TEST REPORT

Report Number: 101503629DEN-001B
Project Number: G101503629

Report Issue Date: 2/24/2014

Product Designation: **Model: W2400-01 with Superpass SPAPG20 (Directional Panel Antenna)**

Standards: **FCC Part 15 Subpart C (15.247)**
Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz
IC RSS-210, Issue 8: 2010
IC RSS-GEN, Issue 3: 2010

Tested by:
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Louisville, CO 80027

Client:
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1 Introduction and Conclusion

The tests indicated in section 2.0 were performed on the product constructed as described in section 3.0. The remaining test sections are the verbatim text from the actual data sheets used during the investigation. These test sections include the test name, the specified test Method, a list of the actual Test Equipment Used, documentation Photos, Results and raw Data. No additions, deviations, or exclusions have been made from the standard(s) unless specifically noted.

Based on the results of our investigation, we have concluded **the product tested complies with the requirements of the standard(s) indicated.** The results obtained in this test report pertain only to the item(s) tested.

1.1 Test Report Scope

FCC/IC Class II Permissive Change

The scope of this report was to qualify the existing approved radio module Model: W2400-01 with new antennas. This specific report covers the following antenna:

- Model: Superpass SPAPG20 (Directional Panel antenna)

This radio operates in the following 802.11 b/g/n Tx Band: 2400 – 2483.5MHz.

The Model: W2400-01 has previously been fully qualified and documented in the following SPORTON LAB test reports:

- FCC Test Report Number: FR362202
- IC Test Report Number: CR362202-01

Below is a summary of Intertek Test Reports initiated for the above Class II Permissive Change.

- 4' Parabolic "Dish" Antenna (2.4GHz): 101503629DEN-001A
- **Directional Panel Antenna (2.4GHz): 101503629DEN-001B (This Report)**
- 60º Sector Antenna (2.4GHz): 101503629DEN-001C

1.2 Test Methodology

All measurements were performed according to the procedures in the following documents:

- ANSI C63.10:2013 – ANSI Standard for Testing Unlicensed Wireless Devices
- FCC Publication 558074, April 9, 2013 (Guidelines for Compliance Measurements on DTS Operating Under 15.247)

Radiated emissions tests were performed at an antenna-to-product distance of 3-meters.

1.3 Test Facility

Intertek Denver's testing facilities are located at 1795 Dogwood St. Suite 200 Louisville, CO 80027. The testing facility is ISO17025:2005 accredited by A2LA, our lab code is 2506.02, our VCCI registration numbers are. R-1643, C-1752 and T-1558, our FCC designation no. US1121 and our IC lab no. 2042N.

Testing contained in this test report may not be covered under the laboratories scope of accreditation. A note will be placed in the specific test section for testing not coved under the laboratories scope.

2 Test Summary

TEST SECTION	TESTS	FCC/IC REFERENCE	TEST DATE	RESULT
5	AC Voltage Variation	FCC 15.31(e)	-----	N/A
6	Antenna Requirement	FCC 15.203	-----	N/A
7	DTS Requirement	FCC 15.247(a) RSS-210 A8.2	-----	N/A
8	6dB Bandwidth	FCC 15.247(a)(2) RSS-210 A8.2(a)	-----	N/A
9	RF Conducted Output Power (includes requirements for antenna gain > 6dBi)	FCC 15.247(b)(3)(4) FCC 15.247(c)(1) RSS-210 A8.4(4)	-----	N/A
10	RF Conducted Spurious Emissions (-20dBc) Includes Band Edge	FCC 15.247(d) RSS-210 A8.5	-----	N/A
11	Transmitter Radiated Spurious Emissions (Restricted Bands – Band Edge)	FCC 15.247(d) FCC 15.209/ 15.205 RSS-210 A8.5 RSS-Gen 7.2.5	02/03/2014 to 02/04/2014	Complies
12	Power Spectral Density (PSD)	FCC 15.247(e) RSS-210 A8.2(b)	-----	N/A
13	Radiated Emissions – Digital Receiver	FCC 15.109 RSS-Gen 6.1	-----	N/A
14	Tx AC Line Conducted Emissions	FCC 15.207 RSS-Gen 7.2.4	-----	N/A
15	RF Exposure Requirement	FCC 15.247(i) FCC 15.1.1307(b)(1) RSS 102	-----	N/A
16	Duty Cycle/ Duty Cycle Correction Factor	FCC 15.35(c) RSS-Gen 4.5	-----	N/A

Notes:

1) All Tx Radiated Emission measurements in this report utilized the transmit channels and worst-case 802.11 band(s), modulation and data rates reported in the FCC and IC test reports listed on page 3 of this report. Note HT20/HT40 and both SISO and MIMO Tx operating modes were tested.
2) Only selected testing required for the specific Class II Permissive change was performed.

General Radio Test Notes:

- ANSI C63.10, Section 4.2.3.2/ FCC 15.35: Measurement detector functions and bandwidths utilized in this testing were per the preceding guidelines.
- ANSI C63.10, Section 4.2.3.2.2/ FCC 15.35(b): When an average limit is specified, the peak emission must also be measured to ensure the emissions is less than 20dB above the average limit and/or below the peak limit specified. This report includes both average and peak test data.
- ANSI C63.10, Section 5.3/ FCC 15.31: All radiated field strength measurements taken at an antenna-to-product test distance of 3-meters.
- ANSI C63.10, Section 6.3/ FCC 15.31(m): Measurements were taken at the lowest, near the middle and highest channels of the product tested.

3 Description of Product Under Test

Model:	W2400-01 (2.4GHz)
Type of EUT:	802.11 b/g/n PCIe Module
Serial Number:	DEN1402111313
FCC ID:	KNYASM1101CR
Industry Canada ID:	IC ID: 2329B-ASM1101CR
Related Submittal(s) Grants:	-----
Company:	FreeWave Technologies, Inc.
Customer:	FreeWave Technologies, Inc.
Address:	5395 Pearl Parkway, Suite 100
Phone:	(303) 962-7879
Fax:	-----
e-mail:	dbusch@freewave.com
Test Standards:	☒ 47 CFR, Part 15C:§15.247 DTS ☒ RSS–210, Issue 8, 2010 ☒ RSS-Gen, Issue 3, 2010 ☐ 47 CFR, Part 15C:§15.207 ☐ Other
Type of radio:	☐ Stand -alone ☒ Module ☐ Hybrid
Date Sample Submitted:	01/27/2014
Test Work Started:	02/03/2014
Test Work Completed:	02/04/2014
Test Sample Conditions:	☐ Damaged ☐ Poor (Usable) ☒ Good

Product Description:	
Transmitter Type:	☐ FHSS ☒ Digital Modulation ☐ WiFi ☐ Blue Tooth
Operating Frequency Range(s):	2412MHz to 2462MHz
Number of Channels:	IEEE 802.11b, IEEE 802.11g, 802.11n HT20, 11-Channels 802.11n HT40, 1-Channel 2400 – 2483.5 MHz
Modulation:	802.11b: DSSS-DBPSK, DQPSK, CCK 802.11 g/n: OFDM-BPSK, QPSK, 16QAM, 64QAM
Antenna(s) Info:	Antenna: Type: 2.4GHz Directional Panel) Gain: +20.5 dBi Connector Type: "N" External Antenna(s) (Dedicated) – Point-to-Point
Rated Power:	EIRP 27.86 dBm (610.94 mW)
Antenna Installation:	☐ User ☒ Professional ☐ Factory
Transmitter power configuration:	☐ Internal battery ☒ External power source
Special Test Arrangement:	Mounted on antenna tripod
Test Facility Accreditation:	A2LA (Certificate No. 2506.02)
Test Methodology:	Measurements performed according to the procedures in ANSI C63.10-2013 and FCC Guidance Publication 558074

3.1 Channel Configurations

CHANNELS IN THE 2400 – 2483.5 MHZ BAND					
Channel Number	**Frequency (MHz)**	**802.11n HT20**	**802.11n HT40**	**SISO $N_{TX = 1}$**	**MIMO $N_{TX = 3}$**
1	2412	xt	---	tested	---
2	2417	x	---	x	---
3	2422	x	---	x	---
4	2427	x	---	x	---
5	2432	x	---	x	---
6	2437	xt	xt	tested	tested
7	2442	x	---	x	---
8	2447	x	---	x	---
9	2452	x	---	x	---
10	2457	x	---	x	---
11	2462	xt	---	tested	---

Note: x = available channels xt = tested channels

3.2 Product Description – Detailed

Description of Equipment Under Test (provided by client)
The system tested is the Model: W2400-01 (2.4GHz) radio module configured with: ▪ Model: Superpass SPAPG20 (Directional Panel antenna) The product is a wireless router utilized in M2M industrial applications Signal & I/O Cables: Ethernet The product is powered from an external power source.

For the testing of this specific test report, the product supports the following data rates in the 2400 – 2483.5 MHz band:

- IEEE 802.11n HT20: MCS0-MCS15
- IEEE 802.11n HT40: MSC0-MCS15

In 802.11n HT20 mode, the nominal bandwidth is 20MHz.
In 802.11n HT40 mode, the nominal bandwidth is 40MHz.

The product operates in both SISO (1-transmit chain) and MIMO (2-transmit chains) modes.

Equipment Under Test Power Configuration			
Rated Voltage	Rated Current	Rated Frequency	Number of Phases
AC Adapter Input: 100-240VAC	0.9 A	50/60	1
AC Adapter Output: 12VDC	3.0 A	---	---

Descriptions of EUT Exercising
☐ Standby/Idle Mode
☐ Continuous transmission, un-modulated carrier (CW)
☒ Continuous transmission, modulated carrier (CW)
☐ Continuous Receive Mode

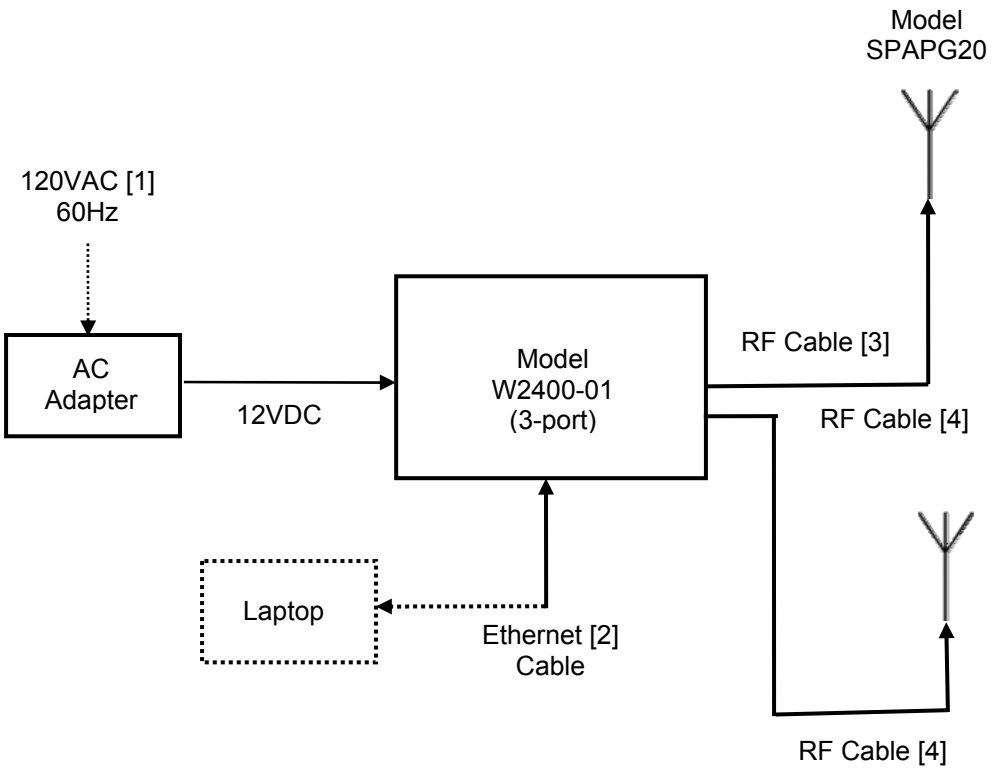
Note: The chosen mode of operation described above is dependent upon the specific test to be performed.

4 System setup including cable interconnection details, support equipment and simplified block diagram

4.1 Method:

Record the details of EUT cabling, document the support equipment, and show the interconnections in a block diagram.

4.2 EUT Block Diagram: Directional Panel Antenna (1-port)



Note: Dashed lines indicate auxiliary/support equipment outside the test area. Ethernet cable was routed partially outside the test chamber with ~ 1-meter inside the test chamber – connected to the Model W2400-01 Ethernet port.

4.3 Antenna Specifications:

2.4 GHz					
Model	**Type**	**Gain (dBi)**	**Beamwidth (degrees)**	**Polarization**	**Datasheet**
Superpass SPAPG20	Directional Panel	20.5	-----	Single	Appendix A of this report

4.4 Determination of RF Power supplied to antenna input for testing

Per FCC 15.247(b)(4)(i): Systems operating in the 2400-2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

Antenna tested:

- Model SPAPG20 (Directional Panel Antenna) Gain: 20.5dBi

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Maximum Peak Conducted Output Power: If G_{Tx} > 6dBi, then $P_{Out} = 30 – ((G_{Tx} – 6)/3)$ dBm

Where:

P_{Out} = maximum peak conducted output power (dBm)

G_{Tx} = maximum transmitting antenna directional gain (dBi)

==========

$P_{Out} = 30 – ((G_{Tx} – 6)/3)$ dBm = 30 – ((20.5-6)/3) dBm = 25.17 dBm

All Radiated measurements taken with the Model: W2400-01 transmitting at 23dBm. This represents the absolute worst-case since the actual rated maximum output power is less than the allowed 30dBm.

Actual Rated Output Power: 27.86dBm (610.94 mW)

4.5 Support Data:

ID	Description/ Function	Shield Type	Length	Connector	Connection	Ferrites
1	DC Cable (ac adapter)	none	0.5 meter	DC	VDC – Model W2400-01	none
2	Ethernet Cable	none	4-meter	RJ45	RJ-45 – Model W2400-01	none
3-4	RF Cable(s)	Braid	3-meter	SMA-to-N	Model W2400-01 to Antenna	none

Support Equipment			
Description	Manufacturer	Model Number	Serial Number
Laptop	HP	---	---
Switching Power Supply	Sceptre Power	S036CQ1200300	---

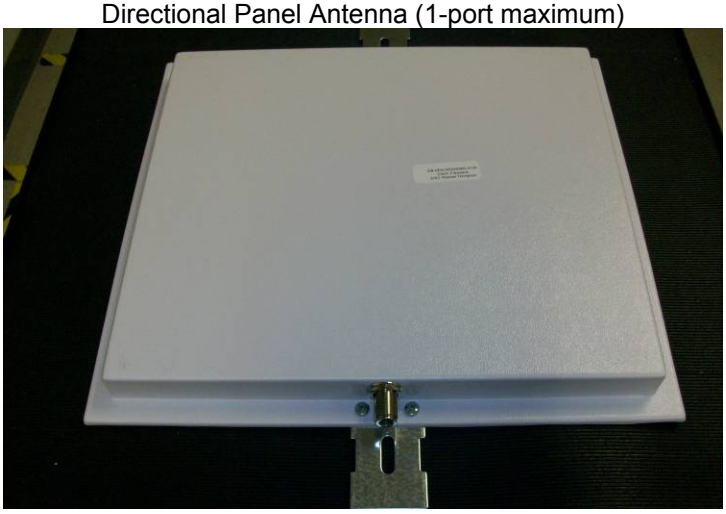
Notes:

1) The laptop was utilized only to configure the product during testing (i.e. set channel, modulation, data rates, etc.).
2) The product has RF ports and Ethernet Cable ports.

4.6 Photograph: Product Tested - Model W2400-01 with Directional Panel Antenna

Model W2400-01 Radio Module (3-port maximum)

Directional Panel Antenna (1-port maximum)



5 AC Voltage Variation/ Battery Requirement

5.1 Results:

Test not required for Class II Permissive Change.

6 Antenna Requirement

6.1 Results:

Test not required for Class II Permissive Change.

7 DTS Requirement

7.1 Results:

Test not required for Class II Permissive Change.

8 DTS Bandwidth (6dB Bandwidth)

8.1 Test Results:

Test not required for Class II Permissive Change.

9 RF Conducted Output Power

9.1 Results:

Not required for Class II permissive change. However, the software utility utilized to configure the radio output power supplied to the antenna(s) during testing was verified to provide at least the minimum output power selected for testing.

10 RF Conducted Spurious Emissions (-20dBc) – Including Band Edge

10.1 Test Results:

Test not required for Class II Permissive Change.

11 Transmitter Radiated Spurious Emissions – Restricted Band/ Band Edge

11.1 Method

Unless otherwise stated no deviations were made from FCC Part 15.209/205.

This testing was performed at Intertek Denver, located at 1795 Dogwood St. Suite 200, Louisville, CO 80027.

11.2 Test Requirement/ Specification:

Radiated emissions which fall in the restricted bands, as defined in FCC Part 15.205(a), must also comply with the radiated emission limits specified in Part 15.209(a) and Part 15.205(c). Measurements in the restricted bands include both peak detector and average detector measurements.
Measurements in non-restricted bands include peak detector measurements.

Unwanted emissions below 1GHz must comply with the general field strength limits defined in FCC Part 15.209, when measured with a quasi-peak detector.

11.3 Test Equipment Used:

Asset ID	Description	Manufacturer	Model	Serial	Cal Date	Cal Due
DEN-073	EMI Receiver (10Hz – 26.5GHz)	RHODE & SCHWARZ	ESU 26	100265	01/29/2014	01/29/2015
18913	Spectrum Analyzer	Hewlett-Packard	E7405A	My44211889	07/26/2013	07/26/2014
18912	9 kHz- 1.3GHz Pre Amp	Hewlett-Packard	8447F	3113A05545	06/07/2013	06/07/2014
18906	RF Pre-Amp (1-4GHz)	Mini-Circuits Lab	ZHL-42	N052792-2	06/10/2013	06/10/2014
DEN-032	4-18GHz Preamp (LNA)	Narda	DBL-0618N615	031	03/07/2013	03/07/2014
DEN - 154	2.4GHz Notch Filter	Micro-Tronics	BRM50702	151	09/24/2013	09/24/2014
19937	Bilog Antenna 30MHz – 6GHz	Sunol Sciences	JB6	A050707-2	03/20/2013	03/20/2014
18887	Horn Antenna 1-18GHz	EMCO	3115	9205-3886	03/19/2013	03/19/2014
SW-6	Software for Radiated and Conducted emissions.	Intertek	OATS vba	V. 3.0	VBU	VBU

11.4 Test Procedure:

The Resolution Bandwidth is 120 kHz or greater for frequencies 30 MHz -1000 MHz and 1 MHz for frequencies above 1000 MHz. The Video Bandwidth was at least 3x the RBW.

The EUT is placed on a plastic turntable that is 80 cm in height. If the EUT attaches to peripherals, they are connected and operational (as typical as possible). During testing, all cables are manipulated to produce worst-case emissions. The signal is maximized by rotating the turntable through a 360º rotation. The antenna height is varied from 1-4 meters. Both vertical and horizontal antenna configurations are utilized in the testing.

Radiated emissions 30MHz to 18GHz are taken at 3-meter antenna-to-product test distance.

Radiated emissions above 18GHz are taken using a harmonic mixer antenna/pre-amp setup at 1-meter antenna-to-product test distance.

Data is included for the worst-case configuration - the configuration which resulted in the highest emission levels.

The following procedures described in FCC Publication 558074 (Guidelines for Compliance Measurements on DTS Operating Under 15.247), were used:

- 558074, Section 12.1 & 13.1
- ANSI C63.10: 2009 – General Guidance

11.5 Test Results:

The sample tested was found to Comply.

11.6 Test Summary – Worst-Case Measurements

Test Data Summary: Tx Radiated Spurious Emissions in Restricted Band

SISO Mode of Operation: 802.11n HT40

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Average	FCC 15.35(b) Peak	(MHz)
Measurements: Mid Channel 1GHz to 18GHz, Average/Peak, RBW 1MHz, VBW 3MHz, max hold													
4874.0000	62.64	**Pk**	5.20	32.98	39.49	0.00	61.32	V	1.32	11.9	N/A	- 12.68	1.000
4874.0000	53.04	**Av**	5.20	32.98	39.49	0.00	51.72	V	1.32	11.9	- 2.28	NA	1.000

Test Data Summary: Tx Spurious Emissions – Band Edge/Restricted Band

SISO Mode of Operation: 802.11n HT20

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Average	FCC 15.35(b) Peak	(MHz)
Measurements: Upper Band Edge, Average/Peak, RBW 1MHz, VBW 3MHz, max hold													
2483.5000	47.31	**Av**	3.50	28.51	37.57	9.48	51.24	V	1.42	8.0	- 2.74	NA	1.000
2483.5000	52.53	**Pk**	3.50	28.51	37.57	9.48	56.46	V	1.42	8.0	NA	- 17.54	1.000

Test Data Summary: Tx Radiated Spurious Emissions in Restricted Band

MIMO Mode of Operation: 802.11n HT20

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Average	N/A	(MHz)
Measurements: Mid Channel 30MHz to 1000MHz, Quasi-peak, RBW 120kHz, VBW 300kHz, max hold													
61.6868	57.79	**Qp**	0.77	7.57	28.21	0.00	37.92	V	1.00	20.7	- 2.08	NA	0.120

Test Data Summary: Tx Spurious Emissions – Band Edge/Restricted Band

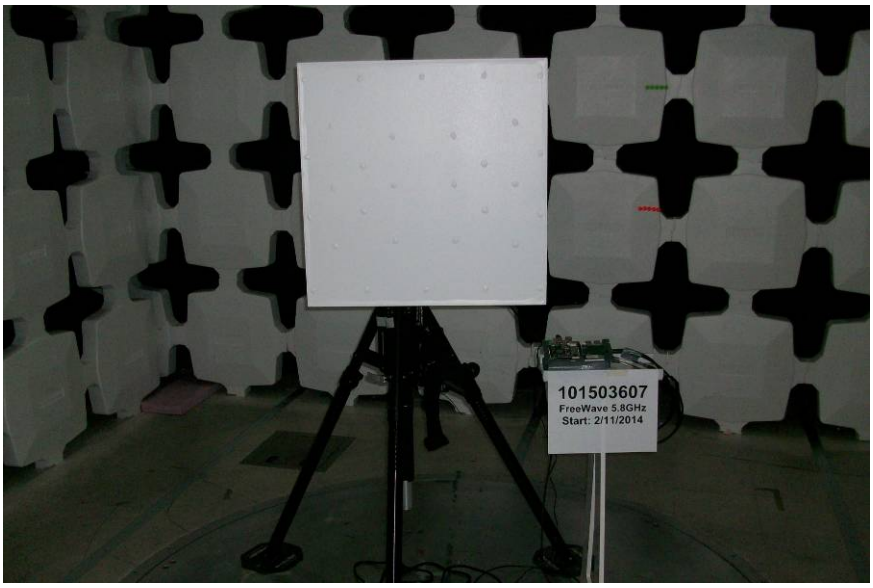
MIMO Mode of Operation: 802.11n HT20

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Average	FCC 15.35(b) Peak	(MHz)
Measurements: Lower Band Edge, Average/Peak, RBW 1MHz, VBW 3MHz, max hold													
2390.0000	48.62	**Av**	3.50	28.51	37.57	9.48	52.55	V	1.51	8.0	- 1.43	NA	1.000
2390.0000	53.66	**Pk**	3.50	28.51	37.57	9.48	57.59	V	1.51	8.0	NA	- 16.41	1.000

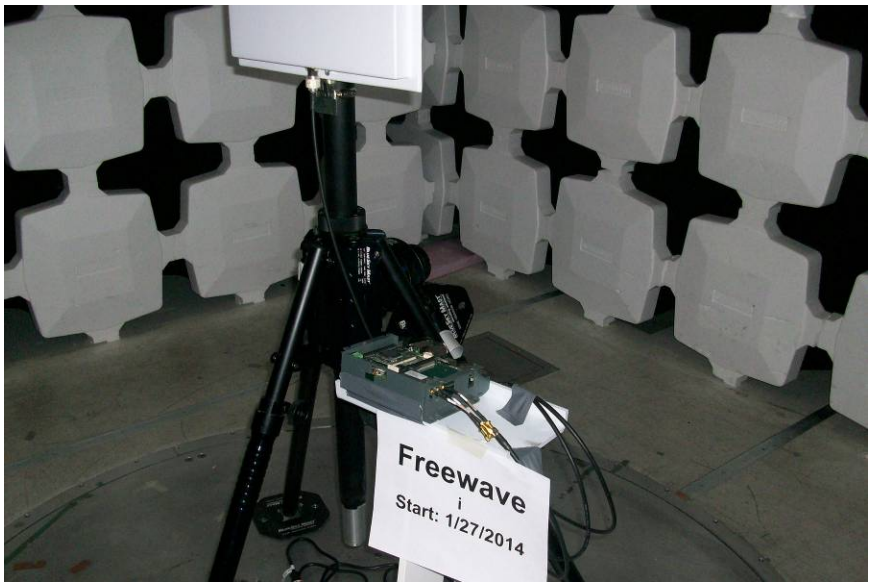
Note: The above represents the worst-case measurements.

11.7 Setup Photographs: SISO Mode of Operation

Transmitter Spurious Radiated Emissions - Test Setup (Front View)

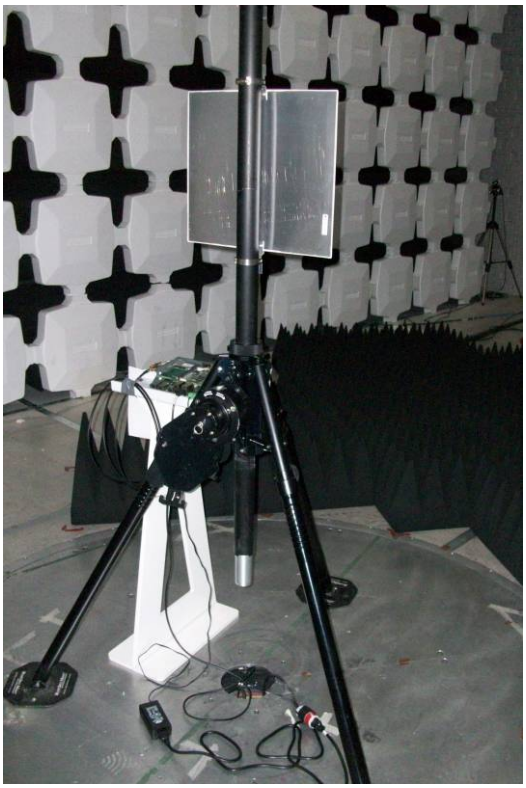


Model W2400-01

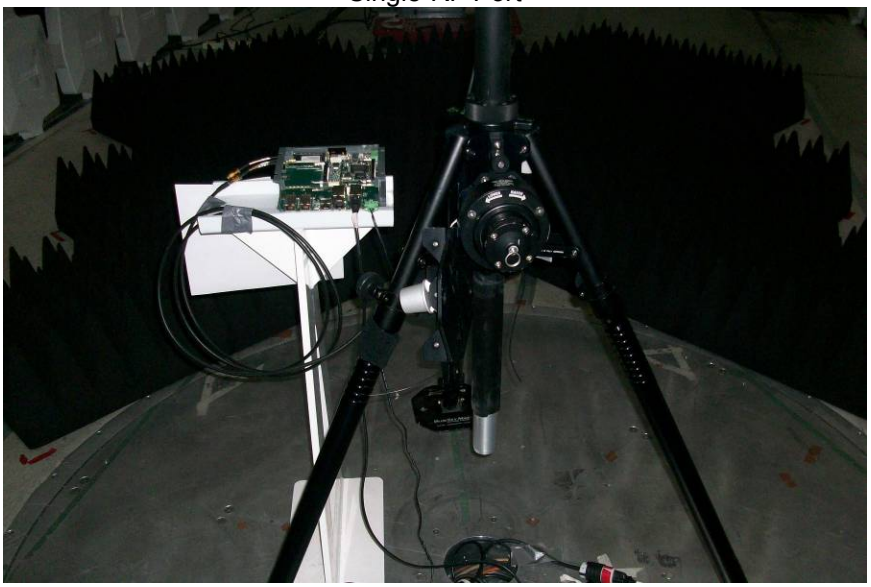


11.8 Setup Photographs: SISO Mode of Operation

Transmitter Spurious Radiated Emissions - Test Setup (Rear View)

