LS RESEARCH, LLC
Wireless Product Development

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

ENGINEERING TEST REPORT # TR 314337 A
LSR Job #: C-2089

Compliance Testing of:
8000-WiFi Module

Test Date(s):
April-June, 2015
November 3-29, 2015

Prepared For:
Tridium
3951 Westerre Parkway
Suite 350
Richmond, VA 23233

This Test Report is issued under the Authority of:
Peter Feilen, EMC Engineer

Signature: Peter Feilen Date: 11/13/2015

Test Report Reviewed by:	**Report by:**
Thomas Smith, VP-Test Services	Peter Feilen, EMC Engineer
Signature: Thomas T. Smith Date: 11/13/2015	Signature: Peter Feilen Date: 11/4/15

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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 3 Meter Semi-Anechoic Chamber based on Title 47 CFR – Part 2.948
FCC Registration Number: 90756

Industry Canada

On file, 3 Meter Semi-Anechoic Chamber based on RSS-212 – Issue 1
File Number: IC 3088-A
On file, 3 and 10 Meter OATS based on RSS-212 – Issue 1
File Number: IC 3088

U. S. Conformity Assessment Body (CAB) Validation

Validated by the European Commission as a U. S. Competent Body operating under the U. S./EU, Mutual Recognition Agreement (MRA) operating under the European Union Electromagnetic Compatibility –Council Directive 2004/108/EC (formerly 89/336/EEC, Article 10.2).
Date of Validation: January 16, 2001

Validated by the European Commission as a U.S. Notified Body operating under the U.S. /EU, Mutual Recognition Agreement (MRA) operating under the European Union Telecommunication Equipment – Council Directive 99/5/EC, Annex V.
Date of Validation: November 20, 2002
Notified Body Identification Number: 1243

1.0 Summary of Test Report

In May-November 2015 the EUT, Titan Controller, as supplied by Tridium was tested and MEETS the following requirements:

FCC Requirement	IC Requirement	Test Requirements	Measurement Procedure	Compliance (Yes/No)
15.247 (a)(2)	RSS-247 Section 5.2 (1)	6 dB Bandwidth of a Digital Modulation System	ANSI C63.10-2013 Section 11.8	Yes
15.247(b) & 1.1310	RSS-247 Section 5.4 (4)	Maximum Output Power	ANSI C63.10-2013 Section 11.9	Yes
15.247 (e)	RSS-247 Section 5.2 (2)	Power Spectral Density of a Digital Modulation System	ANSI C63.10-2013 Section 11.10	Yes
15.247(d)	RSS-247 Section 5.5	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	ANSI C63.10-2013 Section 11.11	Yes
15.247(c), 15.209 & 15.205	RSS-GEN Section 8.9, 8.10	Transmitter Radiated Emissions in Restricted Bands	ANSI C63.10-2013 Section 11.12 (6.3,6.5,6.6)	Yes
2.1055 (d)	RSS-GEN Section 6.11	Frequency Stability	ANSI C63.10-2013 Section 6.8	Yes
15.207	RSS-GEN Section 8.8	Power Line Conducted Emissions Measurements	ANSI C63.10-2013 Section 6.2	Yes

2.0 Test Facilities

All testing was performed at:

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

LS Research, LLC is accredited by A2LA (American Association for Laboratory Accreditation) to the requirements of 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.

3.0 Client Information

Manufacturer Name:	Tridium
Address:	3951 Westerre Parkway, Suite 350, Richmond, VA 23233
Contact Person:	Gene Allgood

3.1 Equipment Under Test (EUT) Information

The following information has been supplied by the applicant.

Product Name:	8000-WiFi Module
Model Number:	8000-WIFI
Serial Number:	Eng. Sample
FCC ID:	W98-12977
IC:	8339A-12977

3.2 Product Description

802.11 b/g/n device using HT20 channels 1-11

3.3 Modifications Incorporated In the EUT for Compliance Purposes

None noted at time of test

3.4 Deviations & Exclusions from Test Specifications

None noted at time of test

3.5 Additional Information

HT20 Channels: Low Channel 1(2412 MHz), Middle Channel 6 (2437 MHz), High Channel 11 (2462 MHz)

4.0 Conditions of Test

Environmental:

Temperature: 20-25º C
Relative Humidity: 30-60%
Atmospheric Pressure: 86-106 kPa

Mains Voltage: 120 VAC 60 Hz Power Pack Input, 5 VDC outputs

5.0 Test Equipment

All test equipment is calibrated by a calibration laboratory accredited by A2LA to the requirements of ISO 17025. For a complete list of test equipment and calibration dates, see Appendix A. Unless otherwise noted, resolution bandwidth of measuring instrument used during testing for given frequency range, see below.

Frequency Range	Resolution Bandwidth
9 kHz – 150 kHz	200 Hz
150 kHz – 30 MHz	9 kHz
30 MHz – 1000 MHz	120 kHz
Above 1000 MHz	1 MHz

6.0 Conformance Summary

The EUT was found to MEET the requirements as described within the specification of FCC Title 47, CFR Part 15.247, 15.207 as well as Industry Canada RSS-247 Issue 1, RSS-GEN Issue 4.

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

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

Appendix A – Test Data

A.1 – RF Conducted Emissions

Manufacturer	Tridium
Test Location	LS Research, LLC
Rule Part	FCC 15.247 IC RSS-247
General Measurement Procedure	ANSI C63.10 Section 6.7
General Description of Measurement	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.1.1 – RF Conducted – Fundamental Bandwidth

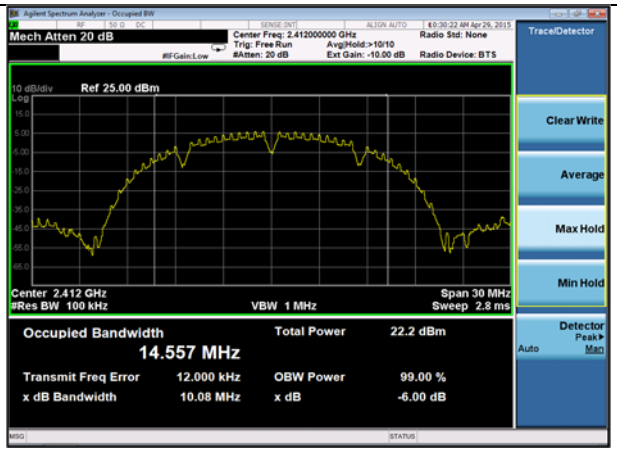
Manufacturer	Tridium
Date	April 24-29, 2015
Operator	Peter F.
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247 (a)(2) IC RSS-247 Section 5.2(1)
Specific Measurement Procedure	ANSI C63.10-2013 Section 11.8
Additional Description of Measurement	Peak detector used
Additional Notes	Continuous transmit modulated used for this test.

Table

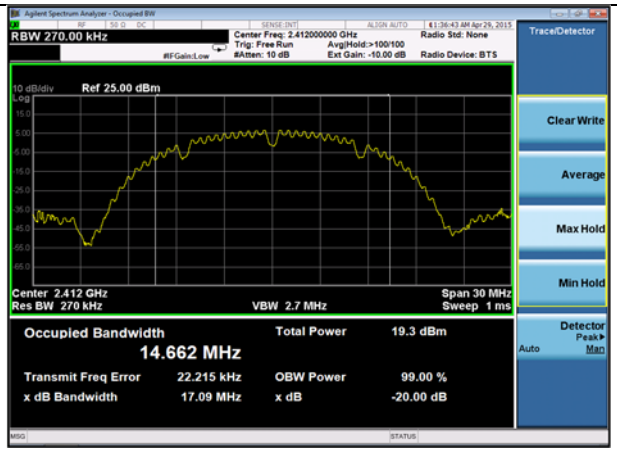
802.11 Standard	Data Rate (MBPS)	Channel	6dB Bandwidth (MHz)	-20dB Bandwidth (MHz)	99% Bandwidth (MHz)
b	1	1	10.1	17.1	14.7
		6	10.1	17.1	14.7
		11	10.1	17.1	14.6
b	11	1	11.1	14.7	14.6
		6	11.1	14.7	14.6
		11	11.1	14.6	14.6
g	6	1	15.1	18.8	16.6
		6	15.1	20.5	17.1
		11	15.1	18.7	16.5
g	54	1	15.1	18.0	16.5
		6	15.2	18.9	16.7
		11	15.1	18.1	16.5
n	MCS0	1	15.1	19.7	17.7
		6	15.1	21.1	18.1
		11	15.1	19.6	17.6
n	MCS7	1	15.1	19.3	17.6
		6	15.1	20.1	17.9
		11	15.1	19.1	17.6

