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TEST REPORT # 316019
LSR Job #: C-2526

Compliance Testing of:
Halo/Halo+

Test Date(s):
9/2/16 – 10/26/16

Prepared For:
Attn: Stephen Sheppard
White Stagg, LLC dba Halo Smart Labs
222 S. Church St. Suite 100
Charlotte, NC 28202

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

Signature: Date: 12/14/16

Test Report Reviewed by:	**Project Engineer:**
Adam Alger, Quality Systems Engineer	Shane Dock, EMC Engineer
Signature: Date: 12/13/16	Signature: Date: 12/14/16

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EXHIBIT 1. INTRODUCTION

1.1 - Scope

References:	FCC Part 15, Subpart C, Section 15.247
Title:	FCC : Telecommunication – Code of Federal Regulations, CFR 47, Part 15.
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 v03r05 ANSI C63.10 ANSI C63.4
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.
ANSI C63.10	2013	American National Standard for Testing Unlicensed Wireless Devices
FCC KDB 558074 D01 DTS Measurement Guidance v03r05	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.org

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:	White Stagg, LLC dba Halo Smart Labs
Address:	222 S. Church St. Suite 100 Charlotte, NC 28202
Contact Name:	Stephen Sheppard

2.2 - Equipment Under Test (EUT) Information

The following information has been supplied by the applicant.

Product Name:	Halo/Halo+
Model Number:	SABCA1 (Halo)/ SABDA1 (Halo+)
Serial Number:	Engineering Sample 1 (Halo+ Radiated Emissions < 1 GHz) Engineering Sample 2 (Halo Radiated Emissions) Engineering Sample 3 (Conducted Radio Measurements) S163400038 (Radiated Emissions > 1 GHz)

2.3 - Associated Antenna Description

The antenna is a chip antenna and it is manufactured by Taiyo Yuden, model number AH316M245001-T. This antenna has a peak gain of 1.9 dB.

2.4 - EUT'S Technical Specifications

EUT Frequency Range (in MHz)	2412MHz – 2462MHz
Type of Modulation	DSSS (802.11b) OFDM (802.11G and n)
Transmitter Spurious (worst case) at 3 meters (Average)	51.0 dBuV/m at 4820 MHz for Halo+ (51.5 dBuV/m at 4820 MHz for Halo)
Frequency Tolerance %, Hz, ppm	Better than 100 ppm
Microprocessor Model # (if applicable)	WLAN: Texas Instruments CC3200R1M2RGCR
Antenna Information	
Detachable/non-detachable	Non-detachable
Type	Chip Antenna
Gain	1.9 dBi
EUT will be operated under FCC Rule Part(s)	Title 47 part 15.247
Modular Filing	☐ Yes ☒ No

	802.11b	802.11g	802.11n
Maximum Conducted Output Power (dBm)	10.447	17.606	16.408
Maximum Conducted Output Power (Watts)	0.011	0.058	0.044
Minimum Conducted Output Power (dBm)	9.148	10.217	8.751
Minimum Conducted Output Power (Watts)	0.008	0.011	0.008
99% Bandwidth (MHz)	14.390	18.952	19.438
6 dB Bandwidth (MHz)	10.430	15.130	17.740

2.5 - Product Description

Halo and Halo+ are both Dual-Principal Smoke and Carbon Monoxide ("CO") Alarms that utilize a 120 VAC Mains connected primary power source with a non-user serviceable battery backup as a secondary power source. Halo and Halo+ both have 2.4 GHz WLAN send and receive wireless connectivity and 2.4 GHz ZigBee send and receive wireless connectivity. Halo+ comes with a National Oceanic and Atmospheric Administration ("NOAA") All Hazards Weather Receiver Integrated Circuit ("IC") and associated antenna. The Weather Receiver IC is receive only and does not have transmit functionality. Halo and Halo+ are both designed to detect hazardous levels of Smoke and CO, are intended for open area protection in indoor locations of residential units, and are equipped with visual and audible alarm indicators. Also integrated into the design is an alarm silencing feature, a smart-device application ("App") remote control receiver for Testing and silencing, and a low battery indicator with silence functionality.

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	Power Line Conducted Emissions Measurements	Yes
FCC : 15.247 (a)(2)	99% Bandwidth	Yes
FCC : 15.247(b)(3) & 1.1310	Maximum Output Power	Yes
FCC :15.247(d)	RF Exposure Limit	Yes
FCC:15.247 (a)(2)	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
FCC:15.247 (e)	6 dB Bandwidth of a Digital Modulation System	Yes
FCC : 15.247(d), 15.209 & 15.205	Power Spectral Density of a Digital Modulation System	Yes
FCC : 15.207	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. CONFORMANCE SUMMARY

When tested between September 2nd and October 26 of 2016, it was determined that the EUT, the HALO and HALO+, were compliant with the requirements of:

FCC Title 47 CFR Part 15.247

Using the methods of ANSI C63.10-2013

Any modifications made to the EUT after the specified test date(s) will invalidate the data herein.

If some emissions 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. 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 and ANSI C63.10-2013. The EUT was placed on a 150 cm high non-conductive pedestal (80 cm for measurements under 1 GHz), centered on a flush mounted turntable inside a 3 meter Semi-Anechoic, FCC listed Chamber. The EUT was operated in continuous transmit mode for final testing. 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 for measurements above 1 GHz.

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. 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 at least 300 kHz), and a resolution bandwidth of 1 MHz for measurements above 1 GHz (video bandwidth of at least 3 MHz). For some plots, a reduced video bandwidth was used in order to identify spurious emissions (The relevant plots are labeled as such). In these cases, the standard video bandwidth was used with the appropriate detectors for measurement.

5.4 - Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247 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) + 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), radiated emissions that fall within the restricted band described in 15.205(c) for FCC 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:	White Stagg/Halo Smart Labs					
Date(s) of Test:	9/2/16, 10/21/16 – 10/26/16					
Project Engineer(s):	Shane Dock					
Test Engineer(s):	Shane Dock					
Voltage:	120 VAC, 60 Hz					
Operation Mode:	Continuous transmit, modulated					
Environmental Conditions in the Lab:	Temperature: 70-74° F Relative Humidity: 30-42%					
EUT Power:	X	Single Phase 120VAC		3 Phase ___VAC		
		Battery		Other: Bench DC Supply		
EUT Placement:	X	150 cm non-conductive pedestal (80 cm for <1 GHz)		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 (m)	Azimuth (degree)	Quasi Peak Reading (dBµV/m)	Quasi Peak Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation	Notes
39.4	1.00	105.30	21.3	40.0	18.7	H	Vertical	-
68.0	1.00	0.00	19.9	40.0	20.1	V	Vertical	Due to turn table noise
997.0	1.00	0.00	29	54.0	25.0	H	Vertical	Noise Floor
859.0	1.00	0.00	28.3	46.0	17.7	V	Vertical	Noise Floor

Measurements above 1 GHz:

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

Channel	Frequency (MHz)	Orientation	Antenna	Height (cm)	Angle (degree)	Peak (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dBuV/m)	Average (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dBuV/m)
Low	4019.237	H	V	209.28	197.25	53.73	74.00	20.27	51.01	54.00	2.99
Mid	4060.896	H	V	190.52	195.50	53.70	74.00	20.30	50.73	54.00	3.27
High	4102.578	H	V	198.04	192.25	53.01	74.00	20.99	50.41	54.00	3.59

Frequency (MHz)	Tx Channel	Height (m)	Azimuth (degrees)	Peak Reading (dBuV/m)	Peak Limit (dBuV/m)	Margin (dB)	Average Reading (dBuV/m)	Average Limit (dBuV/m)	Margin (dB)	EUT Orientation	Polarity
19296	Low	1.30	170.00	53.79	74.00	20.21	46.97	54.00	7.03	V	H
19496	Mid	1.45	172.00	55.63	74.00	18.37	49.16	54.00	4.84	V	H
19696	High	1.39	179.00	52.39	74.00	21.61	44.84	54.00	9.16	V	V

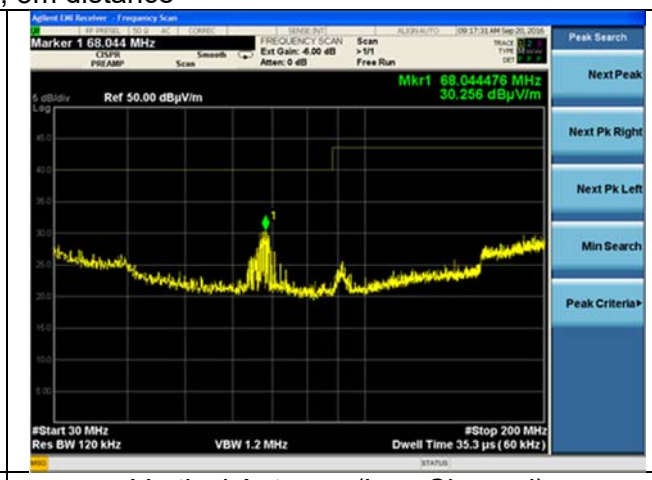
5.7 – Screen Captures.

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.

1 MBPS used for below screenshots. Screenshots shown are worst-case.

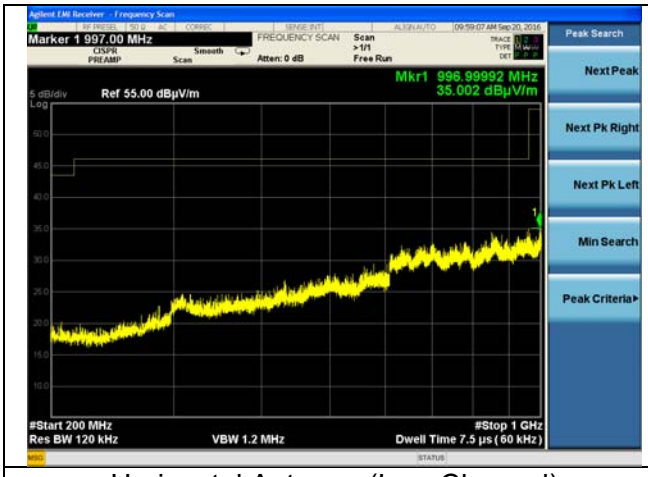
30 to 200 MHz, 3m distance

Horizontal Antenna (Low Channel)

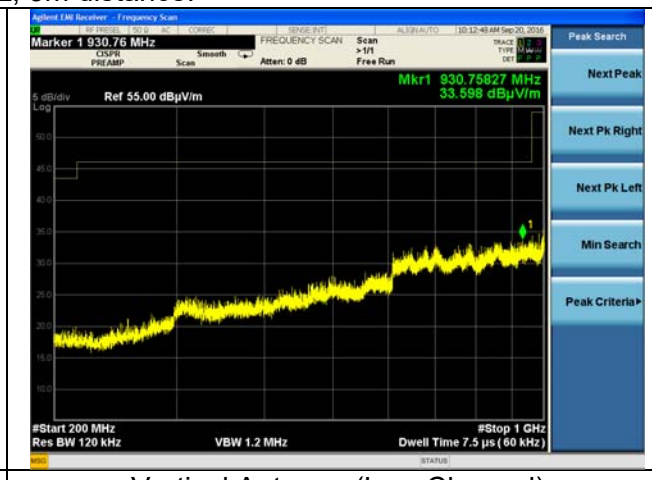


Vertical Antenna (Low Channel)

200 to 1000 MHz, 3m distance.

