

TEST REPORT

Report Number: 103436674MPK-002
Project Numbers: G103436674, G103442604
April 05, 2018

Testing performed on
Controllers
Model: FAST-60-601-000002
FCC ID: 2APK7-9705079V1-0
IC: 23979-9705079V10

to

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

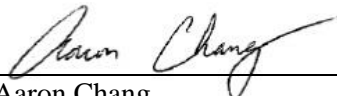
For

Fastenal Company

Test Performed by:
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Menlo Park, CA 94025 USA

Test Authorized by:
Fastenal Company
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Winona, MN 55987 USA

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Date: April 05, 2018

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Date: April 05, 2018

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Report No. 103436674MPK-002

Equipment Under Test:

Trade Name:

Model Number:

Controllers

Fastenal Company

FAST-60-601-000002

Applicant:

Contact:

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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

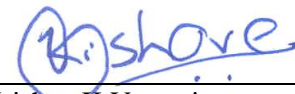
Date of Test:

March 5-27, 2018

We attest to the accuracy of this report:



Aaron Chang
Project Engineer



Krishna K Vemuri
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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 |
| Transmitter Radiated Emissions | 15.247(d), 15.209, 15.205 | RSS-247, 5.5 | Complies |
| AC Line Conducted Emission | 15.207 | RSS-GEN | Complies |
| Antenna Requirement | 15.203 | RSS-GEN | Complies (Internal Antenna) |
| RF Exposure | 15.247(i), 2.1093(d) | RSS-102 | Complies |
| Radiated Emissions | 15.109 | ICES-003 | Complies |
| AC Line Conducted Emission | 15.107 | ICES-003 | Complies |

EUT receive date: March 05, 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: March 5, 2018

Test completion date: March 27, 2018

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

2.0 General Information

2.1 Product Description

Fastenal Company supplied the following description of the EUT:

Device that receives LoRa messages from in-range Repeaters, Readers, and BLE Bins. Messages received by the Controller will be forwarded to the Fastenal Store after filtering out all redundant information. Method of forwarding data is by Ethernet, WiFi, or Cellular connections.

Information about the LoRa radio is presented below:

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

Information about the 900 MHz radio is presented below:

| | |
|-------------------------------------|--|
| Applicant | Fastenal Company |
| Model No. | FAST-60-601-000002 |
| FCC Identifier | 2APK7-9705079V1-0 |
| IC Identifier | 23979-9705079V10 |
| Type of transmission | Digital Transmission System (DTS) |
| Rated RF Output | 17.67 dBm |
| Antenna(s) & Gain | PCB Antenna, Gain: 5.1 dBi |
| Frequency Range | 923.3 – 927.5 MHz (Tx); 903 – 914.2 MHz (Rx) |
| Type of modulation | LoRa® Technology |
| Data rate | 1760 bps |
| Number of Channel(s) | 16 Total (8 Tx and 8 Rx) |
| Applicant Name & Address | Fastenal Company 2001 Theurer Blvd Winona, MN 55987 USA |

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 (DTS) Operating under §15.247” (KDB 558074 D01 DTS Meas Guidance v04), and RSS-247, RSS-GEN Issue 4.

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

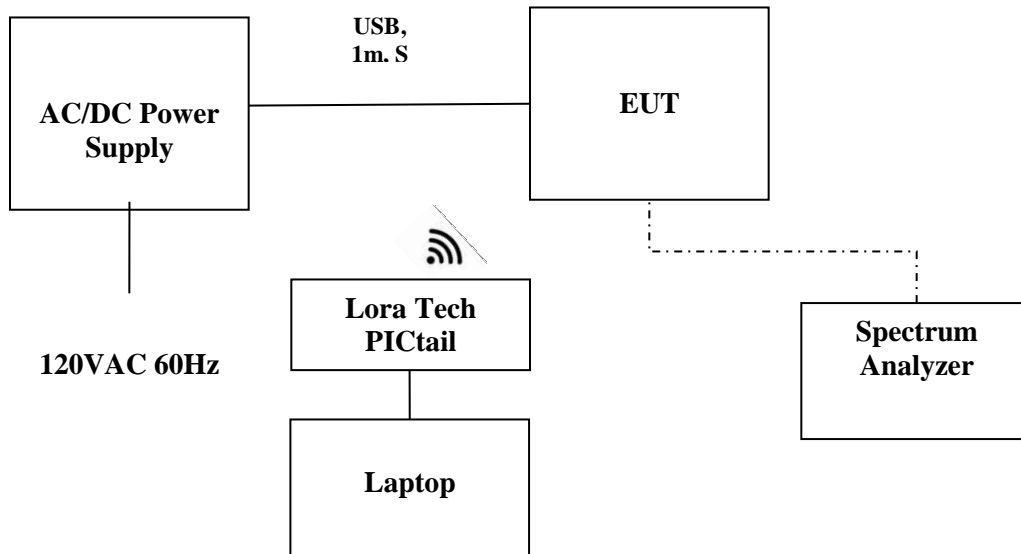
3.1 Support Equipment

| Description | Manufacturer | Model Number |
|-------------------|--------------|--------------|
| Laptop | HP | ProBook 430 |
| LoRa Tech PICtail | MicroChip | MTI160581148 |

3.2 Block Diagram of Test Setup

| Equipment Under Test | | | |
|----------------------|------------------|--------------------|---------------|
| Description | Manufacturer | Model Number | Serial Number |
| Controllers | Fastenal Company | FAST-60-601-000002 | C-0000007 |
| AC/DC Power Supply | CUI Inc | SWI12-5-N | No markings |

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



| | |
|-----------------------|-----------------------------|
| S = Shielded | F = With Ferrite |
| U = Unshielded | 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 Fastenal Company

3.5 Mode of Operation during Test

During transmitter testing, the transmitter was setup to transmit at maximum RF power on low, middle and high frequencies/channels.

3.5 Modifications Required for Compliance

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

3.6 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 A8.2 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 558074 D01 DTS Meas Guidance v04 was used to determine the DTS occupied bandwidth. Section 8.1 Option 1 was used.

1. Set RBW = 100 kHz.
2. Set the video bandwidth (VBW) $\geq 3 \times$ 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.

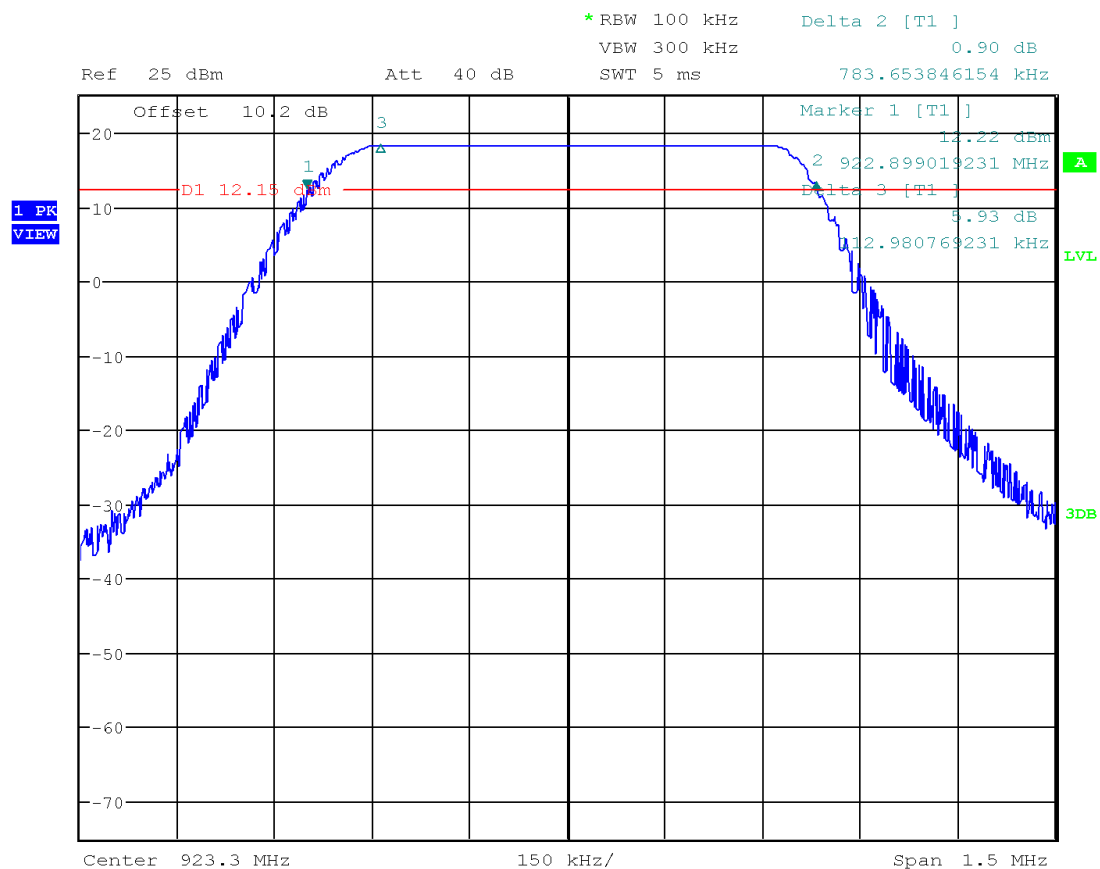
For 99% power bandwidth measurement, the bandwidth was determined by using the built-in 99% occupied bandwidth function of the spectrum analyzer. The resolution bandwidth is set to 1% of the selected span as is without being below 1%. The video bandwidth shall be set to 3 times the resolution bandwidth.

4.1.3 Test Result

| Frequency (MHz) | 6-dB bandwidth FCC 15.247 & RSS-GEN, kHz | Occupied bandwidth, RSS-GEN, kHz | Plot |
|-----------------|---|--|------|
| 923.3 | 783.654 | -- | 1.1 |
| | -- | 640 | 1.4 |
| 925.1 | 790.865 | -- | 1.2 |
| | -- | 636 | 1.5 |
| 927.5 | 781.250 | -- | 1.3 |
| | -- | 634 | 1.6 |

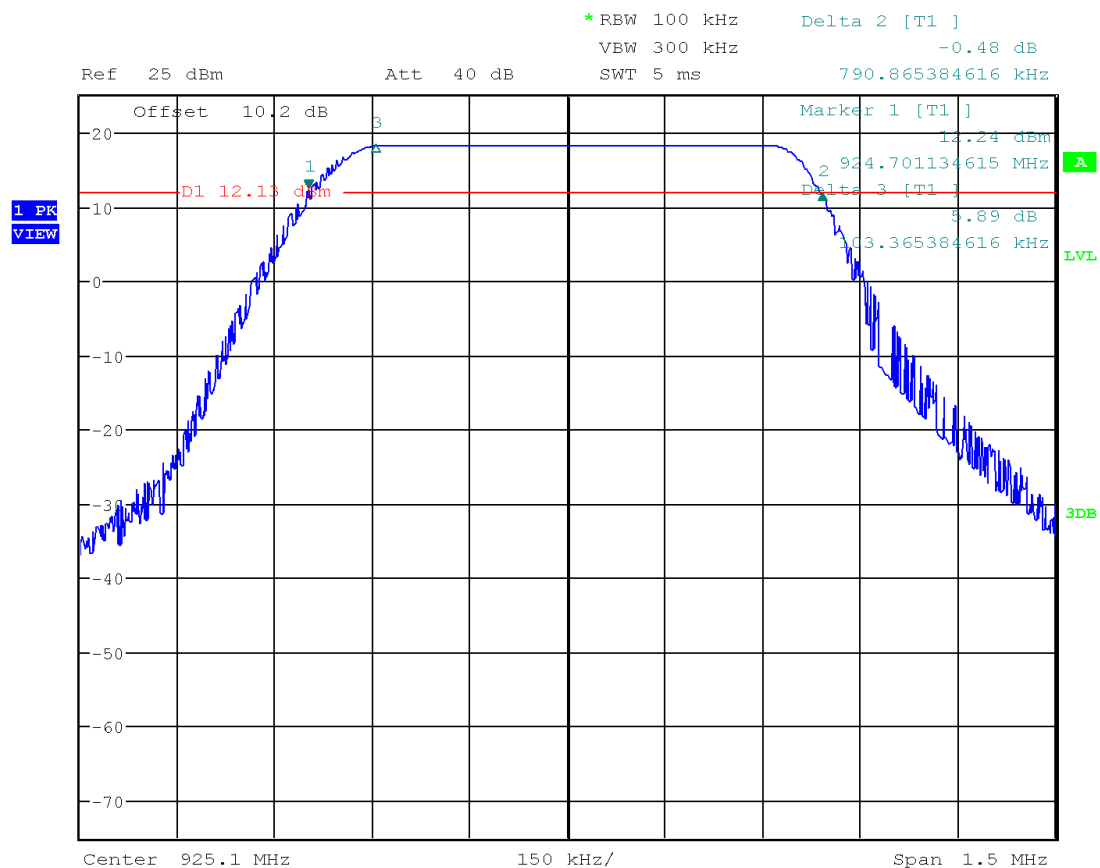
| | |
|----------------------|-----------------|
| Date of Test: | March 9, 2018 |
| Results | Complies |