Plots 802.11b – 1 Mbps

Low Channel – 2412 MHz

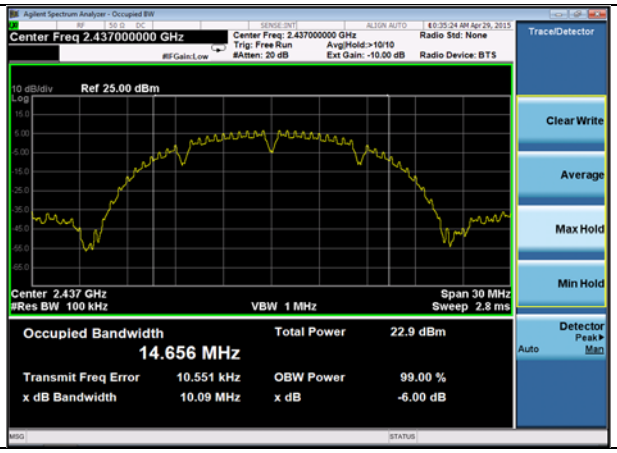


6 dB DTS BW

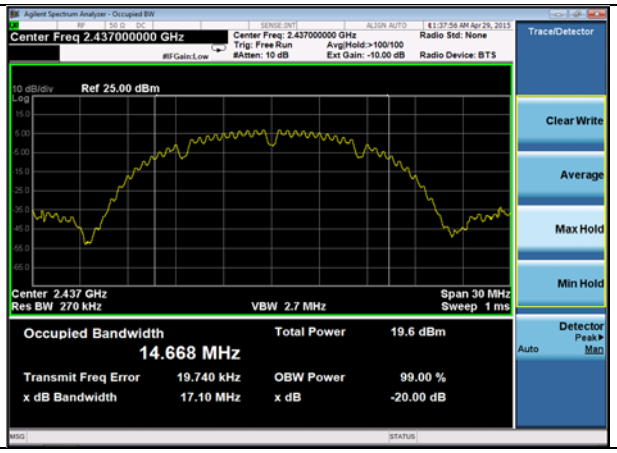


20 dB OBW + 99% BW

Mid Channel – 2437 MHz



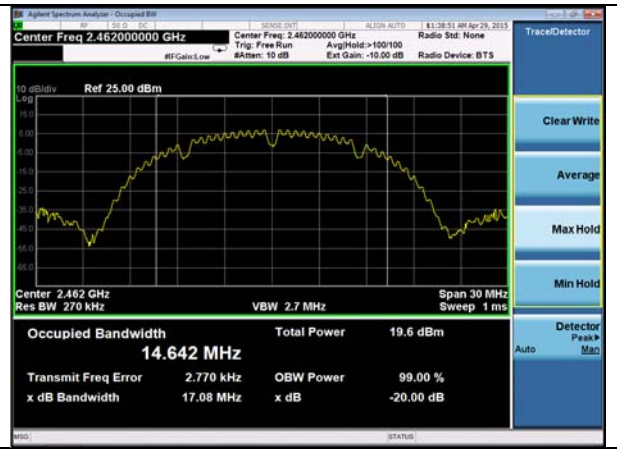
6 dB DTS BW



20 dB OBW + 99% BW

High Channel – 2462 MHz

6 dB DTS BW

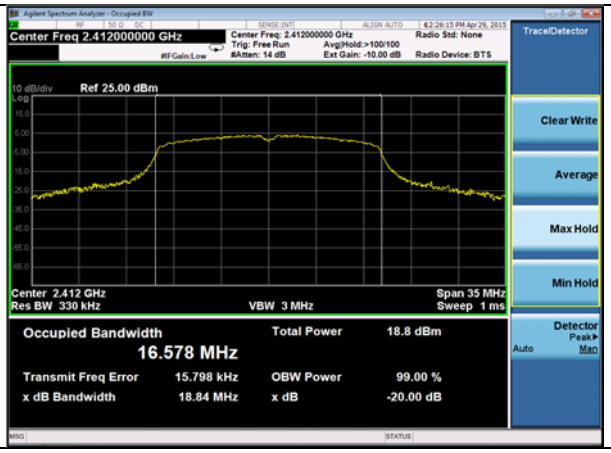


20 dB OBW + 99% BW

802.11g – 6 Mbps

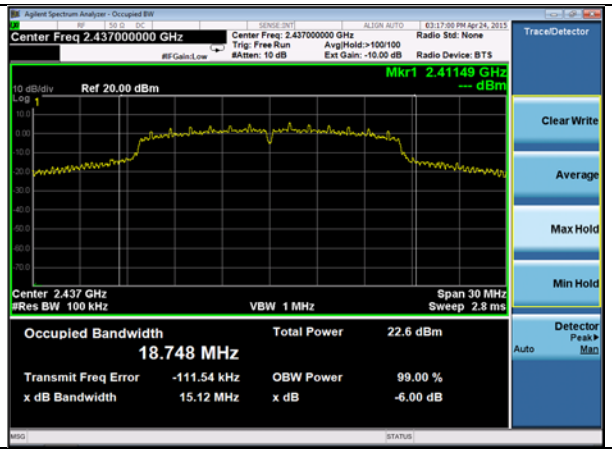
Low Channel – 2412 MHz

6 dB DTS BW

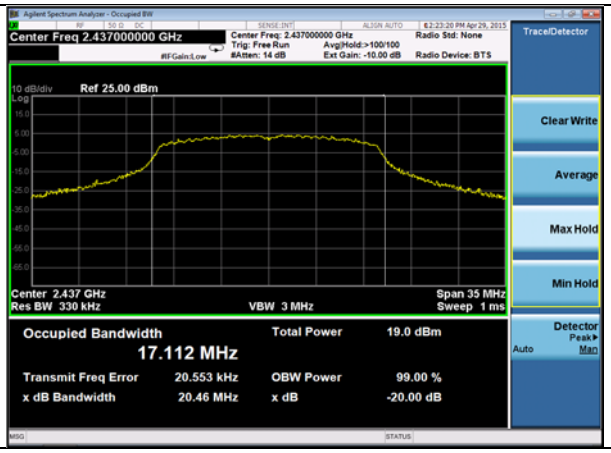


20 dB OBW + 99% BW

Mid Channel – 2437 MHz

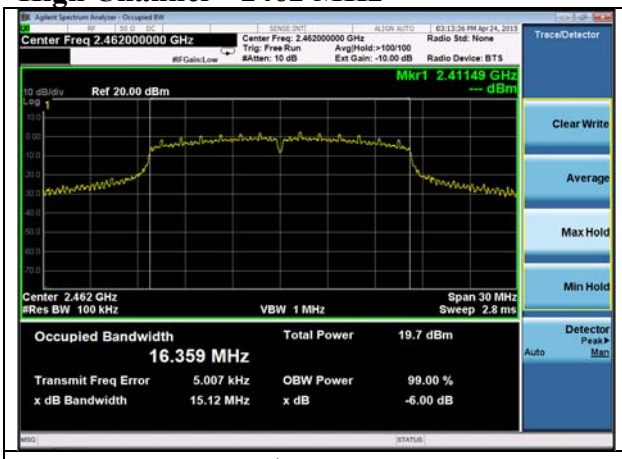


6 dB DTS BW



20 dB OBW + 99% BW

High Channel – 2462 MHz

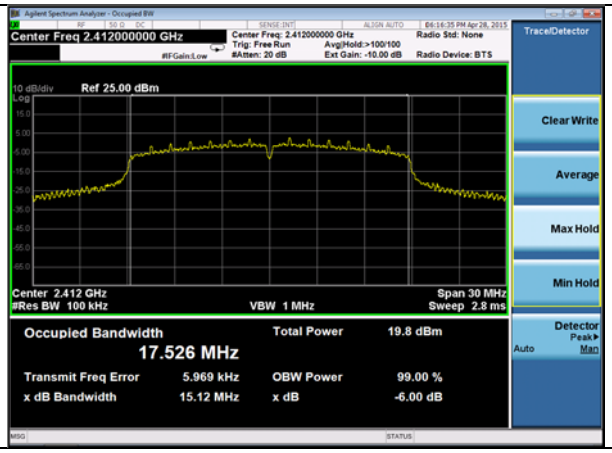


6 dB DTS BW

20 dB OBW + 99% BW

802.11n – 6.5 Mbps

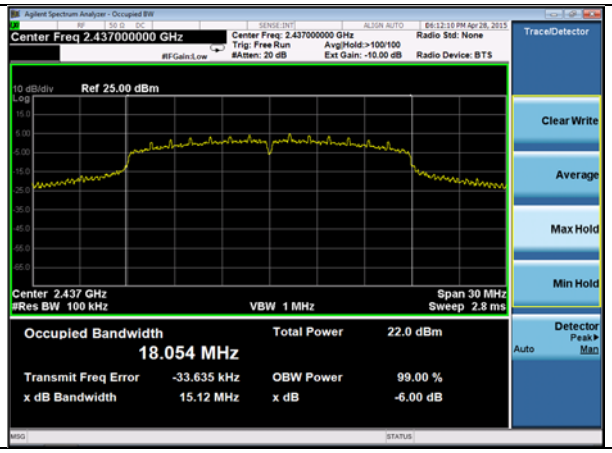
Low Channel – 2412 MHz



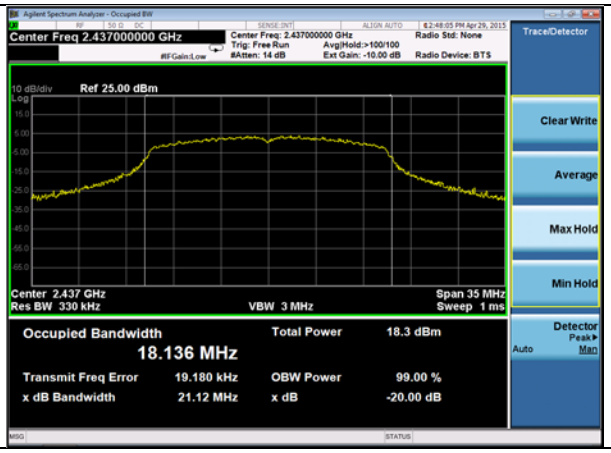
6 dB DTS BW

20 dB OBW + 99% BW

Mid Channel – 2437 MHz



6 dB DTS BW



20 dB OBW + 99% BW

High Channel – 2462 MHz

6 dB DTS BW

20 dB OBW + 99% BW

A.1.2 – RF Conducted – Fundamental Power and Spectral Density

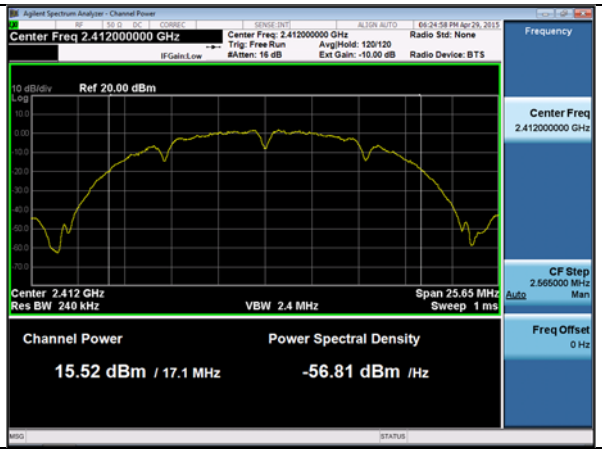
Manufacturer	Tridium
Date	April-November 2015
Operator	Peter F.
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247 (b) & (e) IC RSS-247 Section 5.4 (4) & 5.2 (2)
Specific Measurement Procedure	ANSI C63.10-2013 Power - 11.9.2.2.4 PSD – Section 11.10.5
Additional Description of Measurement	Average methods
Additional Notes	Sample Calculation: Margin (dB) = Limit – Measured level

Table

802.11 Standard	Data Rate (MBPS)	Channel	6dB Bandwidth (MHz)	-20dB Bandwidth (MHz)	6dB Bandwidth minimum limit (MHz)	Maximum Conducted (average) Power (dBm)	Duty Cycle correction for average measurement (dB)	Corrected Maximum Conducted Power (dBm)	Power Limit (dBm)	Power margin (dB)	Peak PSD (dBm)	PSD in 3kHz limit(dBm)	PSD margin (dBm)
b	1 (DBPSK)	1	10.1	17.1	0.5	15.5	0.0	15.5	30.0	14.5	3.9	8.0	4.1
		6	10.1	17.1	0.5	15.7	0.0	15.7	30.0	14.3	3.7	8.0	4.3
		11	10.1	17.1	0.5	15.8	0.0	15.8	30.0	14.2	2.7	8.0	5.3
b	11 (8 QPSK)	1	11.1	14.7	0.5	15.4	0.5	15.9	30.0	14.2	1.9	8.0	6.1
		6	11.1	14.7	0.5	15.5	0.5	16.0	30.0	14.1	2.2	8.0	5.8
		11	11.1	14.6	0.5	15.3	0.5	15.8	30.0	14.2	3.4	8.0	4.6
g	6	1	15.1	18.8	0.5	11.1	0.3	11.4	30.0	18.6	-3.9	8.0	11.9
		6	15.1	20.5	0.5	11.5	0.3	11.8	30.0	18.3	-2.9	8.0	10.9
		11	15.1	18.7	0.5	11.6	0.3	11.9	30.0	18.1	-2.9	8.0	10.9
g	54	1	15.1	18.0	0.5	9.5	2.1	11.6	30.0	18.4	-2.4	8.0	10.4
		6	15.2	18.9	0.5	9.6	2.1	11.7	30.0	18.3	-3.1	8.0	11.1
		11	15.1	18.1	0.5	9.7	2.1	11.8	30.0	18.2	-2.9	8.0	10.9
n	MCS0	1	15.1	19.7	0.5	10.7	0.3	11.0	30.0	19.0	-3.8	8.0	11.8
		6	15.1	21.1	0.5	11.0	0.3	11.3	30.0	18.7	-3.7	8.0	11.7
		11	15.1	19.6	0.5	10.9	0.3	11.2	30.0	18.8	-3.8	8.0	11.8
n	MCS7	1	15.1	19.3	0.5	8.9	2.3	11.2	30.0	18.9	-2.9	8.0	10.9
		6	15.1	20.1	0.5	9.2	2.3	11.5	30.0	18.5	-2.6	8.0	10.6
		11	15.1	19.1	0.5	9.2	2.3	11.5	30.0	18.5	-3.1	8.0	11.1

