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Map Large, Inc. TEST REPORT

SCOPE OF WORK

EMC TESTING – MLBTS-FS1 BLUETOOTH MODULE

REPORT NUMBER

104290762LEX-004

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EMC TEST REPORT

(FULL COMPLIANCE)

Report Number: 104290762LEX-004

Project Number: G104290762

Report Issue Date: 7/7/2020

Model(s) Tested: MLBTS-FS1 Bluetooth Module
MLBTS-FS1

Standards: FCC Part 15B, 15C
(Verification of Spurious Emissions)

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

Client:
Map Large, Inc.
742 Yorkshire Rd NE
Atlanta, GA 30306
USA

Report prepared by



Brian Lackey, Staff Engineer

Report reviewed by



Bryan Taylor, Team Leader

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Table of Contents

1	<i>Introduction and Conclusion.....</i>	4
2	<i>Test Summary</i>	4
3	<i>Client Information</i>	5
4	<i>Description of Equipment under Test and Variant Models.....</i>	6
5	<i>System Setup and Method</i>	7
6	<i>Radiated Emissions</i>	8
7	<i>Conducted Emissions</i>	21
8	<i>Revision History.....</i>	27



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	Radiated Emissions (Transmitter Idle) (ANSI C63.4:2014)	Pass
6	Radiated Spurious Emissions (Transmitter Active) (ANSI C63.10:2013)	Pass
7	Conducted Emissions (ANSI C63.4:2014)	Pass



3 Client Information

This product was tested at the request of the following:

Client Information	
Client Name:	Map Large, Inc.
Address:	742 Yorkshire Rd NE Atlanta, GA 30306 USA
Contact:	Daniel Smith
Email:	Daniel.smith@maplarge.com
Manufacturer Information	
Manufacturer Name:	Map Large, Inc.
Manufacturer Address:	742 Yorkshire Rd NE Atlanta, GA 30306 USA



4 Description of Equipment under Test and Variant Models

Equipment Under Test	
Product Name	MLBTS-FS1 Bluetooth Module
Model Number	MLBTS-FS1
Serial Number	0001
Wireless Modules And Antennas	Espressif ESP32-WROOM-32U(FCCID: 2AC7Z-ESP32WROOM32U) - L-Com model HG2405MGU antenna, 5dBi gain - L-Com model HG2408MGUR-RSP antenna, 8dBi gain
Supported Transmit Bands	Bluetooth, Bluetooth Low Energy (BLE) (2400-2483.5MHz)
Test Channels	Bluetooth: Ch0 (2402MHz), Ch38 (2440MHz), Ch39 (2480MHz) BLE: Ch37 (2402MHz), Ch17 (2440MHz), Ch39 (2480MHz)
Receive Date	4/13/2020
Test Start Date	4/14/2020
Test End Date	7/1/2020
Device Received Condition	Good
Test Sample Type	Production
Software Version	ESP32_RF_TEST_BIN_V1.5.0_20190812.bin
Input Rating	5VDC
Description of Equipment Under Test (provided by client)	
High gain Bluetooth module	

4.1 Variant Models:

There were no variant models covered by this evaluation.



5 System Setup and Method

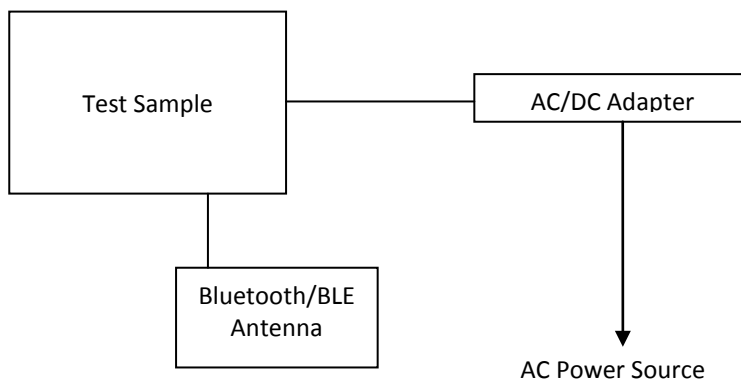
5.1 Method:

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

No.	Descriptions of EUT Exercising
1	The EUT was powered via an AC/DC adapter at 120V/60Hz with radios idle (powered, not transmitting)
2	For Bluetooth/BLE testing, the EUT was powered via an AC/DC adapter at 120V/60Hz. The Bluetooth radio was configured to transmit constantly on a low, middle, and high channel in Bluetooth (1Mbps DH5 PBR9) and BLE modes.

Cables					
ID	Description	Length (m)	Shielding	Ferrites	Termination
1	AC Mains	2	No	No	AC/DC Adapter
2	Bluetooth Antenna Cable	2	Yes	No	Antenna

5.2 EUT Block Diagram:





6 Radiated Emissions

6.1 Method

Tests are performed in accordance with ANSI C63.4:2014 and ANSI C63.10:2013

TEST SITE: 10m ALSE

Site Designation: 10m Chamber

Measurement Uncertainty

Measurement	Frequency Range	Expanded Uncertainty (k=2)	Ucisp
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 dB μ V/m
- RA = Receiver Amplitude (including preamplifier) in dB μ V
- 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 dB μ V 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 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/m
CF = 1.6 dB
AG = 29.0 dB
FS = 32 dB μ V/m

To convert from dB μ V to μ V or mV the following was used:

$$UF = 10^{(NF / 20)} \text{ where } UF = \text{Net Reading in } \mu\text{V}$$

NF = Net Reading in dB μ V

Example:

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

6.3 Field Strength to Power Calculation

As allowable by ANSI C63.26: 2015 section 5.2.7, the output power of unwanted emissions can be calculated from a field strength measurement. The transmitter measurements that follow in this report have applied the following calculation to the -13dBm limit to arrive an equivalent field strength limit at 3 meters as follows:

$E \text{ (dB}\mu\text{V/m)} = \text{EIRP (dBm)} - 20\log(D) + 104.8$; where D is the measurement distance (in the far field region) in m.

