Testing Tomorrow's Technology

Report of

Title 47 CFR Part 95 Subpart J, Multi User Radio Services (MURS) and TIA-603-E (2016) Land Mobile FM or PM- Communications Equipment Measurement and Performance Standard

For the
Radio Systems Corporation

Boundary Plus 2.0

Consisting of

BP 2.0 INDOOR AND OUTDOOR SHIELDS WIRED 10X
Models: RAC00-16949 & RAC00-16992, & RAC00-16952

FCC ID: KE3-3003643

Issue Date: April 15, 2020
Test Dates: October 12, 2019 – April 15, 2020

UST Project No.: 20-0073

Total Number of Pages Contained in this Report: 22

3505 Francis Circle Alpharetta, GA 30004
PH: 770-740-0717 Fax: 770-740-1508
www.ustech-lab.com

Testing Tomorrow's Technology

I certify that I am authorized to sign for the test facility and that all of the statements in this report and in the Exhibits attached hereto are true and correct to the best of my knowledge and belief:

US TECH (Agent Responsible For Test):

By: 

Name: George Yang

Title: Laboratory Manager

Date: April 15, 2020

NVLAP LAB CODE 200162-0

3505 Francis Circle Alpharetta, GA 30004
PH: 770-740-0717 Fax: 770-740-1508
www.ustech-lab.com

Table of Contents

ParagraphTitle **Page**

List of Figures

Figure **Title** **Page**

List of Tables

Table **Title** **Page**

1 General Information

1.1 Product Description

The Equipment under Test (EUT) is the Radio Systems, Boundary Plus ® 2.0 Transmitter, Models RAC00-16949, RAC00-16992, and RAC00-16952. The difference between the models are as follows: The model RAC00-16949 and RAC-16992 are indoor versions of the EUT and the RAC00-16952 is an outdoor version of the EUT. The hardware and components within all models are essentially identical expect for the power input circuits. The outdoor version is designed to be used with either an internal lithium poly battery or with four D cell batteries. The indoor version of the EUT is designed to be used with a rechargeable lithium battery or an approved AC/DC power supply adapter. The intentional circuits for all models are identical therefore in this report the model RAC00-16992 was tested as the representative sample for all models.

All models are part of the Boundary Plus 2.0 pet containment and avoidance system. The Boundary Plus 2.0 pet containment and avoidance system consists of a central data collection unit, a long wire transmitter that defines the containment perimeter, one or more remote receivers that are attached to pet collars, zero or more avoidance transmitters (either short wire or coil transmitters), and zero or more appliance transmitters (coil transmitters that integrated into entry/exit doors, water fountains, feeders, etc.). The system services an area consistent with a residential property.

The Boundary Plus 2.0 Indoor & Outdoor Two Port Hosts with short wire transmitter are optional avoidance transmitters. The units and wire are placed at the location of the intended avoidance area. The short wire transmitter output driver consists of an “H-Bridge” amplifier. The amplifier produces an OOK modulated current in the wire which results in a similarly modulated magnetic field about the wire. The typical maximum length of the external avoidance perimeter wire is 250 feet. It operates at one of the following fundamental frequencies: 15kHz, 20kHz, or 25kHz. The modulation data rate is 1250 bps and the data represent an 8-bit “field ID” unique within the local system. The field ID may be repeated at one of the following rates: 3, 4, 8, or 16 Hz (only for the outdoor unit). Magnetic field detection range for a compatible receiver is also controlled in the short wire transmitter and may be set from 1.5 to 4.5 feet for the indoor unit or 1.5 to 9.5 feet for the outdoor unit in one-half foot increments.

The model designation signifies whether the transmitter is transmitting a signal to activate the pet collar or a masked signal that will not activate the pet collar. Models RAC00-16949 and RAC00-16552 both transmit a signal that activates the pet collar, the model RAC00-16992 transmits a signal that does not activate the pet collar (Masked signal). This signal is generated from the low frequency transmitter at either 15 kHz, 20 kHz or 25 kHz and has been evaluated in a separate test report.

The present report is an evaluation of the MURS radio feature. From a hardware and electrical design perspective the models are identical therefore the MURS radio feature is the same regardless of which model is tested, in this case the model RAC00-16992 was tested as the representative sample for all models.