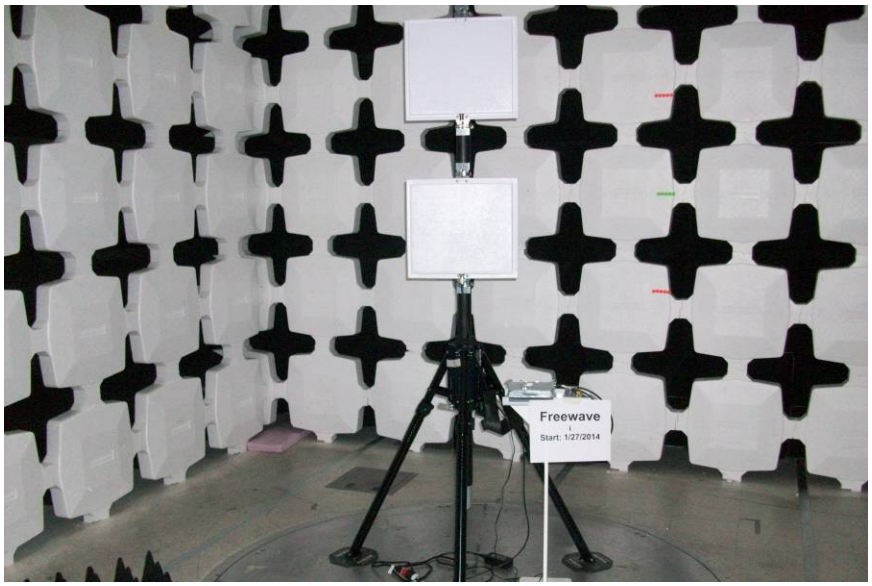


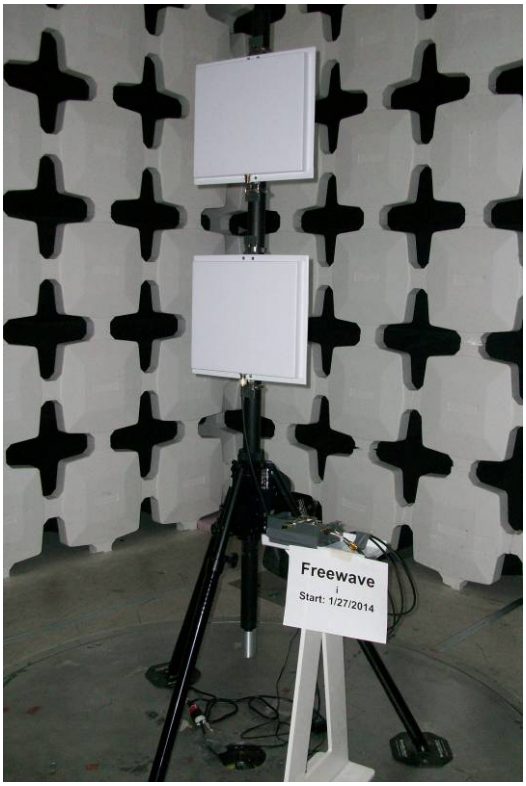
Single-RF Port



11.9 Setup Photographs: MIMO Mode of Operation

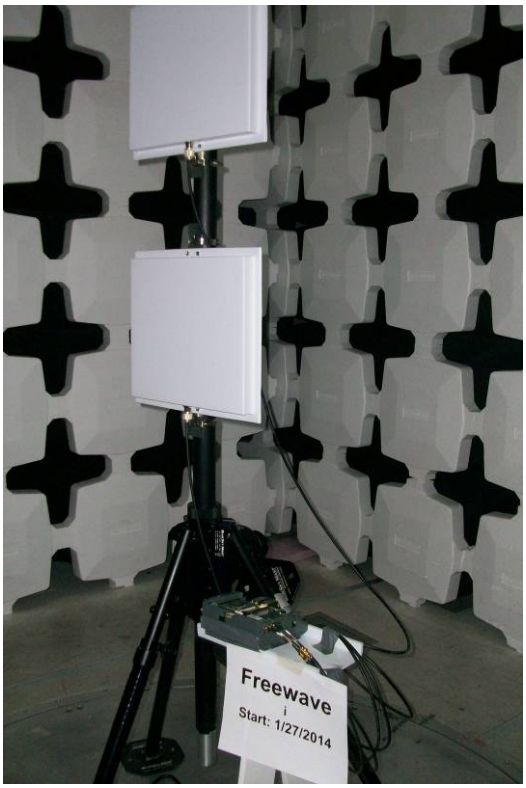
Transmitter Spurious Radiated Emissions - Test Setup (Front View)



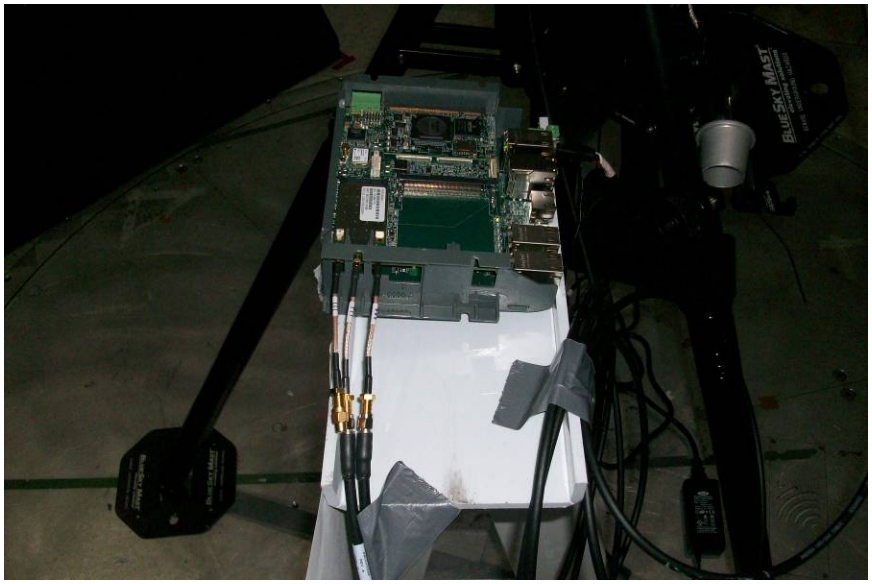


11.10 Setup Photographs: MIMO Mode of Operation

Transmitter Spurious Radiated Emissions - Test Setup (Rear View)

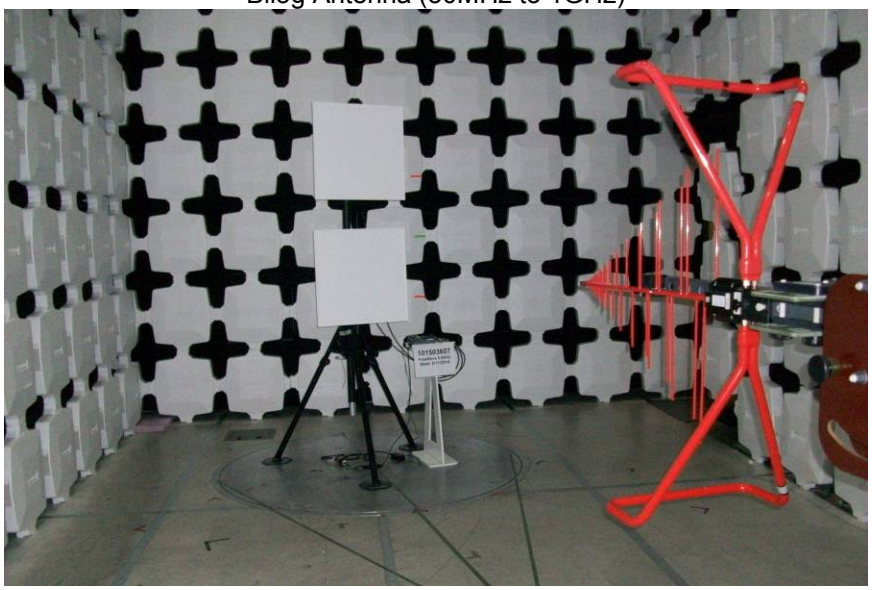


3-RF Port

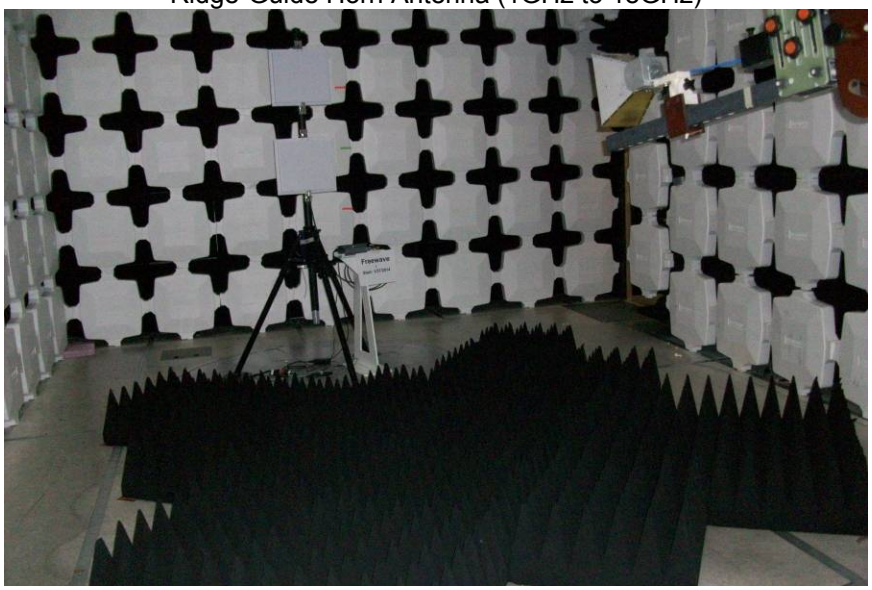


11.11 Antenna Setups:

Bilog Antenna (30MHz to 1GHz)



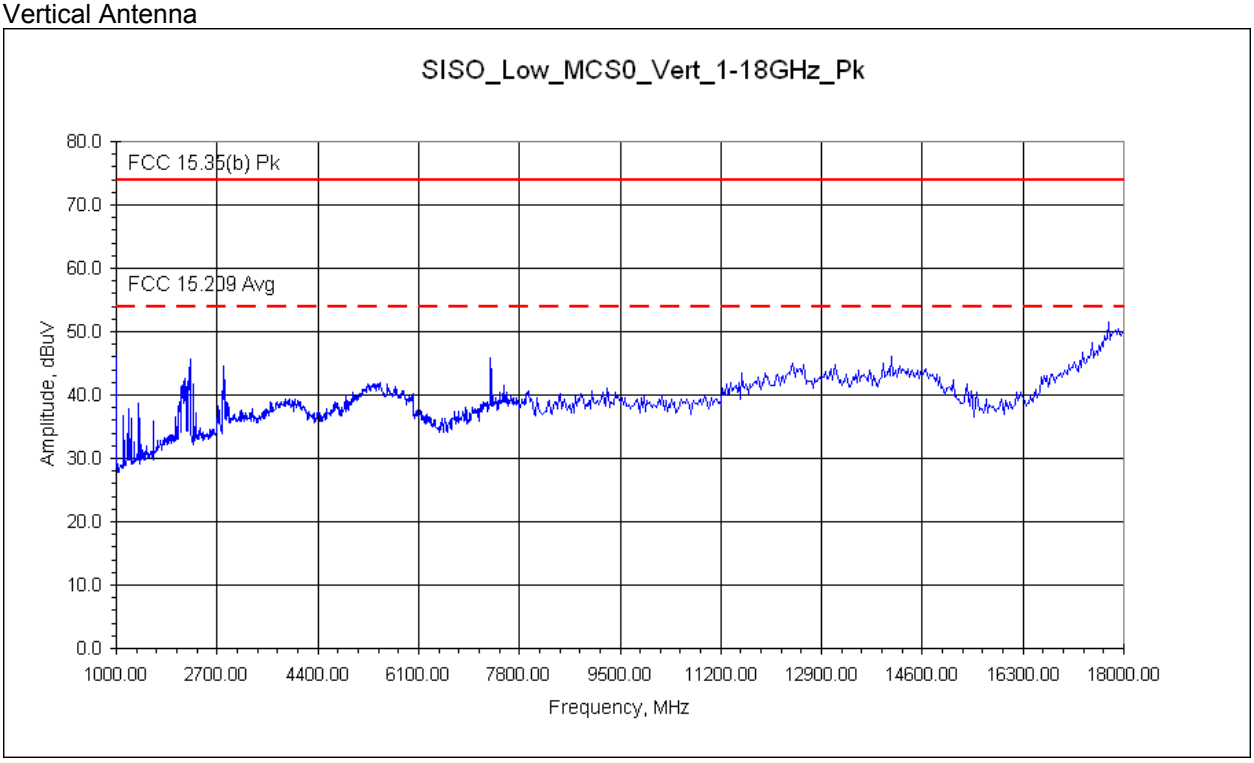
Ridge-Guide Horn Antenna (1GHz to 18GHz)



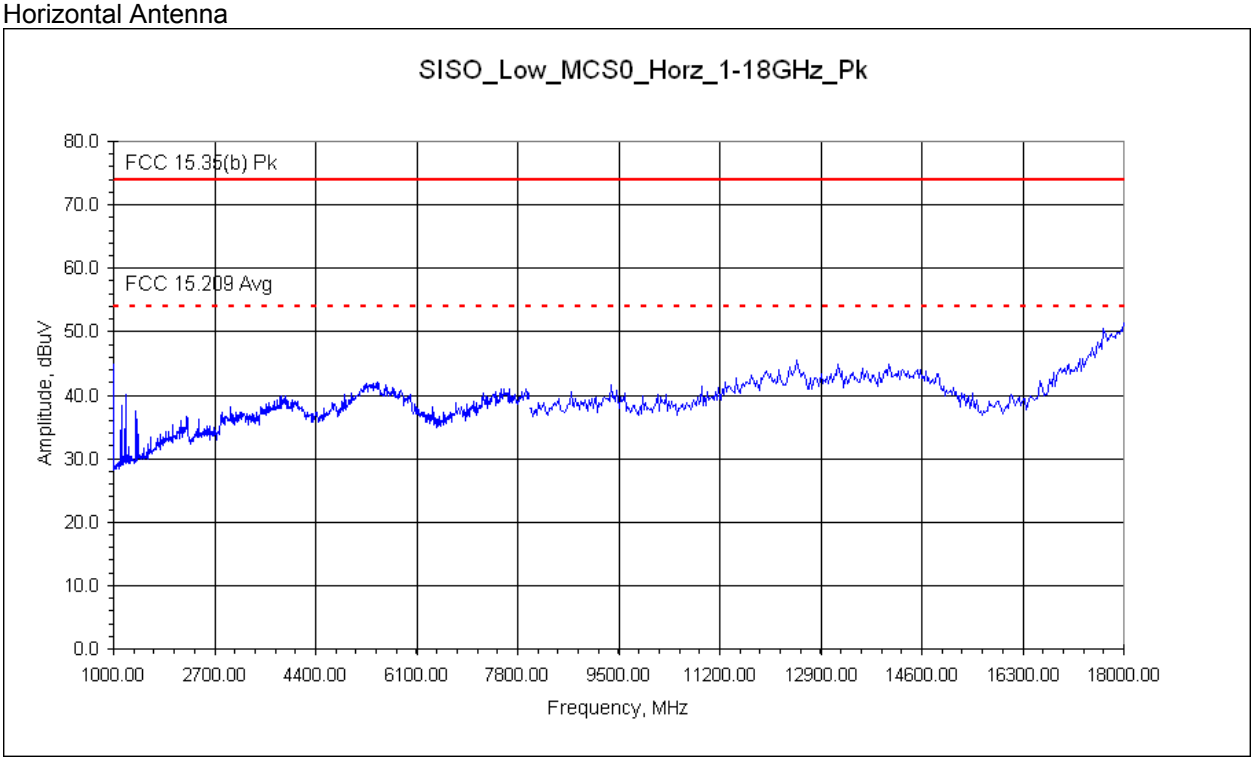
11.12 Plots: SISO Mode of Operation – HT20 Low Channel: 2412 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna

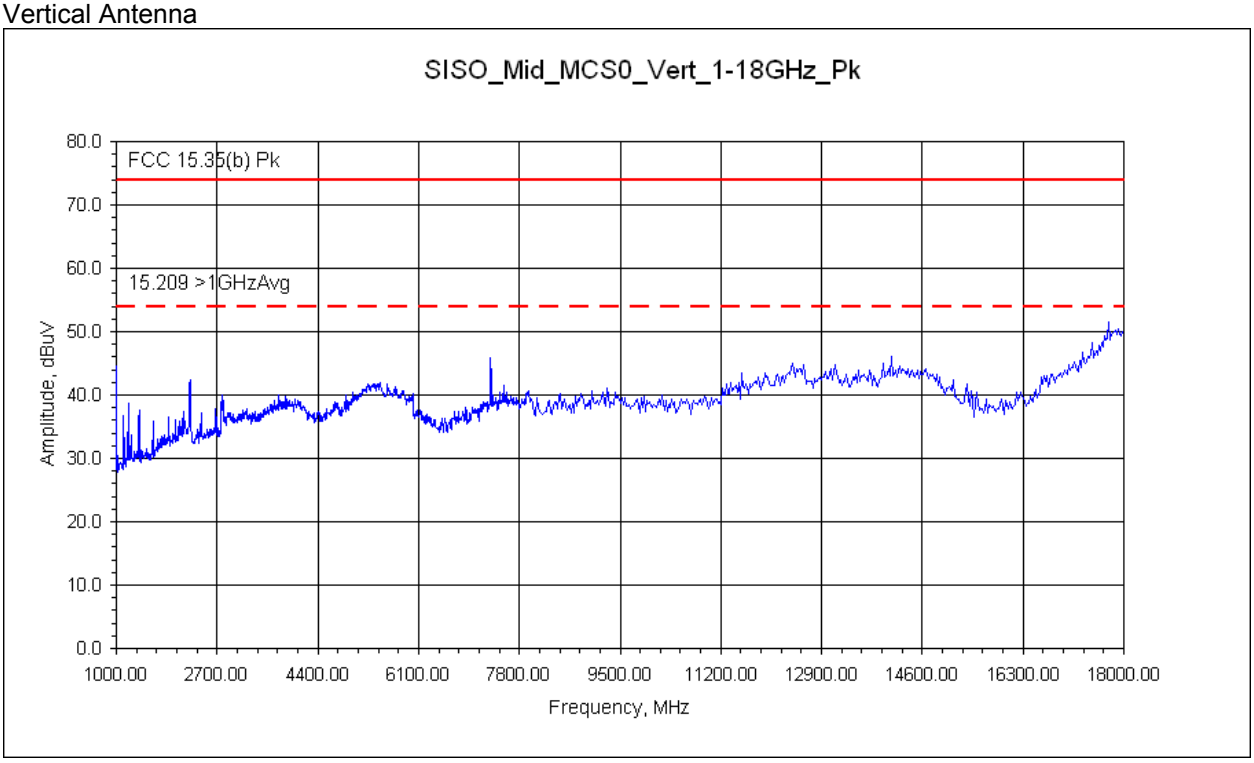


Reference only – max hold peak detector measurements referenced to average & peak limits

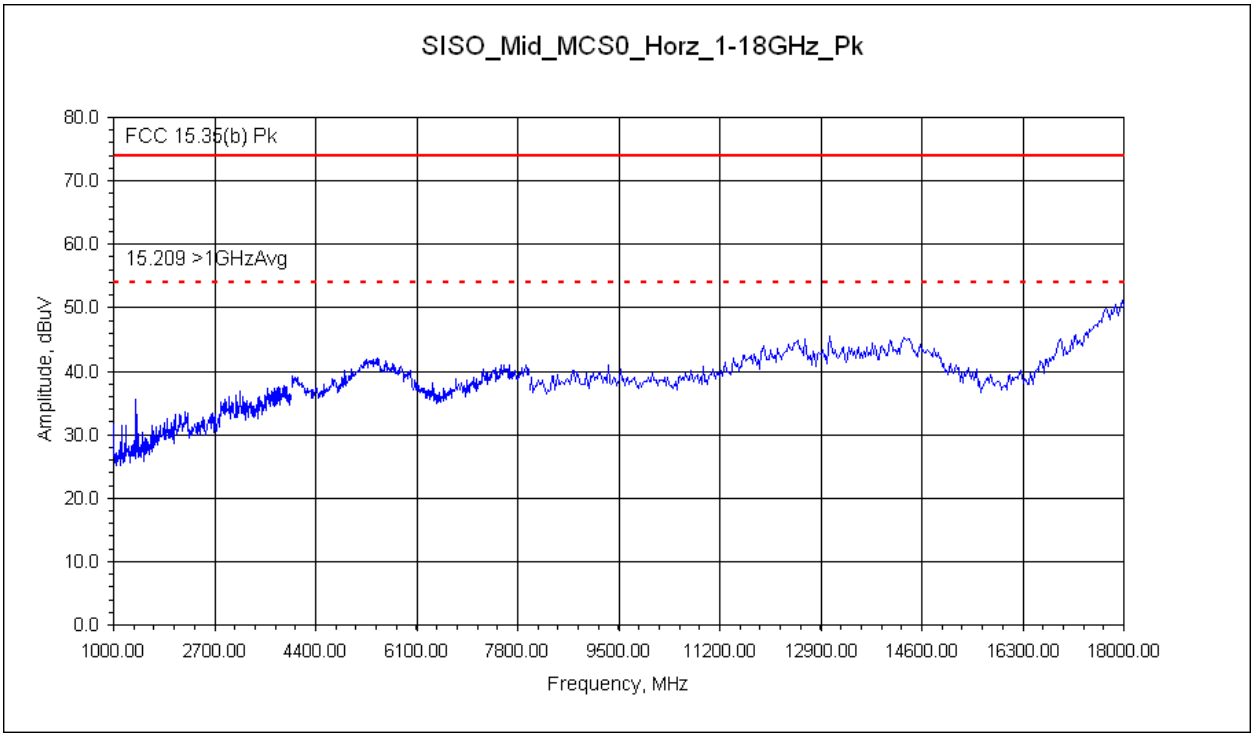
11.13 Plots: SISO Mode of Operation – HT20 Mid Channel: 2437 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna

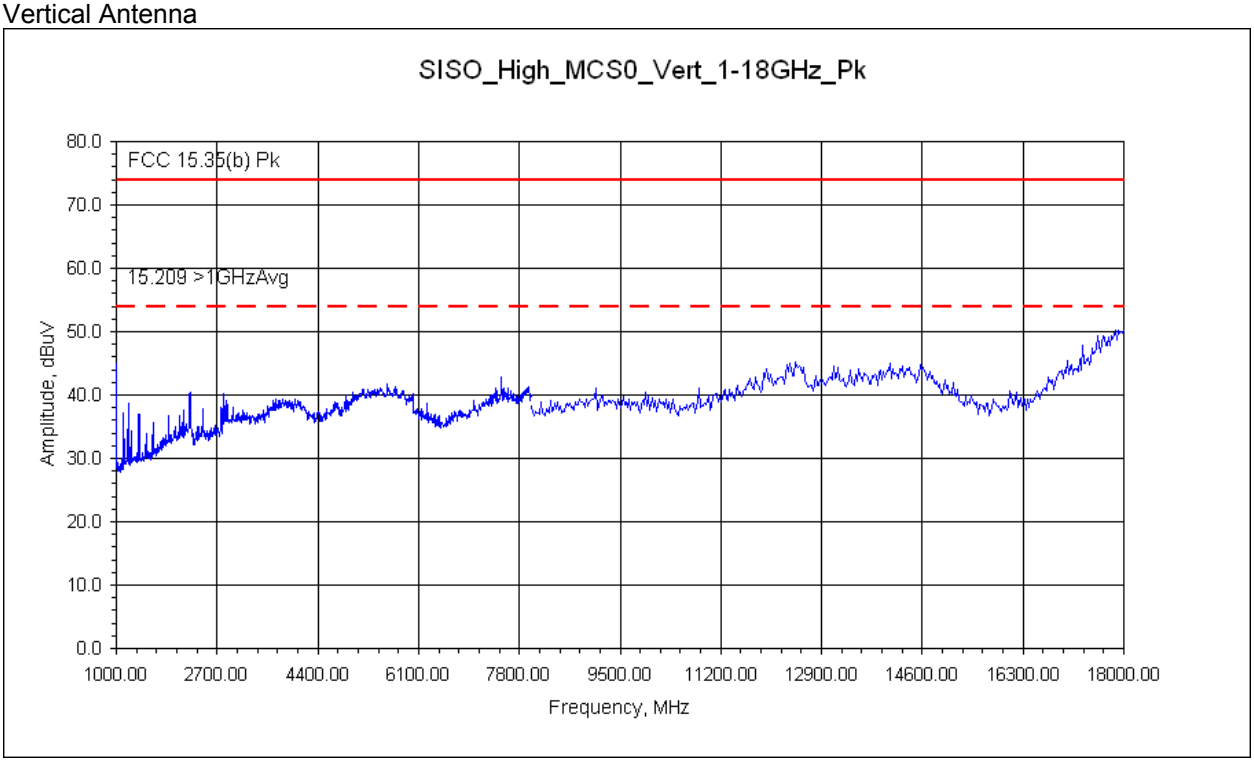


Reference only – max hold peak detector measurements referenced to average & peak limits

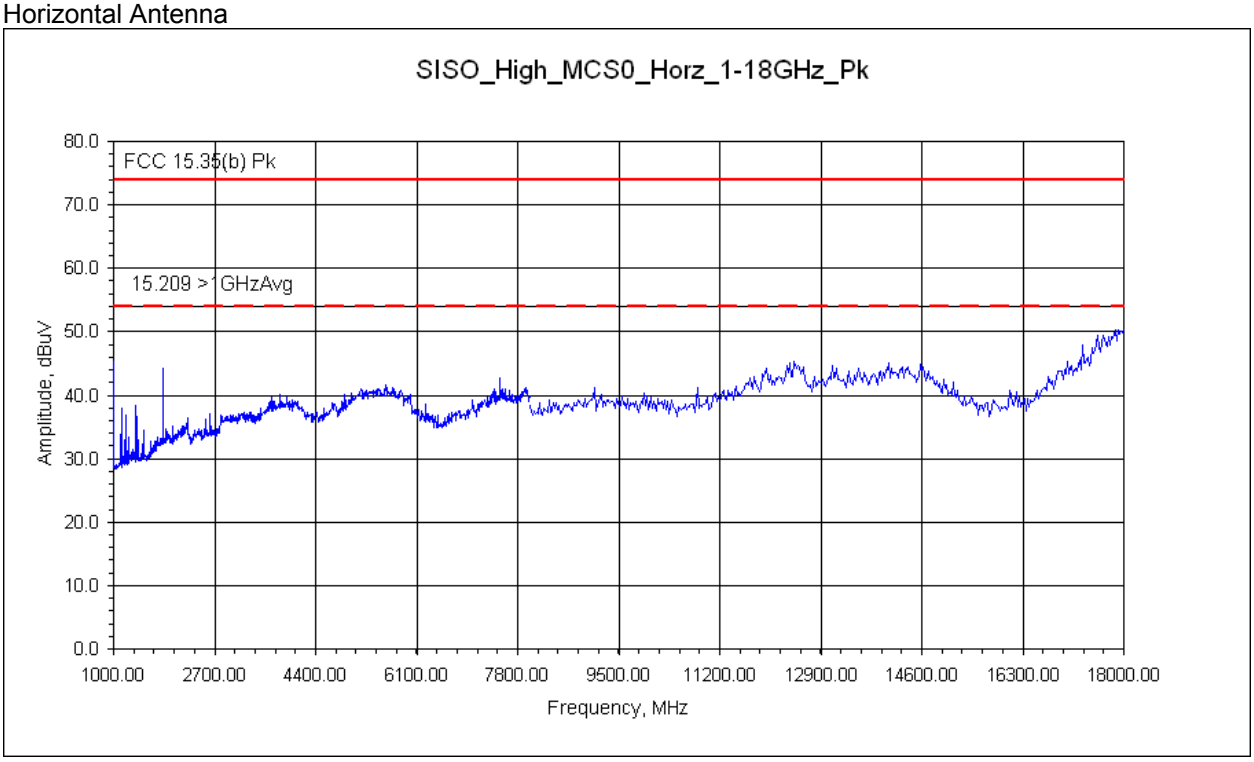
11.14 Plots: SISO Mode of Operation – HT20 High Channel: 2462 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna

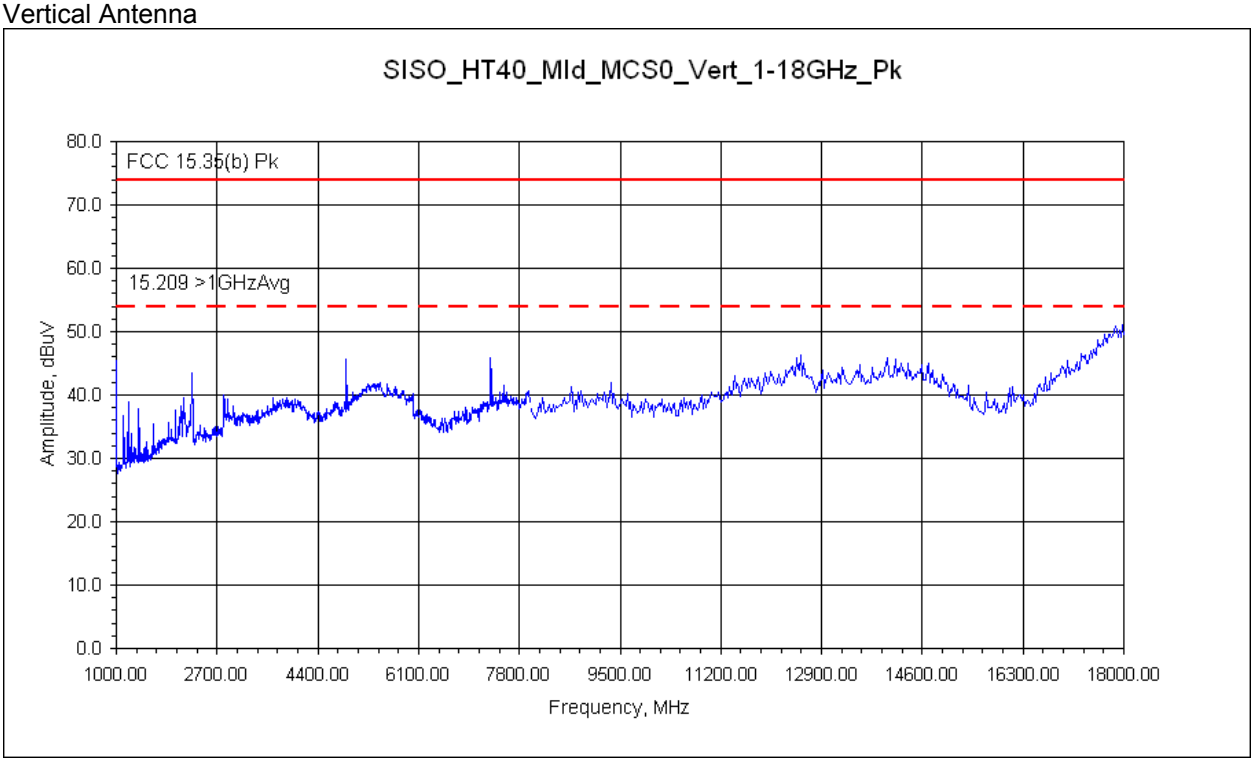


Reference only – max hold peak detector measurements referenced to average & peak limits

