4.5 Transmitter Radiated Emissions & Antenna Port Emissions
FCC Rule 15.247(d), 15.209, 15.205; RSS-247

4.5.1 Requirement

Radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

For out of band radiated emissions (except for frequencies in restricted bands), in any 100 kHz bandwidths outside the EUT pass-band, the RF power shall be at least 20dB (peak) or 30 dB (average) below that of the maximum in-band 100 kHz emissions.

4.5.2 Procedure – Radiated Emissions

Radiated emission measurements were performed from 30 MHz to 25 GHz according to the procedure described in ANSI C64.10. Spectrum Analyzer Resolution Bandwidth is 100 kHz or greater for frequencies 30 MHz to 1000 MHz, 1 MHz for frequencies above 1000 MHz. Above 1000 MHz Peak and Average measurements were performed.

The EUT is placed on a plastic turntable that is 80 cm in height for below 1000MHz and 1.5m in height for above 1GHz. If the EUT attaches to peripherals, they are connected and operational (as typical as possible). During testing, all cables were manipulated to produce worst-case emissions. The signal is maximized through rotation. The antenna height and polarization are varied during the search for maximum signal level. The antenna height is varied from 1 to 4 meters.

Radiated emissions are taken at 3 meters for frequencies above 1 GHz and at 10 meters for frequencies below 1 GHz.

Measurements made from 1 GHz to 18GHz had a 2.4-2.5GHz notch filter in place. A preamp was used from 30MHz to 26GHz.

All measurements were made with a Peak Detector and compared to QP limits for 30MHz – 1GHz and Average limits for 1GHz – 26GHz.

EUT was positioned vertically and horizontally and emissions were measured. Data and pictures recorded below is the worst-case configuration (the configuration which resulted in the highest emission levels).

4.5.3 Field Strength Calculation

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

FS = RA + AF + CF – AG; if measurement is performed at a distance other than specified in the rule, a Distance Correction Factor (DCF) shall be added.

Where FS = Field Strength in dB(μV/m)
RA = Receiver Amplitude (including preamplifier) in dB(μV); AF = Antenna Factor in dB(1/m)
CF = Cable Attenuation Factor in dB; AG = Amplifier Gain in dB

Assume a receiver reading of 52.0 dB(μV) is obtained. The antennas factor of 7.4 dB(1/m) and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving field strength of 32 dB(μV/m). This value in dB(μV/m) was converted to its corresponding level in μV/m.
RA = 52.0 dB(μV)
AF = 7.4 dB(1/m)
CF = 1.6 dB
AG = 29.0 dB
FS = 52.0+7.4+1.6-29.0 = 32 dB(μV/m).
Level in μV/m = Common Antilogarithm [(32 dBμV/m)/20] = 39.8 μV/m.

Test Date:	April 17 – 21, 2017

4.5.4 Antenna-port conducted measurements

Antenna-port conducted measurements may also be used as an alternative to radiated measurements for demonstrating compliance in the restricted frequency bands. If conducted measurements are performed, then proper impedance matching must be ensured and an additional radiated test for cabinet/case spurious emissions is required.

4.5.6 General Procedure for conducted measurements in restricted bands

a) Measure the conducted output power (in dBm) using the detector specified for determining quasi-peak, peak, and average conducted output power, respectively.

b) Add the maximum transmit antenna gain (in dBi) to the measured output power level to determine the EIRP level (see 12.2.5 for guidance on determining the applicable antenna gain)

c) Add the appropriate maximum ground reflection factor to the EIRP level (6 dB for frequencies ≤ 30 MHz, 4.7 dB for frequencies between 30 MHz and 1000 MHz, inclusive and 0 dB for frequencies > 1000 MHz).

d) For devices with multiple antenna-ports, measure the power of each individual chain and sum the EIRP of all chains in linear terms (*e.g.*, Watts, mW).

e) Convert the resultant EIRP level to an equivalent electric field strength using the following relationship:
E = EIRP – 20log D + 104.8+DCF (DCF for Average measurements)
where:
E = electric field strength in dBμV/m,
EIRP = equivalent isotropic radiated power in dBm
D = specified measurement distance in meters.
DCF = Duty Cycle Correction Factor
f) Compare the resultant electric field strength level to the applicable limit.
g) Perform radiated spurious emission test

4.5.7 Test Results

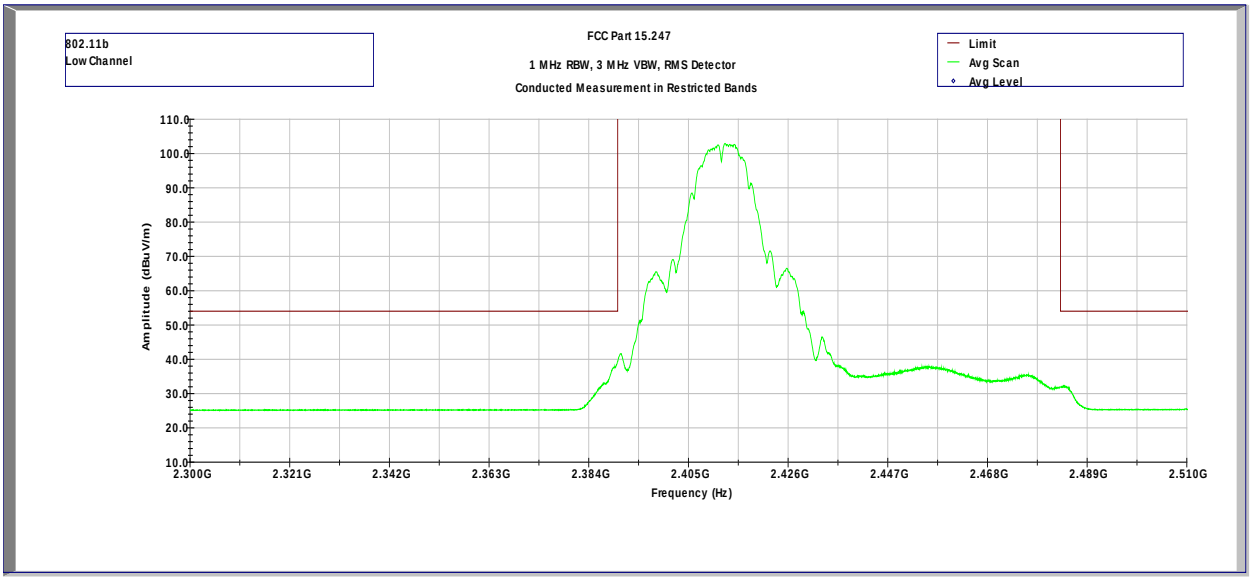
The data on the following pages list the significant emission frequencies, the limit and the margin of compliance where emissions are within 3dB of the limit. The offset programmed on the analyzer is corrected to include cable loss, attenuator and duty cycle correction.

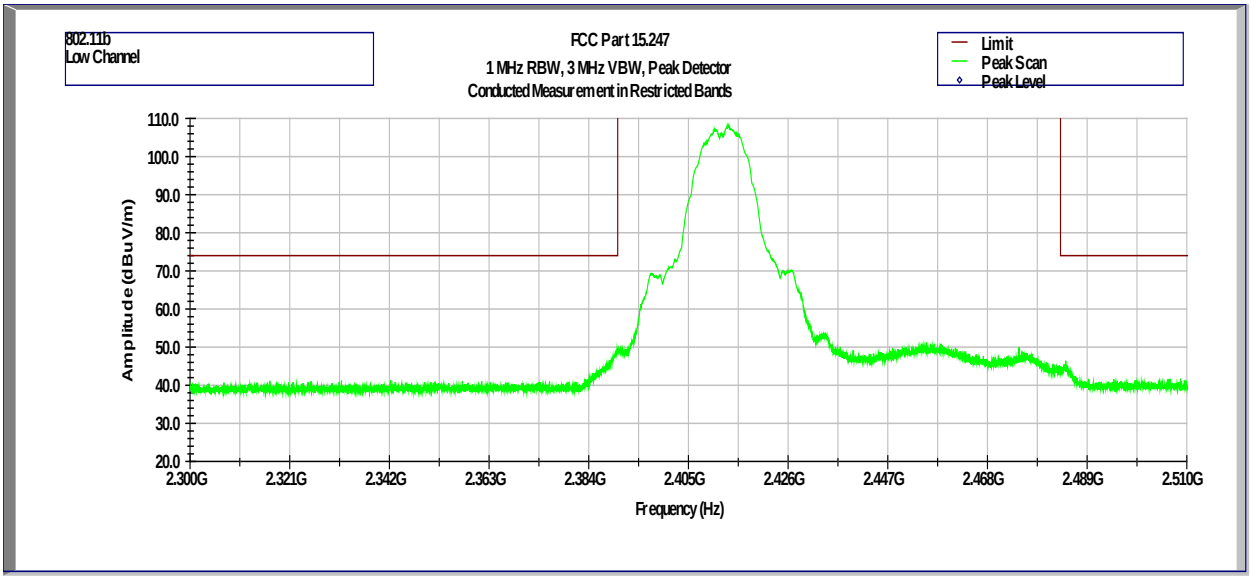
The maximum antenna gain used by the EUT is 1.48 dBi in the 2.4GHz range. As per KDB 558074 D01 DTS MEAS GUIDANCE V04, the minimum antenna gain for calculating out of band emissions shall be no less than 2.0 dBi. All conducted antenna port plots are corrected with the consideration of a 2.0 dBi Antenna Gain. See KDB 558074 D01 DTS MEAS GUIDANCE V04 section 12.2.6 for more details.

Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz.

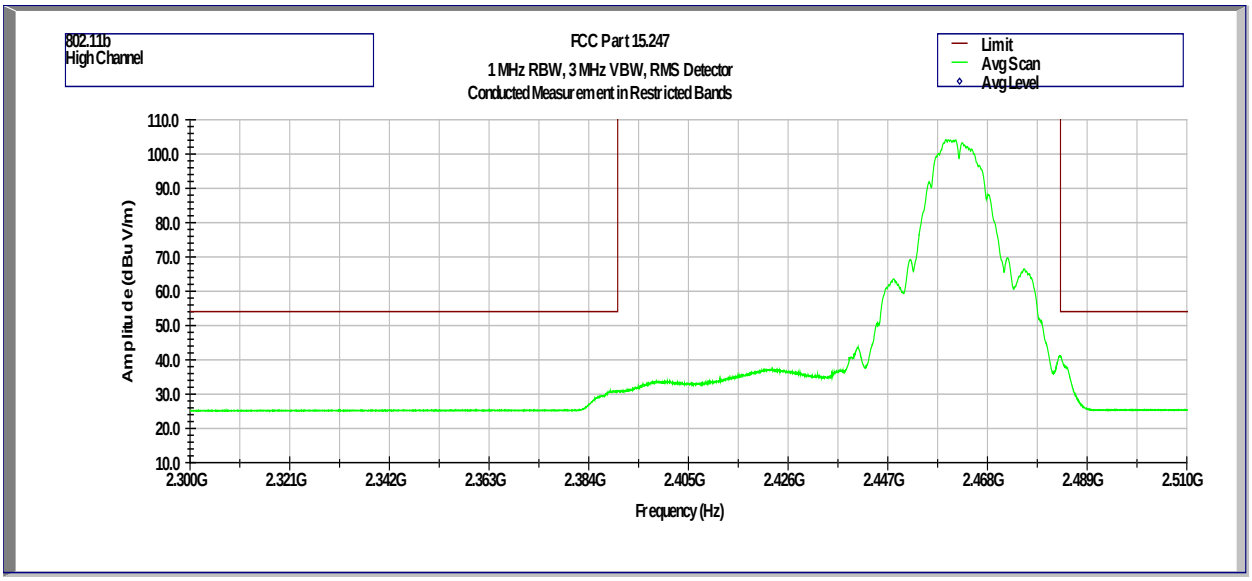
Test Results: 15.209/15.205 Restricted Band Emissions at Antenna Port

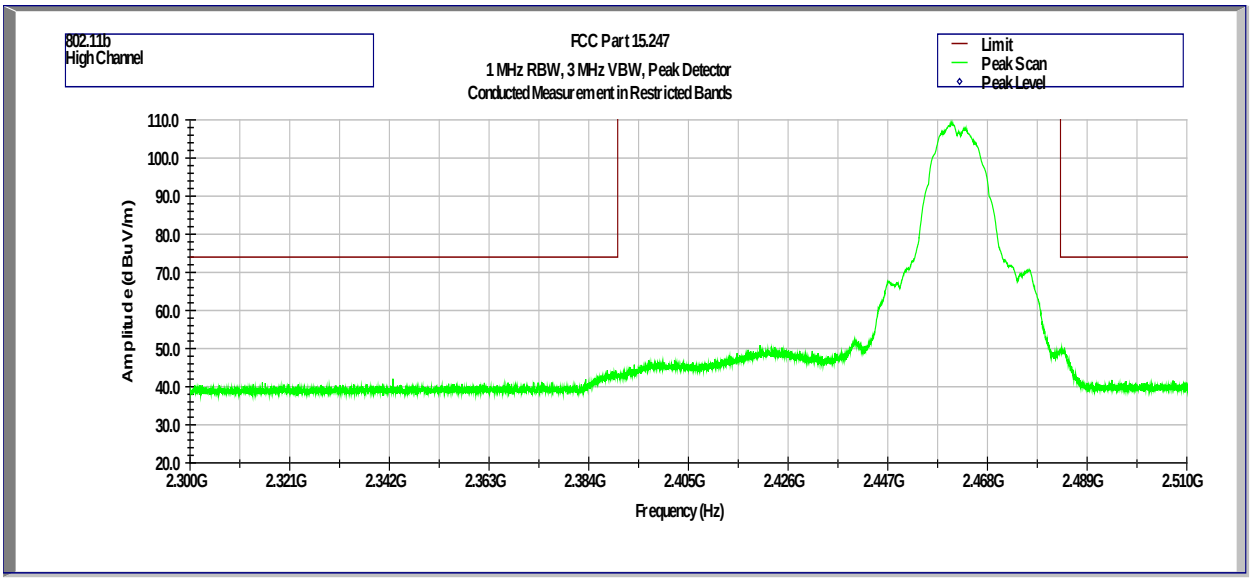
Out-of-Band Spurious Emissions at the Band Edge - 802.11b, 2412 MHz



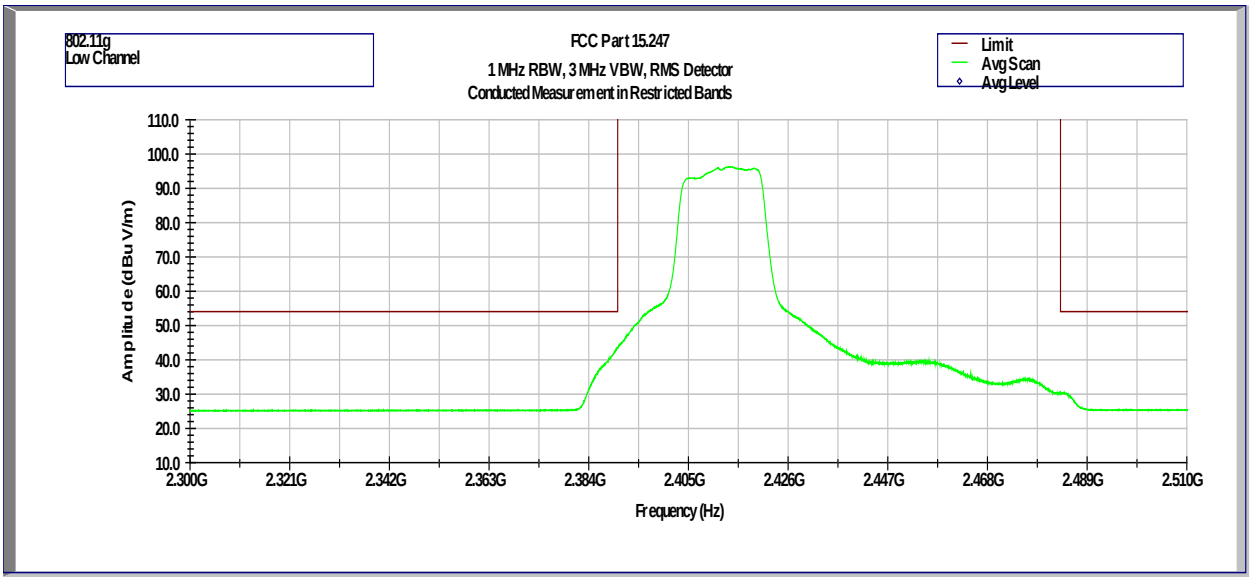


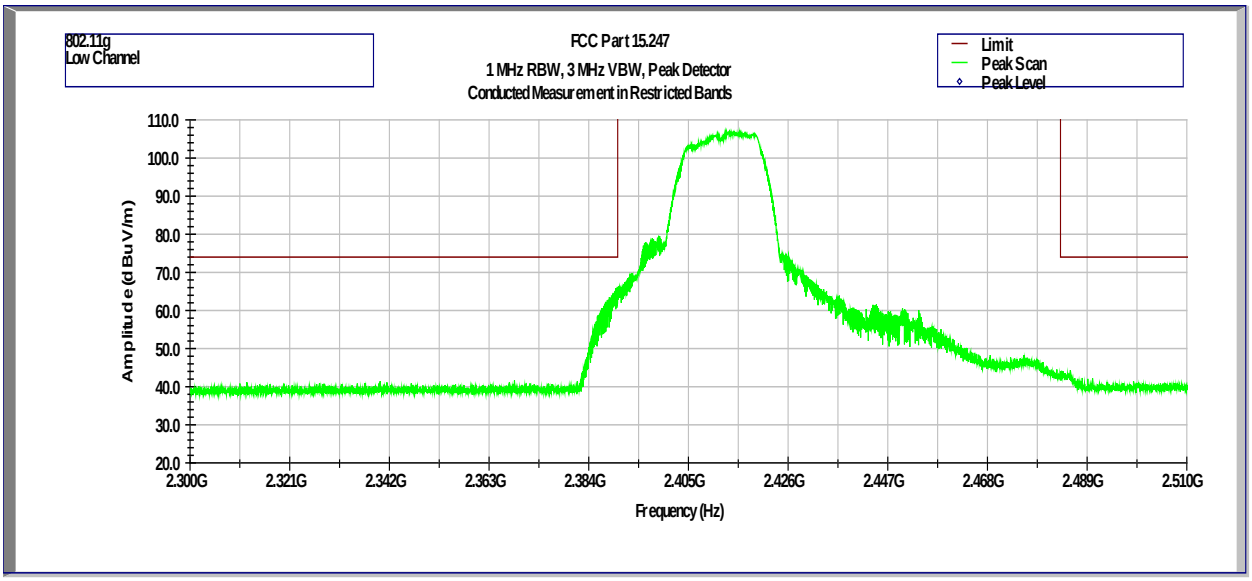
Out-of-Band Spurious Emissions at the Band Edge - 802.11b, 2462 MHz



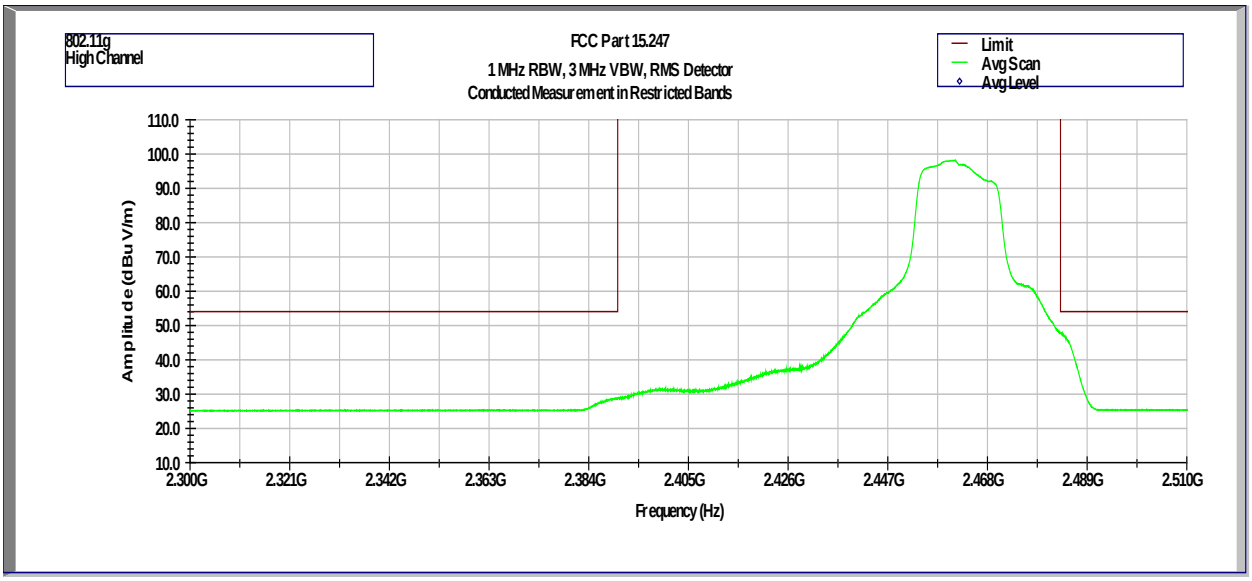


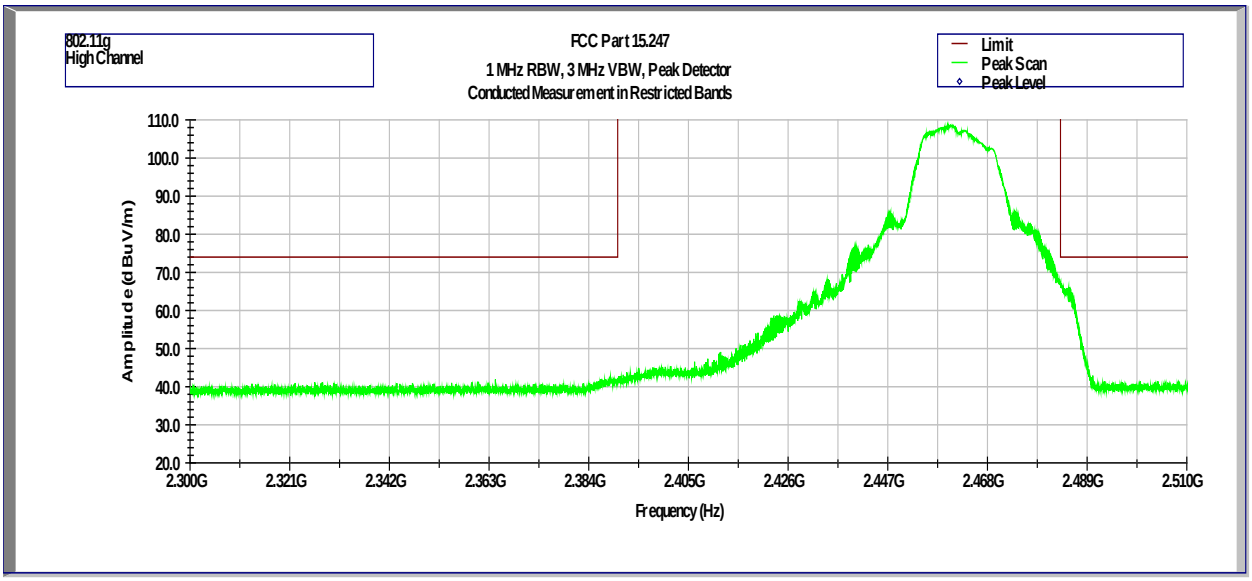
Out-of-Band Spurious Emissions at the Band Edge - 802.11g, 2412 MHz



