TEST REPORT

Report Number: 103479767MPK-014R
Project Number: G103479767
December 05, 2018

Testing performed on
Repeater
Marketing Name: Repeater HWR-D

FCC ID: OG3-HWRREP
IC ID: 10447A-HWRREP
to

FCC Part 15 Subpart C (15.247)
Industry Canada RSS-247 Issue 2
FCC Part 15, Subpart B
Industry Canada ICES-003

For

Grundfos Holding A/S

Test Performed by:	Test Authorized by:
Intertek	Grundfos Holding A/S
1365 Adams Court	Poul Due Jensens Vej 7
Menlo Park, CA 94025 USA	8850 Bjerringbro Denmark

Prepared by: _____ **Date:** December 05, 2018
Anderson Soungpanya

Reviewed by: _____ **Date:** December 05, 2018
Krishna K Vemuri

Report No. 103479767MPK-014R	
Equipment Under Test:	Repeater
Trade Name:	Grundfos Holding A/S
Marketing Name:	Repeater HWR-D
Applicant:	Grundfos Holding A/S
Contact:	Allan Moos
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Email:	amoos@grundfos.com
Applicable Regulation:	FCC Part 15 Subpart C (15.247) Industry Canada RSS-247 Issue 2 FCC Part 15, Subpart B Industry Canada ICES-003 Issue 6
Date of Test:	August 23 – November 20, 2018

We attest to the accuracy of this report:

Anderson Soungpanya
Project Engineer

Krishna K Vemuri
Engineering Team Lead

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1.0 Summary of Tests

Test	Reference FCC	Reference Industry Canada	Result
RF Output Power	15.247(b)(3)	RSS-247, 5.4.4	Complies
6 dB Bandwidth	15.247(a)(2)	RSS-247, 5.2.1	Complies
Power Density	15.247(e)	RSS-247, 5.2.2	Complies
Out of Band Antenna Conducted Emission	15.247(d)	RSS-247, 5.5	Complies
Digital Radiated Emissions	15.109	ICES-003	Complies
Transmitter Radiated Emissions	15.247(d), 15.209, 15.205	RSS-247, 5.5	Complies
AC Line Conducted Emission	15.107 & 15.207	ICES-003 & RSS-GEN	Complies
Antenna Requirement	15.203	RSS-GEN	Complies (Internal Antenna)

EUT receive date: August 18, 2018

EUT receive condition: The pre-production version of the EUT was received in good condition with no apparent damage. As declared by the Applicant, it is identical to the production units.

Test start date: August 23, 2018

Test completion date: November 20, 2018

The test results in this report pertain only to the item tested.

2.0 General Information

2.1 Product Description

Grundfos Holding A/S supplied the following description of the EUT:

System Overview
Figure 1 depicts the HWR-D system with all possible types of devices and communication paths.

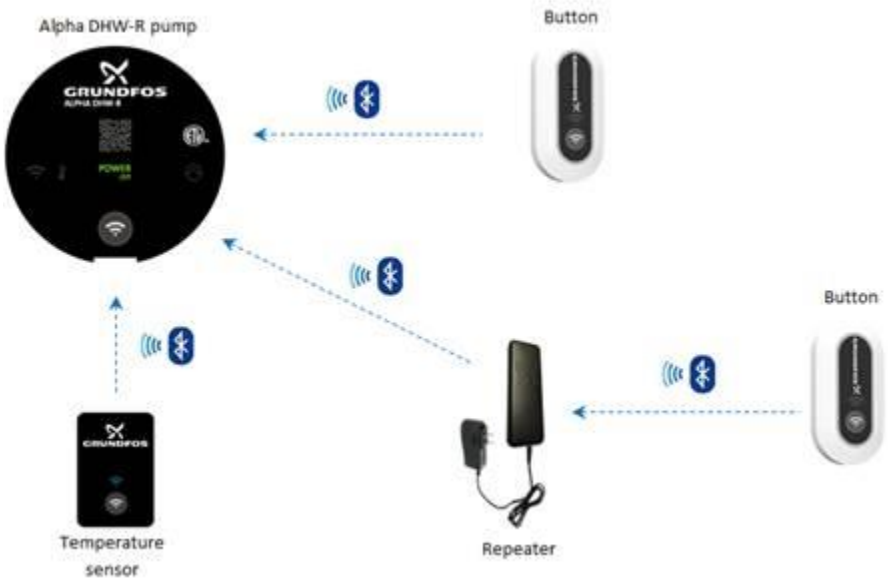


Figure 1 – Block diagram of the HWR-D system

Communication between devices is BLE and devices in the system are the following:

- Alpha 15-55 HWR-D (1)
- Temp. sensor HWR-D (1)
- Push Button HWR-D (1..10)
- Repeater HWR-D (0..*)

2.1 Product Description (continued)

Overall function specification
The purpose of the HWR-D system is to save Energy, as per "California Water Heater Regulations - Title 24". This means that contrary to running the recirculation pump permanently, thus wasting energy when hot water is not needed, this pump system is only recirculating hot water when there is a demand.

Alpha 15-55 HWR-D pump
This is the central unit in the system to control water recirculation based on inputs from Push button(s) (via repeater if needed) and temperature sensor. Furthermore, it monitors the time of recirculation to provide an extra means for shutting off recirculation. All intelligence regarding start and stop of recirculation resides in the Display Board software in the pump.

Push button HWR-D 99410377
The number of buttons in the system can be one or several depending on the physical need in the household. The button is simply a unit for activating water recirculation from remote with the extra functionality that it monitors its own battery level.

Temp. sensor HWR-D 99410349
Only one temperature sensor is needed in the system and the placement is in proximity of the pump. It measures temperature, monitors its own battery level and transmits the data to the pump.

Repeater HWR-D 99410216
A repeater is not always present in the system, or it may be necessary to have several. It has the task to relay data from the button(s) to the pump.

For more information, refer to the following product specification, declared by the manufacturer.

Information about the Repeater 2.4 GHz radio is presented below:

Applicant	Grundfos Holding A/S
Marketing Name	Repeater HWR-D
FCC Identifier	OG3-HWRREP
IC Identifier	10447A-HWRREP
Type of transmission	Digital Transmission System (DTS)
Rated RF Output	12.65 dBm
Antenna(s) & Gain	Internal Antenna, Peak Gain: 2 dBi
Frequency Range	2402 – 2480 MHz
Type of modulation/data rate	GFSK / 1Mbit/s
Number of Channel(s)	40
Applicant Name & Address	Grundfos Holding A/S Poul Due Jensens Vej 7 8850 Bjerringbro Denmark

2.2 Related Submittal(s) Grants

None.

2.3 Test Facility

The test site used to collect the radiated data is site 1 (10-m semi-anechoic chamber). This test facility and site measurement data have been fully placed on file with the FCC, IC and A2LA accredited.

2.4 Test Methodology

Antenna conducted measurements were performed according to the FCC documents "Guidance for Performing Compliance Measurement on Digital Transmission Systems, Frequency Hopping Spread Spectrum System, and Hybrid System devices Operating under §15.247" (KDB 558074 D01 Meas Guidance v05), RSS-247 Issue 2, ANSI C63.10: 2013 and RSS-GEN Issue 5.

Radiated emissions and AC mains conducted emissions measurements were performed according to the procedures in ANSI C63.10: 2013. Radiated tests were performed at an antenna to EUT distance of 3 meters, unless stated otherwise in the "Data Sheet" of this report.

2.5 Measurement Uncertainty

Compliance with the limits was based on the results of the measurements and doesn't take into account the measurement uncertainty.

Estimated Measurement Uncertainty

Measurement	Expanded Uncertainty (k=2)		
	0.15 MHz – 1 GHz	1 GHz – 2.5 GHz	> 2.5 GHz
RF Power and Power Density – antenna conducted	-	0.7 dB	-
Unwanted emissions - antenna conducted	1.1 dB	1.3 dB	1.9 dB
Bandwidth – antenna conducted	-	30 Hz	-

Measurement	Expanded Uncertainty (k=2)			
	0.15 MHz – 30MHz	30 – 200 MHz	200 MHz – 1 GHz	1 GHz – 18 GHz
Radiated emissions	-	4.7	4.6	5.1 dB
AC mains conducted emissions	2.1 dB	-	-	-

3.0 System Test Configuration

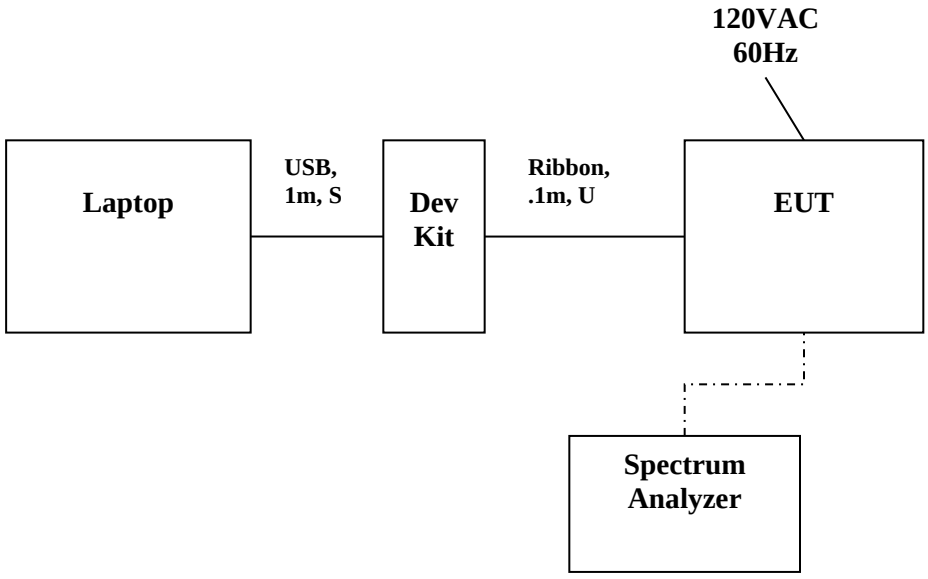
3.1 Support Equipment

Support Equipment		
Description	**Manufacturer**	**Model Number**
Laptop	Pakard Bell	ENTG71BM
Development kit	TI	CC2640R2

3.2 Block Diagram of Test Setup

Equipment Under Test			
Description	**Manufacturer**	**Marketing Name**	**Serial Number**
Radiated Sample of Repeater	Grundfos Holding A/S	Repeater HWR-D	MPK1808231102-006
Conducted Sample of Repeater	Grundfos Holding A/S	Repeater HWR-D	MPK1808231102-005
USB Power Adapter	I.T.E Power Supply	FW8002USB/05	MPK1808231102-013

Antenna was removed and co-axial connector with a cable was installed for Conducted Measurements.



S = Shielded **U** = Unshielded	**F** = With Ferrite **m** = Length in Meters

3.3 Justification

For radiated emission measurements the EUT is placed on a non-conductive table.

3.4 Software Exercise Program

The EUT exercise program used during radiated and conducted testing was provided by Grundfos Holding A/S

3.5 Mode of Operation during Test

As instructed by the manufacturer, the EUT's power setting was set to 2 dBm on the low, middle and high frequencies/channels.

3.6 Modifications Required for Compliance

No modifications were made by the manufacturer or Intertek to the EUT in order to bring the EUT into compliance.

3.7 Additions, Deviations and Exclusions from Standards

No additions, deviations or exclusions from the standard were made.

4.0 Measurement Results

4.1 6-dB Bandwidth and 99% Occupied Bandwidth
FCC Rule: 15.247(a)(2); RSS-247, 5.2.1 and RSS-GEN;

4.1.1 Requirement

The minimum 6-dB bandwidth shall be at least 500 kHz

4.1.2 Procedure

A spectrum analyzer was connected to the antenna port of the transmitter.

For FCC 6dB Channel Bandwidth the Procedure described in the FCC Publication KDB 558074 D01 Meas Guidance v05 was used to determine the DTS occupied bandwidth. Section 11.8.1 Option 1 of ANSI 63.10 was used.

1. Set RBW = 100 kHz.
2. Set the video bandwidth (VBW) ≥ 3 x RBW.
3. Detector = Peak.
4. Trace mode = max hold.
5. Sweep = auto couple.
6. Allow the trace to stabilize.
7. Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

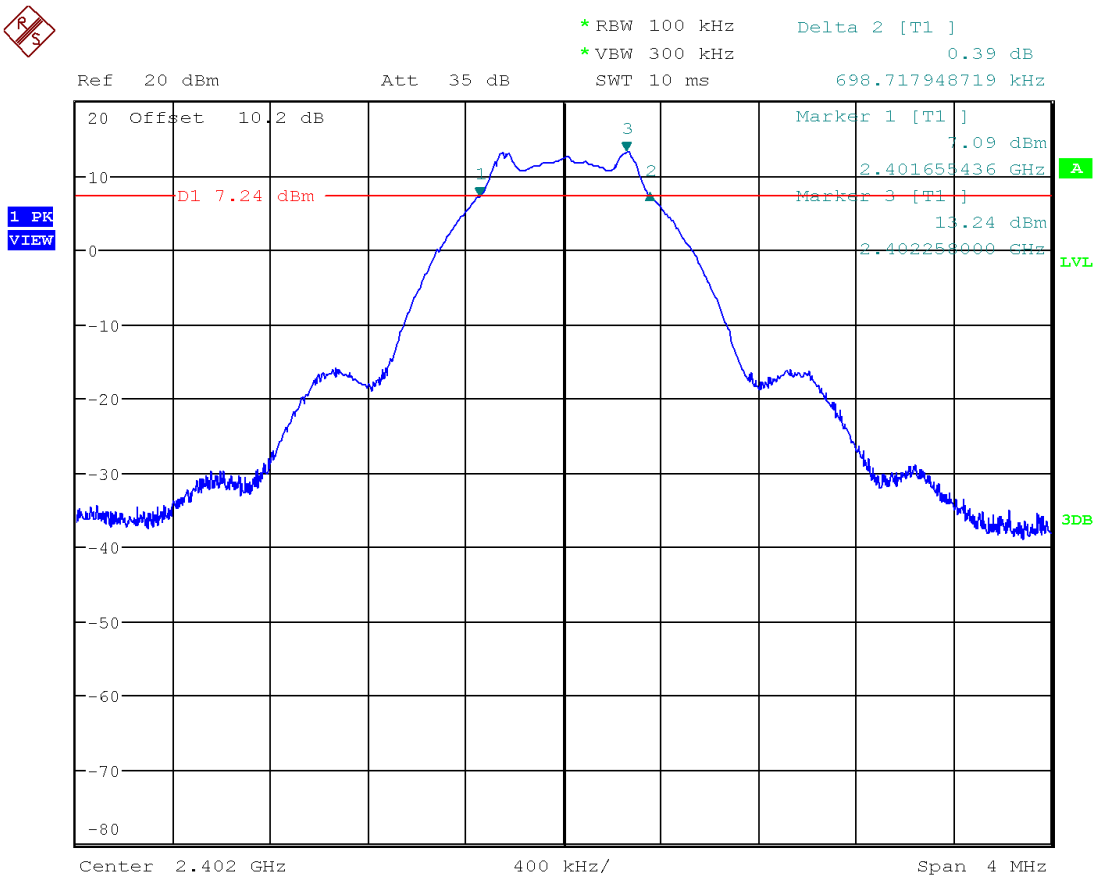
For 99% power bandwidth measurement, the bandwidth was determined by using the built-in 99% occupied bandwidth function of the spectrum analyzer. The resolution bandwidth is set to 1% of the selected span as is without being below 1%. The video bandwidth shall be set to 3 times the resolution bandwidth.

