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W66 N220 Commerce Court ● Cedarburg, WI 53012
Phone: 262.375.4400 ● Fax: 262.375.4248
www.lsr.com

TEST REPORT #: 316191-1b
LSR Job #: C-2496

Compliance Testing of:
W1001

Test Date(s):
7/12/2016 – 7/15/2016, 7/19/2016, 7/21/2016, 7/22/2016, 7/26/2016, 7/27/2016, 8/15/2016, and 8/23/2016

Prepared For:
ThermoFisher Scientific
Attn: David Perez
2 Radcliff Road
Tewksbury, MA 1876

This Test Report is issued under the Authority of:
John Johnston, EMC Engineer

Signature:  Date: 9/21/2016

Quality Assurance by:
Michael Hintzke, EMC Engineer III

Signature:  Date: 9/12/16

Project Engineer:
John Johnston, EMC Engineer

Signature:  Date: 9/21/2016

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EXHIBIT 1. INTRODUCTION

1.1 - Scope

References:	FCC Part 15, Subpart C, Section 15.247 and 15.209 FCC Part 2, RSS-GEN, and RSS-247
Title:	FCC: Telecommunication – Code of Federal Regulations, CFR 47, Part 15. IC : License-exempt Radio Apparatus (All Frequency Bands): Category I Equipment
Purpose of Test:	To gain FCC and IC Certification Authorization for Radio Apparatus
Test Procedures:	Both conducted and radiated emissions measurements were conducted in accordance with American National Standards Institute ANSI C63.10 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
Environmental Classification:	Commercial, Industrial or Business Residential

1.2 – Normative References

Publication	Year	Title
47 CFR, Parts 0-15 (FCC)	2016	Code of Federal Regulations - Telecommunications
RSS-247	2015-05 Issue 1	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices
RSS-GEN	2014-11 Issue 4	General Requirements for Compliance of Radio Apparatus
ANSI C63.10	2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
CISPR 16-1-1	2015-09 Ed. 4	Specification for radio disturbance and immunity measuring apparatus and methods. Part 1-1: Radio disturbance and measuring apparatus – Measuring apparatus
CISPR 16-2-1	2014-02 Ed. 3	Specification for radio disturbance and immunity measuring apparatus and methods. Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements

1.3 - LS Research, LLC in Review

As an EMC Testing Laboratory, our Accreditation and Assessments are recognized through the following:

TESTING CERT #1255.01

A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025: 2005 with Electrical (EMC) Scope of Accreditation
A2LA Certificate Number: 1255.01

Federal Communications Commission (FCC) – USA

Listing of two 3 Meter Semi-Anechoic Chambers based on Title 47 CFR – Part 2.948
FCC Registration Number: 90756

Industrie Canada Industry Canada

Industry Canada

On file, 3 Meter Semi-Anechoic Chamber based on RSS-GEN – Issue 4
File Number: IC 3088A-2
On file, 3 Meter Semi-Anechoic Chamber based on RSS-GEN – Issue 4
File Number: IC 3088A-3

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1 – Client Information

Manufacturer Name:	Thermo Fisher Scientific
Address:	2 Radcliff Road, Tewksbury, MA 1876
Contact Name:	David Perez

2.2 - Equipment Under Test (EUT) Information

Product Name:	W1001
Model Number:	W1001
Serial Numbers:	3-016181 and 3-016205

2.3 - Associated Antenna Description

The 2.4 GHz FlexPIFA antenna is flexible planar inverted-f antenna (PIFA) exhibiting a peak gain of +2 dBi. The 2.4 GHz FlexPIFA antenna includes a 001-0014 Rev. 3 U.FL connector

2.4 - EUT'S Technical Specifications

Bluetooth:

EUT Frequency Range (in MHz)	2402-2480 MHz
EIRP (in mW)	
Minimum:	12.552 @ EDR2, Channel 39
Maximum:	15.255 @ EDR3, Channel 78
Occupied Bandwidth (20 dB BW)	GFSK: 937.8 kHz EDR2: 1340 kHz EDR3: 1338 kHz
Type of Modulation	GFSK, EDR2, and EDR3
Emission Designator	GFSK: 838KG1D EDR2: 1M20GXD EDR3: 1M21GXD
Transmitter Spurious (worst case) at 3 meters	52.2 dBuV/m @ 4960 MHz
Frequency Tolerance %, Hz, ppm	Better than 100 ppm
Antenna Information	
Detachable/non-detachable	Detachable
Type	2.4 GHz FlexPIFA
Gain (in dBi)	2 dBi peak
EUT will be operated under FCC Rule Part(s)	15.247
EUT will be operated under RSS Rule Part(s)	247
Modular Filing	☒ Yes ☐ No
Portable or Mobile?	Portable

2.5 - Product Description

The W1001 includes an LSR TiWi-BLE module and 2.4 GHz FlexPIFA antenna. The W1001 is a multi-standard module with support for WLAN (802.11 b/g/n), Bluetooth, and BLE. Both WLAN and Bluetooth/ BLE share the same antenna port.

The W1001 operates on the following patch file for Bluetooth operation: 480-0026-R3.hci.

EXHIBIT 3. EUT OPERATING CONDITIONS & CONFIGURATIONS DURING TESTS

3.1 - Climate Test Conditions

Temperature:	15-35 ˚C
Humidity:	30-60%
Pressure:	725-745 mmHg

3.2 - Applicability & Summary of EMC Emission Test Results

FCC and IC Paragraph	Test Requirements	Compliance (Yes/No)
FCC : 15.247(a)(1) IC : RSS 247 Section 5.1(1)-(2)	Channel Spacing and 20 dB Bandwidth of a Frequency Hopping System	Yes
FCC: 15.247(a)(1)(iii) IC: RSS 247 Section 5.1(4)	Channel Occupancy	Yes
FCC : 15.247(b)(1) & 1.1310 IC : RSS 247 Section 5.4(2)	Maximum Peak Conducted Output Power	Yes
FCC : 15.247(i), 1.1307, 1.1310, 2.1091 & 2.1093 IC : RSS 102	RF Exposure Limit	Yes
FCC :15.247(d) IC : RSS 247 Section 5.5	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
FCC : 15.247(d) IC : RSS 247 Section 5.2(2)	Transmitted Power Spectral Density of a Digital Modulation System	Yes
FCC : 15.247(d), 15.209 & 15.205	Transmitter Radiated Emissions	Yes
FCC: 15.207 IC: ICES-003	AC Line Conducted 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

When tested on the specified dates, it was determined that the EUT was compliant with the requirements of FCC Title 47 Part 15.207, 15.209, Part 15.247, Industry Canada RSS-247, and RSS-GEN for a Frequency Hopping System (FHS) Transmitter using the methods of ANSI C63.10.

Any modifications made to the EUT after the specified test dates will invalidate the data contained herein.

If some measurements are seen to be within the uncertainty value, as listed in Appendix C, there is a possibility that this unit may not meet the required limit specification if subsequently tested.

EXHIBIT 5. RADIATED EMISSIONS TEST

5.1 - Test Setup

The test setup was assembled in accordance with ANSI C63.10. The EUT was placed on an 80 cm (when investigating below 1GHz) or 150 cm (when investigating above 1 GHz) high non-conductive pedestal, centered on a flush mounted turntable inside a Semi-Anechoic, FCC listed Chamber. The EUT was operated at various modulations and data rates in continuous transmit mode. Final testing was performed with the EUT operating in continuous transmit mode and being provided 3.3 V DC from a variable power supply. The EUT, serial no. 3-016205 and 3-016181, operates as a Bluetooth FHSS device, configured to transmit at any of 79 channels and programmable via a programming application and a beta board.

It should be noted that radiated emission testing below 1 GHz and between 18-25 GHz was performed on unit 3-016205 while all other testing (radiated emission testing and conducted measurements) was performed on unit 3-016181.

Applicable limits apply at a 3 meter distance. The calculations to determine these limits are provided in the following pages. Please refer to Appendix A for a complete list of test equipment. The EUT was configured to operate on one of three (3) standard channels: Bluetooth - low (2402 MHz), middle (2441 MHz) and high (2480 MHz), to comply with FCC/IC regulations. The channels and operating modes were changed using the programming application on a personal computer.

5.2 - Test Procedure

Radiated RF measurements were performed on the EUT in the 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 Semi-Anechoic Chamber, with the antenna mast situated such that the antenna was 3 meters from the EUT. A biconical antenna coupled to a 6 dB attenuator was used to measure emissions from 30 MHz to 200 MHz, and a log periodic dipole 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 and a horn antenna was used from 18 GHz to 25 GHz. The maximum radiated RF emissions were found by raising and lowering the antenna between 1 and 4 meters in height, using both horizontal and vertical antenna polarities. The EUT was rotated along three orthogonal axes during the investigations to find the highest emission levels. The EUT was situated on the turntable in three orientations using a support. The three orientations are illustrated in the images below.

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.

5.4 - Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247, FCC Part 15.209, Canada RSS-247, and RSS-GEN for a FHSS transmitter. The frequencies with significant RF signal strength were recorded and plotted as shown in the data charts and screen captures provided below.

5.5 - Calculation of Radiated Emissions Limits

The maximum peak output power of an intentional radiator in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, as specified for a FHSS device in Title 47 CFR 15.247 (b)(1) and RSS 247 Section 5.4(2) is 1 Watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 W. The harmonic and spurious RF emissions, as measured in any 100 kHz bandwidth, as specified in 15.247(d) and RSS Section 5.5, shall be at least 20 dB below the measured power of the desired signal, and must also meet the requirements described in 15.205(c) for FCC and the applicable Industry Canada standard.

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.

Frequency (MHz)	3 m Quasi-Peak Limit μV/m	3 m Quasi-Peak Limit (dBμV/m)	3 m Peak Limit (dBμV/m)	3 m Average Limit (dBμV/m)
30-88	100	40.0	-	-
88-216	150	43.5	-	-
216-960	200	46.0	-	-
960+	500	54.0	-	-
1000	-	-	74	54

Sample conversion of field strength (μV/m to dBμV/m):

$$dB\mu V/m = 20 \log_{10} (100) = 40\ dB\mu V/m \text{ (from 30-88 MHz)}$$

Reported data is the raw data corrected for all applicable factors such as antenna factors, cable loss, etc.

Sample reported data for 200MHz:

Raw Data + Antenna Factor + Cable Factor = Reported Data

18.2 dBμV/m + 15.8 dB + 1.45 dB = 35.45 dBμV/m

5.6 - Radiated Emissions Test Data Chart

3 Meter Measurements of Electromagnetic Radiated Emissions
Test Standard: 47 CFR, Part 15.205 and 15.247(FHSS)
RSS 247 (FHSS)
Frequency Range Inspected: 30 MHz to 25000 MHz

Manufacturer:	LS Research					
Date(s) of Test:	7/12/2016, 7/13/2016,7/21/2016, 7/22/2016, 7/26/2016, 7/27/2016, and 8/15/2016					
Test Engineer(s):	John Johnston and Kim Bay					
Voltage:	3.3 VDC					
Operation Mode:	Continuous Transmit					
Environmental Conditions in the Lab:	Temperature: 20 – 25° C Relative Humidity: 30 – 60 %					
EUT Power:		Single Phase ___VAC		3 Phase ___VAC		
		Battery	**X**	Other: DC Bench Supply		
EUT Placement:	**X**	80 cm non-conductive table	**X**	150 cm non-conductive table		
EUT Test Location:	**X**	3 Meter Semi-Anechoic FCC Listed Chamber		Other		
Measurements:		Pre-Compliance		Preliminary	**X**	Final
Detectors Used:	**X**	Peak	**X**	Quasi-Peak	**X**	Average

Bluetooth DATA:

Below 1 GHz

Frequency (MHz)	Height (m)	Azimuth (degree)	Quasi Peak Reading (dBµV/m)	Quasi Peak Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation	Channel	Notes
185.0	1.66	244	35.2	43.50	8.30	H	V	Low	
185.1	3.17	254	28.85	43.50	14.70	V	V	Low	
184.8	1.67	283	35.48	43.50	8.00	H	S	Low	
191.2	1.71	255	34.80	43.50	8.70	H	F	Low	
194.8	1.60	101	31.87	43.50	11.60	H	V	Mid	
185.1	1.76	275	36.48	43.50	7.00	H	S	Mid	
185.5	1.69	264	35.82	43.50	7.70	H	F	Mid	
185.2	1.65	260	34.61	43.50	8.90	H	V	High	
185.3	1.69	272	36.46	43.50	7.00	H	S	High	
185.4	1.72	252	35.95	43.50	7.60	H	F	High	
826.7	1.10	174	33.42	46.00	12.60	V	F	High	
826.7	1.08	215	41.16	46.00	4.80	H	S	High	
826.7	1.00	254	37.30	46.00	8.70	H	V	High	
813.4	1.00	130	38.47	46.00	7.50	H	V	Mid	
813.4	1.00	210	40.20	46.00	5.80	H	S	Mid	

Tx Harmonics – Restricted Bands – Between 1-4 GHz

Tx Channel	Orientation	Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBuV/m)	Avg Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Antenna	Notes
Low	V	1601	1.14	0	48.42	41.40	54.00	12.60	H	
Low	V	1601	-	-	-	-	-	-	V	Note 1
Low	S	1601	2.23	42	46.69	37.88	54.00	16.12	H	
Low	S	1601	1.00	345	48.93	41.52	54.00	12.48	V	
Low	F	1601	1.31	164	50.01	43.39	54.00	10.61	H	
Low	F	1601	1.00	240	48.37	39.79	54.00	14.21	V	
Mid	V	1626	2.35	0	48.56	40.12	54.00	13.88	H	
Mid	V	1626	-	-	-	-	-	-	V	Note 1
Mid	S	1626	-	-	-	-	-	-	H	Note 1
Mid	S	1626	1.00	239	47.83	39.75	54.00	14.25	V	
Mid	F	1626	1.29	160	48.47	39.81	54.00	14.19	H	
Mid	F	1626	-	-	-	-	-	-	V	Note 1

**Note 1: Measurements denoted by "Noise floor" were not large enough in magnitude to be distinguished from noise floor and, thus, were not measured.*

Tx Harmonics – Restricted Bands above 4 GHz

Tx Channel	Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBuV/m)	Avg Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Antenna Polarity	EUT Orientation
Low	4804	1.00	122	48.40	41.30	54.00	12.70	V	S
Low	19216	3.30	165	54.60	44.00	54.00	10.00	H	S
Mid	4880	1.30	213	49.60	44.30	54.00	9.70	H	F
Mid	7320	1.00	117	48.10	38.90	54.00	15.10	H	F
Mid	19520	2.00	330	57.00	46.30	54.00	7.70	H	S
High	4960	1.00	208	52.20	48.10	54.00	5.90	H	F
High	7440	1.00	36	47.40	37.30	54.00	16.70	H	F
High	19840	1.45	330	56.30	46.10	54.00	7.90	H	S

Note: The data provided above depicts the highest harmonic emissions at the low, middle, and high channels.

Bluetooth Screen Captures - Radiated Emissions Test

Note: These screen captures represent peak emissions. For radiated emission measurements, a quasi-peak detector is utilized when measuring frequencies below 1 GHz, and a peak detector is utilized when measuring frequencies above 1 GHz. In the 30-200 MHz and 200-1000 MHz range, screen shots provided are representative of the worst-case EUT orientation for each channel and antenna polarization.

Low Channel (2402 MHz), Vertical Orientation, Antenna Vertically Polarized, 30-200 MHz, at 3m

Low Channel, Flat Orientation, Antenna Horizontally Polarized, 300-200 MHz, at 3m

Mid Channel (2440 MHz), Side Orientation, Antenna Vertically Polarized, 30-200 MHz, at 3m

Mid Channel, Flat Orientation, Antenna Horizontally Polarized, 30-200 MHz, at 3m

High Channel (2480 MHz), Vertical Orientation, Vertically Polarized, 30-200 MHz, at 3m

High Channel, Side Orientation Antenna Horizontally Polarized, 30-200 MHz, at 3m

Low Channel, Vertical Orientation, Antenna Vertically Polarized, 200 - 1000 MHz, at 3m

Low Channel, Vertical Orientation, Antenna Horizontally Polarized, 200 - 1000 MHz, at 3m

Mid Channel, Side Orientation, Antenna Vertically Polarized, 200 - 1000 MHz, at 3m

Mid Channel, Side Orientation, Antenna Horizontally Polarized, 200 - 1000 MHz, at 3m

High Channel, Flat Orientation, Antenna Vertically Polarized, 200 - 1000 MHz, at 3m

High Channel, Side Orientation, Antenna Horizontally Polarized, 200 - 1000 MHz, at 3m

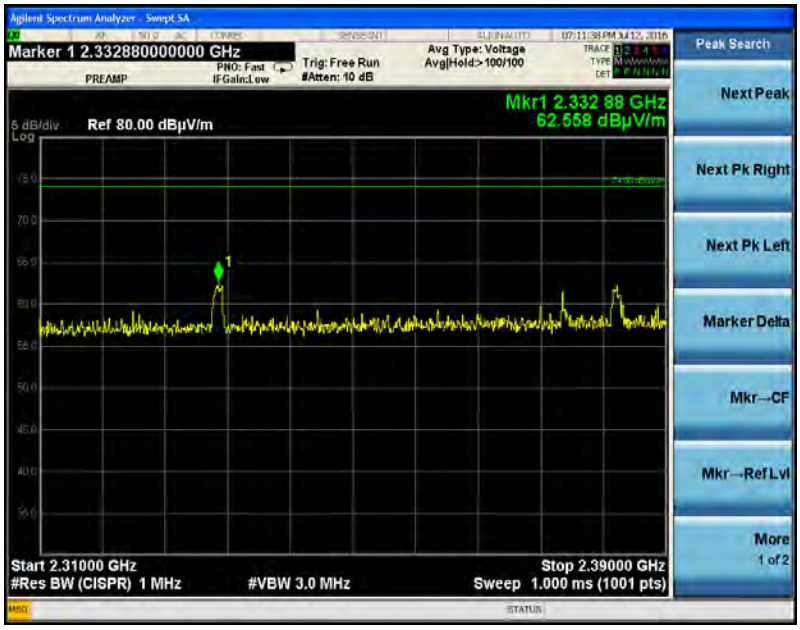
Low Channel, Vertical Orientation, Antenna Horizontally Polarized, 1000 MHz to 2310 MHz, Reduced VBW

Low Channel, Side Orientation, Antenna Vertically Polarized, 1000 MHz to 2310 MHz, Reduced VBW

Mid Channel, Vertical Orientation, Antenna Horizontally Polarized, 1000 MHz to 2310 MHz, Reduced VBW

Mid Channel, Vertical Orientation, Antenna Vertically Polarized, 1000 MHz to 2310 MHz, Reduced VBW

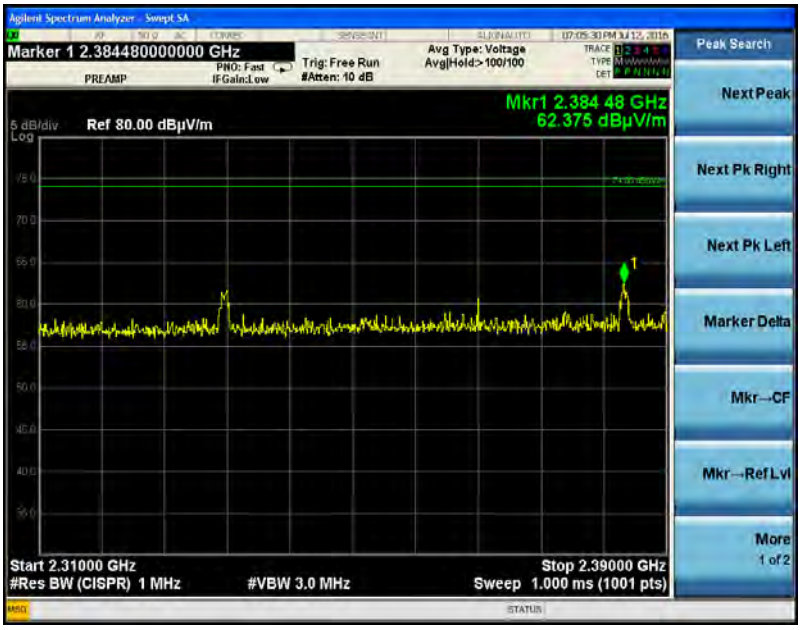
Low Channel, Flat Orientation, Antenna Horizontally Polarized, GFSK, 2310-2390 MHz, Peak at 3m



Low Channel, Flat Orientation, Antenna Horizontally Polarized, GFSK, 2310-2390 MHz, Avg at 3m[1]

[1] Note: The video bandwidth was configured by determining the time the transmitter is on. For GFSK, the transmitter "on time" was measured to be 2.892 ms. The reciprocal of the transmitter on time is 346. Thus, a video bandwidth of 390 Hz is used for the average measurement.