Plot 1. 1



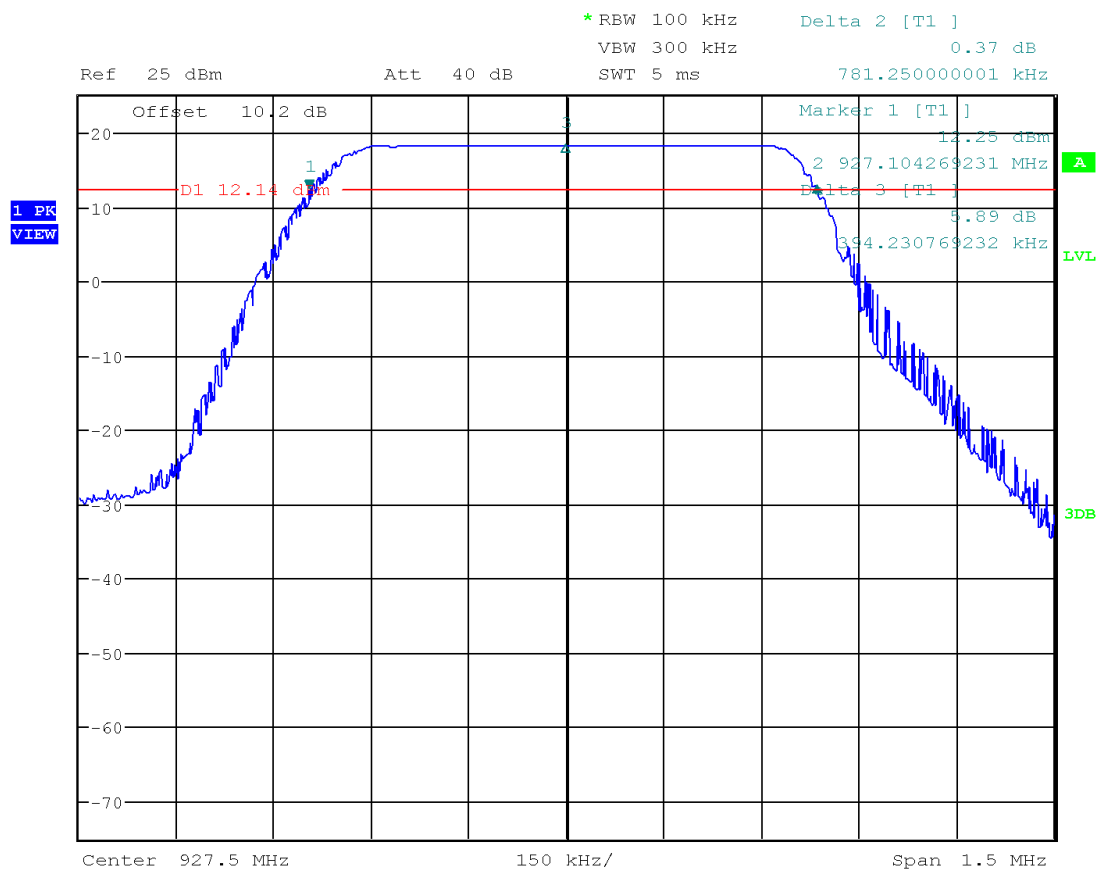
Date: 9.MAR.2018 17:52:27

Plot 1.2



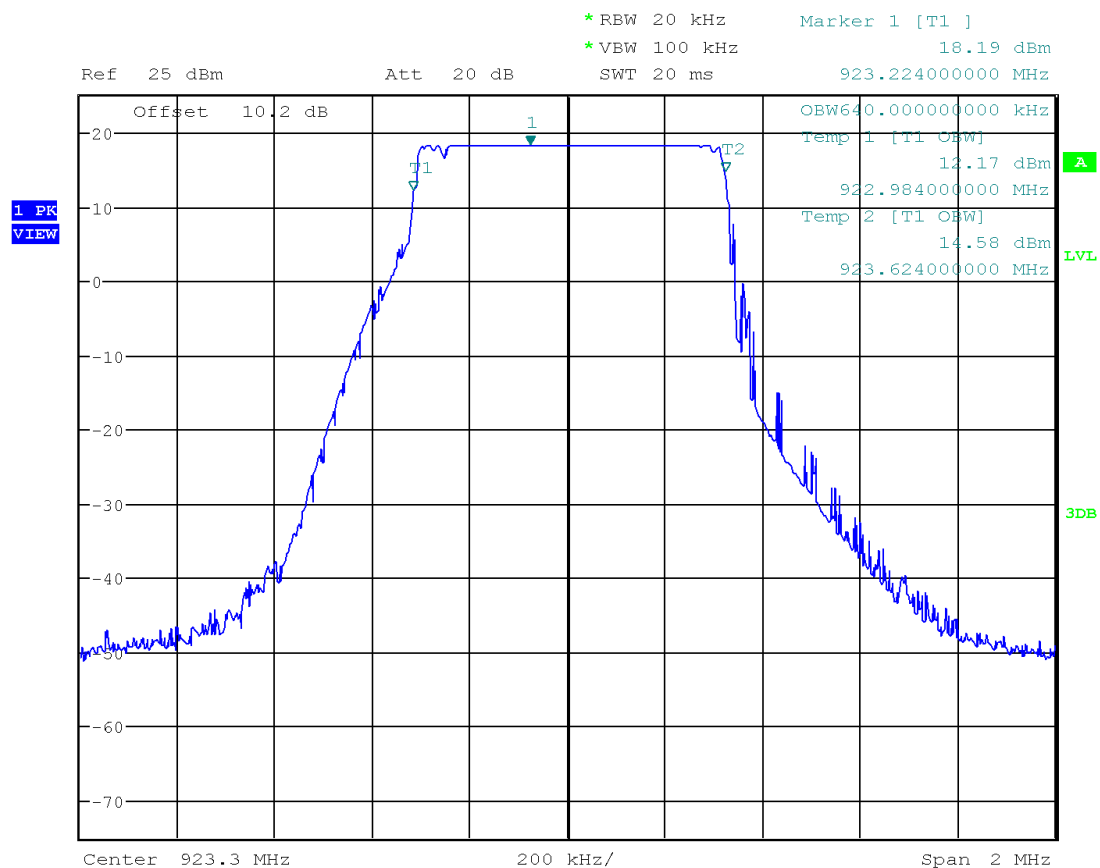
Date: 9.MAR.2018 18:01:28

Plot 1.3



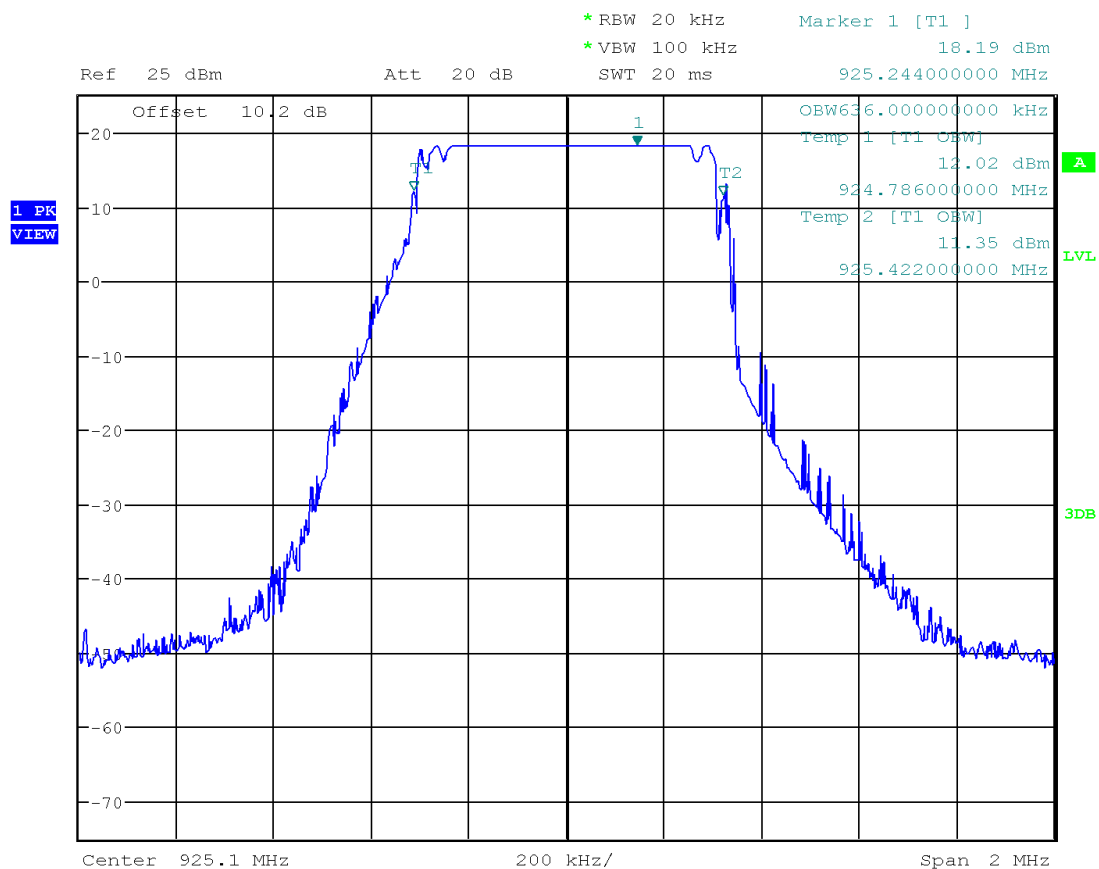
Date: 9.MAR.2018 18:09:27

Plot 1.4



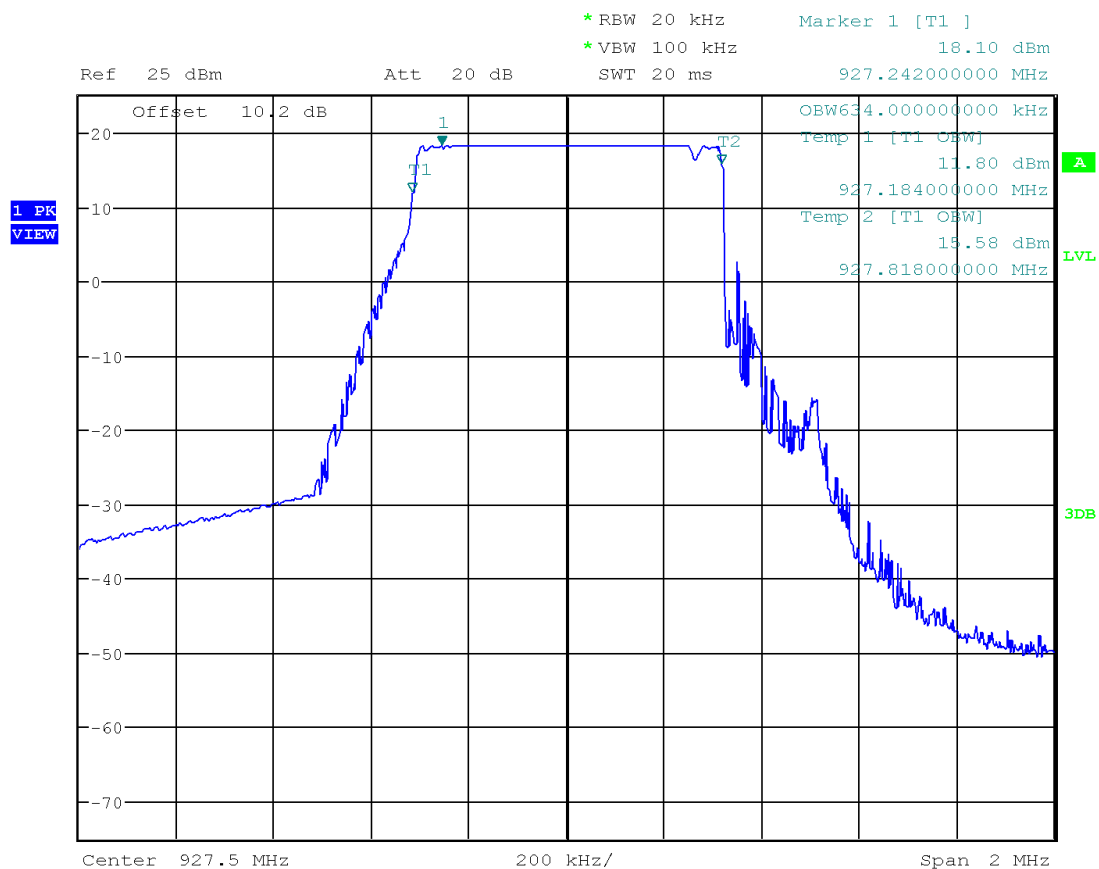
Date: 9.MAR.2018 18:27:50

Plot 1.5



Date: 9.MAR.2018 18:34:11

Plot 1.6



Date: 9.MAR.2018 18:14:20

4.2 Maximum Peak Conducted Output Power at Antenna Terminals FCC Rule: 15.247(b)(3); RSS-247 A8.4;

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 558074 D01 DTS Meas Guidance v04 was used.
Specifically, section 9.2.2.1 Method AVGSA-1 Alternative (RMS detection with slow sweep and EUT transmitting continuously at full power) was utilized.

1. Set span to at least 1.5 x OBW.
2. Set RBW = 1 % to 5 % of the OBW, not to exceed 1 MHz.
3. Set VBW $\geq 3 \times$ RBW.
4. Number of points in sweep $\geq 2 \times$ span / RBW.
5. Manually set sweep time $\geq 10 \times$ (number of points in sweep) x (transmission symbol period), but not less than the automatic default sweep time.
6. Detector = RMS
7. The EUT shall be operated at ≥ 98 % duty cycle or sweep triggering/signal gating shall be employed such that the sweep time is less than or equal to the transmission duration T.
8. Perform a single sweep.
9. Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function, with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.

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

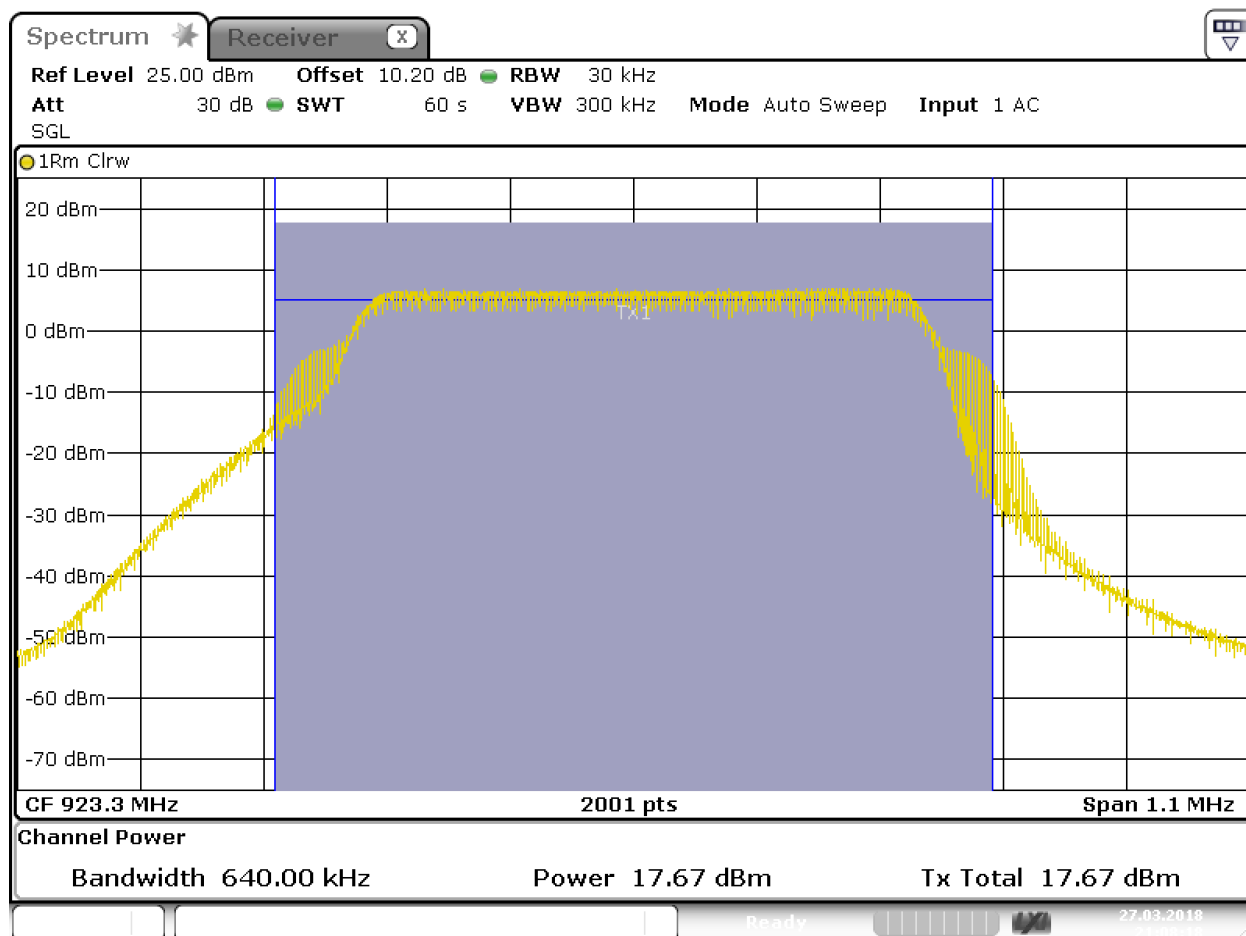
4.3.3 Test Result

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

| Frequency, MHz | Conducted Power (peak), dBm | Conducted Power (peak), mW | Plot |
|-------------------|-----------------------------------|-------------------------------|------|
| 923.3 | 17.67 | 58.48 | 2.1 |
| 925.1 | 17.61 | 57.68 | 2.2 |
| 927.5 | 17.59 | 57.41 | 2.3 |

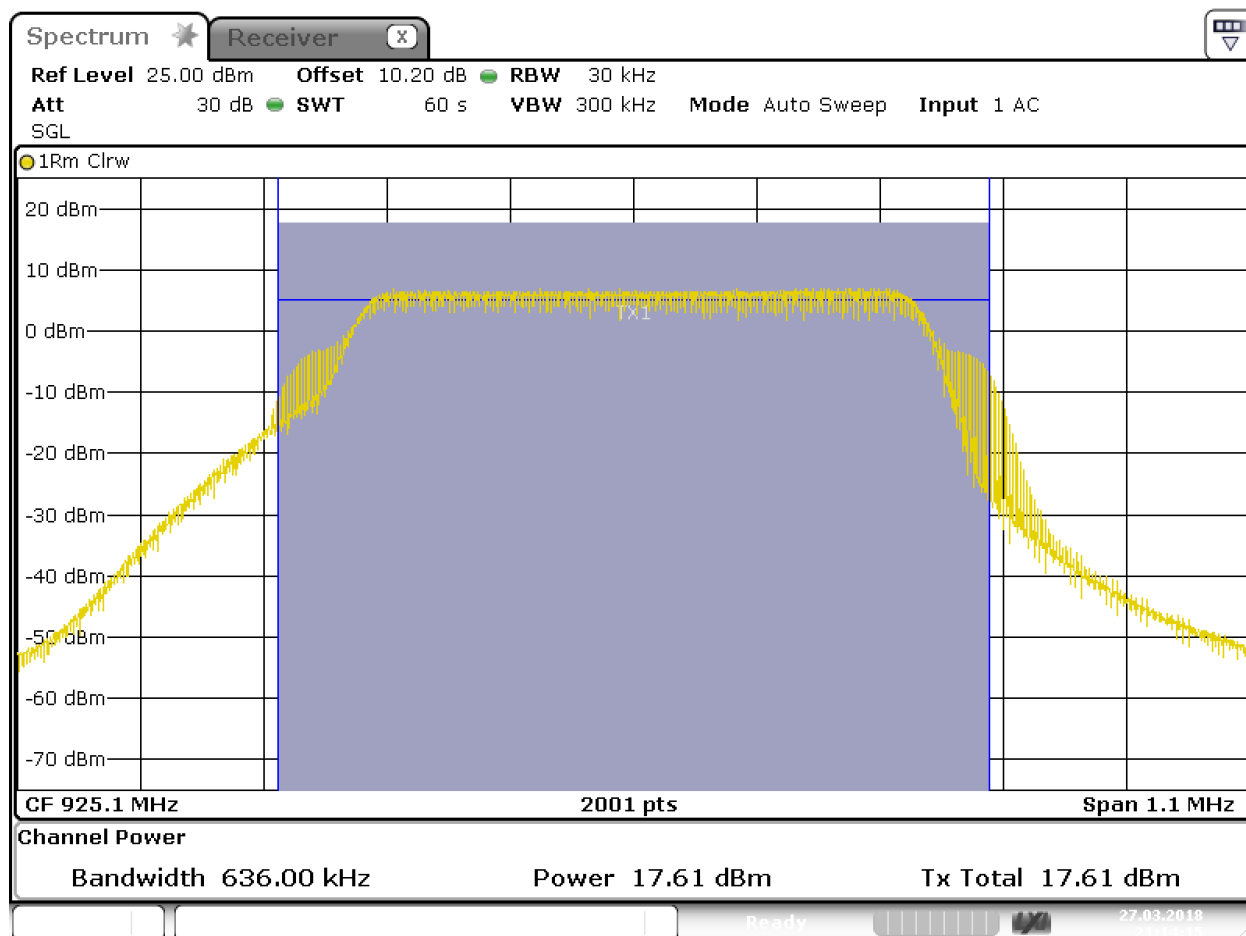
| | |
|----------------------|-----------------|
| Date of Test: | March 27, 2018 |
| Results | Complies |