4.1.3 Test Result

Frequency (MHz)	6-dB bandwidth FCC 15.247 & RSS-GEN	Occupied bandwidth, RSS-GEN	Plot
MHz	kHz	MHz	
2402	698.718	--	1.1
	--	1.050	1.4
2440	717.128	--	1.2
	--	1.056	1.5
2480	737.180	--	1.3
	--	1.068	1.6

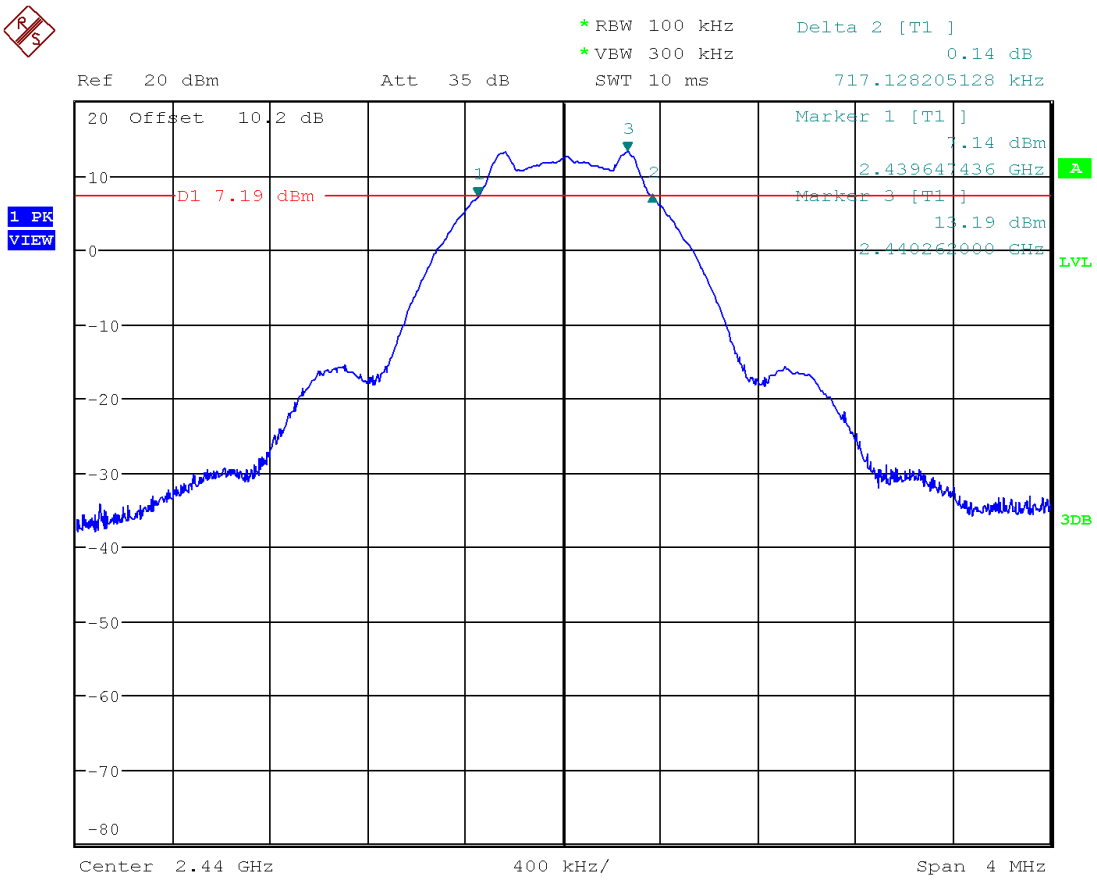
Tested By	Test Date
Anderson Soungpanya	August 23, 2018

Plot 1. 1



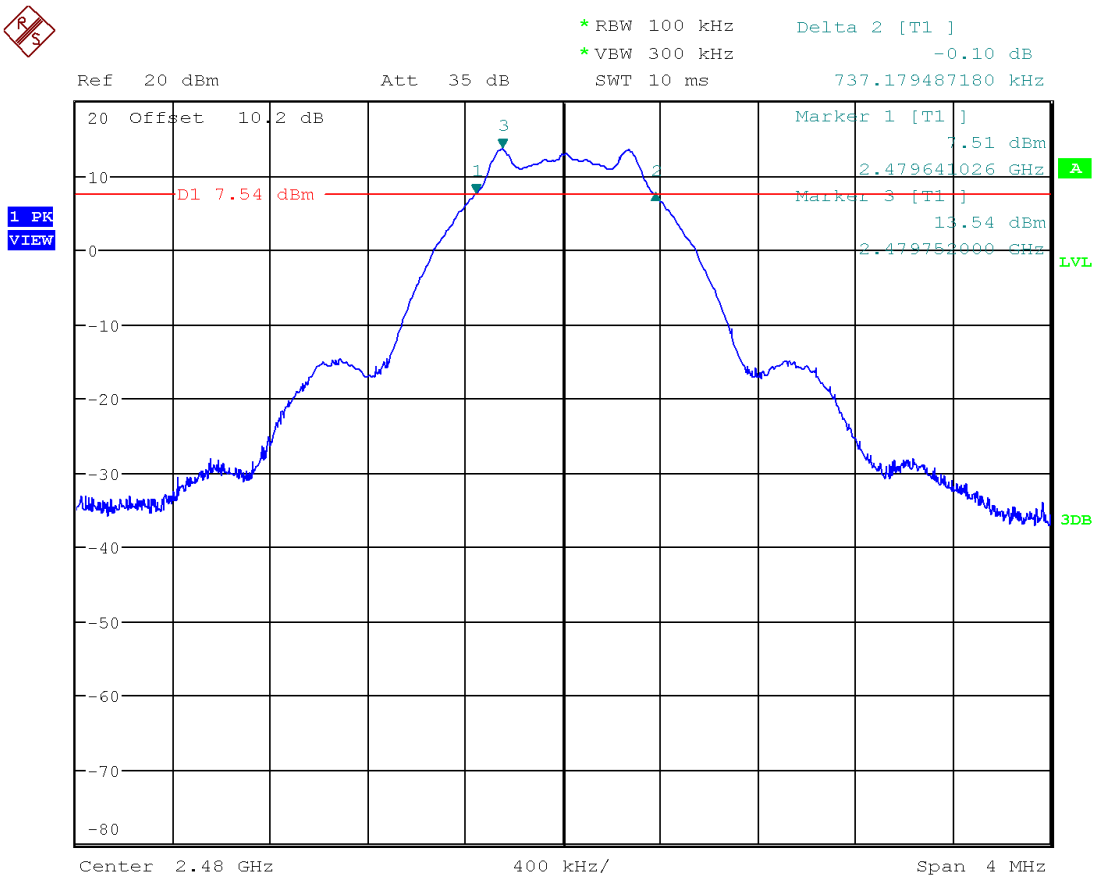
Date: 23.AUG.2018 10:04:51

Plot 1. 2



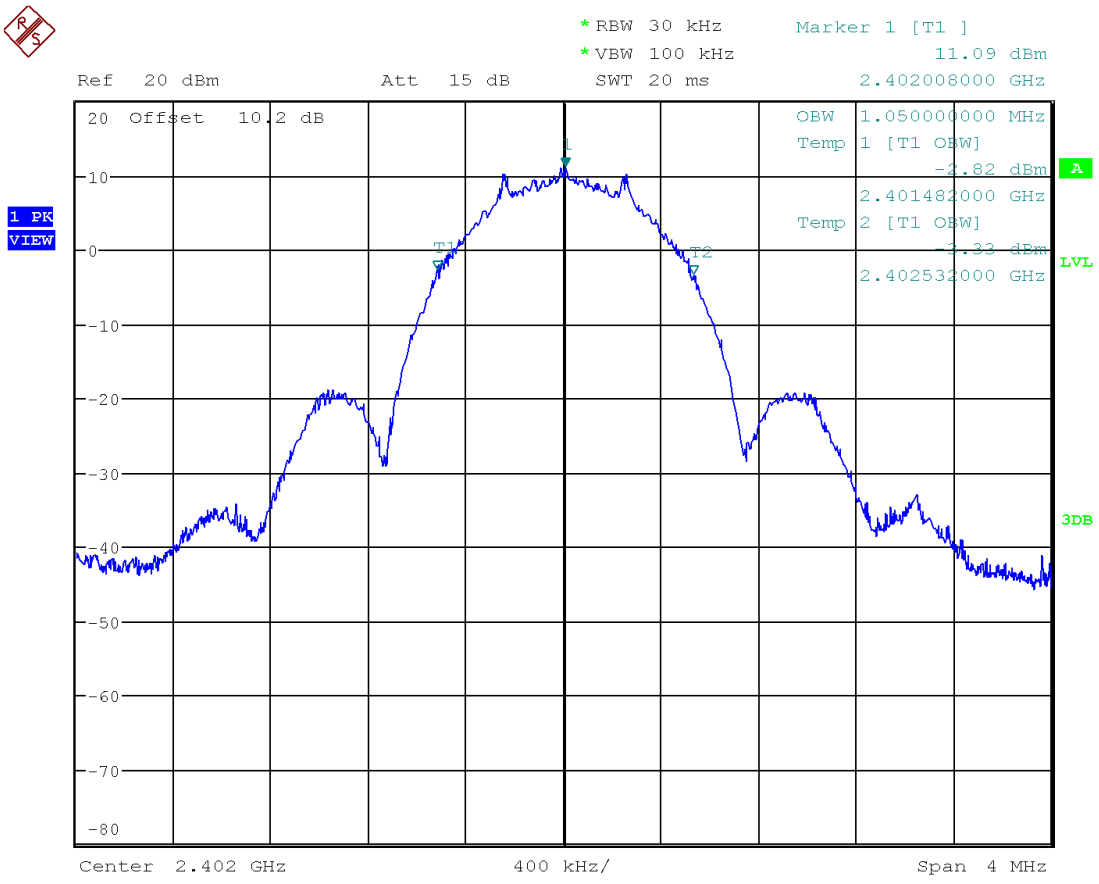
Date: 23.AUG.2018 10:08:49

Plot 1. 3



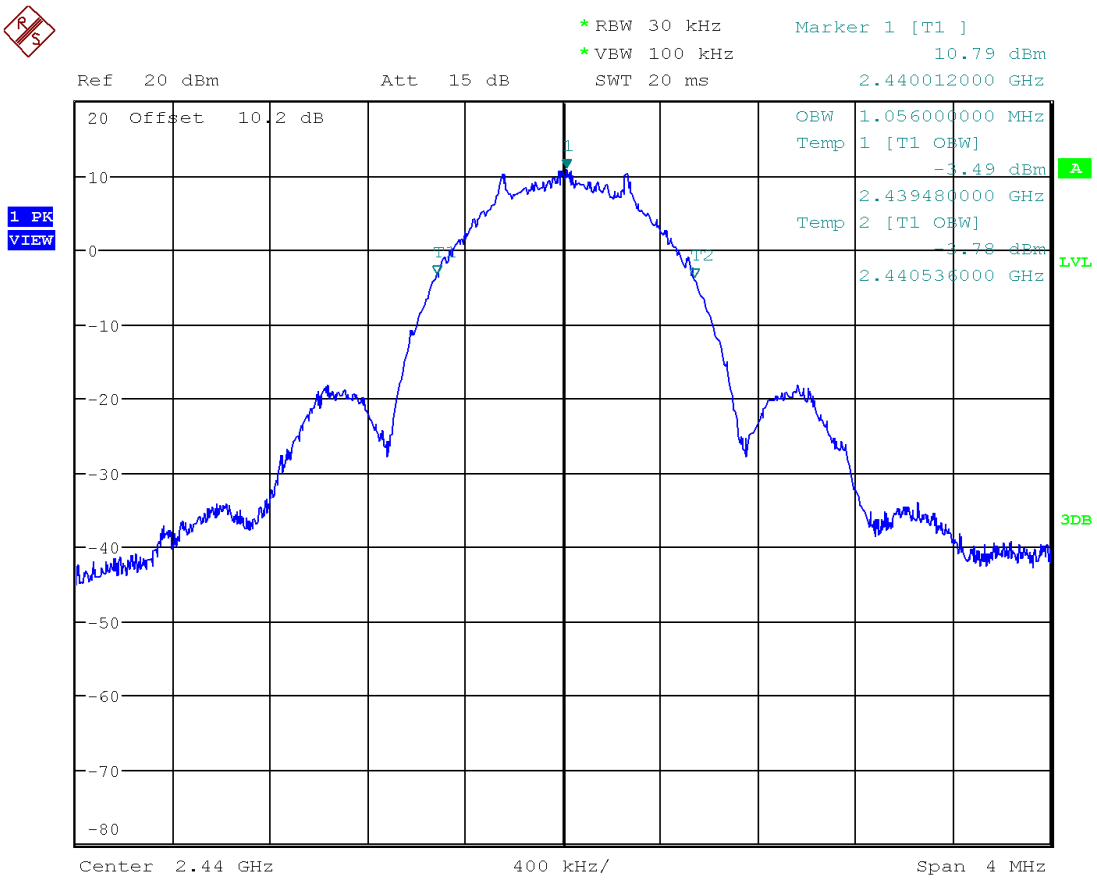
Date: 23.AUG.2018 10:14:04

Plot 1. 4



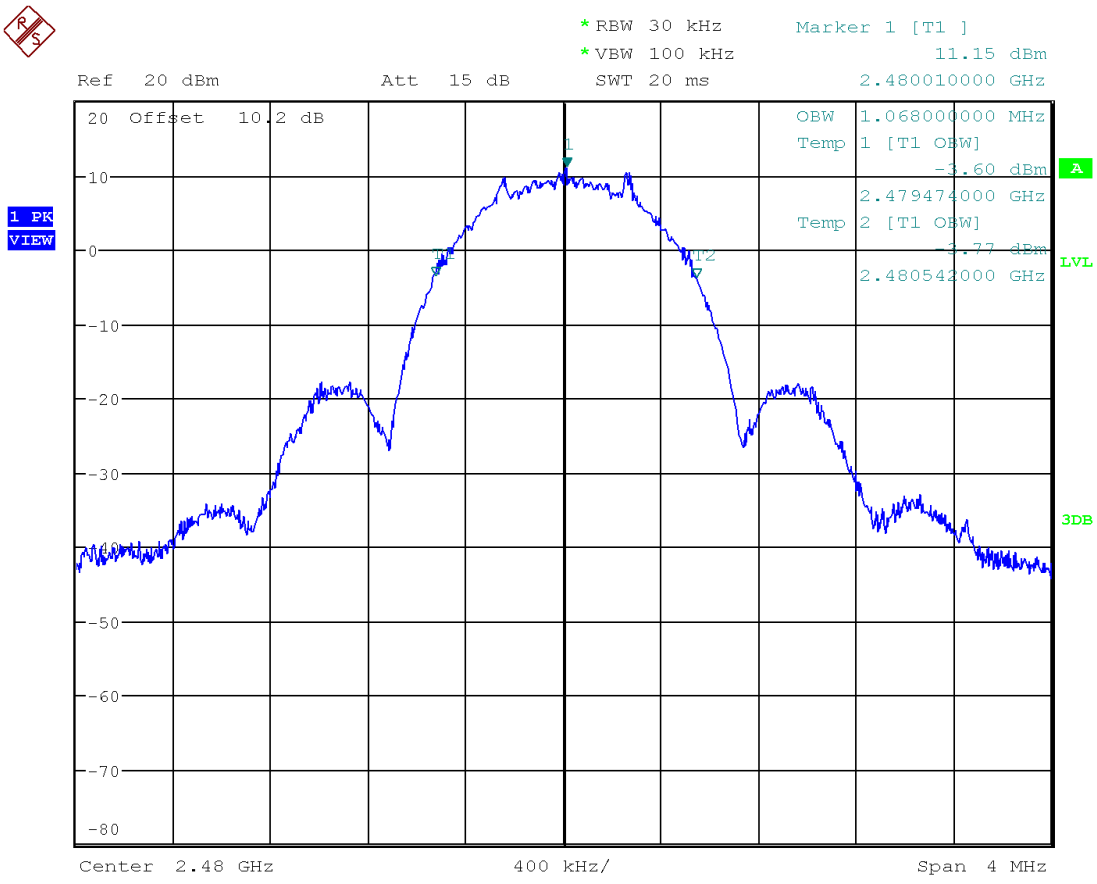
Date: 23.AUG.2018 10:21:04

Plot 1.5



Date: 23.AUG.2018 10:18:33

Plot 1.6



Date: 23.AUG.2018 10:16:04

4.2 Maximum Peak Conducted Output Power at Antenna Terminals
FCC Rule: 15.247(b)(3); RSS-247, 5.4.4;

4.2.1 Requirement

For antennas with gains of 6 dBi or less, maximum allowed transmitter output is 1 watt or 30 dBm.
For antennas with gains greater than 6 dBi, transmitter output level must be decreased appropriately, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

4.2.2 Procedure

The procedure described in FCC Publication KDB 558074 D01 Meas Guidance v05 was used. Specifically, section 11.9.1.1 RBW ≥ DTS bandwidth in ANSI 63.10.

1. Set the RBW ≥ DTS Bandwidth
2. Set the VBW ≥ 3 x RBW
3. Set the span ≥ 3 x RBW
4. Detector = Peak
5. Sweep time = Auto couple
6. Trace mode = Max Hold
7. Allow trace to fully stabilize
8. Use peak marker function to determine the peak amplitude level.

A spectrum analyzer was connected to the antenna port of the transmitter.

