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# Cubic Transportation Systems Ltd.
# TEST REPORT

**SCOPE OF WORK**
EMC TESTING – VALIDATOR 2

**REPORT NUMBER**
103679095LEX-006.2

| **ISSUE DATE** | **REVISION DATE** |
|---|---|
| 1/18/2019 | 9/8/2019 |

**PAGES**
38

**DOCUMENT CONTROL NUMBER**
Non-Specific EMC Report Shell Rev. December 2017


# EMC TEST REPORT

(FULL COMPLIANCE)

**Report Number:** 103679095LEX-006.2
**Project Number:** G103679095

**Report Issue Date:** 9/8/2019

**Model(s) Tested:** Validator 2

**Standards:** Title 47 CFR Part 15.225
RSS-210 Issue 9
RSS-Gen Issue 4

Tested by:
Intertek Testing Services NA, Inc.
731 Enterprise Dr.
Lexington, KY 40510
USA

Client:
Cubic Transportation Systems Ltd.
AFC House,
Honeycrock Lane,
Salfords,
Redhill,
RH1 6LA, UK

Report prepared by

Brian Lackey, Project Engineer

Report reviewed by

Bryan Taylor, Team Leader

Table of Contents

## 1 Introduction and Conclusion

The tests indicated in section 2.0 were performed on the product constructed as described in section 4.0. The remaining test sections are the verbatim text from the actual data sheets used during the investigation. These test sections include the test name, the specified test Method, a list of the actual Test Equipment Used, documentation Photos, Results and raw Data. No additions, deviations, or exclusions have been made from the standard(s) unless specifically noted.

Based on the results of our investigation, we have concluded the product tested **complies** with the requirements of the standard(s) indicated. The results obtained in this test report pertain only to the item(s) tested. Intertek does not make any claims of compliance for samples or variants which were not tested.

## 2 Test Summary

| Section | Test full name | Result |
|---|---|---|
| 6 | Receiver Spurious Emissions<br>(ANSI C63.4: 2014) | Pass |
| 7 | Transmitter Fundamental and Spurious Emissions<br>(FCC Part 15.209, 15.225(a)-(d), RSS-210 Issue 9 § B.6(a)-(d), RSS-Gen Issue 4 § 8.9) | Pass |
| 8 | Frequency Stability<br>(FCC Part 15.225(e), RSS-210 Issue 9 § B.6) | Pass |
| 9 | Occupied Bandwidth<br>(RSS-Gen Issue 4 § 6.6) | Pass |
| 10 | Conducted Emissions<br>(ANSI C63.4: 2014) | Pass |
| 11 | Antenna Requirement<br>(FCC Part 15.203, RSS-Gen Issue 4 § 8.3) | Pass |

## 3 Client Information

**This product was tested at the request of the following:**

| Client Information | |
|---|---|
| **Client Name:** | Cubic Transportation Systems Ltd. |
| **Address:** | AFC House,<br>Honeycrock Lane,<br>Salfords,<br>Redhill,<br>RH1 6LA, UK |
| **Contact:** | Robert Johnson |
| **Telephone:** | +44 1737 786556 |
| **Email:** | Robert.johnson@cubic.com |
| **Manufacturer Information** | |
| **Manufacturer Name:** | Cubic Transportation Systems Inc. |
| **Manufacturer Address:** | 1308 South Washington Street,<br>Tullahoma, TN 37388<br>USA |

## 4 Description of Equipment under Test and Variant Models

| Equipment Under Test | |
|---|---|
| **Product Name** | Validator 2 |
| **Model Number** | 5300-08066 |
| **Serial Number** | PROT2040 |
| **Receive Date** | 12/4/2018 |
| **Test Start Date** | 12/4/2018 |
| **Test End Date** | 12/28/218 |
| **Device Received Condition** | Good |
| **Test Sample Type** | Production |
| **Input Rating** | 24Vdc via AC-DC adapter, 100V-240V, 0.8A, 50/60Hz |
| **Number of Phases** | 1 |
| **Software Used By EUT** | V1.12.1 |
| **Frequency Band(s)** | 13.56MHz |
| **Description of Equipment Under Test (provided by client)** | |
| The Validator 2 is intended to be used as a revenue collection device for transit operators. It is typically installed on buses or transit stations and used to “tag on” and “tag off” Contactless Smart Cards or Barcodes carried by passengers intending to pay for their journey. | |

### 4.1 Variant Models:

The original samples tested were updated by Cubic Transportation Systems Ltd. The changes to the unit were as follows:

- *The Validator 2 will not have the 4G antenna board (5300-57014) fitted anymore, so cables 5300-06049-3 and 5300-06049-4 will also be omitted*
- *5300-57012 Rev. C [Barcode Illumination and Proximity PCB ASSEMBLY] – Copper on both layers was pulled back from the stud holes to give greater electrical clearance. Parts that were no-fit parts in previous revision were completely removed in copper in this revision.*
- *5300-57015 Rev. E [NFC and User LED PCB Assembly] – Minor capacitor and resistor changes for EMV CO. compliance testing. (180pF ->160pF | 2x0.05 Ohm -> 1x 0.75Ohm and 1x 0.1 Ohm)*
- *53000-57011 Rev. E [PZ Personality Module PCB Assembly]*
    - *2 copper layers / planes added to the board stack to give better GND return paths to traces/signals on the board.*
    - *Additional ground stitching added throughout the board (particularly all around the outer edges) to improve ground return paths of signals (attempt to reduce on board noise).*
    - *Silkscreen and ResDef changes around the WiFi module (previously a low pass filter was created (and tested) to remove the 5GHz spur by fitting components to no-fit resistors pads, now LPF is placed properly in designated footprints)*
    - *4G modem (U5) removed as 4G connectivity not required*
    - *WiFi and 4G modem modules are now on islands i.e. moats created around the modules on the PCB with narrow bridges allowing the comms signals to modules to reduce noise interacting with the modules*
    - *Battery Fuel Gauge (U54 - BQ27Z561YPHR) added to monitor the battery voltage*
    - *Switcher components around U33 - TPS61088RHLR switcher adjusted for more efficient operation. Switching coil reduced from 4.8uH to 1.5uH*
    - *Series resistance (6.8k) added to GPS UART line to reduce conducted noise from the board to the off-board GPS module, common mode choke added to the GND connected to the GPS module connector*
    - *Current inrush limiting circuitry added (N-MOSFET limiter) to POE voltage input*
    - *Battery switchover circuitry modified to allow the device to operate/switchover at lower voltages, approx. 8V. Leaky ORing IC replaced with MOSFET switches which have much lower leakage*
    - *Second speaker connection added (only one speaker is still fitted to the Validator 2)*
    - *PCB clearances of power traces increased to meet Low Voltage Directive requirements*

These modified units are considered to also be covered by the test results presented in this report.

# 5 System Setup and Method

## 5.1 Method:

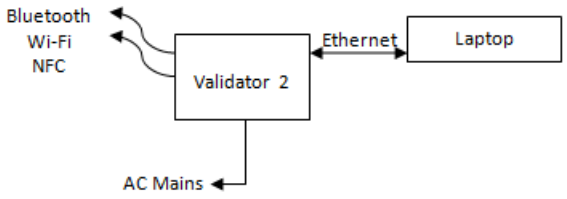
Configuration as required by ANSI C63.4: 2014 and ANSI C63.10:2013.

| No. | Descriptions of EUT Exercising |
|---|---|
| 1 | Transmitting an NFC signal at 13.56MHz |

| Cables | | | | | |
|---|---|---|---|---|---|
| ID | Description | Length (m) | Shielding | Ferrites | Termination |
| 1 | AC-DC Power | 2 | No | No | Plug |
| 2 | Ethernet | 10 | No | No | USB |

| Support Equipment | | | |
|---|---|---|---|
| Description | Manufacturer | Model Number | Serial Number |
| Laptop | HP | - | - |

## 5.2 EUT Block Diagram:



### 5.3 EUT Photo (Front):

### 5.4 EUT Photo (Back):

# 6 Receiver Spurious Emissions

## 6.1 Test Method

Tests are performed in accordance with ANSI C63.4: 2014

**TEST SITE:** 10m ALSE

**Site Designation:** 10m Chamber

**Measurement Uncertainty**

| Measurement | Frequency Range | Expanded Uncertainty (k=2) | Ucispr |
|---|---|---|---|
| Radiated Emissions, 10m | 30-1000 MHz | 3.9dB | 6.3 dB |
| Radiated Emissions, 3m | 30-1000 MHz | 4.0dB | 6.3 dB |
| Radiated Emissions, 3m | 1-6 GHz | 4.7dB | 5.2 dB |
| Radiated Emissions, 3m | 6-15 GHz | 4.7dB | 5.5 dB |
| Radiated Emissions, 3m | 15-18 GHz | 4.7dB | 5.5 dB |
| Radiated Emissions, 3m | 18-40 GHz | 4.7dB | 5.5 dB |

As shown in the table above our radiated emissions $U_{lab}$ is less than the corresponding $U_{CISPR}$ reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required.

## 6.2 Sample 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
Where FS = Field Strength in dBμV/m
RA = Receiver Amplitude (including preamplifier) in dBμV
CF = Cable Attenuation Factor in dB
AF = Antenna Factor in dB
AG = Amplifier Gain in dB

In the following table(s), the reading shown on the data table reflects the preamplifier gain. An example for the calculations in the following table is as follows.

Assume a receiver reading of 52.0 dBμV is obtained. The antenna factor of 7.4 dB and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving a field strength of 32 dBμV/m. This value in dBμV/m was converted to its corresponding level in μV/m.

