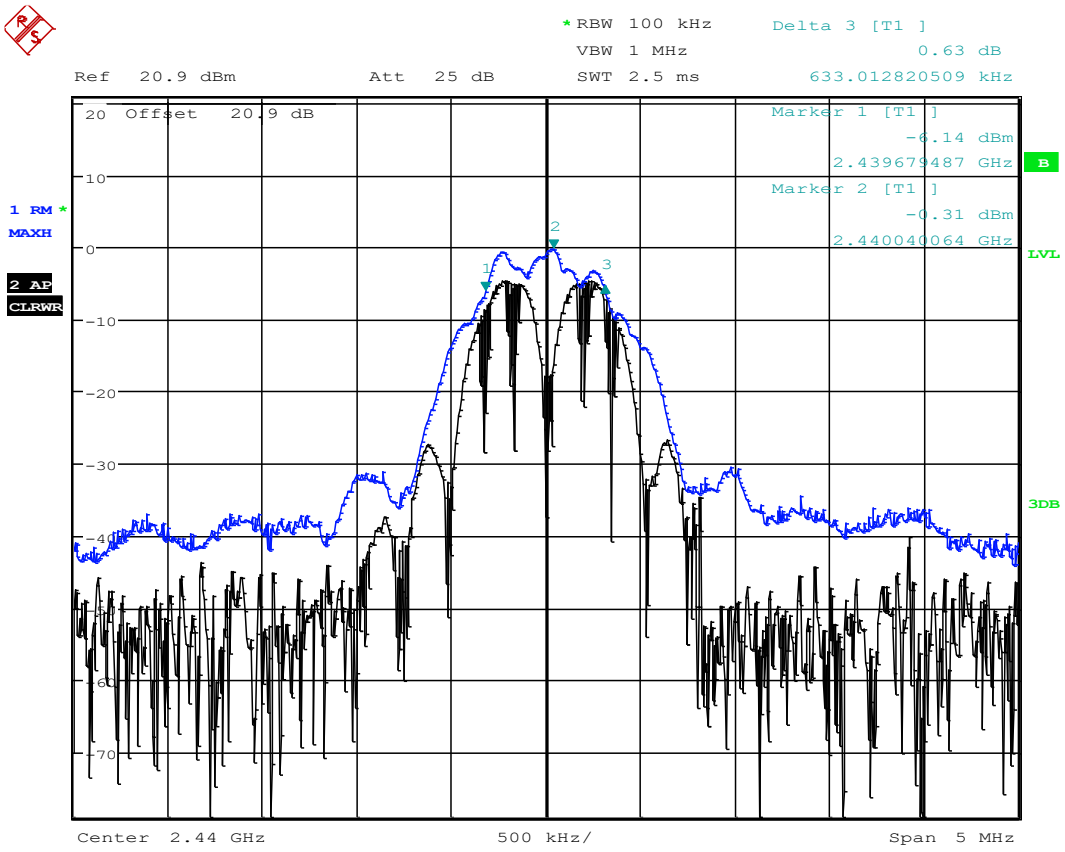
Result: The EUT complies with the standard.

Measurement Data and Plots:

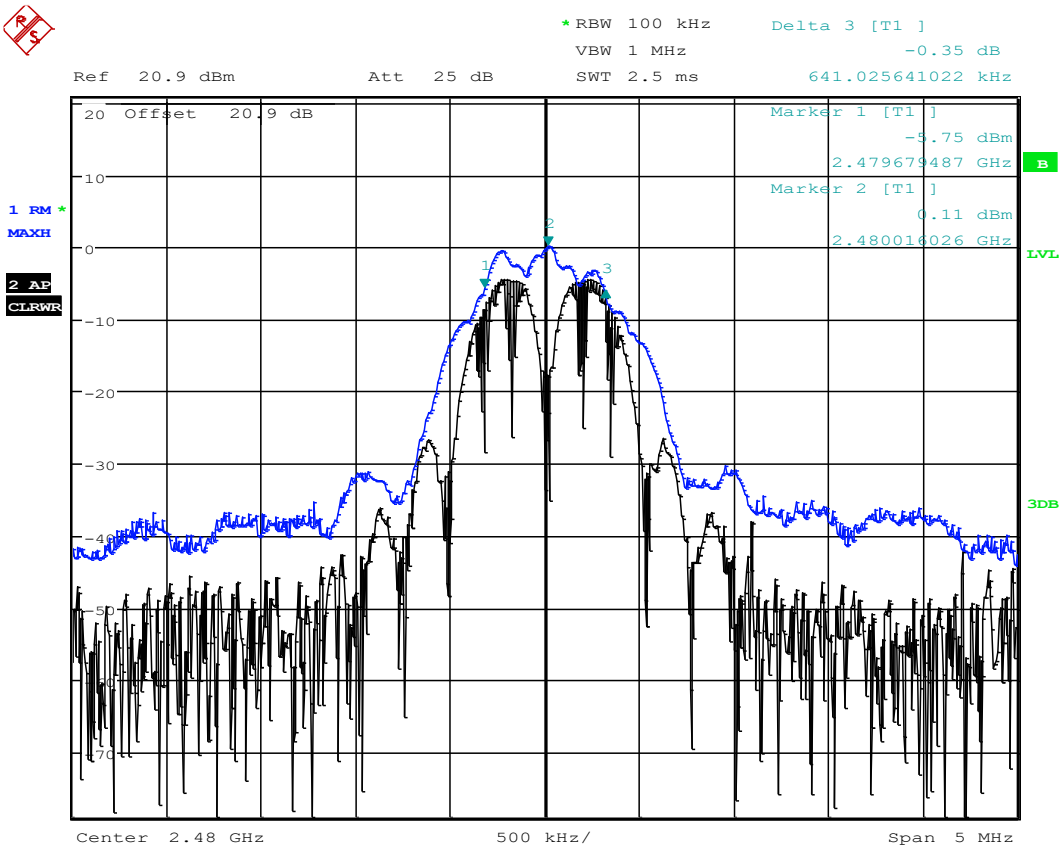
Channel	Frequency	6.dBBandwidth	Result
	MHz	kHz	
Low	2402	641	Complies
Mid	2440	633	Complies
High	2480	641	Complies



Low Channel - 6-dB Bandwidth



Mid Channel - 6-dB Bandwidth



High Channel - 6-dB Bandwidth

3.6 99% Bandwidth

Date Performed: January 30, 2019

Test Standard: FCC Title 47 CFR Part 15: Subpart C - §15.247, RSS-247 Issue 2, RSS-Gen Issue 5

Minimum Requirement: The Occupied Channel Bandwidth is the bandwidth that contains 99 % of the power of the signal. The bandwidth shall fall completely within the frequency range specified by the standard.

Measurement Method: ANSI C63.10-2013.

Result: The EUT complies with the applicable standard.

Measurement Data and Plot:

99% Occupied Bandwidth, Bluetooth Low Energy GFSK

Channel	Frequency MHz	99% Bandwidth kHz	Result
Low	2402	1013	PASS
Mid	2440	1050	PASS
High	2480	1025	PASS

Refer to Figures 1-3.

3.7 2.4 GHz Bandedge and Out-of-Band Emissions

Date Performed: January 30, 2019

Test Standard: FCC Title 47 CFR Part 15: Subpart C - §15.247 (d), RSS-247-Issue 2 §5.5

Test Method: ANSI C63.10:2013

Test Requirement:

3) §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. 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) (see § 15.205(c)).