Example:

$$\text{Limit (dB}\mu\text{V/m)} = -13 - 20\log(3) + 104.8 = 82.25\text{dB}\mu\text{V/m}$$

**6.4 Test Equipment Used:**

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
EMI Test Receiver	3900	Rohde & Schwarz	ESU40	9/18/2019	9/18/2020
Bilog Antenna (30MHz-1GHz)	7085	SunAR	JB6	8/8/2019	8/8/2020
Horn Antenna	3780	ETS Lindgren	3117	6/18/2020	6/18/2021
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
Coaxial Cable	3074			12/4/2019	12/4/2020
3m Cable Preamplifier	3918	Rohde & Schwarz	TS-PR18	12/4/2019	12/4/2020
Coaxial Cable	2588			12/4/2019	12/4/2020
Coaxial Cable	2593			12/4/2019	12/4/2020
Coaxial Cable	2592			12/4/2019	12/4/2020
Coaxial Cable	3339			12/4/2019	12/4/2020

6.5 Software Utilized:

Name	Manufacturer	Version
EMC32	Rohde & Schwarz	Version 9.15.02

6.6 Results:

The sample tested was found to Comply.

**6.7 L-Com HG2405MGU 5dBi Antenna****6.7.1 Plots/Data: Radiated Emissions, 30MHz – 18GHz (Transmitter Idle)**

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
30.053889	26.43	40.00	13.57	120.000	296.7	H	129.0	28.8
44.496111	15.64	40.00	24.36	120.000	400.0	H	46.0	18.5
116.761111	18.68	43.52	24.84	120.000	104.8	H	54.0	21.7
155.130000	19.44	43.52	24.08	120.000	165.9	H	36.0	21.6
197.810000	20.35	43.52	23.17	120.000	104.6	H	330.0	22.0
341.962778	23.35	46.02	22.67	120.000	266.8	H	0.0	25.3
409.701111	25.10	46.02	20.92	120.000	100.0	H	74.0	27.3
486.870000	27.39	46.02	18.63	120.000	400.0	V	313.0	29.1
690.031111	33.60	46.02	12.42	120.000	237.4	H	118.0	33.8
957.427778	37.50	46.02	8.52	120.000	141.9	H	156.0	37.5

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
2113.000000	38.54	73.98	35.44	1000.000	232.0	V	228.0	2.5
2462.500000	41.95	73.98	32.03	1000.000	410.0	H	336.0	4.0
5748.500000	44.38	73.98	29.60	1000.000	100.0	V	33.0	9.6
8007.500000	45.25	73.98	28.73	1000.000	410.0	V	247.0	12.4
16816.000000	57.71	73.98	16.27	1000.000	100.0	V	338.0	26.1

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
2113.000000	24.42	53.98	29.56	1000.000	232.0	V	228.0	2.5
2462.500000	25.20	53.98	28.78	1000.000	410.0	H	336.0	4.0
5748.500000	29.46	53.98	24.52	1000.000	100.0	V	33.0	9.6
8007.500000	32.02	53.98	21.96	1000.000	410.0	V	247.0	12.4
16816.000000	44.14	53.98	9.84	1000.000	100.0	V	338.0	26.1

Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: NA
(Where Applicable)
Product Standard: FCC Part 15B
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient
Signals or BB Source: Yes

Test Date: 7/1/2020
Limit Applied: Class B
Ambient Temperature: 23.8C
Relative Humidity: 54.8%
Atmospheric Pressure: 981.5mbar

Deviations, Additions, or Exclusions: None

**6.7.2 Radiated Spurious Emissions (Bluetooth)**

Channel 0

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1355.000000	34.94	73.98	39.04	1000.000	100.0	H	0.0	-0.6
4832.500000	42.37	73.98	31.61	1000.000	100.0	H	359.0	8.3
8233.500000	45.34	73.98	28.64	1000.000	100.0	V	0.0	12.5
16096.500000	56.51	73.98	17.47	1000.000	117.0	H	160.0	25.6

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1355.000000	21.26	53.98	32.72	1000.000	100.0	H	0.0	-0.6
4832.500000	29.48	53.98	24.50	1000.000	100.0	H	359.0	8.3
8233.500000	31.41	53.98	22.57	1000.000	100.0	V	0.0	12.5
16096.500000	43.25	53.98	10.73	1000.000	117.0	H	160.0	25.6

Channel 38

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
37.652222	20.47	40.00	19.53	120.000	106.5	H	102.0	23.2
134.436667	19.43	43.52	24.09	120.000	276.6	V	72.0	22.3
334.580000	22.62	46.02	23.40	120.000	228.9	V	108.0	24.6
409.485556	25.04	46.02	20.98	120.000	284.6	H	18.0	27.3
608.928333	31.65	46.02	14.37	120.000	344.3	V	102.0	31.7
999.245556	38.37	53.98	15.61	120.000	272.7	H	250.0	38.2

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1300.000000	34.32	73.98	39.66	1000.000	174.0	V	265.0	-0.5
2267.000000	37.32	73.98	36.66	1000.000	100.0	V	0.0	3.2
4810.500000	42.49	73.98	31.49	1000.000	100.0	H	211.0	8.2
16089.000000	55.99	73.98	17.99	1000.000	224.0	H	112.0	25.4
18851.500000	55.75	73.98	18.23	1000.000	177.0	H	200.0	18.3
22695.000000	54.12	73.98	19.86	1000.000	389.0	V	0.0	6.8
23861.000000	53.50	73.98	20.48	1000.000	410.0	V	313.0	6.1

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1300.000000	21.14	53.98	32.84	1000.000	174.0	V	265.0	-0.5
2267.000000	23.99	53.98	29.99	1000.000	100.0	V	0.0	3.2
4810.500000	29.06	53.98	24.92	1000.000	100.0	H	211.0	8.2
16089.000000	43.05	53.98	10.93	1000.000	224.0	H	112.0	25.4
18851.500000	42.28	53.98	11.70	1000.000	177.0	H	200.0	18.3
22695.000000	40.77	53.98	13.21	1000.000	389.0	V	0.0	6.8
23861.000000	39.78	53.98	14.20	1000.000	410.0	V	313.0	6.1



Channel 78

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1359.000000	34.54	73.98	39.44	1000.000	117.0	V	294.0	-0.5
3266.500000	40.42	73.98	33.56	1000.000	100.0	H	88.0	5.5
3994.500000	40.97	73.98	33.01	1000.000	100.0	H	284.0	7.1
12189.500000	50.49	73.98	23.49	1000.000	100.0	V	218.0	18.5
16090.500000	56.86	73.98	17.12	1000.000	100.0	H	153.0	25.5

