H.B. Compliance Solutions

Intentional Radiator Test Report

For the

Sentinel System

Sentinel Transceiver Gen2

Tested under

The FCC Rules contained in Title 47 of the CFR, Part 90 for

Private Land Mobile Radio Services

December 2, 2015

Prepared for:

Sentinel System, LLC

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Oxford, MI 48371

Prepared By:

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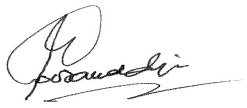
Reviewed By:



Hoosamuddin Bandukwala

Cert # ATL-0062-E

Engineering Statement: The measurements shown in this report were made in accordance with the procedure indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurement made, the equipment tested is capable of operation in accordance with the requirements of Part 90 of the FCC Rules under normal use and maintenance.

Report Status Sheet

Revision #	Report Date	Reason for Revision
Ø	December 2, 2015	Initial Issue
1	December 16, 2015	Update Calibration Date

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EXECUTIVE SUMMARY

1. Testing Summary

These tests were conducted on a sample of the equipment for the purpose of demonstrating compliance with Part 90. All tests were conducted using measurement procedure from ANSI TIA/EIA-603-D-2010 as appropriate.

Test Name	Test Method/Standard	Result	Comments
RF Output Power	2.1046; 90.205	Pass	
Modulation Characteristics	2.1047(a)	Pass	The EUT does not transmit voice. The device transmit data signal only
Occupied Bandwidth	2.1049; 90.210	Pass	EUT Meets Mask D
Spurious Emissions at Antenna Terminals	2.1051; 90.210	Pass	
Radiated Spurious Emissions	2.1053; 90.210	Pass	
Frequency Stability over Temperature Variations	2.1055(a)(1); 90.213	Pass	
Frequency Stability over Voltage Variations	2.1055(d)	Pass	
Transient Frequency Behavior	90.214	Pass	

EQUIPMENT CONFIGURATION

1. Overview

H.B Compliance Solutions was contracted by Sentinel System to perform testing on the Sentinel Transceiver Gen2 under the purchase order number 500047.

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform compliance testing of the Sentinel System, Sentinel Transceiver Gen2.

The tests were based on FCC Part 90 Rules. The tests described in this document were formal tests as described with the objective of the testing was to evaluate compliance of the Equipment Under Test (EUT) to the requirements of the aforementioned specifications. Sentinel System should retain a copy of this document and it should be kept on file for at least five years after the manufacturing of the EUT has been permanently discontinued. The results obtained relate only to the item(s) tested.

Product Name:	Sentinel Transceiver Gen2
Model(s) Tested:	S450IM
FCC ID:	2AF9J-S450IM
Supply Voltage Input:	Primary Power : 120 Vac
Frequency Range:	451MHz to 459MHz
No. of Channels:	Single Channel
Necessary Bandwidth	12.5kHz
Type(s) of Modulation:	GFSK
Range of Operation Power:	4.87W
Voltage into final Transistor	7.2 volts
Current into final Transistor	1.6 amps
Emission Designator:	8K00F1D (For Frequency Modulation Bn=2M+2DK) Where M= B/2 = 1500 D = 8.0KHz and K = 1
Channel Spacing(s)	None
Test Item:	Pre-Production
Type of Equipment :	Fixed
Antenna:	50 ohm BNC Connector
Environmental Test Conditions:	Temperature: 15-35°C Humidity: 30-60% Barometric Pressure: 860-1060 mbar
Modification to the EUT:	None
Evaluated By:	Staff at Artesyn Embedded & H.B. Compliance Solutions
Test Date(s):	09/17/15 till 10/21/15

2. Test Facility

Radiated Emission testing was performed at Artesyn Embedded Technologies. This facility is located at 2900 S. Diablo Way, Suite 190, Tempe, AZ 85282. All equipment used in making physical determination is accurate and bears recent traceability to the National Institute of Standards and Technology.

Test facility at Artesyn Embedded Technologies is an A2LA accredited test site. The A2LA certificate number is 2716.01. The scope of accreditation covers the FCC Method - 47 CFR Part 15, ICES-003, CISPR 22, AS/NZS 3548 and VCCI

Conducted testing was performed at H.B. Compliance Solutions. This facility is located at 5005 S. Ash Avenue, Suite # A-10, Tempe AZ 85282.

Radiated Emissions measurements were performed in a semi-anechoic chamber (equivalent to an Open Area Test Site). In accordance with §2.948(a)(3), a complete site description is contained at Emerson Network Power.

3. Description of Test Sample

The Sentinel System, Sentinel Radio Transceiver, is a microprocessor controlled transceiver incorporating an AC/DC power supply, energy meter, and dimming control circuits for used in wireless control and monitoring of LED streetlights. The components are contained in a plastic enclosure.

4. Equipment Configuration

Ref. ID	Name / Description	Model Number	Serial Number
# 1	Sentinel Transceiver Gen2	S450IM	N/A

Table 1. Equipment Configuration

5. Support Equipment

All support equipment supplied is listed in the following Support Equipment List.

Ref ID	Name / Description	Manufacturer	Model #	Serial #
-	-	-	-	-

Table 2. Support Equipment

6. Ports and Cabling Information

Ref ID	Port name on the EUT	Cable Description	Qty.	Length (m)	Shielded? (Y/N)	Termination Box ID & Port ID
# 2	Power	2 wire	1	2	N	AC Mains
# 3	Aux	2 wire	1	0.1	N	Push Switch

Table 3. Ports and Cabling Information

7. Method of Monitoring EUT Operation

A test receiver will be used to monitor the data transmission from the EUT.

8. Mode of Operation

The EUT will be configured to transmit at maximum power level. Test mode was provided to select the lower, middle and upper band of the transmitter. A special version of software was installed that would cycle through the transmit frequencies based upon detection of a switch input on the Event I/O pin. This push switch programmed the transmitter from three frequencies modulated and the other three in CW mode. These settings were created for testing purpose only.

9. Modifications

9.1 Modifications to EUT

No modifications were made to the EUT

9.2 Modifications to Test Standard

No Modifications were made to the test standard.

10. Disposition of EUT

The test sample including all support equipment submitted to H.B Compliance Solutions for testing will be returned to Sentinel System upon completion of testing & certification

1. RF Power Output

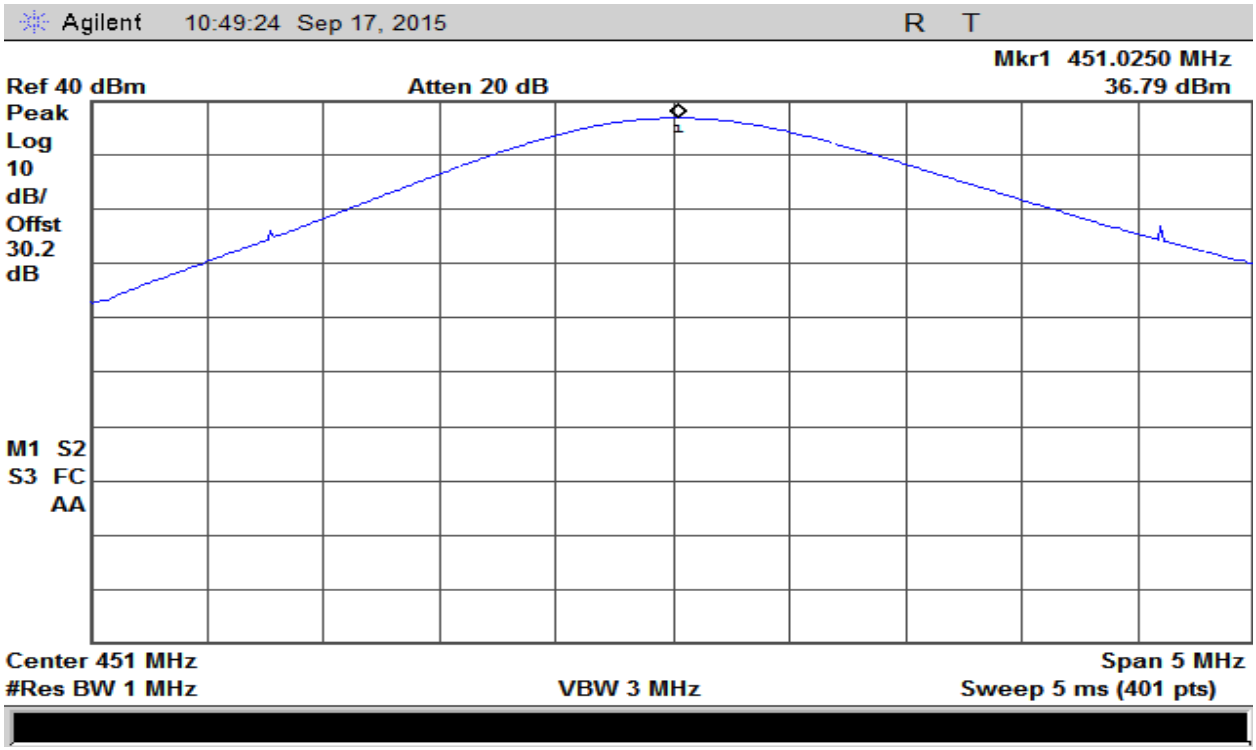
Test Requirement(s):	§2.1046 and §90.215	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	09/17/2015

Test Procedures: As required by 47 CFR 2.1046, RF Power output measurements were made at the RF output terminals of the EUT.

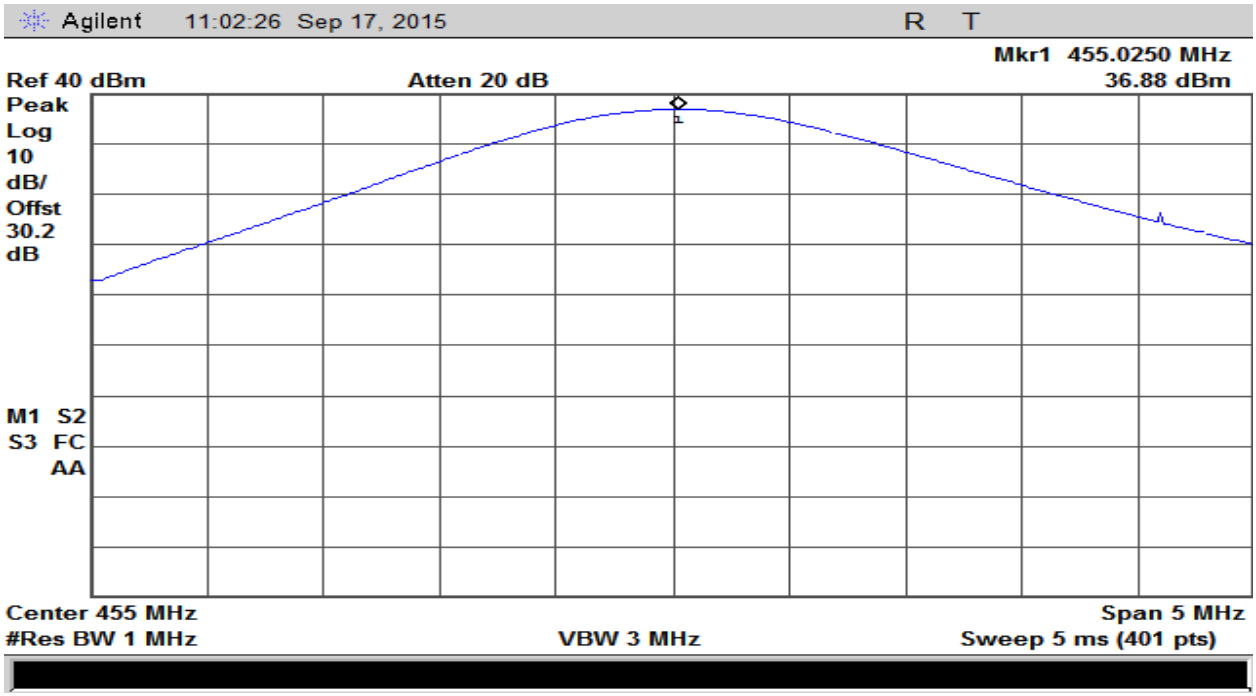
Customer provided a test mode internal to the EUT to control the RF modulation, and frequency channel. The EUT was connected through an attenuator to a Spectrum Analyzer capable of making power measurements. Measurements were made at the low, mid, and high channels of the entire frequency band.

Frequency (MHz)	Conducted Power (dBm)	Conducted Power (W)
451.0	36.79	4.77
455.0	36.88	4.87
459.0	36.85	4.84

Table 4. RF Power Output, Test Results



Plot 1 – Output Power – Low



Plot 2 – Output Power – Mid

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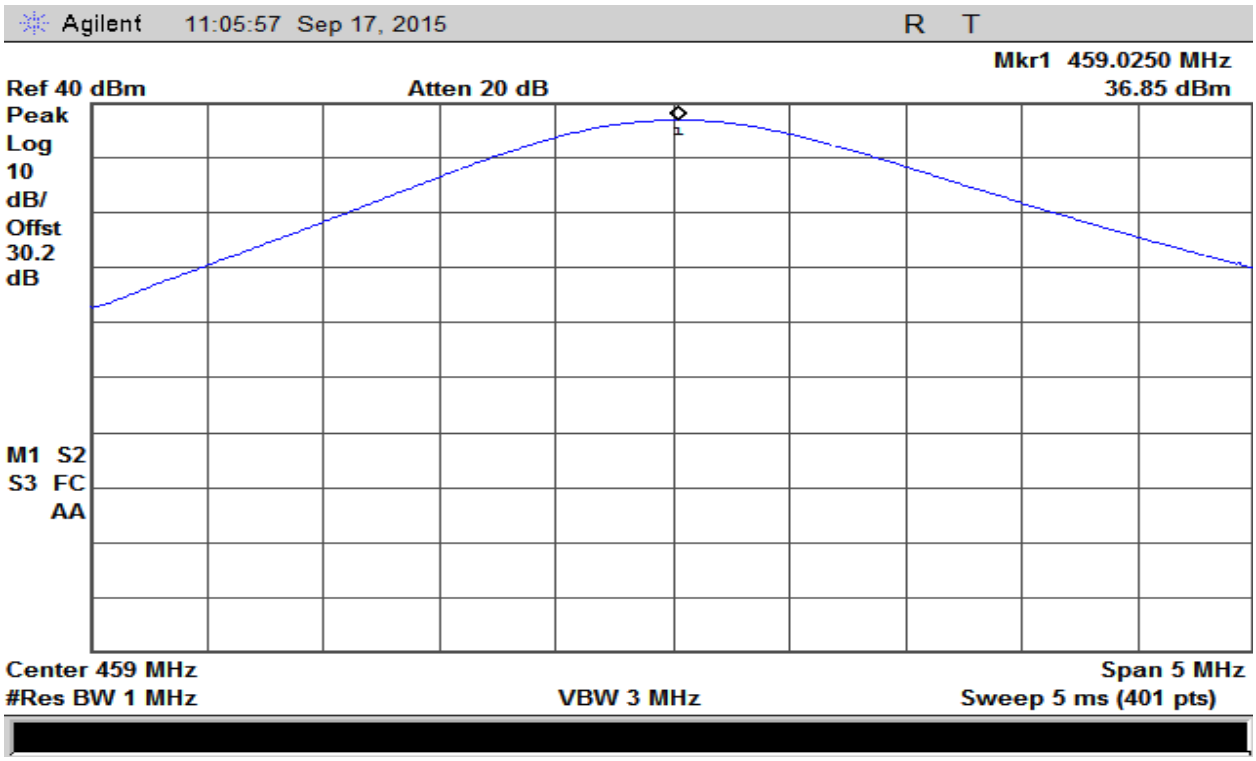


Plot 3 – Output Power – High

2. Modulation Characteristics

Test Requirement(s):	2.1047 and §90.207	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	09/17/2015

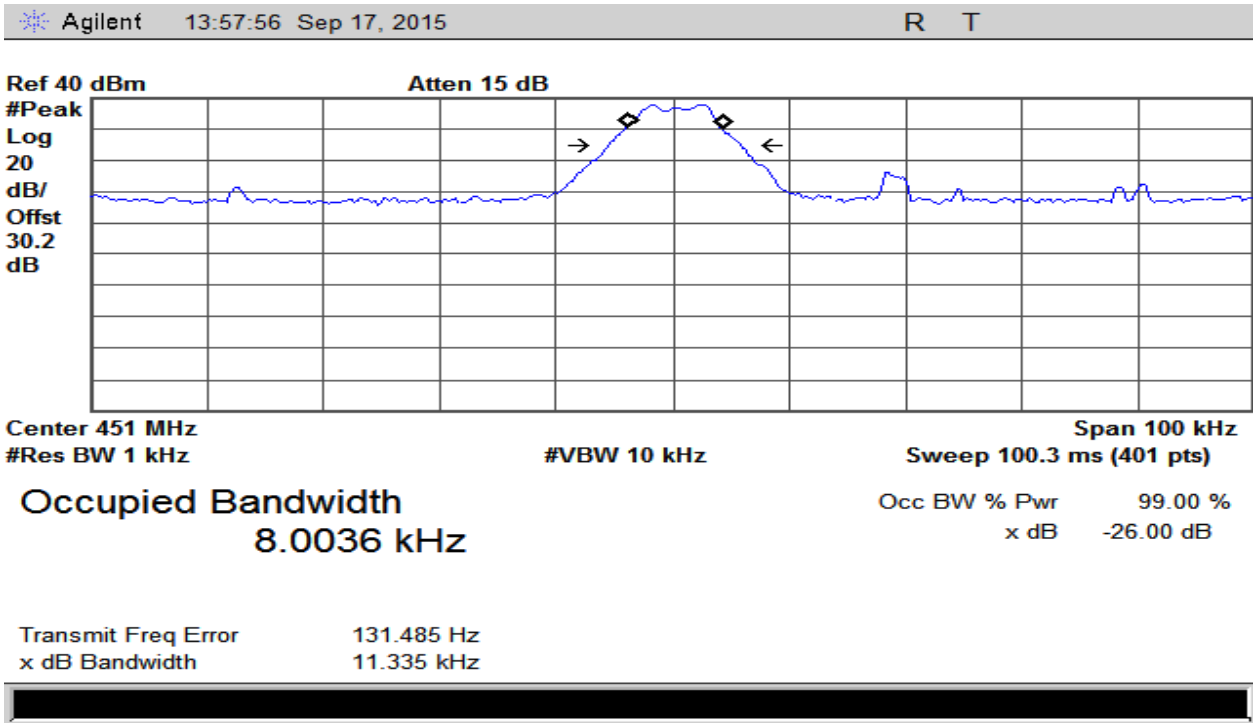
Test Procedure:

As required by 47 CFR 2.1047, Modulation characteristics measurements were made at the RF output terminals of the EUT.

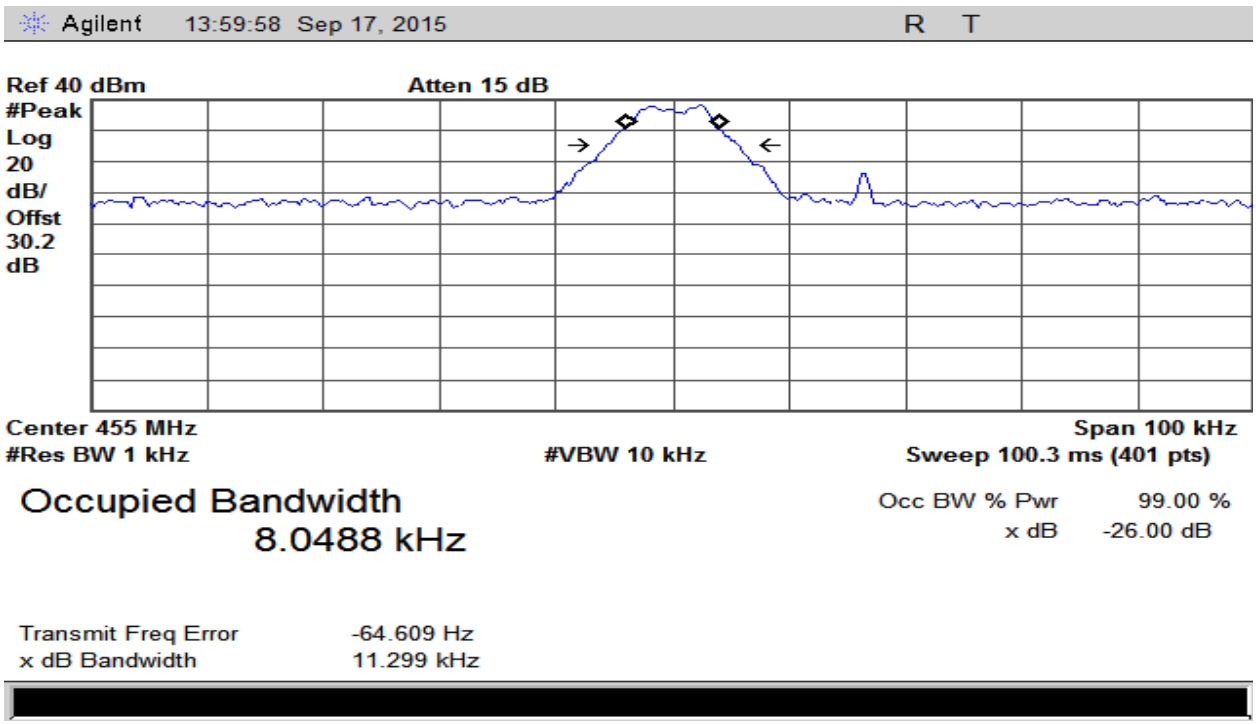
Customer provided a test mode internal to the EUT to control the RF modulation, and frequency channel. The EUT was connected through an attenuator to a Spectrum Analyzer.

As per standard a curve or equivalent data of the EUT is shown

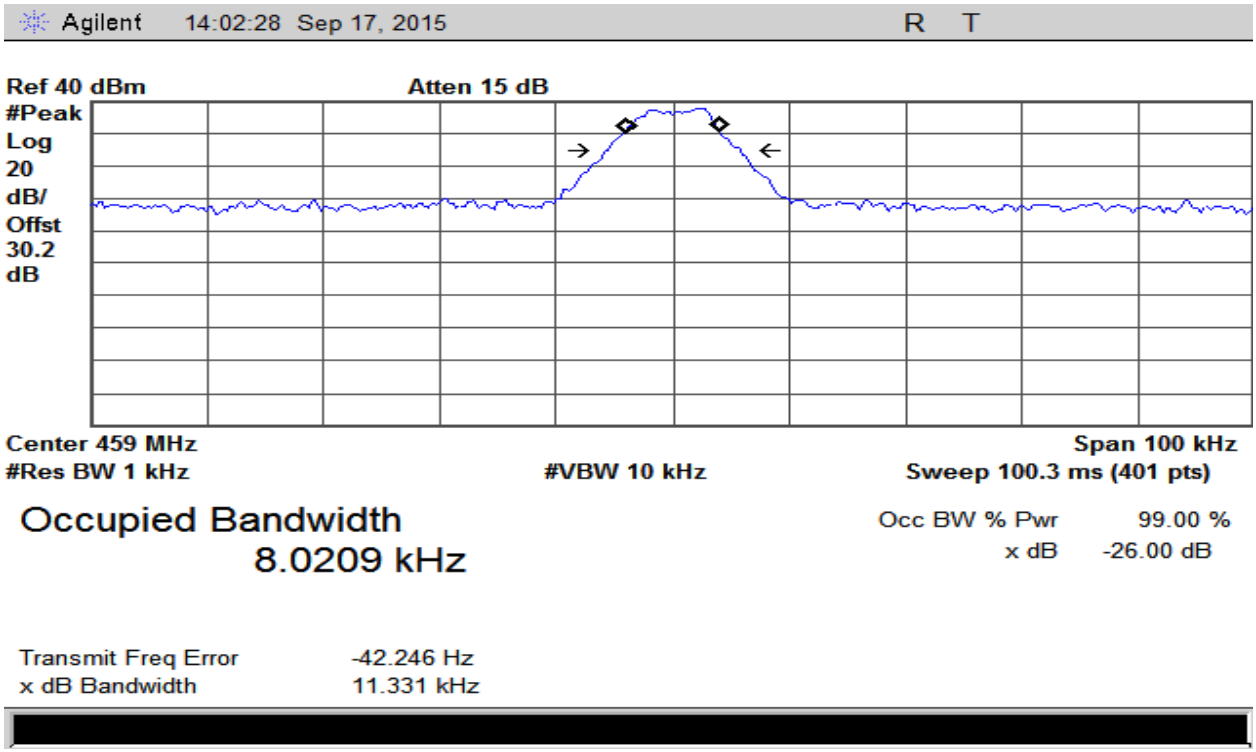
The plot(s) of the modulation characteristic is presented hereinafter as reference.



Plot 4 – Low Channel



Plot 5 – Mid Channel



Plot 6 –High Channel

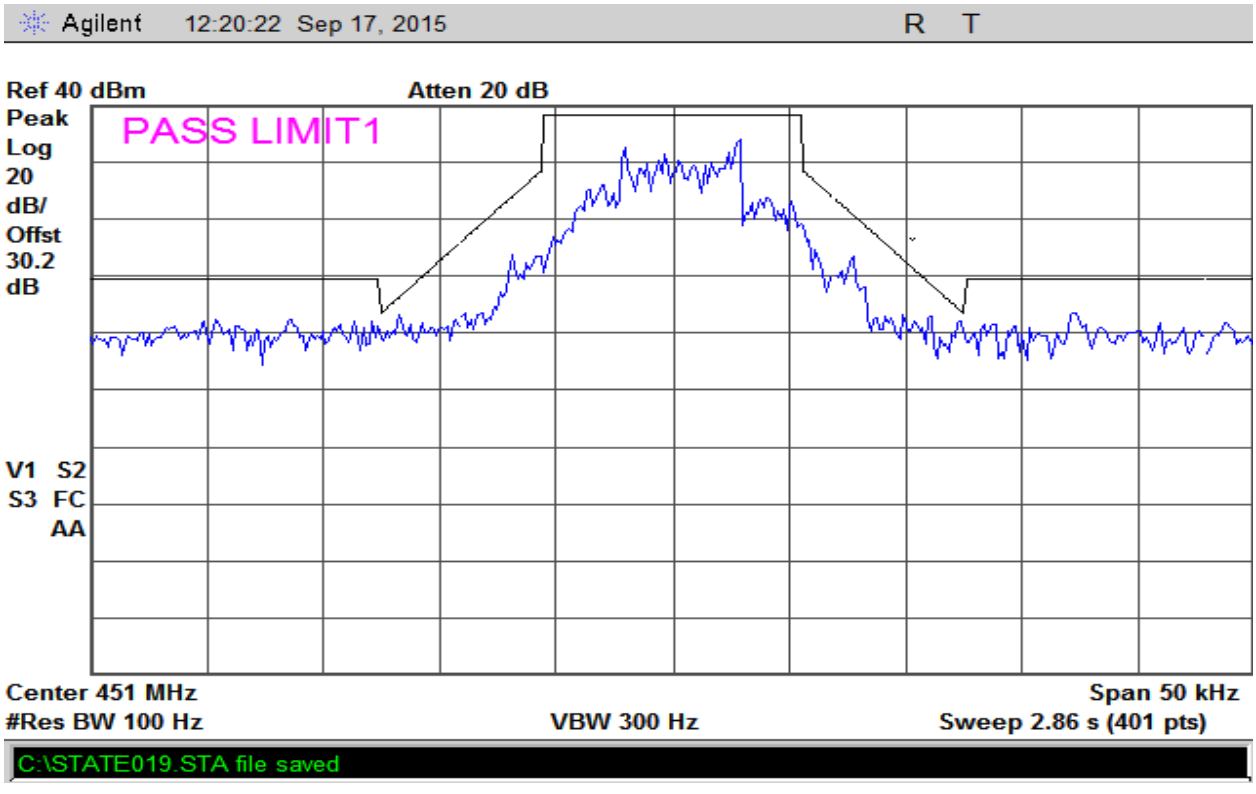
3. Occupied Bandwidth (Emission Mask)

Test Requirement(s):	2.1049 and §90.210 with FCC (Emission Mask D)	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	09/17/2015

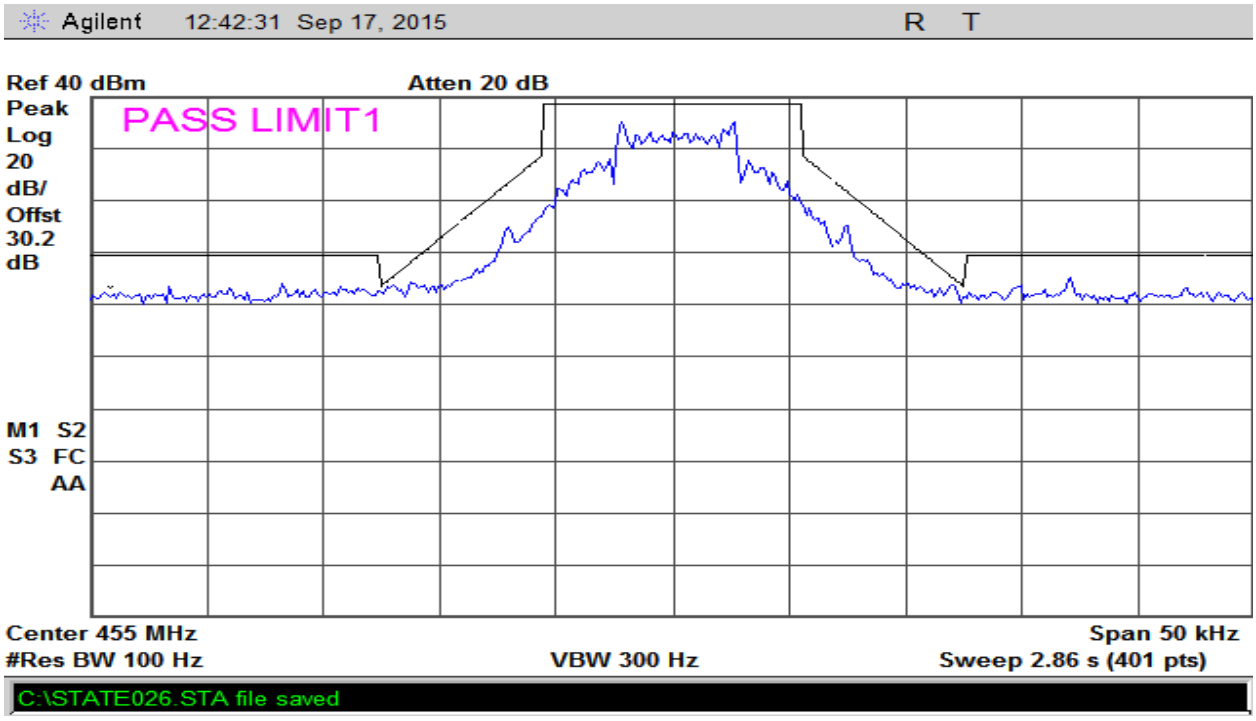
Test Procedure: As required by 47 CFR 2.1049, occupied bandwidth measurements were made at the output terminals of the EUT.

Customer provided a test mode internal to the EUT to control the RF modulation, and frequency channel. The EUT was connected through an attenuator to a Spectrum Analyzer. The measured highest peak power was set relative to zero dB reference. The RBW of the Spectrum Analyzer was set to at least 1% of the channel bandwidth. Measurements were carried out at the low, mid and high channels of the TX band.

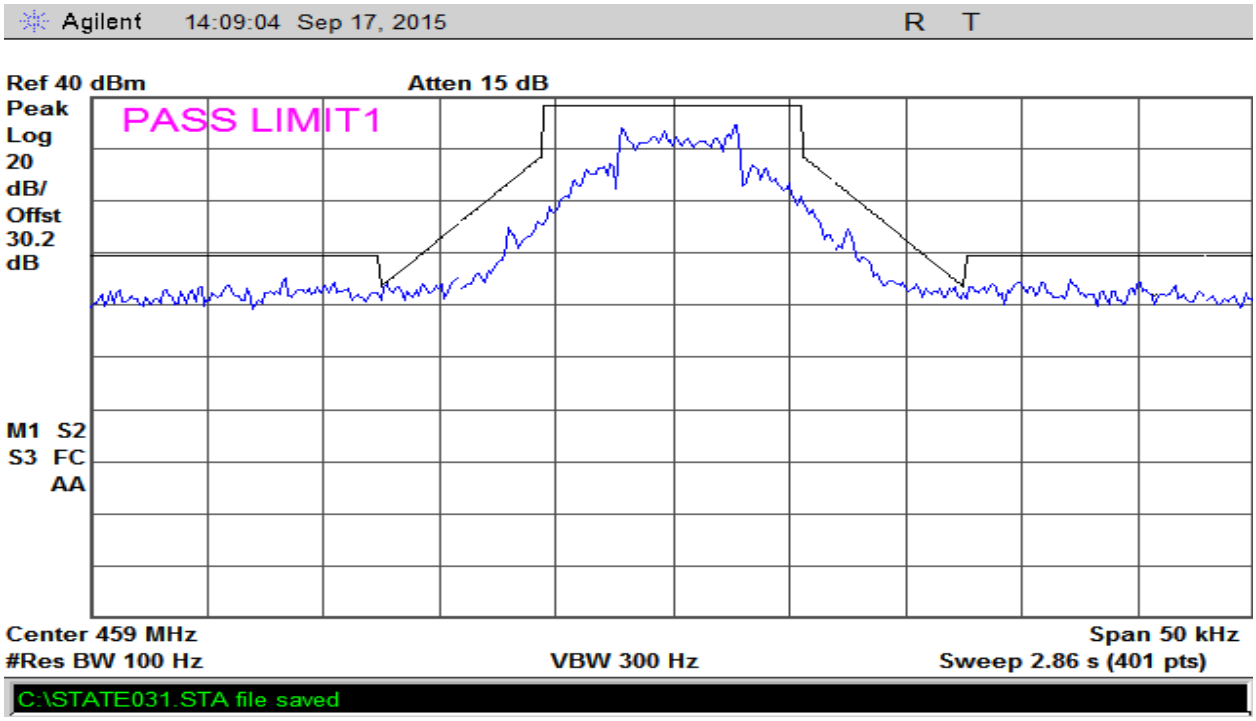
The following pages show measurements of Emission Mask plots:



Plot 7 – Low Chanel at 12.5 kHz Spacing – Mask D



Plot 8 – Mid Chanel at 12.5kHz Spacing – Mask D



Plot 9 – High Chanel at 12.5 kHz Spacing – Mask D

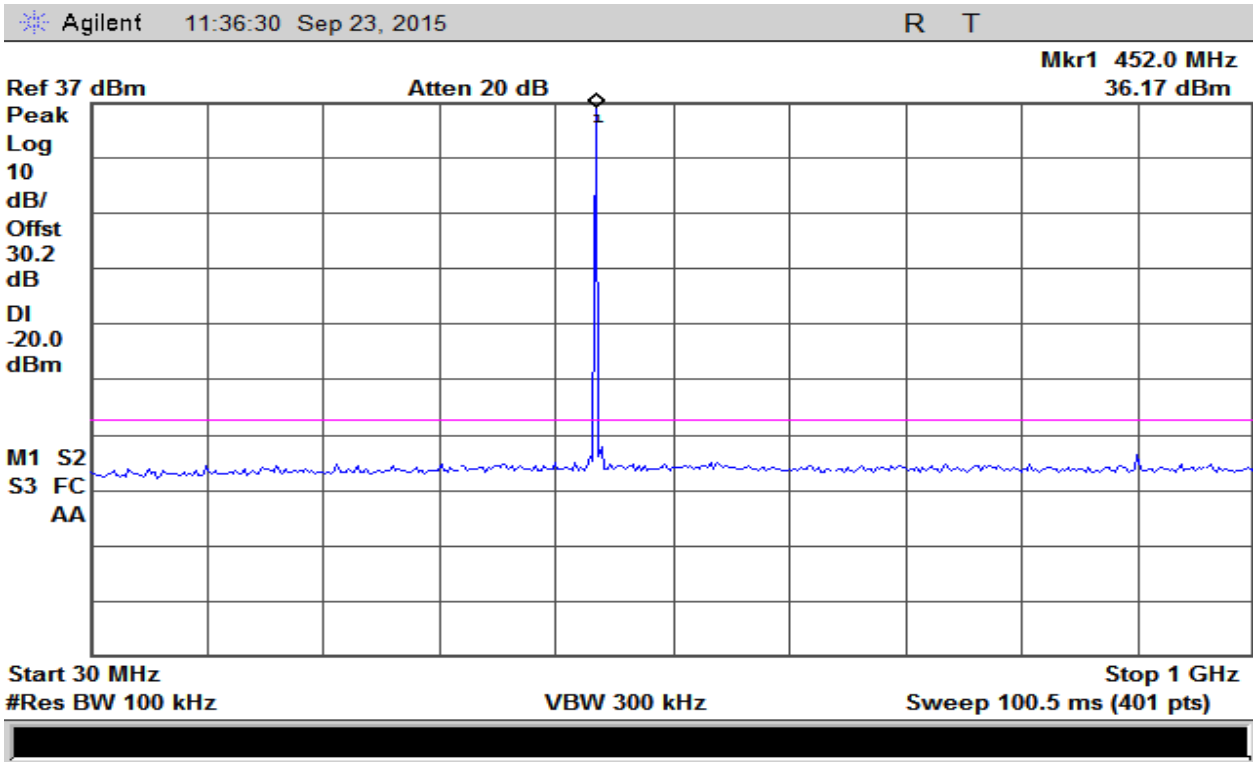
4. Spurious Emissions at Antenna Terminals

Test Requirement(s):	§2.1051 and 90.210(m)	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	09/23/2015

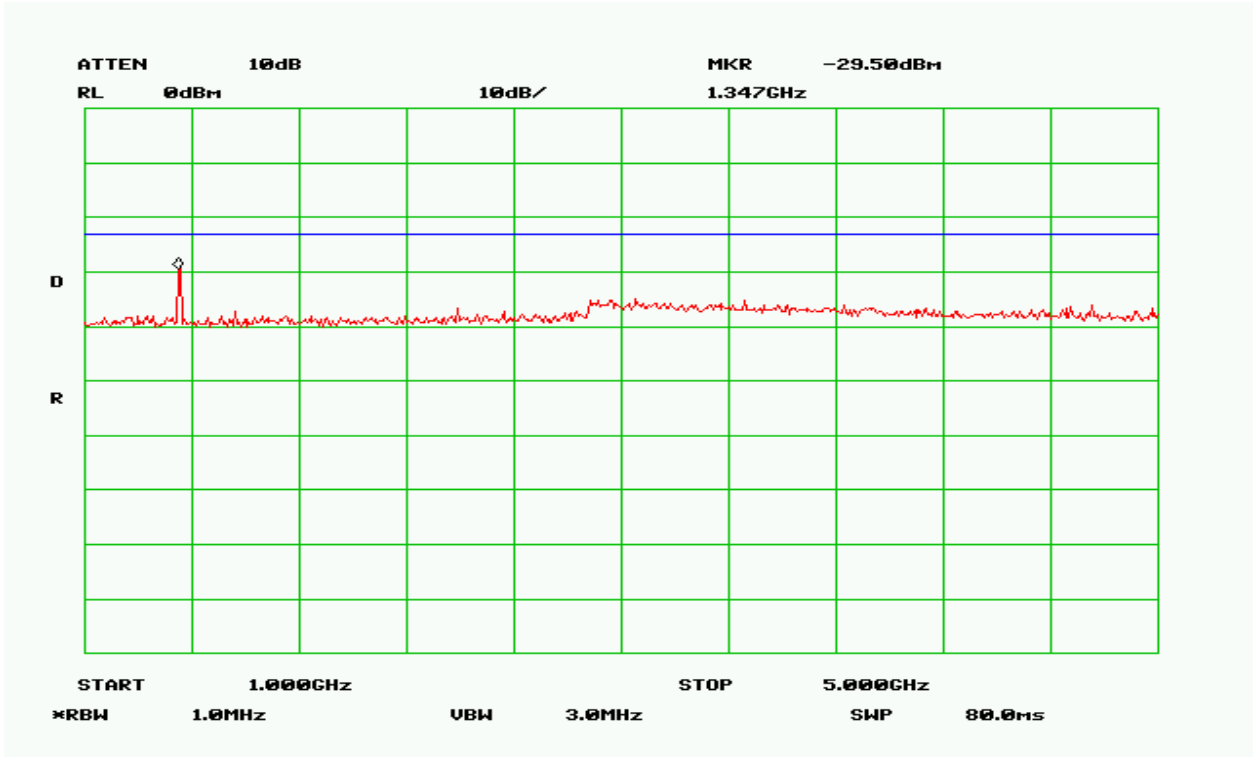
Test Procedures:

As required by 47 CFR 2.1051, spurious emissions at antenna terminal measurements were made at the RF output antenna terminal of the EUT.

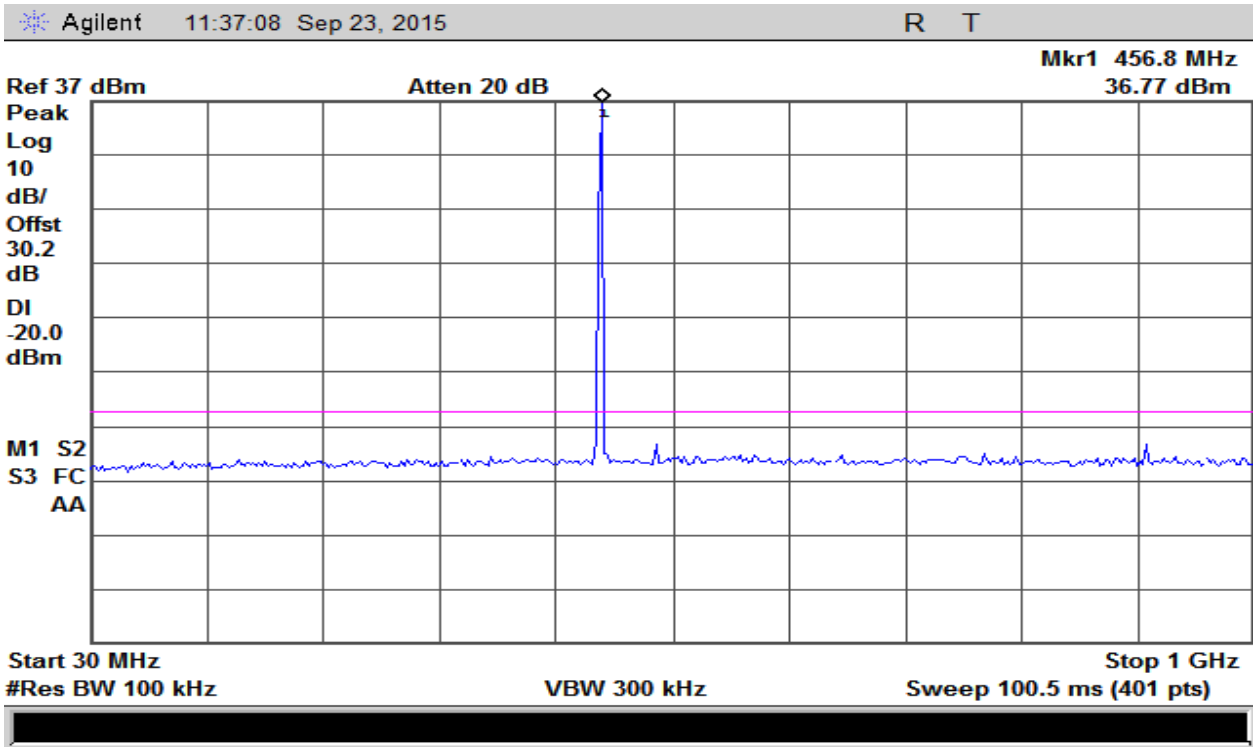
Customer provided a test mode internal to the EUT to control the RF modulation, and frequency channel. The EUT was connected through an attenuator to a Spectrum Analyzer. The Spectrum Analyzer was set to sweep from 30MHz up to 10th harmonic of the fundamental or 40GHz whichever is the lesser. Measurements were made at the low, mid and high frequency of the transmit band.



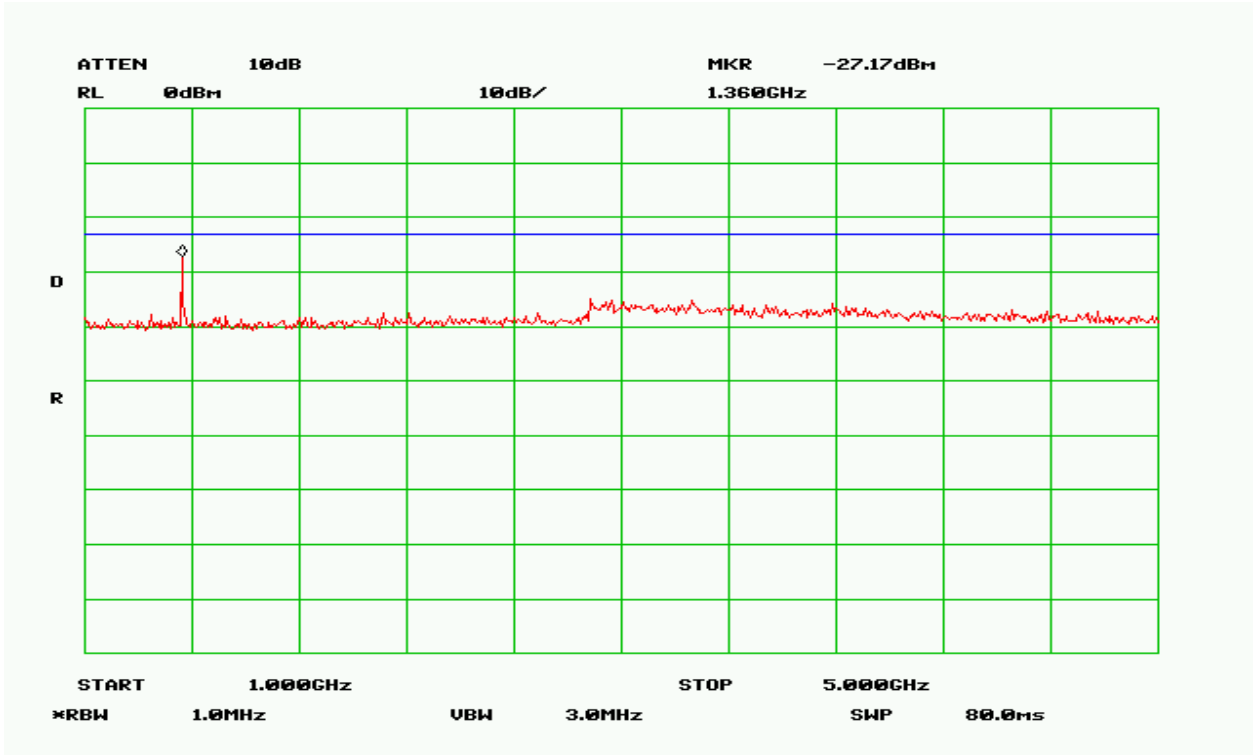
Plot 10 – Low Band



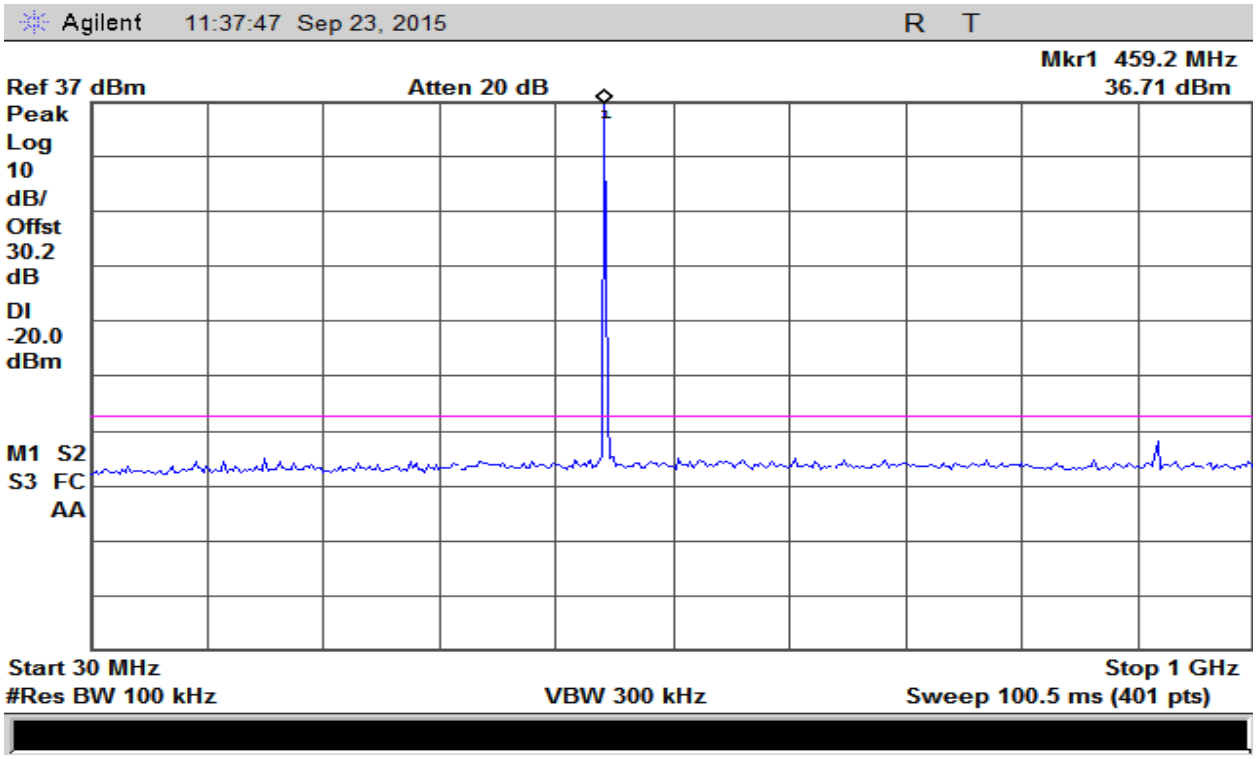
Plot 11 – Low Band



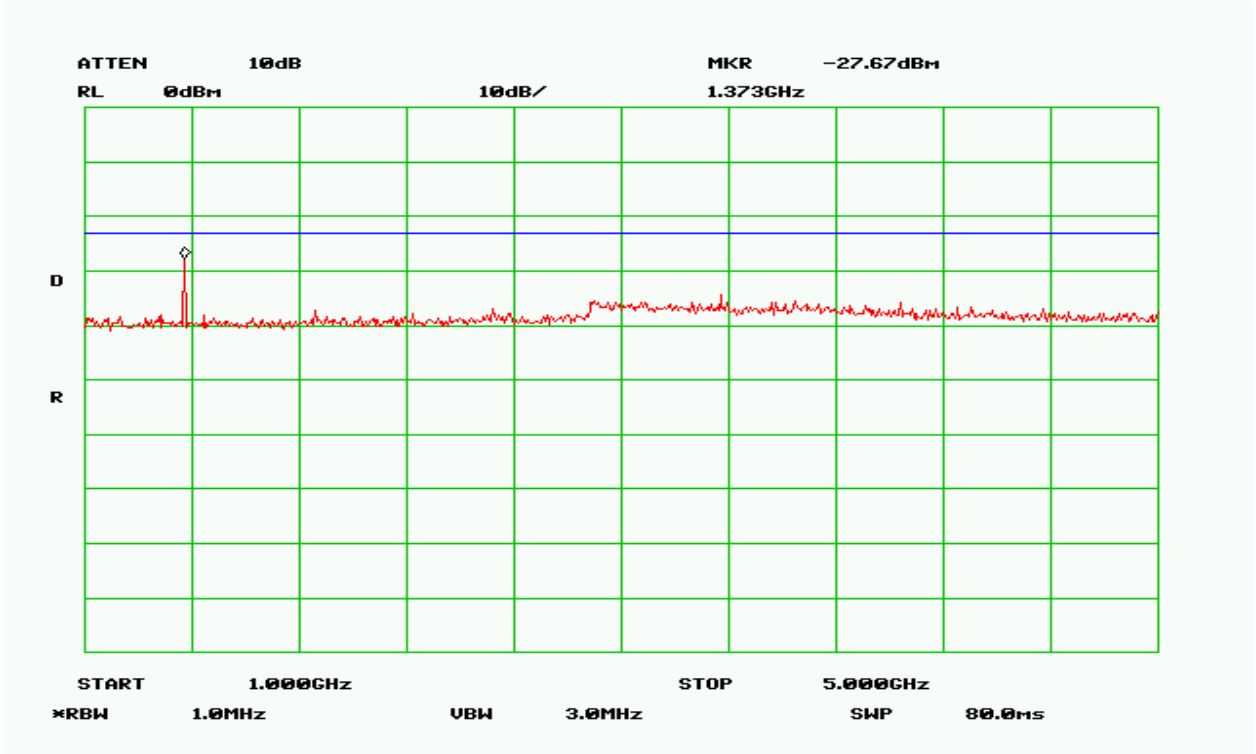
Plot 12 – Mid Band



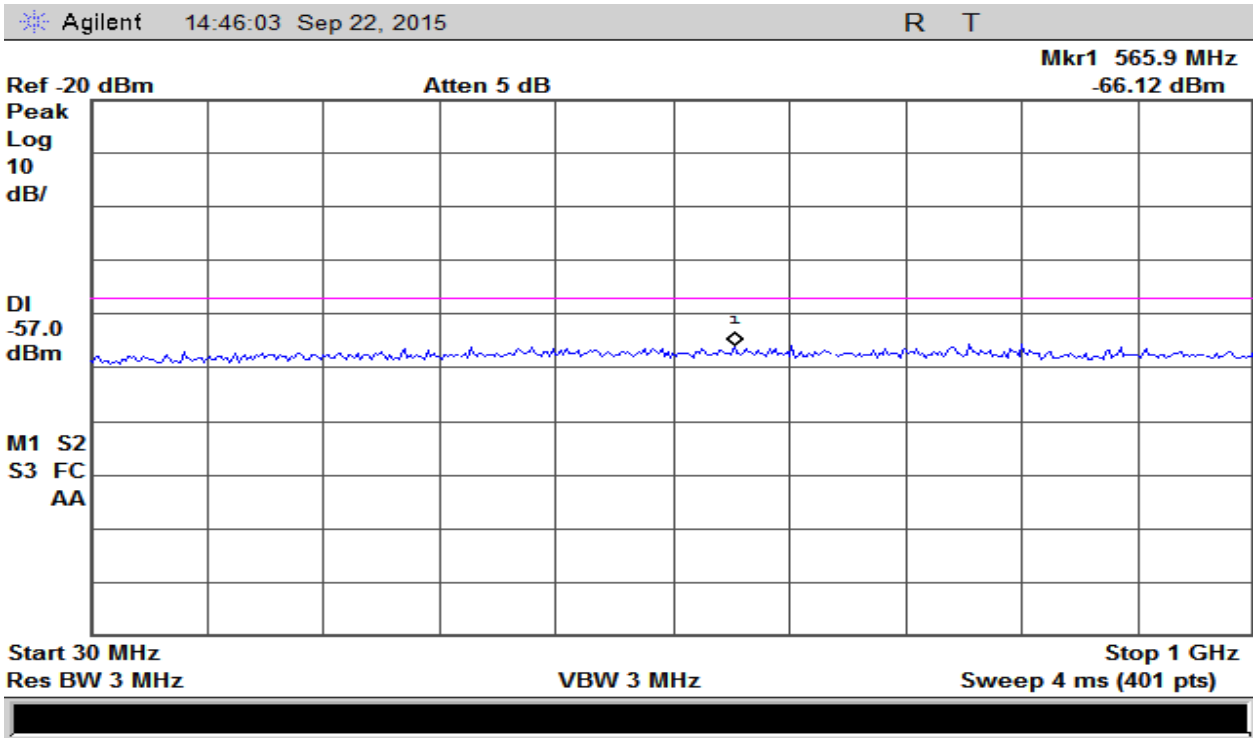
Plot 13 – Mid Band



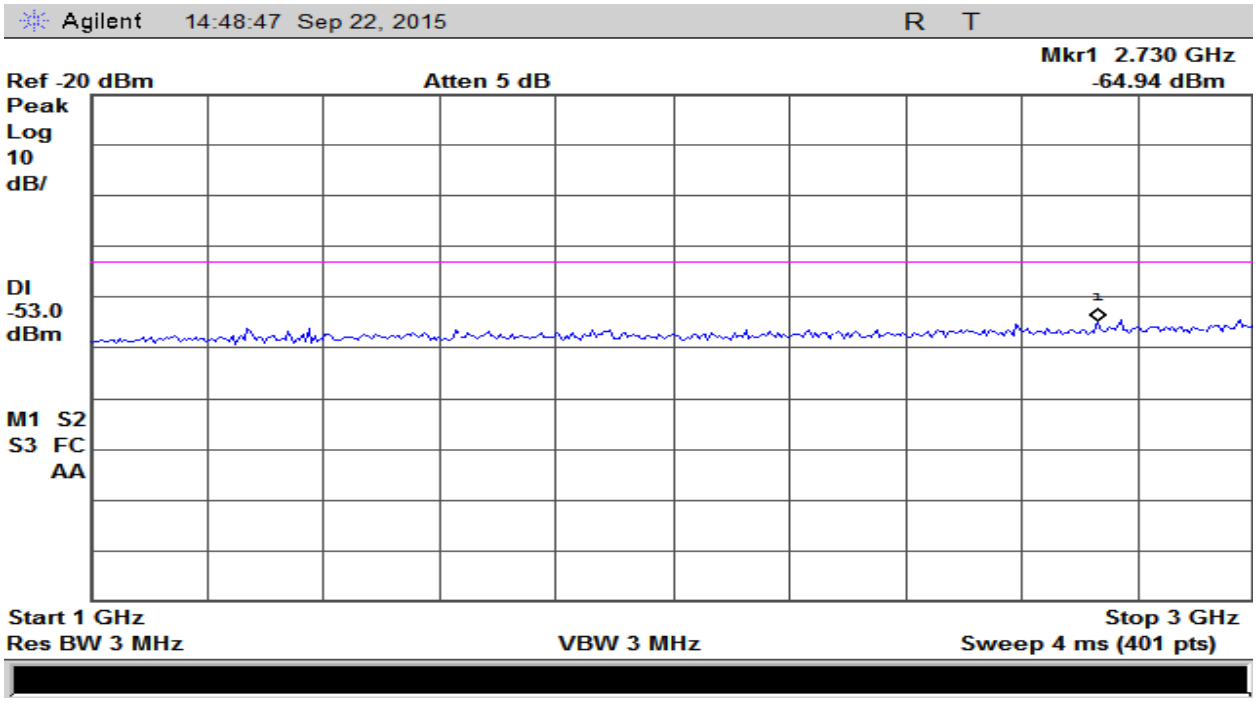
Plot 14 – High Band



Plot 15 – High Band



Plot 16 – Rx mode – For Industry Canada Only (RSS-GEN)



Plot 17 – Rx mode – For Industry Canada Only (RSS-GEN)

5. Radiated Spurious Emissions

Test Requirement(s):	§2.1053 and 90.210(j)	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	10/21/2015

Test Procedures: As required by 47 CFR 2.1053, field strength of radiated spurious measurements were made in accordance with the procedures of the TIA/EIA-603-D-2010.

The EUT was placed on a wooden table inside a 3 meter semi-anechoic chamber. The EUT was transmitting into a non-radiating load which was directly connected to the EUT antenna port.

The measurement antenna was placed at a distance of 3 meters 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 test was performed by placing the EUT on 3 orthogonal axis. The frequency range up to the 10^{th} harmonic was investigated.

The EUT is removed and replaced with a substitution antenna. A signal generator was connected to the substitution antenna by a non-radiating cable. The absolute levels of the spurious emissions were measured by the substitution.

Spurious emissions in dB = 10 log (Txpwr in Watts/0.001)-the absolute level

Spurious attenuation limit in dB = 50 + 10 $\log_{10}$ (power out in Watts) for EUT with a 12.5 KHz channel

Frequency (MHZ)	Amplitude (dbuV)	Antenna Polarity	Cable Loss	Substitution Generator Level (dbm)	Transmit Antenna Gain	Corrected Amplitude (dBm)	Limit (dBm)
902.0	62.33	Horz	0.94	-38.9	-3.5	-41.46	-20
1353	55.33	Vert	1.35	-47.9	0.03	-46.52	-20
1804	43.5	Horz	1.4	-70.1	4.57	-64.13	-20
2255	46.5	Horz	1.56	-59.1	4.17	-53.37	-20
2706	54.83	Horz	1.86	-43.8	4.68	-37.26	-20

Table 5 - Spurious Radiated Emission Data – Low Band

Frequency	Amplitude (dbuV)	Antenna Polarity	Cable Loss	Substitution Generator Level (dbm)	Transmit Antenna Gain	Corrected Amplitude (dBm)	Limit (dBm)
910	56.17	Horz	0.94	-43	-3.5	-45.56	-20
1365	56.17	Horz	1.35	-45	0.03	-43.62	-20
1820	47.33	Vert	1.4	-56.5	4.57	-50.53	-20
2275	52.33	Horz	1.56	-48.1	4.17	-42.37	-20
2730	61.5	Vert	1.86	-39.5	4.68	-32.96	-20

Table 6 – Spurious Radiated Emission Data – Mid Band

Frequency	Amplitude (dbuV)	Antenna Polarity	Cable Loss	Substitution Generator Level (dbm)	Transmit Antenna Gain	Corrected Amplitude (dBm)	Limit (dBm)
918	62.67	Horz	0.94	-38.6	-3.5	-41.16	-20
1377	55.83	Horz	1.35	-50.1	0.03	-48.72	-20
1836	45	Vert	1.4	-59.5	4.57	-53.53	-20
2295	49.17	Vert	1.56	-55	4.17	-49.27	-20
2754	60.33	Vert	1.86	-42	4.68	-35.46	-20

Table 7 – Spurious Radiated Emission Data – High Band

NOTE: There were no detectable emissions above the 6th harmonic.

6. Frequency Stability vs Temperature

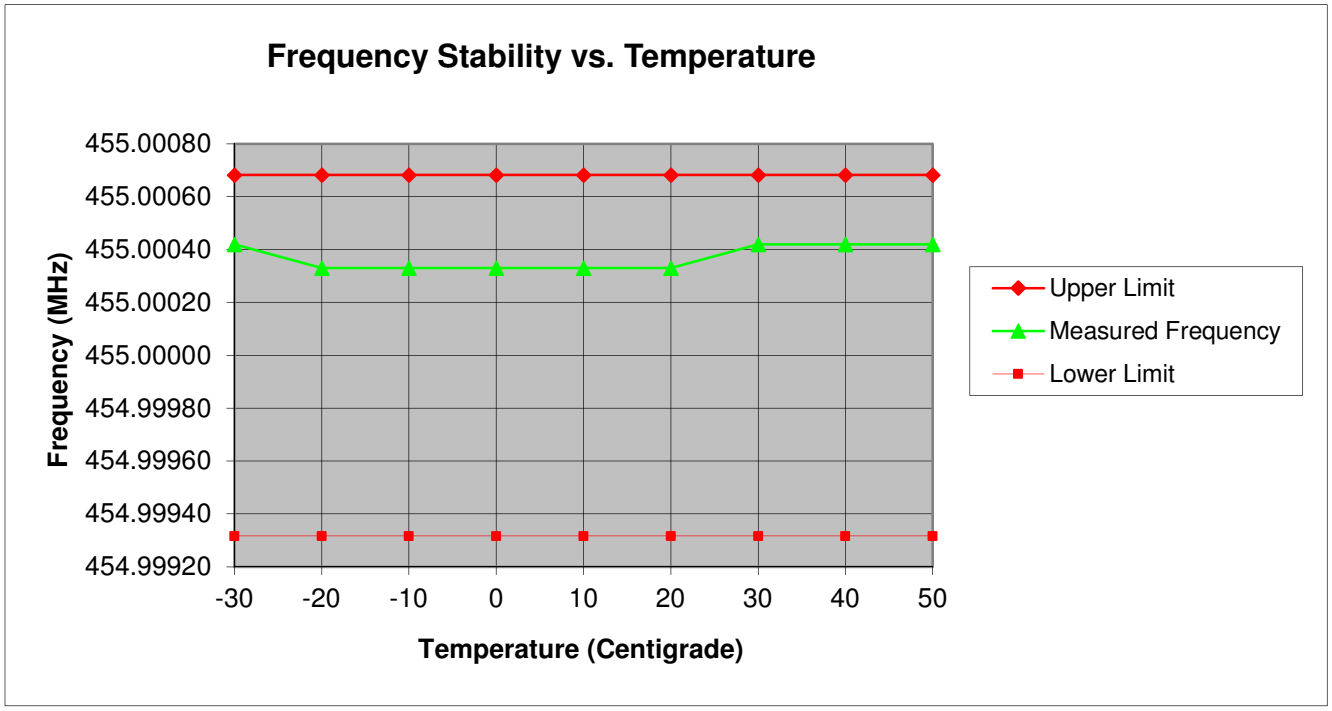
Test Requirement(s):	§2.1055 and 90.213	**Test Engineer(s):**	Jerry Mejak
Test Results:	Pass	**Test Date(s):**	10/14/2015

Test Procedures: As required by 47 CFR 2.0155, Frequency Stability measurements were made at the RF antenna output terminals of the EUT.

The EUT was placed in an Environmental Chamber with all the support equipment outside the chamber. The EUT was set to transmit a modulated carrier. The reference frequency at 20°C was observed and noted down. The frequency drift was investigated for every 10°C increment until the unit was stabilized then recorded the reading in tabular format with the temperature range of -30°C to 50°C.

Temperature centigrade	Measured Frequency (MHz)	Upper Margin (MHz)	Lower Margin (MHz)
-30	455.00042	-0.00026	0.00110
-20	455.00033	-0.00035	0.00101
-10	455.00033	-0.00035	0.00101
0	455.00033	-0.00035	0.00101
10	455.00033	-0.00035	0.00101
20	455.00033	-0.00035	0.00101
30	455.00042	-0.00026	0.00110
40	455.00042	-0.00026	0.00110
50	455.00042	-0.00026	0.00110

Table 8 – Temperature vs Frequency Test Result



Plot 18 – Temperature vs Frequency

7. Frequency Stability vs Voltage

Test Requirement(s):	§2.1055	**Test Engineer(s):**	Jerry Mejak
Test Results:	Pass	**Test Date(s):**	10/14/2015

Test Procedures: As required by 47 CFR 2.0155, Frequency Stability measurements were made at the RF antenna output terminals of the EUT.

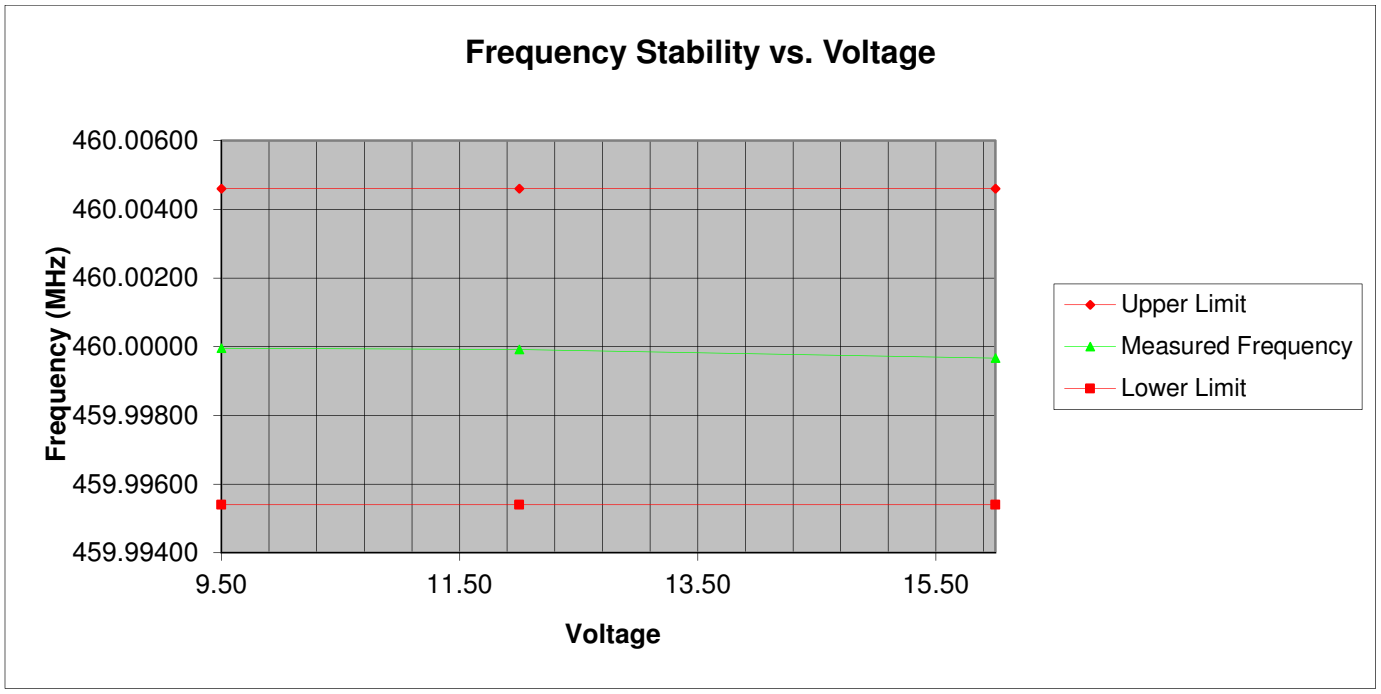
The EUT was connected to a variable AC source. The frequency was measured at both the nominal 120 Vac of the EUT and at the extreme ±15% of nominal which is 85% level or 102Vac and at the 115% level or 138Vac

With the voltage set to a measurement point, the transmitted signal was captured by the spectrum analyzer and the frequency value determined. The frequencies are compared to the tuned frequency. All data for these measurements are found in the table 9.

Reference Frequency: 455.0MHz at 120Vac at 20°C

Input Voltage (Vac)	Measured Frequency (MHz)	Upper Margin (MHz)	Lower Margin (MHz)
102.0	455.00033	-0.00035	0.00101
120.0	455.00033	-0.00035	0.00101
138.0	455.00033	-0.00035	0.00101

Table 9. Temperature vs. Voltage Test Result



Plot 19 – Temperature vs Voltage

8. Transient Frequency Behavior

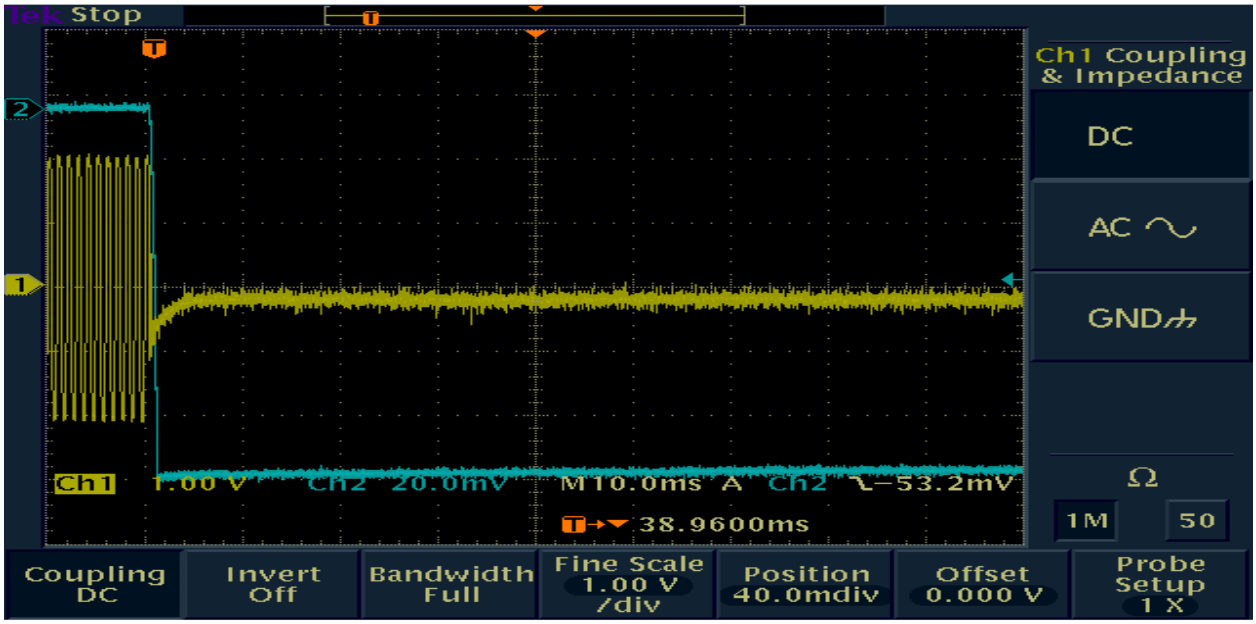
Test Requirement(s):	§90.214	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	09/23/15

Test Procedures: The EUT was tested for transient frequency behavior using the test method of TIA/EIA 603.

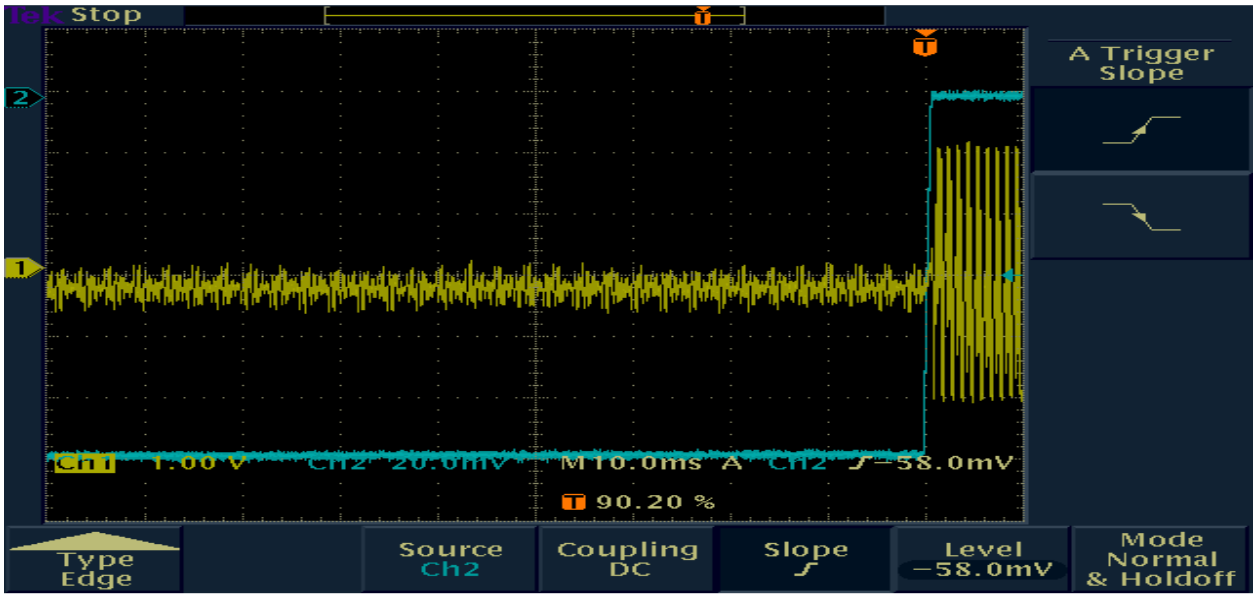
RF Frequency	Channel Bandwidth	Transient Period	Transient Behavior	Result
450MHz	12.5KHz	t1= 10ms	<±12.5kHz	Pass
		t2= 25ms	<±6.25kHz	Pass
		t3= 10ms	<±12.5kHz	Pass

Table 10. Transient Frequency – Test Requirement

The following pages show measurements of Transient Frequency Behavior plots:



Plot 20 – On Time



Plot 21 – Off Time

I. Test Equipment

Equipment	Manufacturer	Model	Serial #	Last Cal Date	Cal Due Date
Power Supply	Lambda	LA-200	LA2AA201433535	Verified	
Digital Multimeter	Fluke	77 III	72550270	Nov/30/15	Nov/30/16
Spectrum Analyzer	Agilent	E4402B	US41192757	Jan/27/15	Jan/27/16
Temperature Chamber	Thermotron	SM-3.5S	12817	Sep/18/15	Sep/18/16
Spectrum Analyzer	Hewlett Packard	8563E	3821A09316	Oct/10/15	Oct/03/16
Temperature Meter	Control Company	6066N53	140536623	Aug/08/14	Aug/08/16
Attenuator 10dB	Huber+Suhner	6810.17.A	757300	Verified	
High Pass Filter	Mini-Circuits	VHF-3100+	1023	Verified	
Variable Attenuator	H.P.	None	None	NCR	None
EMI Receiver	R&S	ESCS-30	825788/008	Dec/02/14	Dec/02/15
Signal Generator	R&S	SMY02	1062.5502.12	NCR	None
Attenuator 20dB	Weinschel	41-20-12	86332	Verified	
Horn Antenna	Com-Power	AHA-118	711150	Feb/10/15	Feb/10/16
Bilog Antenna	Chase	CBL6140	1040	Mar/30/15	Mar/30/16
Diode/Crystal Detector	H.P.	8470B	None	Verified	
Combiner/Splitter	MiniCircuits	ZFSC-2-2	None	Verified	
Oscilloscope	Tektronix	TDS 3052	B013389	Jun/03/15	Jun/03/16

Table 11 – Test Equipment List

***Statement of Traceability:** Test equipment is maintained and calibrated on a regular basis. All calibrations have been performed by a 17025 accredited test facility, traceable to National Institute of Standards and Technology (NIST)

END OF TEST REPORT