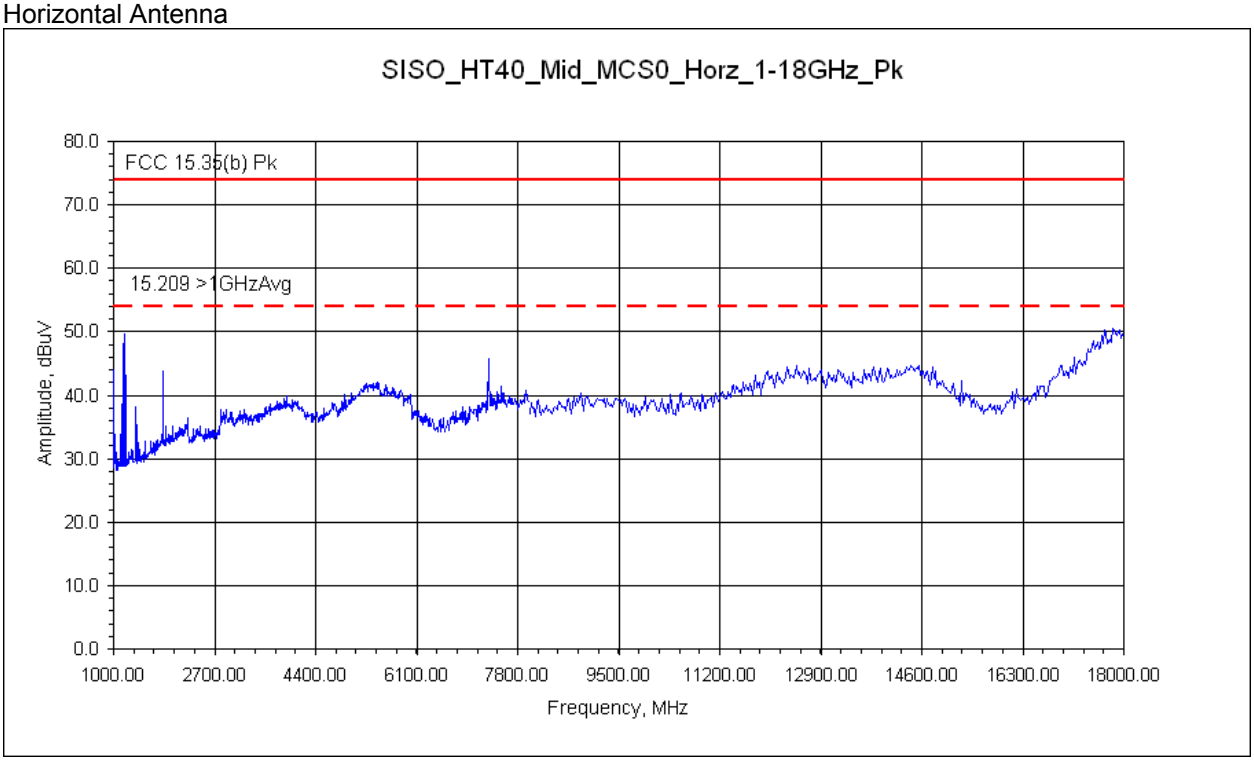
11.15 Plots: SISO Mode of Operation – HT40Channel: 2437 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna



Reference only – max hold peak detector measurements referenced to average & peak limits

11.16 Test Data: SISO Mode of Operation

Tx Spurious Radiated Electromagnetic Emissions

Test Report #:	**G101503629**	Test Area:	CC1 Radiated	Temperature:	23.7	°C
Test Method:	FCC 15.209/ 15.205/ 15.35(b)	Test Date:	02/03/2014 02/04/2014	Relative Humidity:	27.2	%
EUT Model #:	Radio Module: W2400-01 Directional Panel Antenna: SPAPG20	EUT Power:	120VAC/60Hz	Air Pressure:	83.5	kPa
EUT Serial #:	Radio: DEN1402111313 Directional Panel Antennas: 001, 002					
Manufacturer:	FreeWave Technologies, Inc.					
EUT Description:	Wireless router utilized in M2M industrial applications					
Notes:	Product tested in SISO mode: single transmit chain/port – single antenna					
	Product continuously transmitting during all testing – worst-case modulation/data					
	SISO mode of Operation, MCS0 Data Rate, 25dBm power (worst-case)					

Level Key
Pk – Peak
Qp – Quasi Peak
Av - Average

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Avg	FCC 15.35(b) Pk	(MHz)
Radio System: Model W2400-01 Radio Module with Directional Panel Antenna – SISO Mode of Operation													
Measurements: 1GHz to 18GHz – HT20 Low Channel 2412 MHz													
1001.0000	53.07	**Pk**	2.22	23.82	37.13	0.34	42.31	V	1.34	151.1	- 11.69	- 31.69	1.000
1000.1100	58.19	**Pk**	2.21	23.82	37.13	0.34	47.43	V	1.34	151.1	N/A	- 26.57	1.000
1000.1100	51.63	**Av**	2.21	23.82	37.13	0.34	40.87	V	1.34	151.1	- 13.13	NA	1.000
1200.0000	53.96	**Pk**	2.44	25.07	37.18	0.40	44.68	V	1.72	97.6	N/A	- 29.32	1.000
1200.0000	46.47	**Av**	2.44	25.07	37.18	0.40	37.19	V	1.72	97.6	- 16.81	NA	1.000
1375.0000	52.88	**Pk**	2.61	25.13	36.76	0.47	44.32	V	1.82	180.9	N/A	- 29.68	1.000
1375.0000	47.17	**Av**	2.61	25.13	36.76	0.47	38.61	V	1.61	165.8	- 15.39	NA	1.000
2170.0000	54.40	**Pk**	3.33	27.79	37.32	1.50	49.70	V	1.60	- 0.1	N/A	- 24.30	1.000
2170.0000	37.22	**Av**	3.33	27.79	37.32	1.50	32.52	V	1.60	14.2	- 21.48	NA	1.000
2252.5000	56.96	**Pk**	3.39	27.87	37.46	3.68	54.44	V	1.49	9.9	N/A	- 19.56	1.000
2252.5000	37.34	**Av**	3.39	27.87	37.46	3.68	34.82	V	1.49	9.9	- 19.18	NA	1.000
2814.7400	47.71	**Pk**	3.84	29.09	37.57	2.48	45.56	V	1.32	20.2	N/A	- 28.44	1.000
2814.7400	36.81	**Av**	3.84	29.09	37.57	2.48	34.66	V	1.32	20.2	- 19.34	NA	1.000
1000.0100	58.12	**Pk**	2.21	23.82	37.13	0.34	47.36	H	1.78	51.1	N/A	- 26.64	1.000
1000.0100	52.98	**Av**	2.21	23.82	37.13	0.34	42.22	H	1.78	51.1	- 11.78	NA	1.000
1200.0000	54.42	**Pk**	2.44	25.07	37.18	0.40	45.14	H	1.64	132.4	N/A	- 28.86	1.000
1200.0000	45.05	**Av**	2.44	25.07	37.18	0.40	35.77	H	1.64	132.4	- 18.23	NA	1.000
Measurements: 1GHz to 18GHz – HT20 Mid Channel 2437 MHz													
1000.0100	60.19	**Pk**	2.21	23.82	37.13	0.34	49.43	V	1.99	154.0	N/A	- 24.57	1.000
1000.0100	54.32	**Av**	2.21	23.82	37.13	0.34	43.56	V	1.99	154.0	- 10.44	NA	1.000
1200.0000	54.00	**Pk**	2.44	25.07	37.18	0.40	44.72	V	1.99	154.0	N/A	- 29.28	1.000
1200.0000	47.62	**Av**	2.44	25.07	37.18	0.40	38.34	V	1.99	154.0	- 15.66	NA	1.000
2237.5000	62.49	**Pk**	3.38	27.84	37.43	2.76	59.05	V	1.69	0.0	N/A	- 14.95	1.000
2237.5000	37.10	**Av**	3.38	27.84	37.43	2.76	33.66	V	1.69	0.0	- 20.34	NA	1.000
4880.0000	64.61	**Pk**	5.20	32.99	39.51	0.00	63.29	V	1.40	8.7	N/A	- 10.71	1.000

4880.0000	39.93	**Av**	5.20	32.99	39.51	0.00	38.61	V	1.40	8.7	- 15.39	NA	1.000
1375.0000	53.09	**Pk**	2.61	25.13	36.76	0.47	44.53	H	1.74	311.0	N/A	- 29.47	1.000
1375.0000	46.53	**Av**	2.61	25.13	36.76	0.47	37.97	H	1.74	311.0	- 16.03	NA	1.000
Measurements: 1GHz to 18GHz – HT20 High Channel 2462 MHz													
1000.0100	59.87	**Pk**	2.21	23.82	37.13	0.34	49.11	V	1.24	345.0	N/A	- 24.89	1.000
1000.0100	52.88	**Av**	2.21	23.82	37.13	0.34	42.12	V	1.24	345.0	- 11.88	NA	1.000
1200.0000	54.39	**Pk**	2.44	25.07	37.18	0.40	45.11	V	1.74	86.0	N/A	- 28.89	1.000
1200.0000	47.72	**Av**	2.44	25.07	37.18	0.40	38.44	V	1.77	82.0	- 15.56	NA	1.000
4924.0000	54.03	**Pk**	5.22	33.08	39.65	0.00	52.68	V	1.33	2.6	N/A	- 21.32	1.000
4924.0000	41.52	**Av**	5.22	33.08	39.65	0.00	40.17	V	1.33	2.6	- 13.83	NA	1.000
1000.0001	57.56	**Pk**	2.21	23.82	37.13	0.34	46.80	H	1.98	190.0	N/A	- 27.20	1.000
1000.0001	50.11	**Av**	2.21	23.82	37.13	0.34	39.35	H	1.98	190.0	- 14.65	NA	1.000
1375.0000	53.04	**Pk**	2.61	25.13	36.76	0.47	44.48	H	1.89	96.0	N/A	- 29.52	1.000
1375.0000	46.85	**Av**	2.61	25.13	36.76	0.47	38.29	H	1.89	96.0	- 15.71	NA	1.000
1832.5000	48.23	**Pk**	3.05	26.96	37.08	0.69	41.85	H	1.89	96.0	N/A	- 32.15	1.000
1832.5000	36.92	**Av**	3.05	26.96	37.08	0.69	30.54	H	1.89	96.0	- 23.46	NA	1.000
Measurements: 1GHz to 18GHz – HT40 Channel 2437 MHz													
1000.0100	57.73	**Pk**	2.21	23.82	37.13	0.34	46.97	V	1.31	189.0	N/A	- 27.03	1.000
1000.0100	51.89	**Av**	2.21	23.82	37.13	0.34	41.13	V	1.31	189.0	- 12.87	NA	1.000
1200.0500	57.44	**Pk**	2.44	25.07	37.18	0.40	48.16	V	1.72	88.0	N/A	- 25.84	1.000
1200.0500	47.13	**Av**	2.44	25.07	37.18	0.40	37.85	V	1.72	88.0	- 16.15	NA	1.000
2282.5000	58.17	**Pk**	3.42	27.92	37.47	0.00	52.03	V	1.62	0.0	N/A	- 21.97	1.000
2282.5000	38.82	**Av**	3.42	27.92	37.47	0.00	32.68	V	1.19	0.0	- 21.32	NA	1.000
4874.0000	62.64	**Pk**	5.20	32.98	39.49	0.00	61.32	V	1.32	11.9	N/A	- 12.68	1.000
4874.0000	53.04	**Av**	5.20	32.98	39.49	0.00	51.72	V	1.32	11.9	- 2.28	NA	1.000
1000.0100	57.41	**Pk**	2.21	23.82	37.13	0.34	46.65	H	1.89	331.0	N/A	- 27.35	1.000
1000.0100	52.64	**Av**	2.21	23.82	37.13	0.34	41.88	H	1.83	351.0	- 12.12	NA	1.000

Example calculation:

Measured Level	+	**Cable Loss**	+	**Antenna Factor**	-	**Pre-Amp**	+	**Atten**	=	**Final Corrected Reading**	**Specification Limit**	-	**Final Corrected Reading**	=	**Delta Specification**
(dBμV)		(dB)		(dB)		(dB)		(dB)		(dBμV/m)	(dBμV/m)		(dBμV/m)		
20.0		**3.0**		**5.0**		**10.0**		**0.0**		**18.0**	**40.0**		**18.0**		**- 22.0**

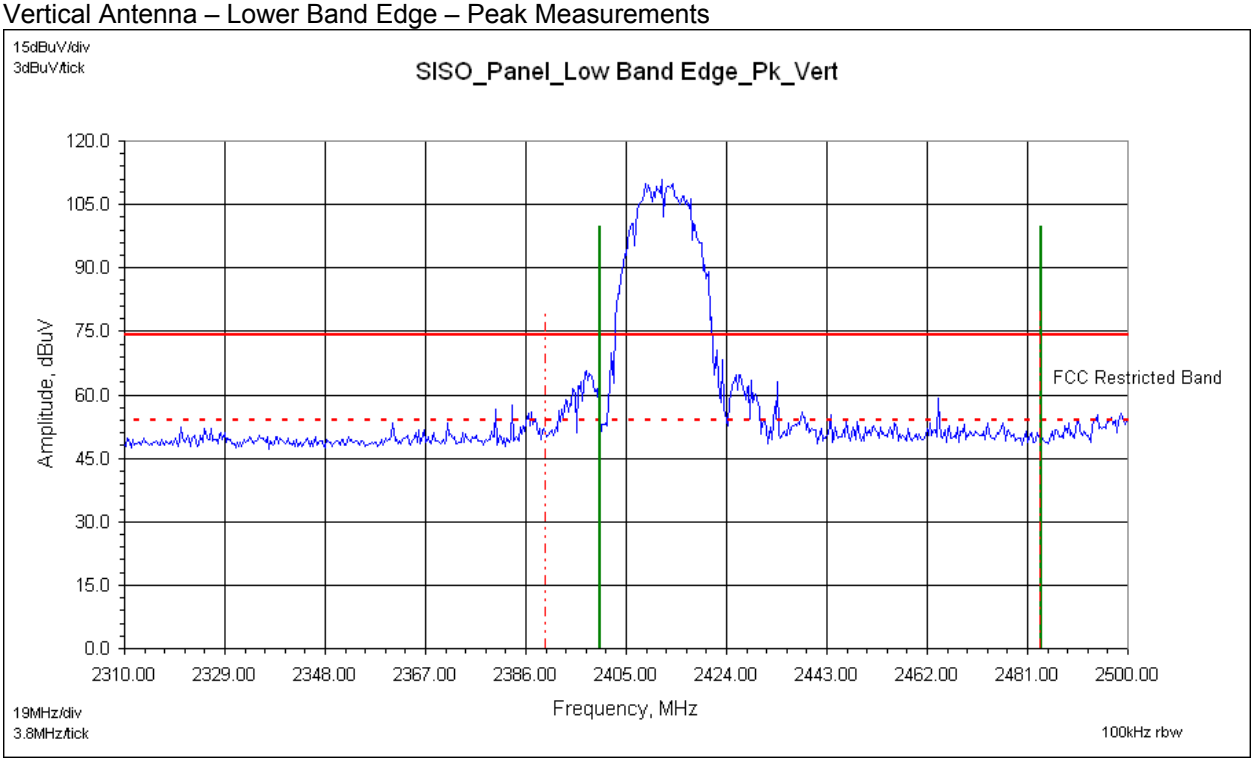
Notes:

1) The highest signals – as determined from pre-scan plots – were fully-maximized and measured.
2) For the general pre-scan plots 1-4GHz, a notch filter was utilized. Note the notch filter was <u>not used</u> during band edge plots/measurements.
3) 802.11 HT20/HT40 included in measurements as well as both SISO/MIMO modes of Tx operation.

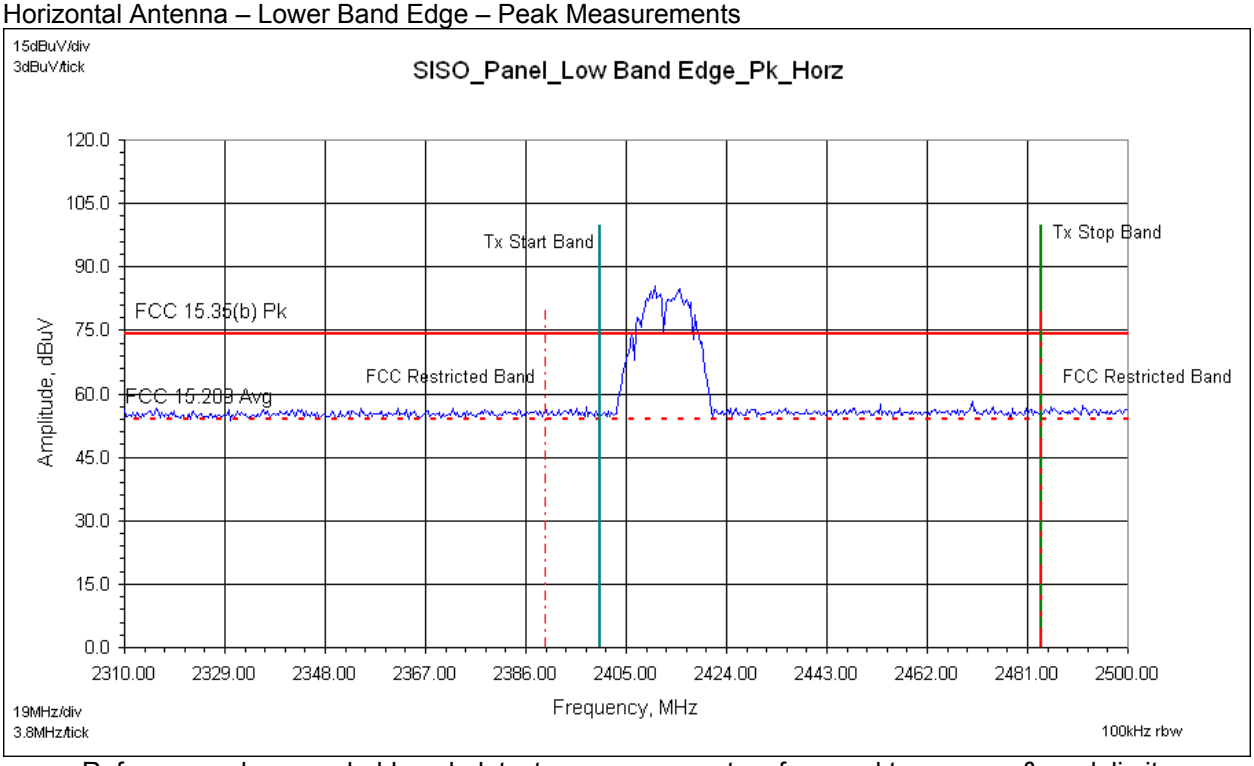
Deviations, Additions, or Exclusions: None

11.17 Band Edge Plots: SISO Mode of Operation – HT20 Low Channel 2412 MHz

Vertical Antenna – Lower Band Edge – Peak Measurements



Horizontal Antenna – Lower Band Edge – Peak Measurements

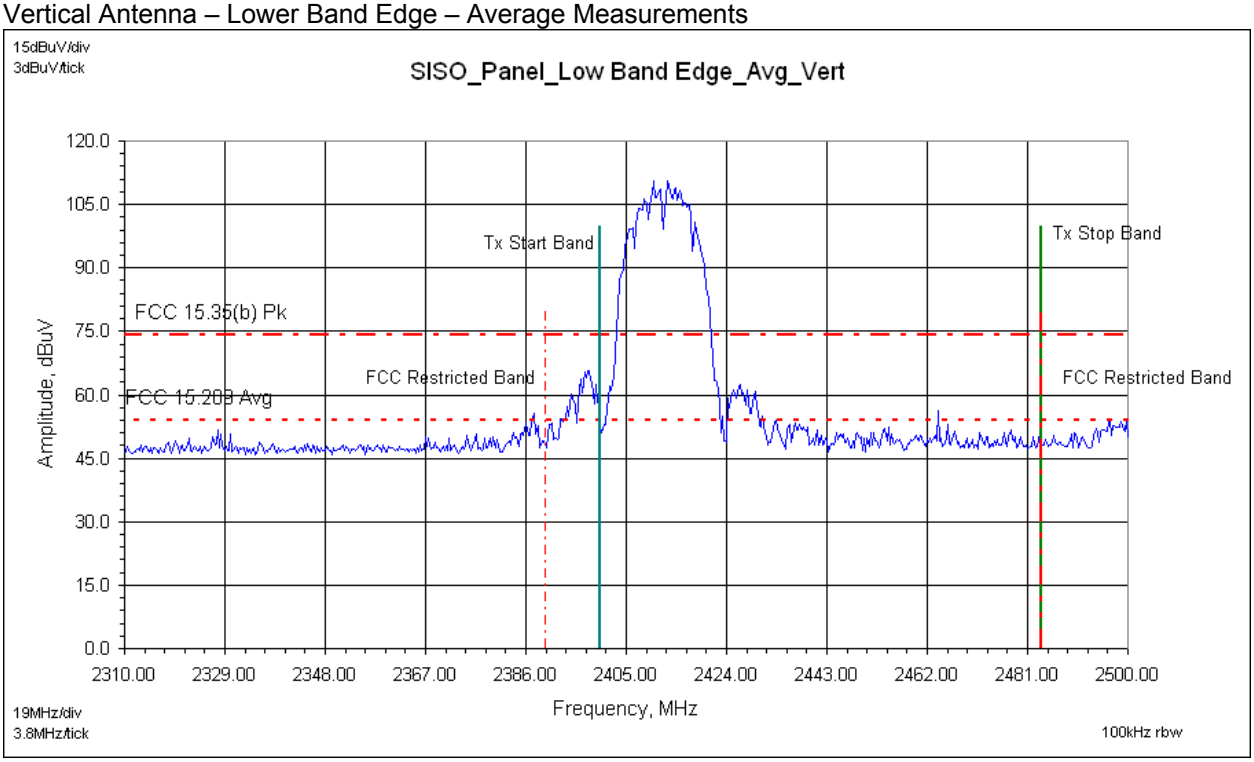


Reference only – max hold peak detector measurements referenced to average & peak limits

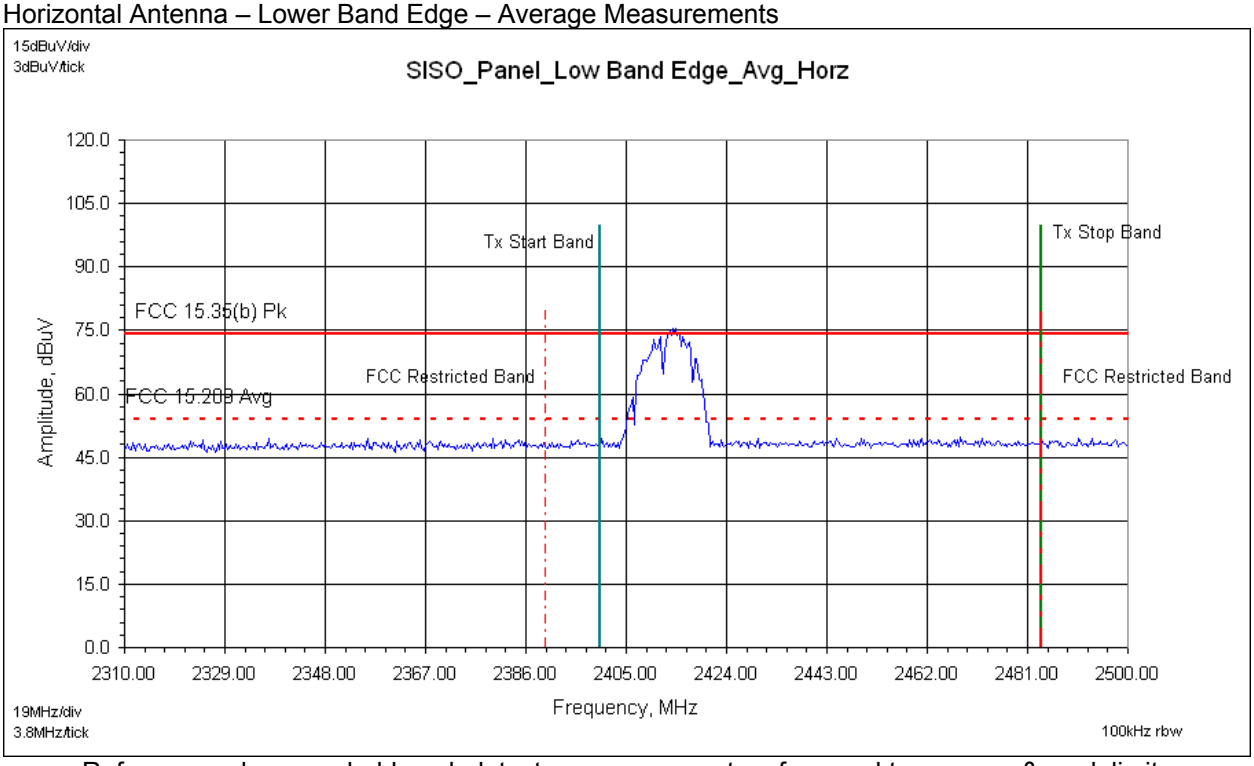
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Dashed-Lines (Restricted Band)
Blue Trace (Peak trace line)

11.18 Band Edge Plots: SISO Mode of Operation – HT20 Low Channel 2412 MHz

Vertical Antenna – Lower Band Edge – Average Measurements



Horizontal Antenna – Lower Band Edge – Average Measurements

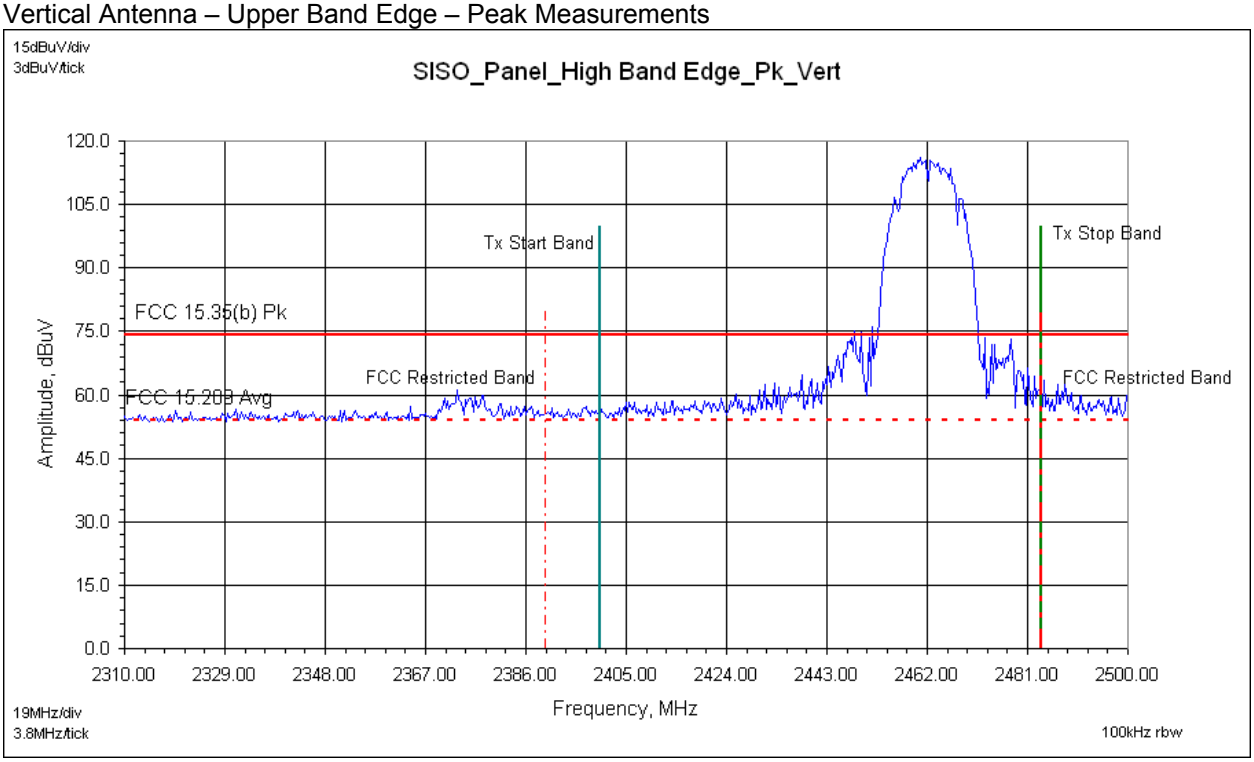


Reference only – max hold peak detector measurements referenced to average & peak limits

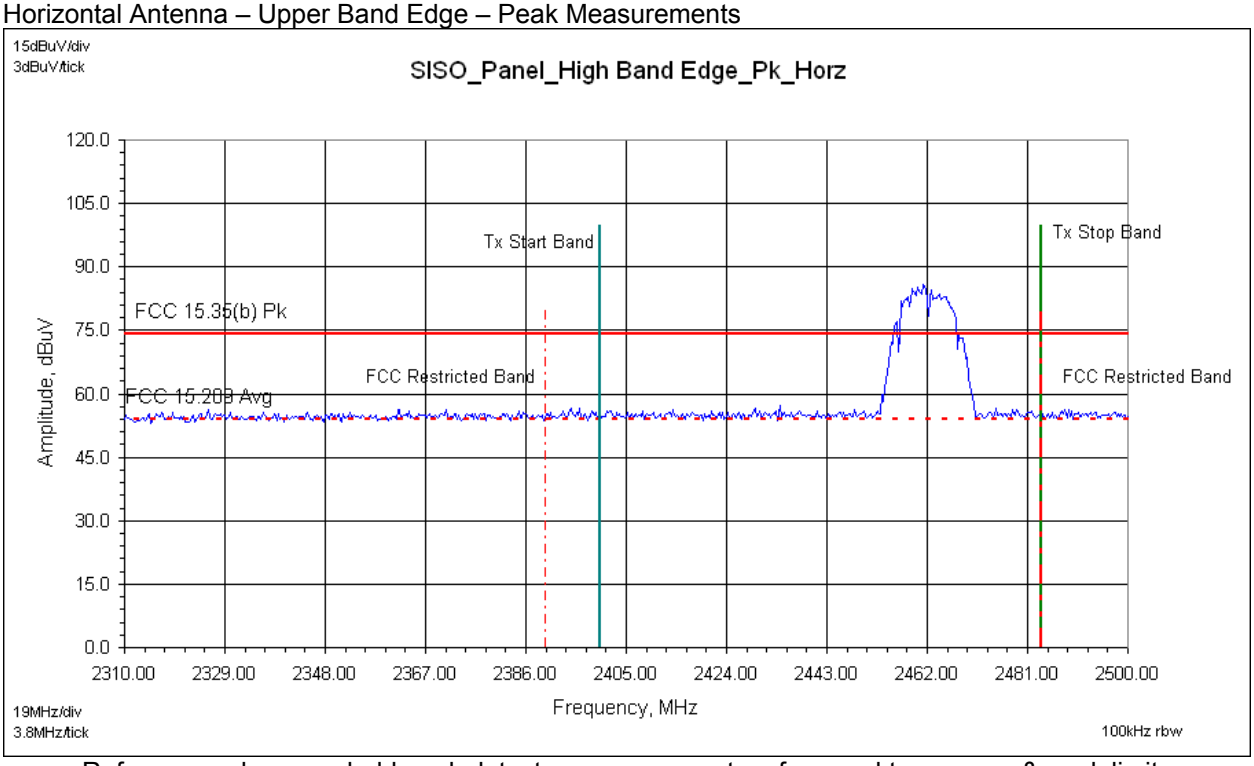
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Dashed-Lines (Restricted Band)
Blue Trace (Average trace line)

11.19 Band Edge Plots: SISO Mode of Operation – HT20 High Channel 2462 MHz

Vertical Antenna – Upper Band Edge – Peak Measurements



Horizontal Antenna – Upper Band Edge – Peak Measurements

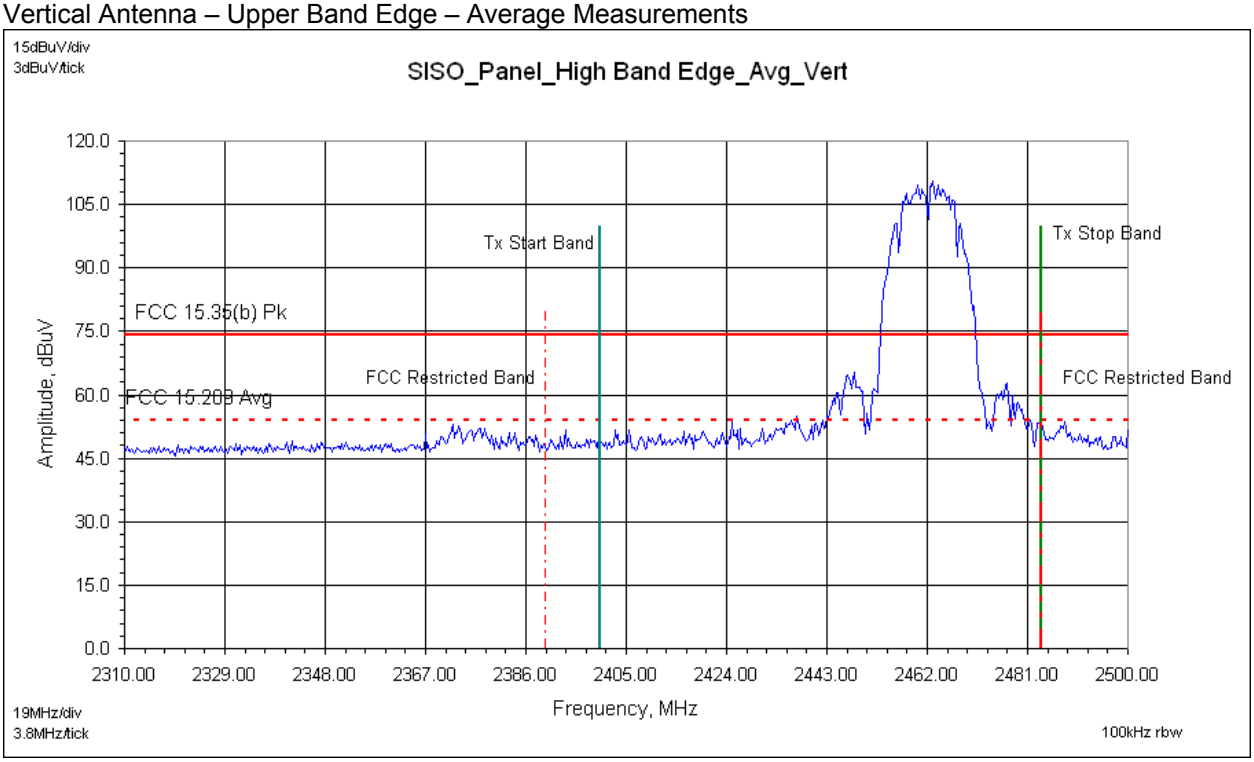


Reference only – max hold peak detector measurements referenced to average & peak limits

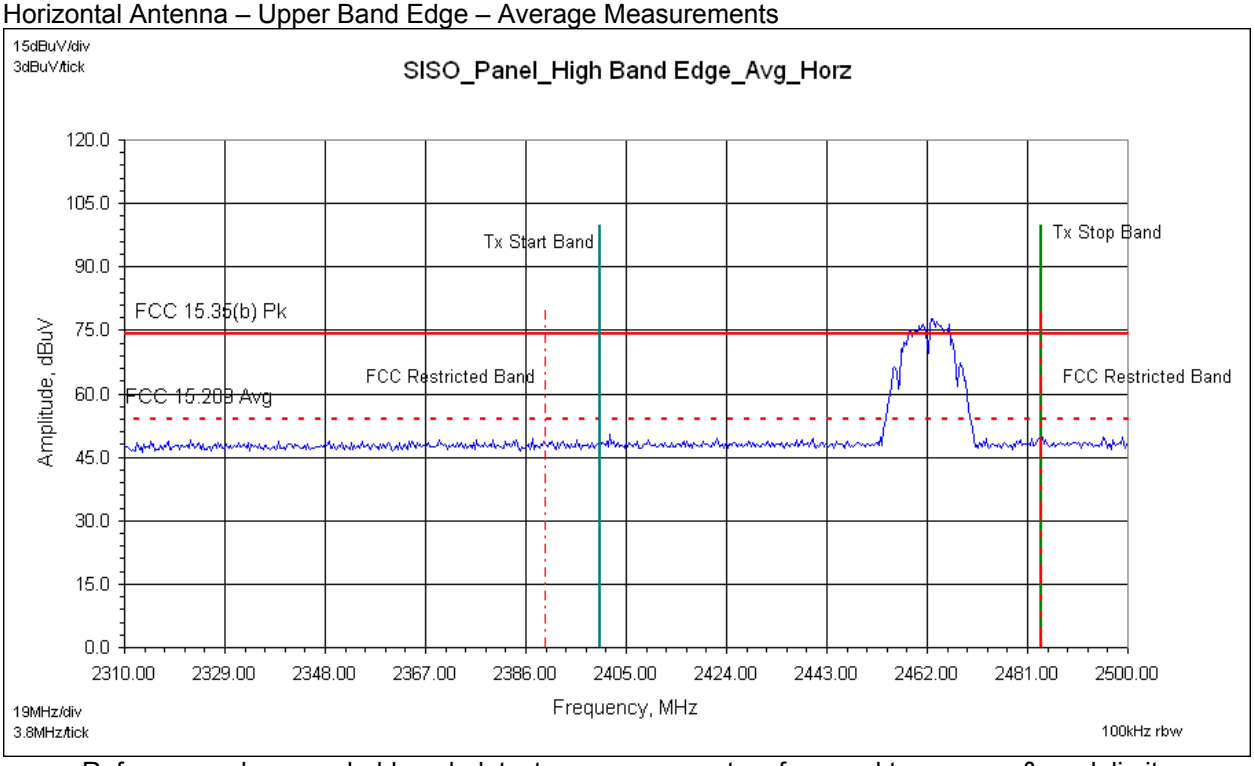
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Peak trace line)

11.20 Band Edge Plots: SISO Mode of Operation – HT20 High Channel 2462 MHz

Vertical Antenna – Upper Band Edge – Average Measurements



Horizontal Antenna – Upper Band Edge – Average Measurements

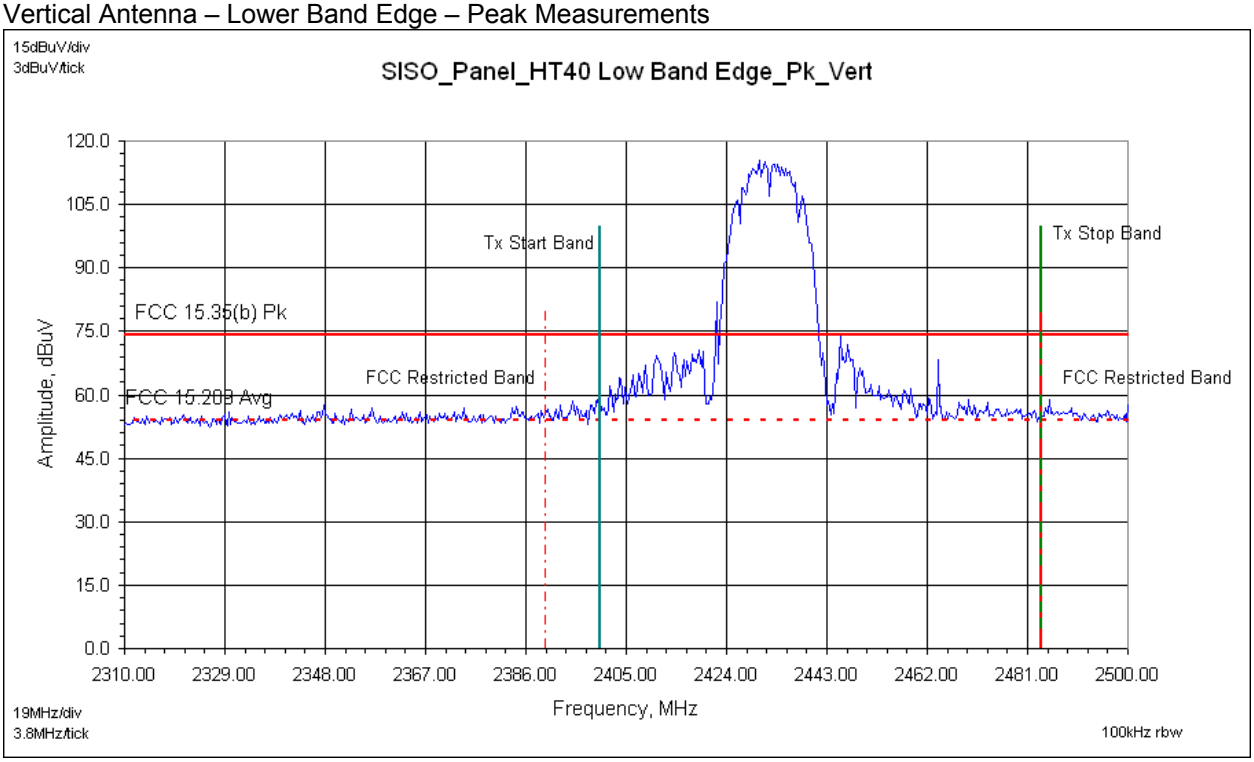


Reference only – max hold peak detector measurements referenced to average & peak limits

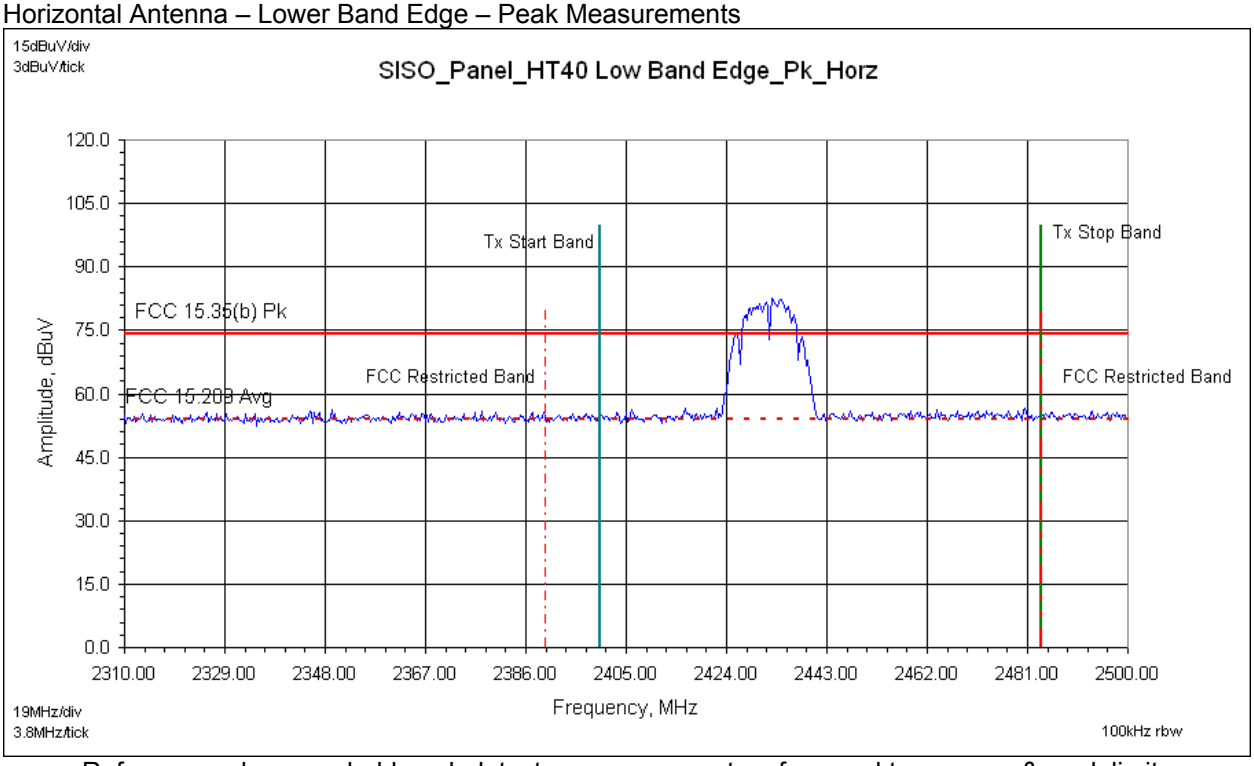
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Average trace line)

11.21 Band Edge Plots: SISO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Lower Band Edge – Peak Measurements



Horizontal Antenna – Lower Band Edge – Peak Measurements

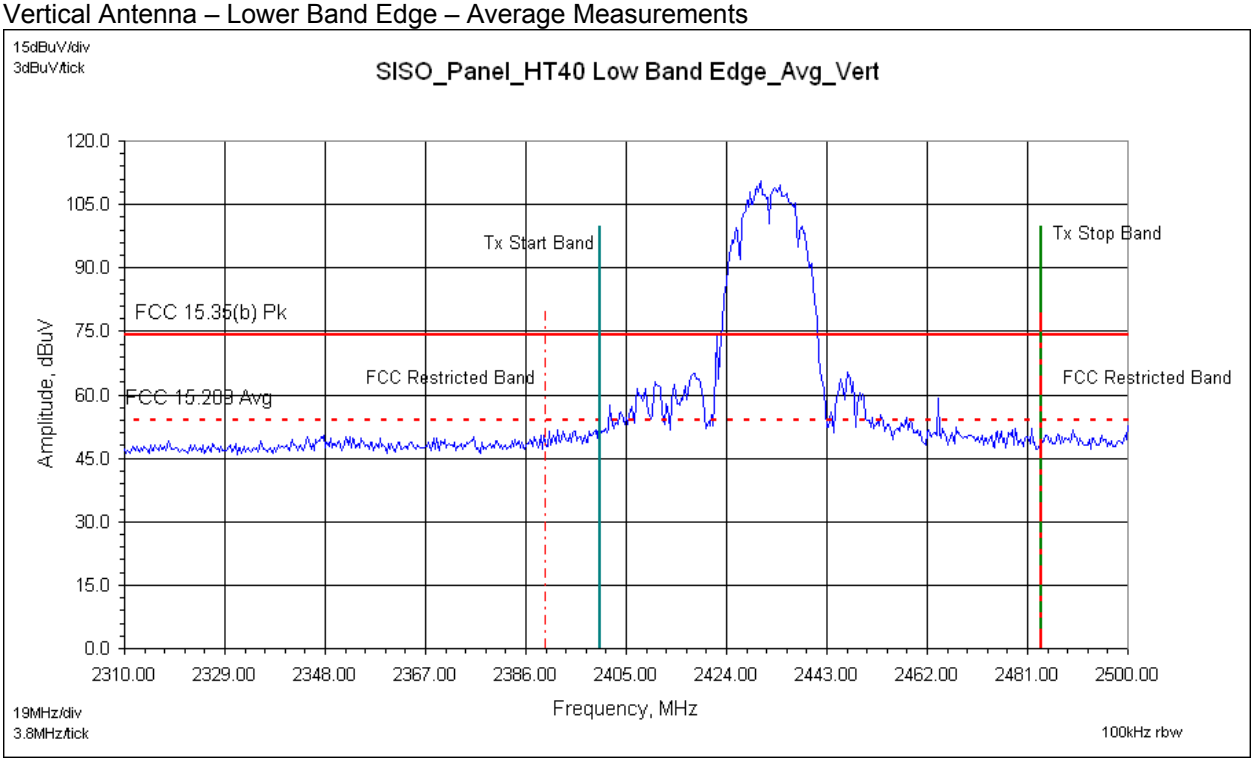


Reference only – max hold peak detector measurements referenced to average & peak limits

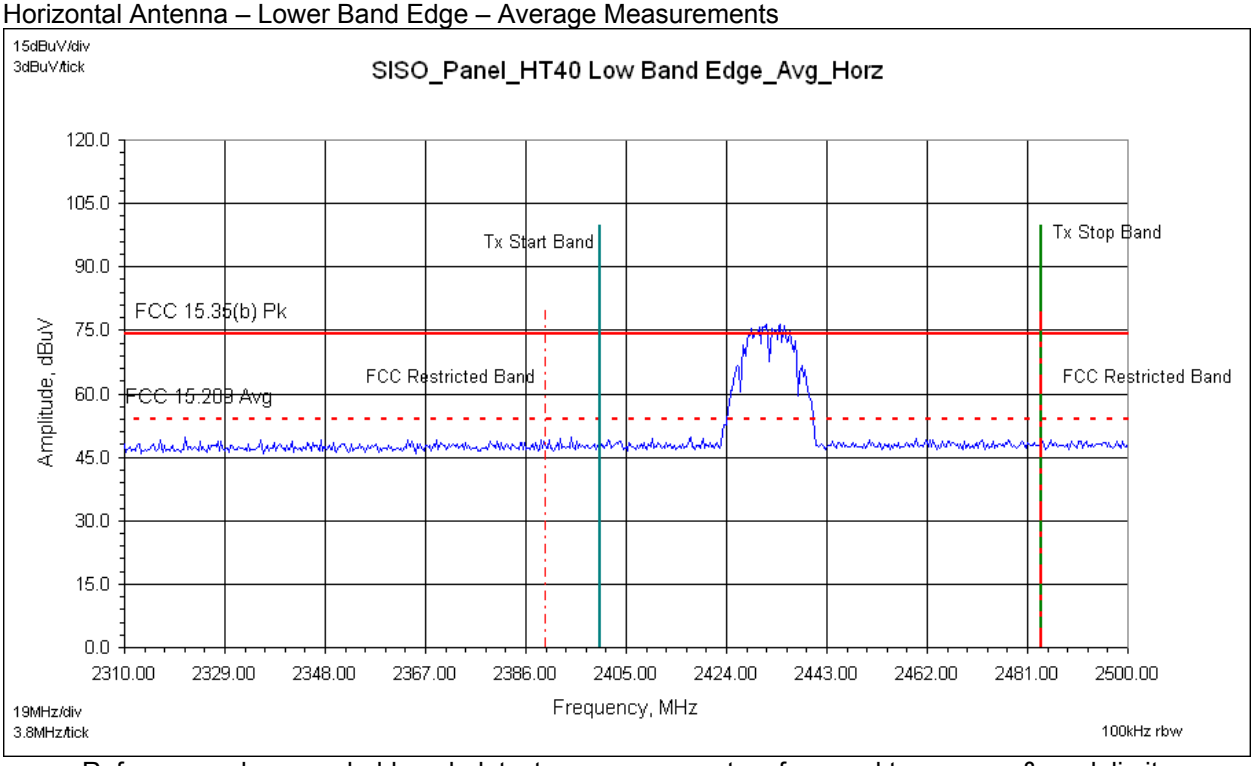
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Peak trace line)

11.22 Band Edge Plots: SISO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Lower Band Edge – Average Measurements



Horizontal Antenna – Lower Band Edge – Average Measurements

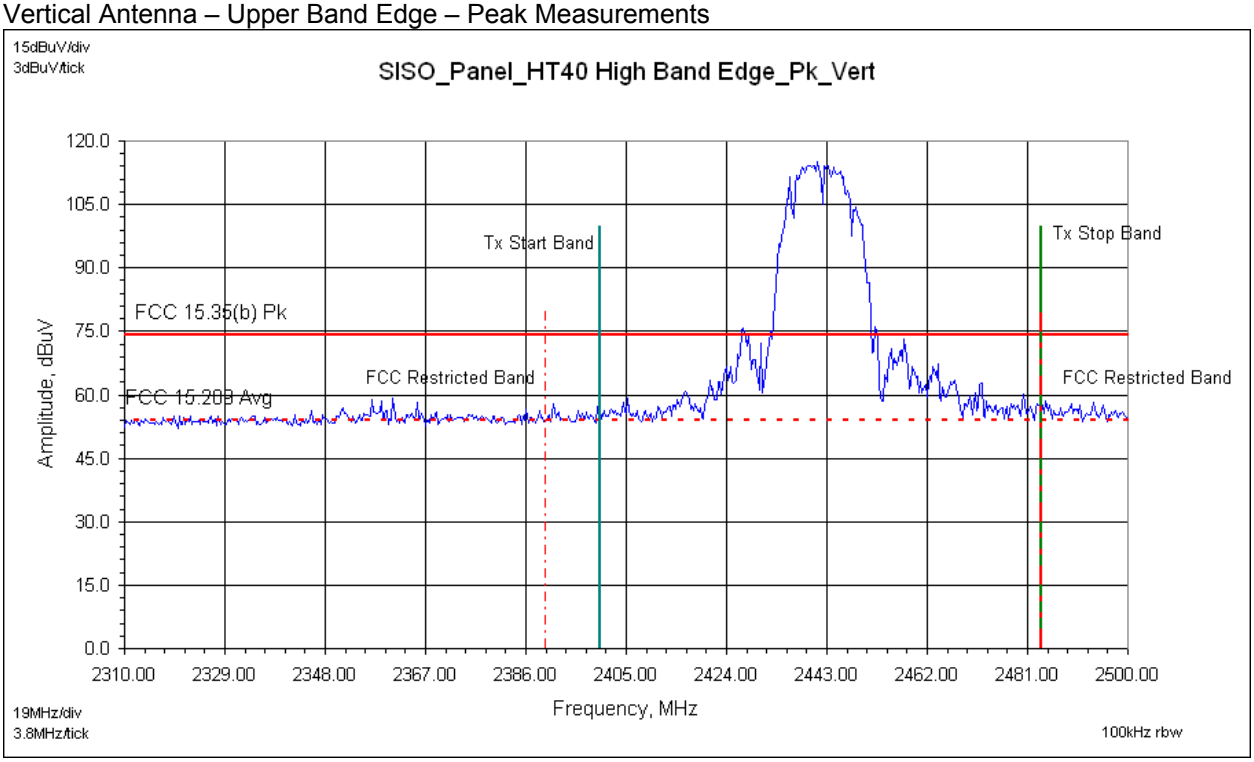


Reference only – max hold peak detector measurements referenced to average & peak limits

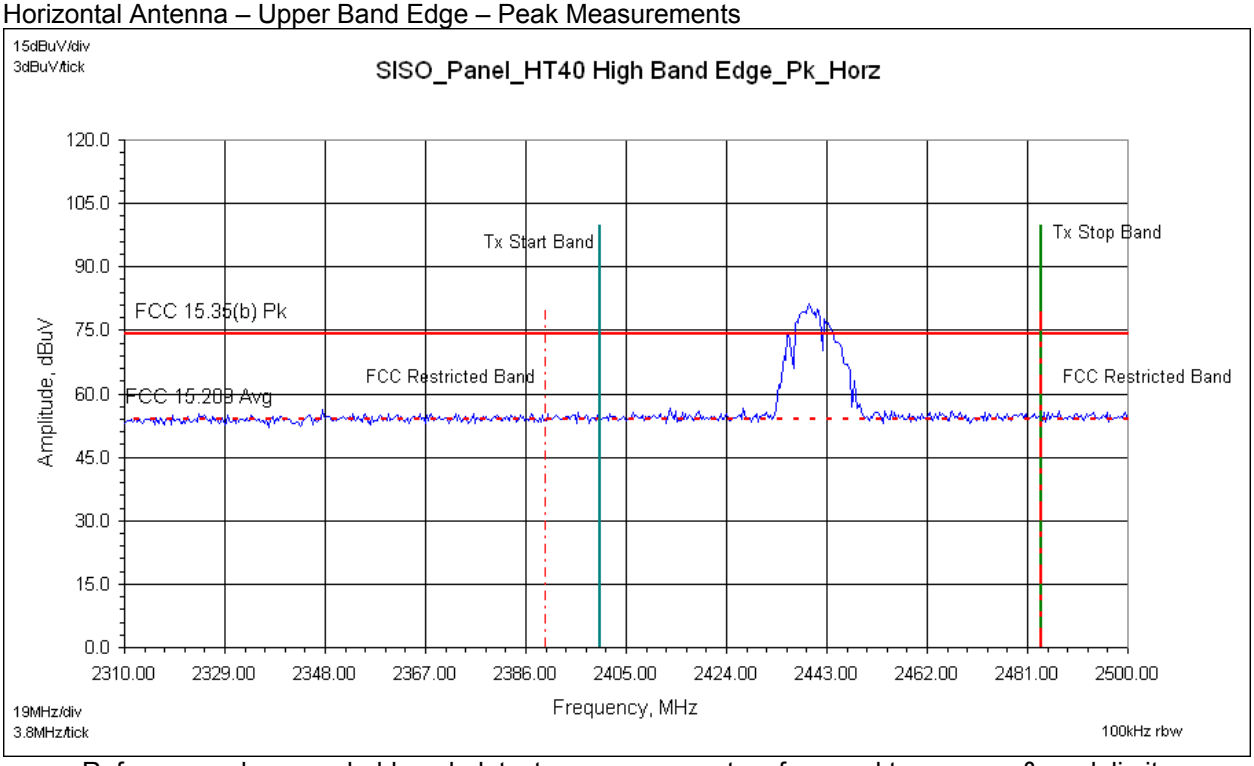
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Average trace line)

11.23 Band Edge Plots: SISO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Upper Band Edge – Peak Measurements



Horizontal Antenna – Upper Band Edge – Peak Measurements

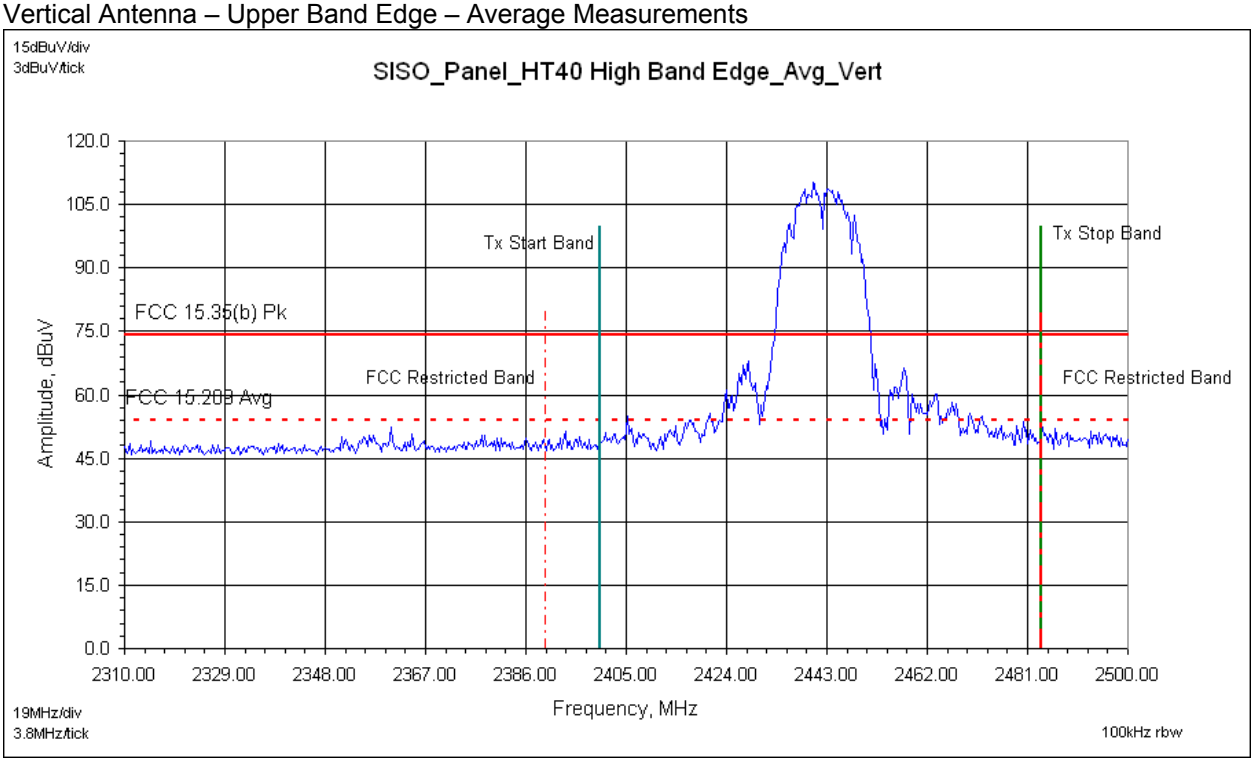


Reference only – max hold peak detector measurements referenced to average & peak limits