Adjacent restricted bands of 2310 - 2390 MHz and 2483.5 – 2500 MHz are considered.

Result:

The EUT complies with the applicable standard.

Measurement Data and Plot:

2.4 GHz Bandedge Emissions:

Refer to Figure 1 and 3 for conducted bandedge details. Radiated (restricted) bandedge measurements are performed on data within 6dB of limit. Conducted bandedge measurement shows margins greater than 6dB.

Result: EUT complies.

Out-of-Band Emissions - Conducted:

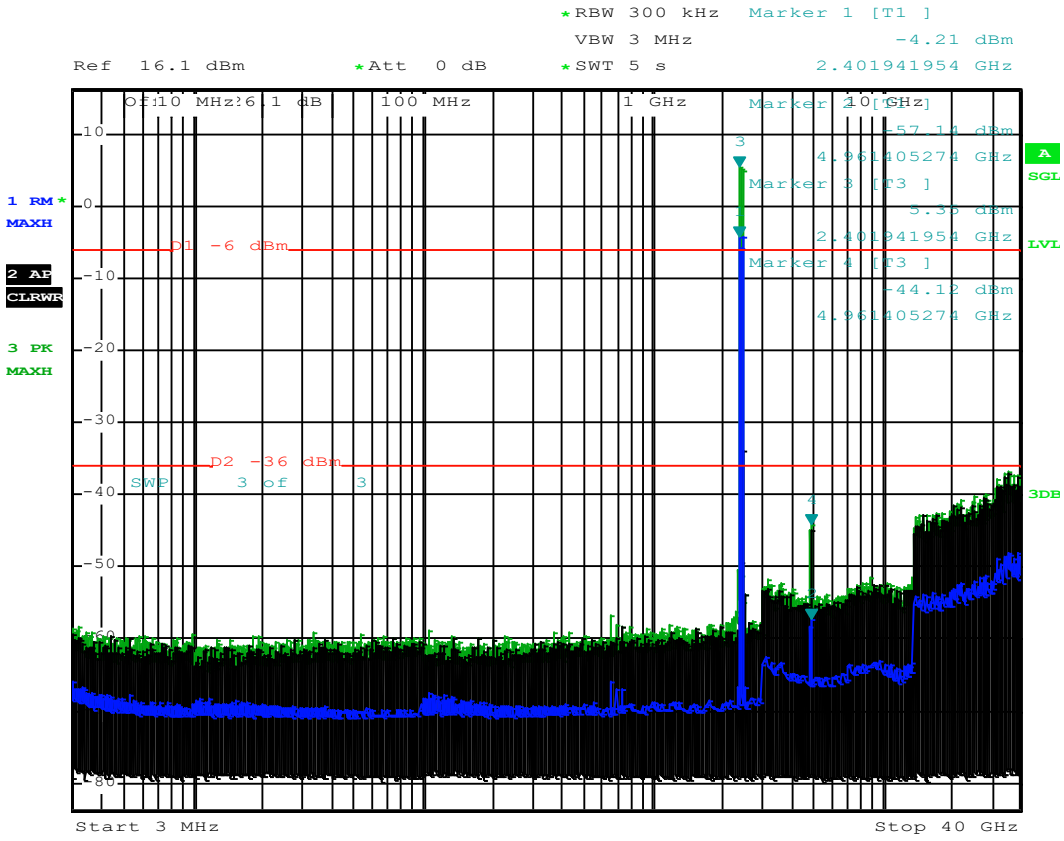


Figure 4: Accumulative plot of low, mid and high channels (3 MHz – 40 GHz)

Result: No out-of-band emissions observed.

3.8 Spurious Emissions

Date Performed:

10 kHz – 30 MHz	February 15, 2019
30 MH – 1 GHz	January17, 2019
1 -18 GHz	January 16, 2019
18 – 26 GHz	January 16, 2019

Test Standard: RSS-247-Issue 2, RSS-Gen Issue 5

FCC Subpart C §15.205, 15.209 & 15.247

Required Limits:

1) Radiated emission limits; general requirements.
The emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency, *f* (MHz)	Field strength (dBµV/m)
0.009 – 0.490	(20*log(2400/*f* (kHz))) + 40 dB
0.490 – 1.705	(20*log(24000/*f* (kHz))) + 20 dB
1.705 – 30.0	49.5
30 – 88	40.0
88 – 216	43.5
216 – 960	46.0
above 960	54.0

Note 1: The above field strength limits are specified at a distance of 3 meters. The tighter limits apply at the band edges.
Note 2: The emissions limits shown in the above table are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

2) Restricted bands of operation.
Unwanted emissions that fall into the restricted bands specified on the table below shall comply with the limits specified on the table limits above as per §15.209 and Clause 8.9 of RSS-Gen.

IC Restricted Bands:

MHz	MHz	GHz
0.090 - 0.110	149.9 - 150.05	9.0 - 9.2
0.495 - 0.505	156.52475 - 156.52525	9.3 - 9.5
2.1735 - 2.1905	156.7 - 156.9	10.6 - 12.7
3.020 - 3.026	162.0125 - 167.17	13.25 - 13.4
4.125 - 4.128	167.72 - 173.2	14.47 - 14.5
4.17725 - 4.17775	240 - 285	15.35 - 16.2
4.20725 - 4.20775	322 - 335.4	17.7 - 21.4
5.677 - 5.683	399.9 - 410	22.01 - 23.12
6.215 - 6.218	608 - 614	23.6 - 24.0
6.26775 - 6.26825	960 - 1427	31.2 - 31.8
6.31175 - 6.31225	1435 - 1626.5	36.43 - 36.5
8.291 - 8.294	1645.5 - 1646.5	Above 38.6
8.362 - 8.366	1660 - 1710	
8.37625 - 8.38675	1718.8 - 1722.2	
8.41425 - 8.41475	2200 - 2300	
12.29 - 12.293	2310 - 2390	
12.51975 - 12.52025	2483.5 - 2500	
12.57675 - 12.57725	2655 - 2900	
13.36 - 13.41	3260 - 3267	
16.42 - 16.423	3332 - 3339	
16.69475 - 16.69525	3345.8 - 3358	
16.80425 - 16.80475	3500 - 4400	
25.5 - 25.67	4500 - 5150	
37.5 - 38.25	5350 - 5460	
73 - 74.6	7250 - 7750	
74.8 - 75.2	8025 - 8500	
108 - 138	--	

* Certain frequency bands listed in table 7 and in bands above 38.6 GHz are designated for licence-exempt applications. These frequency bands and the requirements that apply to related devices are set out in the 200 and 300 series of RSSs.

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	2690-2900	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])
13.36-13.41			

FCC Restricted Bands:

3) §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. 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) (see § 15.205(c)).