RA = 52.0 dBμV
AF = 7.4 dB/m
CF = 1.6 dB
AG = 29.0 dB
FS = 32 dBμV/m

To convert from dBμV to μV or mV the following was used:

$UF = 10^{(NF / 20)}$ where UF = Net Reading in μV
NF = Net Reading in dBμV

**Example:**

FS = RA + AF + CF – AG = 52.0 + 7.4 + 1.6 – 29.0 = 32.0
$UF = 10^{(32\ dB\mu V / 20)}$ = 39.8 μV/m

### 6.3 Test Equipment Used

| Description | Asset | Manufacturer | Model | Cal Date | Cal Due |
|---|---|---|---|---|---|
| EMI Test Receiver | 3900 | Rohde & Schwarz | ESU40 | 9/18/2018 | 9/18/2019 |
| Bilog Antenna | 7088 | SunAR | JB6 | 7/24/2018 | 7/24/2019 |
| System Controller | 4096 | ETS Lindgren | 2090 | Verify at Time of Use | Verify at Time of Use |
| System Controller | 3957 | Sunol Sciences | SC99V | Verify at Time of Use | Verify at Time of Use |
| 3m Cable Chamber→Control Room | 2593 | | | 11/26/2018 | 11/26/2019 |
| 3m Cable Control Room→Receiver | 2592 | | | 11/26/2018 | 11/26/2019 |
| 10m Cable Antenna→Preamp | 3339 | | | 11/26/2018 | 11/26/2019 |

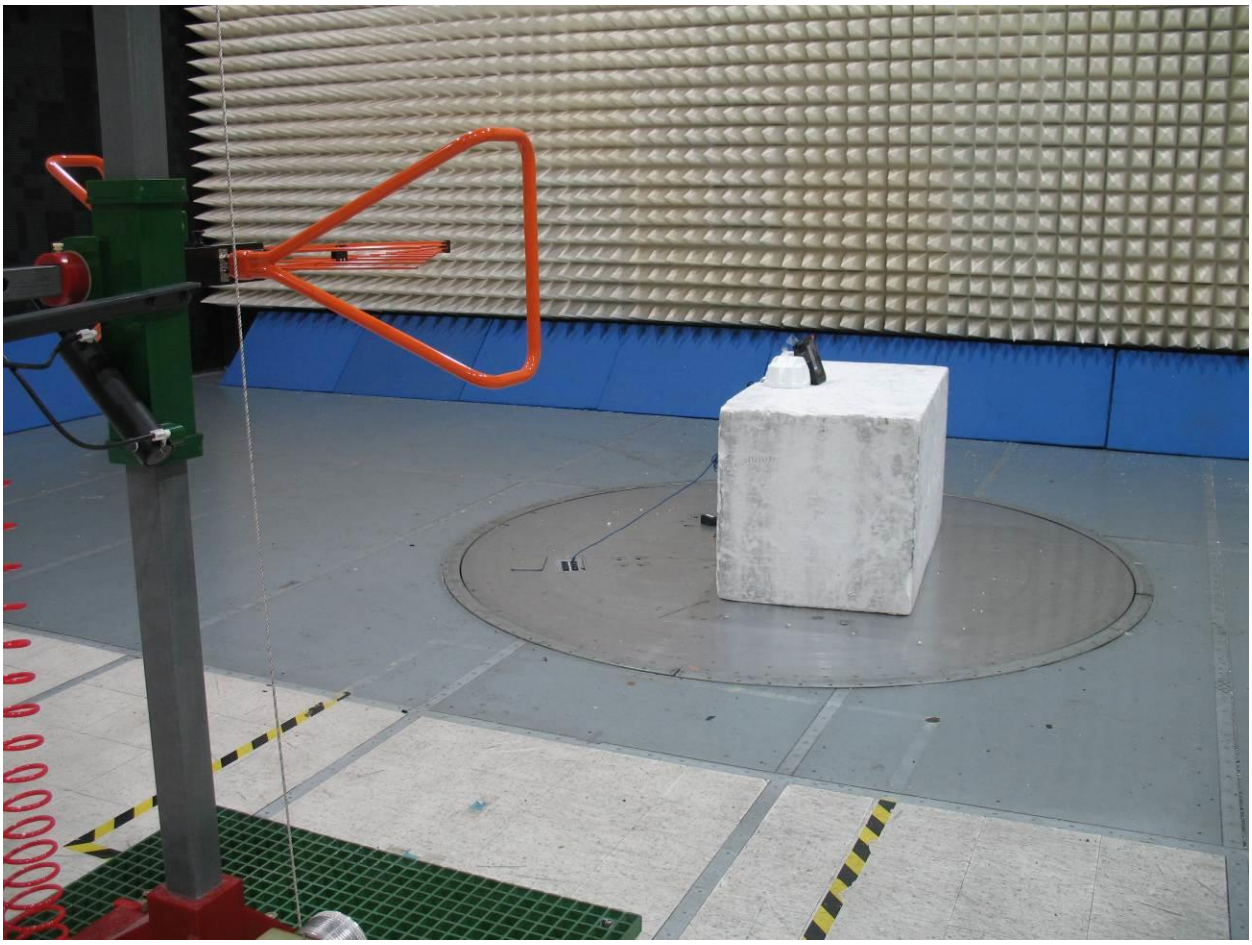
### 6.4 Software Utilized

| Name | Manufacturer | Version |
|---|---|---|
| EMC32 | Rohde & Schwarz | Version 9.15.02 |

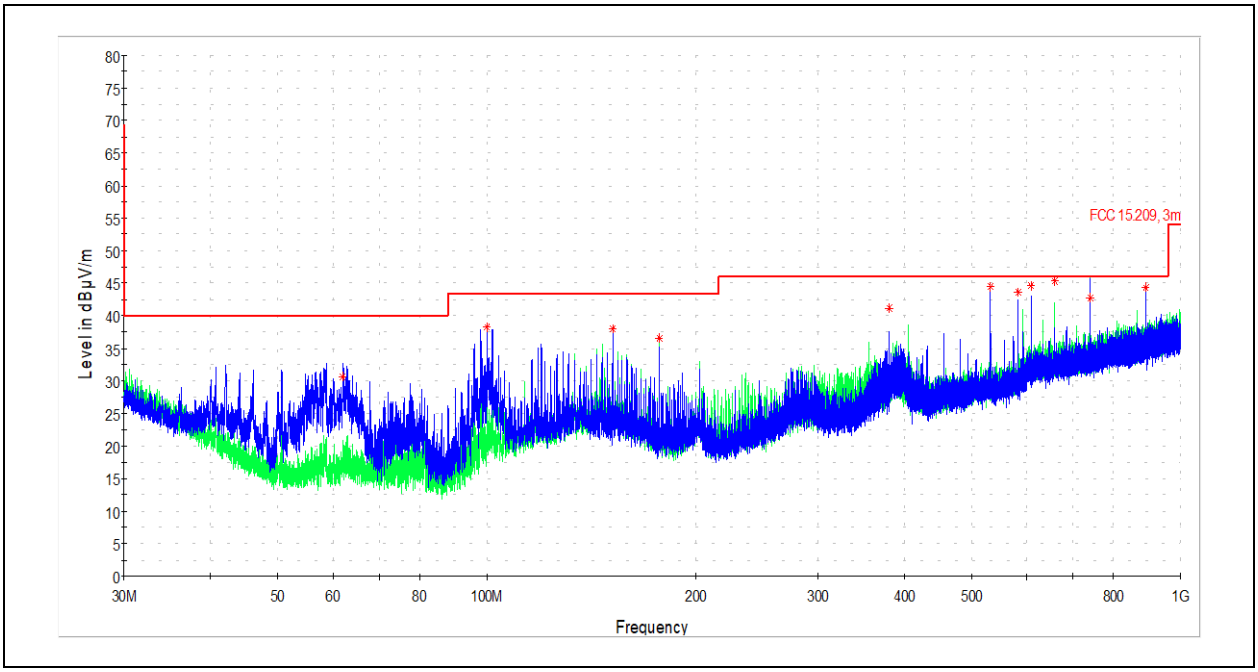
### 6.5 Test Results

The sample tested was found to be **compliant**.

## 6.6 Setup Photographs: 30MHz – 1GHz



## 6.7 Test Data: 30MHz – 1GHz




| Frequency (MHz) | QuasiPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 61.983000 | 30.62 | 40.00 | 9.38 | 120.000 | 100.0 | V | 92.0 | 14.7 |
| 100.000000 | 38.30 | 43.52 | 5.22 | 120.000 | 100.2 | V | 18.0 | 18.9 |
| 151.980000 | 37.96 | 43.52 | 5.56 | 120.000 | 100.0 | V | 0.0 | 21.2 |
| 177.320000 | 36.54 | 43.52 | 6.98 | 120.000 | 156.3 | H | 92.0 | 19.9 |
| 380.020000 | 41.15 | 46.02 | 4.87 | 120.000 | 129.7 | V | 264.0 | 24.9 |
| 532.010000 | 44.51 | 46.02 | 1.51 | 120.000 | 100.0 | V | 0.0 | 28.2 |
| 582.650000 | 43.66 | 46.02 | 2.36 | 120.000 | 100.1 | V | 108.0 | 29.0 |
| 608.000000 | 44.55 | 46.02 | 1.47 | 120.000 | 100.0 | V | 91.0 | 29.5 |
| 658.670000 | 45.38 | 46.02 | 0.64 | 120.000 | 106.8 | H | 184.0 | 30.9 |
| 741.800000 | 42.80 | 46.02 | 3.22 | 120.000 | 129.3 | H | 8.0 | 31.8 |
| 890.100000 | 44.27 | 46.02 | 1.75 | 120.000 | 212.4 | V | 8.0 | 33.5 |

| | | | |
|---|---|---|---|
| Test Personnel: | Ben Coolbear | Test Date: | 12/27/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | See Above |
| Product Standard: | FCC Part 15.225 RSS-210 Issue 9 | Ambient Temperature: | 21.7C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 22.6% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 985.4mbar |

Deviations, Additions, or Exclusions: None

# 7 Transmitter Fundamental and Spurious Emissions

## 7.1 Test Limits

**FCC Part 15.225:**

(a) The field strength of any emissions within the band 13.553-13.567 MHz shall not exceed 15,848 microvolts/meter at 30 meters.

(b) Within the bands 13.410-13.553 MHz and 13.567-13.710 MHz, the field strength of any emissions shall not exceed 334 microvolts/meter at 30 meters.

(c) Within the bands 13.110-13.410 MHz and 13.710-14.010 MHz the field strength of any emissions shall not exceed 106 microvolts/meter at 30 meters.

(d) The field strength of any emissions appearing outside of the 13.110-14.010 MHz band shall not exceed the general radiated emission limits in §15.209.