MURS: 151.82 MHz
Rated Maximum Output Power: +16 dBm
Measured Output Power (ERP): 2.80 dBm
Modulation type: GFSK; Data Rate: 3.6 kbps
Frequency Deviation: < 5 ppm

1.2 Related Submittal(s)/Grant(s)

The EUT is subject to the following authorizations:

a) Certification as a 151.82 MHz, MURS transmitter per FCC Part 2, Subpart J and Part 95, Subpart J, MURS and Subpart E, Technical Requirements.
b) Verification under 15.101 as a digital device and receiver.
c) Certification under FCC Part 15 as a Low Power Transmitter (submitted under a separate report)

1.3 Test Methodology

These measurements were conducted in accordance with the requirements of Title 47 CFR Part 95, Subpart J and TIA-603-E (2016). All measurements are in terms of peak values unless stated otherwise. The measurement system video bandwidth was set to at least three times that of the resolution bandwidth to prevent the introduction of amplitude smoothing throughout the evaluation process. If interconnecting cables are part of the measurement setup then they were manipulated as necessary to maximize emissions. A block diagram of the tested system is shown in Figure 1.

1.4 Test Facility

Testing was performed at US Tech's measurement facility at 3505 Francis Circle, Alpharetta, GA, 30004. This site has been fully described and registered with the FCC under registration number US5301. US Tech is an accredited laboratory under the National Voluntary Laboratory Accreditation Program (NVLAP), Lab Code: 200162-0.

The shielded semi anechoic EMC Chamber and the conducted disturbance measurement facilities used to collect the radiated and conducted emissions data are located at 3505 Francis Circle, Alpharetta, GA (USA). These test sites meet the requirements given in ANSI C63.4:2014.

1.4.1 Radiated Emissions Test Site (Shielded Semi Anechoic EMC Chamber)

The radiated emissions disturbance measurement facility consists of an 8.5 m long by 5.5 m wide and 5.6 m high shielded semi anechoic EMC Chamber. The chamber is lined with ferrite core and RF absorbers. The quiet zone is 2.0 m.

The test facility layout is shown in the figure below. A remotely controlled 2.0 m diameter flush-mounted turntable is provided for rotating (through at least 360 degrees) the EUT. A non-conductive table, 1.5 m long by 1.0 m wide by 0.8 m high is used in conjunction with the turntable for tabletop equipment. Electrical service for the EUT is provided through openings at the center of the turntable.

Provision for receiving antenna power and data wires is provided by junction boxes placed at the perimeter of the chamber. The receive antenna mast is remotely controlled and can be varied in height from 1 m to 4 m.

Power and data cables for the radiated disturbance measurement facility are run through PVC tubing under the raised floor or are laid directly upon the ground plane.

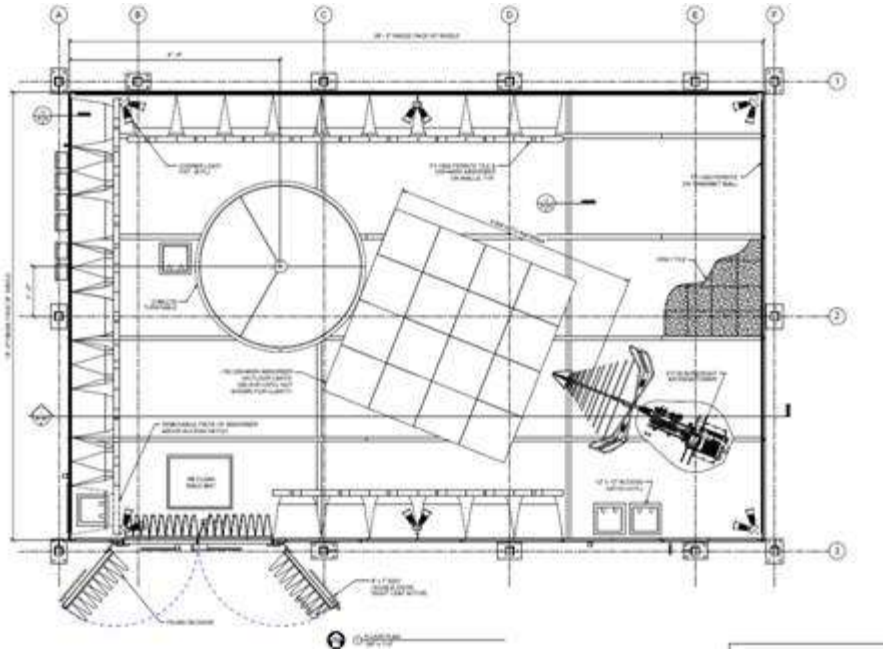

Figure 1. Radiated Emissions Disturbance Measurement Facility Diagram

1.5 Test Equipment

A list of test equipment used for these measurements is found in Table 1 below.