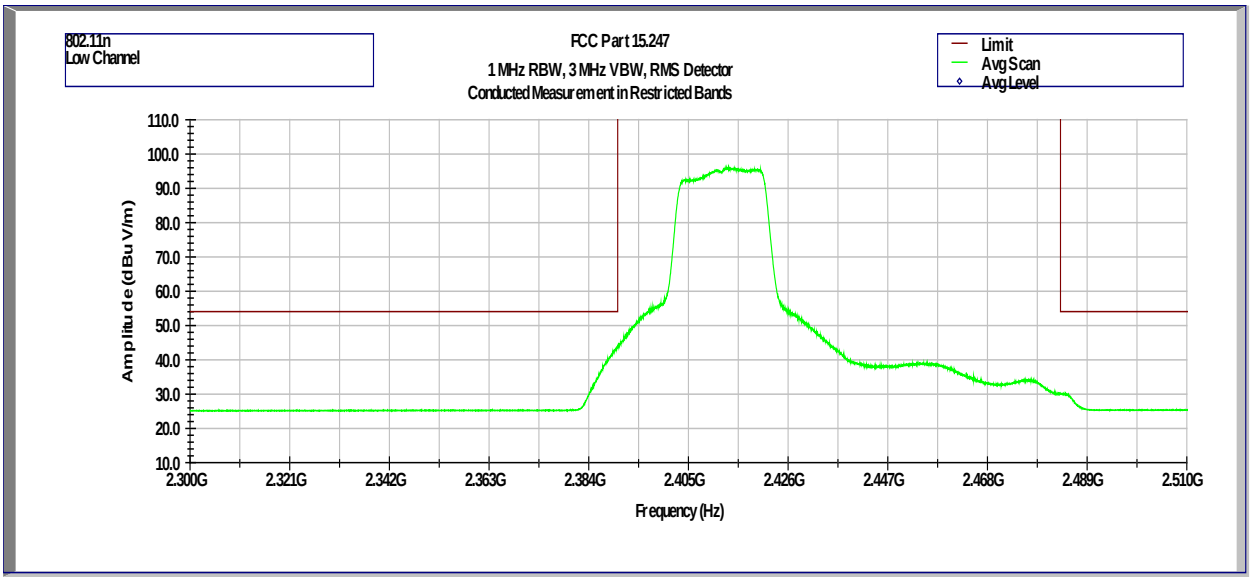


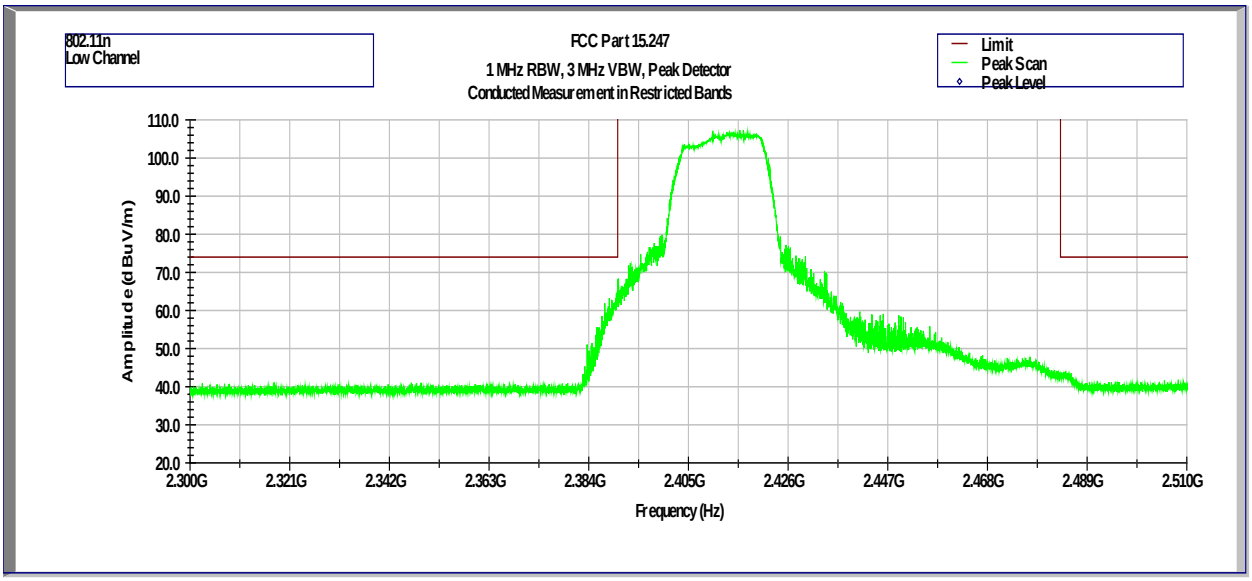
Out-of-Band Spurious Emissions at the Band Edge - 802.11g, 2462 MHz



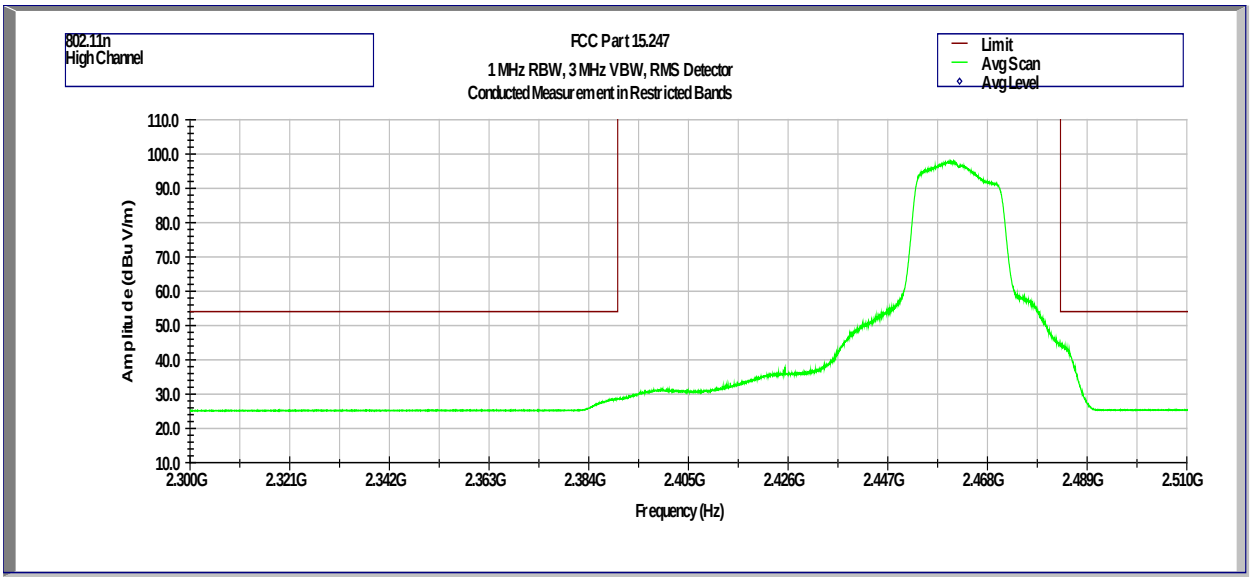


Out-of-Band Spurious Emissions at the Band Edge - 802.11n, 2412 MHz

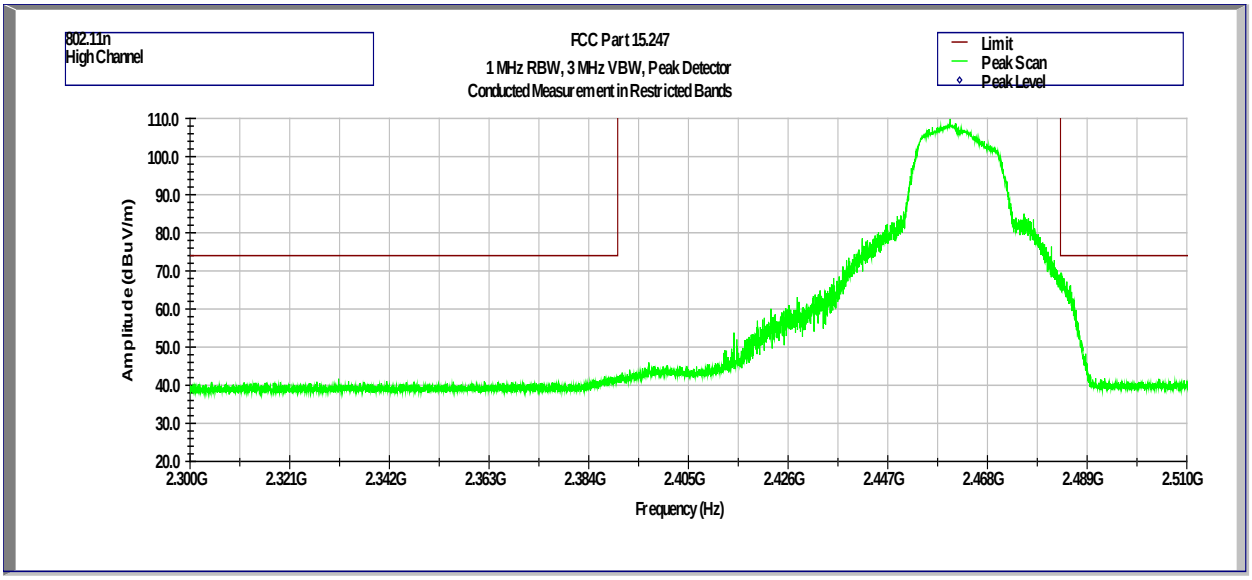




Out-of-Band Spurious Emissions at the Band Edge - 802.11n, 2462 MHz



Frequency GHz	Average dBuV	Limit dBuV	Margin dB
2483.5	45.6	54.0	-8.4

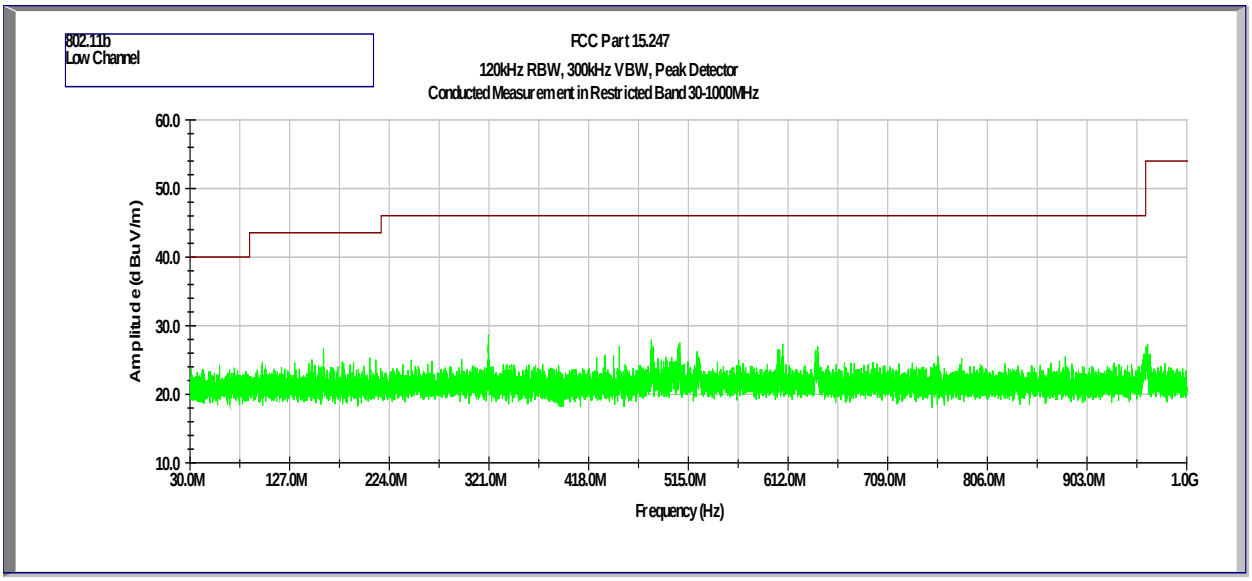


Frequency GHz	Peak dBuV	Limit dBuV	Margin dB
2483.5	69.8	74.0	-4.2

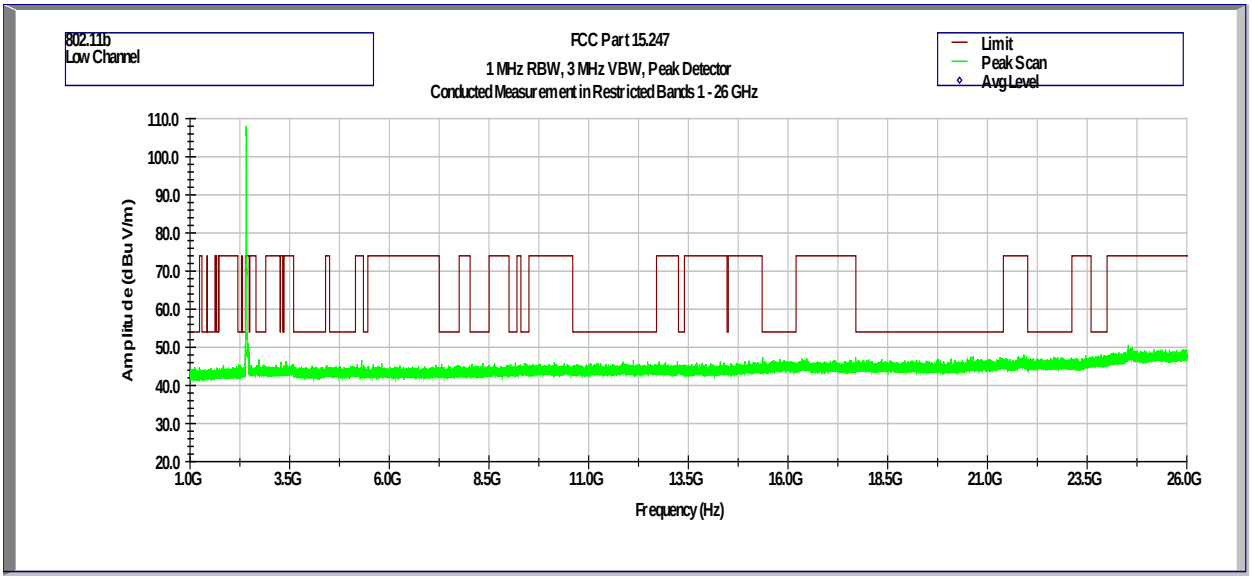
Out-of-Band Conducted Spurious Emissions (at Antenna Port)