**FCC Part 15.209:**

(a) Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

| Frequency (MHz) | Field strength (microvolts/meter) | Measurement distance (meters) |
|---|---|---|
| 0.009-0.490 | 2400/F(kHz) | 300 |
| 0.490-1.705 | 24000/F(kHz) | 30 |
| 1.705-30.0 | 30 | 30 |
| 30-88 | 100** | 3 |
| 88-216 | 150** | 3 |
| 216-960 | 200** | 3 |
| Above 960 | 500 | 3 |

**RSS-210 Issue 9 § B.6:**

The field strength of any emission shall not exceed the following limits:

1. 15.848 mV/m (84 dBµV/m) at 30 m, within the band 13.553-13.567 MHz;
2. 334 µV/m (50.5 dBµV/m) at 30 m, within the bands 13.410-13.553 MHz and 13.567-13.710 MHz;
3. 106 µV/m (40.5 dBµV/m) at 30 m, within the bands 13.110-13.410 MHz and 13.710-14.010 MHz; and
4. RSS-Gen general field strength limits for frequencies outside the band 13.110-14.010 MHz.

**RSS-Gen Issue 4 § 8.9:**

Except when the requirements applicable to a given device state otherwise, emissions from licence-exempt transmitters shall comply with the field strength limits shown in Table 4 and Table 5 below. Additionally, the level of any transmitter emission shall not exceed the level of the transmitter's fundamental emission.

**Table 4 – General Field Strength Limits for Licence-Exempt Transmitters at Frequencies Above 30 MHz**

| Frequency (MHz) | Field Strength (µv/m at 3 metres |
|---|---|
| 30-88 | 100 |
| 88-216 | 150 |
| 216-960 | 200 |
| Above 960* | 500 |

**Table 5 – General Field Strength Limits for Licence-Exempt Transmitters at Frequencies Below 30 MHz**

| Frequency | Electric Field Strength (µV/m) | Magnetic Field Strength (H-Field) (µA/m) | Measurement Distance (metres) |
|---|---|---|---|
| 9-490 kHz | 2,400/F (F in kHz) | 2,400/377F (F in kHz) | 300 |
| 490-1,705 kHz | 24,000/F (F in kHz) | 24,000/377F (F in kHz) | 30 |
| 1,705-30 MHz | 30 | N/A | 30 |

## 7.2 Test Method

Tests are performed in accordance with ANSI C63.10:2013.

**TEST SITE:** 10m ALSE

**Site Designation:** 10m Chamber

**Measurement Uncertainty**

| Measurement | Frequency Range | Expanded Uncertainty (k=2) | Ucispr |
|---|---|---|---|
| Radiated Emissions, 10m | 30-1000 MHz | 3.9dB | 6.3 dB |
| Radiated Emissions, 3m | 30-1000 MHz | 4.0dB | 6.3 dB |
| Radiated Emissions, 3m | 1-6 GHz | 4.7dB | 5.2 dB |
| Radiated Emissions, 3m | 6-15 GHz | 4.7dB | 5.5 dB |
| Radiated Emissions, 3m | 15-18 GHz | 4.7dB | 5.5 dB |
| Radiated Emissions, 3m | 18-40 GHz | 4.7dB | 5.5 dB |

As shown in the table above our radiated emissions $U_{lab}$ is less than the corresponding $U_{CISPR}$ reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required.

## 7.3 Sample 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
Where FS = Field Strength in dBμV/m
RA = Receiver Amplitude (including preamplifier) in dBμV
CF = Cable Attenuation Factor in dB
AF = Antenna Factor in dB
AG = Amplifier Gain in dB

In the following table(s), the reading shown on the data table reflects the preamplifier gain. An example for the calculations in the following table is as follows.

Assume a receiver reading of 52.0 dBμV is obtained. The antenna factor of 7.4 dB and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving a field strength of 32 dBμV/m. This value in dBμV/m was converted to its corresponding level in μV/m.

RA = 52.0 dBμV
AF = 7.4 dB/m
CF = 1.6 dB
AG = 29.0 dB
FS = 32 dBμV/m

To convert from dBμV to μV or mV the following was used:

$UF = 10^{(NF / 20)}$ where UF = Net Reading in μV
NF = Net Reading in dBμV

**Example:**

FS = RA + AF + CF – AG = 52.0 + 7.4 + 1.6 – 29.0 = 32.0
$UF = 10^{(32\ dB\mu V / 20)}$ = 39.8 μV/m

### 7.4 Test Equipment Used

| Description | Asset | Manufacturer | Model | Cal Date | Cal Due |
|---|---|---|---|---|---|
| EMI Test Receiver | 3900 | Rohde & Schwarz | ESU40 | 9/18/2018 | 9/18/2019 |
| Bilog Antenna | 7088 | SunAR | JB6 | 7/24/2018 | 7/24/2019 |
| Loop Antenna | 2387 | EMCO | 6511 | 6/7/2018 | 6/7/2019 |
| System Controller | 4096 | ETS Lindgren | 2090 | Verify at Time of Use | Verify at Time of Use |
| System Controller | 3957 | Sunol Sciences | SC99V | Verify at Time of Use | Verify at Time of Use |
| 3m Cable Chamber→Control Room | 2593 | | | 11/26/2018 | 11/26/2019 |
| 3m Cable Control Room→Receiver | 2592 | | | 11/26/2018 | 11/26/2019 |
| 10m Cable Antenna→Preamp | 3339 | | | 11/26/2018 | 11/26/2019 |

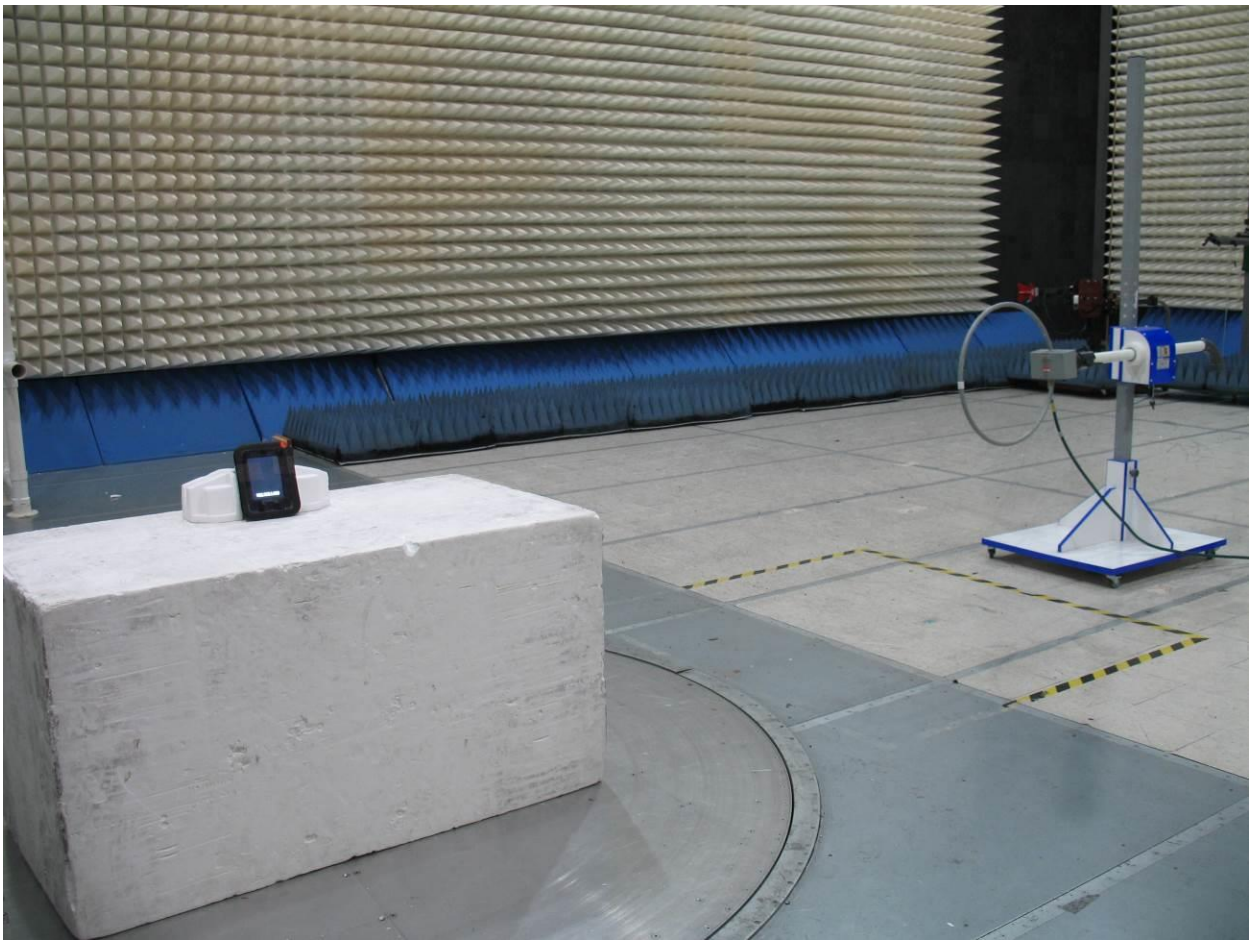
### 7.5 Software Utilized

| Name | Manufacturer | Version |
|---|---|---|
| EMC32 | Rohde & Schwarz | Version 9.15.02 |