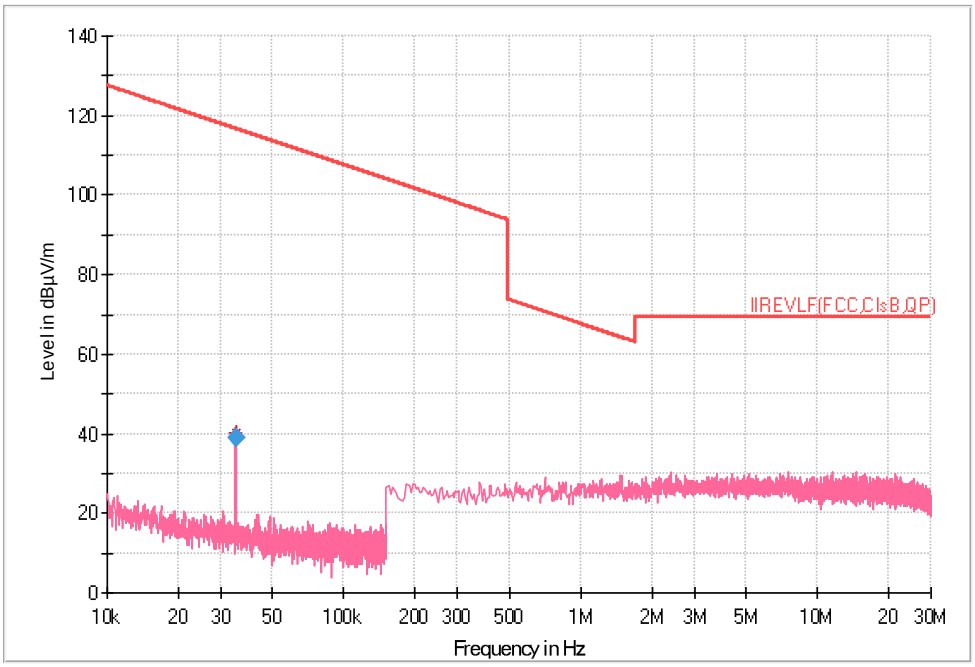
Method of Measurement:

The EUT was tested in our 3 m SAC and was positioned on the center of the turntable. The transmitter was set for continuous transmission. The operating frequency of the device was measured for all radiated emissions 10 kHz to the 10th harmonic of the highest fundamental frequency. The EUT was pre-scanned in 3 different orthogonal orientations and was found to radiate highest when placed flat on the table top as indicated in the test photos.

Result: The EUT complies with the applicable standard.

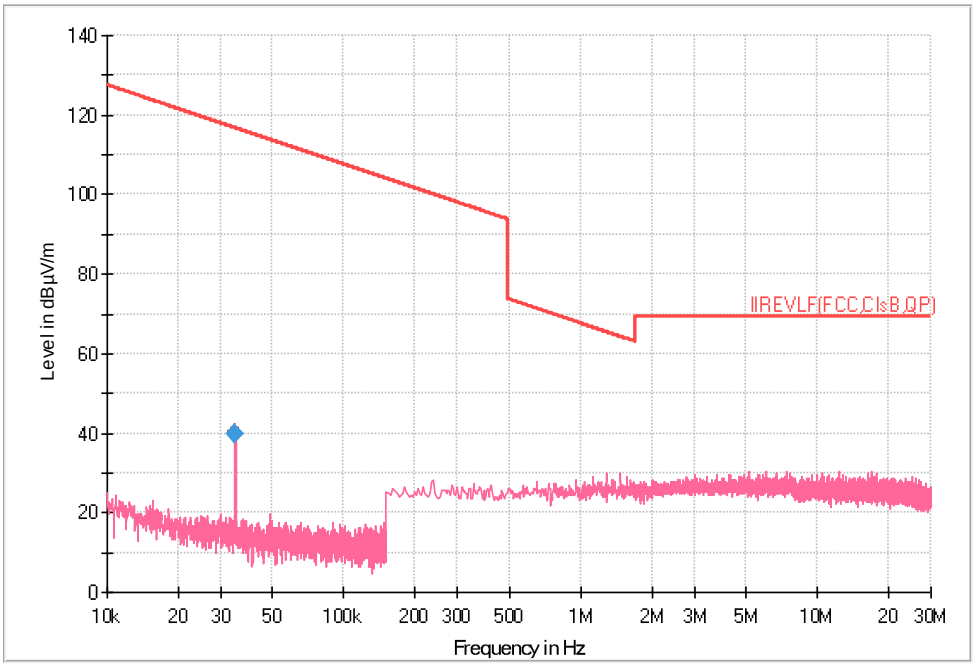
Measurement Data and Plot:

10 kHz – 30 MHz - Test Voltage: Battery.



Radiated Spurious Emissions at 3m, 10k -30M Hz – battery, parallel

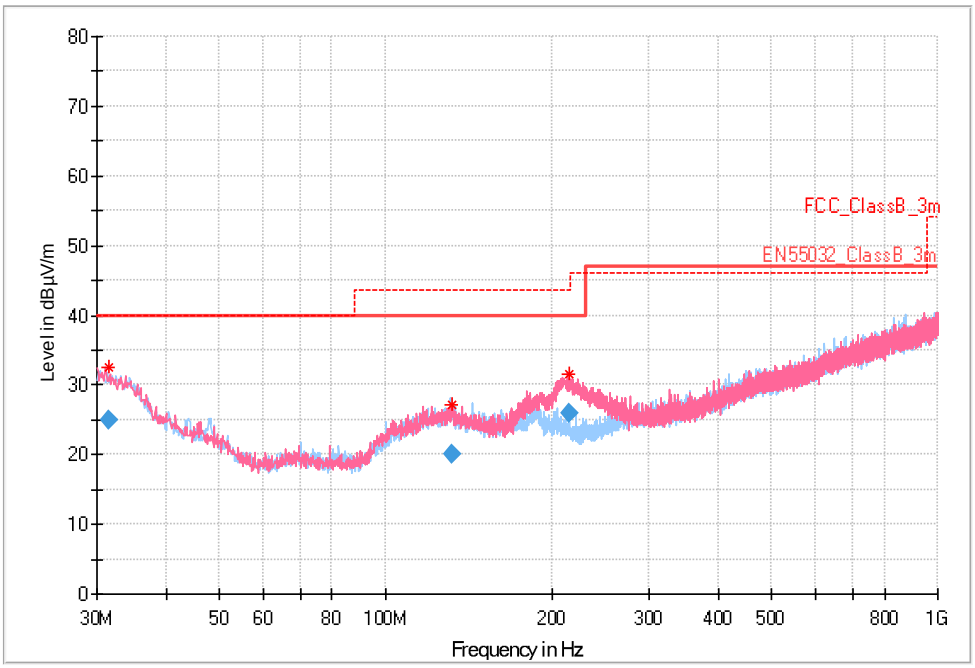
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
0.034850	39.11	116.75	77.64	1000.0	0.200	115.0	V	323.0	23.5



Radiated Spurious Emissions at 3m, 10k -30M Hz – battery, perpendicular

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
0.034745	39.74	116.77	77.04	1000.0	0.200	115.0	V	183.0	23.5