Table 1. Test Instruments

INSTRUMENT	MODEL NUMBER	MANUFACTURER	SERIAL NUMBER	CALIBRATION DUE DATE
SPECTRUM ANALYZER	E4407B	AGILENT	US41442935	8/17/2020 2 yr. Cal
BICONICAL ANTENNA	3110B	EMCO	9306-1708	6/27/2021 2 yr. Cal
LOG PERIODIC ANTENNA	3146	EMCO	9110-3236	8/22/2021 2 yr. Cal
HORN ANTENNA	3115	EMCO	9107-3723	11/28/2020 2 yr.
PRE-AMPLIFIER*	8449B	HEWLETT-PACKARD	3008A00480	4/8/2020*
PRE-AMPLIFIER	8447D	HEWLETT-PACKARD	1937A02980	5/7/2020

(*)= all tests completed before 4/8/2020
Note: The calibration interval of the above test instruments is 12 months unless stated otherwise and all calibrations are traceable to NIST/USA.

1.6 Modifications to EUT

No modifications were necessary to bring the EUT into compliance with FCC Part 95.

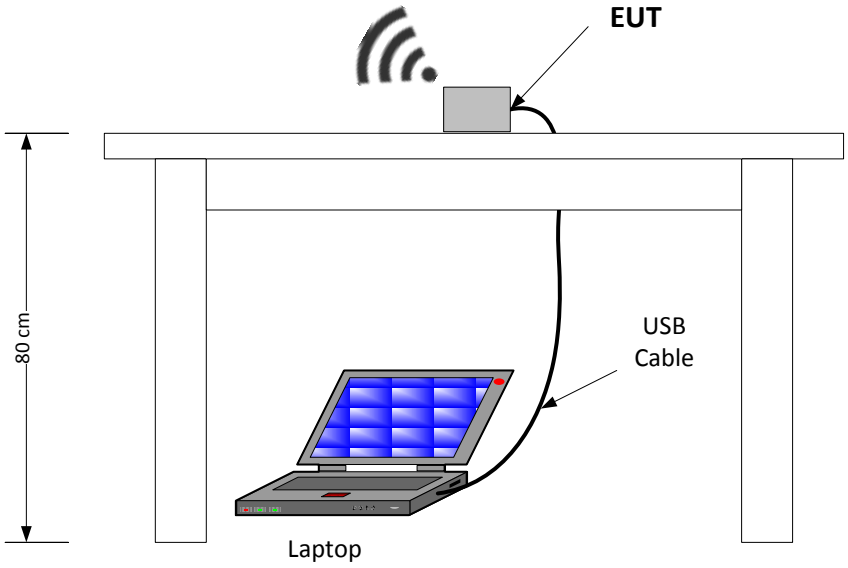

Figure 2. Test Configuration Block Diagram

Table 2. EUT and Peripherals

PERIPHERAL/ MANUFACTURER	MODEL NUMBER	SERIAL NUMBER	FCC/ IC ID	CABLES P/D
Transmitter/ Radio Systems (EUT)	BP 2.0 INDOOR SHIELDS WIRED 10X, Model RAC00-16949	0DB800042A	FCC ID: KE3-3003643 IC: 2721A-300643	1.0 m U D
Transmitter/ Radio Systems (EUT)	BP 2.0 OUTDOOR SHIELDS WIRED 10X, Model RAC00-16952	0DB80003f3	FCC ID: KE3-3003643 IC: 2721A-300643	1.0 m U D
Transmitter/ Radio Systems (EUT)	BP 2.0 WIRED MASK Model RAC00-16992	0DB8000426	FCC ID: KE3-3003643 IC: 2721A-300643	1.0 m U D
Power Adapter/ Radio Systems	SPS-02C5-1C-US-VI	Production Sample	N/A	2.0 m U P
Laptop	Dell	Various	Various	P D