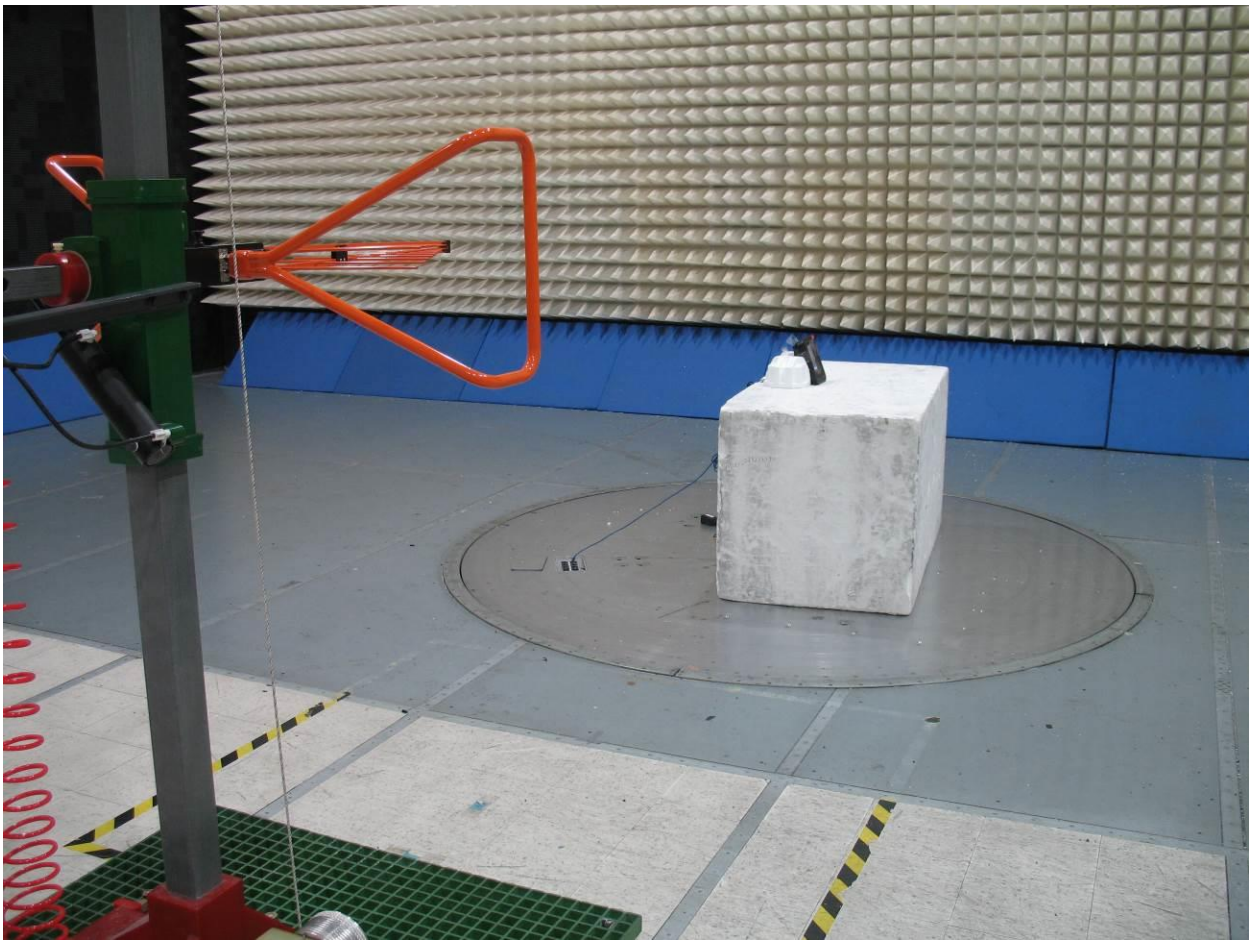
### 7.6 Test Results

The sample tested was found to be **compliant**.

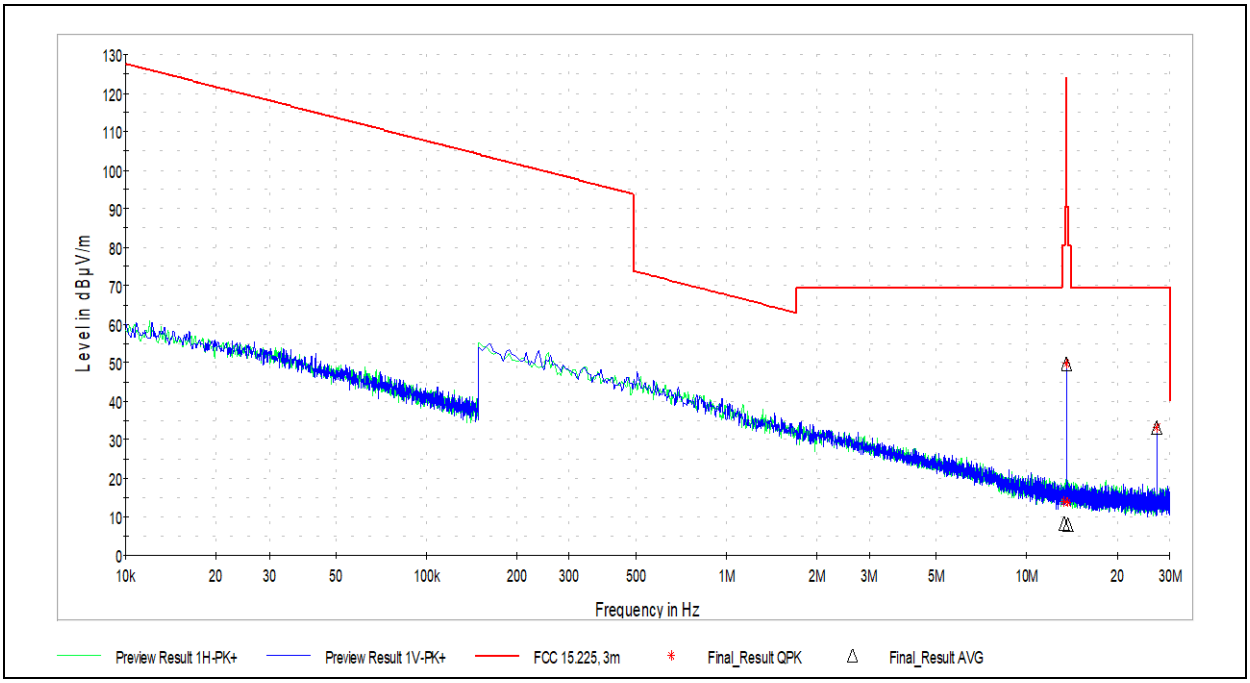
## 7.7 Setup Photographs: 10kHz – 30MHz



## 7.8 Setup Photographs: 30MHz – 1GHz



## 7.9 Test Data: 10kHz – 30MHz



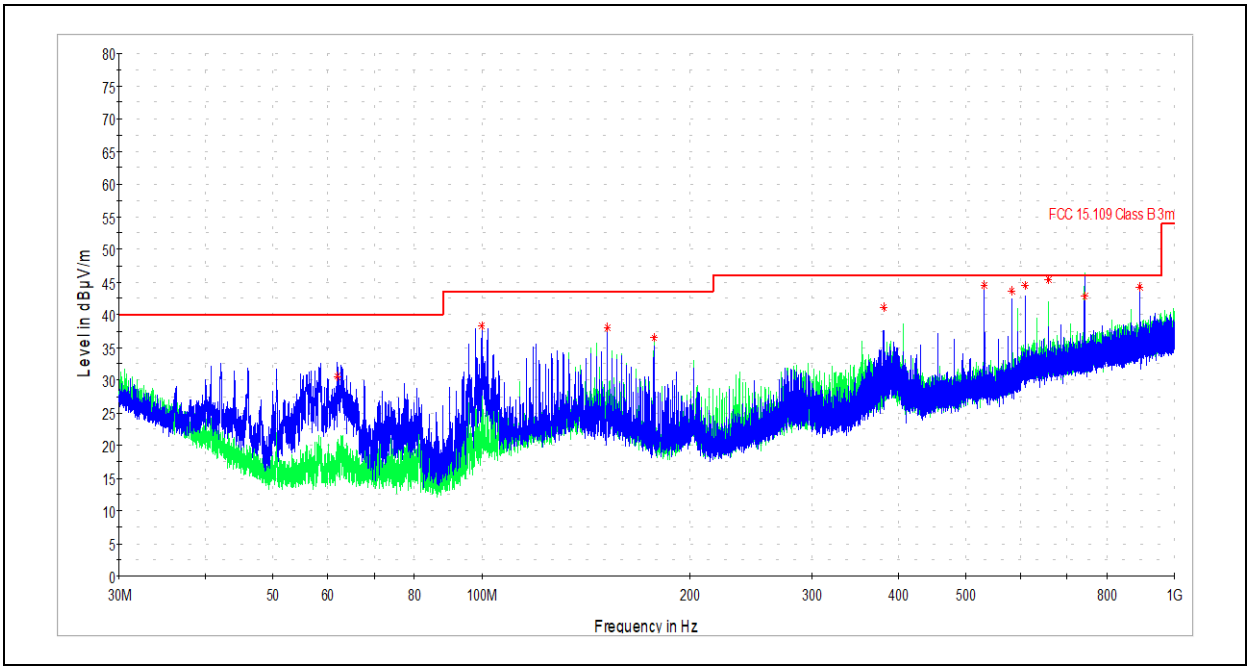

| Frequency (MHz) | QuasiPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Bandwidth (kHz) | Azimuth (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|
| 0.632868 | 39.93 | 71.58 | 31.65 | 9.000 | 22.0 | 12.6 |
| 13.354235 | 42.17 | 80.50 | 38.33 | 9.000 | 92.0 | 11.5 |
| 13.437640 | 49.46 | 90.50 | 41.04 | 9.000 | 177.0 | 11.5 |
| 13.551772 | 67.91 | 90.50 | 22.59 | 9.000 | 0.0 | 11.5 |
| 13.560552 | 86.33 | 124.00 | 37.67 | 9.000 | 0.0 | 11.5 |
| 13.569331 | 59.27 | 90.50 | 31.23 | 9.000 | 0.0 | 11.5 |
| 13.626397 | 45.51 | 90.50 | 44.99 | 9.000 | 92.0 | 11.5 |
| 13.771257 | 54.10 | 80.50 | 26.40 | 9.000 | 174.0 | 11.5 |
| 24.003662 | 28.61 | 69.50 | 40.89 | 9.000 | 24.0 | 10.3 |
| 26.000978 | 25.79 | 69.50 | 43.71 | 9.000 | 42.0 | 9.9 |
| 27.159860 | 19.93 | 69.50 | 49.57 | 9.000 | 24.0 | 9.7 |

| Frequency (MHz) | Average (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Bandwidth (kHz) | Azimuth (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|
| 0.632868 | 34.17 | 71.58 | 37.41 | 9.000 | 22.0 | 12.6 |
| 13.354235 | 15.98 | 80.50 | 64.52 | 9.000 | 92.0 | 11.5 |
| 13.437640 | 22.61 | 90.50 | 67.89 | 9.000 | 177.0 | 11.5 |
| 13.551772 | 67.88 | 90.50 | 22.62 | 9.000 | 0.0 | 11.5 |
| 13.560552 | 86.29 | 124.00 | 37.71 | 9.000 | 0.0 | 11.5 |
| 13.569331 | 59.17 | 90.50 | 31.33 | 9.000 | 0.0 | 11.5 |
| 13.626397 | 20.29 | 90.50 | 70.21 | 9.000 | 92.0 | 11.5 |
| 13.771257 | 21.95 | 80.50 | 58.55 | 9.000 | 174.0 | 11.5 |
| 24.003662 | 26.93 | 69.50 | 42.57 | 9.000 | 24.0 | 10.3 |
| 26.000978 | 22.46 | 69.50 | 47.04 | 9.000 | 42.0 | 9.9 |
| 27.159860 | 14.58 | 69.50 | 54.92 | 9.000 | 24.0 | 9.7 |

| | | | |
|---|---|---|---|
| Test Personnel: | Brian Lackey | Test Date: | 12/27/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | See Above |
| Product Standard: | FCC Part 15.255 RSS-210 Issue 9 | Ambient Temperature: | 21.7C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 22.6% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 985.4mbar |

Deviations, Additions, or Exclusions: Limits were adjusted for testing at 3m by 40dB/decade per FCC Part 15.31(f)(2). The field strength of the fundamental and all spurious emisisons was below the limits in FCC Part 15.209.