Plot 2. 1



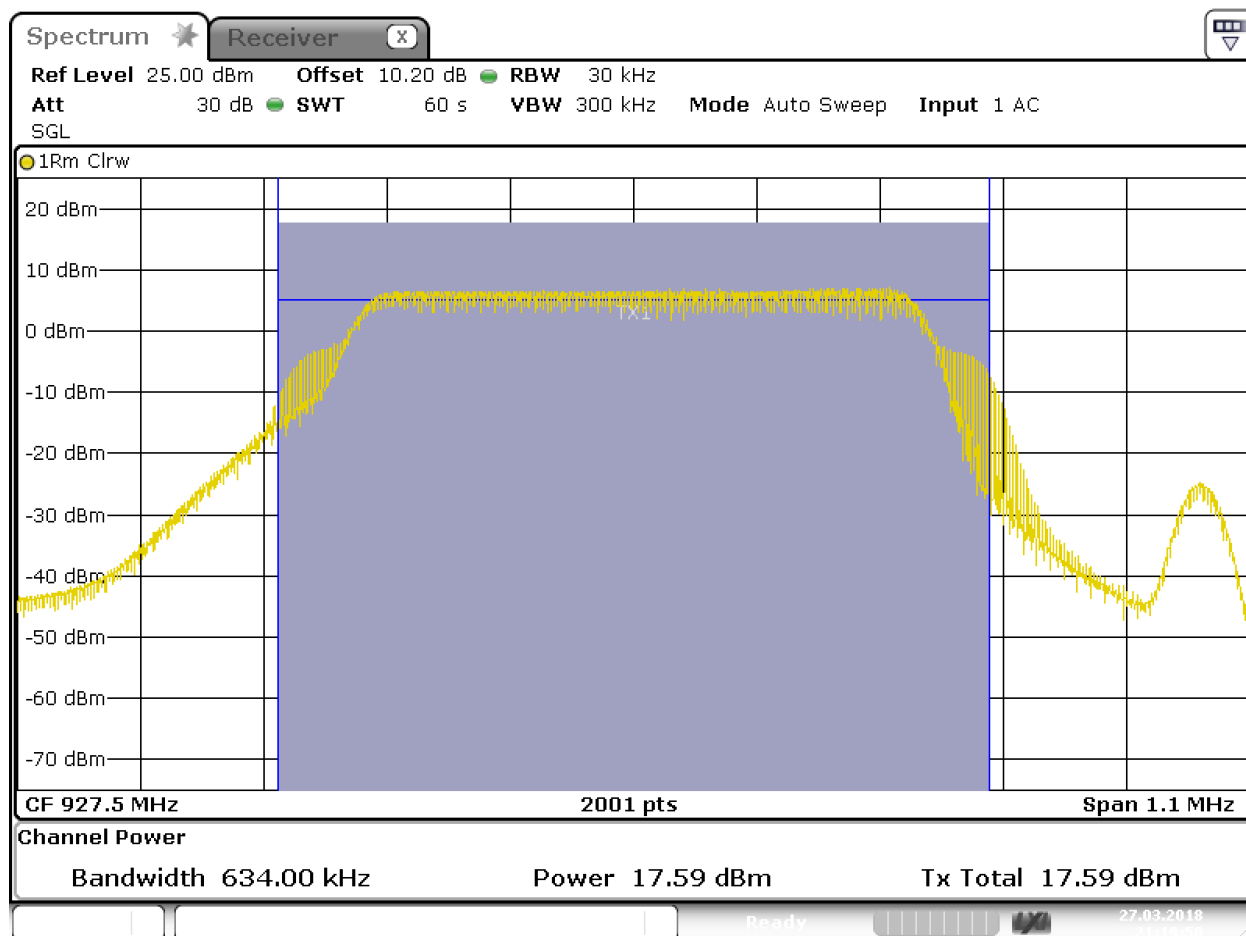
Date: 27.MAR.2018 21:08:18

Plot 2. 2



Date: 27.MAR.2018 21:14:15

Plot 2.3



Date: 27.MAR.2018 21:19:50

4.3 Maximum Power Spectral Density FCC: 15.247 (e); RSS-247 A8.2b;

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

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

The procedure described in FCC Publication 558074 D01 DTS Meas Guidance v04, specifically section 10.3 Method AVGPS-1 (trace averaging with EUT transmitting at full power throughout each sweep).

1. Set instrument center frequency to DTS channel center frequency.
2. Set the span to at least $1.5 \times \text{OBW}$.
3. Set the RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
4. Set the VBW $\geq 3 \times \text{RBW}$.
5. Detector = power averaging (RMS) or sample detector (when RMS not available).
6. Ensure that the number of measurement points in the sweep $\geq 2 \times \text{span/RBW}$.
7. Sweep time = auto couple.
8. Employ trace averaging (RMS) mode over a minimum of 100 traces.
9. Use the peak marker function to determine the maximum amplitude level.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

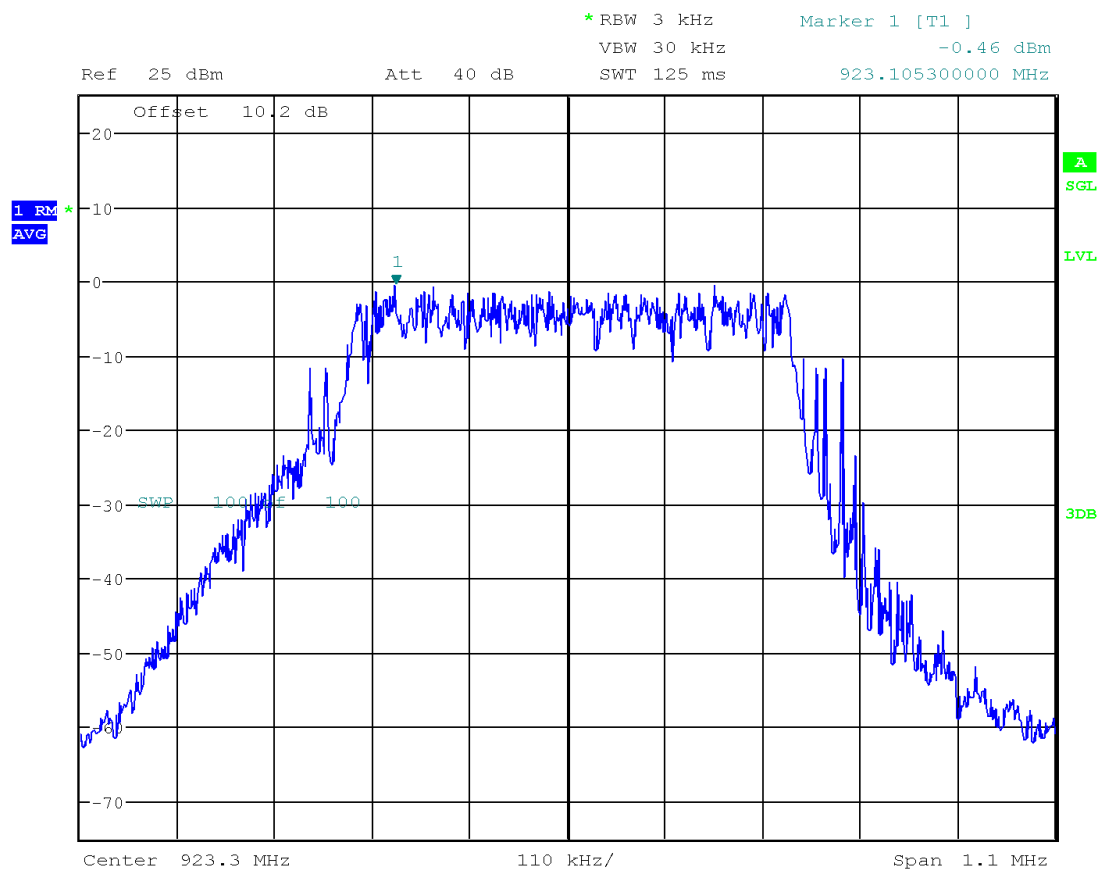
4.3.3 Test Result

Refer to the following plots for the test result

| Frequency, MHz | Maximum Power Spectral Density, dBm | Maximum Power Spectral Density Limit, dBm | Margin, dB | Plot |
|-------------------|---|---|---------------|------|
| 923.3 | -0.46 | 8.0 | -8.46 | 3.1 |
| 925.1 | 0.11 | 8.0 | -7.89 | 3.2 |
| 927.5 | -0.54 | 8.0 | -8.54 | 3.3 |

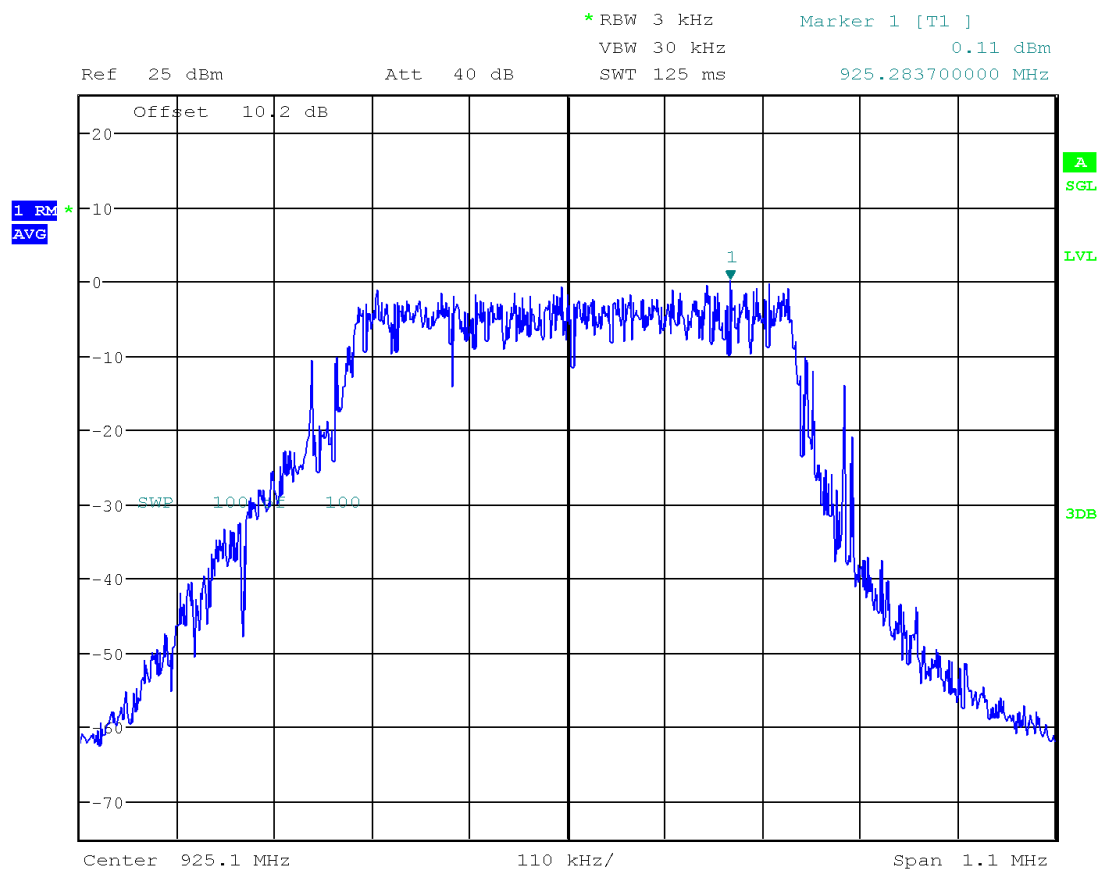
| | |
|----------------------|-----------------|
| Date of Test: | March 9, 2018 |
| Results | Complies |

Plot 3. 1



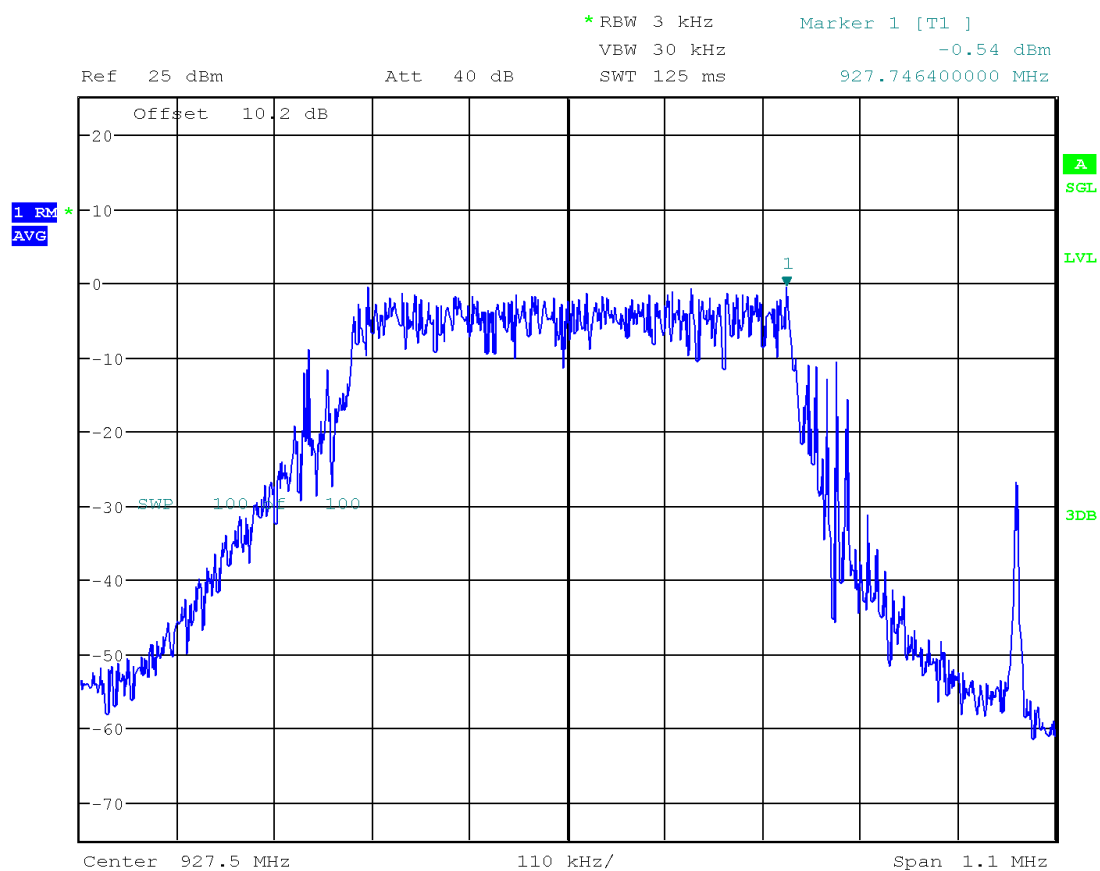
Date: 9.MAR.2018 18:49:32

Plot 3.2



Date: 9.MAR.2018 18:47:38

Plot 3.3



Date: 9.MAR.2018 18:45:38

4.4 Unwanted Conducted Emissions
FCC: 15.247(d); RSS-247 A8.5;

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 558074 D01 DTS Meas Guidance v04, specifically section 11.0 Emissions in non-restricted frequency bands.

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

1. Set the RBW = 100 kHz.
2. Set the VBW $\geq 3 \times$ 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.

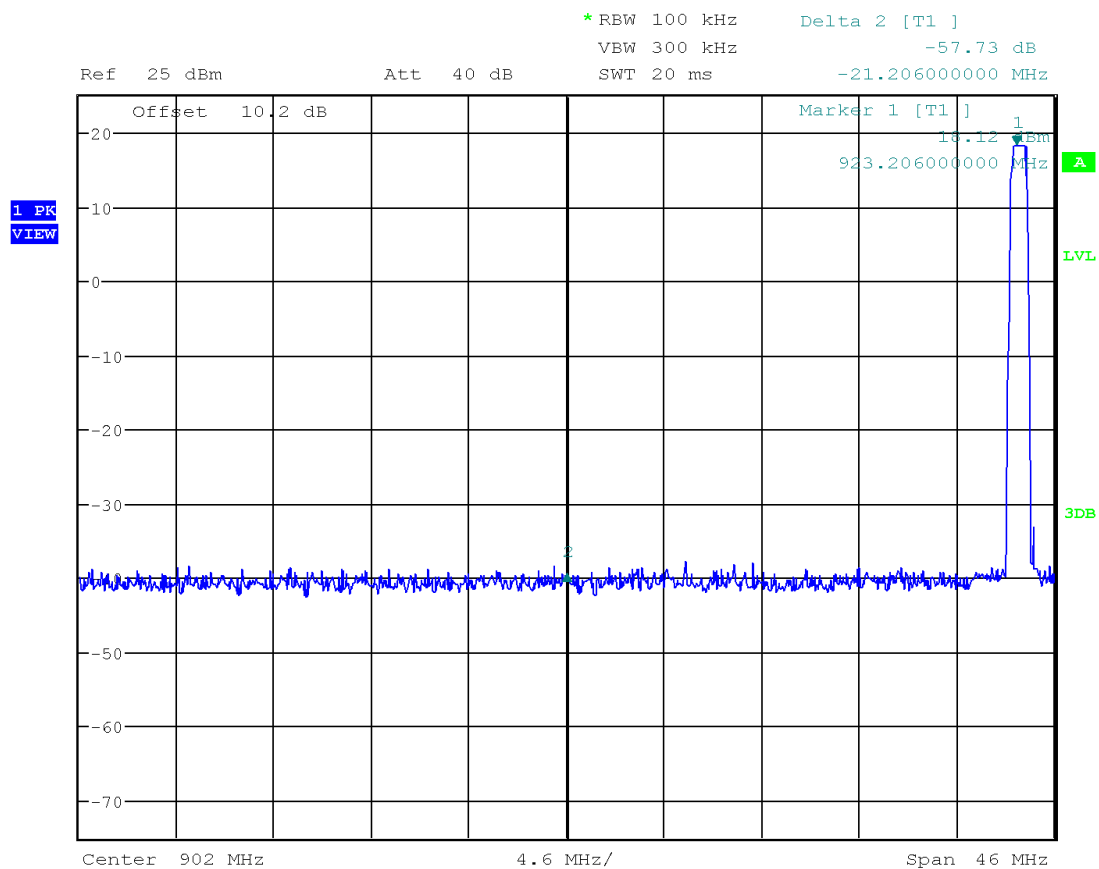
The unwanted emissions were measured from 30 MHz to 25 GHz. Plots below are corrected for cable loss and then compared to the limits.