802.11b – 1 Mbps

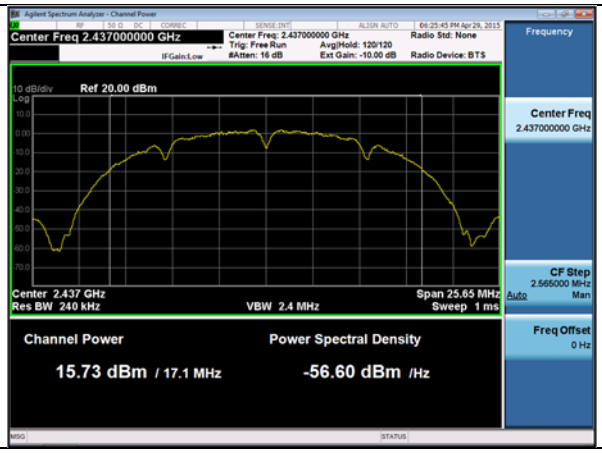
Low Channel – 2412 MHz



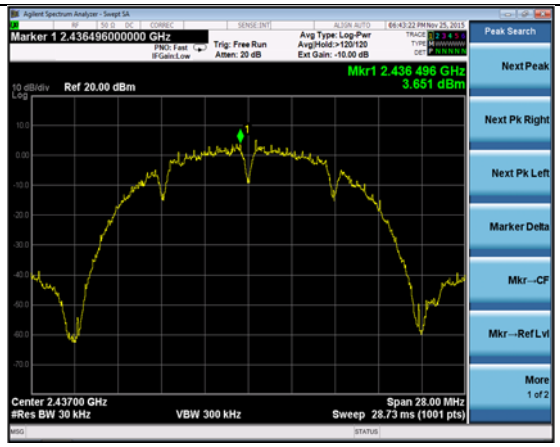
Output Power

Power Spectral Density

Mid Channel – 2437 MHz



Output Power



Power Spectral Density

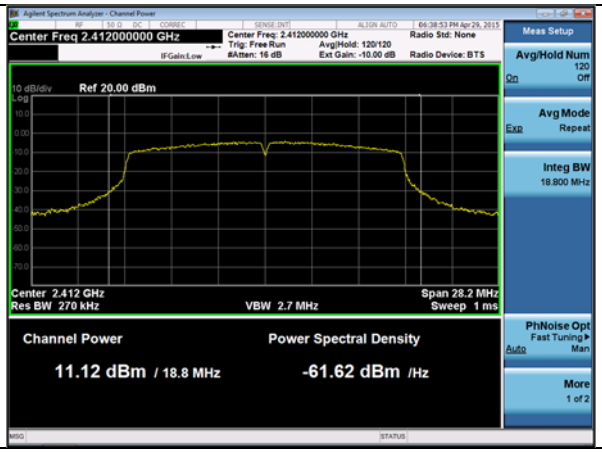
High Channel – 2462 MHz

Output Power

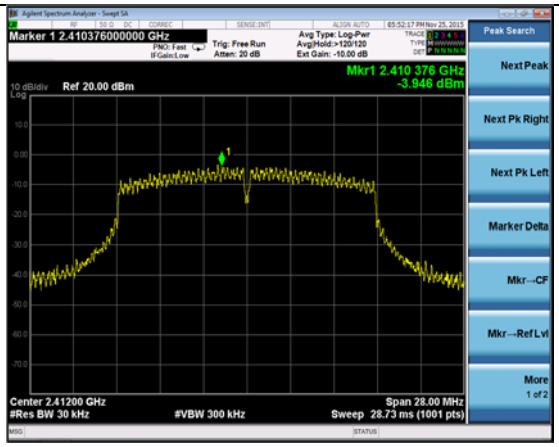
Power Spectral Density

802.11g – 6 Mbps

Low Channel – 2412 MHz

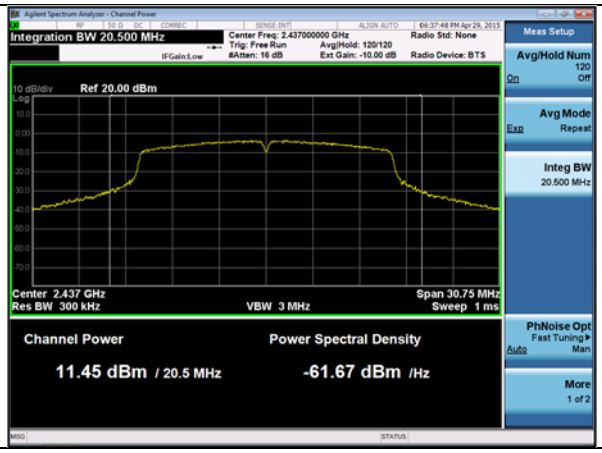


Output Power

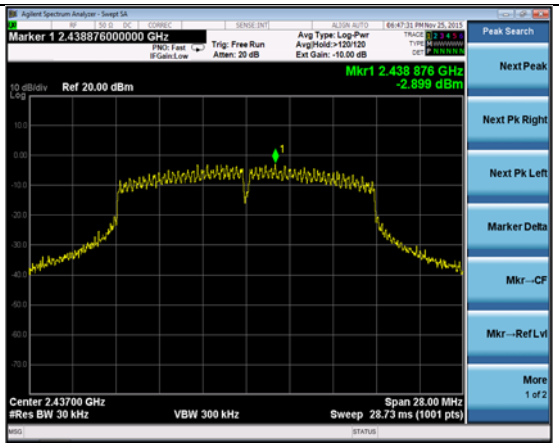


Power Spectral Density

Mid Channel – 2437 MHz

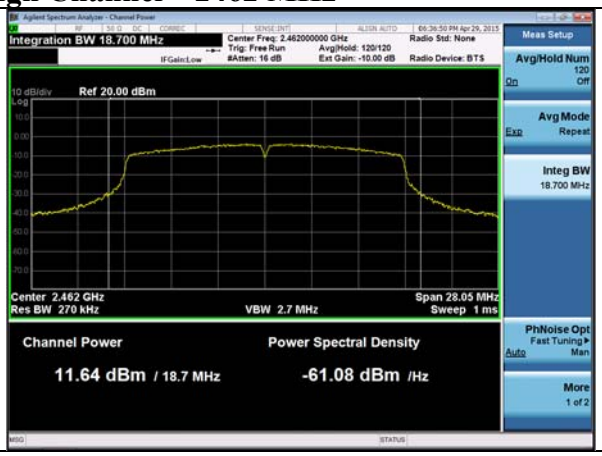


Output Power

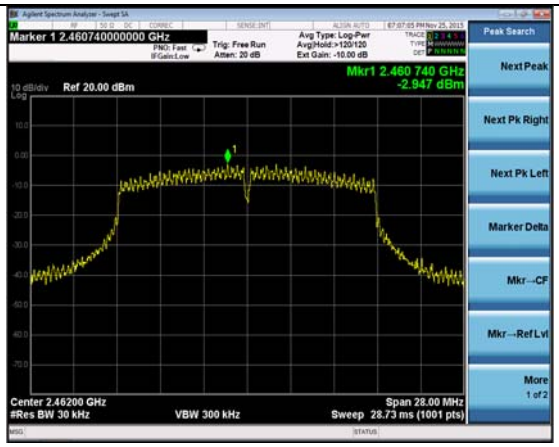


Power Spectral Density

High Channel – 2462 MHz



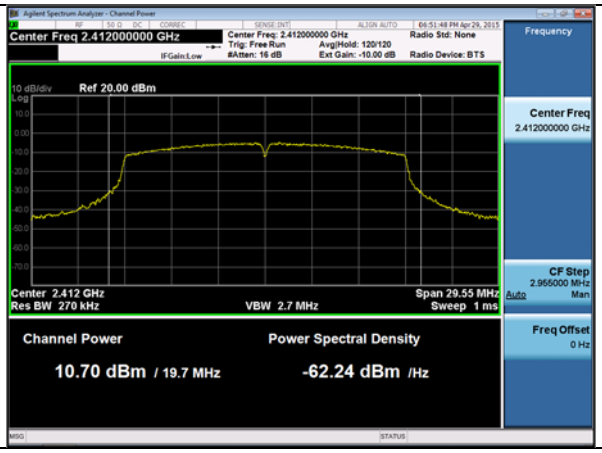
Output Power



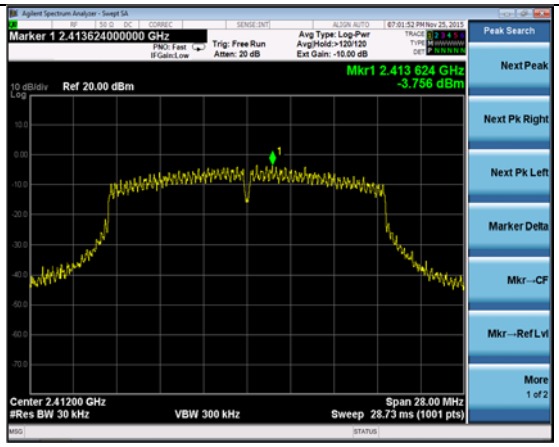
Power Spectral Density

Plots - 802.11n – 6.5 Mbps (MCS 0)

Low Channel – 2412 MHz

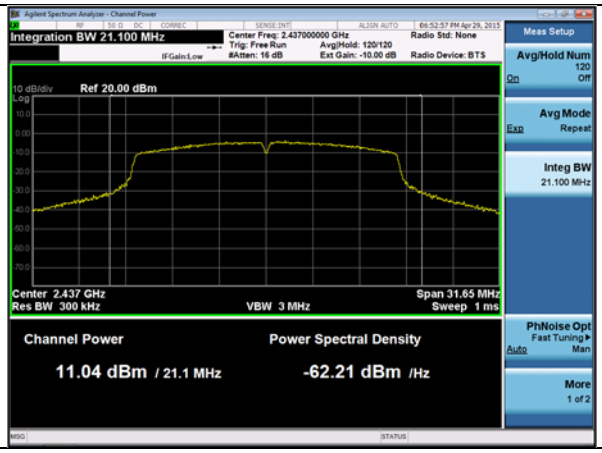


Output Power

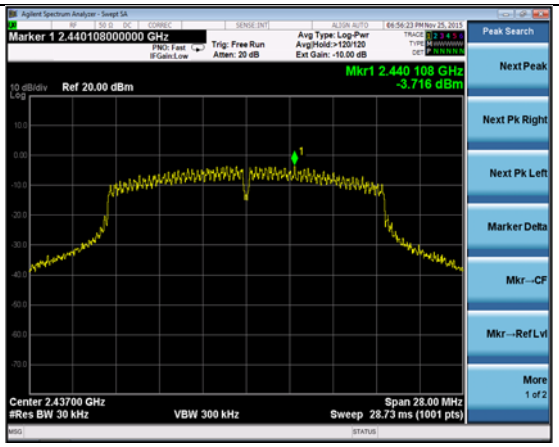


Power Spectral Density

Mid Channel – 2437 MHz



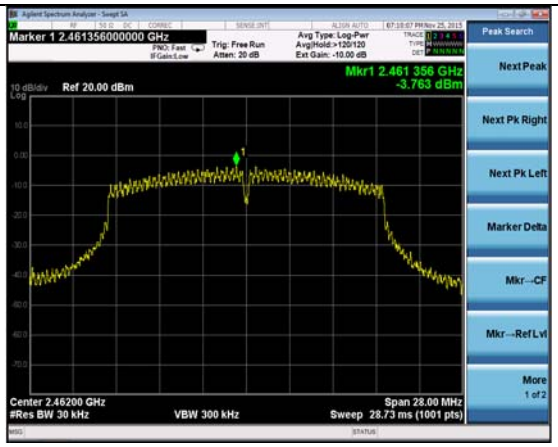
Output Power



Power Spectral Density

High Channel – 2462 MHz

Output Power

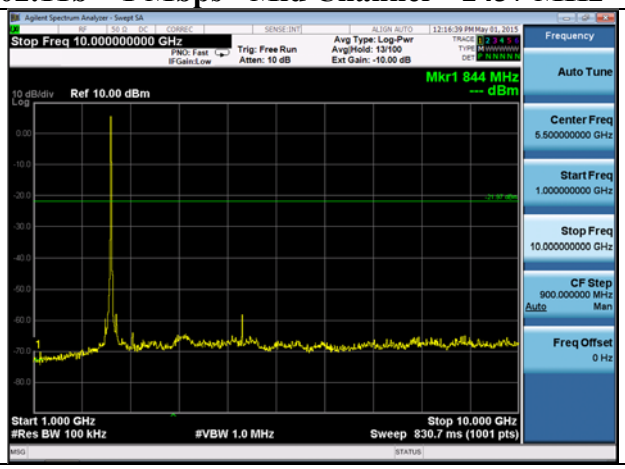


Power Spectral Density

A.1.3 – RF Conducted – Transmitter Spurious Emissions

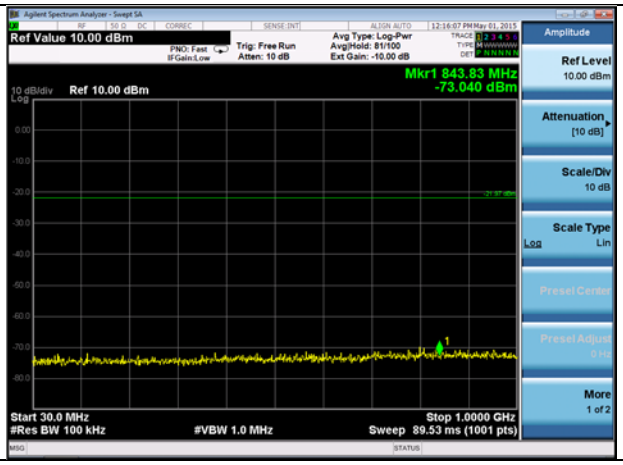
Manufacturer	Tridium
Date	5/1/15
Operator	Peter F.
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247 (d) IC RSS-247 Section 5.5
Specific Measurement Procedure	ANSI C63.10-2013 Section 11.11
Additional Description of Measurement	RF Conducted Measurement
Additional Notes	1. Mid channel worst case data shown 2. Power measurements made with average method therefore emissions attenuated 30 dB relative in band PSD level. 3. For reference level measurement see DTS BW plots. 4. For antenna port conducted measurements of spurious emissions in the restricted band, the peak and average limit was converted from field strength to power limits per KDB 558074 section 10: Example: EIRP = E (electric field strength in dBµV/m) + 20log(d)-104.8 E = EIRP – 20log(d) + 104.8 Sample conversion: For EIRP = -56.6 dBm, E (dBµV/m) = -56.6 – 20log(3m) +104.8 = 38.7 dBµV/m For EIRP = -60.9 dBm, E (dBµV/m) = -60.9 – 20log(3m) + 104.8 = 34.4 dBµV/m **Above 1 GHz Peak and average limit for RF conducted measurements** Peak limit : EIRP = 74.0 dBuV/m + 20log(3m) – 104.8 = -21.2dBm Average limit : EIRP = 54.0 dBuV/m + 20log(3m) – 104.8 = -41.2dBm

