LSR
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TESTING CERT #1255.01
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TEST REPORT # 316054B
LSR Job #: C-2401

Compliance Testing of:
RM191-SM

Test Date(s):
2/17/16 – 3/18/16

Prepared For:
N. Zach Hogya
Laird
11160 Thompson Ave
Lenexa, KS 66219

This Test Report is issued under the Authority of:
Shane Dock, EMC Engineer

Signature: Date: 4-8-16

Test Report Reviewed by:	**Project Engineer:**
Michael Hintzke, EMC Engineer	Shane Dock, EMC Engineer
Signature: Date: 4-8-16	Signature: Date: 4-8-16

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EXHIBIT 1. INTRODUCTION

1.1 - Scope

References:	FCC Part 15, Section 15.247 RSS GEN issue 4 and RSS 247
Title:	FCC : Telecommunication – Code of Federal Regulations, CFR 47, Part 15. IC : Low-power License-exempt Radio-communication Devices (All Frequency Bands): Category I Equipment
Purpose of Test:	To gain FCC and IC Certification Authorization for Low-Power License-Exempt Transmitters.
Test Procedures:	FCC KDB 558074 D01 DTS Measurement Guidance v03r04
Environmental Classification:	Residential

1.2 – Normative References

Publication	Year	Title
FCC CFR Parts 0-15	2016	Code of Federal Regulations – Telecommunications
ANSI C63.4	2014	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
RSS-247 Issue 1	2015	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices
RSS-GEN Issue 4	2014	General Requirements and Information for the Certification of Radio Apparatus
ANSI C63.10	2013	American National Standard for Testing Unlicensed Wireless Devices
FCC KDB 558074 D01 DTS Measurement Guidance v03r04	2016	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247

1.3 - LS Research, LLC Test Facility

LS Research, LLC is accredited by A2LA (American Association for Laboratory Accreditation) as conforming to ISO/IEC 17025, 2005 “General Requirements for the Competence of Calibration and Testing Laboratories”.

LS Research, LLC’s scope of accreditation includes all test methods listed herein, unless otherwise noted. Accreditation status can be verified at A2LA’s web site: www.a2la2.net.

1.4 – Location of Testing

All testing was performed at the following location utilizing the facilities listed below, unless otherwise noted.

LS Research, LLC
W66 N220 Commerce Court
Cedarburg, Wisconsin, 53012 USA,

List of Facilities Located at LS Research, LLC:

Semi-Anechoic Chamber

1.5 – Test Equipment Utilized

A complete list of equipment utilized in testing is provided in Appendix A of this test report. Calibration dates are indicated in Appendix A. All test equipment is calibrated by a calibration laboratory accredited to the requirements of ISO/IEC 17025, and traceable to the SI standard.

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1 – Client Information

Manufacturer Name:	Laird Technologies, Inc.
Address:	11160 Thompson Ave Lenexa, KS 66219
Contact Name:	N. Zach Hogya

2.2 - Equipment Under Test (EUT) Information

The following information has been supplied by the applicant.

Product Name:	RM191-SM
Model Number:	RM191-SM
Serial Number:	LEN DVT 20 (Conducted Testing) LEN DVT 1 (Radiated Testing) LEN DVT 13 (Colocation Testing)

2.3 - Associated Antenna Description

The antenna included on the product is a built-in AT5020 monolithic chip antenna with a gain of 0 dBi.

2.4 - EUT'S Technical Specifications

EUT Frequency Range (in MHz)	2402 - 2480 MHz
RF Power in Watts (Conducted measurement)	
Minimum:	1.93 milliwatts at 2402 MHz
Maximum:	1.98 milliwatts at 2440 MHz
Conducted Output Power, peak(in dBm)	Maximum = 2.85 dBm at 2402 MHz Minimum = 2.96 dBm at 2440 MHz
Field Strength at 3 meters (Maximum)	Not Applicable
99% Bandwidth	1.07 MHz
Type of Modulation	Gaussian Frequency Shift Keying (GFSK)
Occupied Bandwidth (6dB BW)	686.2 kHz
Transmitter Spurious (worst case) at 3 meters	55.9 dBµV/m at 4804 MHz
Frequency Tolerance %, Hz, ppm	Better than 100 ppm
Microprocessor Model # (if applicable)	N/A
Antenna Information	
Detachable/non-detachable	Non-detachable
Type	Chip
Gain	0 dBi
EUT will be operated under FCC Rule Part(s)	Title 47 part 15.247
EUT will be operated under RSS Rule Part(s)	RSS 247
Modular Filing	☒ Yes ☐ No
Portable or Mobile?	Portable
Emission Designator	686KF1D

2.5 - Product Description

The RM191-SM module is designed to enable OEMs to add a long range LoRa radio link as well as central role Bluetooth Low Energy (BLE) to small, portable, power-conscious devices. The RM191-SM module is enabled with Laird's smart BASIC, an event-driven programming language that enables OEMs to make their product development quicker and simpler, significantly reducing time to market. smartBASIC enables customers to develop a complete embedded application inside the compact RM191 hardware, connecting to a wide array of external sensors via its I2C, SPI, UART, ADC or GPIO interfaces. The module is based on the world-leading Nordic Semiconductor nRF51822 (BLE) and Semtech Sx1272 (LoRa) chipsets, the RM191-SM module provides ultra-low power consumption with outstanding wireless range using the LoRa radio link and local BLE connections. The unit can accept a voltage between 1.8 – 3.6V.

The unit has the capability to operate on 3 channels, controllable via a proprietary software provided by the manufacturer (UWTerminalX v1.01) and was run continuously with a modulated transmission. For this EUT:
Low Channel: 2402 MHz
Mid Channel: 2440 MHz
High Channel: 2480 MHz

EXHIBIT 3. EUT OPERATING CONDITIONS & CONFIGURATIONS DURING TESTS

3.1 - Climate Test Conditions

Temperature:	70 -74° F
Humidity:	30-42%
Pressure:	728-741mmHg

3.2 - Applicability & Summary Of EMC Emission Test Results

FCC and IC Paragraph	Test Requirements	Compliance (Yes/No)
FCC : 15.207 IC : RSS GEN sect. 7.2.2	Power Line Conducted Emissions Measurements	Yes
FCC : 15.247 (a)(1) IC : RSS 247	20 dB Bandwidth	Yes
FCC : 15.247(b) & 1.1310 IC : RSS 247	Maximum Output Power	Yes
FCC : 15.247(i), 1.1307, 1.1310, 2.1091 & 2.1093 IC : RSS 247	RF Exposure Limit	Yes
FCC :15.247(d) IC : RSS 247	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
FCC:15.247 (a)(2) IC: RSS 247	6 dB Bandwidth of a Digital Modulation System	Yes
FCC:15.247 (d) IC: RSS 247	Power Spectral Density of a Digital Modulation System	Yes
FCC : 15.247(c), 15.209 & 15.205 IC : RSS 247	Transmitter Radiated Emissions	Yes

3.3 - Modifications Incorporated In The EUT For Compliance Purposes

☒ None ☐ Yes (explain below)

3.4 - Deviations & Exclusions From Test Specifications

☒ None ☐ Yes (explain below)

EXHIBIT 4. DECLARATION OF CONFORMITY

The EUT was found to MEET the requirements as described within the specification of FCC Title 47, CFR Part 15.247, and Industry Canada RSS-247, Issue 1 (2015).

Note: If some emissions are seen to be within 3 dB of their respective limits; as these levels are within the tolerances of the test equipment and site employed, there is a possibility that this unit, or a similar unit selected out of production may not meet the required limit specification if tested by another agency.

LS Research, LLC certifies that the data contained herein was taken under conditions that meet or exceed the requirements of the test specifications. The results in this Test Report apply only to the item(s) tested on the above-specified dates. Any modifications made to the EUT subsequent to the indicated test date(s) will invalidate the data herein, and void this certification.

EXHIBIT 5. UNWANTED EMISSIONS INTO THE RESTRICTED FREQUENCY BANDS.

5.1 - Test Setup

The test setup was assembled in accordance with Title 47, CFR FCC Part 15, RSS GEN and ANSI C63.10-2013. The EUT was placed on an 150 cm high non-conductive pedestal, centered on a flush mounted 2-meter diameter turntable inside a 5 meter Semi-Anechoic, FCC listed Chamber. The EUT was operated in continuous transmit mode for final testing using power as provided by an AC to DC power supply that comes with the EUT. The unit has the capability to operate on 3 channels, controllable via proprietary software provided by the manufacturer.

The applicable limits apply at a 3 meter distance. The calculations to determine these limits are detailed in the following pages. Please refer to Appendix A for a complete list of test equipment. The test sample was operated on one of three (3) standard channels to comply with FCC Part 15.31(m).

5.2 - Test Procedure

Radiated RF measurements were performed on the EUT in a 3 meter Semi-Anechoic, FCC listed Chamber. The frequency range from 30 MHz to 25000 MHz was scanned and investigated. The radiated RF emission levels were manually noted at the various fixed degree settings of azimuth on the turntable and antenna height. The EUT was placed on a non-conductive pedestal in the 3 meter Semi-Anechoic Chamber, with the antenna mast placed such that the antenna was 3 meters from the EUT. A Biconical Antenna was used to measure emissions from 30 MHz to 200 MHz, and a Log Periodic Antenna was used to measure emissions from 200 MHz to 1000 MHz. A Double-Ridged Waveguide Horn Antenna was used from 1 GHz to 18 GHz while a standard gain horn antenna was used in the 18 GHz to 25 GHz range. The maximum radiated RF emissions between 30MHz to 25 GHz were found by raising and lowering the sense antenna between 1 and 4 meters in height, using both horizontal and vertical antenna polarities. A tilt gear was utilized to keep the EUT within the cone of radiation.