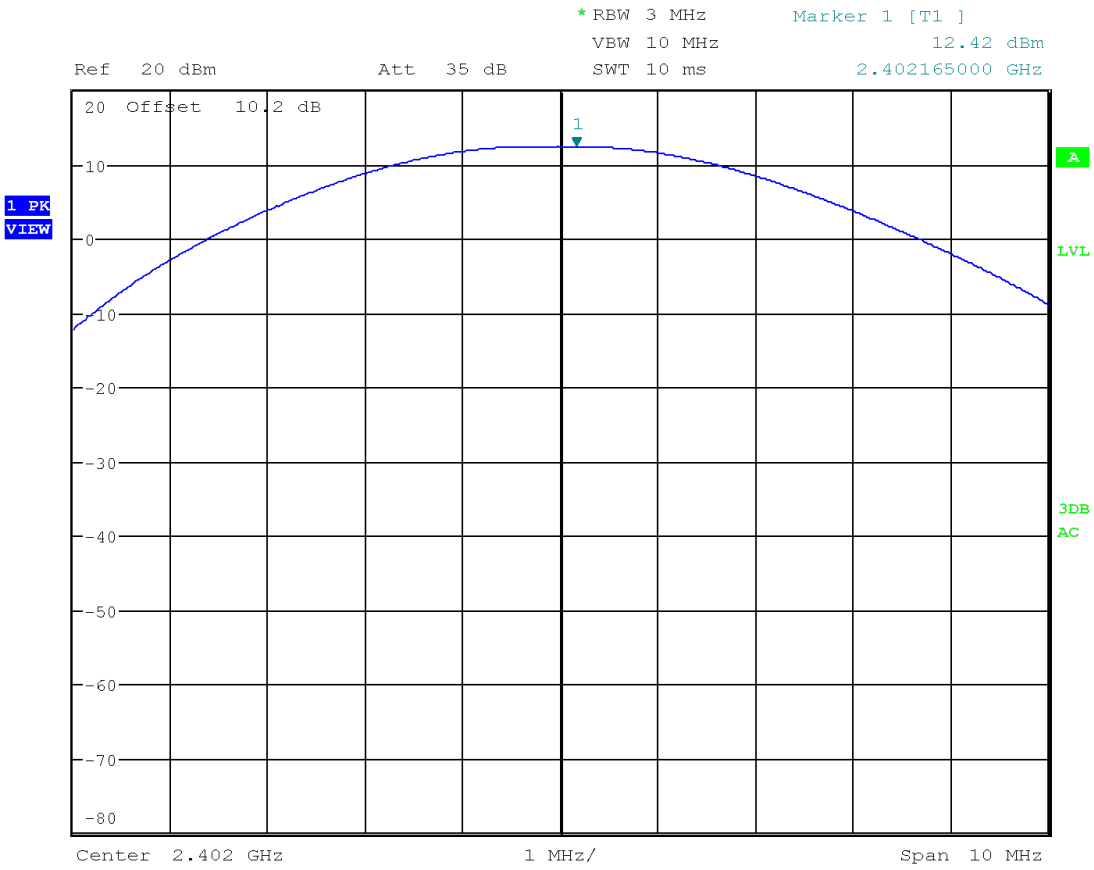
4.2.3 Test Result

Refer to the following plots 2.1 – 2.3 for the test details.

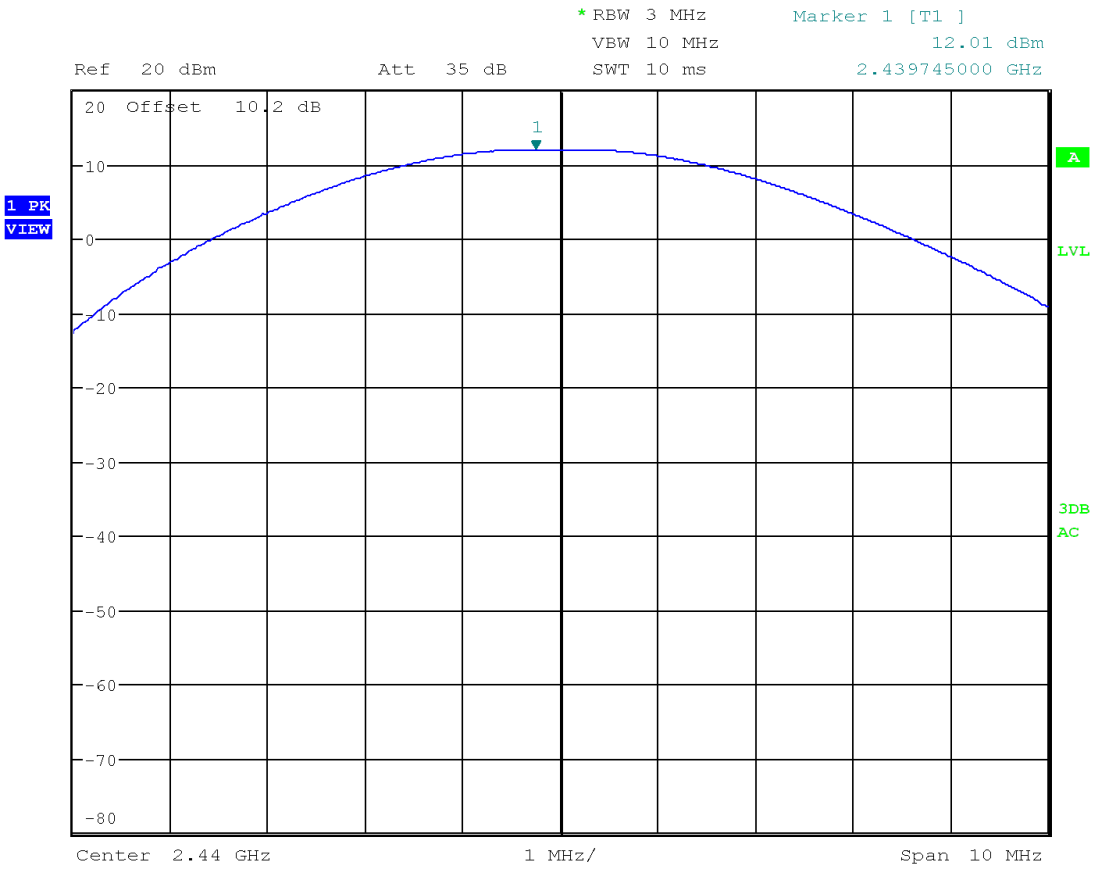
Frequency,	Conducted Power (peak)	Conducted Power (peak)	Plot
MHz	dBm	mW	
2402	12.42	17.458	2.1
2440	12.01	15.885	2.2
2480	12.65	18.408	2.3

Tested By	Test Date
Anderson Soungpanya	November 20, 2018

Plot 2. 1

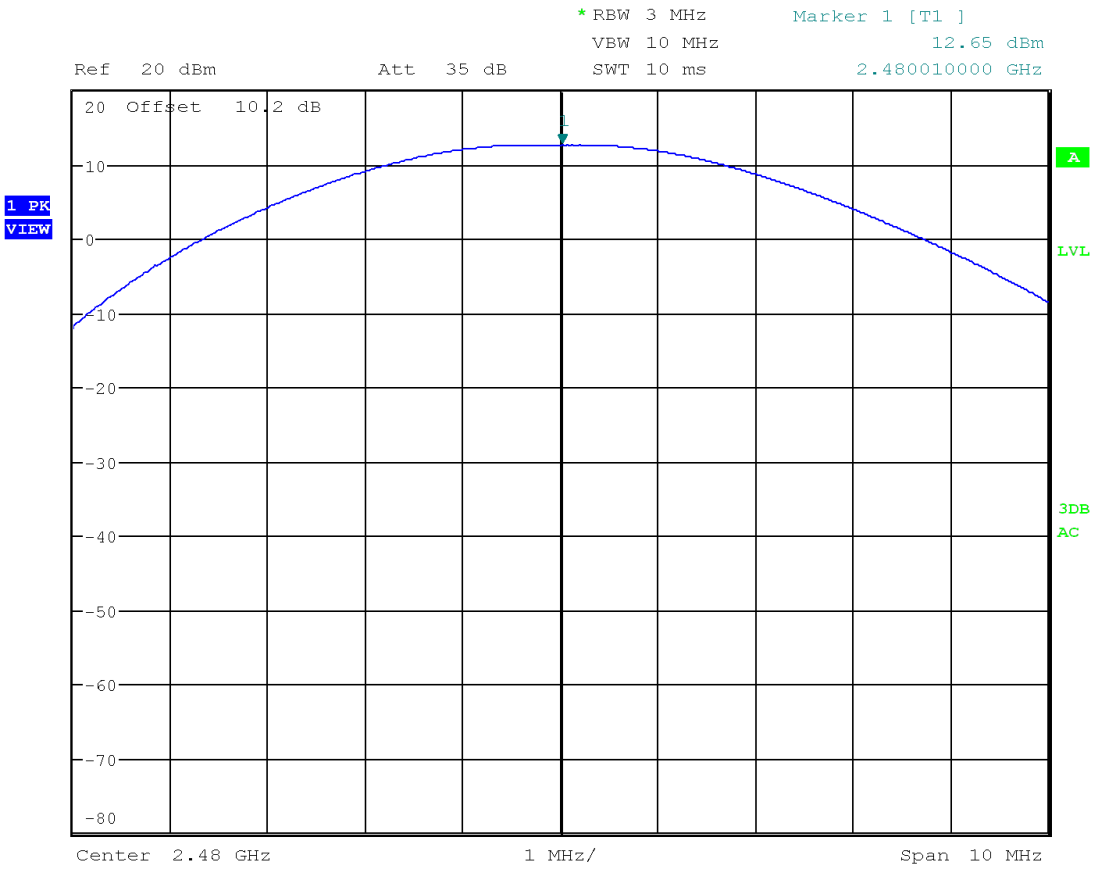

* RBW 3 MHz
VBW 10 MHz
SWT 10 ms
Marker 1 [T1]
12.42 dBm
2.402165000 GHz
Ref 20 dBm
Att 35 dB
20 Offset 10.2 dB
1 PK
VIEW
A
LVL
3DB
AC
Center 2.402 GHz
1 MHz/
Span 10 MHz
Date: 20.NOV.2018 07:26:32

Plot 2. 2



Date: 20.NOV.2018 07:27:50

Plot 2. 3



Date: 20.NOV.2018 07:24:54

4.3 Maximum Power Spectral Density
FCC: 15.247 (e); RSS-247, 5.2.2;

4.3.1 Requirement

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna should not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

4.3.2 Procedure

The antenna port of the EUT was connected to the input of a spectrum analyzer to measure the Transmitter Power Density (PSD). The offset programmed on the analyzer is corrected to include cable loss, attenuator.

The procedure described in FCC Publication KDB 558074 D01 Meas Guidance v05, specifically section 11.10.2 Method PKPSD (peak PSD) of ANSI 63.10.

1. Set analyzer center frequency to DTS channel center frequency.
2. Set the span to 1.5 times the *DTS bandwidth*.
3. Set the RBW to: 3 kHz ≤ RBW ≤ 100 kHz.
4. Set the VBW ≥ 3 x RBW.
5. Detector = peak.
6. Sweep time = auto couple.
7. Trace mode = max hold.
8. Allow trace to fully stabilize.
9. Use the peak marker function to determine the maximum amplitude level within the RBW.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

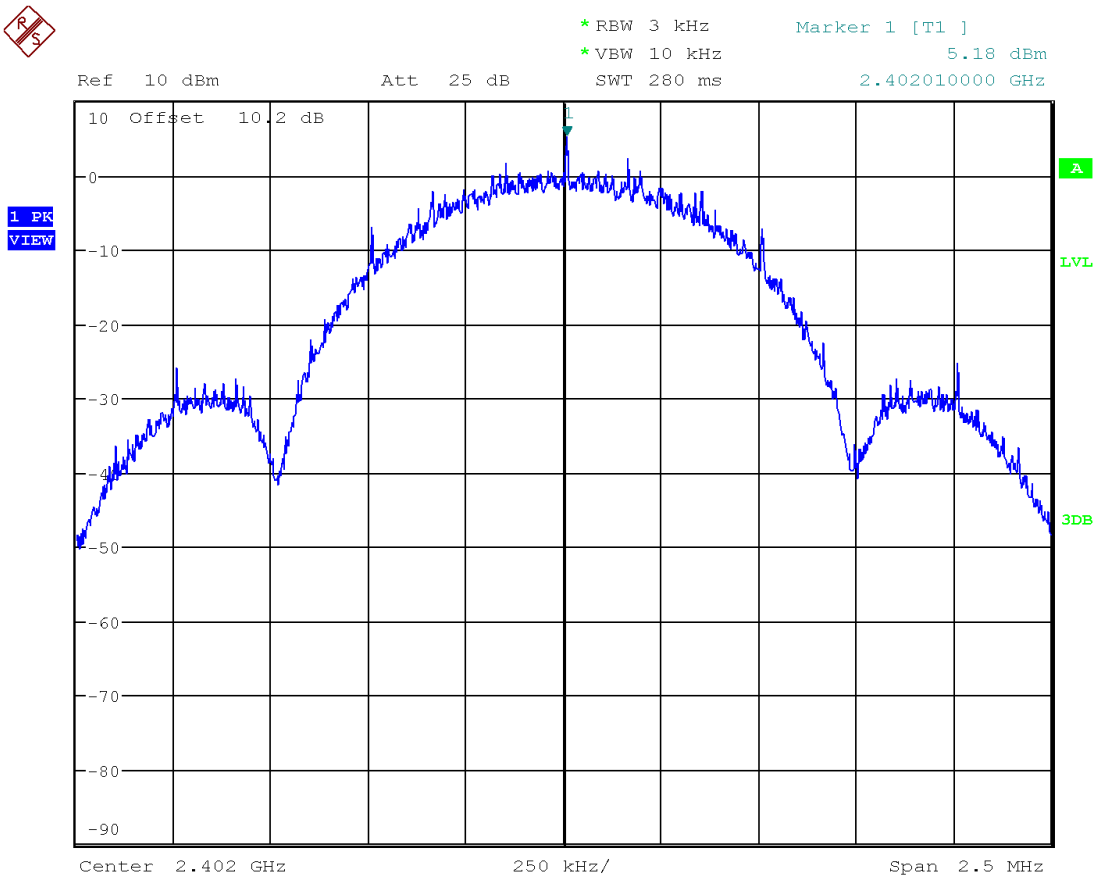
4.3.3 Test Result

Refer to the following plots for the test result

Frequency,	Maximum Power Spectral Density	Maximum Power Spectral Density Limit	Margin	Plot
MHz	dBm	dBm	dB	
2402	5.18	8.0	-2.82	3.1
2440	5.31	8.0	-2.69	3.2
2480	5.07	8.0	-2.93	3.3

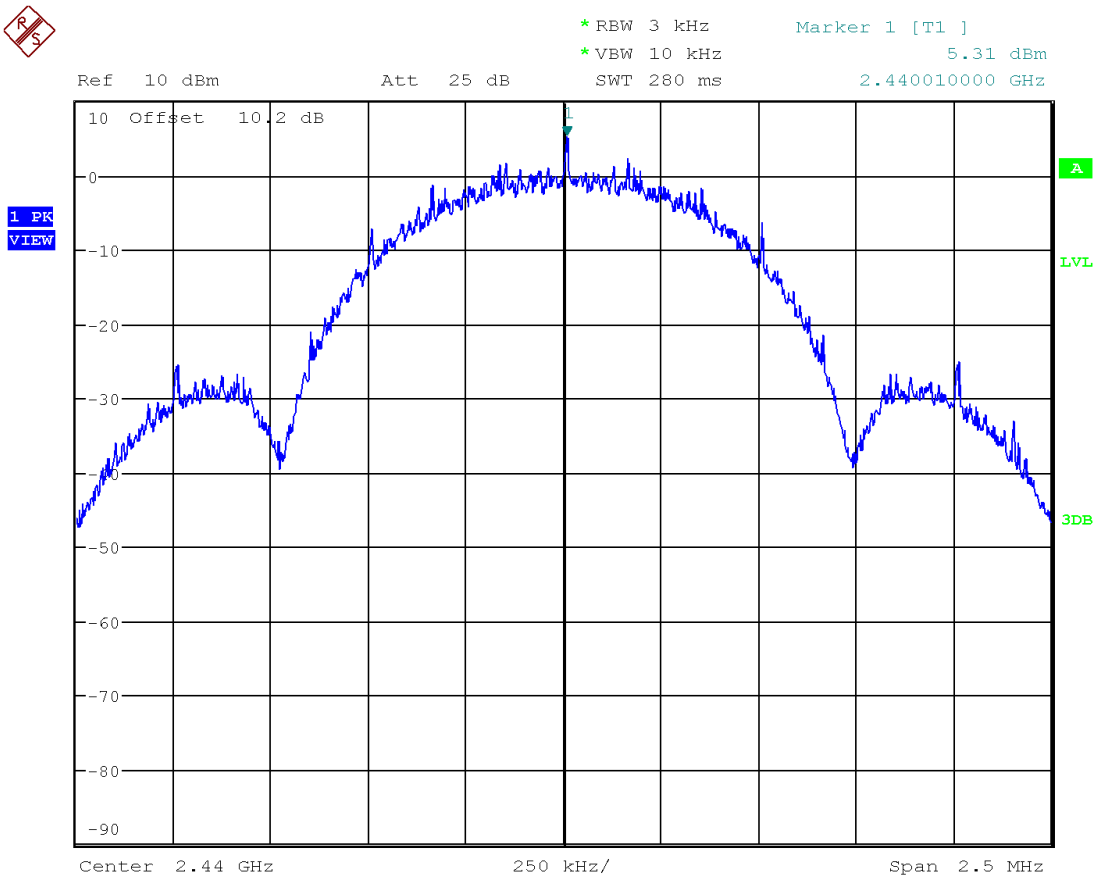
Tested By	Test Date
Anderson Soungpanya	August 23, 2018