Tx @ 2412MHz 802.11b

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

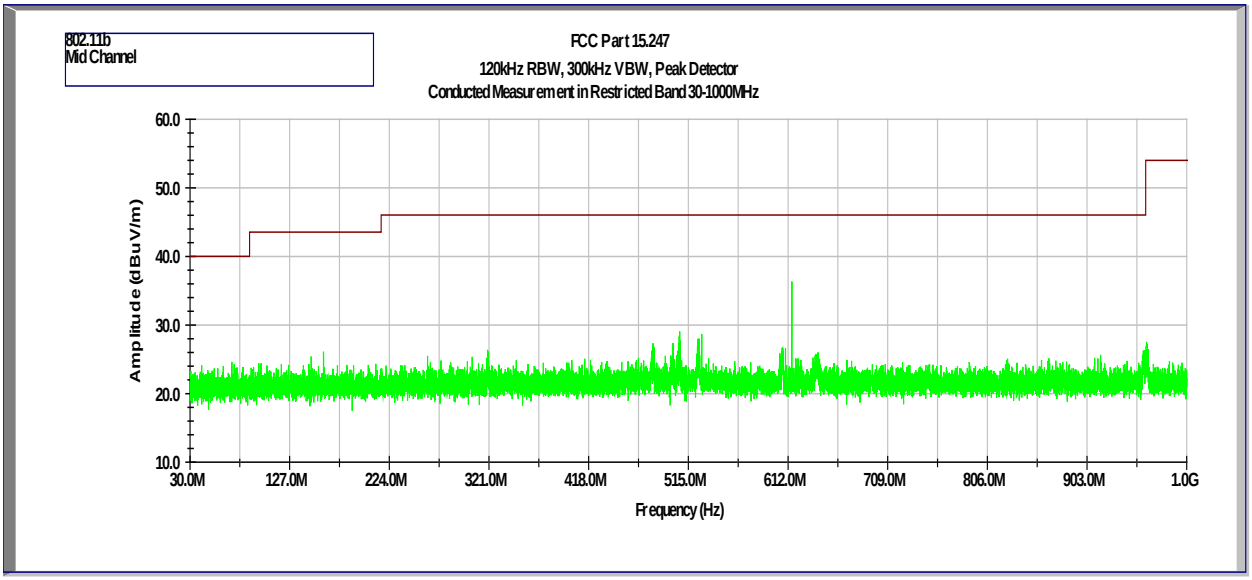


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

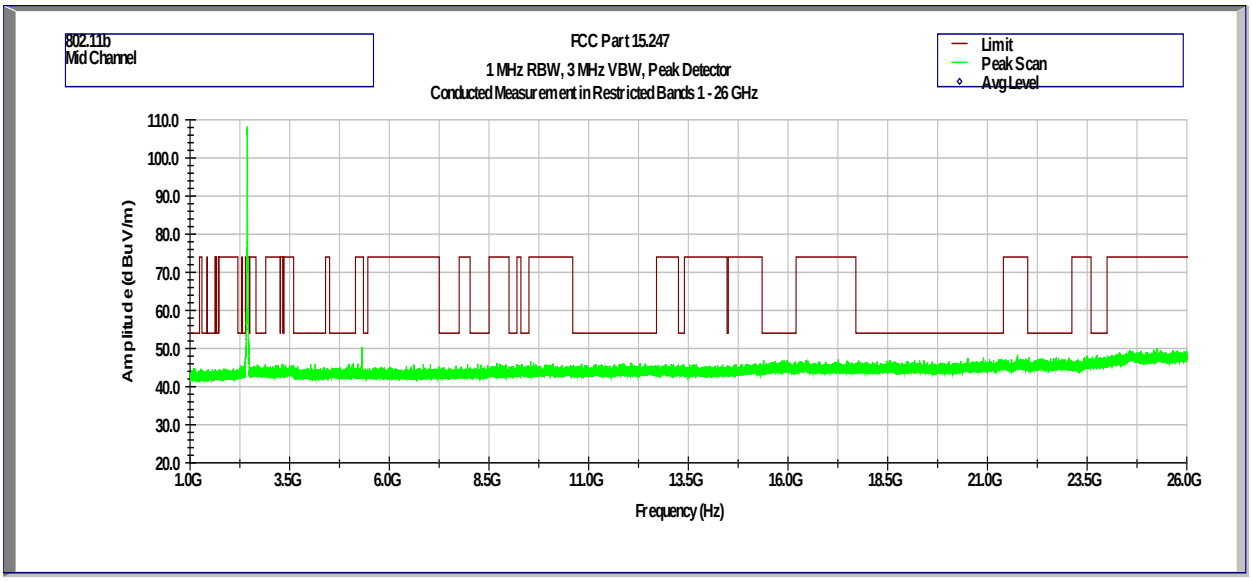


Tx @ 2437MHz 802.11b

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

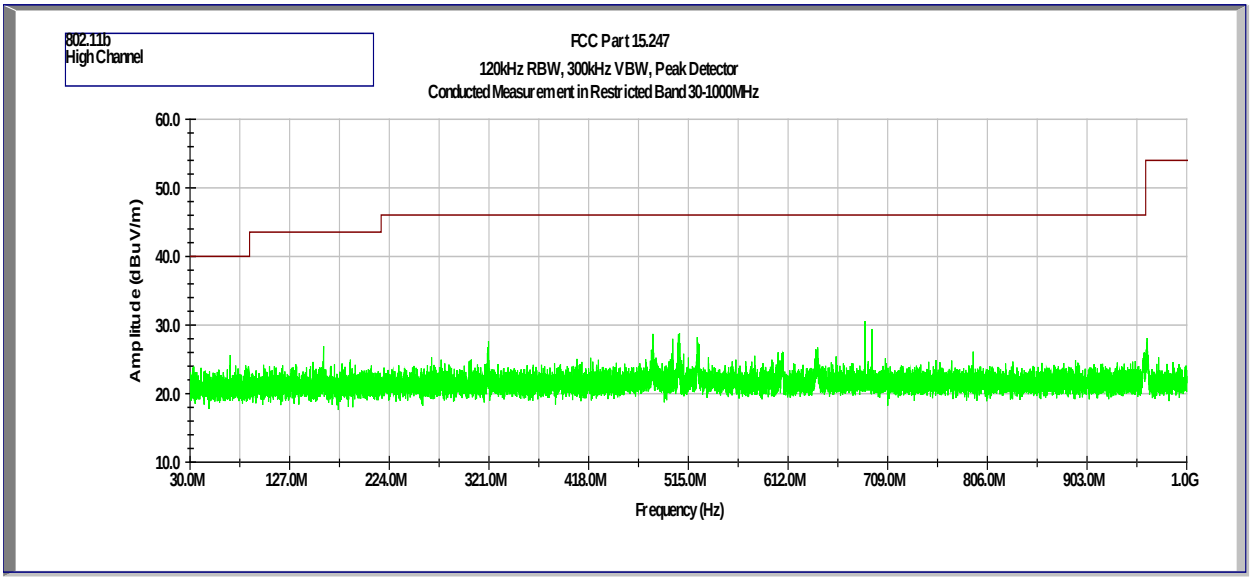


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

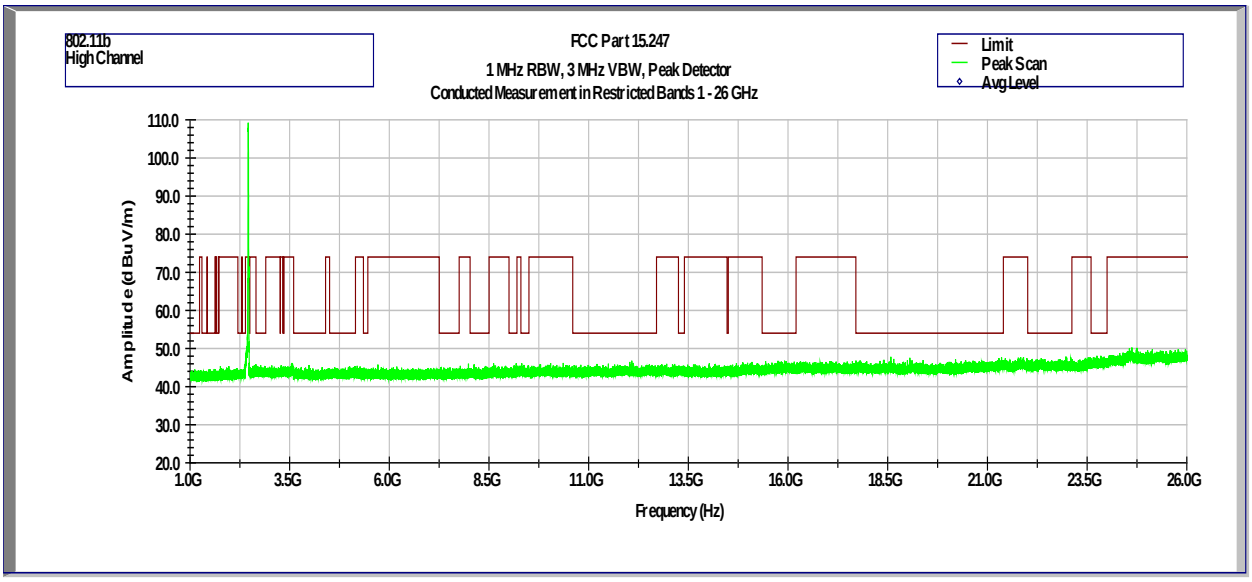


Tx @ 2462MHz 802.11b

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

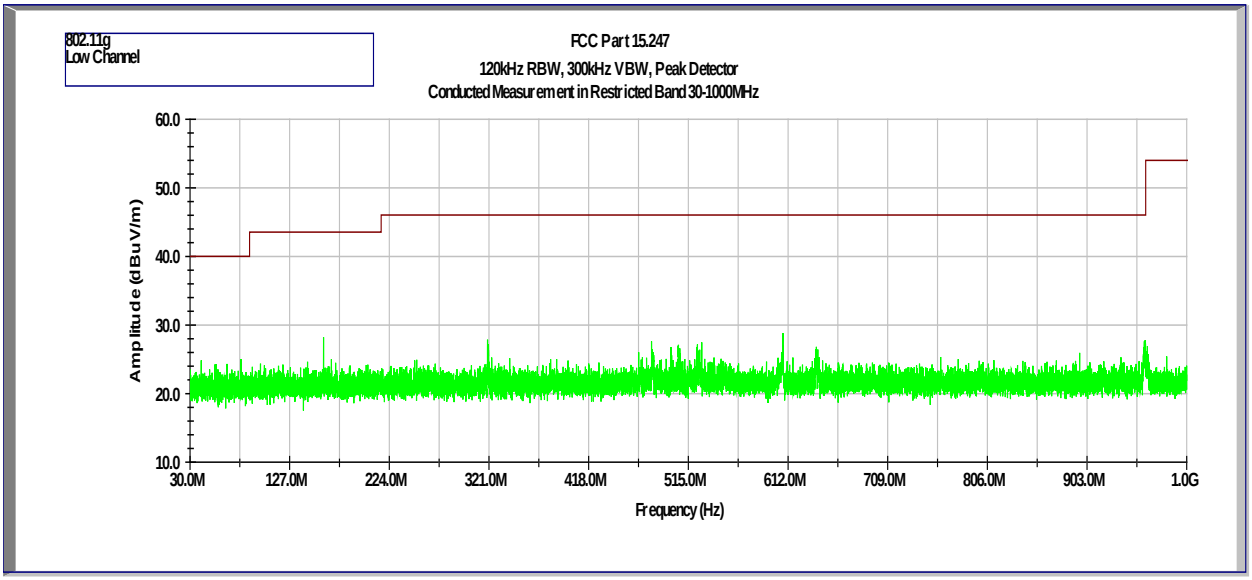


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

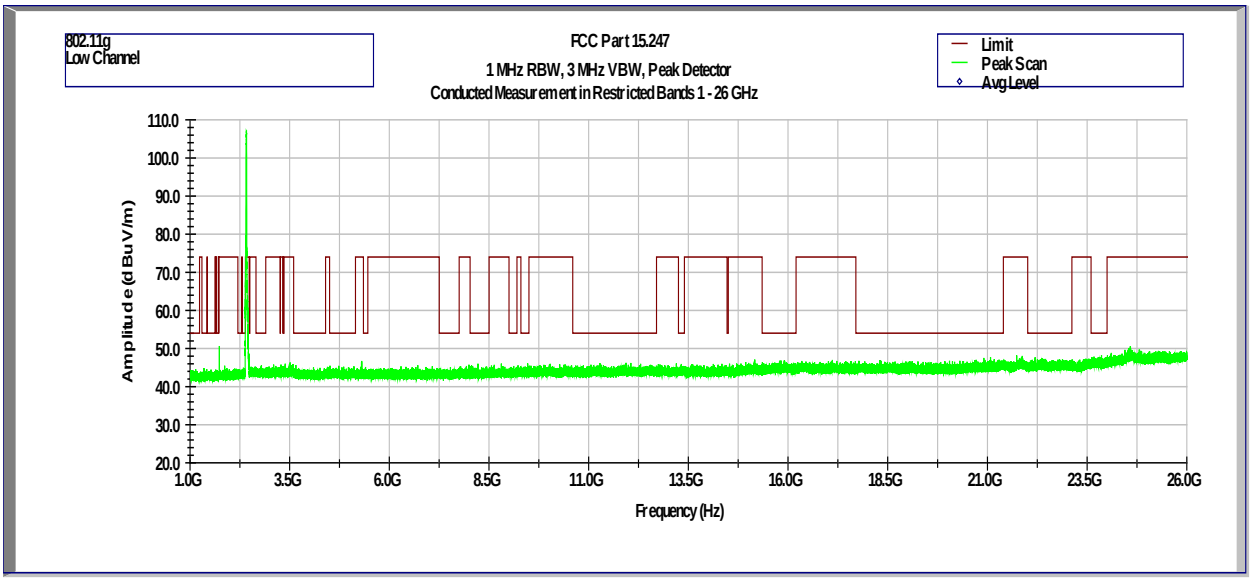


Tx @ 2412MHz 802.11g

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

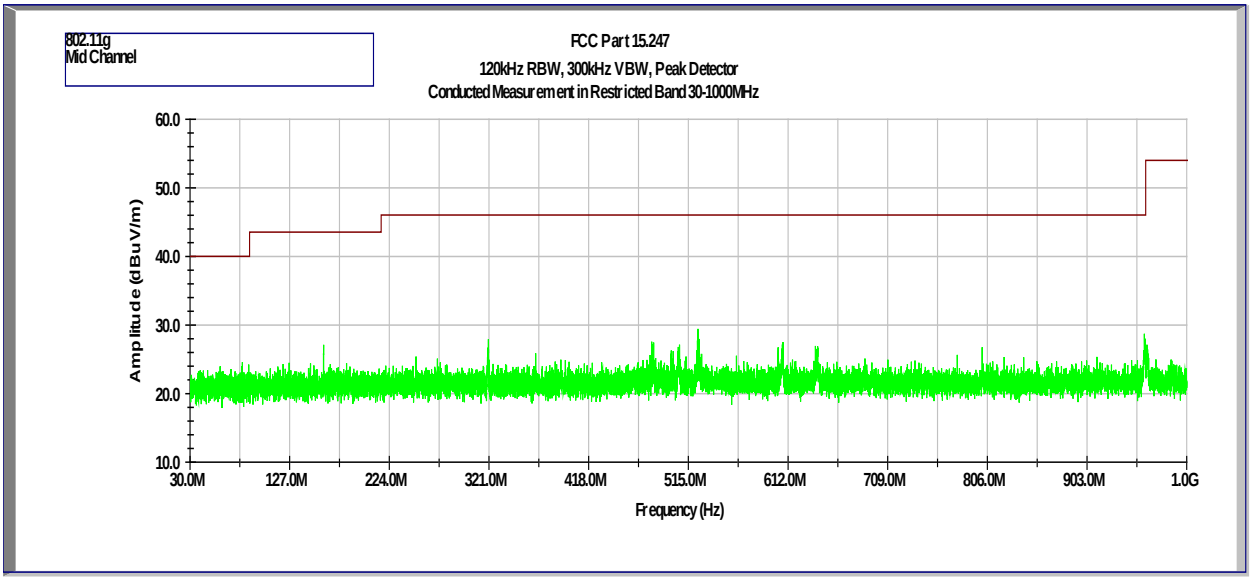


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

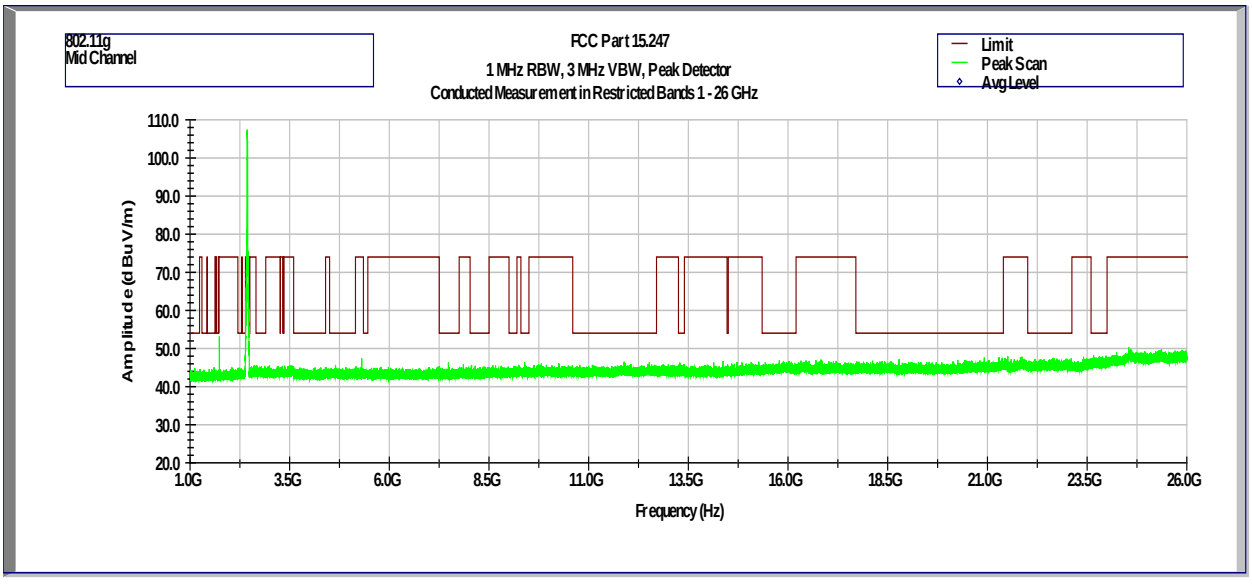


Tx @ 2437MHz 802.11g

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz



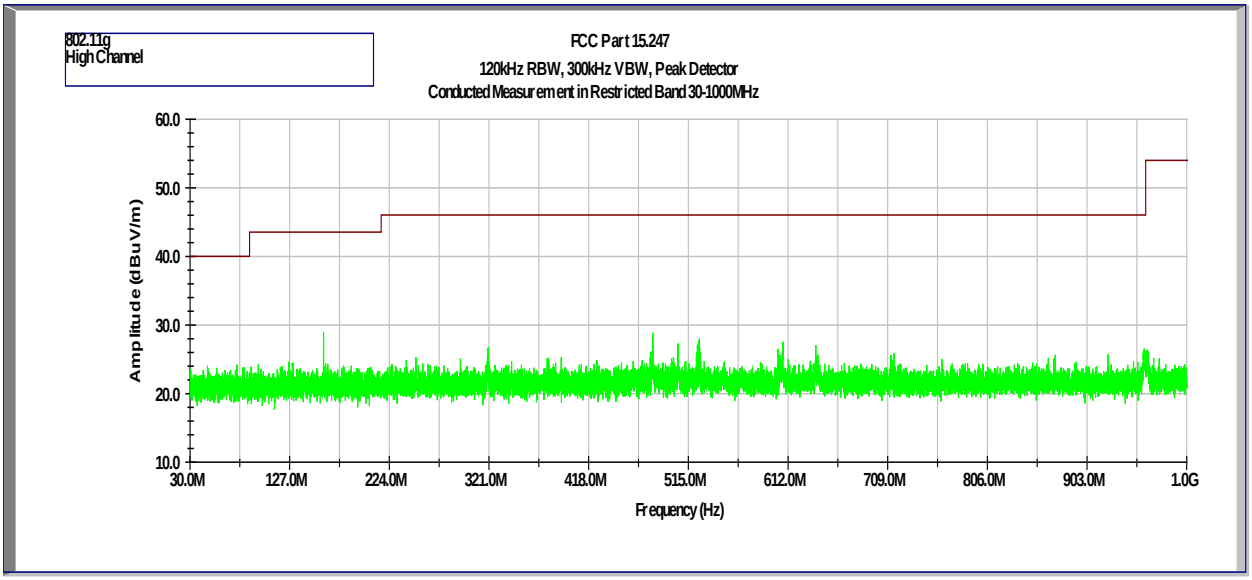
Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz



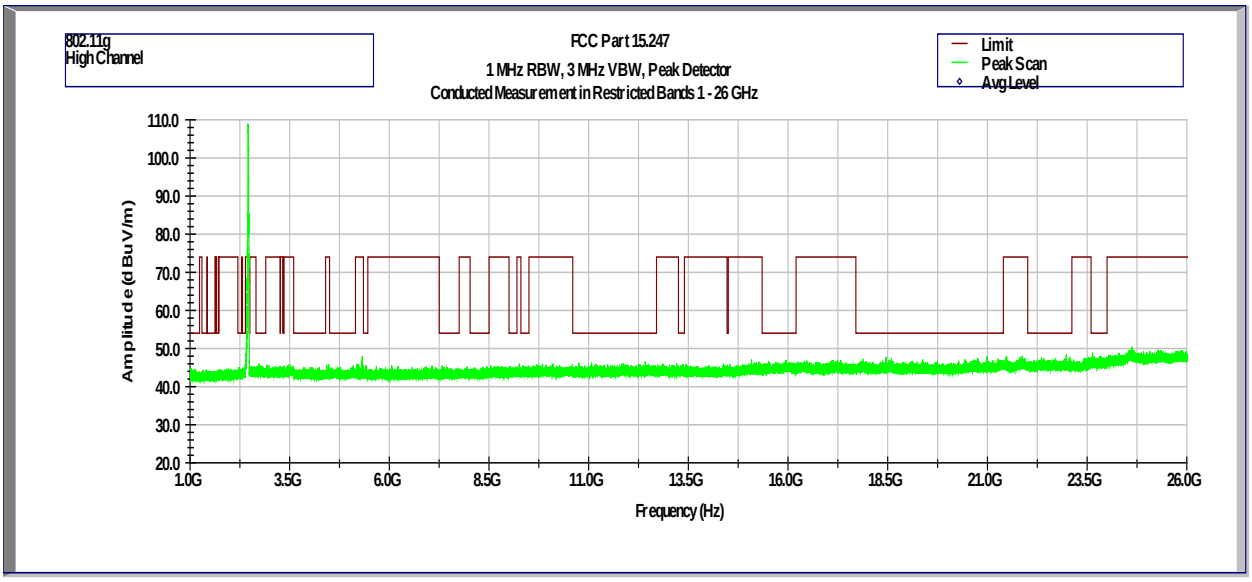
Frequency GHz	Peak dBuV	Limit (dBc) dBuV	Margin dB
1.7375	52.6	78.0	-25.4