The EUT was positioned in 3 orthogonal orientations.

5.3 - Test Equipment Utilized

A list of the test equipment and antennas utilized for the Radiated Emissions test can be found in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. All calibrations of the antennas used were performed at a calibration laboratory accredited to ISO 17025, and are traceable to the SI standard. In addition, the Connecting Cables were measured for losses using a calibrated Signal Generator and an EMI Receiver. The resulting correction factors and the cable loss factors from these calibrations were entered into the EMI Receiver database. As a result, the data taken from the EMI Receiver accounts for the antenna correction factor as well as cable loss or other corrections, and can therefore be entered into the database as a corrected meter reading. The EMI Receiver was operated with a resolution bandwidth of 120 kHz for measurements below 1 GHz (video bandwidth of 300 kHz), and a resolution bandwidth of 1 MHz for measurements above 1 GHz (video bandwidth of at least 3 MHz).

5.4 - Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247 and Canada RSS-247, Issue 1 for a DTS transmitter. The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

5.5 - Calculation of Radiated Emissions Limits and reported data.

Reported data:

For both fundamental and spurious emissions measurement, the data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement (dBµV/m) + Antenna correction Factor + Cable factor (dB) + Miscellaneous factors when applicable (dB) – amplification factor when applicable (dB).

Generic example of reported data at 200 MHz:

Reported Measurement data = 18.2 (raw receiver measurement) + 15.8 (antenna factor) + 1.45 (cable factor) = 35.45 (dBµV/m).

As specified in 15.247 (d) and RSS 210 A8.5, radiated emissions that fall within the restricted band described in 15.205(c) for FCC and section 2.2 of RSS 210 for IC, must comply with the general emissions limit.

The following table depicts the general radiated emission limits above 30 MHz. These limits are obtained from Title 47 CFR, Part 15.209, for radiated emissions measurements. These limits were applied to any signals found in the 15.205 restricted bands. The mentioned limits correspond to those limits listed in RSS GEN.

Frequency (MHz)	3 m Limit µV/m	3 m Limit (dBµV/m)	1 m Limit (dBµV/m)
30-88	100	40.0	-
88-216	150	43.5	-
216-960	200	46.0	-
960-40,000	500	54.0	63.5

Sample conversion of field strength (µV/m to dBµV/m):
dBµV/m = 20 $\log_{10}$ (100)= 40 dBµV/m (from 30-88 MHz)

5.6 - Data:

Manufacturer:	Laird Technologies						
Date(s) of Test:	2/17/16 – 3/17/16						
Project Engineer(s):	Shane Dock						
Test Engineer(s):	Shane Dock, Kim Bay						
Voltage:	3.6/1.8 VDC						
Operation Mode:	Continuous transmit, modulated						
Environmental Conditions in the Lab:	Temperature: 70-74° F Relative Humidity: 30-42%						
EUT Power:		Single Phase 24VAC		3 Phase ___VAC			
		Battery	X	Other: 3.6/1.8 VDC			
EUT Placement:	X	150 cm non-conductive pedestal		10cm Spacers			
EUT Test Location:	X	3 Meter Semi-Anechoic FCC Listed Chamber		3/10m OATS			
Measurements:		Pre-Compliance		Preliminary	X	Final	
Detectors Used:	X	Peak	X	Quasi-Peak	X	Average	

Measurements below 1 GHz:

Frequency (MHz)	Height (cm)	Azimuth (degree)	Quasi Peak Reading (dBµV/m)	Quasi Peak Limit B (dBµV/m)	Margin B (dB)	Antenna Polarity	EUT orientation	Channel	Noise Floor?
992.0	100.0	0.0	28.3	54.0	25.7	V	V	High	Yes
210.9	100.0	0.0	17.1	43.5	26.4	V	V	High	Yes
306.7	100.0	0.0	18.9	46.0	27.1	H	V	High	Yes
703.1	100.0	0.0	26.5	46.0	19.5	H	V	High	Yes
199.6	100.0	0.0	18.3	43.5	25.2	V	V	Low	Yes
31.4	100.0	0.0	16.1	40.0	23.9	H	V	Low	Yes

Measurements between 1-25 GHz:

Note: Table below shows the emissions from each channel in the restricted band in their worst-case orientations.

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBµV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4804	1.0711	38	55.9	39.2	54.0	14.8	Horizontal	Flat
4880	1.0066	60	54.3	37.7	54.0	16.3	Horizontal	Vertical
4960	1.975	0	51.5	33.6	54.0	20.4	Vertical	Side
7440	1.0062	98	46.0	35.4	54.0	18.6	Vertical	Side

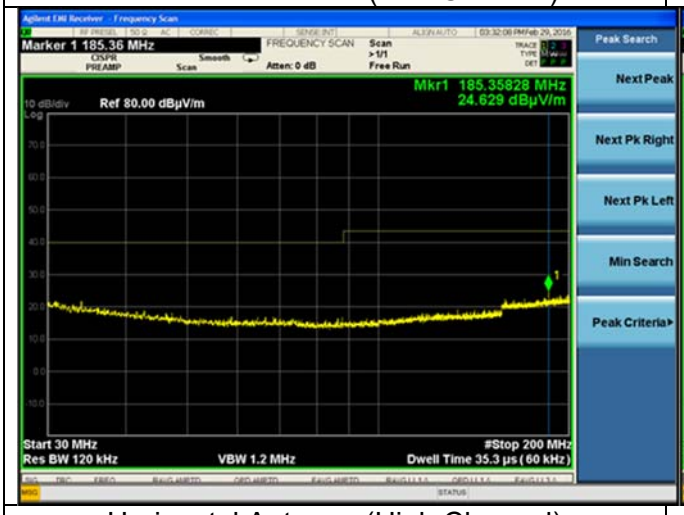
5.7 – Screen Captures.

The screen captures below are those using the Peak detector of the analyzer. In addition, the screen captures presented are those which were deemed to be an appropriate representation of the spectrum scan.

30 to 200 MHz, 3m distance

Horizontal Antenna (Low Channel)

Vertical Antenna (Low Channel)



Horizontal Antenna (High Channel)

Vertical Antenna (High Channel)

200 to 1000 MHz, 3m distance.

Horizontal Antenna (Low Channel)

Vertical Antenna (Low Channel)

Horizontal Antenna (High Channel)

Vertical Antenna (High Channel)

1000 to 2310 MHz, 3m distance (Reduced BW)

Horizontal Antenna (Low Channel)	Vertical Antenna (Low Channel)

.

2310 to 2400 MHz, 3m distance (Reduced BW)

Average	Peak

Note: The range 2483.5 to 2500 MHz is in section 8 of this report (Band-edges).

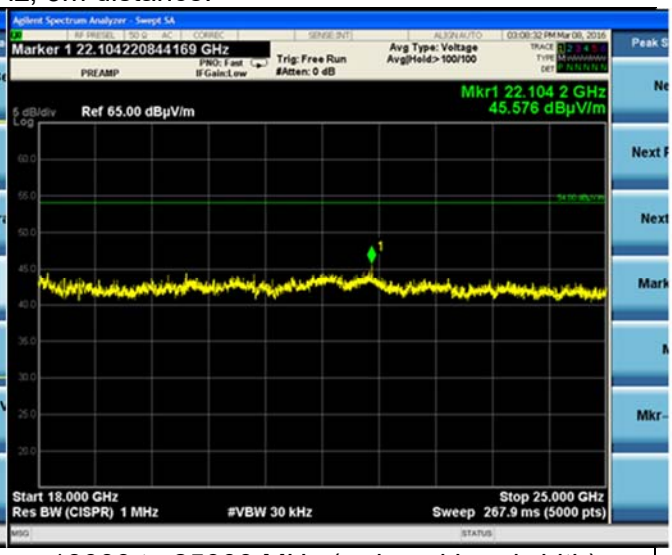
2500 to 4000 MHz, 3m distance. (Reduced Bandwidth)

Horizontal (High)

Vertical (High)

4000 to 25000 MHz, 3m distance.