4.4.3 Test Result

Refer to the following plots 4.1 – 4.5 for unwanted conducted emissions. The plot shows -20dB attenuation limit line.

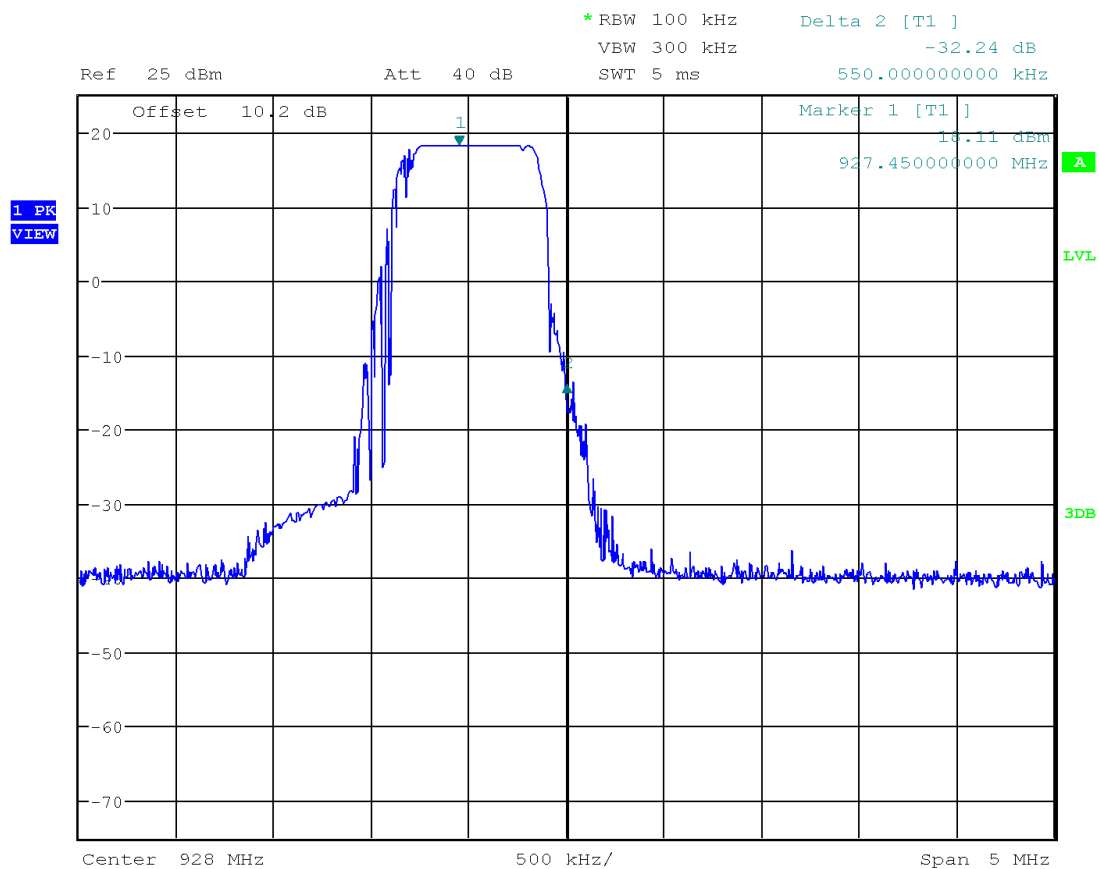
| | |
|----------------------|-----------------|
| Date of Test: | March 9, 2018 |
| Results | Complies |

Tx @ Low Channel, 902 MHz Band Edge
Plot 4.1



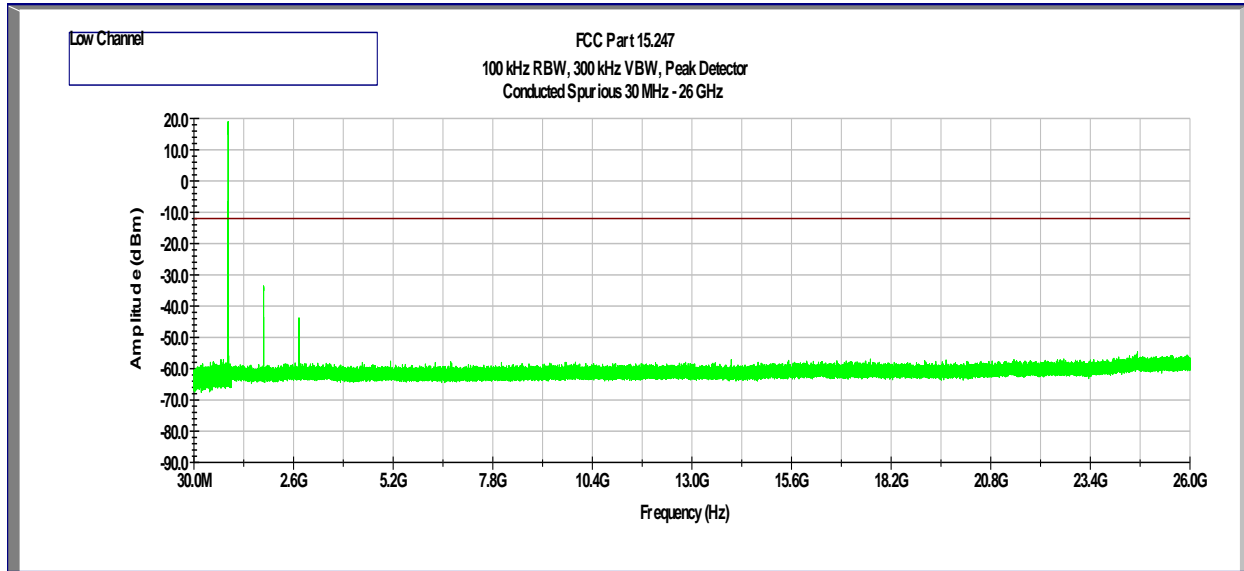
Date: 9.MAR.2018 18:53:57

Tx @ High Channel, 928 MHz Band Edge Plot 4.2

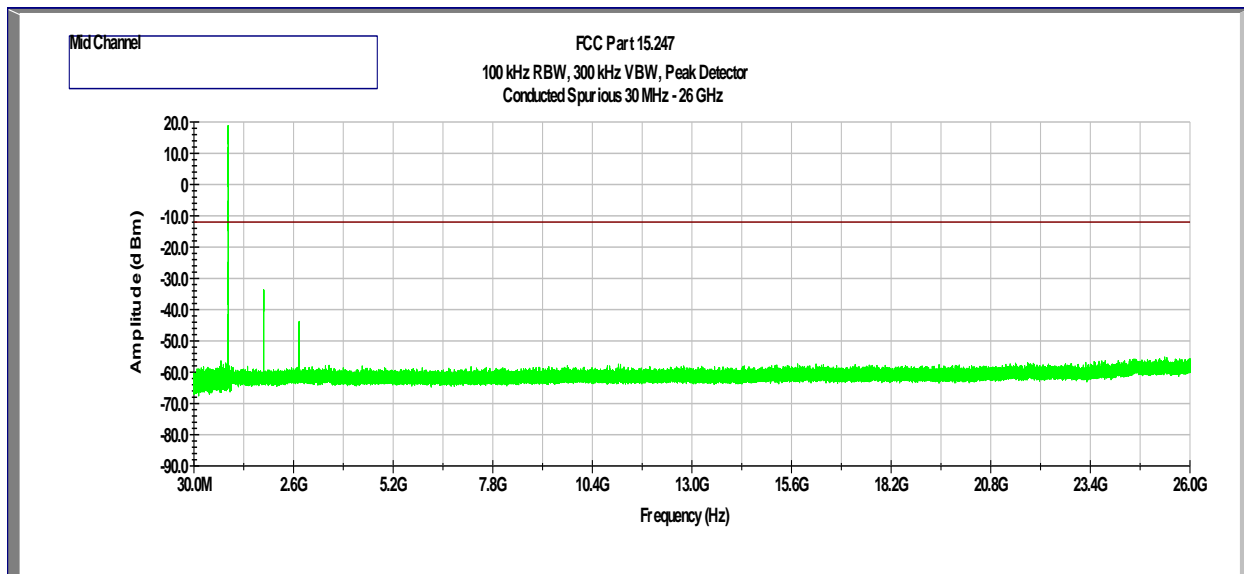


Date: 9.MAR.2018 19:01:50

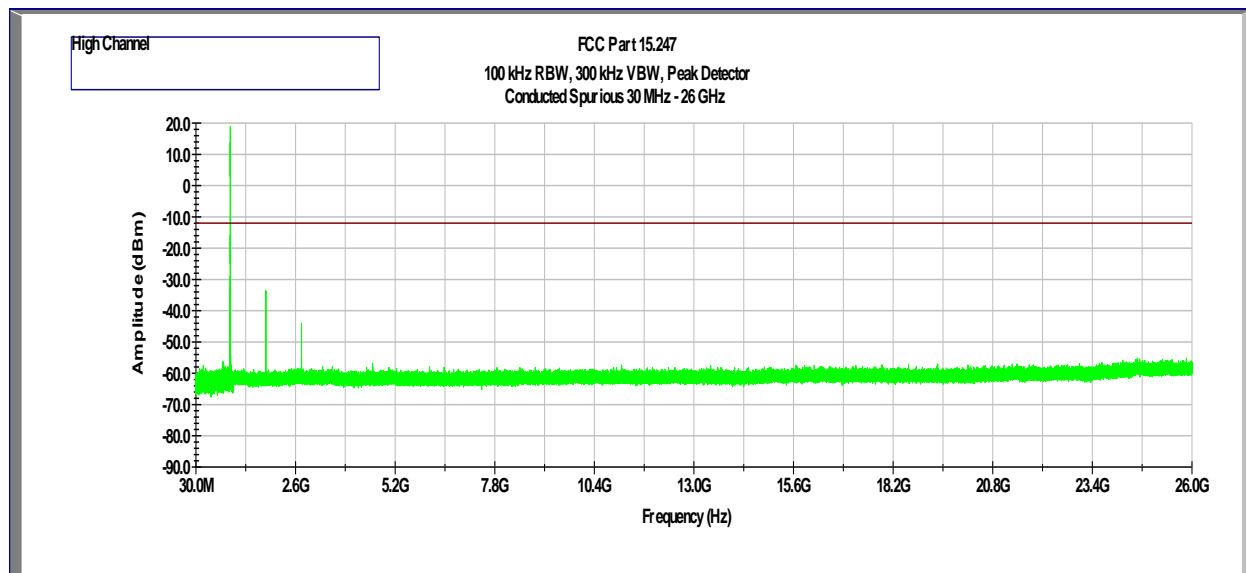
Tx @ Low Channel, 923.3 MHz
30MHz -26GHz Conducted Spurious
Plot 4.3



Tx @ Mid Channel, 925.1 MHz
30MHz -26GHz Conducted Spurious
Plot 4.4



Tx @ High Channel, 927.5 MHz
30MHz -26GHz Conducted Spurious
Plot 4.5



4.5 Transmitter Radiated Emissions
FCC Rules: 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 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.

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.

Data is included of 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(μ V/m)

RA = Receiver Amplitude (including preamplifier) in dB(μ V); 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(μ V) 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(μ V/m). This value in dB(μ V/m) was converted to its corresponding level in μ V/m.

RA = 52.0 dB(μ V)

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(μ V/m).

Level in μ V/m = Common Antilogarithm [(32 dB μ V/m)/20] = 39.8 μ V/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.

4.5.6 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:

$$E = \text{EIRP} - 20\log D + 104.8 + \text{DCF}$$
(DCF for Average measurements)
where:
E = electric field strength in dB μ V/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.

All conducted antenna port plots are corrected with the consideration of a 5.1 dBi Antenna Gain.

All radiated measurements were conducted with the AC adapter. The worst case data was reported.

Vertical and Horizontal orientations were pre-tested. Worst case orientation was used throughout emission measurements.

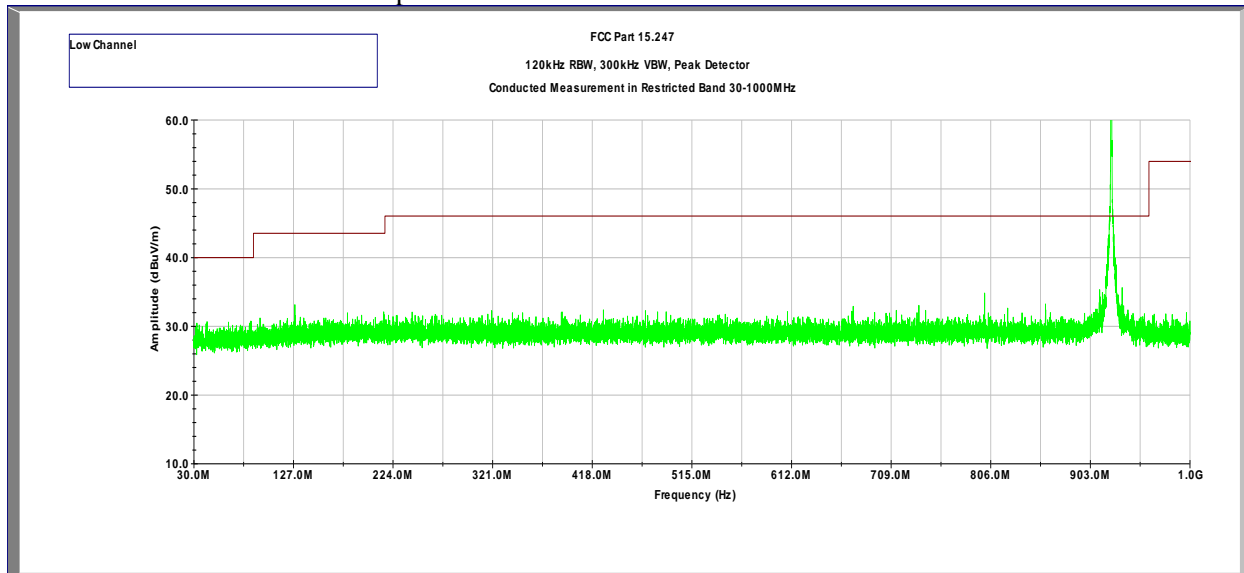
| | |
|----------------------|-------------------|
| Date of Test: | March 4 - 5, 2018 |
| Results | Complies |

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

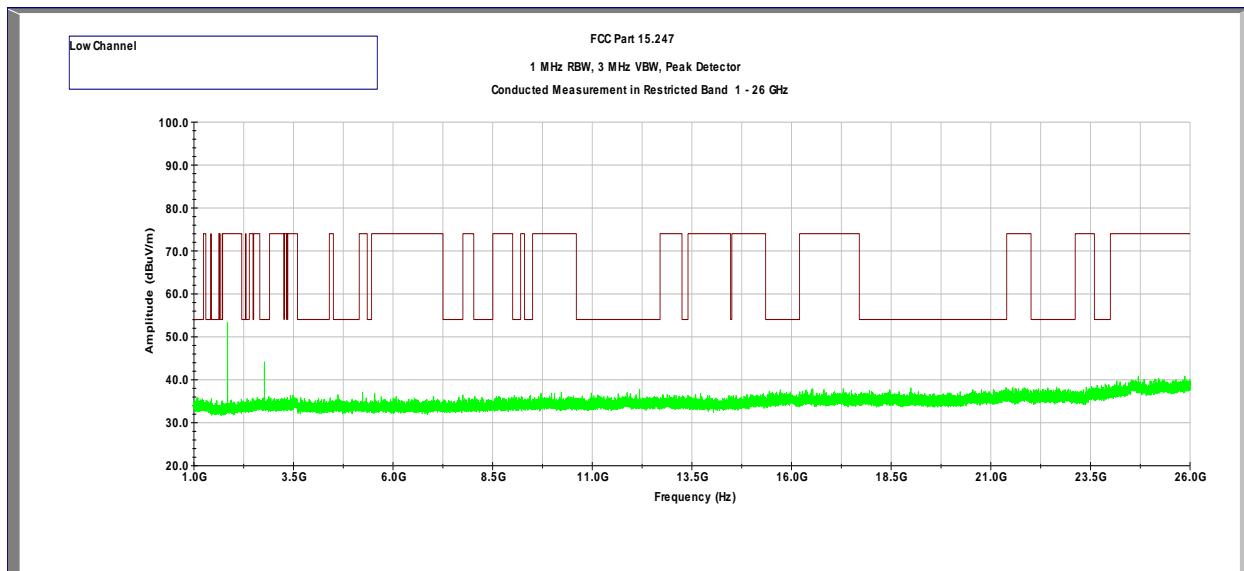
Out-of-Band Conducted Spurious Emissions (at Antenna Port)