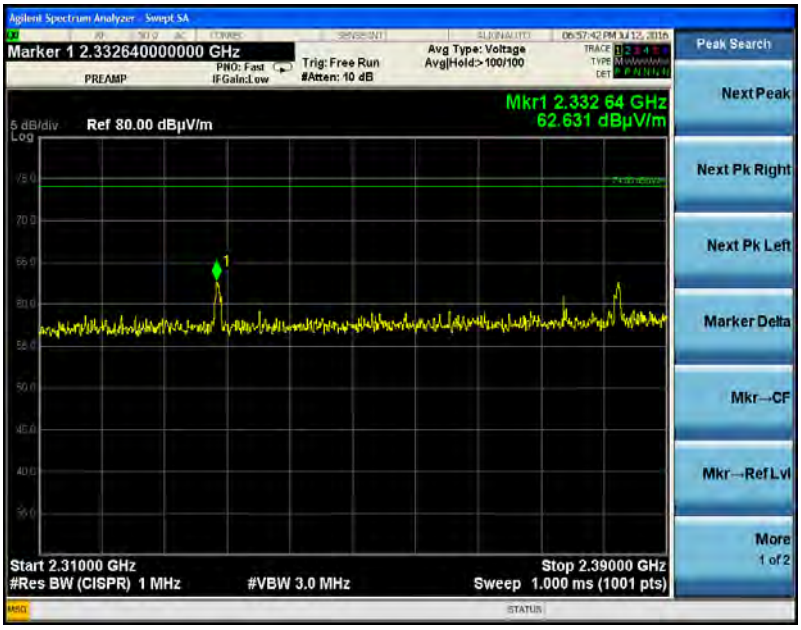
Low Channel, Flat Orientation, Antenna Horizontally Polarized, EDR2, 2310-2390 MHz, Peak at 3m



Low Channel, Flat Orientation, Antenna Horizontally Polarized, EDR2, 2310-2390 MHz, Avg at 3m[2]

[2] Note: The video bandwidth was configured by determining the time the transmitter is on. For EDR2, the transmitter "on time" was measured to be 2.894 ms. The reciprocal of the transmitter on time is 346. Thus, a video bandwidth of 390 Hz is used for the average measurement.

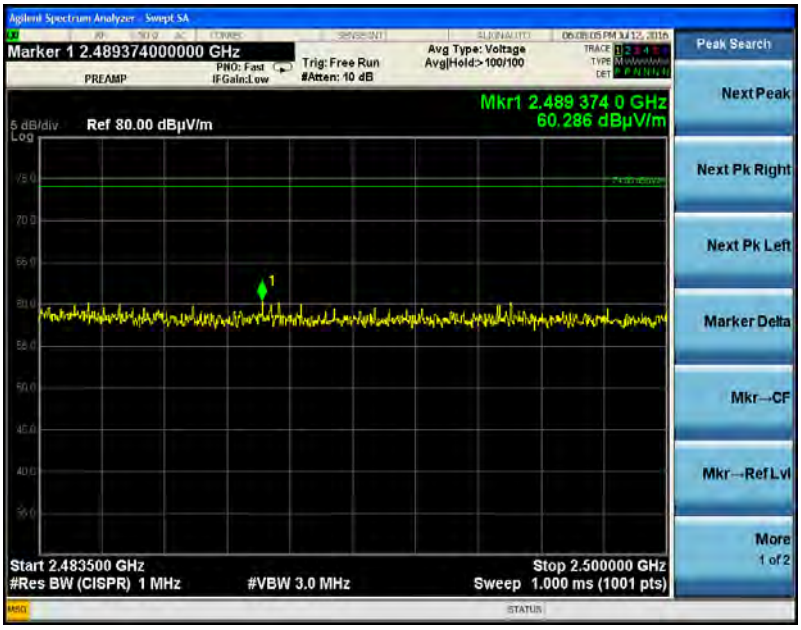
Low Channel, Flat Orientation, Antenna Horizontally Polarized, EDR3, 2310-2390 MHz, Peak at 3m



Low Channel, Flat Orientation, Antenna Horizontally Polarized, EDR3, 2310-2390 MHz, Avg at 3m[3]

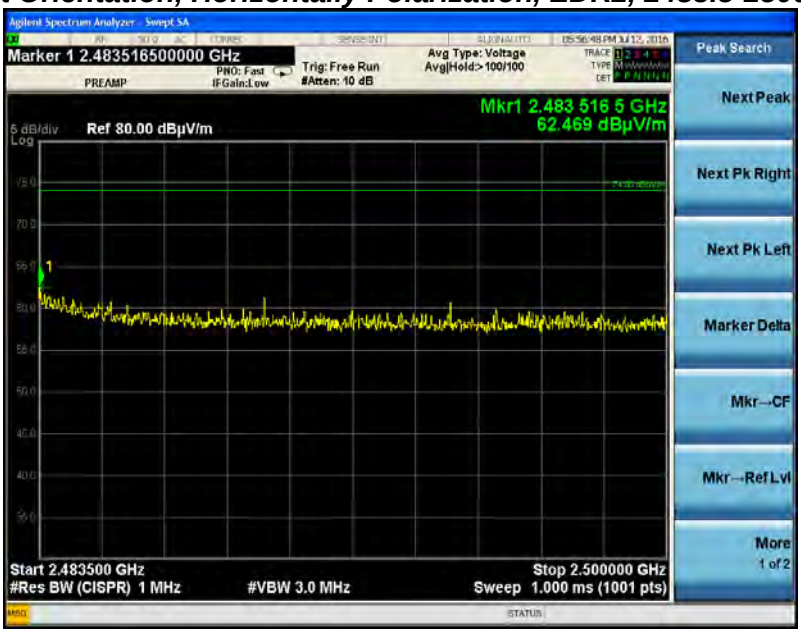
[3] Note: The video bandwidth was configured by determining the time the transmitter is on. For EDR2, the transmitter "on time" was measured to be 2.896 ms. The reciprocal of the transmitter on time is 345. Thus, a video bandwidth of 390 Hz is used for the average measurement.

High Channel, Flat Orientation, Horizontally Polarization, GFSK, 2483.5-2500 MHz, Peak at 3m



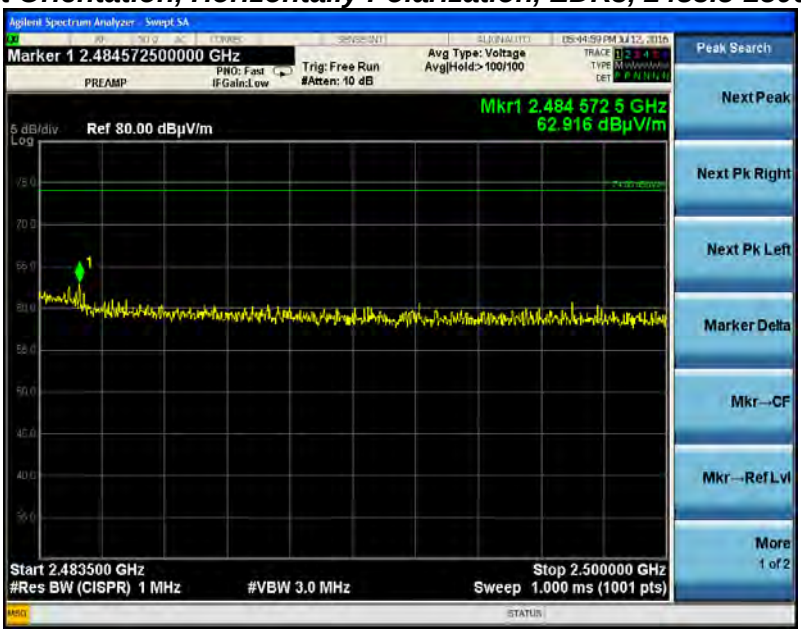
High Channel, Flat Orientation, Horizontally Polarization, GFSK, 2483.5-2500 MHz, Avg at 3m

High Channel, Flat Orientation, Horizontally Polarization, EDR2, 2483.5-2500 MHz, Peak at 3m



High Channel, Flat Orientation, Horizontally Polarization, EDR2, 2483.5-2500 MHz, Avg at 3m

High Channel, Flat Orientation, Horizontally Polarization, EDR3, 2483.5-2500 MHz, Peak at 3m



High Channel, Flat Orientation, Horizontally Polarization, EDR3, 2483.5-2500 MHz, Avg at 3m

Channel 39, Vertical Orientation, Antenna Horizontally Polarized, 2500 MHz to 4000 MHz, Reduced VBW

Channel 39, Vertical Orientation, Antenna Vertically Polarized, 2500 MHz to 4000 MHz, Reduced VBW

Low Channel, Side Orientation, Antenna Vertically Polarized, 4-18 GHz, Reduced VBW at 3m

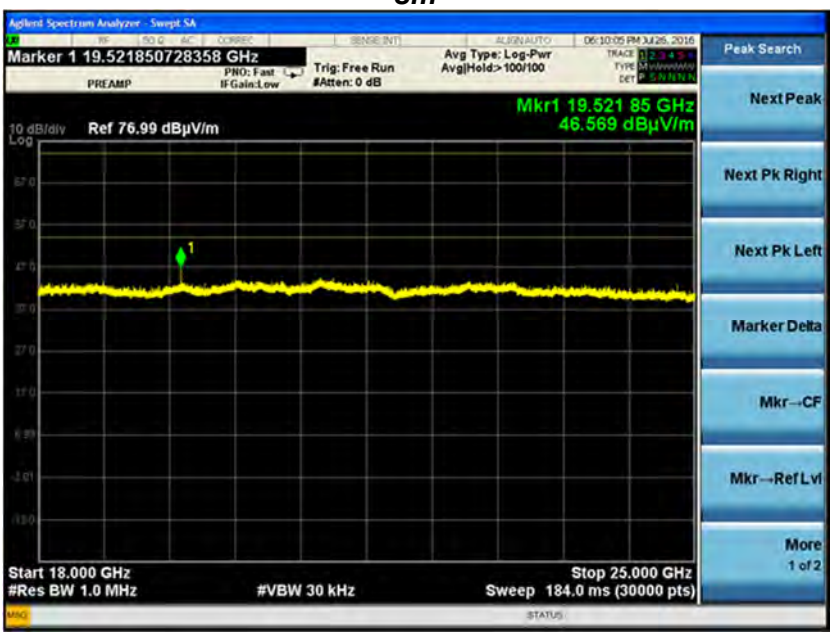
Low Channel, Side Orientation, Antenna Horizontally Polarized, 4-18 GHz, Reduced VBW at 3m

Mid Channel, Flat Orientation, Antenna Horizontally Polarized, 4-18 GHz, Reduced VBW at 3m

Mid Channel, Flat Orientation, Antenna Horizontally Polarized, 4-18 GHz, Reduced VBW at 3m

Low Channel, Side Orientation, Antenna Horizontally Polarized, 18-25 GHz, Reduced VBW at 3m

Mid Channel, Side Orientation, Antenna Horizontally Polarized, 18-25 GHz, Reduced VBW at 3m



High Channel, Side Orientation, Antenna Horizontally Polarized, 18-25 GHz, Reduced VBW at 3m

High Channel, Vertical Orientation, Antenna Vertically Polarized, 18-25 GHz, Reduced VBW at 3m

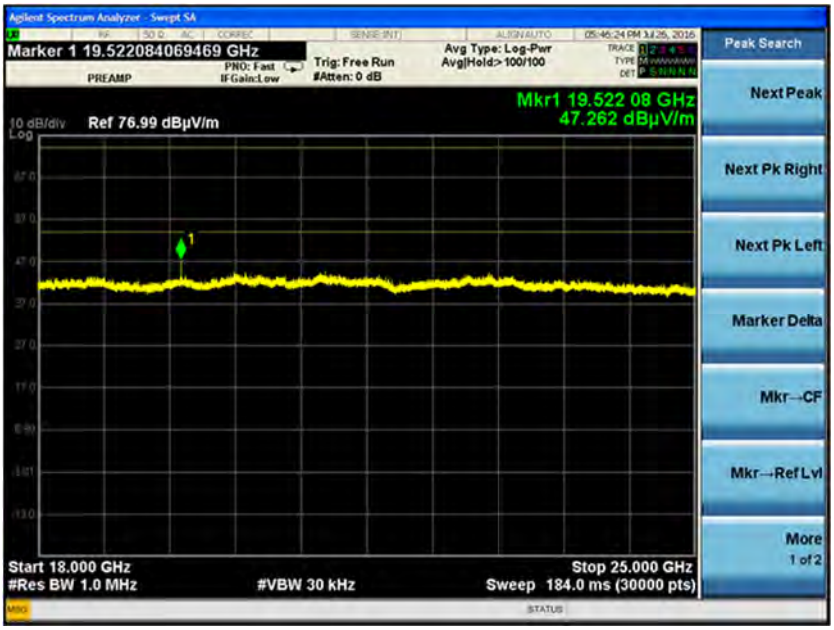


EXHIBIT 6. OCCUPIED BANDWIDTH

6.1 - Limits

For a Frequency Hopping System, the hopping channel carrier frequencies shall be separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater.

6.2 - Method of Measurements

Refer to ANSI C63.10 (2013) Sections 6.9.2 and 7.8.7.

The transmitter output was connected to the Spectrum Analyzer via a 10 dB attenuator. The bandwidth requirement found in FCC Part 15.247(a)(1) and the applicable Canadian standard requires hopping channel carrier frequencies be separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel. The EUT was coupled to a low loss cable via a U.FL connector and provided to the spectrum analyzer via the 10 dB attenuator see images. The EUT was connected to a programming board that enabled modification of data rate, modulation type, and output power, thereby promoting quick and efficient collection of all applicable measurements. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, thereby allowing direct measurements, without the need for any further corrections. The EUT was configured to run in a continuous transmit mode.

6.3 - Test Equipment List

A complete list of test equipment that was used for this test can be found in Appendix A.

6.4 - Test Data

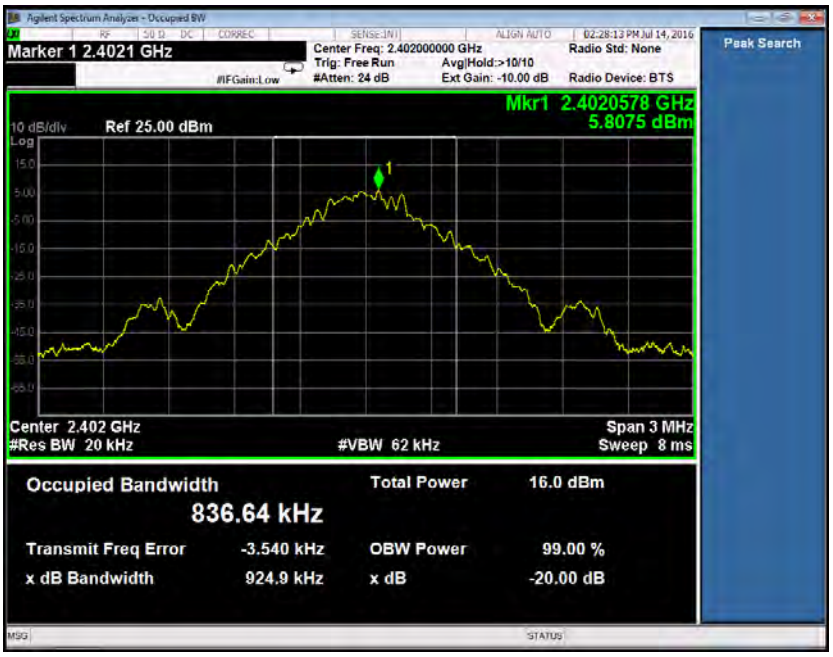
Bluetooth:

Data Rate (MBPS)	Channel	Frequency (MHz)	20 dB BW (kHz)	99% BW (kHz)
1	0	2402	924.9	836.6
1	39	2441	937.8	837.6
1	78	2480	931.6	835.5
2	0	2402	1340	1200
2	39	2441	1340	1200
2	78	2480	1333	1200
3	0	2402	1337	1209
3	39	2441	1338	1206
3	78	2480	1334	1205

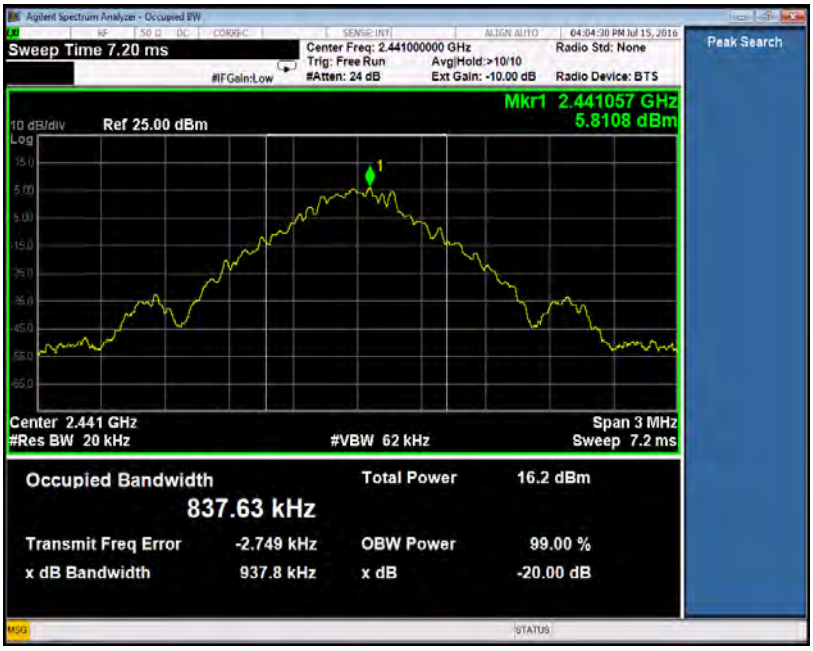
6.5 - Screen Captures - Occupied Bandwidth