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1359.000000	21.32	53.98	32.66	1000.000	117.0	V	294.0	-0.5
3266.500000	25.21	53.98	28.77	1000.000	100.0	H	88.0	5.5
3994.500000	27.79	53.98	26.19	1000.000	100.0	H	284.0	7.1
12189.500000	37.08	53.98	16.90	1000.000	100.0	V	218.0	18.5
16090.500000	43.11	53.98	10.87	1000.000	100.0	H	153.0	25.5

Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: _____
(Where Applicable) NA
Product Standard: FCC Part 15.247
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient
Signals or BB Source: Yes

Test Date: 6/30/2020-7/1/2020
Limit Applied: FCC Part 15.209 in restricted bands
Ambient Temperature: 23.8C
Relative Humidity: 54.8%
Atmospheric Pressure: 981.5mbar

Deviations, Additions, or Exclusions: None

**6.7.3 Radiated Spurious Emissions (Bluetooth Low Energy)**

Channel 37

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1380.500000	34.84	73.98	39.14	1000.000	410.0	H	0.0	-0.6
4804.000000	42.55	73.98	31.43	1000.000	100.0	H	320.0	8.2
12214.500000	50.54	73.98	23.44	1000.000	410.0	H	0.0	18.5
16098.000000	56.84	73.98	17.14	1000.000	410.0	H	232.0	25.6

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1380.500000	21.32	53.98	32.66	1000.000	410.0	H	0.0	-0.6
4804.000000	29.01	53.98	24.97	1000.000	100.0	H	320.0	8.2
12214.500000	37.14	53.98	16.84	1000.000	410.0	H	0.0	18.5
16098.000000	43.24	53.98	10.74	1000.000	410.0	H	232.0	25.6

Channel 17

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
37.706111	20.38	40.00	19.62	120.000	166.2	H	117.0	23.2
162.135556	19.50	43.52	24.02	120.000	104.9	H	311.0	21.7
332.047222	23.05	46.02	22.97	120.000	272.7	H	187.0	25.0
407.653333	24.99	46.02	21.03	120.000	181.1	H	242.0	27.2
608.982222	32.26	46.02	13.76	120.000	100.2	H	118.0	32.3
992.778889	38.17	53.98	15.81	120.000	142.1	H	80.0	38.0

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1164.000000	34.85	73.98	39.13	1000.000	410.0	V	306.0	-1.7
4880.000000	42.84	73.98	31.14	1000.000	100.0	H	324.0	8.3
16101.500000	56.31	73.98	17.67	1000.000	325.0	V	62.0	25.6
18418.000000	56.42	73.98	17.56	1000.000	100.0	V	229.0	19.7
22844.000000	54.18	73.98	19.80	1000.000	100.0	V	77.0	6.3
23894.500000	53.40	73.98	20.58	1000.000	410.0	H	336.0	5.9

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1164.000000	20.69	53.98	33.29	1000.000	410.0	V	306.0	-1.7
4880.000000	29.21	53.98	24.77	1000.000	100.0	H	324.0	8.3
16101.500000	43.15	53.98	10.83	1000.000	325.0	V	62.0	25.6
18418.000000	42.86	53.98	11.12	1000.000	100.0	V	229.0	19.7
22844.000000	40.54	53.98	13.44	1000.000	100.0	V	77.0	6.3
23894.500000	39.79	53.98	14.19	1000.000	410.0	H	336.0	5.9



Channel 39

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1198.500000	49.85	73.98	24.13	1000.000	172.0	V	294.0	-1.4
1595.000000	43.74	73.98	30.24	1000.000	100.0	V	122.0	-1.3
2215.000000	38.66	73.98	35.32	1000.000	410.0	H	60.0	3.3
4828.500000	42.34	73.98	31.64	1000.000	100.0	H	336.0	8.2
7407.500000	44.53	73.98	29.45	1000.000	410.0	H	328.0	11.7
16114.500000	56.14	73.98	17.84	1000.000	410.0	H	13.0	25.3
17769.500000	58.87	73.98	15.11	1000.000	410.0	H	327.0	26.5

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1198.500000	21.23	53.98	32.75	1000.000	172.0	V	294.0	-1.4
1595.000000	20.57	53.98	33.41	1000.000	100.0	V	122.0	-1.3
2215.000000	24.39	53.98	29.59	1000.000	410.0	H	60.0	3.3
4828.500000	29.15	53.98	24.83	1000.000	100.0	H	336.0	8.2
7407.500000	31.02	53.98	22.96	1000.000	410.0	H	328.0	11.7
16114.500000	42.86	53.98	11.12	1000.000	410.0	H	13.0	25.3
17769.500000	44.76	53.98	9.22	1000.000	410.0	H	327.0	26.5

Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: _____
(Where Applicable) NA
Product Standard: FCC Part 15.247
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient
Signals or BB Source: Yes

Test Date: 6/30/2020-7/1/2020
Limit Applied: FCC Part 15.209 in restricted bands
Ambient Temperature: 23.8C
Relative Humidity: 54.8%
Atmospheric Pressure: 981.5mbar

Deviations, Additions, or Exclusions: None

**6.8 L-Com HG2408MGUR-RSP 8dBi Antenna****6.8.1 Plots/Data: Radiated Emissions, 30MHz – 18GHz (Transmitter Idle)**

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
30.107778	26.42	40.00	13.58	120.000	100.3	H	271.0	28.7
35.712222	21.92	40.00	18.08	120.000	300.2	H	118.0	24.7
42.663889	16.78	40.00	23.22	120.000	309.1	H	72.0	19.7
117.569445	18.94	43.52	24.58	120.000	106.9	V	0.0	21.9
125.760556	19.24	43.52	24.28	120.000	100.6	H	91.0	22.0
164.560556	19.40	43.52	24.12	120.000	214.3	V	0.0	21.7
201.743889	20.54	43.52	22.98	120.000	104.9	H	192.0	22.2
202.929445	20.54	43.52	22.98	120.000	105.3	V	320.0	22.2
347.782778	23.53	46.02	22.49	120.000	299.5	H	313.0	25.5
487.732222	27.74	46.02	18.28	120.000	141.6	H	247.0	29.4
669.391667	33.43	46.02	12.59	120.000	332.0	H	64.0	33.5
780.672222	34.82	46.02	11.20	120.000	332.5	V	7.0	34.9
938.081667	37.31	46.02	8.71	120.000	162.2	H	184.0	37.4
951.230556	37.42	46.02	8.60	120.000	142.1	H	144.0	37.4