Tx @ 2462MHz 802.11g

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

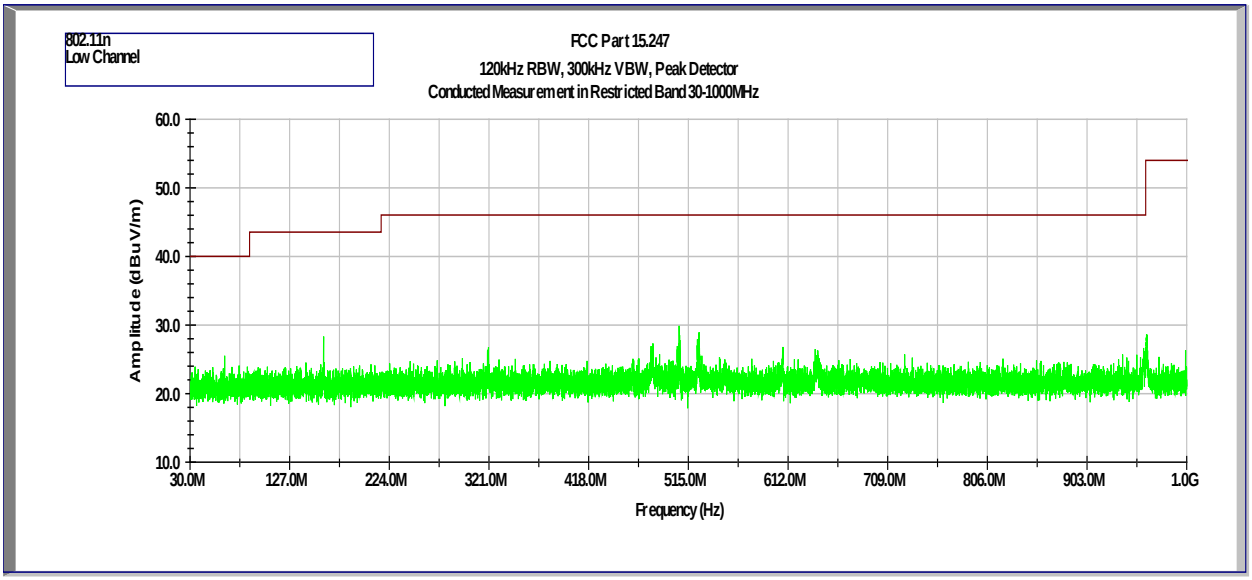


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

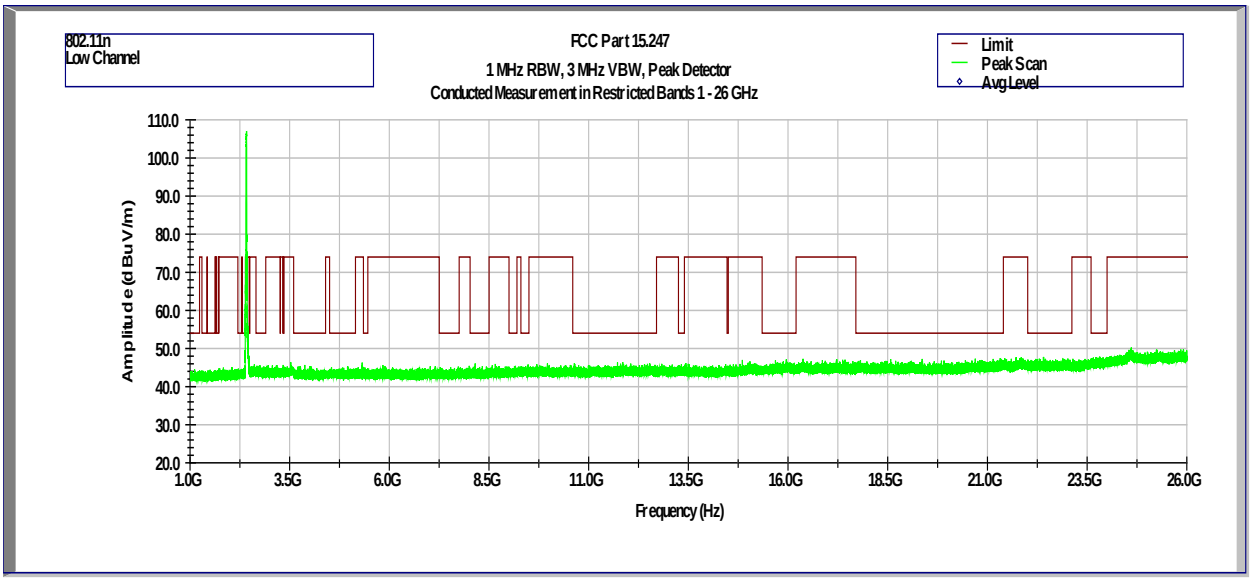


Tx @ 2412MHz 802.11n

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

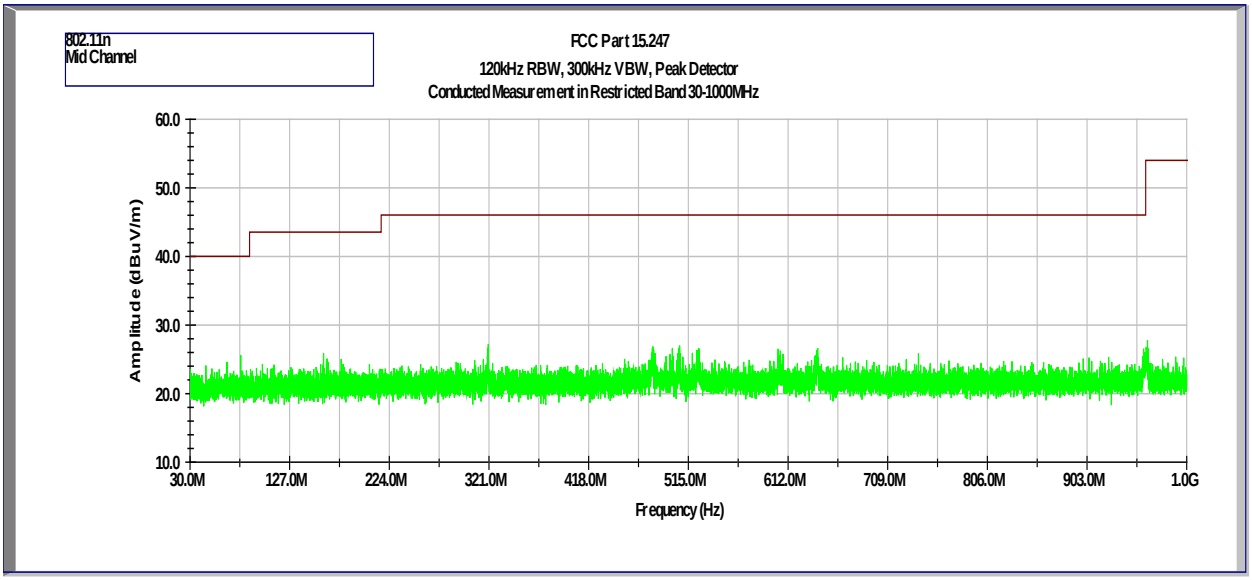


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

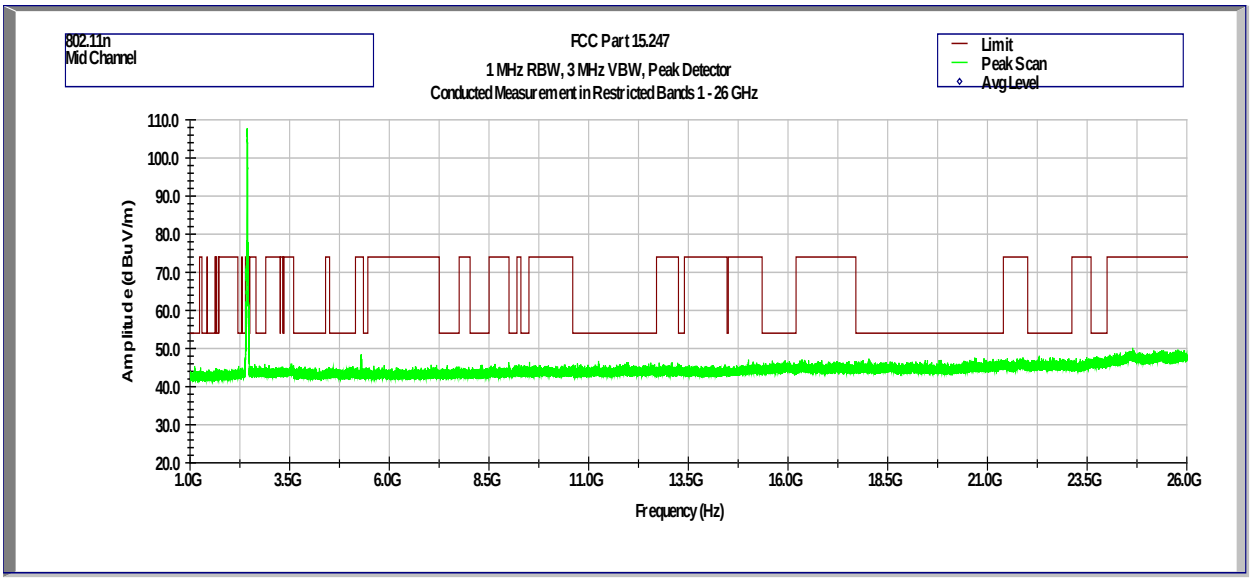


Tx @ 2437MHz 802.11n

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz

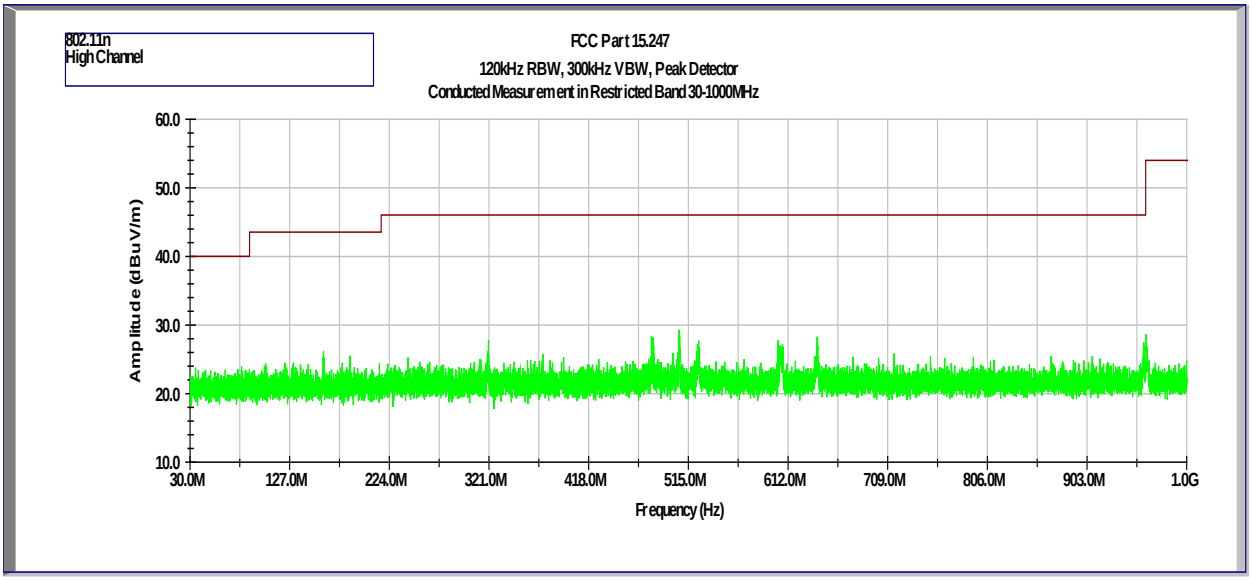


Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz

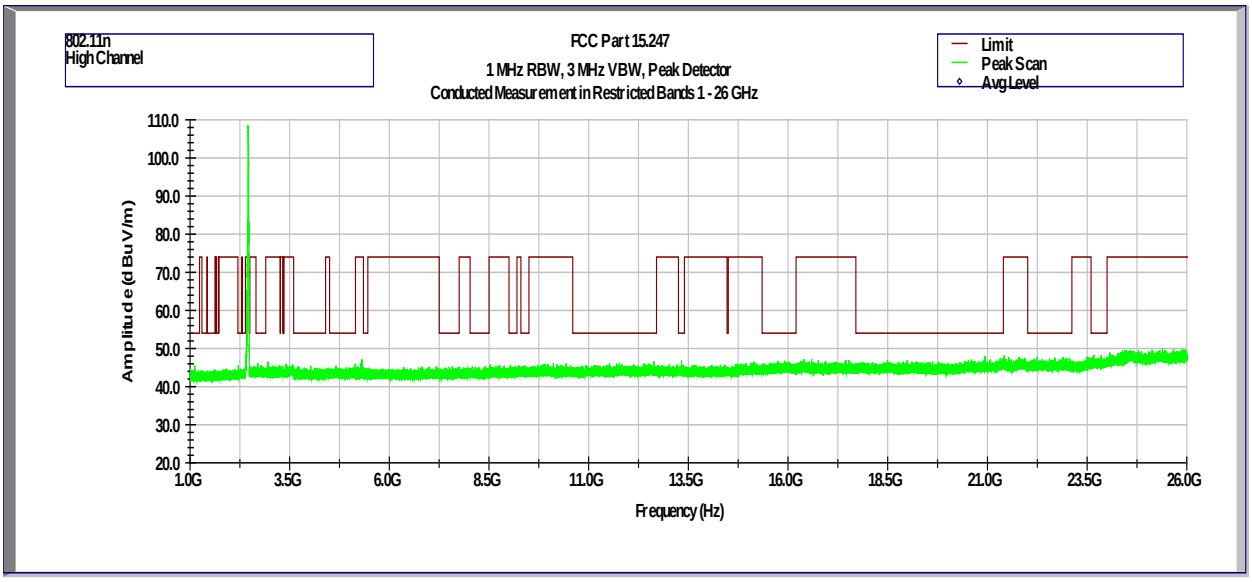


Tx @ 2462MHz 802.11n

Out-of-Band Spurious Emissions at Antenna Port - 30 MHz to 1 GHz



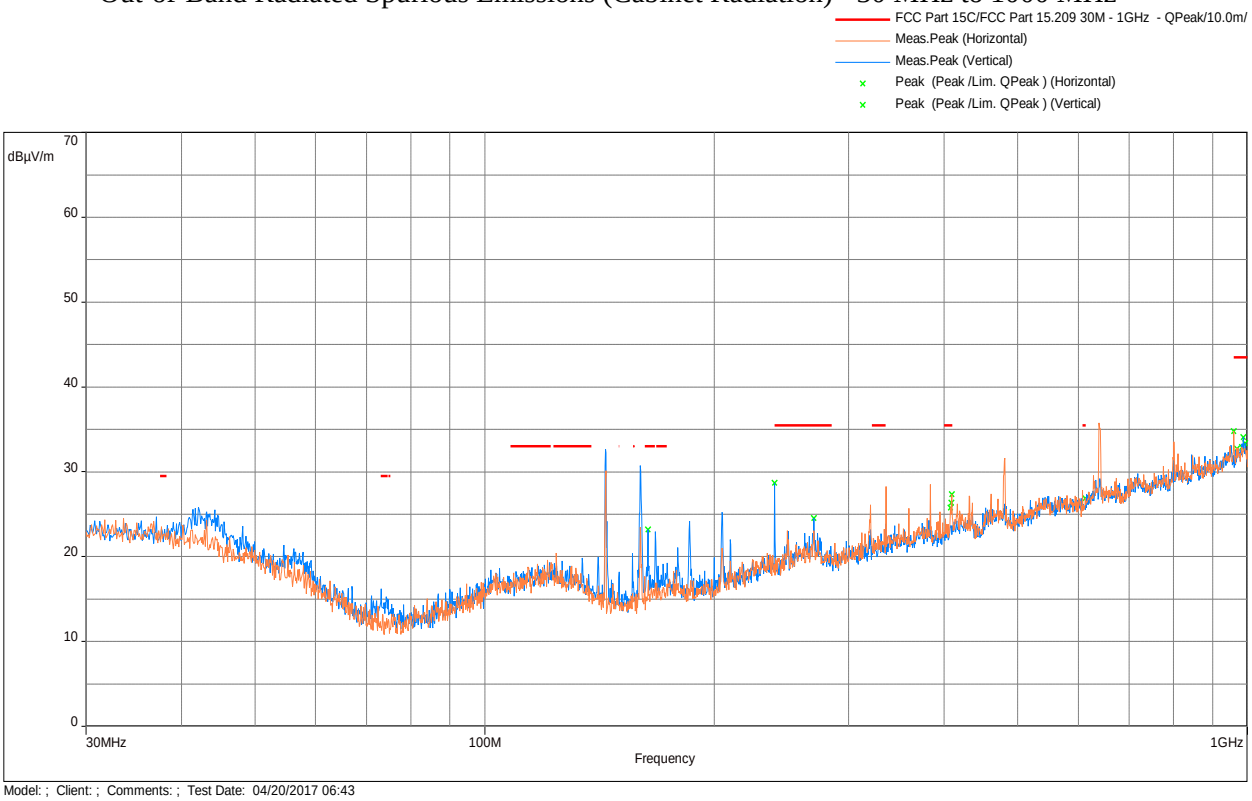
Out-of-Band Spurious Emissions at Antenna Port - 1 GHz to 26 GHz



Out-of-Band Radiated Spurious Emissions (Cabinet Radiation)

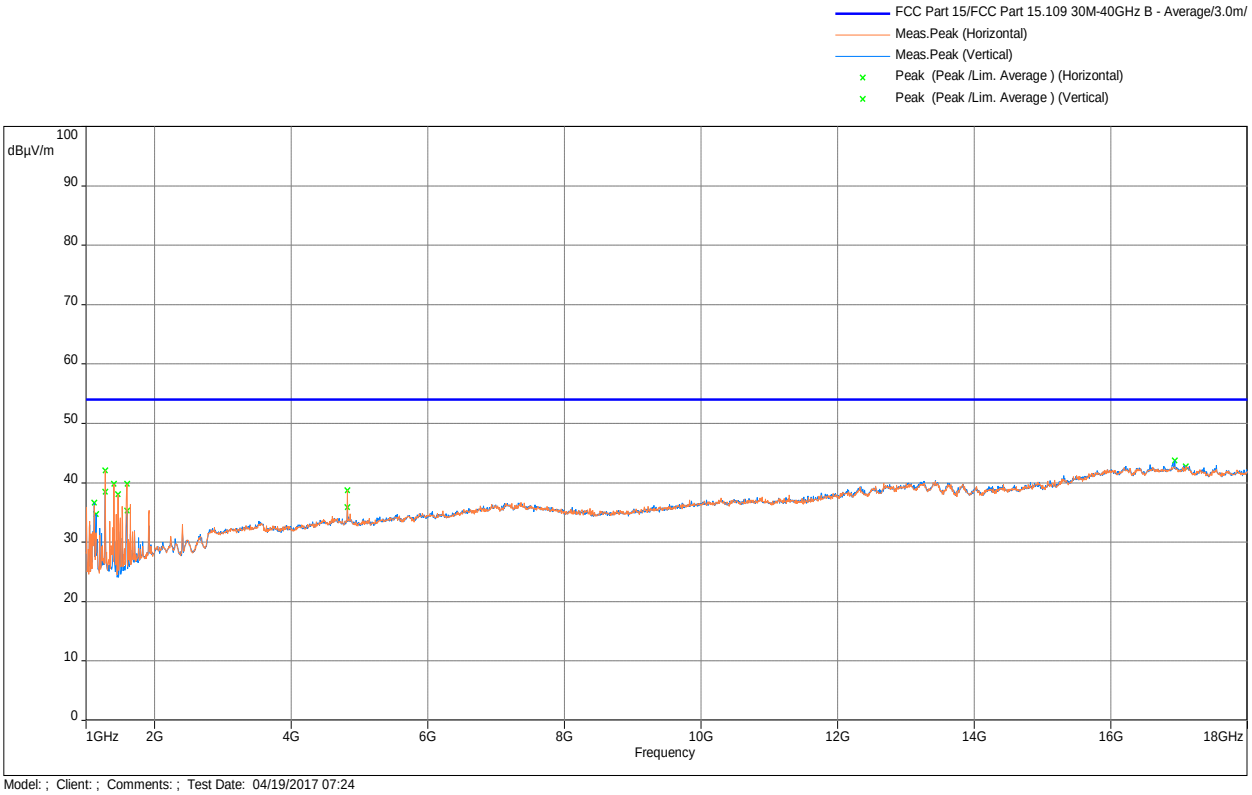
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11b 2412MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



Frequency (MHz)	Peak (dBµV/m)	Lim. QP (dBµV/m)	Margin (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
240.005	28.6	35.5	-6.9	1.98	256	Vertical	-8.31

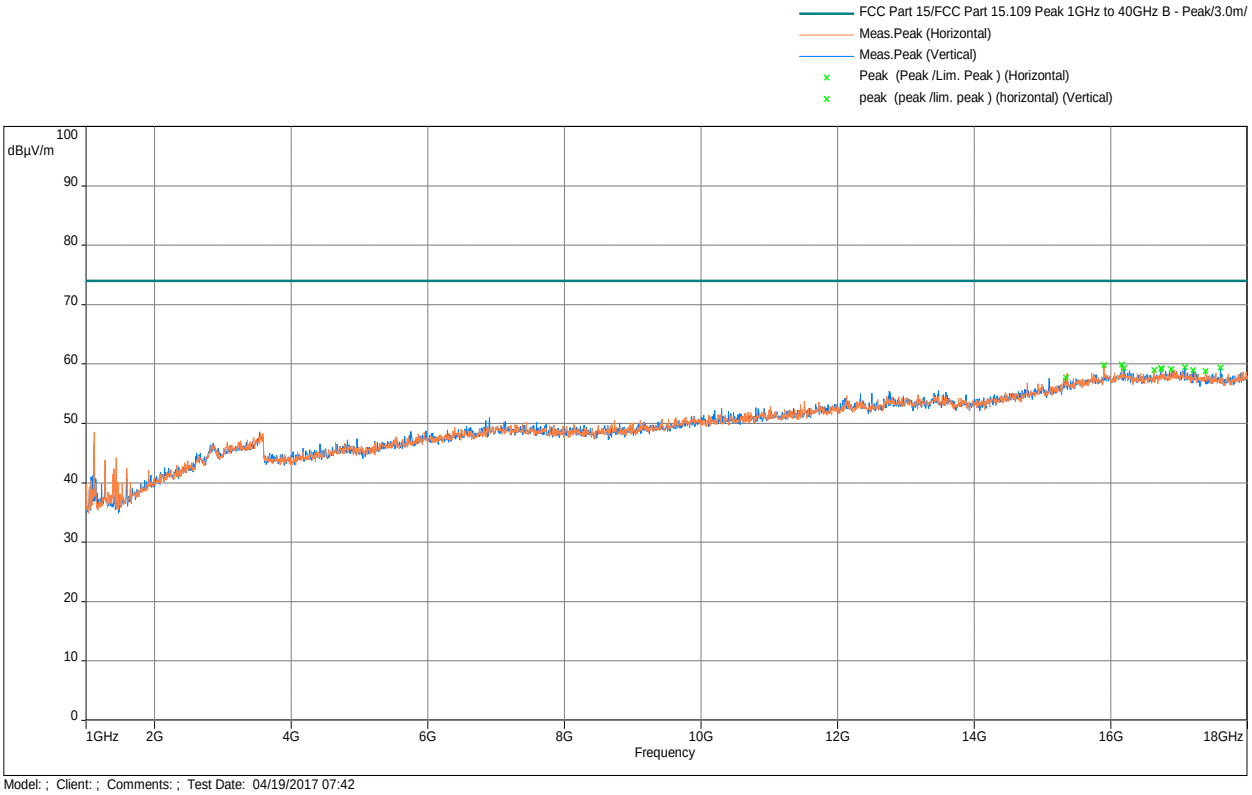
Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 07:24

Frequency (MHz)	Ave (dBµV/m)	Lim. Average (dBµV/m)	Margin (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
1278.8	42.1	54	-11.9	1.02	243	Horizontal	-3.32
4823.3	38.7	54	-15.3	1.99	304	Horizontal	5.82

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

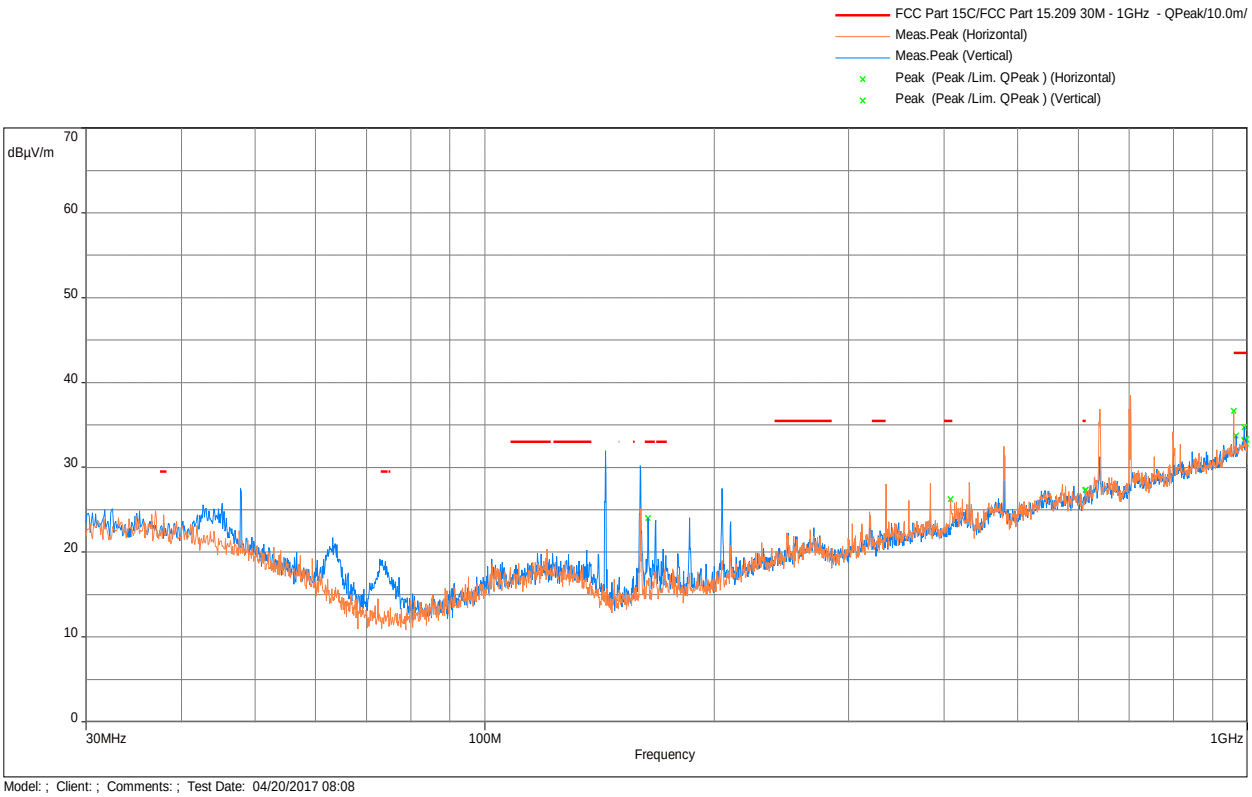


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 07:42

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

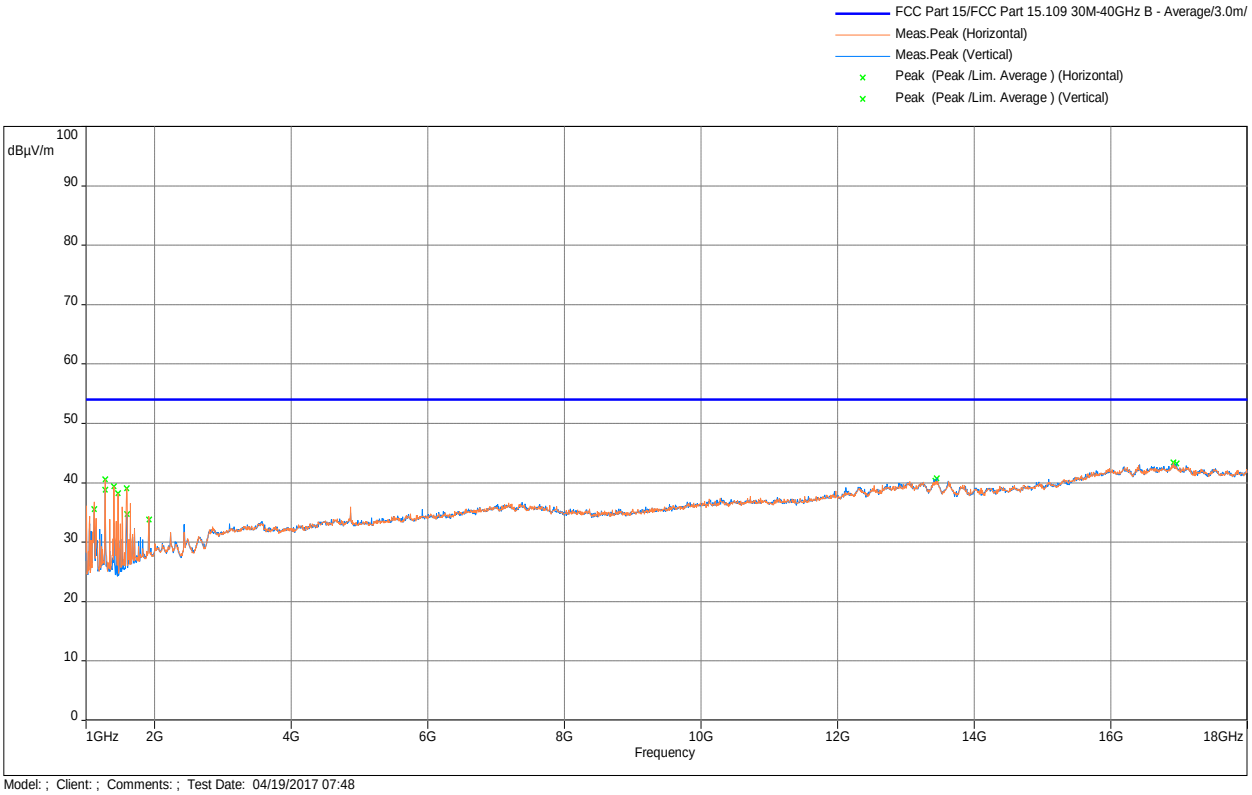
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11b 2437MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



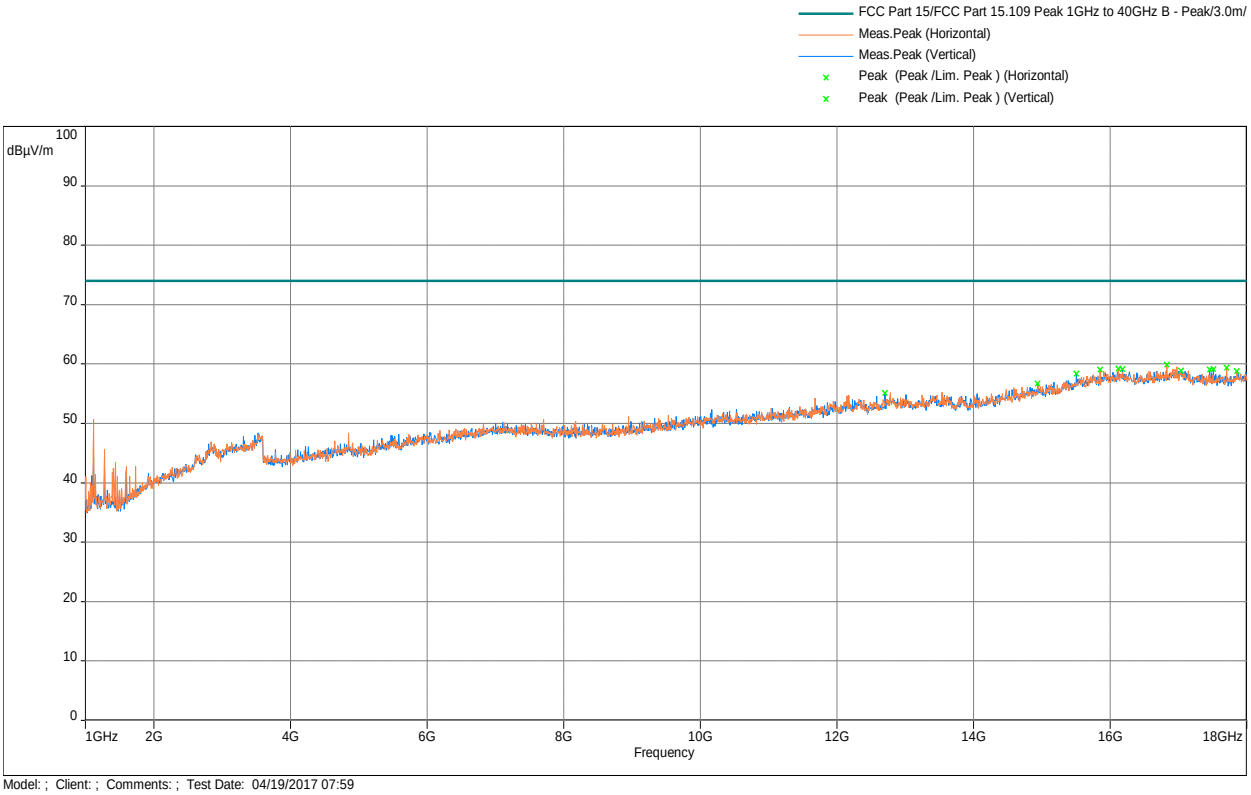
Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:08

Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 07:48

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

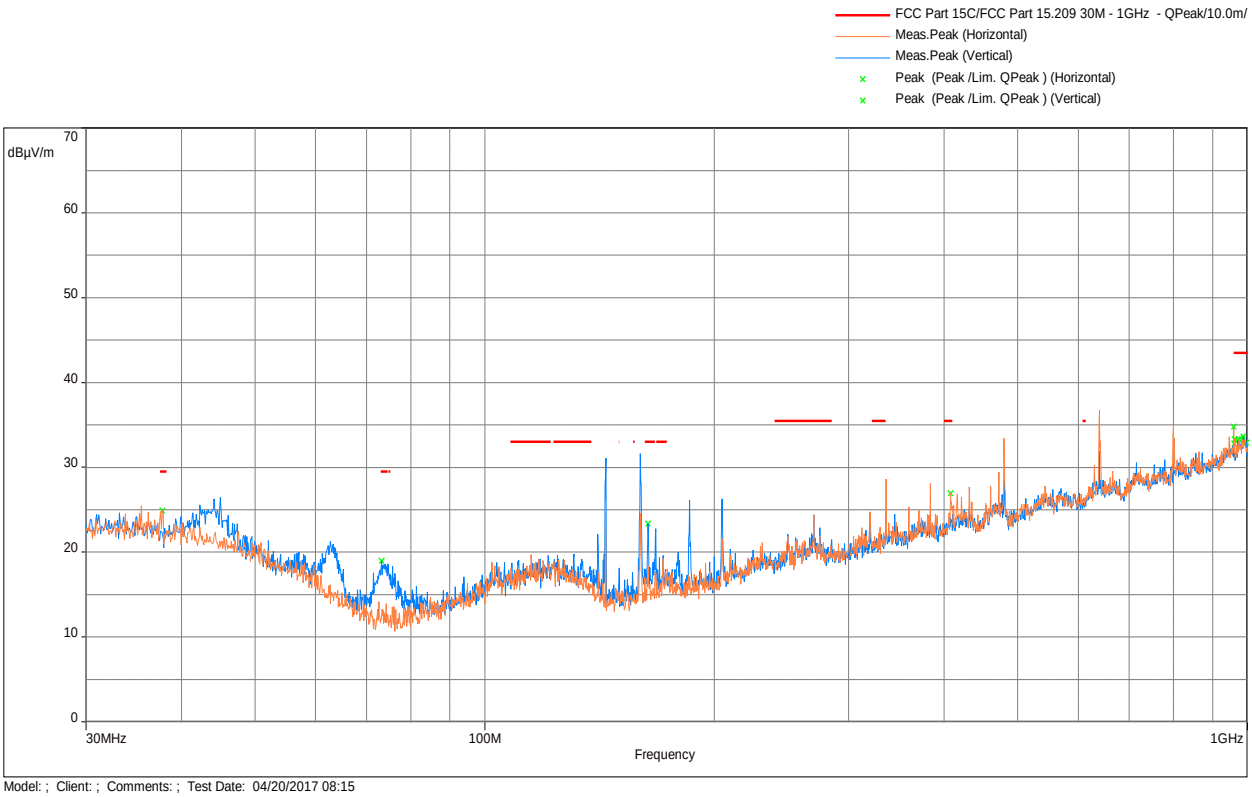


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 07:59

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

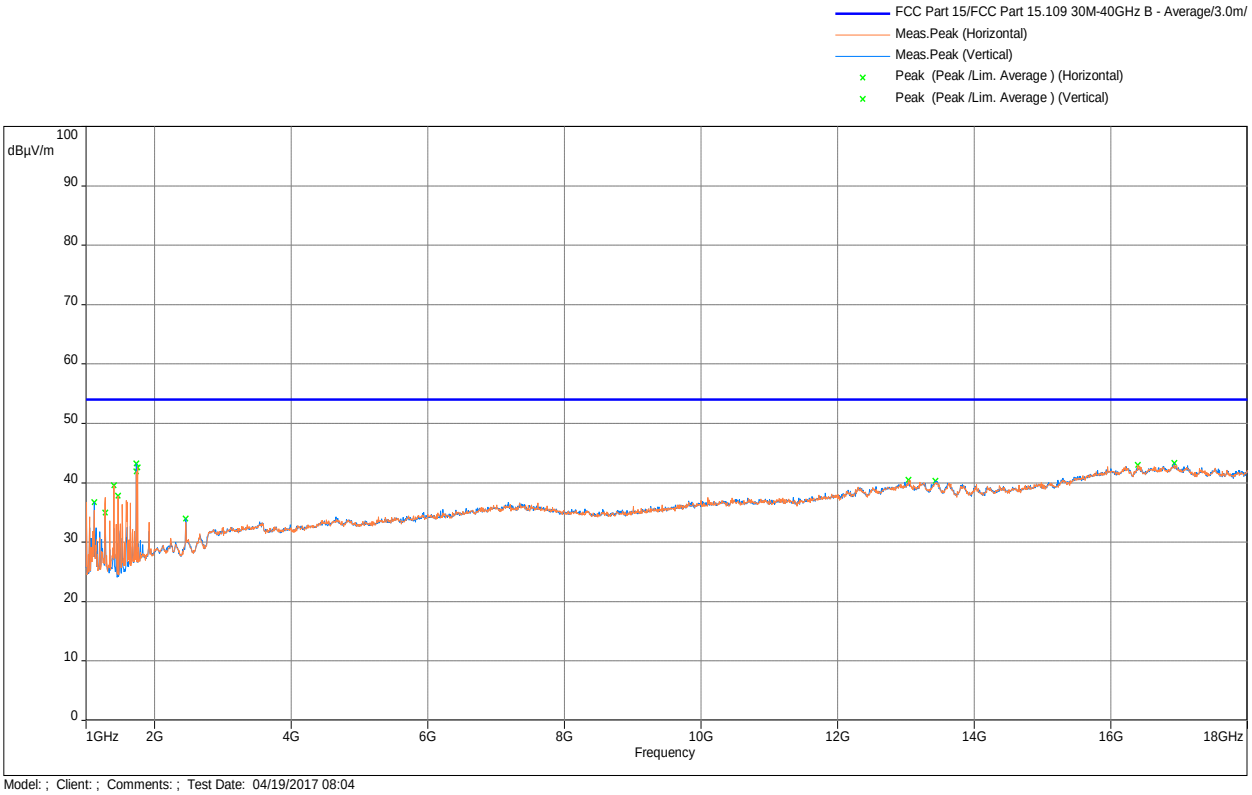
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11b 2462MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



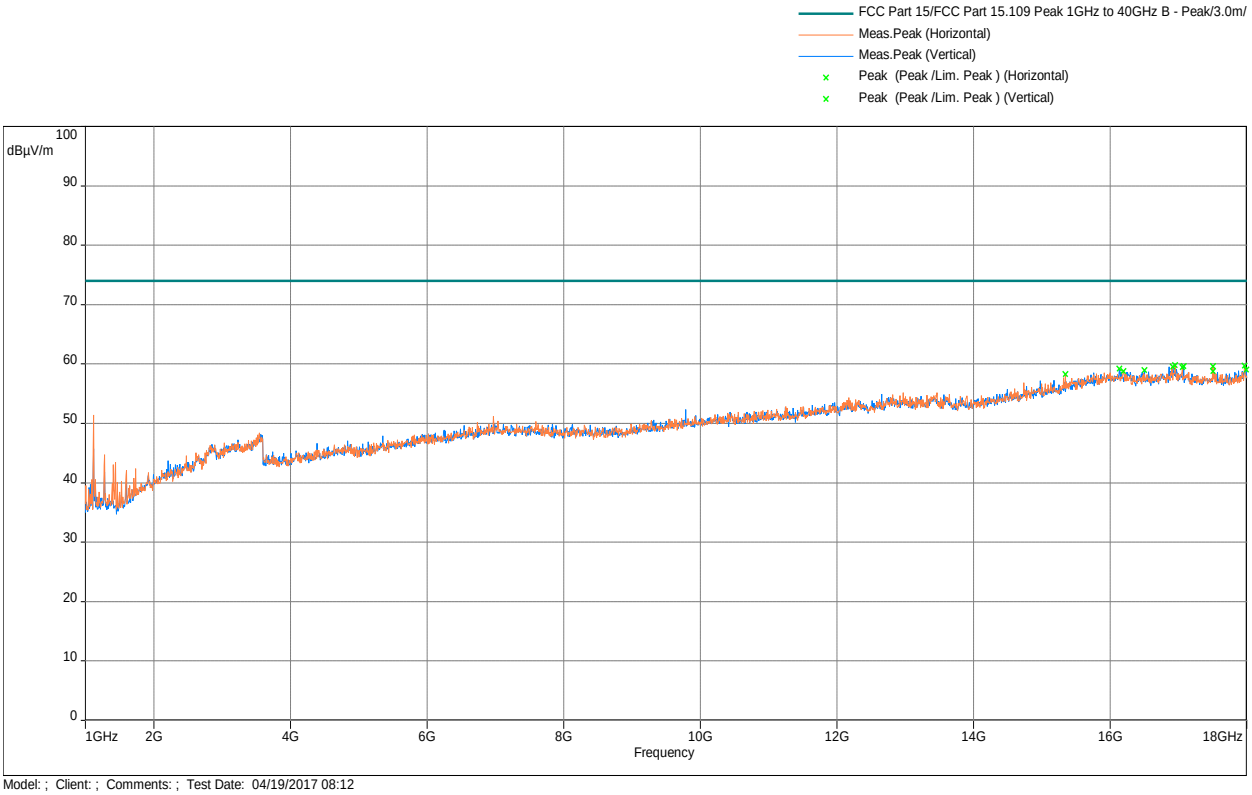
Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:15

Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 08:04

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

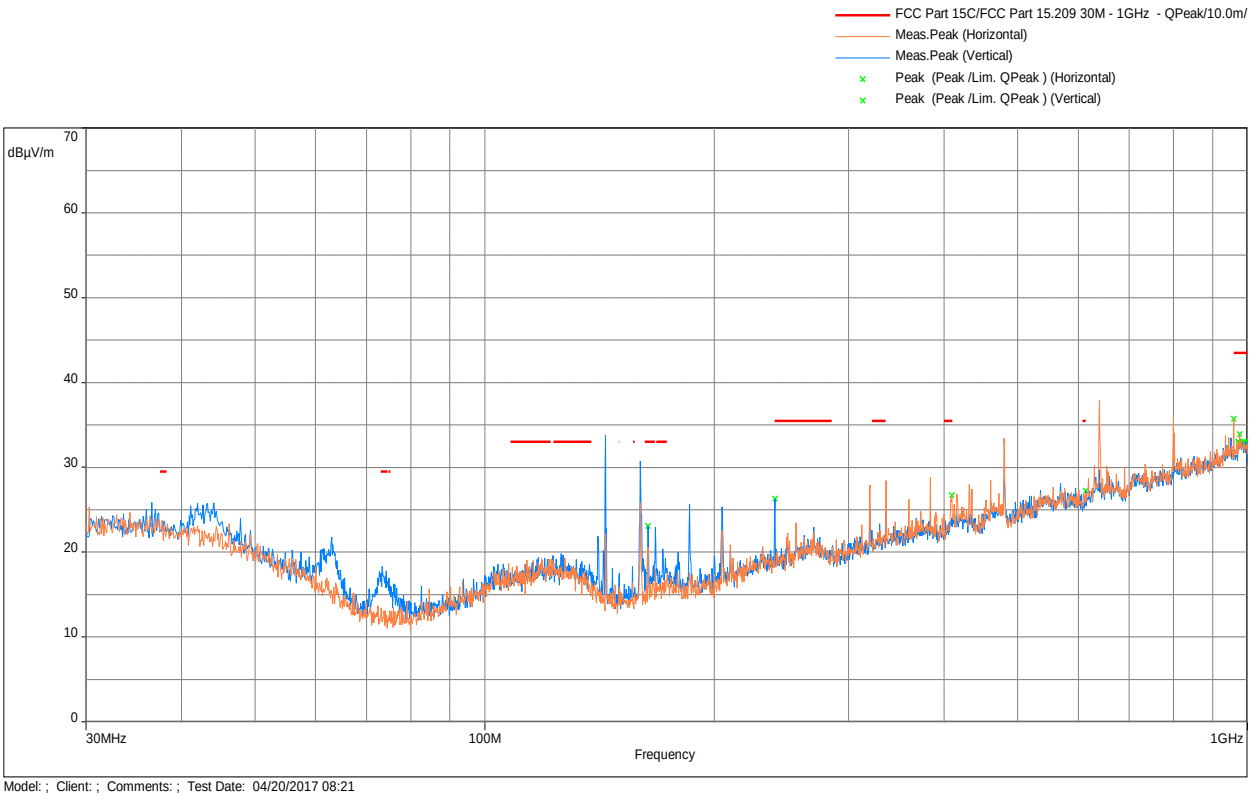


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 08:12

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11g 2412MHz

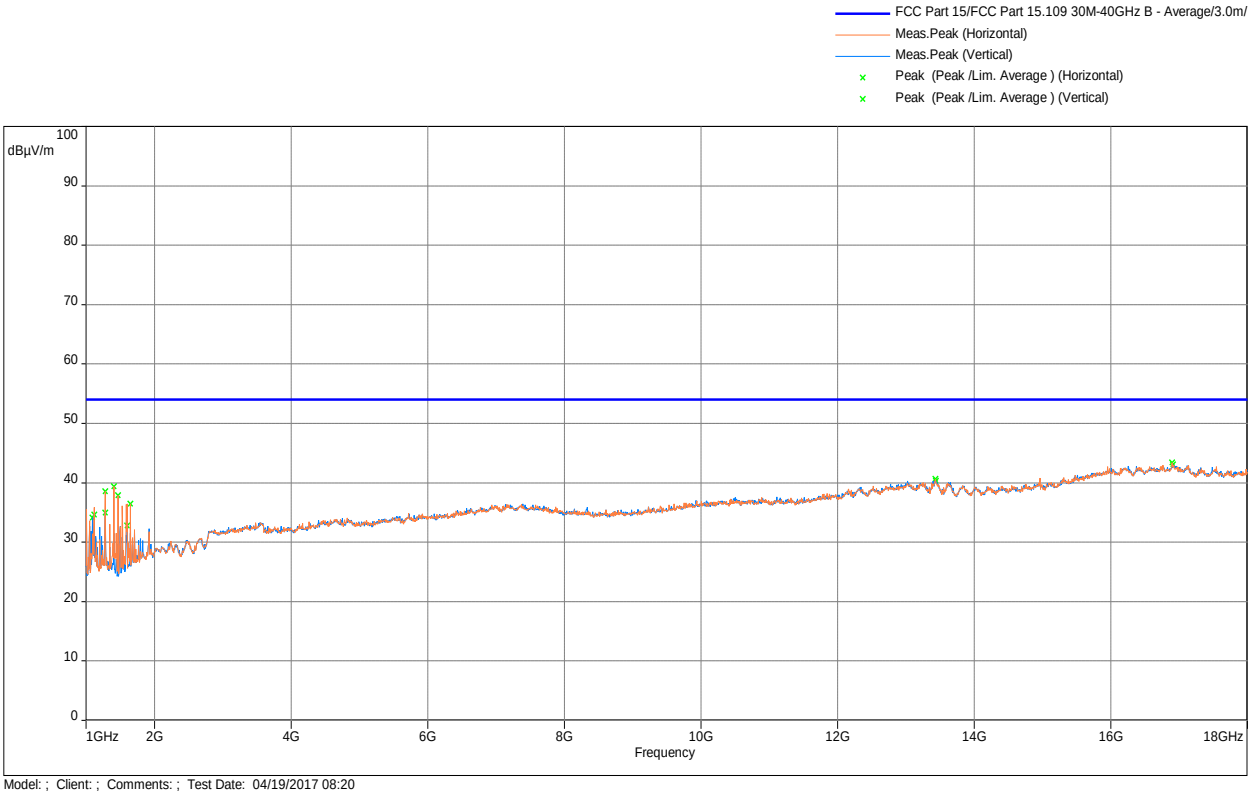
Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:21

Frequency (MHz)	Peak (dBµV/m)	Lim. QP (dBµV/m)	Margin (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
409.367	26.67	35.5	-8.83	2	316	Horizontal	-3.84

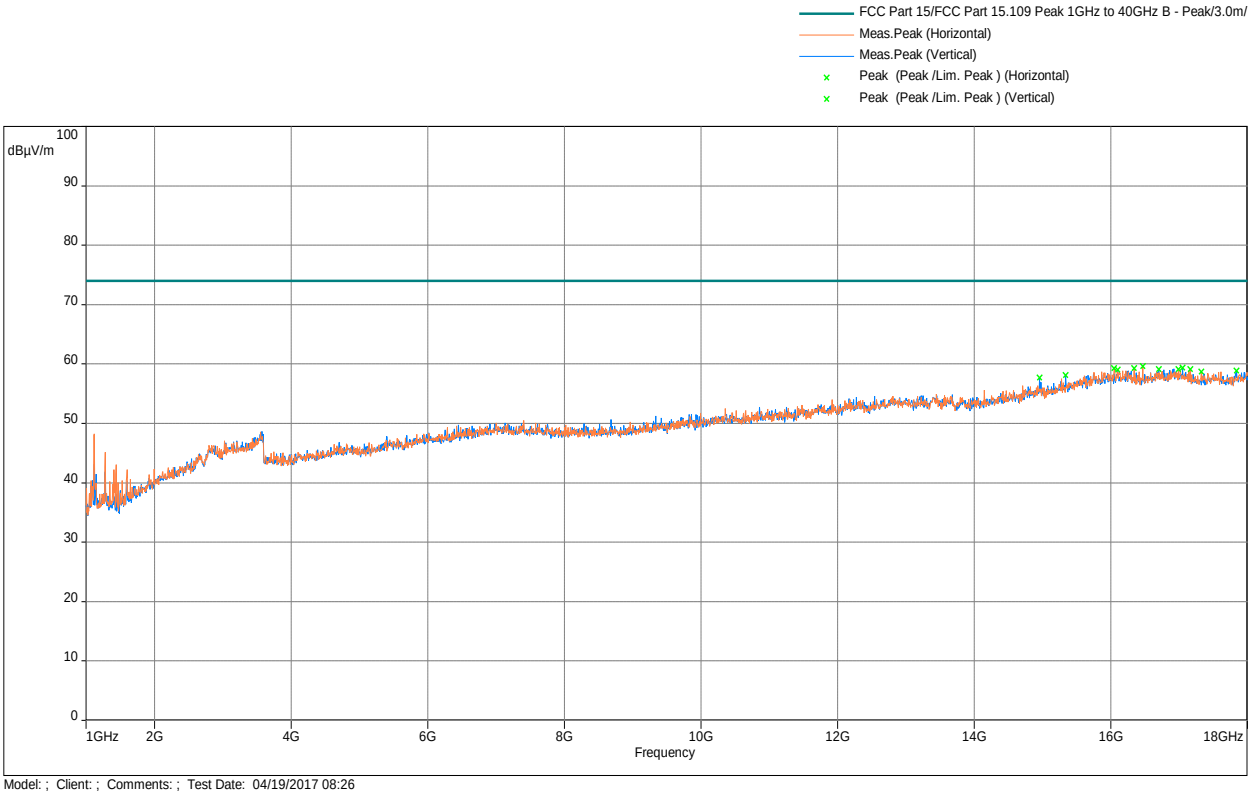
Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 08:20

Frequency (MHz)	Ave (dBµV/m)	Lim. Average (dBµV/m)	Margin (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
1409.7	39.41	54	-14.59	1.01	245	Horizontal	-3.84