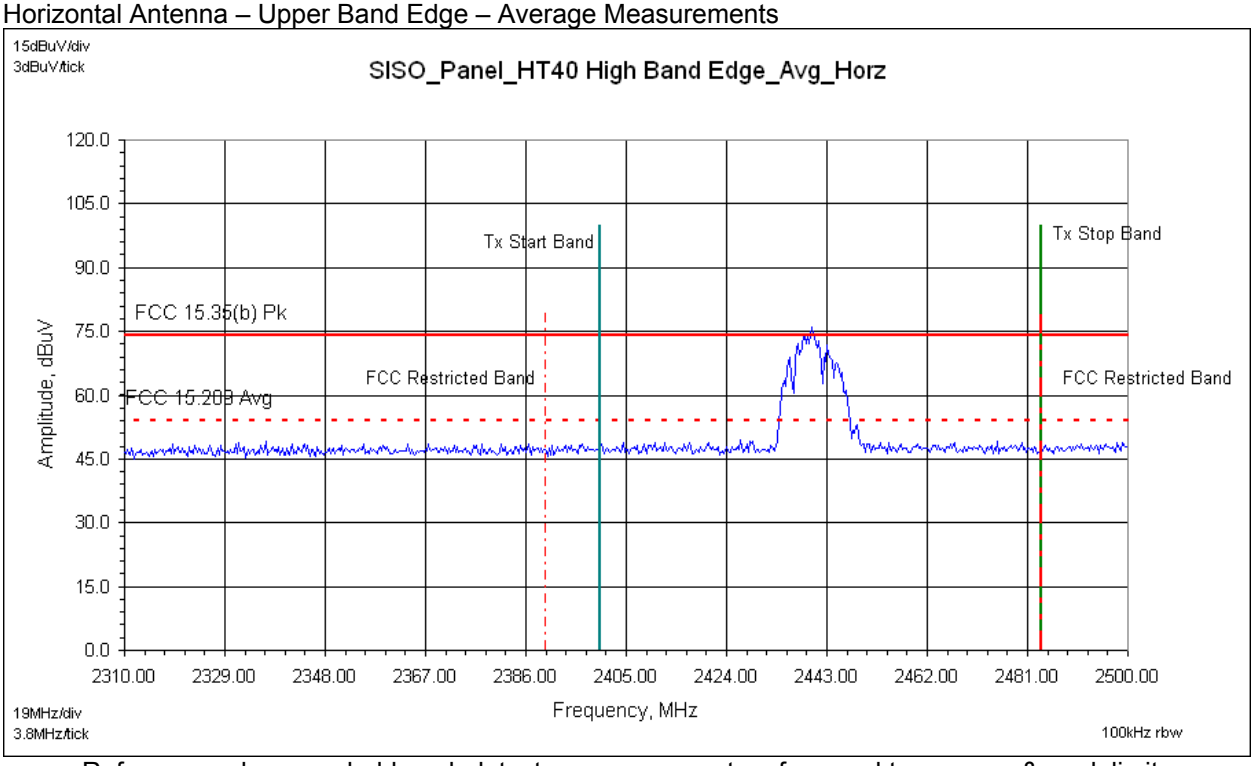
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Peak trace line)

11.24 Band Edge Plots: SISO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Upper Band Edge – Average Measurements



Horizontal Antenna – Upper Band Edge – Average Measurements



Reference only – max hold peak detector measurements referenced to average & peak limits

Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Average trace line)

11.25 Test Data: SISO Band Edge – FCC Restricted Band

Tx Spurious Radiated Emissions – Band Edge

Test Report #:	**G101503629**	Test Area:	CC1 Radiated	Temperature:	23.7	°C
Test Method:	FCC 15.209/ 15.205/ 15.35(b)	Test Date:	02/03/2014 02/04/2014	Relative Humidity:	27.2	%
EUT Model #:	Radio Module: W2400-01 Directional Panel Antenna: SPAPG20	EUT Power:	120VAC/60Hz	Air Pressure:	83.5	kPa
EUT Serial #:	Radio Module: DEN1402111313 Directional Panel Antennas: 001, 002					
Manufacturer:	FreeWave Technologies, Inc.					
EUT Description:	Wireless router utilized in M2M industrial applications					
Notes:	Product tested in SISO mode: single transmit chain/port – single antenna					
	Product continuously transmitting during all testing – worst-case modulation/data					
	SISO mode of Operation, MCS0 Data Rate, 25dBm power (worst-case)					

Level Key
Pk – Peak
Qp – Quasi Peak
Av - Average

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Avg	FCC 15.35(b) Pk	(MHz)
Radio System: Model W2400-01 Radio Module with Directional Panel Antenna – SISO Mode of Operation													
Measurements: HT20 Lower Band Edge – FCC Restricted Band													
2390.0000	47.06	**Av**	3.50	28.51	37.57	9.48	50.99	V	1.43	4.4	- 2.99	NA	1.000
2390.0000	54.76	**Pk**	3.50	28.51	37.57	9.48	58.69	V	1.43	4.4	NA	- 15.31	1.000
2390.0000	43.74	**Av**	3.50	28.51	37.57	9.48	47.67	H	1.43	6.7	- 6.31	NA	1.000
2390.0000	49.56	**Pk**	3.50	28.51	37.57	9.48	53.49	H	1.43	6.7	NA	- 20.51	1.000
Measurements: HT20 Upper Band Edge – FCC Restricted Band													
2483.5000	47.31	**Av**	3.50	28.51	37.57	9.48	51.24	V	1.42	8.0	- 2.74	NA	1.000
2483.5000	52.53	**Pk**	3.50	28.51	37.57	9.48	56.46	V	1.42	8.0	NA	- 17.54	1.000
2483.5000	40.74	**Av**	3.50	28.51	37.57	9.48	44.67	H	1.42	7.2	- 9.31	NA	1.000
2483.5000	46.89	**Pk**	3.50	28.51	37.57	9.48	50.82	H	1.42	7.2	NA	- 23.18	1.000
Measurements: HT40 Lower Band Edge – FCC Restricted Band													
2390.0000	46.07	**Av**	3.50	28.51	37.57	9.48	50.00	V	1.45	7.2	- 3.98	NA	1.000
2390.0000	54.53	**Pk**	3.50	28.51	37.57	9.48	58.46	V	1.45	7.2	NA	- 15.54	1.000
2390.0000	39.86	**Av**	3.50	28.51	37.57	9.48	43.79	H	1.41	5.5	- 10.19	NA	1.000
2390.0000	47.72	**Pk**	3.50	28.51	37.57	9.48	51.65	H	1.41	5.5	NA	- 22.35	1.000
Measurements: HT40 Upper Band Edge – FCC Restricted Band													
2483.5000	44.02	**Av**	3.58	28.69	37.67	10.11	48.73	V	1.44	4.9	- 5.25	NA	1.000
2483.5000	53.26	**Pk**	3.58	28.69	37.67	10.11	57.97	V	1.44	4.9	NA	- 16.03	1.000
2483.5000	44.56	**Av**	3.58	28.69	37.67	10.11	49.27	H	1.40	3.3	- 4.71	NA	1.000
2483.5000	48.06	**Pk**	3.58	28.69	37.67	10.11	52.77	H	1.40	3.3	NA	- 21.23	1.000

Example calculation:

Measured Level	+	Cable Loss	+	Antenna Factor	-	Pre-Amp	+	Atten	=	Final Corrected Reading	Specification Limit	-	Final Corrected Reading	=	Delta Specification
(dBμV)		(dB)		(dB)		(dB)		(dB)		(dBμV/m)	(dBμV/m)		(dBμV/m)		
20.0		**3.0**		**5.0**		**10.0**		**0.0**		**18.0**	**40.0**		**18.0**		**- 22.0**

Notes:

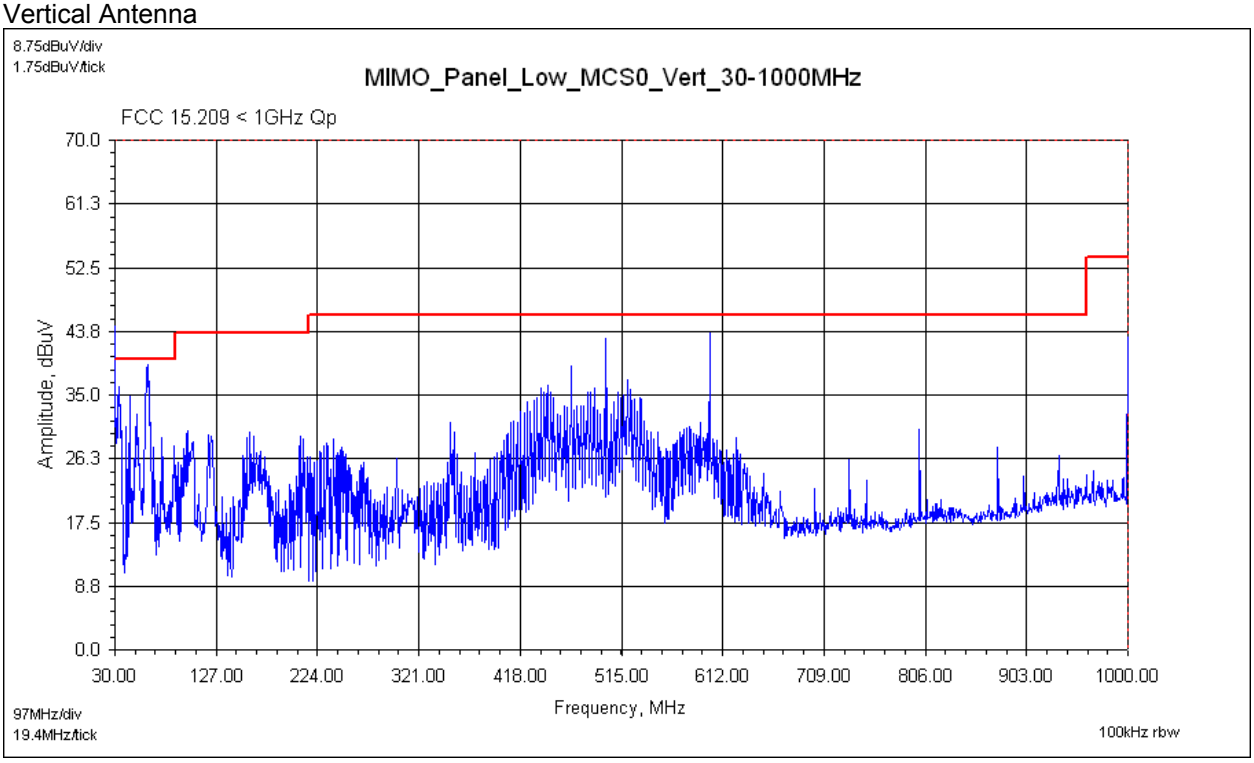
1) The highest signals – as determined from pre-scan plots – were fully-maximized and measured.
2) The notch filter was not used during band edge plots/measurements.
3) 802.11 HT20/HT40 included in measurements as well as both SISO/MIMO modes of Tx operation.

Deviations, Additions, or Exclusions: None

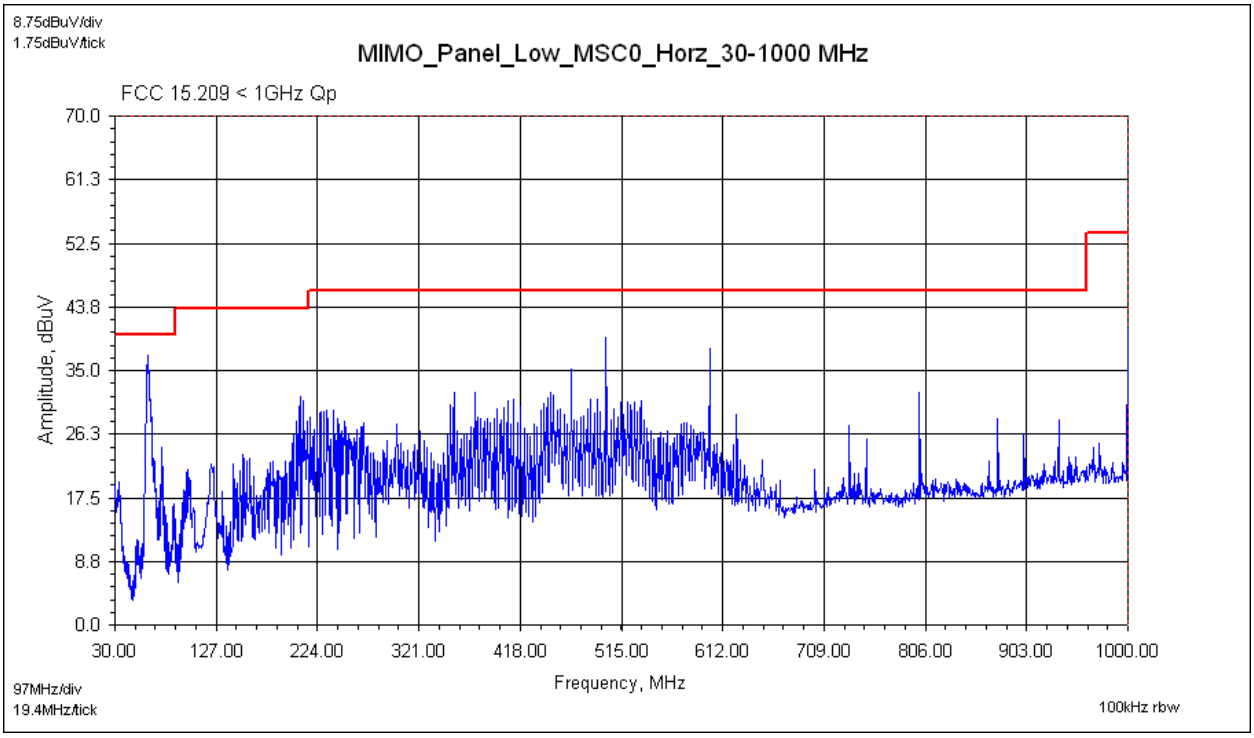
11.26 Plots: MIMO Mode of Operation – HT20 Low Channel: 2412MHz

30MHz to 1000MHz

Vertical Antenna



Horizontal Antenna

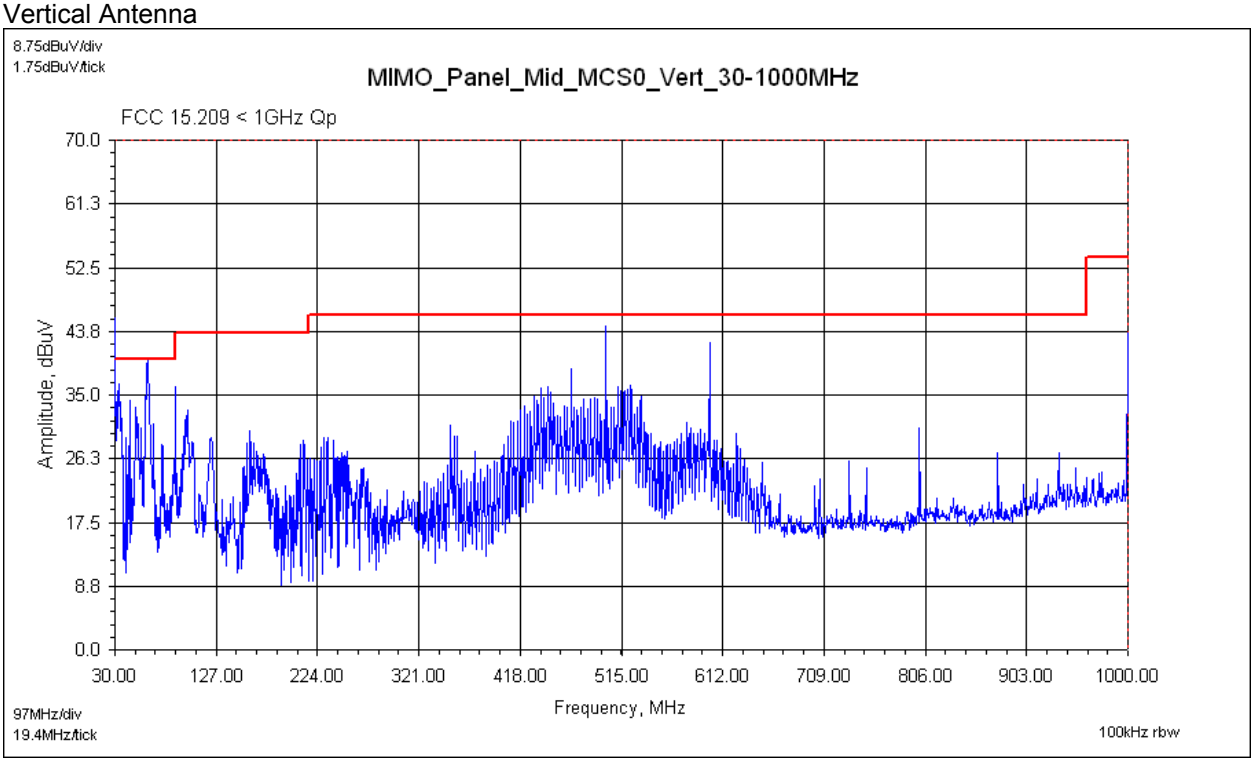


Reference only – max hold peak detector measurements referenced to quasi-peak limit

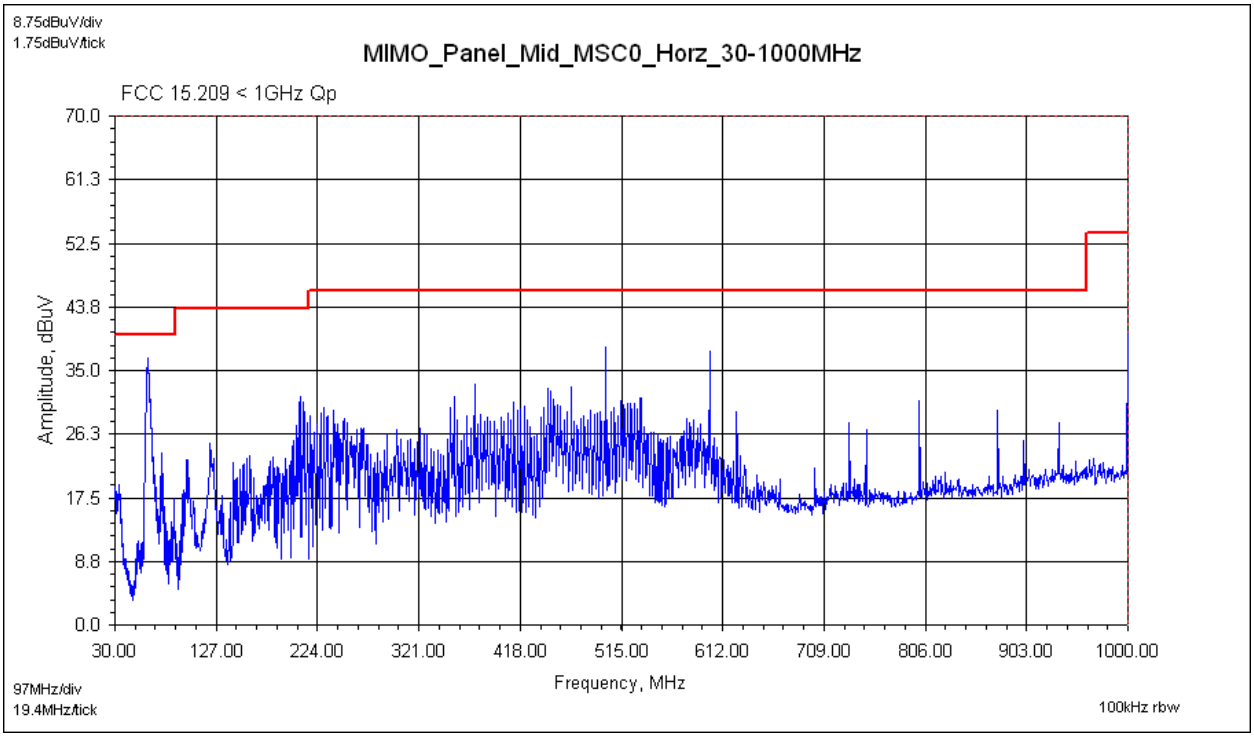
11.27 Plots: MIMO Mode of Operation – HT20 Mid Channel: 2437MHz

30MHz to 1000MHz

Vertical Antenna



Horizontal Antenna

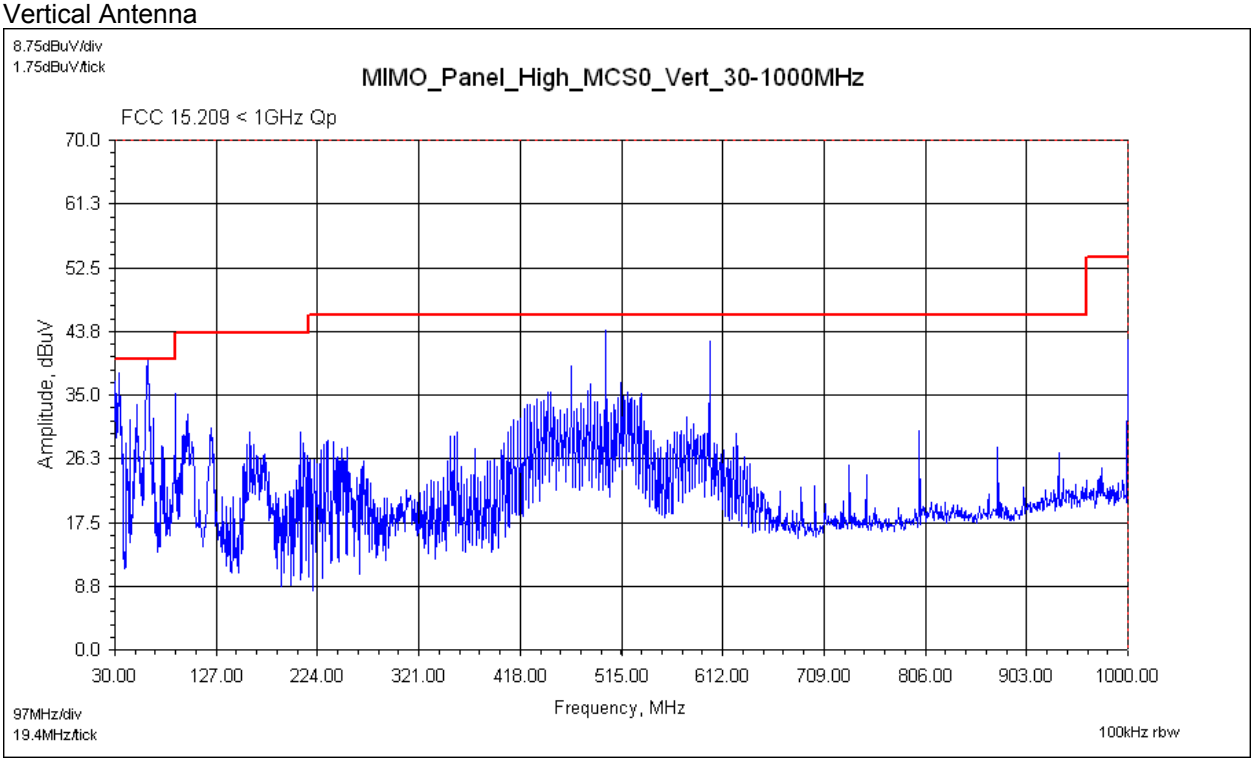


Reference only – max hold peak detector measurements referenced to quasi-peak limit

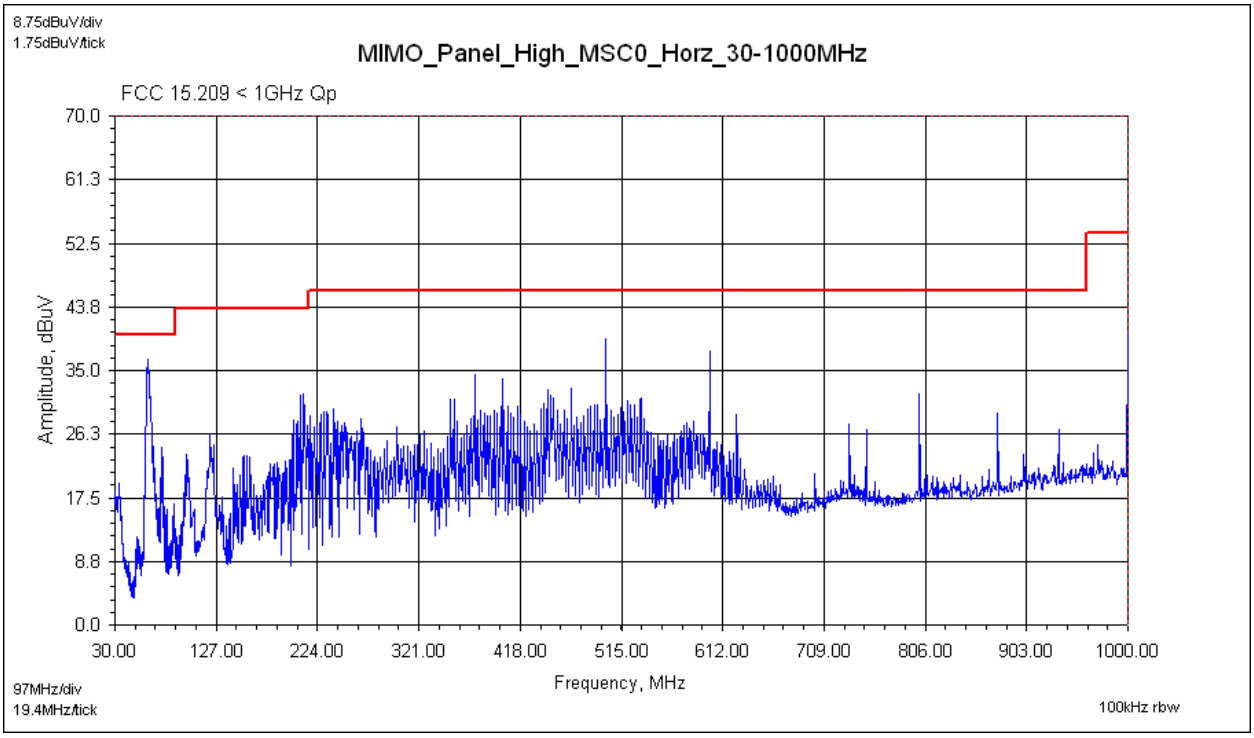
11.28 Plots: MIMO Mode of Operation – HT20 High Channel: 2462MHz

30MHz to 1000MHz

Vertical Antenna



Horizontal Antenna

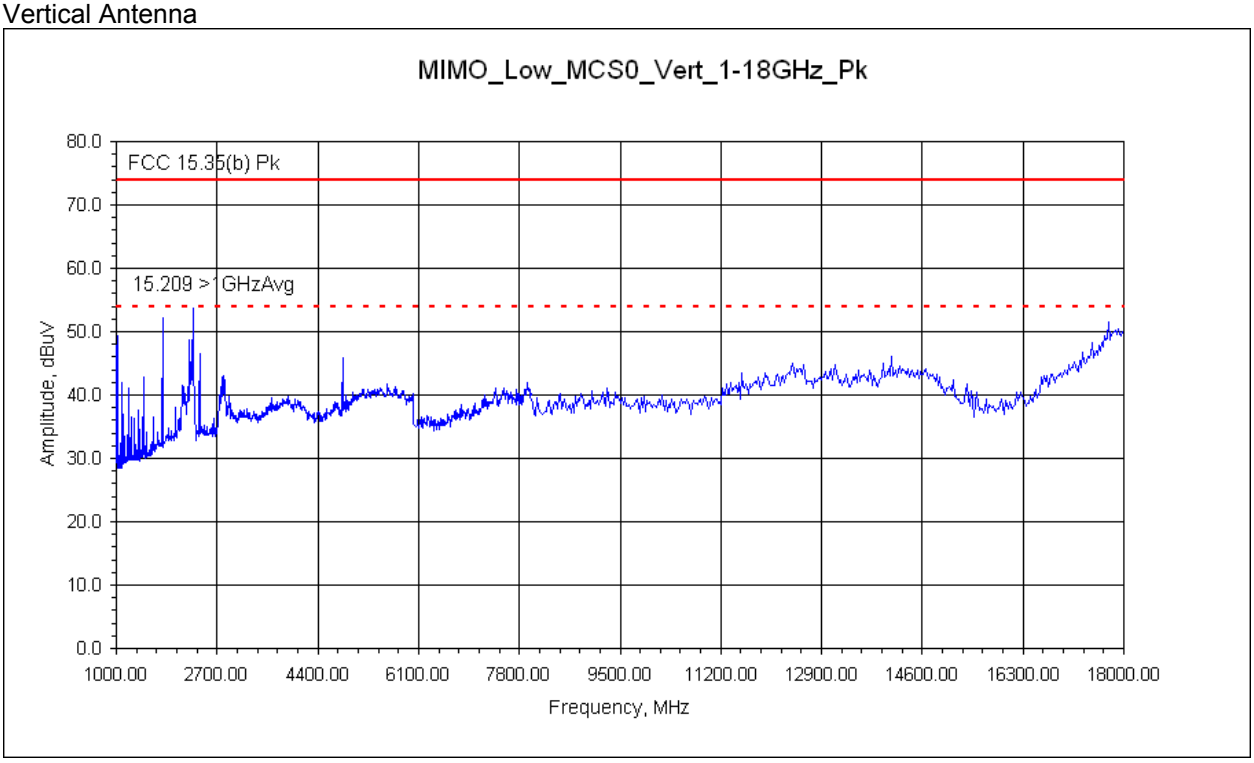


Reference only – max hold peak detector measurements referenced to quasi-peak limit