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1304.500000	34.38	73.98	39.60	1000.000	108.0	V	324.0	-0.5
2172.000000	37.95	73.98	36.03	1000.000	185.0	V	162.0	2.9
2464.000000	48.36	73.98	25.62	1000.000	100.0	V	0.0	3.9
5749.000000	44.52	73.98	29.46	1000.000	100.0	V	308.0	9.6
9956.500000	46.92	73.98	27.06	1000.000	410.0	V	0.0	15.1
17698.500000	59.15	73.98	14.83	1000.000	410.0	H	280.0	26.2

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1304.500000	21.20	53.98	32.78	1000.000	108.0	V	324.0	-0.5
2172.000000	24.42	53.98	29.56	1000.000	185.0	V	162.0	2.9
2464.000000	25.14	53.98	28.84	1000.000	100.0	V	0.0	3.9
5749.000000	29.54	53.98	24.44	1000.000	100.0	V	308.0	9.6
9956.500000	33.82	53.98	20.16	1000.000	410.0	V	0.0	15.1
17698.500000	44.74	53.98	9.24	1000.000	410.0	H	280.0	26.2

Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: NA
(Where Applicable)
Product Standard: FCC Part 15B
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient
Signals or BB Source: Yes

Test Date: 7/1/2020
Limit Applied: Class B
Ambient Temperature: 23.8C
Relative Humidity: 54.8%
Atmospheric Pressure: 981.5mbar

Deviations, Additions, or Exclusions: None

**6.8.2 Radiated Spurious Emissions (Bluetooth)**

Channel 0

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1196.500000	39.67	73.98	34.31	1000.000	261.0	H	316.0	-1.7
1596.000000	47.45	73.98	26.53	1000.000	260.0	V	165.0	-1.3
2233.500000	38.03	73.98	35.95	1000.000	153.0	V	337.0	3.0
4982.500000	42.15	73.98	31.83	1000.000	100.0	V	-1.0	8.2
16103.000000	56.47	73.98	17.51	1000.000	297.0	H	287.0	25.6
17720.500000	58.09	73.98	15.89	1000.000	332.0	H	324.0	26.3

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1196.500000	20.79	53.98	33.19	1000.000	261.0	H	316.0	-1.7
1596.000000	20.52	53.98	33.46	1000.000	260.0	V	165.0	-1.3
2233.500000	23.99	53.98	29.99	1000.000	153.0	V	337.0	3.0
4982.500000	29.26	53.98	24.72	1000.000	100.0	V	-1.0	8.2
16103.000000	43.14	53.98	10.84	1000.000	297.0	H	287.0	25.6
17720.500000	44.92	53.98	9.06	1000.000	332.0	H	324.0	26.3

Channel 38

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
38.029445	20.15	40.00	19.85	120.000	355.9	H	212.0	22.9
119.994445	23.86	43.52	19.66	120.000	100.0	V	295.0	22.0
329.083333	22.49	46.02	23.53	120.000	249.3	V	10.0	24.5
407.491667	24.65	46.02	21.37	120.000	237.7	V	156.0	26.9
612.592778	32.34	46.02	13.68	120.000	320.2	H	0.0	32.3
965.026111	37.65	53.98	16.33	120.000	249.0	H	82.0	37.6

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1086.500000	36.70	73.98	37.28	1000.000	357.0	V	135.0	-2.9
1596.000000	43.47	73.98	30.51	1000.000	286.0	H	114.0	-1.2
2206.500000	38.11	73.98	35.87	1000.000	410.0	V	0.0	3.0
2790.500000	38.88	73.98	35.10	1000.000	100.0	V	0.0	4.5
4757.000000	42.01	73.98	31.97	1000.000	100.0	V	0.0	8.0
16100.000000	56.37	73.98	17.61	1000.000	410.0	H	138.0	25.7
20858.500000	54.43	73.98	19.55	1000.000	365.0	H	165.0	11.4
22856.500000	53.95	73.98	20.03	1000.000	100.0	V	306.0	6.4
31519.500000	55.59	73.98	18.39	1000.000	320.0	H	49.0	11.1
36473.000000	56.66	73.98	17.32	1000.000	117.0	V	35.0	11.2



Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1086.500000	19.12	53.98	34.86	1000.000	357.0	V	135.0	-2.9
1596.000000	20.95	53.98	33.03	1000.000	286.0	H	114.0	-1.2
2206.500000	24.20	53.98	29.78	1000.000	410.0	V	0.0	3.0
2790.500000	24.99	53.98	28.99	1000.000	100.0	V	0.0	4.5
4757.000000	28.80	53.98	25.18	1000.000	100.0	V	0.0	8.0
16100.000000	43.25	53.98	10.73	1000.000	410.0	H	138.0	25.7
20858.500000	41.27	53.98	12.71	1000.000	365.0	H	165.0	11.4
22856.500000	40.74	53.98	13.24	1000.000	100.0	V	306.0	6.4
31519.500000	42.65	53.98	11.33	1000.000	320.0	H	49.0	11.1
36473.000000	42.45	53.98	11.53	1000.000	117.0	V	35.0	11.2

Channel 78

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1084.000000	38.31	73.98	35.67	1000.000	285.0	V	336.0	-3.0
1598.500000	44.49	73.98	29.49	1000.000	303.0	V	321.0	-1.3
2201.500000	40.85	73.98	33.13	1000.000	100.0	V	232.0	2.9
4793.000000	46.84	73.98	27.14	1000.000	100.0	V	0.0	8.1
12171.000000	50.95	73.98	23.03	1000.000	410.0	H	272.0	18.5
16098.500000	56.62	73.98	17.36	1000.000	410.0	V	70.0	25.6