Bluetooth:

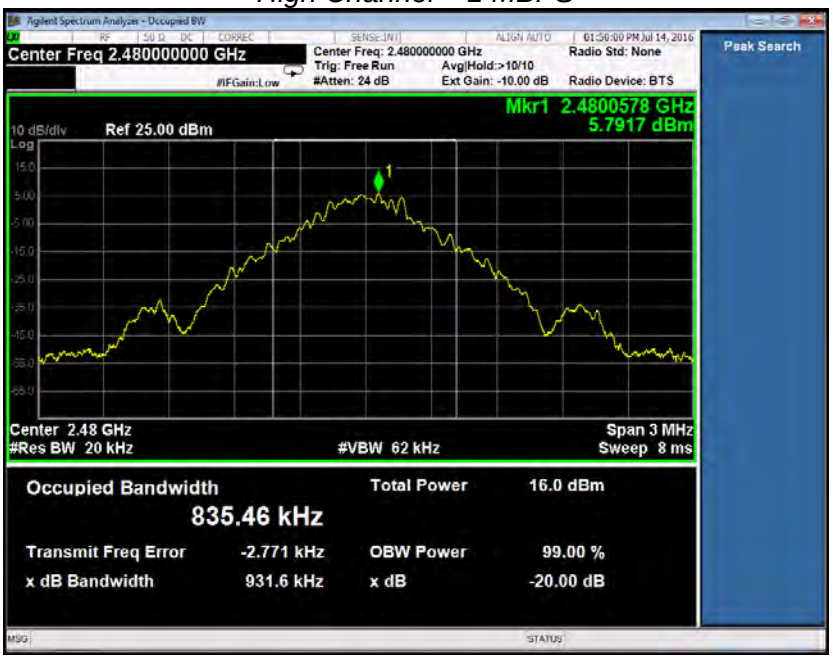
Low Channel – 1 MBPS



Mid Channel – 1 MBPS



High Channel – 1 MBPS



Low Channel – 2 MBPS

Mid Channel – 2 MBPS

High Channel – 2 MBPS

Low Channel – 3 MBPS

Mid Channel – 3 MBPS

High Channel – 3 MBPS

EXHIBIT 7. BAND EDGE MEASUREMENTS

7.1 - Method of Measurements

47 CFR Part 15.247(d) requires spurious emission levels to be at least 20 dB lower than the radio frequency power produced by the intentional radiator. The following screen captures demonstrate compliance of the intentional radiator at the 2400-2483.5 MHz Band-Edges. The EUT was operated in continuous transmit mode at each data rate and modulation type. The EUT operated at the low channel for investigation of the lower band-edge, and at the high channel for the investigation of the upper band-edge. The delta measurement represents the margin between the peak fundamental emission and the band edge or highest modulation product of the fundamental emission, whichever is higher.

The testing was performed in continuous transmit mode and frequency hopping mode per ANSI C63.10 Sections 6.10 and 7.8.6.

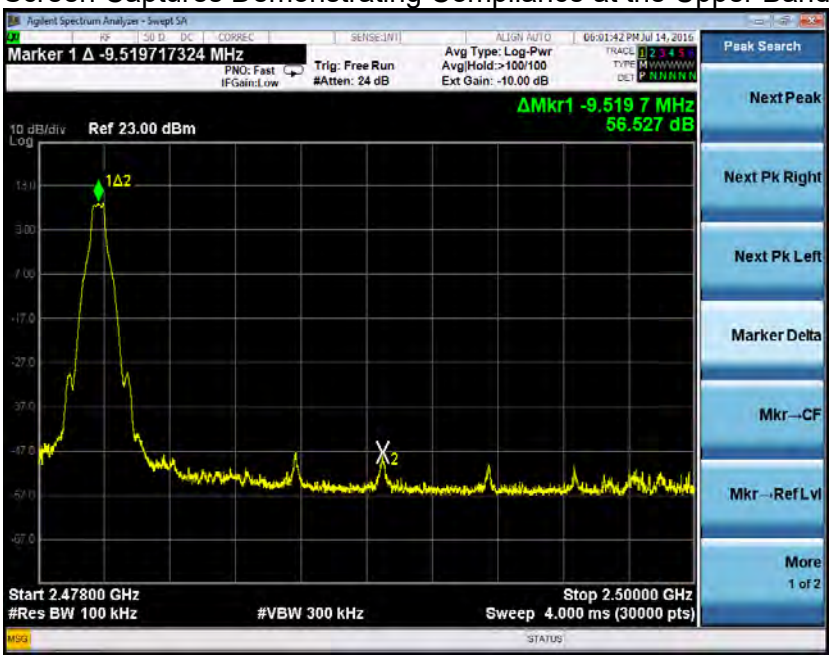
Bluetooth

1 MBPS[4]

Screen Capture Demonstrating Compliance at the Lower Band-Edge

[4] The screen captures were collected with the frequency hopping function of the transmitter turned off.

Screen Captures Demonstrating Compliance at the Upper Band-Edge



2 MBPS[5]

Screen Capture Demonstrating Compliance at the Lower Band-Edge

[5] The screen captures were collected with the frequency hopping function of the transmitter turned off.

Screen Capture Demonstrating Compliance at the Upper Band-Edge

3 MBPS[6]

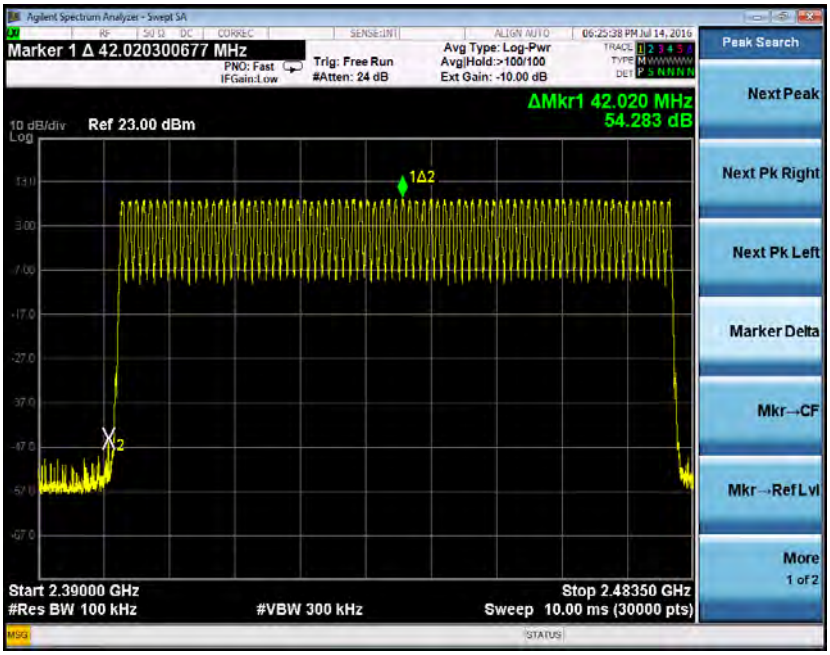
Screen Capture Demonstrating Compliance at the Lower Band-Edge

[6] The screen captures were collected with the frequency hopping function of the transmitter turned off.

Screen Capture Demonstrating Compliance at the Upper Band-Edge

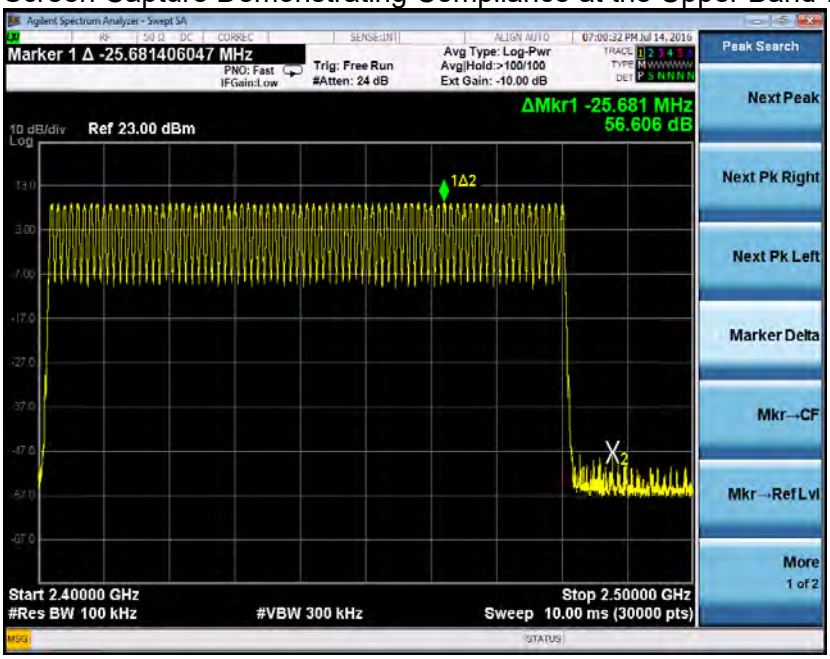
1 MBPS[7]

Screen Capture Demonstrating Compliance at the Lower Band-Edge



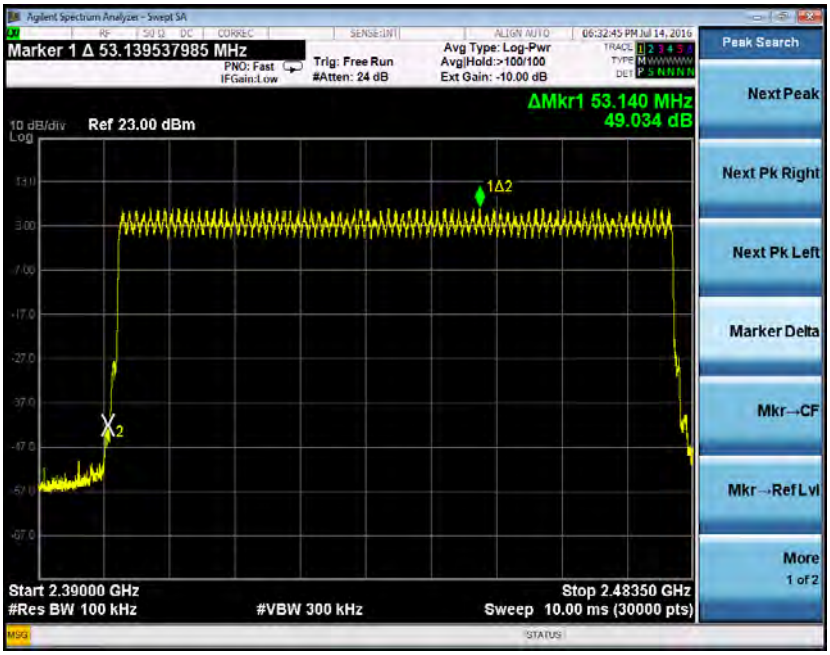
[7] The screen captures were collected with the frequency hopping function of the transmitter turned on.

Screen Capture Demonstrating Compliance at the Upper Band-Edge



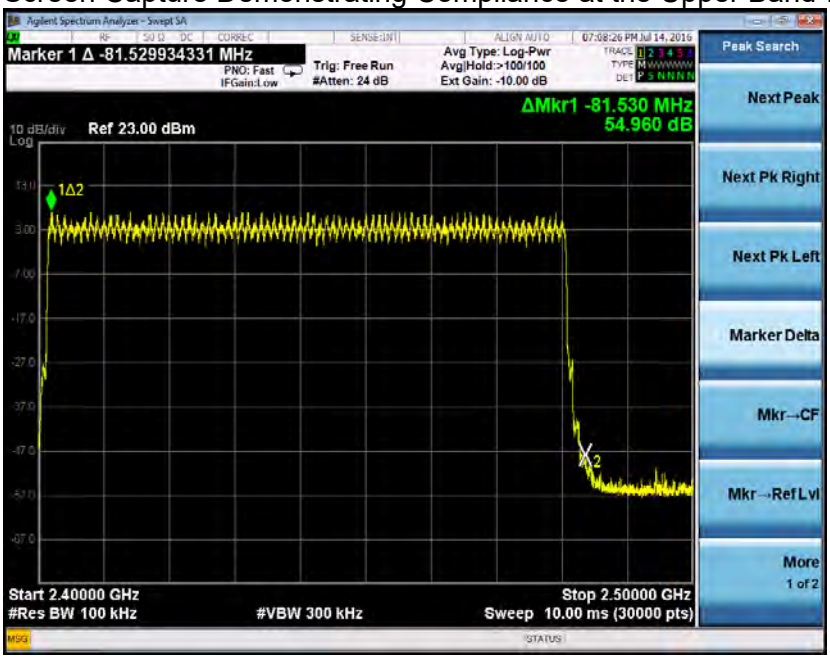
2 MBPS[8]

Screen Capture Demonstrating Compliance at the Lower Band-Edge



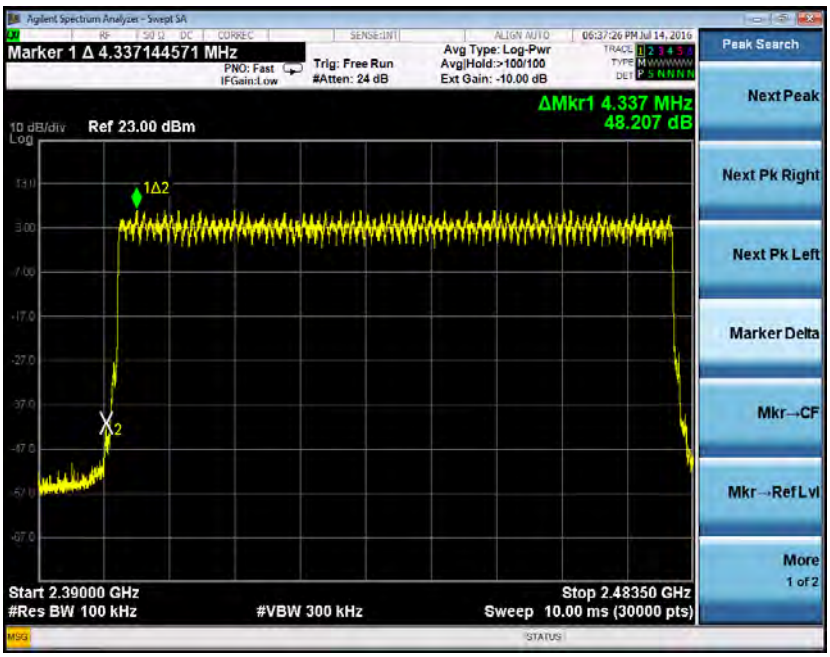
[8] The screen captures were collected with the frequency hopping function of the transmitter turned on.

Screen Capture Demonstrating Compliance at the Upper Band-Edge



3 MBPS[9]

Screen Capture Demonstrating Compliance at the Lower Band-Edge



[9] The screen captures were collected with the frequency hopping function of the transmitter turned on.

Screen Capture Demonstrating Compliance at the Upper Band-Edge

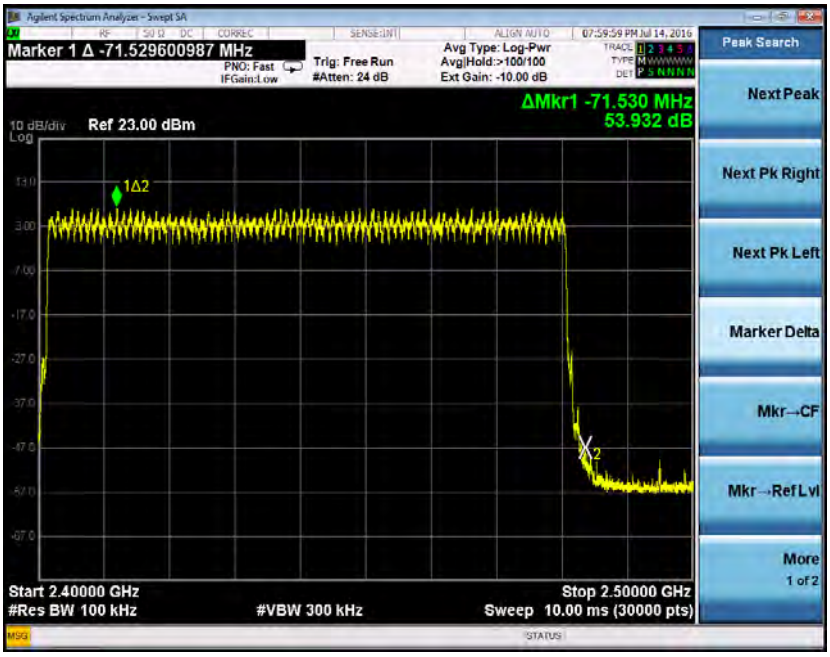


EXHIBIT 8. POWER OUTPUT (CONDUCTED): 15.247(b)

8.1 - Method of Measurements

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. For Bluetooth, a spectrum analyzer was used and configured to detect maximum peak conducted output power using a 2 MHz resolution bandwidth and a 6 MHz video bandwidth per ANSI C63.10 Section 7.8.5.

8.2 - Test Equipment List

A complete list of test equipment that was used for this test can be found in Appendix A.