P = Power; D = Data U = Unshielded

Table 3. Antennas

REPORT REFERENCE	MANUFACTURER	TYPE OF ANTENNA	PART NUMBER	GAIN dB_i	TYPE OF CONNECTOR
Antenna	Radio Systems Corp	Loop	100-1366 rev 4	-15.0	Trace

2 Output Power

2.1 Maximum Transmitter Power (FCC 2.1046 & 95.2767)

On the test site, the EUT was placed on top of a non-conductive table, 80 cm above the floor for measurements below 1 GHz and 150 cm above the floor for measurements > 1 GHz. The EUT was also evaluated in three orthogonal positions to determine the worst case position. The front of the EUT faced the measurement antenna located 3 meters away. Each signal measured was maximized by raising and lowering the receive antenna between 1 and 4 meters in height while monitoring the ever changing spectrum analyzer display (with channel A in the Clear-Write mode and channel B in the Max-Hold mode) for the largest signal visible. That exact antenna height where the signal was maximized was recorded for reproducibility purposes. Also, the EUT was rotated about its Z-axis while monitoring the Spectrum Analyzer display for maximum. The EUT azimuth was recorded for reproducibility purposes. The EUT was measured when both maxima were simultaneously satisfied.

The maximum power was measured using the radiated method. The EUT was setup to transmit a continuous signal with >98% duty cycle. The receiver and video bandwidth on the spectrum analyzer was maximized and the span was sufficiently large enough to capture the peak emissions. The peak measurement of the signal was recorded.

2.1.1 Maximum Power Allowed

The maximum power allowed is 2 Watts (or 33dBm) per FCC 95.2767.

2.1.2 Measured Fundamental Signal

The maximum output power of the EUT as measured below is 0.0024 W.

3.83 dBm into 50 ohm measurement system = 0.0024 W <<2 Watts
Antenna gain = -15.00 dBi

The EUT was determined to comply with the Maximum Allowed Power.

Table 4. Maximum Output Power

Frequency MHz	Maximum RX Reading (Units A)	Recreated Reading During Substitution (Using Same Units A) - Ideally 0	Difference Column A - B	TX Cable Loss (dB)	TX Gain (dBi)	RF Power into TX antenna (dBm) (SG Value-CL)	RF Power into substitution TX antenna (dBm)	Limit (dBm)	Margin Below Limit (dB)
151.82	91.8	92.0	-0.17	1.1	1.1	4.0	3.83	33	29.17
151.82	91.4	92.0	-0.62	1.1	1.1	4.0	3.38	33	29.62

Sample Calculation at 151.82 MHz:

SG Power Into TX Antenna	4.0	(dBm)
+ TX Gain	1.1	(dB)
+Difference between recreated and Actual	-0.17	(dB)
+TX Cable Loss	-1.1	(dB)
RF Power Into TX Antenna	3.83	(dBm)
Limit	33.00	(dBm)
RF Power into TX Antenna	3.83	(dBm)
Margin	29.17	(dB)

Test Date: April 15, 2020

Tested By
Signature:  Name: Afzal Fazal

3 Emissions Bandwidth (Part 95.2773(a))

The EUT was modulated by its own internal sources. The Bandwidth of the Fundamental was measured using a spectrum analyzer, as shown below. A RBW that was > 1% of the authorized bandwidth was used to measure the EUT's bandwidth.

Using the Emission Bandwidth measurement technique of ANSI C63.10-2009 as a guide, the measurement of the Emission Bandwidth is found to be 6.895 kHz.

3.1 Maximum Authorized Bandwidth

The maximum authorized Bandwidth per 95.2773 (a) = 11.25 kHz. The EUT was found to comply with the Maximum Authorized Bandwidth since 5.0329 kHz < 11.25 kHz.