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

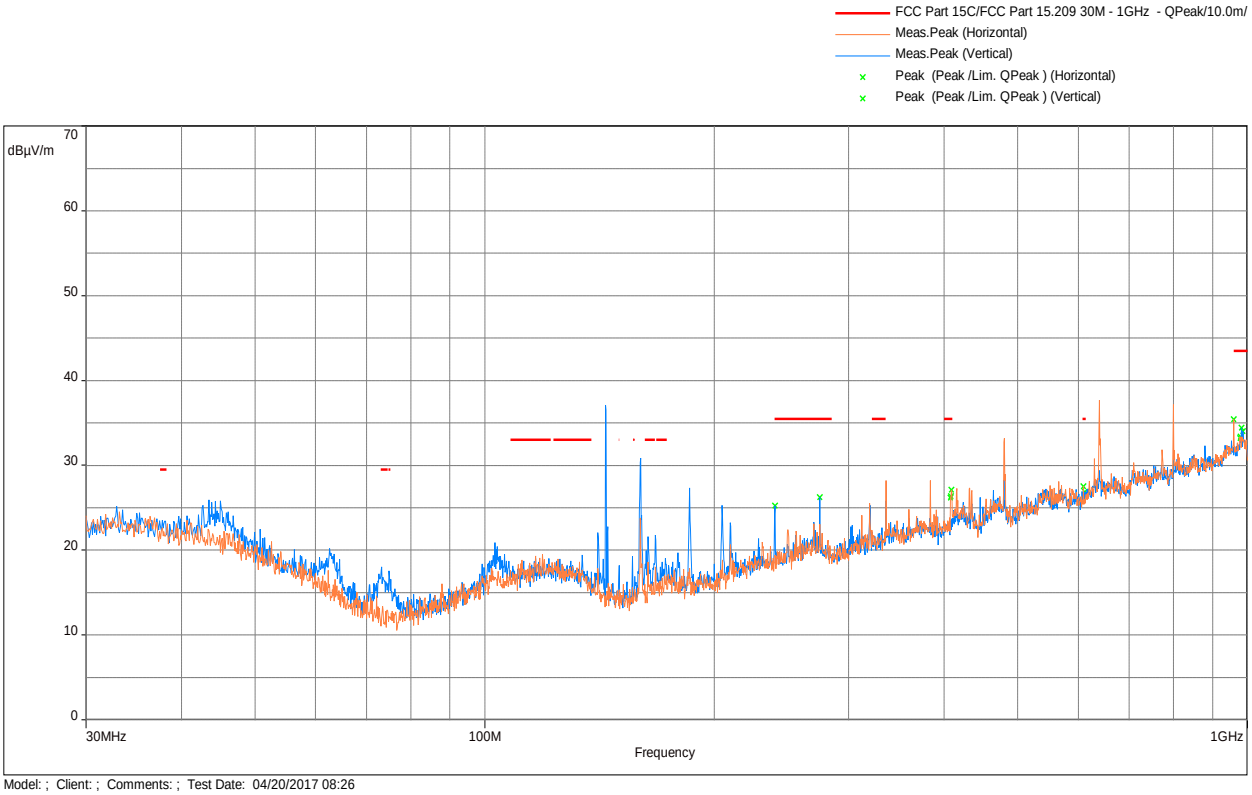


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 08:26

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

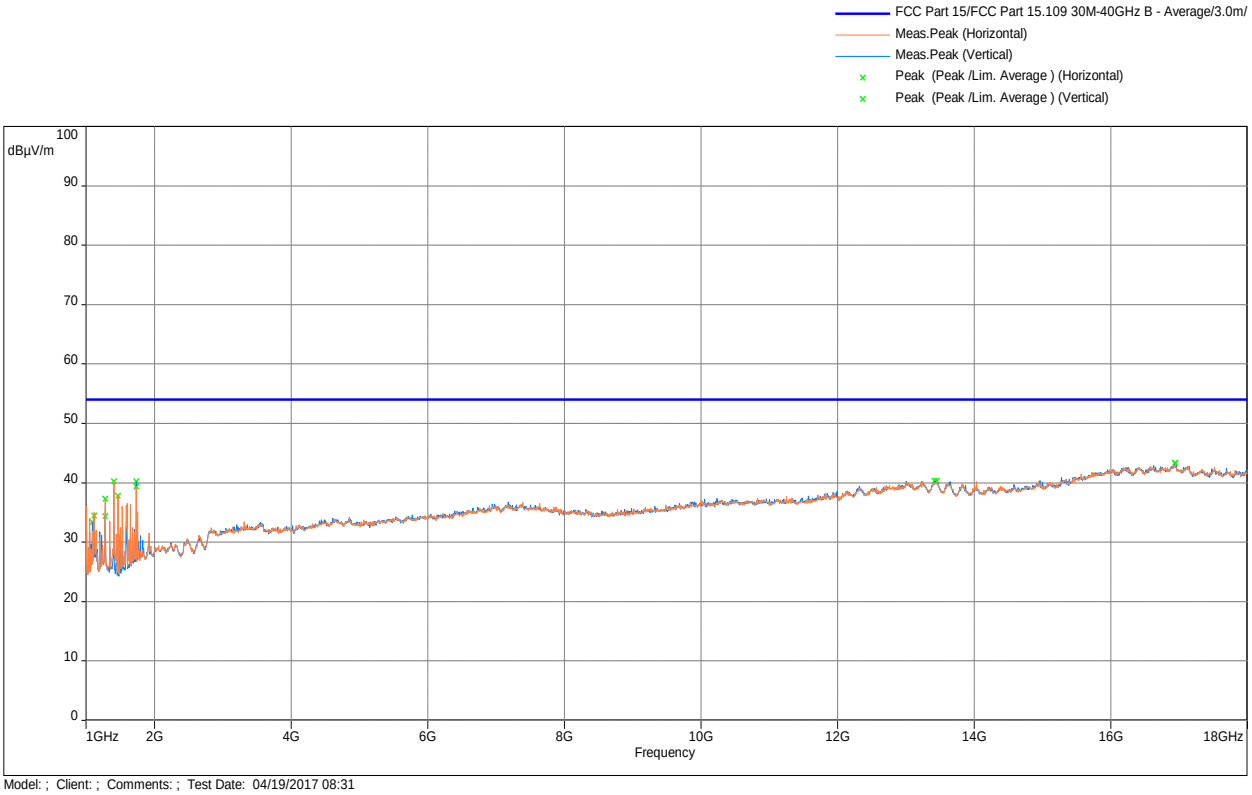
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11g 2437MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



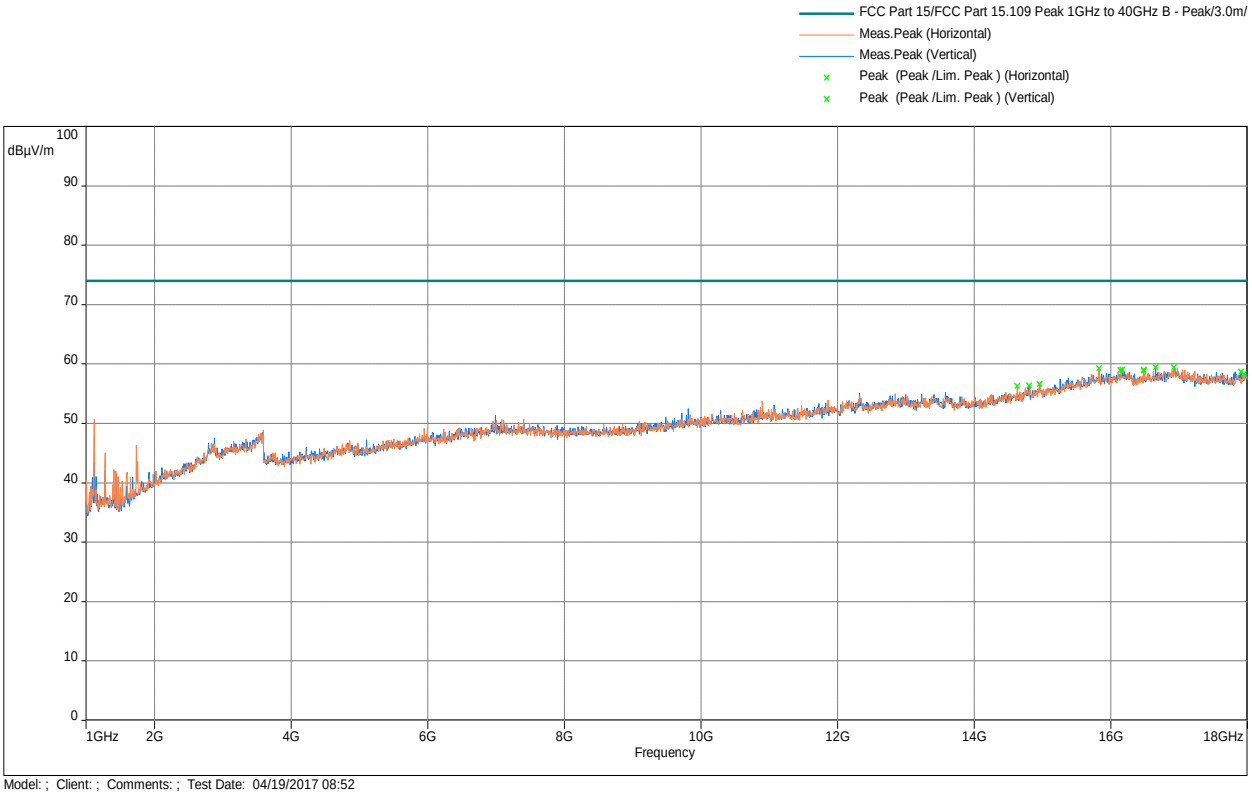
Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:26

Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 08:31

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

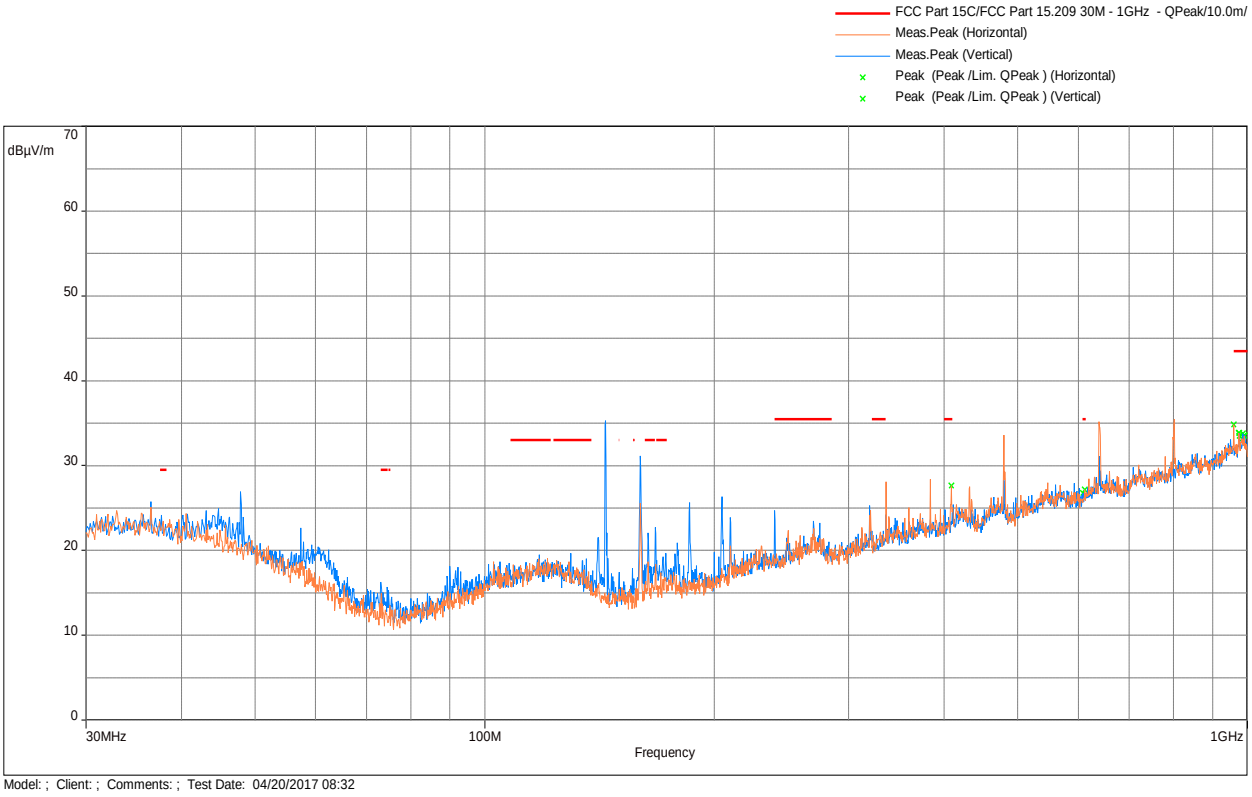


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 08:52

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

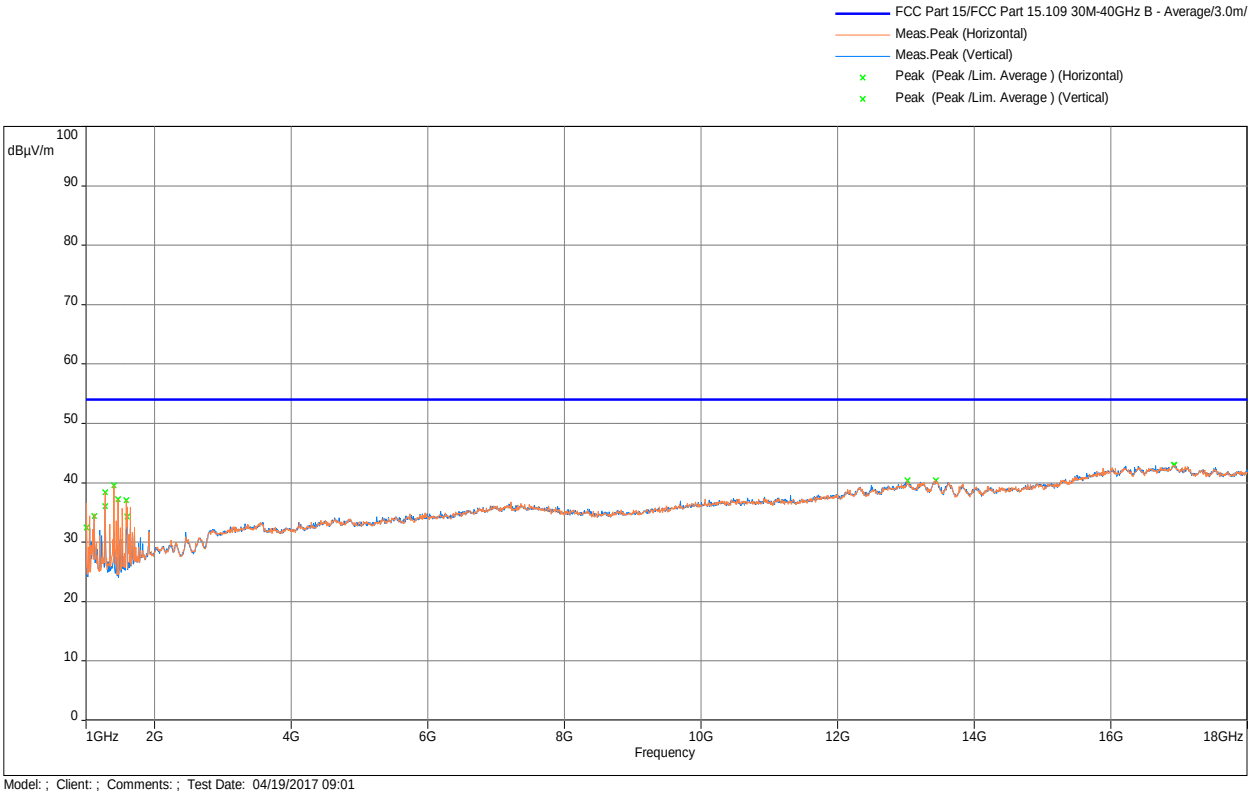
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11g 2462MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



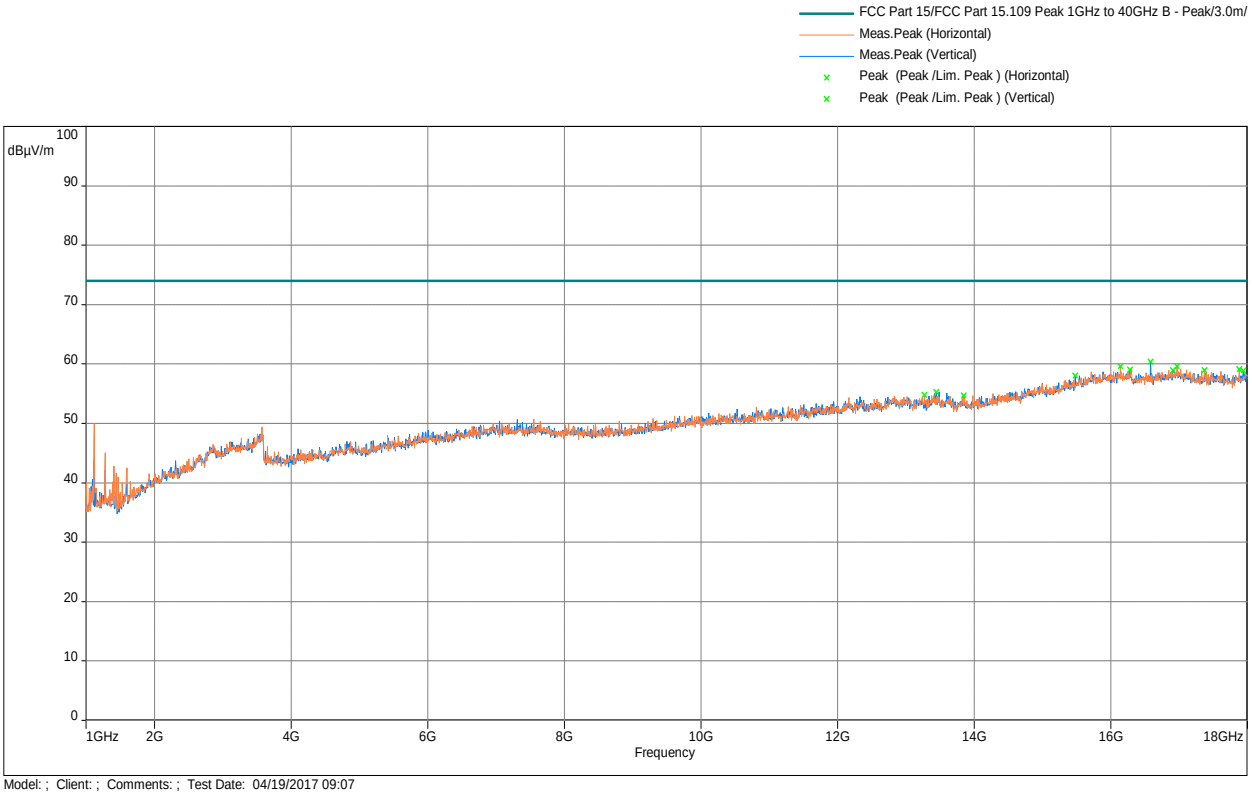
Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:32

Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 09:01

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

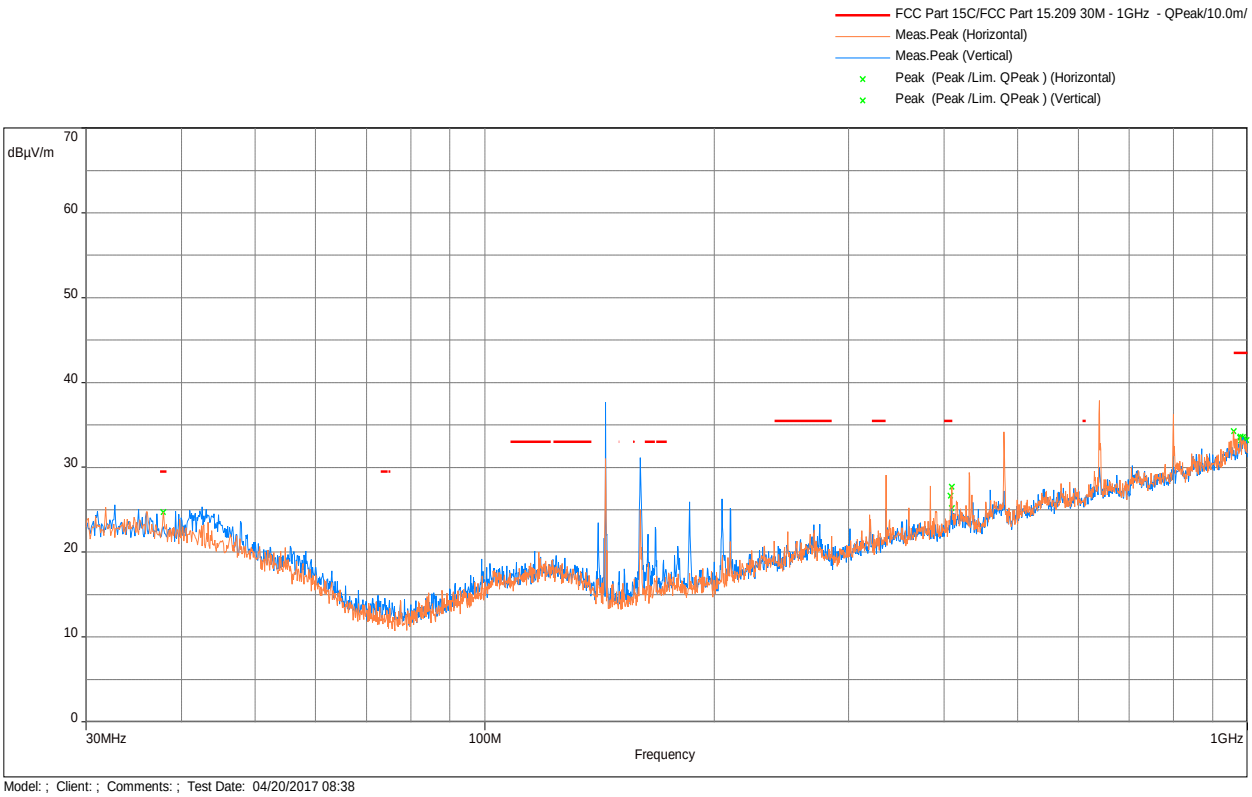


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 09:07

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11n, 2412MHz

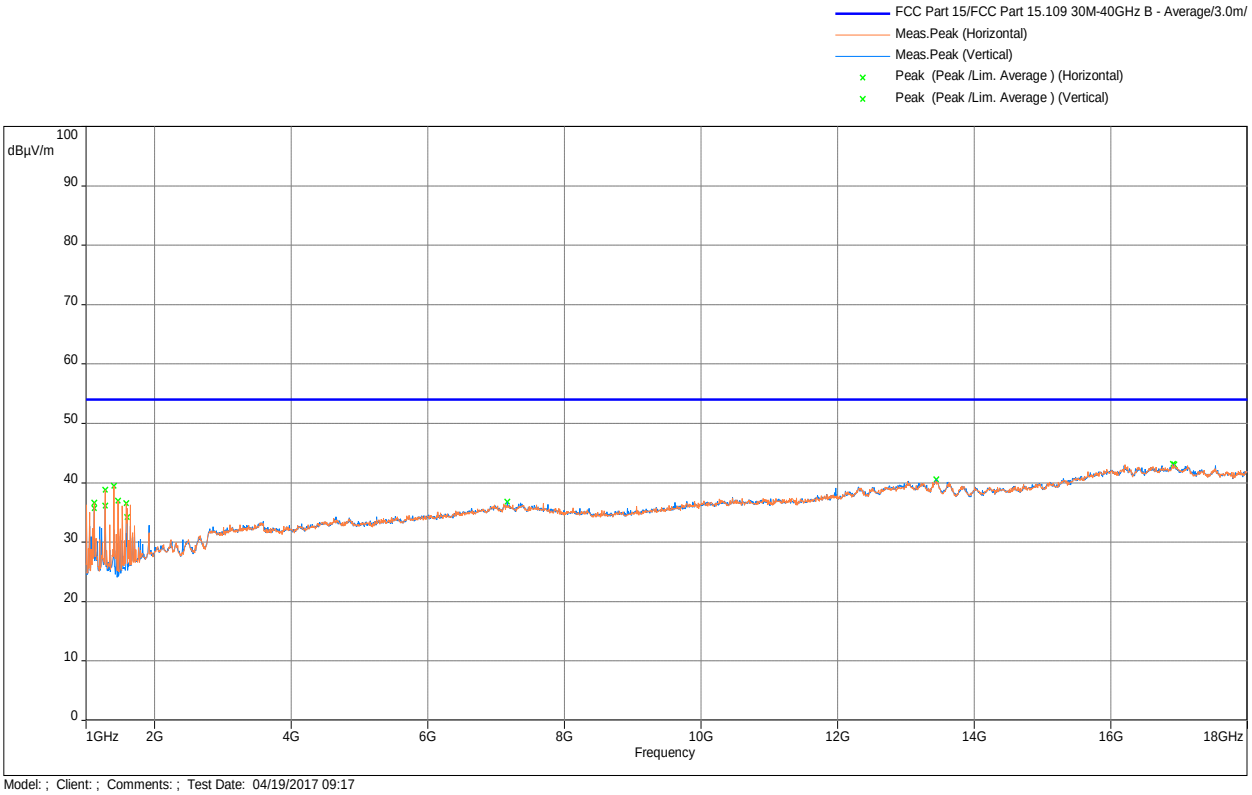
Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:38

Frequency (MHz)	Peak (dBµV/m)	Lim. QP (dBµV/m)	Margin (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
409.561	27.68	35.5	-7.82	2	335.5	Horizontal	-3.82