30 MHz – 1 GHz - Test Voltage: 120V/60Hz.

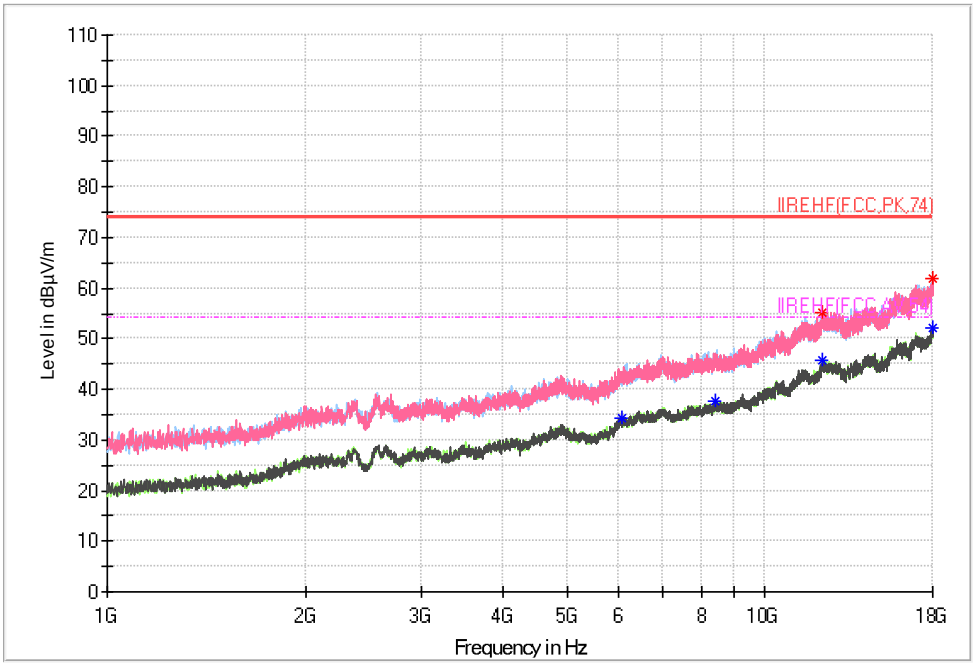


Radiated Spurious Emissions at 3m, 30 MHz – 1 GHz - 120V60Hz

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
31.435182	25.04	40.00	14.96	1000.0	120.000	301.0	V	331.0	26.2
131.755950	19.95	40.00	20.05	1000.0	120.000	206.0	H	273.0	22.0
214.716600	25.95	40.00	14.05	1000.0	120.000	98.0	V	0.0	20.4

1 - 18 GHz - Test Voltage: Battery.

2.4-2.5 GHz notch filter used to supress fundamental.



Radiated Spurious Emissions at 3m, 1G – 18G Hz – battery

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
6050.700000	---	34.48	54.00	19.52	1000	185.0	H	0.0	9.0
8395.000000	---	37.70	54.00	16.30	1000	160.0	H	0.0	12.4
12221.700000	55.10	---	74.00	18.90	1000	160.0	V	359.0	19.8
12260.800000	---	45.76	54.00	8.24	1000	185.0	H	332.0	19.9
17983.000000	61.88	---	74.00	12.12	1000	185.0	H	0.0	27.2

18 – 26 GHz – Test Voltage: battery.

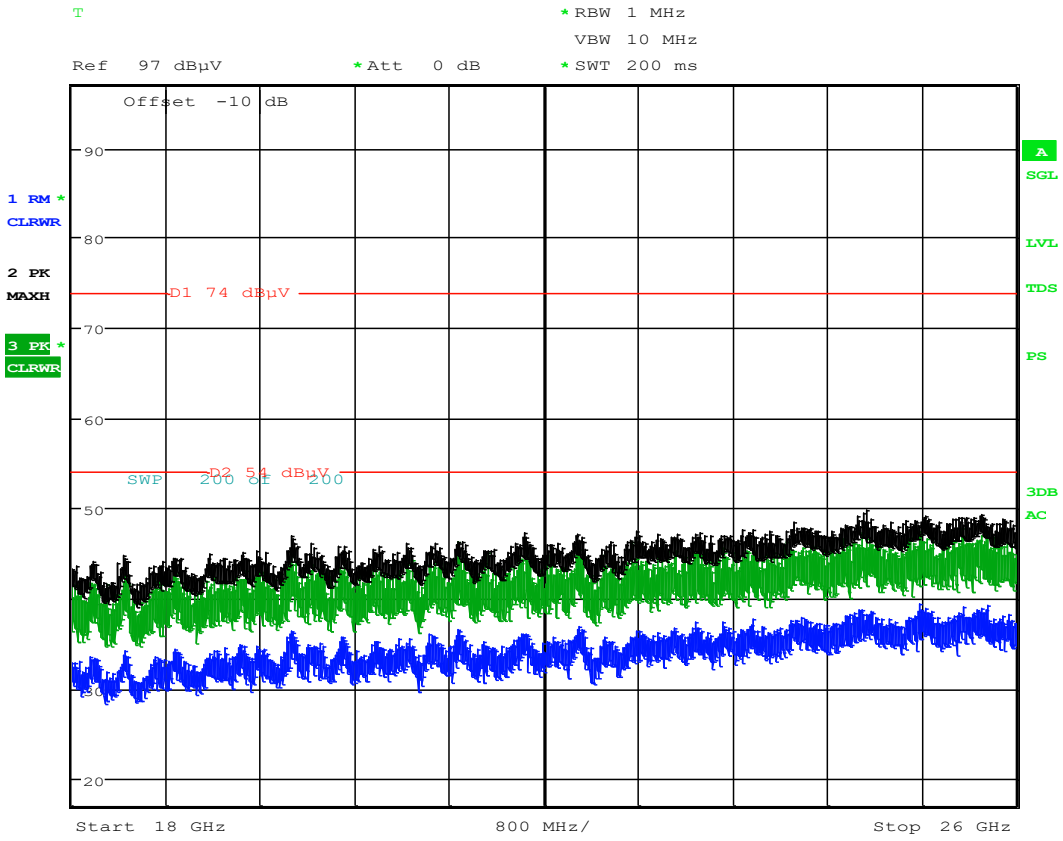


Figure 5: Radiated Spurious Emissions at 3m – 18 – 26 GHz – battery

Note: No emissions observed above the noise floor (18 -26 GHz).

3.9 Harmonic Emissions

Date Performed:

January 30, 2019

Test Standard:

FCC Title 47 CFR Part 15: Subpart C - §15.247, RSS-247 Issue 2

Test Method:

- ANSI C63.10 2013
- CISPR 11:2009/A1:2010

Required Limit:

3) §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. Attenuation below the general limits specified in § 15.209(a) is not required.

Method of Measurement:

Antenna port of EUT connected to spectrum analyzer. The equipment was operated and tested while in "Continuous Transmit" mode of operation.

Modifications:

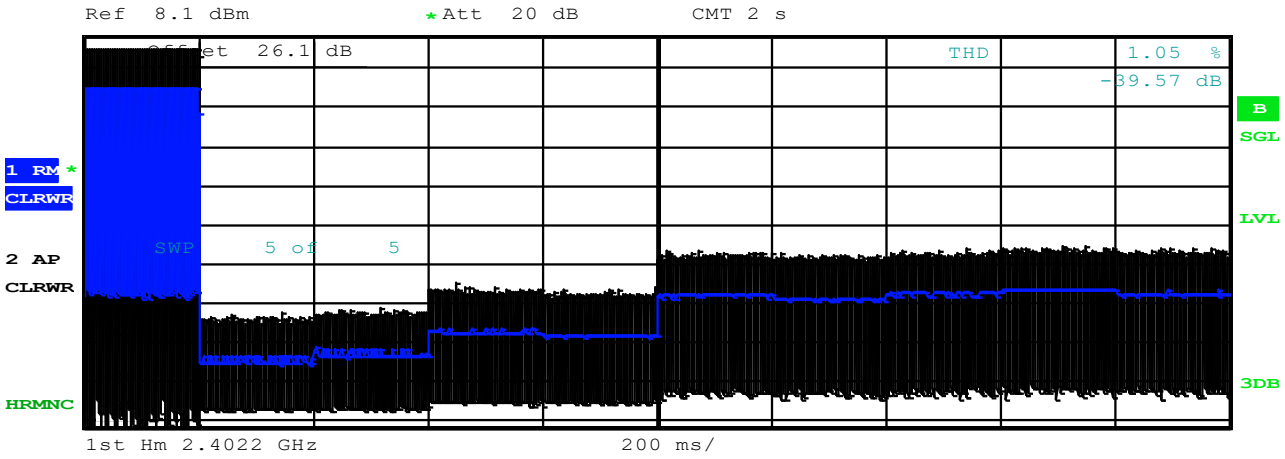
No modification was required to comply for this test.