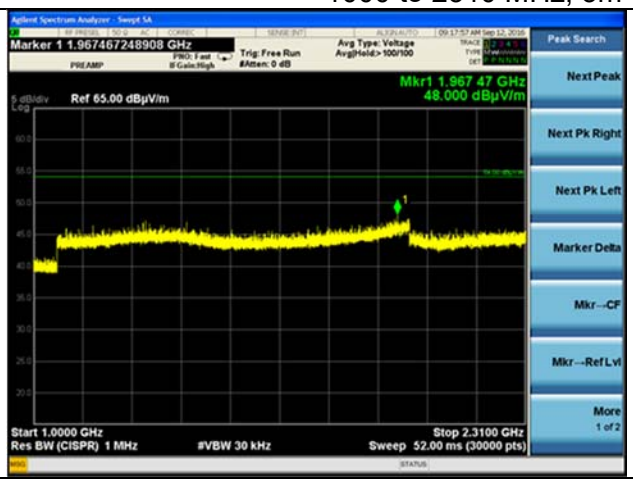
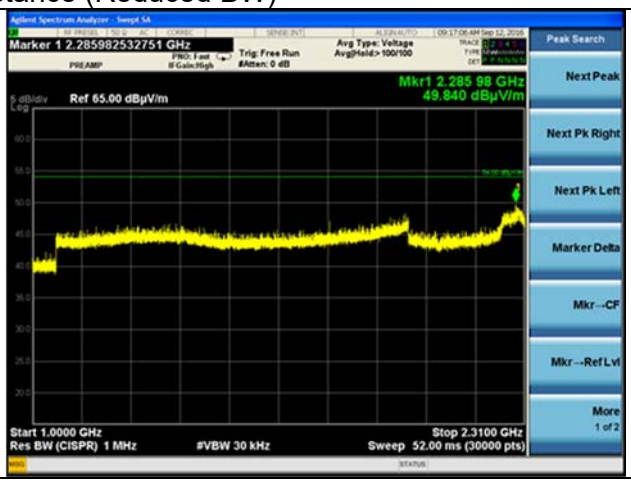


Horizontal Antenna (Low Channel)



Vertical Antenna (Low Channel)

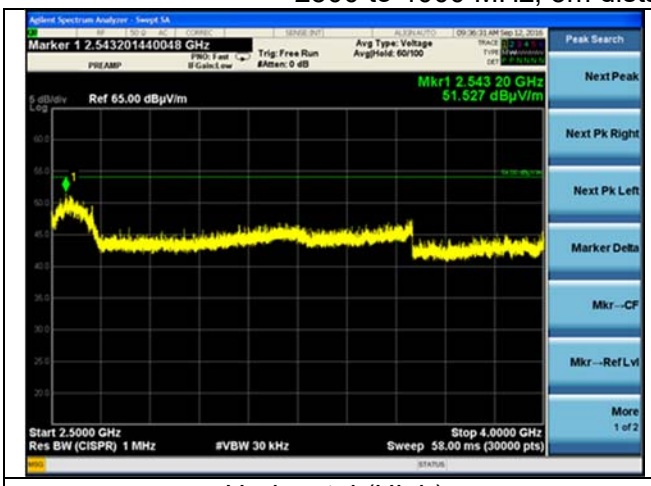
1000 to 2310 MHz, 3m distance (Reduced BW)

	
Horizontal Antenna (Low)	Vertical Antenna (Low)

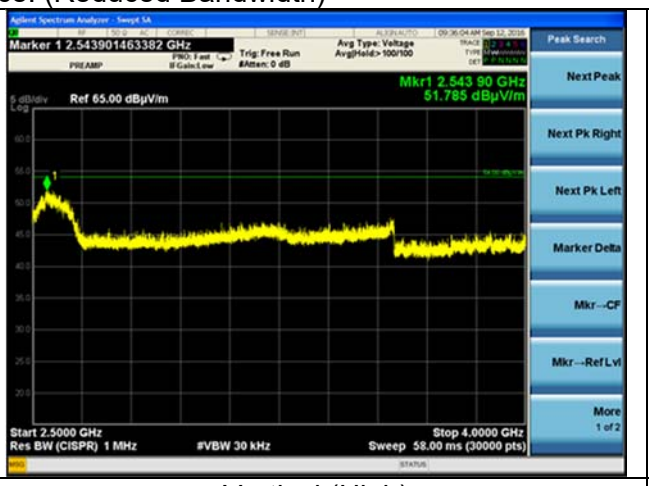
.

Note: The ranges 2310 to 2390, and 2483.5 to 2500 MHz is in section 8 of this report (Band-edges).

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

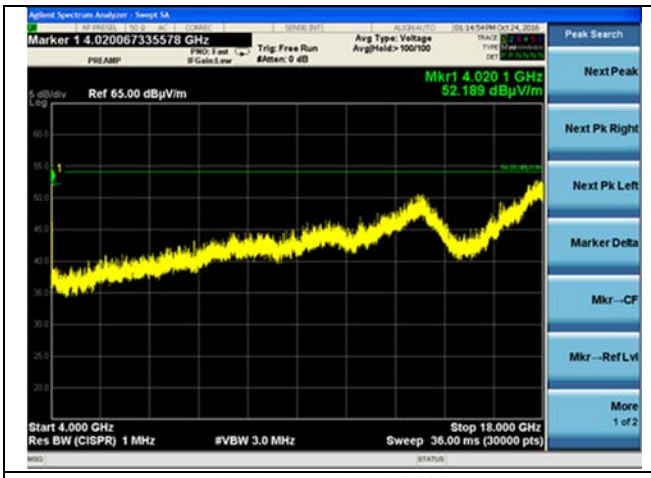


Horizontal (High)

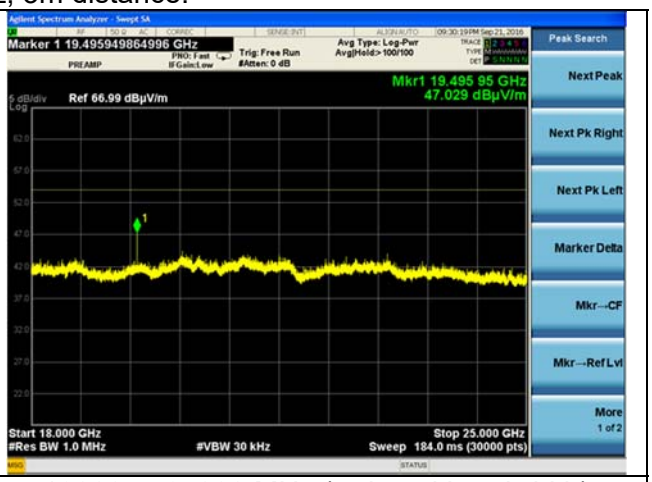


Vertical (High)

4000 to 25000 MHz, 3m distance.



4000 to 18000 MHz



18000 to 25000 MHz (reduced bandwidth)

Halo Unit

The worst-case harmonic emission found in a restricted band for the Halo+ unit was checked on the same orientation and channel on the Halo unit. The emission was the second harmonic of channel 12:

Channel	Frequency (MHz)	Orientation	Antenna	Height (cm)	Angle (degree)	Peak (dBuV/m)	Peak Limit	Peak Margin	Average (dBuV/m)	Average Limit	Average Margin
Low	4020	H	V	170	200	53.97	74.00	20.03	51.46	54.00	2.54

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. 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 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 through an internal limiter to EMI receiver System. 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).

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 4, 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. The emissions are measured on the EMI System, which contains correction factors to account for the equipment used in measurements.

6.4 Test Results

The EUT was found to **MEET** the Conducted Emission requirements of FCC Part 15.207 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:	White Stagg/Halo Smart Labs					
Date(s) of Test:	9/21/16					
Project Engineer:	Shane Dock					
Test Engineer:	Shane Dock					
Voltage:	120 VAC, 60 Hz					
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

Note: All points measured below were measured with both radios transmitting on mid channel simultaneously, as this is worst case.

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	0.150	59.7	66.0	6.3	38.0	56.0	18.0
1	0.168	57.1	65.1	8.0	36.7	55.1	18.4
1	0.190	54.8	64.0	9.2	34.1	54.0	19.9
2	0.150	59.4	66.0	6.6	37.7	56.0	18.3
2	0.177	56.5	64.6	8.1	35.4	54.6	19.2
2	0.478	42.3	56.4	14.1	30.6	46.4	15.8

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 (Mid Channel)

Line 1	Line 2

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 minimum 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.**

7.3 - Test Data

Data Rate (MBPS)	Channel	6dB Bandwidth (MHz)	99% Bandwidth (MHz)
1 (DBPSK)	1	9.134	14.179
	6	9.140	14.268
	11	9.132	14.273
11 (8QPSK)	1	9.988	14.306
	6	10.010	14.390
	11	10.430	14.360
6 (BPSK)	1	15.130	17.146
	6	15.130	18.952
	11	15.130	17.092
54 (64QAM)	1	16.470	17.252
	6	16.460	17.406
	11	16.490	17.244
MCS0 (BPSK)	1	15.130	17.929
	6	15.130	19.438
	11	15.130	18.023
MCS7 (64QAM)	1	17.730	18.226
	6	17.710	18.228
	11	17.740	18.226

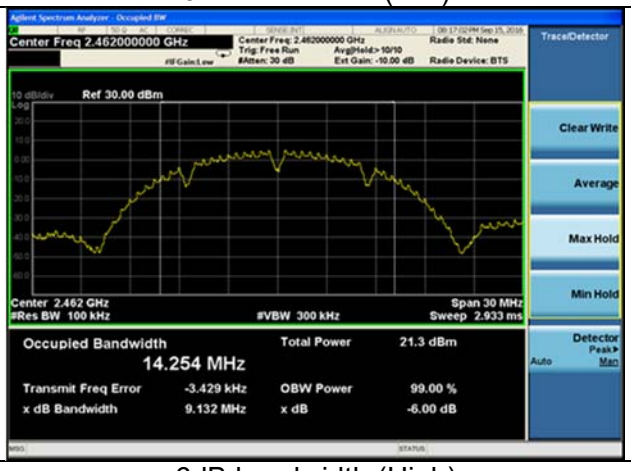
7.4 – Screen Captures

Examples of bandwidth measurements:

WLAN 1 MBPS

6dB bandwidth (Low)

6dB bandwidth (Mid)



6dB bandwidth (High)

99% bandwidth (Low)

99% bandwidth (Mid)

99% 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. 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 v03r05 (section 11), conducted measurements were performed with 100 kHz bandwidth for all emissions outside of the band of operation. For measuring radiated emissions in the restricted band, a bandwidth of 120 kHz (below 1000MHz) or 1MHz (above 1000MHz) was used in accordance with C63.4.

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.**

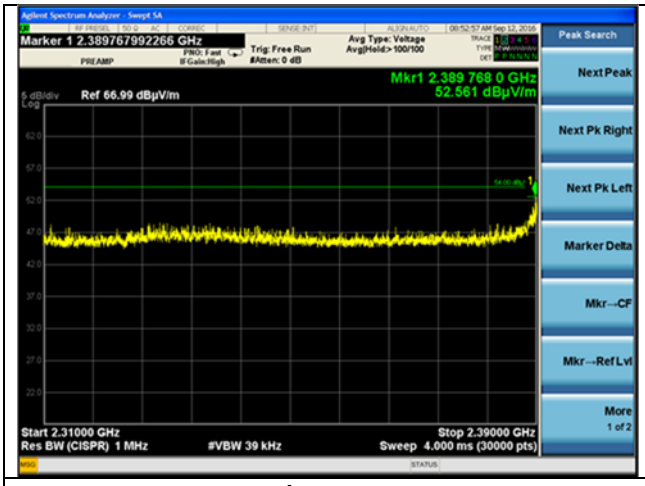
8.2. Band Edge Screen Captures.