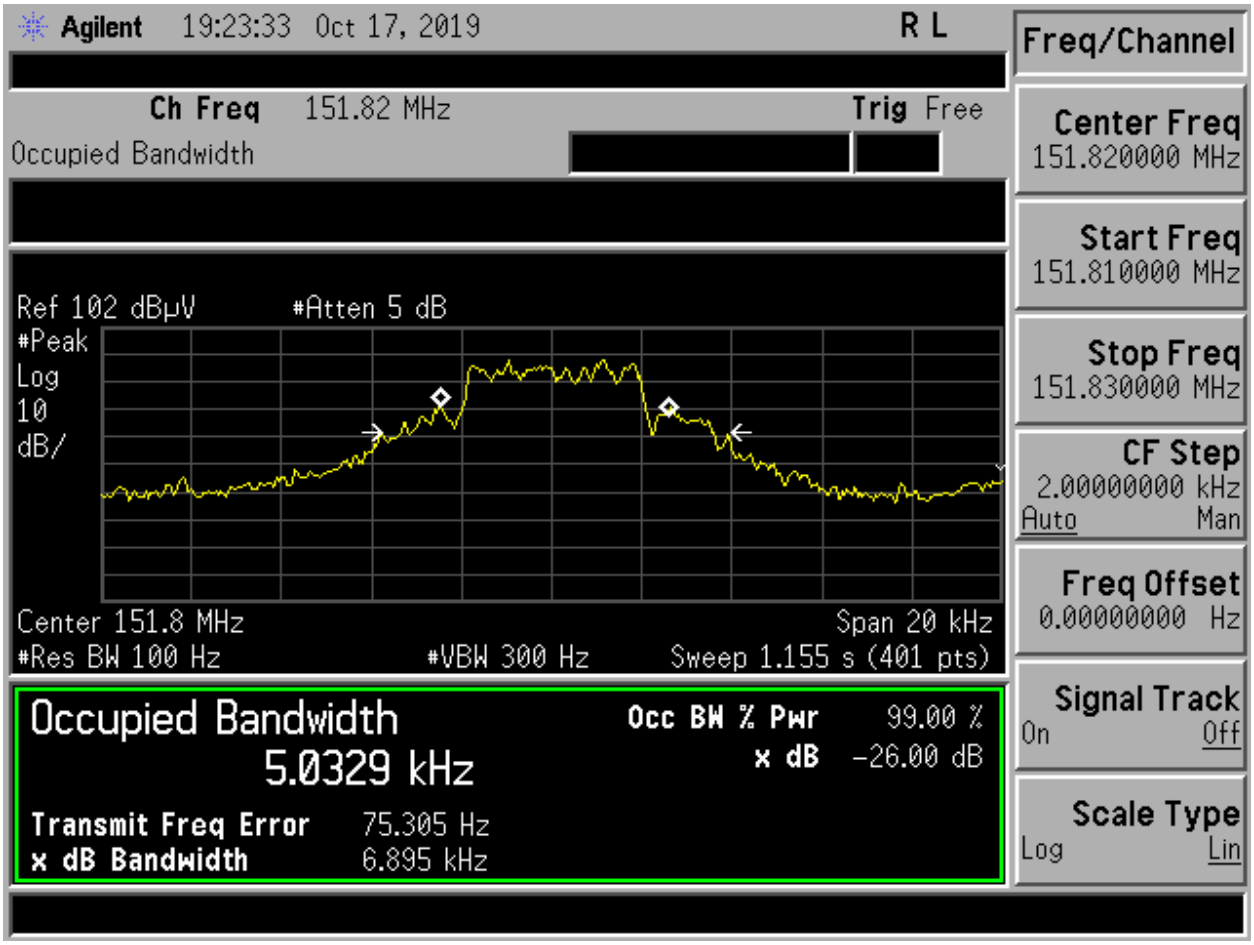

Figure 3. Bandwidth Measurement

Test Date: October 17, 2019

Tested By
Signature: Afzal Fazal Name: Afzal Fazal

4 MURS Unwanted Radiation Emissions(CFR 95.2779)

This requirement is from 47 CFR Part 2, Subpart J, Sections 1053 and 95.2779(b). The power of each unwanted emission shall be less than the transmitter power as specified in paragraph 5.2 below.

4.1 Test Method

These emissions were measured on the Spectrum Analyzer using the radiated method.

4.2 FCC Limits

Per CFR Part 95.2779(b), the power of unwanted emissions must be attenuated below the transmitter output power in Watts (P) by at least:

(1) 7.27(f_d−2.88 kHz) dB on any frequency removed from the channel center frequency by a displacement frequency (f_d in kHz) that is more than 5.625 kHz, but not more than 12.5 kHz.
(2) 50 + 10 log (P) dB or 70 dB, whichever is the lesser attenuation, on any frequency removed from the channel center frequency by more than 12.5 kHz.

4.3 Test Results

The EUT is designed to operate at 151.8200 MHz and is assumed not to be using any audio low pass filter circuits, therefore only Emissions Mask 1 was applied.

