TEST REPORT

Report Number: 102576886MPK-001
Project Number: G102576886
May 27, 2016

Testing performed on the
PCBA, VMC GPS+Iridium Module
Model Number: IGM9603

FCC ID: 2AHZH- IGM9603

To

FCC Part 25
RSS-170 Issue 3, July 2015

for

Liquid Robotics Inc.

Test Performed by:	**Test Authorized by:**
Intertek	Liquid Robotics Inc.
1365 Adams Court	1329 Moffett Park Drive
Menlo Park, CA 94025	Sunnyvale, CA 94089, USA

Prepared by: _____ **Date:** May 27, 2016
Anderson Soungpanya

Reviewed by: _____ **Date:** May 27, 2016
Krishna K Vemuri

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Report No. 102576886MPK-001

Equipment Under Test:	PCBA, VMC GPS+Iridium Module
Model No.:	IGM9603
FCC ID:	2AHZH- IGM9603
Serial No.:	M105H7
Applicant:	Liquid Robotics Inc.
Contact:	Somphone Sayavong
Address:	484 Oakmead Parkway Sunnyvale, CA 94089
Country	USA
Tel. Number:	(650) 218-6210
Email:	somphone.sayavong@liquidr.com
Applicable Regulation:	FCC Part 25 RSS-170 Issue 3, July 2015
Test Site Location:	Intertek 1365 Adams Drive Menlo Park, CA 94025
Date of Test:	May 4 – 27, 2016

We attest to the accuracy of this report:

Anderson Soungpanya EMC Project Engineer	Krishna K Vemuri Engineering Team Lead

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1.0 Introduction

1.1 Product Description

IGM stands for IRIDIUM, GPS MODULE. This device provides Iridium and GPS services to SV3 Command and Control Unit (CCU).

Radio Specifications	
Applicant	Liquid Robotics Inc.
Model No.	IGM9603
Use of Product	SV3 command and control unit (CCU)
Rated RF Output Power	3.42 (EIRP)
Frequency Ranges	1616 – 1626 MHz
Type of Modulation	DE-QPSK/DE-BPSK
Channel Bandwidth and Maximum Data Rate	41.667kHz, 24kBp/s
Antenna & Gain	DUAL ANTENNA, GPS AND IRIDIUM, SMA:, P/N: S5GIR1516RR-AP-XSS-1, Gain = +5.0 dBi, 50 Ohms, RHCP
Detachable Antenna	Internal Antenna, Non-Detachable
Manufacture Name & Address	Liquid Robotics Inc. 1329 Moffett Park Drive Sunnyvale, CA 94089 USA

EUT receive date: April 29, 2016
EUT receive condition: The prototype version of the EUT was received in good condition with no apparent damage. As declared by the Applicant it is identical to the production units.
Test start date: May 4, 2016
Test completion date: May 27, 2016

1.2 Summary of Test Results

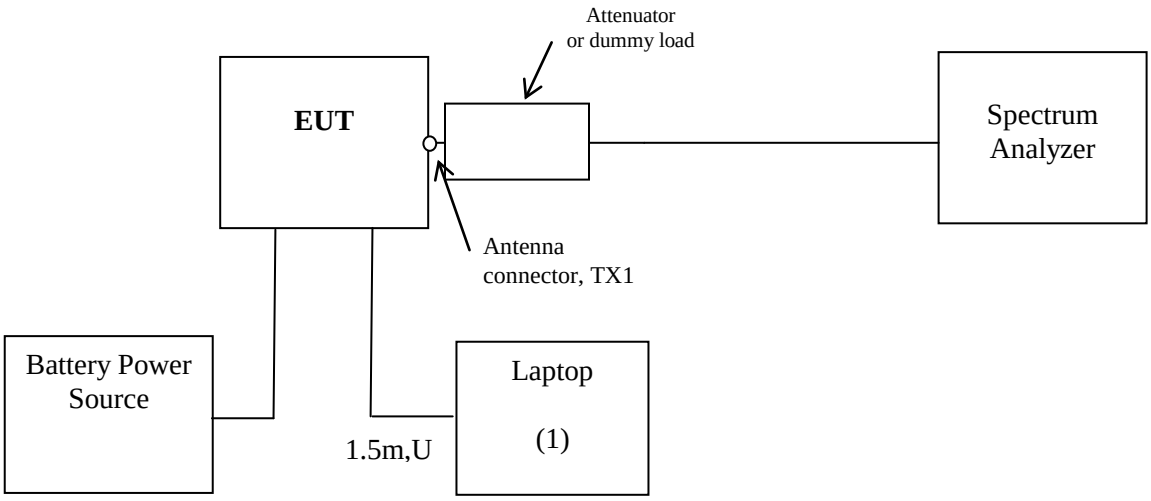
FCC Rule	RSS Rule	Description of Test	Result
25.204	RSS 170, 5.3	RF Power Output	Complies
2.1047(d)	-	Modulation Characteristics	Complies
2.1049	RSS Gen, 6.6	Occupied Bandwidth	Complies
2.1053, 25.202(f)	RSS 170; 5.4	Emission Masks	Complies
2.1053, 25.216, 25.202 (f)	RSS 170; 5.4	Out of Band Emissions at Antenna Terminals	Complies
2.1053, 25.216, 25.202 (f)	RSS 170; 5.4	Spurious Radiation	Complies
25.216 (a-j)	RSS 170; 5.4.3, 5.4.4	Limits on Emissions from Mobile Earth Stations for Protection of Aeronautical Radio navigation-Satellite Service	Complies
2.1055, 25.202(d)	RSS 170; 5.2	Frequency Stability vs. Temperature and Voltage	Complies

1.3 Test Configuration

1.3.1 Support Equipment

Item #	Description	Manufacturer	Model No.
1	Laptop	Dell	Latitude E6500
2	Power Source	Liquid Robotics	Surfer SV3

1.3.2 Block Diagram of Test Setup



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

During testing, the EUT was connected to a Laptop through a USB cable. Test software loaded on the computer was adjusted to exercise the EUT.

1.4 Related Submittal(s) Grants

None

2.0 RF Power Output

FCC CFR 47 Part 25, Clause 25.204
Industry Canada RSS-170, Clause 5.3

2.1 Requirement

Limit Clause FCC CFR 47, 25.204
+40 dBW in any 4 kHz band for $\theta \leq 0°$
$+40 + 3\theta$ dBW in any 4 kHz band for $0° < \theta \leq 5°$

Limit Clause RSS-170, 5.3
The application for MES certification shall state the MES e.i.r.p. that is necessary for satisfactory communication. The maximum permissible e.i.r.p. will be the stated necessary e.i.r.p. plus a 2 dB margin. If a detachable antenna is used, the certification application shall state the recommended antenna type and manufacturer, the antenna gain and the maximum transmitter output power at the antenna terminal.

2.2 Test Procedure

The EUT was connected to a spectrum analyzer with a RF cable and 30dB attenuator. The path loss was entered as a reference level offset into the spectrum analyzer.

The test procedure spelled out in 971168 D01 Power Meas License Digital Systems v02r02 was utilized to measure the peak output power.

The EIRP was calculated by adding the antenna gain to the output power in dBm.

$EIRP = P_{max} + G_{dBi}$

2.3 Test Results

Conducted Power

Mode	Frequency (MHz)	Measured Output Power (dBm)	Measured Output Power (Watt)	Graph
Low Channel	1616.020833	30.34	1.08	2.1
Mid Channel	1621.020833	30.22	1.05	2.2
High Channel	1625.979167	30.17	1.04	2.3

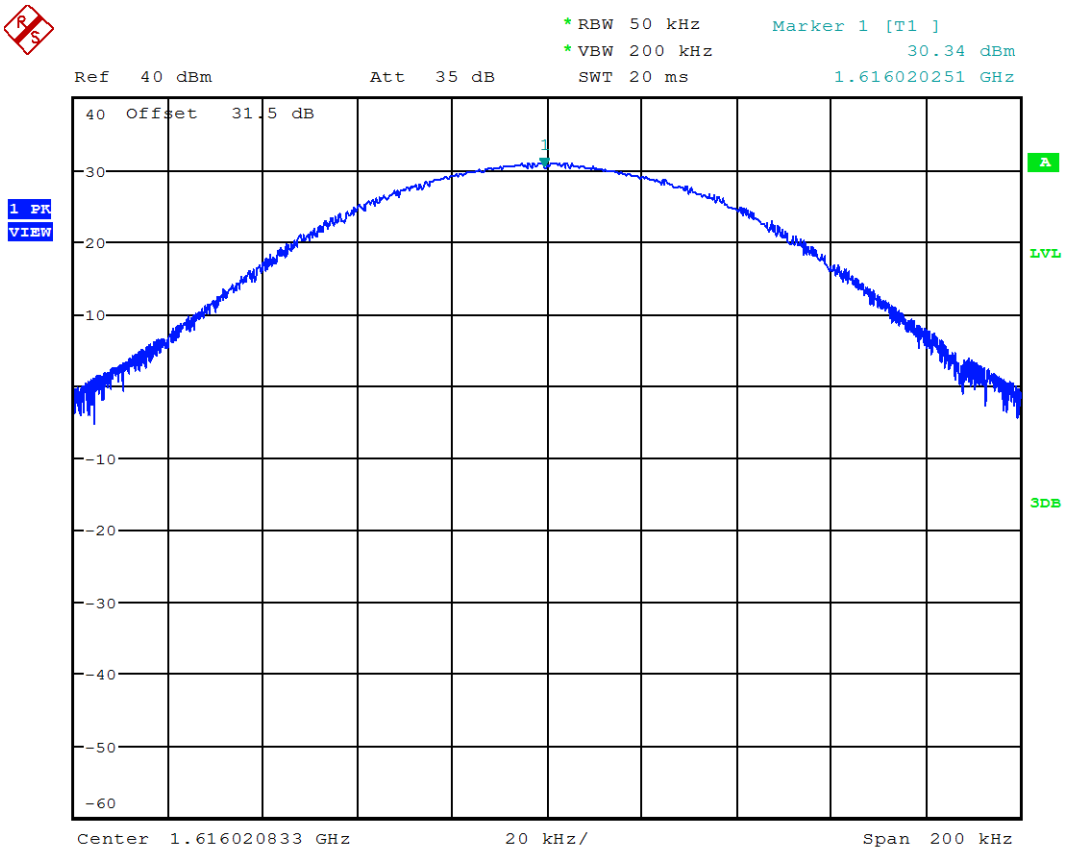
Refer to the attached graphs.