4000 to 18000 MHz (reduced bandwidth)

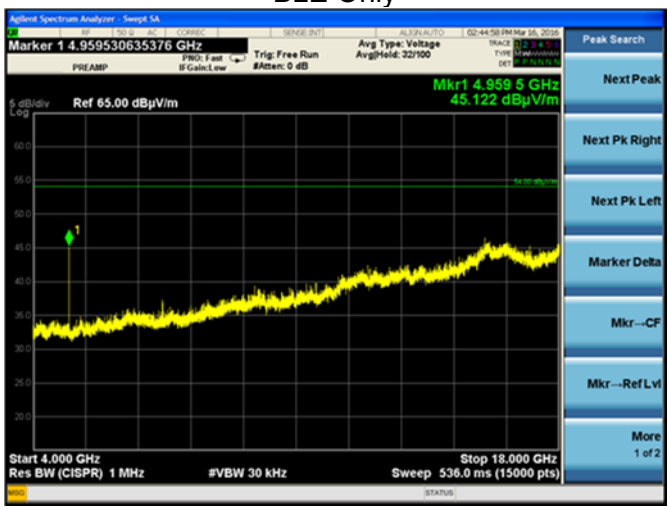


18000 to 25000 MHz (reduced bandwidth)

Co-location Data

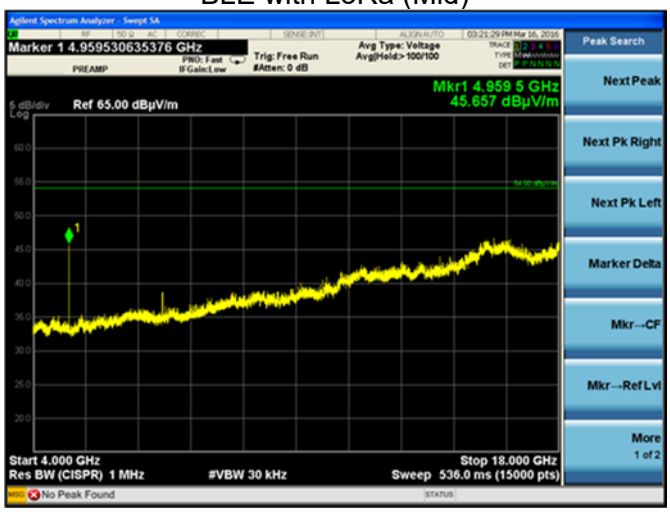
Note: The screen captures below feature both radios. The BLE was turned on and peaked out, and the three LoRa channels were toggled to measure their impact. All captures have a reduced RBW, and show the 4-18 GHz range.

BLE Only



BLE with LoRa (Low)

BLE with LoRa (Mid)



BLE with LoRa (High)

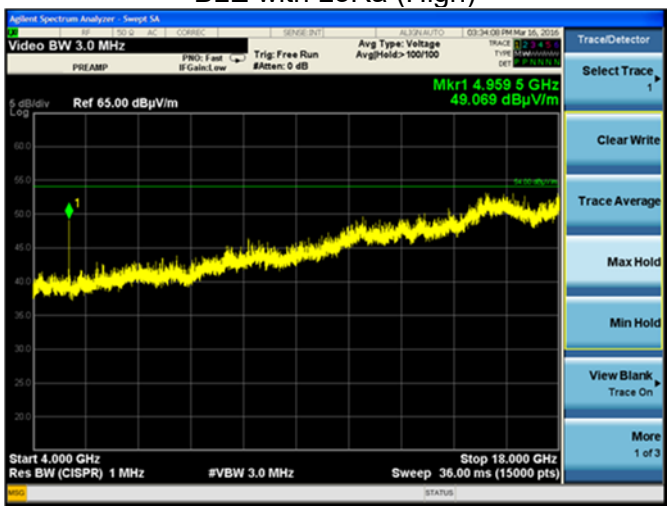


EXHIBIT 6. CONDUCTED EMISSIONS TEST, AC POWER LINE

6.1 Test Setup

The test area and setup are in accordance with ANSI C63.4 and with Title 47 CFR, FCC Part 15, Industry Canada RSS-247 and RSS GEN. The EUT was placed on a non-conductive wooden table, with a height of 80 cm above the reference ground plane. The power supply was then plugged into a 50Ω (ohm) Line Impedance Stabilization Network (LISN). The AC power supply of 120V was provided via an appropriate broadband EMI Filter, and then to the LISN line input. Final readings were then taken and recorded. After the EUT was setup and connected to the LISN, the RF Sampling Port of the LISN was connected to a 10 dB Attenuator-Limiter, and then to EMI receiver System. The Compower LISN used has the ability to terminate the unused port with a 50Ω (ohm) load when switched to either L1 (line) or L2 (neutral).

6.2 Test Procedure

The EUT was investigated in continuous modulated transmit mode for this portion of the testing. The appropriate frequency range and bandwidths were selected on the EMI Receiver, and measurements were made. The bandwidth used for these measurements is 9 kHz, as specified in CISPR 16-1, Section 1, Table 1, for Quasi-Peak and Average detectors in the frequency range of 150 kHz to 30 MHz. Final readings were then taken and recorded.

6.3 Test Equipment Utilized

A list of the test equipment and accessories utilized for the Conducted Emissions test is provided in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. Calibrations of the LISN and Limiter were performed at an IEC/ISO 17025 accredited calibration laboratory, traceable to the SI standard. All cables are calibrated and checked periodically for conformance. The emissions are measured on the EMI System, which has automatic correction for all factors stored in memory and allows direct readings to be taken.

6.4 Test Results

The EUT was found to **MEET** the Conducted Emission requirements of FCC Part 15.207 and RSS GEN 7.2.4 for Conducted Emissions for an Intentional Radiator. See the Data Charts and Graphs for more details of the test results.

6.5 FCC Limits of Conducted Emissions at the AC Mains Ports

Frequency Range (MHz)	Class B Limits (dBµV)		Measuring Bandwidth
	Quasi-Peak	Average	
0.150 -0.50 *	66-56	56-46	RBW = 9 kHz VBW ≥ 9 kHz for QP VBW = 1 Hz for Average
0.5 – 5.0	56	46	
5.0 – 30	60	50	
* The limit decreases linearly with the Logarithm of the frequency in this range.			

6.6 CONDUCTED EMISSIONS TEST DATA CHART

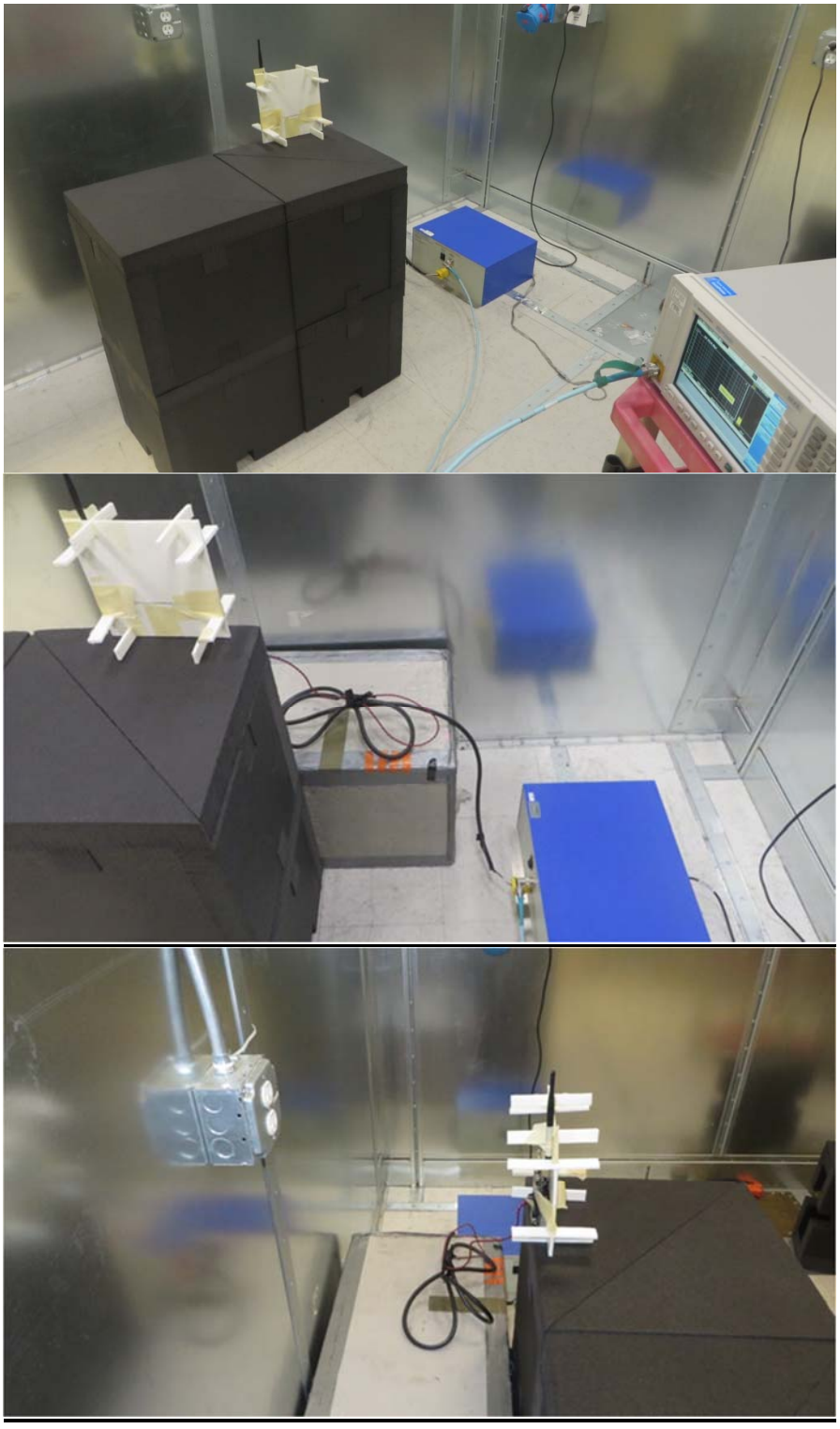
Frequency Range inspected: 150 KHz to 30 MHz

Manufacturer:	Laird Technologies					
Date(s) of Test:	3/10/16 – 3/11/16					
Project Engineer:	Shane Dock					
Test Engineer:	Shane Dock					
Voltage:	3.6/1.8VDC					
Operation Mode:	Continuous transmit, modulated					
Environmental Conditions in the Lab:	Temperature: 71° F Relative Humidity: 40%					
Test Location:	X	AC Mains Test area				Chamber
EUT Placed On:	X	40cm from Vertical Ground Plane				10cm Spacers
	X	80cm above Ground Plane				Other:
Measurements:		Pre-Compliance		Preliminary	X	Final
Detectors Used:		Peak	X	Quasi-Peak	X	Average

