Testing Tomorrow's Technology

Application
For

Title 47 USC, Part 2, Subpart J, Paragraph 2.902, Equipment Authorization of Verification for an Unintentional Radiator per Part 15, Subpart B, Paragraphs 15.107 and 15.109

And

Part 2, Subpart J, Paragraph 2.907 Equipment Authorization of Certification for an Intentional Radiator per Part 15, Subpart C, paragraphs 15.207, 15.209 and 15.247

And

Innovation, Science, and Economic Development Canada
Certification Per
IC RSS-Gen General Requirements for Radio Apparatus
And
RSS-247Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices

For the

Wren

Model Number: HMG1

FCC ID: 2ARTD-HMG1
IC: 24568-HMG1

UST Project: 18-0419
Issue Date: January 23, 2019

Total Pages:54

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

I certify that I am authorized to sign for the Test Agency 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: Alan Ghasiani

Name: 

Title: Compliance Engineer – President

Date: January 23, 2019

NVLAP LAB CODE 200162-0

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

MEASUREMENT TECHNICAL REPORT

COMPANY NAME: Wren Associates, LTD.
MODEL: HMG1
FCC ID: 2ARTD-HMG1
IC: 24568-HMG1
DATE: January 23, 2019

This report concerns (check one): Original grant [X]
Class II change

Equipment type: 900 MHz Transmitter Module

Deferred grant requested per 47 CFR 0.457(d)(1)(ii)? Yes_____ No X

If yes, defer until:_____N/A_____
date
agrees to notify the Commission by N/A
date
of the intended date of announcement of the product so that the grant can be issued on that date.

Report prepared by:

US Tech
3505 Francis Circle
Alpharetta, GA 30004

Phone Number: (770) 740-0717
Fax Number: (770) 740-1508

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1 General Information

1.1 Purpose of this Report

This report is prepared as a means of conveying test results and information concerning the suitability of this exact product for public distribution according to IC RSS-247 and FCC Rules and Regulations Part 15, Section 247.

1.2 Characterization of Test Sample

The sample used for testing was received by US Tech on November 28, 2018 in good operating condition.

1.3 Product Description

The Equipment under Test (EUT) is the Wren HMG1 Module. It is a wireless module designed to be used with a multitude of host devices. The module operates in the 900 MHz ISM band and is designed to be used with two types of antennas. The antenna types are a) wired antenna, b) dipole antenna with max gain of 8 dBi.

1.4 Configuration of Tested System

The Test Sample was tested per *ANSI C63.10:2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices* for the intentional radiator aspect of the device and *ANSI C63.4:2014, Methods of Measurement of Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz (2014)* for the unintentional radiator aspect of the device as well as FCC subpart B and Cof Part 15 and per FCC KDB Publication number 558074 v05r01 for Digital Transmission Systems Operating Under section 15.247.

Digital RF conducted and radiated verification emissions data (FCC 15.107 and 109) below 1 GHz were taken with the measuring receiver (or spectrum analyzer's) resolution bandwidth adjusted to 9 kHz and 120 kHz, respectively. All measurements performed above 1.0 GHz were made with a RBW of 1 MHz. All measurements are peak unless stated otherwise. The video filter associated with the spectrum analyzer was set to 3 times the RBW or as required per the standard throughout the evaluation process.

A list of EUT and Peripherals is found in Table 1 below. A block diagram of the tested system is shown in Figure 1. Test configuration photographs for spurious and fundamental emissions are provided in separate Appendices.

1.5 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. Its designation number is 186022. Additionally this site has also been fully described and submitted to Industry Canada (IC), and has been approved under file number 9900A-1.

1.6 Related Submittal(s)/Grant(s)

The EUT is subject to the following FCC Equipment Authorizations:

a) Certification of the transmitter incorporated within the EUT, see test data presented herein.

b) Verification as a class B digital device.

Table 1. EUT and Peripherals

EUT MANUFACTURER	MODEL NUMBER	SERIAL NUMBER	FCC/IC ID	CABLES P/D
Radio Module Wren	HMG1	Engineering Sample	FCC ID: 2ARTD-HMG1 IC: 24568-HMG1	-
PERIPHERAL MANUFACTURER	**MODEL NUMBER**	**SERIAL NUMBER**	**FCC/IC ID**	**CABLES P/D**
Module Programmer for EUT	N/A	N/A	N/A	Micro USB P/D
ASUS (Laptop)	J202N	J202NA-DH01T	PPD-QCNFA425	-
ASUS (Power Supply Adapter)	AD2055320	010-8LF	Not Applicable	2.0 m UP
Antenna See antenna details	FXP70	--	--	--

S= Shielded, U= Unshielded, P= Power, D= Data

2 Tests and Measurements

2.1 Test Equipment

The table below lists test equipment used to evaluate this product.

Table 2. Test Instruments

TEST INSTRUMENT	MODEL NUMBER	MANUFACTURER	SERIAL NUMBER	CALIBRATION DUE DATE
SPECTRUM ANALYZER	E4407B	AGILENT	US41442935	8/17/2020
SPECTRUM ANALYZER	8593E	HEWLETT-PACKARD	3205A00124	10/25/2019
RF PREAMP 100 kHz to 1.3 GHz	8447D	HEWLETT-PACKARD	1937A02980	3/7/2019
PREAMP 1.0 GHz to 26.0 GHz	8449B	HEWLETT-PACKARD	3008A00480	2/28/2019
LOOP ANTENNA	SAS-200/562	A. H. Systems	142	1/22/2020 2 yr
BICONICAL ANTENNA	3110B	EMCO	9307-1431	5/2/2019 2 yr
LOG PERIODIC ANTENNA	3146	EMCO	9305-3600	5/1/2019 2 yr
HORN ANTENNA	3115	EMCO	9107-3723	11/28/2020 2 yr
HIGH PASS FILTER	VHF-1320 15542	MICROWAVE CHIRCUITS	30843	3/08/2019
LISN X 2	9247-50-TS-50-N	SOLAR ELECTRONICS	955824/ 955825	3/19/2019
POWER SUPPLY	72-7675	TENMA	0601131	Not Required

Note: The calibration interval of the above test instruments are 12 months unless stated otherwise and all calibrations are traceable to NIST/USA.
(*)= used for power line conducted emissions testing

2.2 Modifications to EUT Hardware

No modifications were made by US Tech to bring the EUT into compliance with FCC Part 15.247 or IC RSS-210 requirements.

2.3 Number of Measurements for Intentional Radiators (CFR 15.31(m), RSS-Gen 6.8)

Measurements of intentional radiators or receivers shall be performed and reported for each band in which the device can be operated, with the device operating at the number of frequencies in each band specified in Table 3 as follows:

Table 3. Number of Test Frequencies for Intentional Radiators

Frequency Range over which the device operates	Number of Frequencies	Location in the Range of operation
1 MHz or less	1	Middle
1 to 10 MHz	2	1 near the top 1 near the bottom
Greater than 10 MHz	3	1 near top 1 near middle 1 near bottom

Because the EUT operates over 905 MHz to 926 MHz, 3 test frequencies will be used.

2.4 Frequency Range of Radiated Measurements (CFR 15.33, RSS-Gen 6.13)

2.4.1 Intentional Radiator

The spectrum shall be investigated for the intentional radiator from the lowest RF signal generated in the EUT, without going below 9 kHz to the 10^{th} harmonic of the highest fundamental frequency generated or 40 GHz, whichever is the lowest.

2.4.2 Unintentional Radiator

For the digital device, an unintentional radiator, the frequency range shall be 30 MHz to 1000 MHz, or to the range specified in 2.4.1 above, whichever is the higher range of investigation.

2.5 Measurement Detector Function and Bandwidth (CFR 15.35, RSS-Gen 6.9, 6.13)

The radiated and conducted emissions limits shown herein are based on the parameters listed following.

2.5.1 Detector Function and Associated Bandwidth

On frequencies below 1000 MHz, the limits herein are based upon measurement equipment employing a CISPR Quasi-peak detector function and related measurement bandwidths (i.e. 9 kHz from 150 kHz to 30 MHz and 120 kHz from 30 MHz to 1000 MHz). Alternatively, measurements may be made with equipment employing a peak detector function as long as the same bandwidths specified for the Quasi-peak device are used.

2.5.2 Corresponding Peak and Average Requirements

Above 1000 MHz, radiated limits are based on measuring instrumentation employing an average detector function. When average radiated emissions are specified there is also a corresponding Peak requirement, as measured using a peak detector, of 20 dB greater than the average limit. For all measurements above 1000 MHz the Resolution Bandwidth shall be at least 1 MHz.

2.5.3 Pulsed Transmitter Averaging

When the radiated emissions limit is expressed as an average value, and the transmitter is pulsed, the measured field strength shall be determined by applying a Duty Cycle Correction Factor based upon dividing the total ON time during the first 100 ms period by 100 ms (or by the period if less than 100 ms). The duty cycle may also be expressed logarithmically in dB.

2.6 EUT Antenna Requirements (CFR 15.203, RSS-Gen 6.7)

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. Only the antenna(s) listed in Table 4 will be used with this module.

Table 4. Allowed Antenna(s)

REPORT REFERENCE	MANUFACTURER	TYPE OF ANTENNA	MODEL	GAIN dB_i	TYPE OF CONNECTOR
Dipole	L-com	Omni-directional dipole	HG908UP-NF	8	U.FL
Wire	Wren Solutions	Omni-directional wire	HYP-HMG1WA2	2.3	Permanently soldered to PCB

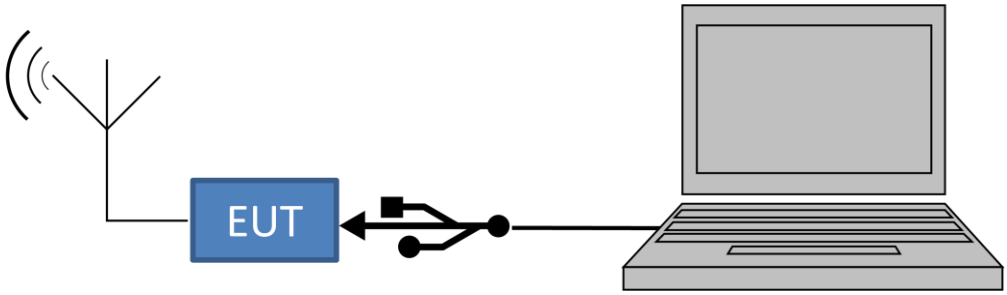


Figure 1. Block Diagram of Test Configuration

Note: The laptop is used for programming and powering the EUT.

2.7 Restricted Bands of Operation (Part 15.205, RSS-Gen 8.10)

Only spurious emissions can fall in the frequency bands of CFR 15.205. The field strength of these emissions cannot exceed the limits of 15.209. Radiated harmonics and other spurious emissions are examined for this requirement see paragraph 2.10.

2.8 Transmitter Duty Cycle (Part15.35 (c), RSS-Gen 6.10)

The EUT employs pulse transmission however for testing purpose the EUT was programmed to transmit at a rate >98%. The pulse transmission requirements of this subpart were acknowledge and considered during testing.

When the radiated emissions limit is expressed as an average value, and the transmitter is pulsed, the measured field strength shall be determined by applying a Duty Cycle Correction Factor based upon dividing the total ON time during the first 100 ms period by 100 ms (or by the period if less than 100 ms). The duty cycle may also be expressed logarithmically in dB.

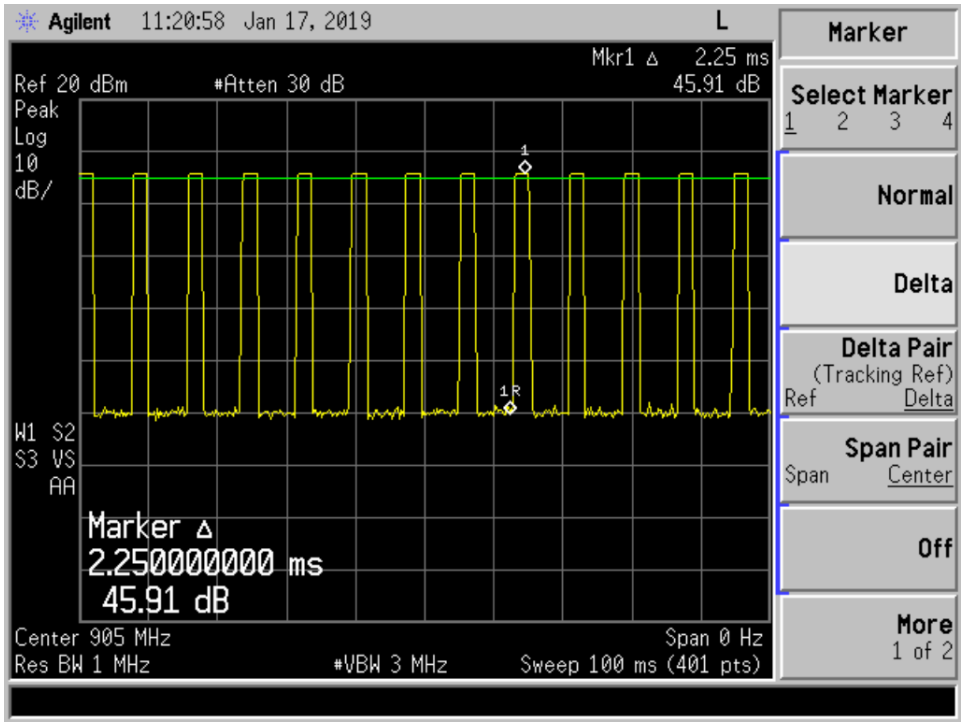


Figure 2. Duty Cycle On Time

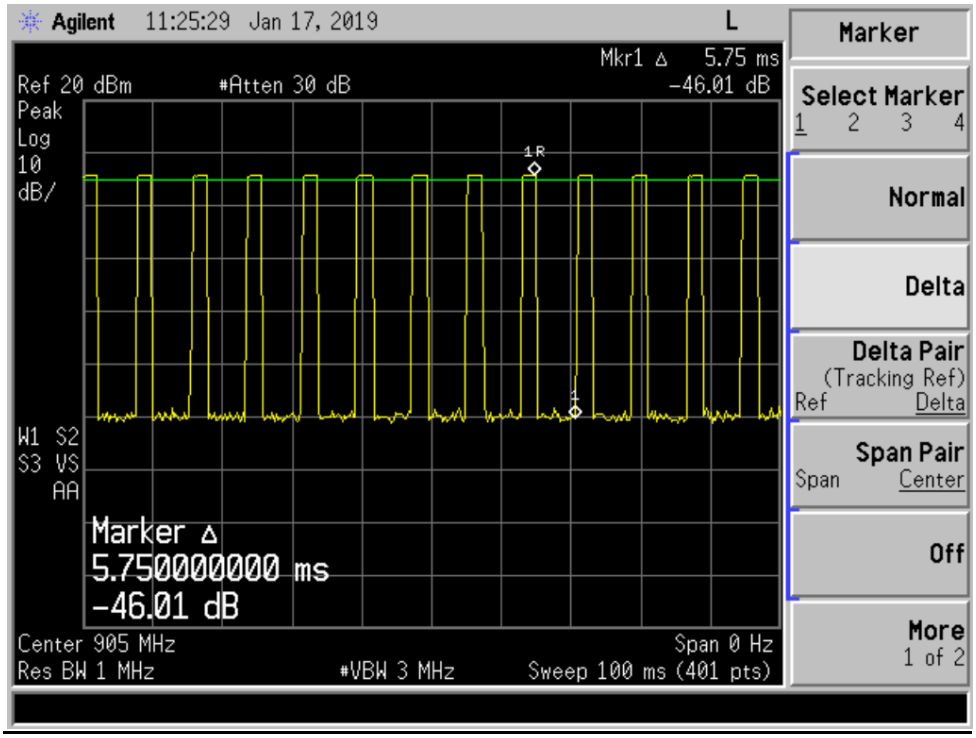


Figure 3. Duty Cycle Off Time

The duty cycle de-rating factor used in the calculation of average radiated limits per CFR 15.35(c) is described below. This factor was calculated by first determining the worst case scenario for system operation. With the worst case operating scenario the transmission duty cycle is calculated as:

2.25 mSec = ON time (Figure 2 above)
5.75 mSec = OFF time (Figure 3 above)

Duty Cycle Factor= ON time / (ON time+OFF time) = X
20 Log (X) = DC factor

2.25 mSec/ (8 mSec) = 0.28 or 28%
20 log (.28) = -11.05 dB = DC factor

2.9 Maximum Peak Conducted Output Power (CFR 15.247(b)(3), RSS-247 (5.4(d)))

For the HMG1, two transmitter configurations were programmed to operate at a maximum output power across the bandwidth. For this test the output power of the radio was set to the following highest level settings: 26 for Dipole Antenna configuration and 20 for wire antenna configuration.

Peak power within the band 905 MHz to 926 MHz was measured per FCC KDB Publication 558074 v05r01 as an Antenna Conducted test with a spectrum analyzer by connecting the spectrum analyzer directly via a short RF cable to the antenna output terminals on the EUT. The spectrum analyzer was set for an impedance of 50Ω with the RBW set greater than the 6 dB bandwidth of the EUT, and the VBW ≥ RBW.

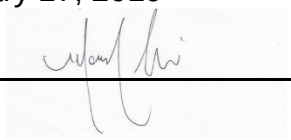
Table 5. Peak Antenna Conducted Output Power (Wire Antenna) per Part 15.247 (b)(3)

Frequency of Fundamental (MHz)	Raw Test Data dBm	Converted Data (mW)	FCC Limit (mW Maximum)
905	6.40	4.37	1000
915	6.06	4.04	1000
926	5.71	3.72	1000

Table 6. Peak Antenna Conducted Output Power (Dipole Antenna) per Part 15.247 (b)(3)

Frequency of Fundamental (MHz)	Raw Test Data dBm	Converted Data (mW)	FCC Limit (mW Maximum)
905	12.24	16.7	631
915	12.17	16.5	631
926	11.75	15.0	631

Note: the directional gain of the Dipole Antenna exceeds the requirements of CFR 15.247(b)(4) therefore the conducted output power limit has been reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi. In this case the value is 2 dB.

Test Date: January 17, 2019
Tested By
Signature:  Name: Mark Afroozi

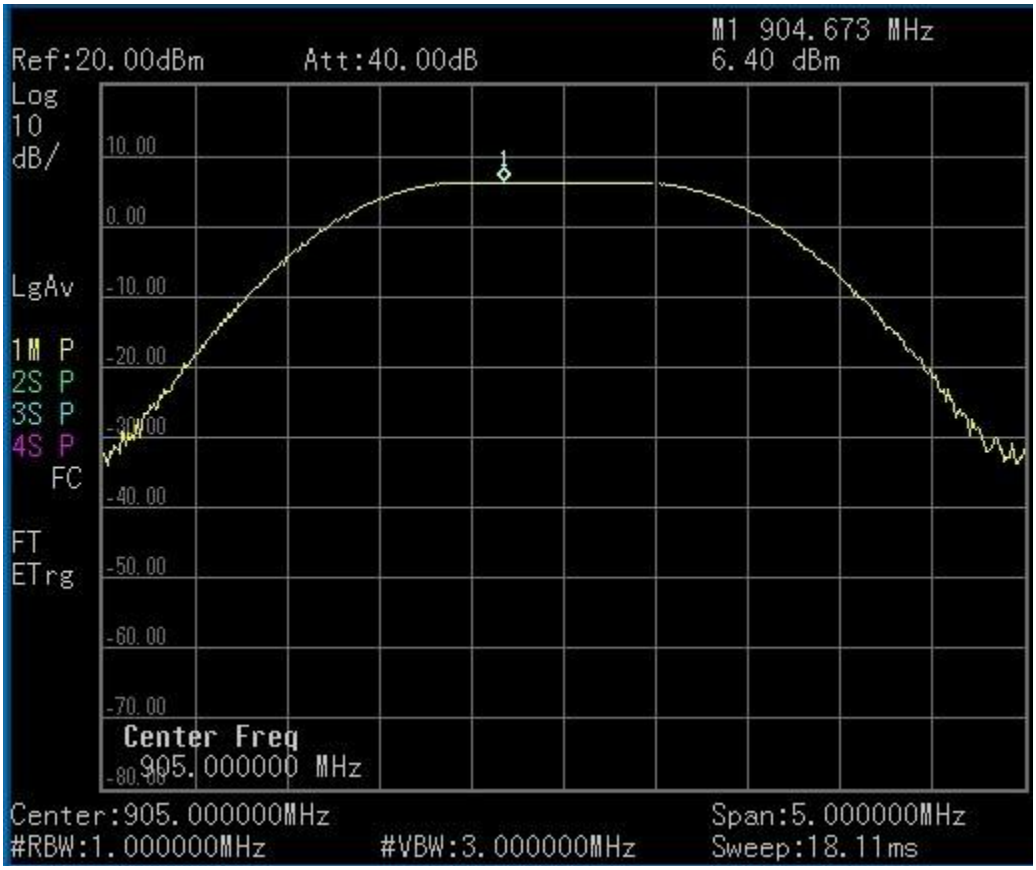


Figure 4. Peak Antenna Conducted Output Power, Low Channel (Wire Antenna)

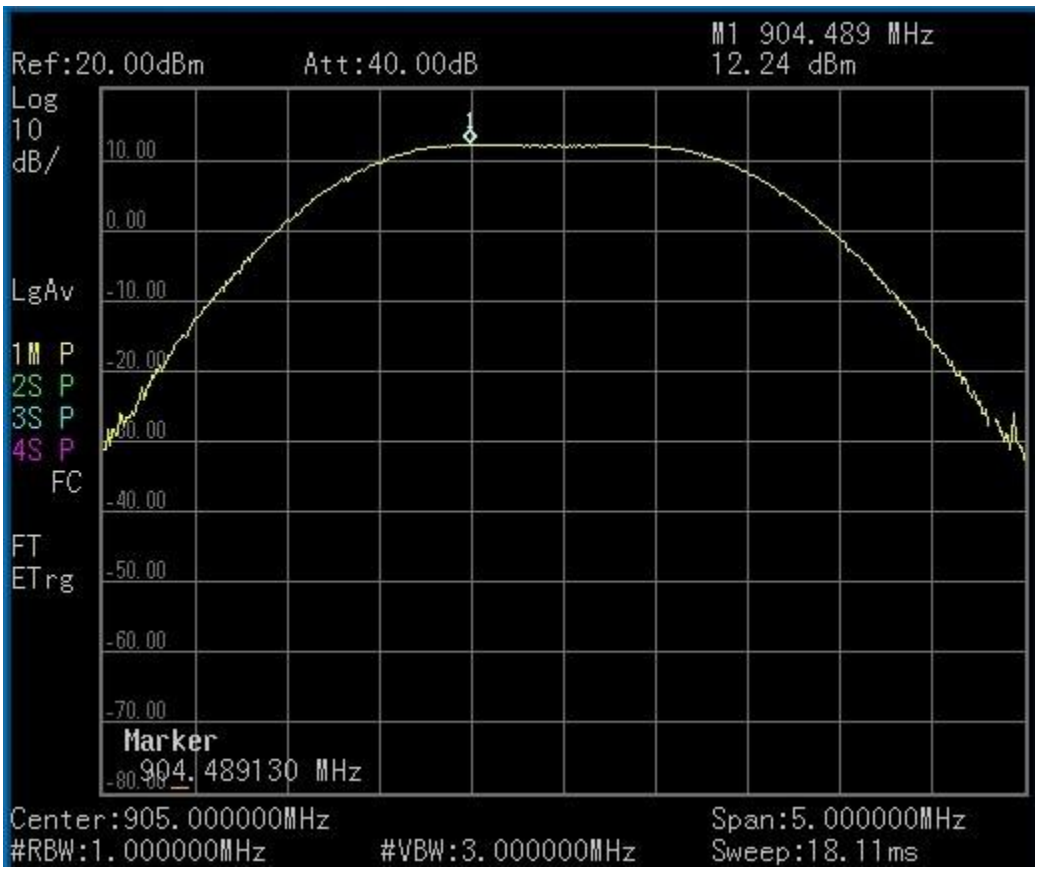


Figure 5. Peak Antenna Conducted Output Power, Low Channel (Dipole Antenna)

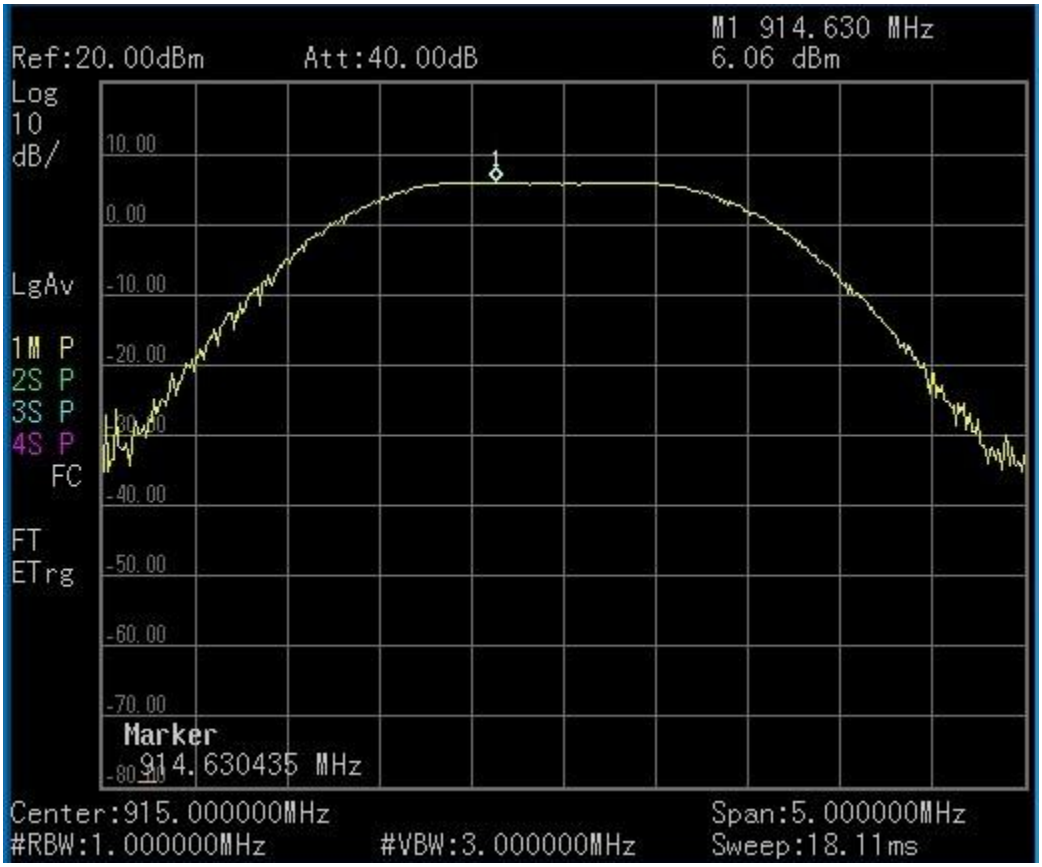


Figure 6. Peak Antenna Conducted Output Power, Mid Channel (Wire Antenna)

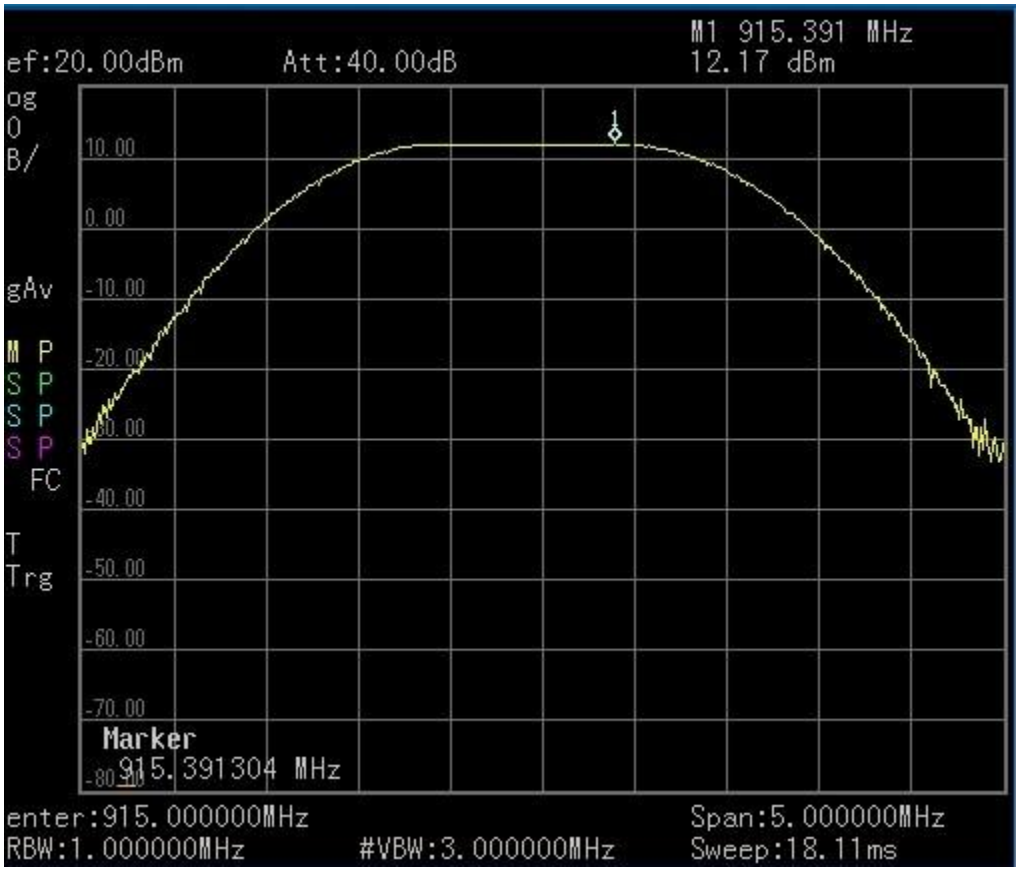


Figure 7. Peak Antenna Conducted Output Power, Mid Channel (Dipole Antenna)

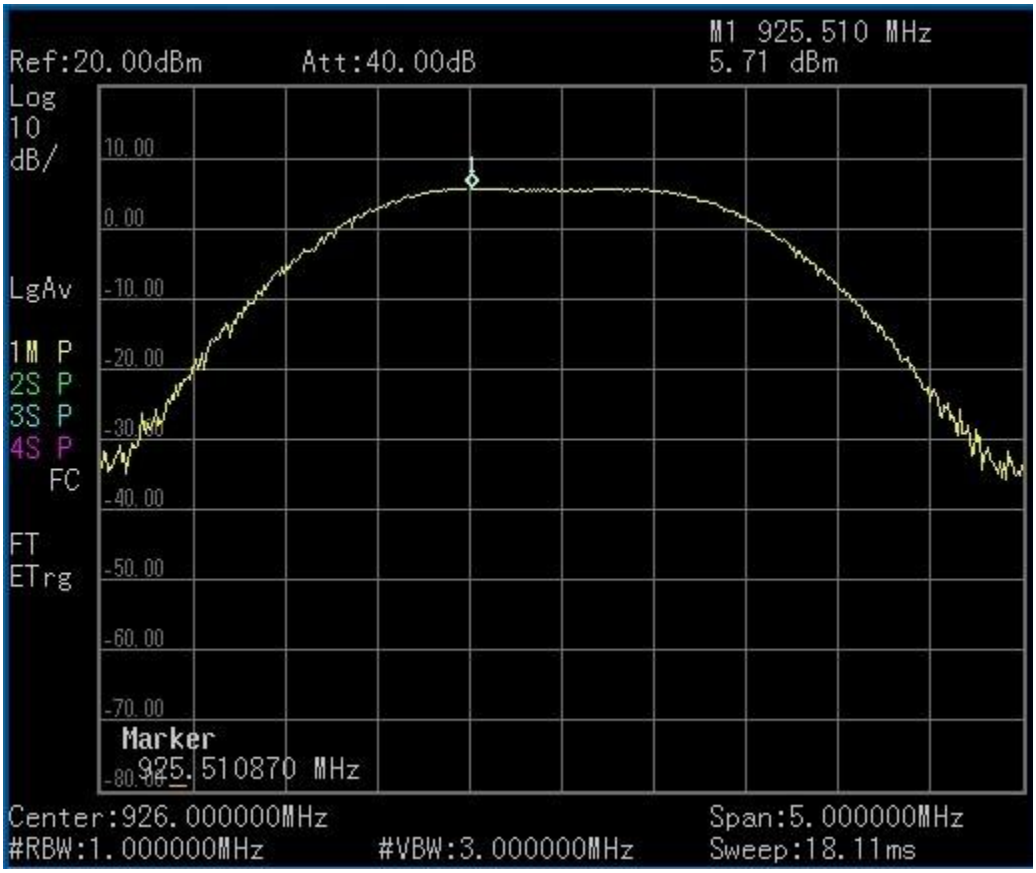


Figure 8. Peak Antenna Conducted Output Power, High Channel (Wire Antenna)

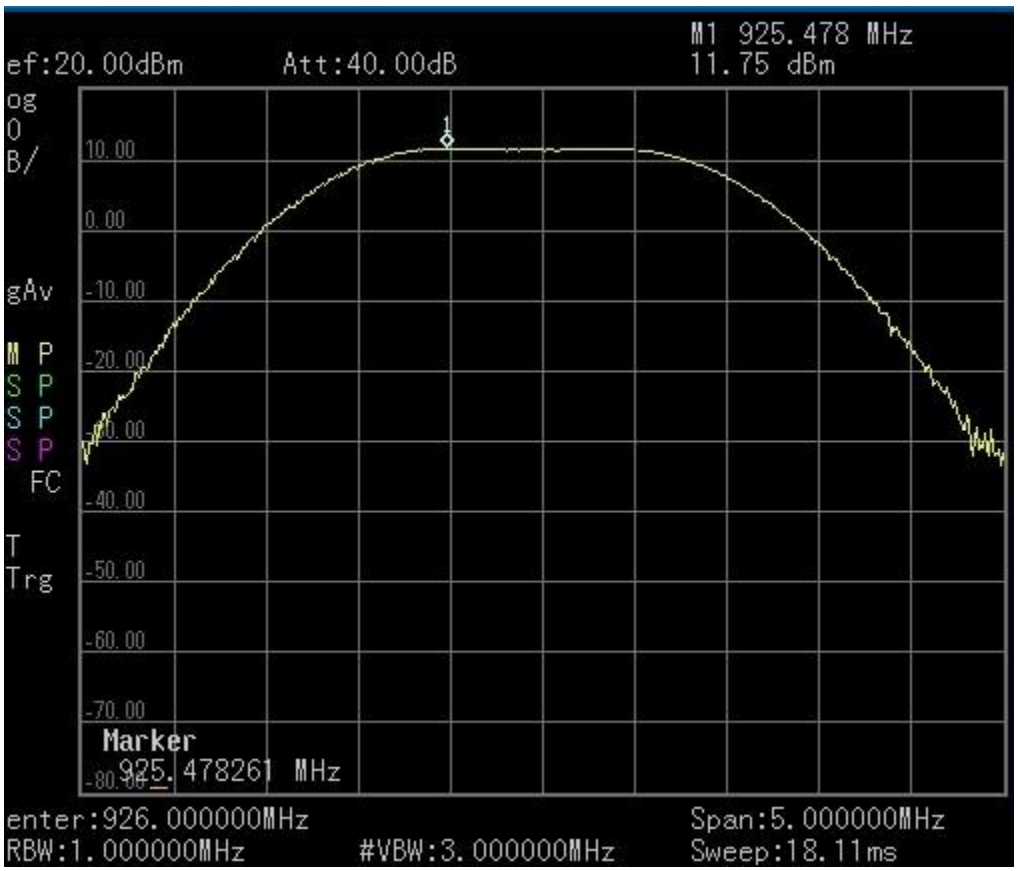


Figure 9. Peak Antenna Conducted Output Power, High Channel (Dipole Antenna)

2.10 Power Spectral Density (CFR 15.247(e), RSS-247 (5.2(b)))

The transmitter was placed into a continuous mode of operation at all applicable frequencies. The power level was set to "26", the maximum output power setting used for this radio module for this certification.

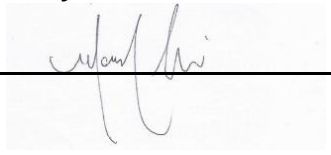
The measurements were performed per the procedures of FCC KDB Procedure 558074 v05r01. The RBW was set to 100 kHz and the Video Bandwidth was set to ≥3 x RBW.

In accordance with 15.247 (e), the power spectral density shall be no greater than +8 dBm per any 3 kHz band.

Results are shown in the table below and figures below. All are less than +8 dBm per 3 kHz band.

Table 7. Power Spectral Density for Low, Mid and High Bands

Frequency (MHz)	Results (dBm/3 kHz)	FCC Limit (dBm/3 kHz)
Wire Antenna Configuration		
905	5.446	+8.0
915	5.336	+8.0
926	5.084	+8.0
Dipole Antenna Configuration		
905	5.446	+6.0
915	5.336	+6.0
926	5.084	+6.0
Comments: For Dipole antenna the PSD limit was reduce by 2 dB. The PSD limit was met with the radio module output power value programmed to "26". This represents the max output power that the radio can be set to for operation.		

Test Date: January 17, 2019
Tested By
Signature:  Name: Mark Afroozi

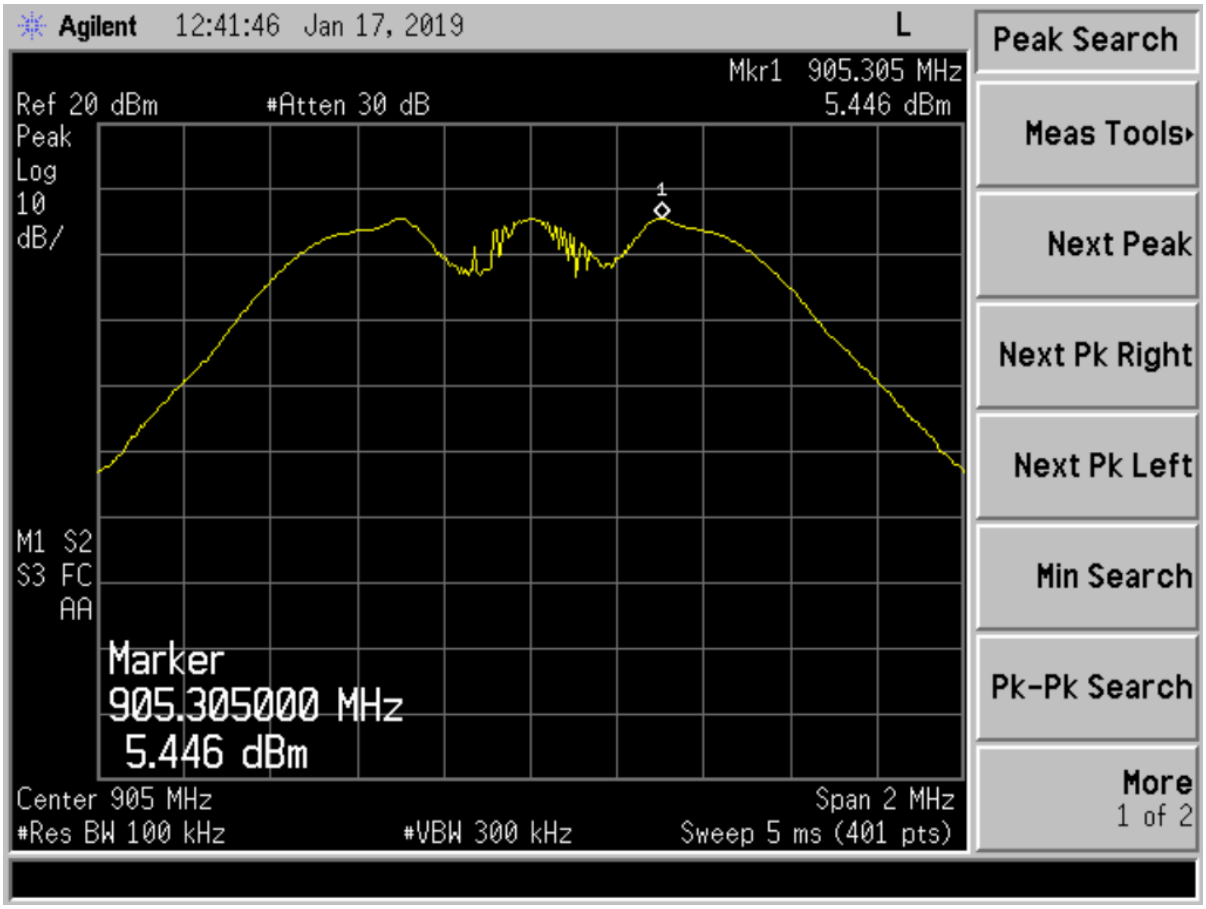


Figure 10. Power Spectral Density, Low Channel

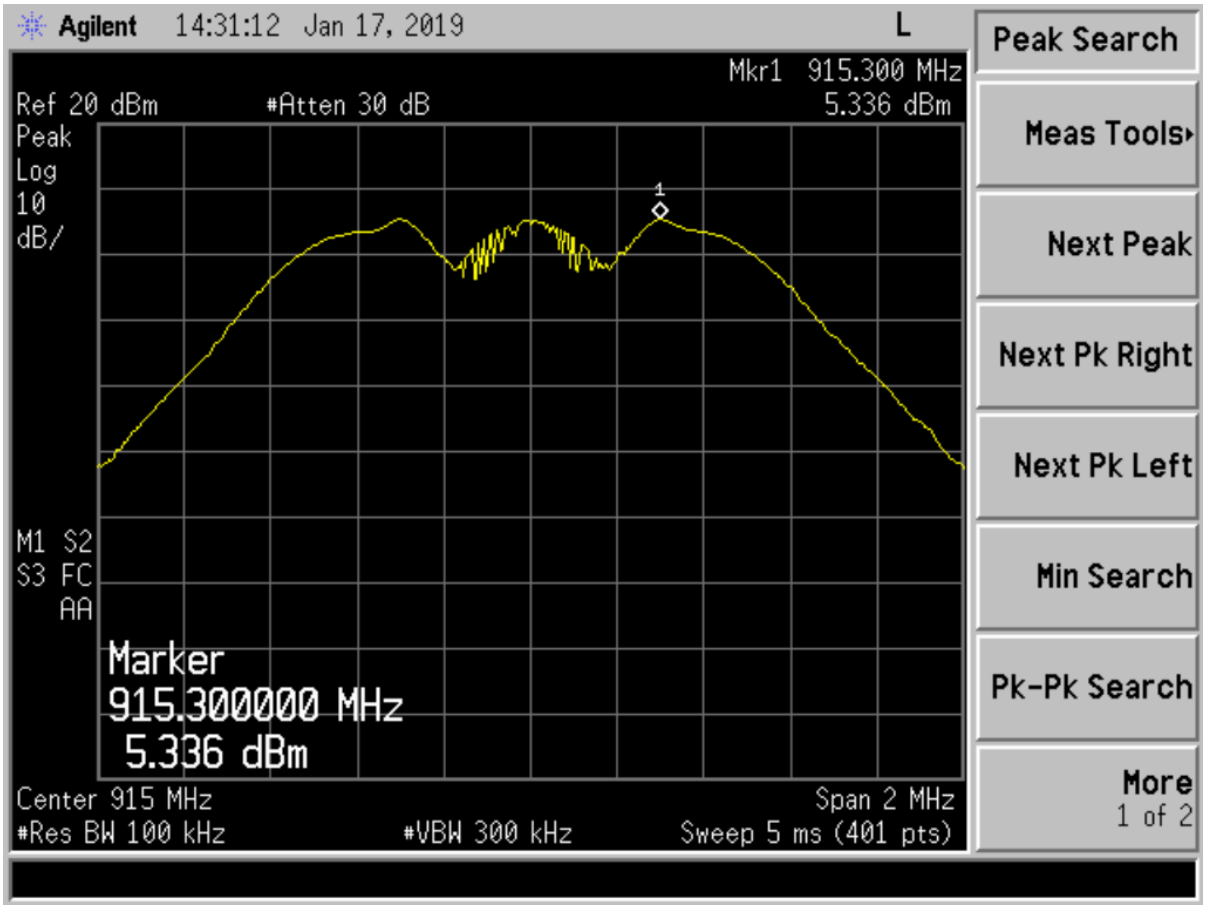


Figure 11. Power Spectral Density, Mid Channel

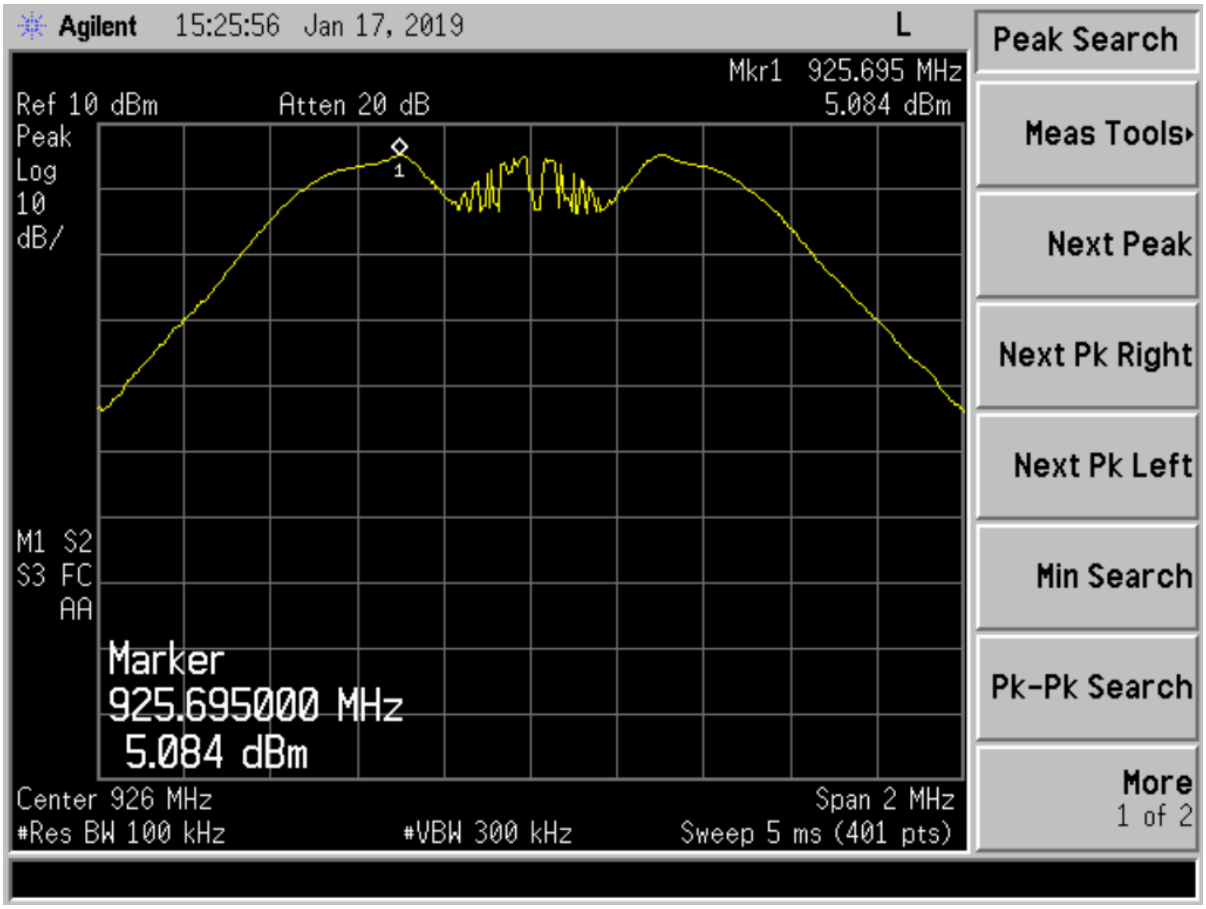


Figure 12. Power Spectral Density, High Channel

2.11 Antenna Conducted Intentional and Spurious Emissions (CFR 15.209, 15.247(d)) (RSS-247 (5.5), RSS-Gen 8.9)

The EUT was put into a continuous-transmit mode of operation and tested per FCC KDB Publication 558074v05r01 for conducted out of band emissions radiating from the antenna port over the frequency range of 30 MHz to ten times the highest clock frequency generated or used in this case, 10 GHz. A conducted scan was performed on the EUT to identify and record spurious signals that were related to the transmitter. Antenna Conducted Emissions of a significant magnitude that fell within restricted bands were then measured as radiated emissions in the semi-anechoic chamber. The conducted emissions graphs are found in Figures 3 through 8 below. The limit for antenna conducted power is 1 Watt (30 dBm) per 15.247 (b)(3).

For Conducted RF antenna conducted tests, the RBW was set to 100 kHz, video bandwidth (VBW)> RBW, scan up through the 10^{th} harmonic of the fundamental frequency. All harmonics/spurs must be at least 20 dB down from the highest emission level within the authorized band.

For radiated measurements, the EUT was set into a continuous transmission mode. Below 1 GHz, the RBW of the measuring instrument was set equal to 120 kHz. Peak measurements above 1 GHz were measured using a RBW = 1 MHz, with a VBW ≥3 x RBW. The results of peak radiated spurious emissions falling within restricted bands are given in Table 6 below.

Note: For these conducted output measurements the power level of the radio was set to “26”, the maximum output power setting used for this radio module for this certification

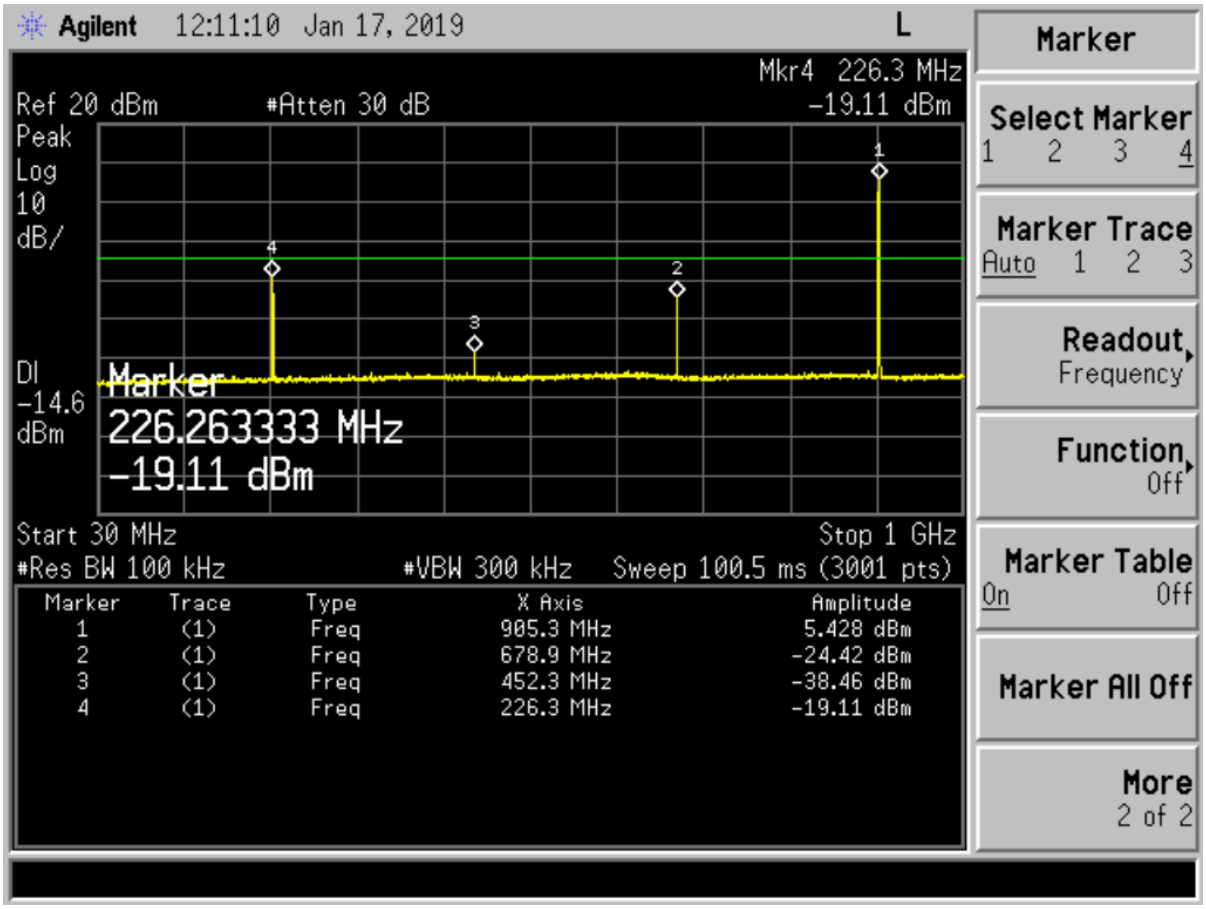


Figure 13. Conducted Spurious Emissions – Low Channel, 30 MHz – 1 GHz

Note: Large Signal shown is Fundamental Frequency

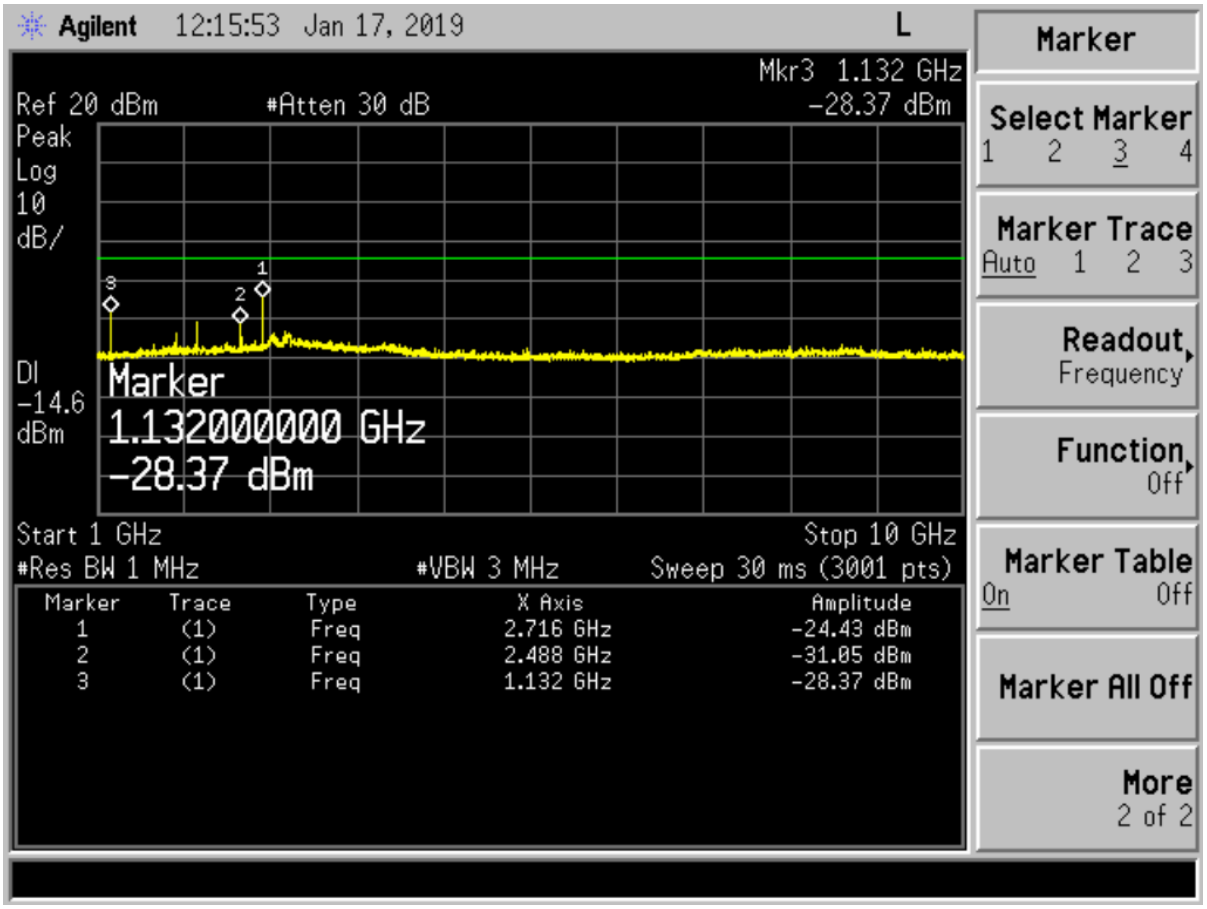


Figure 14. Conducted Spurious Emissions – Low Channel, 1 GHz - 10 GHz

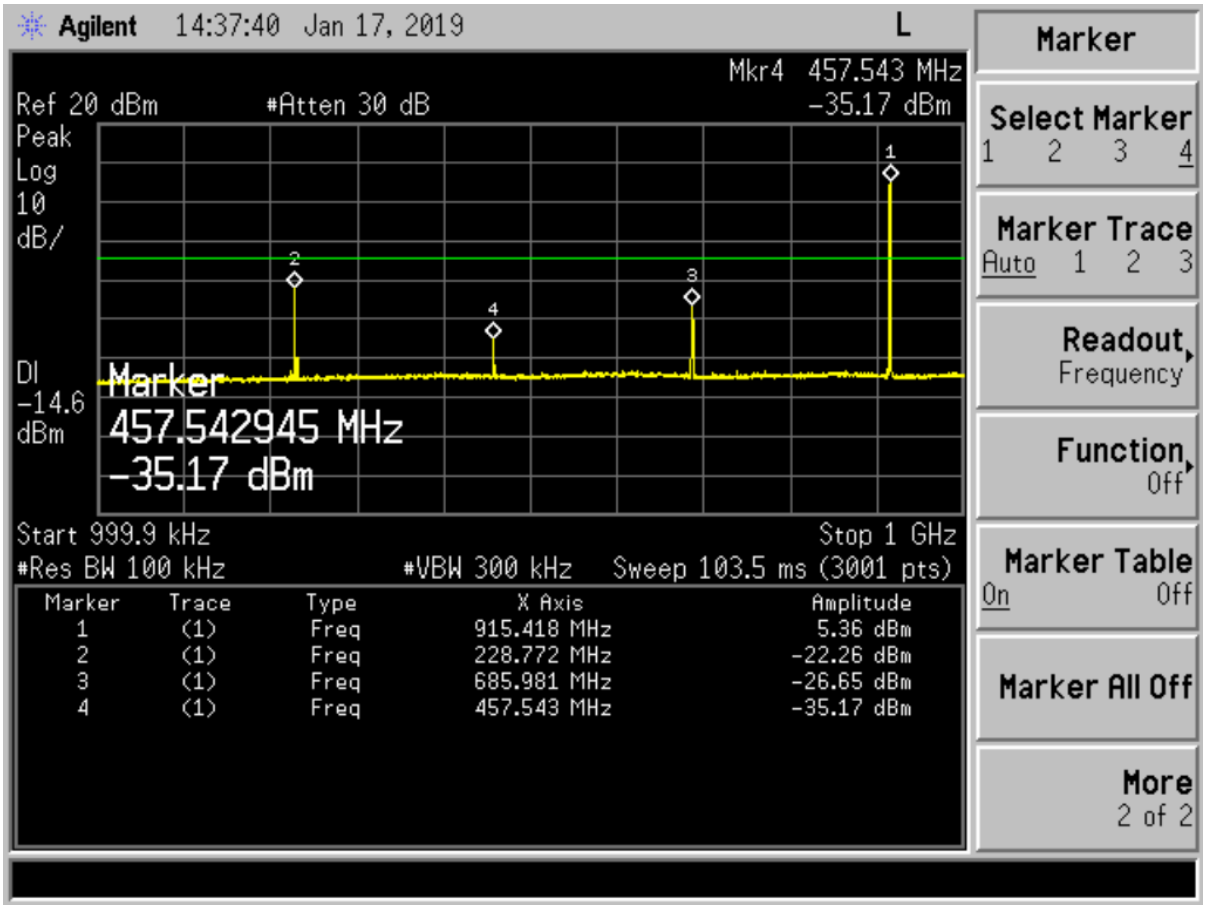


Figure 15. Conducted Spurious Emissions – Mid Channel, 30 MHz - 1 GHz

Note: Large Signal shown is Fundamental Frequency

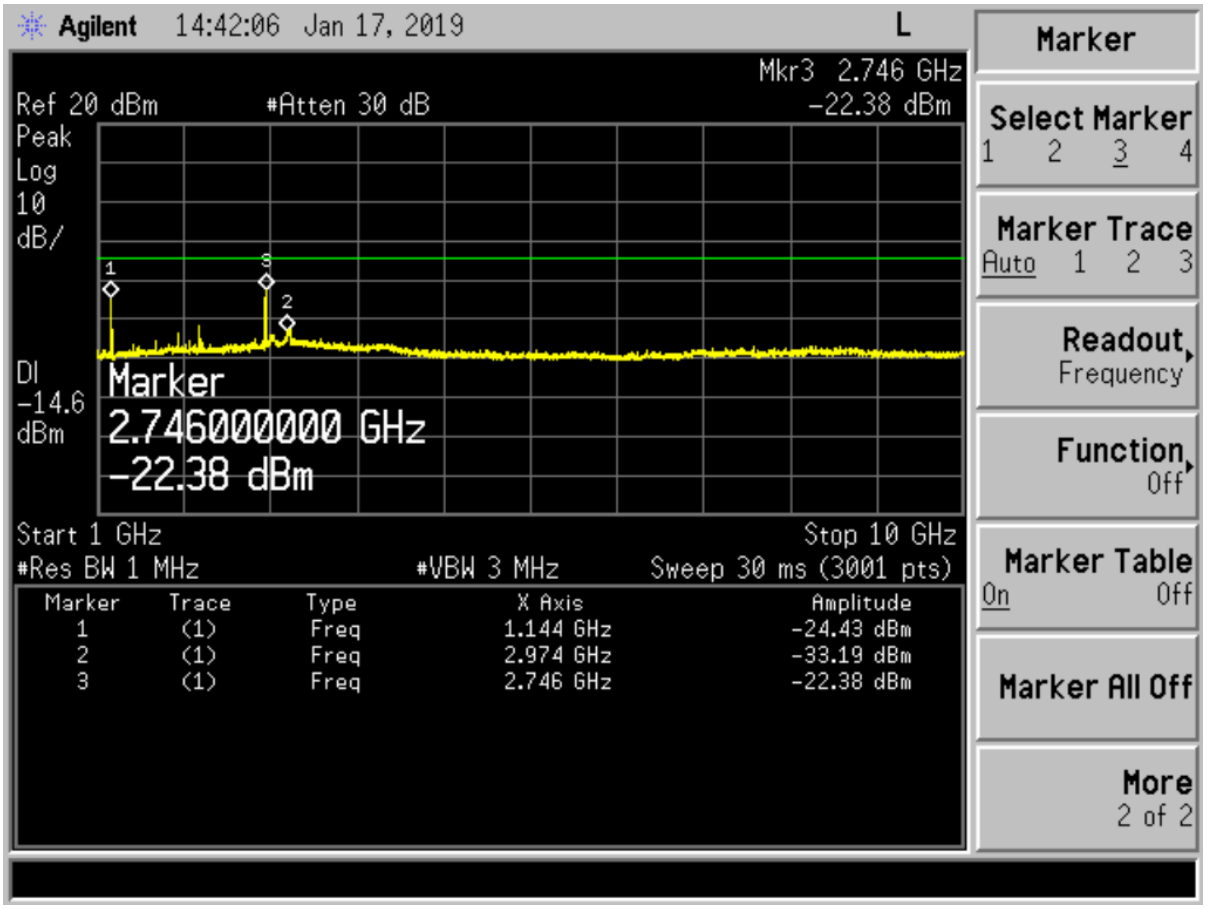


Figure 16. Conducted Spurious Emissions – Mid Channel, 1 GHz - 10 GHz

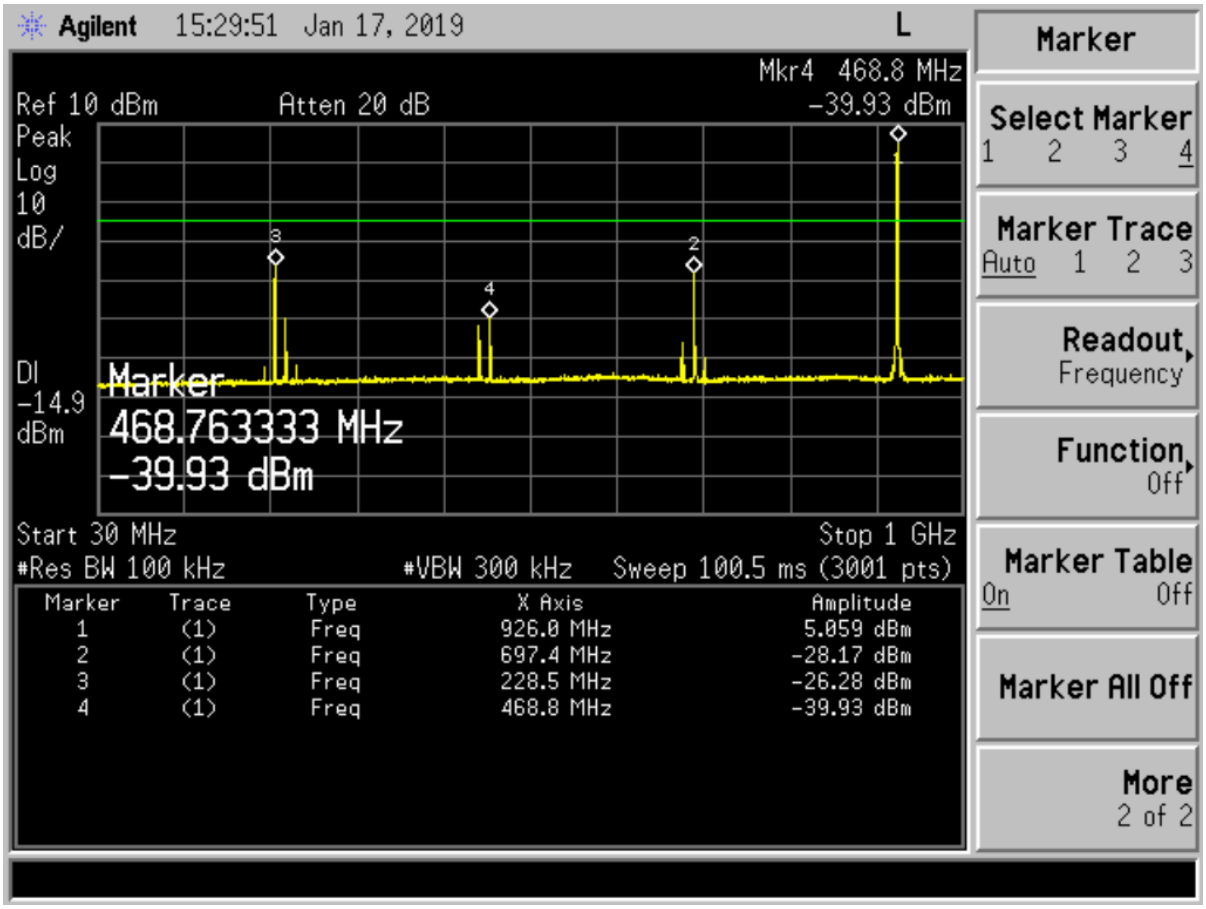


Figure 17. Conducted Spurious Emissions – High Channel, 30 MHz – 1 GHz

Note: Large Signal shown is Fundamental Frequency

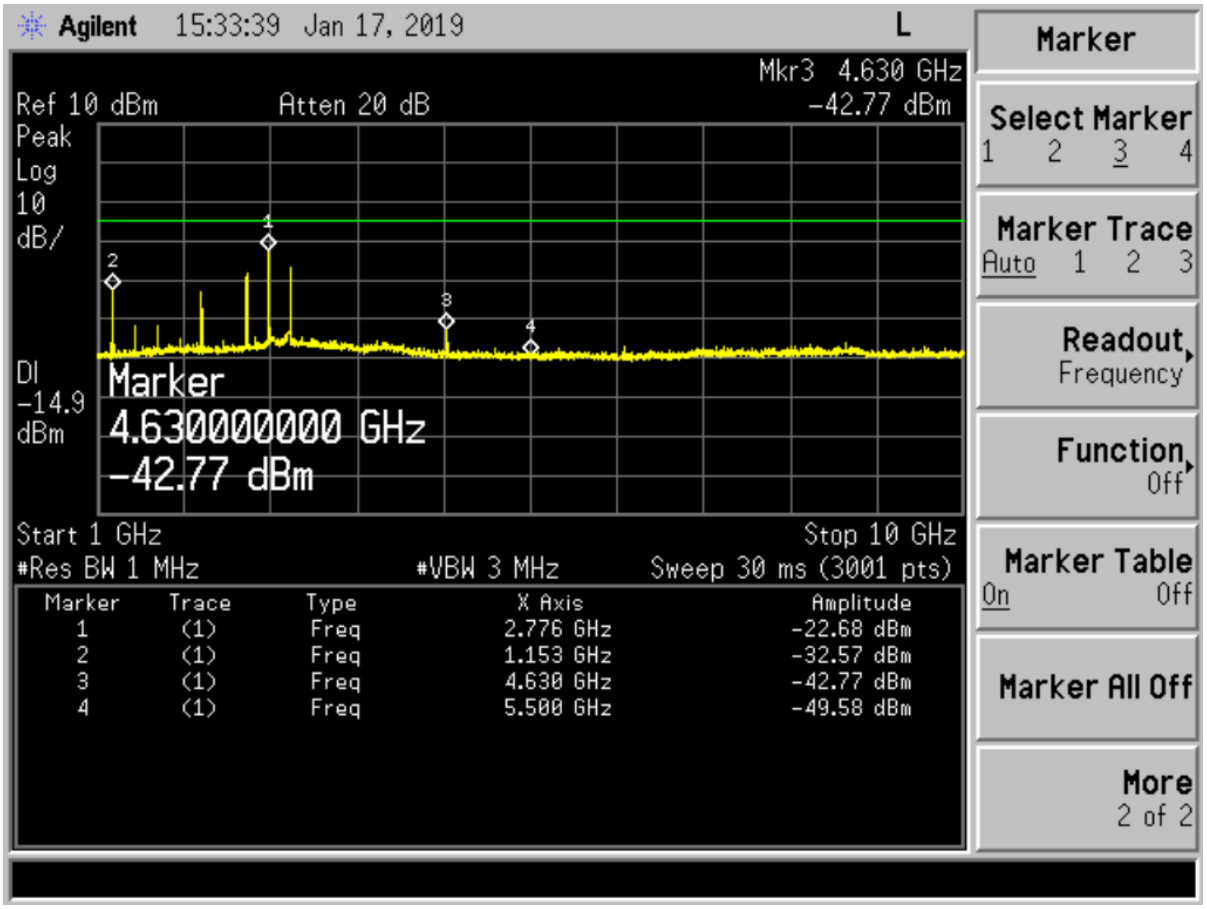


Figure 18. Conducted Spurious Emissions – High Channel, 1 GHz - 10 GHz

2.12 Intentional Radiator, Radiated Emissions (CFR 15.209, 15.247(d), RSS-247 (5.2),(5.5))

On the test site, the EUT was mounted on top of a non-conductive table, 80 cm above the floor, by placing it in the X-Z plane along the Z axis with its bottom cover in parallel with the ground. 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 Y-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.

For radiated measurements, the EUT was set into a continuous transmission mode. Below 1 GHz, the RBW of the measuring instrument was set equal to 120 kHz. Peak measurements above 1 GHz were measured using a RBW = 1 MHz, with a VBW ≥3 x RBW. The results of peak radiated spurious emissions falling within restricted bands are given in Table 5 below.

For Average measurements above 1 GHz, the emissions were measured using an average detector or the duty cycle correction factor was applied to the Peak recorded value.

Note: For this test the output power of the radio was set to the following highest level settings: 26 for Dipole Antenna configuration and 20 for wire antenna configuration.

Table 8. Peak Radiated Fundamental & Harmonic Emissions (Wired Antenna)

Tested By: MA	Test: FCC Part 15,247(d)	Client: Wren Associates, LTD.
	Project: 18-0419	Model: HMG1

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarization	Margin (dB)	Detector
Low Channel								
905.00	76.92	--	25.79	102.71	--	3.0m./HORZ	--	**PK**
2715.00	70.03	--	-2.86	67.17	74.0*	3.0m./HORZ	6.8	**PK**
7240.00	43.70	--	11.99	55.69	74.0	1.0m./HORZ	18.3	**PK**
8145.00	45.39	--	13.96	59.35	74.0*	1.0m./HORZ	14.6	**PK**
Middle Channel								
915.00	76.43	--	25.79	102.22	--	3.0m./HORZ	--	**PK**
2745.00	70.52	--	-2.79	67.73	74.0*	3.0m./HORZ	6.3	**PK**
7320.00	43.10	--	13.01	56.11	74.0*	1.0m./HORZ	17.9	**PK**
8235.00	43.56	--	13.74	57.30	74.0*	1.0m./HORZ	16.7	**PK**
High Channel								
926.00	76.30	--	25.79	102.09	--	3.0m./HORZ	--	**PK**
2778.00	70.78	--	-2.77	68.01	74.0*	3.0m./HORZ	6.0	**PK**
7408.00	45.82	--	13.13	58.95	74.0*	1.0m./HORZ	15.0	**PK**
8334.00	43.22	--	14.24	57.46	74.0*	1.0m./HORZ	16.5	**PK**

1. (*) Falls within the restricted bands of CFR 15.205. Limits based on CFR15.209& 15.247.
2. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic

Sample Calculation at 2715 MHz:

Magnitude of Measured Frequency	70.03	dBuV
+Additional Factor	0.00	dB
+Antenna Factor + Cable Loss+ Amplifier Gain	-2.86	dB/m
Corrected Result	67.17	dBuV/m

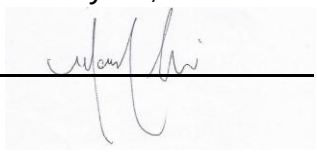
Test Date: January 11, 2019
Tested By
Signature:  Name: Mark Afroozi

Table 9. Average Radiated Fundamental & Harmonic Emissions (Wired Antenna)

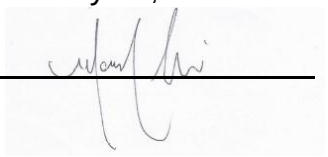
Tested By: MA	Test: FCC Part 15,247(d)	Client: Wren Associates, LTD.
	Project: 18-0419	Model: HMG1

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarization	Margin (dB)	Detector
Low Channel								
905.00	76.92	-11.05	25.79	102.71	--	3.0m./HORZ	--	**AVG**
2715.00	31.69	--	-2.86	28.83	54.0*	3.0m./HORZ	25.2	**AVG**
7240.00	28.57	--	11.99	40.56	54.0	1.0m./HORZ	13.4	**AVG**
8145.00	27.76	--	13.96	41.72	54.0*	1.0m./HORZ	12.3	**AVG**
Middle Channel								
915.00	76.43	-11.05	25.79	91.17	--	3.0m./HORZ	--	**AVG**
2745.00	32.21	--	-2.79	29.42	54.0*	3.0m./HORZ	24.6	**AVG**
7320.00	27.40	--	13.01	40.41	54.0*	1.0m./HORZ	13.6	**AVG**
8235.00	27.61	--	13.74	41.35	54.0*	1.0m./HORZ	12.6	**AVG**
High Channel								
926.00	76.30	-11.05	25.79	91.07	--	3.0m./HORZ	--	**AVG**
2778.00	32.53	--	-2.77	29.76	54.0*	3.0m./HORZ	24.2	**AVG**
7408.00	28.24	--	13.13	41.37	54.0*	1.0m./HORZ	12.6	**AVG**
8334.00	27.58	--	14.24	41.82	54.0*	1.0m./HORZ	12.2	**AVG**

1. (*) Falls within the restricted bands of CFR 15.205. Limits based on CFR15.209& 15.247.
2. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic
3. Duty Cycle correction factor of -11.05 dB applied to correct the PK values to AVG values.

Sample Calculation at 2715 MHz:

Magnitude of Measured Frequency	31.69	dBuV
+Additional Factor	0.00	dB
+Antenna Factor + Cable Loss+ Amplifier Gain	-2.86	dB/m
Corrected Result	28.83	dBuV/m

Test Date: January 11, 2019
Tested By
Signature: 

Name: Mark Afroozi

Note: The transmitter was programmed to transmit at >98% during all testing. Therefore where applicable (when using AVG detection) the duty cycle factor calculated above was applied.

Table 10. Peak Radiated Fundamental & Harmonic Emissions (Omni Antenna)

Tested By: MA	Test: FCC Part 15,247(d)	Client: Wren Associates, LTD.
	Project: 18-0419	Model: HMG1

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarization	Margin (dB)	Detector
Low Channel								
905.00	74.24	--	25.79	100.03	--	3.0m./HORZ	--	**PK**
2715.00	68.96	--	-2.86	66.10	74.0*	3.0m./HORZ	7.9	**PK**
7240.00	46.09	--	11.99	58.08	74.0	1.0m./HORZ	15.9	**PK**
8145.00	45.63	--	13.96	59.59	74.0*	1.0m./HORZ	14.4	**PK**
9050.00	44.77	--	13.48	58.25	74.0*	1.0m./HORZ	15.8	**PK**
Middle Channel								
915.00	74.38	--	25.79	100.17	--	3.0m./HORZ	--	**PK**
2745.00	72.93	--	-2.79	70.14	74.0*	3.0m./HORZ	3.9	**PK**
7320.00	46.50	--	13.01	59.51	74.0*	1.0m./HORZ	14.5	**PK**
8235.00	43.85	--	13.74	57.59	74.0*	1.0m./HORZ	16.4	**PK**
9150.00	44.85	--	13.86	58.71	74.0*	1.0m./HORZ	15.3	**PK**
High Channel								
926.00	72.43	--	25.79	98.22	--	3.0m./HORZ	--	**PK**
2778.00	74.52	--	-2.77	71.75	74.0*	3.0m./HORZ	2.3	**PK**
7408.00	48.39	--	13.13	61.52	74.0*	1.0m./HORZ	12.5	**PK**
8334.00	42.87	--	14.24	57.11	74.0*	1.0m./HORZ	16.9	**PK**
9260.00	41.93	--	14.91	56.84	78.2	1.0m./HORZ	21.4	**PK**

1. (*) Falls within the restricted bands of CFR 15.205. Limits based on CFR15.209& 15.247.
2. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic

Sample Calculation at 2715 MHz:

Magnitude of Measured Frequency	68.96	dBuV
+Additional Factor	0.00	dB
+Antenna Factor + Cable Loss+ Amplifier Gain	-2.86	dB/m
Corrected Result	66.10	dBuV/m

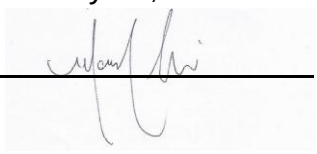
Test Date: January 10, 2019
Tested By
Signature:  Name: Mark Afroozi

Table 11. Average Radiated Fundamental & Harmonic Emissions (Omni Antenna)

Tested By: MA	Test: FCC Part 15,247(d)	Client: Wren Associates, LTD.
	Project: 18-0419	Model: HMG1

Frequency (MHz)	Test Data (dBuV)	Additional Factor	AF+CL-PA (dB/m)	Corrected Results (dBuV/m)	Limits (dBuV/m)	Distance / Polarization	Margin (dB)	Detector
Low Channel								
905.00	74.24	-11.05	25.79	88.98	--	3.0m./HORZ	--	**AVG**
2715.00	31.90	--	-2.86	29.04	54.0*	3.0m./HORZ	25.0	**AVG**
7240.00	27.56	--	11.99	39.55	54.0	1.0m./HORZ	14.4	**AVG**
8145.00	27.33	--	13.96	41.29	54.0*	1.0m./HORZ	12.7	**AVG**
9050.00	28.84	--	13.48	42.32	54.0*	1.0m./HORZ	11.7	**AVG**
Middle Channel								
915.00	74.38	-11.05	25.79	89.12	--	3.0m./HORZ	--	**AVG**
2745.00	32.53	--	-2.79	29.74	54.0*	3.0m./HORZ	24.3	**AVG**
7320.00	28.18	--	13.01	41.19	54.0*	1.0m./HORZ	12.8	**AVG**
8235.00	27.99	--	13.74	41.73	54.0*	1.0m./HORZ	12.3	**AVG**
9150.00	29.27	--	13.86	43.13	54.0*	1.0m./HORZ	10.9	**AVG**
High Channel								
926.00	72.43	-11.05	25.79	87.17	--	3.0m./HORZ	--	**AVG**
2778.00	31.63	--	-2.77	28.86	54.0*	3.0m./HORZ	25.1	**AVG**
7408.00	28.08	--	13.13	41.21	54.0*	1.0m./HORZ	12.8	**AVG**
8334.00	28.08	--	14.24	42.32	54.0*	1.0m./HORZ	11.7	**AVG**
9260.00	26.98	--	14.91	41.89	54.0	1.0m./HORZ	12.1	**AVG**

1. (*) Falls within the restricted bands of CFR 15.205. Limits based on CFR15.209& 15.247.
2. No other signals detected within 20 dB of specification limit. Harmonics investigated up to the 10th harmonic
3. Duty Cycle correction factor of -11.05 dB applied to correct the PK values to AVG values.

Sample Calculation at 2715 MHz:

Magnitude of Measured Frequency	31.90	dBuV
+Additional Factor	0.00	dB
+Antenna Factor + Cable Loss+ Amplifier Gain	-2.86	dB/m
Corrected Result	29.04	dBuV/m

Test Date: January 10, 2019
Tested By
Signature: _____ Name: Mark Afroozi

Note: The transmitter was programmed to transmit at >98% during all testing. Therefore where applicable (when using AVG detection) the duty cycle factor calculated above was applied.

2.13 Band Edge Measurements – (CFR 15.247(d), RSS-Gen 8.10)

Band Edge measurements are made following the guidelines in FCC KDB Publication No. 558074 v05r01 with the EUT initially operating on the Lowest Channel and then operating on the Highest Channel within its band of operation. Antenna port conducted measurements are performed to demonstrate compliance with the requirement of 15.247(d) that all emissions outside of the band edges be attenuated by at least 20 dB when compared to its highest in-band value (contained in a 100 kHz band).

To capture the band edge set the Spectrum Analyzer frequency span large enough (usually around 10 MHz) to capture the peak level of the emission operating on the channel closest to the band edge as well as any modulation products falling outside of the authorized band of operation. Conducted measurements are performed with RBW ≥1% of the frequency span. In all cases, the VBW is set ≥3 x RBW. See figures and calculations below for more detail.

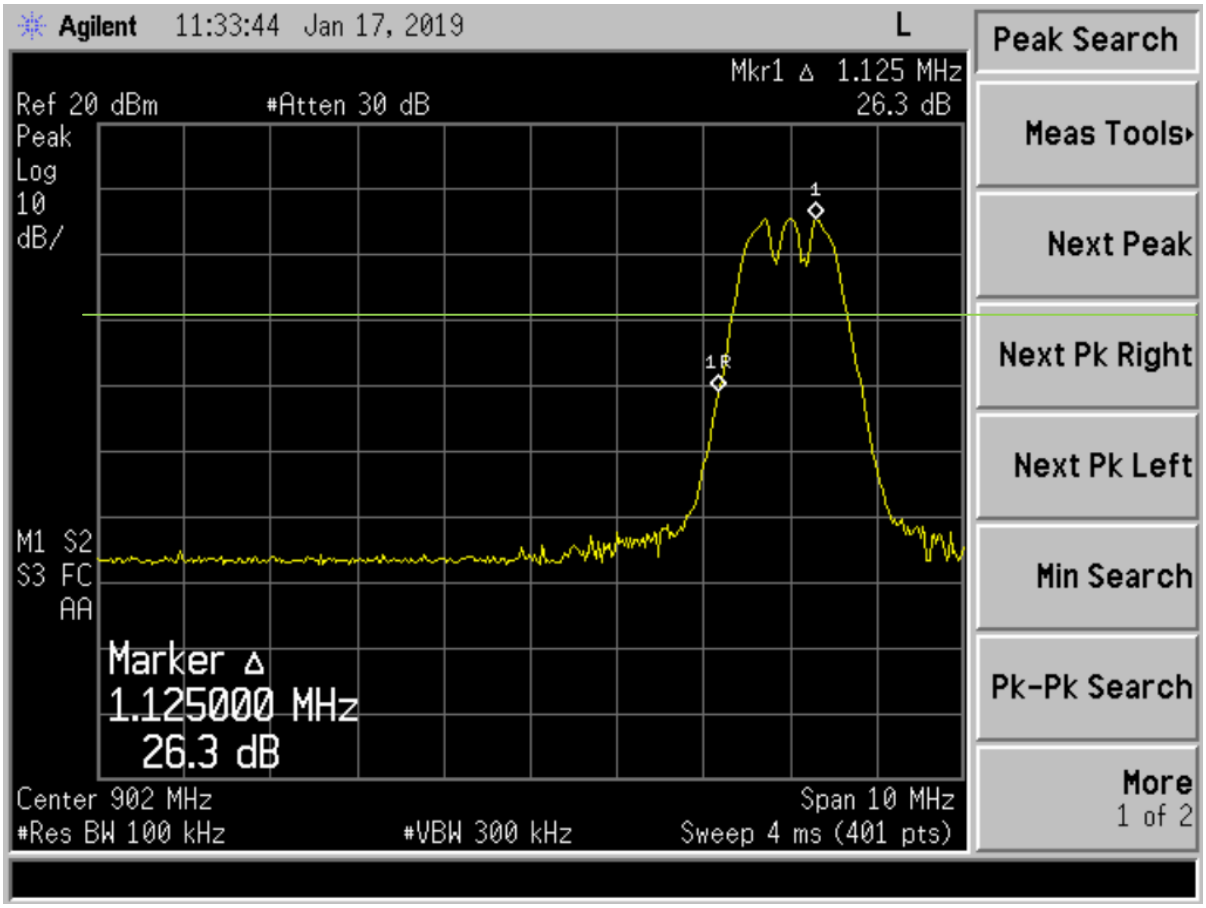


Figure 19. Band Edge Compliance – Low Channel Delta - Peak

Lower band edge must be 20 dB below the fundamental. This requirement is met.

Measured Result	26.30	dB
Band Edge Limit	20.00	dB
Band Edge Margin	6.30	dB

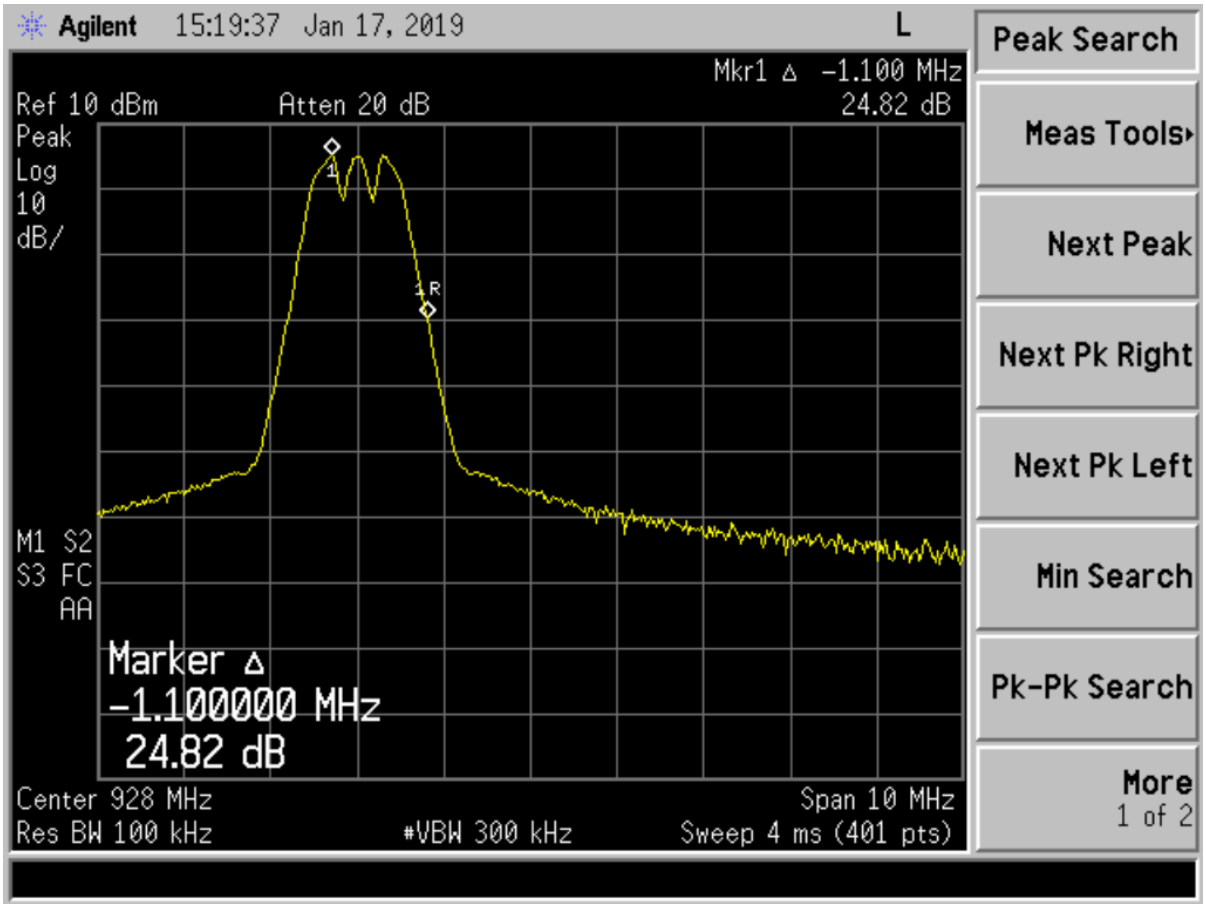


Figure 20. Band Edge Compliance – High Channel Delta - Peak

Higher band edge must be 20 dB below the fundamental. This requirement is met.

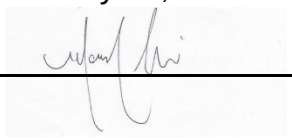
Measured Result	24.82	dB
Band Edge Limit	20.00	dB
Band Edge Margin	4.82	dB

2.14 Six (6) dB Bandwidth (CFR 15.247(a)(2), RSS-247 (5.2(a)))

The EUT antenna port was connected to a spectrum analyzer having a 50 Ω input impedance. Measurements were performed similar to the method of FCC, KDB Publication No. 558074 v05r01 for a bandwidth of 6 dB. The RBW was set to approximately 1/100 of the manufacturers claimed RBW and with the VBW ≥ RBW. The results of this test are given in the table below and figures below.

Table 12. Six (6) dB Bandwidth

Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum FCC Bandwidth (MHz)
905	1.2655	0.5
915	1.2879	0.5
926	1.2705	0.5

Test Date: January 17, 2019
Tested By
Signature:  Name: Mark Afroozi

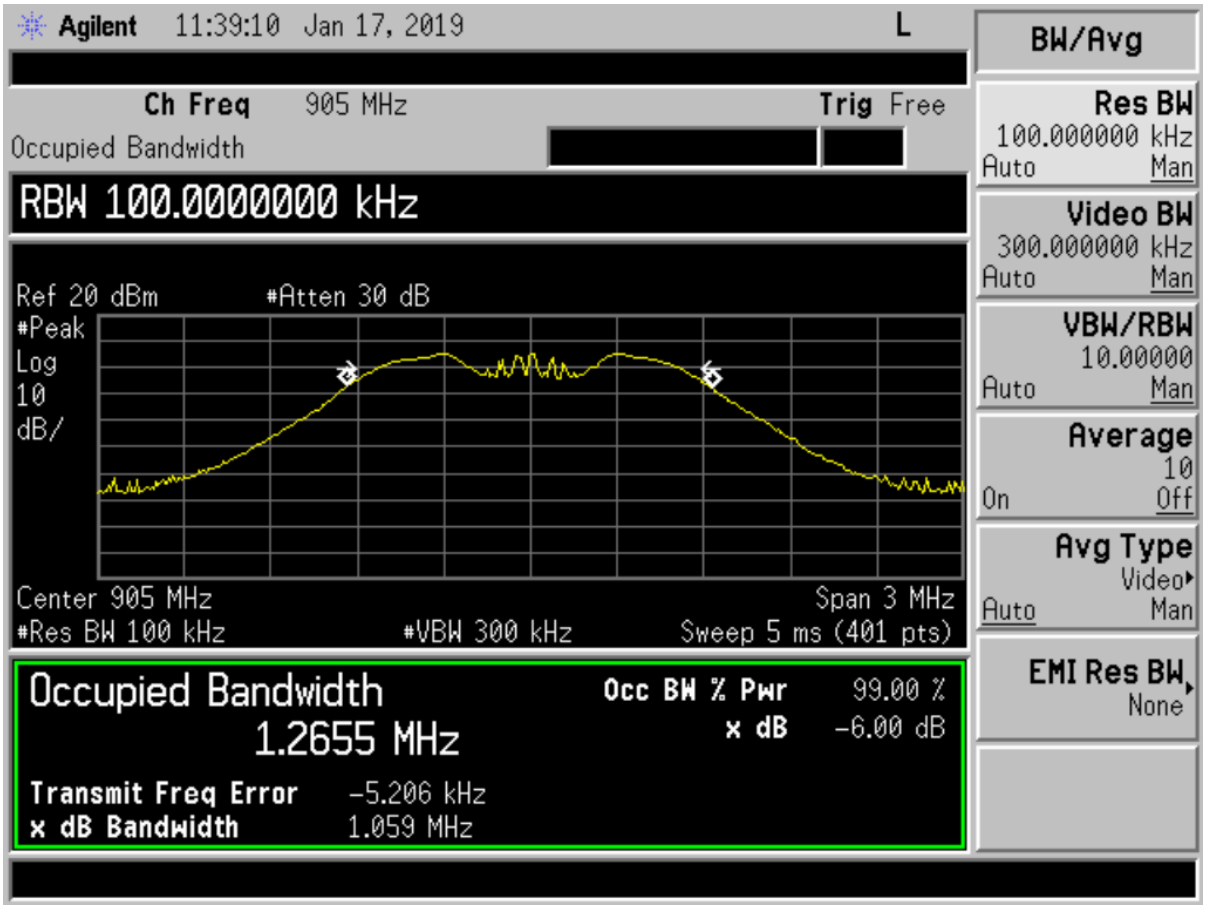


Figure 21. 6 dB Bandwidth Low Channel

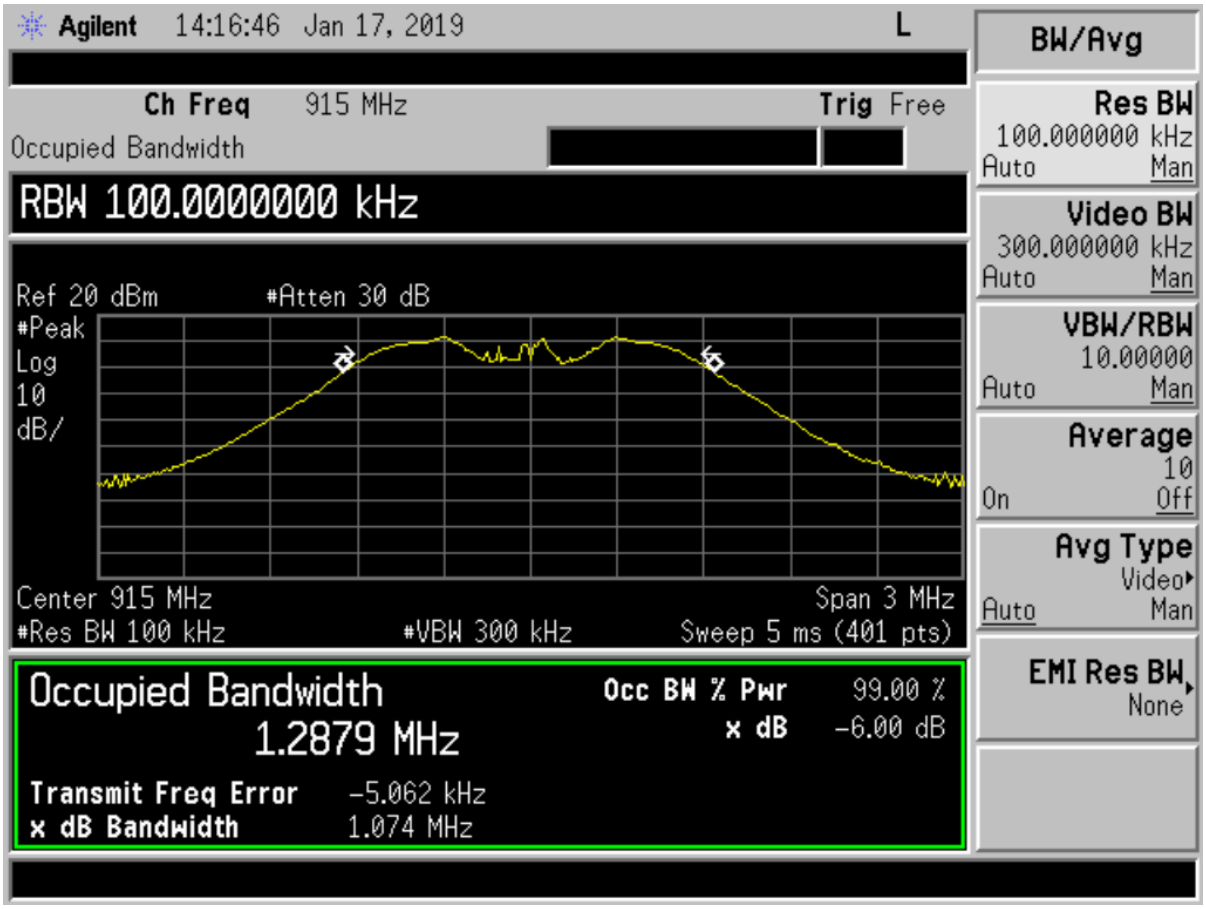


Figure 22. 6 dB Bandwidth Mid Channel

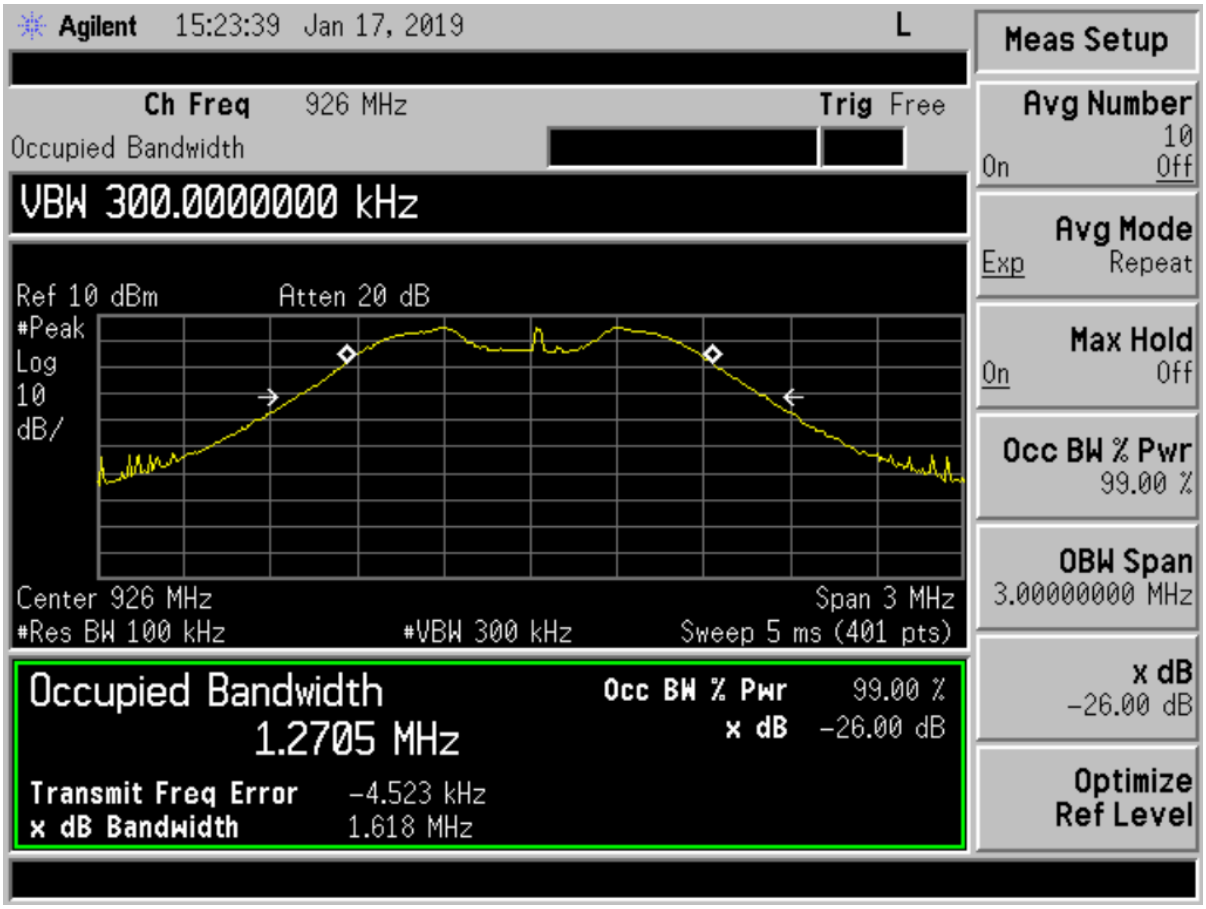


Figure 23. 6 dB Bandwidth High Channel

2.15 99% Occupied Bandwidth (RSS-GEN (6.6))

The EUT antenna port was connected to a spectrum analyzer having a 50Ω input impedance. Measurements were performed similar to the method of FCC, KDB Publication No. 558074 v05r01 for a bandwidth of 20 dB. The RBW was set to approximately 1/100 of the manufacturers claimed RBW and with the VBW ≥ RBW. The results of this test are given in the table below and figures below.

Table 13. 99% Occupied Bandwidth

Frequency (MHz)	(99%) Occupied Bandwidth (MHz)
905	1.266
915	1.288
926	1.271

Test Date: January 17, 2019
Tested By
Signature: _____ Name: Mark Afroozi

2.16 Unintentional Radiator and Intentional Radiator Power Lines Conducted Emissions (CFR 15.107, 15.207, RSS-Gen 8.8)

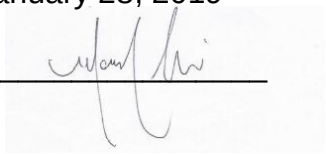
The test data provided in this section is to support the Verification requirement for the digital apparatus. The power line conducted voltage measurements for Receiver and Digital Devices have been carried out in accordance with CFR 15.107 and ANSI C63.4:2014, Paragraph 7, with a spectrum analyzer connected to a LISN and the EUT placed into an idle condition or a continuous mode of receive (non-transmitting). Please refer to the results as shown in the table below.

The power line conducted voltage emission measurements have been carried out in accordance with CFR 15.207, per ANSI C63.10:2013, Clause 6.2, with a spectrum analyzer connected to an LISN and the EUT placed into a continuous mode of transmission.

The worst-case results for conducted emissions were determined to be produced when the EUT was operating under continuous transmission. The worst case measurement was 6.9 dB from the applicable limit. All other emissions were at least 9.3 dB from the limit. Those results are given in the table below.

Table 14. Power Line Conducted Emissions

CONDUCTED EMISSIONS 150 kHz to 30 MHz						
Tested By: M. Afroozi	Specification Requirement: FCC Part 15.207		Project No.: 18-0419	Manufacturer: Wren Associates, LTD. Model: HMG1		
Frequency (MHz)	**Test Data (dBuV)**	**LISN+CL (dB)**	**Corrected Results (dBuV)**	**Limits (dBuV)**	**Margin (dB)**	**Detector**
Phase @ 120VAC/60Hz						
0.1868	32.25	0.38	32.63	54.2	21.6	**AVG**
0.5363	26.08	0.15	26.23	46.0	19.8	**AVG**
1.19	38.97	0.14	39.11	46.0	6.9	**QP**
6.45	34.56	0.28	34.84	50.0	15.2	**QP**
13.45	37.54	0.57	38.11	50.0	11.9	**QP**
24.25	40.00	0.73	40.73	50.0	9.3	**QP**
Neutral @ 120VAC/60Hz						
0.1868	36.98	0.35	37.33	54.2	16.9	**AVG**
0.5213	27.13	0.14	27.27	46.0	18.7	**AVG**
1.31	36.34	0.14	36.48	46.0	9.5	**QP**
10	39.71	0.35	40.06	50.0	9.9	**PK**
12.93	41.22	0.49	41.71	50.0	8.3	**PK**
26.23	35.46	0.81	36.27	50.0	13.7	**PK**

Test Date: January 28, 2019
Tested By
Signature: 

Name: Mark Afroozi

2.17 Unintentional Radiator and Intentional Radiator, Radiated Emissions (CFR 15.109, 15.209, RSS-Gen 8.9)

The test data provided herein is to support the verification requirement for radiated emissions coming from the EUT in a transmitting state per 15.209 and were investigated from 9kHz or the lowest operating clock frequency to 10 GHz and tested as detailed in ANSI C63.10:2013, Clause 6.4-6.6. Data is presented in the table below.

Radiated emissions within the band of 9 kHz to 30 MHz were investigated using a calibrated Loop Antenna and per the requirements of ANSI C63.10:2013.

Measurements were made with the analyzer's resolution bandwidth set to 120 kHz for measurements made below 1 GHz and 1 MHz for measurements made above 1 GHz. The video bandwidth was set to three times the resolution bandwidth; 1 MHz RBW and 3 MHz VBW. The test data were maximized for magnitude by rotating the turn-table through 360 degrees and raising and lowering the receiving antenna between 1 to 4 meters in height as a part of the measurement procedure.

The measurements were taken of the EUT transmitting at 905 MHz, 915 MHz and 926MHz. For this test the output power of the radio was set to the following highest level settings: 26 for Dipole Antenna configuration and 20 for wire antenna configuration.

The worst-case radiated emission for both antenna configurations are recorded below. The worst case margin was 6.9 dB below the specification limit at 452.70 MHz and 686.98 MHz. All other measured signals were at least 15.2 dB below the specification limit. The results are shown in the table below. These results are meant to show that this EUT has met the intentional transmitter requirements of CFR Part 15.209.

Table 15. Spurious Radiated Emissions (9 kHz – 30 MHz)

Test By: M.Afroozi	Test: FCC Part 15.209			Client: Wren Associates, LTD.			
	Project: 18-0419 Class B			Model: HMG1			
Frequency (MHz)	**Test Data (dBuV)**	**AF+CL-PA (dB)**	**Results (dBuV/m)**	**Limits (dBuV/m)**	**Distance / Polarization**	**Margin (dB)**	**DETECTOR PK / QP/AVG**
All emissions were at least 20 dB below the applicable limit.							

No other emissions detected other than those presented in this table and the tables in section 2.10 above.
AF is antenna factor. CL is cable loss. PA is preamplifier gain.

SAMPLE CALCULATION: N/A

Test Date: January 21, 2019
Tested By
Signature: _____ Name: Mark Afroozi

Table 16. Spurious Radiated Emissions (30 MHz – 1 GHz)

Test By: M. Afroozi	Test: FCC Part 15.109/15.209				Client: Wren Associates, LTD.			
	Project: 18-0419 Class B				Model: HMG1			
Frequency (MHz)	**Test Data (dBuV)**	**Additional Factors**	**AF+CL-PA (dB)**	**Results (dBuV/m)**	**Limits (dBuV/m)**	**Distance / Polarization**	**Margin (dB)**	**DETECTOR PK / QP/AVG**
37.40	39.12	--	-14.80	24.32	40.0	3m./VERT	15.7	**PK**
45.37	39.01	--	-16.27	22.74	40.0	3m./VERT	17.3	**PK**
59.15	46.01	--	-17.73	28.28	43.5	3m./VERT	15.2	**PK**
81.77	42.78	--	-17.95	24.83	40.0	3m./VERT	15.2	**PK**
151.65	38.72	--	-13.39	25.33	43.5	3m./VERT	18.2	**PK**
452.70	47.34	--	-8.23	39.11	46.0	3m./VERT	6.9	**PK**
686.98	42.26	--	-3.14	39.12	46.0	3m./HORZ	6.9	**QP**
All other emissions were greater than 20 dB from the applicable limit.								

AF is Antenna Factor. CL is Cable Loss. PA is Preamplifier Gain.

SAMPLE CALCULATION AT: 37.40 MHz

Magnitude of Measured Frequency	39.12	dBuV
Additional Factor	0.00	dB
+Antenna Factor + Cable Loss+ Amplifier Gain	-14.80	dB
Corrected Result	24.32	dBuV/m

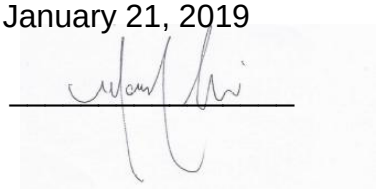
Test Date: January 21, 2019
Tested By
Signature:  Name: Mark Afroozi

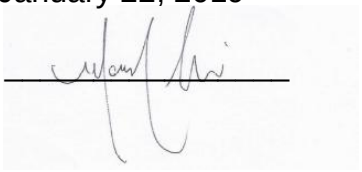
Table 17. Spurious Radiated Emissions (1 GHz – 10 GHz)

Test By: M. Afroozi	Test: FCC Part 15.109/15.209				Client: Wren Associates, LTD.			
	Project: 18-0419 Class B				Model: HMG1			
Frequency (MHz)	**Test Data (dBuV)**	**Additional Factors**	**AF+CL-PA (dB)**	**Results (dBuV/m)**	**Limits (dBuV/m)**	**Distance / Polarization**	**Margin (dB)**	**DETECTOR PK / QP/AVG**
1131.70	38.49	--	-8.92	29.57	54.0	3.0m./HORZ	24.4	**AVG**
2490.00	35.51	--	-3.88	31.63	54.0	3.0m./HORZ	22.4	**AVG**
2518.30	34.39	--	-3.69	30.70	54.0	3.0m./HORZ	23.3	**AVG**
All other emissions were more than 20 dB below the applicable limit.								

AF is antenna factor. CL is cable loss. PA is preamplifier gain.

SAMPLE CALCULATION AT: 1131.70 MHz

Magnitude of Measured Frequency	38.49	dBuV
Additional Factor	0.00	dB
+Antenna Factor + Cable Loss+ Amplifier Gain	-8.92	dB
Corrected Result	29.57	dBuV/m

Test Date: January 22, 2019
Tested By
Signature: 

Name: Mark Afroozi

2.18 Measurement Uncertainty

The measurement uncertainties given were calculated using the method detailed in CISPR 16-4-2:2011. A coverage factor of k=2 was used to give a level of confidence of approximately 95%.

2.18.1 Conducted Emissions Measurement Uncertainty

Measurement Uncertainty (within a 95% confidence level) for this test is ±2.78 dB.

2.18.2 Radiated Emissions Measurement Uncertainty

For a measurement distance of 3 m the measurement uncertainty (with a 95% confidence level) for this test using a Biconical Antenna (30 MHz to 200 MHz) is ±5.3 dB. This value includes all elements of measurement.

The measurement uncertainty (with a 95% confidence level) for this test using a Log Periodic Antenna (200 MHz to 1000 MHz) is ±5.1 dB.

The measurement uncertainty (with a 95% confidence level) for this test using a Horn Antenna is ±5.1 dB.

3 Test Results

The EUT is deemed to have met the requirements of the standards cited within the test report when tested as detailed in the present test report.