Plot 3. 1



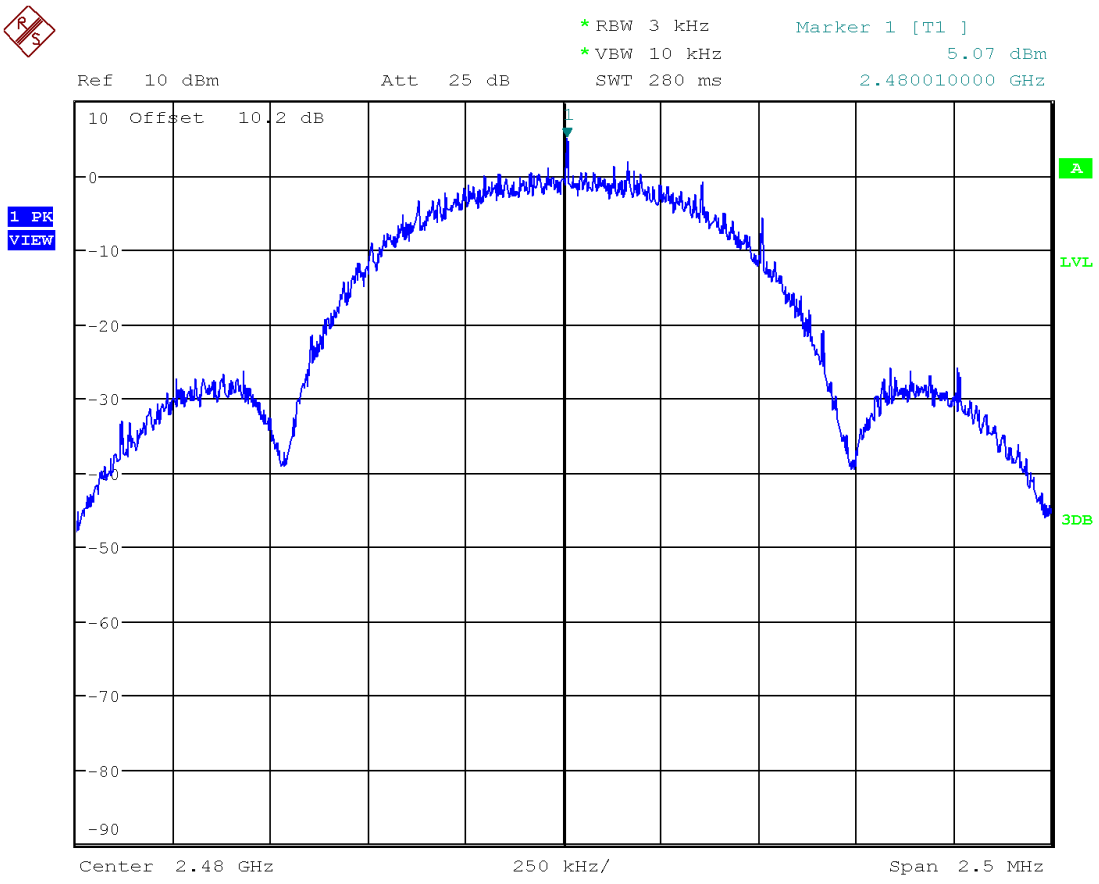
Date: 23.AUG.2018 10:00:26

Plot 3. 2



Date: 23.AUG.2018 09:58:15

Plot 3. 3



Date: 23.AUG.2018 09:50:07

4.4 Out of Band Antenna Conducted Emission
FCC: 15.247(d); RSS-247, 5.5;

4.4.1 Requirement

In any 100 kHz bandwidth outside the EUT pass-band, the RF power shall be below the maximum in-band 100 kHz emissions by at least 20 dB (if peak power of in-band emission is measured) or 30 dB (if average power of in-band emission is measured).

In addition, 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)

4.4.2 Procedure

The procedure described in FCC Publication KDB 558074 D01 Meas Guidance v05, specifically section 11.11 DTS Emissions in non-restricted frequency bands of ANSI 63.10.

A spectrum analyzer was connected to the antenna port of the transmitter.

1. Set the RBW = 100 kHz.
2. Set the VBW ≥ 3 x RBW.
3. Detector = peak.
4. Sweep time = auto couple.
5. Trace mode = max hold.
6. Allow trace to fully stabilize.
7. Use the peak marker function to determine the maximum amplitude level.

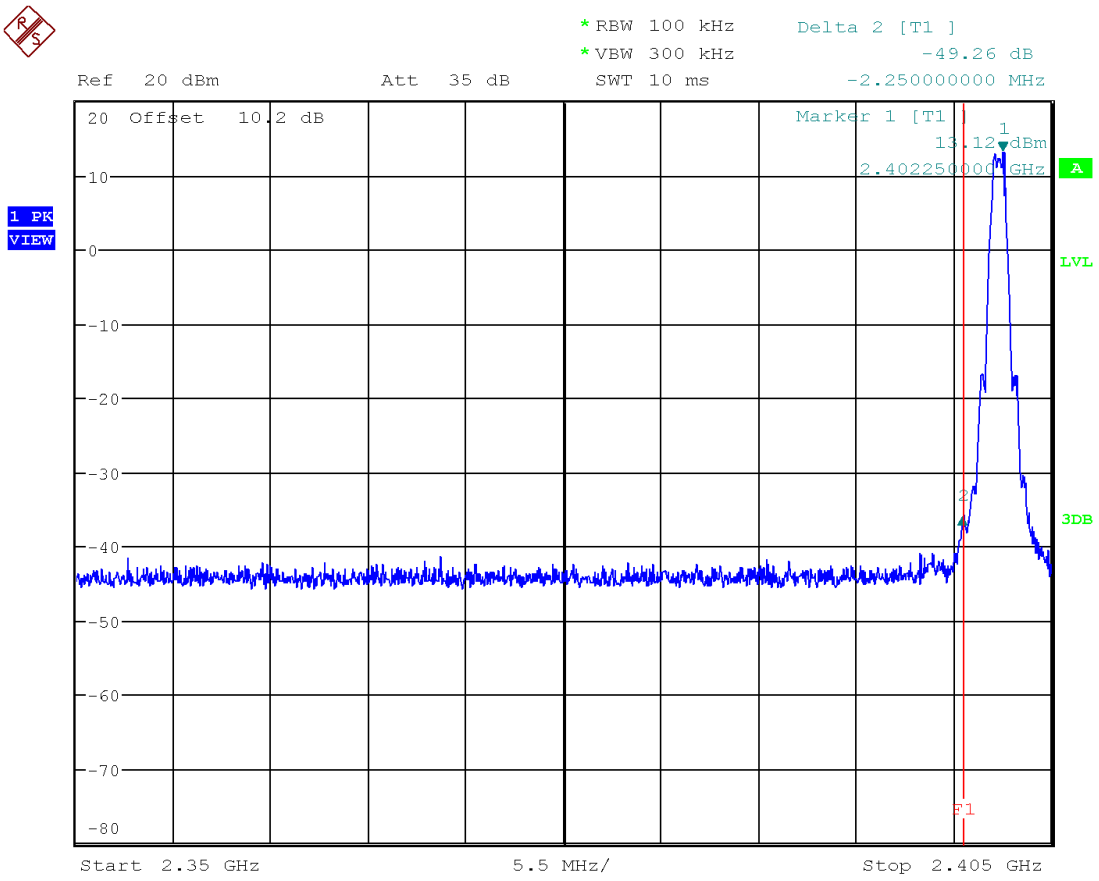
The unwanted emissions were measured from 30 MHz to 25 GHz. Plots below are corrected for cable loss and then compared to the limits.

4.4.3 Test Result

Refer to the following plots 4.1 – 4.5 for unwanted conducted emissions. Plot 4.1 & 4.2 shows the delta marker greater than -20dBc at the band edge. Plot 4.3-4.5shows the delta -20dB attenuation limit line.

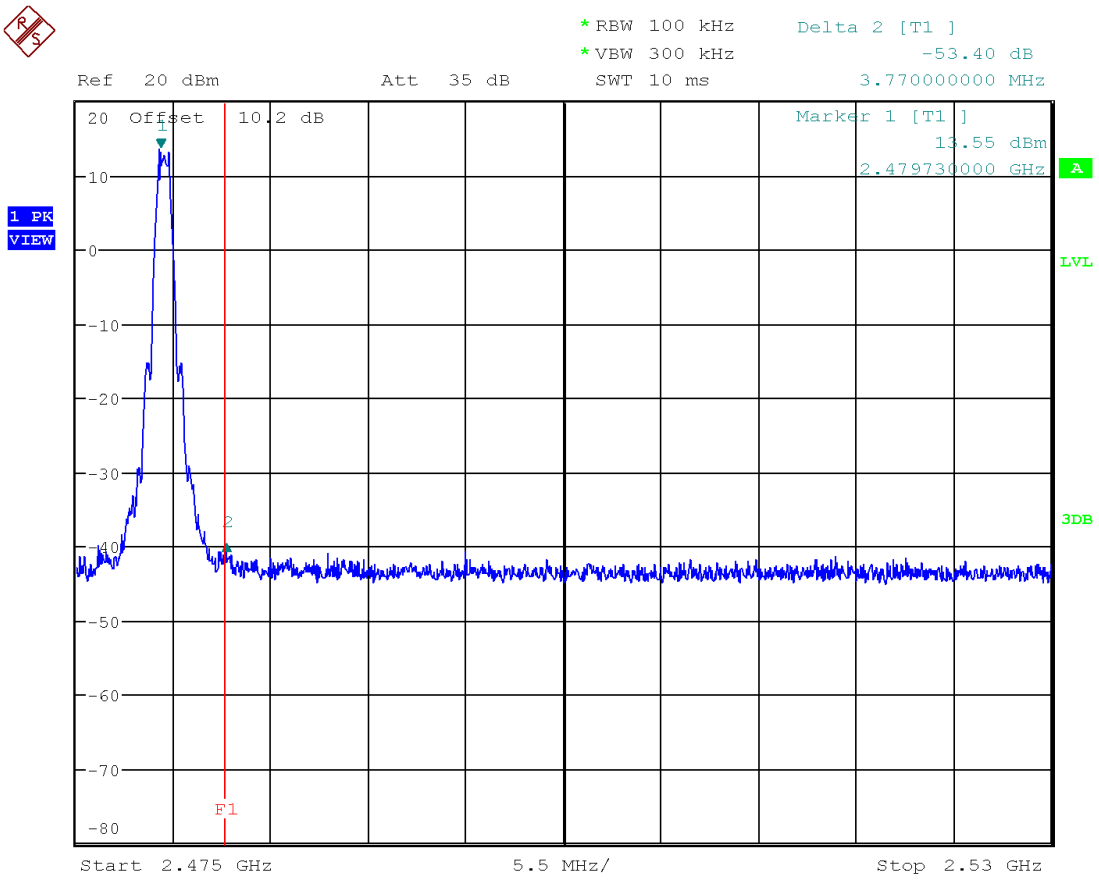
Tested By	Test Date
Anderson Soungpanya	August 23, 2018

Tx @ Low Channel, 2400 MHz Band Edge
Plot 4.1



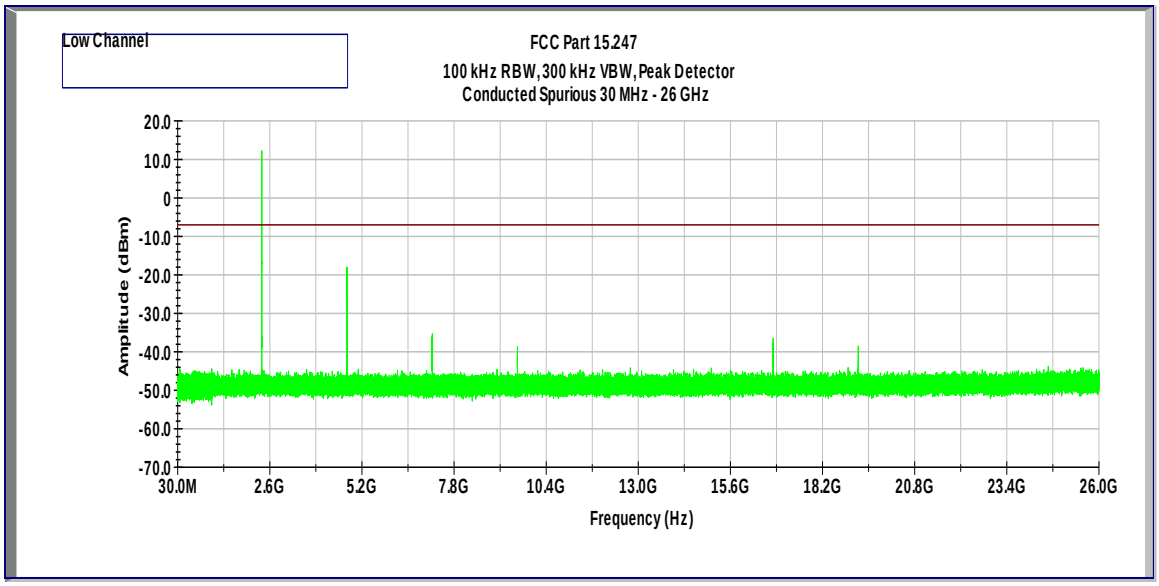
Date: 23.AUG.2018 10:26:27

Tx @ Low Channel, 2483.5 MHz Band Edge
Plot 4.2

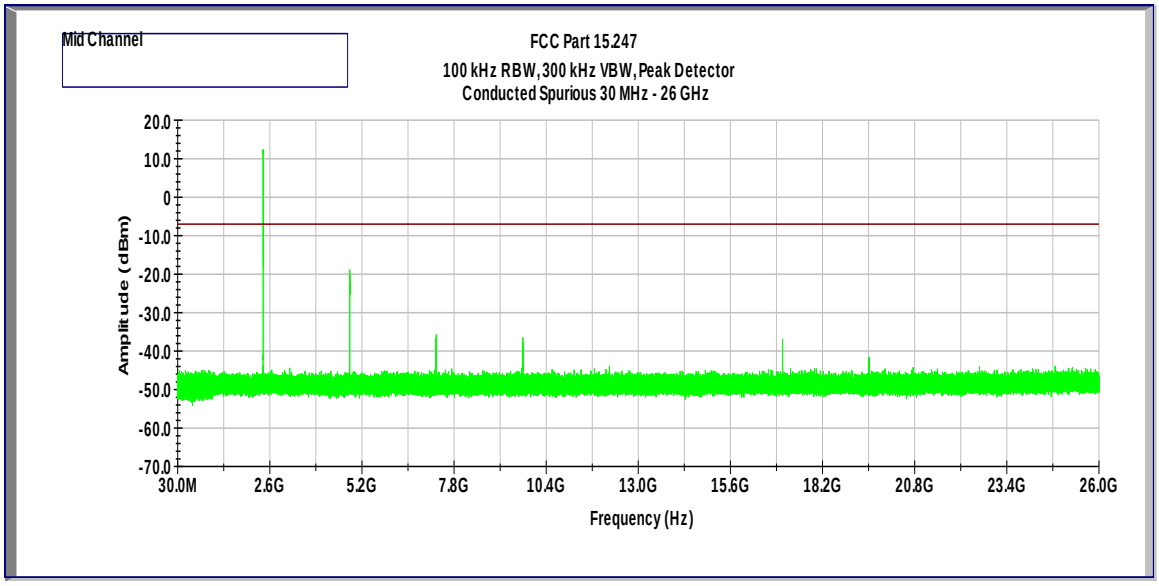


Date: 23.AUG.2018 10:29:18

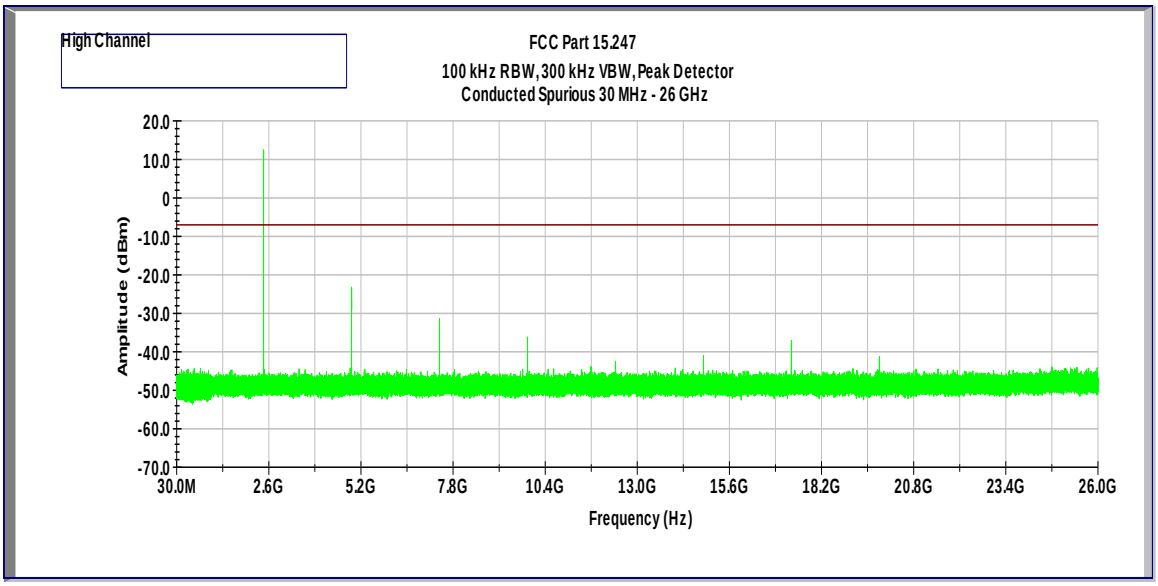
Tx @ Low Channel, 2402 MHz
30MHz -26GHz Conducted Spurious
Plot 4.3



Tx @ Mid Channel, 2440 MHz
30MHz -26GHz Conducted Spurious
Plot 4.4



Tx @ High Channel, 2480 MHz
30MHz -26GHz Conducted Spurious
Plot 4.5



4.5 Transmitter Radiated Emissions
FCC Rules: 15.247(d), 15.209, 15.205; RSS-247, 5.5;

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 emission measurements were performed from 30 MHz to 25 GHz according to the procedure described in ANSI C63.10: 2013. 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.