High Channel							
Line	Frequency (MHz)	Q-Peak Reading (dBµV)	Q-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
1	0.163	37.0	65.3	28.3	18.0	55.3	37.3
1	0.222	32.5	62.7	30.2	15.3	52.7	37.4
1	0.330	30.4	59.5	29.1	14.6	49.5	34.9
2	0.163	37.1	65.3	28.2	18.0	55.3	37.3
2	0.249	30.6	61.8	31.2	17.0	51.8	34.8
2	0.316	30.6	59.8	29.2	14.8	49.8	35.0

Low Channel							
Line	Frequency (MHz)	Q-Peak Reading (dBµV)	Q-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
1	0.159	37.6	65.5	27.9	18.7	55.5	36.8
1	0.294	30.7	60.4	29.7	15.3	50.4	35.1
1	0.348	29.7	59.0	29.3	13.8	49.0	35.2
2	0.150	37.8	66.0	28.2	18.7	56.0	37.3
2	0.195	35.2	63.8	28.6	16.9	53.8	36.9
2	0.312	30.4	59.9	29.5	14.6	49.9	35.3

6.7 Test Setup Photo(s) – Conducted Emissions Test



Prepared For: Laird Technologies	Model #: RM191-SM	Report #: 316054B
EUT: RM191-SM	Serial #: See Section 2.2	LSR Job #: C-2401

6.8 Screen Captures – Conducted Emissions Test

These screen captures represent the worst-case Peak Emissions. For conducted emission measurements, both a Quasi-Peak detector function and an Average detector function are utilized.

Transmit Mode (High Channel)

Line 1	Line 2

Note: The display lines in the plot above represent the limit lines for Class B, Quasi-Peak (Upper) and Average (Lower).

Transmit Mode (Low Channel)

Line 1	Line 2

Note: The display lines in the plot above represent the limit lines for Class B, Quasi-Peak (Upper) and Average (Lower).

EXHIBIT 7. OCCUPIED BANDWIDTH

Test Engineer(s): Shane Dock

7.1 – Limits

For a DTS system operating in the 2400 to 2483.5 MHz band, the 6dB emission bandwidth limit is 500 kHz.

7.2 - Method of Measurements

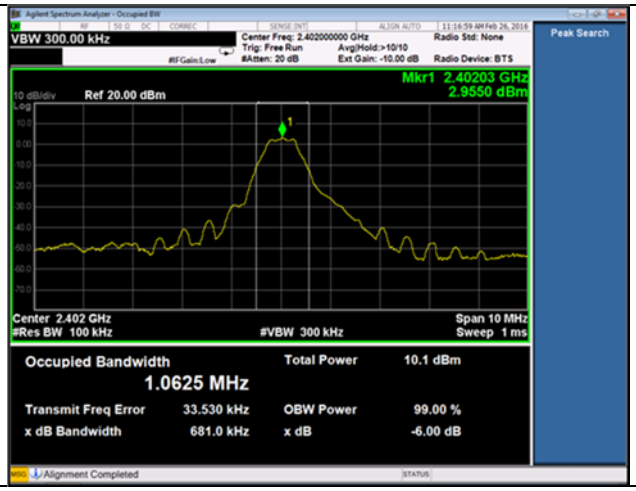
For this portion of the tests, a direct measurement of the transmitted signal was performed at the antenna port of the EUT, via a cable connection to a spectrum analyzer. An attenuator was placed in series with the cable to protect the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings there by allowing direct measurements, without the need for any further corrections. The EUT was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. A bandwidth measurement function that is built into the spectrum analyzer was used to measure the 20dB/emission bandwidth while the 6dB bandwidth was measured using **FCC OET KDB 558074 section 8 option 2.**

7.3 - Test Data

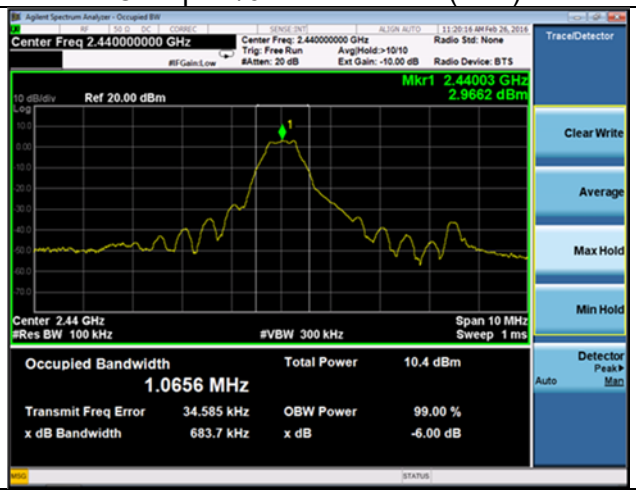
Channel	Low	Mid	High
Frequency (MHz)	2402	2440	2480
Occupied Bandwidth (MHz)	1.06	1.07	1.07
6 dB BW (kHz) (DTS)	681.0	683.7	686.2

7.4 – Screen Captures

Examples of bandwidth measurements:



Occupied/6dB bandwidth (Low)



Occupied/6dB bandwidth (Mid)

Occupied/6dB bandwidth (High)

EXHIBIT 8. BAND EDGE MEASUREMENTS

Test Engineer(s): Shane Dock

8.1 - Method of Measurements

FCC 15.247 require a measurement of spurious emission levels at the restricted band to be compliant to the general emissions limit, in particular at the Band-Edges where the intentional radiator operates. Also, RSS 247 requires that unwanted emissions meet limits listed in RSS GEN and also to the limits in the applicable annex. The EUT was operated in continuous transmit mode with continuous modulation, with internally generated data as the modulating source. The EUT was operated at the lowest channel for the investigation of the lower Band-Edge, and at the highest channel for the investigation of the higher Band-Edge.

The Band-edge measurements were performed conducted (100kHz bandwidth) and radiated. The measurement of band-edge was performed to satisfy FCC 15.247(d).

Per FCC KDB 558074 D01 Measurement Guidance v03r04 (section 11), conducted measurements were performed with 100 kHz bandwidth for all emissions outside of the band of operation. Emissions in the restricted band, a bandwidth of 120kHz (below 1000MHz) and 1MHz (above 1000MHz) were used in accordance with C63.4 and was performed radiated.

For both conducted and radiated measurements, correction factors and the cable loss factors were entered into the EMI Receiver database. **As a result, the plots taken from the EMI Receiver accounts for all applicable correction factor as well as cable loss, and can therefore be entered into the database as a corrected meter reading.**

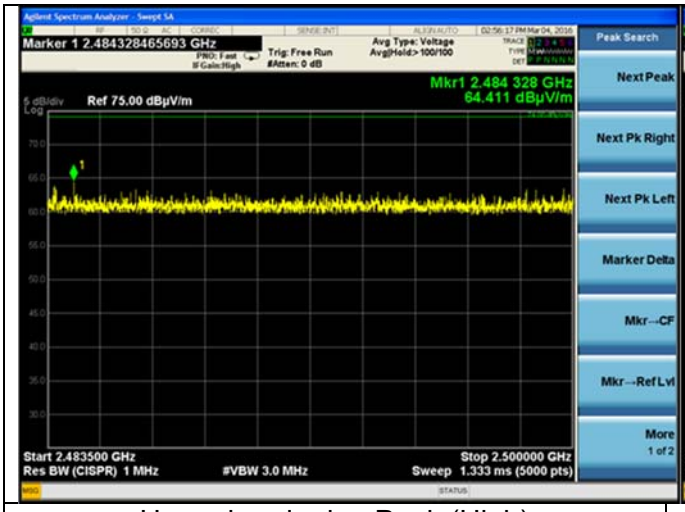
8.2. Band Edge Screen Captures.

The data presented below are samples selected from the various data rates and channels tested.