## 7.10 Test Data: 30MHz – 1GHz




| Frequency (MHz) | QuasiPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 61.983000 | 30.62 | 40.00 | 9.38 | 120.000 | 100.0 | V | 92.0 | 14.7 |
| 100.000000 | 38.30 | 43.52 | 5.22 | 120.000 | 100.2 | V | 18.0 | 18.9 |
| 151.980000 | 37.96 | 43.52 | 5.56 | 120.000 | 100.0 | V | 0.0 | 21.2 |
| 177.320000 | 36.54 | 43.52 | 6.98 | 120.000 | 156.3 | H | 92.0 | 19.9 |
| 380.020000 | 41.15 | 46.02 | 4.87 | 120.000 | 129.7 | V | 264.0 | 24.9 |
| 532.010000 | 44.51 | 46.02 | 1.51 | 120.000 | 100.0 | V | 0.0 | 28.2 |
| 582.650000 | 43.66 | 46.02 | 2.36 | 120.000 | 100.1 | V | 108.0 | 29.0 |
| 608.000000 | 44.55 | 46.02 | 1.47 | 120.000 | 100.0 | V | 91.0 | 29.5 |
| 658.670000 | 45.38 | 46.02 | 0.64 | 120.000 | 106.8 | H | 184.0 | 30.9 |
| 741.800000 | 42.80 | 46.02 | 3.22 | 120.000 | 129.3 | H | 8.0 | 31.8 |
| 890.100000 | 44.27 | 46.02 | 1.75 | 120.000 | 212.4 | V | 8.0 | 33.5 |

| | | | |
|---|---|---|---|
| Test Personnel: | Ben Coolbear | Test Date: | 12/27/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | See Above |
| Product Standard: | FCC Part 15.255 RSS-210 Issue 9 | Ambient Temperature: | 21.7C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 22.6% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 985.4mbar |

Deviations, Additions, or Exclusions: None

# 8 Frequency Stability

## 8.1 Test Limits

**FCC Part 15.225:**

(e) The frequency tolerance of the carrier signal shall be maintained within ±0.01% of the operating frequency over a temperature variation of −20 degrees to + 50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. For battery operated equipment, the equipment tests shall be performed using a new battery.

**RSS-210 Issue 9 § B.6:**

Carrier frequency stability shall be maintained to ±0.01% (±100 ppm).

## 8.2 Test Method

Tests are performed in accordance with ANSI C63.10:2013.

## 8.3 Test Equipment Used

| Description | Asset | Manufacturer | Model | Cal Date | Cal Due |
|---|---|---|---|---|---|
| Spectrum Analyzer | 3099 | Rohde & Schwarz | FSP7 | 9/20/2018 | 9/20/2019 |

## 8.4 Test Results

The sample tested was found to be **compliant**.

## 8.5 Test Conditions

| | | | |
|---|---|---|---|
| Test Personnel: | Brian Lackey | Test Date: | 12/5/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | See Above |
| Product Standard: | FCC Part 15.255 RSS-210 Issue 9 | Ambient Temperature: | 21.7C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 37.1% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 985.4mbar |

## 8.6 Test Data

| Temperature (C) | Supply Voltage (V) | Frequency (MHz) | Deviation (Hz) | Deviation (%) | Limit (%) | Result |
|---|---|---|---|---|---|---|
| -30 | 120 | 13,559,812 | -188 | -0.0014 | ±0.01 | Pass |
| -20 | 120 | 13,559,789 | -211 | -0.0016 | ±0.01 | Pass |
| -10 | 120 | 13,559,790 | -210 | -0.0015 | ±0.01 | Pass |
| 0 | 120 | 13,559,792 | -208 | -0.0015 | ±0.01 | Pass |
| 10 | 120 | 13,559,794 | -206 | -0.0015 | ±0.01 | Pass |
| 20 | 120 | 13,559,760 | -240 | -0.0018 | ±0.01 | Pass |
| 30 | 120 | 13,559,763 | -237 | -0.0017 | ±0.01 | Pass |
| 40 | 120 | 13,559,772 | -228 | -0.0017 | ±0.01 | Pass |
| 50 | 120 | 13,559,771 | -229 | -0.0017 | ±0.01 | Pass |
| 20 | 138 | 13,559,768 | -232 | -0.0017 | ±0.01 | Pass |
| 20 | 102 | 13,559,771 | -229 | -0.0017 | ±0.01 | Pass |

Deviations, Additions, or Exclusions: None

# 9 Occupied Bandwidth

## 9.1 Test Method

Tests are performed in accordance with ANSI C63.10:2013.

## 9.2 Test Equipment Used

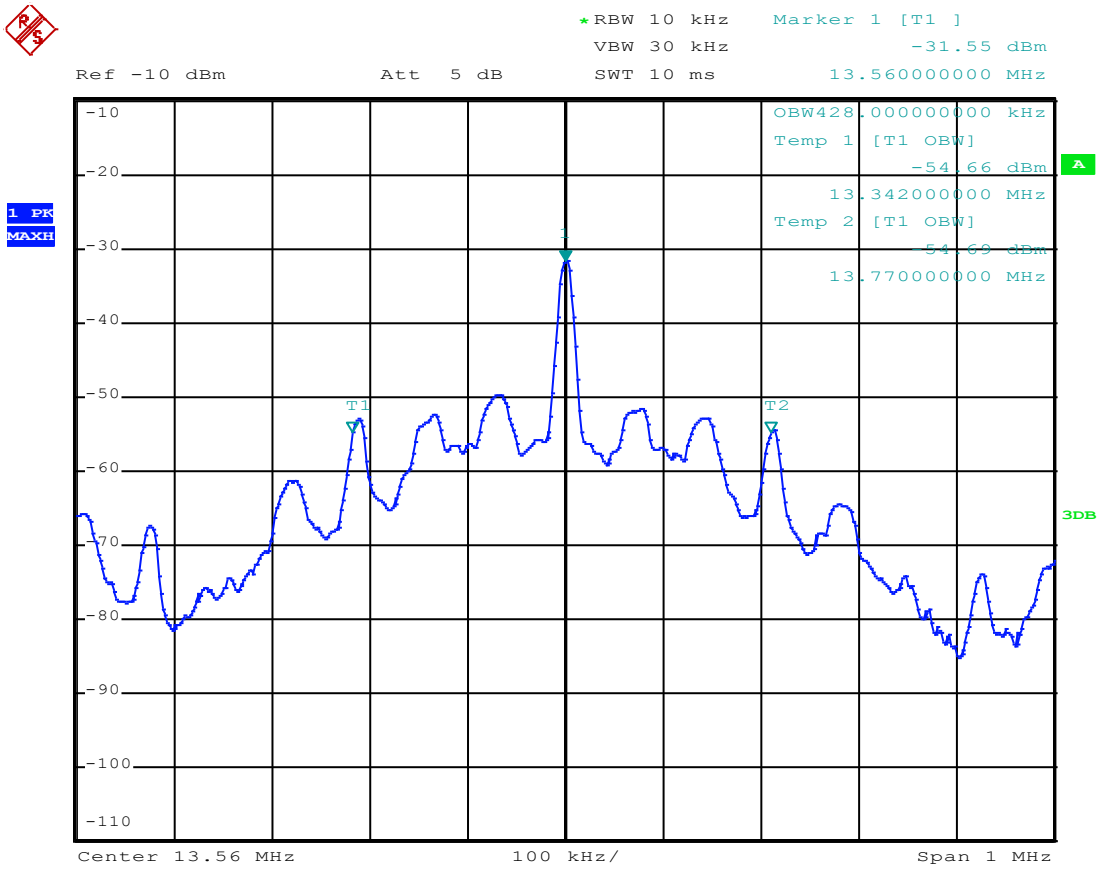
| Description | Asset | Manufacturer | Model | Cal Date | Cal Due |
|---|---|---|---|---|---|
| Spectrum Analyzer | 3099 | Rohde & Schwarz | FSP7 | 9/20/2018 | 9/20/2019 |

## 9.3 Test Conditions

| | | | |
|---|---|---|---|
| Test Personnel: | Brian Lackey | Test Date: | 12/4/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | See Above |
| Product Standard: | FCC Part 15.255 RSS-210 Issue 9 | Ambient Temperature: | 21.5C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 37.9% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 985.4mbar |

## 9.4 Test Data

| RBW | VBW | 99% BW |
|---|---|---|
| 10 kHz | 30 kHz | 428 kHz |




Date: 4.DEC.2018 09:59:52

**99% Occupied Bandwidth**

Deviations, Additions, or Exclusions: None

# 10 Conducted Emissions

## 10.1 Method

Tests are performed in accordance with ANSI C63.4:2014.

**TEST SITE:** Ground Plane

**Site Designation:** Ground Plane

**Measurement Uncertainty**

| Measurement | Frequency Range | Expanded Uncertainty (k=2) | Ucispr |
|---|---|---|---|
| AC Line Conducted Emissions | 150 kHz - 30 MHz | 3.1dB | 3.4dB |
| Telco Port Emissions | 150 kHz - 30 MHz | 3.2dB | 5.0dB |

As shown in the table above our conducted emissions $U_{lab}$ is less than the corresponding $U_{CISPR}$ reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required.