The measured emissions comply with the specified mask as shown below.

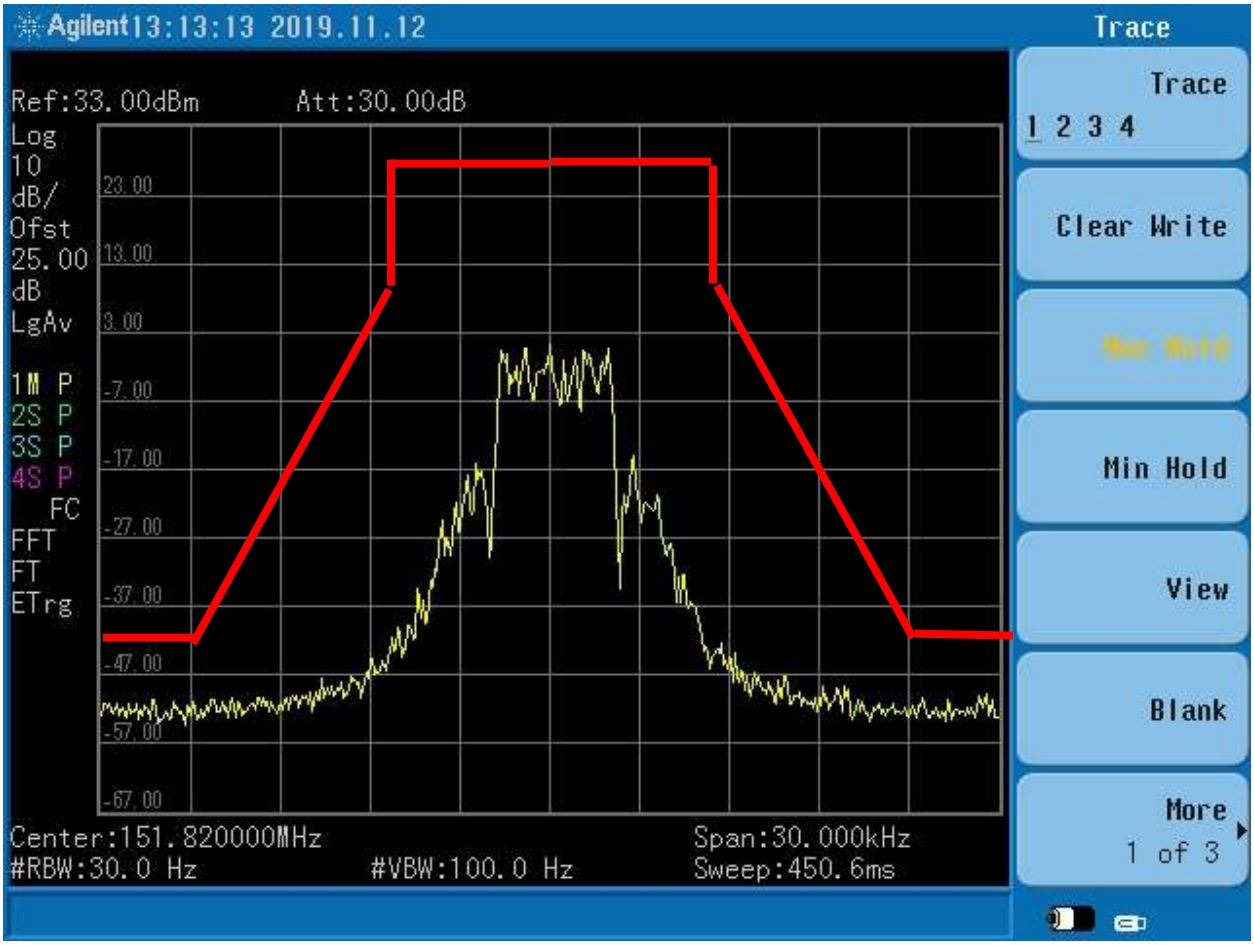

Figure 4. Emission Mask

Test Date: November 12, 2019

Tested By
Signature: Afzal Fazal Name: Afzal Fazal

5 Field Strength of Spurious Radiation, (FCC 2.1051 & 95.2779(b)(2))

5.1 Test Method

Spurious emissions were evaluated by the substitution method from 30 MHz to 1.0 GHz at a EUT to antenna distance of 3 meters. The EUT was tested in the far field. Measurements for 30 to 1000 MHz were made with the analyzer's bandwidth set to 120 kHz. Measurements above 1000 MHz were made with analyzer's bandwidth set to 1 MHz and 3 MHz.Since the EUT is part of a portable configuration, the EUT was rotated through the three orthogonal planes to produce the highest emissions relative to the limits. Results are shown in the Table below.