8.3 - Test Data

Bluetooth:

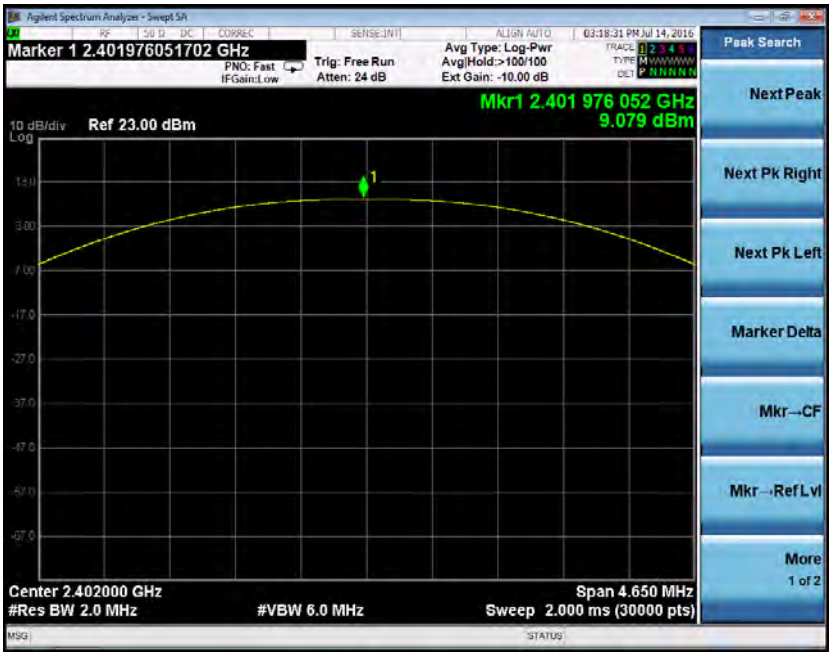
Data Rate (MBPS)	Channel	Frequency (MHz)	Output Power (dBm)	Power Limit (dBm)	2.4 GHz Flex Pifa Antenna Gain (dBi)	Calculated EIRP (dBm)[1]	EIRP Limit (dBm)	Margin (dB)
1	0	2402	9.079	30	2	11.079	36	24.921
1	39	2441	9.005	30	2	11.005	36	24.995
1	78	2480	9.064	30	2	11.064	36	24.936
2	0	2402	9.069	30	2	11.069	36	24.931
2	39	2441	8.987	30	2	10.987	36	25.013
2	78	2480	9.134	30	2	11.134	36	24.866
3	0	2402	9.698	30	2	11.698	36	24.302
3	39	2441	9.633	30	2	11.633	36	24.637
3	78	2480	9.834	30	2	11.834	36	24.166

1 – EIRP Calculation – (Peak power at antenna terminal (in dBm)) + (EUT antenna gain (in dBi))

8.4 - Screen Captures – Power Output (Conducted)

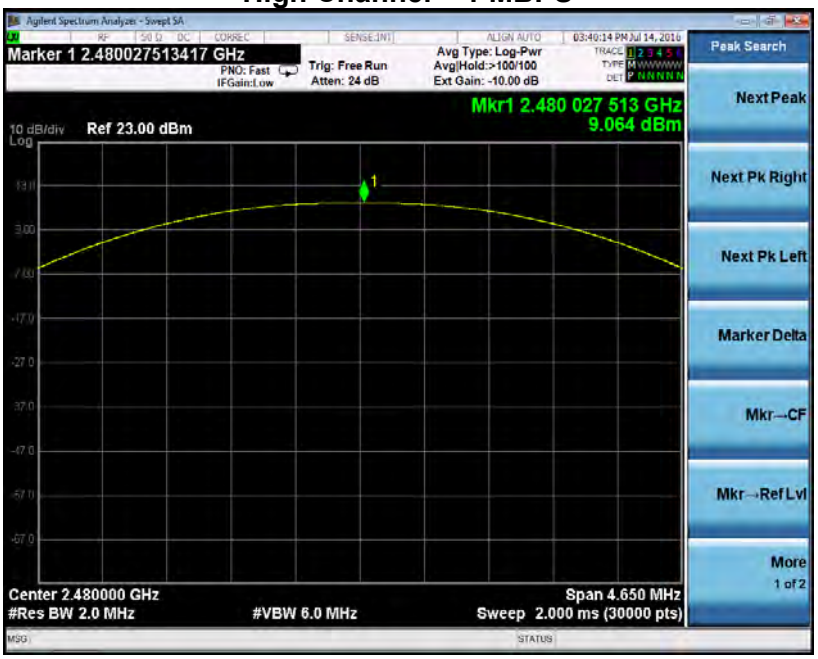
Bluetooth:

Low Channel – 1 MBPS



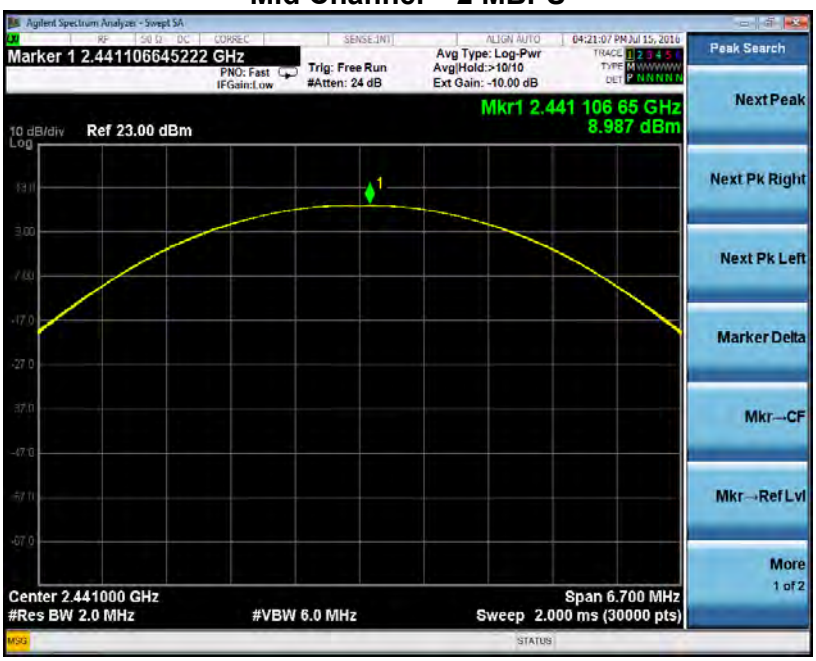
Mid Channel – 1 MBPS

High Channel – 1 MBPS

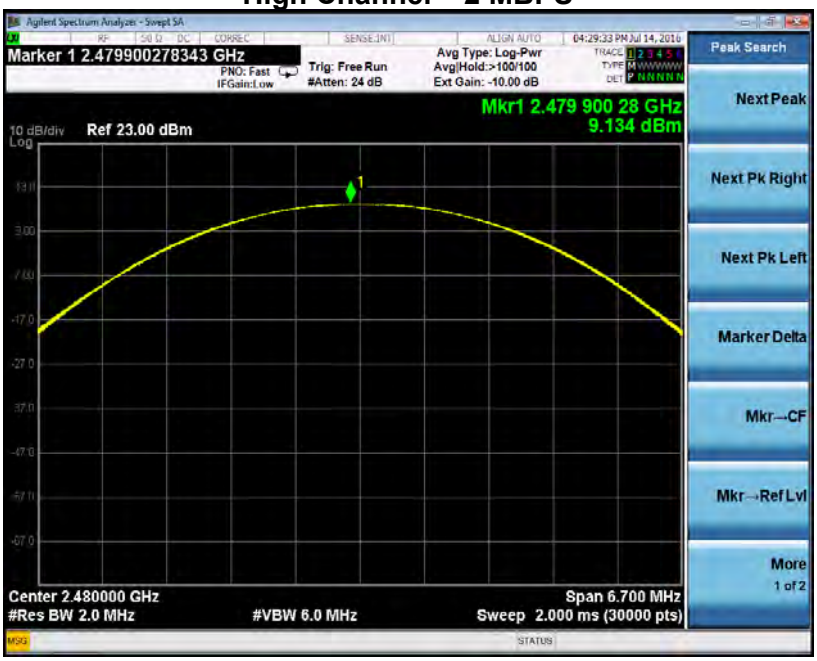


Low Channel – 2 MBPS

Mid Channel – 2 MBPS

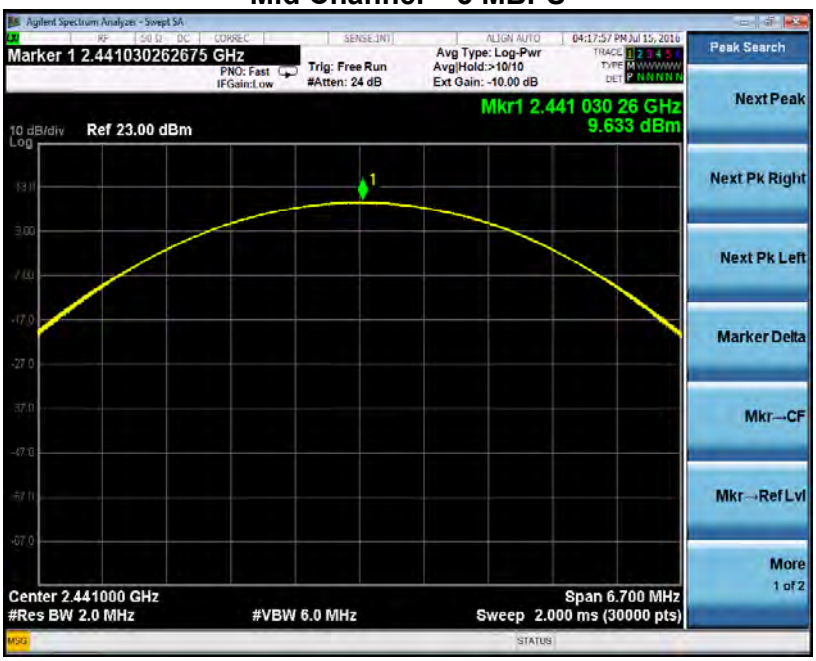


High Channel – 2 MBPS



Low Channel – 3 MBPS

Mid Channel – 3 MBPS



High Channel – 3 MBPS

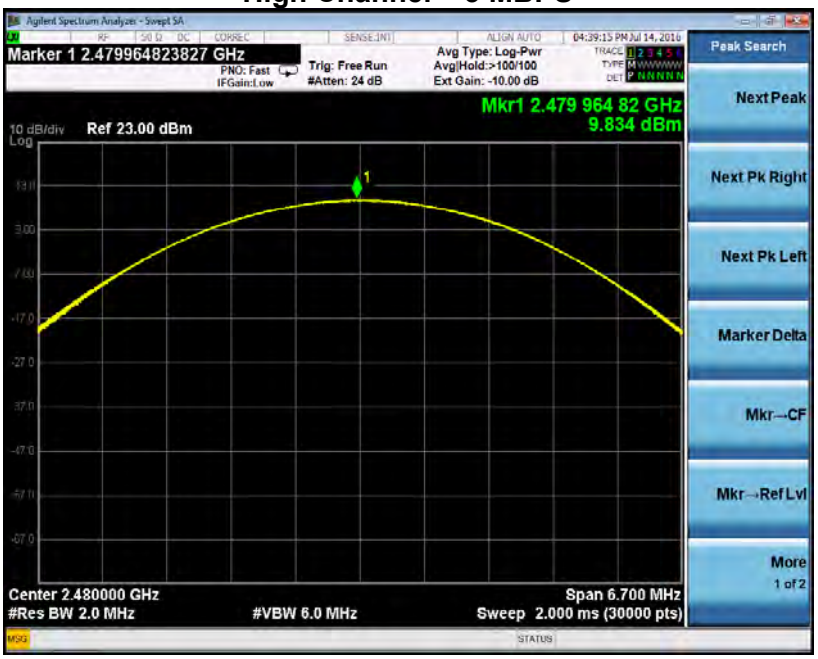


EXHIBIT 9. SPURIOUS CONDUCTED EMISSIONS: 15.247(d)

9.1 - 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.

In addition, radiated emissions, which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(e)

Reported data is the raw data corrected for all applicable factors such as antenna factors, cable loss, etc.

9.2 – Conducted Harmonic and Spurious RF Measurements

FCC Part 15.247(d) require a measurement of conducted harmonic 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. A spectrum analyzer was used with a resolution bandwidth of 100 kHz for this portion of the test. A reference level was determined by measuring the peak conducted output power of the EUT in a 100 kHz bandwidth and subtracting 20 dB from that measurement. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer utilized a peak detector during the testing. Screen captures were acquired and any noticeable spurious and harmonic signals were identified and measured. The three highest spurious emissions are provided in the tables below for Bluetooth operability.

Bluetooth:

Tx Channel	Data Rate	Frequency (MHz)	Peak Level (dBm)	Reference Level (dBm)	Margin (dB)
0	3 MBPS	2399.7	-44.142	-12.98	31.162
0	3 MBPS	24992	-45.283	-12.98	32.303
78	1 MBPS	24010	-46.313	-10.94	35.373

9.3 - Test Equipment List

A complete list of test equipment that was used for this test can be found in Appendix A.

9.4 - Screen Captures – Spurious Radiated Emissions

Reference Levels:

Low Channel, 1 MBPS

Mid Channel, 1 MBPS

High Channel, 1 MBPS

Low Channel, 2 MBPS

Mid Channel, 2MBPS

High Channel, 2 MBPS

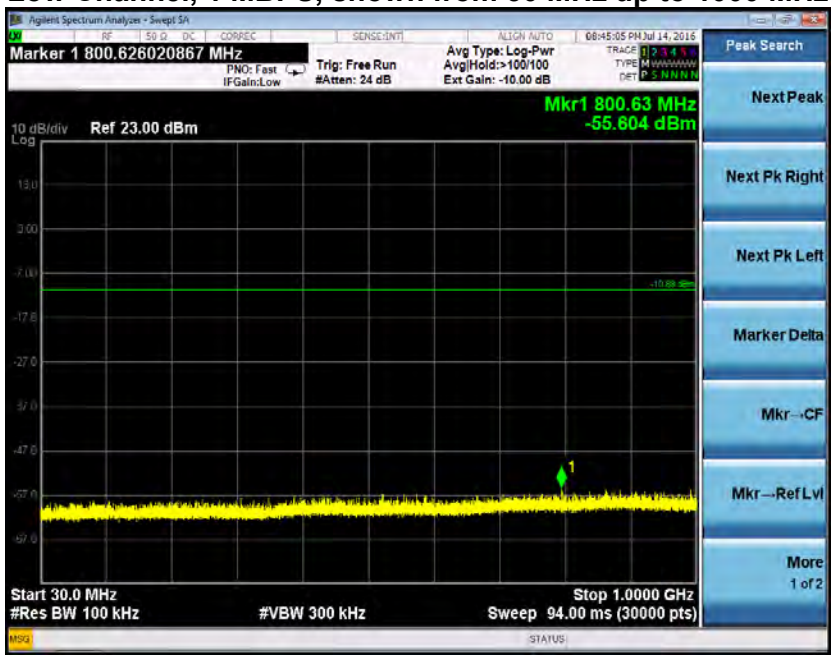
Low Channel, 3 MBPS

Mid Channel, 3 MBPS

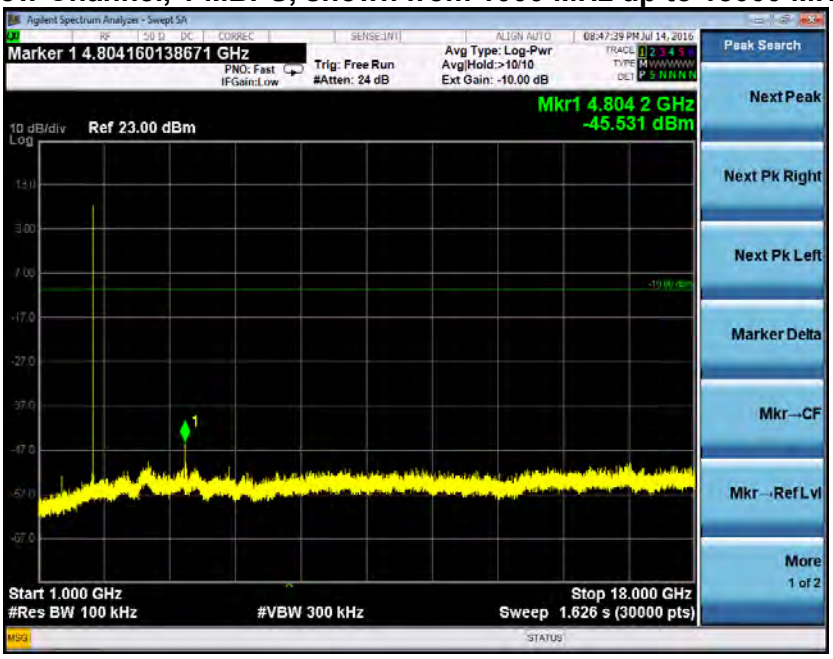
High Channel, 3 MBPS

Bluetooth Spurious Conducted Emissions:

Low Channel, 1 MBPS, shown from 30 MHz up to 1000 MHz

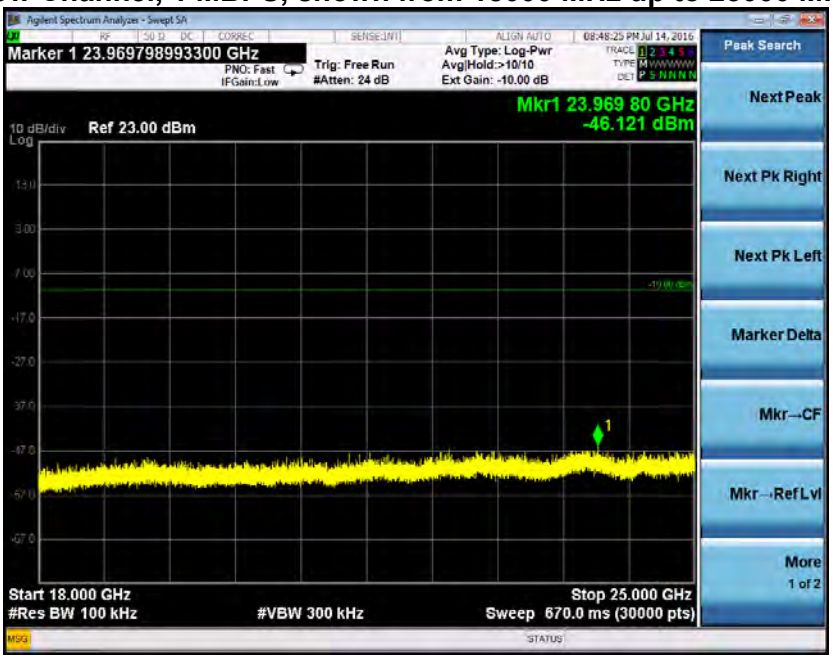


Low Channel, 1 MBPS, shown from 1000 MHz up to 18000 MHz



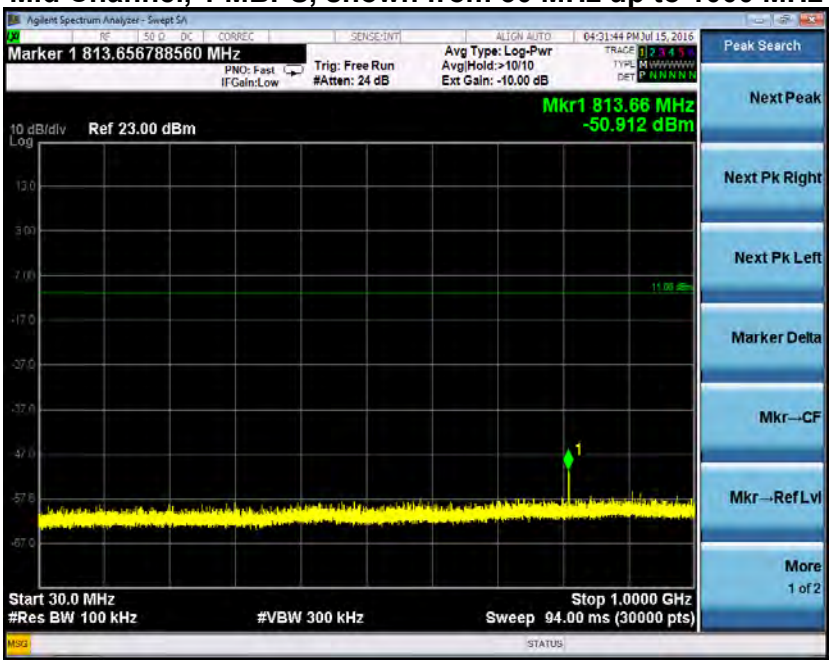
***Emission shown in restricted frequency band**