## 10.2 Sample Calculations

The following is how net line-conducted readings were determined:

NF = RF + LF + CF + AF
Where NF = Net Reading in dBμV
RF = Reading from receiver in dBμV
LF = LISN or ISN Correction Factor in dB
CF = Cable Correction Factor in dB
AF = Attenuator Loss Factor in dB

To convert from dBμV to μV or mV the following was used:

$UF = 10^{(NF / 20)}$ where UF = Net Reading in μV
NF = Net Reading in dBμV

**Example:**

NF = RF + LF + CF + AF = 28.5 + 0.2 + 0.4 + 20.0 = 49.1 dBμV
$UF = 10^{(49.1\ dB\mu V / 20)}$ = 285.1 μV/m

### 10.3 Test Equipment Used:

| Description | Asset | Manufacturer | Model | Cal Date | Cal Due |
|---|---|---|---|---|---|
| EMI Test Receiver | 2327 | Rohde & Schwarz | ESI26 | 9/21/2018 | 9/21/2019 |
| LISN | 2509 | Fischer Custom Communication | FCC-LISN-50-50-2M | 4/10/2018 | 4/10/2019 |
| Coaxial Cable (COND 2) | 5025 | | | 11/26/2018 | 11/26/2019 |

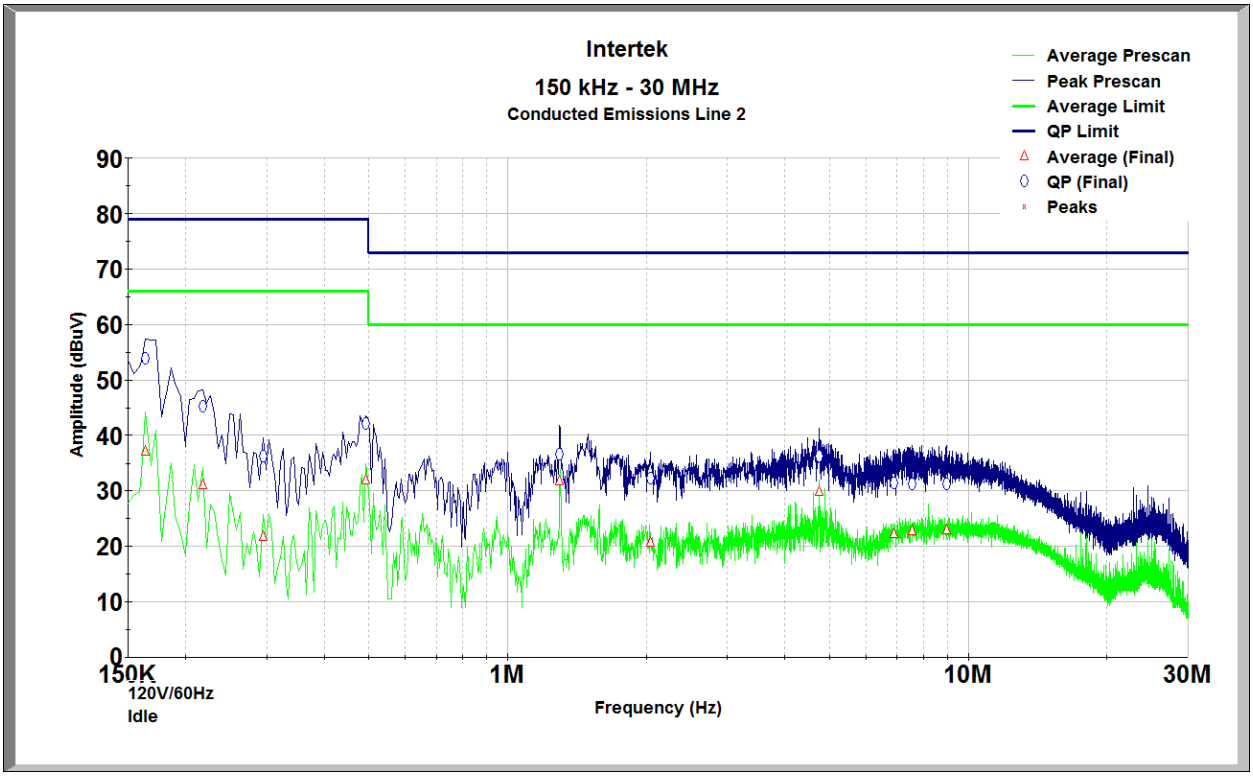
### 10.4 Software Utilized:

| Name | Manufacturer | Version |
|---|---|---|
| TILE | ETS Lindgren | V7.0.6.545 |

### 10.5 Results:

The sample tested was found to Comply.

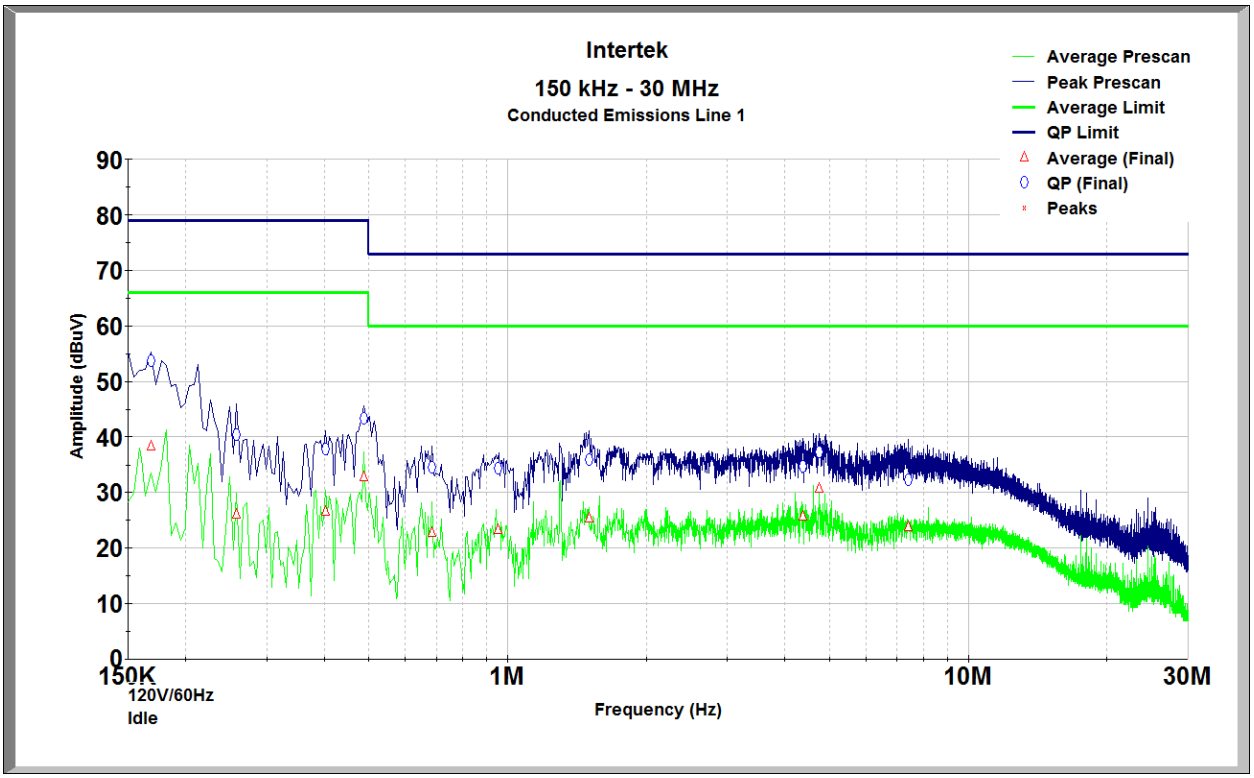
## 10.6 Plots/Data: Conducted Emissions (Idle)




Line

| Frequency (MHz) | Quasi-Peak (dBuV) | Quasi-Peak Limit (dBuV) | Quasi-Peak Margin (dB) | Average (dBuV) | Average Limit (dBuV) | Average Margin (dB) |
|---|---|---|---|---|---|---|
| 0.168 | 53.801 | 79.000 | 25.199 | 38.307 | 66.000 | 27.693 |
| 0.258 | 40.414 | 79.000 | 38.586 | 25.980 | 66.000 | 40.020 |
| 0.402 | 37.882 | 79.000 | 41.118 | 26.591 | 66.000 | 39.409 |
| 0.487 | 43.331 | 79.000 | 35.669 | 32.729 | 66.000 | 33.271 |
| 0.686 | 34.582 | 73.000 | 38.418 | 22.864 | 60.000 | 37.136 |
| 0.956 | 34.284 | 73.000 | 38.716 | 23.360 | 60.000 | 36.640 |
| 1.504 | 35.997 | 73.000 | 37.003 | 25.419 | 60.000 | 34.581 |
| 4.371 | 34.663 | 73.000 | 38.337 | 25.736 | 60.000 | 34.264 |
| 4.749 | 37.343 | 73.000 | 35.657 | 30.638 | 60.000 | 29.362 |
| 7.395 | 32.346 | 73.000 | 40.654 | 23.882 | 60.000 | 36.118 |