802.11b – 1 Mbps - Mid Channel – 2437 MHz



1 – 10 GHz

10-25 GHz

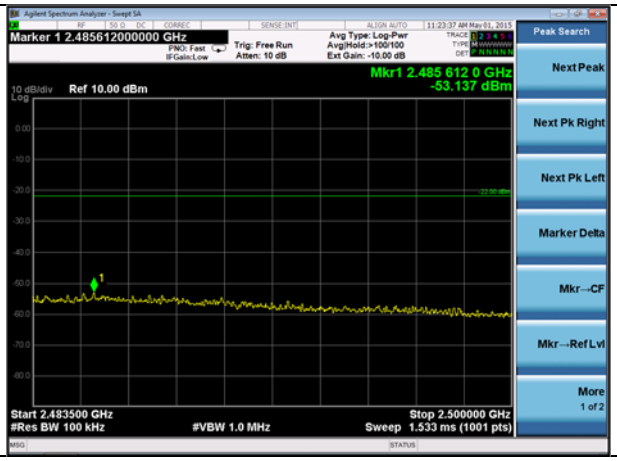


30-1000 MHz

Conducted Band edge Measurements

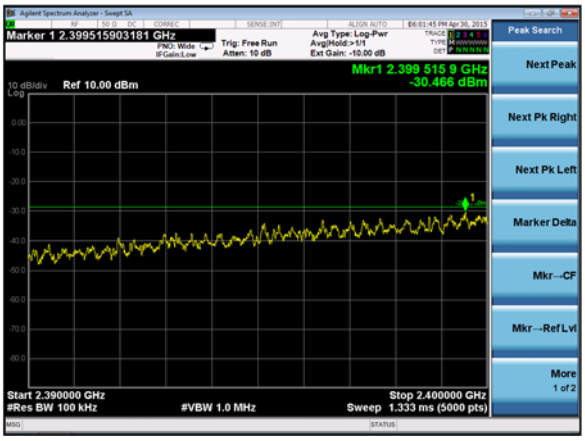
11 MBPS

LBE

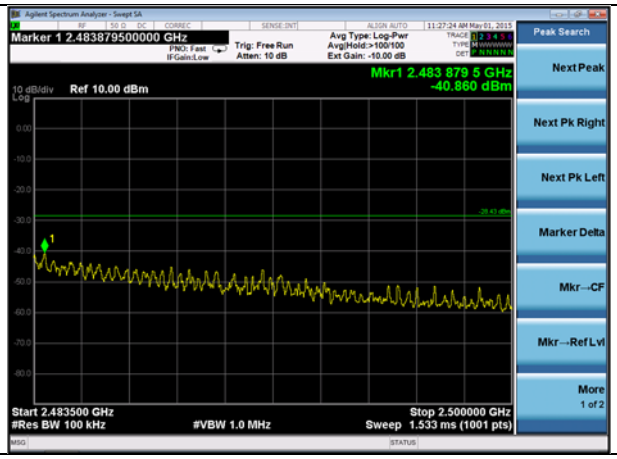


UBE

54 MBPS

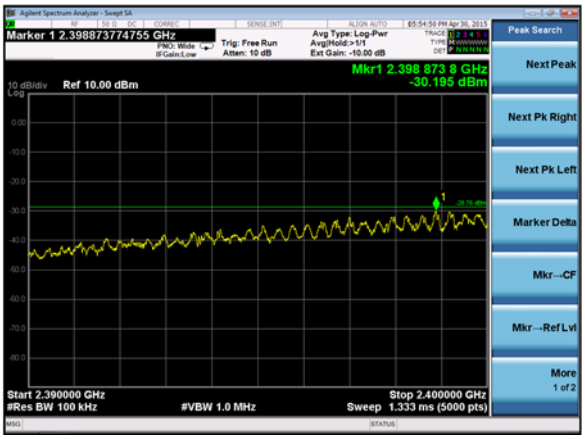


LBE

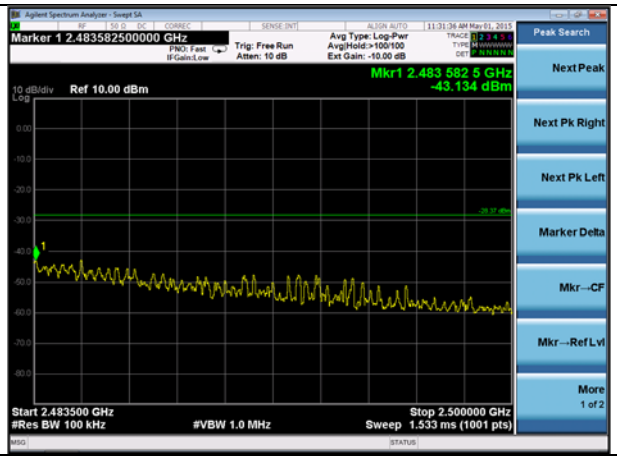


UBE

MCS7



LBE



UBE

Antenna port conducted measurements in restricted band frequency

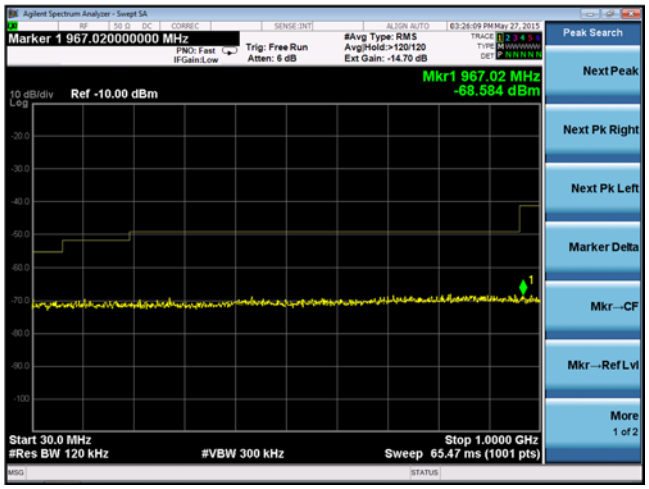
(ANSI C63.10 – 2013 Section 11.12.2)

Data

Peak data Frequency (MHz)	Restricted band : Peak (dBm)	Average data Frequency (MHz)	Restricted band : Avg (dBm)	Duty Cycle correction for average measurement (dB)	Antenna gain (dBi)	Final peak Band-edge (dBm)	Peak Limit (dBm)	Peak Margin (dB)	Final average Band-edge (dBm)	Average Limit (dBm)	Average Margin (dB)
4824.0	-49.4	4824.0	-51.3	0.0	4.6	-44.8	-21.2	23.6	-46.7	-41.2	5.5
4874.0	-48.2	4874.0	-50.1	0.0	4.6	-43.6	-21.2	22.4	-45.5	-41.2	4.3
4924.0	-47.2	4924.0	-48.4	0.0	4.6	-42.6	-21.2	21.3	-43.8	-41.2	2.6

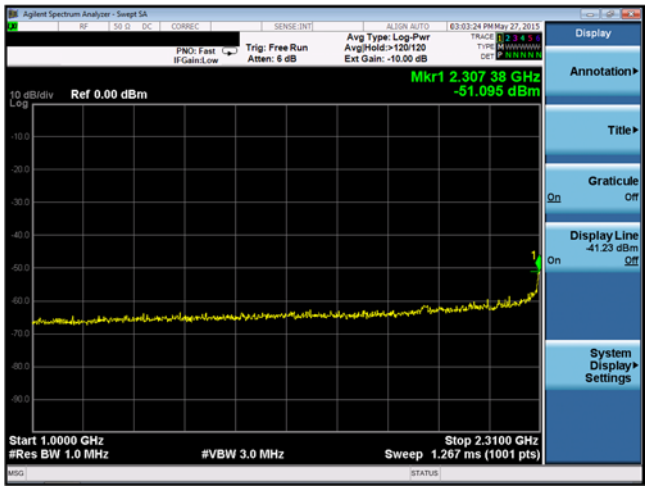
Screen Captures

30 to 1000 MHz

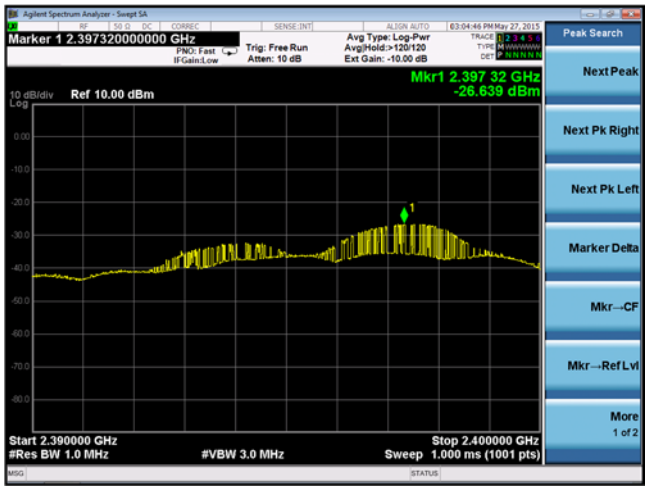


Note: 4.7 dB added as ground plane reflection characteristic

1000 to 2310 MHz



2390 to 2400 MHz



2500 to 10000 MHz

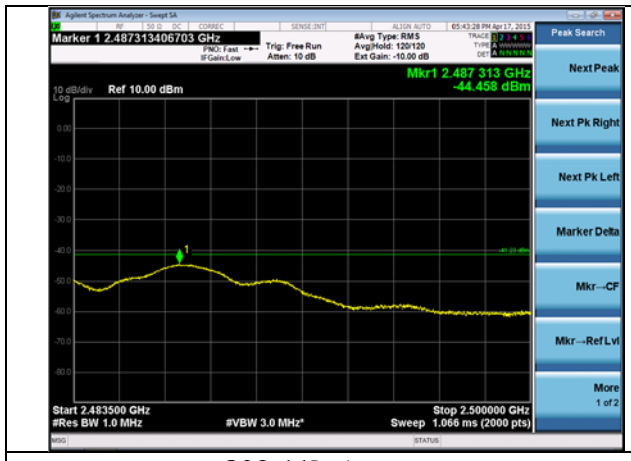
10000 to 25000 MHz

Restricted band Band-edges:

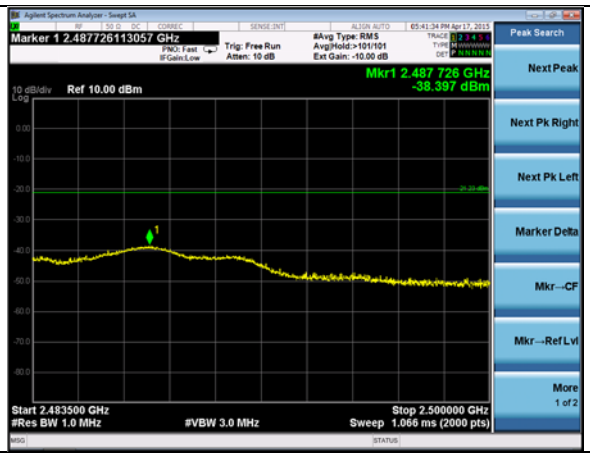
A. 2483.5 to 2500 MHz

802.11 Standard	Data Rate (MBPS)	Peak data Frequency (MHz)	Restricted band Band-edge: Peak (dBm)	Average data Frequency (MHz)	Restricted band Band-edge: Avg (dBm)	Duty Cycle correction for average measurement (dB)	Antenna gain (dBi)	Final peak Band-edge (dBm)	Peak Limit (dBm)	Peak Margin (dB)	Final average Band-edge (dBm)	Average Limit (dBm)	Average Margin (dB)
b	1	2487.7	-38.4	2487.3	-44.5	0.0	2.5	-35.9	-21.2	14.7	-42.0	-41.2	0.7
g	6	2483.9	-26.2	2483.6	-45.7	0.3	2.5	-23.7	-21.2	2.4	-42.9	-41.2	1.7
n	MCS0	2483.9	-25.6	2483.7	-46.1	0.3	2.5	-23.1	-21.2	1.9	-43.3	-41.2	2.1

Note: Table above shows highest emissions at band-edge

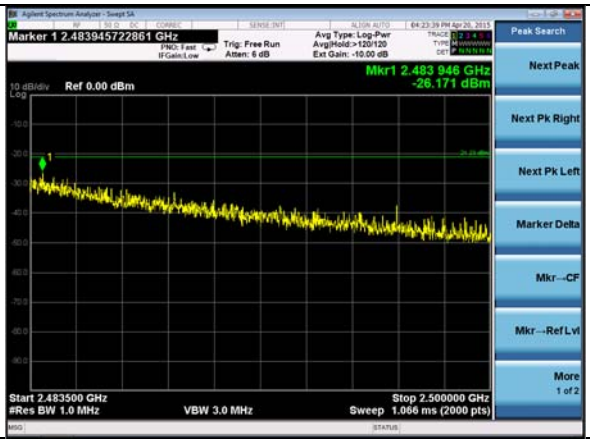


802.11b Average

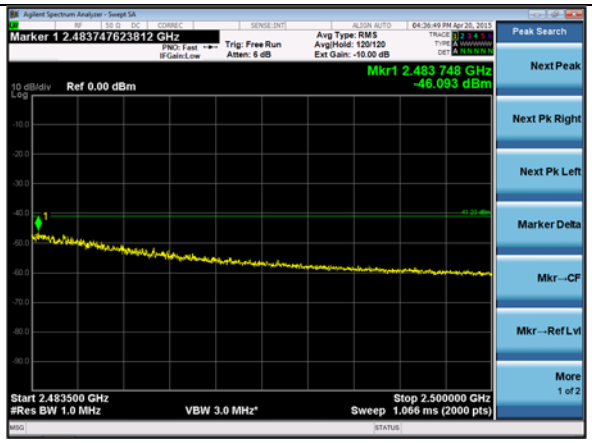


802.11b Peak

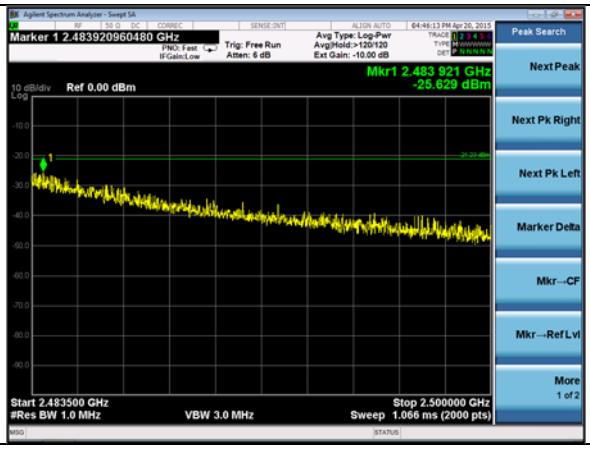
802.11g Average



802.11g Peak



802.11n Average



802.11n Peak

B. 2310 to 2390 MHz

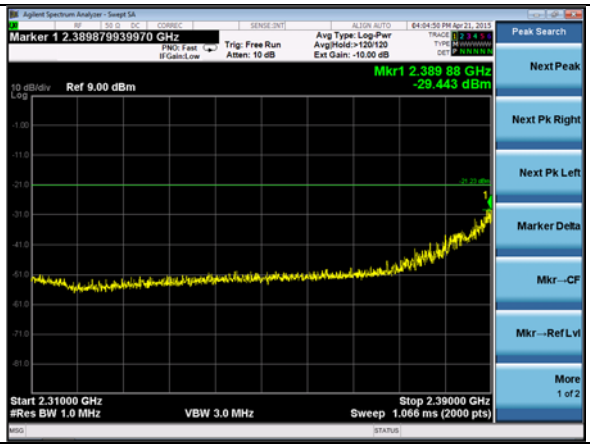
802.11 Standard	Data Rate (MBPS)	Peak data Frequency (MHz)	Restricted band Band-edge: Peak (dBm)	Average data Frequency (MHz)	Restricted band Band-edge: Avg (dBm)	Duty Cycle correction for average measurement (dB)	Antenna gain (dBi)	Final peak Band-edge (dBm)	Peak Limit (dBm)	Peak Margin (dB)	Final average Band-edge (dBm)	Average Limit (dBm)	Average Margin (dB)
b	1	2386.3	-43.2	2386.2	-45.3	0.0	2.5	-40.7	-21.2	19.4	-42.8	-41.2	1.6
g	6	2389.9	-29.4	2390.0	-47.2	0.3	2.5	-26.9	-21.2	5.7	-44.4	-41.2	3.2
n	MCS0	2389.7	-27.2	2389.8	-46.5	0.3	2.5	-24.7	-21.2	3.5	-43.7	-41.2	2.4

Note: Table above shows highest emissions at band-edge

802.11b Average

802.11b Peak

802.11g Average



802.11g Peak

802.11n (HT20) Average

802.11n (HT20) Peak

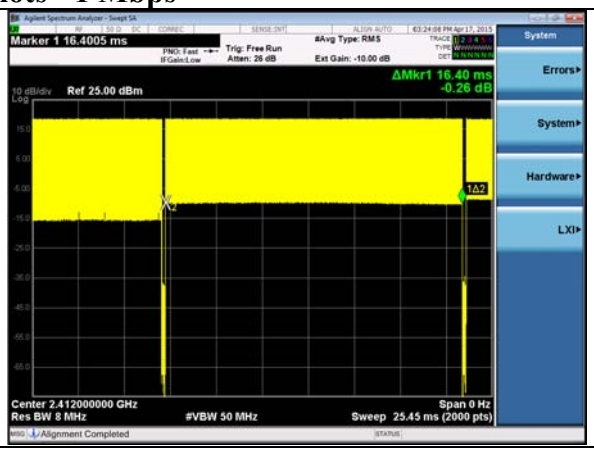
A.1.5 – RF Conducted – Duty Cycle

Manufacturer	Tridium
Date	5/1/15
Operator	Peter
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	N/A
Specific Measurement Procedure	ANSI C63.10-2013 Section 11.6
Additional Description of Measurement	RF Conducted Measurement
Additional Notes	Duty cycle used for average power and average PSD procedures

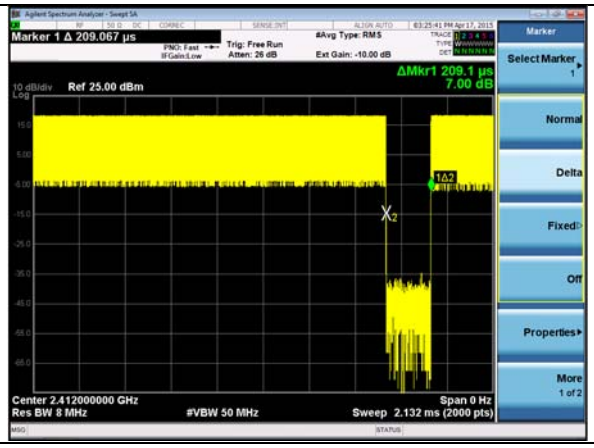
Table

Modulation	802.11 Standard	Data Rate (MBPS)	TX on time (ms)	TX off time (ms)	Duty Cycle	Duty cycle correction factor (dB)
DBPSK	b	1.0	16.400	0.209	0.99	0.0
BPSK	a,g	6.0	2.731	0.193	0.93	0.3
8-QPSK	b	11.0	1.665	0.196	0.89	0.5
64-QAM	a,g	54.0	0.324	0.196	0.62	2.1
BPSK	n	MCS0	2.538	0.198	0.93	0.3
64-QAM	n	MCS7	0.288	0.196	0.59	2.3

Plots - 1 Mbps

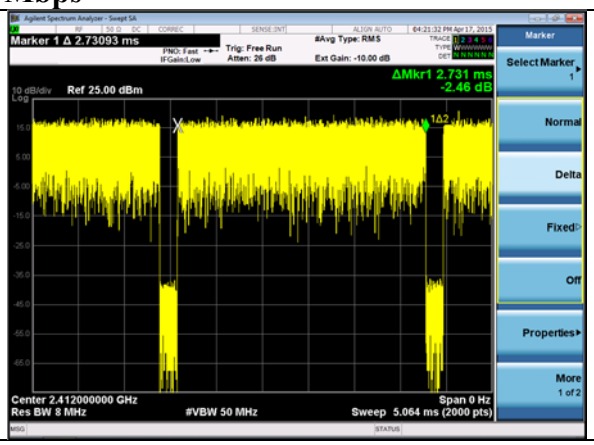


On-time

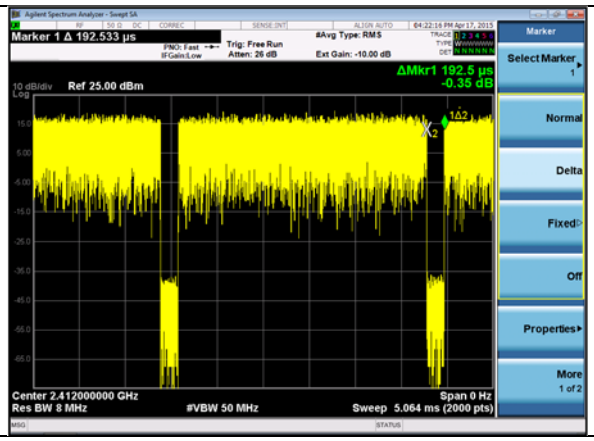


Off-time

6 Mbps

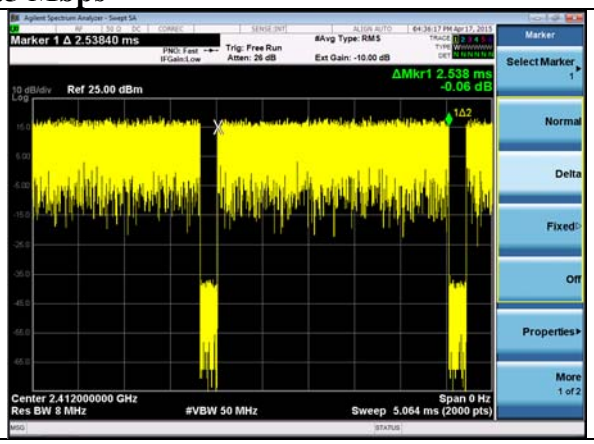


On-time

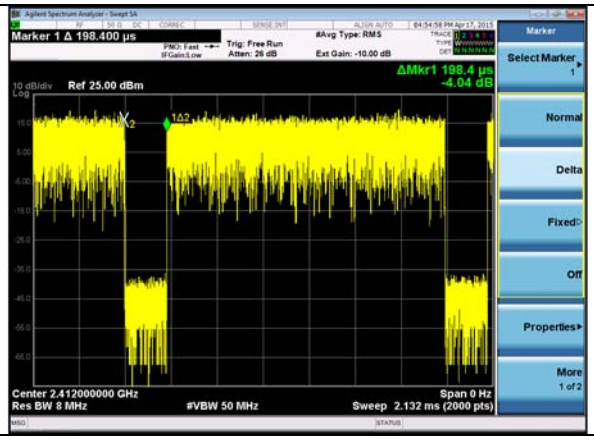


Off-time

6.5 Mbps

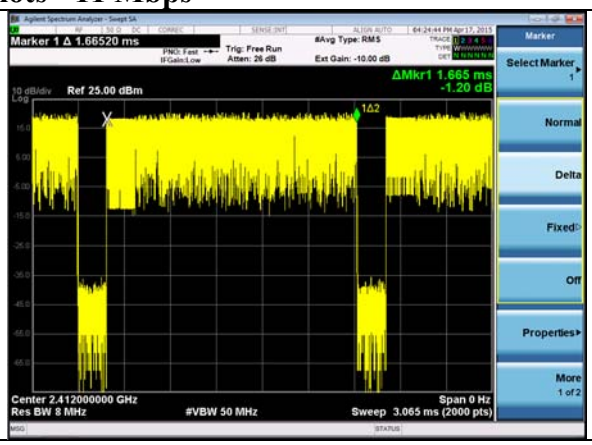


On-time

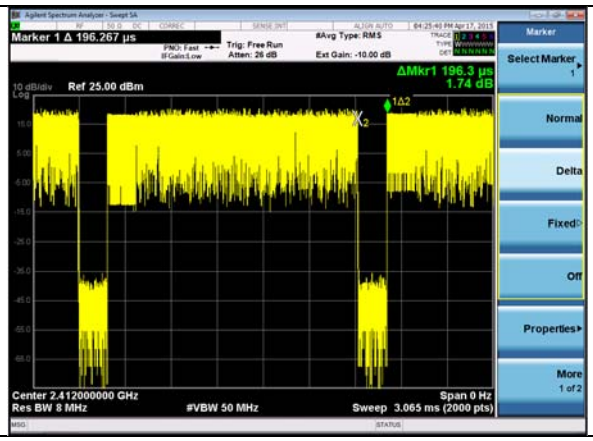


Off-time

Plots - 11 Mbps

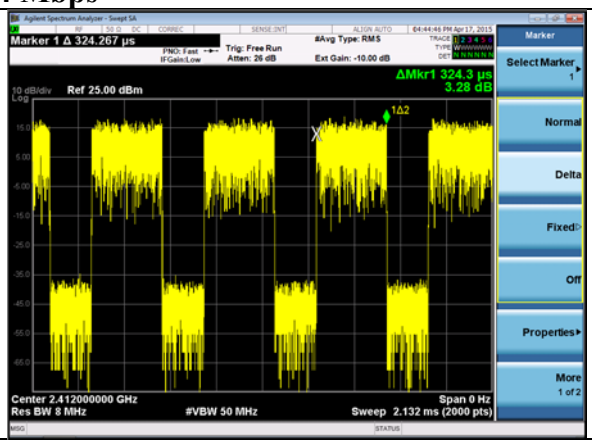


On-time

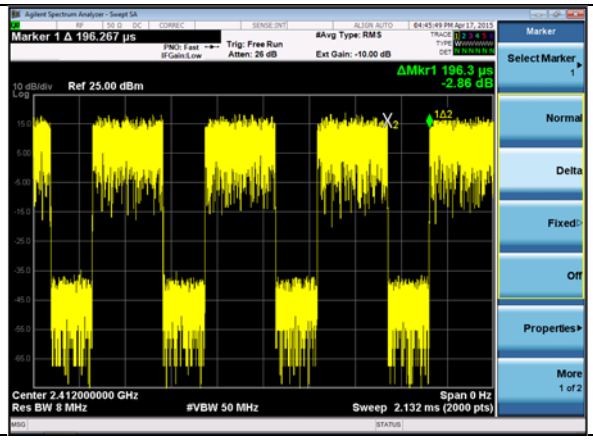


Off-time

54 Mbps

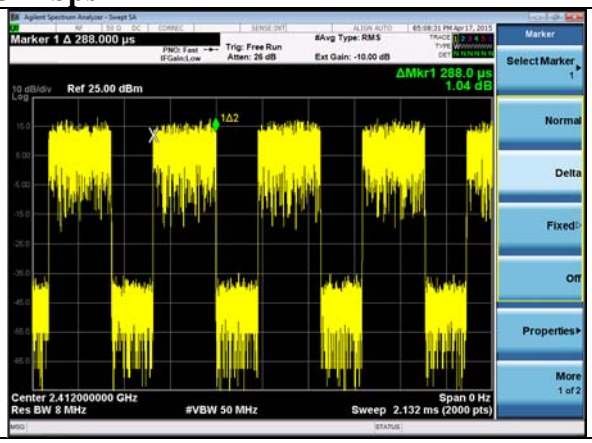


On-time

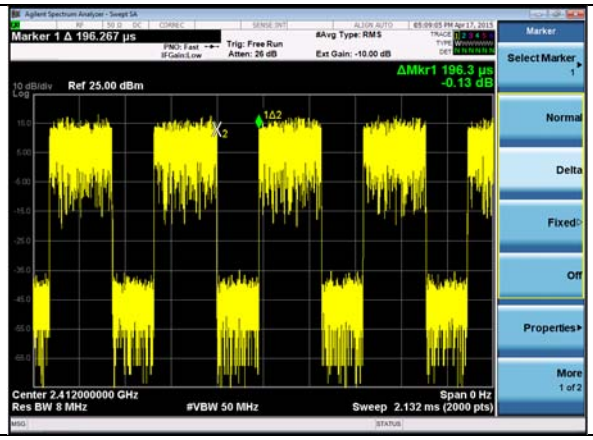


Off-time

65 Mbps



On-time



Off-time

A.1.6 – RF Conducted – Frequency stability over supply

Manufacturer	Tridium
Date	11/29/15
Operator	Aidi Zainal
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Additional Description of Measurement	RF Conducted Measurement
Additional Notes	1. Nominal voltage at 24.0VDC 2. Maximum supply voltage at 26.0 VDC, minimum set at 20.4VDC

Table:

	Frequency (Hz)			
	20.4 VDC	24.0 VDC	26.0VDC	Drift (Hz)
Chan 1	2412000271	2412000282	2412000275	11
Chan 6	2437000115	2437000114	2437000111	4
Chan 11	2462000446	2462000448	2462000439	9

Frequency stability better than 100 ppm

A.2 – Transmitter Radiated Emissions in Restricted Bands

Rule Part(s)	FCC: 15.247 / 15.205 / 15.209 IC: RSS-GEN Section 8.9,8.10			
Measurement Procedure	ANSI C63.10 – 2013 Section 11.12 (6.3,6.5,6.6)			
Test Location	LS Research, LLC – FCC/IC Listed 3 meter Chamber			
Test Distance	See data section			
EUT Placement	Above 1 GHz: 150 cm height non-conductive table above reference ground plane covered with absorbers Below 1 GHz: 80 cm height non-conductive table above reference ground plane			
Frequency Range of Measurement	Biconical: 30-300 MHz	Log Periodic Dipole Array: 300-1000 MHz	Double-Ridged Waveguide Horn: 1-18 GHz	Standard Gain Horn: 18-26GHz
Measurement Detectors	30-1000MHz RBW: 120 kHz VBW: At least 300 kHz		1 - 40 GHz: RBW : 1MHz VBW: At least 3 MHz Peak VBW: ≤ 30 Hz Average	
Description of Measurement	1) The antenna, cable, pre-amp, and other necessary measurement system correction factors are loaded onto the EMI receiver / spectrum analyzer when the measurements are preformed. The data is gathered and reported as the corrected values. 2) The EUT is placed on a non-conductive pedestal centered on a turn-table in the test location with the antenna at the test distance from the EUT 3) Maximum radiated RF emissions are determined by rotation of azimuth and scanning the sense antenna between 1 and 4 meters in height using both horizontal and vertical antenna polarities. Maximized levels are manually noted at degree values of azimuth and at sense antenna height.			
Example Calculations	Reported Measurement data = Raw receiver measurement + Antenna Correction Factor + Cable factor (dB) - amplification factor (when applicable) + Additional factor (when applicable)			

Limits:

Frequency (MHz)	3 m Limit (µV/m)	3 m Limit (dBµV/m)	Type
30-88	100	40.0	Quasi-Peak
88-216	150	43.5	Quasi-Peak
216-960	200	46.0	Quasi-Peak
Above 960	500	54.0	Average (>1 GHz)

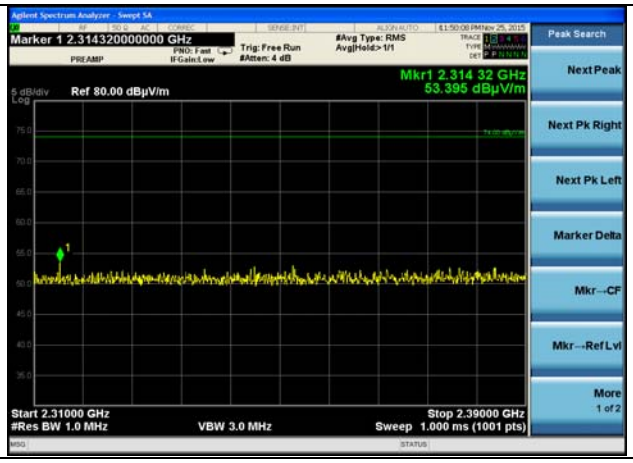
A.2.1 – Radiated Band-Edge Restricted Bands

Manufacturer	Tridium
Date	11/25/15
Operator	Adam Alger
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247/ 15.205 / 15.209 IC RSS-247 / RSS-GEN
Measurement Procedure	ANSI C63.10-2013 Section 11.12
Test Distance	3 meter
EUT Placement	150 cm height non-conductive table centered on turn-table , absorbers covering ground plane
Detectors	Final Measurements: Peak / Max Hold: RBW=1 MHz, Peak VBW=3 MHz Average: RBW=1 MHz, VBW 10Hz,
Additional Notes	Cabinet radiation method (ANSI C63.10 -2013 Section 11.12.2.1) EUT maximized in orientation, azimuth, and antenna height with maximum results reported.

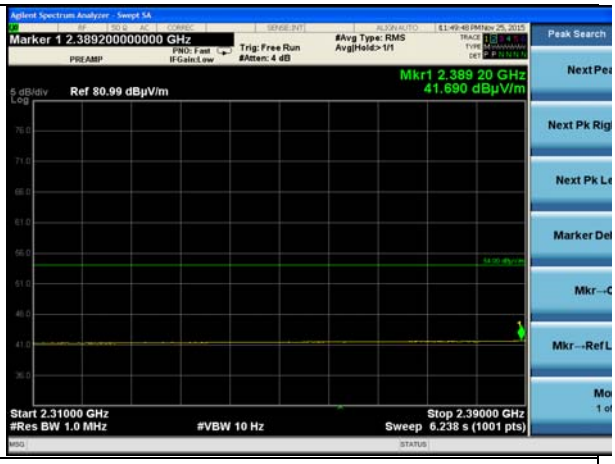
Example Calculation:

Limit (dBµV/m) – Reading (dBµV/m) = Margin (dB)