Result:

The EUT complies with the 30dBc rms criterion.

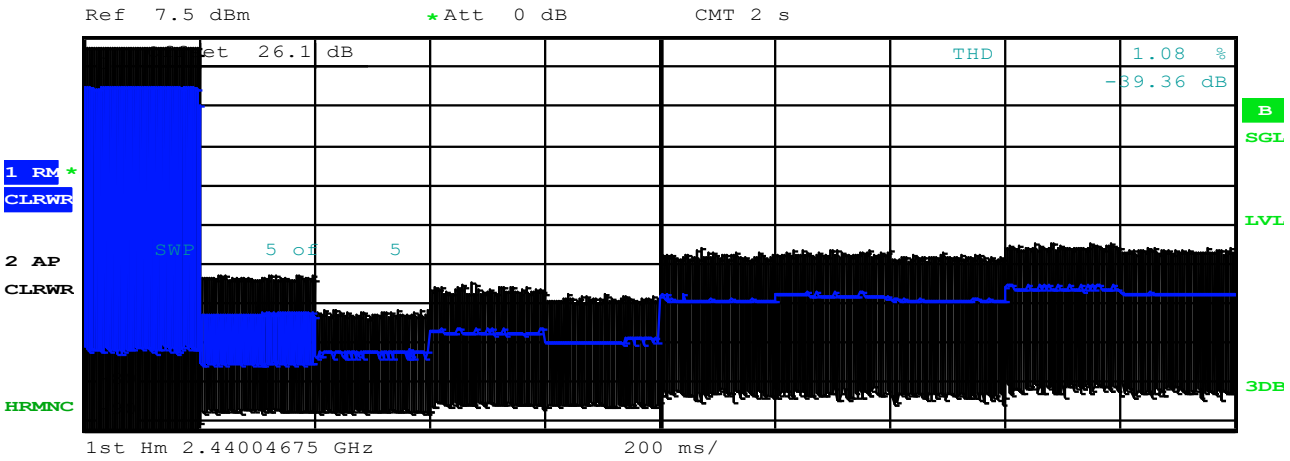
.

Measurements and Plots:



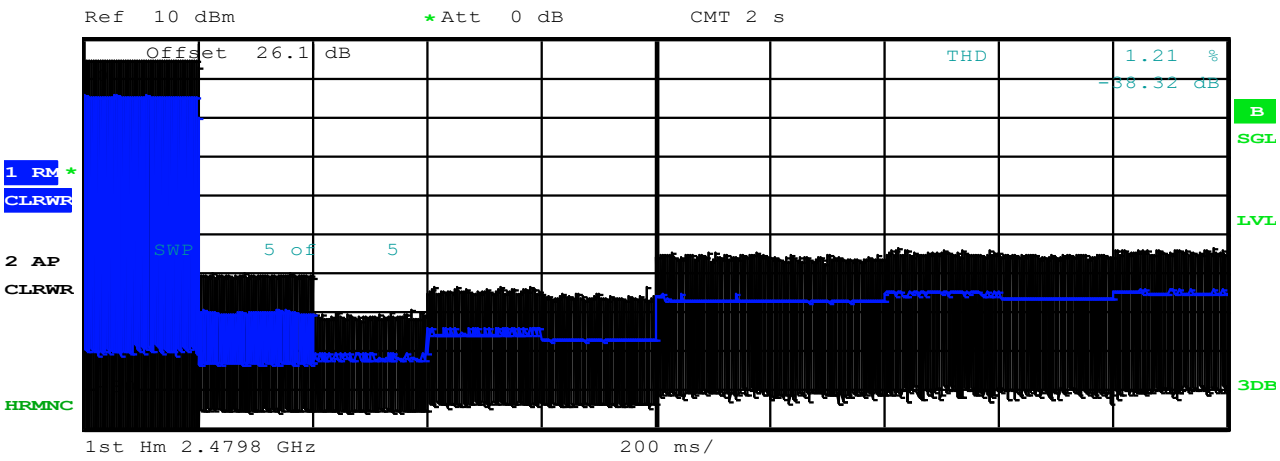
No	Frequency	RBW	Power
1	2.40 GHz	100 kHz	-10.98 dBm
2	4.80 GHz	300 kHz	-63.41 dBc
3	7.21 GHz	300 kHz	-61.75 dBc
4	9.61 GHz	1 MHz	-56.17 dBc
5	12.01 GHz	1 MHz	-57.08 dBc
6	14.41 GHz	1 MHz	-47.25 dBc
7	16.82 GHz	1 MHz	-47.69 dBc
8	19.22 GHz	1 MHz	-46.73 dBc
9	21.62 GHz	1 MHz	-46.00 dBc
10	24.02 GHz	1 MHz	-46.41 dBc

Figure 6: Low Channel Harmonics



No	Frequency	RBW	Power
1	2.44 GHz	100 kHz	-10.97 dBm
2	4.88 GHz	300 kHz	-54.50 dBc
3	7.32 GHz	300 kHz	-62.08 dBc
4	9.76 GHz	1 MHz	-56.30 dBc
5	12.20 GHz	1 MHz	-58.48 dBc
6	14.64 GHz	1 MHz	-47.68 dBc
7	17.08 GHz	1 MHz	-46.95 dBc
8	19.52 GHz	1 MHz	-47.94 dBc
9	21.96 GHz	1 MHz	-45.12 dBc
10	24.40 GHz	1 MHz	-46.23 dBc

Figure 7: Mid Channel Harmonics



No	Frequency	RBW	Power
1	2.48 GHz	100 kHz	-10.04 dBm
2	4.96 GHz	300 kHz	-52.56 dBc
3	7.44 GHz	300 kHz	-61.28 dBc
4	9.92 GHz	1 MHz	-54.74 dBc
5	12.40 GHz	1 MHz	-56.40 dBc
6	14.88 GHz	1 MHz	-46.19 dBc
7	17.36 GHz	1 MHz	-46.61 dBc
8	19.84 GHz	1 MHz	-45.15 dBc
9	22.32 GHz	1 MHz	-45.91 dBc
10	24.80 GHz	1 MHz	-44.79 dBc

Figure 8: High Channel Harmonics

3.10 Unintentional Radiated Emissions – Receiver Mode

Date Performed:

30 MHz – 1 GHz: January 18, 2019
1 – 18 GHz: January 16, 2019

Test Standard:

- FCC Title 47 CFR Part 15: Subpart B - §15.109
- ICES-003 Issue 6

Test Method:

- ANSI C63.4-2014

Required Limit:

The field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values:

Frequency, *f* (MHz)	Field strength (dBµV/m)
30 – 88	40.0
88 – 216	43.5
216 – 960	46.0
above 960	54.0
Note 1: The above field strength limits are specified at a distance of 3 meters. The tighter limits apply at the band edges.	
Note 2: The emissions limits shown in the above table are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz Radiated emission limits in these three bands are based on measurements employing an average detector.	