EIRP

According to the antenna provided, the antenna gain used with the EUT is 5dBi; therefore, the maximum calculated peak radiated power is:

Mode	Frequency (MHz)	EIRP Output Power (dBm)	EIRP Output Power (Watt)
Low Channel	1616.020833	35.34	3.42
Mid Channel	1621.020833	35.22	3.33
High Channel	1625.979167	35.17	3.29

Graph 2. 1



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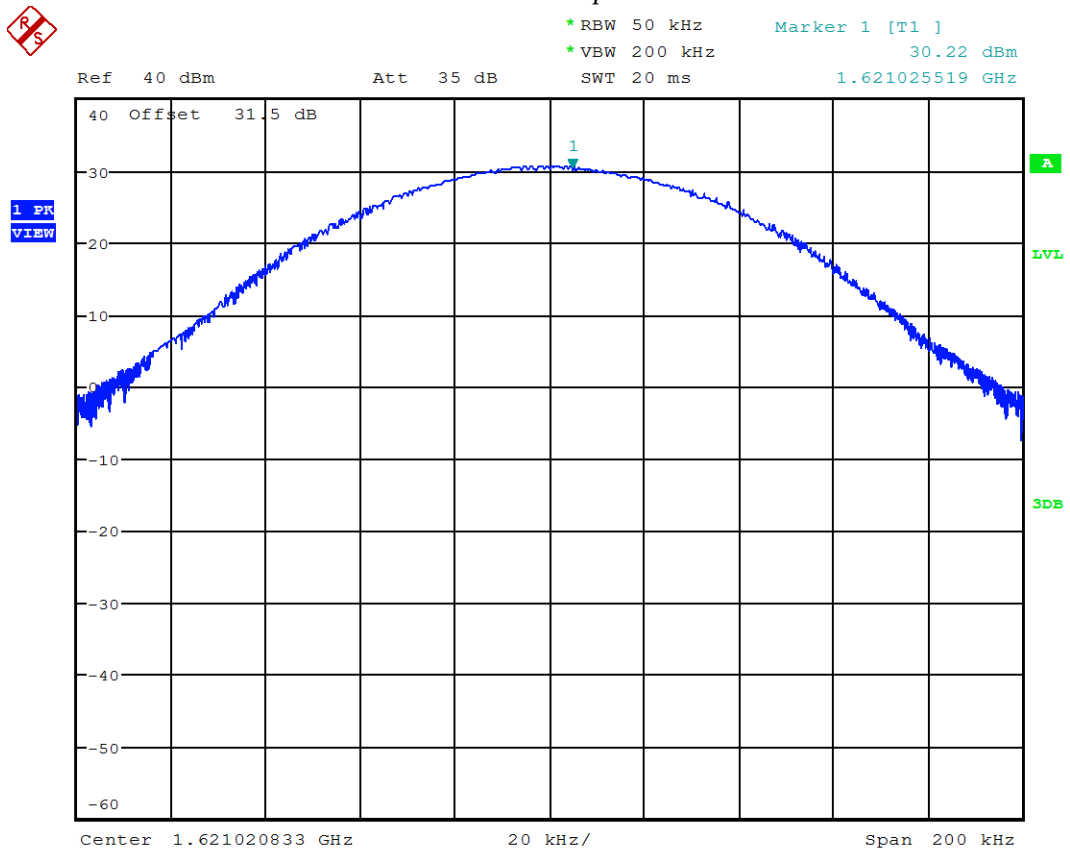
Graph 2. 2



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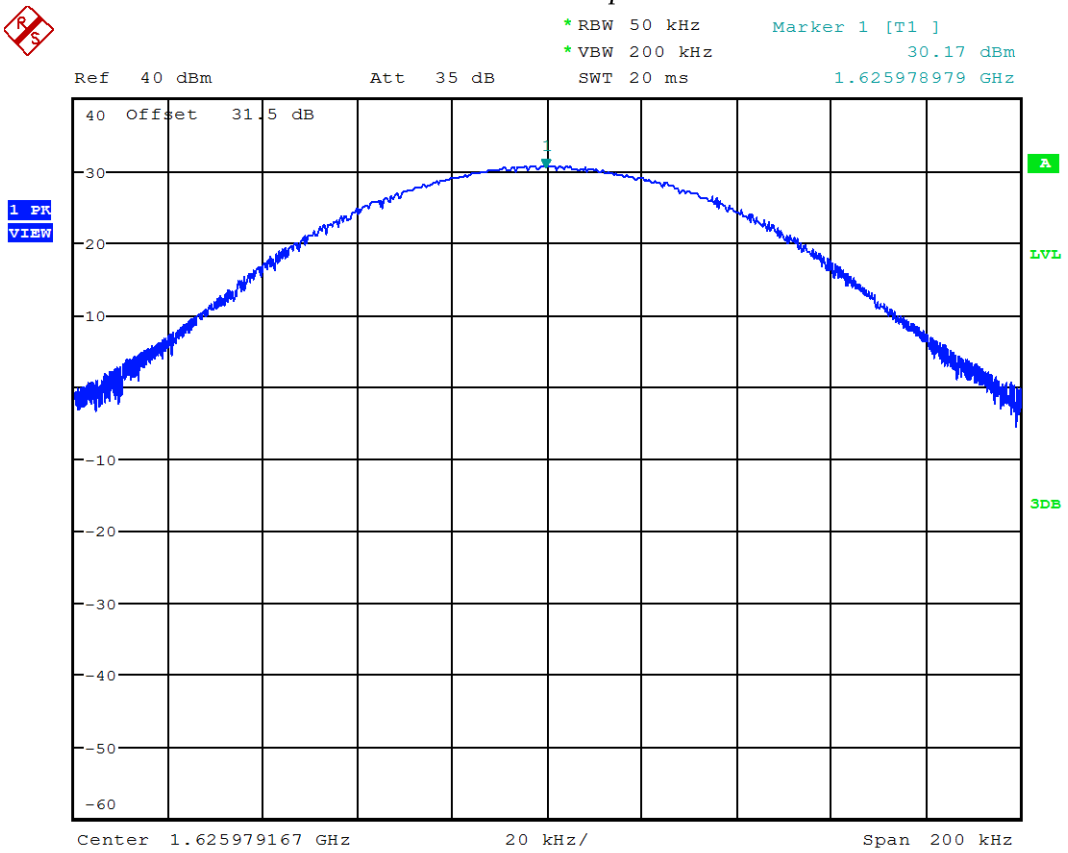
Graph 2. 3



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3.0 Modulation Characteristics

FCC CFR 47 Part 2, Clause 2.1047(d)

3.1 Requirement

Other types of equipment. A curve or equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed.

3.2 Test Procedure

The EUT RF output was connected as shown on the diagram in report section 1.3.2. The EUT was setup to transmit the maximum power.

3.3 Test Results

See plots in Section 4.0.

4.0 Occupied Bandwidth

FCC 2.1049
RSS Gen – 6.6

4.1 Test Procedure

The EUT RF output was connected as shown on the diagram in report section 1.3.2. The EUT was setup to transmit the maximum power.

The spectrum analyzer was setup to measure the Occupied Bandwidth (defined as the 99% Power Bandwidth). The Occupied Bandwidth was measured for all modes and authorized bandwidths.

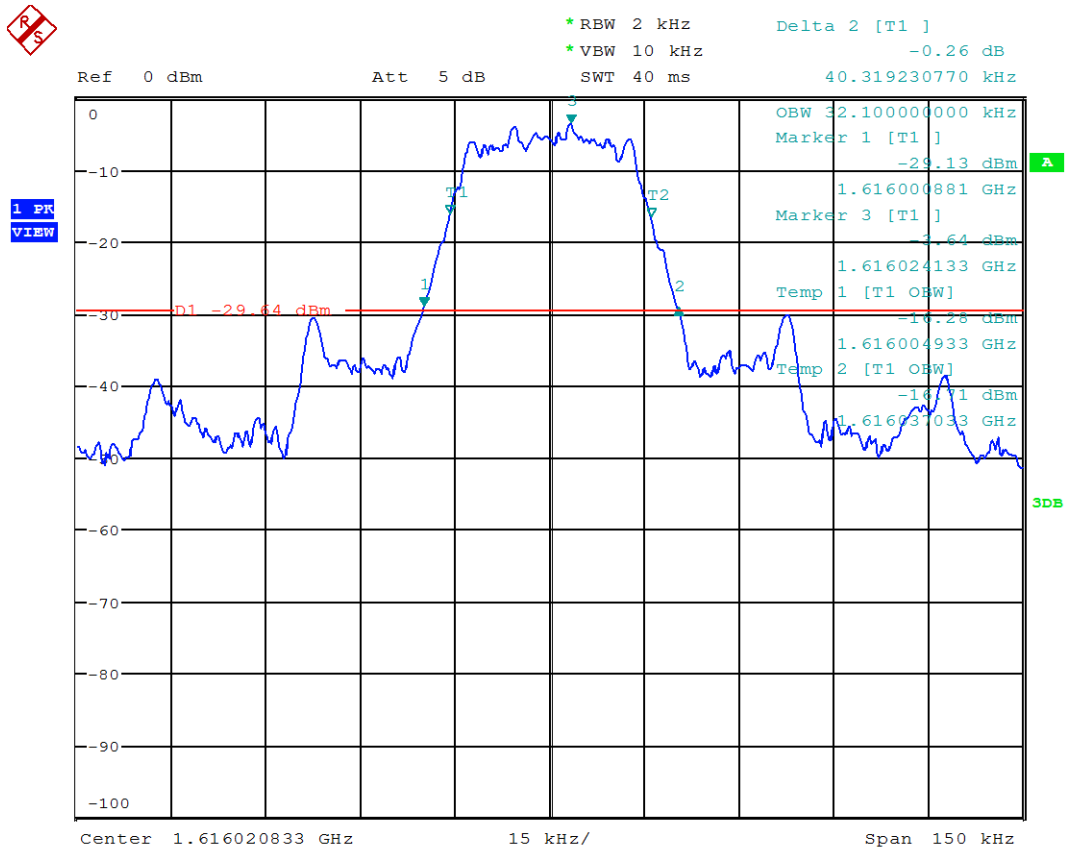
4.2 Test Results

Mode	Frequency (MHz)	99% Bandwidth (kHz)	-26dB Bandwidth (kHz)	Graph
Low Channel	1616.020833	32.100	40.319	4.1
Mid Channel	1621.020833	32.250	40.381	4.2
High Channel	1625.979167	32.700	40.625	4.3

Refer to the following Graphs

Result	**Complies**

Graph 4. 1



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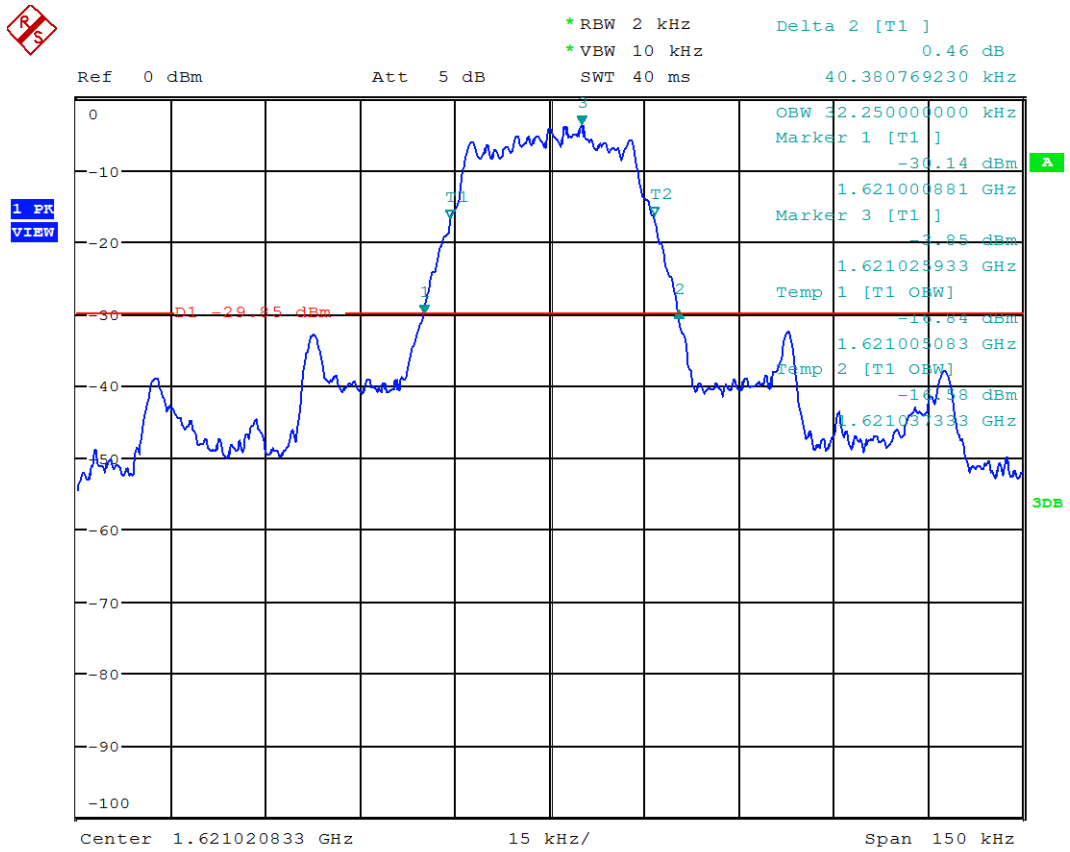
Graph 4. 2