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1084.000000	19.11	53.98	34.87	1000.000	285.0	V	336.0	-3.0
1598.500000	20.38	53.98	33.60	1000.000	303.0	V	321.0	-1.3
2201.500000	24.12	53.98	29.86	1000.000	100.0	V	232.0	2.9
4793.000000	28.93	53.98	25.05	1000.000	100.0	V	0.0	8.1
12171.000000	37.18	53.98	16.80	1000.000	410.0	H	272.0	18.5
16098.500000	43.19	53.98	10.79	1000.000	410.0	V	70.0	25.6

Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: NA
(Where Applicable)
Product Standard: FCC Part 15.247
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient
Signals or BB Source: Yes

Test Date: 6/30/2020-7/1/2020
Limit Applied: FCC Part 15.209 in restricted bands
Ambient Temperature: 23.8C
Relative Humidity: 54.8%
Atmospheric Pressure: 981.5mbar

Deviations, Additions, or Exclusions: None

**6.8.3 Radiated Spurious Emissions (Bluetooth Low Energy)**

Channel 37

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1206.000000	34.97	73.98	39.01	1000.000	321.0	H	214.0	-1.5
1596.500000	44.36	73.98	29.62	1000.000	249.0	V	0.0	-1.3
2276.000000	37.06	73.98	36.92	1000.000	100.0	H	0.0	3.4
3985.000000	41.53	73.98	32.45	1000.000	100.0	H	146.0	7.1
7690.500000	44.99	73.98	28.99	1000.000	410.0	H	338.0	12.0
12492.000000	51.42	73.98	22.56	1000.000	100.0	H	276.0	19.1
16087.500000	56.21	73.98	17.77	1000.000	394.0	H	260.0	25.4

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1206.000000	20.92	53.98	33.06	1000.000	321.0	H	214.0	-1.5
1596.500000	20.34	53.98	33.64	1000.000	249.0	V	0.0	-1.3
2276.000000	24.13	53.98	29.85	1000.000	100.0	H	0.0	3.4
3985.000000	27.74	53.98	26.24	1000.000	100.0	H	146.0	7.1
7690.500000	31.68	53.98	22.30	1000.000	410.0	H	338.0	12.0
12492.000000	37.53	53.98	16.45	1000.000	100.0	H	276.0	19.1
16087.500000	43.02	53.98	10.96	1000.000	394.0	H	260.0	25.4

Channel 17

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
37.544445	19.63	40.00	20.37	120.000	400.1	V	172.0	22.4
168.494445	19.40	43.52	24.12	120.000	153.6	V	277.0	21.6
325.418889	22.84	46.02	23.18	120.000	273.1	H	136.0	24.8
408.677222	24.73	46.02	21.29	120.000	249.6	V	117.0	26.9
611.838333	32.38	46.02	13.64	120.000	400.0	H	192.0	32.3
990.353889	38.12	53.98	15.86	120.000	275.7	H	254.0	38.0

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1189.500000	43.30	73.98	30.68	1000.000	251.0	V	60.0	-1.5
1598.000000	43.99	73.98	29.99	1000.000	348.0	V	342.0	-1.3
2215.500000	39.52	73.98	34.46	1000.000	232.0	V	145.0	3.1
4982.000000	43.10	73.98	30.88	1000.000	410.0	H	328.0	8.2
12277.000000	50.90	73.98	23.08	1000.000	410.0	V	342.0	18.5
16098.500000	56.16	73.98	17.82	1000.000	410.0	H	304.0	25.6
18840.500000	55.45	73.98	18.53	1000.000	110.0	V	118.0	18.3
22678.000000	53.92	73.98	20.06	1000.000	340.0	V	331.0	6.8
23834.000000	53.92	73.98	20.06	1000.000	100.0	H	146.0	6.2
31485.500000	55.34	73.98	18.64	1000.000	110.0	V	152.0	11.1
36460.500000	55.20	73.98	18.78	1000.000	100.0	V	150.0	11.2



Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1189.500000	21.02	53.98	32.96	1000.000	251.0	V	60.0	-1.5
1598.000000	20.71	53.98	33.27	1000.000	348.0	V	342.0	-1.3
2215.500000	24.03	53.98	29.95	1000.000	232.0	V	145.0	3.1
4982.000000	29.57	53.98	24.41	1000.000	410.0	H	328.0	8.2
12277.000000	37.17	53.98	16.81	1000.000	410.0	V	342.0	18.5
16098.500000	43.23	53.98	10.75	1000.000	410.0	H	304.0	25.6
18840.500000	42.19	53.98	11.79	1000.000	110.0	V	118.0	18.3
22678.000000	40.85	53.98	13.13	1000.000	340.0	V	331.0	6.8
23834.000000	39.78	53.98	14.20	1000.000	100.0	H	146.0	6.2
31485.500000	42.47	53.98	11.51	1000.000	110.0	V	152.0	11.1
36460.500000	42.24	53.98	11.74	1000.000	100.0	V	150.0	11.2

Channel 39

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1143.500000	40.84	73.98	33.14	1000.000	186.0	V	265.0	-2.0
1594.000000	38.60	73.98	35.38	1000.000	373.0	V	139.0	-1.3
2230.500000	37.15	73.98	36.83	1000.000	100.0	V	181.0	3.0
3261.500000	38.20	73.98	35.78	1000.000	410.0	V	305.0	5.2
16098.000000	56.67	73.98	17.31	1000.000	395.0	H	283.0	25.6
17725.500000	58.15	73.98	15.83	1000.000	410.0	H	102.0	26.3

Frequency (MHz)	Average (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1143.500000	20.32	53.98	33.66	1000.000	186.0	V	265.0	-2.0
1594.000000	20.16	53.98	33.82	1000.000	373.0	V	139.0	-1.3
2230.500000	23.86	53.98	30.12	1000.000	100.0	V	181.0	3.0
3261.500000	25.17	53.98	28.81	1000.000	410.0	V	305.0	5.2
16098.000000	43.25	53.98	10.73	1000.000	395.0	H	283.0	25.6
17725.500000	44.87	53.98	9.11	1000.000	410.0	H	102.0	26.3

Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: NA
(Where Applicable)
Product Standard: FCC Part 15.247
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient
Signals or BB Source: Yes

Test Date: 6/30/2020-7/1/2020
Limit Applied: FCC Part 15.209 in restricted bands
Ambient Temperature: 23.8C
Relative Humidity: 54.8%
Atmospheric Pressure: 981.5mbar

Deviations, Additions, or Exclusions: None



7 Conducted Emissions

7.1 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)	Ucisp
Power Line Conducted Emissions	150 kHz - 30 MHz	3.1dB	3.4dB

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.