Line




Neutral

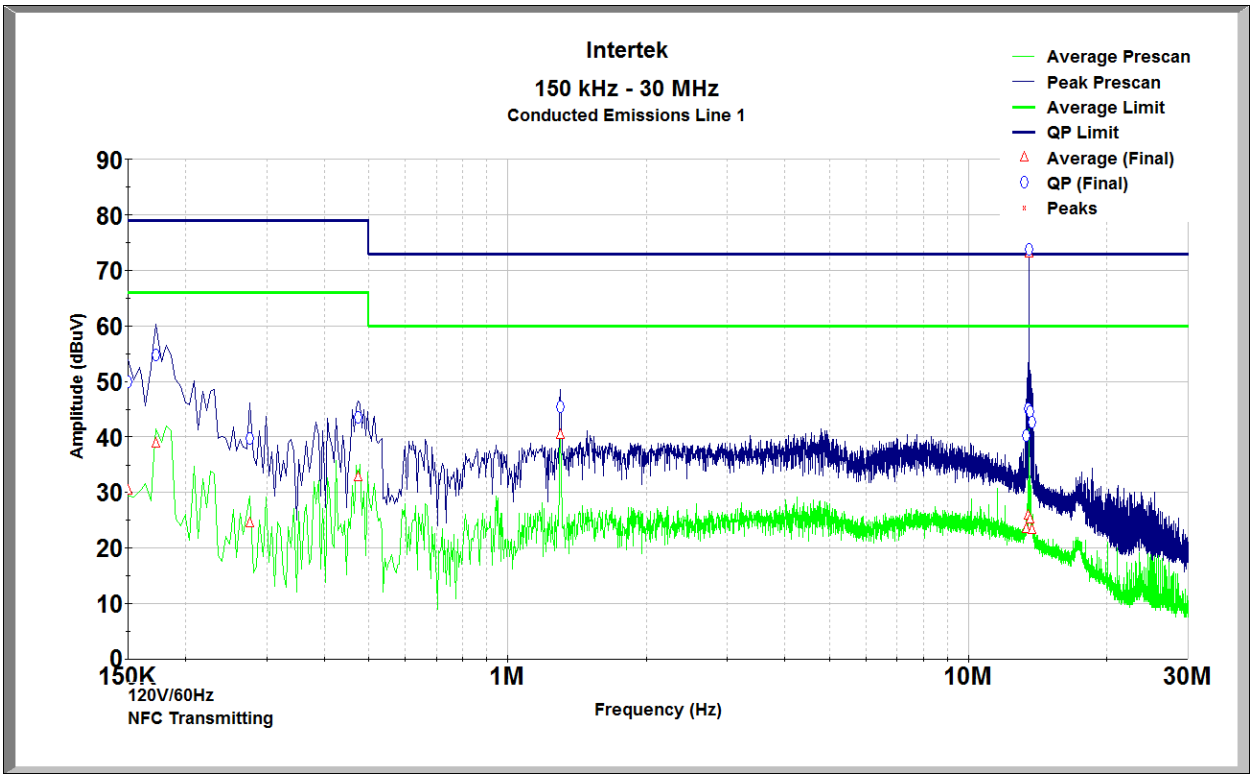
| Frequency (MHz) | Quasi-Peak (dBuV) | Quasi-Peak Limit (dBuV) | Quasi-Peak Margin (dB) | Average (dBuV) | Average Limit (dBuV) | Average Margin (dB) |
|---|---|---|---|---|---|---|
| 0.164 | 53.881 | 79.000 | 25.119 | 37.084 | 66.000 | 28.916 |
| 0.218 | 45.327 | 79.000 | 33.673 | 31.020 | 66.000 | 34.980 |
| 0.294 | 36.234 | 79.000 | 42.766 | 21.703 | 66.000 | 44.297 |
| 0.492 | 42.091 | 79.000 | 36.909 | 31.936 | 66.000 | 34.064 |
| 1.298 | 36.632 | 73.000 | 36.368 | 31.775 | 60.000 | 28.225 |
| 2.040 | 32.324 | 73.000 | 40.676 | 20.686 | 60.000 | 39.314 |
| 4.753 | 36.298 | 73.000 | 36.702 | 29.940 | 60.000 | 30.060 |
| 6.900 | 31.397 | 73.000 | 41.603 | 22.302 | 60.000 | 37.698 |
| 7.543 | 31.316 | 73.000 | 41.684 | 22.766 | 60.000 | 37.234 |
| 8.972 | 31.206 | 73.000 | 41.794 | 23.036 | 60.000 | 36.964 |

Neutral

| | | | |
|---|---|---|---|
| Test Personnel: | Brian Lackey | Test Date: | 12/4/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | Class A |
| Product Standard: | FCC Part 15B ICES-003 Issue 6 | Ambient Temperature: | 21.5C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 37.9% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 985.4mbar |

Deviations, Additions, or Exclusions: None

## 10.7 Plots/Data: Conducted Emissions - NFC Transmitting, Antenna Attached

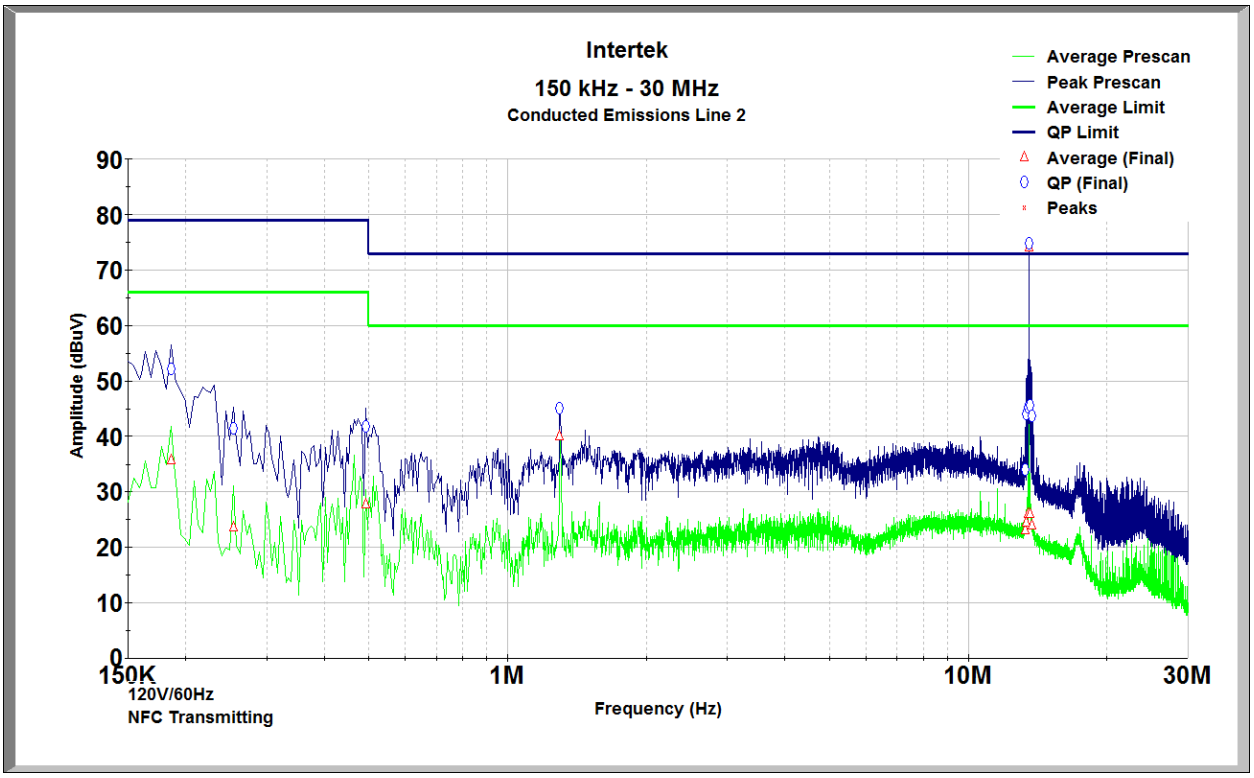



Line

| Frequency (MHz) | Quasi-Peak (dBuV) | Quasi-Peak Limit (dBuV) | Quasi-Peak Margin (dB) | Average (dBuV) | Average Limit (dBuV) | Average Margin (dB) |
|---|---|---|---|---|---|---|
| 0.150 | 49.935 | 66.000 | 16.065 | 30.304 | 56.000 | 25.696 |
| 0.172 | 54.721 | 65.357 | 10.636 | 38.851 | 55.357 | 16.506 |
| 0.276 | 39.761 | 62.400 | 22.639 | 24.572 | 52.400 | 27.828 |
| 0.474 | 43.496 | 56.743 | 13.247 | 32.773 | 46.743 | 13.970 |
| 1.302 | 45.360 | 56.000 | 10.640 | 40.342 | 46.000 | 5.658 |
| 13.355 | 40.147 | 60.000 | 19.853 | 23.508 | 50.000 | 26.492 |
| 13.490 | 45.155 | 60.000 | 14.845 | 25.895 | 50.000 | 24.105 |
| 13.562[1] | 73.755 | 60.000 | -13.755 | 73.055 | 50.000 | -23.055 |
| 13.634 | 44.582 | 60.000 | 15.418 | 25.241 | 50.000 | 24.759 |
| 13.769 | 42.670 | 60.000 | 17.330 | 23.335 | 50.000 | 26.665 |

Line

[1] Fundamental emission of intentional 13.56MHz radio




Neutral

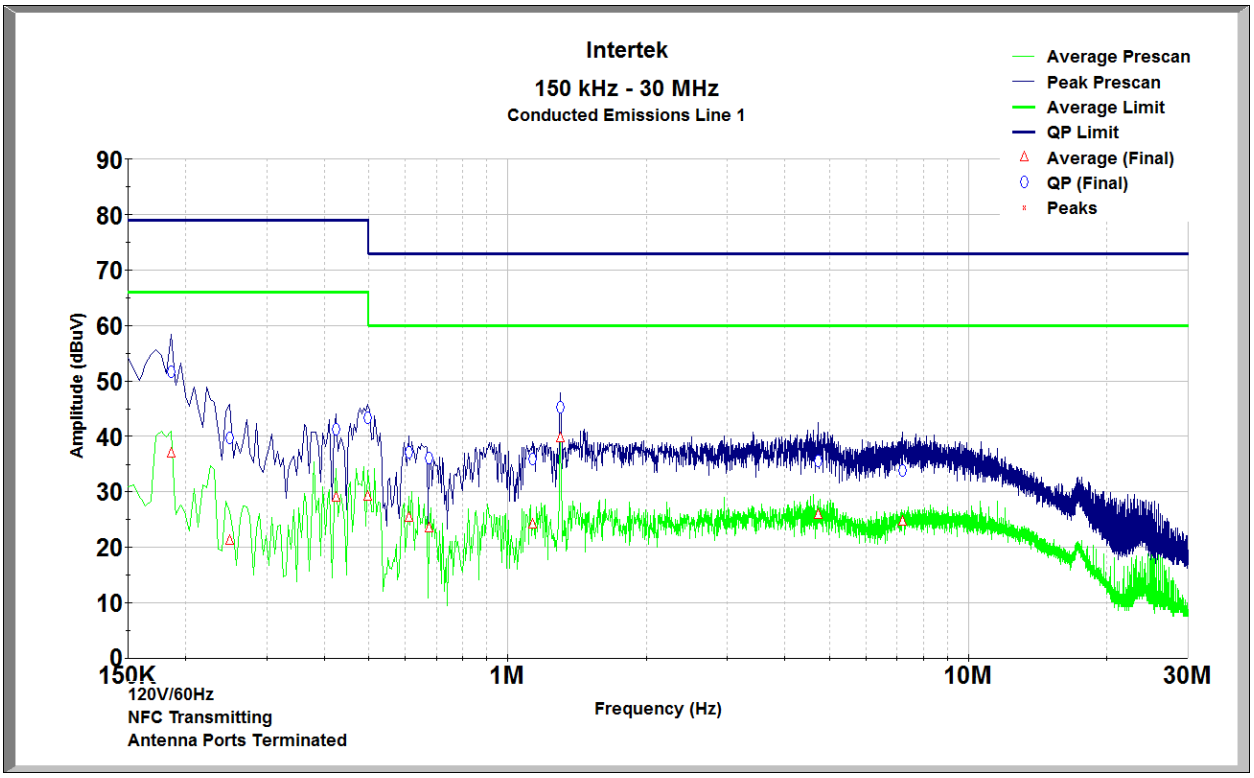
| Frequency (MHz) | Quasi-Peak (dBuV) | Quasi-Peak Limit (dBuV) | Quasi-Peak Margin (dB) | Average (dBuV) | Average Limit (dBuV) | Average Margin (dB) |
|---|---|---|---|---|---|---|
| 0.186 | 52.247 | 64.971 | 12.725 | 35.697 | 54.971 | 19.275 |
| 0.254 | 41.433 | 63.043 | 21.609 | 23.676 | 53.043 | 29.367 |
| 0.492 | 41.799 | 56.229 | 14.430 | 27.770 | 46.229 | 18.458 |
| 1.298 | 45.038 | 56.000 | 10.962 | 40.126 | 46.000 | 5.874 |
| 13.278 | 33.961 | 60.000 | 26.039 | 23.197 | 50.000 | 26.803 |
| 13.345 | 44.025 | 60.000 | 15.975 | 24.561 | 50.000 | 25.439 |
| 13.480 | 45.207 | 60.000 | 14.793 | 26.011 | 50.000 | 23.989 |
| 13.562[1] | 74.823 | 60.000 | -14.823 | 74.165 | 50.000 | -24.165 |
| 13.634 | 45.646 | 60.000 | 14.354 | 26.051 | 50.000 | 23.949 |
| 13.769 | 43.692 | 60.000 | 16.308 | 24.074 | 50.000 | 25.926 |