Method of Measurement:

The EUT was positioned in the center of the turntable in the SAC. The EUT was then measured for all the radiated emissions in the frequency range of 30MHz – 1GHz. Measurements were made using the spectrum analyzer and receiver using the appropriate antennas, amplifiers, attenuators, and filters.

Emissions in both horizontal and vertical polarizations were measured while rotating the Equipment Under Test (EUT) on the turntable to maximize signal strength. In the case of high ambient noises, the measurements are performed at a closer distance and the limit is adjusted per the equation below. The result is added or subtracted to the required emission level to ensure compliance at the new distance.

$$20 \log\left(\frac{D1}{D2}\right);$$ Where D1 = Current Distance
D2 = Required Distance

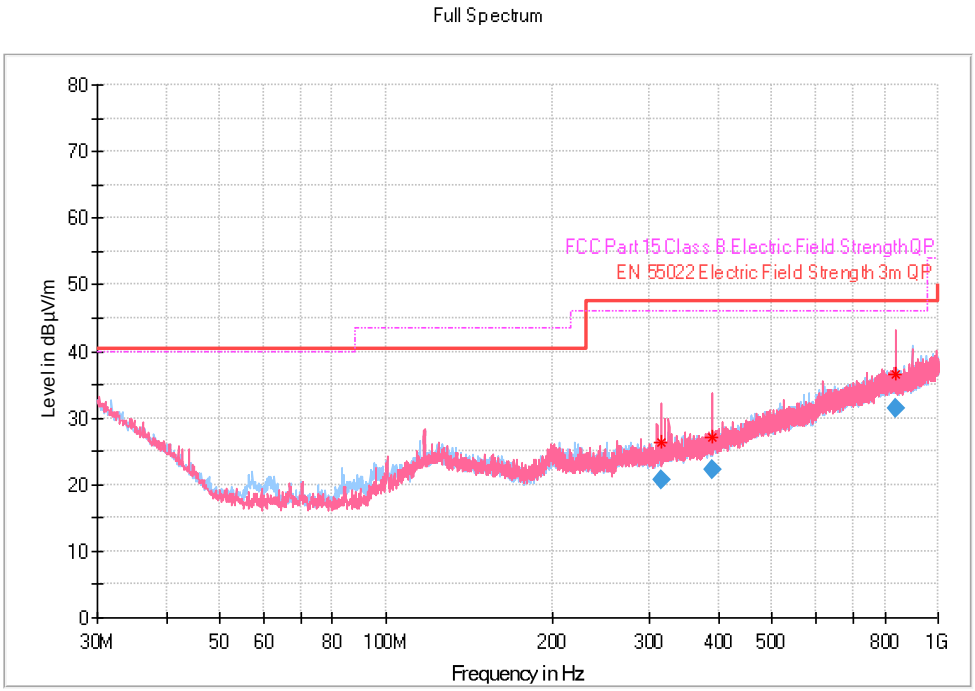
Result:

The EUT complies with the applicable standard.
No emissions observed when transmitter off.

EUT complies with receiver emissions limit in transmit mode 1-18GHz.

Measurement Data and Plot:

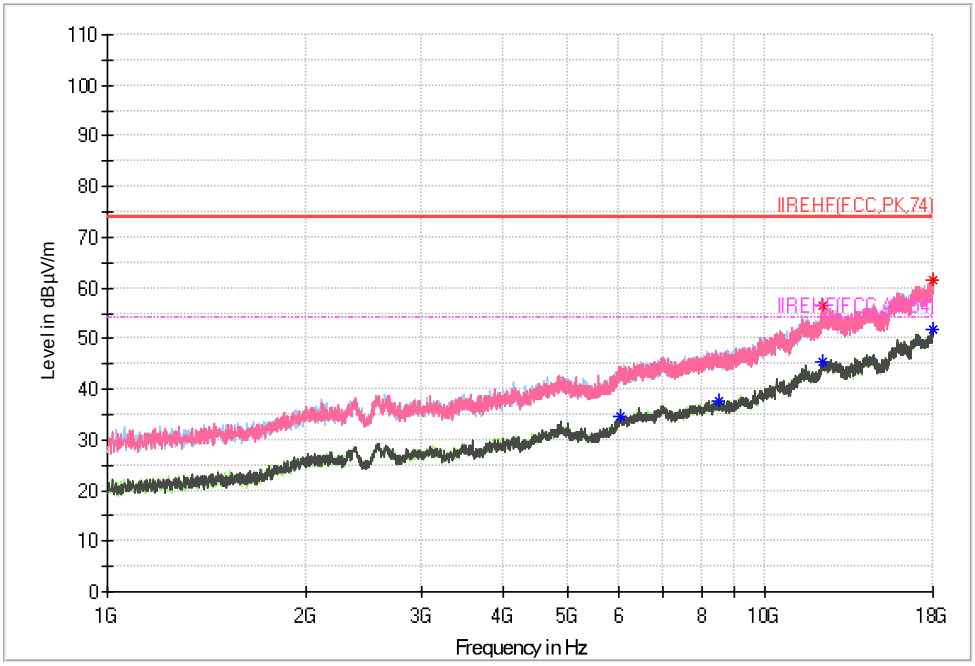
30 MHz – 1 GHz – Test Voltage: Battery.



Unintentional Radiated Emissions at 3m SAC, 30MHz – 1GHz – battery

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
315.121920	20.63	47.50	26.87	1000.0	120.000	238.0	V	157.0	22
390.313240	22.34	47.50	25.16	1000.0	120.000	402.0	V	107.0	24
840.539800	31.55	47.50	15.95	1000.0	120.000	342.0	V	253.0	31

1- 18 GHz – Test Voltage: Battery.



Receiver Unintentional Radiated Emissions at 3m SAC, 1 – 18 GHz – battery

Note: No emissions above the noise floor observed (1-18 GHz).

3.11 AC Mains Conducted Emissions

Date Performed:

January 17, 2019

Test Standard:

- FCC Title 47 CFR Part 15: Subpart B - §15.109
- ICES-003 Issue 6

Test Method:

- ANSI C63.10-2013

Required Limit:

The radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the following limits

Frequency (MHz)	Conducted Limit (dBµV)	
	Quasi-Peak	Average
0.15 – 0.50	66 to 56	56 to 46
0.50 – 5	56	46
5.0 – 30.0	60	50
Note 1: *The lower limit shall apply at the transition frequencies.*		

Method of Measurement:

Measurements were made using a test receiver with 9kHz bandwidth, CISPR Quasi-Peak and Average detector.

EUT Configuration:

EUT was configured per ANSI C63.10, Section 6.2.