Radiated measurements were performed on the X, Y and Z orientation of the EUT. Data is presented with 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.

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.

4.5.5 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

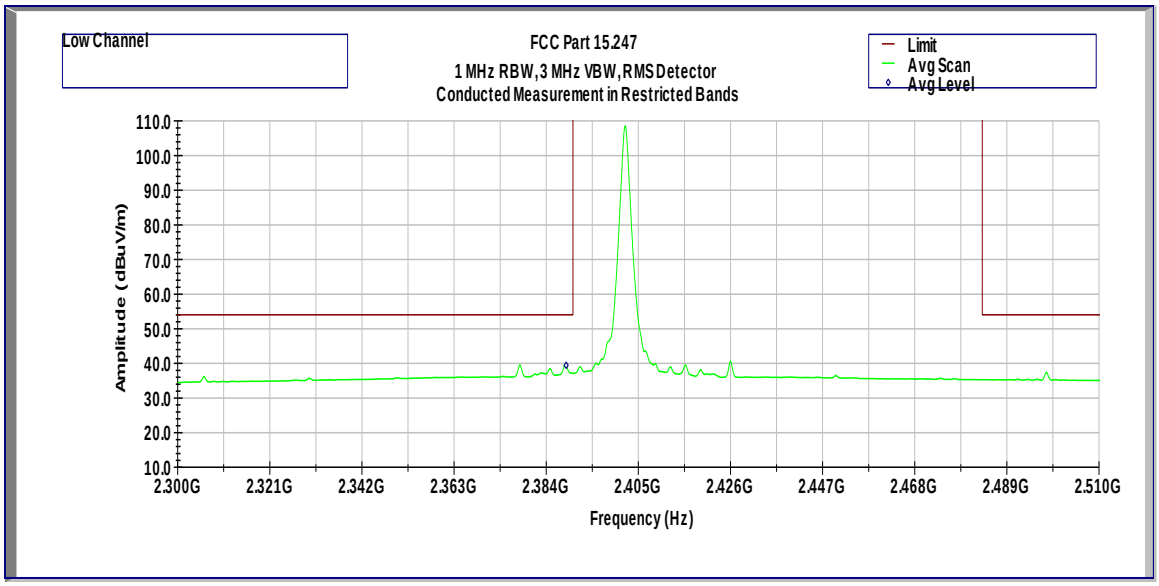
4.5.6 Test Results

Tested By	Test Date
Anderson Soungpanya	August 23 – November 16, 2018

Conducted Out-of-Band Spurious Emissions at the Band Edge were made with the consideration of cable loss and the addition of a 2dBi Antenna.

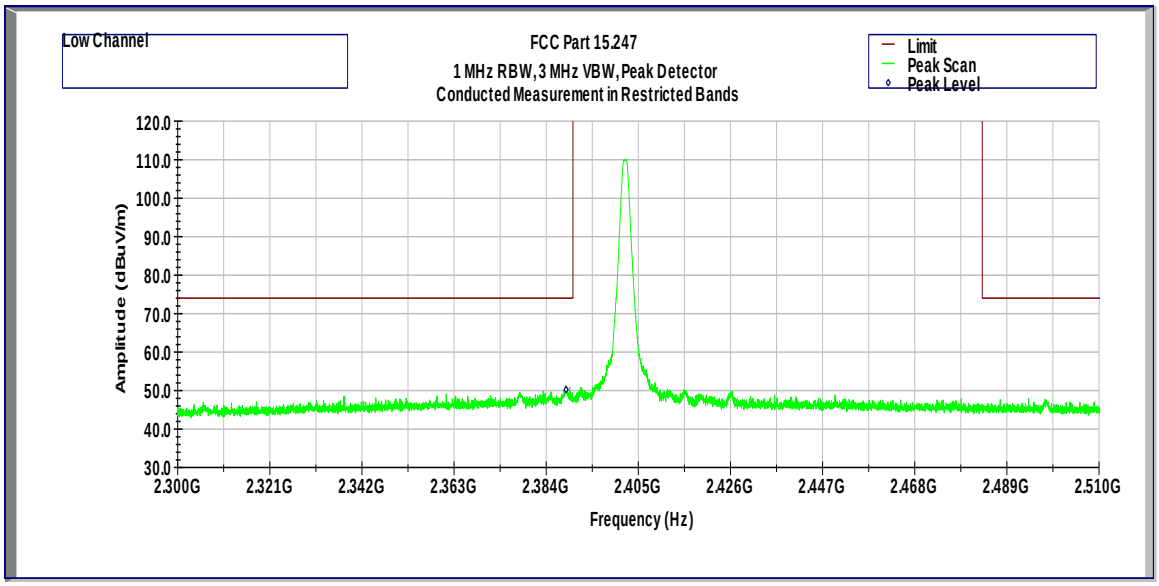
Test Results: 15.209/15.205 Radiated Restricted Band Emissions

Conducted Out-of-Band Spurious Emissions at the Band Edge – Tx @ 2402 MHz, Average



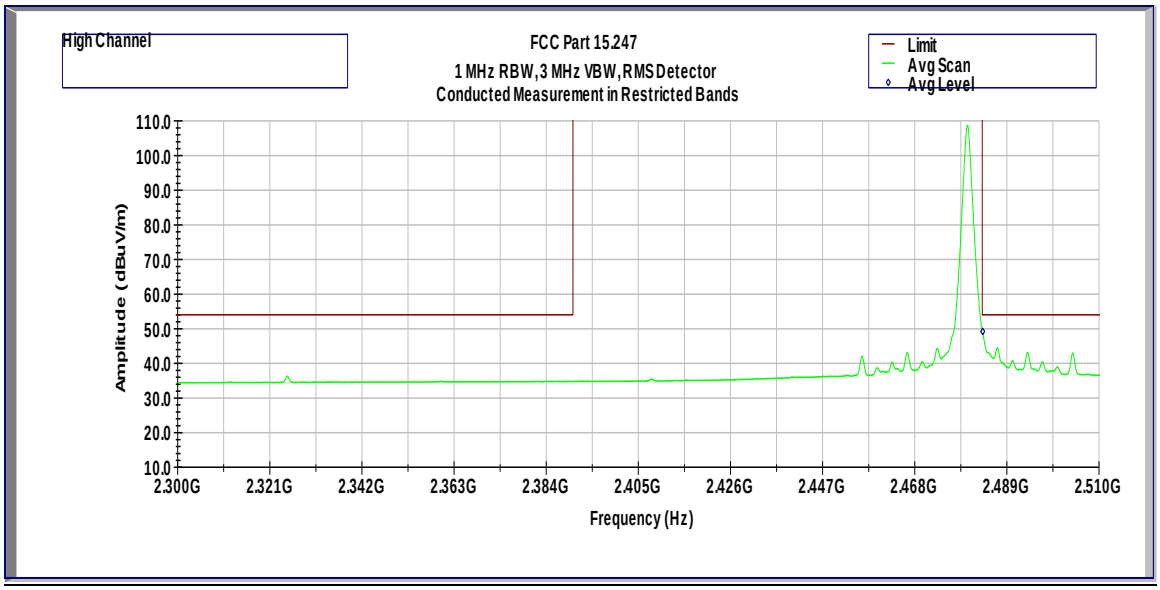
Frequency	Corrected Amplitude	Limit	Margin	Detector	Results
GHz	dB(µV/m)	dB(µV/m)	dB		
2.389	39.43	54	-14.57	RMS	Pass

Conducted Out-of-Band Spurious Emissions at the Band Edge – Tx @ 2402 MHz, Peak



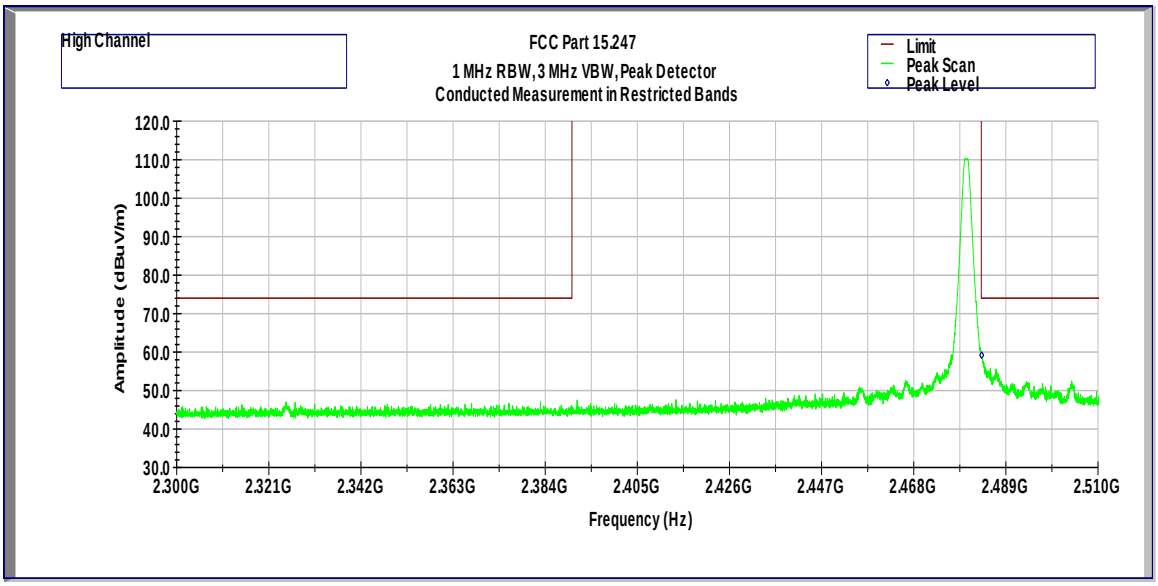
Frequency	Corrected Amplitude	Limit	Margin	Detector	Results
GHz	dB(µV/m)	dB(µV/m)	dB		
2.378	50.25	74	-23.75	Peak	Pass

Conducted Out-of-Band Spurious Emissions at the Band Edge – Tx @ 2480 MHz, Average



Frequency	Corrected Amplitude	Limit	Margin	Detector	Results
GHz	dB(µV/m)	dB(µV/m)	dB		
2.4835	49.2	54	-4.80	RMS	Pass

Conducted Out-of-Band Spurious Emissions at the Band Edge – Tx @ 2480 MHz, Peak

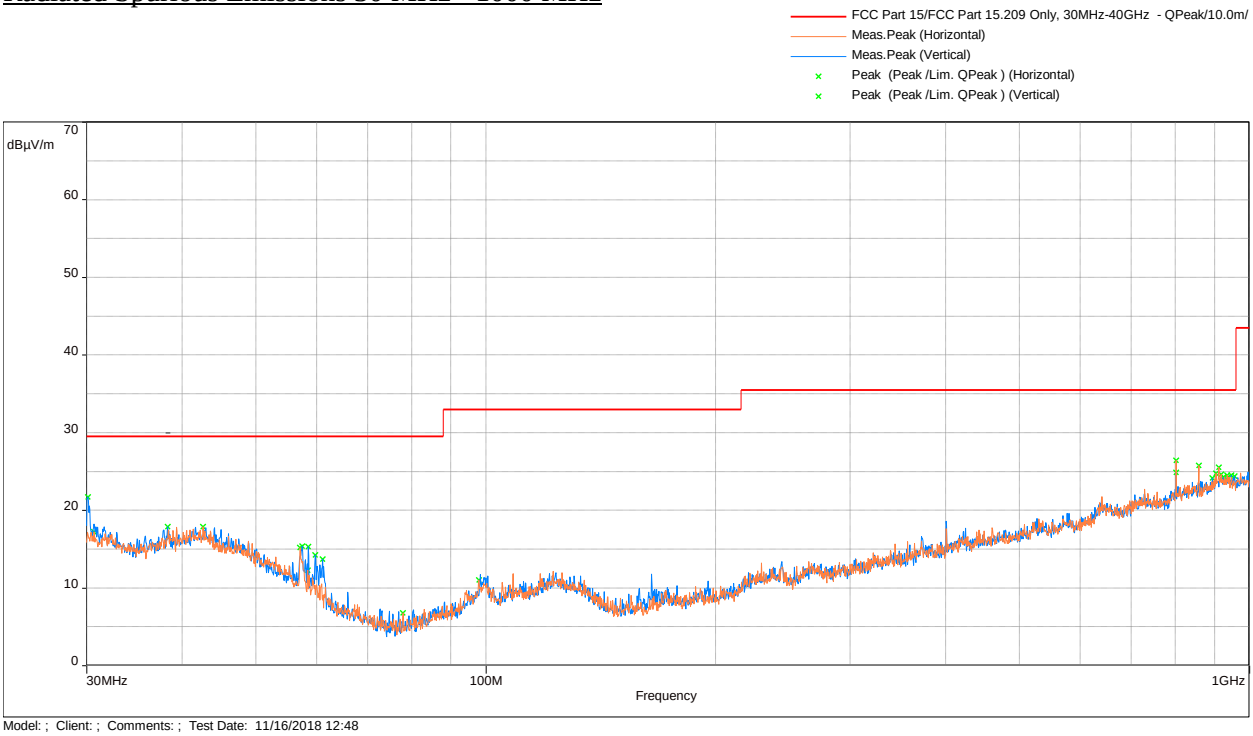


Frequency	Corrected Amplitude	Limit	Margin	Detector	Results
GHz	dB(µV/m)	dB(µV/m)	dB		
2.4835	59.20	74	-14.80	Peak	Pass

Out-of-Band Radiated Spurious Emissions

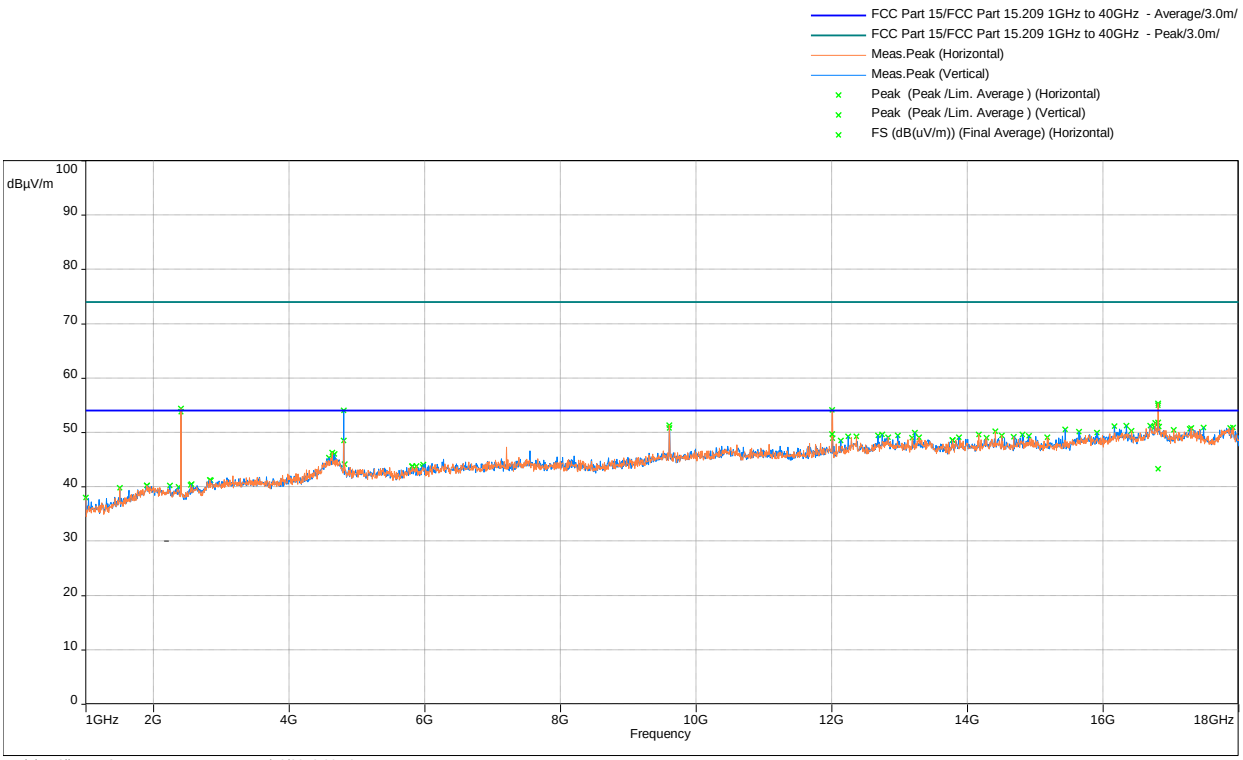
Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 2402MHz