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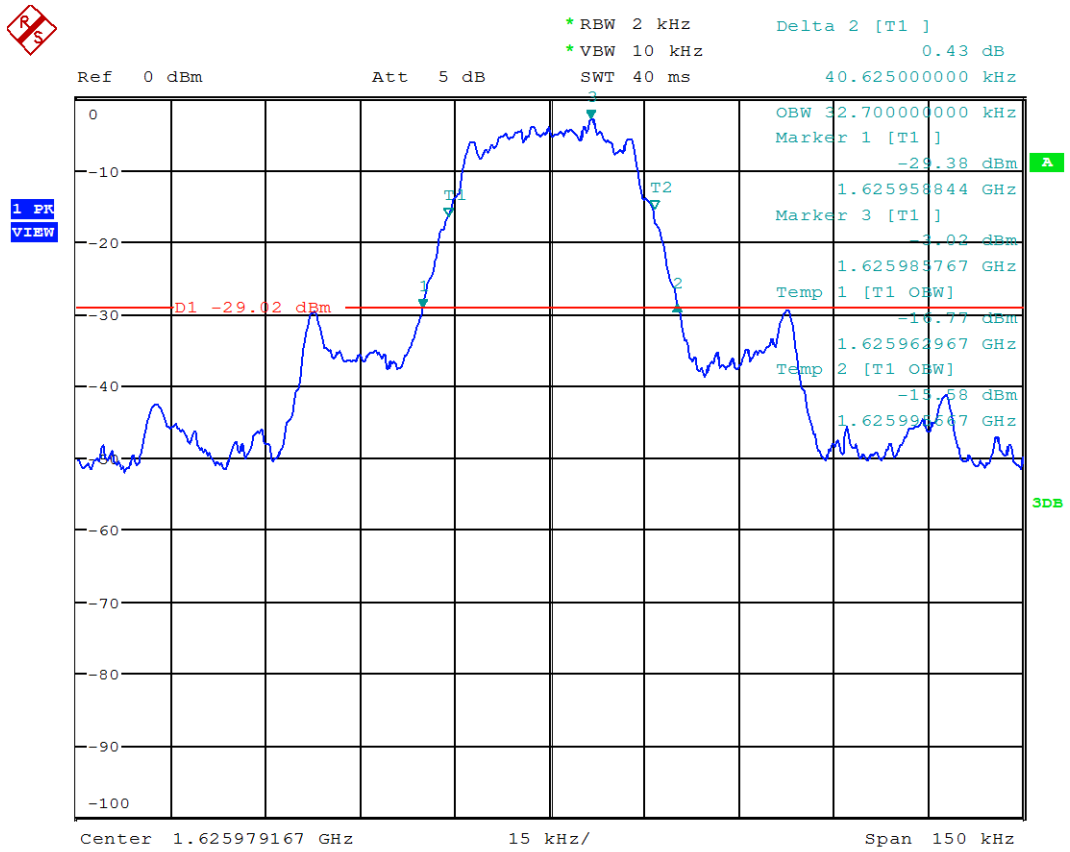
Graph 4. 3



Date: 9.MAY.2016 10:15:31

5.0 Emission Mask

FCC CFR 47 Part 2, Clause 2.1053
FCC CFR 47 Part 25, Clause 25.202(f)
Industry Canada RSS-170, Clause 5.4

5.1 Requirement

Emission limitations. Except for SDARS terrestrial repeaters and as provided for in paragraph (i), the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the schedule set forth in paragraphs (f)(1) through (f)(4) of this section. The out-of-band emissions of SDARS terrestrial repeaters shall be attenuated in accordance with the schedule set forth in paragraph (h) of this section.

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;

(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts;

(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (f) (1), (2) and (3) of this section.

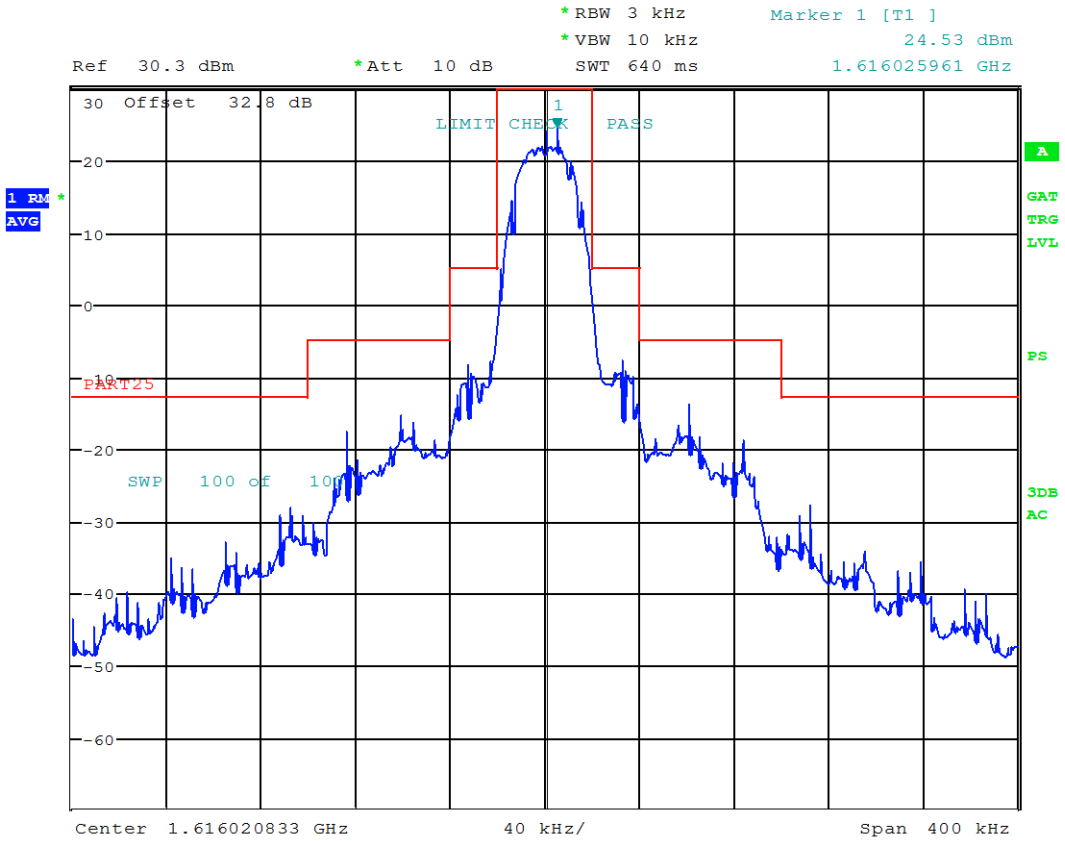
5.2 Test Procedure

The EUT was connected to a spectrum analyzer with a RF cable and 30dB attenuator. The path loss was entered as a reference level offset into the spectrum analyzer. The spectrum analyzer was configured with an RBW of 3 kHz and VBW of 10 kHz. 10Log(4/3) = 1.25 dB was added to the reference level offset to make the result relative to any 4 kHz band as per the requirement in 25.204(a). The transmit power was measured over the active part of the burst by utilizing the spectrum analyzers gating option and burst trigger. The detector used was a RMS detector with trace averaging of at least 100.