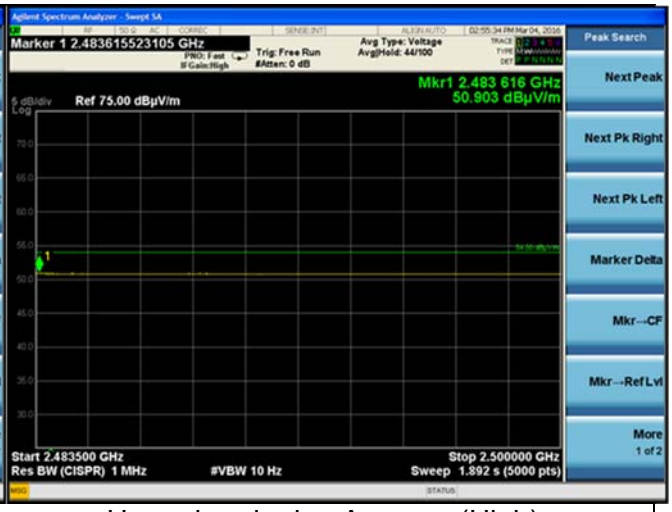
Band-edge in Restricted Band

Radiated Band-edge in Restricted Band:

2483.5 to 2500 MHz Restricted band



Upper band edge Peak (High)

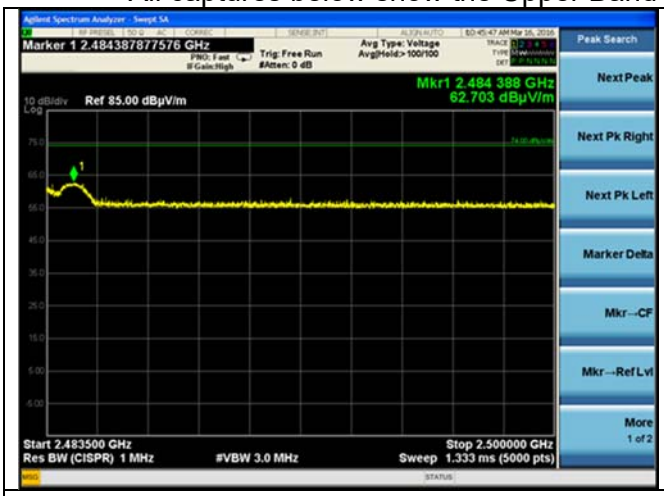


Upper band edge Average (High)

Co-Location

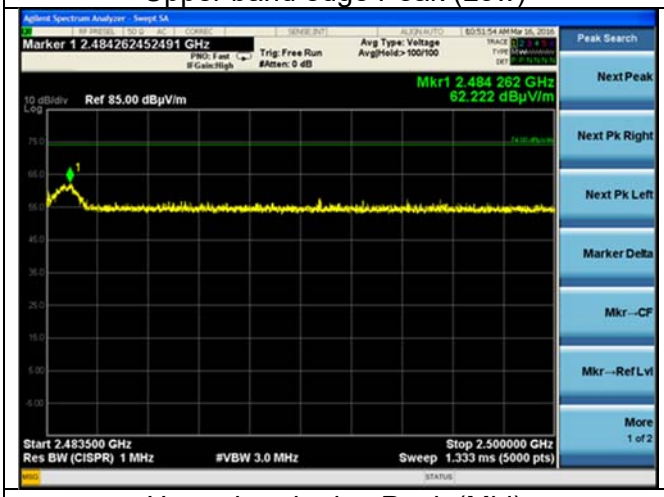
Effects of co-location of the LoRa and BLE transmitters were investigated and were found that the module was still in compliance with requirements. There were no degradation of the emissions associated with the individual transmitters when it is transmitting on its own. Example plots are shown below.

All captures below show the Upper Band Edge with each respective LoRa channel.



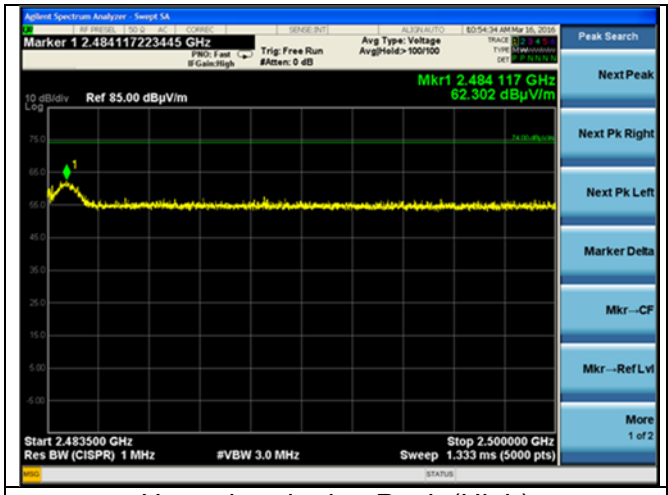
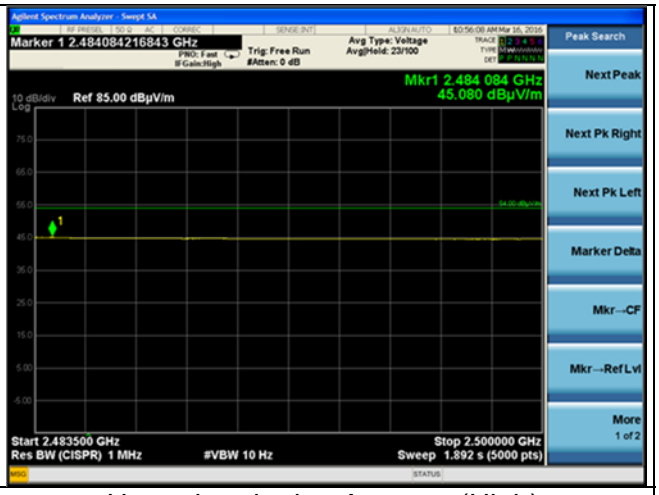
Upper band edge Peak (Low)

Upper band edge Average (Low)



Upper band edge Peak (Mid)

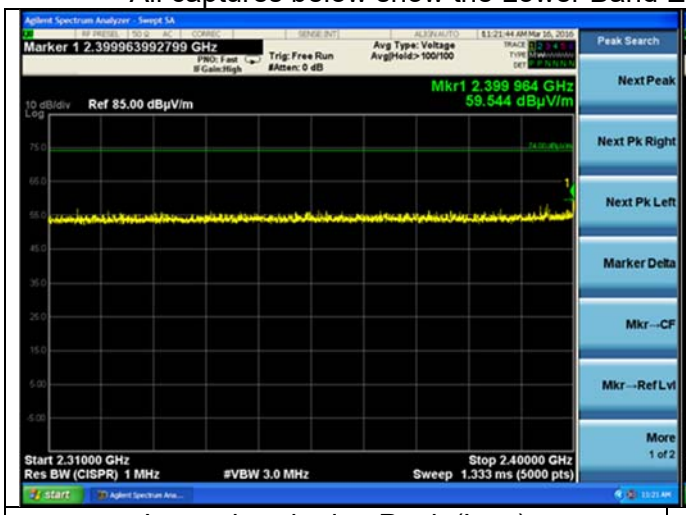
Upper band edge Average (Mid)

	
Upper band edge Peak (High)	Upper band edge Average (High)

All captures below show the Lower Band Edge with each respective LoRa channel.

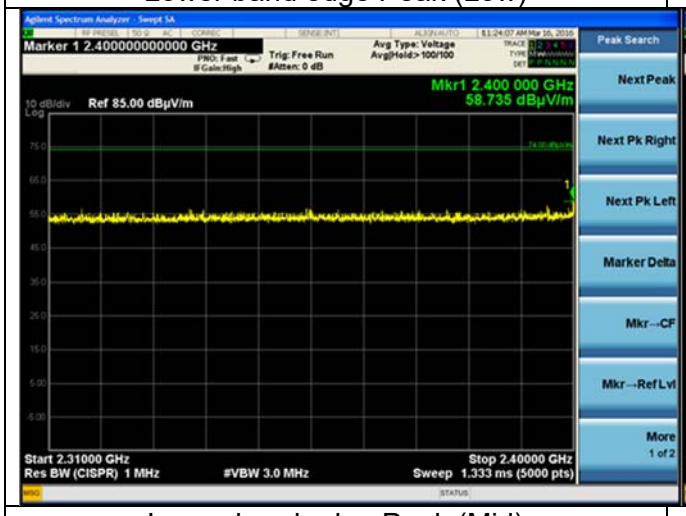
Co-Location

All captures below show the Lower Band Edge with each respective LoRa channel.



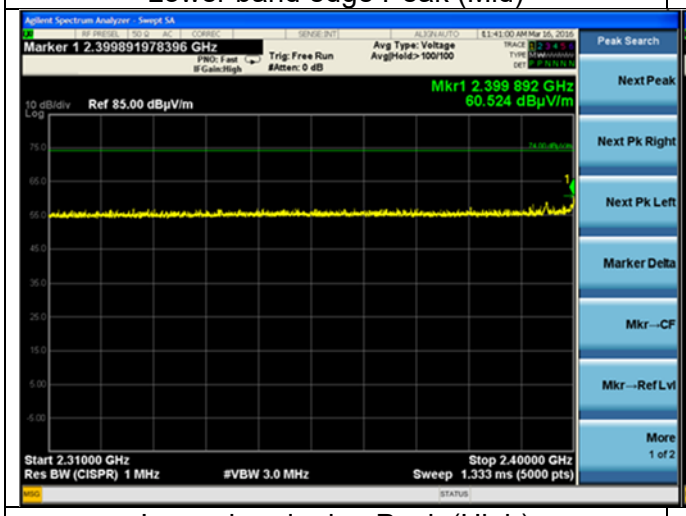
Lower band edge Peak (Low)

Lower band edge Average (Low)

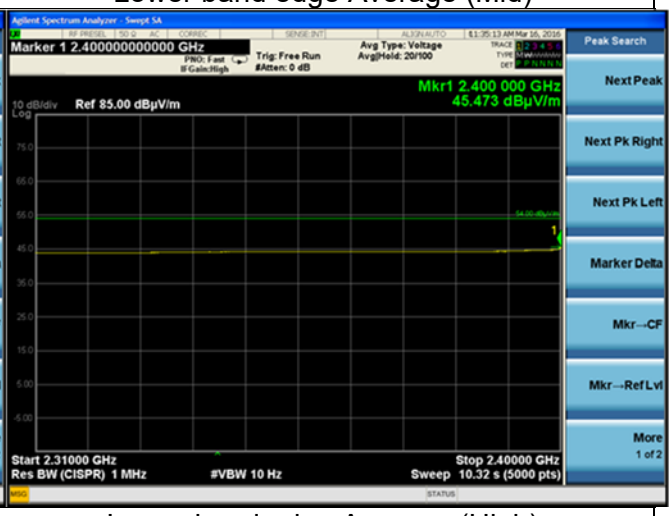


Lower band edge Peak (Mid)