7.2 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:

$$UF = 10^{(NF / 20)} \text{ where } UF = \text{Net Reading in } \mu V$$

$$NF = \text{Net Reading in dB}\mu V$$

Example:

$$NF = RF + LF + CF + AF = 28.5 + 0.2 + 0.4 + 20.0 = 49.1 \text{ dB}\mu V$$

$$UF = 10^{(49.1 \text{ dB}\mu V / 20)} = 285.1 \mu V/m$$

**7.3 Test Equipment Used:**

Description	Asset	Manufacturer	Model	Cal Date	Cal Due
EMI Test Receiver	3900	Rohde & Schwarz	ESU40	9/18/2019	9/18/2020
LISN	2508	Fischer Custom Communication	FCC-LISN-50-50-2M	6/9/2020	6/9/2021
Coaxial Cable (COND 3)	8064			12/4/2019	12/4/2020

7.4 Software Utilized:

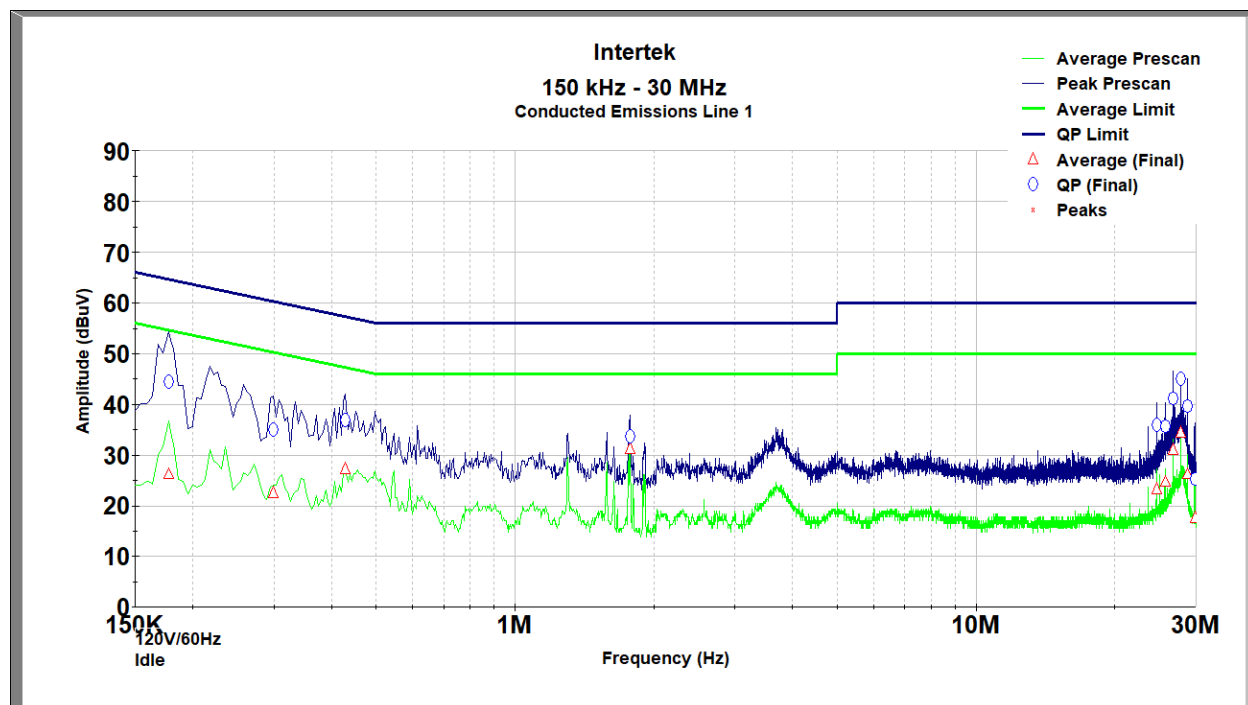
Name	Manufacturer	Version
TILE	ETS Lindgren	V7.0.6.545

7.5 Results:

The sample tested was found to Comply.



7.6 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)
0.177	44.394	65.229	20.835	26.399	55.229	28.830
0.298	35.105	61.757	26.652	22.566	51.757	29.191
0.429	36.841	58.029	21.188	27.168	48.029	20.860
1.775	33.772	56.000	22.228	31.296	46.000	14.704
24.666	35.938	60.000	24.062	23.251	50.000	26.749
25.692	35.721	60.000	24.279	24.724	50.000	25.276
26.723	41.344	60.000	18.656	30.970	50.000	19.030
27.749	45.055	60.000	14.945	34.392	50.000	15.608
28.779	39.817	60.000	20.183	26.376	50.000	23.624
29.805	25.451	60.000	34.549	17.599	50.000	32.401