5.3 Test Results

Complies	Refer to the following Graphs

Graph 5. 1



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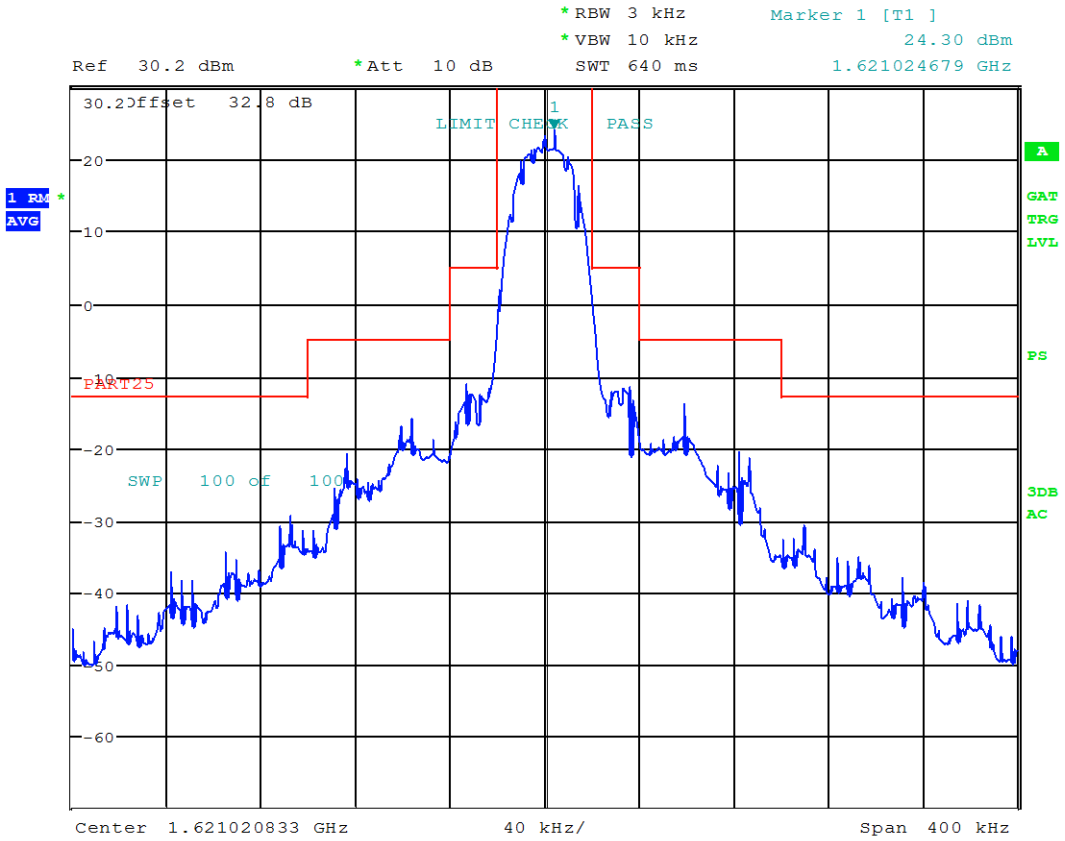
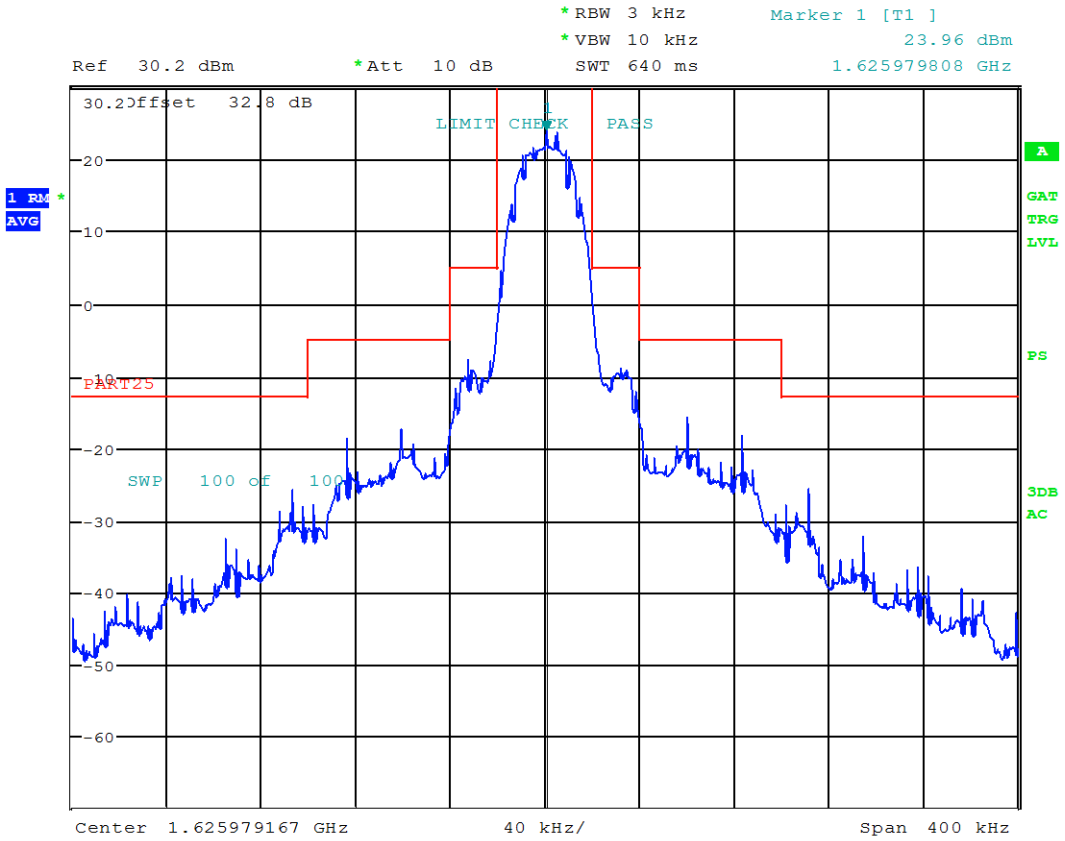
Graph 5. 2



Date: 11.MAY.2016 09:08:09

Graph 5. 3



Date: 11.MAY.2016 09:45:32

6.0 Spurious Emissions

6.1 Emissions at Antenna Terminal
FCC CFR 47 Part 2, Clause 2.1053
FCC CFR 47 Part 25, Clause 25.202(f)
Industry Canada RSS-170, Clause 5.4

6.1.2 Requirement

Emission limitations. Except for SDARS terrestrial repeaters and as provided for in paragraph (i), the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the schedule set forth in paragraphs (f)(1) through (f)(4) of this section. The out-of-band emissions of SDARS terrestrial repeaters shall be attenuated in accordance with the schedule set forth in paragraph (h) of this section.

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;

(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts;

(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (f) (1), (2) and (3) of this section.

6.1.2 Test Procedure

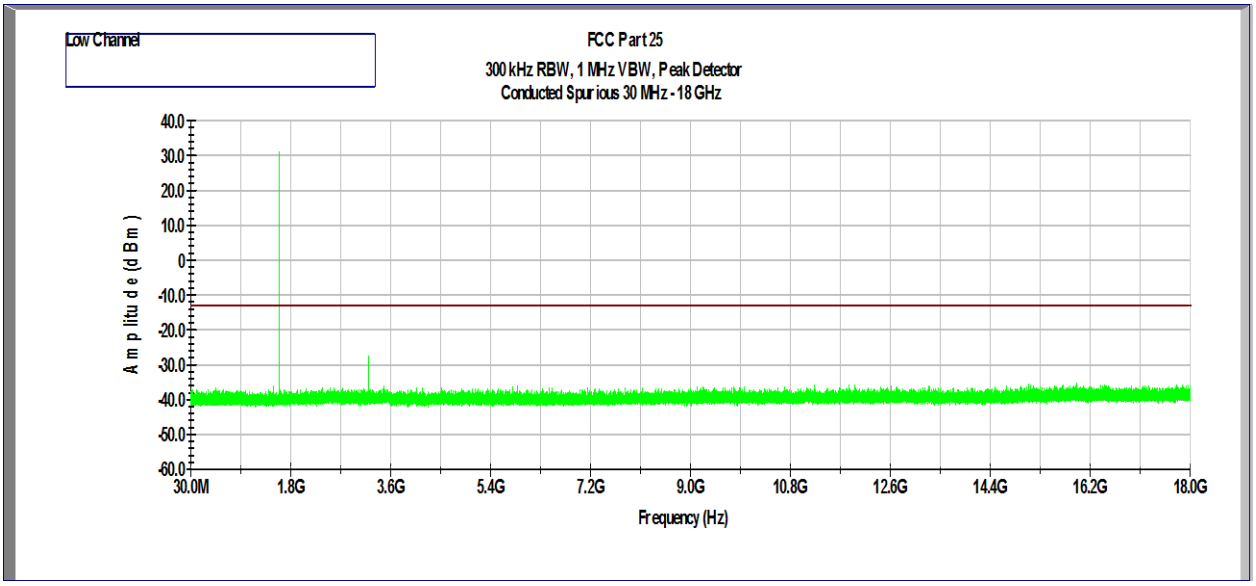
The EUT RF output was connected as shown on the diagram in report section 1.3.2. The EUT was setup to transmit the maximum power.

Sufficient scans were taken to show the spurious emissions up to 10th harmonic.

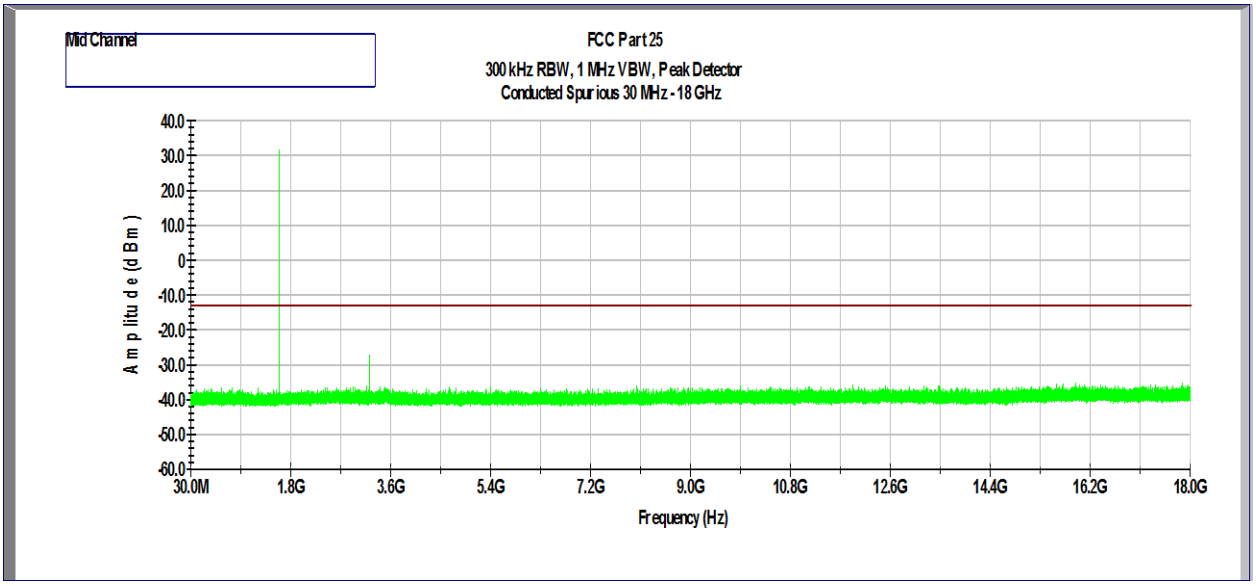
6.1.3 Test Results

Complies	Refer to the following Graphs

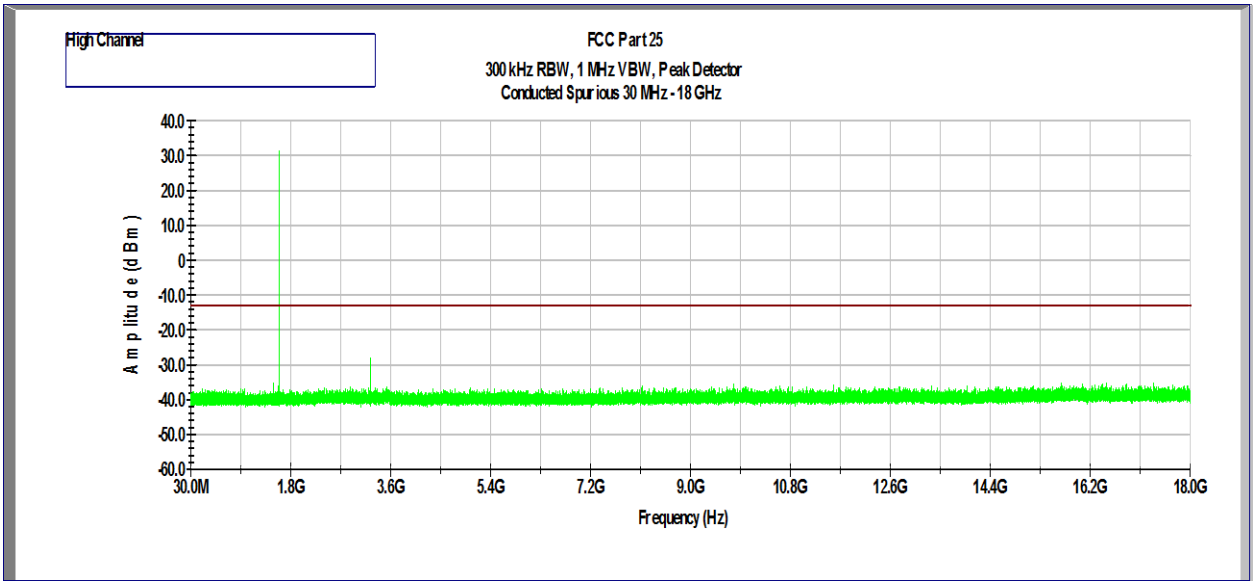
Graph 6. 1



Graph 6. 2



Graph 6. 3



Result	Complies

6.2 Spurious Radiation

6.2.1 Test Procedure

The measurement antenna was placed at a distance of 10 meters for 30MHz – 1GHz and 3 meters for 1-17GHz from the EUT. During the tests, the antenna height and polarization as well as EUT azimuth were varied in order to identify the maximum level of emissions from the EUT.