Radiated Spurious Emissions 30 MHz - 1000 MHz



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 12:48

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



Frequency	Average @ 3m	Limit @ 3m	Margin	Angle	Height	Polarization	Correction
MHz	dB(µV/m)	dB(µV/m)	(dB)	(°)	(m)		(dB)
4803.45	50.91	54	-3.09	212	2.64	Vertical	-7.25
12008.81	49.62	54	-4.38	131	1.92	Horizontal	-1.01
16815.64	48.23	54	-5.77	301	3.27	Horizontal	6.52

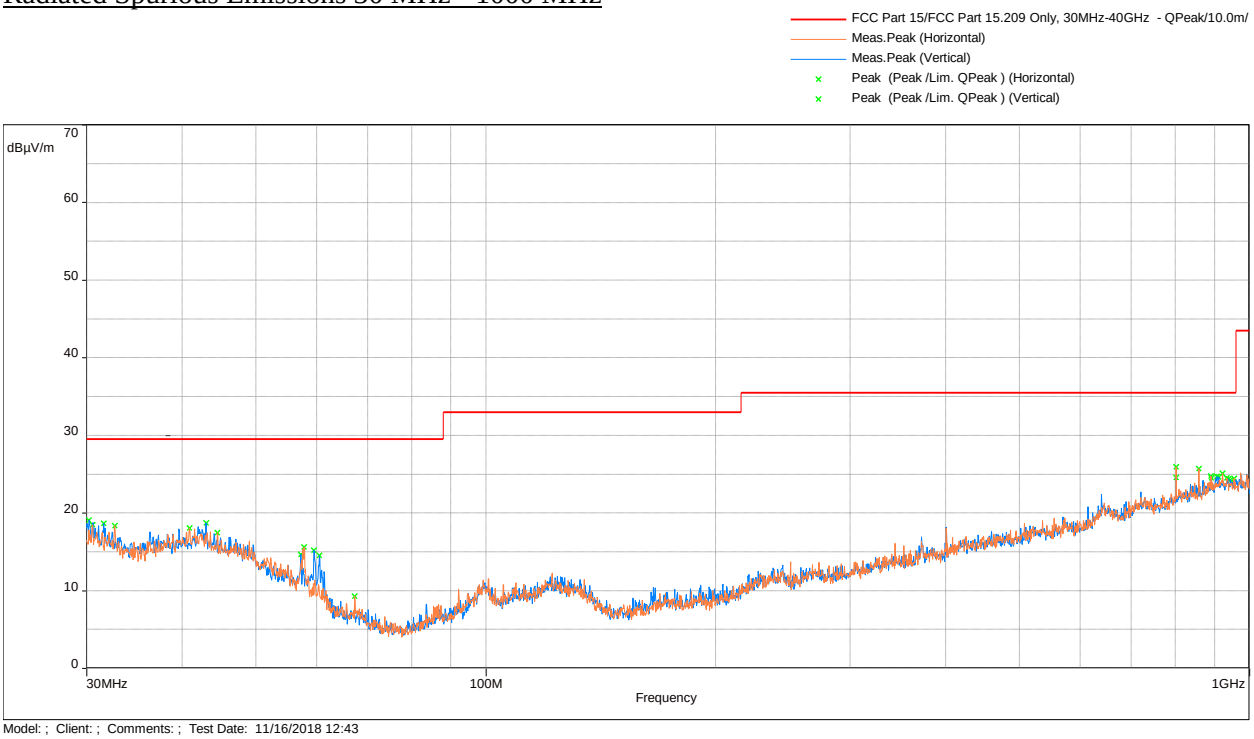
Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Note: FS@3m = RA + AF + CF - Preamp

Results	Complies

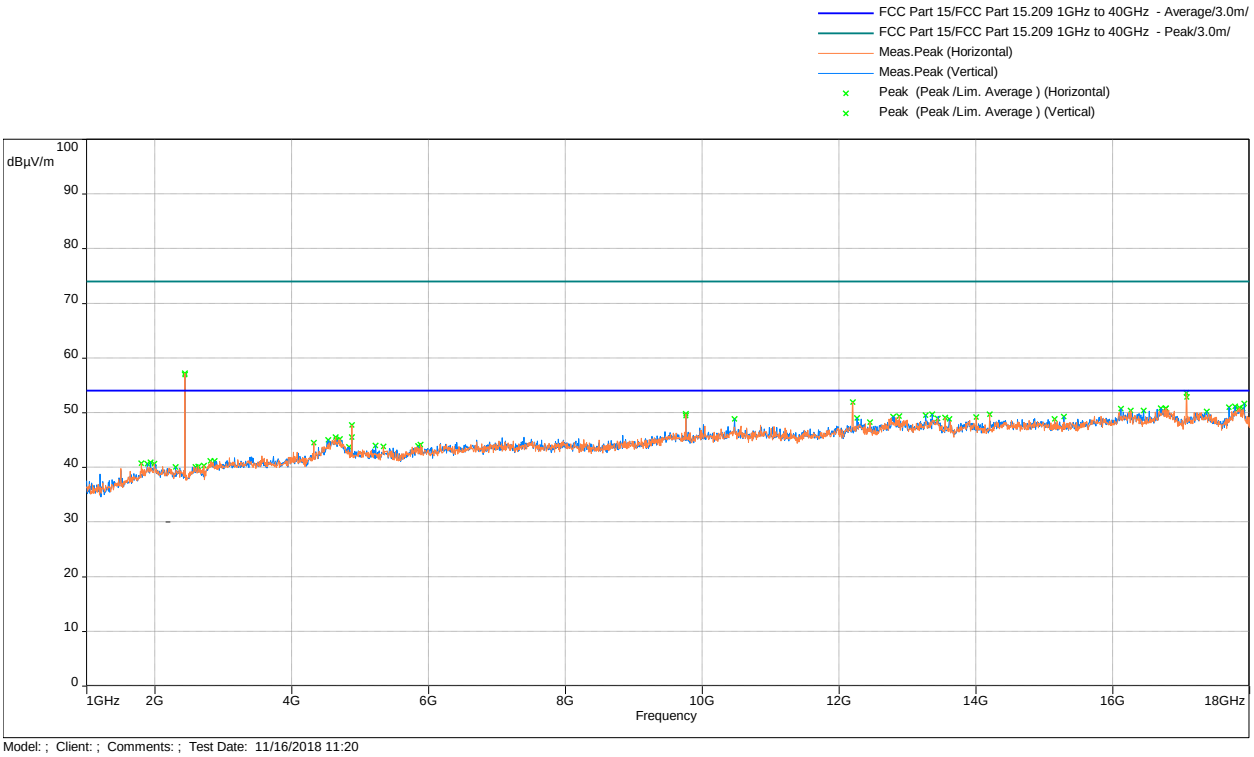
Test Results: 15.209 Radiated Spurious Emissions Mid Channel, Tx at 2440MHz

Radiated Spurious Emissions 30 MHz - 1000 MHz



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 12:43

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



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 11:20

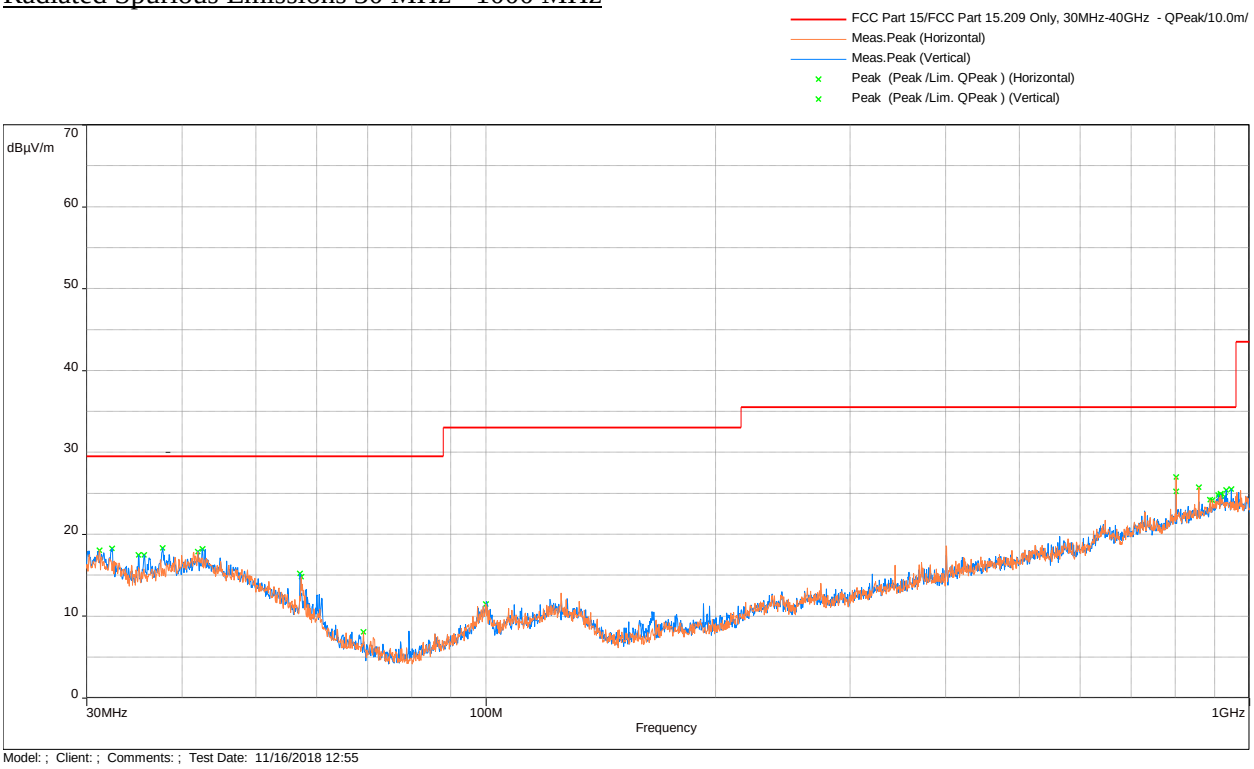
Frequency	Average @ 3m	Limit @ 3m	Margin	Angle	Height	Polarization	Correction
MHz	dB(µV/m)	dB(µV/m)	(dB)	(°)	(m)		(dB)
12201.34	51.92	54	-2.08	128	1.73	Horizontal	-0.83
17078.60	48.51	54	-5.49	182	1.87	Horizontal	6.57

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

Note: FS@3m = RA + AF + CF - Preamp

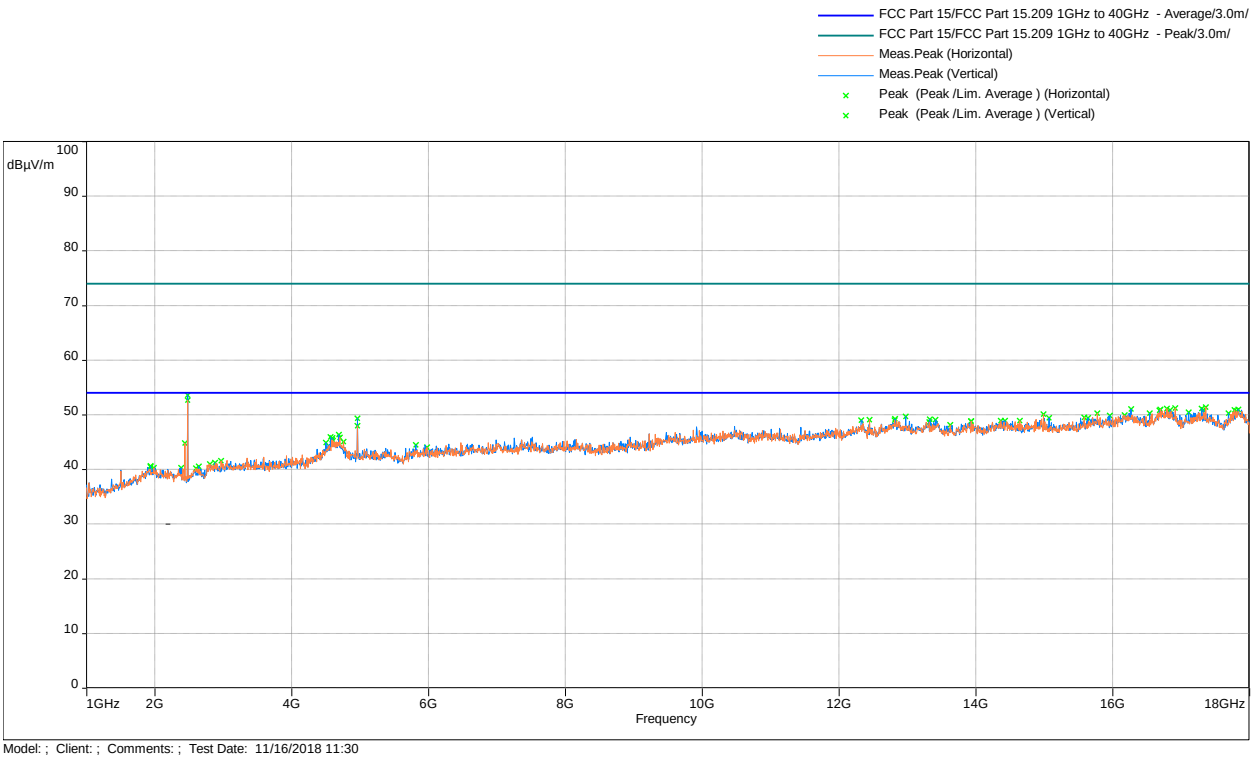
Results	Complies

Radiated Spurious Emissions 30 MHz - 1000 MHz



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 12:55

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



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 11:30

Frequency	Average @ 3m	Limit @ 3m	Margin	Angle	Height	Polarization	Correction
MHz	dB(µV/m)	dB(µV/m)	(dB)	(°)	(m)		(dB)
4959.323	46.29	54	-7.71	225	2.10	Vertical	-8.03

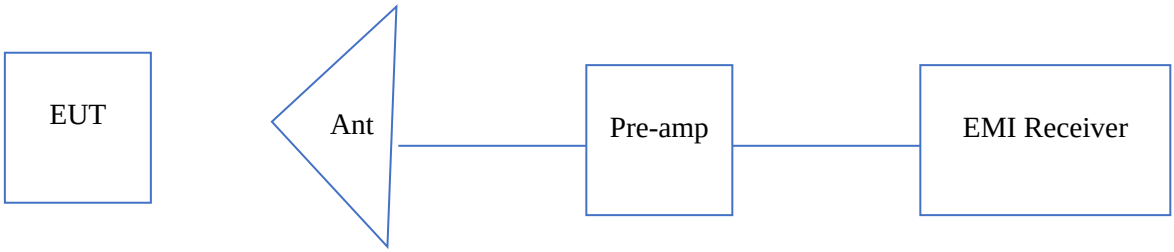
Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Note: FS@3m = RA + AF + CF - Preamp

Results	Complies

4.5.7 Test Setup Configuration

The following show the testing configurations used.



4.6 Radiated Emissions from Digital Parts

FCC Ref: 15.109, ICES 003

4.6.1 Requirement

Limits for Electromagnetic Radiated Emissions FCC Section 15.109(b), ICES 003*, RSS GEN

Frequency (MHz)	**Class A at 10m dB(µV/m)**	**Class B at 3m dB(µV/m)**
30-88	39	40.0
88-216	43.5	43.5
216-960	46.4	46.0
Above 960	49.5	54.0

* According to FCC Part 15.109(g) an alternative to the radiated emission limits shown above, digital devices may be shown to comply with the limit of CISPR Pub. 22

4.6.2 Procedures

Measurements are conducted with a quasi-peak detector instrument in the frequency range of 30 MHz to 1000 MHz and with the average detector instrument in the frequency range above 1000 MHz. The measuring receiver meets the requirements of Section One of CISPR 16 and the measuring antenna correlates to a balanced dipole.

Measurements of the radiated field are made with the antenna located at a distance of 10 meters from the EUT. If the field-strength measurements at 10m cannot be made because of high ambient noise level or for other reasons, measurements of Class B equipment may be made at a closer distance, for example 3m. An inverse proportionality factor of 20 dB per decade should be used to normalize the measured data or limit line to the specified distance for determining compliance.

The antenna is adjusted between 1m and 4m in height above the ground plane for maximum meter reading at each test frequency.

The antenna-to-EUT azimuth is varied during the measurement to find the maximum field-strength readings.

The antenna-to-EUT polarization (horizontal and vertical) is varied during the measurements to find the maximum field-strength readings.

The EUT, where intended for tabletop use, is placed on a table whose top is 0.8m above the ground plane. The table is constructed of non-conductive materials. Its dimensions are 1m by 1.5m, but may be extended for a larger EUT.

Floor standing EUT are placed on a horizontal metal ground plane and isolated from the ground plane by resting on an insulating material.