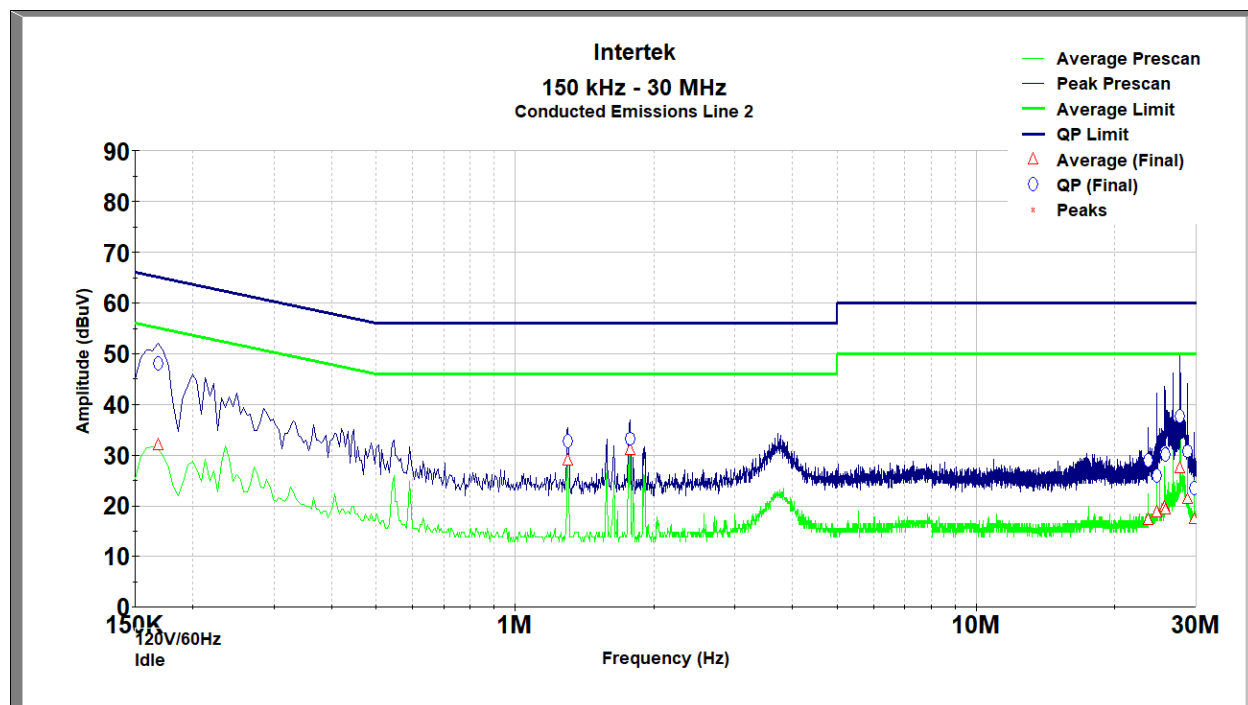
Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: _____
(Where Applicable) NA
Product Standard: FCC Part 15B
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient Signals or BB Source: Yes

Test Date: 4/14/2020
Limit Applied: Class B
Ambient Temperature: 22.9C
Relative Humidity: 45.7%
Atmospheric Pressure: 985.4mbar

Deviations, Additions, or Exclusions: None



7.7 Plots/Data: Conducted Emissions (Idle, Neutral)



Frequency (MHz)	Quasi-Peak (dBuV)	Quasi-Peak Limit (dBuV)	Quasi-Peak Margin (dB)	Average (dBuV)	Average Limit (dBuV)	Average Margin (dB)
0.168	48.076	65.486	17.409	32.040	55.486	23.446
1.302	32.836	56.000	23.164	28.897	46.000	17.103
1.775	33.268	56.000	22.732	31.071	46.000	14.929
23.618	28.985	60.000	31.015	17.223	50.000	32.777
24.648	25.968	60.000	34.032	18.664	50.000	31.336
25.674	30.560	60.000	29.440	19.820	50.000	30.180
25.764	30.131	60.000	29.869	19.224	50.000	30.776
27.721	37.629	60.000	22.371	27.361	50.000	22.639
28.756	30.829	60.000	29.171	21.305	50.000	28.695
29.782	23.473	60.000	36.527	17.371	50.000	32.629

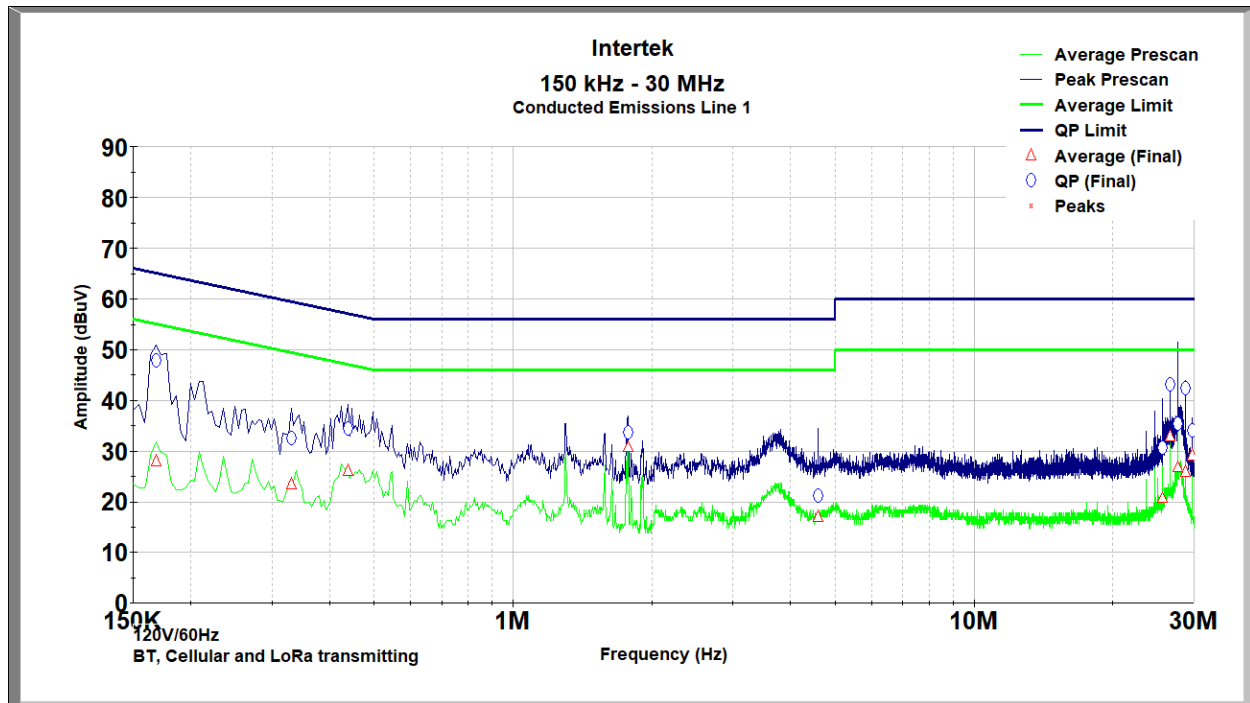
Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: _____
(Where Applicable) NA
Product Standard: FCC Part 15B
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient Signals or BB Source: Yes

Test Date: 4/14/2020
Limit Applied: Class B
Ambient Temperature: 22.9C
Relative Humidity: 45.7%
Atmospheric Pressure: 985.4mbar