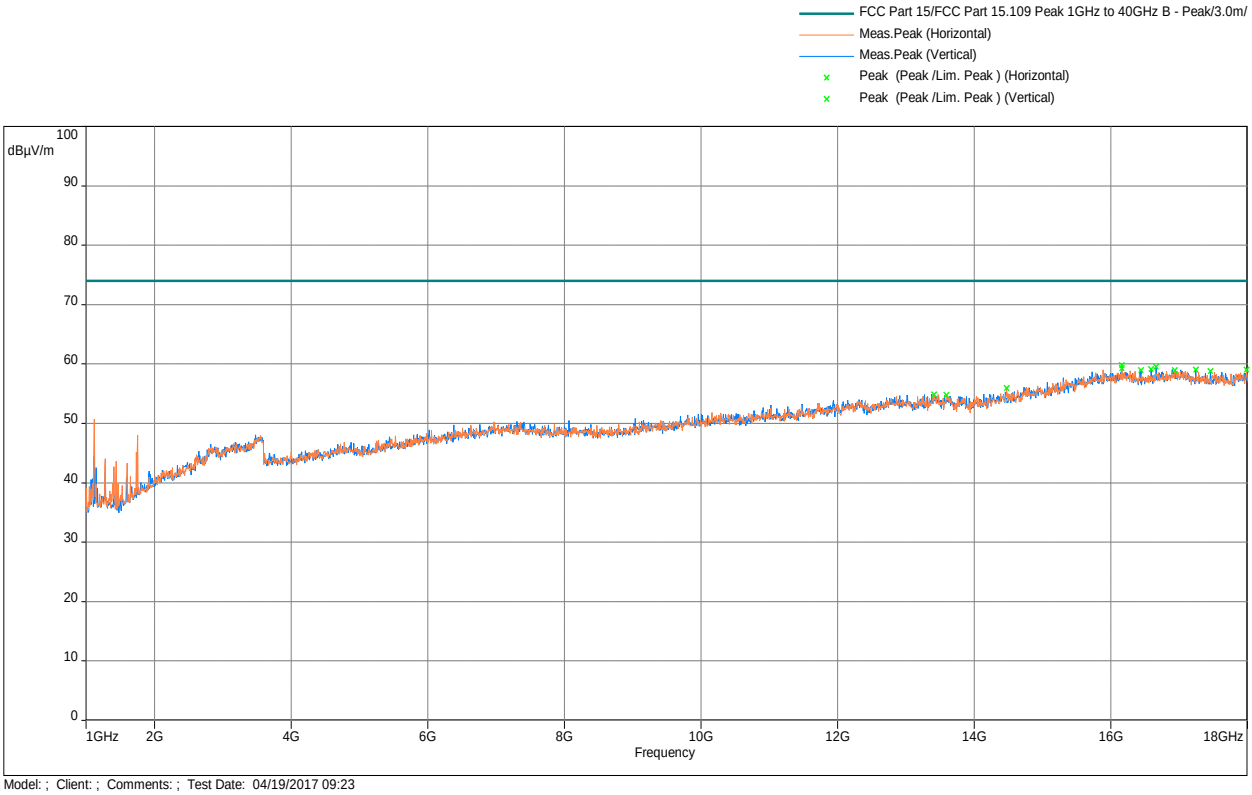
Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 09:17

Frequency (MHz)	Ave (dBµV/m)	Lim. Average (dBµV/m)	Margin (dB)	Height (m)	Angle (°)	Comment	Correction (dB)
1409.7	39.49	54	-14.51	1.01	213	Horizontal	-3.84

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

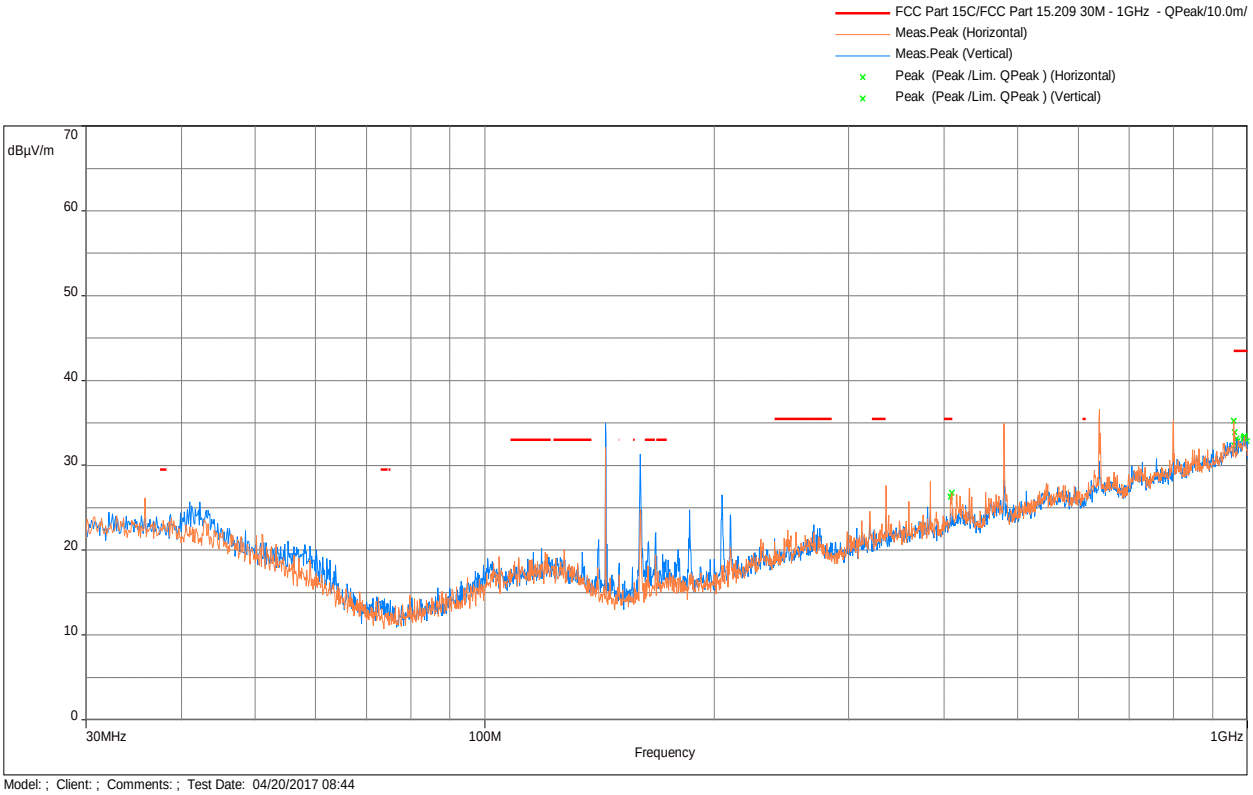


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 09:23

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

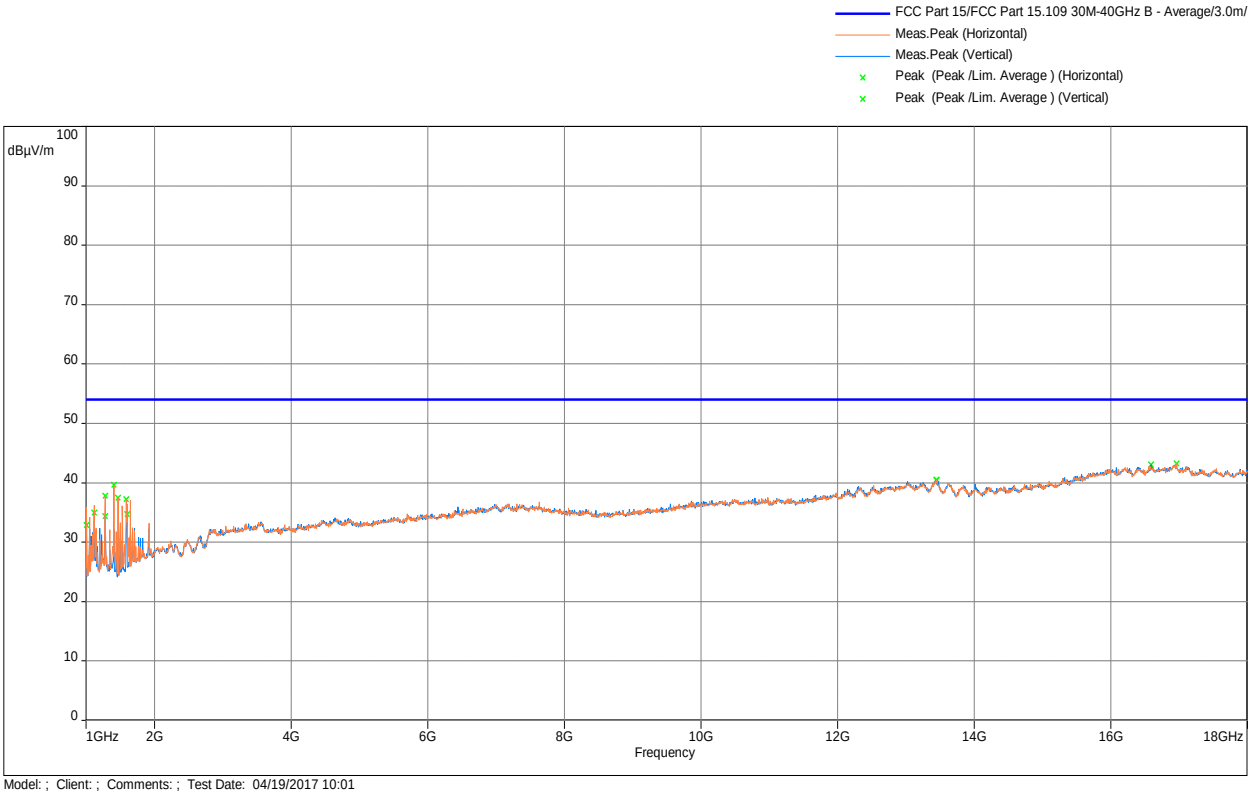
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11n, 2437MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



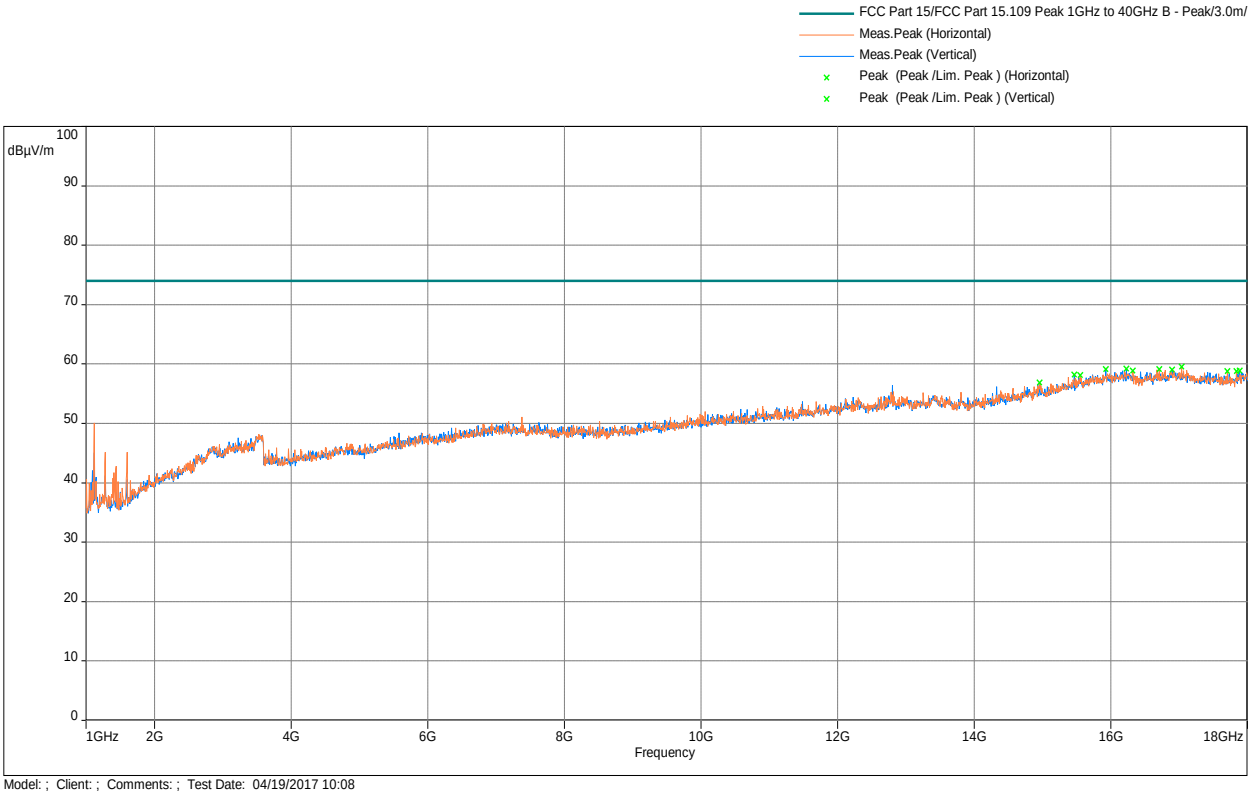
Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:44

Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 10:01

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

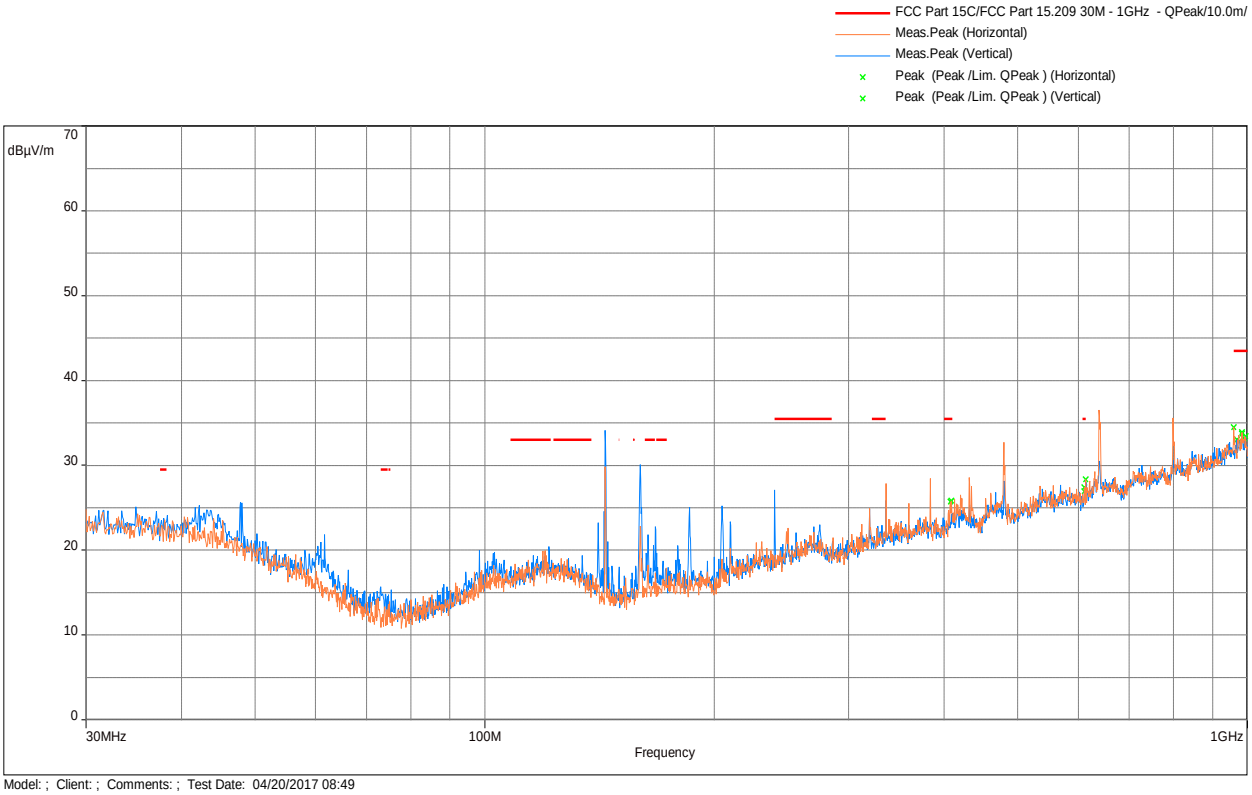


Model: ; Client: ; Comments: ; Test Date: 04/19/2017 10:08

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

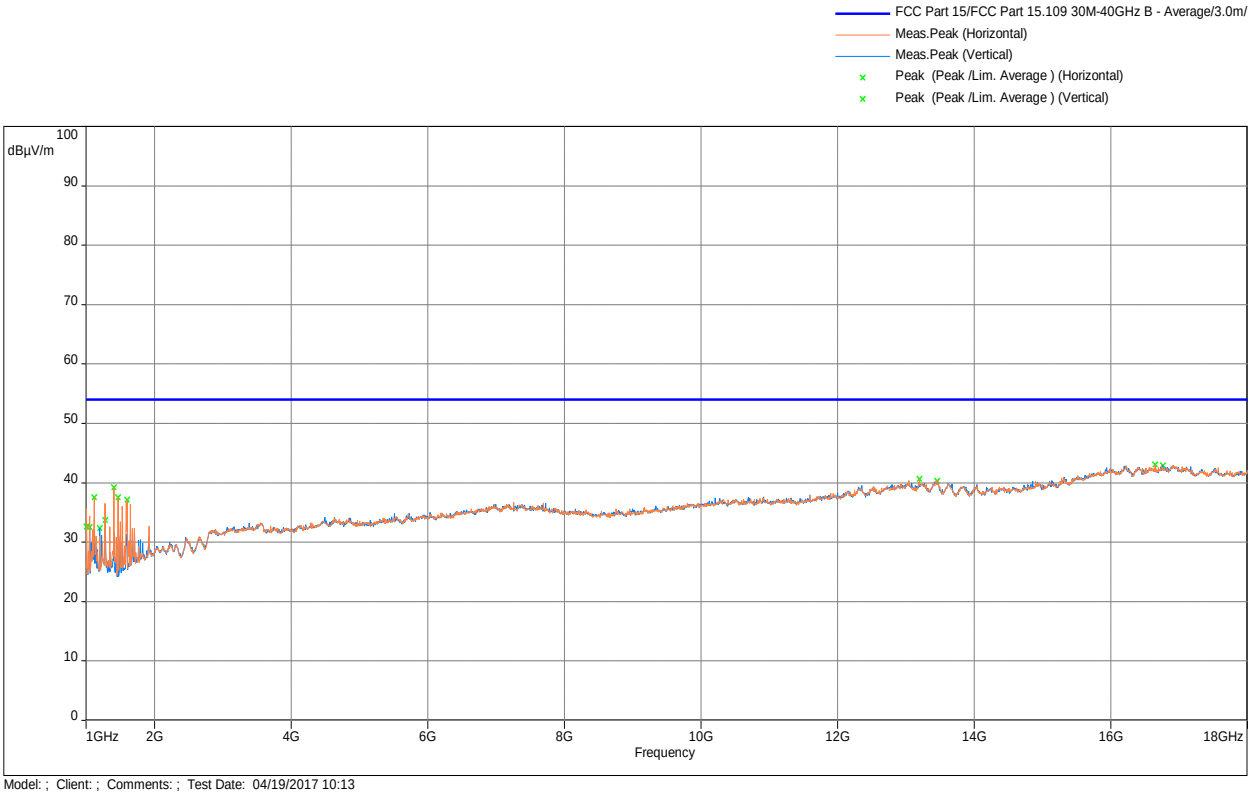
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 802.11n, 2462MHz

Out-of-Band Radiated Spurious Emissions (Cabinet Radiation) - 30 MHz to 1000 MHz



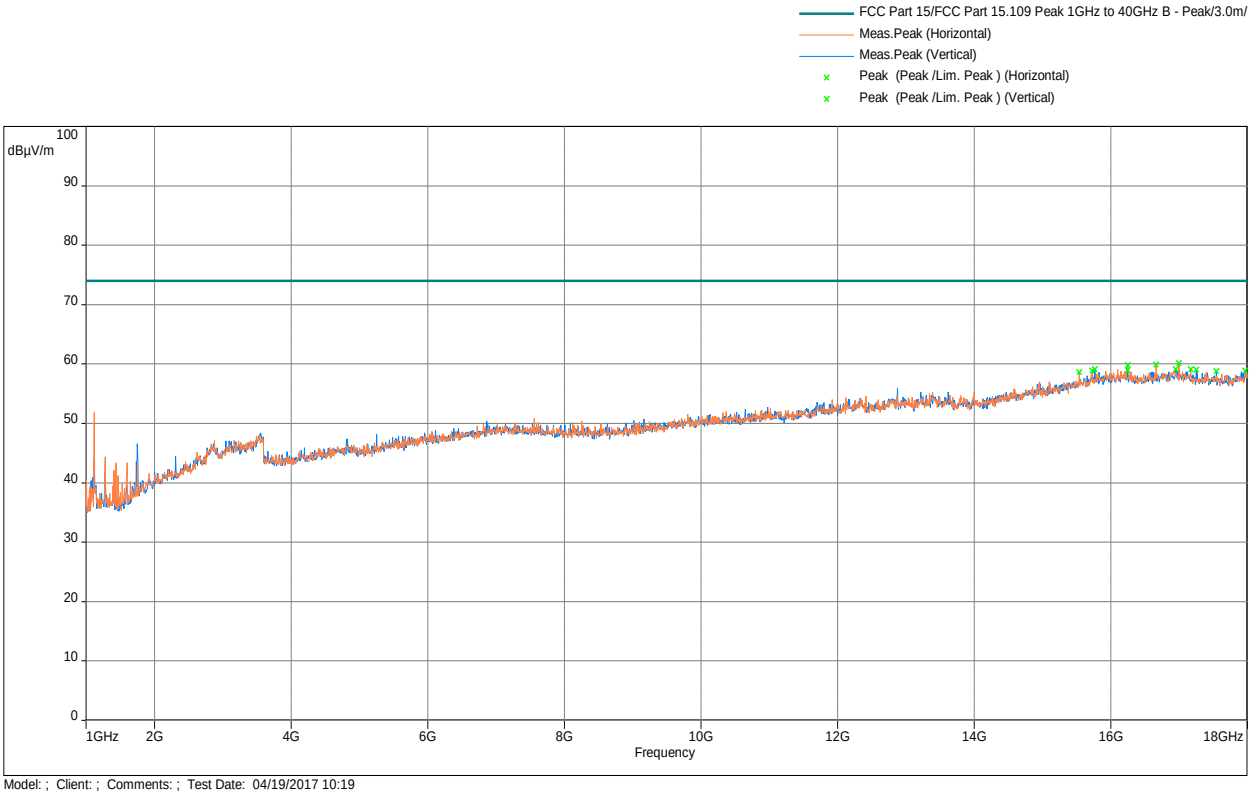
Model: ; Client: ; Comments: ; Test Date: 04/20/2017 08:49