The frequency range up to 10th harmonic was investigated. The worst case of emissions was reported.

Spectrum Analyzer Resolution Bandwidth was set to 1 MHz, and Video Bandwidth was set to 3 MHz.

The EUT is placed on a plastic turntable that is 80 cm in height for below 1000MHz and 1.5m in height for above 1GHz. If the EUT attaches to peripherals, they are connected and operational (as typical as possible). During testing, all cables were manipulated to produce worst-case emissions. The signal is maximized through rotation. The antenna height and polarization are varied during the search for maximum signal level. The antenna height is varied from 1 to 4 meters.

Radiated emissions are taken at 3 meters for frequencies above 1 GHz and at 10 meters for frequencies below 1 GHz.

Measurements made from 30 MHz to 17 GHz were measured with 50 ohm terminator on the output of the EUT RF port. A preamp was used from 30MHz to 17GHz.

Data is included of the worst-case configuration (the configuration which resulted in the highest emission levels).

All measurements were made with a Peak Detector and compared to the EIRP limits. All measurements are corrected for cable, antenna, preamp and distance then compared to a 3m limit of 82.23 dBuV/m

The limit of -13dBm EIRP was converted to a Field Strength of 82.23dBuV/m at 3m using the calculation below.

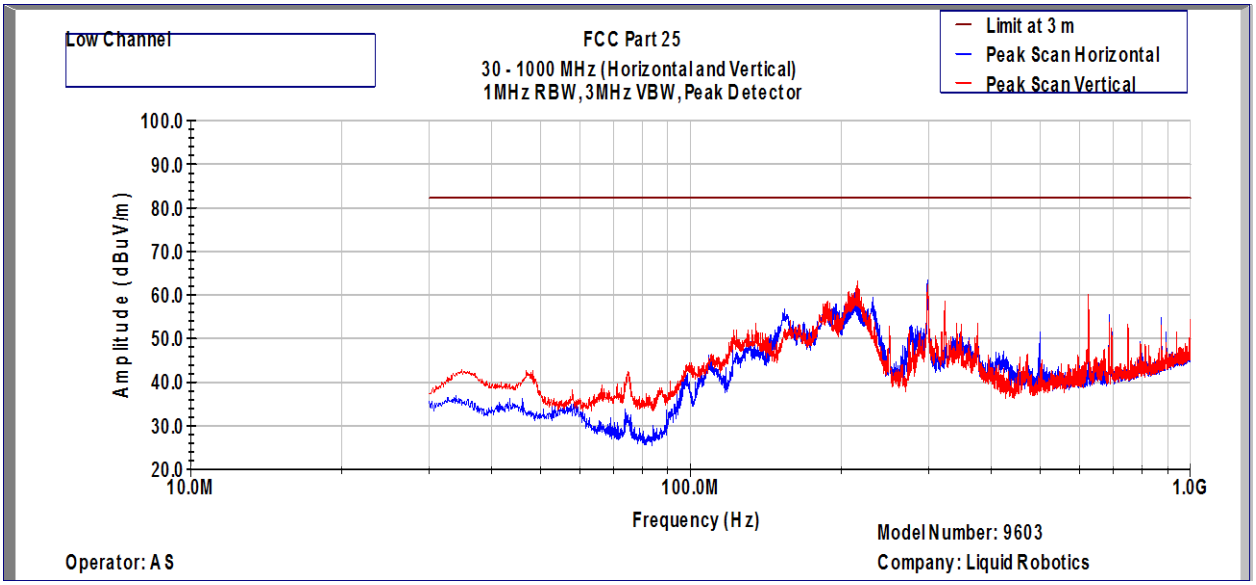
<u>Limit Line Calculation at 3m</u>
Eo = EIRP - 20log D + 104.8

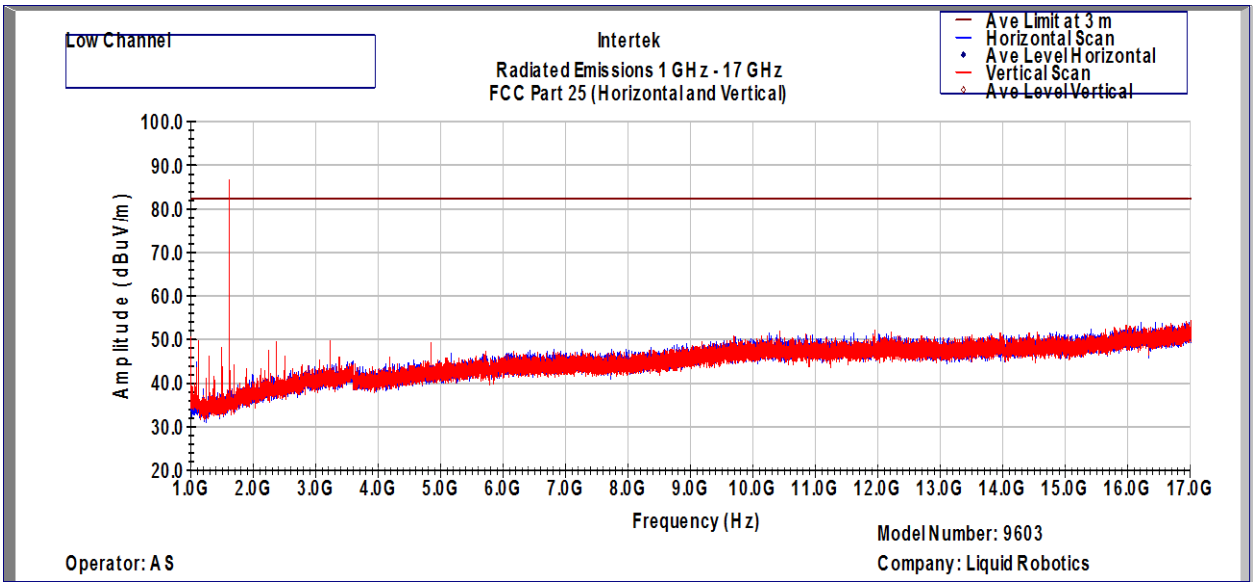
where:

Eo = electric field strength limit in dBμV/m, 3m
EIRP = equivalent isotropic radiated power in dBm
D = specified measurement distance in meters, 3m