Low Channel, 1 MBPS, shown from 18000 MHz up to 25000 MHz

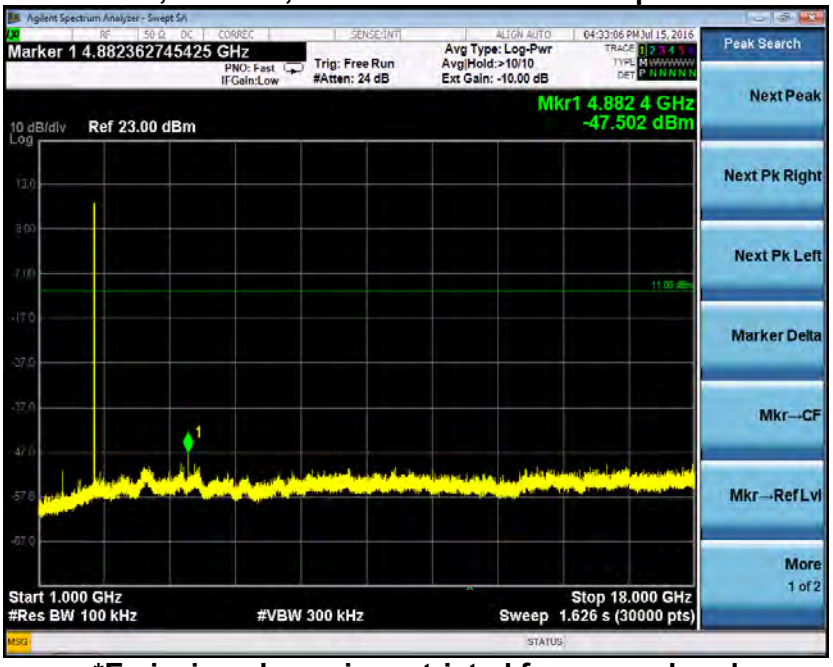


***Emission shown in restricted frequency band**

Mid Channel, 1 MBPS, shown from 30 MHz up to 1000 MHz

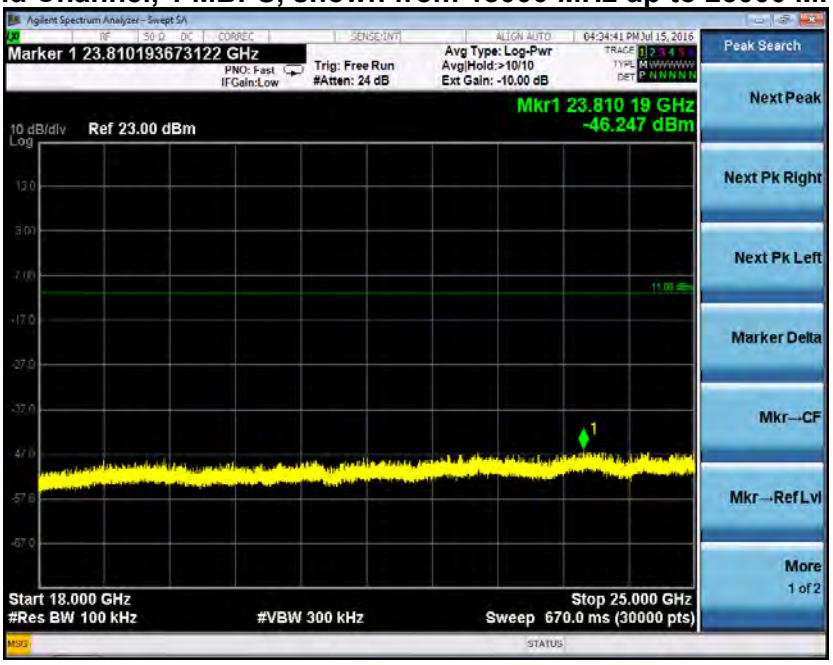


Mid Channel, 1 MBPS, shown from 1000 MHz up to 18000 MHz



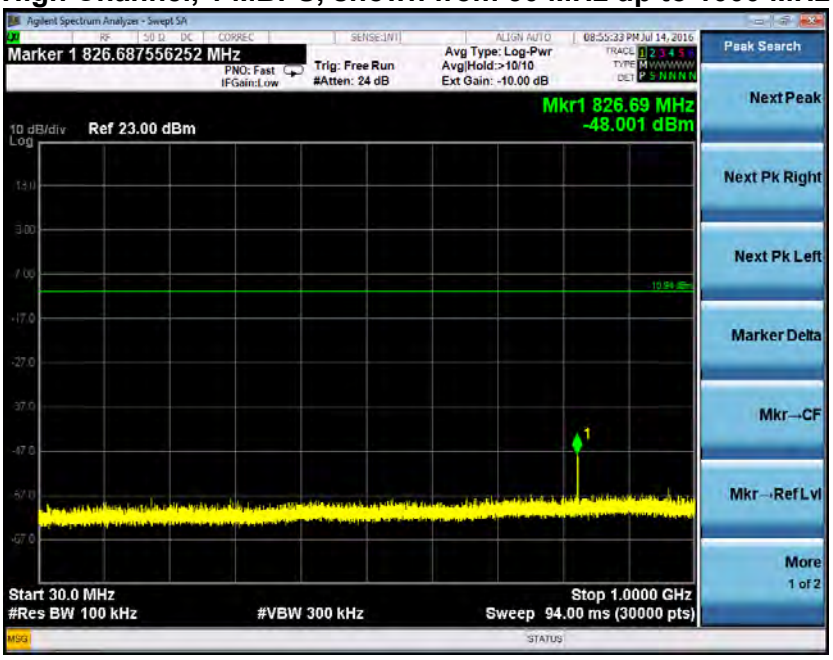
***Emission shown in restricted frequency band**

Mid Channel, 1 MBPS, shown from 18000 MHz up to 25000 MHz

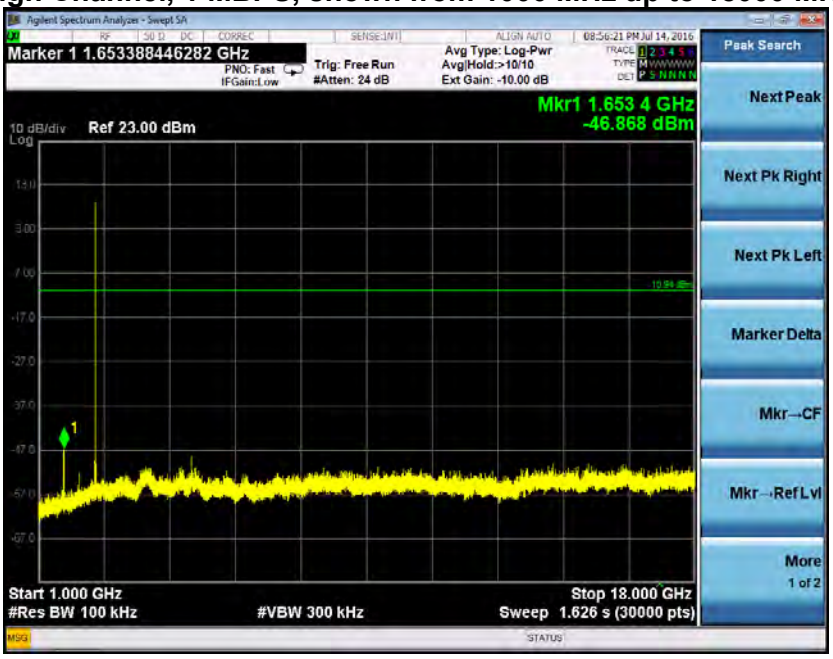


***Emission shown in restricted frequency band**

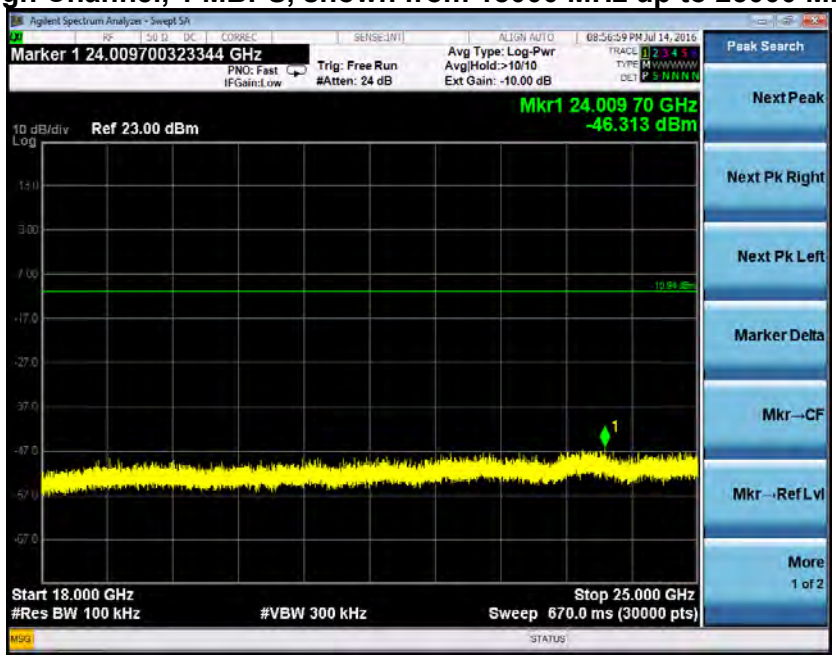
High Channel, 1 MBPS, shown from 30 MHz up to 1000 MHz



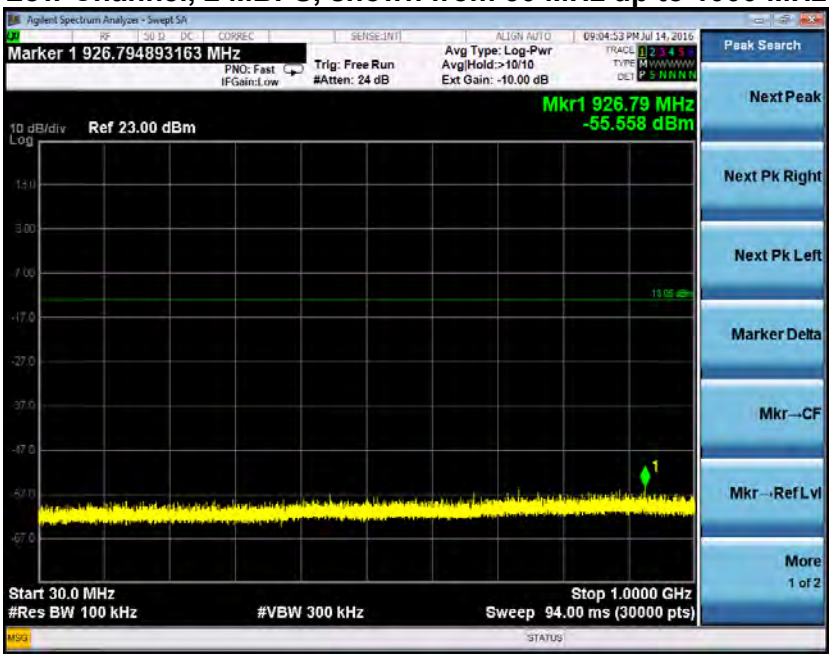
High Channel, 1 MBPS, shown from 1000 MHz up to 18000 MHz



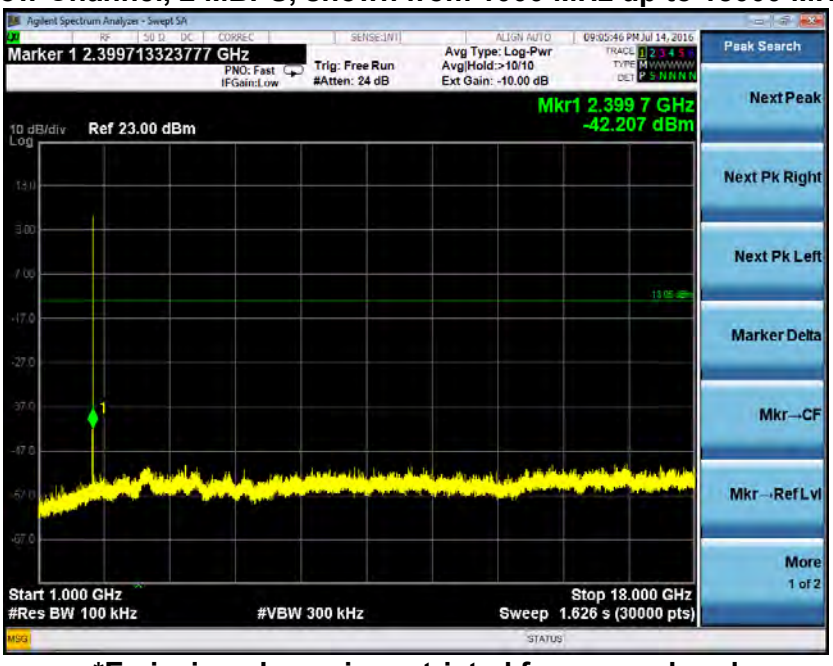
High Channel, 1 MBPS, shown from 18000 MHz up to 25000 MHz



Low Channel, 2 MBPS, shown from 30 MHz up to 1000 MHz

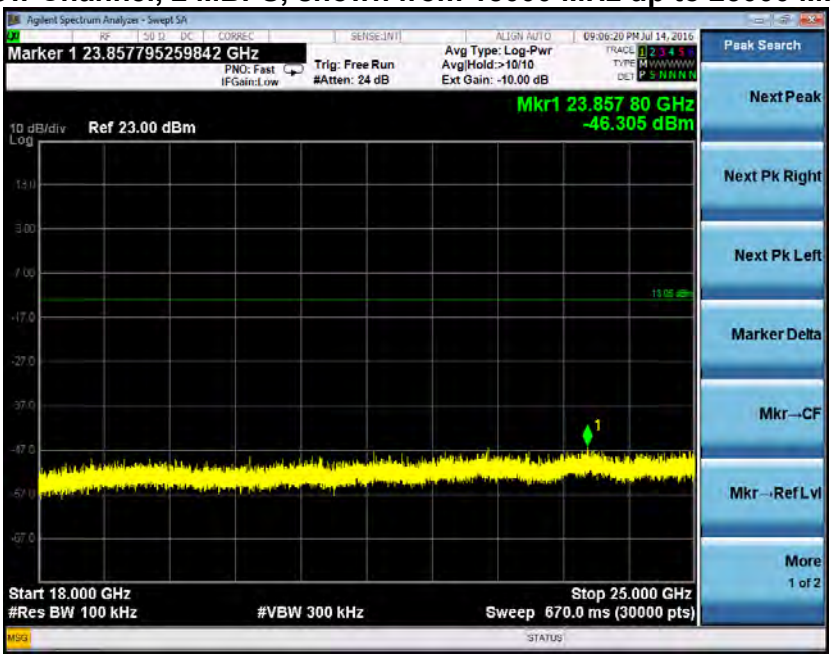


Low Channel, 2 MBPS, shown from 1000 MHz up to 18000 MHz



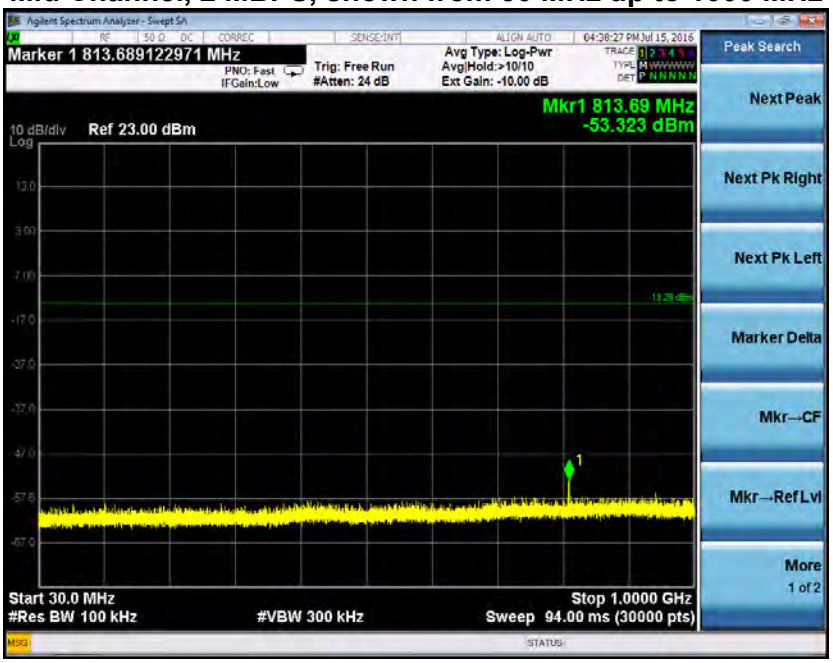
***Emission shown in restricted frequency band**