5.2 FCC Limits

The limit is determined using the following information: On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 12.5 kHz, the limit will be at least 50 + 10 log (P) dB or 70 dB, whichever is the lesser attenuation.

Measured Conducted Output Power= 0.0024 Watts = 3.83 dBm
Attenuation Calculation = 50 + 10Log (0.0024) = 23.8 dB
Power Limit = 3.83 dBm – 23.8 dB = -20 dBm

5.3 Test Results

Table 5. Field Strength of Spurious Radiation

Frequency MHz	Maximum RX Reading (Units A)	Recreated Reading During Substitution (Using Same Units A) - Ideally 0	Difference Column A - B	TX Cable Loss (dB)	TX Gain Relative to Dipole (dB)	RF Power into TX antenna (dBm) (SG Value-CL)	RF Power into substitution TX antenna (dBm)	Limit (dBm)	Margin Below Limit (dB)
35.67	36.42	36.64	-0.22	-0.03	-10.6	-70	-80.85	-20	60.85
96.12	50.35	52.04	-1.69	-0.91	0.1	-65	-67.30	-20	47.30
141.59	47.66	47.52	0.14	-1.1	0.3	-65	-65.47	-20	45.47
142.84	46.44	46.87	-0.43	-1.1	0.8	-70	-70.54	-20	50.54
242.52	46.15	44.98	1.17	-1.3	5.5	-75	-69.57	-20	49.57
248.46	45.8	44.3	1.5	-1.3	5.4	-75	-69.34	-20	49.34

Sample Calculation at 35.67 MHz:

SG Power Into TX Antenna	-70.00	(dBm)
+ TX Gain	-10.60	(dB)
+Difference between recreated and Actual	-0.22	(dB)
+TX Cable Loss	-0.03	(dB)
RF Power Into TX Antenna	-80.85	(dBm)
Limit	-20.00	(dBm)
RF Power into TX Antenna	-80.85	(dBm)
Margin	60.85	(dB)

Test Date: October 15, 2019

Tested By
Signature: Afzal Fazal Name: Afzal Fazal

6 Frequency Stability (CFR 2.1055, 95.2765)

6.1 Test Method

The EUT was tested in the Thermotron Environmental Chamber. The humidity was tested to a relative value of no more than 50%. The temperature was varied between -30°C to +50°C in 10° increments. All measurements were referenced back to the frequency measured at +20°C. At each set point the temperature was allowed to stabilize for no less than 30 minutes before measurements were recorded and the temperature changed.

6.2 FCC Limits

Per CFR 95.2765 (a)(b), MURS transmitters must maintain a frequency stability of 2.0 ppm, or 5.0 ppm if designed to operate with a 6.25 kHz bandwidth. Since this EUT was measured to have a bandwidth of 5.03 kHz the limit applied was 5.0 ppm.

6.3 Test Results

Table 6. Frequency Deviation/Stability

Temperature (˚C)	Measured Frequency (MHz)	Allocated Frequency (MHz)	Deviation (ppm)	Limit (ppm)
-30	151.820000	151.820000	0	5.00
-20	151.820000	151.820000	0	5.00
-10	151.820000	151.820000	0	5.00
0	151.820000	151.820000	0	5.00
10	151.820000	151.820000	0	5.00
20 (low voltage)	151.820000	151.820000	0	5.00
20 (nominal voltage)	151.820000	151.820000	0	5.00
20 (high voltage)	151.820000	151.820000	0	5.00
30	151.820000	151.820000	0	5.00
40	151.820000	151.820000	0	5.00
50	151.820000	151.820000	0	5.00

Actual TX Frequency was: 151.820000 MHz

Sample Calculation at -30˚C

$$\text{Deviation} = \frac{|(151.820000 - 151.820000)|}{151.820000} = 0.0\ 0 = 0.00\text{ppm} < 5\text{ppm}$$

Test Date: October 17, 2019

Tested By
Signature:  Name:Afzal Fazal