Worst-case channel reported

Modifications:

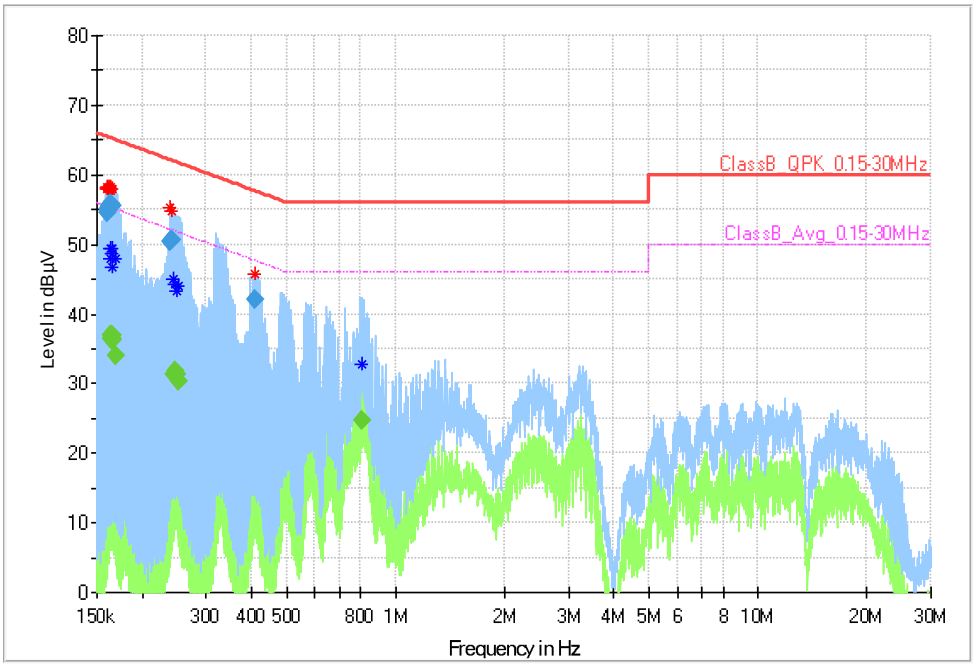
No modification was required to comply for this test.

Result:

The EUT complies with the applicable standard.

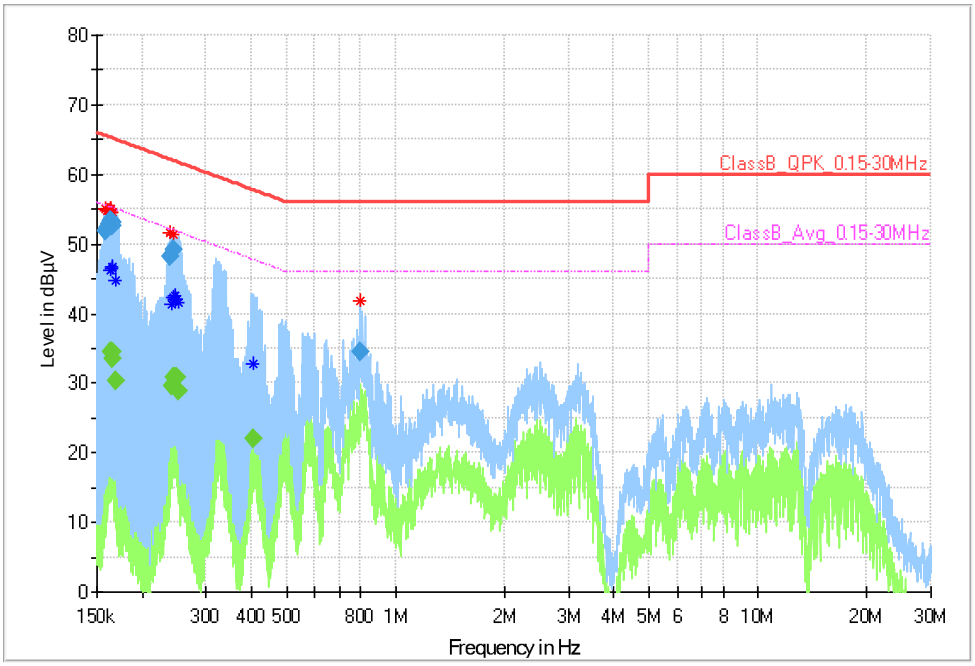
Measurement Data and Plot:

Conducted Emissions – AC main power, Line 1, 120V/60Hz



Frequency (MHz)	Quasi Peak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	PE	Corr. (dB)
0.159749	54.45	---	65.48	11.03	1000.0	9.000	GND	10.8
0.160871	55.06	---	65.42	10.36	1000.0	9.000	GND	10.8
0.161515	55.33	---	65.39	10.06	1000.0	9.000	GND	10.8
0.162487	55.61	---	65.34	9.72	1000.0	9.000	GND	10.8
0.163137	---	36.39	55.30	18.91	1000.0	9.000	GND	10.8
0.163137	55.65	---	65.30	9.66	1000.0	9.000	GND	10.8
0.163627	55.79	---	65.28	9.49	1000.0	9.000	GND	10.8
0.164283	---	37.02	55.25	18.23	1000.0	9.000	GND	10.8
0.164283	55.83	---	65.25	9.41	1000.0	9.000	GND	10.8
0.164776	---	36.52	55.22	18.70	1000.0	9.000	GND	10.8
0.165436	---	36.24	55.19	18.95	1000.0	9.000	GND	10.8
0.165933	55.58	---	65.16	9.58	1000.0	9.000	GND	10.8
0.165933	---	36.99	55.16	18.18	1000.0	9.000	GND	10.8
0.168271	---	33.99	55.05	21.06	1000.0	9.000	GND	10.8
0.239464	50.44	---	62.12	11.67	1000.0	9.000	GND	10.7
0.240423	50.67	---	62.08	11.42	1000.0	9.000	GND	10.7
0.244543	---	31.39	51.94	20.55	1000.0	9.000	GND	10.7
0.246999	---	31.70	51.86	20.15	1000.0	9.000	GND	10.7
0.248734	---	31.24	51.80	20.56	1000.0	9.000	GND	10.7
0.250480	---	30.29	51.74	21.45	1000.0	9.000	GND	10.7
0.410810	42.05	---	57.63	15.59	1000.0	9.000	GND	10.7
0.806573	---	24.66	46.00	21.34	1000.0	9.000	GND	10.6

Conducted Emissions – AC main power, Line 2, 120V/60Hz



Frequency (MHz)	Quasi Peak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	PE	Corr. (dB)
0.158794	51.91	---	65.53	13.61	1000.0	9.000	GND	10.8
0.159909	52.46	---	65.47	13.01	1000.0	9.000	GND	10.8
0.161515	52.83	---	65.39	12.56	1000.0	9.000	GND	10.8
0.162649	53.14	---	65.33	12.19	1000.0	9.000	GND	10.8
0.163301	53.24	---	65.29	12.05	1000.0	9.000	GND	10.8
0.163791	---	34.51	55.27	20.76	1000.0	9.000	GND	10.8
0.163791	53.25	---	65.27	12.02	1000.0	9.000	GND	10.8
0.164941	---	34.61	55.21	20.60	1000.0	9.000	GND	10.8
0.164941	53.07	---	65.21	12.14	1000.0	9.000	GND	10.8
0.166099	---	33.63	55.15	21.52	1000.0	9.000	GND	10.8
0.166099	52.53	---	65.15	12.63	1000.0	9.000	GND	10.8
0.168945	---	30.30	55.01	24.71	1000.0	9.000	GND	10.8
0.239703	48.09	---	62.11	14.02	1000.0	9.000	GND	10.7
0.241386	---	29.59	52.05	22.46	1000.0	9.000	GND	10.7
0.243811	---	30.89	51.97	21.08	1000.0	9.000	GND	10.7
0.243811	49.14	---	61.97	12.83	1000.0	9.000	GND	10.7
0.245523	---	30.76	51.91	21.15	1000.0	9.000	GND	10.7
0.246260	---	30.77	51.88	21.11	1000.0	9.000	GND	10.7
0.247989	---	30.71	51.82	21.11	1000.0	9.000	GND	10.7
0.250480	---	28.81	51.74	22.94	1000.0	9.000	GND	10.7
0.402680	---	22.12	47.80	25.68	1000.0	9.000	GND	10.7
0.795365	34.49	---	56.00	21.51	1000.0	9.000	GND	10.6

3.12 Frequency Stability

Date Performed:

February 28, 2019

Test Standard:

FCC Title 47 CFR Part 15: Subpart C §15.247, 2.1055, RSS-Gen Issue 5

Test Method:

- ANSI C63.10 2013
- CISPR 11:2009/A1:2010

Required Limit:

The carrier frequency stability shall be maintained within band. The carrier frequency shall be maintained over a temperature variation of −20C to +55C at normal supply voltage, and for a variation in the primary supply voltage from 89% to 110% of the rated supply voltage at nominal temperature.