Low Channel, 2 MBPS, shown from 18000 MHz up to 25000 MHz

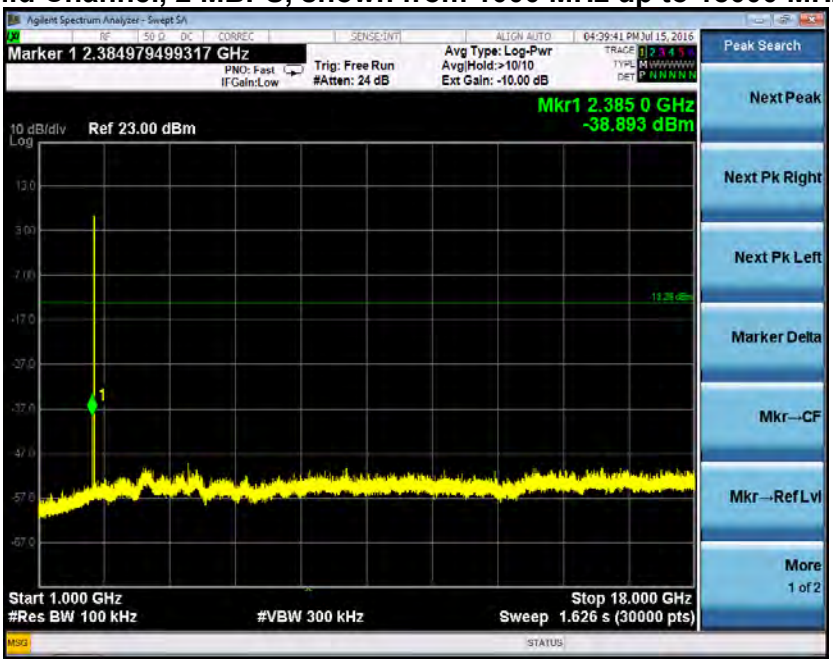


***Emission shown in restricted frequency band**

Mid Channel, 2 MBPS, shown from 30 MHz up to 1000 MHz

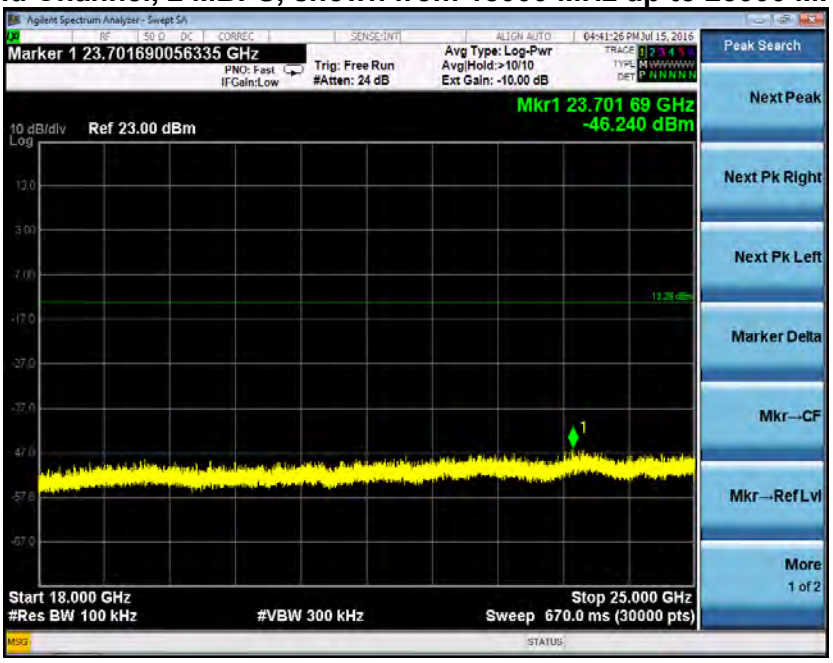


Mid Channel, 2 MBPS, shown from 1000 MHz up to 18000 MHz



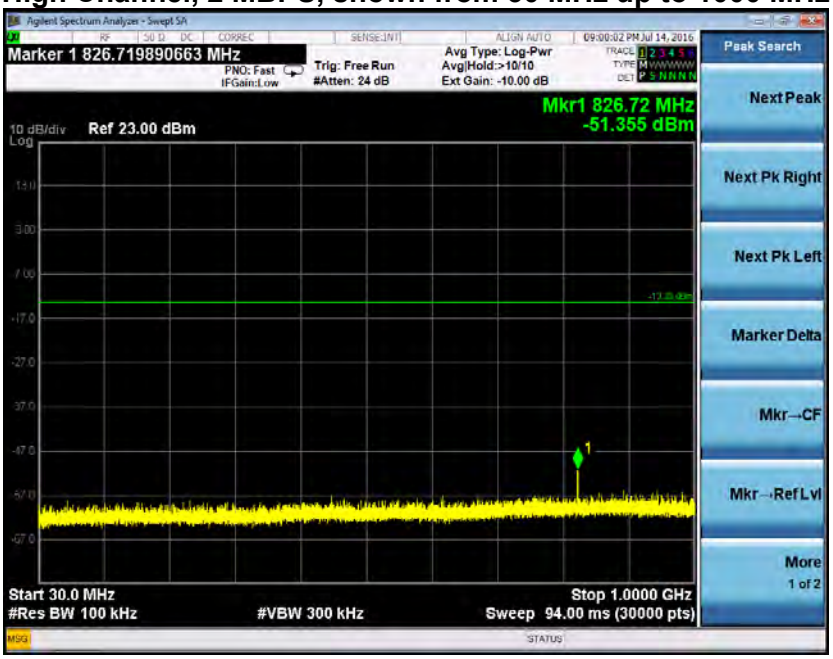
***Emission shown in restricted frequency band**

Mid Channel, 2 MBPS, shown from 18000 MHz up to 25000 MHz

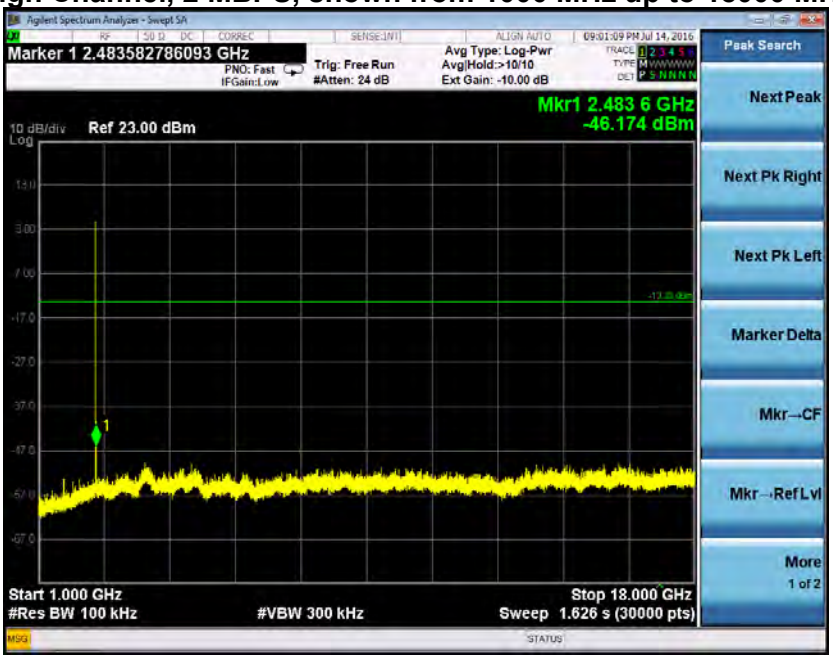


***Emission shown in restricted frequency band**

High Channel, 2 MBPS, shown from 30 MHz up to 1000 MHz

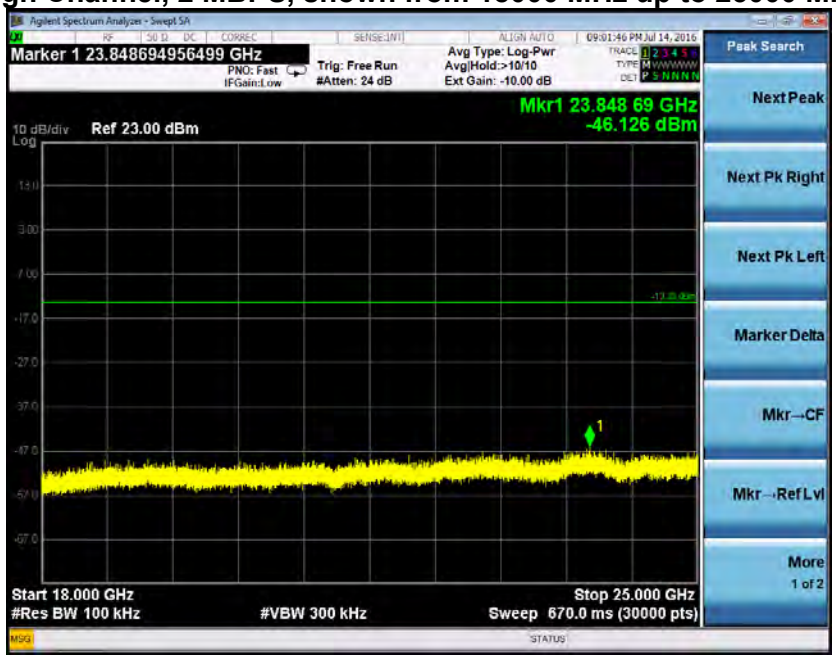


High Channel, 2 MBPS, shown from 1000 MHz up to 18000 MHz



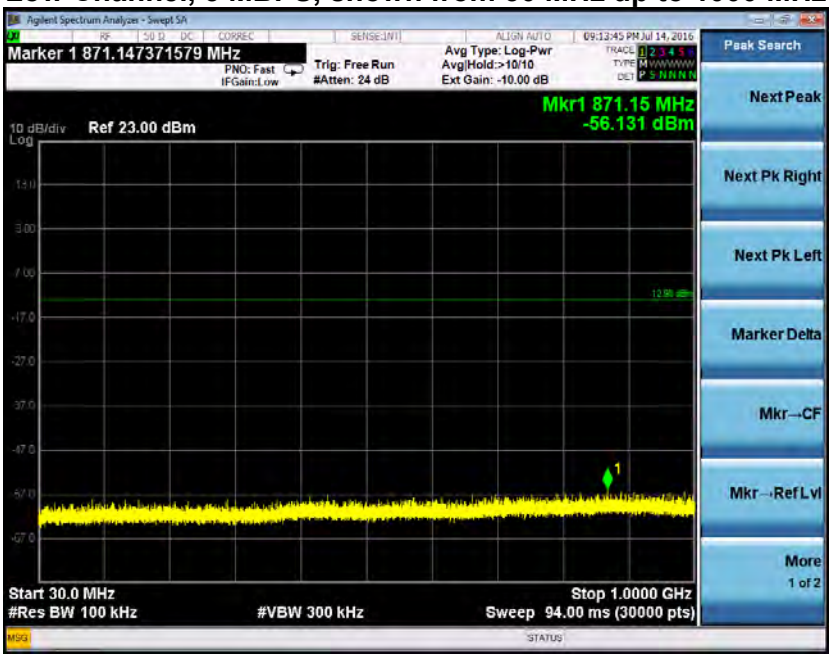
***Emission shown in restricted frequency band**

High Channel, 2 MBPS, shown from 18000 MHz up to 25000 MHz

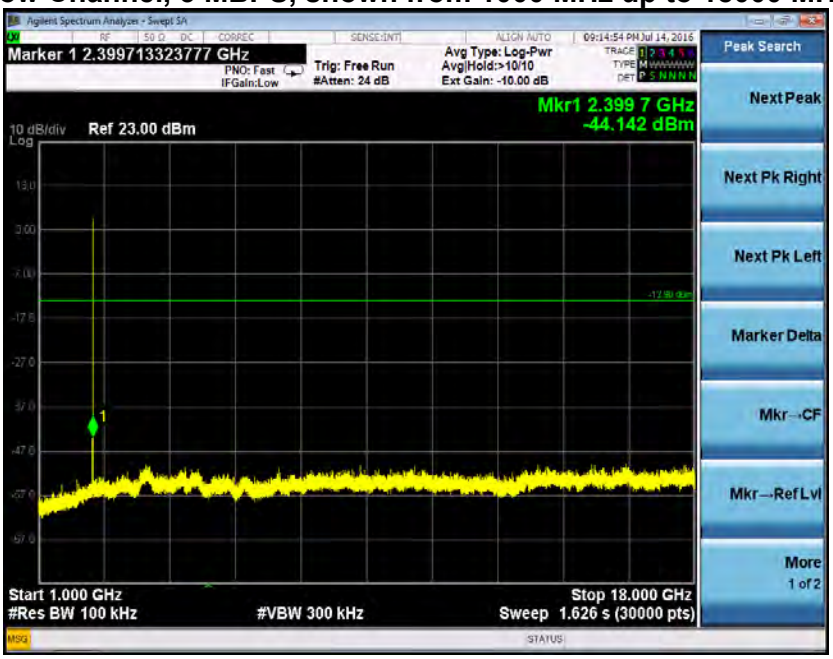


***Emission shown in restricted frequency band**

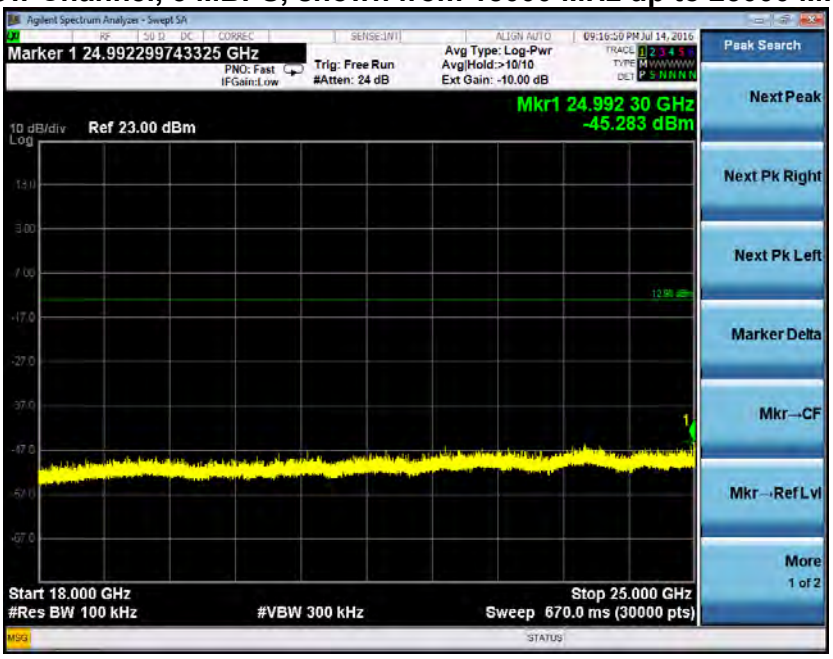
Low Channel, 3 MBPS, shown from 30 MHz up to 1000 MHz



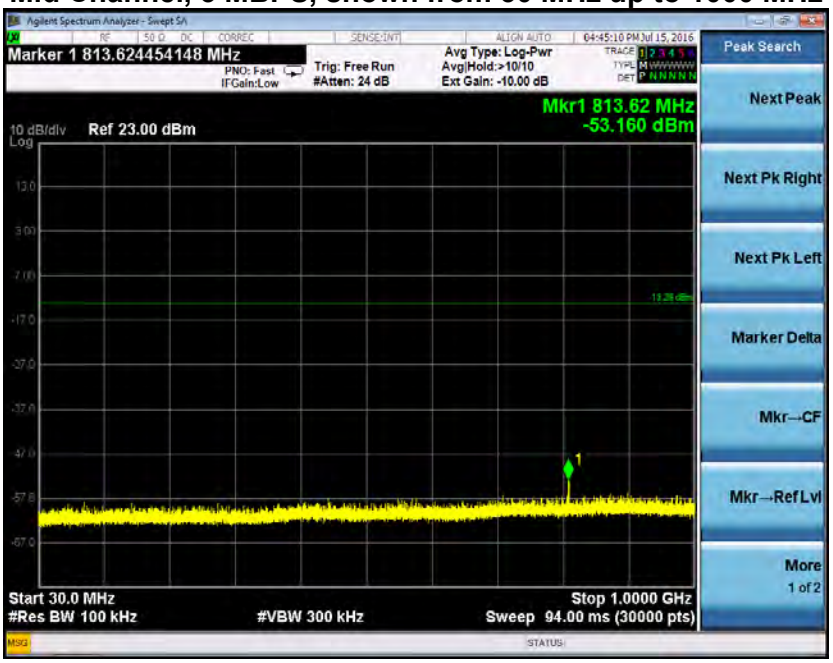
Low Channel, 3 MBPS, shown from 1000 MHz up to 18000 MHz



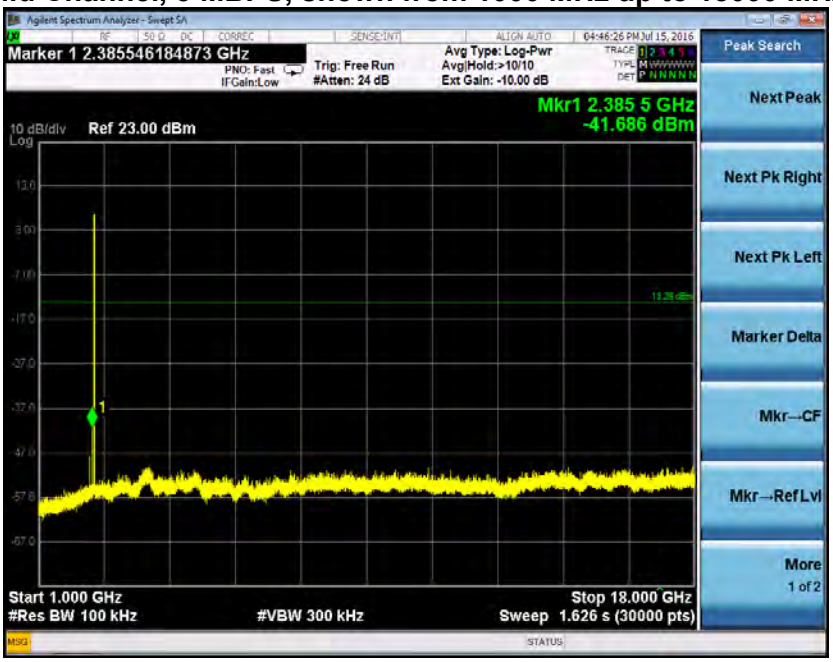
Low Channel, 3 MBPS, shown from 18000 MHz up to 25000 MHz



Mid Channel, 3 MBPS, shown from 30 MHz up to 1000 MHz

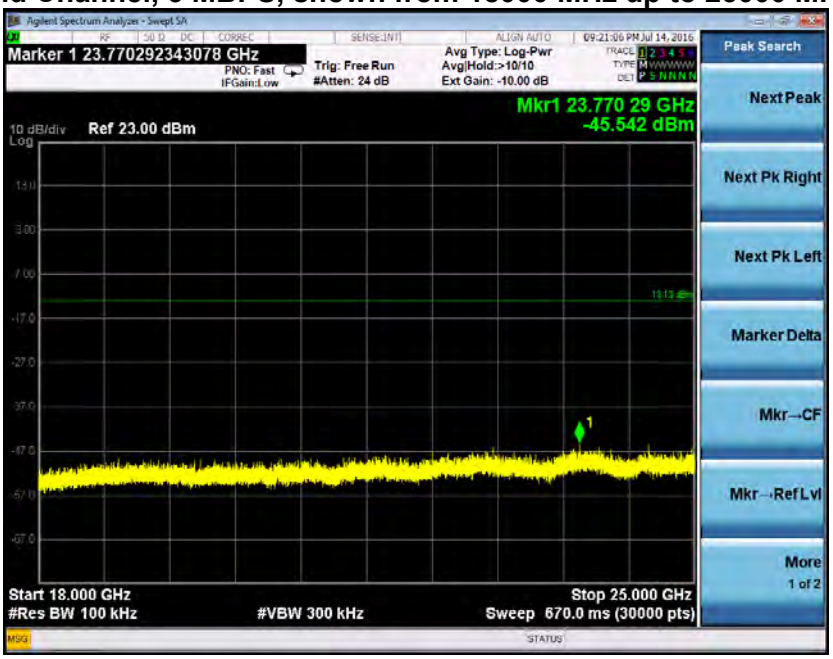


Mid Channel, 3 MBPS, shown from 1000 MHz up to 18000 MHz



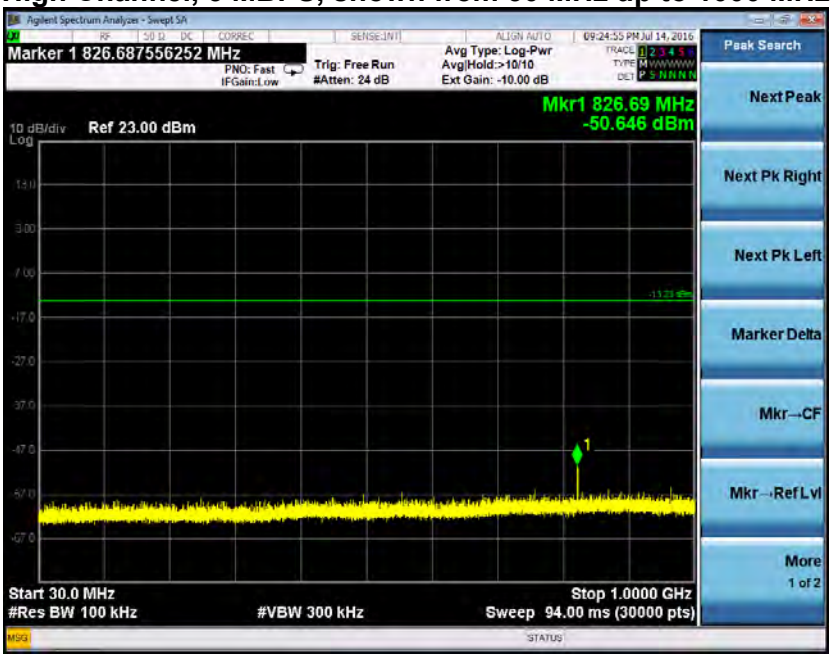
***Emission shown in restricted frequency band**

Mid Channel, 3 MBPS, shown from 18000 MHz up to 25000 MHz

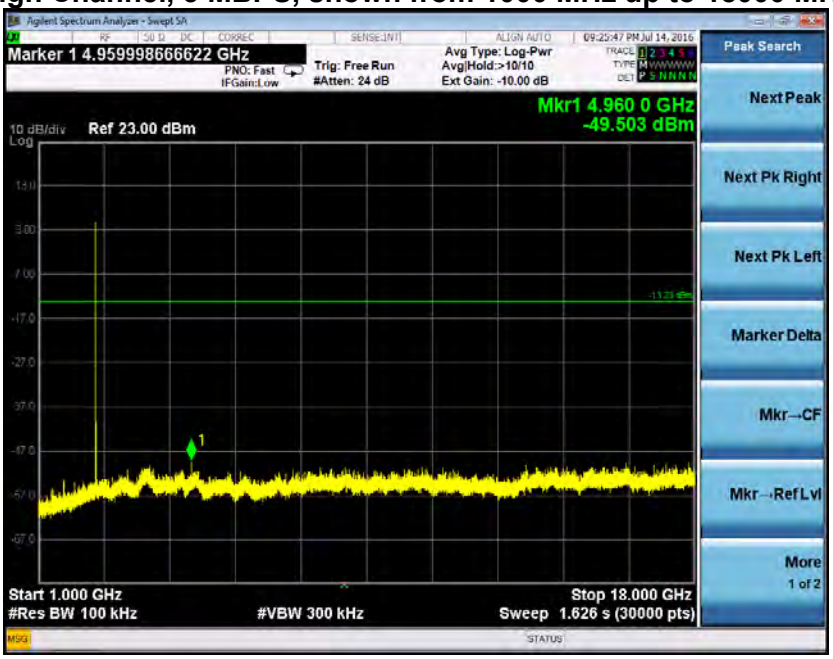


***Emission shown in restricted frequency band**

High Channel, 3 MBPS, shown from 30 MHz up to 1000 MHz



High Channel, 3 MBPS, shown from 1000 MHz up to 18000 MHz



***Emission shown in restricted frequency band**

High Channel, 3 MBPS, shown from 18000 MHz up to 25000 MHz

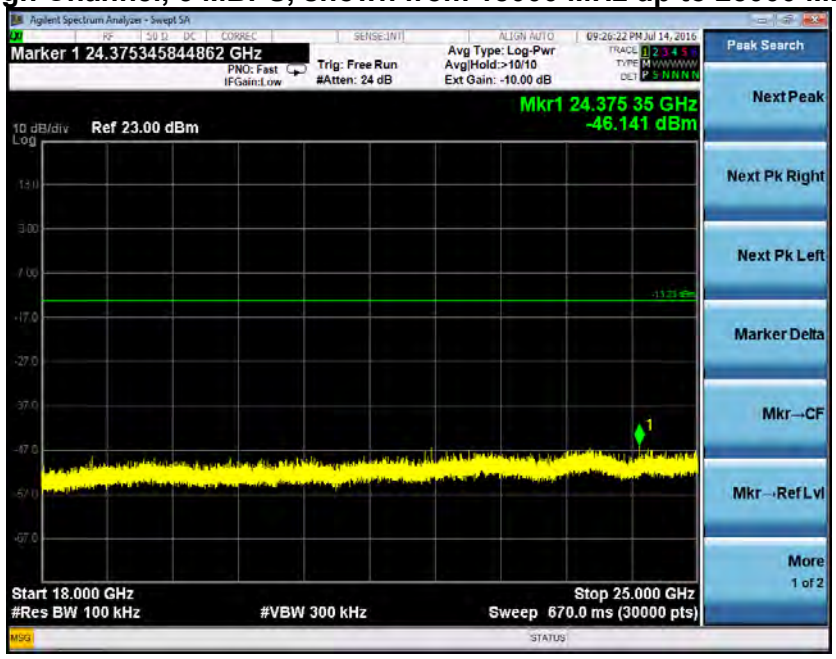


EXHIBIT 10. FREQUENCY STABILITY OVER VOLTAGE VARIATIONS

A spectrum analyzer was used to measure the frequency at the appropriate frequency markers. For this test, the EUT was placed in continuous transmit CW mode (i.e., transmitting unmodulated carrier signal). Power to the EUT was supplied by a variable power supply. The tables below meet the requirements of 47 CFR Part 15 Section 2.1055. The equations below illustrate how the margin was calculated.

Limit (Hz) = Channel Frequency (Hz)/10,000

Margin (Hz) = Limit (Hz) – | (Channel Frequency (Hz) – Measured Frequency (Hz)) |

Bluetooth

Low Channel

Frequency Stability f = 2402 MHz				
Supply Voltage (VDC)	Frequency (Hz)	Deviation		
		Hz	Limit (Hz)	Margin (Hz)
2.8	2402000000	2402023632	240200	216568
3.3	2402000000	2402028914	240200	211286
3.8	2402000000	2402022226	240200	217974

Middle Channel

Frequency Stability f = 2441 MHz				
Supply Voltage (VDC)	Frequency (Hz)	Deviation		
		Hz	Limit (Hz)	Margin (Hz)
2.8	2441000000	2441026971	244100	217129
3.3	2441000000	2441022800	244100	221300
3.8	2441000000	2441002774	244100	241326

High Channel

Frequency Stability f = 2480 MHz				
Supply Voltage (VDC)	Frequency (Hz)	Deviation		
		Hz	Limit (Hz)	Margin (Hz)
2.8	2480000000	2479996838	248000	244838
3.3	2480000000	2480029720	248000	218280
3.8	2480000000	2480028396	248000	219604

EXHIBIT 11. CHANNEL PLAN AND SEPARATION, AVERAGE TIME OF OCCUPANCY, AND NUMBER OF CHANNELS EMPLOYED

A spectrum analyzer was used with a resolution bandwidth of 300 kHz to measure the channel separation of the Bluetooth FHSS Radio on the W1001. The test was performed per ANSI C63.10 section 7.8.2. The testing was performed with the device operating at 1 MBPS. Channel plan and separation testing was not performed at 2 MBPS and 3 MBPS due to larger occupied bandwidth (i.e., larger than the channel spacing) resulting in the inability to resolve channel spacing.

The minimum and maximum channel-separations measured for this device are 997.50 kHz and 1021.25 kHz respectively. The following plots describe this spacing, and also establish the channel separation and plan.

11.1 Data Table

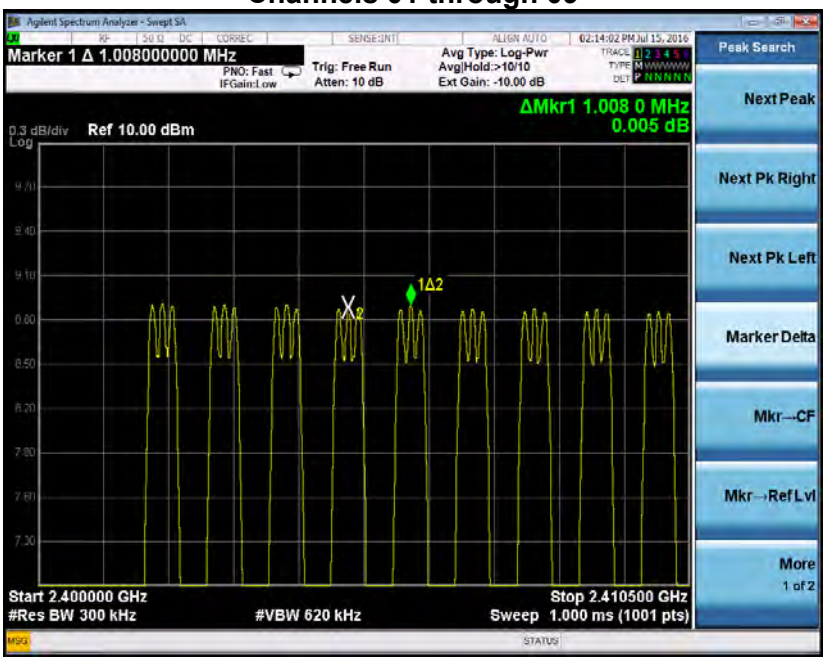
Range (MHz)	Number of Channels	Max Separation (MHz)	Min Separation (MHz)
2400 - 2410.5	9	1.008	0.9975
2409.5 – 2419.5	10	1.01	0.99
2418.5 – 2429.5	11	1.023	0.99
2428.5 – 2439.5	11	1.166	0.99
2438.5-2449.5	11	1.001	0.99
2448.5-2459.5	11	1.001	0.99
2458.5-2469.5	11	1.001	0.99
2468.5-2483.5	12	1.005	0.99

11.2 Summary Table

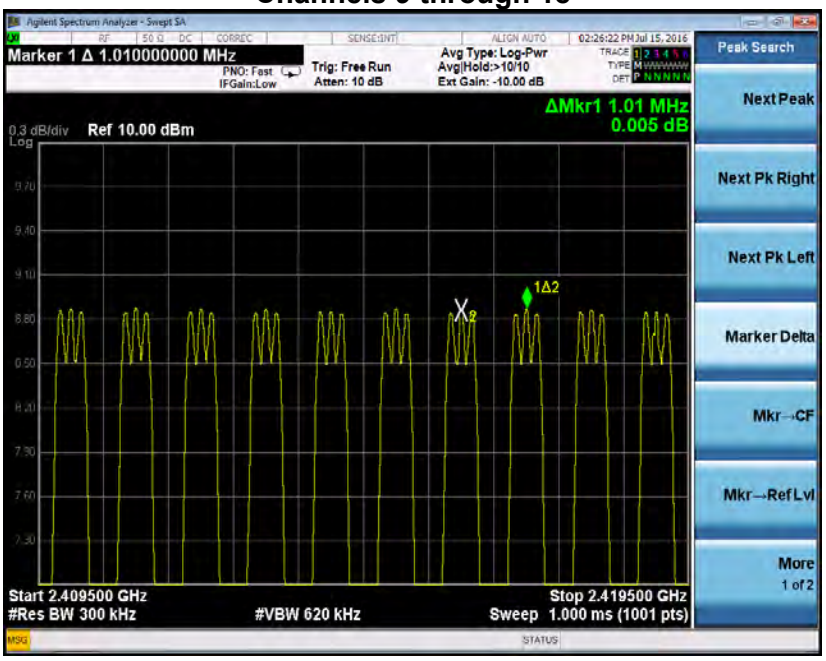
Total Channels	79
Max separation	1.166 MHz
Min Separation	0.99 MHz