Lower band edge Average (Mid)

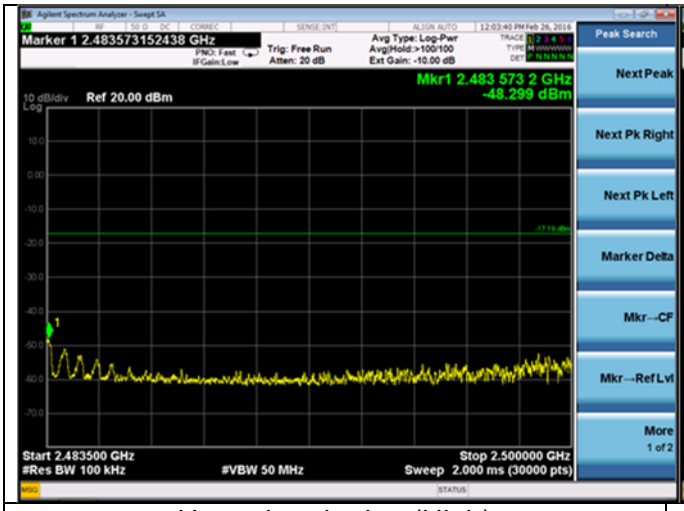


Lower band edge Peak (High)

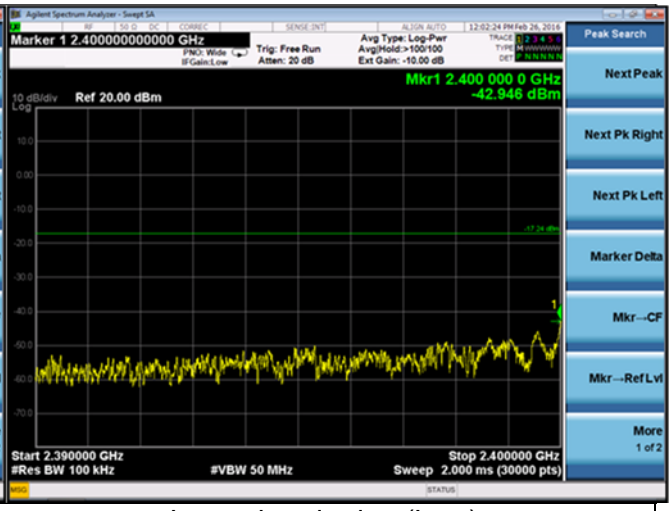


Lower band edge Average (High)

Band-edge in 100kHz bandwidth (Conducted Band Edge)



Upper band edge (High)



Lower band edge (Low)

EXHIBIT 9. POWER OUTPUT (CONDUCTED): 15.247(b)

Test Engineer(s): Shane Dock

9.1 - Method of Measurements

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings there by allowing direct measurements without the need for any further corrections. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source.

Measurement procedure used was FCC OET KDB 558074 D01 Measurement Guidance v03r04 section 9.1.1.

9.2 - Test Data

The data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement (dBm) + Cable factor (dB) + Miscellaneous factors when applicable (dB).

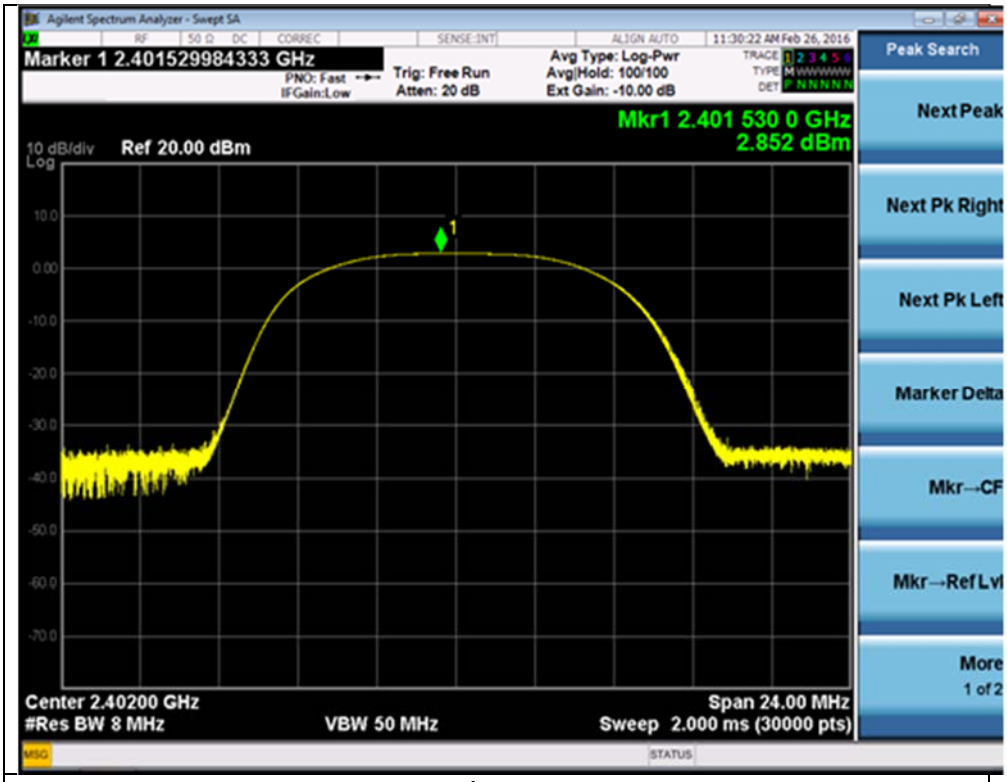
Generic example of reported data at 2440 MHz:

Reported Measurement data = 8.55 (raw receiver measurement in dBm) + 0.85 (cable factor in dB) = 9.4 (dBm).

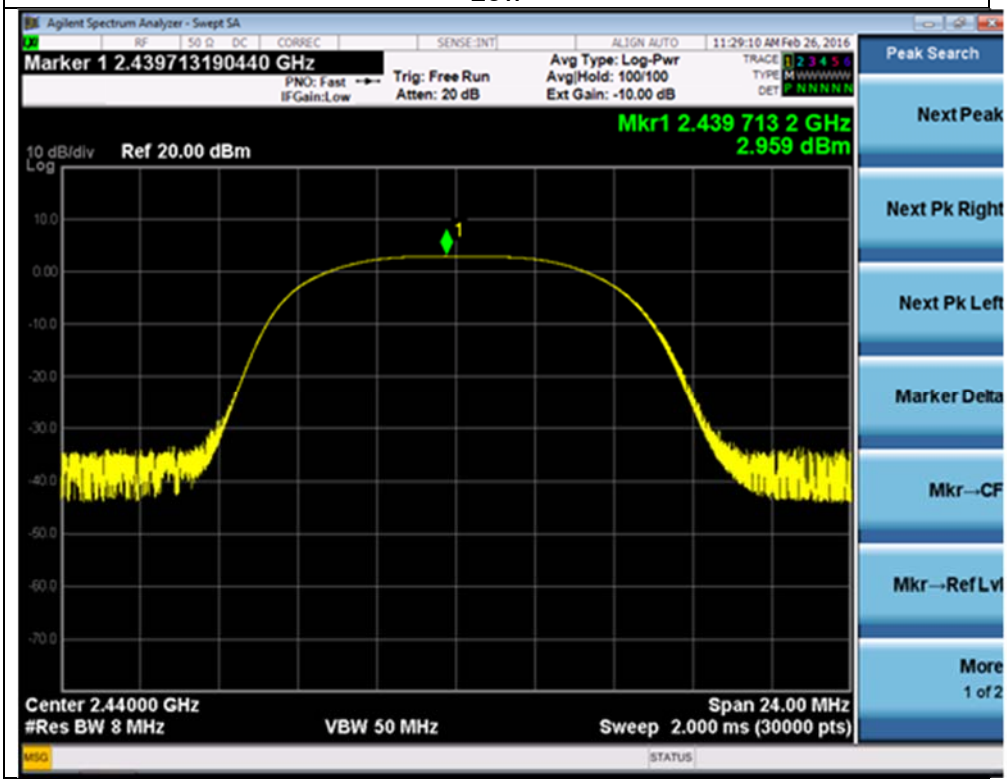
9.2.1. Maximum conducted peak power:

Channel	Low	Mid	High
Frequency (MHz)	2402	2440	2480
Max Peak Cond Output Power (dBm)	2.85	2.96	2.88
Limit (dBm)	30	30	30
Margin (dBm)	27.15	27.04	27.12