6.2.2 Test Results

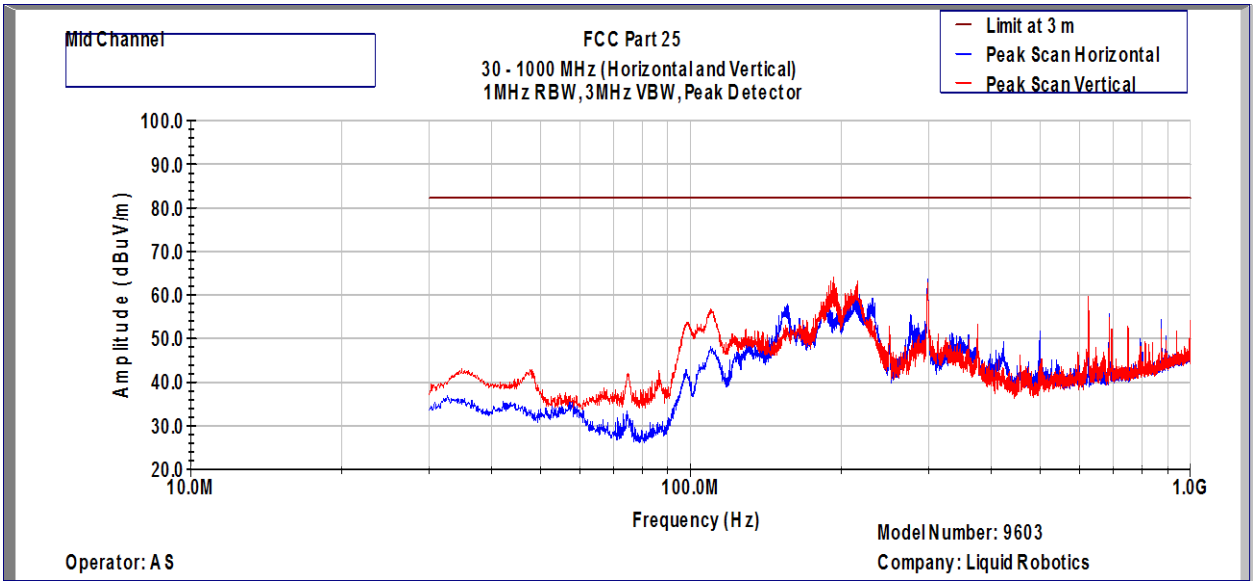
Spurious Radiated Emissions
Low Channel

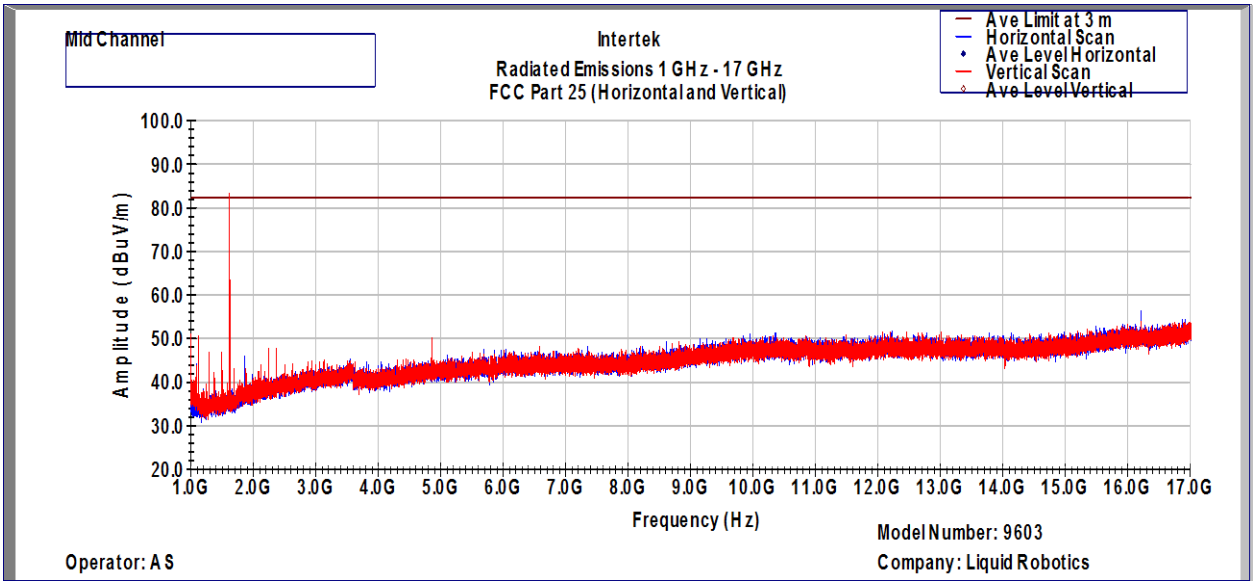




Result	Complies

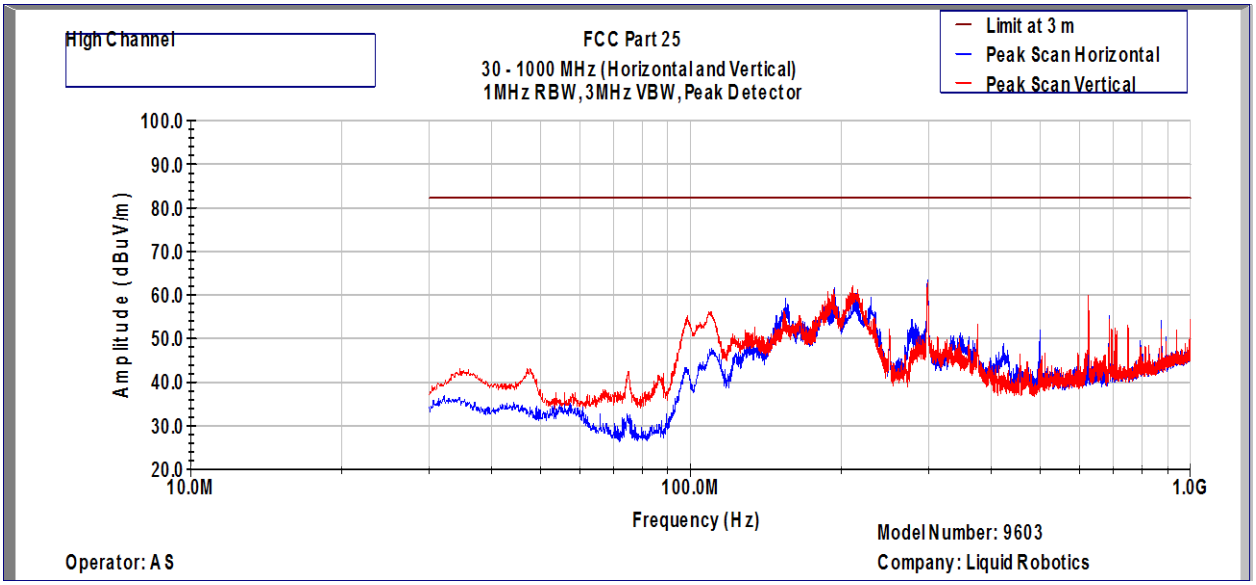
Spurious Radiated Emissions
Mid Channel

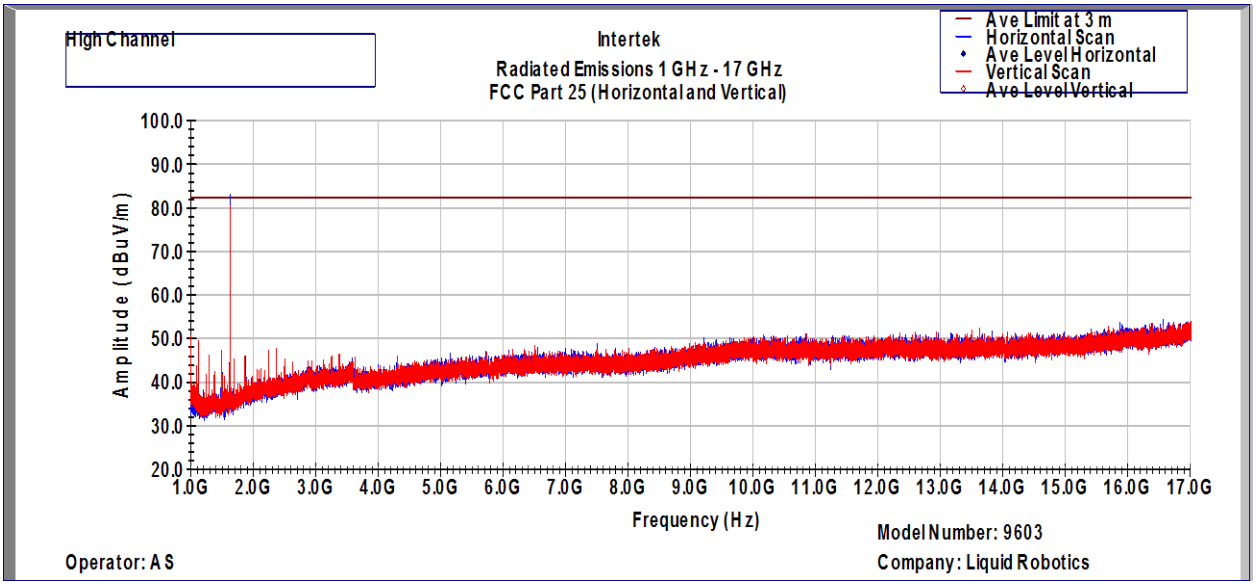




Result	Complies

Spurious Radiated Emissions
High Channel

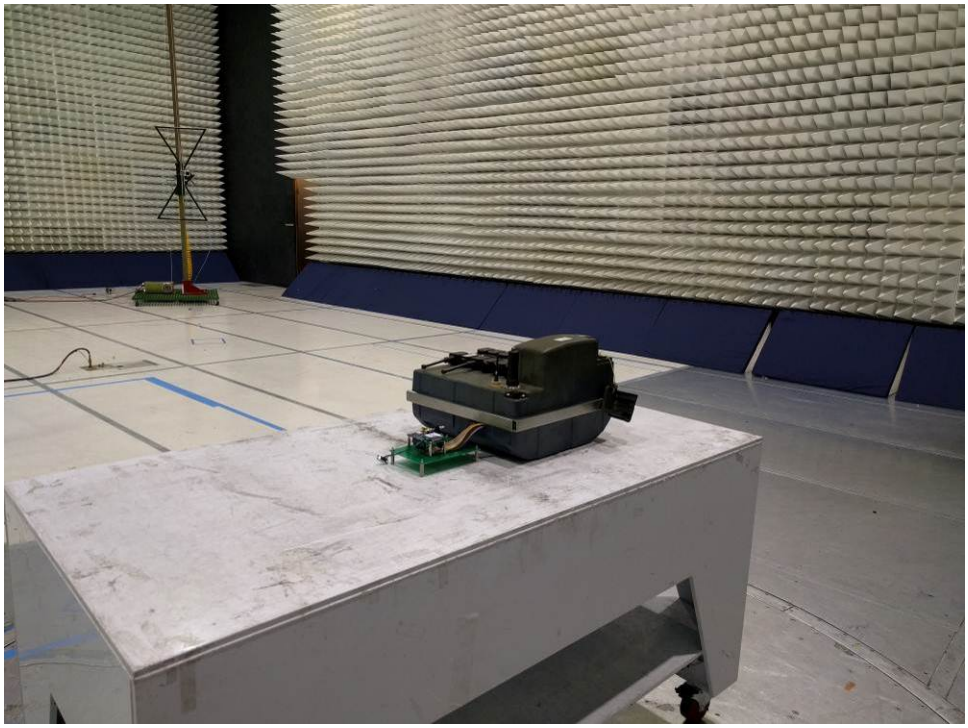




Result	Complies

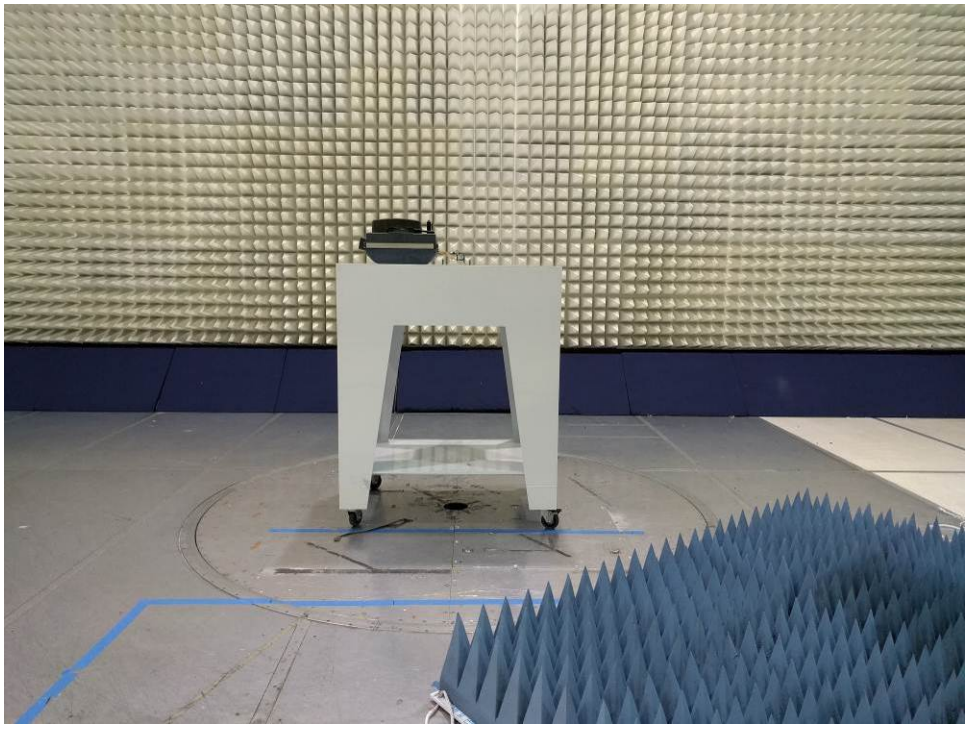
6.2.3 Test Setup Photographs

Radiated Emission Test Setup



Test setup photographs

Radiated Emission Test Setup



7.0 Limits on Emissions from Mobile Earth Stations for Protection of Aeronautical Radio navigation-Satellite Service

FCC CFR 47 Part 25, Clause 25.216 (a-j)
Industry Canada RSS-170, Clause 5.4.3, 5.4.4

7.1 Requirement

The e.i.r.p. density of emissions from mobile earth stations placed in service after July 21, 2002 with assigned uplink frequencies between 1610 MHz and 1660.5 MHz shall not exceed −70 dBW/MHz, averaged over any 2 millisecond active transmission interval, in the band 1559-1605 MHz. The e.i.r.p. of discrete emissions of less than 700 Hz bandwidth from such stations shall not exceed −80 dBW, averaged over any 2 millisecond active transmission interval, in the 1559-1605 MHz band.

Mobile earth stations placed in service after July 21, 2002 with assigned uplink frequencies in the 1610-1660.5 MHz band shall suppress the power density of emissions in the 1605-1610 MHz band to an extent determined by linear interpolation from −70 dBW/MHz at 1605 MHz to −10 dBW/MHz at 1610 MHz.`

The e.i.r.p density of carrier-off state emissions from mobile earth stations manufactured more than six months after Federal Register publication of the rule changes adopted in FCC 03-283 with assigned uplink frequencies between 1 and 3 GHz shall not exceed −80 dBW/MHz in the 1559-1610 MHz band averaged over any two millisecond interval.

Mobile equipment with transmitting frequencies between 1 GHz and 3 GHz shall have the e.i.r.p. density of carrier-off state emissions in the band 1559-1610 MHz not exceed −80 dBW/MHz.