Equipment setup for radiated disturbance tests followed the guidelines of ANSI C63.4: 2014

4.6.3 Test Results

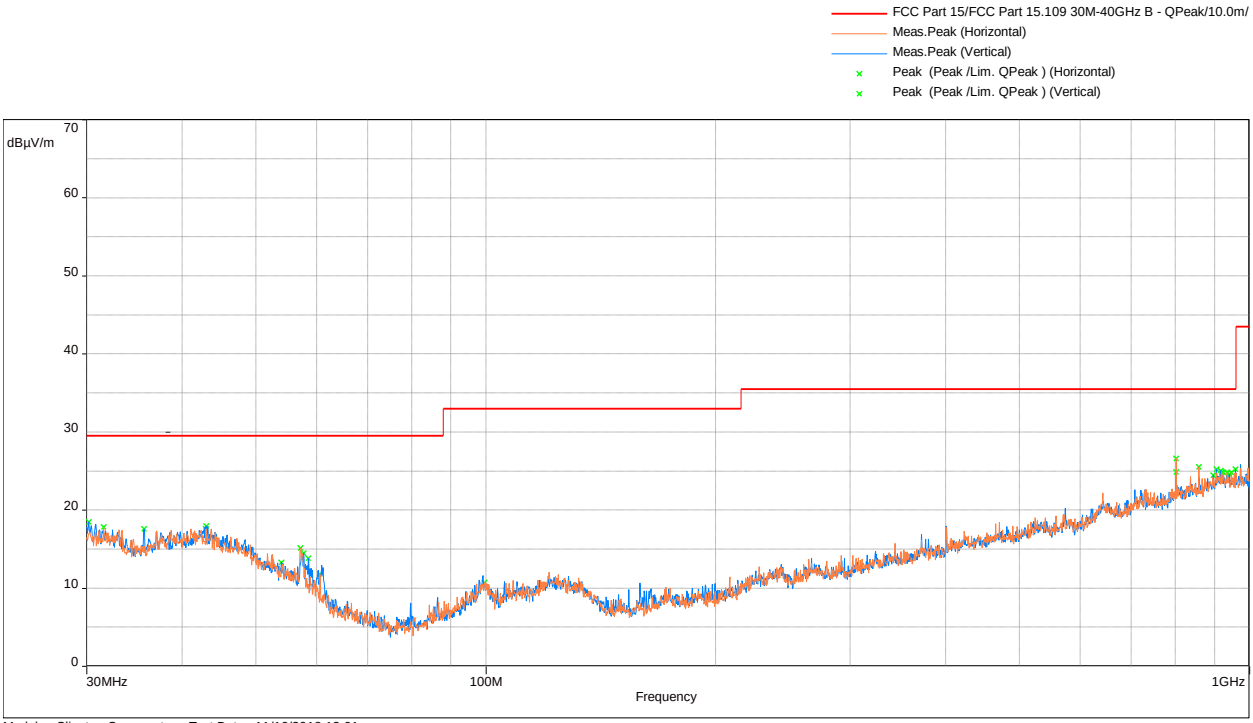
Radiated emission measurements were performed from 30 MHz to 1000 MHz. The data on the following pages list the significant emission frequencies, the limit and the margin of compliance.

An inverse proportionality factor of 20 dB per decade was used to normalize the limit line of 30MHz to 1000MHz to the specified distance for determining compliance

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

Tested By	Test Date
Anderson Soungpanya	November 16, 2018

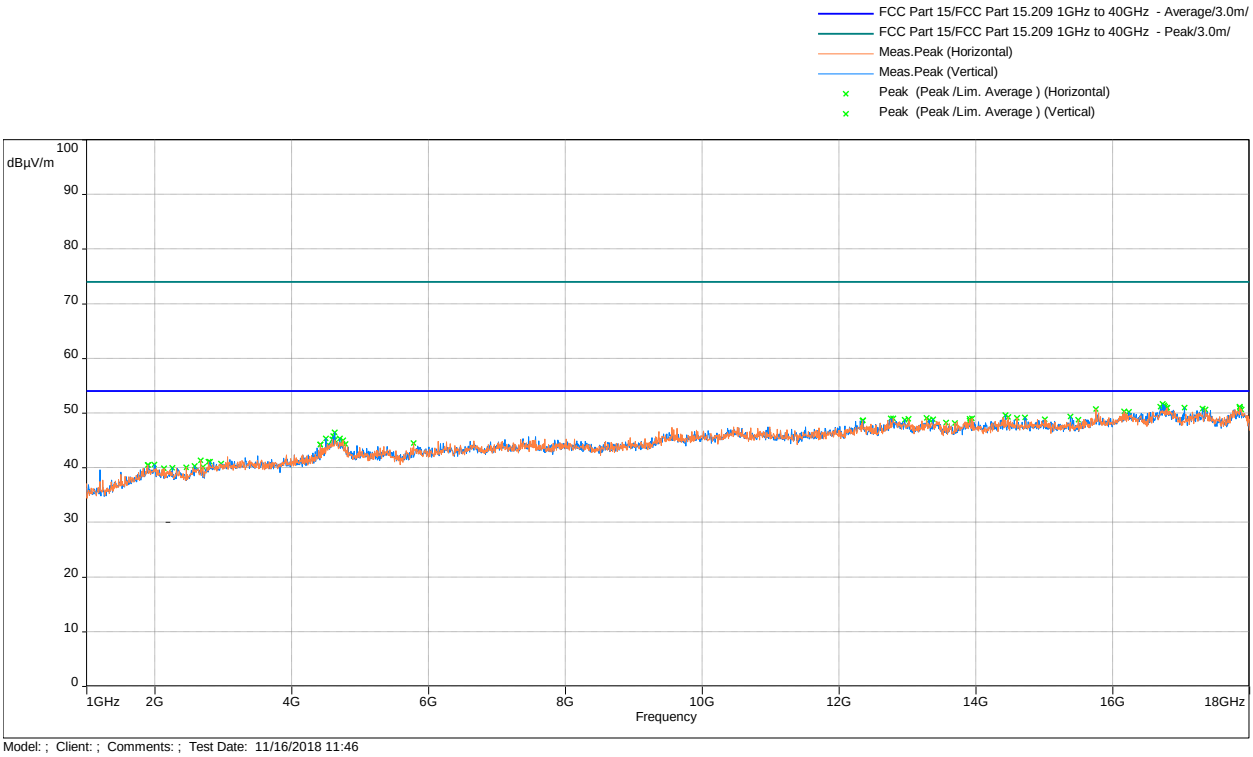
Test Results: Radiated Emissions 30 MHz - 1000



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 13:01

Frequency MHz	FS@10m dB(µV/m)	Limit@10m dB(µV/m)	Margin (dB)	Azimuth (deg)	Height (m)	Polarity	RA (dBuV)	Correction (dB)
30.194	18.45	29.5	-11.05	0	1.21	Vertical	27.99	-9.54
31.584	17.79	29.5	-11.71	10	1.98	Horizontal	27.14	-9.35
42.998	17.59	29.5	-11.91	328	1.00	Horizontal	20.73	-3.14
43.030	17.90	29.5	-11.60	43	1.02	Vertical	20.36	-2.46
801.829	26.61	35.5	-8.89	238	1.37	Horizontal	36.34	-9.73
859.091	25.48	35.5	-10.02	16	1.80	Horizontal	34.84	-9.36
Result:	**Complies** by 8.89 dB							

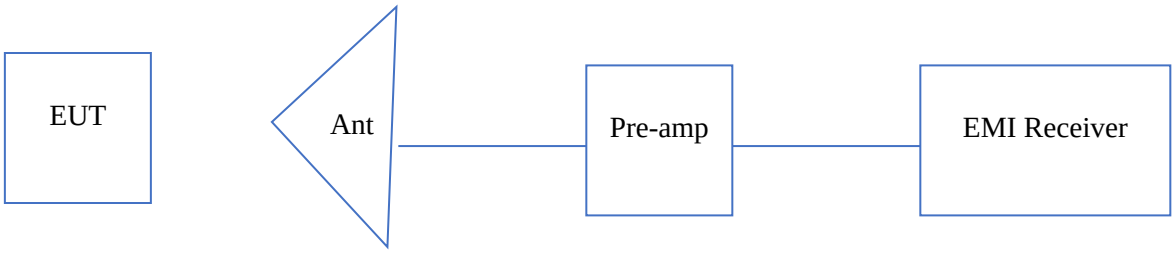
Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan vs Average & Peak Limit



Model: ; Client: ; Comments: ; Test Date: 11/16/2018 11:46

4.6.4 Test Setup Configuration

The following photographs show the testing configurations used.



4.7 AC Line Conducted Emission
FCC: 15.207, 15.107; RSS-GEN;

4.7.1 Requirement

Frequency Band MHz	Class B Limit dB(µV)		Class A Limit dB(µV)	
	Quasi-Peak	Average	Quasi-Peak	Average
0.15-0.50	66 to 56 *	56 to 46 *	79	66
0.50-5.00	56	46	73	60
5.00-30.00	60	50	73	60

*Note: *Decreases linearly with the logarithm of the frequency*
At the transition frequency the lower limit applies.

4.7.2 Procedure

Measurements are carried out using quasi-peak and average detector receivers in accordance with CISPR 16. An AMN is required to provide a defined impedance at high frequencies across the power feed at the point of measurement of terminal voltage and also to provide isolation of the circuit under test from the ambient noise on the power lines. An AMN as defined in CISPR 16 shall be used.

The EUT is located so that the distance between the boundary of the EUT and the closest surface of the AMN is 0.8m.

Where a flexible mains cord is provided by the manufacturer, this shall be 1m long or if in excess of 1m, the excess cable is folded back and forth as far as possible so as to form a bundle not exceeding 0.4m in length.

The EUT is arranged and connected with cables terminated in accordance with the product specification.

Conducted disturbance is measured between the phase lead and the reference ground, and between the neutral lead and the reference ground. Both measured values are reported.

The EUT, where intended for tabletop use, is placed on a table whose top is 0.8m above the ground plane. A vertical, metal reference plane is placed 0.4m from the EUT. The vertical metal reference-plane is at least 2m by 2m. The EUT shall be kept at least 0.8m from any other metal surface or other ground plane not being part of the EUT. The table is constructed of non-conductive materials. Its dimensions are 1m by 1.5m, but may be extended for larger EUT.

Floor standing EUT are placed on a horizontal metal ground plane and isolated from the ground plane by resting on an insulating material. The metal ground plane extends at least 0.5m beyond the boundaries of the EUT and has minimum dimensions of 2m by 2m.

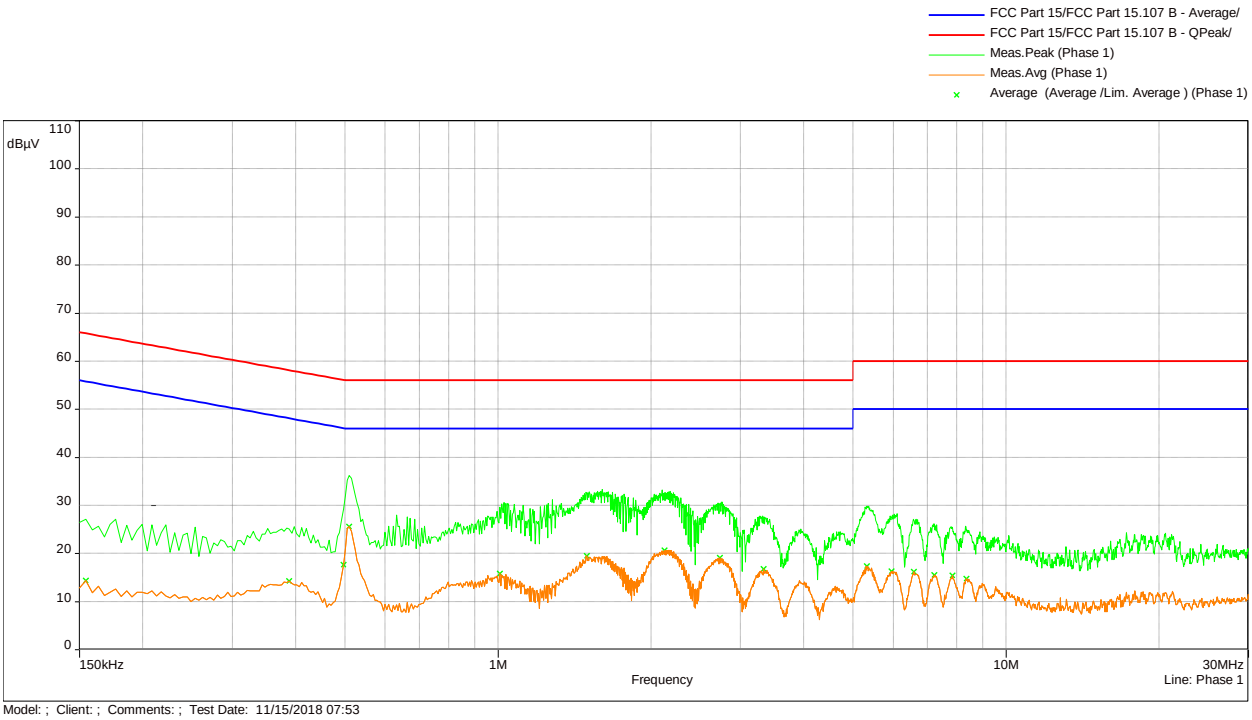
Equipment setup for conducted disturbance tests followed the guidelines of ANSI C63.4:2014.

Tested By	Test Date
Anderson Soungpanya	November 15, 2018

4.7.3 Test Results

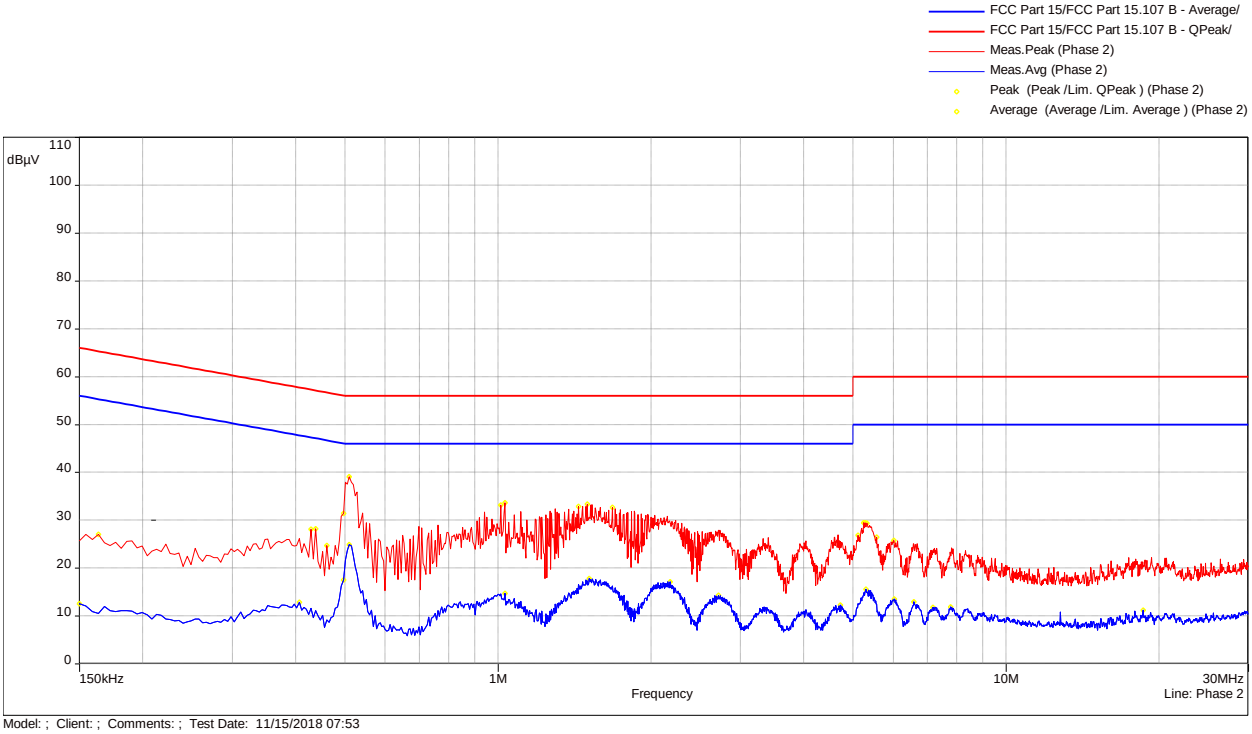
FCC Part 15B Conducted Disturbances, 120V 60Hz, Transmitter Off