Tx @ 923.3 MHz

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



Out-of-Band Spurious Emissions at Antenna Port – 1 - 26 GHz Peak Detector vs Avg Limit

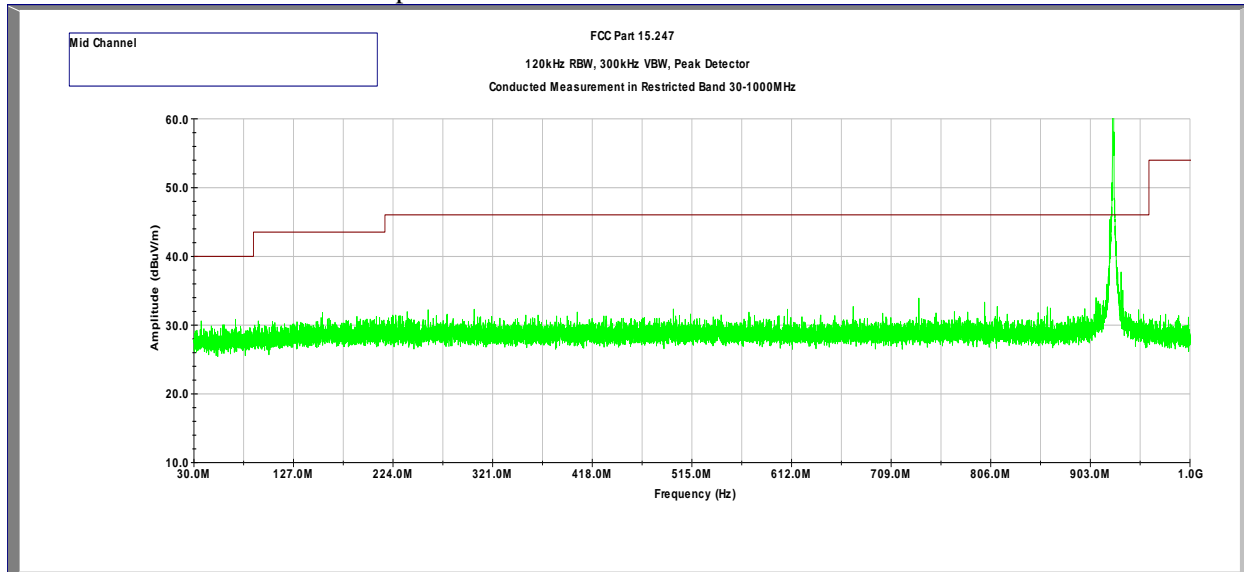


| Frequency | Corrected Amplitude | Avg Limit | Margin | Detector | Results |
|-----------|---------------------|-----------|--------|----------|---------|
| GHz | dBμV/m | dBμV/m | dB | | |
| 2.77 | 44.11 | 54 | -9.89 | Peak | Pass |

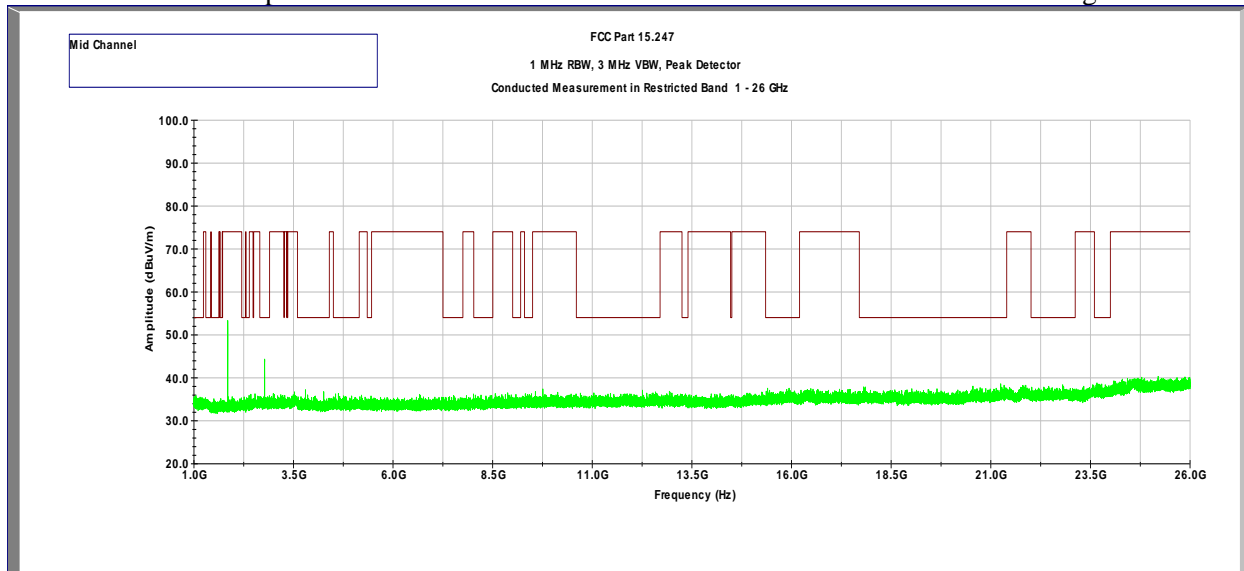
Out-of-Band Conducted Spurious Emissions (at Antenna Port)

Tx @ 925.1 MHz

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



Out-of-Band Spurious Emissions at Antenna Port – 1 - 26 GHz Peak Detector vs Avg Limit

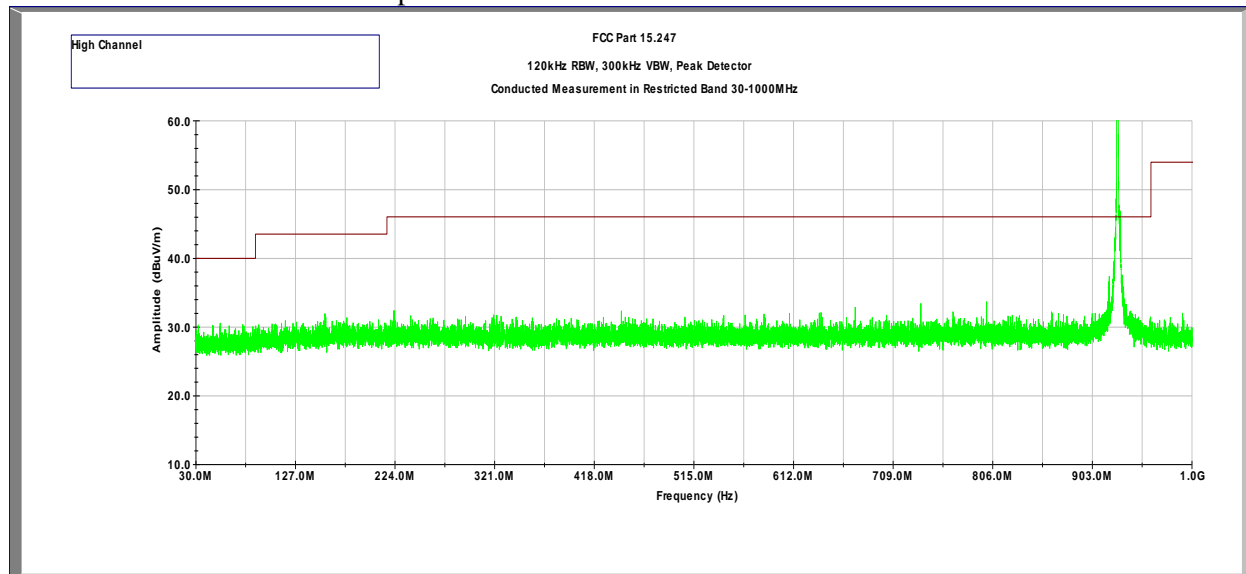


| Frequency | Corrected Amplitude | Avg Limit | Margin | Detector | Results |
|-----------|---------------------|-----------|--------|----------|---------|
| GHz | dBμV/m | dBμV/m | dB | | |
| 2.774 | 44.3 | 54 | -7.8 | Peak | Pass |

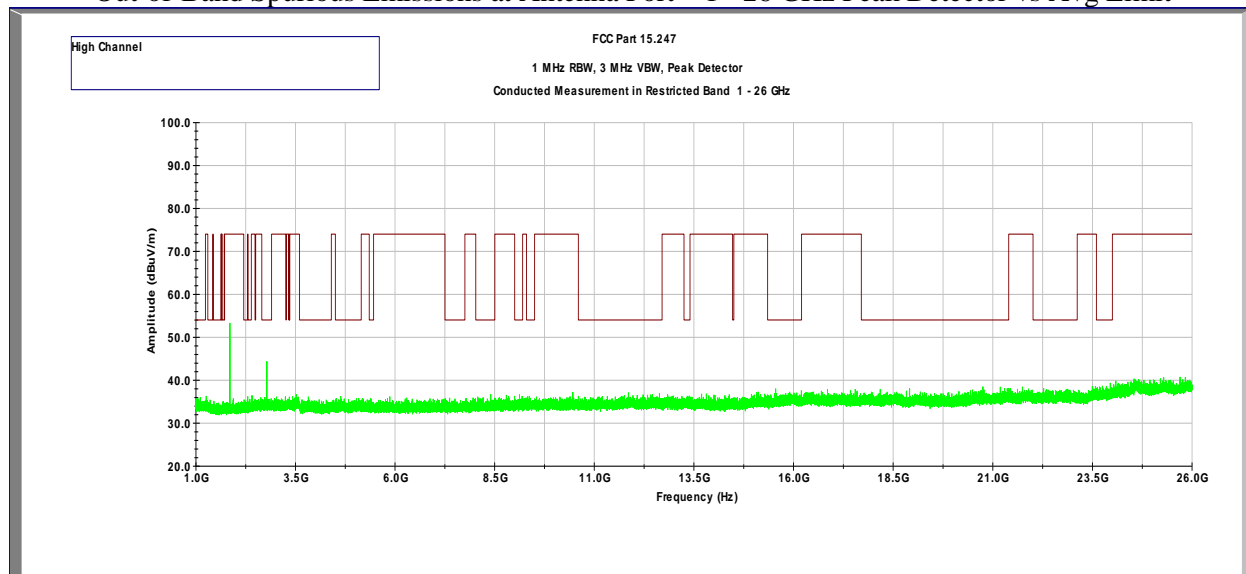
Out-of-Band Conducted Spurious Emissions (at Antenna Port)

Tx @ 927.5 MHz

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



Out-of-Band Spurious Emissions at Antenna Port – 1 - 26 GHz Peak Detector vs Avg Limit

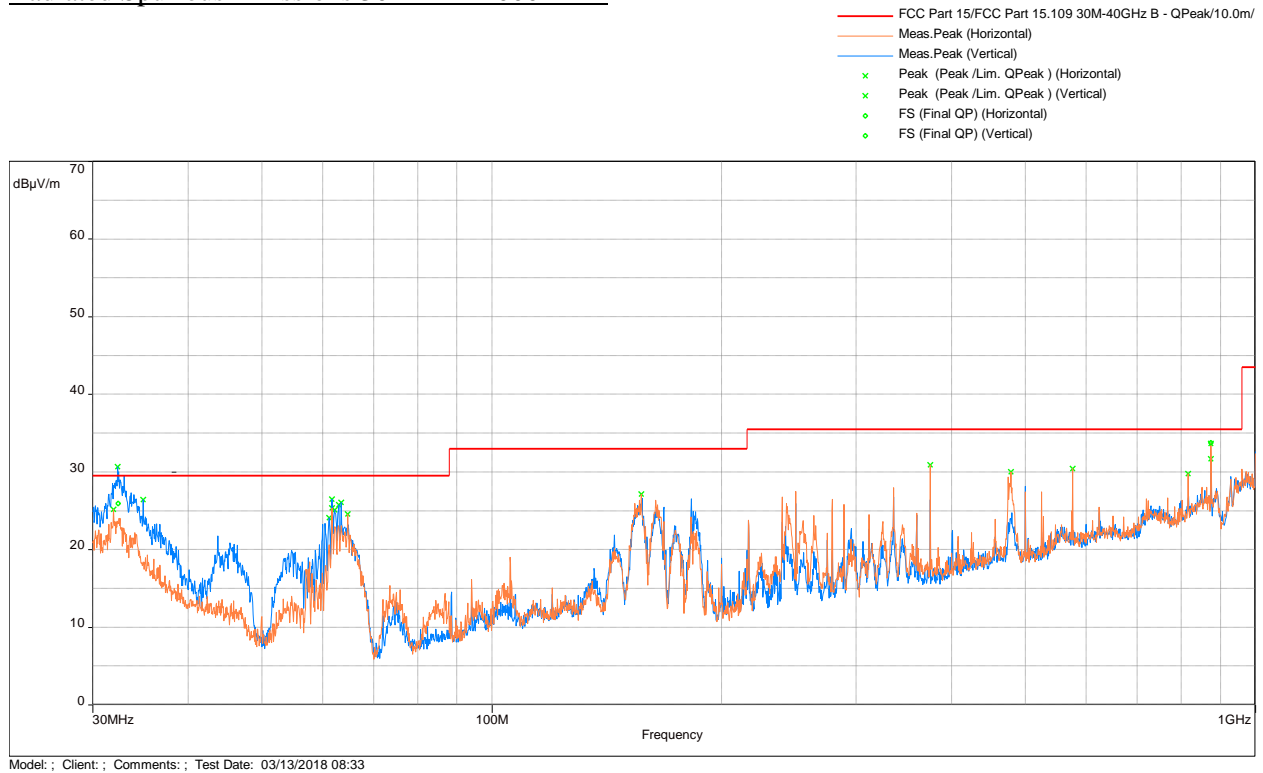


| Frequency | Corrected Amplitude | Avg Limit | Margin | Detector | Results |
|-----------|---------------------|-----------|--------|----------|---------|
| GHz | dBμV/m | dBμV/m | dB | | |
| 2.783 | 44.2 | 54 | -9.8 | Peak | Pass |

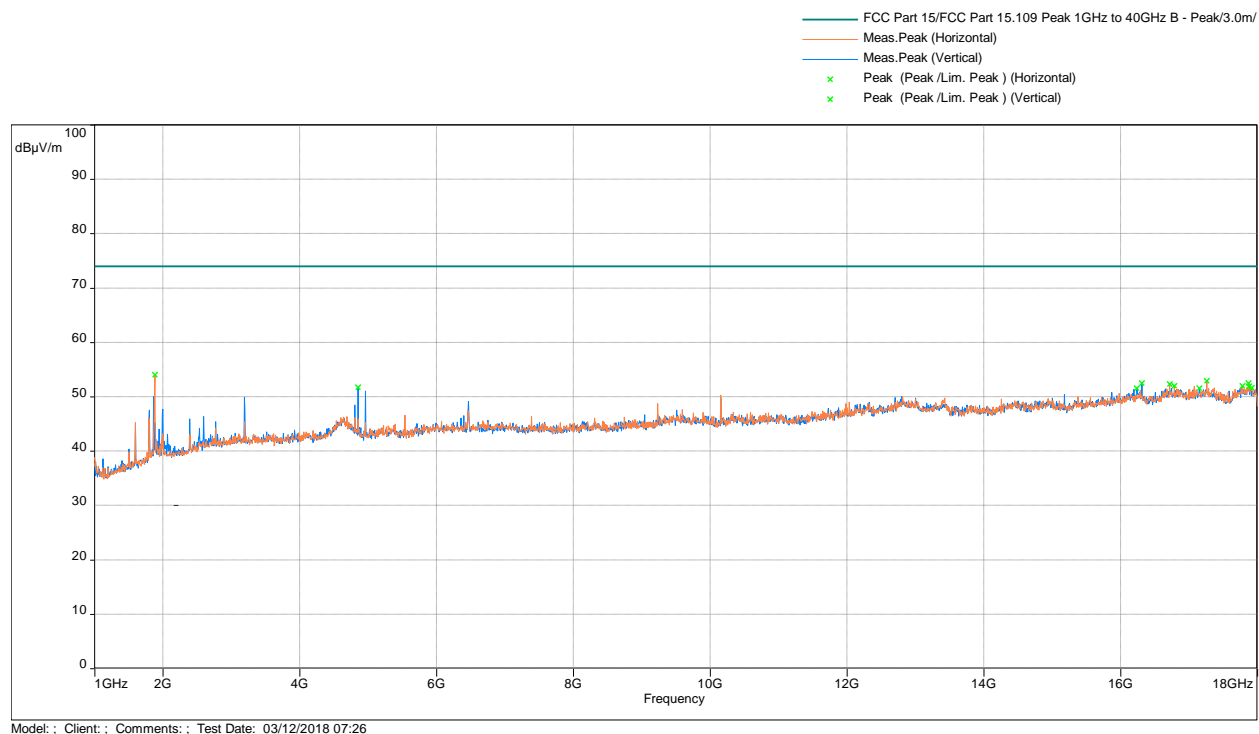
Out-of-Band Radiated Spurious Emissions (Cabinet Radiation)

Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 923.3 MHz

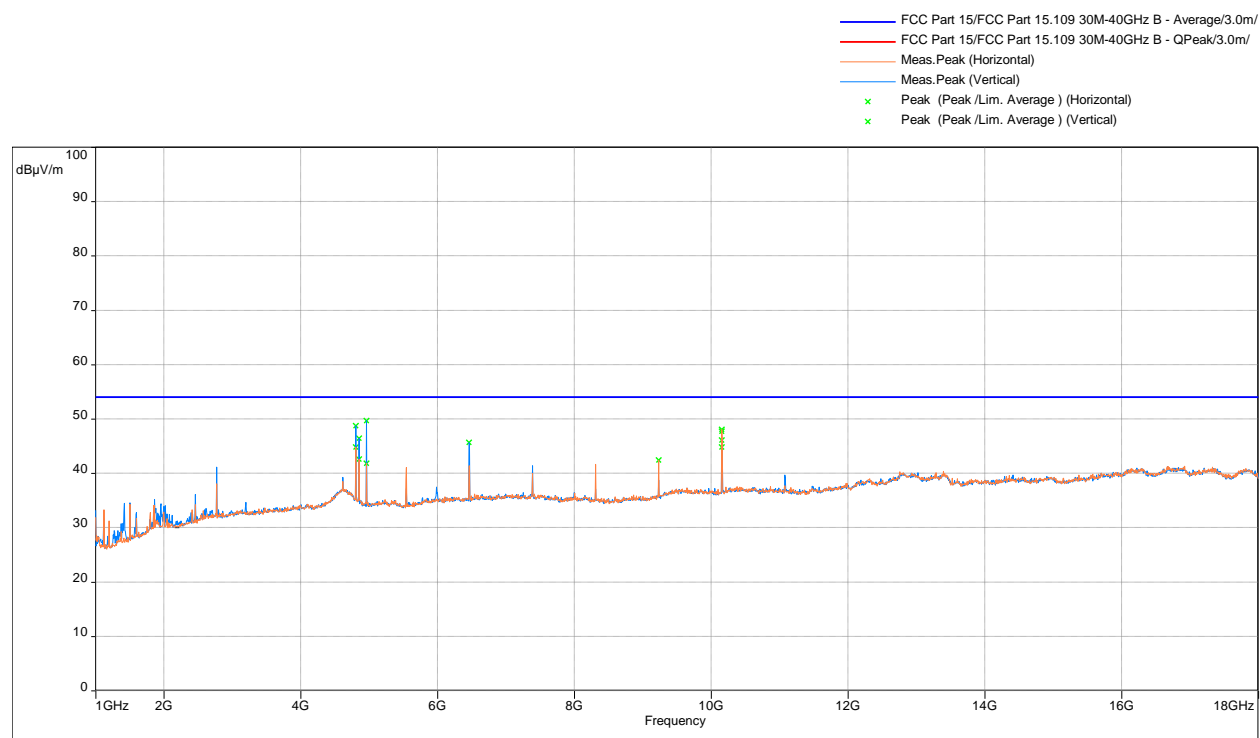
Radiated Spurious Emissions 30 MHz - 1000 MHz



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



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



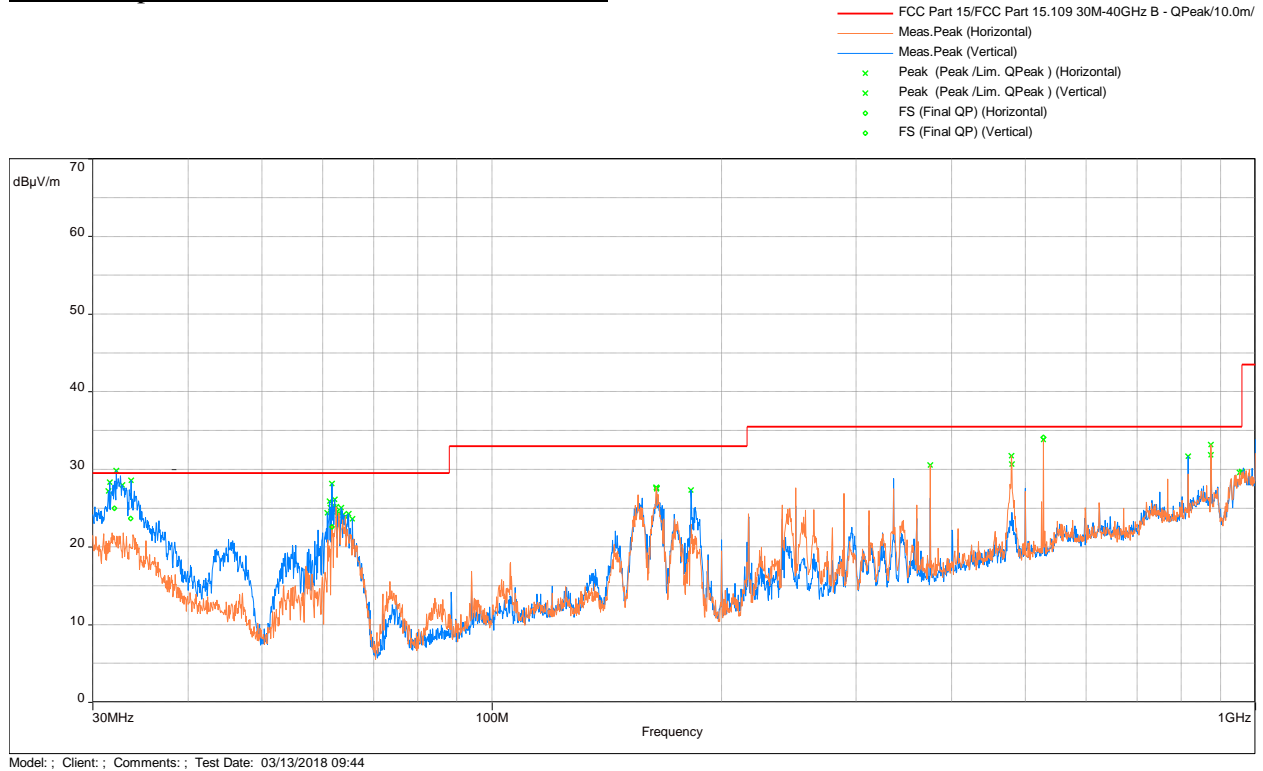
| Frequency | FS@3m | Avg Limit | Margin | Detector | Results |
|-----------|--------|-----------|--------|----------|---------|
| MHz | dBμV/m | dBμV/m | dB | | |
| 4801.767 | 48.8 | 54 | -5.2 | Avg | Pass |

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

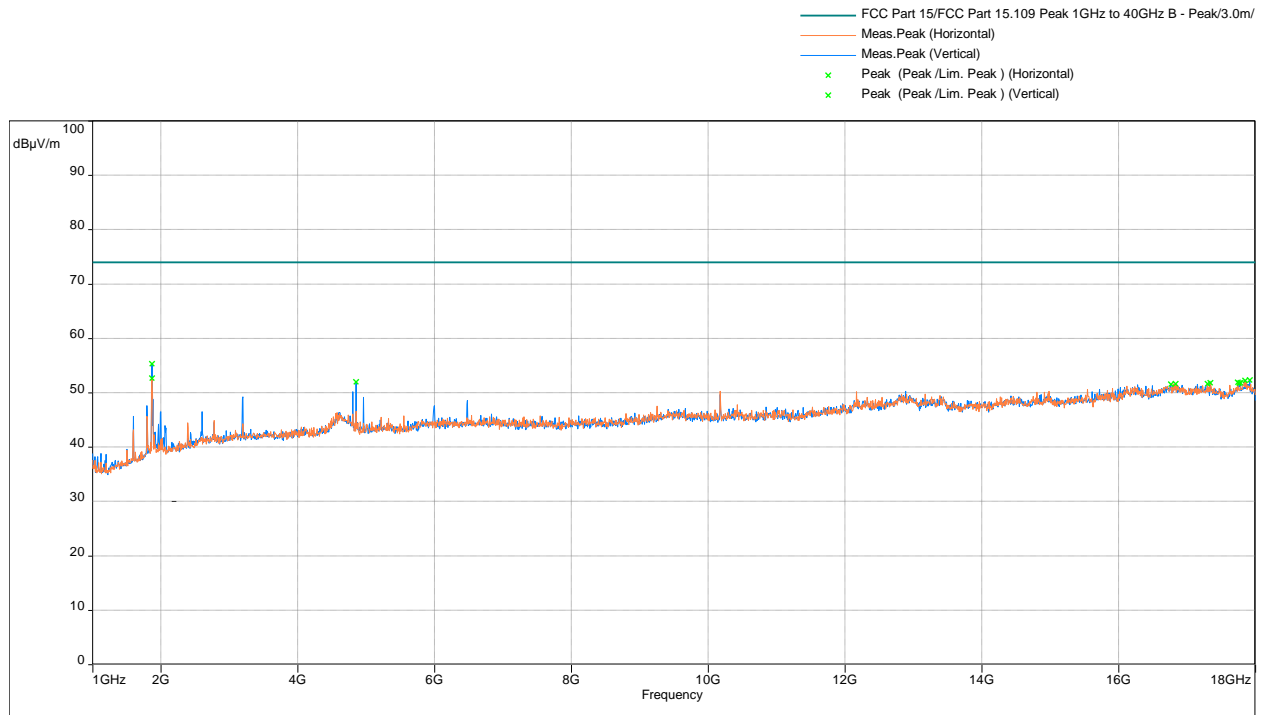
| | |
|----------------|-----------------|
| Results | Complies |
|----------------|-----------------|

Test Results: 15.209 Radiated Spurious Emissions Mid Channel, Tx at 925.1 MHz

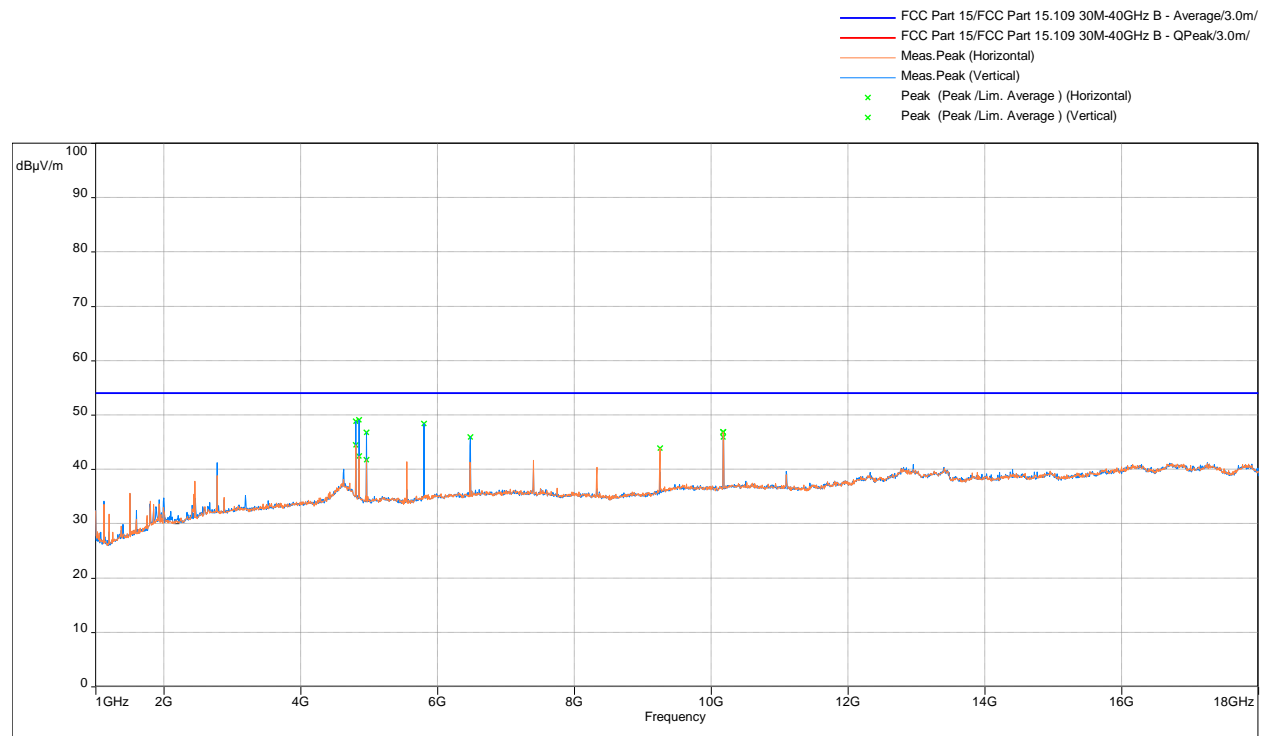
Radiated Spurious Emissions 30 MHz - 1000 MHz



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



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



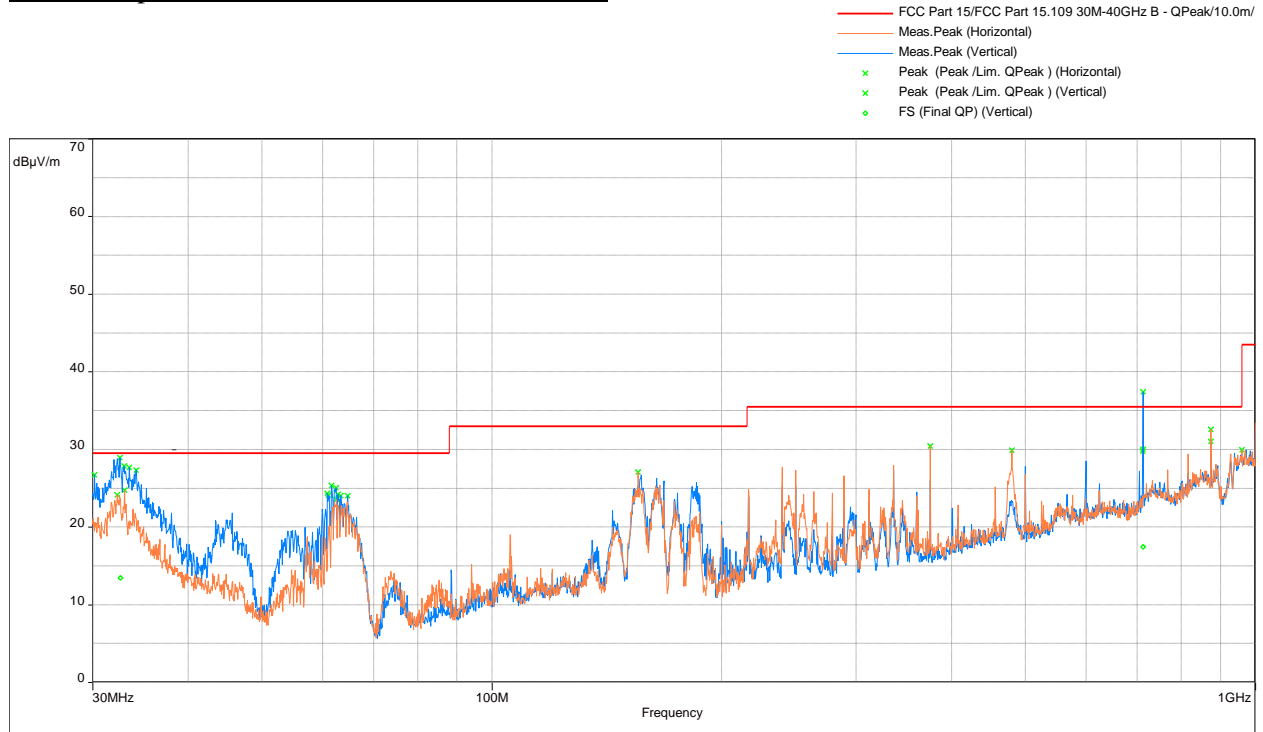
| Frequency | FS@3m | Avg Limit | Margin | Detector | Results |
|-----------|--------|-----------|--------|----------|---------|
| MHz | dBμV/m | dBμV/m | dB | | |
| 4849.933 | 49.0 | 54 | -5.0 | Avg | Pass |