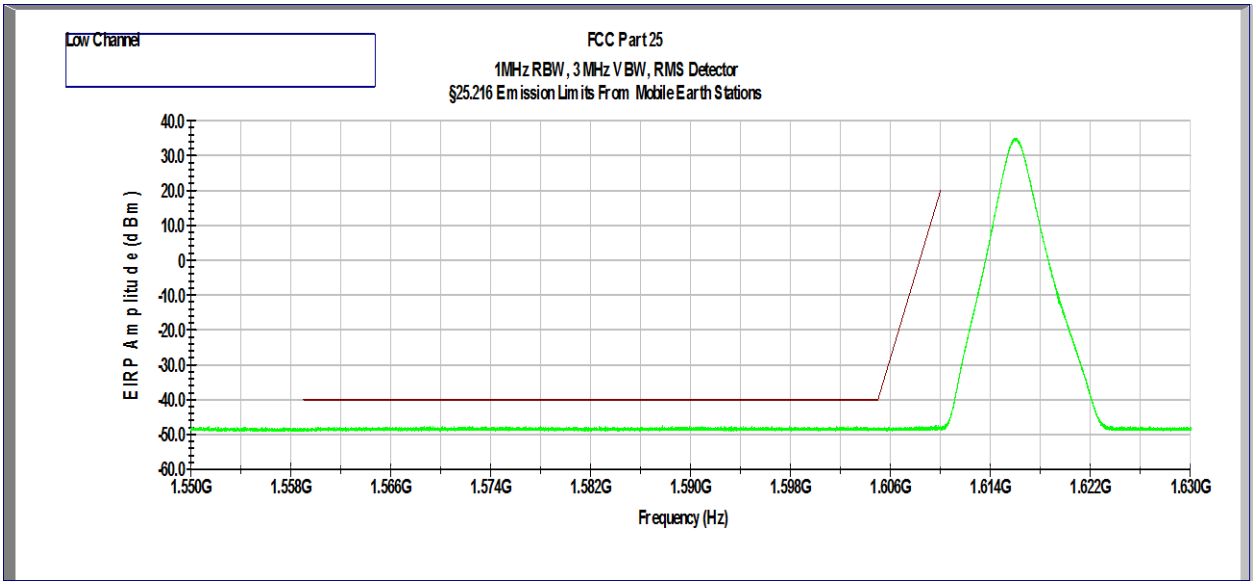
A Root-Mean-Square detector shall be used for all power density measurements.

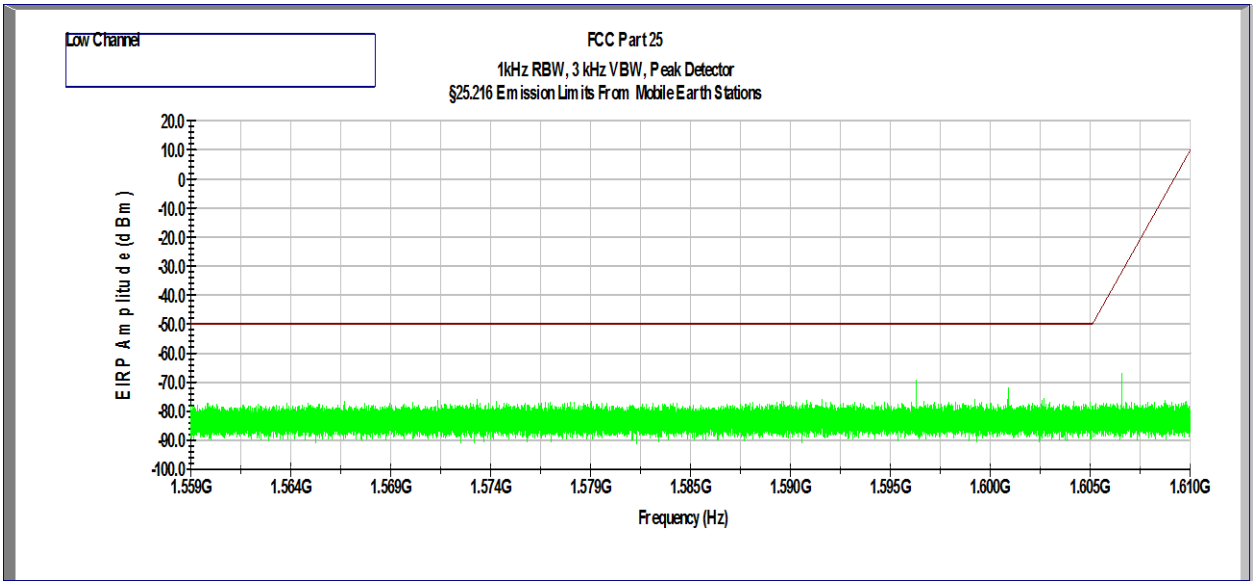
7.2 Test Procedure

The EUT RF output was connected as shown on the diagram in report section 1.3.2. The EUT was setup to transmit the maximum power.