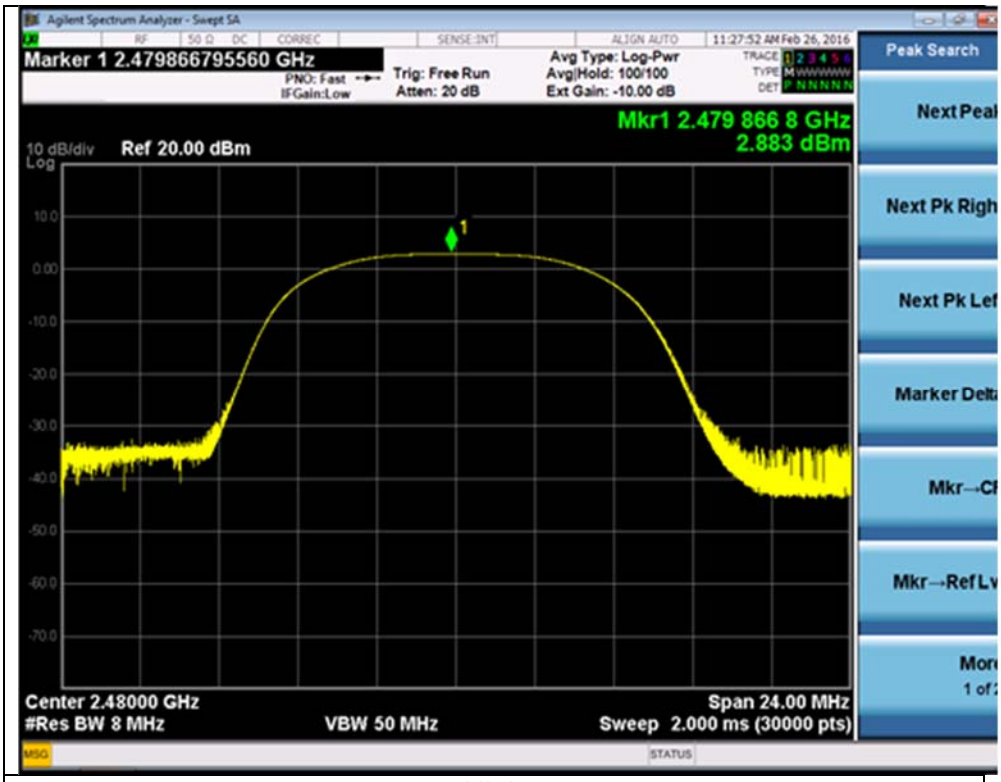
9.3 – Screen Captures.



Low



Mid


Agilent Spectrum Analyzer - Swept SA
Marker 1 2.479866795560 GHz
PNO: Fast
IFGain:Low
Trig: Free Run
Atten: 20 dB
Avg Type: Log-Pwr
Avg|Hold: 100/100
Ext Gain: -10.00 dB
11:27:52 AM Feb 26, 2016
Mkr1 2.479 866 8 GHz
2.883 dBm
10 dB/div
Log
Ref 20.00 dBm
Center 2.48000 GHz
#Res BW 8 MHz
VBW 50 MHz
Span 24.00 MHz
Sweep 2.000 ms (30000 pts)
Peak Search
Next Peak
Next Pk Right
Next Pk Left
Marker Delta
Mkr→CF
Mkr→Ref Lvl
More
1 of 2
MSG
STATUS

High

EXHIBIT 10. CONDUCTED SPURIOUS EMISSIONS: 15.247(d)

Test Engineer(s): Shane Dock

10.1 - Limits

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.

10.2 – Conducted Harmonic And Spurious RF Measurements

FCC Part 15.247(d) and IC RSS 247 both require a measurement of conducted harmonic and spurious RF emission levels, as reference to the carrier level when measured in a 100 kHz bandwidth. For this test, the spurious and harmonic RF emissions from the EUT were measured at the EUT antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, thereby allowing direct readings of the measurements made without the need for any further corrections. A spectrum analyzer was used with the resolution bandwidth set to 100 kHz for this portion of the tests. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with measurements from a peak detector presented in the chart below. Screen captures were acquired and any noticeable spurious and harmonic signals were identified and measured.

Measurement procedure used was FCC OET KDB 558074 D01 Measurement Guidance v03r04 section 11.

The data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement (dBm) + Cable factor (dB) + Miscellaneous factors when applicable (dB).

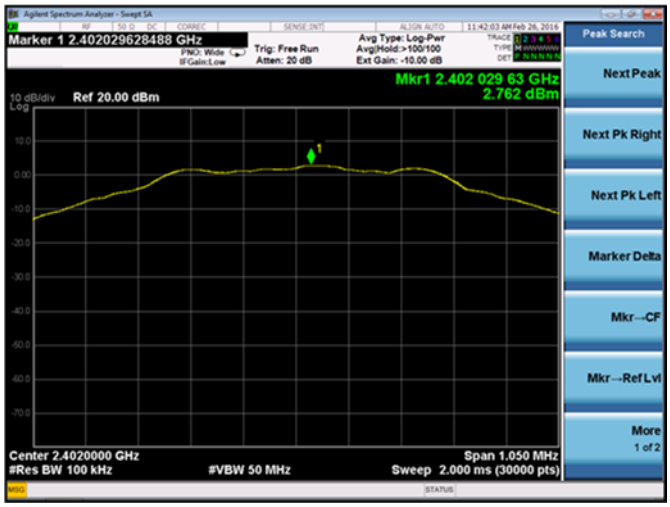
Generic example of reported data at 2440 MHz:

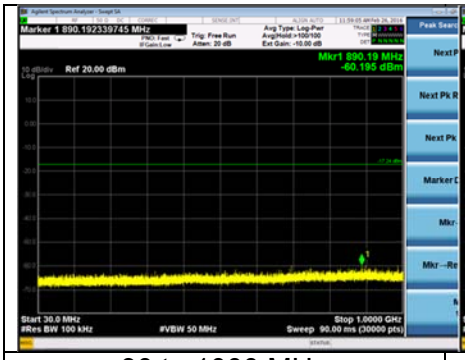
Reported Measurement data = 8.55 (raw receiver measurement in dBm) + 0.85 (cable factor in dB) = 9.4 (dBm).

10.3 - Test Data

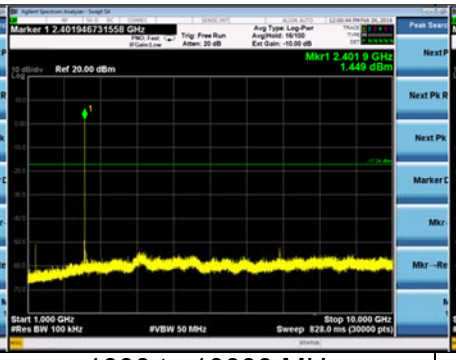
The data presented below are samples selected from the various data rates and channels tested.

Low fundamental in 100 kHz:

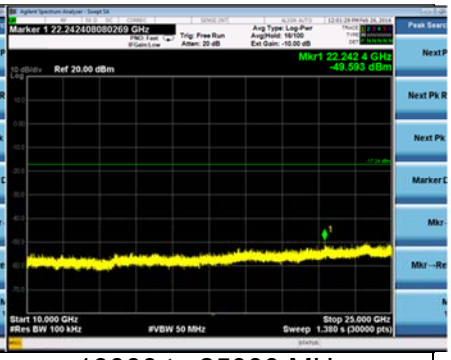




30 to 1000 MHz

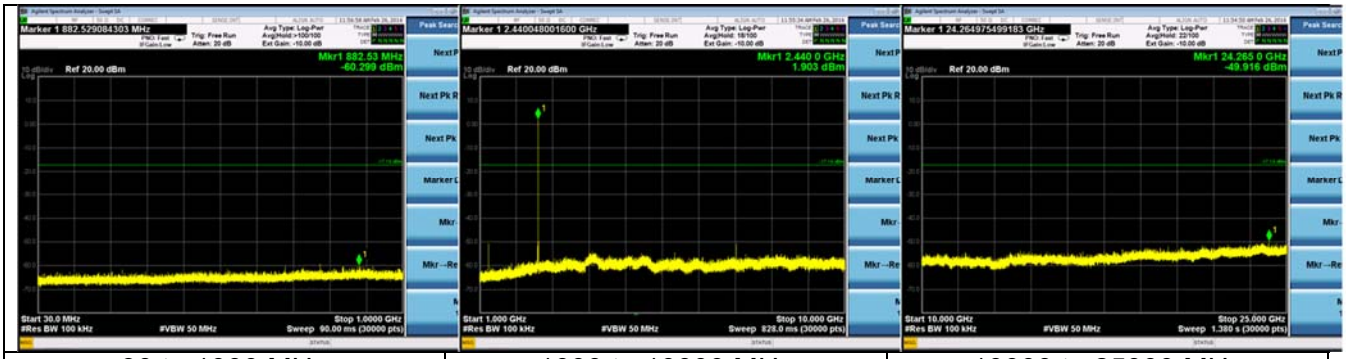


1000 to 10000 MHz



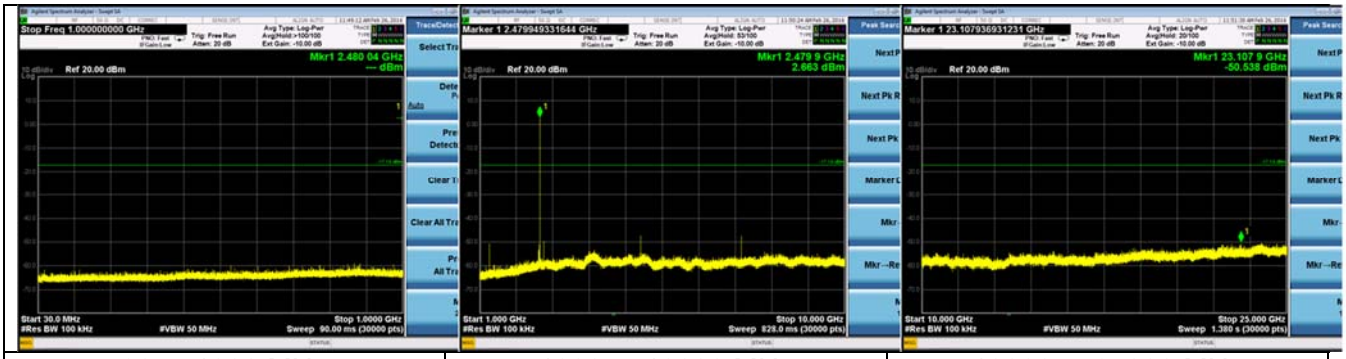
10000 to 25000 MHz

Mid fundamental in 100 kHz:



30 to 1000 MHz	1000 to 10000 MHz	10000 to 25000 MHz

High fundamental in 100 kHz:



30 to 1000 MHz	1000 to 10000 MHz	10000 to 25000 MHz

EXHIBIT 11. POWER SPECTRAL DENSITIES: 15.247(e)

11.1 Limits

For digitally modulate 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.