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

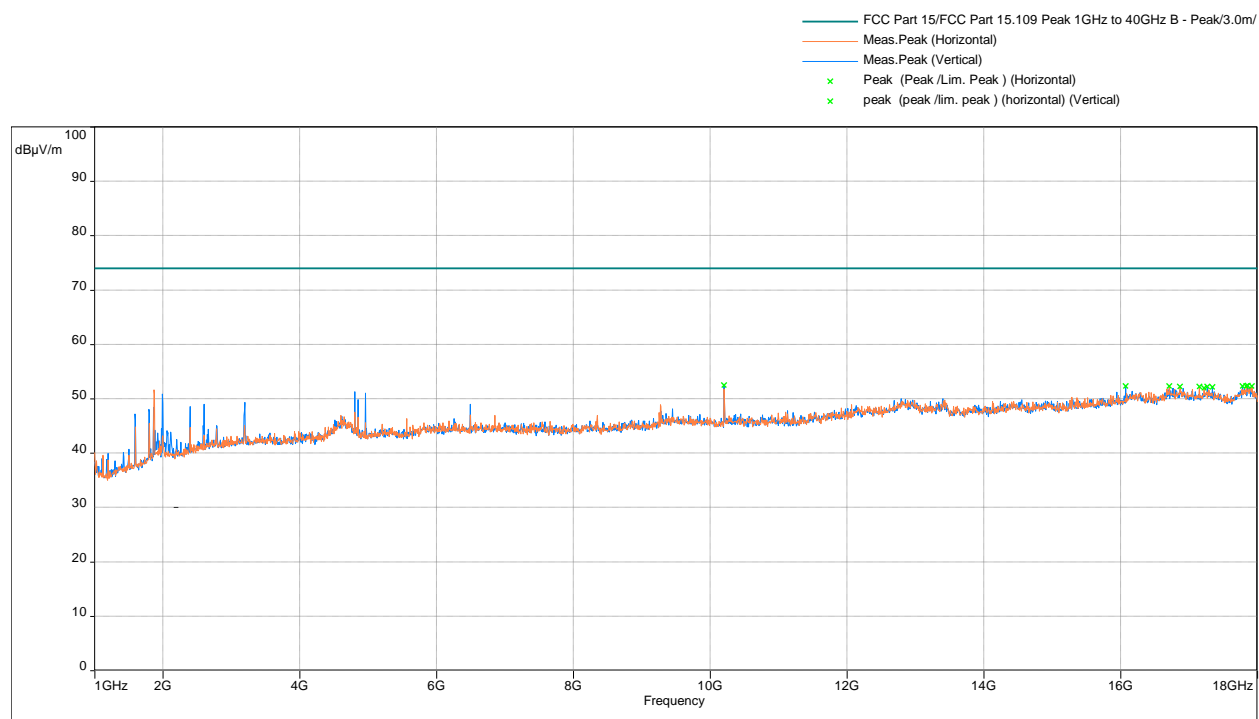
| | |
|----------------|-----------------|
| Results | Complies |
|----------------|-----------------|

Test Results: 15.209 Radiated Spurious Emissions High Channel, Tx at 927.5 MHz

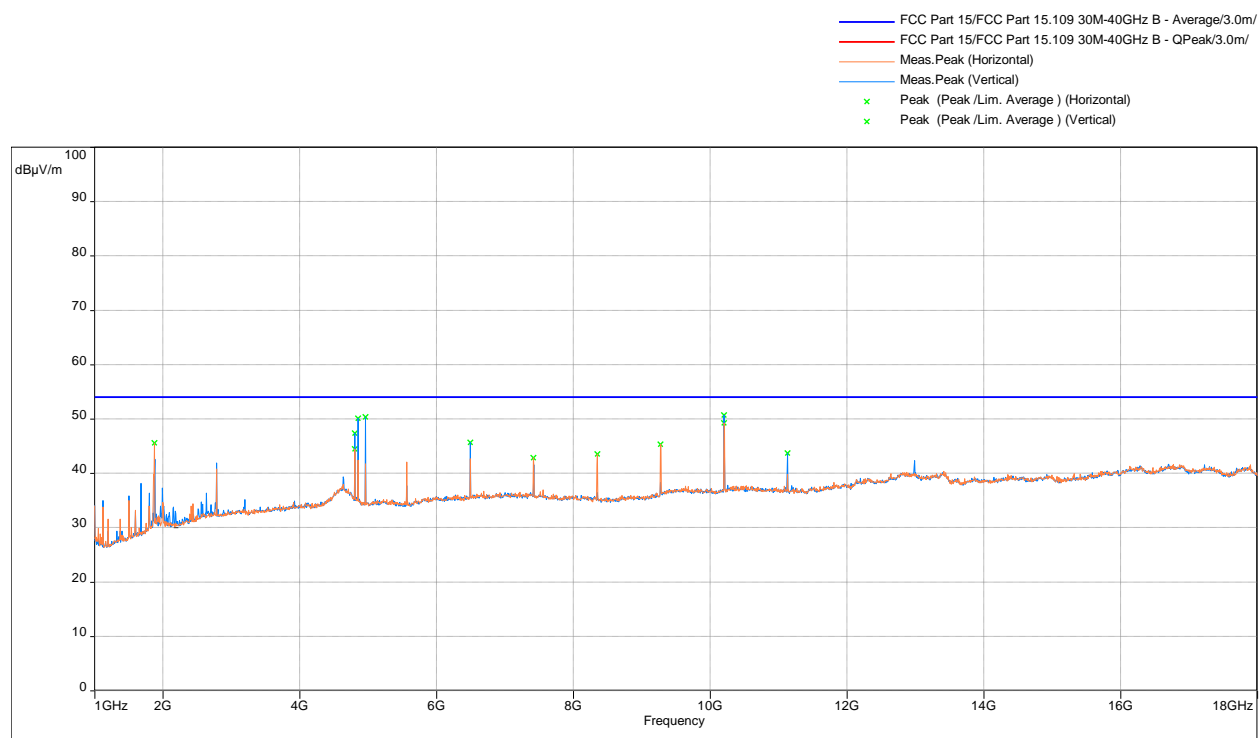
Radiated Spurious Emissions 30 MHz - 1000 MHz



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



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



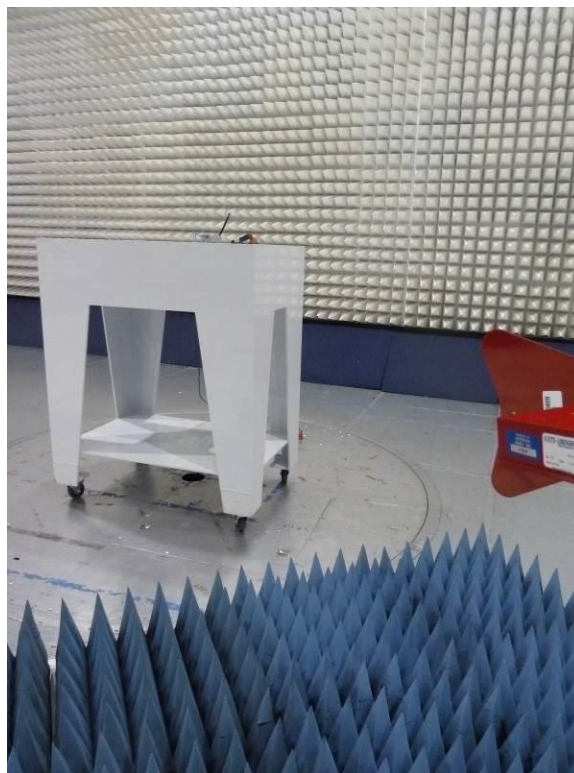
| Frequency | FS@3m | Avg Limit | Margin | Detector | Results |
|-----------|--------|-----------|--------|----------|---------|
| MHz | dBμV/m | dBμV/m | dB | | |
| 4849.933 | 50.4 | 54 | -3.6 | Avg | Pass |

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

| | |
|----------------|-----------------|
| Results | Complies |
|----------------|-----------------|

4.5.8 Test setup photographs

The following photographs show the testing configurations used.



4.6 Radiated Emissions

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 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.

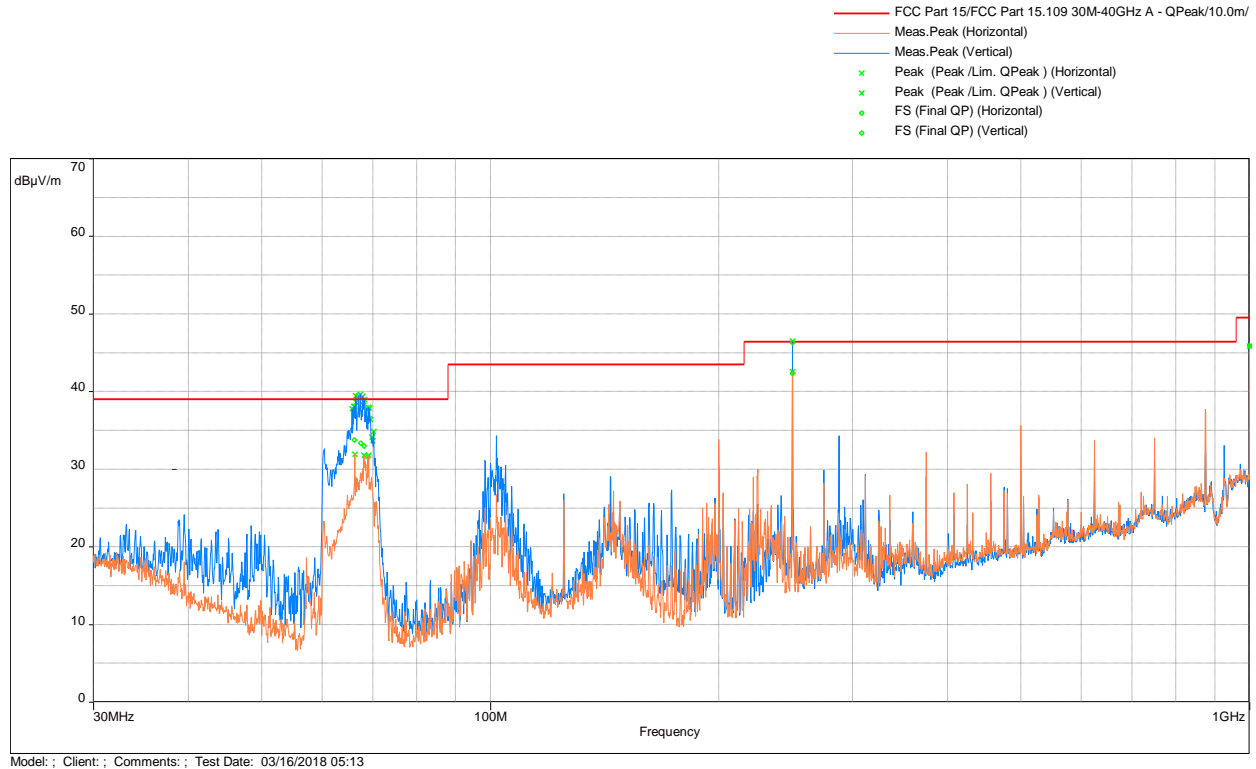
Equipment setup for radiated disturbance tests followed the guidelines of ANSI C63.4-2014.

| | |
|-------------------|----------------|
| Tested By: | Aaron Chang |
| Test Date: | March 16, 2018 |

4.6.3 Test Results

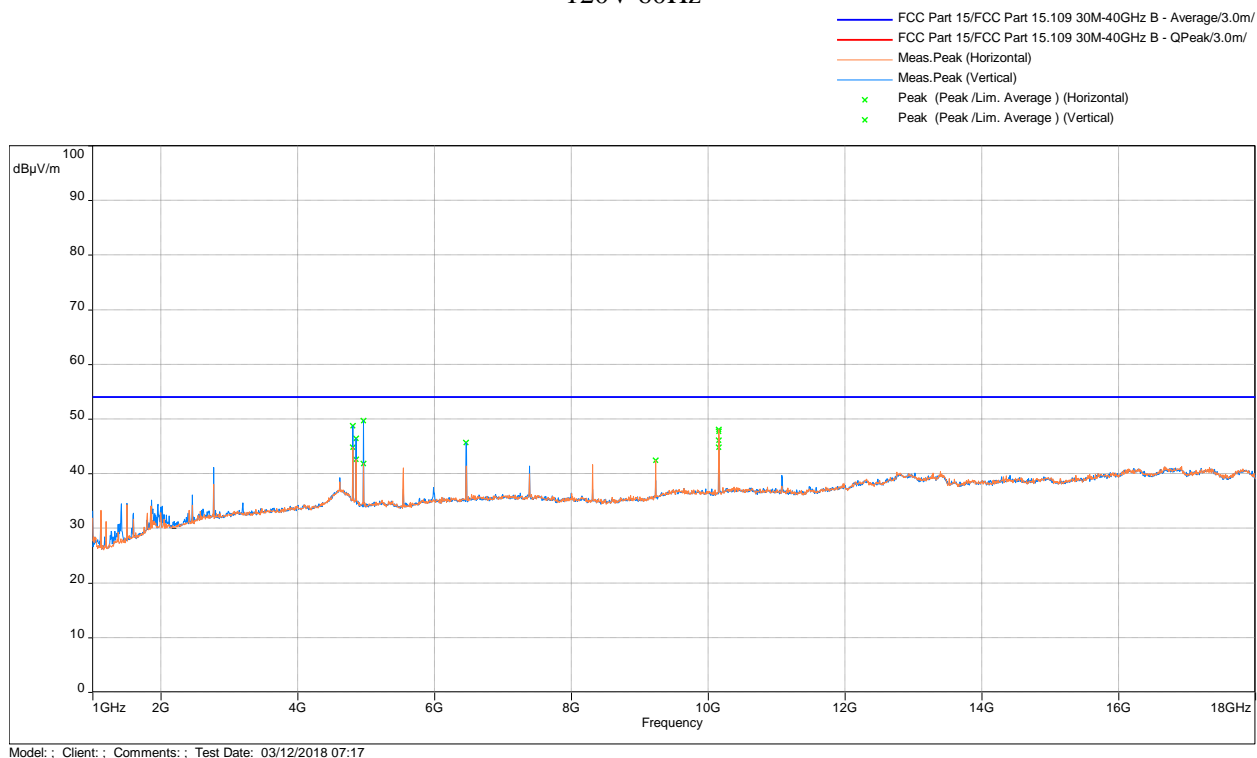
The EUT met the radiated disturbance requirements of FCC & ICES 003 for a Class A device.

FCC & ICES 003 Radiated Disturbance **30MHz to 1GHz** **120V 60Hz**

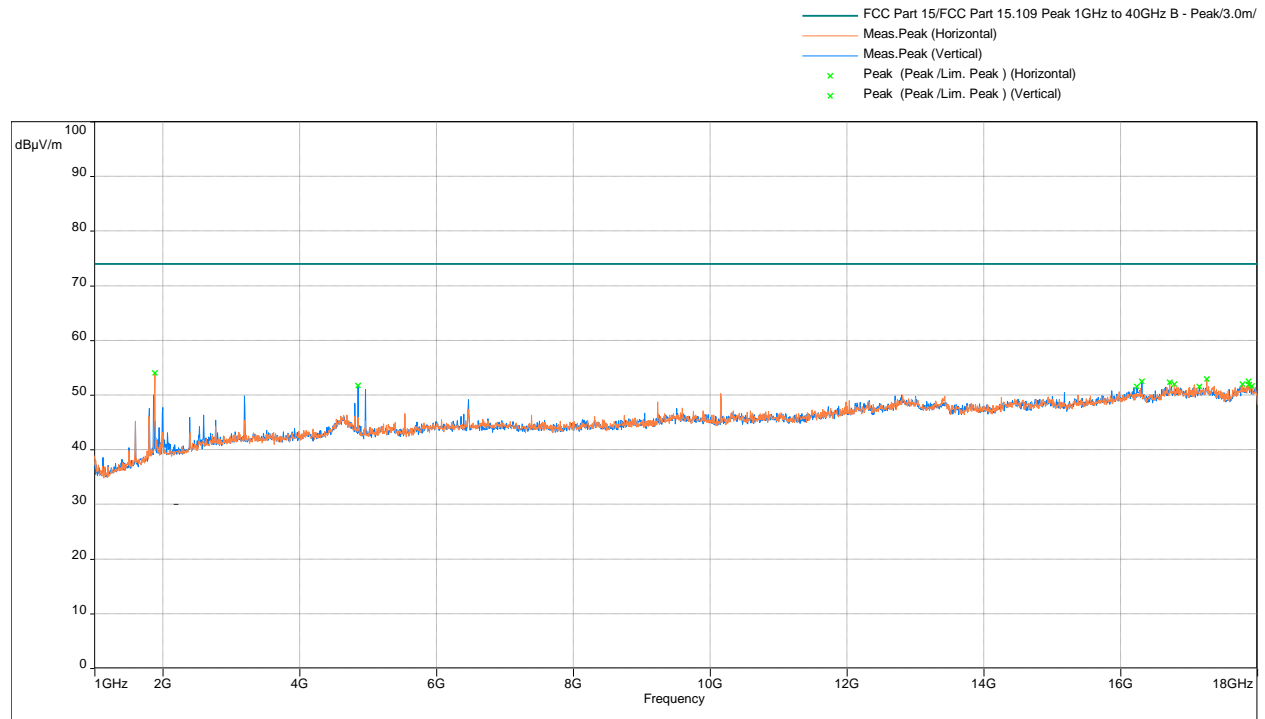


| Frequency | FS | Limit | Margin | Azimuth | Height | Polarity | RA | Correction |
|-----------|--------|--------|--------|---------|--------|------------|-------|------------|
| MHz | dBμV/m | dBμV/m | dB | deg | m | | dBμV | dB |
| 250.007 | 42.35 | 46.4 | -4.05 | 49 | 3.46 | Horizontal | 55.76 | -13.41 |
| 999.987 | 45.85 | 49.5 | -3.65 | 324.5 | 1 | Horizontal | 43.11 | 2.74 |
| 66.209 | 33.72 | 39 | -5.28 | 98.75 | 1.72 | Vertical | 54.64 | -20.95 |
| 67.491 | 33.33 | 39 | -5.67 | 118.75 | 1.94 | Vertical | 54.14 | -20.8 |
| 68.224 | 32.97 | 39 | -6.03 | 122.25 | 1.85 | Vertical | 53.67 | -20.71 |
| 250.007 | 46.30 | 46.4 | -0.10 | 322.75 | 1 | Vertical | 59.71 | -13.41 |