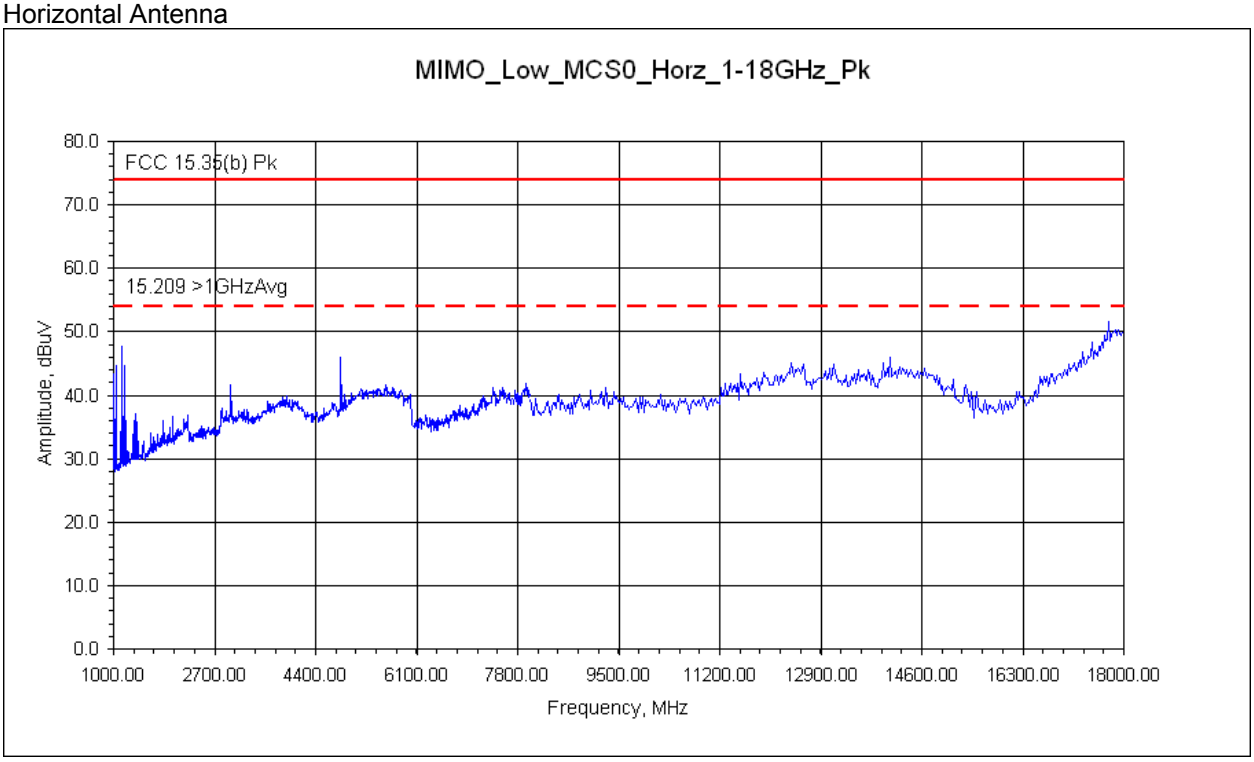
11.29 Plots: MIMO Mode of Operation – HT20 Low Channel: 2412 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna

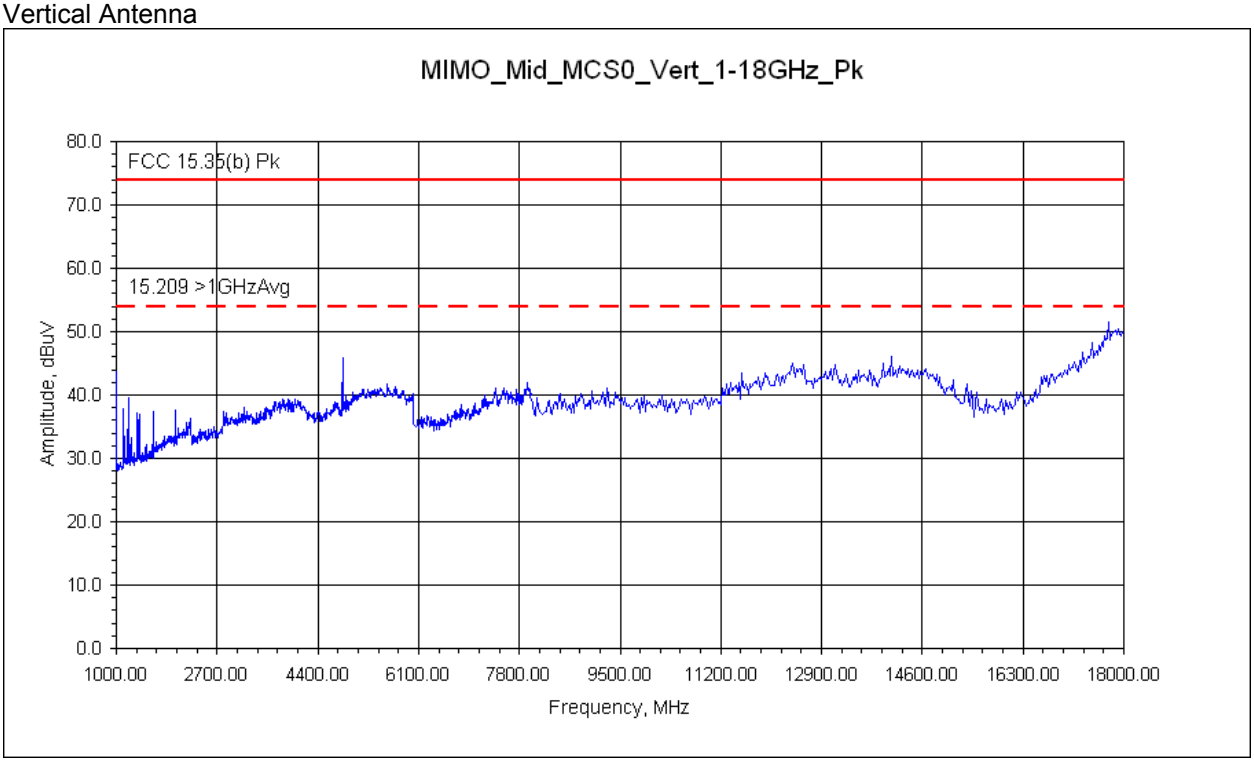


Reference only – max hold peak detector measurements referenced to average & peak limits

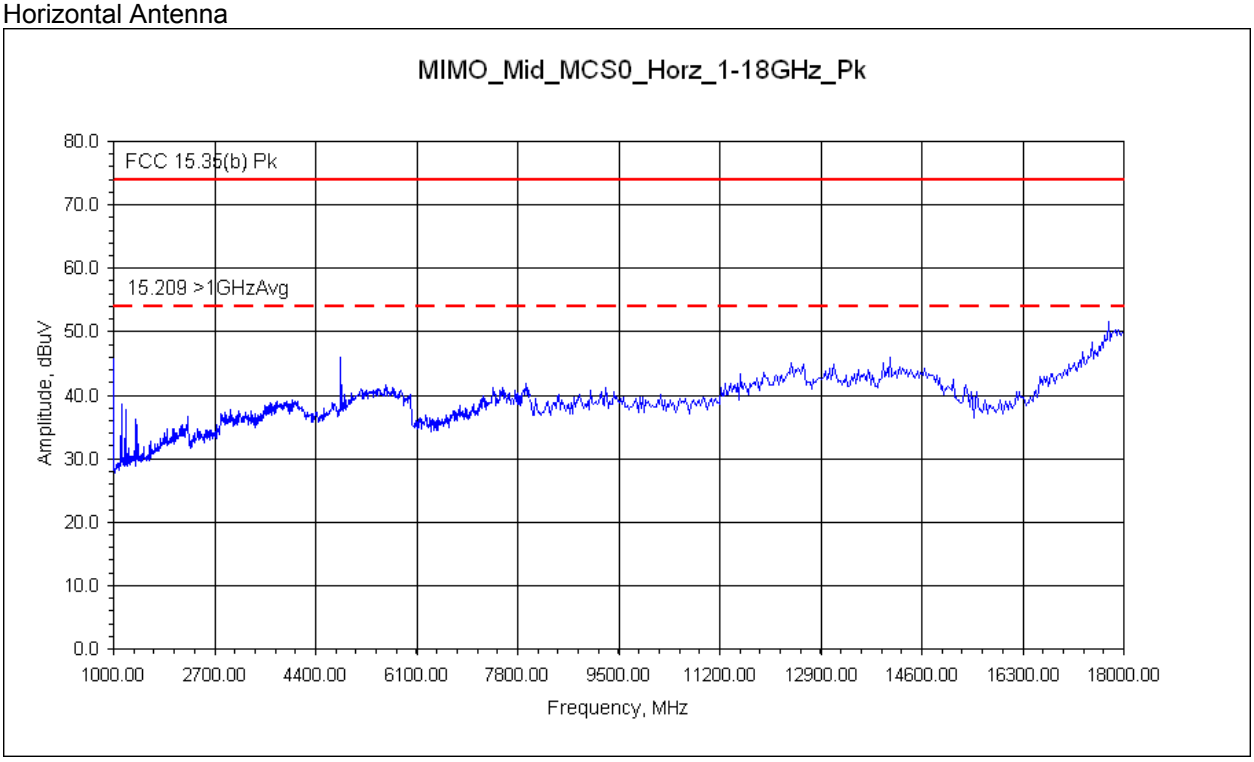
11.30 Plots: MIMO Mode of Operation – HT20 Mid Channel: 2437 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna

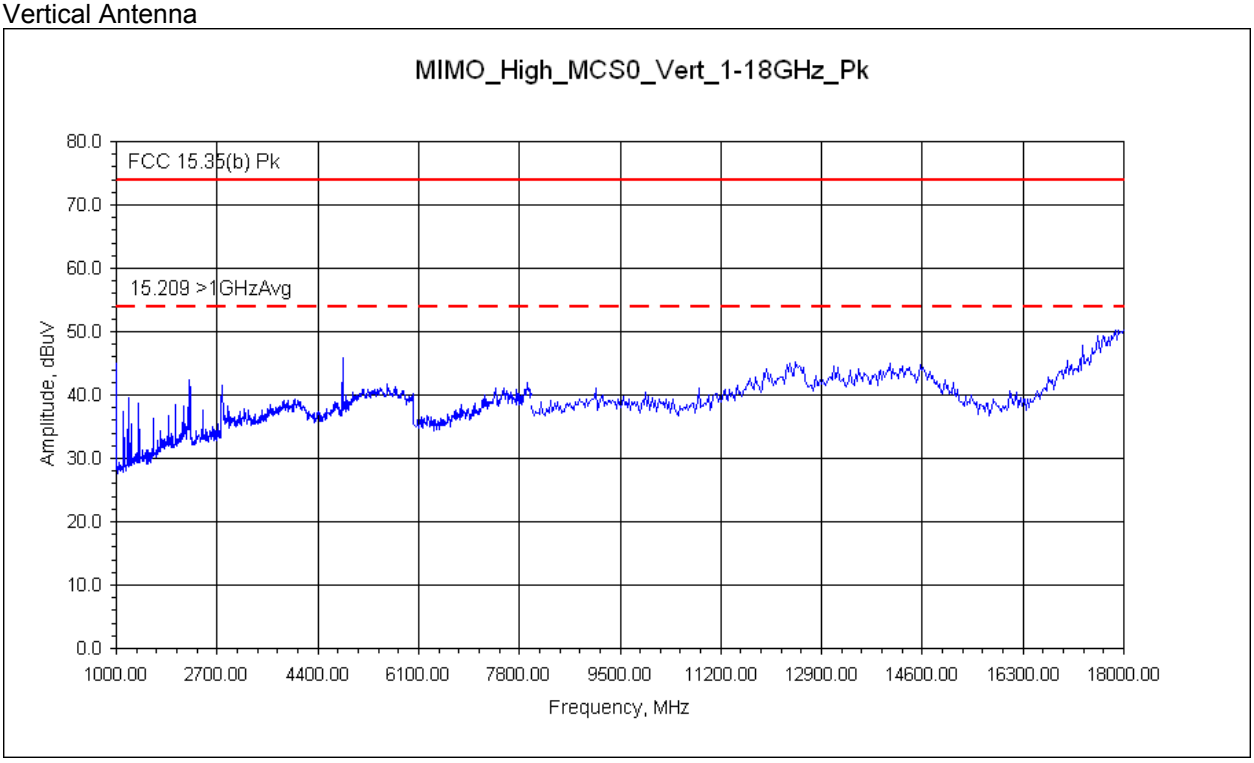


Reference only – max hold peak detector measurements referenced to average & peak limits

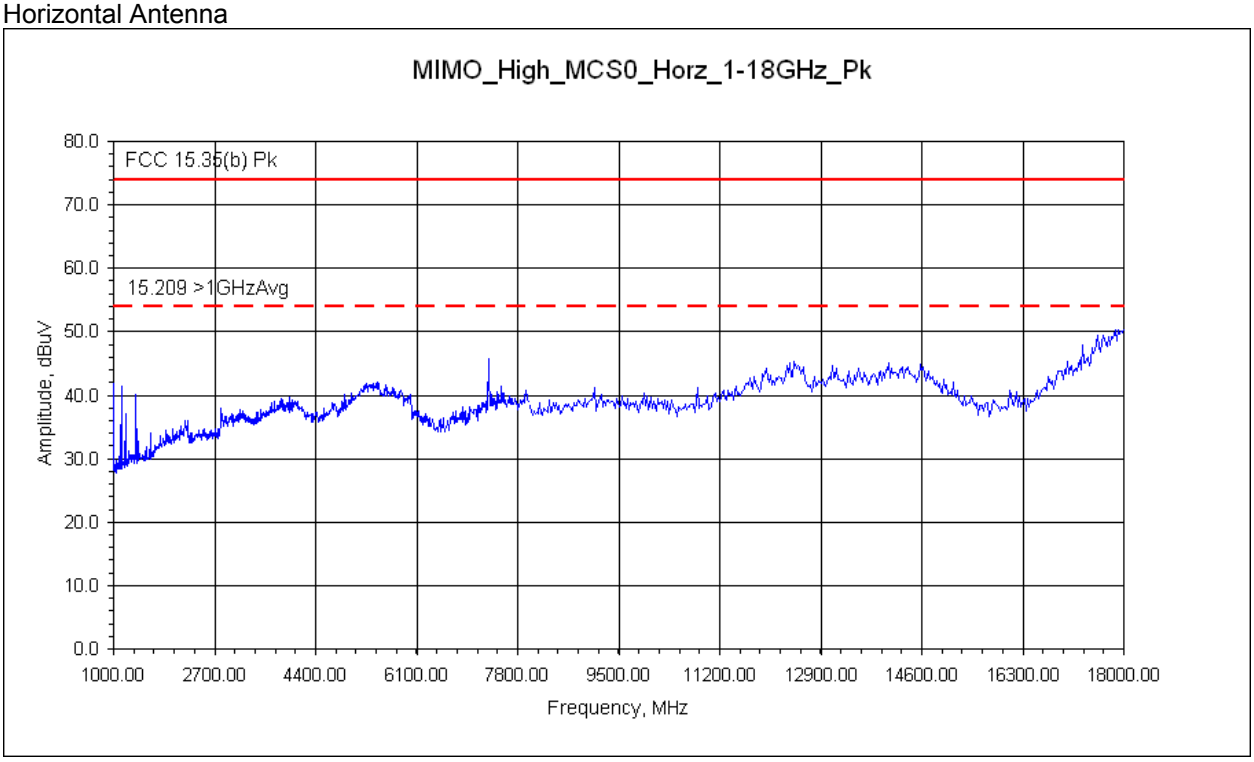
11.31 Plots: MIMO Mode of Operation – HT20 High Channel: 2462 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna

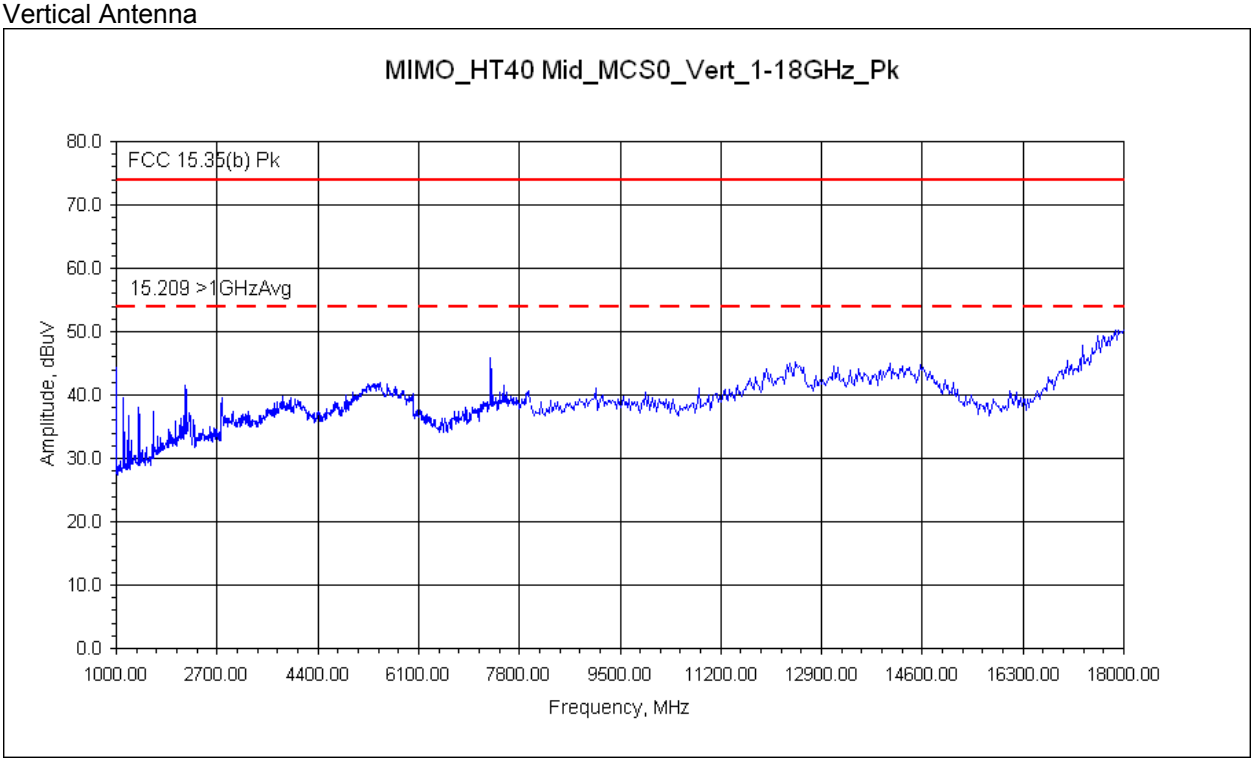


Reference only – max hold peak detector measurements referenced to average & peak limits

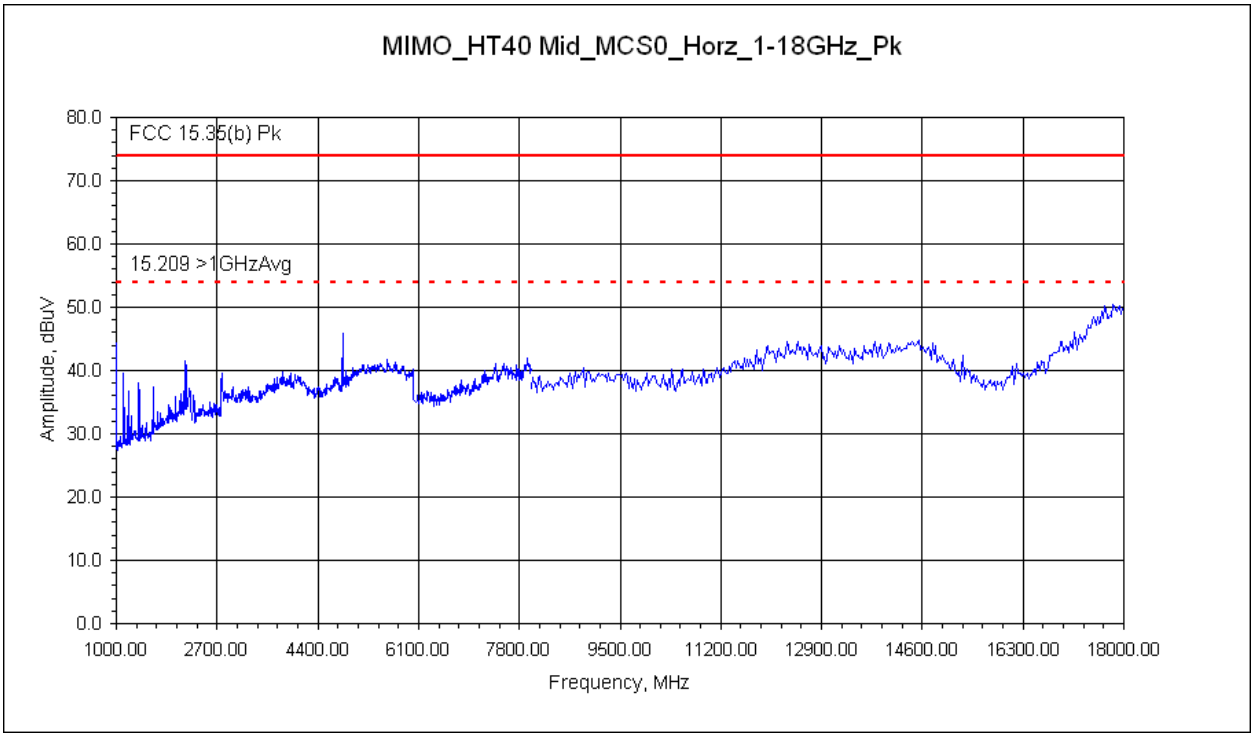
11.32 Plots: MIMO Mode of Operation – HT40Channel: 2437 MHz

1GHz to 18GHz

Vertical Antenna



Horizontal Antenna



Reference only – max hold peak detector measurements referenced to average & peak limits

11.33 Test Data: MIMO Mode of Operation

Tx Spurious Radiated Electromagnetic Emissions

Test Report #:	**G101503629**	Test Area:	CC1 Radiated	Temperature:	23.7	°C
Test Method:	FCC 15.209/ 15.205/ 15.35(b)	Test Date:	02/03/2014 02/04/2014	Relative Humidity:	27.2	%
EUT Model #:	Radio Module: W2400-01 Directional Panel Antenna: SPAPG20	EUT Power:	120VAC/60Hz	Air Pressure:	83.5	kPa

EUT Serial #: Radio Module: DEN1402111313
Directional Panel Antennas: 001, 002

Manufacturer: FreeWave Technologies

EUT Description: Wireless router utilized in M2M industrial applications

Notes: Product tested in MIMO mode: 2 transmit chains/ports – dual antennas

Product continuously transmitting during all testing – worst-case modulation/data

MIMO mode of Operation, MCS0 Data Rate, 25dBm power, 22dBm/port (worst-case power)

Level Key
Pk – Peak
Qp – Quasi Peak
Av - Average

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Qp	N/A	(MHz)
Radio System: Model W2400-01 Radio Module with Directional Panel Antenna(s) – MIMO Mode of Operation													
Measurements: 30MHz to 1000MHz – HT20 Mid Channel 2437 MHz													
30.1122	39.85	**Qp**	0.40	20.90	28.30	0.00	32.85	V	1.00	78.3	- 7.15	NA	0.120
30.1122	43.31	**Qp**	0.40	20.90	28.30	0.00	36.31	V	1.00	20.7	- 3.69	NA	0.120
61.6868	57.79	**Qp**	0.77	7.57	28.21	0.00	37.92	V	1.00	20.7	- 2.08	NA	0.120
88.0096	41.13	**Qp**	0.77	7.90	28.11	0.00	21.69	V	1.00	53.0	- 21.83	NA	0.120
500.0004	52.99	**Qp**	1.53	17.70	28.60	0.00	43.62	V	1.33	106.7	- 2.40	NA	0.120
600.0000	50.56	**Qp**	1.70	18.90	28.70	0.00	42.45	V	1.27	7.3	- 3.57	NA	0.120
1000.0000	48.50	**Qp**	2.21	22.60	27.59	0.00	45.73	V	1.13	16.7	- 8.25	NA	0.120
61.9712	55.15	**Qp**	0.77	7.60	28.21	0.00	35.31	H	2.06	182.7	- 4.69	NA	0.120

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	**Qp Av Pk**	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Avg	FCC 15.35(b) Pk	(MHz)
Measurements: 1GHz to 18GHz – HT20 Low Channel 2412 MHz													
1000.0100	59.91	**Pk**	2.21	23.82	37.13	0.34	49.15	V	1.76	12.0	N/A	- 24.85	1.000
1000.0100	54.21	**Av**	2.21	23.82	37.13	0.34	43.45	V	1.76	12.0	- 10.55	NA	1.000
1200.0000	47.69	**Av**	2.44	25.07	37.18	0.40	38.41	V	1.82	64.0	- 15.59	NA	1.000
1200.0000	54.22	**Pk**	2.44	25.07	37.18	0.40	44.94	V	1.82	64.0	N/A	- 29.06	1.000
2288.0000	39.06	**Av**	3.42	27.93	37.48	0.00	32.93	V	1.82	64.0	- 21.07	NA	1.000
2288.0000	63.24	**Pk**	3.42	27.93	37.48	0.00	57.11	V	1.82	64.0	N/A	- 16.89	1.000
1000.0010	53.27	**Av**	2.21	23.82	37.13	0.34	42.51	H	1.18	24.0	- 11.49	NA	1.000
1000.0010	59.43	**Pk**	2.21	23.82	37.13	0.34	48.67	H	1.18	24.0	N/A	- 25.33	1.000

Measurements: 1GHz to 18GHz – HT20 Mid Channel 2437 MHz													
1000.0100	55.25	**Av**	2.21	23.82	37.13	0.34	44.49	V	2.10	155.0	- 9.51	NA	1.000
1000.0100	60.62	**Pk**	2.21	23.82	37.13	0.34	49.86	V	2.10	155.0	N/A	- 24.14	1.000
1200.1000	47.62	**Av**	2.44	25.07	37.18	0.40	38.34	V	1.77	72.0	- 15.66	NA	1.000
1200.1000	58.48	**Pk**	2.44	25.07	37.18	0.40	49.20	V	1.77	72.0	N/A	- 24.80	1.000
1000.0100	53.12	**Av**	2.21	23.82	37.13	0.34	42.36	H	2.04	339.0	- 11.64	NA	1.000
1000.0100	57.68	**Pk**	2.21	23.82	37.13	0.34	46.92	H	2.04	339.0	N/A	- 27.08	1.000
1200.0000	47.63	**Av**	2.44	25.07	37.18	0.40	38.35	H	1.88	118.0	- 15.65	NA	1.000
1200.0000	54.48	**Pk**	2.44	25.07	37.18	0.40	45.20	H	1.88	118.0	N/A	- 28.80	1.000
4830.0000	40.69	**Av**	5.17	32.92	39.36	0.00	39.43	V	1.44	57.6	- 14.57	NA	1.000
4830.0000	48.93	**Pk**	5.17	32.92	39.36	0.00	47.67	V	1.44	57.6	N/A	- 26.33	1.000
Measurements: 1GHz to 18GHz – HT20 High Channel 2462 MHz													
1000.0100	54.55	**Av**	2.21	23.82	37.13	0.34	43.79	V	1.87	4.2	- 10.21	NA	1.000
1000.0100	59.41	**Pk**	2.21	23.82	37.13	0.34	48.65	V	1.87	4.2	N/A	- 25.35	1.000
1200.0000	47.08	**Av**	2.44	25.07	37.18	0.40	37.80	V	1.78	68.1	- 16.20	NA	1.000
1200.0000	52.71	**Pk**	2.44	25.07	37.18	0.40	43.43	V	1.78	68.1	N/A	- 30.57	1.000
1000.1000	51.62	**Av**	2.21	23.82	37.13	0.34	40.86	H	1.18	15.1	- 13.14	NA	1.000
1000.1000	57.63	**Pk**	2.21	23.82	37.13	0.34	46.87	H	1.18	15.1	N/A	- 27.13	1.000
Measurements: 1GHz to 18GHz – HT40 Channel 2437 MHz													
1000.0500	54.16	**Av**	2.21	23.82	37.13	0.34	43.40	V	1.89	4.9	- 10.60	NA	1.000
1000.0500	59.45	**Pk**	2.21	23.82	37.13	0.34	48.69	V	1.89	4.9	N/A	- 25.31	1.000
1125.0000	48.45	**Av**	2.36	24.63	37.26	0.37	38.56	V	1.67	173.2	- 15.44	NA	1.000
1125.0000	53.17	**Pk**	2.36	24.63	37.26	0.37	43.28	V	1.67	173.2	N/A	- 30.72	1.000
4870.0000	68.90	**Pk**	5.19	32.98	39.48	0.00	67.59	V	1.30	9.2	N/A	- 6.41	1.000
4870.0000	44.06	**Av**	5.19	32.98	39.48	0.00	42.75	V	1.30	9.2	- 11.25	NA	1.000
1000.1000	52.35	**Av**	2.21	23.82	37.13	0.34	41.59	H	1.82	54.2	- 12.41	NA	1.000
1000.1000	57.74	**Pk**	2.21	23.82	37.13	0.34	46.98	H	1.82	54.2	N/A	- 27.02	1.000
1375.0000	47.52	**Av**	2.61	25.13	36.76	0.47	38.96	H	1.61	82.7	- 15.04	NA	1.000
1375.0000	52.74	**Pk**	2.61	25.13	36.76	0.47	44.18	H	1.61	82.7	N/A	- 29.82	1.000

Example calculation:

Measured Level	+	Cable Loss	+	Antenna Factor	-	Pre-Amp	+	Atten	=	Final Corrected Reading	Specification Limit	-	Final Corrected Reading	=	Delta Specification
(dBμV)		(dB)		(dB)		(dB)		(dB)		(dBμV/m)	(dBμV/m)		(dBμV/m)		
20.0		**3.0**		**5.0**		**10.0**		**0.0**		**18.0**	**40.0**		**18.0**		**- 22.0**

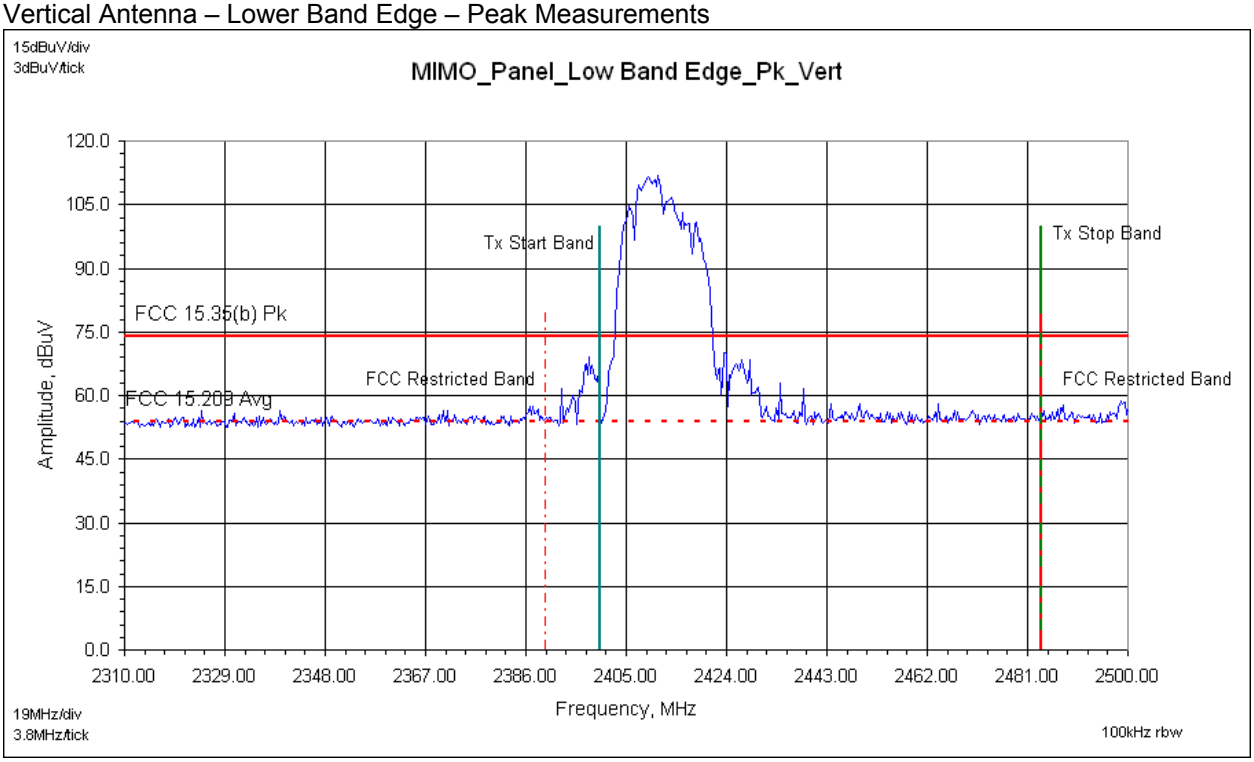
Notes:

1) The highest signals – as determined from pre-scan plots – were fully-maximized and measured.
2) For the general pre-scan plots 1-4GHz, a notch filter was utilized. Note the notch filter was <u>not used</u> during band edge plots/measurements.
3) 802.11 HT20/HT40 included in measurements as well as both SISO/MIMO modes of Tx operation.