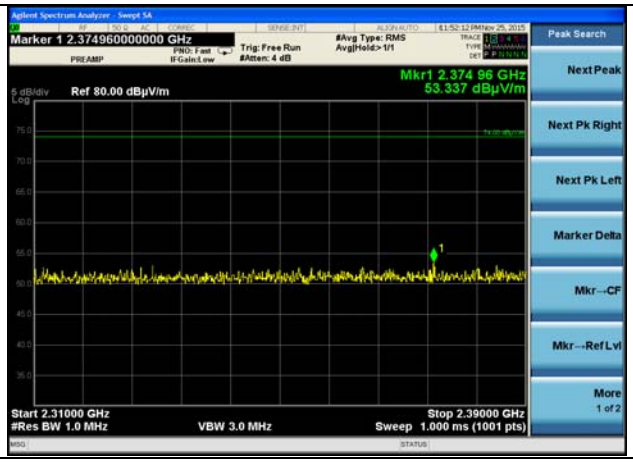
2310 to 2390 MHz



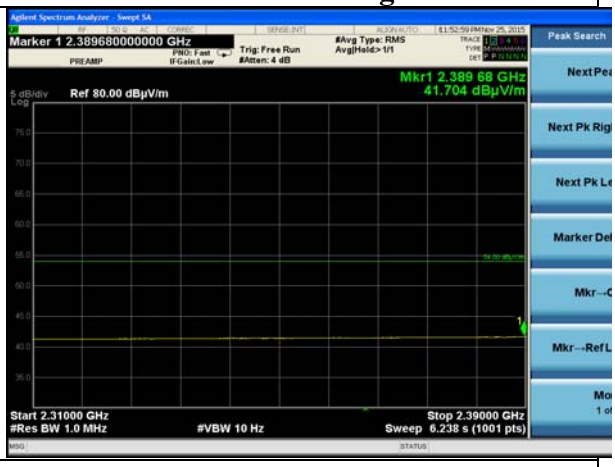
802.11b Peak



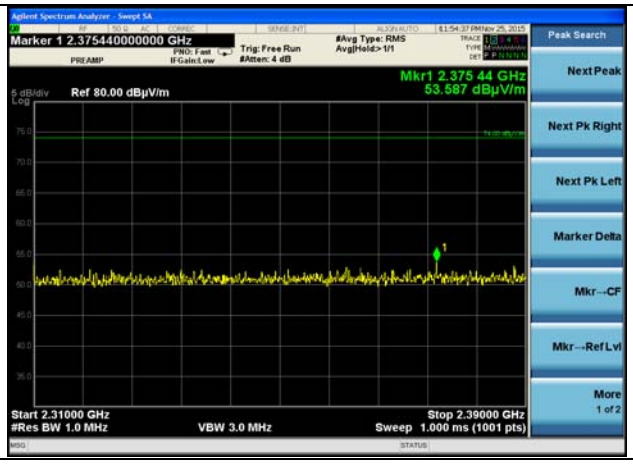
802.11b Average



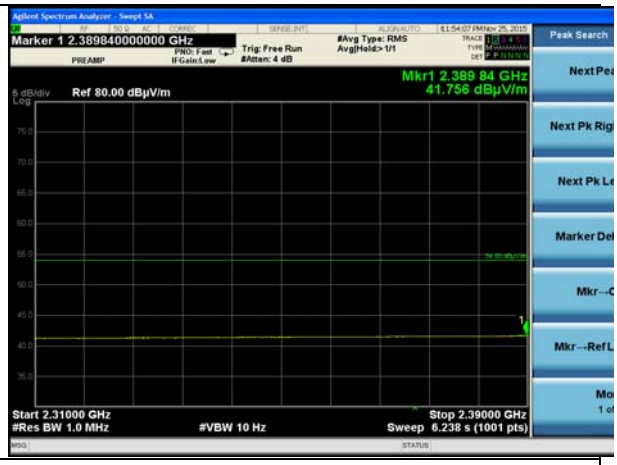
802.11g Peak



802.11g Average

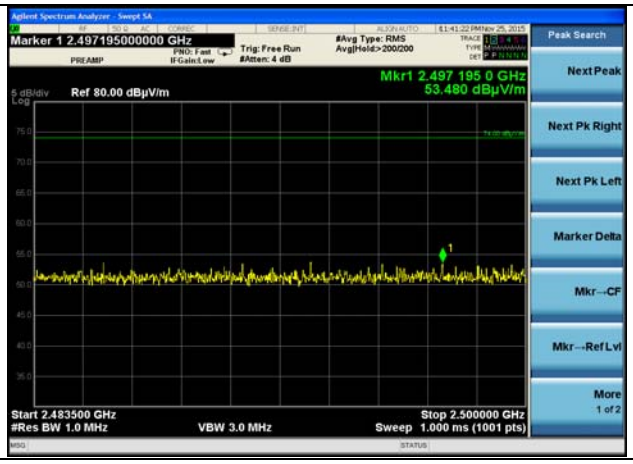


802.11n Peak

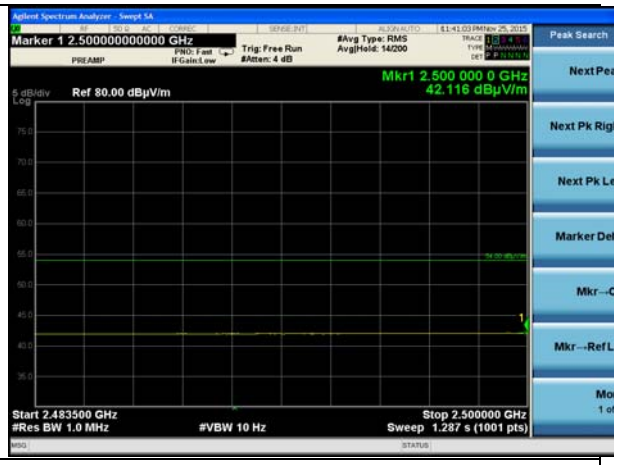


802.11n Average

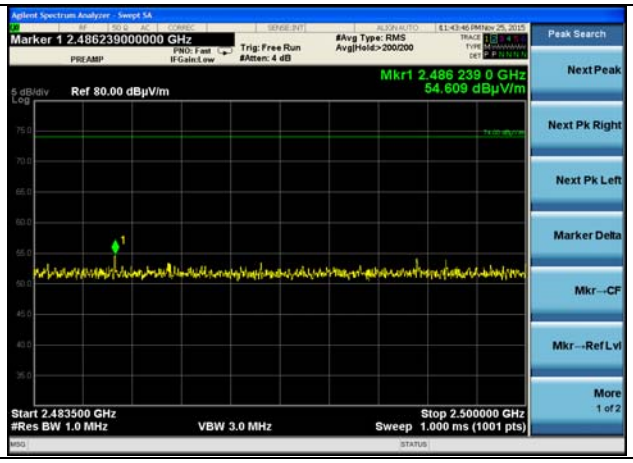
2483.5 to 25000 MHz



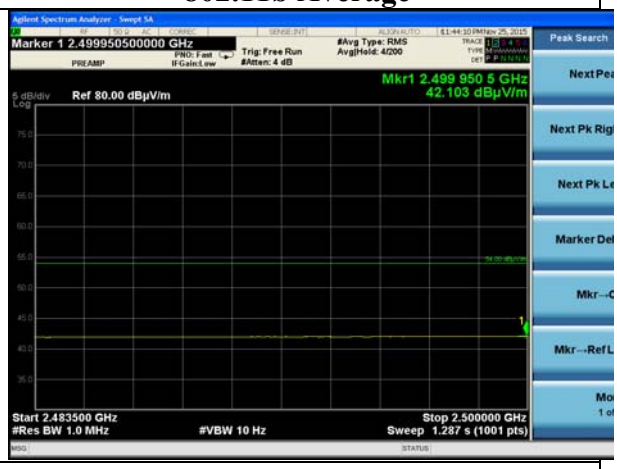
802.11b Peak



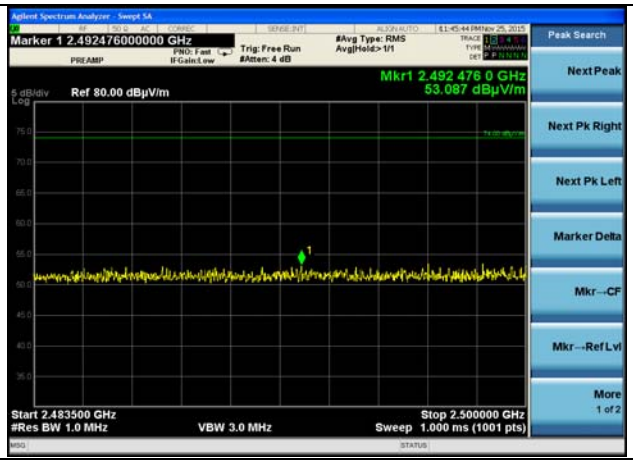
802.11b Average



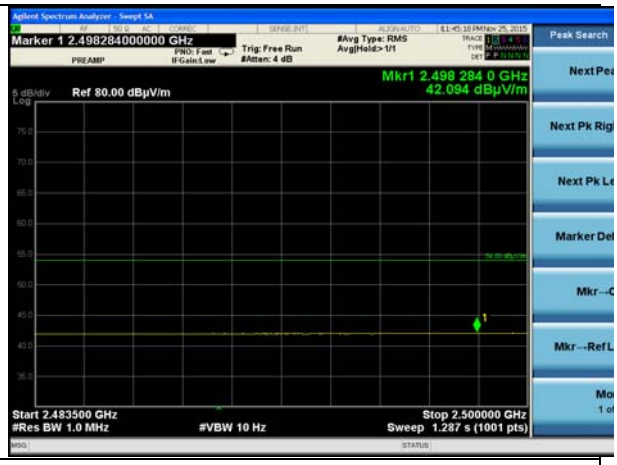
802.11g Peak



802.11g Average



802.11n Peak



802.11n Average

A.2.2 – Radiated Harmonics in Restricted Bands

Manufacturer	Tridium
Date	5-22-15, 11-3-15
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247/ 15.205 / 15.209 IC RSS-247 / RSS-GEN
Measurement Procedure	ANSI C63.10-2013 Section 11.12
Test Distance	3 meter
EUT Placement	150 cm height non-conductive table centered on turn-table , absorbers covering ground plane
Detectors	Final Measurements: Peak / Max Hold, RBW 1 MHz, Peak VBW 3 MHz
Additional Notes	Cabinet radiation method (ANSI C63.10 -2013 Section 11.12.2.1) EUT maximized in orientation, azimuth, and antenna height with maximum results reported.

Example Calculation:
Peak Limit (74 dBµV/m @ 3m) – Peak Reading (dBµV/m) = Peak Margin (dB)
Average Limit (54 dBµV/m @ 3m) – Average Reading (dBµV/m) = Average Margin (dB)

Tables

Low Channel

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBµV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4824	1.00	259	52.2	49.5	54.0	4.5	Horizontal	Side
7236	1.45	0	45.9	34.1	54.0	19.9	Vertical	Side

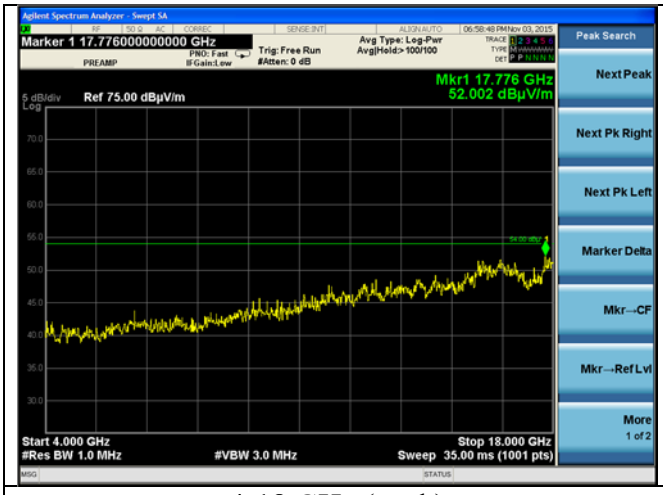
Middle Channel

Frequency	Height (m)	Azimuth	Peak	Avg Reading	Avg Limit	Margin (dB)	Antenna	EUT
4874	1.00	313	53.7	51.0	54.0	3.0	Vertical	Vertical
7311	1.14	351	45.5	34.6	54.0	19.4	Vertical	Side

High Channel

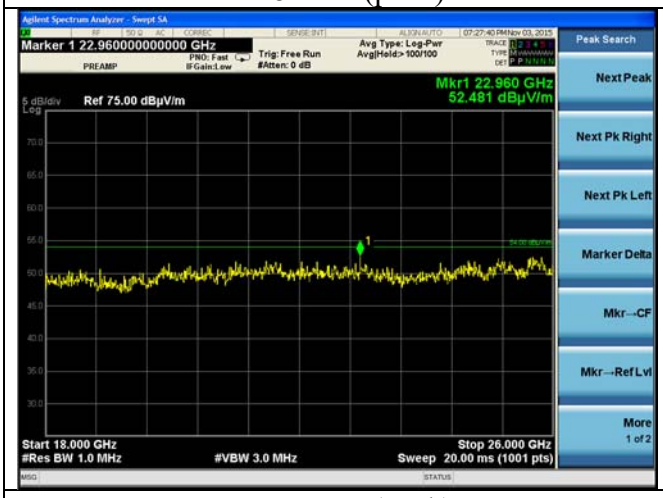
Frequency	Height (m)	Azimuth	Peak	Avg Reading	Avg Limit	Margin (dB)	Antenna	EUT
4924	1.15	305	53.5	50.6	54.0	3.4	Horizontal	Side
7386	1.04	0	46.6	36.6	54.0	17.4	Vertical	Vertical

Plots

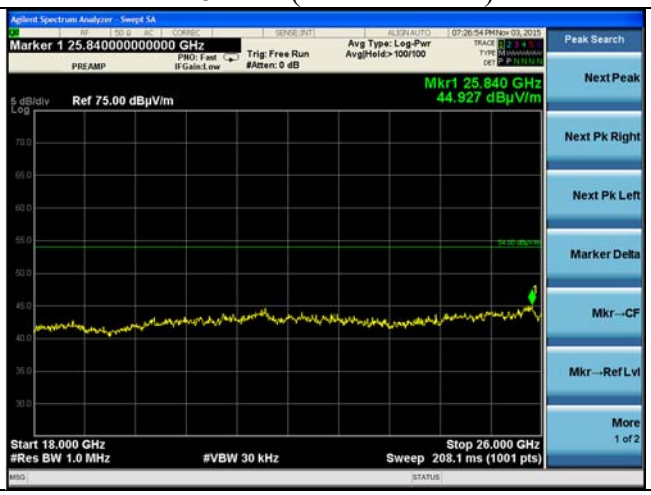


4-18 GHz (peak)

4-18 GHz (reduced VBW)



18-25 GHz (peak)



18-25 GHz (reduced VBW)

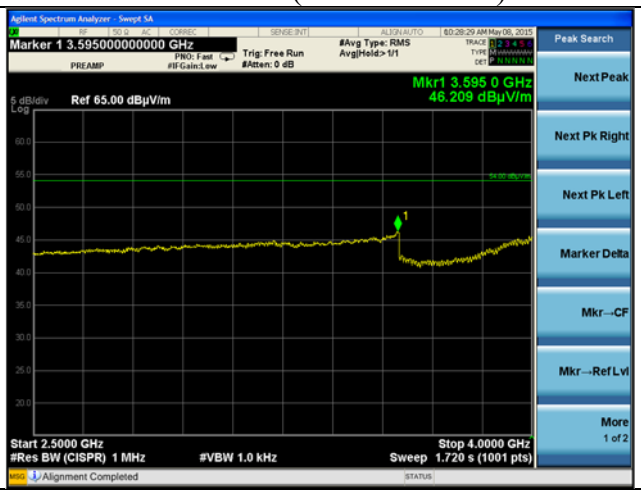
A.2.3 – Radiated Spurious Emissions Transmit Mode (1-4 GHz)

Manufacturer	Tridium
Date	May 8, 2015
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247/ 15.205 / 15.209 IC RSS-247 / RSS-GEN
Measurement Procedure	ANSI C63.10-2013 Section 6.3, 6.6
Test Distance	3 meter 1-18 GHz
EUT Placement	150 cm height non-conductive table centered on turn-table , absorbers covering ground plane
Detectors	Peak; RBW 1 MHz
Additional Notes	1) EUT maximized in orientation, azimuth, and antenna height with maximum results reported. 2) No Emissions found above system noise floor Frequency ranges 2310-2390 MHz, 2483.5-2500 MHz, and 4-25 GHz seen in previous sections.

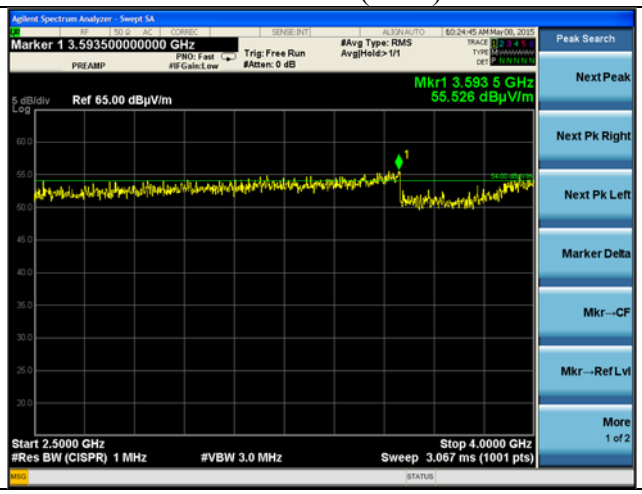
Plots

1-2.31 GHz (Reduced VBW)

1-2.31 GHz (Peak)



2.5-4 GHz (Reduced VBW)



2.5-4 GHz (Peak)

A.2.4 – Radiated Spurious Emissions Transmit Mode (30-1000 MHz)

Manufacturer	Tridium
Date	5-29-15
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC 15.247/ 15.205 / 15.209 IC RSS-247 / RSS-GEN
Measurement Procedure	ANSI C63.10-2013 Section 6.3, 6.5
Test Distance	3 meter 30-1000 MHz
EUT Placement	80 cm height non-conductive table centered on turn-table (no absorbers on ground plane)
Detectors	Peak; RBW 120 kHz
Additional Notes	Tested in continuous transmit modulated mode with EUT in three orientations at maximum power.