***FCC & ICES 003 Radiated Disturbance
1GHz to 18GHz, Average
120V 60Hz***



***FCC & ICES 003 Radiated Disturbance
1GHz to 18GHz, Peak
120V 60Hz***

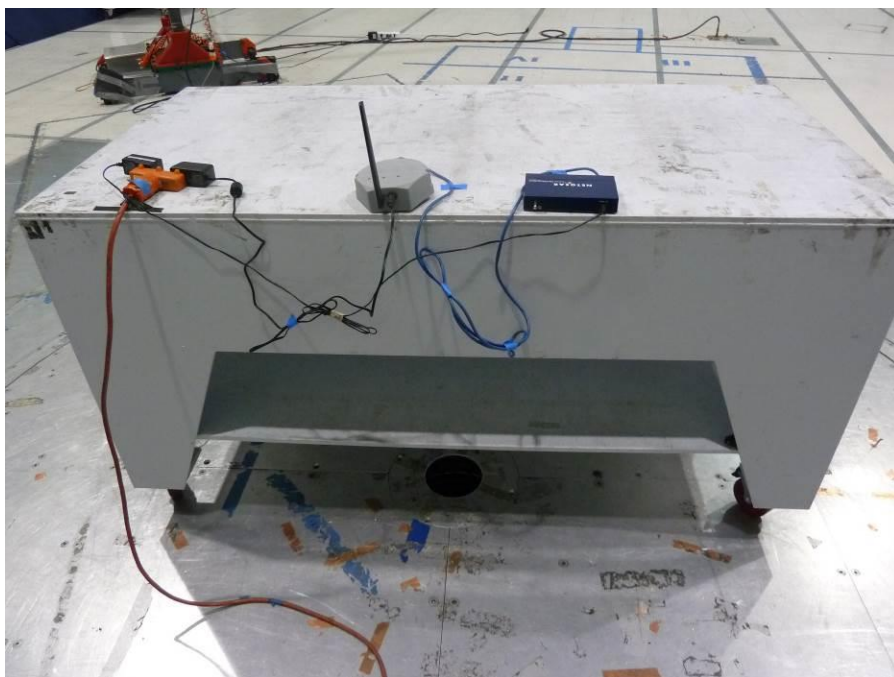


Result: Complies by 0.10* dB

**Measured result is below the specification limit by a margin less than the measurement uncertainty; it is not therefore possible to determine compliance at confidence level of 95%. However, the measured result indicates a higher probability that the product tested complies with the specification limit.*

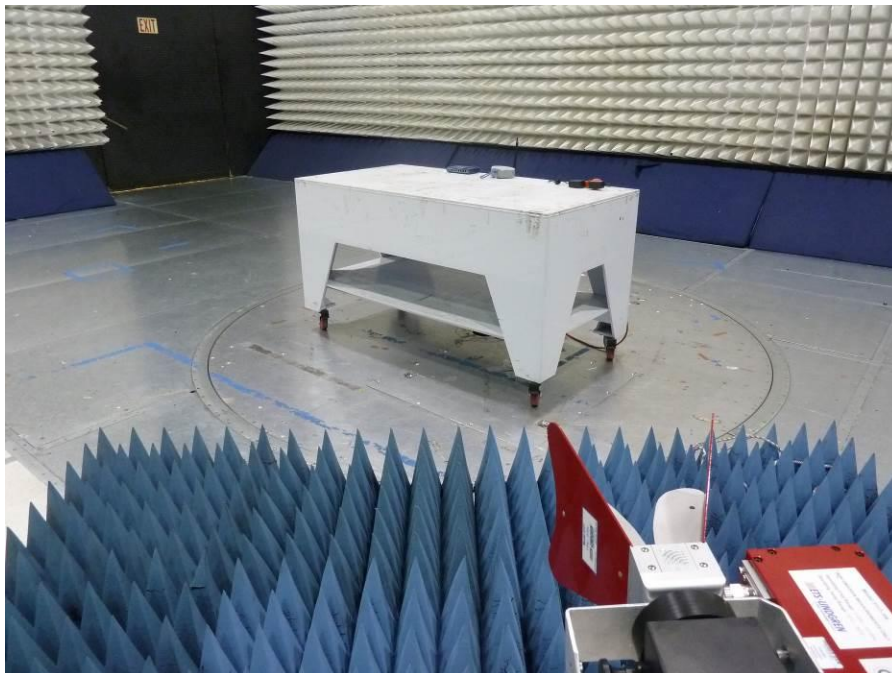
4.6.4 Test Configuration Photographs

The following photographs show the testing configurations used.



Electromagnetic Radiated Disturbance Setup Photograph

4.6.4 Test Configuration Photographs (Continued)



Electromagnetic Radiated Disturbance Setup Photograph

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

4.7.1 Requirement

| Frequency Band MHz | FCC 15.207 Limit dB(μV) | | FCC 15.107 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 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 EUTs are placed on a horizontal metal ground plane and isolated from the ground plane by an insulating material up to 12mm thick. The metal ground plane extends at least 0.5m beyond the boundaries of the EUT and has minimum dimensions of 2m by 2m.

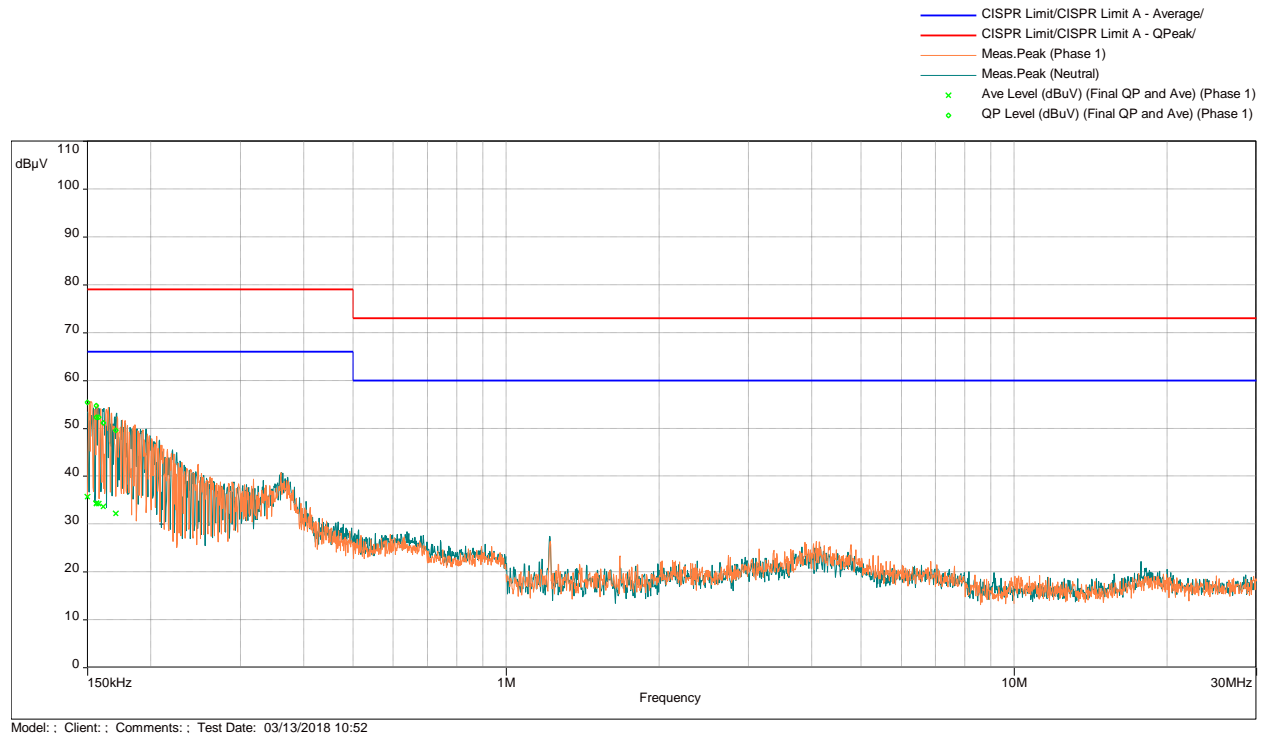
Equipment setup for conducted disturbance tests followed the guidelines of ANSI C63.10: 2013 & ANSI C63.4-2014.

| | |
|-------------------|----------------|
| Tested By: | Aaron Chang |
| Test Date: | March 13, 2018 |

4.7.3 Test Result

The EUT met the conducted disturbance requirement of FCC & ICES 003 for a Class A device.

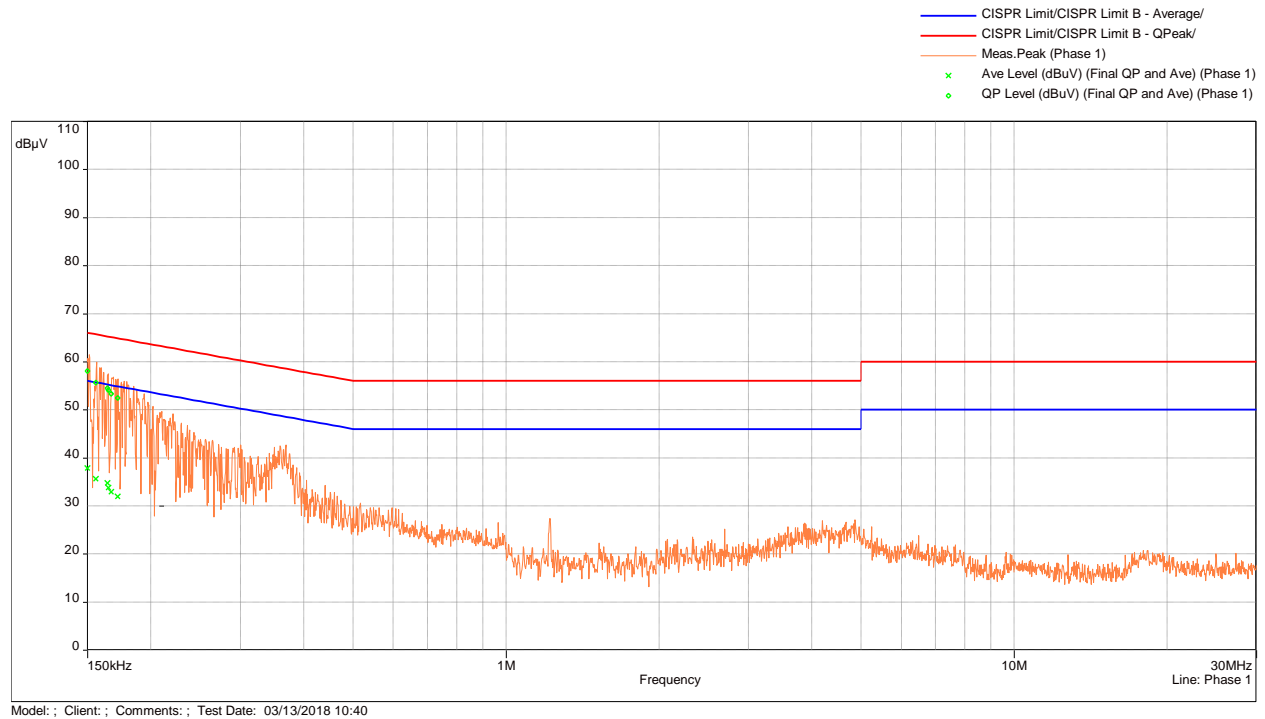
15.107 FCC & ICES 003 Conducted Disturbance at AC Mains 120V 60Hz



| Freq. | Ave Level | QP Level | Ave Limit | QP Limit | Ave Margin | QP Margin | Line | Correction |
|-------|-----------|----------|-----------|----------|------------|-----------|---------|------------|
| MHz | dBμV | dBμV | dBμV | dBμV | dB | dB | | dB |
| 0.150 | 35.71 | 55.43 | 66 | 79 | -30.29 | -23.57 | Phase 1 | 11.01 |
| 0.156 | 34.22 | 54.67 | 66 | 79 | -31.78 | -24.33 | Phase 1 | 11.02 |
| 0.156 | 34.31 | 52.31 | 66 | 79 | -31.69 | -26.69 | Phase 1 | 11.02 |
| 0.158 | 34.22 | 52.27 | 66 | 79 | -31.78 | -26.73 | Phase 1 | 11.02 |
| 0.161 | 33.67 | 51.16 | 66 | 79 | -32.33 | -27.84 | Phase 1 | 11.02 |
| 0.171 | 32.15 | 49.54 | 66 | 79 | -33.85 | -29.46 | Phase 1 | 11.02 |

Result: Complies by 23.57 dB

15.207 FCC & ICES 003 Conducted Disturbance at AC Mains
120V 60Hz

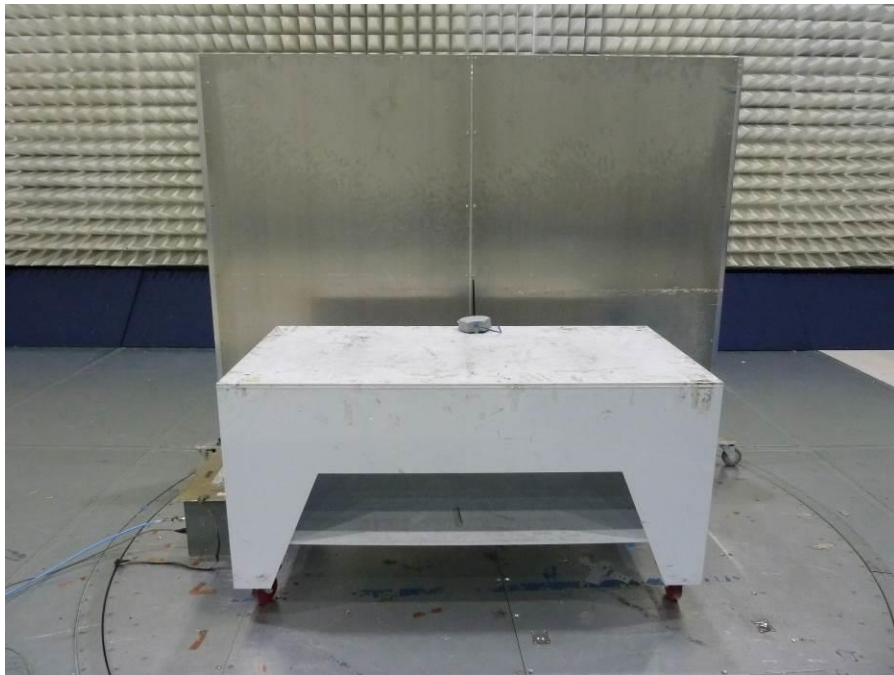


| Freq. | Ave Level | QP Level | Ave Limit | QP Limit | Ave Margin | QP Margin | Line | Correction |
|-------|-----------|----------|-----------|----------|------------|-----------|---------|------------|
| MHz | dBμV | dBμV | dBμV | dBμV | dB | dB | | dB |
| 0.150 | 37.83 | 58.04 | 56 | 66 | -18.17 | -7.96 | Phase 1 | 11.01 |
| 0.156 | 35.64 | 55.61 | 55.69 | 65.69 | -20.05 | -10.08 | Phase 1 | 11.02 |
| 0.164 | 34.69 | 54.45 | 55.24 | 65.24 | -20.55 | -10.79 | Phase 1 | 11.02 |
| 0.165 | 33.77 | 54.05 | 55.22 | 65.22 | -21.45 | -11.17 | Phase 1 | 11.02 |
| 0.167 | 32.88 | 53.34 | 55.11 | 65.11 | -22.24 | -11.78 | Phase 1 | 11.02 |
| 0.172 | 31.96 | 52.45 | 54.85 | 64.85 | -22.89 | -12.41 | Phase 1 | 11.02 |

Result: **Complies by 7.96 dB**

4.7.4 Test Configuration Photographs

The following photographs show the testing configurations used.



AC Mains Line-Conducted Disturbance Setup Photograph

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 | 01/24/19 |
| Spectrum Analyzer | Rohde and Schwarz | ESR | ITS 01607 | 12 | 10/09/18 |
| Active Horn Antenna | ETS-Lindgren | 3117-PA | ITS 01636 | 12 | 01/11/19 |
| EMI Receiver | Rohde and Schwarz | ESU | ITS 00961 | 12 | 07/10/18 |
| BI-Log Antenna | Teseq | CBL 6111D | ITS 01058 | 12 | 08/11/18 |
| Pre-Amplifier | Sonoma Instrument | 310 | ITS 00942 | 12 | 01/26/19 |
| RF Cable | TRU Corporation | TRU CORE 300 | ITS 01462 | 12 | 08/19/18 |
| 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 | Narda | FSCM99899 | ITS 01583 | 12 | 08/31/18 |
| RF Cable | Megaphase | EMC1-K1K1-236 | ITS 01538 | 12 | 06/13/18 |
| LISN | FCC | FCC-LISN-50-50-M-H | ITS 00552 | 12 | 11/14/18 |
| LISN | FCC | FCC-LISN-50-50-M-H | ITS 00551 | 12 | 09/15/18 |
| LISN | COM-POWER | LIN-120A | ITS 01612 | 12 | 02/05/19 |

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 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 | Fastenal G103406457 3-12-2018.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 / G103436674 | AC | KV | April 05, 2018 | Original document |