Radiated Spurious Emissions 1000 - 18000 MHz, Avg Scan vs Avg Limit



Model: ; Client: ; Comments: ; Test Date: 04/19/2017 10:13

Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Peak Limit

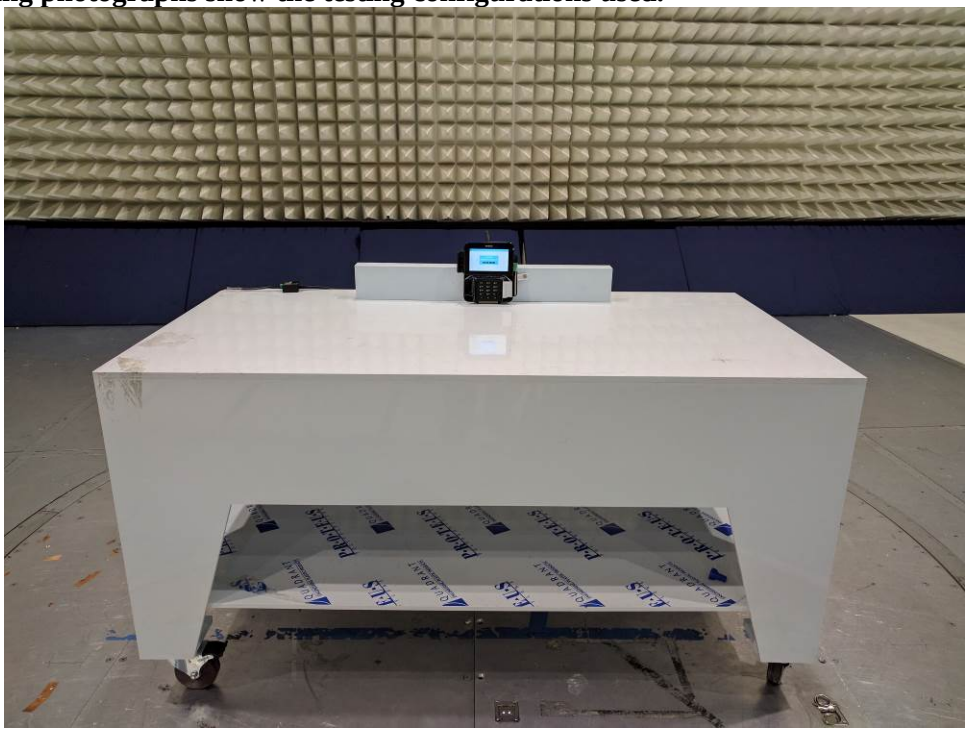


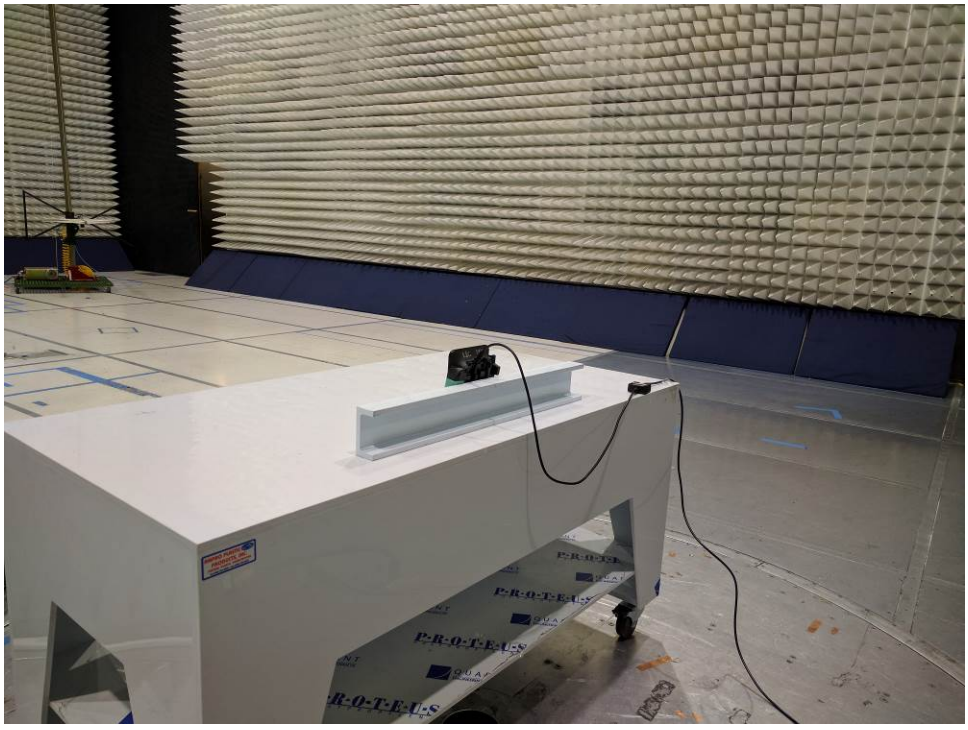
Model: ; Client: ; Comments: ; Test Date: 04/19/2017 10:19

Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

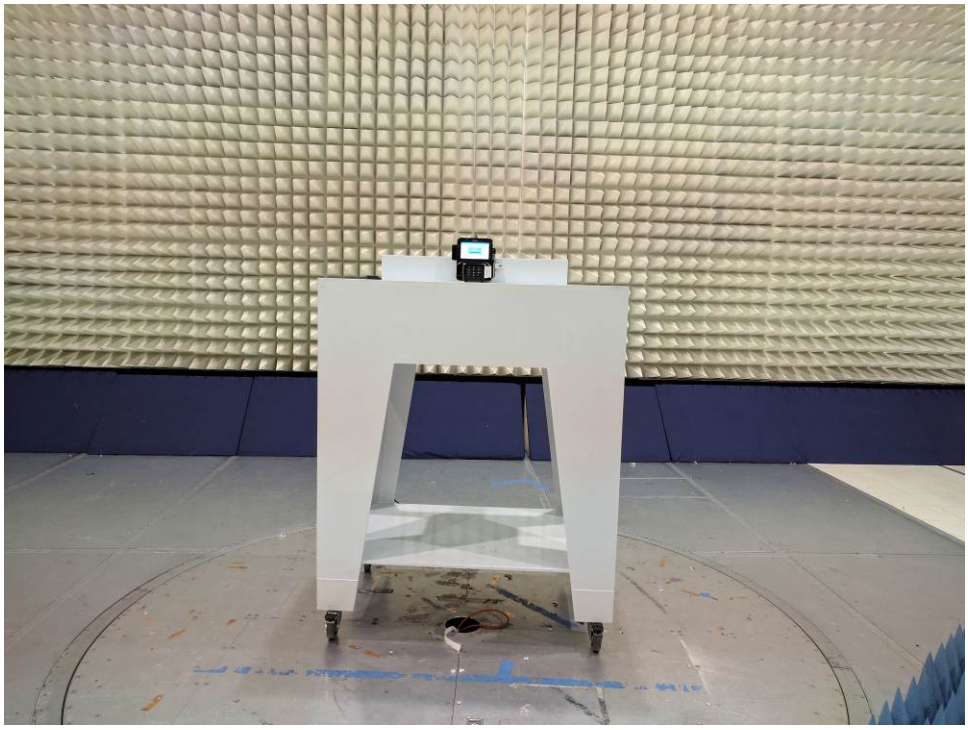
4.5.8 Test Setup Photographs

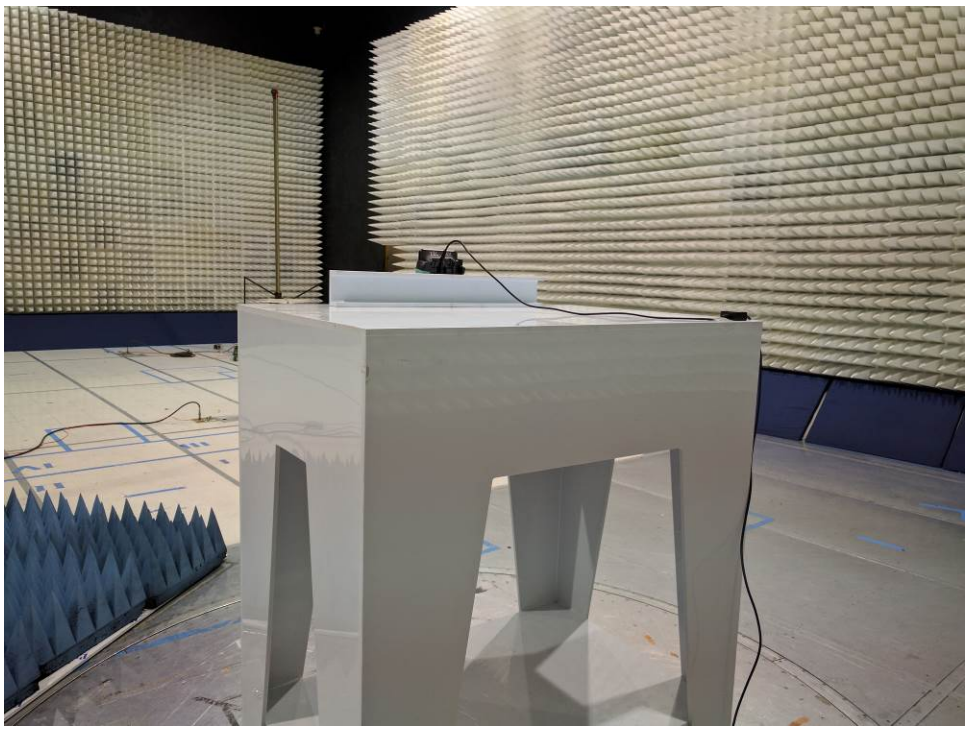
The following photographs show the testing configurations used.





4.5.8 Test Setup Photographs (Continued)





5.0 List of Test Equipment

Measurement equipment used for emission compliance testing utilized the equipment on the following list:

Equipment	Manufacturer	Model/Type	Asset #	Cal Int	Cal Due
Spectrum Analyzer	Rohde and Schwarz	FSU	ITS 00913	12	01/12/18
Pyramidal Horn Antenna	EMCO	3160-09	ITS 00571	#	#
Pre-Amplifier (18-40GHz)	Miteq	TTA1840-35-S-M	ITS 01393	12	04/18/18
Pre-Amplifier (1-18GHz)	Miteq	AMF-4D-001180-24-10P	ITS 00526	12	09/29/17
Horn Antenna	ETS-Lindgren	3117	ITS 01325	12	09/07/17
EMI Receiver	Rohde and Schwarz	ESU	ITS 00961	12	07/10/18
BI-Log Antenna	Antenna Research	LPB-2513	ITS 00355	12	09/09/17
Pre-Amplifier	Sonoma Instrument	310	ITS 01493	12	09/28/17
RF Cable	TRU Corporation	TRU CORE 300	ITS 01462	12	08/19/18
Notch Filter	Micro-Tronics	BRM50702	ITS 01166	12	02/08/18
RF Cable	TRU Corporation	TRU CORE 300	ITS 01465	12	08/19/18
RF Cable	TRU Corporation	TRU CORE 300	ITS 01470	12	08/19/18
Attenuator	Mini Circuits	BW-N3W5+	ITS 01315	12	10/19/17
Notch Filter	MICRO-TRONICS	BRM50702	ITS 01166	12	12/08/18
Attenuator	Narda	FSCM99899	ITS 01583	12	08/31/18
RF Cable	Megaphase	EMC1-K1K1-236	ITS 01538	12	06/13/18
RF Cable	Megaphase	EMC1-K1K1-19	ITS 01482	12	08/25/17
RF Cable	Megaphase	TM40-K1K1-19	ITS 01154	12	01/26/18
Transient Limiter	COM-POWER	LIT-153A	ITS 01452	12	06/19/18
RF Cable	TRU Corporation	TRU CORE 300	ITS 01462	12	08/24/17
RF Cable	Megaphase	TM40-K1K1-59 RF	ITS 01156	12	01/26/18

No Calibration required

Software used for emission compliance testing utilized the following:

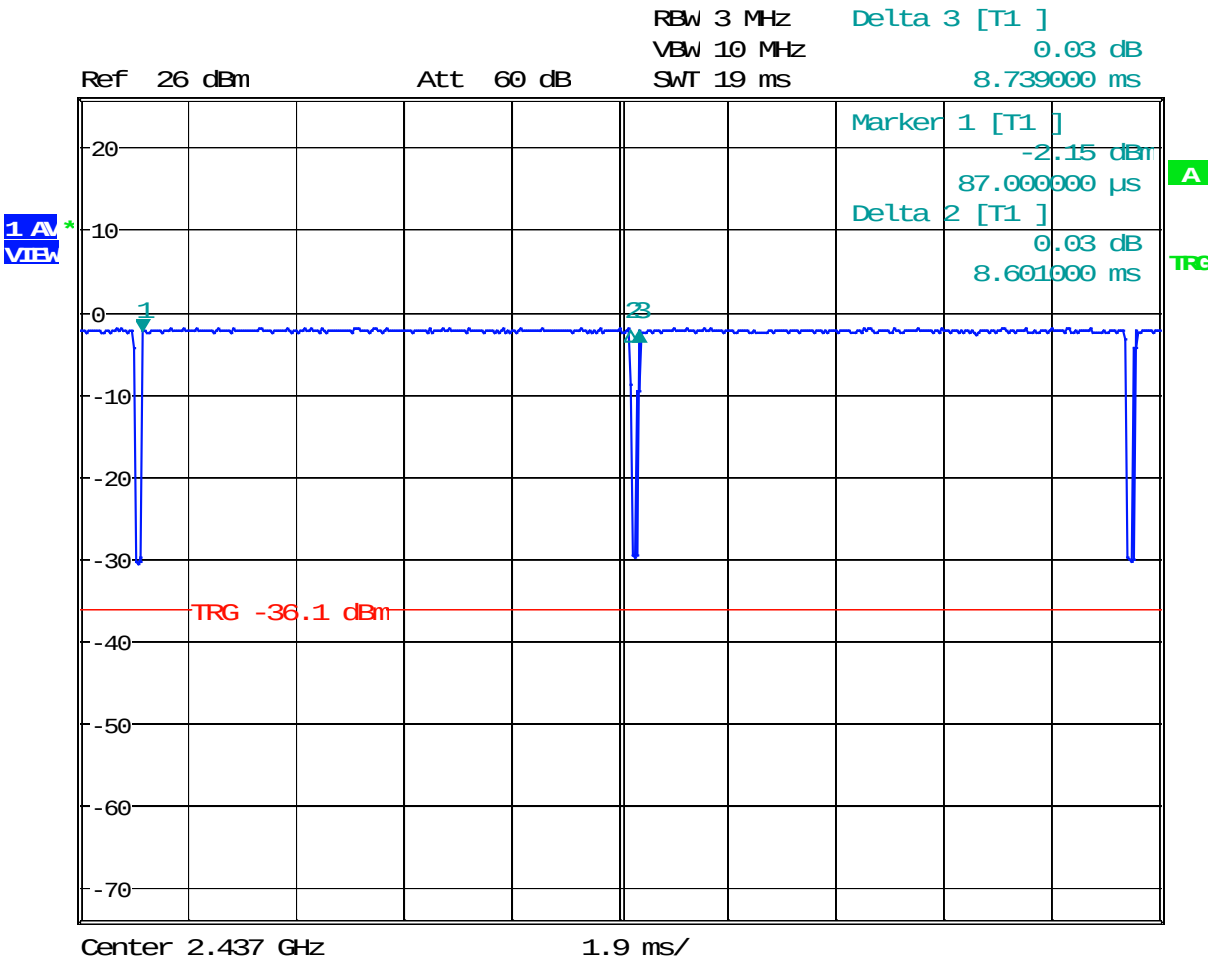
Name	Manufacturer	Version	Template/Profile
Tile	Quantum Change	3.4.K.22	Conducted Restricted Band Edge_Avg Conducted Restricted Band Edge_Peak Conducted Restricted Band_1-26GHz Conducted Restricted Band_30M-1GHz Conducted Spurious_30M-26GHz
BAT-EMC	Nexio	3.16.0.64	102971715_Verifone.bpp
RS Commander	Rohde Schwarz	1.6.4	Not Applicable (Screen grabber)

6.0 Document History

Revision/ Job Number	Writer Initials	Reviewers Initials	Date	Change
1.0 / G102971715	AS	KV	May 26, 2017	Original document

Annex A - Duty Cycle Measurement

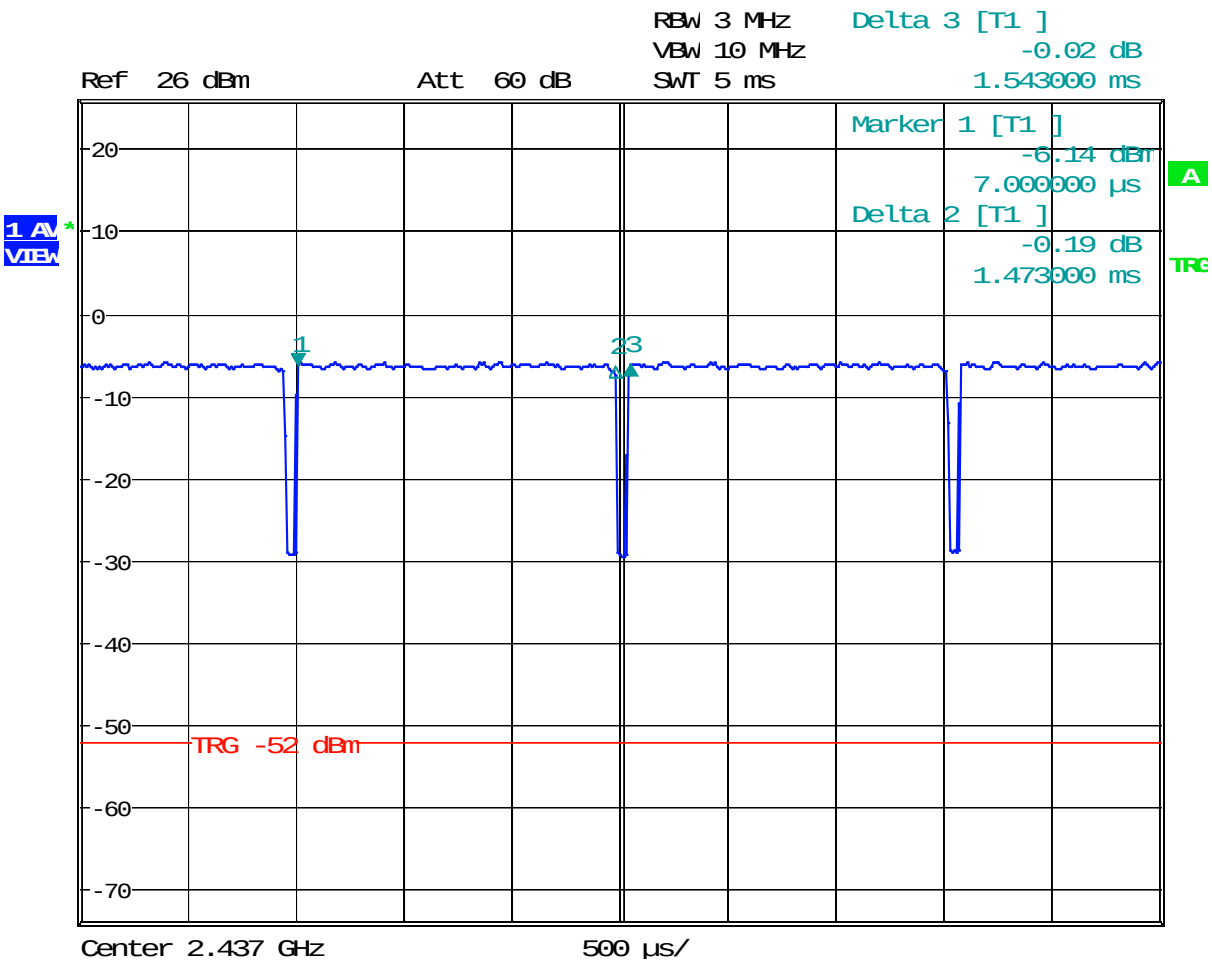
IEEE 802.11b



Date: 13.APR.2017 13:19:04

Duty Cycle: DC = 8.601/ 8.739 = 0.984 or 98.4%
Duty Cycle Correction Factor **δ (dB)** = Not Applicable, Duty Cycle greater than 98%

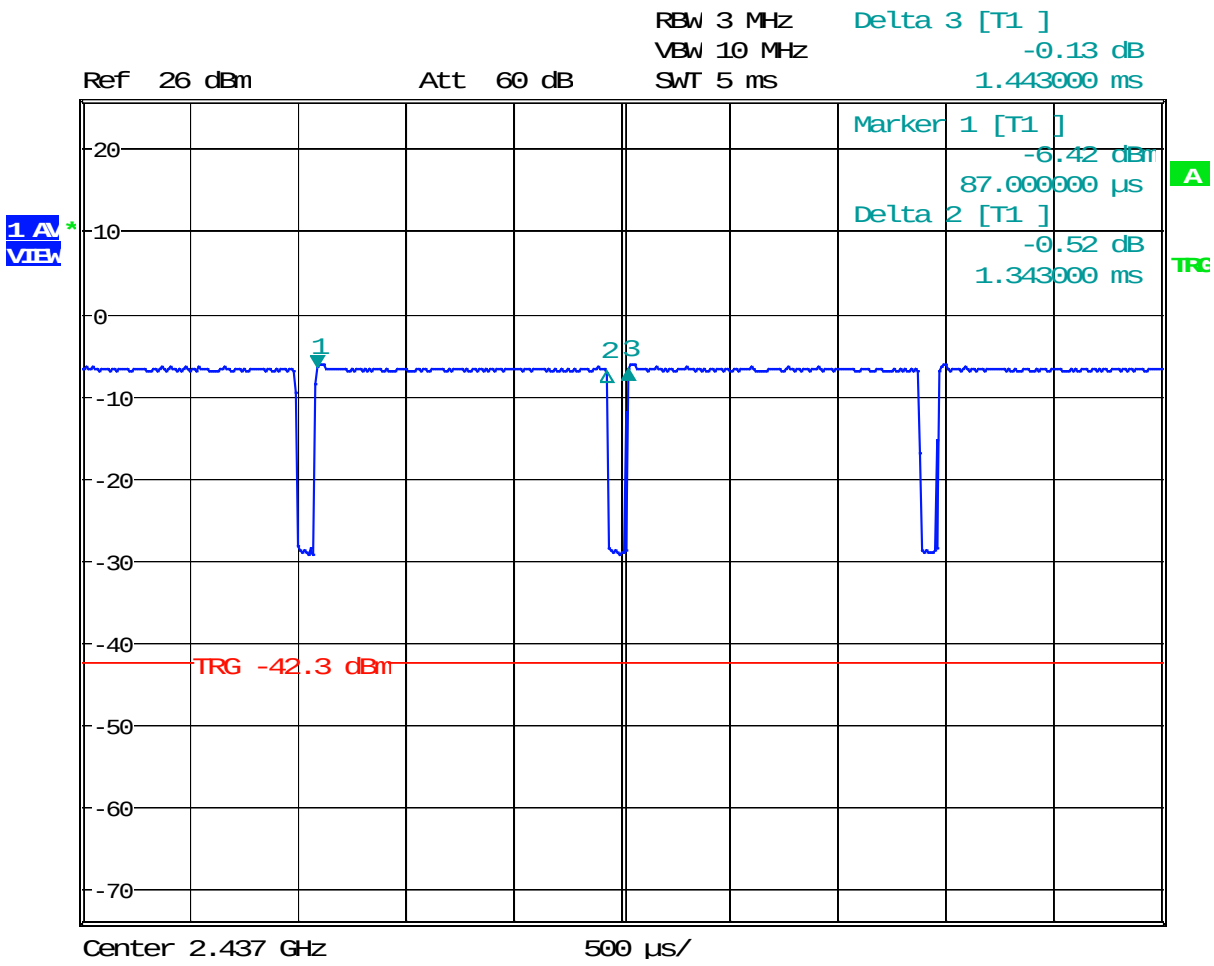
IEEE 802.11g



Date: 13.APR.2017 13:14:21

Duty Cycle: DC = 1.473/ 1.543 = 0.955 or 95.5%
Duty Cycle Correction Factor **δ (dB)** = 10 log (1/0.955) = 0.2 dB

IEEE 802.11n



Date: 13.APR.2017 13:17:48

Duty Cycle: DC = 1.343/ 1.443 = 0.931 or 93.1%
Duty Cycle Correction Factor **δ (dB)** = 10 log (1/0.931) = 0.3 dB