Example Calculation:

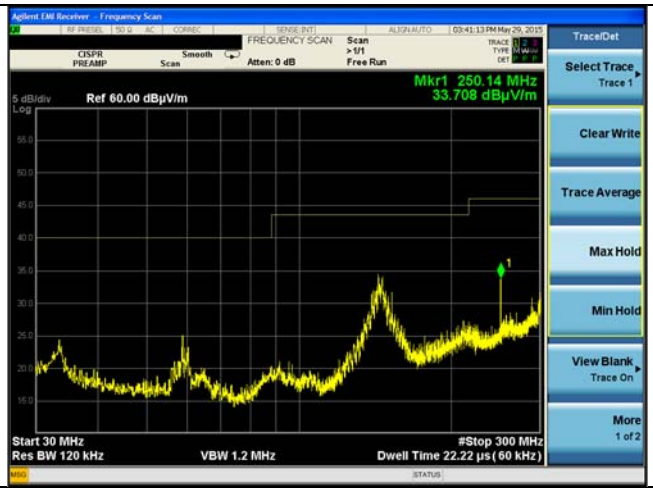
Limit (dBµV/m) – Reading (dBµV/m) = Margin

Table

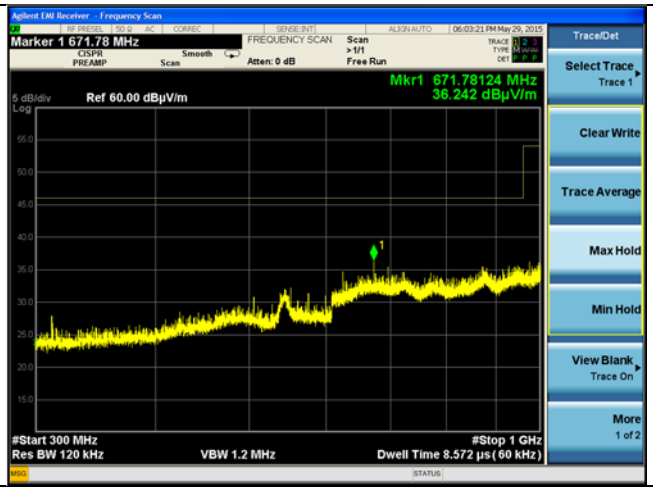
Frequency (MHz)	Height (m)	Azimuth (degree)	Quasi Peak Reading (dBµV/m)	Quasi Peak Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
250.0	1.47	0	35.45	46.0	10.6	H	TT
145.7	2.00	227	38.3	43.5	5.2	H	TT
58.7	1.00	0	26.1	40.0	13.9	H	TT

Plots

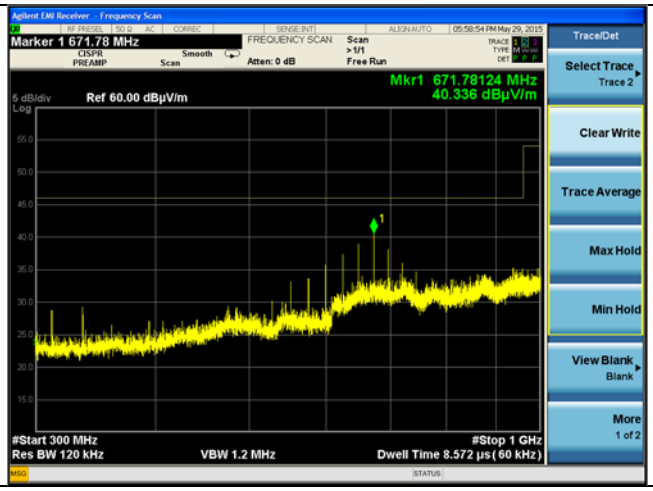
30-300 MHz Vertical



30-300 MHz Horizontal



300-1000 MHz Vertical



300-1000 MHz Horizontal

A.3 – AC Mains Conducted Emissions

Rule Part(s)	FCC: 15.207 IC: RSS-247 / RSS-GEN
Measurement Procedure	ANSI C63.4 - 2014 ANSI C63.10 – 2013
Test Location	LS Research, LLC – Conducted Emissions Area
Test Voltage	120 VAC 60 Hz
EUT Placement	80 cm height non-conductive table above reference ground plane
Frequency Range of Measurement	150 kHz – 30 MHz
Measurement Detectors	Peak, Quasi-Peak, Average RBW: 9 kHz VBW: At least 27 kHz
Description of Measurement	1) The LISN, cable, limiter, and other necessary measurement system correction factors are loaded onto the EMI receiver / spectrum analyzer when the measurements are preformed. The data is gathered and reported as the corrected values. 2) The EUT is placed on a non-conductive pedestal at appropriate distance from ground planes and plugged into LISN. 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). 3) Maximum emissions are determined with peak detector and measurements at select points are made with quasi-peak and average detectors. Results are recorded and compared to limit.
Example Calculations	Reported Measurement data = Raw receiver measurement + LISN Factor + Cable factor (dB) + Additional factor (when applicable)

Limits of Conducted Emissions at the AC Mains Ports:

Frequency Range (MHz)	Class B Limits (dBµV)	
	Quasi-Peak	Average
0.150 -0.50 *	66-56	56-46
0.5 – 5.0	56	46
5.0 – 30	60	50
* The limit decreases linearly with the logarithm of the frequency in this range.		

A.3.1 – AC Mains Conducted Emissions

Manufacturer	Tridium
Date	11-3-15
Operator	Peter Feilen
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	15.207 / RSS-GEN
Measurement Procedure	ANSI C63.4 - 2014 ANSI C63.10 - 2013 Section 6.2
Test Voltage	120 VAC 60 Hz supplied to AC adapter supplied by applicant for use with EUT
EUT Placement	80 cm height non-conductive table, 40 cm from vertical ground plane
Detectors	Peak; RBW 9 kHz Quasi-Peak and Average
Additional Notes	Tested in continuous transmit with no difference between operating modes

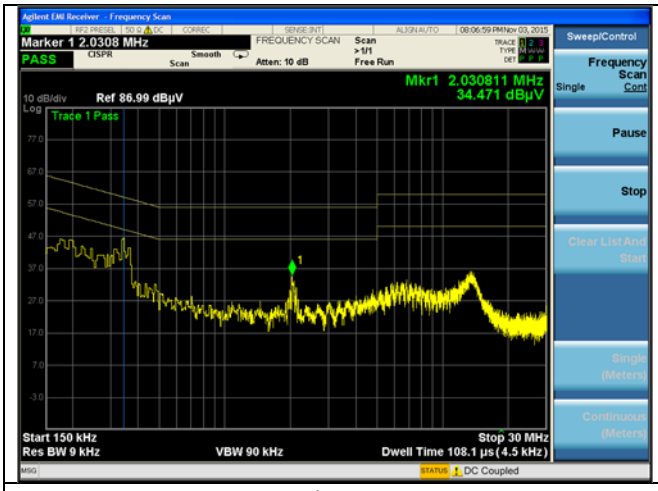
Example Calculation:

Margin (dB) = Limit (dBµV) – Reading (dBµV)

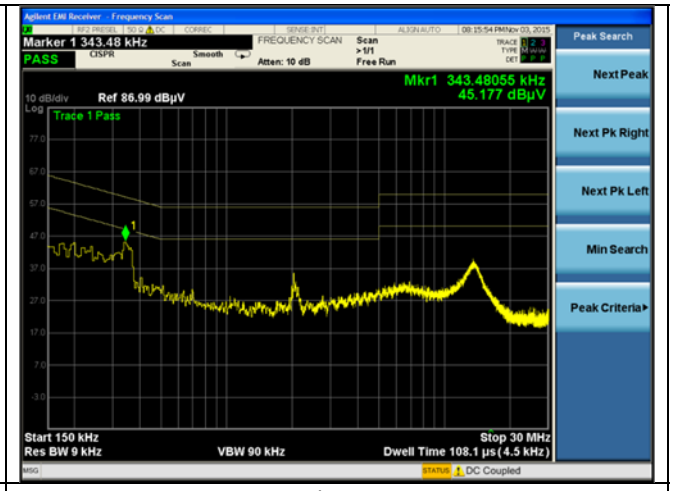
Data Table

		Quasi-Peak			Average		
Frequency (MHz)	Line	Q-Peak Reading (dBµV)	Q-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
0.177	1	44.2	64.6	20.4	35.6	54.6	19.0
0.341	1	45.1	59.2	14.1	37.3	49.2	11.9
2.031	1	34.2	56.0	21.8	30.7	46.0	15.3
0.343	2	44.2	59.1	14.9	36.3	49.1	12.8
2.044	2	29.7	56.0	26.3	19.2	46.0	26.8
13.532	2	35.9	60.0	24.1	30.6	50.0	19.4

Plots



Line 1



Line 2

Appendix C – Instrument sheet

LS RESEARCH LLC
Wireless Product Development
Equipment Calibration

Date : 20-Nov-2015 Type Test : Conducted measurements Job # : C-2089

Prepared By: Peter Customer : Tridium Quote #: 314337

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960087	44GHz EXA Spectrum Analyzer	Agilent	N9010A	MY53400296	12/11/2014	12/11/2015	Active Calibration
2	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/6/2015	5/6/2016	Active Calibration
3	AA 960144	Phaseflex	Gore	EKD01D010720	5800373	Verification	Verification	System
4	AA 960160	UltiFLEX Cable	Micro-Coax	UFC142A-0-0720-2002	218652-001	8/21/2015	8/21/2016	Active Calibration

LS RESEARCH LLC
Wireless Product Development
Equipment Calibration

Date : 20-Nov-2015 Type Test : Radaited measurements Job # : C-2089

Prepared By: Peter Customer : Tridium Quote #: 314337

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/6/2015	5/6/2016	Active Calibration
2	EE 960087	44GHz EXA Spectrum Analyzer	Agilent	N9010A	MY53400296	12/11/2014	12/11/2015	Active Calibration
3	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	1/9/2015	1/9/2016	Active Calibration
4	AA 960143	Phaseflex	Gore	EKD01D01048.0	5546519	6/26/2015	6/26/2017	Active Calibration
5	AA 960144	Phaseflex	Gore	EKD01D010720	5800373	Verification	Verification	System
6	AA 960160	UltiFLEX Cable	Micro-Coax	UFC142A-0-0720-2002	218652-001	8/21/2015	8/21/2016	Active Calibration
7	AA 960004	Log Periodic Antenna	EMCO	93146	9512-4276	8/18/2015	8/18/2016	Active Calibration
8	AA 960005	Biconical Antenna	EMCO	93110B	9601-2280	8/6/2015	8/6/2016	Active Calibration
9	AA 960158	Double Ridge Horn Antenna	ETS Lindgren	3117	109300	7/9/2015	7/9/2016	Active Calibration
10	AA 960007	Double Ridge Horn Antenna	EMCO	3115	9311-4138	8/4/2015	8/4/2016	Active Calibration
11	AA 960159	10dB Dual Directional Coupler	Narda	3202B-10	7016	Verification	Verification	System
12	AA 960153	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-04	4/15/2015	4/15/2016	Active Calibration
13	AA 960154	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-02	8/4/2015	8/4/2016	Active Calibration
14	AA 960137	Standard Gain Horn Ant.	EMCO	3160-10	69259	8/19/2015	8/19/2016	Active Calibration
15	EE 960161	26.5-40GHz LNA	Ducommun Technc	ALN-33144030	1103717-01	8/19/2015	8/19/2016	Active Calibration
16	EE 960146	Std. Gain Horn Ant. w/preamp	Adv. Micro / EMCC	WLA622-4 / 3160-09	123001	8/19/2015	8/19/2016	Active Calibration
17	AA 960161	Highpass Filter	K&L Microwave	11SH10-8000	2	2/6/2015	2/6/2016	Active Calibration
18	EE 960125	SMA Cable	MegaPhase	NC19-S1S1-236	1GVT4 14032106 001	3/6/2015	3/6/2016	Active Verification

Appendix C - Uncertainty Summary

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

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

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

Appendix D - References

Publication	Year	Title
FCC CFR Parts 0-15	2015	Code of Federal Regulations – Telecommunications
RSS-247 Issue 1	2015	Digital Transmissions Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
RSS-GEN Issue 4	2014	General Requirements and Information for the Certification of Radio Apparatus
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 of Procedures for Compliance Testing Unlicensed Wireless Devices

END OF REPORT