In accordance with FCC Part 15.247(e) and RSS 247, the peak power spectral density should not exceed +8 dBm in any 3 kHz band. This measurement was performed along with the conducted power output readings performed as described in previous sections. The peak output frequency for each representative frequency was scanned, with a narrow bandwidth, and reduced sweep, and a power density measurement was performed.

Measurement procedure used was FCC OET KDB 558074 D01 Measurement Guidance v03r04 section 10.2.

The data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement (dBm) + Cable factor (dB) + Miscellaneous factors when applicable (dB).

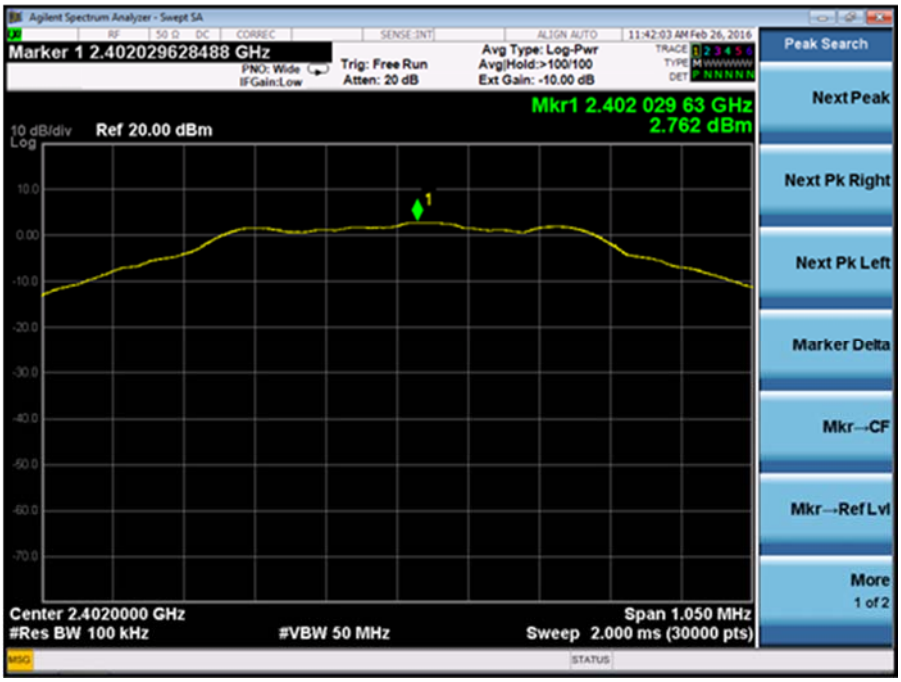
Generic example of reported data at 2440 MHz:

Reported Measurement data = 8.55 (raw receiver measurement in dBm) + 0.85 (cable factor in dB) = 9.4 (dBm).

11.2 Test Data

Channel	Low	Mid	High
Frequency (MHz)	2402	2440	2480
Power Spectral Density (dBm)	2.76	2.89	2.81
Limit (dBm)	8	8	8
Margin (dBm)	5.24	5.11	5.19

11.3 Screen Captures – Power Spectral Density



Low

Mid


Agilent Spectrum Analyzer - Swept SA
Marker 1 2.480035998700 GHz
PNO: Wide
IFGain:Low
Trig: Free Run
Atten: 20 dB
Avg Type: Log-Pwr
Avg|Hold:>100/100
Ext Gain: -10.00 dB
11:44:41 AM Feb 26, 2016
Mkr1 2.480 036 00 GHz
2.812 dBm
10 dB/div
Log
Ref 20.00 dBm
Center 2.4800000 GHz
#Res BW 100 kHz
#VBW 50 MHz
Span 1.050 MHz
Sweep 2.000 ms (30000 pts)
Peak Search
Next Peak
Next Pk Right
Next Pk Left
Marker Delta
Mkr→CF
Mkr→Ref Lvl
More
1 of 2

High

EXHIBIT 12. FREQUENCY STABILITY OVER VOLTAGE VARIATIONS

Test Engineer(s): Shane Dock

The frequency stability of the device was examined as a function of the input voltage available to the EUT. A Spectrum Analyzer was used to measure the RF output power and frequency at the appropriate frequency markers. Power was supplied by an external bench-type DC power supply and was varied ±15% from the nominal.

The power was then cycled On/Off to observe system response. No unusual response was observed, the emission characteristics were well behaved, and the system returned to the same state of operation as before the power cycle.

	1.8 VDC	3.3 VDC	3.6 VDC	
Channel	Frequency (Hz)	Frequency (Hz)	Frequency (Hz)	Frequency Drift (Hz)
Channel 2	2402032080	2402031750	2402030420	1660
Channel 40	2440029920	2440025920	2440029750	4000
Channel 80	2480032920	2480036420	2480030250	6170

APPENDIX A – Test Equipment List

LSR
a Laird Business

Date : 18-Feb-2016 Type Test : Conducted Emissions Job # : C-2401

Prepared By: Shane Customer : Laird Quote #: 316054

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/6/2015	5/6/2016	Active Calibration
2	EE 960162	LISN - 15A	COM-POWER	LI-215A	191969	7/24/2015	7/24/2016	Active Calibration
3	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	2/24/2016	2/24/2017	Active Calibration

LSR
a Laird Business

Date : 18-Feb-2016 Type Test : Radiated Emissions Job # : C-2401

Prepared By: Shane Dock Customer : Laird Quote #: 316054

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	2/24/2016	2/24/2017	Active Calibration
2	AA 960005	Biconical Antenna	EMCO	93110B	9601-2280	1/14/2016	1/14/2017	Active Calibration
3	AA 960004	Log Periodic Antenna	EMCO	93146	95124276	8/18/2015	8/18/2016	Active Calibration
4	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/6/2015	5/6/2016	Active Calibration
5	AA 960153	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-04	4/15/2015	4/15/2016	Active Calibration
6	AA 960143	Phaseflex	Gore	EKD01D01048.0	5546519	6/26/2015	6/26/2017	Active Calibration
7	AA 960144	Phaseflex	Gore	EKD01D010720	5800373	Verification	Verification	System
8	AA 960007	Double Ridge Horn Antenna	EMCO	3115	9311-4138	8/4/2015	8/4/2016	Active Calibration
9	EE 960160	0.8-21GHz LNA	Mini-Circuits	ZVA-213X-S+	977711030	8/4/2015	8/4/2016	Active Calibration
10	AA 960158	Double Ridge Horn Antenna	ETS Lindgren	3117	109300	2/4/2016	2/4/2017	Active Calibration
11	AA 960162	EM Series Cable	MegaPhase	EM26-S1S1-120	12024301 001	6/30/2015	6/30/2016	Active Calibration
12	AA 960153	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-04	4/15/2015	4/15/2016	Active Calibration
13	RENTAL	Horn Antenna 18-40GHz	AH System	SAS-574	193	11/30/2015	11/30/2016	Active Calibration

Project Engineer: Shane Dock Quality Assurance:

APPENDIX B – Test Standards: CURRENT PUBLICATION DATES RADIO

STANDARD #	DATE	Am. 1	Am. 2
ANSI C63.4	2014		
ANSI C63.10	2013		
FCC 47 CFR, Parts 0-15, 18, 90, 95	2016		
RSS GEN	2014		
RSS 247	2015		

APPENDIX C - Uncertainty Statement

Table of Expanded Uncertainty Values, (K=2) for Specified Measurements

Measurement Type	*Particular Configuration*	*Uncertainty Values*
Radiated Emissions	*3 – Meter chamber, Biconical Antenna*	*4.82 dB*
Radiated Emissions	*3-Meter Chamber, Log Periodic Antenna*	*4.88 dB*
Radiated Emissions	*3-Meter Chamber, Horn Antenna*	*4.85 dB*
Radiated Emissions	*10-Meter OATS, Biconical Antenna*	*4.32 dB*
Radiated Emissions	*10-Meter OATS, Log Periodic Antenna*	*3.63 dB*
Absolute Conducted Emissions	*Agilent PSA/ESA Series*	*1.38 dB*
AC Line Conducted Emissions	*Shielded Room/EMCO LISN*	*3.20 dB*
Radiated Immunity	*3 Volts/Meter in 3-Meter Chamber*	*2.05 Volts/Meter*
Conducted Immunity	*3 Volts level*	*2.33 V*
EFT Burst, Surge, VDI	*230 VAC*	*54.4 V*
ESD Immunity	*Discharge at 15kV*	*3200 V*
Temperature/Humidity	*Thermo-hygrometer*	*0.64° / 2.88 %RH*