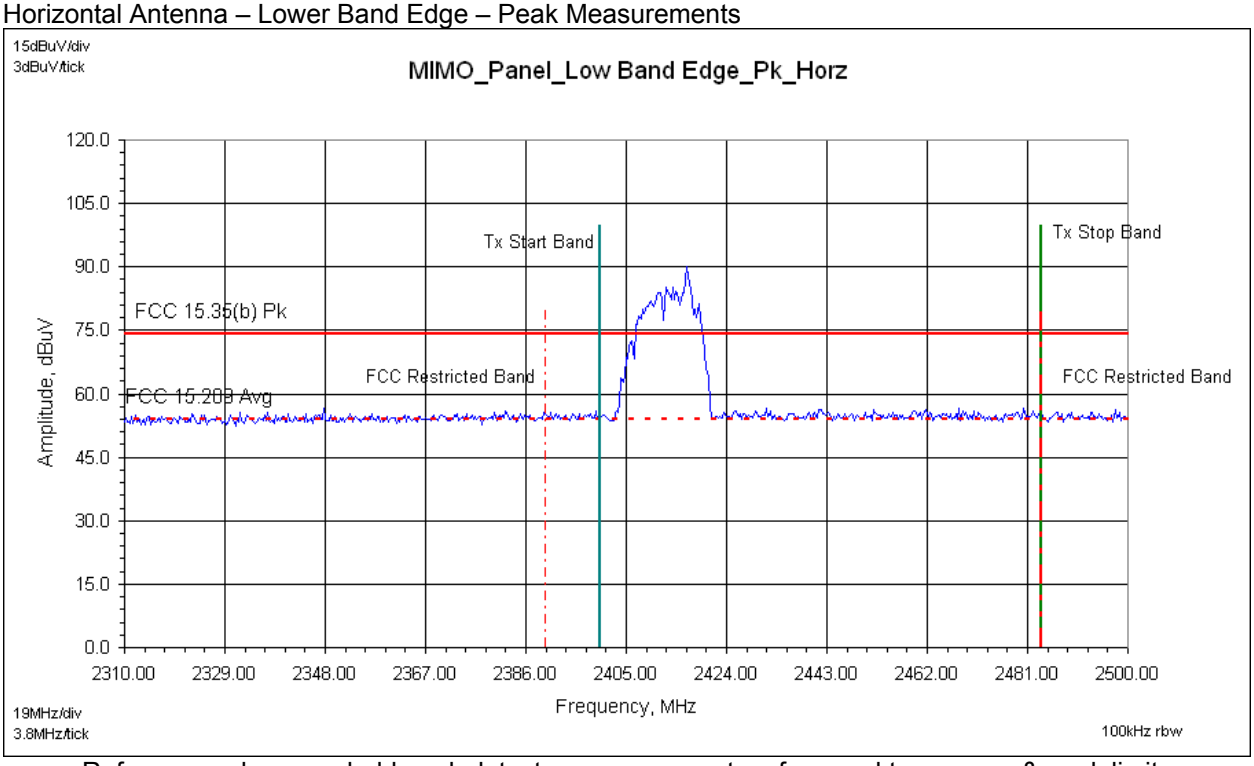
Deviations, Additions, or Exclusions: None

11.34 Band Edge Plots: MIMO Mode of Operation – HT20 Low Channel 2412 MHz

Vertical Antenna – Lower Band Edge – Peak Measurements



Horizontal Antenna – Lower Band Edge – Peak Measurements

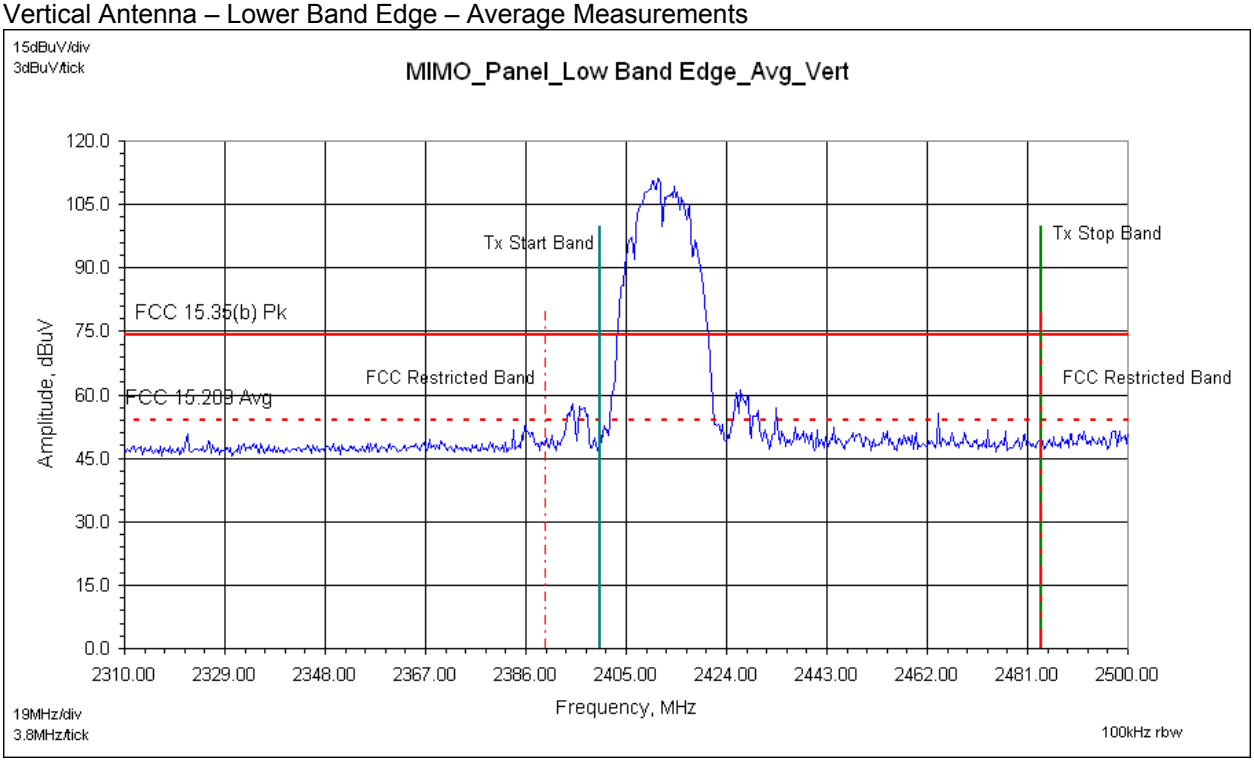


Reference only – max hold peak detector measurements referenced to average & peak limits

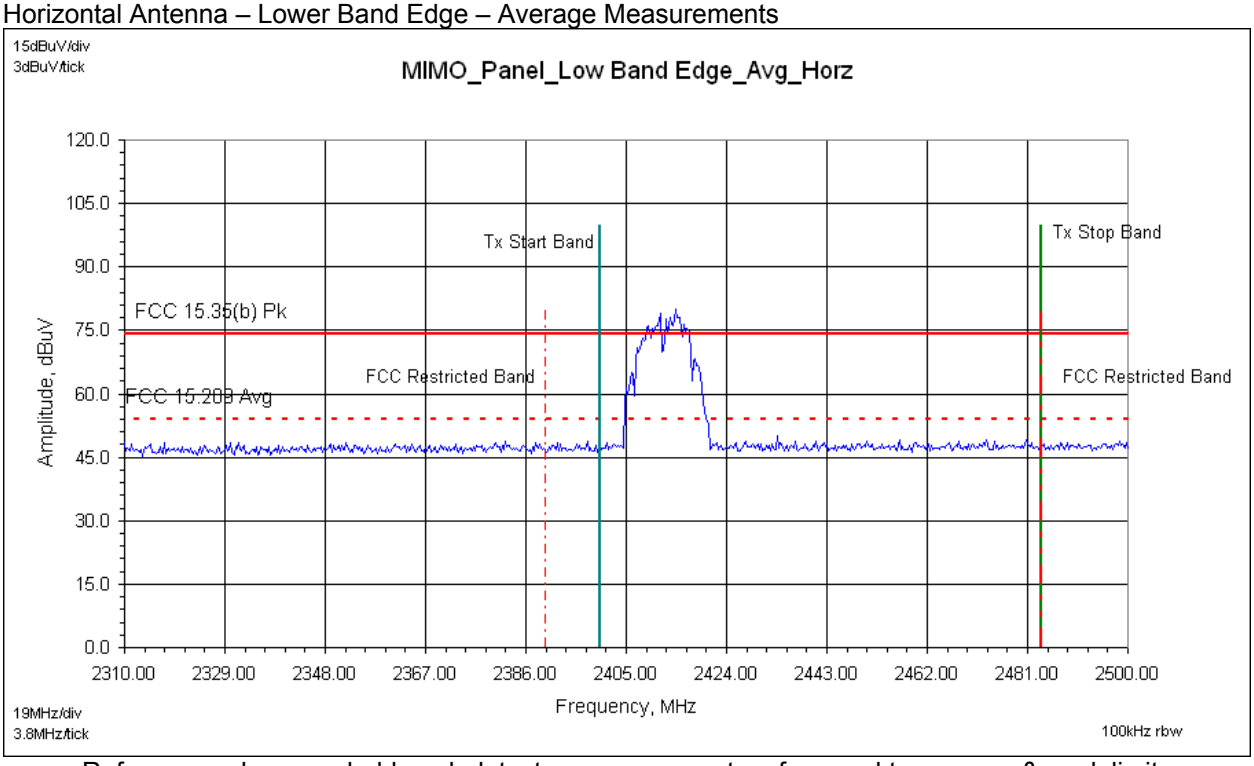
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Dashed-Lines (Restricted Band)
Blue Trace (Peak trace line)

11.35 Band Edge Plots: MIMO Mode of Operation – HT20 Low Channel 2412 MHz

Vertical Antenna – Lower Band Edge – Average Measurements



Horizontal Antenna – Lower Band Edge – Average Measurements

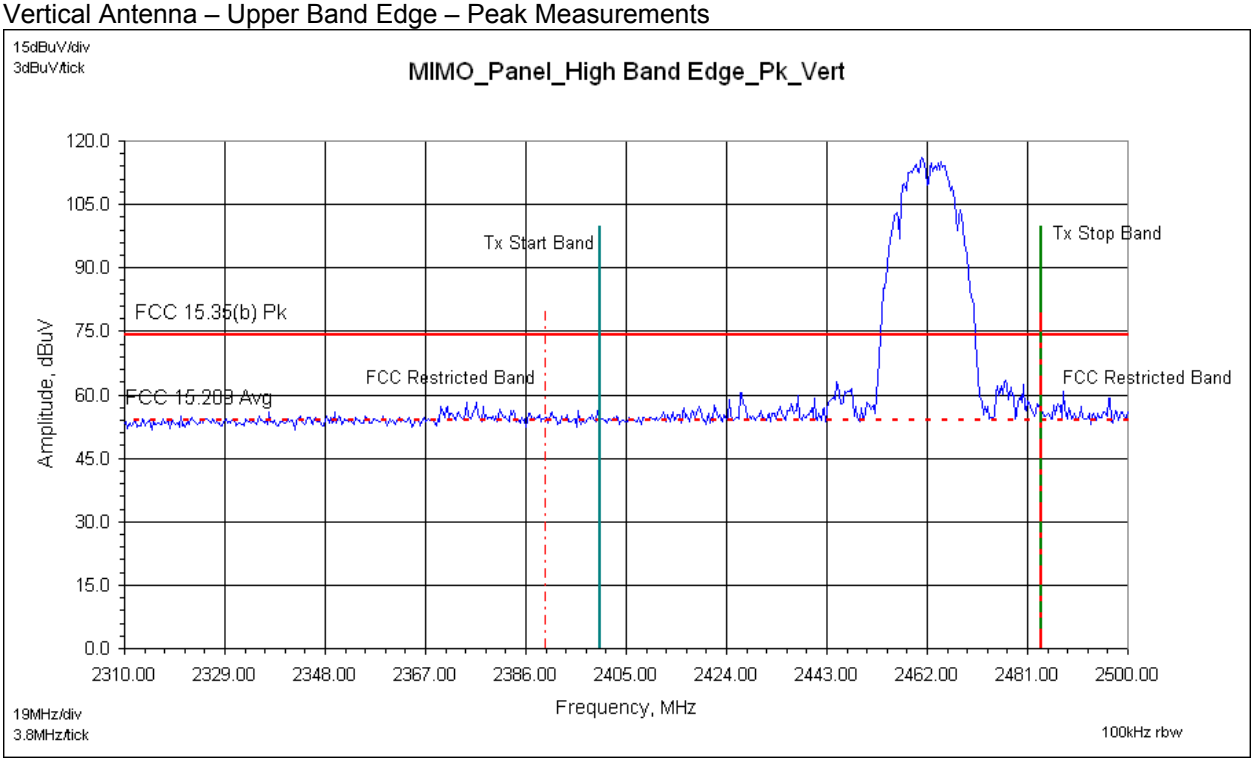


Reference only – max hold peak detector measurements referenced to average & peak limits

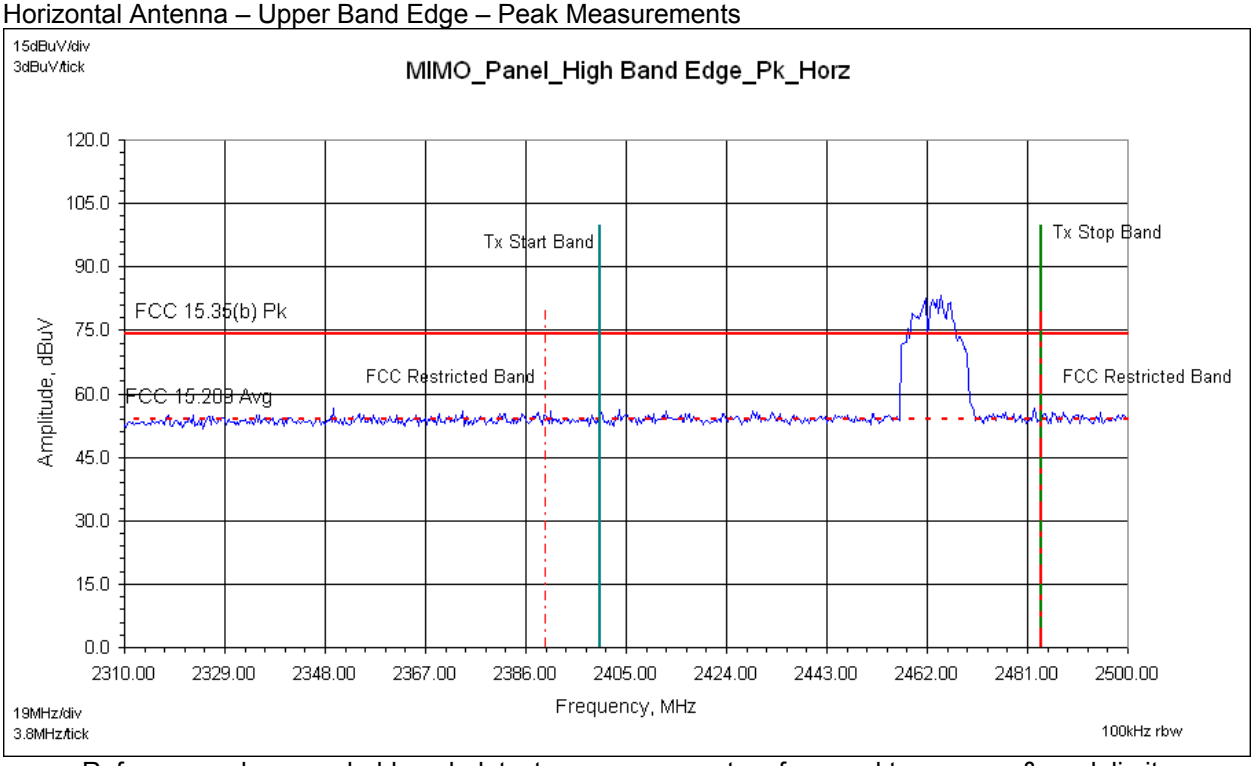
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Dashed-Lines (Restricted Band)
Blue Trace (Average trace line)

11.36 Band Edge Plots: MIMO Mode of Operation – HT20 High Channel 2462 MHz

Vertical Antenna – Upper Band Edge – Peak Measurements



Horizontal Antenna – Upper Band Edge – Peak Measurements

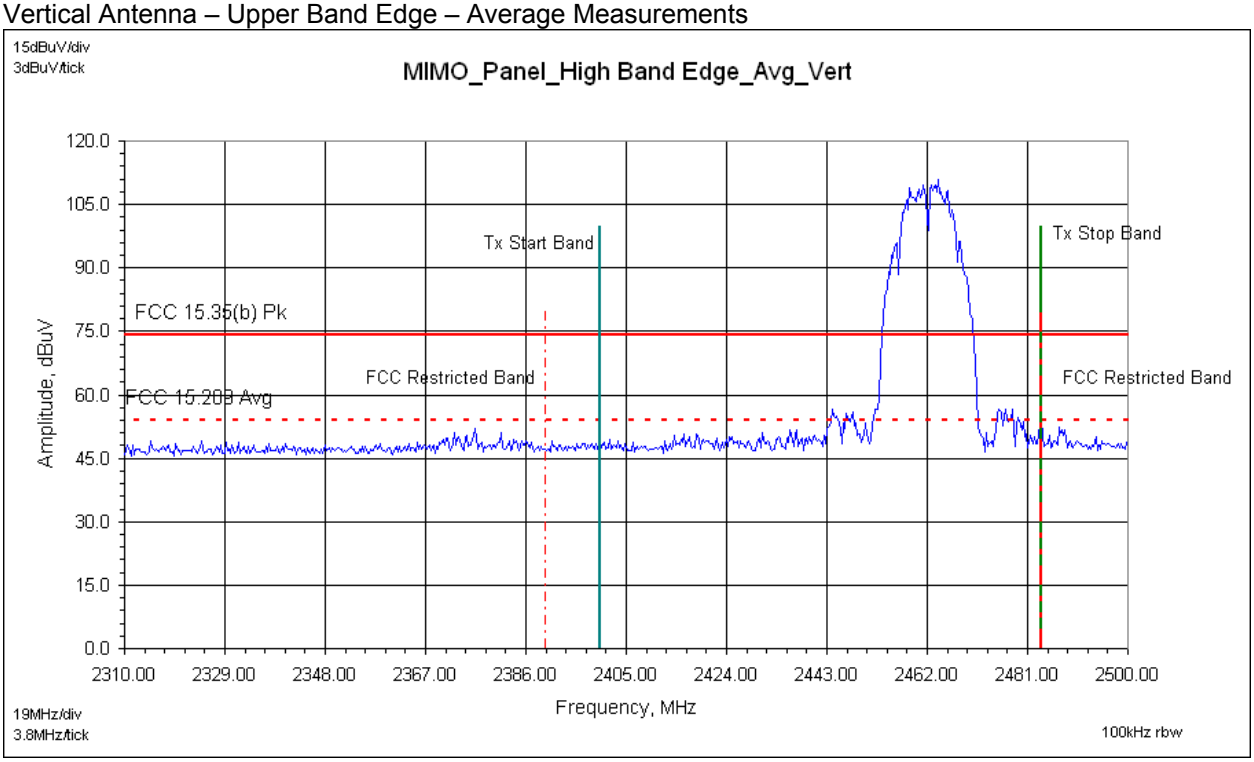


Reference only – max hold peak detector measurements referenced to average & peak limits

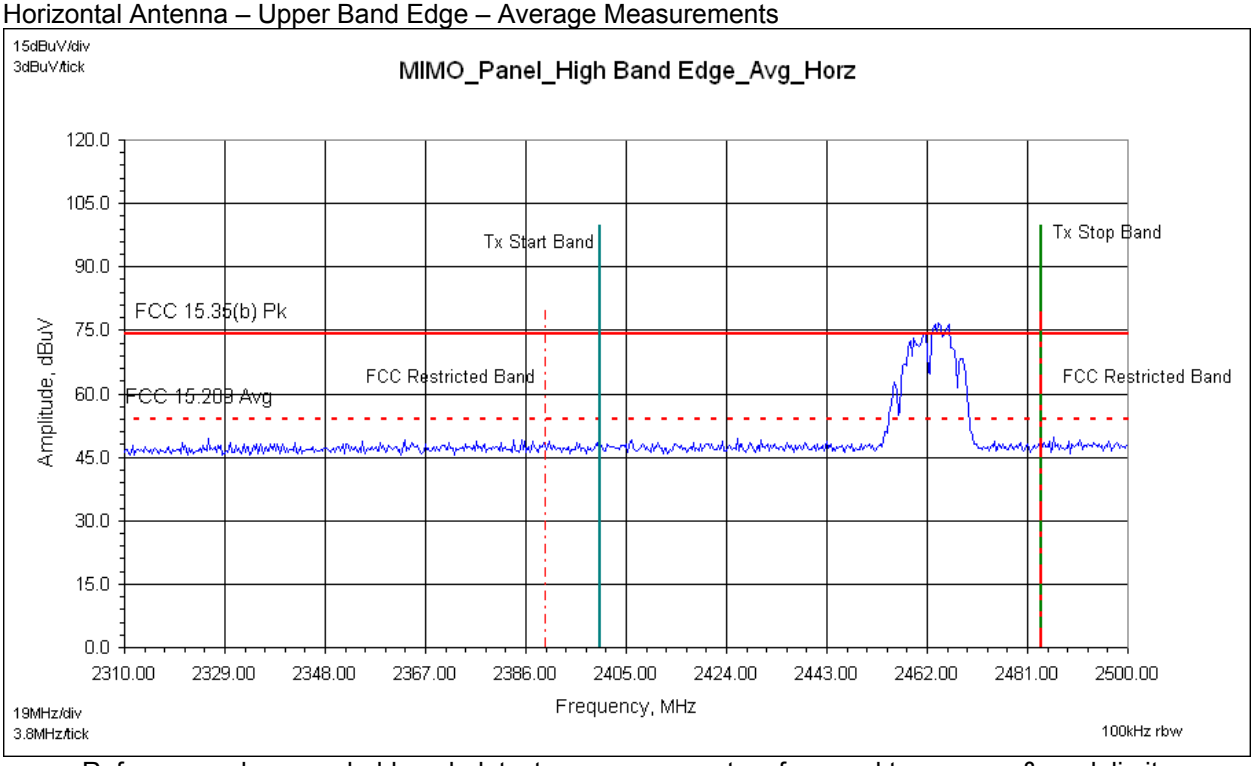
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Peak trace line)

11.37 Band Edge Plots: MIMO Mode of Operation – HT20 High Channel 2462 MHz

Vertical Antenna – Upper Band Edge – Average Measurements



Horizontal Antenna – Upper Band Edge – Average Measurements

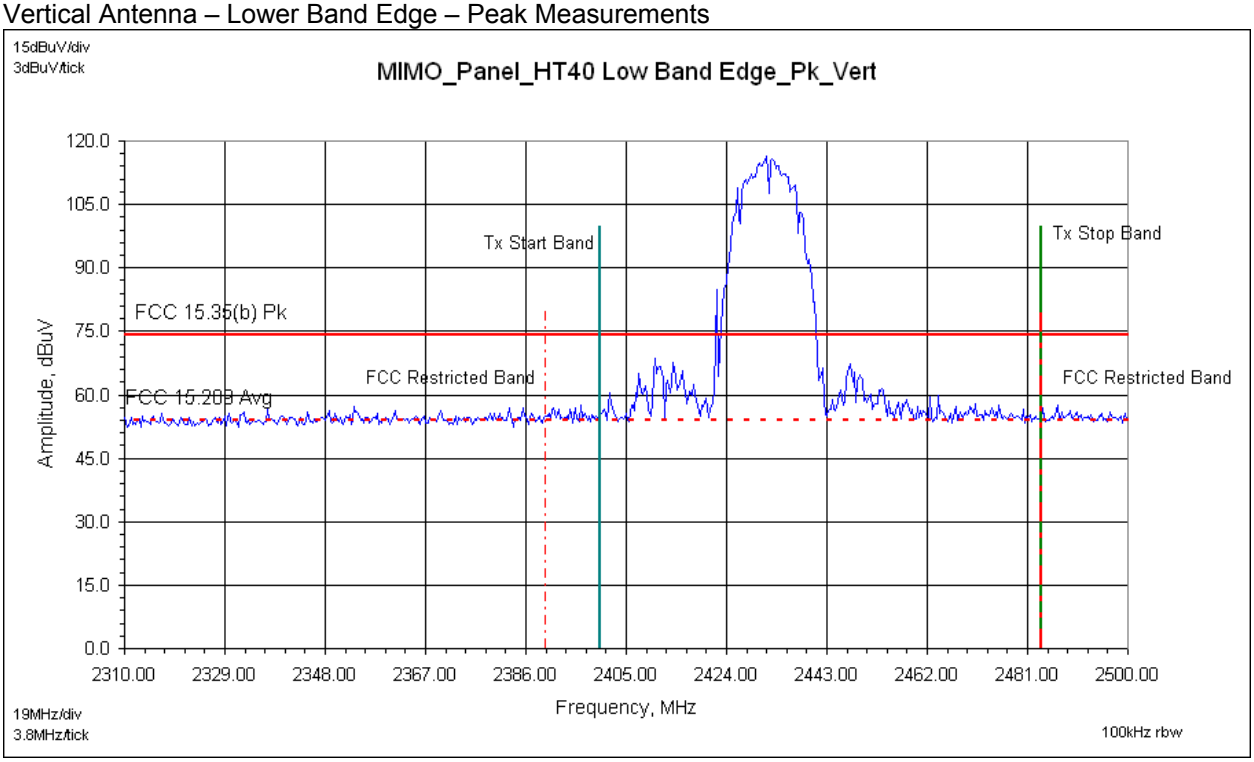


Reference only – max hold peak detector measurements referenced to average & peak limits