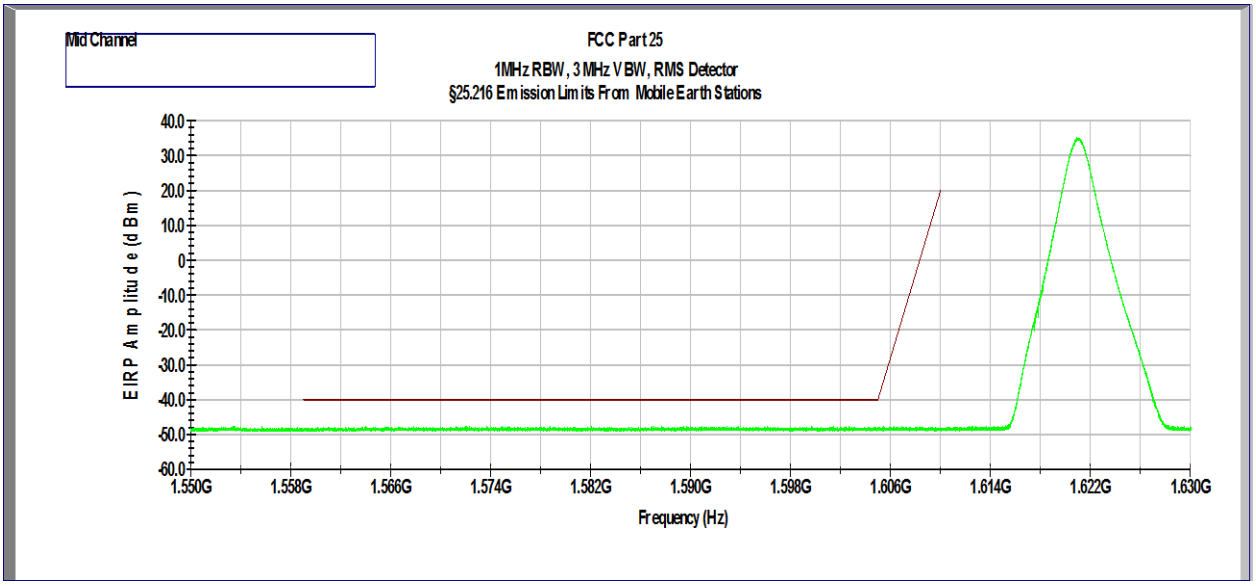
7.3 Test Results

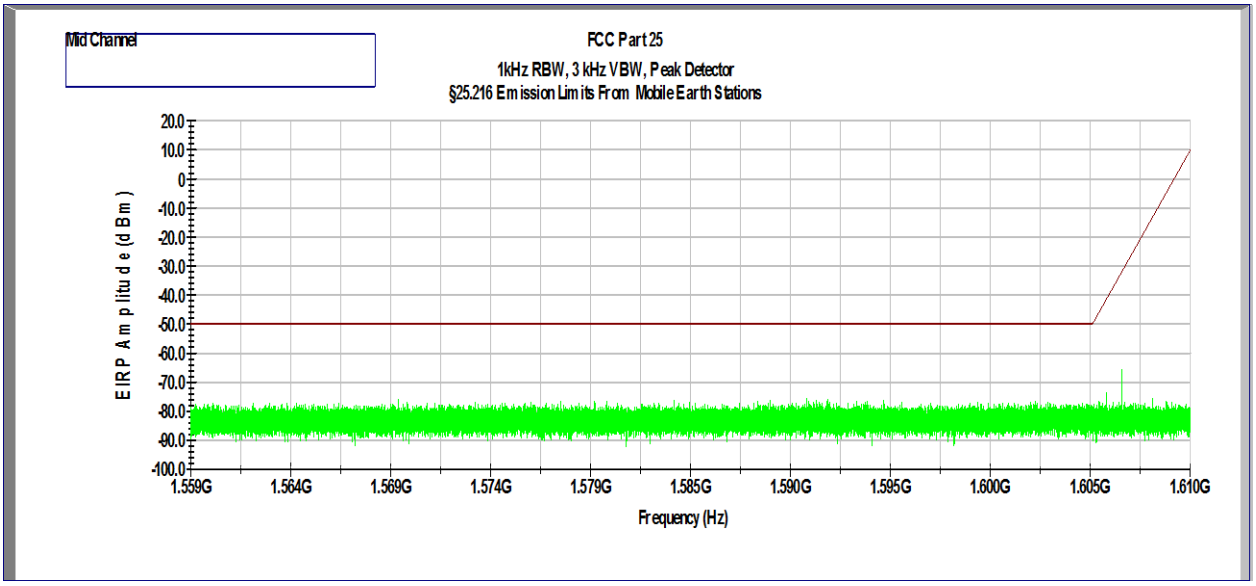
Low Channel



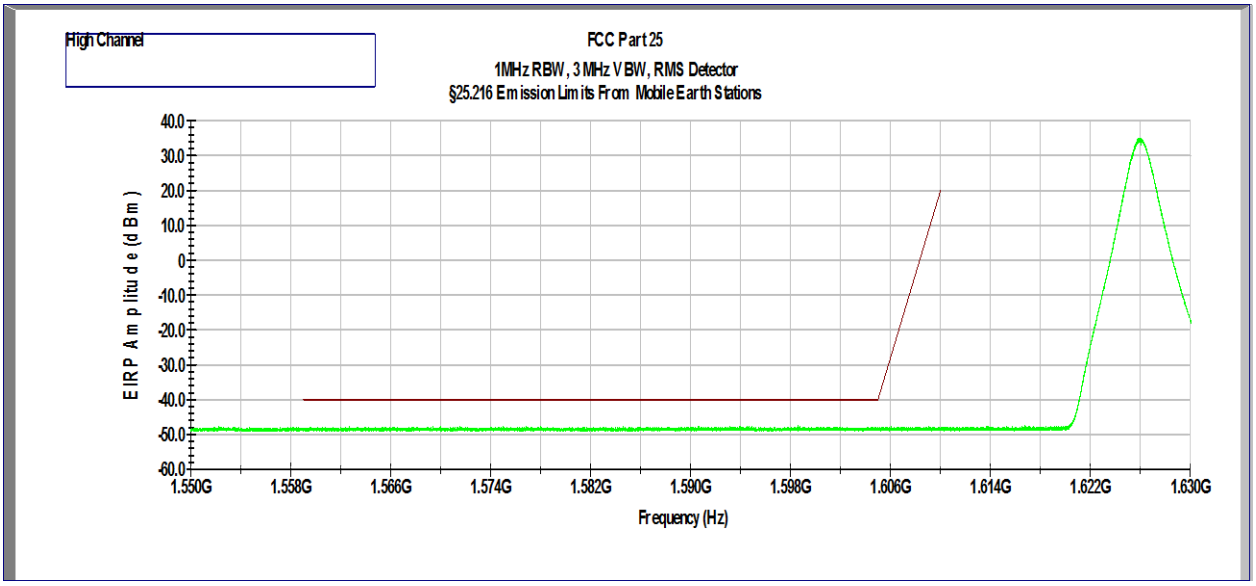


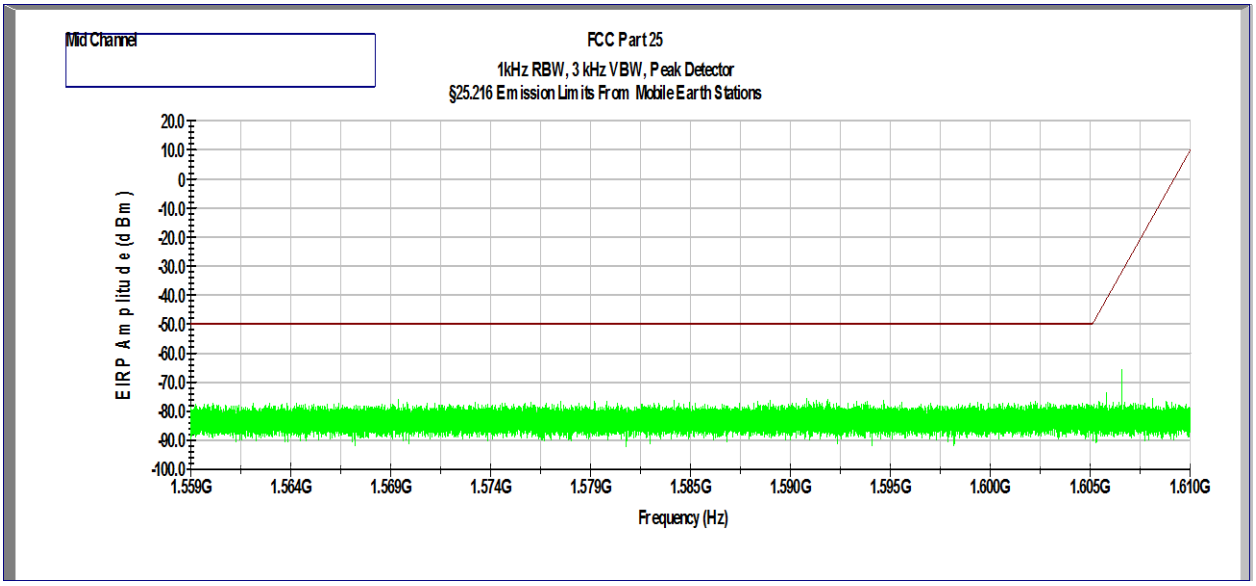
Mid Channel


Mid Channel
FCC Part 25
1MHz RBW, 3 MHz VBW, RMS Detector
§25.216 Emission Limits From Mobile Earth Stations
EIRP Amplitude (dBm)
40.0
30.0
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
1.550G
1.558G
1.566G
1.574G
1.582G
1.590G
1.598G
1.606G
1.614G
1.622G
1.630G
Frequency (Hz)

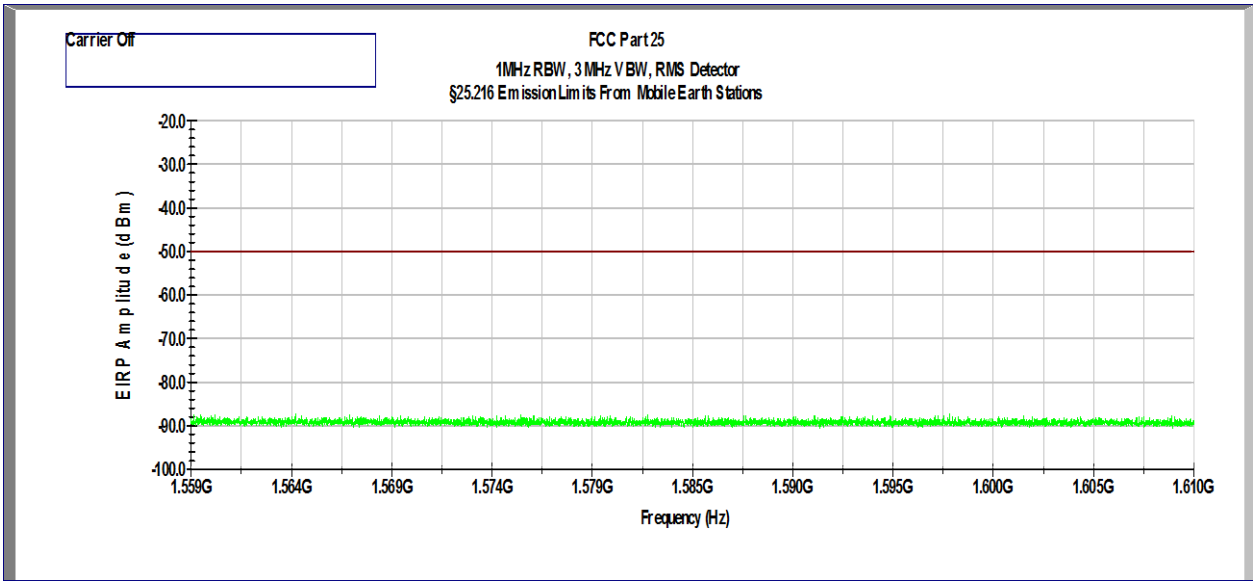

Mid Channel
FCC Part 25
1kHz RBW, 3 kHz VBW, Peak Detector
§25.216 Emission Limits From Mobile Earth Stations
EIRP Amplitude (dBm)
20.0
10.0
0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
1.559G
1.564G
1.569G
1.574G
1.579G
1.585G
1.590G
1.595G
1.600G
1.605G
1.610G
Frequency (Hz)

High Channel





Carrier off state



Results:	Complies

8.0 Frequency Stability vs Temperature and Voltage

FCC 2.1055, 25.202(d)
Industry Canada RSS-170, 5.2

8.1 Requirement

Limit Clause FCC CFR 47, 25.202(d)
Frequency tolerance, Earth stations. The carrier frequency of each earth station transmitter authorized in these services shall be maintained within 0.001 percent of the reference frequency.

Limit Clause RSS-170, 5.2
For mobile earth station equipment, the carrier frequency shall not depart from the reference frequency by more than ±10 ppm.

8.2 Test Procedure

The EUT was placed inside the temperature chamber. The RF power output was connected to frequency counter. The EUT was setup to transmit the maximum power. The EUT was set to transmit.

After the temperature stabilized for approximately 20 minutes, the transmitting frequency was measured by the frequency counter and recorded.

At the room temperature, the frequency was measured when the EUT was powered with 16VDC for temperature testing. As declared by the manufacturer, the voltage range of the EUT is 14VDC to 25VDC.

8.3 Test Results

Temperature (°C)	Frequency at nominal voltage (MHz)	Maximum deviation from frequency at 20°C, ppm	Maximum deviation from frequency at 20°C, %
Nominal Frequency: 1616.020833 MHz			
85	1616.028459	4.714	-0.000471
80	1616.028374	4.661	-0.000466
70	1616.027142	3.899	-0.000390
60	1616.022602	1.090	-0.000109
50	1616.021901	0.656	-0.000066
40	1616.020844	0.002	0.000000
30	1616.020843	0.001	0.000000
20	1616.020841	0.000	0.000000
10	1616.020743	0.061	0.000006
0	1616.019945	0.554	0.000055
-10	1616.019412	0.884	0.000088
-20	1616.015214	3.482	0.000348
-30	1616.014522	3.910	0.000391
-40	1616.013836	4.335	0.000433
Voltage (DC)	**Frequency at nominal Temperature (MHz)**	**Maximum deviation from frequency at 20°C, ppm**	**Maximum deviation from frequency at 20°C, %**
14.0	1616.020893	0.032	-0.000003
25.0	1616.020899	0.036	-0.000004

Temperature (°C)	Frequency at nominal voltage (MHz)	Maximum deviation from frequency at 20°C, ppm	Maximum deviation from frequency at 20°C, %
Nominal Frequency: 1621.020833 MHz			
85	1621.028142	4.473	-0.000447
80	1621.028014	4.394	-0.000439
70	1621.027091	3.825	-0.000382
60	1621.022091	0.740	-0.000074
50	1621.021414	0.322	-0.000032
40	1621.021040	0.092	-0.000009
30	1621.020938	0.029	-0.000003
20	1621.020891	0.000	0.000000
10	1621.020853	0.024	0.000002
0	1621.019178	1.057	0.000106
-10	1621.016382	2.782	0.000278
-20	1621.015841	3.116	0.000312
-30	1621.014814	3.749	0.000375
-40	1621.013471	4.578	0.000458
Voltage (DC)	**Frequency at nominal Temperature (MHz)**	**Maximum deviation from frequency at 20°C, ppm**	**Maximum deviation from frequency at 20°C, %**
14.0	1621.020941	0.031	-0.000003
25.0	1621.020949	0.036	-0.000004

Temperature (°C)	Frequency at nominal voltage (MHz)	Maximum deviation from frequency at 20°C, ppm	Maximum deviation from frequency at 20°C, %
Nominal Frequency: 1625.979167 MHz			
85	1625.986893	4.699	-0.000470
80	1625.986857	4.677	-0.000468
70	1625.986414	4.405	-0.000440
60	1625.985949	4.119	-0.000412
50	1625.984131	3.001	-0.000300
40	1625.981943	1.655	-0.000166
30	1625.979414	0.100	-0.000010
20	1625.979252	0.000	0.000000
10	1625.979144	0.066	0.000007
0	1625.978992	0.160	0.000016
-10	1625.978747	0.311	0.000031
-20	1625.978725	0.324	0.000032
-30	1625.973920	3.279	0.000328
-40	1625.972391	4.220	0.000422
Voltage (DC)	**Frequency at nominal Temperature (MHz)**	**Maximum deviation from frequency at 20°C, ppm**	**Maximum deviation from frequency at 20°C, %**
14.0	1625.979184	0.042	0.000004
25.0	1625.979194	0.036	0.000004

9.0 List of Test Equipment

Measurement equipment used for compliance testing utilized the equipment on the following list:

Equipment	Manufacturer	Model/Type	Asset #	Cal Int	Cal Due
EMI Receiver	Rohde and Schwarz	ESU	ITS 00961	12	06/02/16
Spectrum Analyzer	Rohde and Schwarz	FSU	ITS 00913	12	01/05/17
BI-Log Antenna	Antenna Research	LPB-2513	ITS 00355	12	08/11/16
Pre-Amplifier	Sonoma Instrument	310	ITS 00942	12	01/07/17
Horn Antenna/Preamp	EMCO	3117PA	ITS 01325	12	11/23/16
Environmental Chamber	Thermotron	F-158-CHM-15-15	ITS 01027	12	05/19/16

10.0 Document History

Revision/ Job Number	Writer Initials	Reviewer Initials	Date	Change
1.0 / G102576886	AS	KV	May 27, 2016	Original document