Deviations, Additions, or Exclusions: None



7.8 Plots/Data: Conducted Emissions (Transmitting, Line)



Frequency (MHz)	Quasi-Peak (dBuV)	Quasi-Peak Limit (dBuV)	Quasi-Peak Margin (dB)	Average (dBuV)	Average Limit (dBuV)	Average Margin (dB)
0.168	47.867	65.486	17.618	28.082	55.486	27.403
0.330	32.607	60.857	28.251	23.464	50.857	27.393
0.438	34.500	57.771	23.271	26.206	47.771	21.566
1.775	33.674	56.000	22.326	30.793	46.000	15.207
4.587	21.249	56.000	34.751	16.968	46.000	29.032
25.642	30.658	60.000	29.342	20.788	50.000	29.212
26.655	43.241	60.000	16.759	33.005	50.000	16.995
27.690	35.381	60.000	24.619	26.915	50.000	23.085
28.716	42.343	60.000	17.657	26.018	50.000	23.982
29.733	34.012	60.000	25.988	29.212	50.000	20.788

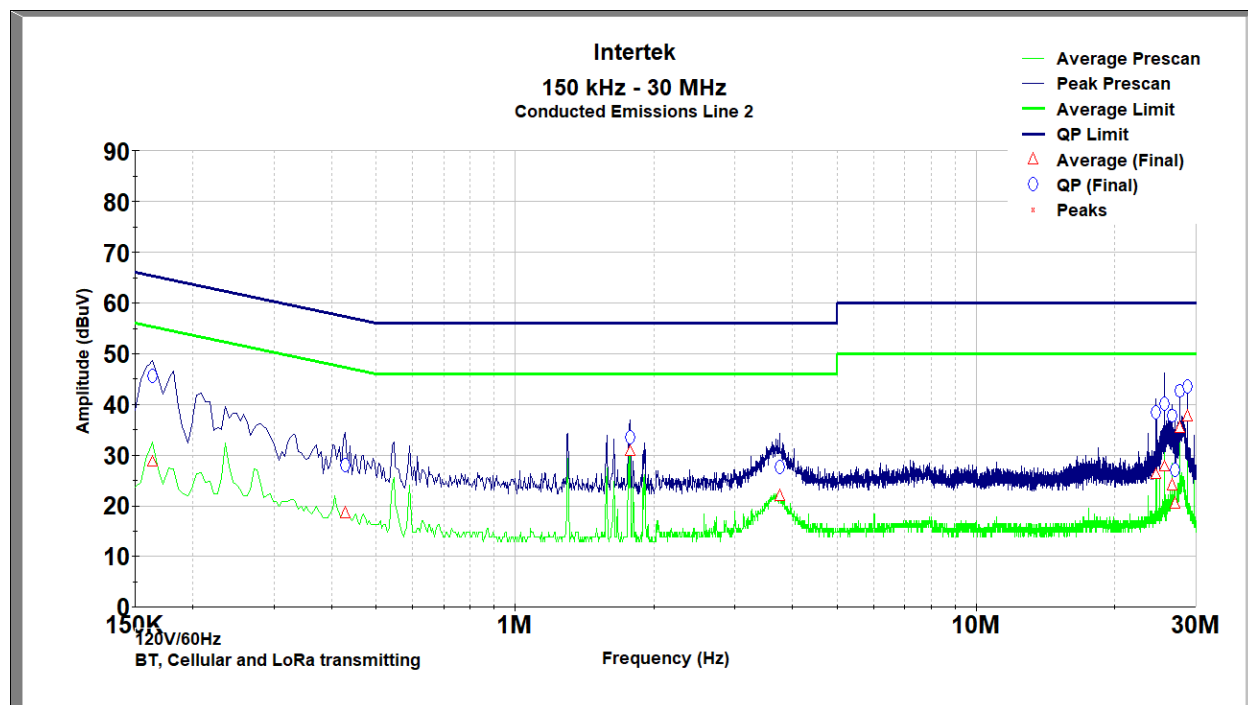
Test Personnel: Brian Lackey
Supervising/Reviewing Engineer: _____
(Where Applicable) NA
Product Standard: FCC Part 15C
Input Voltage: 120V/60Hz
Pretest Verification w / Ambient Signals or BB Source: Yes

Test Date: 4/14/2020
Limit Applied: FCC Part 15.207
Ambient Temperature: 22.9C
Relative Humidity: 45.7%
Atmospheric Pressure: 985.4mbar

Deviations, Additions, or Exclusions: tested with cellular, LoRa, and Bluetooth radios active



7.9 Plots/Data: Conducted Emissions (Transmitting, Neutral)



Frequency (MHz)	Quasi-Peak (dBUV)	Quasi-Peak Limit (dBUV)	Quasi-Peak Margin (dB)	Average (dBUV)	Average Limit (dBUV)	Average Margin (dB)
0.164	45.646	65.614	19.968	28.724	55.614	26.890
0.429	28.020	58.029	30.009	18.572	48.029	29.456
1.775	33.572	56.000	22.428	30.807	46.000	15.193
3.750	27.664	56.000	28.336	22.026	46.000	23.974
24.594	38.367	60.000	21.633	26.304	50.000	23.696
25.620	40.191	60.000	19.809	27.778	50.000	22.222
26.637	37.954	60.000	22.046	24.015	50.000	25.985
27.038	27.106	60.000	32.894	20.383	50.000	29.617
27.672	42.723	60.000	17.277	35.425	50.000	14.575
28.698	43.569	60.000	16.431	37.749	50.000	12.251

Test Personnel: Brian Lackey

Supervising/Reviewing Engineer: NA
(Where Applicable)

Product Standard: FCC Part 15C

Input Voltage: 120V/60Hz

Pretest Verification w / Ambient Signals or BB Source: Yes

Test Date: 4/14/2020

Limit Applied: FCC Part 15.207

Ambient Temperature: 22.9C

Relative Humidity: 45.7%

Atmospheric Pressure: 985.4mbar

Deviations, Additions, or Exclusions: tested with cellular, LoRa, and Bluetooth radios active

**8 Revision History**

Revision Level	Date	Report Number	Prepared By	Reviewed By	Notes
0	7/7/2020	104290762LEX-004	BZ	BCT	Original Issue