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

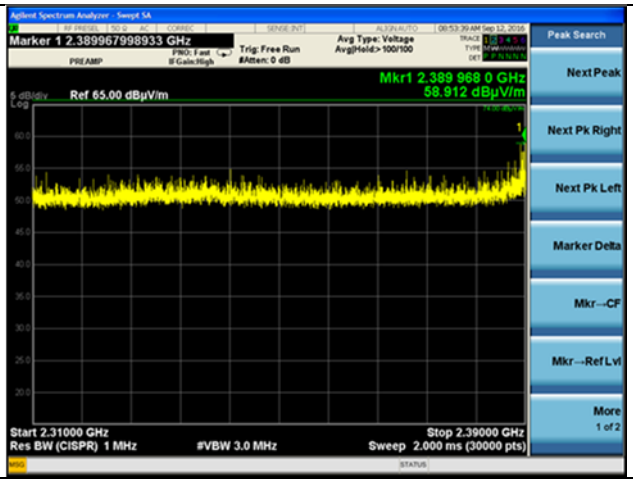
Band-edge in Restricted Band

Radiated Band-edge in Restricted Band:

2310 to 2390 MHz, 3m distance
1 MBPS

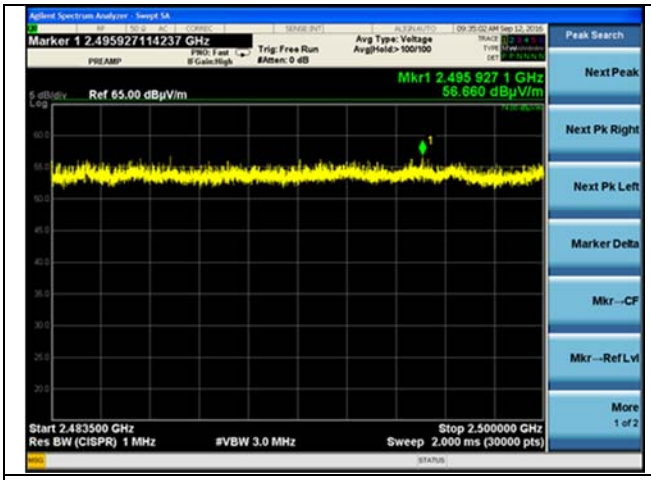


Average

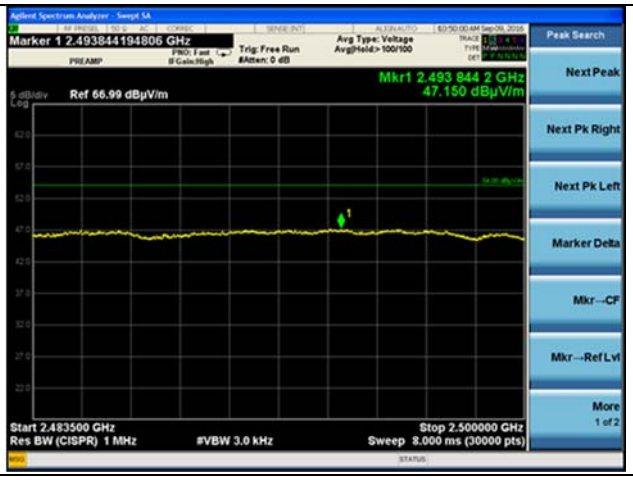


Peak

2483.5 to 2500 MHz Restricted band
1MBPS

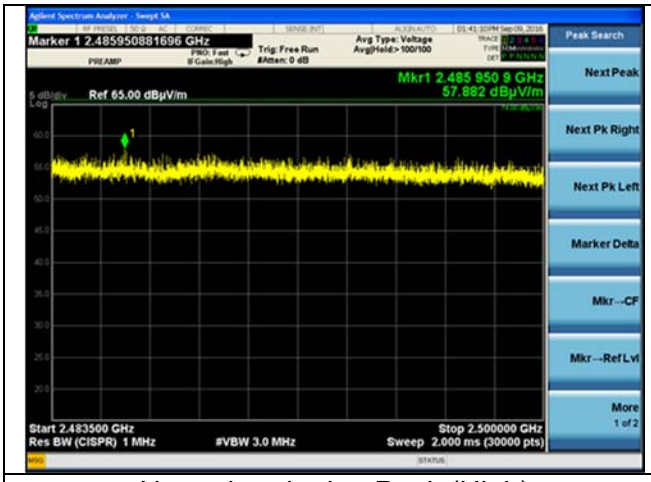


Upper band edge Peak (High)

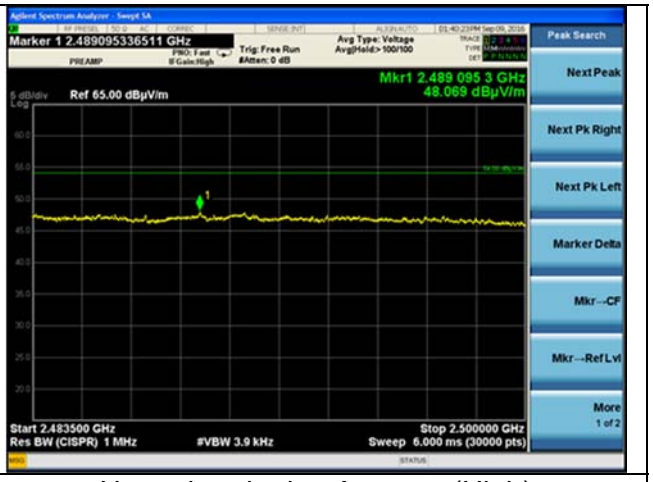


Upper band edge Average (High)

11MBPS

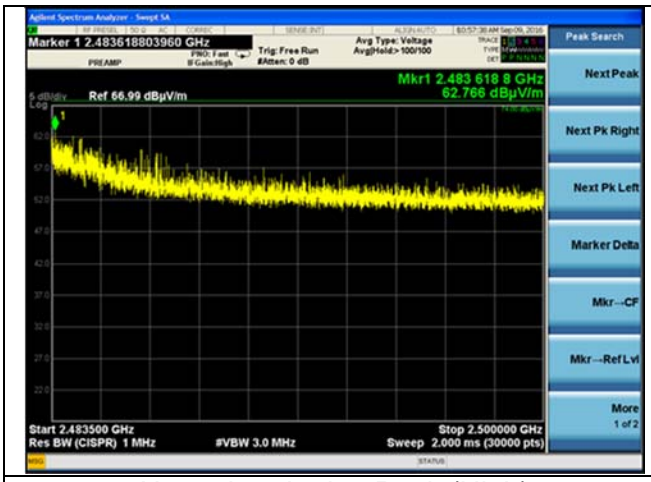


Upper band edge Peak (High)



Upper band edge Average (High)

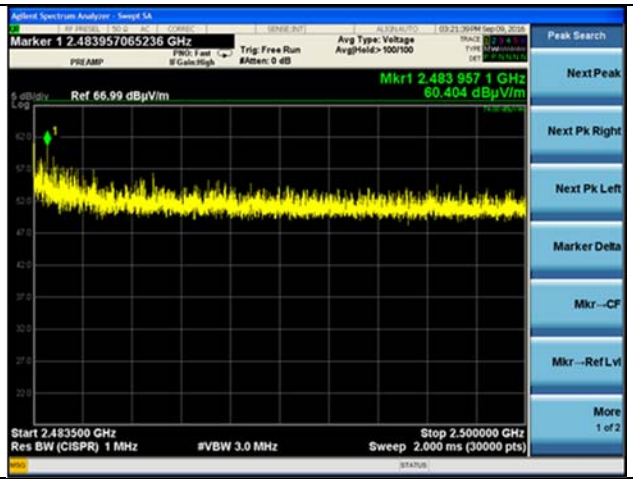
6MBPS



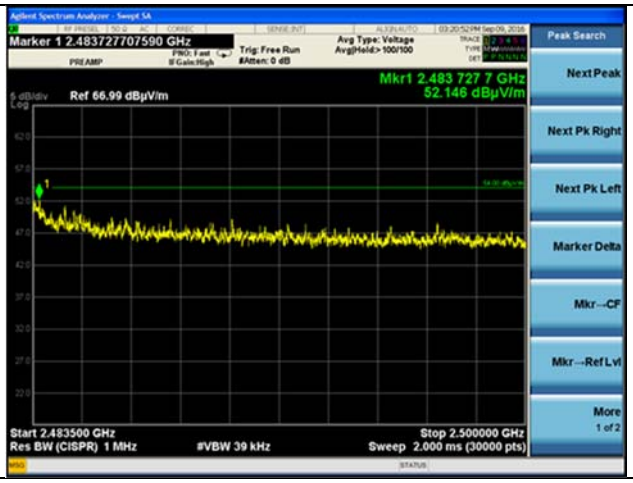
Upper band edge Peak (High)

Upper band edge Average (High)

54MBPS

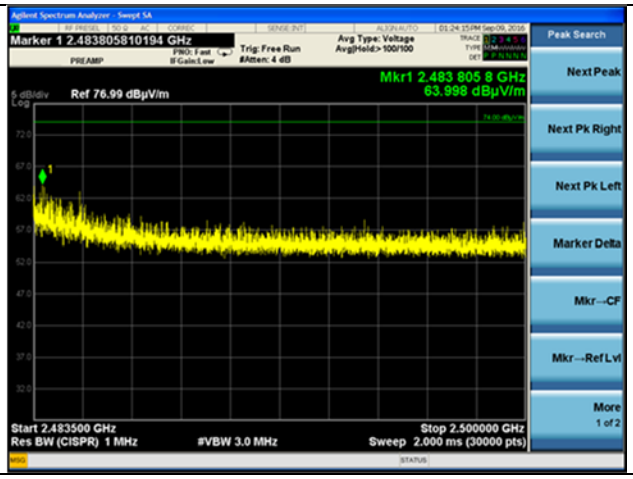


Upper band edge Peak (High)

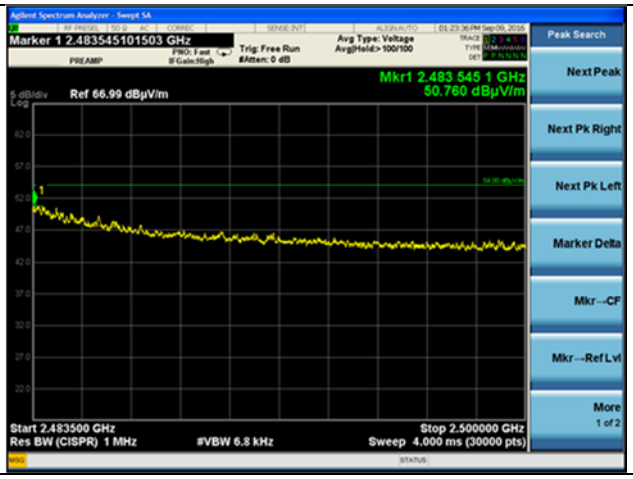


Upper band edge Average (High)

MCS0

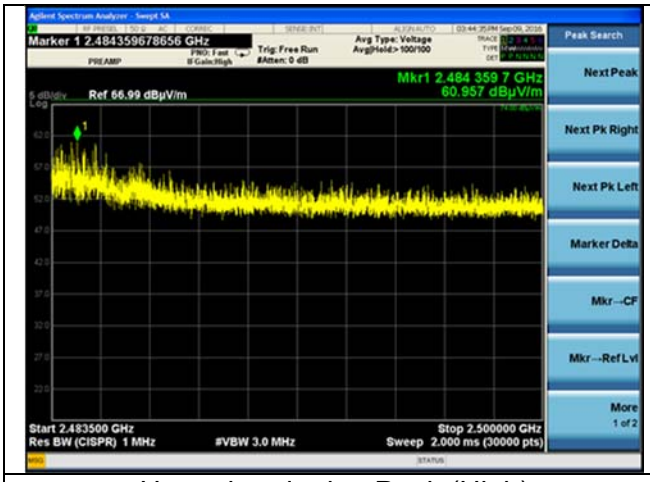
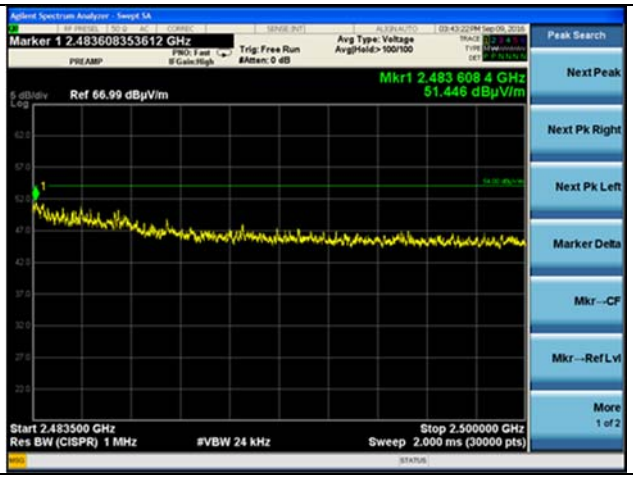


Upper band edge Peak (High)



Upper band edge Average (High)

MCS7

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

Data Tables

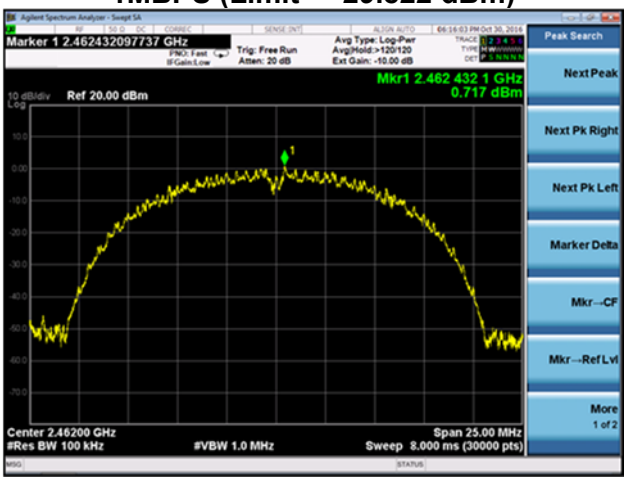
Data Rate	Channel	Frequency (MHz)	Peak (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dBuV/m)
1 MBPS	1	2357.3	61.6	74.0	12.4
	11	2495.9	56.7	74.0	17.3
6 MBPS	1	2388.3	61.4	74.0	12.6
	11	2483.6	62.8	74.0	11.2
11 MBPS	1	2338.2	57.4	74.0	16.6
	11	2486.0	57.9	74.0	16.1
54 MBPS	1	2390.0	58.9	74.0	15.1
	11	2484.0	60.4	74.0	13.6
MCS0	1	2390.0	61.8	74.0	12.2
	11	2483.8	64.0	74.0	10.0
MCS7	1	2387.5	55.6	74.0	18.4
	11	2484.4	61.0	74.0	13.0

Data Rate	Channel	Frequency (MHz)	Average (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dBuV/m)
1 MBPS	1	2340.6	48.5	54.0	5.5
	11	2493.8	47.2	54.0	6.9
6 MBPS	1	2389.5	50.4	54.0	3.6
	11	2483.6	51.3	54.0	2.7
11 MBPS	1	2330.4	47.8	54.0	6.2
	11	2489.1	48.1	54.0	5.9
54 MBPS	1	2389.8	52.6	54.0	1.4
	11	2483.7	52.1	54.0	1.9
MCS0	1	2389.5	49.6	54.0	4.4
	11	2483.5	50.8	54.0	3.2
MCS7	1	2389.1	49.3	54.0	4.7
	11	2483.6	51.4	54.0	2.6

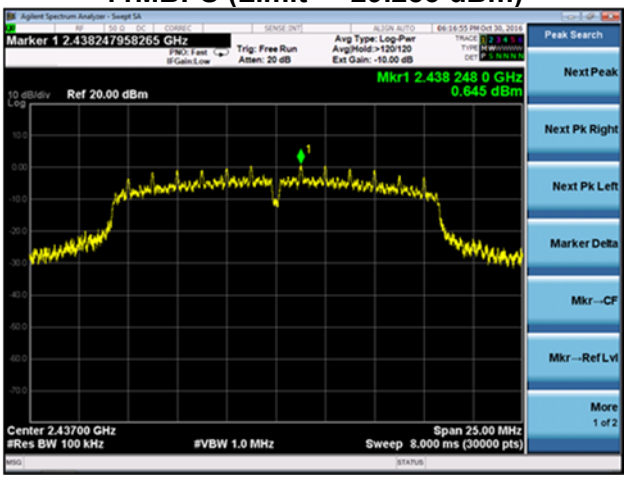
Conducted Band Edge Reference Pictures

Refer to pictures below for reference point for emissions. Display lines on spurious pictures do not represent limit line.

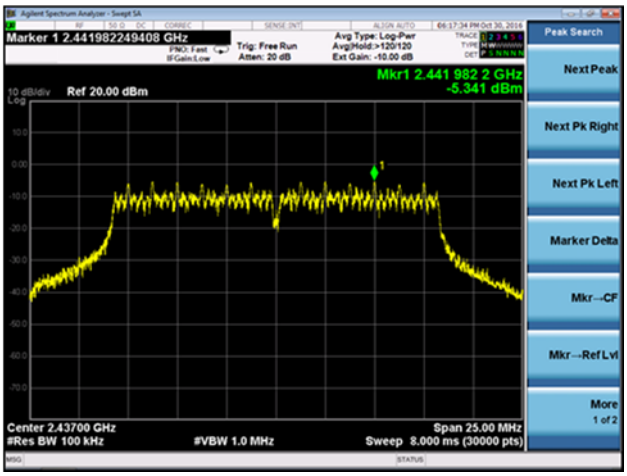
1MBPS (Limit = -29.822 dBm)



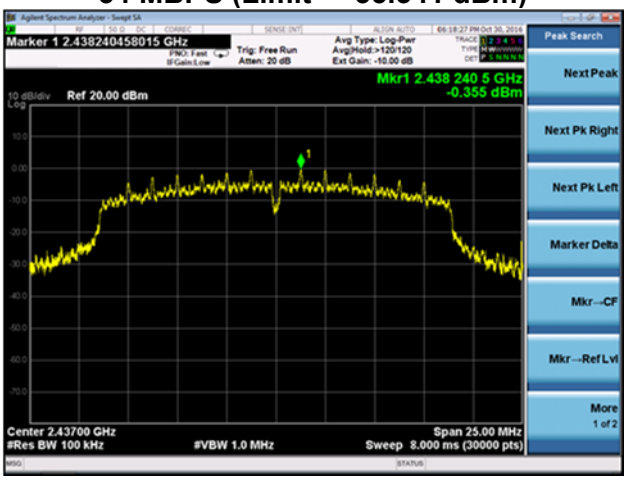
11MBPS (Limit = -29.283 dBm)



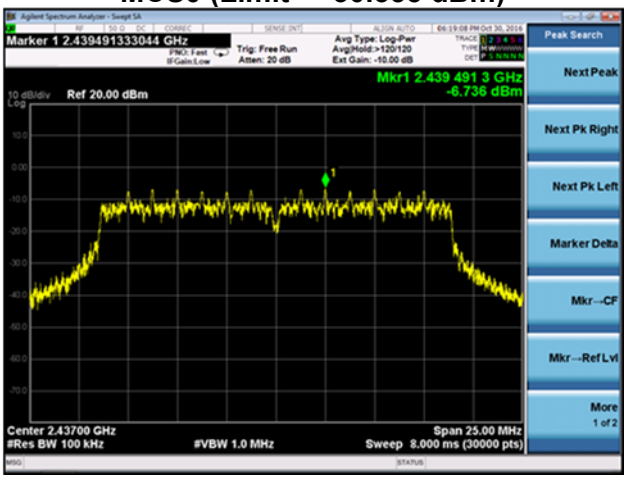
6MBPS (Limit = -29.355 dBm)



54 MBPS (Limit = -35.341 dBm)



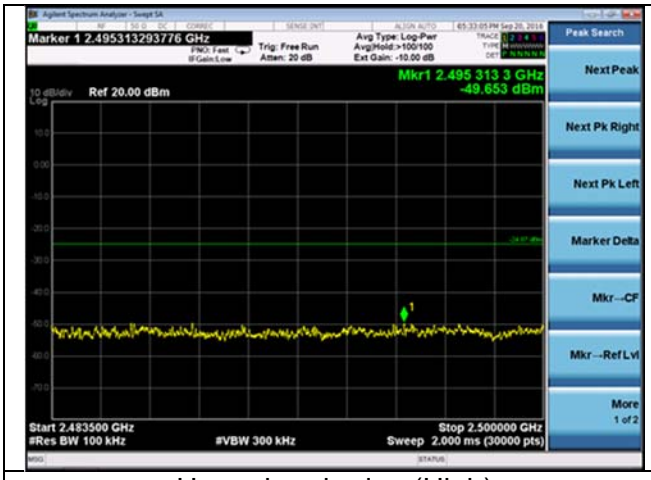
MCS0 (Limit = -30.355 dBm)



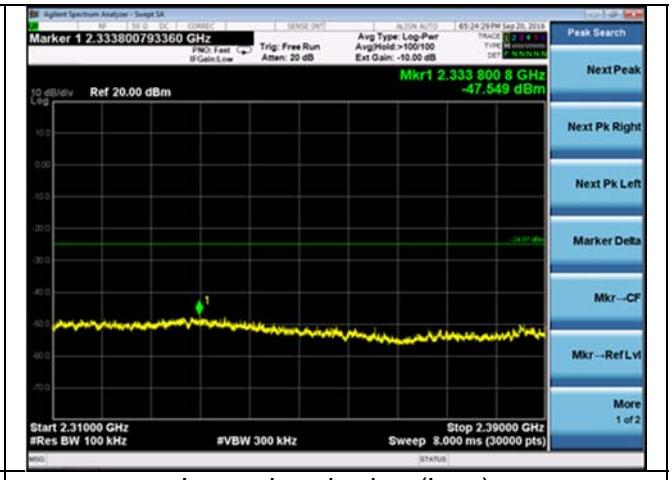
MCS7 (Limit = -36.736 dBm)

Band-edge in 100kHz bandwidth (Conducted Band Edge)
Note: Limits shown are not Conducted Spurious limits.

WLAN
1MBPS

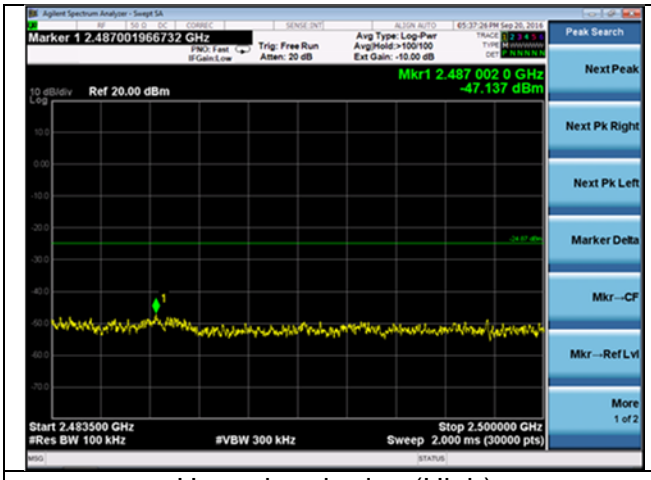


Upper band-edge (High)

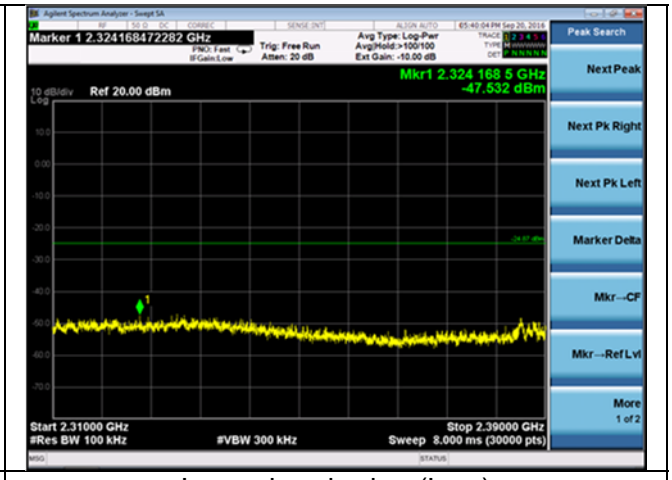


Lower band-edge (Low)

11MBPS

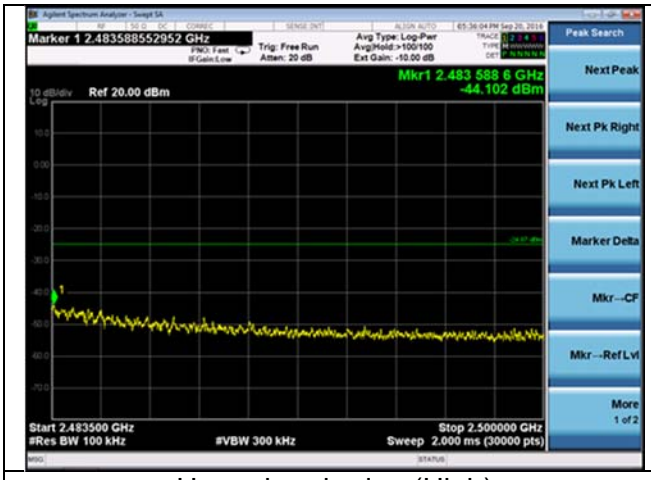


Upper band-edge (High)

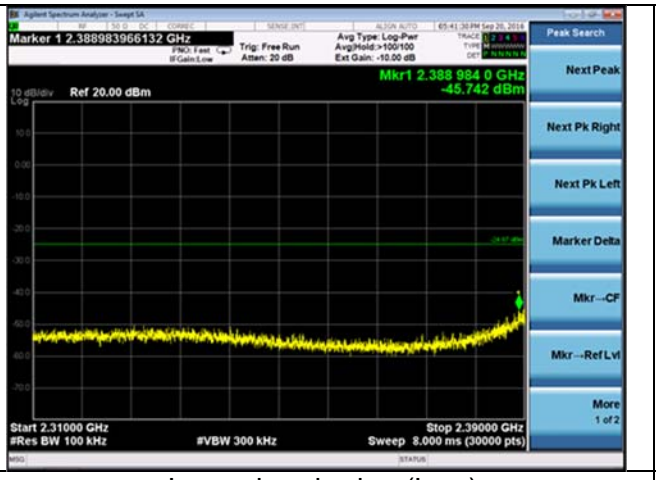


Lower band-edge (Low)

6MBPS

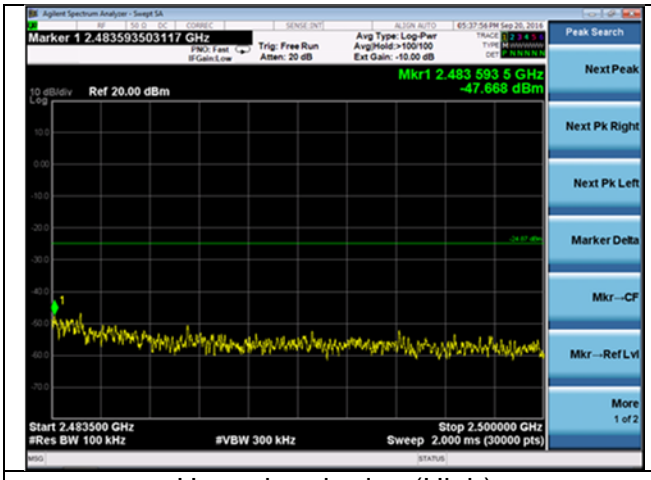


Upper band-edge (High)

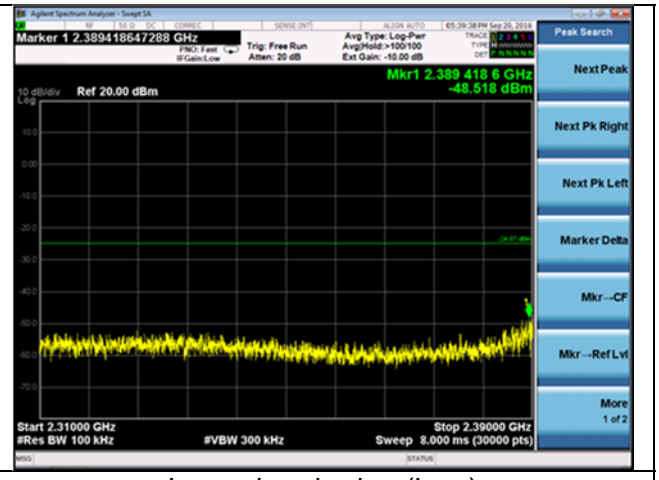


Lower band-edge (Low)

54MBPS

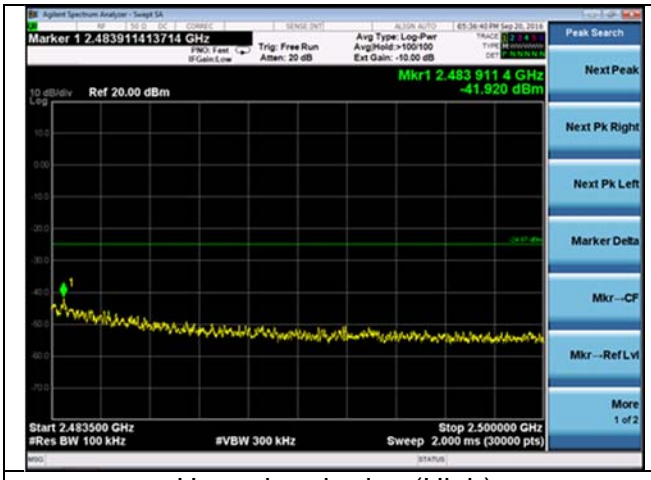


Upper band-edge (High)

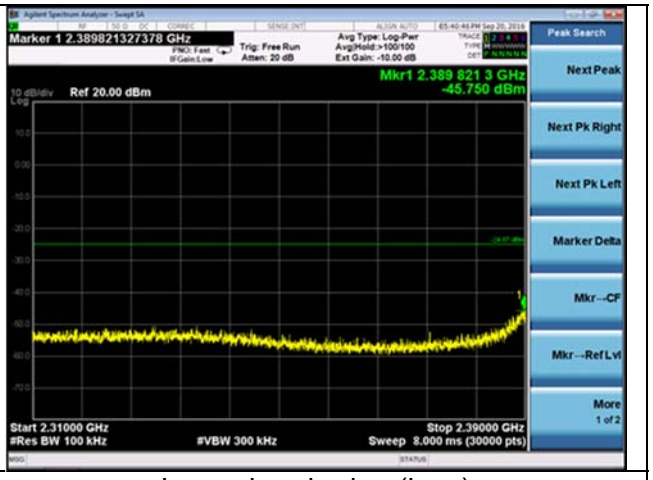


Lower band-edge (Low)

MCS0

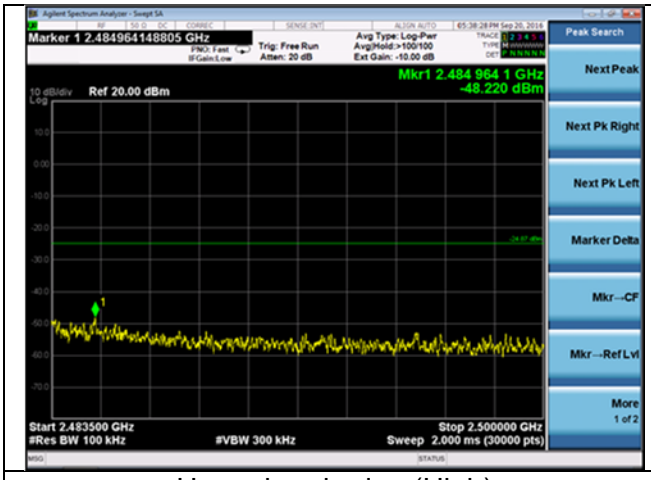


Upper band-edge (High)

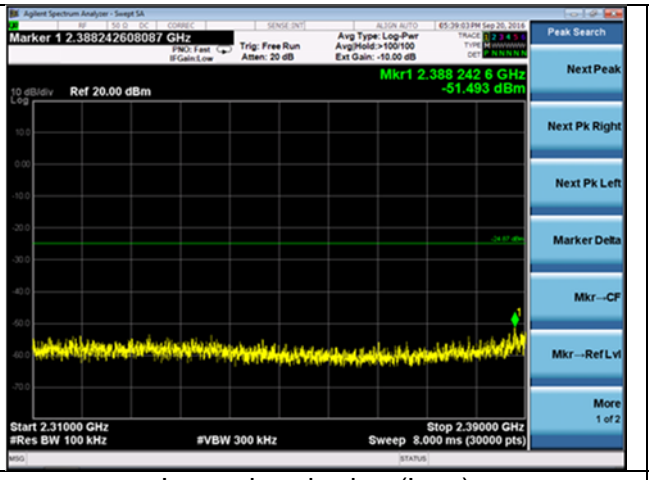


Lower band-edge (Low)

MCS7



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 v03r05 section 9.2.2.4 for 1 and 11 MBPS and 9.2.2.6 for the other data rates.

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).

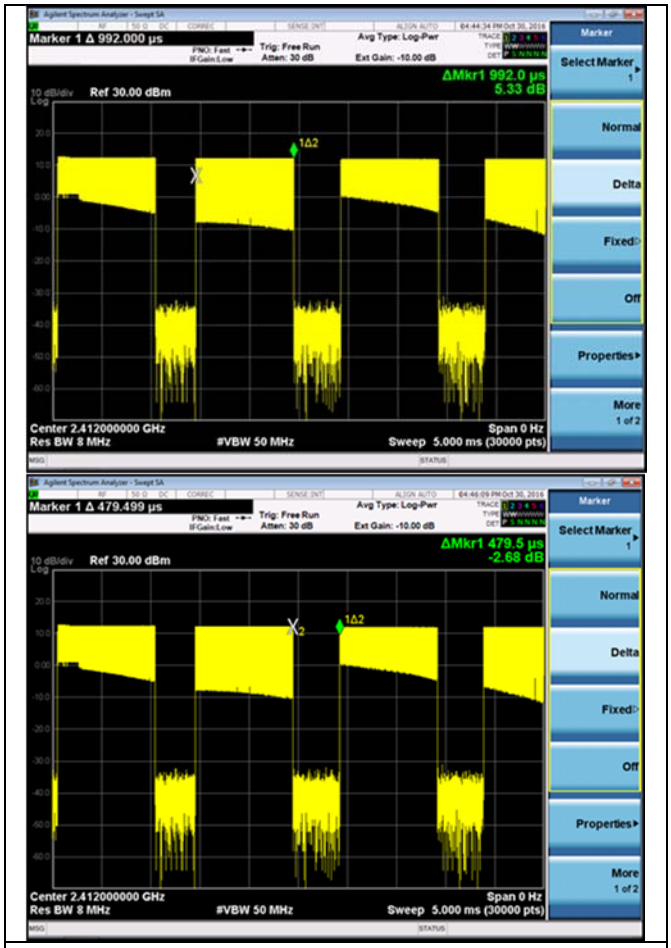
Peak Conducted Output Power Limit = 1 Watt (30 dBm).

9.2.1. Maximum conducted peak power:

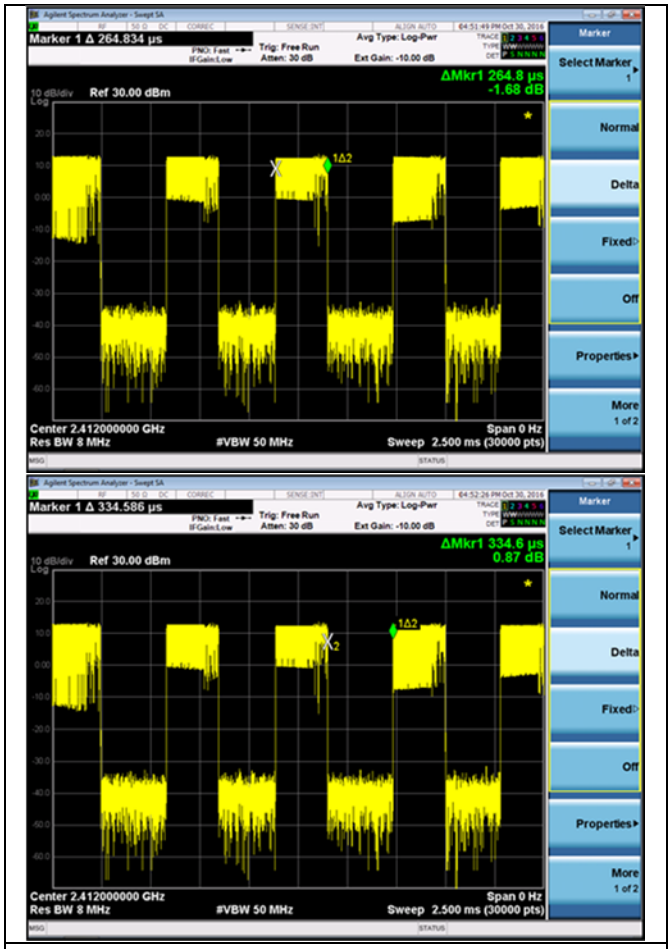
9.2.1.1 Duty cycle:

Measurement procedure: **FCC OET KDB 558074 D01 Measurement Guidance v03r05.**

Screen captures:



Duty Cycle (1 MBPS)



Duty Cycle (11 MBPS)

Note: Only 1 and 11 MBPS data rates had a measurable duty cycle.

Duty Cycle Correction = 10 log (1/x)

1 MBPS: x = On Time/ (On Time + Off Time) = 992.0 us / (992.0 + 479.5) us = .674

Duty Cycle Correction = 10 log (1/.674) = 1.713 dBm

11 MBPS: x = On Time/(On Time + Off Time) = 264.8 us / (264.8 + 334.6) us = .442

Duty Cycle Correction = 10 log (1/.442) = 3.546 dBm

9.2.1.2 Maximum conducted (average) output power:

Data Rate	Channel	Pout (dBm)	Corrected Pout (dBm)
1 MBPS	Low	7.436	9.148
	Mid	8.096	9.808
	High	8.430	10.142
11 MBPS	Low	6.192	9.740
	Mid	6.662	10.210
	High	6.899	10.447

Sample Calculation: (1 MBPS Low Channel)
Final Measurement = Measured Pout + Duty Cycle Correction
=8.430+ (10 log (1/.674)) = 8.430 + 1.712
= 10.142

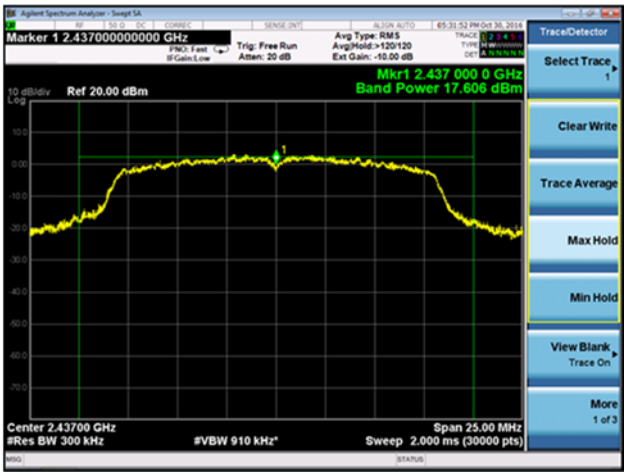
Data Rate	Channel	Pout (dBm)
6 MBPS	Low	15.605
	Mid	17.606
	High	16.435
54 MBPS	Low	10.217
	Mid	12.480
	High	11.529
MCS0	Low	14.574
	Mid	16.408
	High	15.435
MCS7	Low	8.751
	Mid	11.213
	High	10.020

Example Screenshots

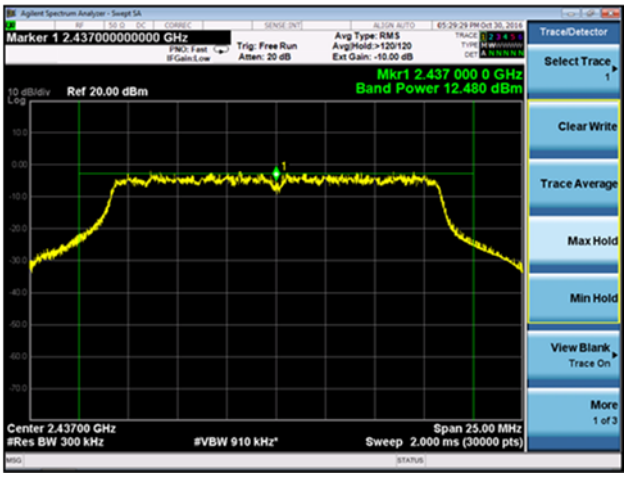
1MBPS

11 MBPS

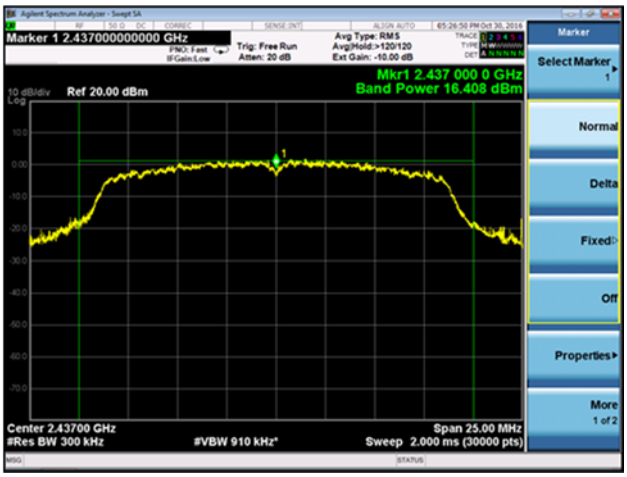
6 MBPS



54 MBPS



MCS0



MCS7

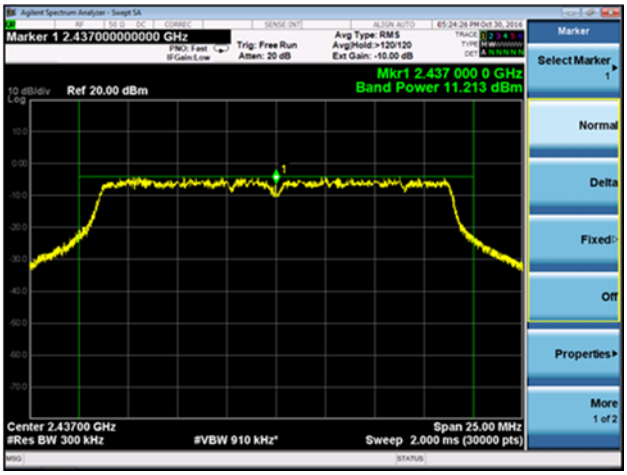


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EXHIBIT 10. CONDUCTED SPURIOUS EMISSIONS: 15.247(d)

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 v03r05 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).

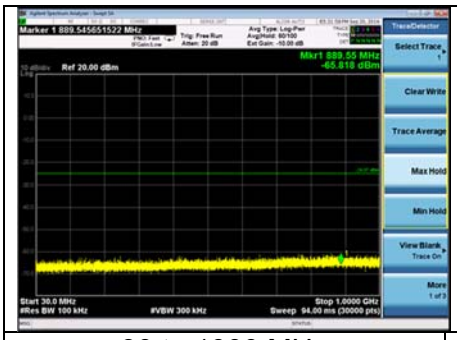
Generic example of reported data at 2440 MHz:

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

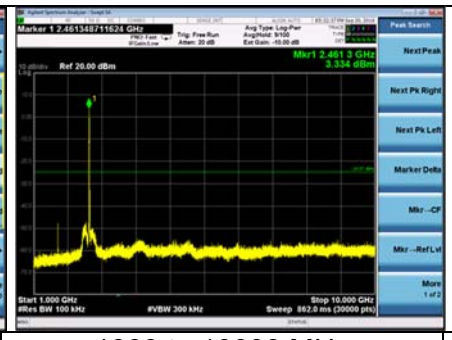
10.3 - Test Data

The data presented below are samples selected from the various data rates and channels tested. Display lines on captures do not represent limit lines, so refer to the fundamental picture for limits. Pictures below are samples.

1 MBPS



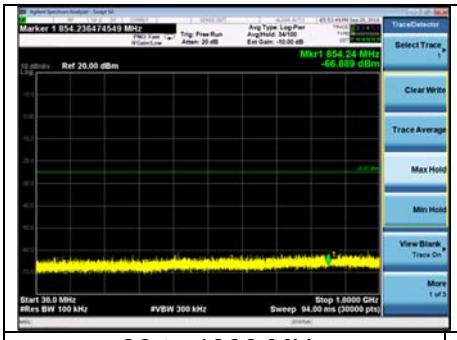
30 to 1000 MHz



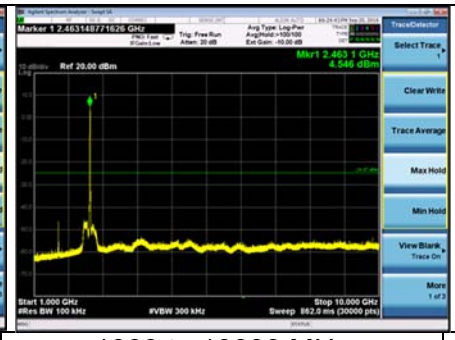
1000 to 10000 MHz

10000 to 25000 MHz

11 MBPS



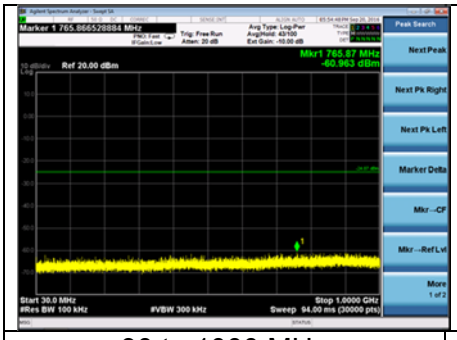
30 to 1000 MHz



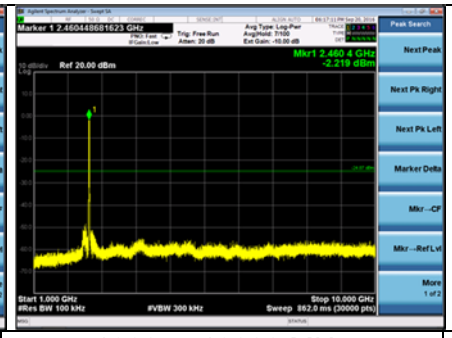
1000 to 10000 MHz

10000 to 25000 MHz

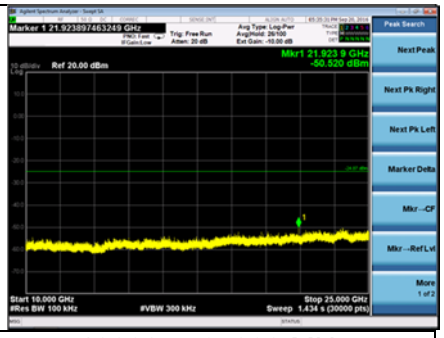
6 MBPS



30 to 1000 MHz

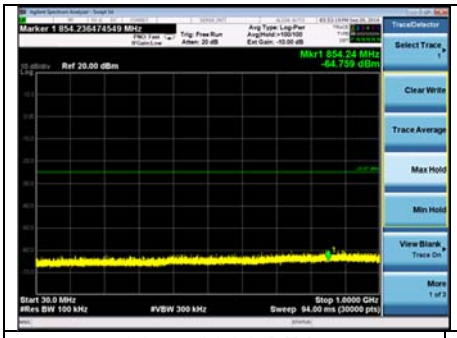


1000 to 10000 MHz

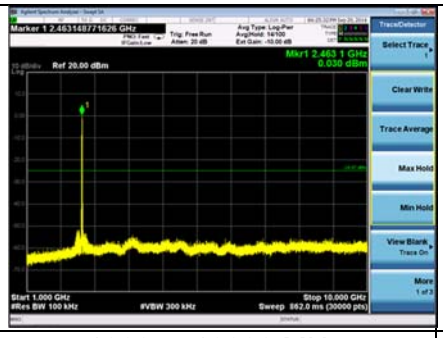


10000 to 25000 MHz

54 MBPS



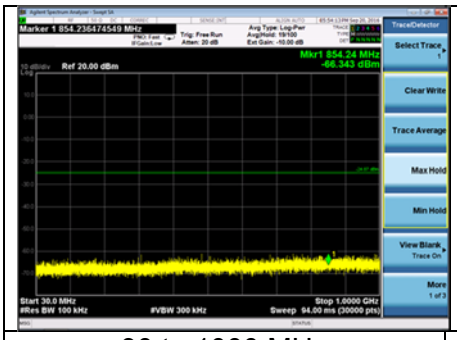
30 to 1000 MHz



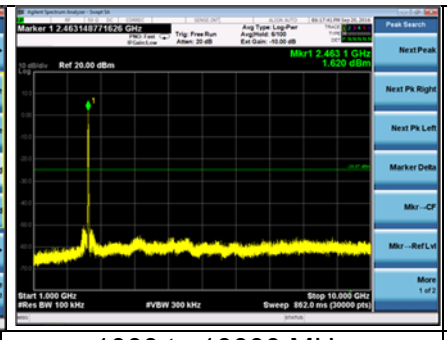
1000 to 10000 MHz

10000 to 25000 MHz

MCS0



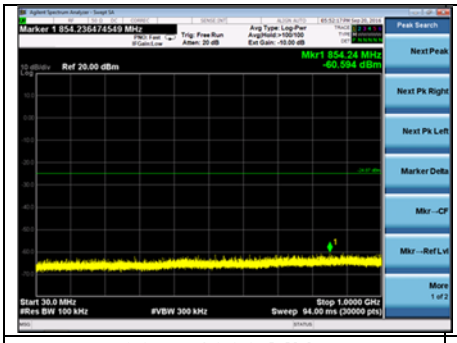
30 to 1000 MHz



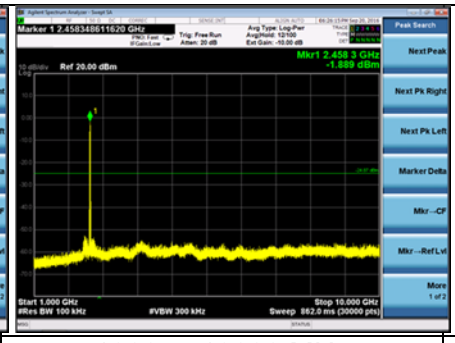
1000 to 10000 MHz

10000 to 25000 MHz

MCS7



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 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 v03r05 section 10.5 for 1 and 11 MBPS, 10.7 for other data rates.

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

Data Rate	Channel	PSD (dBm)	Corrected PSD (dBm)
1 MBPS	Low	-8.850	-7.138
	Mid	-8.219	-6.507
	High	-7.941	-6.229
11 MBPS	Low	-10.609	-7.061
	Mid	-9.437	-5.889
	High	-9.203	-5.655

Note: Refer to Section 9 for DC used for corrections.

Data Rate	Channel	PSD (dBm)
6 MBPS	Low	-1.274
	Mid	0.719
	High	-0.62
54 MBPS	Low	-7.399
	Mid	-5.247
	High	-6.196
MCS0	Low	-2.154
	Mid	-0.353
	High	-1.346
MCS7	Low	-8.832
	Mid	-6.708
	High	-7.634

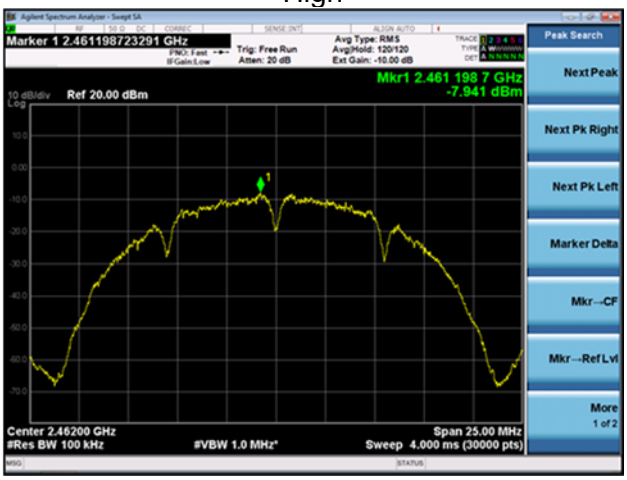
11.3 Screen Captures – Power Spectral Density

WLAN Channel (1MBPS)

Low

Mid

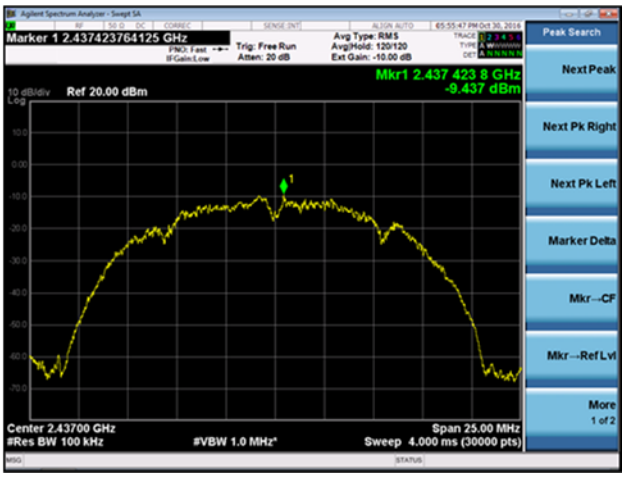
High



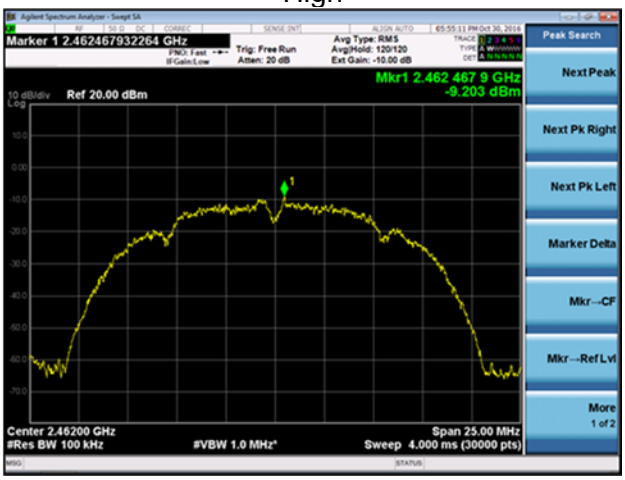
WLAN Channel (11MBPS)

Low

Mid

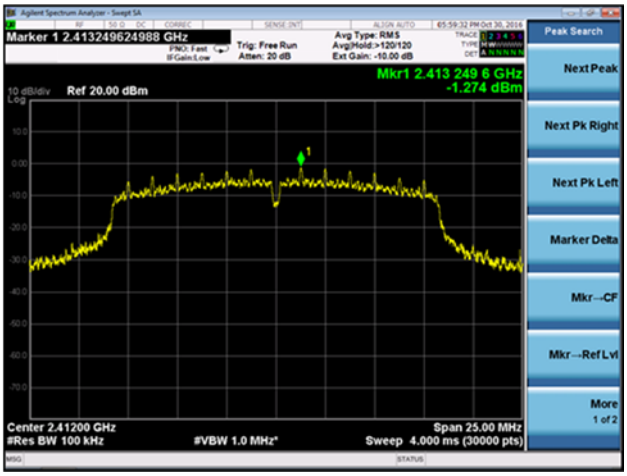


High

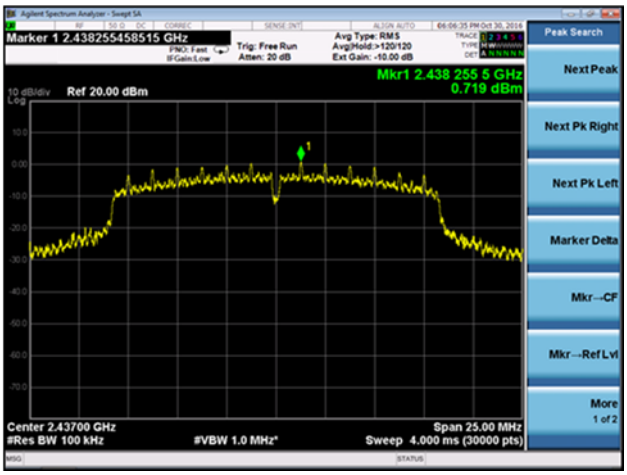


WLAN Channel (6 MBPS)

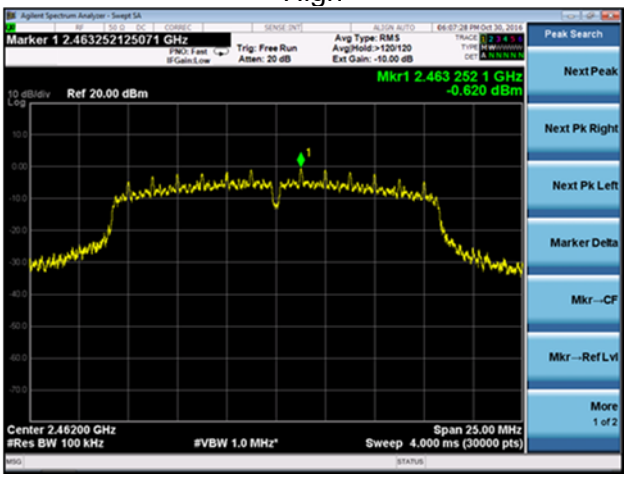
Low



Mid

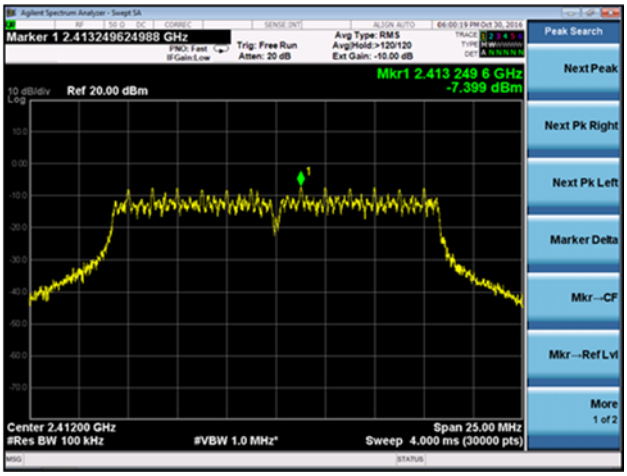


High

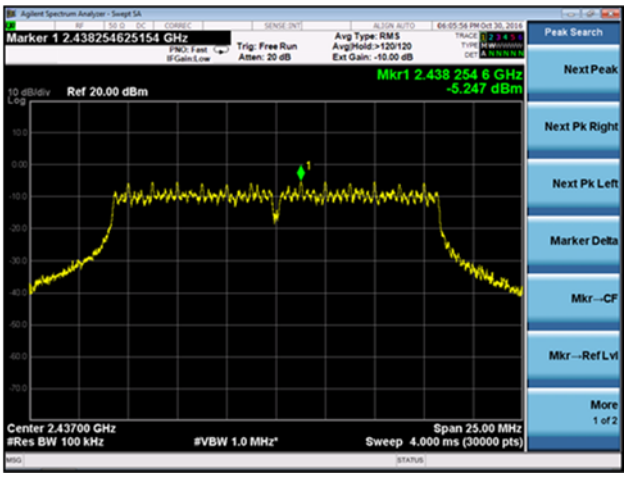


WLAN Channel (54 MBPS)