Line 1



Model: ; Client: ; Comments: ; Test Date: 11/15/2018 07:53

Line 2



Model: ; Client: ; Comments: ; Test Date: 11/15/2018 07:53

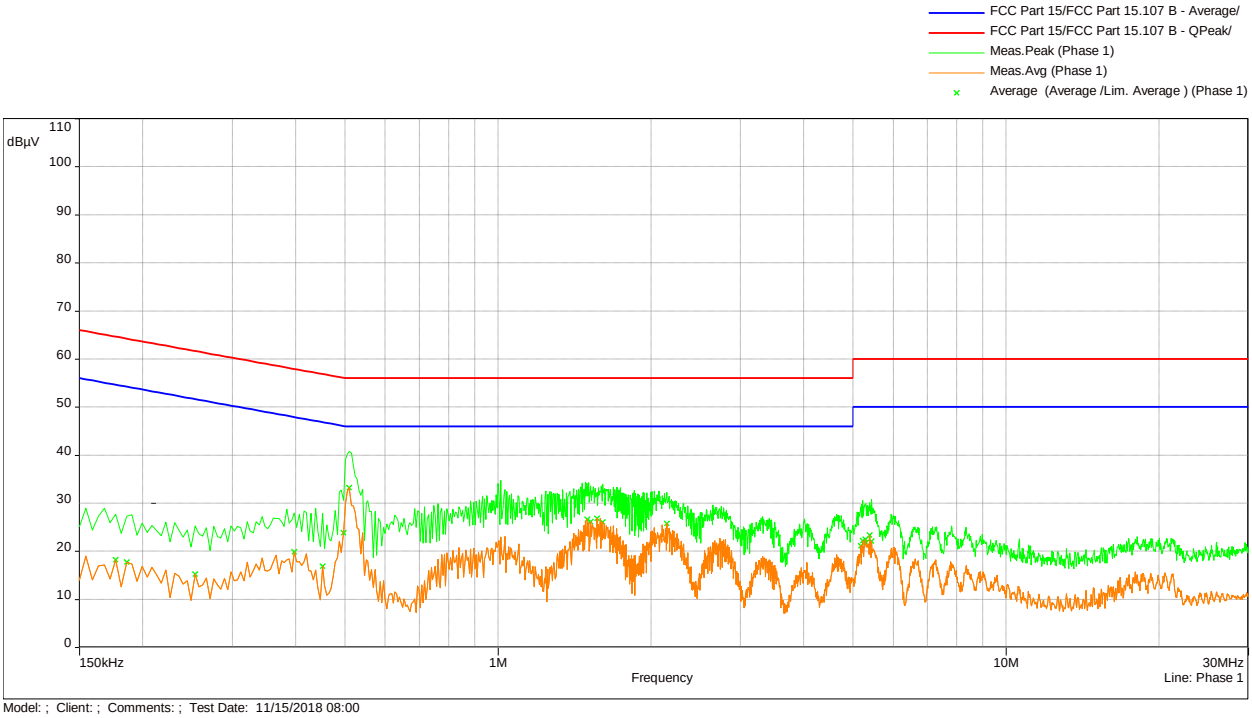
Quasi-Peak Table					
Frequency (MHz)	Q.Peak (dBµV)	Limit (dBµV)	Margin (dB)	Comment	Correction (dB)
0.164	27.05	65.28	-38.23	Phase 2	11.56
0.209	25.97	63.26	-37.29	Phase 1	11.55
0.222	25.95	62.74	-36.79	Phase 1	11.57
0.231	24.26	62.41	-38.15	Phase 1	11.56
0.254	25.45	61.64	-36.19	Phase 1	11.58
0.398	25.55	57.91	-32.35	Phase 1	11.59
0.429	28.11	57.27	-29.16	Phase 2	11.61
0.438	28.23	57.10	-28.86	Phase 2	11.60
0.461	24.64	56.68	-32.04	Phase 2	11.61
0.497	31.36	56.06	-24.70	Phase 2	11.60
0.497	29.18	56.06	-26.87	Phase 1	11.60
0.510	39.03	56.00	-16.97	Phase 2	11.60
0.510	36.21	56.00	-19.79	Phase 1	11.60
1.014	33.16	56.00	-22.84	Phase 2	11.64
1.032	33.62	56.00	-22.38	Phase 2	11.65
1.442	32.89	56.00	-23.11	Phase 2	11.66
1.500	33.35	56.00	-22.65	Phase 2	11.68
1.604	33.26	56.00	-22.74	Phase 1	11.68
1.680	32.61	56.00	-23.39	Phase 2	11.66
1.703	32.36	56.00	-23.64	Phase 1	11.67
1.757	32.07	56.00	-23.93	Phase 1	11.67
1.770	32.30	56.00	-23.70	Phase 1	11.67
2.108	33.15	56.00	-22.85	Phase 1	11.71
5.114	26.82	60.00	-33.18	Phase 2	11.82
5.249	29.48	60.00	-30.52	Phase 2	11.82
5.285	29.49	60.00	-30.51	Phase 2	11.82
5.330	29.32	60.00	-30.68	Phase 2	11.83
5.330	29.82	60.00	-30.18	Phase 1	11.83
5.469	28.97	60.00	-31.03	Phase 1	11.83
5.478	28.83	60.00	-31.17	Phase 1	11.84
5.501	28.07	60.00	-31.93	Phase 1	11.84
5.568	26.47	60.00	-33.53	Phase 2	11.85
6.023	25.79	60.00	-34.21	Phase 2	11.84
6.036	28.14	60.00	-31.86	Phase 1	11.84
6.104	28.25	60.00	-31.75	Phase 1	11.83

Average Table					
Frequency (MHz)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Comment	Correction (dB)
0.150	12.57	56.00	-43.43	Phase 2	11.55
0.155	14.37	55.75	-41.39	Phase 1	11.55
0.389	14.21	48.10	-33.88	Phase 1	11.59
0.407	12.82	47.72	-34.90	Phase 2	11.60
0.497	17.64	46.06	-28.42	Phase 1	11.60
0.497	17.54	46.06	-28.52	Phase 2	11.60
0.510	25.55	46.00	-20.45	Phase 1	11.60
0.510	24.87	46.00	-21.13	Phase 2	11.60
1.010	15.80	46.00	-30.20	Phase 1	11.64
1.032	14.63	46.00	-31.37	Phase 2	11.65
1.496	19.45	46.00	-26.55	Phase 1	11.68
1.514	17.76	46.00	-28.24	Phase 2	11.68
2.130	20.63	46.00	-25.37	Phase 1	11.72
2.184	17.11	46.00	-28.89	Phase 2	11.72
2.720	14.32	46.00	-31.68	Phase 2	11.75
2.733	19.07	46.00	-26.93	Phase 1	11.75
3.332	16.75	46.00	-29.25	Phase 1	11.74
4.718	12.26	46.00	-33.74	Phase 2	11.81
5.307	15.55	50.00	-34.45	Phase 2	11.82
5.330	17.34	50.00	-32.66	Phase 1	11.83
5.955	16.29	50.00	-33.71	Phase 1	11.85
6.032	13.47	50.00	-36.53	Phase 2	11.84
6.594	12.90	50.00	-37.10	Phase 2	11.89
6.594	16.16	50.00	-33.84	Phase 1	11.89
7.179	11.77	50.00	-38.23	Phase 2	11.88
7.229	15.49	50.00	-34.51	Phase 1	11.87
7.782	11.89	50.00	-38.11	Phase 2	11.88
7.845	15.39	50.00	-34.61	Phase 1	11.88
8.363	14.70	50.00	-35.30	Phase 1	11.93
18.650	11.16	50.00	-38.84	Phase 2	12.11

Result: **Complies** by -16.97dB

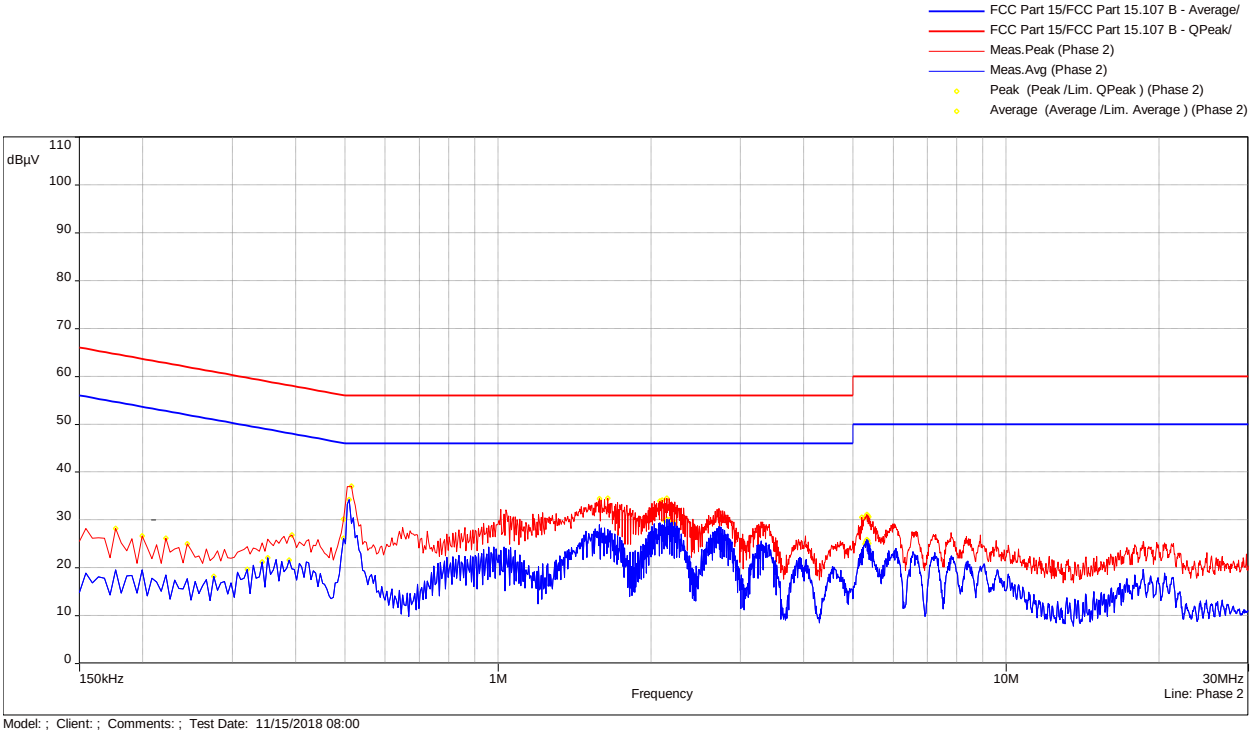
FCC Part 15.207 Conducted Disturbances, 120V 60Hz, Transmitter On

Line 1



Model: ; Client: ; Comments: ; Test Date: 11/15/2018 08:00

Line 2



Model: ; Client: ; Comments: ; Test Date: 11/15/2018 08:00

Quasi-Peak Table					
Frequency (MHz)	Q.Peak (dBµV)	Limit (dBµV)	Margin (dB)	Comment	Correction (dB)
0.177	28.16	64.63	-36.47	Phase 2	11.56
0.200	26.65	63.63	-36.98	Phase 2	11.56
0.222	26.19	62.74	-36.56	Phase 2	11.57
0.245	25.00	61.94	-36.94	Phase 2	11.55
0.393	26.84	58.00	-31.16	Phase 2	11.59
0.416	28.39	57.54	-29.15	Phase 1	11.60
0.429	27.85	57.27	-29.42	Phase 1	11.61
0.438	28.89	57.10	-28.21	Phase 1	11.60
0.452	27.85	56.85	-29.00	Phase 1	11.60
0.479	28.46	56.37	-27.90	Phase 1	11.62
0.492	32.70	56.13	-23.43	Phase 1	11.60
0.497	30.10	56.06	-25.95	Phase 2	11.60
0.510	40.74	56.00	-15.26	Phase 1	11.60
0.515	37.00	56.00	-19.00	Phase 2	11.60
1.001	34.10	56.00	-21.90	Phase 1	11.63
1.014	34.73	56.00	-21.27	Phase 1	11.64
1.464	34.15	56.00	-21.85	Phase 1	11.67
1.487	34.34	56.00	-21.66	Phase 1	11.68
1.586	34.41	56.00	-21.59	Phase 2	11.69
1.608	33.95	56.00	-22.05	Phase 1	11.68
1.644	34.55	56.00	-21.45	Phase 2	11.66
2.085	33.93	56.00	-22.07	Phase 2	11.70
2.108	34.12	56.00	-21.88	Phase 2	11.71
2.153	34.51	56.00	-21.49	Phase 2	11.72
5.199	30.48	60.00	-29.52	Phase 2	11.82
5.199	29.67	60.00	-30.33	Phase 1	11.82
5.222	30.61	60.00	-29.39	Phase 1	11.82
5.253	29.45	60.00	-30.55	Phase 1	11.82
5.276	30.53	60.00	-29.47	Phase 2	11.82
5.289	29.93	60.00	-30.07	Phase 1	11.82
5.298	30.75	60.00	-29.25	Phase 2	11.82
5.321	31.07	60.00	-28.93	Phase 2	11.83
5.343	30.94	60.00	-29.06	Phase 2	11.83
5.366	30.67	60.00	-29.33	Phase 2	11.83
5.393	30.11	60.00	-29.89	Phase 1	11.83
5.433	30.74	60.00	-29.26	Phase 1	11.83

Average Table					
Frequency (MHz)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Comment	Correction (dB)
0.177	18.19	54.63	-36.43	Phase 1	11.56
0.186	17.74	54.21	-36.48	Phase 1	11.57
0.254	15.19	51.64	-36.45	Phase 1	11.58
0.276	18.18	50.94	-32.75	Phase 2	11.57
0.321	19.66	49.68	-30.02	Phase 2	11.57
0.344	21.15	49.12	-27.97	Phase 2	11.57
0.353	22.02	48.90	-26.88	Phase 2	11.57
0.389	21.58	48.10	-26.51	Phase 2	11.59
0.398	19.83	47.91	-28.08	Phase 1	11.59
0.452	16.81	46.85	-30.04	Phase 1	11.60
0.497	23.81	46.06	-22.25	Phase 1	11.60
0.497	26.19	46.06	-19.87	Phase 2	11.60
0.510	33.24	46.00	-12.76	Phase 1	11.60
0.510	34.26	46.00	-11.74	Phase 2	11.60
1.500	26.65	46.00	-19.35	Phase 1	11.68
1.523	26.12	46.00	-19.88	Phase 1	11.69
1.568	26.79	46.00	-19.21	Phase 1	11.70
1.608	26.03	46.00	-19.97	Phase 1	11.68
2.130	29.88	46.00	-16.12	Phase 2	11.72
2.153	25.79	46.00	-20.21	Phase 1	11.72
2.153	30.11	46.00	-15.89	Phase 2	11.72
2.175	30.07	46.00	-15.93	Phase 2	11.72
2.198	29.49	46.00	-16.51	Phase 2	11.71
2.229	29.50	46.00	-16.50	Phase 2	11.71
5.186	21.12	50.00	-28.88	Phase 1	11.82
5.222	22.15	50.00	-27.85	Phase 1	11.82
5.276	24.97	50.00	-25.03	Phase 2	11.82
5.289	22.47	50.00	-27.53	Phase 1	11.82
5.298	21.73	50.00	-28.27	Phase 1	11.82
5.298	25.46	50.00	-24.54	Phase 2	11.82
5.312	24.80	50.00	-25.20	Phase 2	11.83
5.321	25.81	50.00	-24.19	Phase 2	11.83
5.343	25.69	50.00	-24.31	Phase 2	11.83
5.366	25.06	50.00	-24.94	Phase 2	11.83
5.393	23.28	50.00	-26.72	Phase 1	11.83
5.438	22.09	50.00	-27.91	Phase 1	11.83

Result: **Complies** by -11.74dB

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 No.	Calibration Interval	Cal Due
Bi-Log Antenna	Teseq	CBL 6111D	ITS 01058	12	09/20/19
Pre-Amplifier	Sonoma Instrument	310N	ITS 0942	12	01/26/19
EMI Receiver	Rohde and Schwarz	ESU	ITS 00961	12	10/26/19
Active Horn Antenna	ETS-Lindgren	3117-PA	ITS 01636	12	01/11/19
Spectrum Analyzer	Rohde and Schwarz	FSU	ITS 00913	12	01/24/19
Horn Antenna (10-40 GHz)	ETS-Lindgren	3116C	ITS 01376	12	04/25/19
Pre-Amplifier (18-40GHz)	Miteq	TTA1840-35-S-M	ITS 01393	12	01/19/19
LISN	Com Power	LIN-115A	ITS 01283	12	10/03/19
BI-Log Antenna	Antenna Research	LPB-2513	ITS 00355	12	02/21/19
Notch Filter	Micro-Tronics	BRM50702	ITS 01166	12	03/10/19
RF Cable	Megaphase	EMC1-K1K1-236	ITS 01538	12	06/25/19
RF Cable	Megaphase	TM40-K1K1-59	ITS 01657	12	06/26/19
RF Cable	TRU Corporation	TRU CORE 300	ITS 01330	12	11/29/18
RF Cable	TRU Corporation	TRU CORE 300	ITS 01465	12	08/16/19
RF Cable	TRU Corporation	TRU CORE 300	ITS 01470	12	08/16/19
Attenuator	Mini Circuits	BW-S10W5+	ITS 01582	12	10/07/19

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 Spurious_30M-26GHz
BAT-EMC	Nexio	3.16.0.64	103479767_Grundfos.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 / G103479767	AS	KV	December 05, 2018	Original document

END OF REPORT