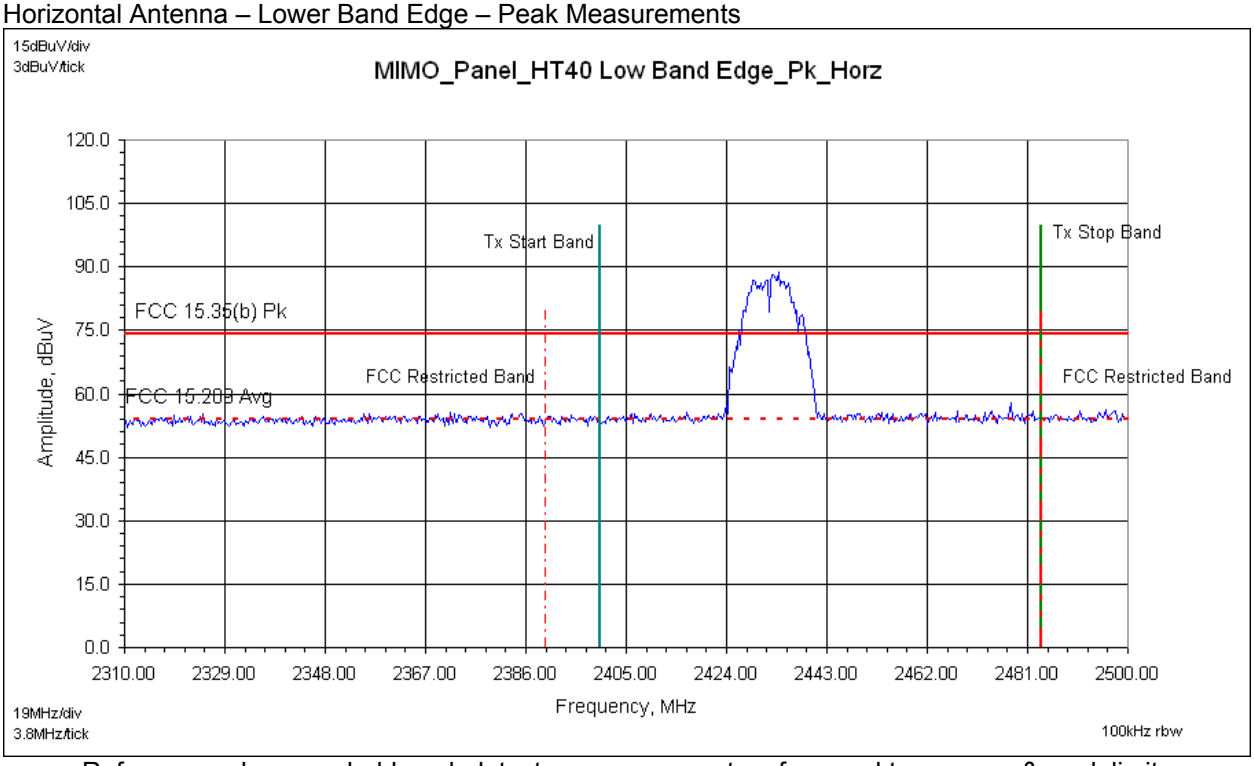
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Average trace line)

11.38 Band Edge Plots: MIMO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Lower Band Edge – Peak Measurements



Horizontal Antenna – Lower Band Edge – Peak Measurements

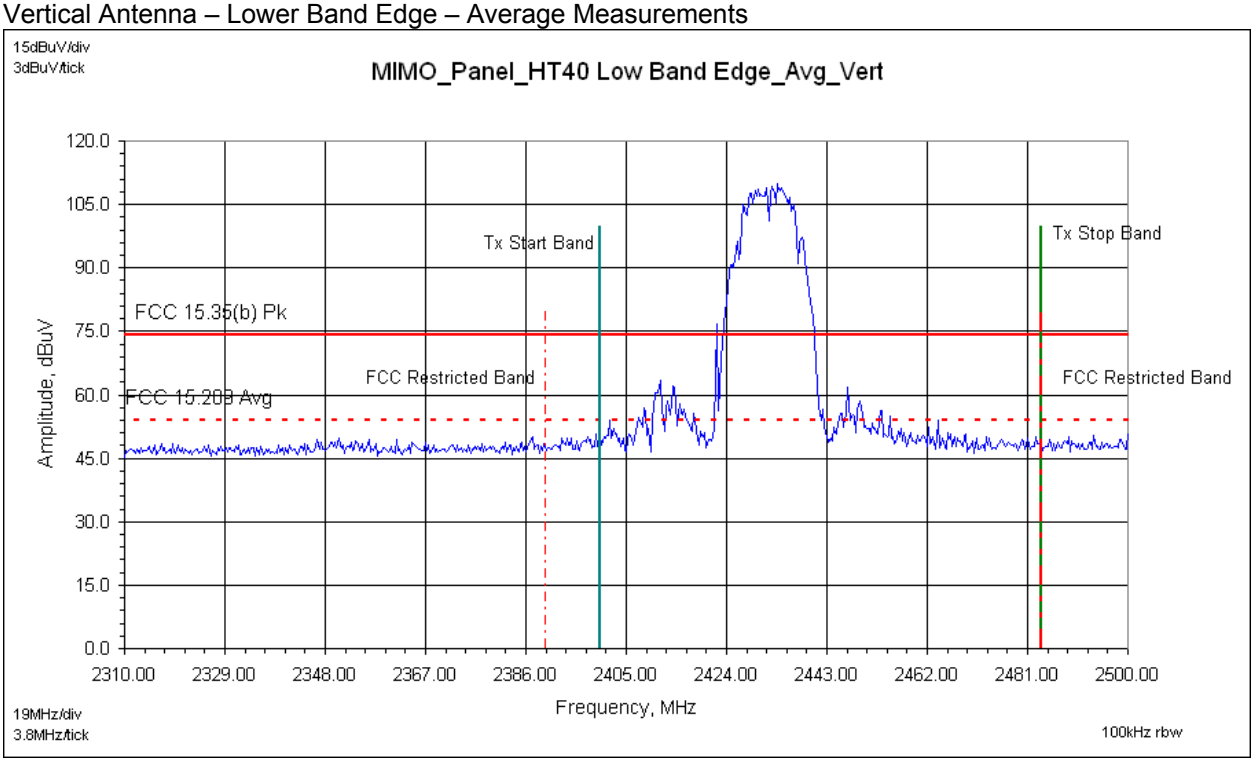


Reference only – max hold peak detector measurements referenced to average & peak limits

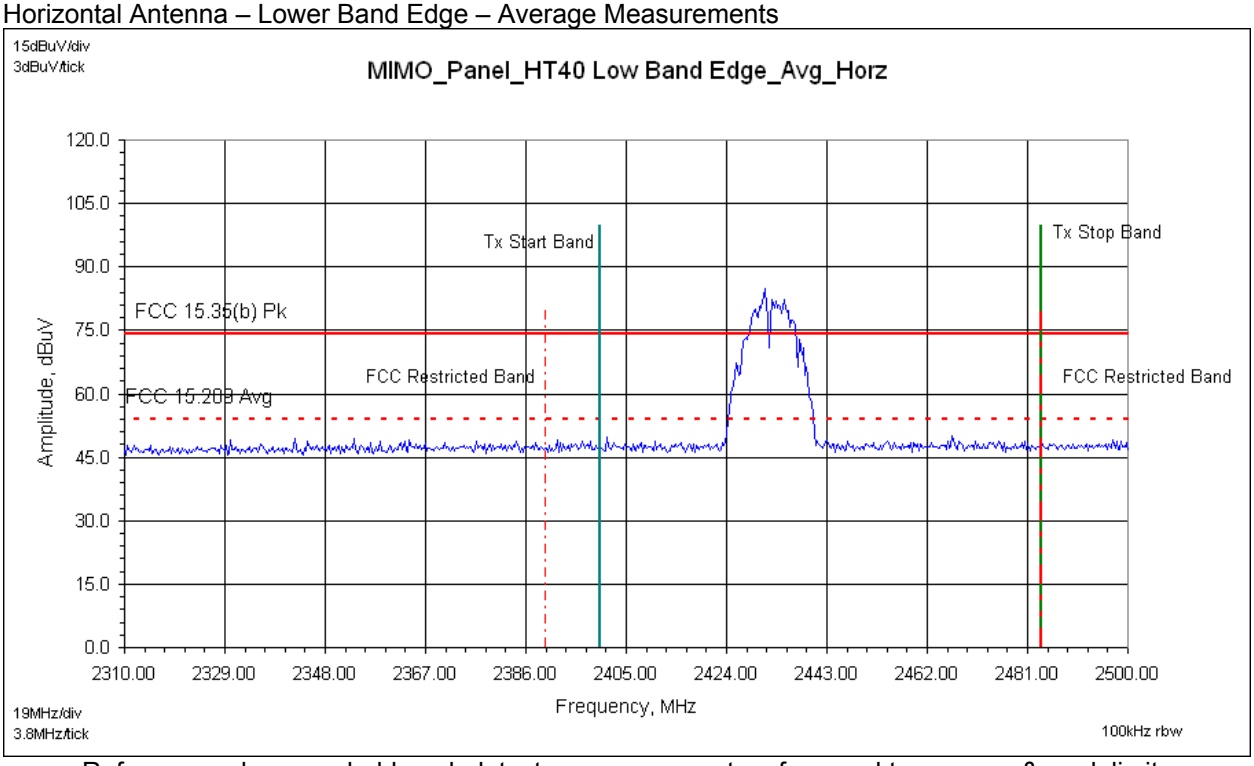
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Peak trace line)

11.39 Band Edge Plots: MIMO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Lower Band Edge – Average Measurements



Horizontal Antenna – Lower Band Edge – Average Measurements

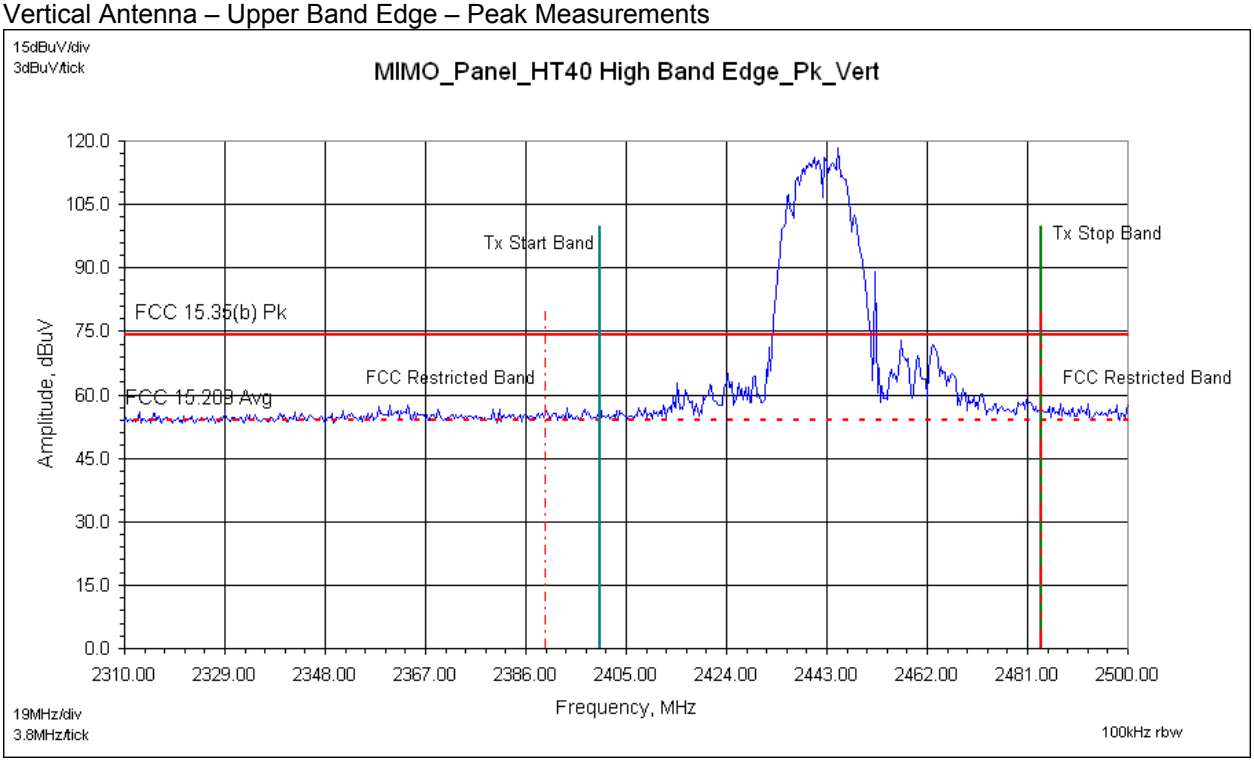


Reference only – max hold peak detector measurements referenced to average & peak limits

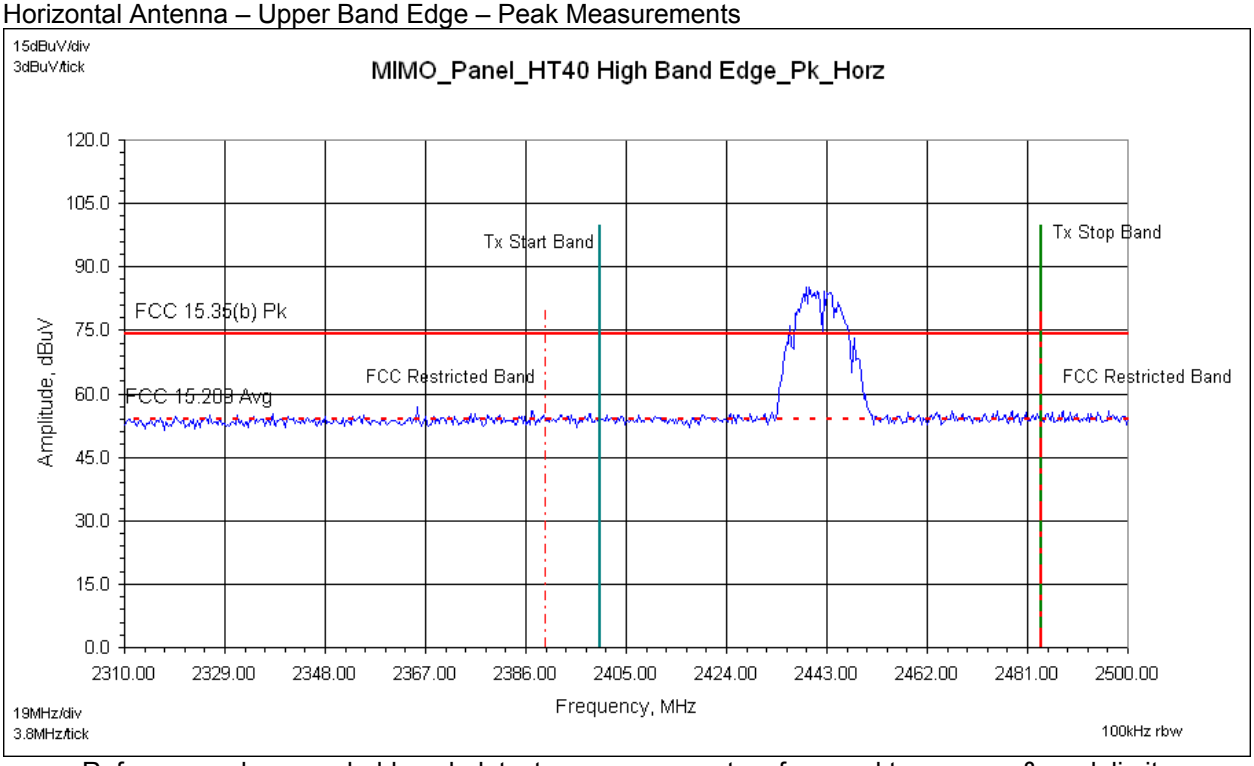
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Average trace line)

11.40 Band Edge Plots: MIMO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Upper Band Edge – Peak Measurements



Horizontal Antenna – Upper Band Edge – Peak Measurements

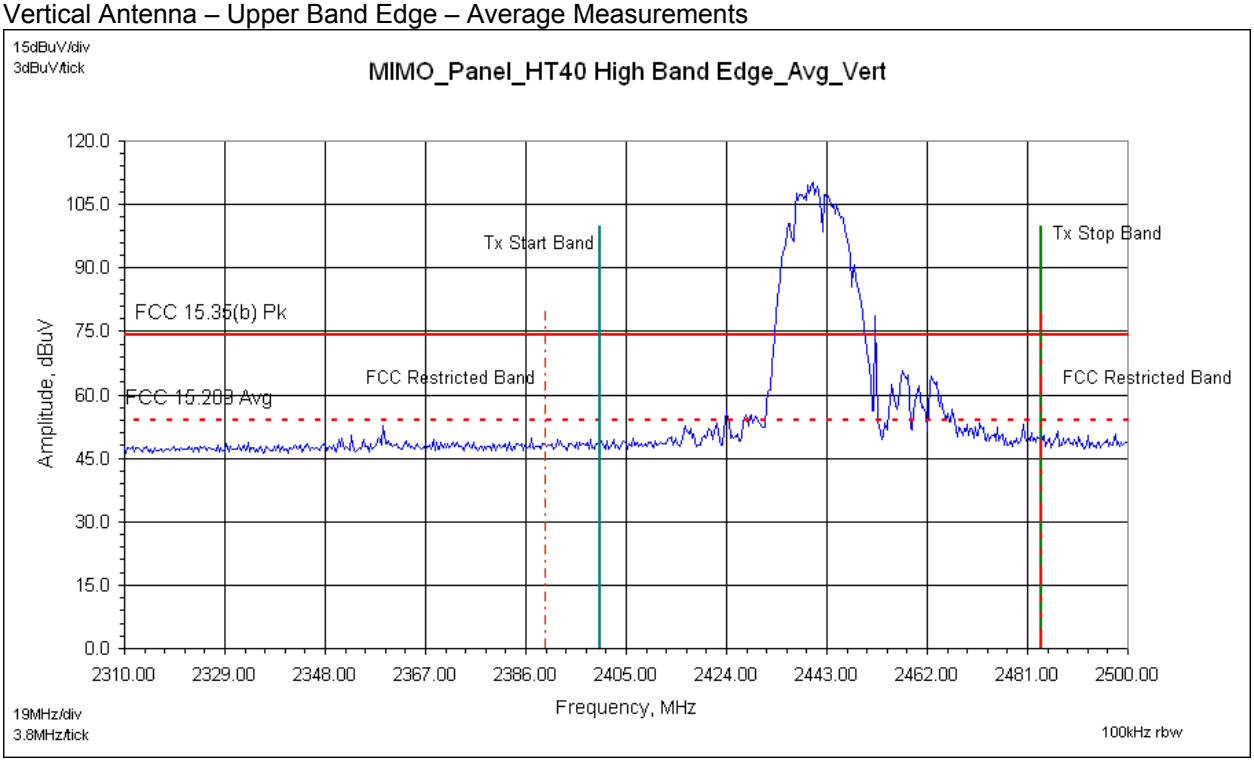


Reference only – max hold peak detector measurements referenced to average & peak limits

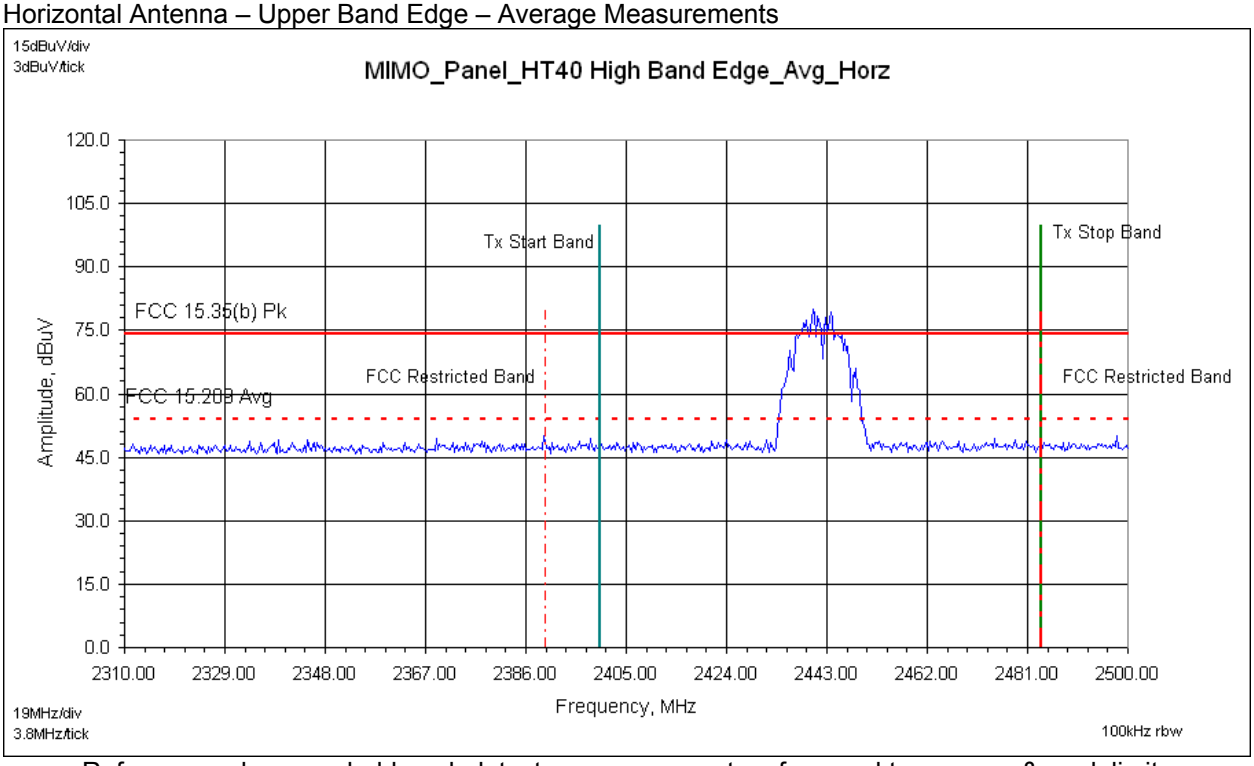
Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Peak trace line)

11.41 Band Edge Plots: MIMO Mode of Operation – HT40 Channel 2437 MHz

Vertical Antenna – Upper Band Edge – Average Measurements



Horizontal Antenna – Upper Band Edge – Average Measurements



Reference only – max hold peak detector measurements referenced to average & peak limits

Legend: Green Vertical Lines (Tx allowable start/stop band)
Red Vertical Lines (Restricted Band)
Blue Trace (Average trace line)

11.42 Test Data: MIMO Band Edge – FCC Restricted Band

Tx Spurious Radiated Emissions – Band Edge

Test Report #:	**G101503629**	Test Area:	CC1 Radiated	Temperature:	23.7	°C
Test Method:	FCC 15.209/ 15.205/ 15.35(b)	Test Date:	02/03/2014 02/04/2014	Relative Humidity:	27.2	%
EUT Model #:	Radio Module: W2400-01 Directional Panel Antenna: SPAPG20	EUT Power:	120VAC/60Hz	Air Pressure:	83.5	kPa

EUT Serial #: Radio Module: DEN1402111313
Directional Panel Antennas: 001, 002

Manufacturer: FreeWave Technologies

EUT Description: Wireless router utilized in M2M industrial applications

Notes: Product tested in MIMO mode: 2 transmit chains/ports – dual antennas

Product continuously transmitting during all testing – worst-case modulation/data

MIMO mode of Operation, MCS0 Data Rate, 25dBm power, 22dBm/port (worst-case power)

Level Key
Pk – Peak
Qp – Quasi Peak
Av - Average

Freq	Level	Det	Cable	Ant	Preamp	Atten	Final	Pol	Hgt	Az	Delta1	Delta2	RBW
MHz	dBuV	Qp Av Pk	+ [dB]	+ [dB/m]	- [dB]	+ [dB]	= [dBuV]	(V/H)	(m)	(DEG)	FCC 15.209 Avg	FCC 15.35(b) Pk	(MHz)
Measurements: HT20 Lower Band Edge – FCC Restricted Band													
2390.0000	48.62	**Av**	3.50	28.51	37.57	9.48	52.55	V	1.51	8.0	- 1.43	NA	1.000
2390.0000	53.66	**Pk**	3.50	28.51	37.57	9.48	57.59	V	1.51	8.0	NA	- 16.41	1.000
2390.0000	42.14	**Av**	3.50	28.51	37.57	9.48	46.07	H	1.47	8.0	- 7.91	NA	1.000
2390.0000	48.79	**Pk**	3.50	28.51	37.57	9.48	52.72	H	1.47	8.0	NA	- 21.28	1.000
Measurements: HT20 Upper Band Edge – FCC Restricted Band													
2483.5000	52.43	**Pk**	3.58	28.69	37.67	10.11	57.14	V	1.54	8.3	NA	- 16.86	1.000
2483.5000	47.64	**Av**	3.58	28.69	37.67	10.11	52.35	V	1.54	8.3	- 1.63	NA	1.000
2483.5000	48.58	**Pk**	3.58	28.69	37.67	10.11	53.29	H	1.50	7.5	NA	- 20.71	1.000
2483.5000	45.91	**Av**	3.58	28.69	37.67	10.11	50.62	H	1.54	8.3	- 3.36	NA	1.000
Measurements: HT40 Lower Band Edge – FCC Restricted Band													
2390.0000	48.25	**Av**	3.50	28.51	37.57	9.48	52.18	V	1.50	7.5	- 1.80	NA	1.000
2390.0000	54.20	**Pk**	3.50	28.51	37.57	9.48	58.13	V	1.50	7.5	NA	- 15.87	1.000
2390.0000	42.47	**Av**	3.50	28.51	37.57	9.48	46.40	H	1.54	4.7	- 7.58	NA	1.000
2390.0000	47.79	**Pk**	3.50	28.51	37.57	9.48	51.72	H	1.54	4.7	NA	- 22.28	1.000
Measurements: HT40 Upper Band Edge – FCC Restricted Band													
2483.5000	41.91	**Av**	3.58	28.69	37.67	10.11	46.62	V	1.52	5.6	- 7.36	NA	1.000
2483.5000	46.80	**Pk**	3.58	28.69	37.67	10.11	51.51	V	1.52	5.6	NA	- 22.49	1.000
2483.5000	40.91	**Av**	3.58	28.69	37.67	10.11	45.62	H	1.52	4.4	- 8.36	NA	1.000
2483.5000	47.87	**Pk**	3.58	28.69	37.67	10.11	52.58	H	1.52	4.4	NA	- 21.42	1.000

Example calculation:

Measured Level	+	Cable Loss	+	Antenna Factor	-	Pre-Amp	+	Atten	=	Final Corrected Reading	Specification Limit	-	Final Corrected Reading	=	Delta Specification
(dBμV)		(dB)		(dB)		(dB)		(dB)		(dBμV/m)	(dBμV/m)		(dBμV/m)		
20.0		**3.0**		**5.0**		**10.0**		**0.0**		**18.0**	**40.0**		**18.0**		**- 22.0**

Notes:

1) The highest signals – as determined from pre-scan plots – were fully-maximized and measured.
2) The notch filter was not used during band edge plots/measurements.
3) 802.11 HT20/HT40 included in measurements as well as both SISO/MIMO modes of Tx operation.

Deviations, Additions, or Exclusions: None

12 Power Spectral Density – PSD

12.1 Test Results:

Test not required for Class II Permissive Change.

13 Radiated Emissions (Digital Part of Receiver)

13.1 Test Results:

Test not required for Class II Permissive Change.

14 AC Mains Conducted Emissions - Transmitter

14.1 Test Results:

Test not required for Class II Permissive Change.

15 RF Exposure Requirement

15.1 Test Results:

To be supplied by the customer.

16 Duty Cycle/ Duty Cycle Correction Factor

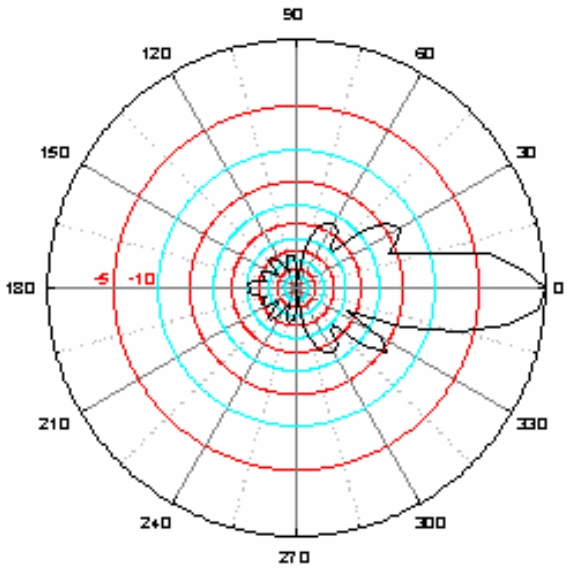
16.1 Results:

Test not required for Class II Permissive Change.

17 Appendix A: Antenna Specifications

Superpass SPAPG20 – Directional Panel Antenna

No.	ITEM	TYPICAL	REMARKS
1	Frequency Range	2300-2500 MHz	
2	Impedance	50 Ω	
3	VSWR (or Return Loss)	< 1.5:1 (or > 14dB)	
4	Gain	20.5dBi	
5	Polarization	Vertical, Linear	
6	3dB Horizontal Beamwidth	15°	
7	3dB Vertical Beamwidth	16°	
8	Front to Back Ratio	>35dB	
9	Max. Power Input	20W	
10	Connector	N female, Bottom Feed	Or Custom Design
11	Appearance	Panel Type	
12	Size	13.8 x 15.5 x 1 [inch]	
13	Housing Material	Powder Coated Aluminum	
14	Radom Material	ABS with UV Protection	
15	Radom Color	White	
16	Case Design	Water Resistance	
17	Weight	3Lb	
18	Wind Loading (Frontal)	> 10Kg	200km/h
19	Temperature Range	-45 to +75°	
20	Storage Temperature	-30 to +75°	
21	Lighting Protection	Direct Grounding	
22	Mounting Hardware	Clamp Set	
23	Life Expectancy	20 years	



E-Plane Radiation Pattern

18 Measurement Uncertainty

The measured value related to the corresponding limit will be used to decide whether the equipment meets the requirements.

The measurement uncertainty figures were calculated and correspond to a coverage factor of k = 2, providing a confidence level of respectively 95.45 % in the case where the distributions characterizing the actual measurement uncertainties are normal (Gaussian).

Measurement uncertainty Table

Parameter	Uncertainty ±	Notes
Radiated emissions, 10kHz to 30 MHz	3.4 dB	
Radiated emissions, 30 to 200 MHz HP	2.2 dB	
Radiated emissions, 30 to 200 MHz VP	3.8 dB	
Radiated emissions, 200 to 1000 MHz HP	2.8 dB	
Radiated emissions, 200 to 1000 MHz VP	2.7 dB	
Radiated emissions, 1 to 18 GHz	5.2 dB	
Conducted port emissions 10kHz to 1000 MHz	1.0 dB	
Conducted port emissions 1 – 26.5 GHz	1.6 dB	
AC mains Conducted emissions, 9kHz to 30 MHz	3.14 dB	

19 Revision History

Revision Level	Date	Report Number	Notes
0	TBD	101503629DEN-001B	Original Issue