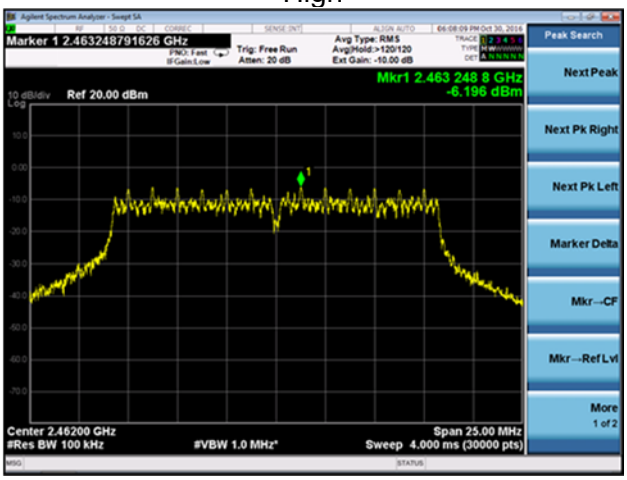
Low



Mid

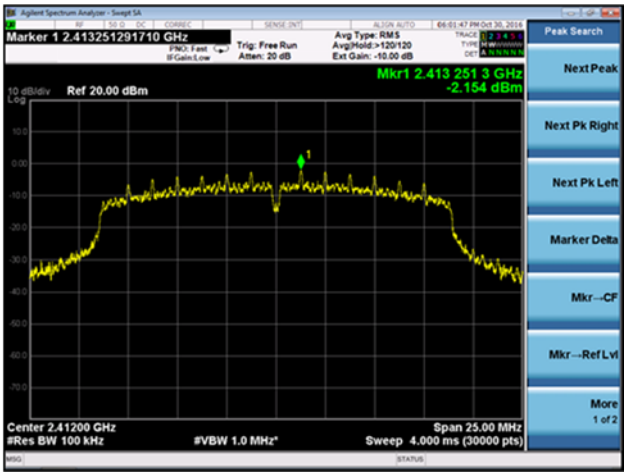


High

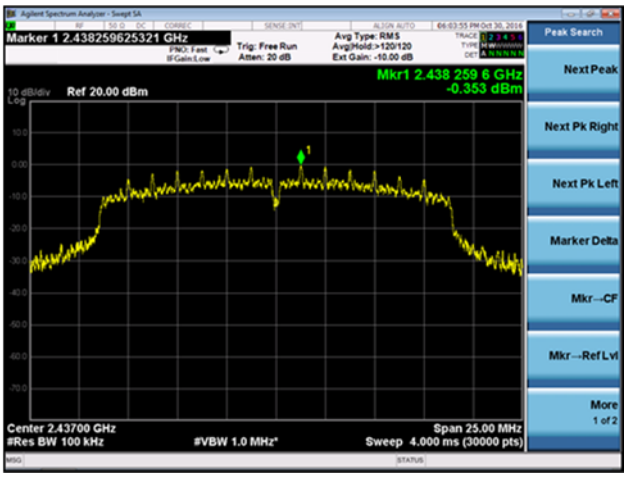


WLAN Channel (MCS0)

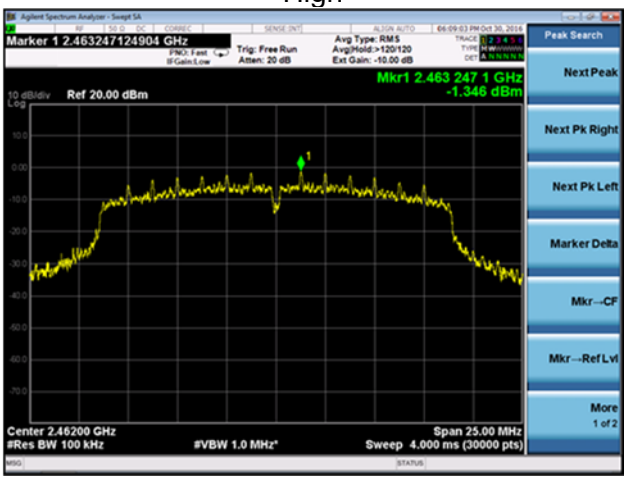
Low



Mid

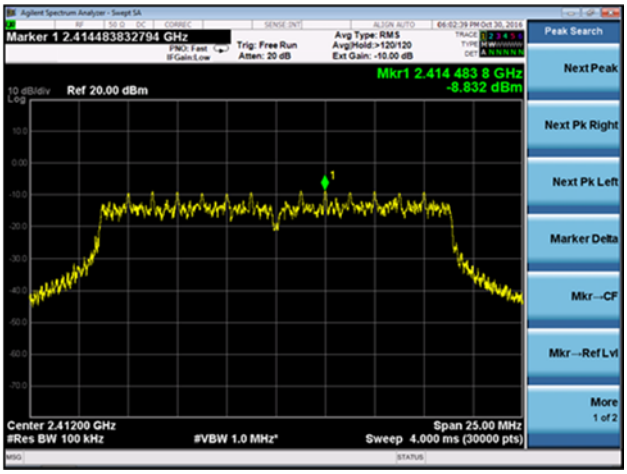


High

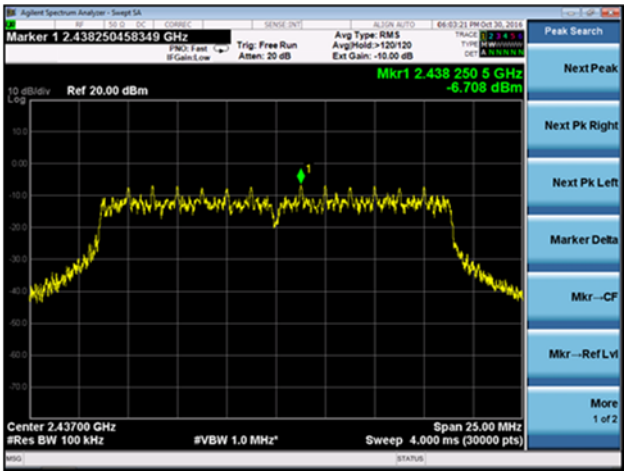


WLAN Channel (MCS7)

Low



Mid



High

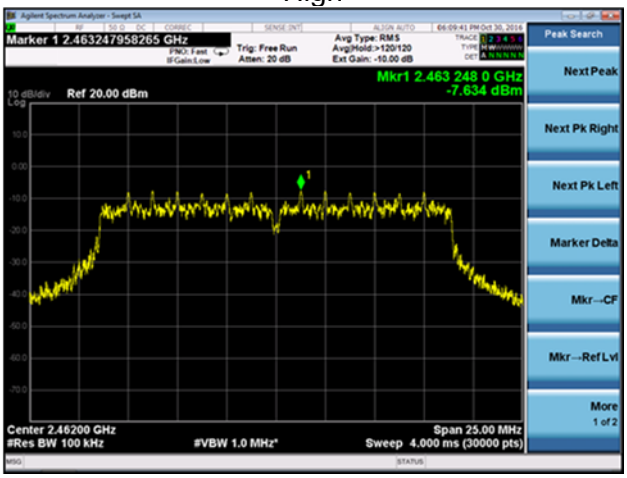


EXHIBIT 12. FREQUENCY STABILITY OVER VOLTAGE VARIATIONS

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 (To simulate battery power) and by a variable AC voltage supply (To simulate AC mains power). Each supply was tested separately and was varied ±15% from the nominal values. If the unit could not be changed by 10% it was instead changed to its minimum or maximum value.

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. The stability was found to be approximately 71.0 ppm.

WLAN (Battery)

	Channels		
Voltage (VDC)	Low (MHz)	Mid (MHz)	High (MHz)
3.4	2411.9899	2436.9594	2462.0264
3.8	2412.0094	2436.9637	2462.0156
4.2	2412.0376	2436.9551	2462.0004
Deviation (Hz)	47700	8600	26000

WLAN (120 VAC)

	Channels		
Voltage (VDC)	Low (MHz)	Mid (MHz)	High (MHz)
108	2411.9552	2436.9832	2462.0112
120	2412.1134	2436.9811	2461.9766
138	2412.1264	2437.0352	2461.9614
Deviation (Hz)	171200	54100	49800

APPENDIX A – Test Equipment List

LSR
a Laird Business

Date : 29-Aug-2016 | Type Test : Conducted AC Mains Emissions | Job # : C-2526

Prepared By: Shane Dock | Customer : White Stagg/Halo Smart Labs | Quote #: 316019

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: Shane Dock | Quality Assurance:

LSR
a Laird Business

Date : 29-Aug-2016 | Type Test : Conducted Radio | Job # : C-2526

Prepared By: Shane Dock | Customer : White Stagg/Halo Smart Labs | Quote #: 316019

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: Shane Dock | Quality Assurance:

LSR
a Laird Business

Date : 21-Sep-2016 | Type Test : Radiated Emissions | Job # : C-2526

Prepared By: Shane Dock | Customer : White Stagg/Halo Smart Labs | Quote #: 316019

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	AA 960174	Small Horn Antenna 18-40 GHz	ETS-Lindgren	3116C-PA	00206880	4/23/2016	4/23/2017	Active Calibration
2	AA 960171	Cable - low loss 6m	A.H. Systems, Inc.	SAC-26G-6	386	3/31/2016	3/31/2017	Active Verification
3	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/12/2016	5/12/2017	Active Calibration
4	AA 960007	Double Ridge Horn Antenna	EMCO	3115	9311-4138	7/22/2016	7/22/2017	Active Calibration
5	EE 960160	0.8-21GHz LNA	Mini-Circuits	ZVA-213X-S+	977711030	7/22/2016	7/22/2017	Active Calibration
6	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	2/24/2016	2/23/2017	Active Calibration
7	AA 960154	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-02	7/25/2016	7/25/2017	Active Calibration
8	AA 960153	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-04	4/29/2016	4/29/2017	Active Calibration
9	AA 960005	Biconical Antenna	EMCO	93110B	9601-2280	1/14/2016	1/13/2017	Active Calibration
10	AA 960078	Log Periodic Antenna	EMCO	93146	9701-4855	3/31/2016	3/31/2017	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		

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	*Configuration*	*Uncertainty Values*
Radiated Emissions	*Biconical Antenna*	*5.0 dB*
Radiated Emissions	*Log Periodic Antenna*	*5.3 dB*
Radiated Emissions	*Horn Antenna*	*4.7 dB*
AC Line Conducted Emissions	*AMN*	*3.4 dB*
Telecom Conducted Emissions	*AAN*	*4.9 dB*
Disturbance Power (Emissions)	*Absorbing Clamp*	*4.1 dB*
Radiated Immunity	*3 Volts/Meter*	*2.2 dB*
Conducted Immunity	*CDN/EM/BCI*	*2.4/3.5/3.4 dB*
EFT Burst / Surge	*Peak pulse voltage*	*164 volts*
ESD Immunity	*15 kV level*	*1377 Volts*

Parameter	**ETSI U.C.+/-**	**U.C.+/-**
Radio Frequency, from F0	$1x10^{-7}$	$0.55x10^{-7}$
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (PM)	1.5 dB	1.2 dB
RF conducted emissions (SA)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
Supply voltages	3 %	1 %