11.3 Screen Captures – Channel Separation

Channels 01 through 09

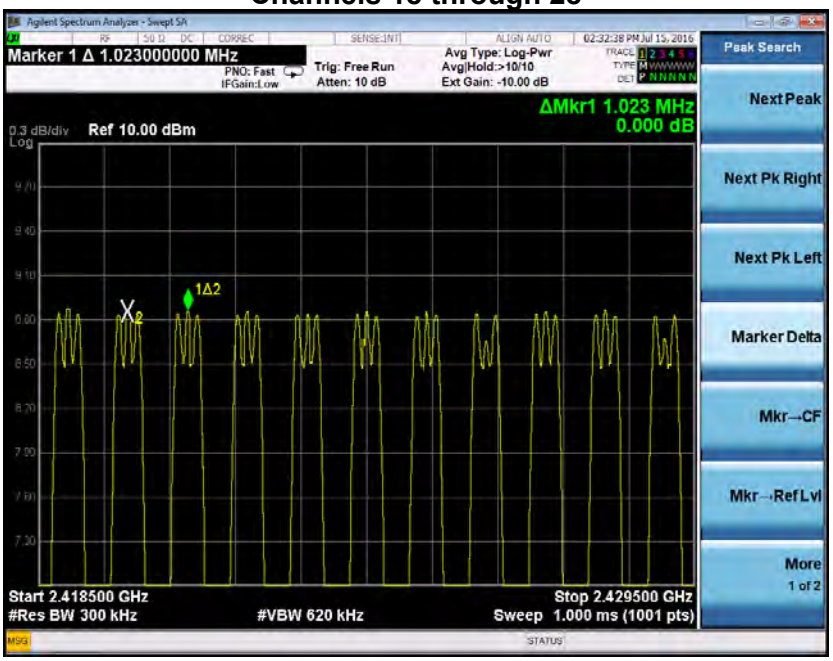


Channels 9 through 18

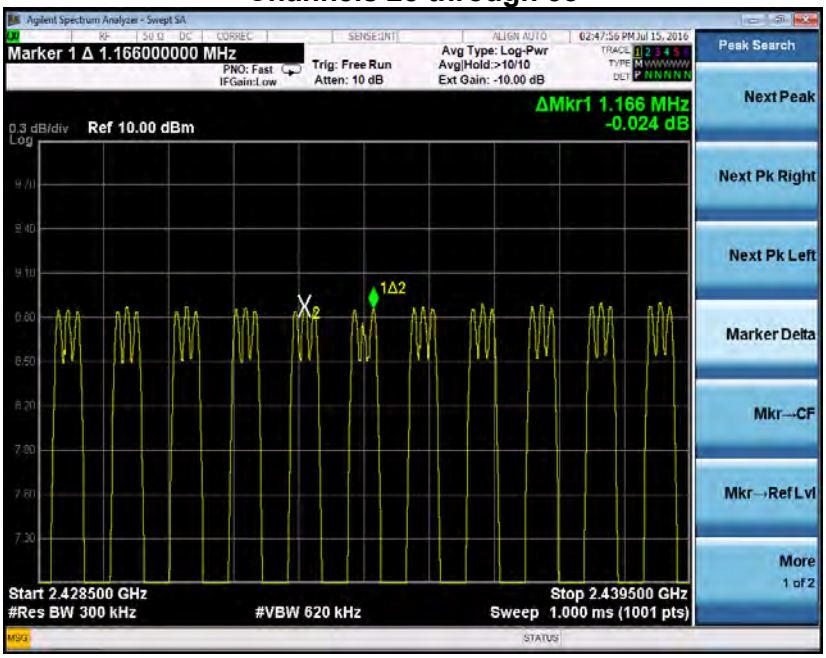


Screen Captures – Channel Separation *(continued)*

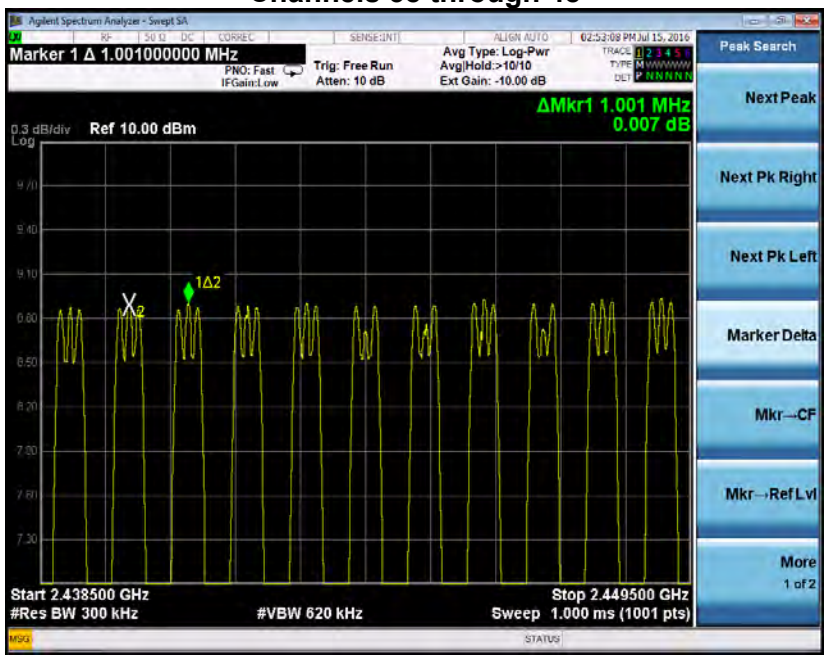
Channels 18 through 28



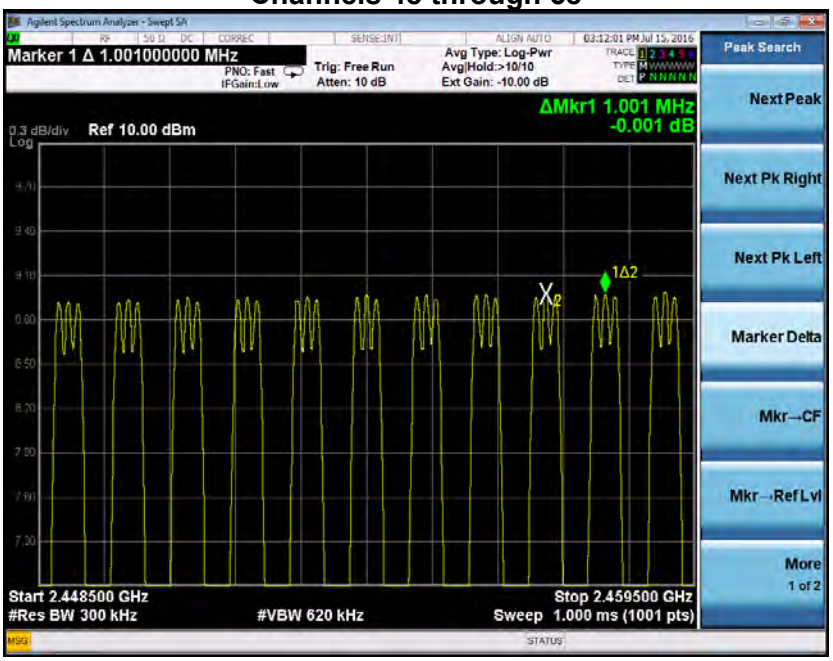
Channels 28 through 38



Channels 38 through 48

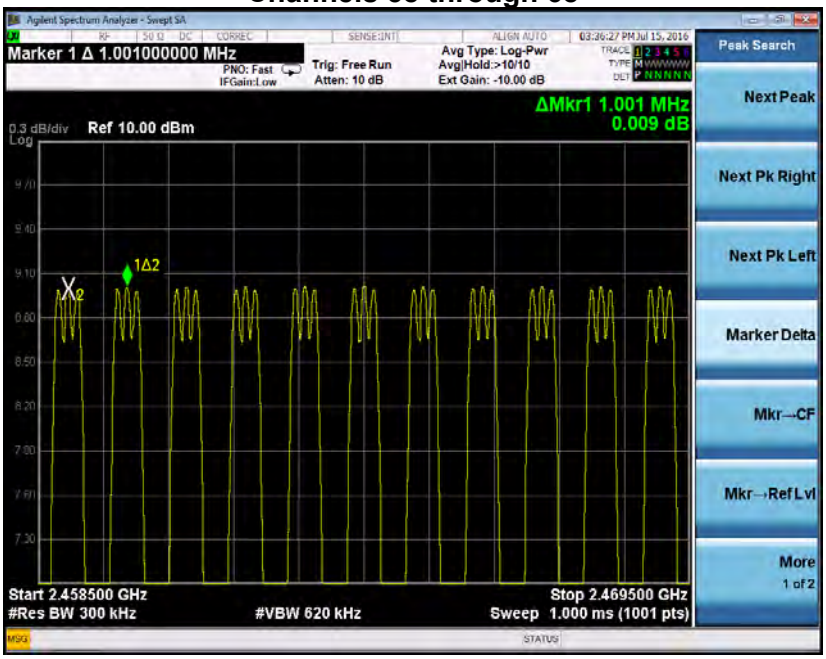


Channels 48 through 58

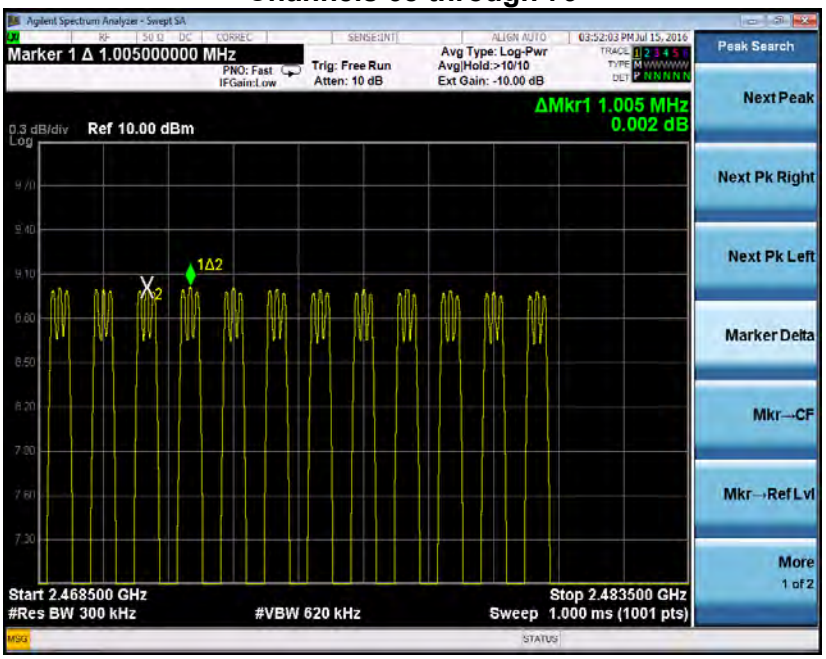


Screen Captures – Channel Separation *(continued)*

Channels 58 through 68



Channels 68 through 79

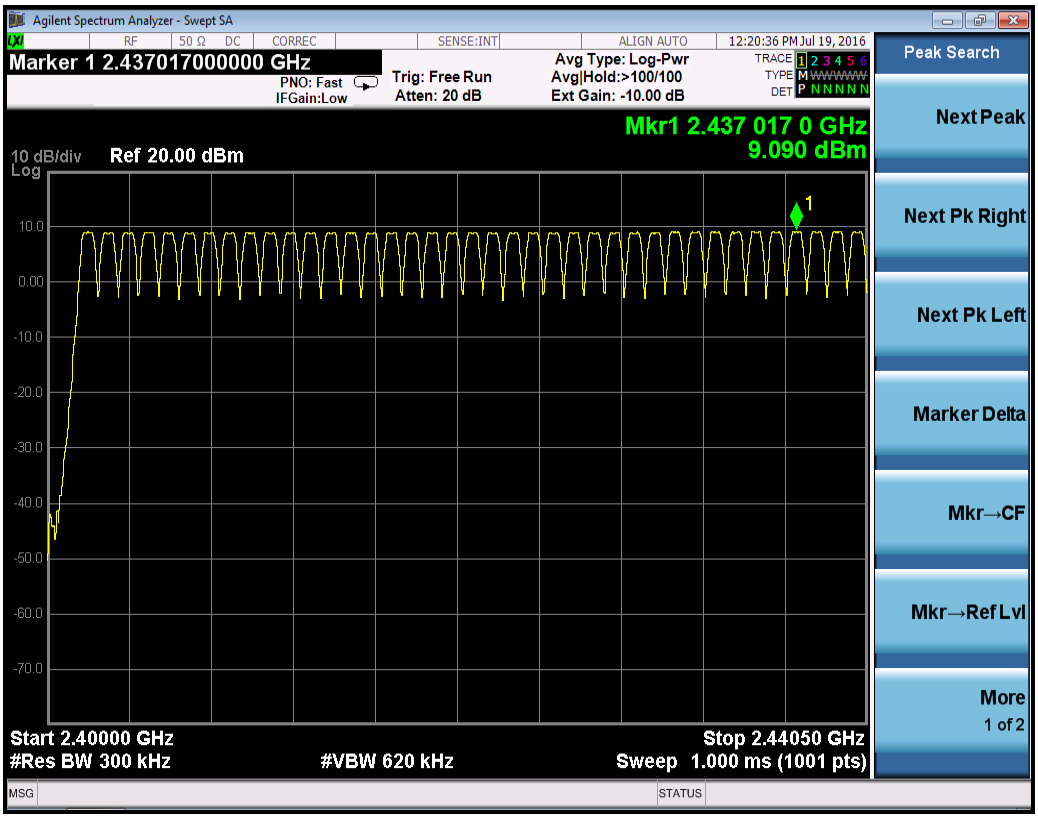


11.4 Time of Occupancy and Number of Hopping Channels

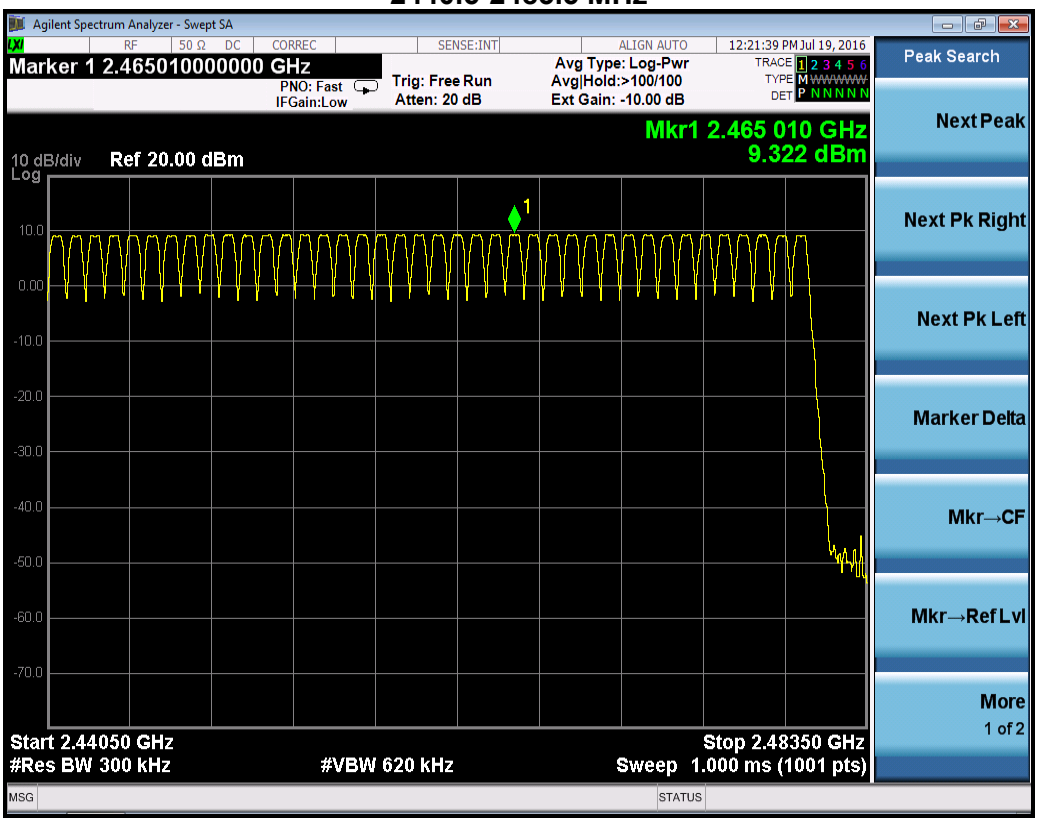
Additionally, to satisfy the requirement of 47 CFR Part 15.247(a)(1)(iii) which states that frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed, additional testing was performed. The additional testing includes detecting the number of hopping frequencies and the time of occupancy.

Per ANSI C63.10 Section 7.8.3, the number of hopping frequencies (79) at a data rate of 1 MBPS is depicted in the screen shots below:

2400-2440.5 MHz



2440.5-2483.5 MHz



Per ANSI C63.10 Section 7.8.4, the time of occupancy for each data rate was measured and provided in the table below:

Data Rate	Transmit Time Per Hop (ms)	Period[1] (s)	Hops Per Period	Average Time of Occupancy[2] (s)	Average Time of occupancy Limit (s)	Margin (s)
1 MBPS	3.1	31.6	72	0.2232	0.4	0.1768
2 MBPS	3	31.6	92	0.276	0.4	0.124
3 MBPS	3	31.6	102	0.306	0.4	0.094

1 – 0.4 seconds * # of hopping channels employed (79)
2 – (Hops per period)*(Transmit Time per Hop)

EXHIBIT 12. CONDUCTED AC MAINS EMISSIONS

12.1 - Test Setup

The test setup was assembled in accordance with ANSI C63.10. The EUT was placed on the rear of an 80 cm high non-conductive pedestal. The EUT was situated 40 cm from a vertical ground plane and appended to a generic, 3.3 V output AC/DC adapter. The generic adapter was coupled to a line impedance stabilization network, which, in turn, was connected to the input of the EMI Receiver. The EUT's power cable was plugged into a 50Ω (ohm), 50/250 μH Line Impedance Stabilization Network (LISN). The AC power supply of 120 V was supplied to the LISN input line and, in turn, the generic adapter via a broadband EMI filter. 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 the EMI receiver. The LISN used has the ability to terminate the unused port with a 50Ω (ohm) load when switched to either L1 (line) or L2 (neutral).

12.2 - 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.

12.3 - Test Equipment Utilized

A list of the test equipment for the conducted emissions test can be found in Appendix A. This list includes calibration information and equipment descriptions.

12.4 - Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.207 and RSS 247 for a FHSS transmitter. The frequencies with significant RF signal strength were recorded and plotted as shown in the data charts and screen captures provided below.

12.5 – Limits of Conducted Emissions

The following table represents the limits for conducted emissions for a transmitter per CFR 15.207.

Frequency of emission (MHz)	Conducted limit (dBµV)	
	Quasi-peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

*Decreases with the logarithm of the frequency

12.6 – Conducted Emissions Test Data Chart

Frequency Range inspected: 150 KHz to 30 MHz

Manufacturer:	LS Research					
Date(s) of Test:	8/24/2016					
Test Engineer:	John Johnston					
Voltage:	3.3 VDC					
Operation Mode:	Continuous Transmit					
Environmental Conditions in the Lab:	Temperature: 20 – 25° C Relative Humidity: 30 – 60 %					
Test Location:	**X**	Other				Chamber
EUT Placed On:	**X**	40cm from Vertical Ground Plane				10cm Spacers
	X	80cm above Ground Plane				Other:
Measurements:		Pre-Compliance		Preliminary	**X**	Final
Detector Used:	**X**	Peak	**X**	Quasi-Peak	**X**	Average

Bluetooth

Test Results:

Line	Frequency (MHz)	Quasi-Peak Measurement (dBuV)	Quasi-Peak Limit (dBuV)	Margin (dB)	Average Measurement (dBuV)	Average Limit (dBuV)	Margin (dB)
1	0.15	43.00	66.00	23.00	34.70	56.00	21.30
1	0.23	39.40	62.45	23.05	29.80	52.45	22.65
1	0.616	35.00	56.00	21.00	25.20	46.00	20.80
2	0.15	42.80	66.00	23.20	31.80	56.00	24.20
2	0.201	36.10	63.57	27.47	25.70	53.57	27.87
2	0.621	33.80	56.00	22.20	25.90	46.00	20.10

Screen Captures

Line 1

Line 2

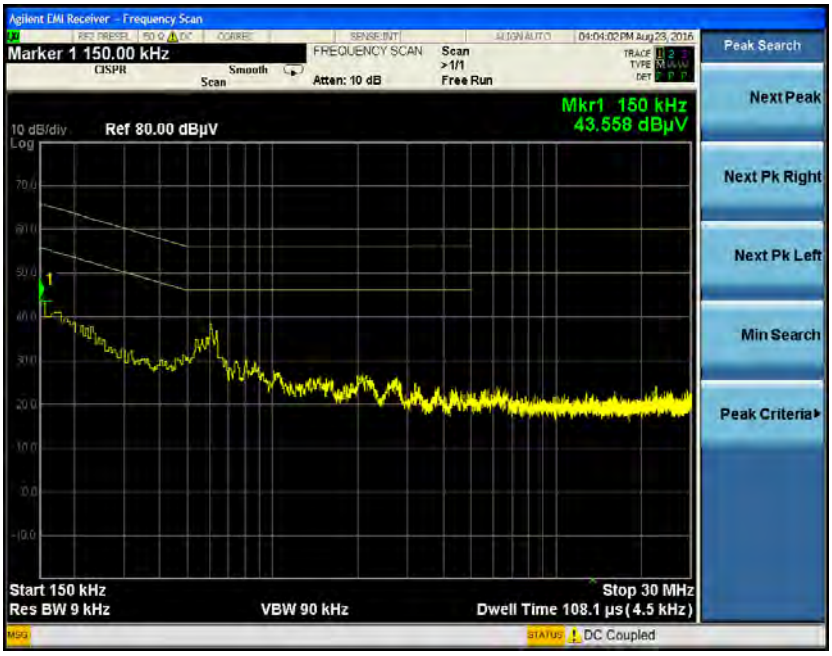


EXHIBIT 13. Appendix A – Test Equipment List

LSR a Laird Business

Date : 26-Jul-2016 Type Test : Bluetooth Radiated Emissions - Below 1 GHz Job # : C-2496

Prepared By: John Johnston Customer : Thermo Fisher Scientific Quote #: 316191

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	AA 960078	Log Periodic Antenna	EMCO	93146	9701-4855	3/31/2016	3/31/2017	Active Calibration
2	AA 960005	Biconical Antenna	EMCO	93110B	9601-2280	1/14/2016	1/14/2017	Active Calibration
3	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	2/24/2016	2/24/2017	Active Calibration

Project Engineer: Quality Assurance:

LSR a Laird Business

Date : 22-Jul-2016 Type Test : BT Tx Harmonics Job # : C-2496

Prepared By: John Johnston Customer : Thermo Fisher Scientific Quote #: 316191

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/12/2016	5/12/2017	Active Calibration
2	AA 960158	Double Ridge Horn Antenna	ETS Lindgren	3117	109300	2/4/2016	2/4/2017	Active Calibration
3	EE 960159	0.8 - 21GHz LNA	Mini-Circuits	ZVA-213X-S+	40201429	2/4/2016	2/4/2017	Active Calibration
4	AA 960171	Cable - low loss 1m	A.H. Systems, Inc	SAC-26G-6	386	3/31/2016	3/31/2017	Active Calibration
5	AA 960153	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-04	4/29/2016	4/29/2017	Active Calibration
6	AA 960174	Small Horn Antenna 18-40 GHz	ETS-Lindgren	3116C-PA	00206880	4/23/2016	4/23/2017	Active Calibration

Project Engineer: Quality Assurance:

LSR a Laird Business

Date : 12-Jul-2016 Type Test : BT Band-Edge Job # : C-2496

Prepared By: John Johnston Customer : Thermo Fisher Scientific Quote #: 316191

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/12/2016	5/12/2017	Active Calibration
2	AA 960158	Double Ridge Horn Antenna	ETS Lindgren	3117	109300	2/4/2016	2/4/2017	Active Calibration
3	AA 960171	Cable - low loss 1m	A.H. Systems, Inc	SAC-26G-6	386	3/31/2016	3/31/2017	Active Calibration

Project Engineer: Quality Assurance:

LSR
a Laird Business

Date : 14-Jul-2016 Type Test : BT Conducted Measurements Job # : C-2496

Prepared By: John Johnston Customer : Thermo Fisher Scientific Quote #: 316191

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960087	44GHz EXA Spectrum Analyzer	Agilent	N9010A	MY53400296	12/18/2015	12/18/2016	Active Calibration
2	AA 960143	Phaseflex	Gore	EKD01D01048.0	5546519	6/26/2015	6/26/2017	Active Calibration

Project Engineer: Quality Assurance:

LSR
a Laird Business

Date : 23-Aug-2016 Type Test : Conducted Emissions Job # : C-2496

Prepared By: John Customer : Thermo Fisher Scientific Quote #: 316191

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	EE 960089	LISN - 15A	COM-POWER	LI-215A	191943	3/8/2016	3/8/2017	Active Calibration

Project Engineer: Quality Assurance:

EXHIBIT 14. Appendix B – Test Standards

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

EXHIBIT 15. Appendix C – Uncertainty Statement

This uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k=2.

Measurement Type	Particular Configuration	Uncertainty Values
Radiated Emissions	Biconical Antenna	4.82 dB
Radiated Emissions	Log Periodic Antenna	4.88 dB
Radiated Emissions	Horn Antenna	4.85 dB
Absolute Conducted Emissions	PSA Series	1.38 dB
AC Line Conducted Emissions	LISN	3.20 dB
Radiated Immunity	3 Volts/Meter	2.05 Volts/Meter
Conducted Immunity	3 Volts rms	2.33 V
EFT Burst, Surge, VDI	230 VAC	54.4 V
ESD Immunity	Discharge at 15 kV	3200 V
Temperature/Humidity	Thermo-hygrometer	0.64 degrees/2.88% RH