Method of Measurement:

The equipment was operated and tested while in "Continuous Transmit" mode of operation. The fundamental was monitored while the temperature was varied from -20C to +55C in an environmental chamber and appropriate data reported. The input power ($V_{nominal}$ = 100V) to the AE (PC) was varied from 89% to 110% in 5% steps at +25C and appropriate data within the required voltage range reported.

Modifications:

No modification was required to comply for this test.

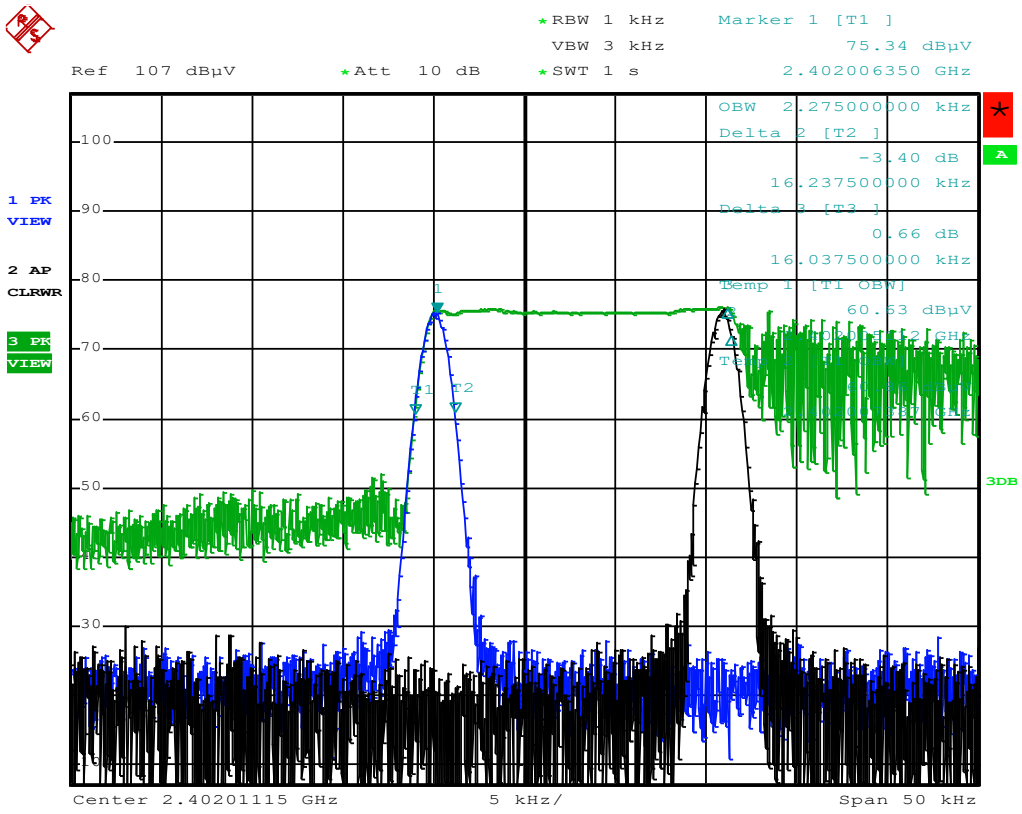
Result:

Manufacturer specified operating temperature range of the EUT: 5 - 45C.
EUT complies with the applicable standard.

Extreme power conditions - Result

The EUT was observed using OBW plot at extremes and no effects observed. EUT Complies with the applicable standard.

Extreme temperature conditions – Measurement Plot



Plot 1: Frequency stability 5 to 45C, Radiated.

Drift = Delta2/2402 MHz = 1624 Hz/2402 MHz = 0.667 ppm

Result: Drift is within band.

3.13 RF Exposure Evaluation

Date Performed: April 16, 2019

Test Standard: FCC 47 CFR §1.1310: RSS-102 Section 2.5.2:

CC CFR 47 §1.1310:

Radiofrequency radiation exposure limits for General Population/Uncontrolled Exposure at Frequency range 1500 - 100000 MHz: 1.0 mW/cm^2.

RSS-102 Section 2.5.2:

RF exposure evaluation is required if the separation distance between the user and/or bystander and the device's radiating element is greater than 20 cm, except when the device operates as follows:

-at or above 300 MHz and below 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 1.31 x 10-2 f^0.6834 W (adjusted for tune-up tolerance), where f is in MHz

In these cases, the information contained in the RF exposure technical brief may be limited to information that demonstrates how the e.i.r.p. was derived.

MPE Results:

The calculation below is used to consider situations in which simultaneous exposure to fields of different frequencies occur. The calculation is performed by the sum of each relative exposure for each equipment according to the following criteria

$$\text{Power Density} = \frac{EIRP}{4\pi r2}\ \text{mW/cm}^2$$

Carrier Frequency	RF Peak Output Power Conducted	Peak Antenna Gain	EIRP	EIRP	Spherical Surface Area at 20 cm	Power Density	Limit	Result
MHz	dBm	dBi	dBm	mW	cm^2	mW/cm^2	mW/cm^2	
2402	5.16	2.3	7.46	5.57	5027	0.0011	1.0	RF Exposure Test not required
2440	5.01	2.3	7.31	5.38	5027	0.0011	1.0	RF Exposure Test not required
2480	4.94	2.3	7.24	5.30	5027	0.0011	1.0	RF Exposure Test not required

EIRP (dBm) = RF Peak Output Power (dBm) + Antenna Gain (dBi)

Notes:

- RF Peak Output Power: power-meter reading + Duty Cycle Correction Factor.
- Calculation includes tune-up tolerance.
- Single antenna: beamforming considerations do not apply.

Appendix A: TEST SETUP PHOTOS – available upon request

Appendix B: ABBREVIATIONS

Abbreviation	Definition
AC	Alternating Current
AM	Amplitude Modulation
CISPR	Comité International Spécial des Perturbations Radioélectriques
DC	Direct Current
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
EUT	Equipment Under Test
FCC	Federal Communications Commission
IC	Industry Canada
ICES	Interference Causing Equipment Standard
IEC	International Electrotechnical Commission
LISN	Line Impedance Stabilizing Network
OATS	Open Area Test Site
RF	Radio Frequency
RMS	Root-Mean-Square
SAC	Semi-Anechoic Chamber

END OF REPORT