Neutral

| | | | |
|---|---|---|---|
| Test Personnel: | Brian Lackey | Test Date: | 12/28/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | Class A |
| Product Standard: | FCC Part 15.247 RSS-247 Issue 2 | Ambient Temperature: | 22.3C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 43.9% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 982.0mbar |

Deviations, Additions, or Exclusions: Per FCC Publication Number 174176, the device was tested with its antenna attached, then again with the antenna replaced by a suitable dummy load to determine compliance within the transmitter's fundamental emission band.

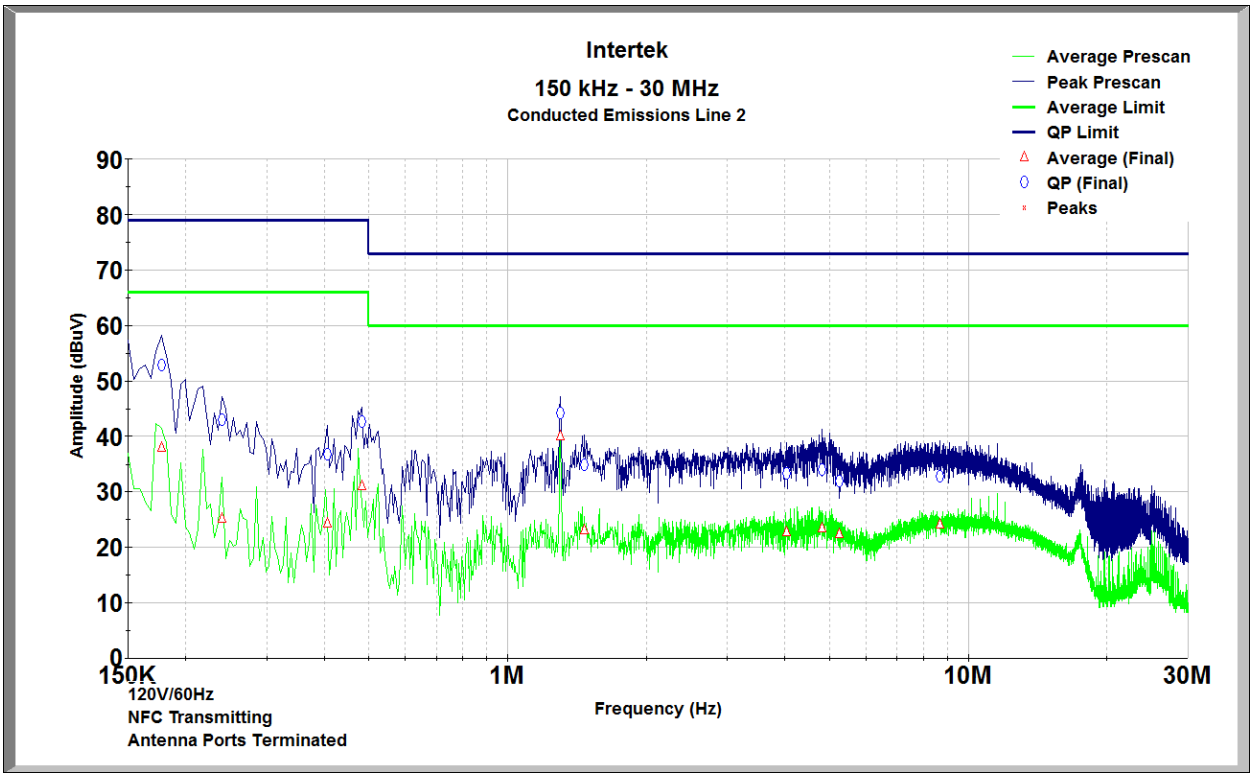
## 10.8 Plots/Data: Conducted Emissions - NFC Transmitting, Antenna Terminated in Matched Load




Line

| Frequency (MHz) | Quasi-Peak (dBuV) | Quasi-Peak Limit (dBuV) | Quasi-Peak Margin (dB) | Average (dBuV) | Average Limit (dBuV) | Average Margin (dB) |
|---|---|---|---|---|---|---|
| 0.186 | 51.624 | 64.971 | 13.347 | 37.006 | 54.971 | 17.965 |
| 0.249 | 39.656 | 63.171 | 23.515 | 21.204 | 53.171 | 31.967 |
| 0.424 | 41.249 | 58.157 | 16.908 | 28.971 | 48.157 | 19.186 |
| 0.497 | 43.300 | 56.100 | 12.800 | 29.193 | 46.100 | 16.907 |
| 0.609 | 37.144 | 56.000 | 18.953 | 25.376 | 46.000 | 20.721 |
| 0.676 | 36.161 | 56.000 | 19.996 | 23.473 | 46.000 | 22.683 |
| 1.131 | 35.995 | 56.000 | 20.566 | 24.134 | 46.000 | 22.427 |
| 1.302 | 45.185 | 56.000 | 11.527 | 39.676 | 46.000 | 7.037 |
| 4.722 | 35.502 | 56.000 | 24.251 | 25.804 | 46.000 | 23.949 |
| 7.206 | 33.867 | 60.000 | 22.486 | 24.650 | 50.000 | 21.703 |

Line




Neutral

| Frequency (MHz) | Quasi-Peak (dBuV) | Quasi-Peak Limit (dBuV) | Quasi-Peak Margin (dB) | Average (dBuV) | Average Limit (dBuV) | Average Margin (dB) |
|---|---|---|---|---|---|---|
| 0.177 | 52.927 | 65.229 | 12.301 | 38.008 | 55.229 | 17.221 |
| 0.240 | 42.993 | 63.429 | 20.435 | 25.122 | 53.429 | 28.306 |
| 0.406 | 36.793 | 58.671 | 21.879 | 24.394 | 48.671 | 24.277 |
| 0.483 | 42.738 | 56.486 | 13.747 | 31.065 | 46.486 | 15.420 |
| 1.302 | 44.288 | 56.000 | 12.425 | 40.009 | 46.000 | 6.704 |
| 1.468 | 34.949 | 56.000 | 21.912 | 23.052 | 46.000 | 23.809 |
| 4.034 | 33.363 | 56.000 | 25.778 | 22.845 | 46.000 | 26.296 |
| 4.816 | 34.092 | 56.000 | 25.745 | 23.439 | 46.000 | 26.398 |
| 5.248 | 31.979 | 60.000 | 24.060 | 22.473 | 50.000 | 23.567 |
| 8.675 | 32.823 | 60.000 | 23.765 | 24.173 | 50.000 | 22.415 |

Neutral

| | | | |
|---|---|---|---|
| Test Personnel: | Brian Lackey | Test Date: | 12/28/2018 |
| Supervising/Reviewing Engineer: (Where Applicable) | NA | Limit Applied: | Class A |
| Product Standard: | FCC Part 15.247 RSS-247 Issue 2 | Ambient Temperature: | 22.3C |
| Input Voltage: | 120V/60Hz | Relative Humidity: | 43.9% |
| Pretest Verification w / Ambient Signals or BB Source: | Yes | Atmospheric Pressure: | 982.0mbar |

Deviations, Additions, or Exclusions: Per FCC Publication Number 174176, the device was tested with its antenna attached, then again with the antenna replaced by a suitable dummy load to determine compliance within the transmitter's fundamental emission band.

# 11 Antenna Requirement

## 11.1 Test Limits

**FCC Part 15.203:**

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of §§15.211, 15.213, 15.217, 15.219, 15.221, or §15.236. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

**RSS-Gen Issue 4 § 8.3:**

The applicant for equipment certification, as per RSP-100, must provide a list of all antenna types that may be used with the licence-exempt transmitter, indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna.

Licence-exempt transmitters that have received equipment certification may operate with different types of antennas. However, it is not permissible to exceed the maximum equivalent isotropically radiated power (e.i.r.p.) limits specified in the applicable standard (RSS) for the licence-exempt apparatus.

Testing shall be performed using the highest gain antenna of each combination of licence-exempt transmitter and antenna type, with the transmitter output power set at the maximum level. When a measurement at the antenna connector is used to determine RF output power, the effective gain of the device's antenna shall be stated, based on a measurement or on data from the antenna manufacturer.

User manuals for transmitters equipped with detachable antennas shall also contain the following notice in a conspicuous location:

*This radio transmitter (identify the device by certification number) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.*

Immediately following the above notice, the manufacturer shall provide a list of all antenna types approved for use with the transmitter, indicating the maximum permissible antenna gain (in dBi).

## 11.2 Test Results

The device was found to be **compliant**. The device has an internal, permanently affixed antenna.

## 12 Revision History

| Revision Level | Date | Report Number | Prepared By | Reviewed By | Notes |
|---|---|---|---|---|---|
| 0 | 1/18/2019 | 103679095LEX-006 | BL | BCT | Original Issue |
| 1 | 1/23/2019 | 103679095LEX-006.1 | BL | BCT | Updated addresses |
| 2 | 9/8/2019 | 103679095LEX-006.2 | BL | BCT | Included a description of updates performed to the product under variant models |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |