

LS Research, LLC

W66 N220 Commerce Court • Cedarburg, WI 53012 • USA

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ENGINEERING TEST REPORT # 307247 TCB

Compliance Testing of:

Apex RF Module, External Antenna

Model # 13-0091-301

and

Apex RF Module, Internal Antenna

Model # 13-0109-301

Test Date(s):

May 1, August 15, 16 & 21, 2007

Prepared For:

Colorado vNet, LLC

Attn.: Mr. Eric Rinard

255 East Sixth Street

Loveland, CO 80537

In accordance with:

Federal Communications Commission (FCC)

Part 15, Subpart C, Section 15.247

**Digital Modulation Transmitters (DTS) Operating in the
Frequency Band 2400 MHz – 2483.5 MHz**

This Test Report has been technically reviewed, and is issued under the Authority of:
Kenneth L. Boston, PE

Signature: 

Date: November 19, 2007

Test Report Reviewed by:

Teresa A. White, Quality Manager

Signature: 

Date: November 19, 2007

Tested by:

Kenneth L. Boston, PE

Signature: 

Date: November 19, 2007

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LSC Revision Control

Date	Revision #	Revised By
9-06-06	2.0	AS/TAW

EXHIBIT 1. INTRODUCTION

1.1 SCOPE

References:	FCC Part 15, Subpart C, Section 15.247
Title:	Telecommunication – Code of Federal Regulations, CFR 47, Part 15
Purpose of Test:	To gain FCC Certification Authorization for Digital Modulation Transmitters operating in the Frequency Band of 2400 MHz – 2483.5 MHz
Test Procedures:	Both conducted and radiated emissions measurements were conducted in accordance with American National Standards Institute ANSI C63.4 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
Environmental Classification:	<ul style="list-style-type: none">• Commercial, Industrial or Business• Residential

1.2 NORMATIVE REFERENCES

Publication	Year	Title
47 CFR, Parts 0-15 (FCC)	2005	Code of Federal Regulations - Telecommunications
ANSI C63.4	2004	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
CISPR 16-1-1	2003	Specification for radio disturbance and immunity measuring apparatus and methods. Part 1-1: Measuring Apparatus.
CISPR 16-2-1	2003	Specification for radio disturbance and immunity measuring apparatus and methods. Part 2-1: Conducted disturbance measurement.
FCC Public Notice DA 00-1407	2000	Part 15 Unlicensed Modular Transmitter Approval
FCC ET Docket No. 99-231	2002	Amendment to FCC Part 15 of the Commission's Rules Regarding Spread Spectrum Devices.
FCC Procedures	2005, 03-23	Measurement of Digital Transmission Systems operating under Section 15.247.

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1.3 LS Research, LLC TEST FACILITY

LS Research, LLC is accredited by A2LA (American Association for Laboratory Accreditation) to conform to ISO/IEC 17025, 2005 "General Requirements for the Competence of Calibration and Testing Laboratories".

LS Research, LLC's scope of accreditation includes all test methods listed herein, unless otherwise noted. A copy of the accreditation may be accessed on our web site: www.lsr.com. Accreditation status can be verified at A2LA's web site: www.a2la2.net.

1.4 LOCATION OF TESTING

All testing was performed at LS Research, LLC, W66 N220 Commerce Court, Cedarburg, Wisconsin, 53012 USA, utilizing the facilities listed below, unless otherwise noted.

List of Facilities Located at LS Research, LLC:

- Compact Chamber
- Semi-Anechoic Chamber
- Open Area Test Site (OATS)

1.5 TEST EQUIPMENT UTILIZED

A complete list of equipment utilized in testing is provided in Appendix A of this test report. Calibration dates are indicated in Appendix A. All test equipment is calibrated in accordance with A2LA standards.

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EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1 CLIENT INFORMATION

Manufacturer Name:	Colorado vNet, LLC
Address:	255 East Sixth Street Loveland, CO 80537
Contact Person:	Eric Rinard, Regulatory Compliance Engineer

2.2 EQUIPMENT UNDER TEST (EUT) INFORMATION

The following information has been supplied by the applicant.

Product Name:	Apex RF Module
Model Number:	13-0091-301 (External Antenna) and 13-0109-301 (Internal Antenna)
Serial Number:	n/a

2.3 ASSOCIATED ANTENNA DESCRIPTION

Ant 1; PCB Antenna, F style.

Ant 2: wire whip $\frac{1}{4}$ wave monopole. Antenna consists of IPEX MHF1 connector on one end of RF113 50 Ohm cable 117 mm long with opposite end jacket and shield stripped 29.2 mm. Center conductor with dielectric covering is the antenna element.

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2.4 EUT'S TECHNICAL SPECIFICATIONS

Additional Information:

Frequency Range (in MHz)	2400-2483.5
RF Power in Watts	0.089 Watts
Conducted Output Power (in dBm)	19.49 dBm
Field Strength (and at what distance)	113.7 dBuV/m @ 3m (2405 MHz)
Occupied Bandwidth (99% BW)	2264 kHz (at 2405 MHz)
Type of Modulation	DSSS 16-ary O-QPSK at a 2 MHz chip rate
Emission Designator	2M26G3D
EIRP (in mW)	100 mw
Transmitter Spurious (worst case)	63.2 dBuV/m (7320 MHz @1 meter)
Frequency Tolerance %, Hz, ppm	< 2 ppm
Microprocessor Model # (if applicable)	n/a
Antenna Information	
Detachable/non-detachable	Both (see type)
Type	¼ wave wire monopole whip, and PCB
Gain (in dBi)	0.0 dBi
EUT will be operated under FCC Rule Part(s)	15.247
Modular Filing	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Type	<input type="checkbox"/> Portable <input checked="" type="checkbox"/> Mobile

RF Technical Information:

Type of Evaluation (check one)		SAR Evaluation: Device Used in the Vicinity of the Human Head
		SAR Evaluation: Body-worn Device
	X	RF Evaluation

If RF Evaluation checked above, test engineer to complete the following:

- Evaluated against exposure limits: ☒ General Public Use ☐ Controlled Use
- Duty Cycle used in evaluation: _____ 100 _____ %
- Standard used for evaluation: _____ OET 65 _____
- Measurement Distance: _____ 0.2 m _____
- RF Value: _____ 0.0199 _____ ☐ V/m ☐ A/m ☒ mW/cm2
☐ Measured ☐ Computed ☒ Calculated

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2.5 PRODUCT DESCRIPTION

The Apex RF Module is a 802.15.4/Zigbee module based upon the Ember EM260 transceiver. It is used in point to point, point to multi-point, and mesh networks. It operates in the 2.4GHz ISM band. The modulation is standard IEEE 802.15.4 format, O-QPSK with half sine filter operating with a chip rate of 2 Mcps. The effective bit rate is 250kbps. The modulation data is generated by the EM260 transceiver itself and spread using 16 orthogonal sequences. 16 channels are used in 5 MHz steps from 2405 to 2480 MHz. An external supply running at 3.3VDC typically is used. A virtual serial port is used to program the test modes with the module. Two antenna configurations are used, an on-board PCB trace antenna and an external quarter wave monopole (cable) antenna. Although this particular design has previously been certified, specific tests have been performed due to a change in the antenna supplied with the product.

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EXHIBIT 3. EUT OPERATING CONDITIONS & CONFIGURATIONS DURING TESTS

3.1 CLIMATE TEST CONDITIONS

Temperature:	21 centigrade
Humidity:	40%
Pressure:	95 kPa

3.2 APPLICABILITY & SUMMARY OF EMC EMISSION TEST RESULTS

FCC Paragraph	Test Requirements	Compliance (yes/no)
15.207	Power Line Conducted Emissions Measurements	Yes
15.247(a)(2)	6 dB Bandwidth of a Digital Modulation System	Yes
15.247(b) & 1.1310	Maximum Output Power	Yes
15.247(i), 1.1307, 1.1310, 2.1091 & 2.1093	RF Exposure Limit	Yes
15.247(c)	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
15.247(d)	Transmitted Power Spectral Density of a Digital Modulation System	Yes
15.247(c), 15.209 & 15.205	Transmitter Radiated Emissions	Yes
<i>The digital circuit portion of the EUT has been tested and verified to comply with FCC Part 15, Subpart B, Class B Digital Devices and the associated Radio Receiver has also been tested and found to comply with Part 15, Subpart B – Radio Receivers. The Receiver Test Report is available upon request.</i>		

3.3 MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES

☒ None ☐ Yes (explain below)

3.4 DEVIATIONS & EXCLUSIONS FROM TEST SPECIFICATIONS

☒ None ☐ Yes (explain below)

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EXHIBIT 4.DECLARATION OF CONFORMITY

The EUT was found to MEET the requirements as described within the specification of FCC Title 47, CFR Part 15.247, and Industry Canada RSS-210 (2005), Section Annex 8 (section 8.2) for a Digital Spread Spectrum (DTS) Transmitter.

If some emissions are seen to be within 3 dB of their respective limits:

As these levels are within the tolerances of the test equipment and site employed, there is a possibility that this unit, or a similar unit selected out of production may not meet the required limit specification if tested by another agency.

LS Research, LLC certifies that the data contained herein was taken under conditions that meet or exceed the requirements of the test specifications. The results in this Test Report apply only to the item(s) tested on the above-specified dates. Any modifications made to the EUT subsequent to the indicated test date(s) will invalidate the data herein, and void this certification.

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EXHIBIT 5. RADIATED EMISSIONS TEST

5.1 Test Setup

The test setup was assembled in accordance with Title 47, CFR FCC Part 15 and ANSI C63.4-2003. The EUT was placed on an 80cm high non-conductive pedestal, centered on a flush mounted 2-meter diameter turntable inside a 3 meter Semi-Anechoic, FCC listed Chamber. The EUT was operated in a continuous modulated transmit mode, and final testing was performed in this manner. The unit has the capability to operate on 16 channels, controllable via programming via a laptop PC.

The applicable limits apply at a 3 meter distance. Measurements above 5 GHz were performed at a 1.0 meter separation distance. The calculations to determine these limits are detailed in the following pages. Please refer to Appendix A for a complete list of test equipment. The test sample was operated on one of three (3) standard channels: low (2405 MHz), middle (2440 MHz) and high (2475/2480 MHz) to comply with FCC Part 15.35. The channels and operating modes were changed using a PC.

5.2 Test Procedure

Radiated RF measurements were performed on the EUT in a 3 meter Semi-Anechoic, FCC listed Chamber. The frequency range from 30 MHz to 25000 MHz was scanned and investigated. The radiated RF emission levels were manually noted at the various fixed degree settings of azimuth on the turntable and antenna height. The EUT was placed on a non-conductive pedestal in the 3 meter Semi-Anechoic Chamber, with the antenna mast placed such that the antenna was 3 meters from the EUT. A Biconical Antenna was used to measure emissions from 30 MHz to 300 MHz, and a Log Periodic Antenna was used to measure emissions from 300 MHz to 1000 MHz. A Double-Ridged Waveguide Horn Antenna was used from 1 GHz to 18 GHz. The maximum radiated RF emissions were found by raising and lowering the antenna between 1 and 4 meters in height, using both horizontal and vertical antenna polarities. From 18 GHz to 25 GHz, the EUT was measured at a 1.0 meter separation, using a standard gain Horn Antenna and pre-amplifier.

The EUT was rotated along three orthogonal axes during the investigations to find the highest emission levels.

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5.3 Test Equipment Utilized

A list of the test equipment and antennas utilized for the Radiated Emissions test can be found in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. All calibrations of the antennas used were performed at an N.I.S.T. traceable site. In addition, the Connecting Cables were measured for losses using a calibrated Signal Generator and a HP 8546A EMI Receiver. The resulting correction factors and the cable loss factors from these calibrations were entered into the HP 8546A EMI Receiver database. As a result, the data taken from the HP 8546A EMI Receiver accounts for the antenna correction factor as well as cable loss or other corrections, and can therefore be entered into the database as a corrected meter reading. The HP 8546A EMI Receiver was operated with a resolution bandwidth of 120 kHz for measurements below 1 GHz (video bandwidth of 300 kHz), and a bandwidth of 1 MHz for measurements above 1 GHz (video bandwidth of 1 MHz) From 5 GHz to 18 GHz, an HP E4446 Spectrum Analyzer and an EMCO Horn Antenna were used. From 18 GHz to 25 GHz, the HP E4446 Spectrum Analyzer with a standard gain horn, and preamp were used.

Test Equipment List

Test Equipment	Manufacturer	Model No.	Serial No.
EMI Receiver	HP	8546A	3617A00320
EMI Receiver Pre-Select.	HP	85460A	3448A00296
Spectrum Analyzer	Agilent	E4446A	US45300564
Log Periodic Antenna	EMCO	93146	9701-4855
Horn Antenna	EMCO	3115	6907
Bicon Antenna	EMCO	93110B	9702-2918
Pre-Amp	Adv. Microwave	WLA612	1145A04094
Horn Antenna – Std. Gain	EMCO	3160-09	9809-1120

5.4 Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247 for a DTS transmitter [Canada RSS-210 (2005), Annex 8 (section 8.2)]. The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

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5.5 CALCULATION OF RADIATED EMISSIONS LIMITS

The maximum peak output power of an intentional radiator in the 2400-2483.5 MHz band, as specified in Title 47 CFR 15.247 (b)(3), is 1 Watt. The harmonic and spurious RF emissions, as measured in any 100 kHz bandwidth, as specified in 15.247 (d), shall be at least 20 dB below the measured power of the desired signal, and must also meet the requirements described in 15.205(c).

The following table depicts the general radiated emission limits above 30 MHz. These limits are obtained from Title 47 CFR, Part 15.209, for radiated emissions measurements. These limits were applied to any signals found in the 15.205 restricted bands.

Frequency (MHz)	3 m Limit $\mu\text{V/m}$	3 m Limit (dB $\mu\text{V/m}$)	1 m Limit (dB $\mu\text{V/m}$)
30-88	100	40.0	-
88-216	150	43.5	-
216-960	200	46.0	-
960-24,000	500	54.0	63.5

Sample conversion from field strength $\mu\text{V/m}$ to dB $\mu\text{V/m}$:

$$\begin{aligned}\text{dB}\mu\text{V/m} &= 20 \log_{10} (100) \\ &= 40 \text{ dB}\mu\text{V/m (from 30-88 MHz)}\end{aligned}$$

For measurements made at 1.0 meter, a 9.5 dB correction has been invoked.

$$\begin{aligned}&960 \text{ MHz to } 10,000 \text{ MHz} \\ &500\mu\text{V/m or } 54.0 \text{ dB}\mu\text{V/m at 3 meters} \\ &54.0 + 9.5 = 63.5 \text{ dB}\mu\text{V/m at 1 meter}\end{aligned}$$

For measurements made at 0.3 meter, a 20 dB correction has been invoked.

$$\begin{aligned}&960 \text{ MHz to } 10,000 \text{ MHz} \\ &500\mu\text{V/m or } 54.0 \text{ dB}\mu\text{V/m at 3 meters} \\ &54.0 + 20 = 74 \text{ dB}\mu\text{V/m at 0.3 meters}\end{aligned}$$

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5.6

RADIATED EMISSIONS DATA CHART

3 Meter Measurements of Electromagnetic Radiated Emissions

Test Standard: 47CFR, Part 15.205 and 15.247(DTS)

Frequency Range Inspected: 30 MHz to 25000 MHz

Manufacturer:	Colorado vNet, LLC				
Date(s) of Test:	May 1, 2007; August 15, 16 & 21, 2007				
Test Engineer(s):	Ken Boston				
Voltage:	3.3 VAC				
Operation Mode:	Continuous transmit, modulated mode				
Environmental Conditions in the Lab:	Temperature: 20 – 25° C Relative Humidity: 30 – 60 %				
EUT Power:		Single Phase ___ VAC		3 Phase ___ VAC	
		Battery	x	Other: 3.3 VDC	
EUT Placement:	x	80cm non-conductive pedestal		10cm Spacers	
EUT Test Location:	x	3 Meter Semi-Anechoic FCC Listed Chamber		3/10m OATS	
Measurements:		Pre-Compliance		Preliminary	x Final
Detectors Used:		Peak		Quasi-Peak	x Average

The following table depicts the level of significant spurious radiated RF emissions found (whip antenna):

Frequency (MHz)	Ant./EUT Polarity	Channel	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.205 Limit (dBμV/m)	Margin (dB)
2389.5	v/v	2405	1.22	228	46.3	54.0	7.7
2381.0	v/v	2405	1.22	228	46.2	54.0	7.8
2486.2	v/v	2475	1.14	154	52.3	54.0	1.7
2484.0	v/v	2480	1.08	260	53.3	54.0	0.7

The following table depicts the measured radiated EIRP

Frequency (MHz)	Ant./EUT Polarity	Antenna Sample	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)
2405.0	v/v	Whip	1.2	220	113.7
2440.0	v/v	Whip	1.2	190	112.2
2475.0	v/v	Whip	1.15	150	107.6
2480.0	v/v	Whip	1.1	270	97.8

Note: These values are compared and verified with the calculated radiated field strength (EIRP) values under Exhibit 9 of this test report.

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RADIATED EMISSIONS DATA CHART (continued)

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 2405(+3):

Frequency (MHz)	Ant./EUT Polarity	Antenna Sample	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
4810	v/v	PCB	1.0	330	53.2	63.5	10.3
7215	v/v	PCB	1.0	90	58.6	93.7	35.1
9620	h/s	PCB	1.0	170	69.9	93.7	23.8
12025	h/s	PCB	1.02	225	54.7	63.5	8.8
14427	v/v	PCB	1.0	110	51.3	93.7	42.4
16831	h/s	PCB	1.0	320	53.2	93.7	40.5
19240	h/v	PCB	.8	182	56.5	63.5	7.0
21645	h/v	PCB	.9	213	57.1	93.7	36.6

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 2440 (+3):

Frequency (MHz)	Ant./EUT Polarity	Antenna Sample	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
4880	v/s	PCB	1.0	330	56.2	63.5	7.3
7320	v/v	PCB	1.0	90	63.2	63.5	0.3
9770	v/v	PCB	1.0	170	69.7	92.2	22.5
12190	h/s	PCB	1.02	225	54.9	63.5	8.6
14640	v/s	PCB	1.0	100	50.5	92.2	41.7
17080	h/s	PCB	1.1	100	52.7	92.2	39.5
19520	h/v	PCB	1.1	180	54.5	63.5	9.0
21960	h/v	PCB	1.02	200	52.5	92.2	39.7

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 2475 (-10):

Frequency (MHz)	Ant./EUT Polarity	Antenna Sample	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
		PCB			Note 3		

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 2480 (-23):

Frequency (MHz)	Ant./EUT Polarity	Antenna Sample	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
		PCB			Note 3		

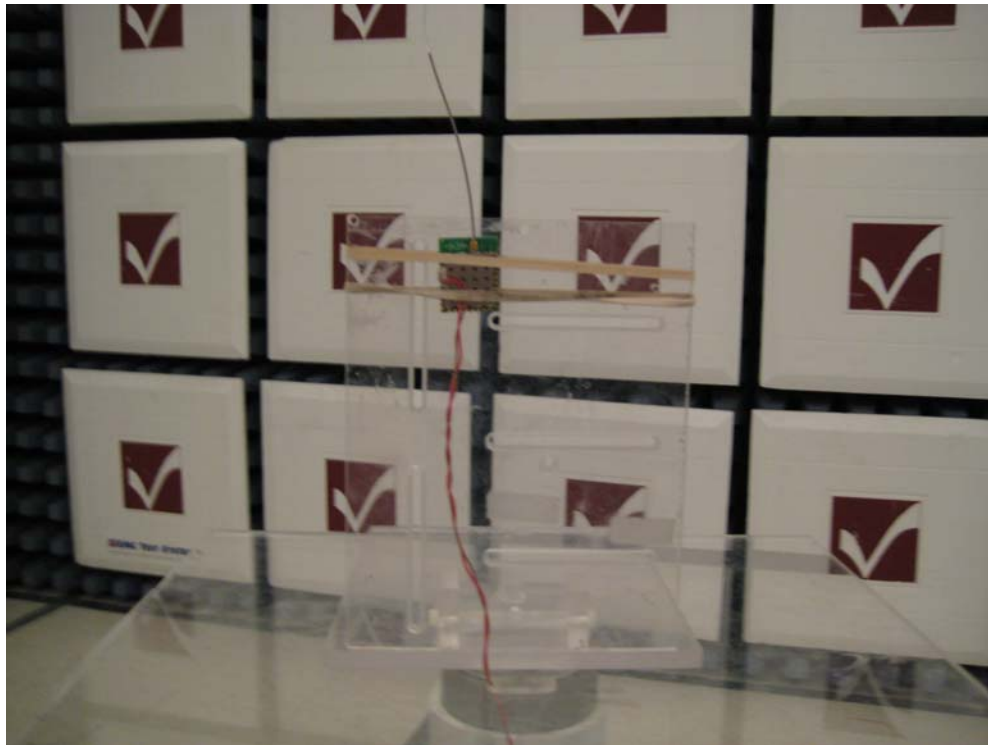
Notes:

- 1) A Quasi-Peak Detector was used in measurements below 1 GHz. The peak detector was used to ensure the peak emissions did not exceed 20 dB above the limits.
- 2) Measurements above 4 GHz were made at 1 meters of separation from the EUT.
- 3) Measurement at receiver system noise floor.
- 4) Value in parenthesis is the manufacturer's power setting.
- 5) The PCB was tested in 3 orthogonal positions with both antennas, orientations with the highest emissions are reported.

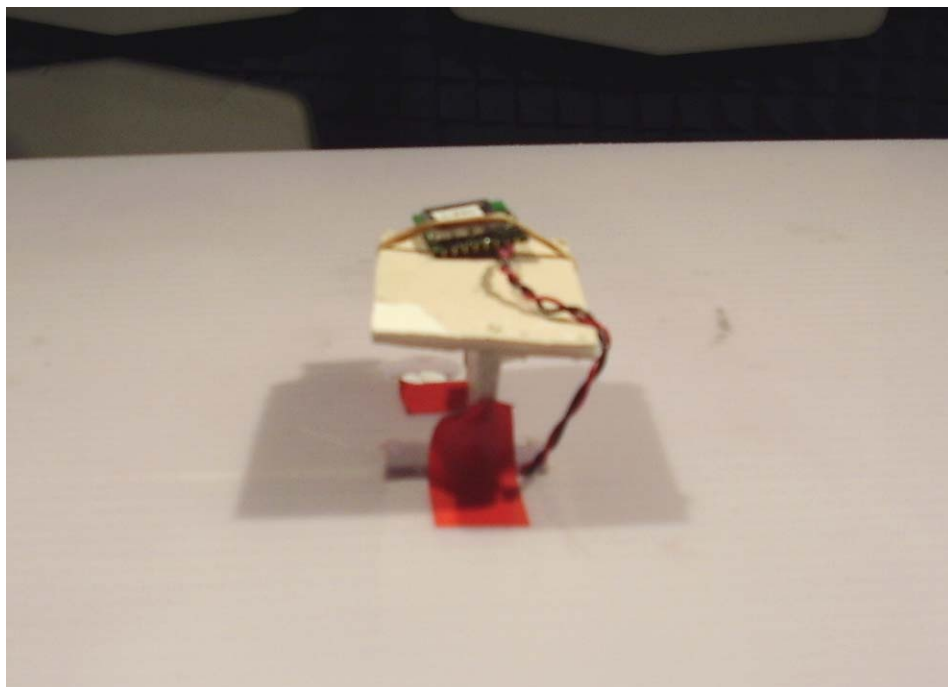
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5.7 Test Setup Photo(s) – Radiated Emissions Test

Vertical Orientation with whip antenna

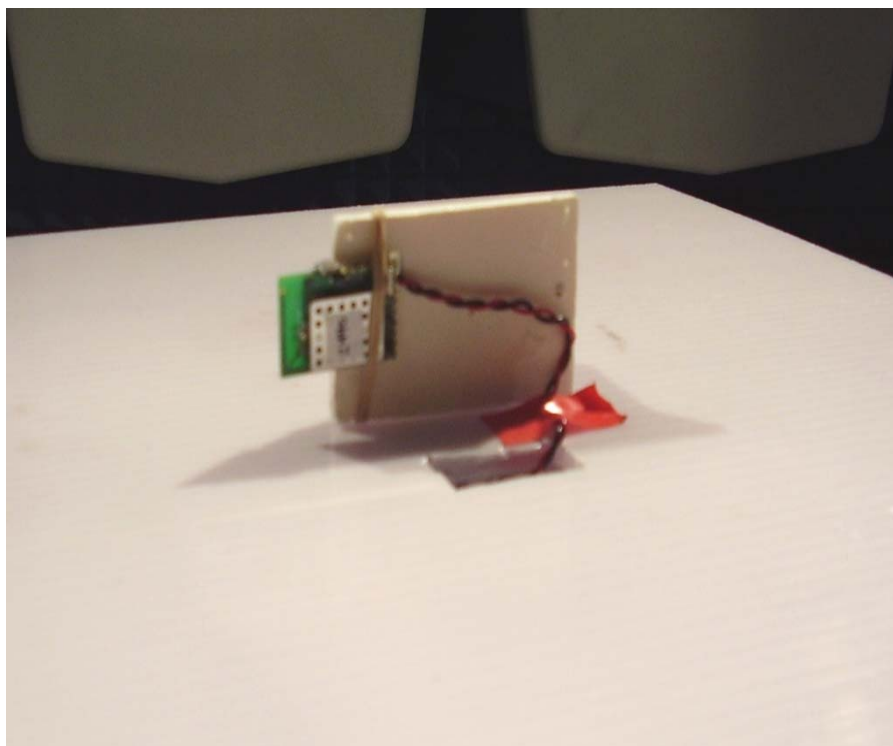


Horizontal Orientation with PCB Antenna



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Side Orientation

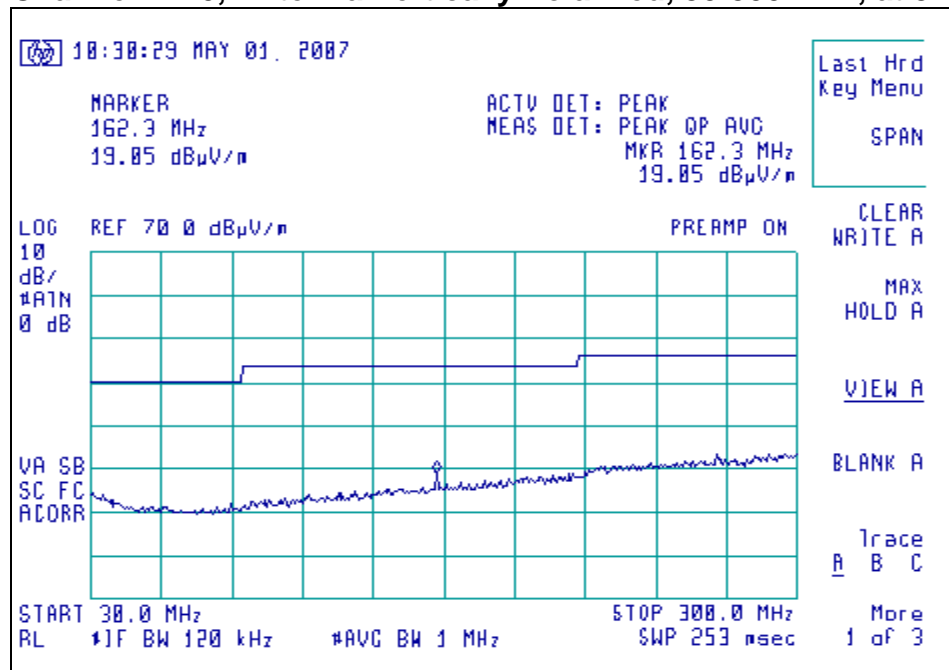


Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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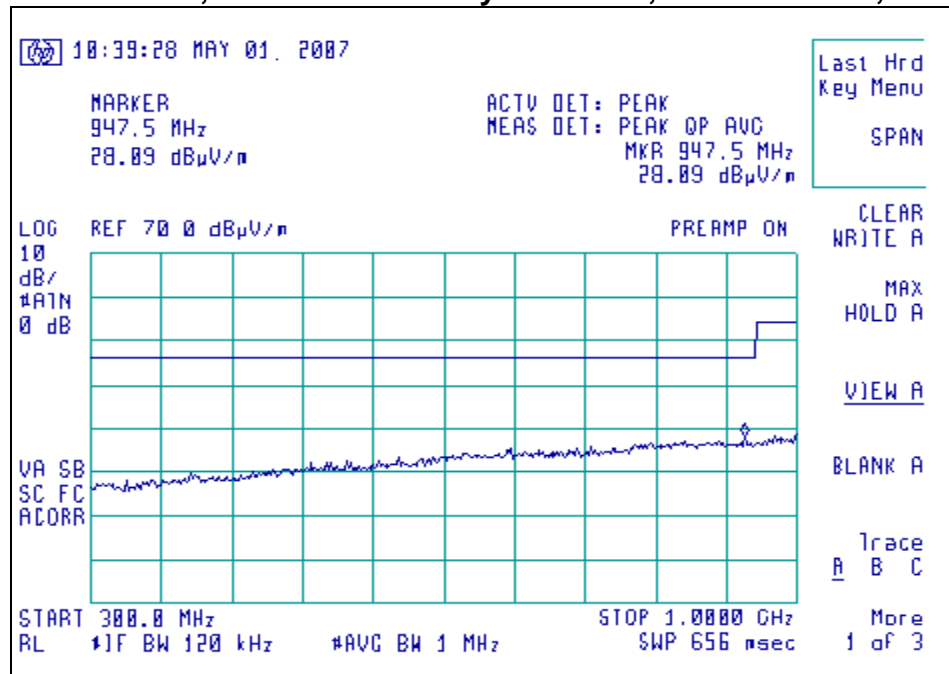
5.8 Screen Captures - Radiated Emissions Testing

These screen captures represent Peak Emissions.

Channel 2440, Antenna Vertically Polarized, 30-300 MHz, at 3m



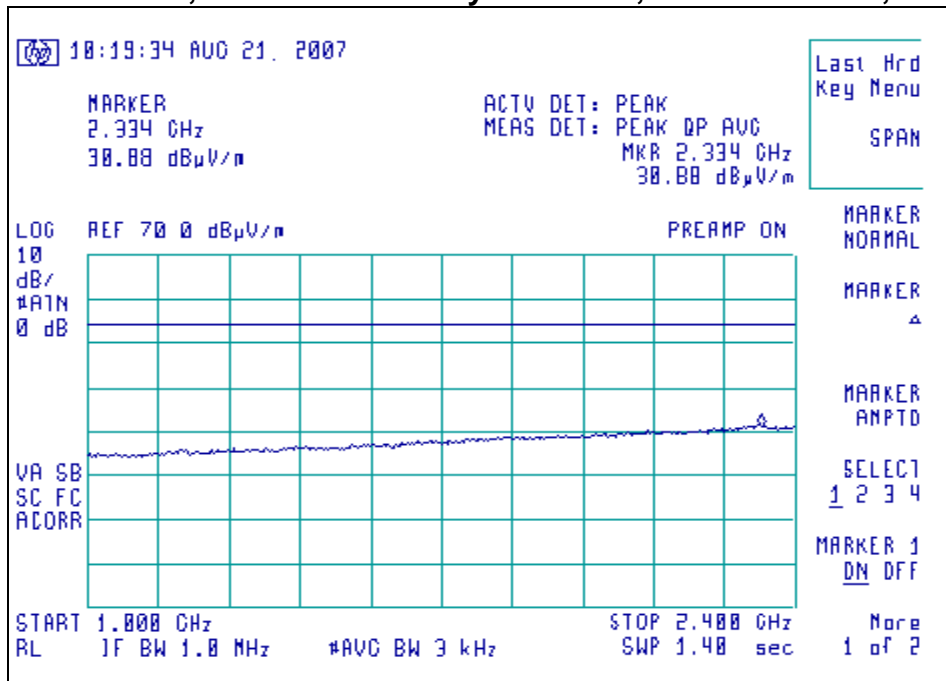
Channel 2440, Antenna Vertically Polarized, 300-1000 MHz, at 3m



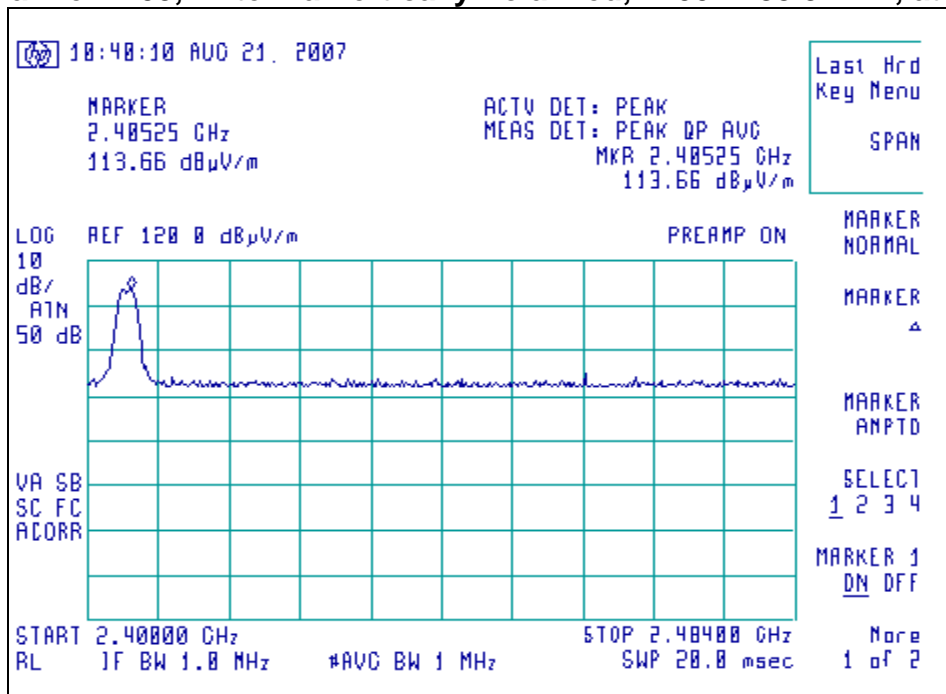
Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Screen Captures - Radiated Emissions Testing (continued)

Channel 2440, Antenna Vertically Polarized, 1000-2400 MHz, at 3m

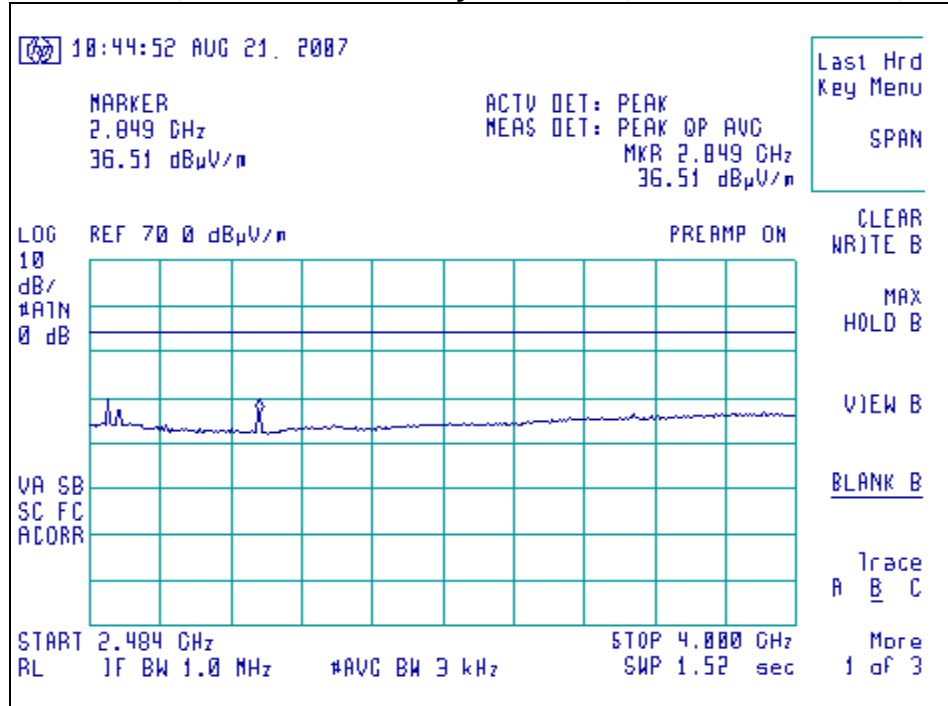


Channel 2405, Antenna Vertically Polarized, 2400-2483.5 MHz, at 3m

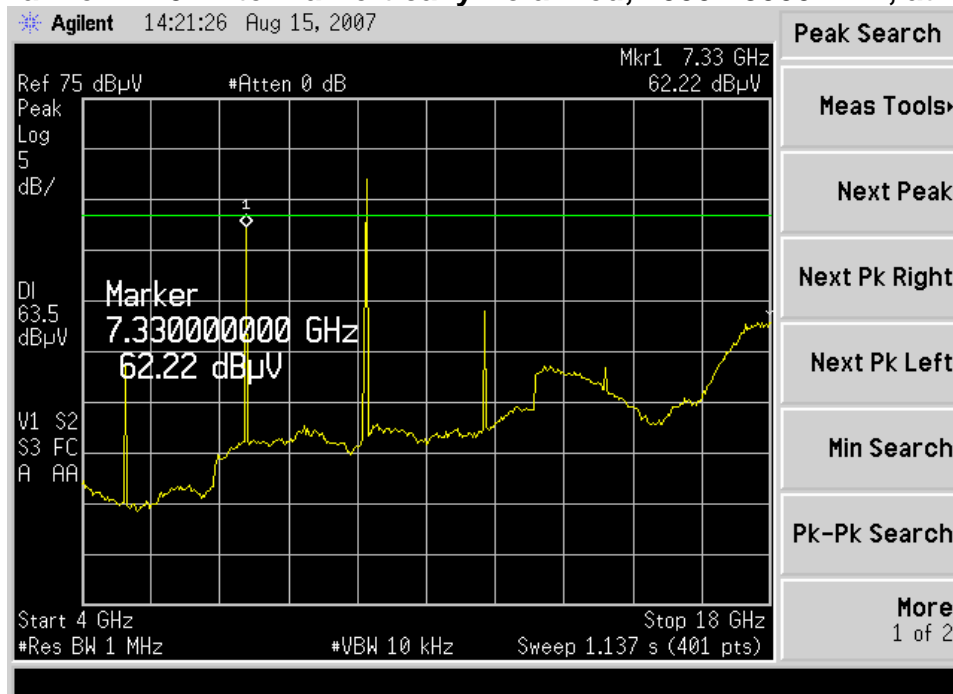


Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Channel 2405, Antenna Vertically Polarized, 2484.0-4000 MHz, at 3m



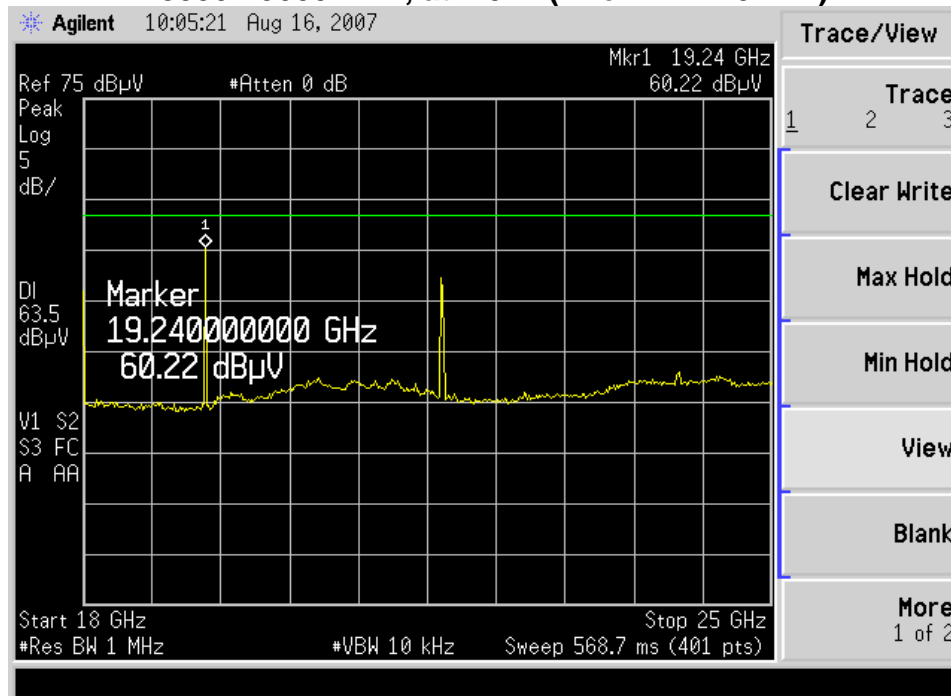
Channel 2440 Antenna Vertically Polarized, 4000-18000 MHz, at 1m



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Screen Captures - Radiated Emissions Testing (continued)

Channel 2405, Antenna Vertically Polarized, 18000-25000 MHz, at 1.0 M (Ave BW = 10 kHz)



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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EXHIBIT 6. CONDUCTED EMISSIONS TEST, AC POWER LINE: 15.207

6.1 Test Setup

The test area and setup are in accordance with ANSI C63.4-2003 and with Title 47 CFR, FCC Part 15 (Industry Canada RSS-210, Issue 6). The EUT was placed on a non-conductive wooden table, with a height of 80 cm above the reference ground plane. The EUT's power cable was plugged into a 50 Ω (ohm), 50/250 μ H Line Impedance Stabilization Network (LISN). The AC power supply of 120V was provided inside the 3 Meter Semi-Anechoic Chamber via an appropriate broadband EMI Filter, and then to the LISN line input. Final readings were then taken and recorded. After the EUT was setup and connected to the LISN, the RF Sampling Port of the LISN was connected to a 10 dB Attenuator-Limiter, and then to the HP 8546A EMI Receiver. The EMCO LISN used has the ability to terminate the unused port with a 50 Ω (ohm) load when switched to either L1 (line) or L2 (neutral).

6.2 Test Procedure

The EUT was investigated in continuous modulated transmit mode for this portion of the testing. The appropriate frequency range and bandwidths were selected on the EMI Receiver, and measurements were made. The bandwidth used for these measurements is 9 kHz, as specified in CISPR 16-1 (2003), Section 1, Table 1, for Quasi-Peak and Average detectors in the frequency range of 150 kHz to 30MHz. Final readings were then taken and recorded.

6.3 Test Equipment Utilized

A list of the test equipment and accessories utilized for the Conducted Emissions test is provided in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. Calibrations of the LISN and Limiter are traceable to N.I.S.T. All cables are calibrated and checked periodically for conformance. The emissions are measured on the HP 8546A EMI Receiver, which has automatic correction for all factors stored in memory and allows direct readings to be taken.

Test Equipment List

Test Equipment	Manufacturer	Model No.	Serial No.
EMI Receiver	HP	8546A	3617A00320
Spectrum Analyzer	Agilent	E4446A	US45300564
LISN	EMCO	3816/2NM	9701-1057
Transient Limiter	HP	119474A	3107A01708

6.4 Test Results

The EUT was found to **MEET** the Conducted Emission requirements of FCC Part 15.207 Conducted Emissions for an Intentional Radiator. See the Data Charts and Graphs for more details of the test results.

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EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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6.5 FCC Limits of Conducted Emissions at the AC Mains Ports

Frequency Range (MHz)	Class B Limits (dBμV)		Measuring Bandwidth
	Quasi-Peak	Average	
0.150 -0.50 *	66-56	56-46	RBW = 9 kHz VBW ≥ 9 kHz for QP VBW = 1 Hz for Average
0.5 – 5.0	56	46	
5.0 – 30	60	50	
* The limit decreases linearly with the logarithm of the frequency in this range.			

6.6

TEST DATA CHART CONDUCTED EMISSION

Frequency Range inspected: 150 KHz to 30 MHz

Test Standard: FCC 15.207 Class B

Manufacturer:	Colorado vNet, LLC				
Date(s) of Test:	May 30, 2007				
Test Engineer:	Ken Boston				
Model #:	Apex RF Module, Model #13-0091-301 (External Antenna) and Apex RF Module, Model #13-0109-301 (Internal Antenna)				
Serial #:	n/a				
Voltage:	115 VAC Source to HP6284A, supplying 3.3 VAC to EUT				
Operation Mode:	continuous transmit, modulated				
Environmental Conditions in the Lab:	Temperature: 20 – 25° C Relative Humidity: 30 – 60 %				
Test Location:	X	CE ground planes			Chamber
EUT Placed On:	X	40cm from Vertical Ground Plane			10cm Spacers
	X	80cm above Ground Plane			Other:
Measurements:		Pre-Compliance		Preliminary	X Final
Detectors Used:		Peak	X	Quasi-Peak	X Average

		<u>QUASI-PEAK</u>			<u>AVERAGE</u>		
Frequency (MHz)	Line	Q-Peak Reading (dBμV)	Q-Peak Limit (dBμ V)	Quasi-Peak Margin (dB)	Average Reading (dBμV)	Average Limit (dBμ V)	Average Margin (dB)
0.16	L1	49.2	65.4	16.2	18.5	55.4	36.9
0.73	L1	39.3	56.0	16.7	8.2	46.0	37.8
19.87	L1	39.7	60.0	20.3	30.6	50.0	19.4
0.16	L2	53.1	65.4	12.3	20.9	55.4	34.5
0.76	L2	40.5	56.0	15.5	9.8	46.0	36.2
20.06	L2	43.4	60.0	16.6	35.2	50.0	14.8

Notes:

- 1) The emissions listed are characteristic of the power supply used, and did not change by the EUT.
- 2) All other emissions were better than 20 dB below the limits.
- 3) The EUT exhibited similar emissions in transmit and receive modes, and across the Low, Middle and High channels tested.

Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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6.7 Test Setup Photo(s) – Conducted Emissions Test

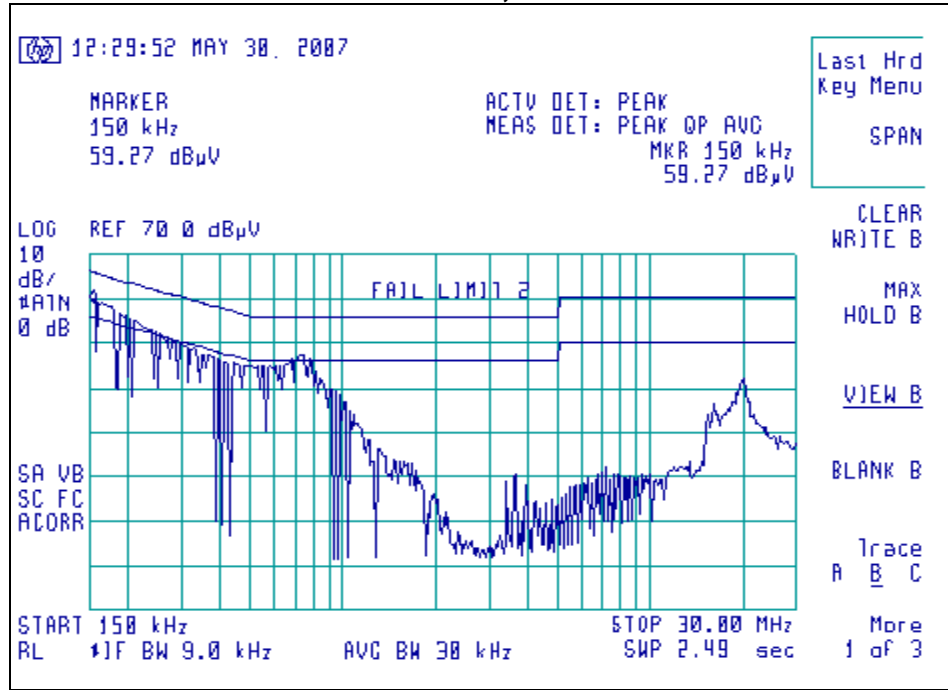


Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
Report #:307247TCB	Customer FCC ID #: VOX-APEXLT	Page 25 of 45

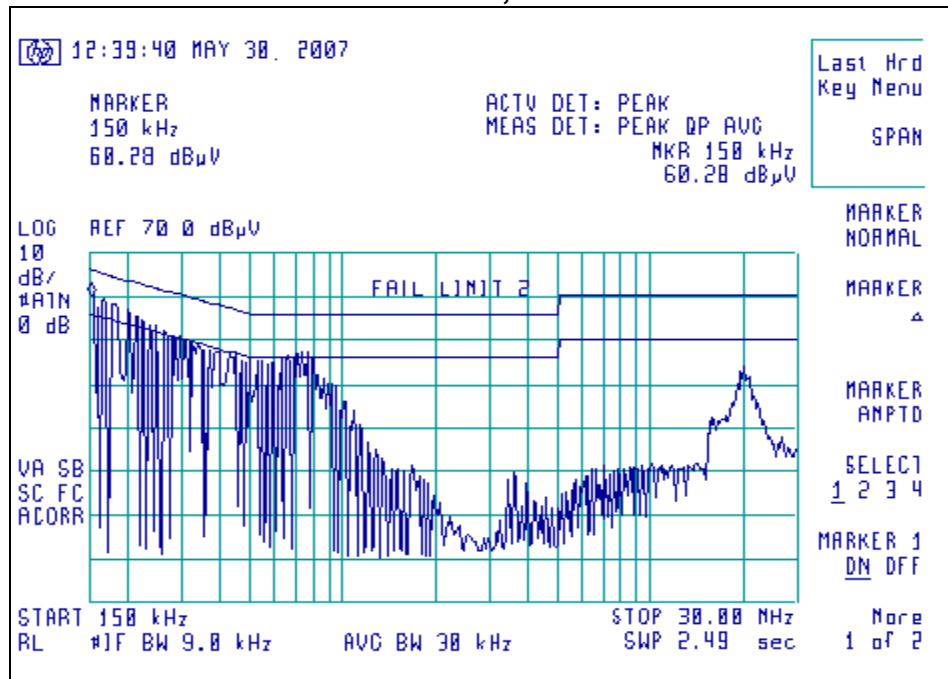
6.8 Screen Captures – Conducted Emissions Test

These screen captures represent Peak Emissions. For conducted emission measurements, both a Quasi-Peak detector function and an Average detector function are utilized. The emissions must meet both the Quasi-peak limit and the Average limit as described in 47 CFR 15.207.

2440 MHz, Line 1



2440 MHz, Line 2



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EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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EXHIBIT 7. OCCUPIED BANDWIDTH: 15.247(a)(2)

7.1 Limits

For a Digital Modulation System, the 6 dB bandwidth shall be at least 500 kHz.

7.2 Method of Measurements

Refer to ANSI C63.4 and FCC Procedures (March 23, 2005) for Digital Transmission Systems operating under 15.247.

The transmitter output was connected to the Spectrum Analyzer. The bandwidth of the fundamental frequency was measured with the Spectrum Analyzer using 100 kHz RBW and VBW=300 kHz.

The bandwidth requirement found in FCC Part 15.247(a)(2) requires a minimum -6dBc occupied bandwidth of 500 kHz. For this portion of the tests, a direct measurement of the transmitted signal was performed at the antenna port of the EUT, via a cable connection to the HP E4407B spectrum analyzer. An attenuator was placed in series with the cable to protect the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, thereby allowing direct measurements, without the need for any further corrections. A Hewlett Packard model E4407B spectrum analyzer was used with the resolution bandwidth set to 100 kHz for this portion of the tests. The EUT was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used in peak-hold mode while measurements were made, as presented in the chart below.

From this data, the closest measurement when compared to the specified limit, is 1536 kHz, which is above the minimum of 500 kHz.

Test Data

Channel	Center Frequency (MHz)	Measured -6 dBc Occ. BW (kHz)	Minimum -6 dBc Limit (kHz)	Measured -20 dBc Occ.Bw (kHz)
B	2405	1590	500	2264
12	2440	1536	500	2230
19	2475	1566	500	2243
1a	2480	1540	500	2243

7.3 Test Equipment List

Test Equipment	Manufacturer	Model No.	Serial No.
Spectrum Analyzer	Agilent	E4407B	US39160256
Spectrum Analyzer	Agilent	E4446A	US45300564

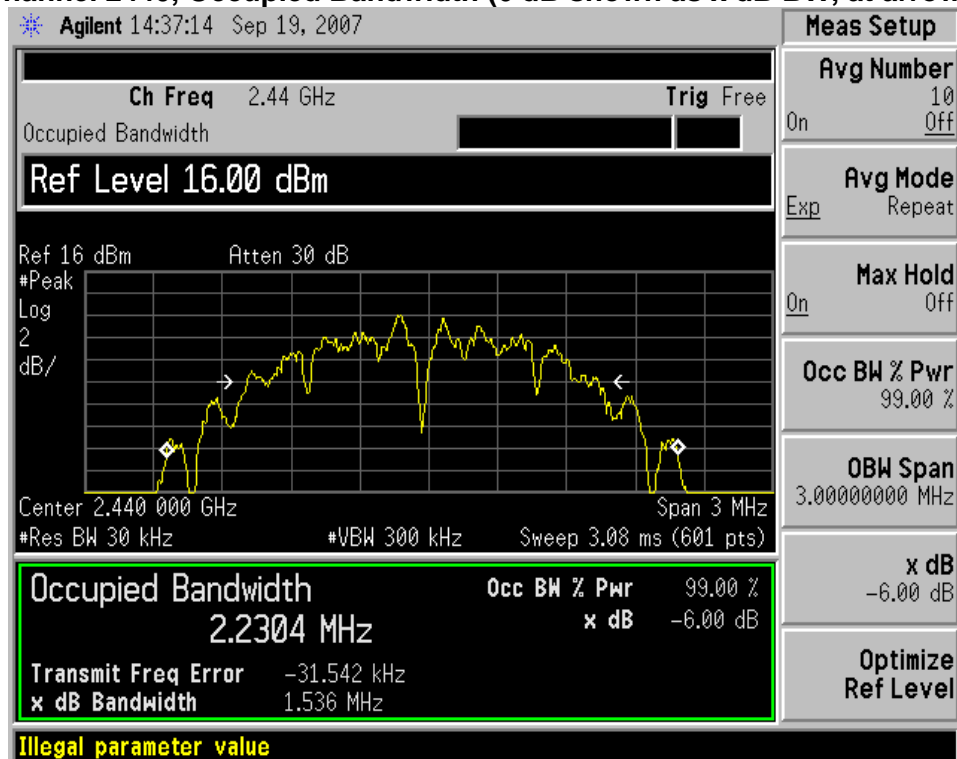
Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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7.4 Screen Captures - OCCUPIED BANDWIDTH (6 dB and 99%)

Channel 2405, Occupied Bandwidth (6 dB shown as x dB BW, at arrows)

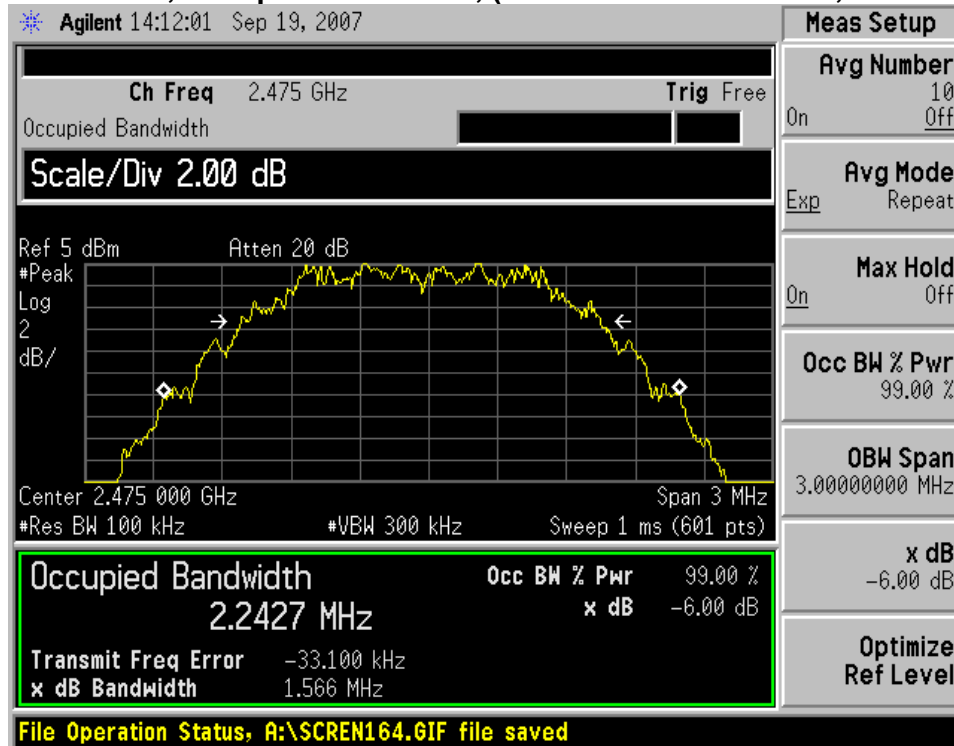


Channel 2440, Occupied Bandwidth (6 dB shown as x dB BW, at arrows)

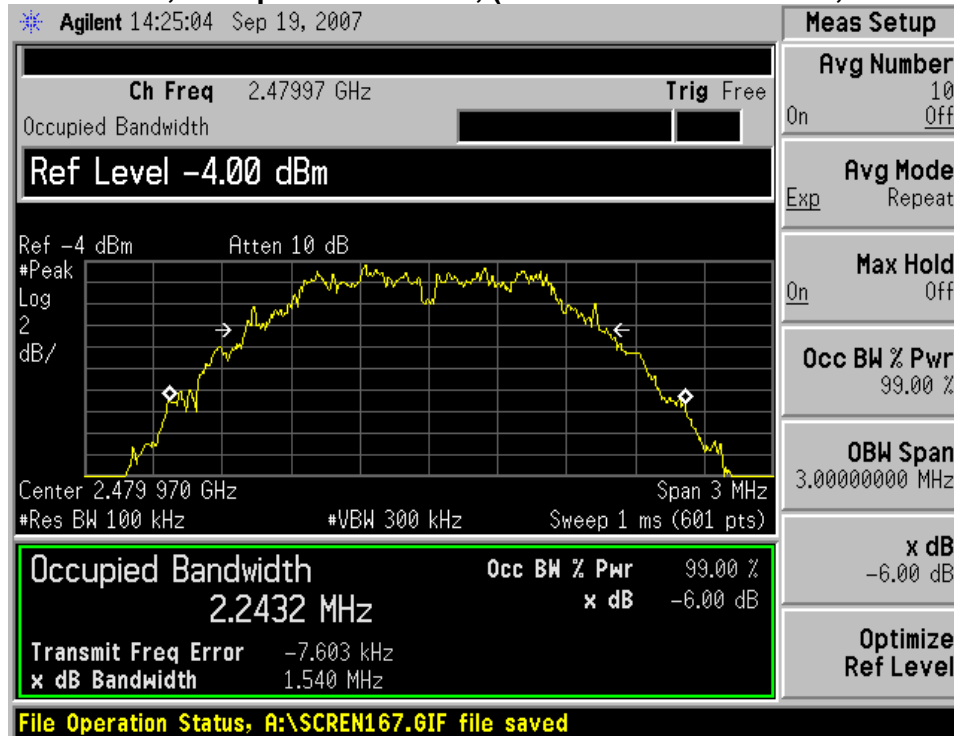


Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Channel 2475, Occupied Bandwidth, (6 dB shown as x dB BW, at arrows)



Channel 2480, Occupied Bandwidth, (6 dB shown as x dB BW, at arrows)



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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EXHIBIT 8.BAND-EDGE MEASUREMENTS

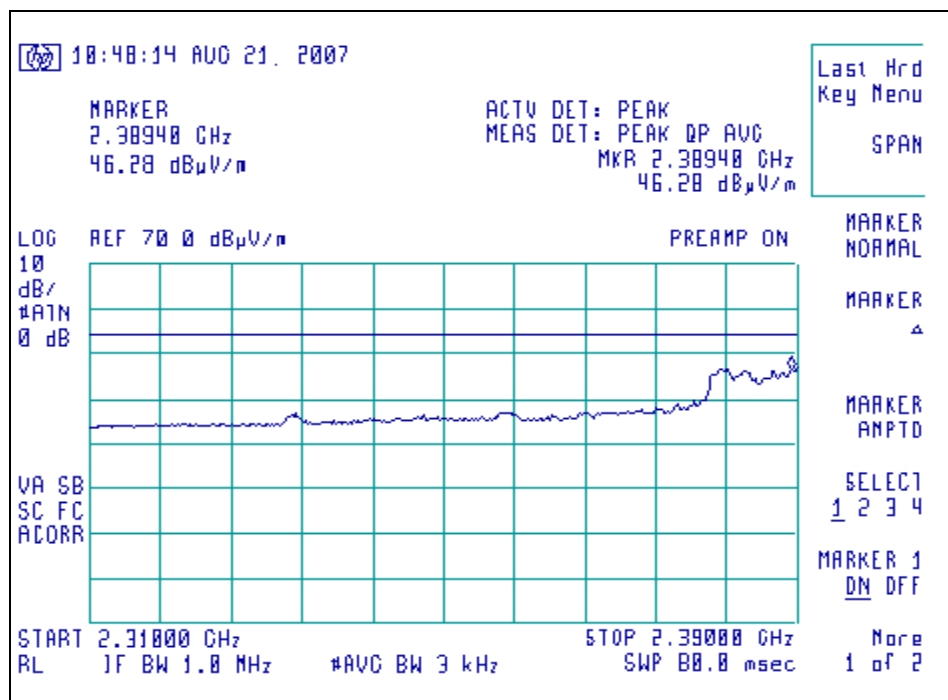
8.1 Method of Measurements

FCC 15.209(b) and 15.247(d) require a measurement of spurious emission levels to be at least 20 dB lower than the fundamental emission level, in particular at the Band-Edges where the intentional radiator operates. The following screen captures demonstrate compliance of the intentional radiator at the 2400-2483.5 MHz Band-Edges. The EUT was operated in continuous transmit mode with continuous modulation, with internally generated data as the modulating source. The EUT was operated at the lowest channel for the investigation of the lower Band-Edge, and at the highest channel for the investigation of the higher Band-Edge.

The Lower Band-Edge limit, in this case, would be -20 dBc with respect to the fundamental level pks. 54 dBuV below 2390 MHz

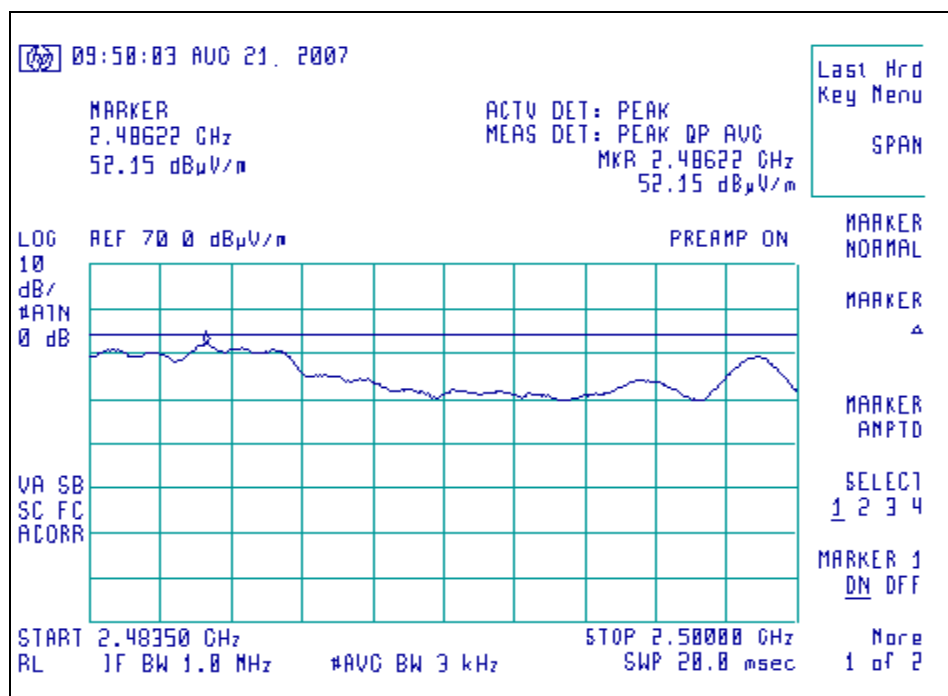
The Upper Band-Edge limit, in this case, would be + 54 dBuV/m at 3m.

Screen Capture Demonstrating Compliance at the Lower Band-Edge, channel 2405 MHz



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Screen Capture Demonstrating Compliance at the Higher Band-Edge, channel 2475 MHz



Screen Capture Demonstrating Compliance at the Higher Band-Edge, channel 2480 MHz

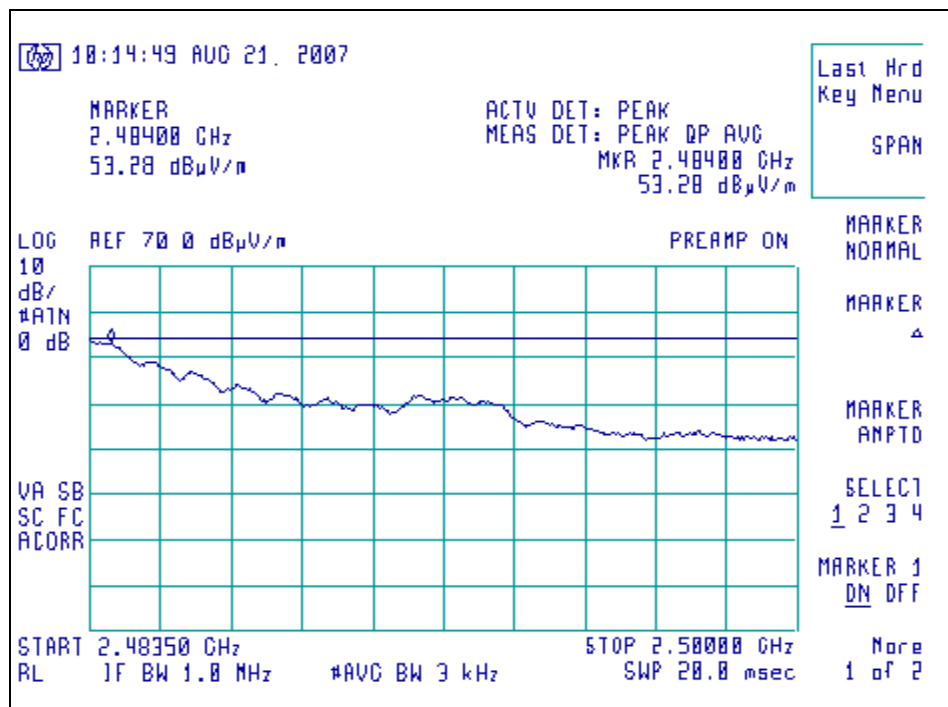


EXHIBIT 9. POWER OUTPUT (CONDUCTED): 15.247(b)

9.1 Method of Measurements

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, there by allowing direct measurements without the need for any further corrections. The unit was configured to run in a continuous transmit mode, while being supplied with an internal data program as a modulation source. The spectrum analyzer was used with resolution and video bandwidths set to 5 MHz, and a span of 9 MHz, with measurements from a peak detector presented in the chart below.

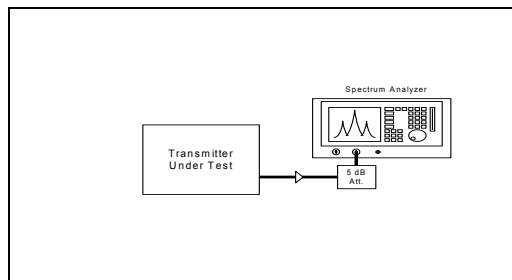
9.2 Test Data

Transmitter Channel	Freq. (MHz)	Peak Power at Antenna Terminal (dBm)	⁽¹⁾ Calculated EIRP (dBuV/m at 3 meters)	Conducted Power Limit (dBm)	EIRP Limit (dBm)
Lowest	2405	19.49	114.72	30.0	36.0
Middle	2445	19.42	114.65	30.0	36.0
Next Highest	2475	9.49	104.72	30.0	36.0
Highest	2480	-0.3	94.93	30.0	36.0

⁽¹⁾ EIRP Calculation:

EIRP = (Peak power at antenna terminal in dBm) + (EUT Antenna gain in dBi) + (95.23 dB correction to convert power to field strength at 3 meters)

Example: at 2405 MHz; 19.49 + 0.0 dBi gain + 95.23 = 114.72.



Rated RF power output (in watts): 0.100

Measured RF Power Output (in Watts): 0.089

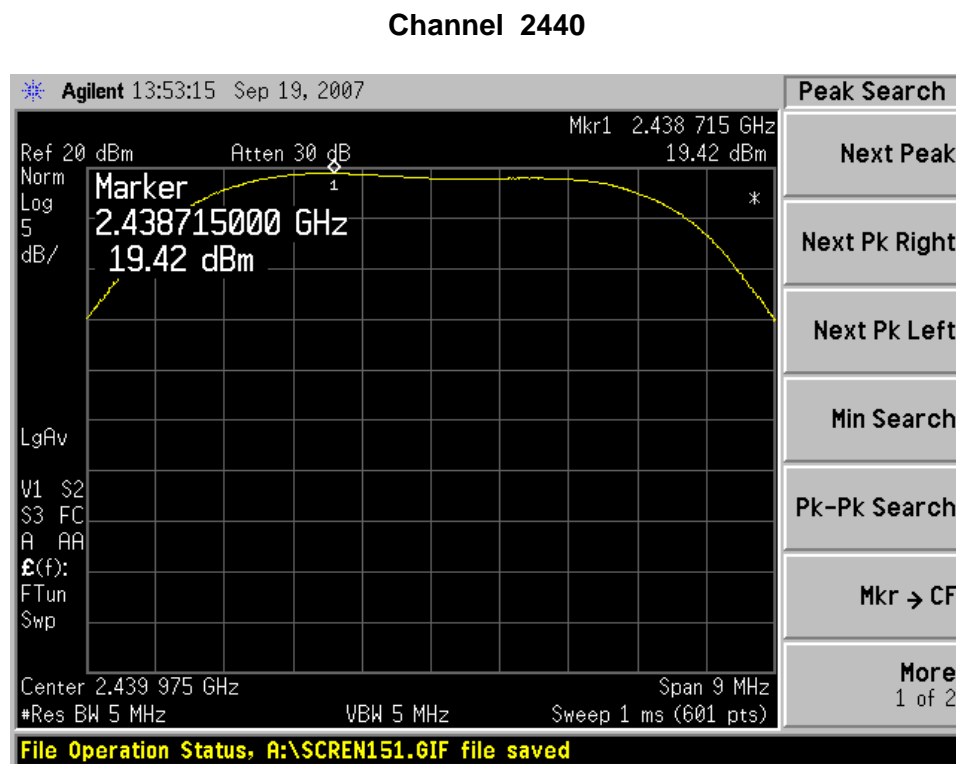
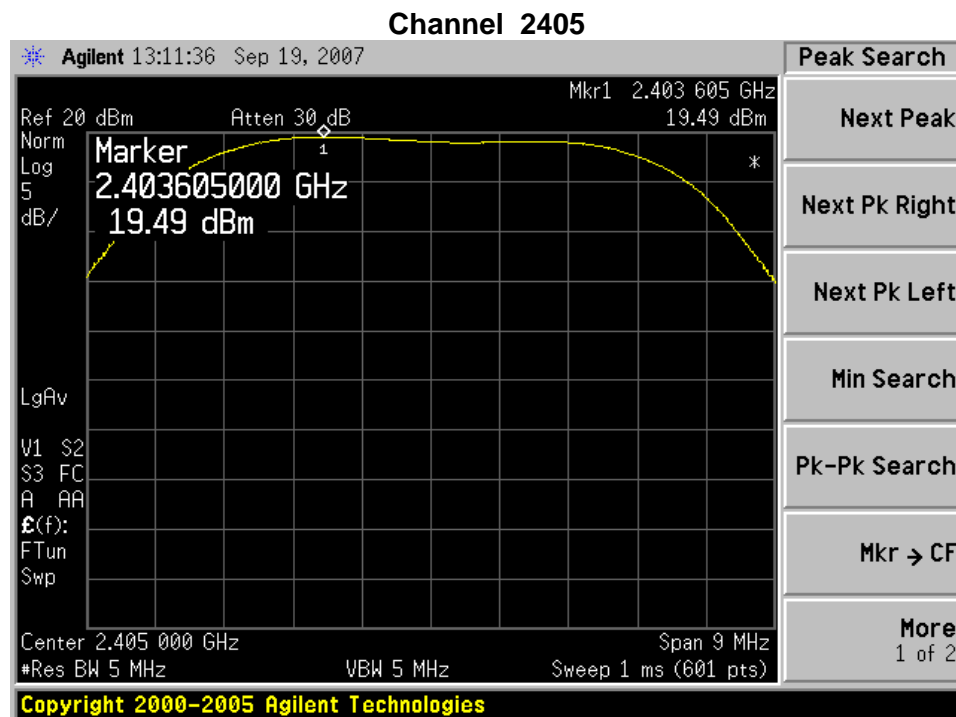
Declared RF Power Output (in Watts): .089

9.3 Test Equipment List

Test Equipment	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer	Agilent	E4446	US45300564	30 hz to 44 GHz

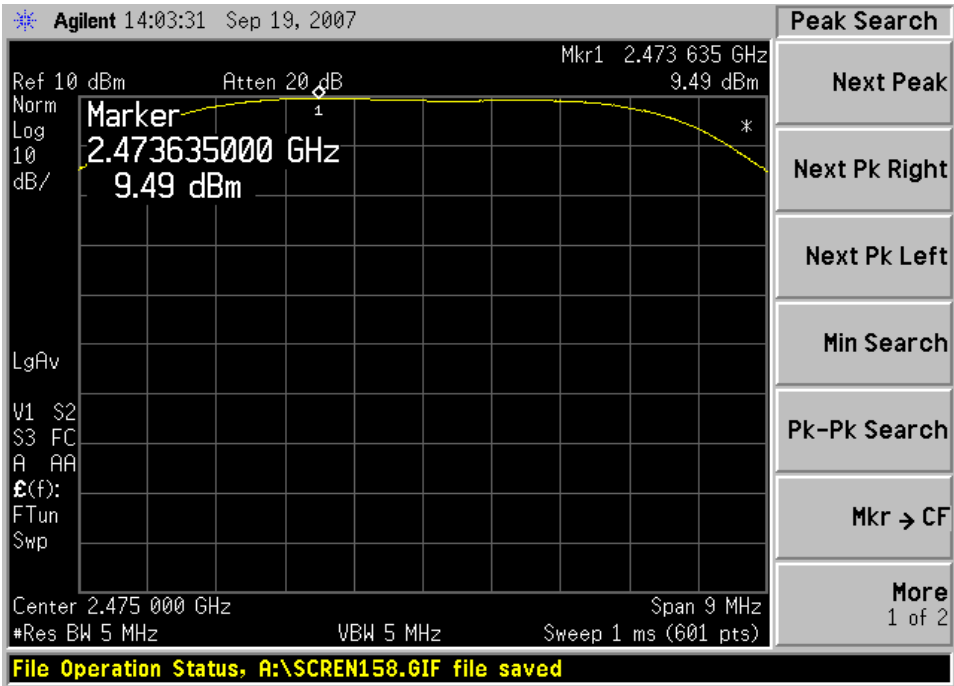
Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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9.4 Screen Captures – Power Output (Conducted)

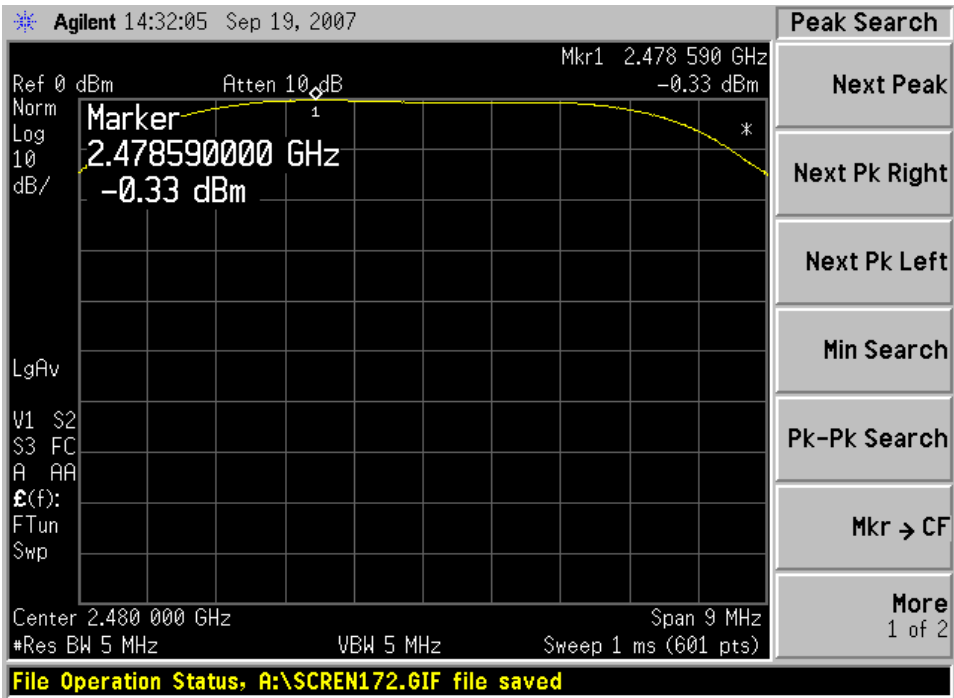


Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Channel 2475



Channel 2480



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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EXHIBIT 10. POWER SPECTRAL DENSITY: 15.247(e)

10.1 Limits

For digitally modulate systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

In accordance with FCC Part 15.247(e), the peak power spectral density should not exceed +8 dBm in any 3 kHz band. This measurement was performed along with the conducted power output readings performed as described in previous sections. The peak output frequency for each representative frequency was scanned, with a narrow bandwidth, and reduced sweep, and a power density measurement was performed. The highest density was found to be no greater than 4.3 dBm, which is under the allowable limit by 3.7 dB.

10.2 Test Equipment List

Test Equipment	Manufacturer	Model No.	Serial No.
Spectrum Analyzer	Agilent	E4446A	US45300564

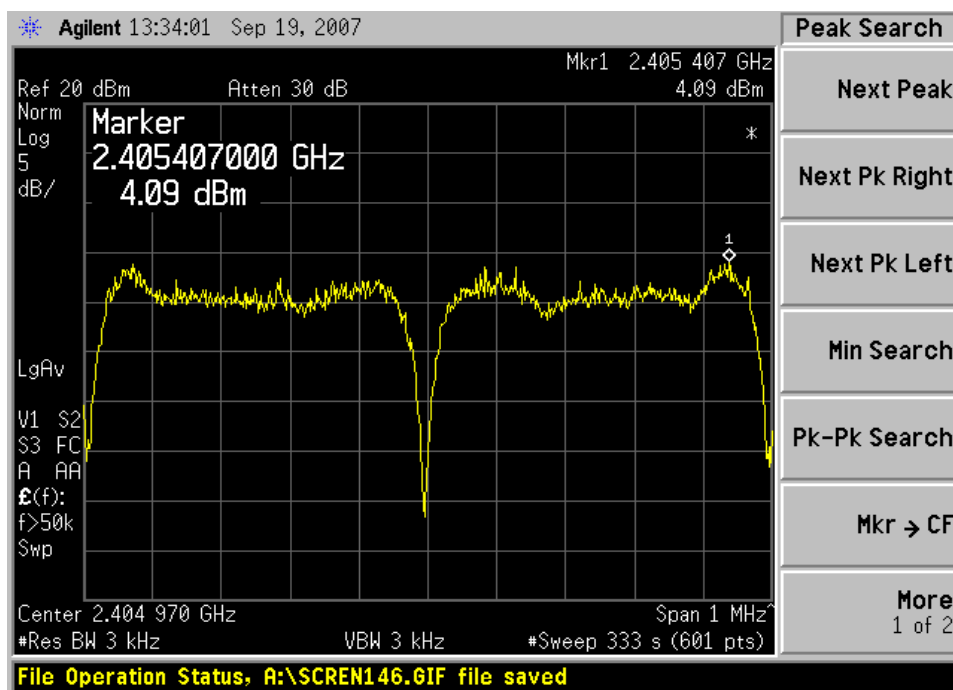
10.3 Test Data

Transmitter Channel	Frequency (MHz)	RF Power Level In 3 kHz BW (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Comments Pass/Fail
Lowest	2405	4.09	8.0	3.91	Pass
Middle	2445	4.32	8.0	3.68	Pass
Next Highest	2475	-5.41	8.0	13.41	Pass
Highest	2480	-16.16	8.0	24.16	Pass

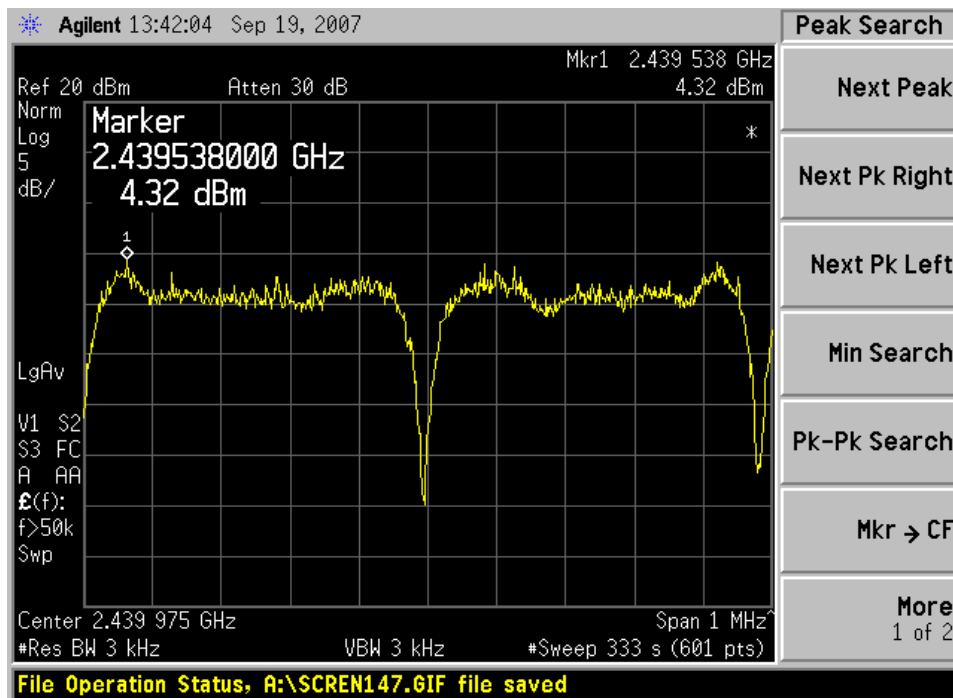
Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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10.4 Screen Captures – Power Spectral Density

Channel 2405

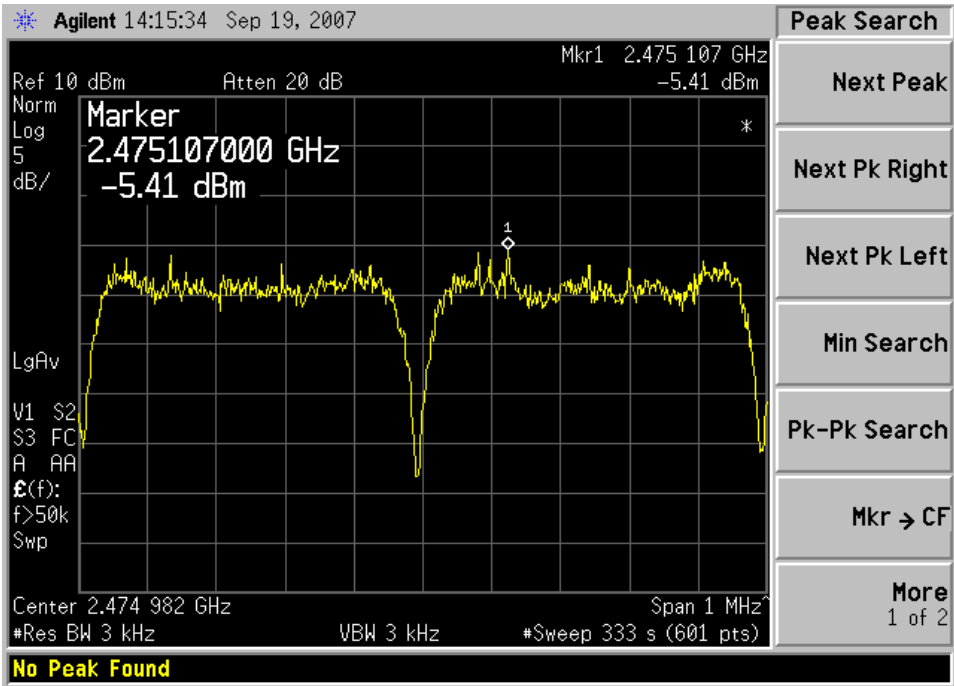


Channel 2440

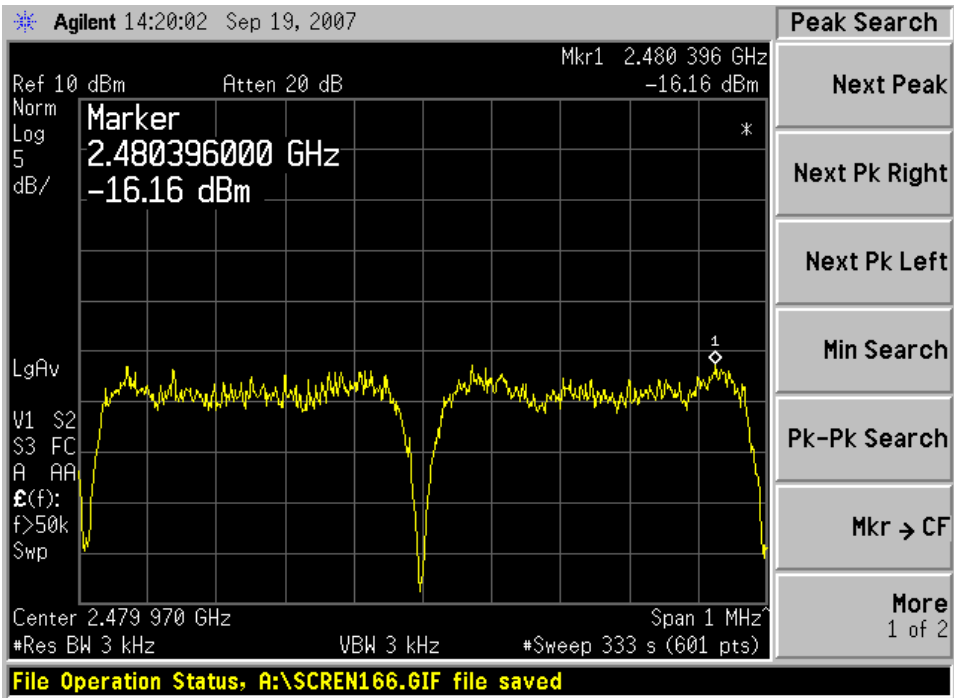


Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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Channel 2475



Channel 2480



Prepared For: Colorado vNet	Model #: see cover page	LS Research, LLC
EUT: Apex RF Module	Serial #: n/a	Template: 15.247 DTS TX (V2 9-06-06)
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EXHIBIT 11. SPURIOUS RADIATED EMISSIONS: 15.247(d)

11.1 Limits

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 db below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement.

In addition, radiated emissions, which fall in the restricted band, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(e)

Remarks:

- Applies to harmonics/spurious emissions that fall in the restricted bands listed in Section 15.205. The maximum permitted average field strength is listed in Section 15.209.
- The emission limits as specified above are based on measurement instrument employing an average detector. The provisions in Section 15.35 for limiting peak emissions apply.

FCC 47 CFR 15.205(a) – Restricted Frequency Bands

MHz	MHz	MHz	GHz
0.090 – 0.110	162.0125 – 167.17	2310 – 2390	9.3 – 9.5
0.49 – 0.51	167.72 – 173.2	2483.5 – 2500	10.6 – 12.7
2.1735 – 2.1905	240 – 285	2655 – 2900	13.25 – 13.4
8.362 – 8.366	322 – 335.4	3260 – 3267	14.47 – 14.5
13.36 – 13.41	399.9 – 410	3332 – 3339	14.35 – 16.2
25.5 – 25.67	608 – 614	3345.8 – 3358	17.7 – 21.4
37.5 – 38.25	960 – 1240	3600 – 4400	22.01 – 23.12
73 – 75.4	1300 – 1427	4500 – 5250	23.6 – 24.0
108 – 121.94	1435 – 1626.5	5350 – 5460	31.2 – 31.8
123 – 138	1660 – 1710	7250 – 7750	36.43 – 36.5
149.9 – 150.05	1718.8 – 1722.2	8025 – 8500	Above 38.6
156.7 – 156.9	2200 – 2300	9000 – 9200	

FCC 47 CFR 15.209(a) Field Strength Limits within Restricted Frequency Bands

Frequency (MHz)	Field Strength Limits (microvolts/m)	Distance (Meters)
0.009 – 0.490	2,400 / F (kHz)	300
0.490 – 1.705	24,000 / F (kHz)	30
1.705 – 30.0	30	30
30 – 88	100	3
88 – 216	150	3
216 – 960	200	3
Above 960	500	3

Calculation of Radiated Emission Measurements

Frequency (MHz)	3 m Limit (μV/m)	3 m Limit (dBμV/m)	1 m Limit (dBμV/m)
30-88	100	40.0	-
88-216	150	43.5	-
216-960	200	46.0	-
960-25,000	500	54.0	63.5

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FCC Part 15.247(d) requires a measurement of conducted harmonic and spurious RF emission levels, as reference to the carrier level when measured in a 100 kHz bandwidth. For this test, the spurious and harmonic RF emissions from the EUT were measured at the EUT antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, thereby allowing direct readings of the measurements made without the need for any further corrections. A Hewlett Packard model E4407B spectrum analyzer was used with the resolution bandwidth set to 100 kHz for this portion of the tests. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with measurements from a peak detector presented in the chart below. Screen captures were acquired and any noticeable spurious and harmonic signals were identified and measured.

No significant emissions could be noted within -50 dBc of the fundamental level for this product.

	2405 MHz	2440 MHz	2475 MHz	2480 MHz
Fundamental	+ 15.4 (dBm)	+ 15.16(dBm)	+ 5.0 (dBm)	-4.7 dBm
2 nd Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
3 rd Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
4 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
5 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
6 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
7 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
8 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
9 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)
10 th Harmonic	Note (1)	Note (1)	Note (1)	Note (1)

Notes:

(1) Measurement at system noise floor.

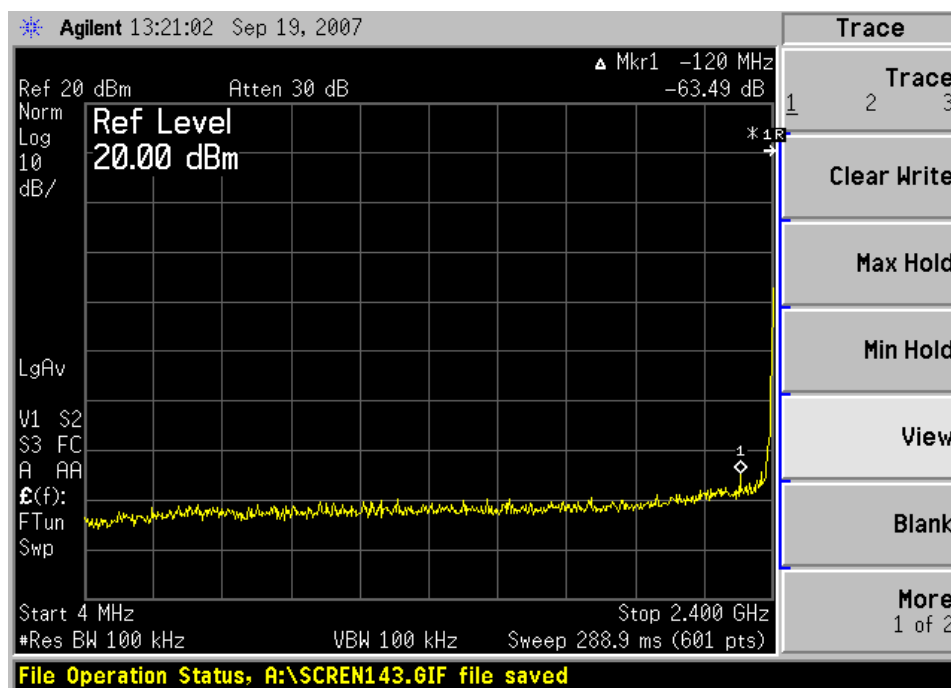
11.2 Test Equipment List

Test Equipment	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer	Agilent	E4446A	US45300564	To 44 GHz

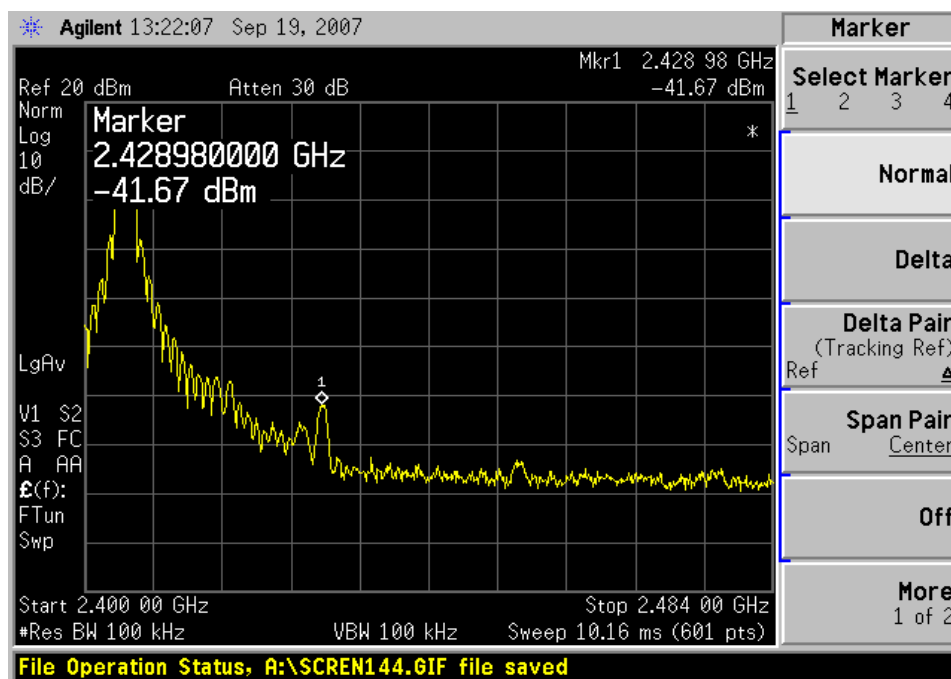
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11.3 Screen Captures – Spurious Conducted Emissions

Channel 2405 MHz, shown from 2 MHz up to 2400 MHz



Channel 2405 MHz, shown from 2400 MHz up to 2484 MHz



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Channel 2405 MHz, shown from 2484 MHz up to 25000 MHz

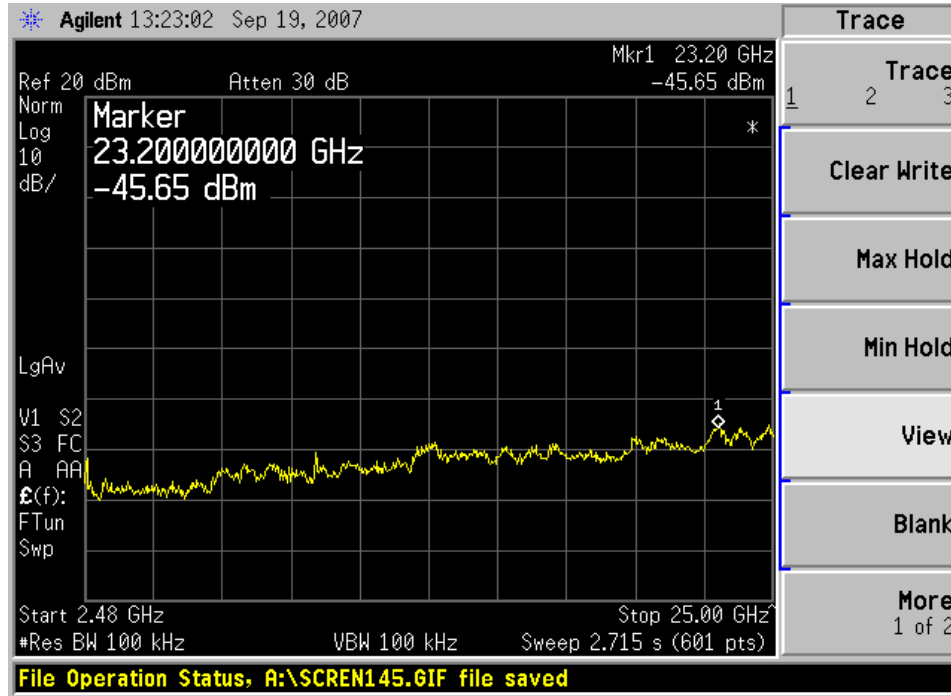


EXHIBIT 12. FREQUENCY & POWER STABILITY OVER VOLTAGE & TEMPERATURE VARIATIONS

A spectrum analyzer was used to measure the frequency at the appropriate frequency markers. For this test, the EUT was placed in continuous transmit CW mode. Power to the EUT was supplied by an external bench-type variable power supply. The frequency of operation was monitored using the spectrum analyzer with RBW=VBW=30 Hz settings while the voltage was varied.

	DC/AC Voltage Source		
	2.8 VDC	3.3 VDC	3.6 VDC
Channel B	2405.0046 (MHz)	2405.0044 (MHz)	2405.0042 (MHz)

Note: The actual operating voltage range is 2.1 VDC to 3.6 VDC. Testing was performed at the voltages listed in the chart above.

No anomalies were noted, in the measured transmit power, varying less than 1 dB, during the voltage variation tests.

EXHIBIT 13. CHANNEL PLAN AND SEPARATION

Optional for DTS. N/A.

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EXHIBIT 14. MPE CALCULATIONS

The following MPE calculations are based on the supplied wire monopole antenna. Although the highest actual measured power was 19.49 dBm on the low channel, 2405 MHz, a nominal conducted RF power of +20.0 dBm was used in the calculation for worst case. The stated gain of the antenna, is calculated at 0.0 dBi, and includes the cable loss depending on cable length. A comparison of measured EIRP and calculated EIRP shows favorable correlation.

<u>Prediction of MPE limit at a given distance</u>					
Equation from page 18 of OET Bulletin 65, Edition 97-01					
$S = \frac{PG}{4\pi R^2}$					
where:	S = power density				
	P = power input to the antenna				
	G = power gain of the antenna in the direction of interest relative to an isotropic radiator				
	R = distance to the center of radiation of the antenna				
Maximum peak output power at antenna input terminal:			20.00	(dBm)	
Maximum peak output power at antenna input terminal:			100.000	(mW)	
Antenna gain(typical):			0	(dBi)	
Maximum antenna gain:			1.000	(numeric)	
Prediction distance:			20	(cm)	
Prediction frequency:			2400	(MHz)	
MPE limit for uncontrolled exposure at prediction frequency:			1	(mW/cm^2)	
Power density at prediction frequency:			0.019894	(mW/cm^2)	
Maximum allowable antenna gain:			17.0	(dBi)	
Margin of Compliance at		20	cm =	17.0	dB

APPENDIX A

Test Equipment List

Asset #	Manufacturer	Model #	Serial #	Description	Date	Due
AA960008	EMCO	3816/2NM	9701-1057	Line Impedance Stabilization Network	12/6/07	12/6/08
AA960031	HP	119474A	3107A01708	Transient Limiter	Note 1	Note 1
AA960077	EMCO	93110B	9702-2918	Biconical Antenna	9/19/07	9/19/08
AA960078	EMCO	93146	9701-4855	Log-Periodic Antenna	9/19/07	9/19/08
AA960081	EMCO	3115	6907	Double Ridge Horn Antenna	12/04/06	12/04/07
CC00221C	Agilent	E4407B	US39160256	Spectrum Analyzer	1/11/07	1/11/08
EE960004	EMCO	2090	9607-1164	Device Controller	N/A	N/A
EE960013	HP	8546A	3617A00320	Receiver RF Section	9/20/07	9/20/08
EE960014	HP	85460A	3448A00296	Receiver Pre-Selector	9/20/07	9/20/08
EE960073	Agilent	E4446A	US45300564	Spectrum Analyzer	8/17/07	8/17/08
N/A	LSC	Cable	0011	3 Meter 1/2" Armored Cable	Note 1	Note 1
N/A	LSC	Cable	0050	10 Meter RG 214 Cable	Note 1	Note 1
N/A	Pasternack	Attenuator	N/A	10 dB Attenuator	Note 1	Note 1

Note 1 - Equipment calibrated within a traceable system.

Uncertainty Statement

This uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k=2.

Table of Expanded Uncertainty Values, (K=2) for Specified Measurements

Measurement Type	Particular Configuration	Uncertainty Values
Radiated Emissions	3 – Meter chamber, Biconical Antenna	4.24 dB
Radiated Emissions	3-Meter Chamber, Log Periodic Antenna	4.8 dB
Radiated Emissions	10-Meter OATS, Biconical Antenna	4.18 dB
Radiated Emissions	10-Meter OATS, Log Periodic Antenna	3.92 dB
Conducted Emissions	Shielded Room/EMCO LISN	1.60 dB
Radiated Immunity	3 Volts/Meter in 3-Meter Chamber	1.128 Volts/Meter
Conducted Immunity	3 Volts level	1.0 V

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