LS Research, LLC
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COMPLIANCE TESTING OF:

Home Heartbeat Water Valve

Prepared For:

Eaton Corporation
Attention: Mr. Richard Harwell
170 Industry Drive
Pittsburgh, PA 15275
United States of America

Test Report Number:

305498-Tx-v2

Test Dates:

March 13TH through 27TH, 2006

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1. LS Research, LLC In Review

LS Research, LLC - Accreditations and Listing's

As an EMC Testing Laboratory, our Accreditation and Assessments are recognized through the following:

A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025 : 2005
with Electrical (EMC) Scope of Accreditation
A2LA Certificate Number: 1255.01

Federal Communications Commission (FCC) – USA

Listing of 3 Meter Semi-Anechoic Chamber based on Title 47 CFR – Part 2.948
FCC Registration Number: 90756

Listing of 3 and 10 meter OATS based on Title 47CFR – Part 2.948
FCC Registration Number: 90757

Industry Canada

On file, 3 Meter Semi-Anechoic Chamber based on RSS-212 – Issue 1
File Number: IC 3088-A

On file, 3 and 10 Meter OATS based on RSS-212 – Issue 1
File Number: IC 3088

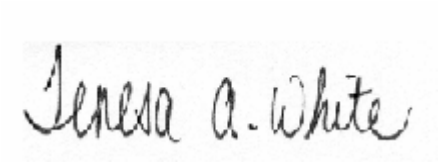
U. S. Conformity Assessment Body (CAB) Validation

Validated by the European Commission as a U. S. Competent Body operating under the U. S. /EU, Mutual Recognition Agreement (MRA) operating under the European Union Electromagnetic Compatibility –Council Directive 89/336/EEC, Article 10.2.
Date of Validation: January 16, 2001

Validated by the European Commission as a U.S. Notified Body operating under the U.S./EU, Mutual Recognition Agreement (MRA) operating under the European Union Telecommunication Equipment – Council Directive 99/5/EC, Annex V.

Date of Validation: November 20, 2002
Notified Body Identification Number: 1243

2. Signature Page



Prepared By: June 20, 2006

Teresa A. White, Document Coordinator Date

Tested By: June 20, 2006

Abtin Spantman, EMC Engineer Date

Approved By: June 20, 2006

Brian E. Petted, VP of Engineering Date

3. Product and General Information

Manufacturer:	Eaton Corporation					
Date(s) of Test:	March 13TH through 27TH, 2006					
Test Engineer(s):		Tom Smith	√	Abtin Spantman		Ken Boston
Model #:	Home Heartbeat Water Valve					
Serial #:	Pre-production Samples					
Voltage:	120 VAC, 60 Hz					
Operation Mode:	Normal operation and continuous transmit					

4. Introduction

Between March 13TH and 27TH, 2006, a series of Conducted and Radiated RF Emission tests were performed on one pre-production sample of the Eaton Corporation's Model Number: *"Home Heartbeat Water Valve",* here forth referred to as the "*Equipment Under Test*" or "*EUT*". These tests were performed using the procedures outlined in ANSI C63.4-2003 for intentional radiators, and in accordance with the limits set forth in FCC Part 15.247 (Industry Canada RSS-210) for a low power transmitter. These tests were performed by Abtin Spantman, EMC Engineer at LS Research, LLC.

All Radiated and Conducted RF Emission tests were performed upon the EUT to measure the emissions in the frequency bands described in Title 47 CFR, FCC Part 15, including 15.35, 15.205, 15.247 and Industry Canada RSS-210 to determine whether these emissions are below the limits expressed within the standards. These tests were performed in accordance with the procedures described in the 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 (ANSI C63.4-2003). Another document used as a reference for the EMI Receiver specification was the Comite International Special Des Perturbations Radioelelectriques (CISPR) Number 16-1, 2003.

All tests were performed at LS Research, LLC, in Cedarburg, Wisconsin, unless otherwise noted.

5. Product Description

The Eaton “Home Heartbeat Water Valve” is part of a Home monitoring system.

The Eaton “Home Heartbeat Water Valve”, also known as the Home Heartbeat Water Cop is a radio controlled water valve. The unit integrates into the Eaton Home Heartbeat system of controller and sensor/actuators using a 2.4 GHz ISM band Direct Sequence Spread Spectrum radio system as the communications link between separate modules. In operation, the Water Cop is inserted into the house water mains at the entrance to the structure. If a water leak is detected, the Home Heartbeat system can issue a radio command to the Water Cop to close the valve. The Water Cop operates off the household AC electrical system using an 120 VAC to 9 VDC wall-type adapter. Other units which communicate to the Water Cop are the Home Heartbeat FOB and the Home Heartbeat Base Station. If an optional Water Sensor is used, it communicates to the Base Station. All components in the HHB system are interconnected via the 2.4 GHz radio in each component.

The device only operates on AC mains. The device uses a ceramic ‘Chip Antenna’ permanently installed on the PC-board, with no contingencies for any other types of antennae. **The transmitter portion of this transceiver is being tested and the results presented here in this report.**

The Eaton “Home Heartbeat Water Valve”

The RF portion of the Home Heartbeat Water Valve is a direct sequence spread spectrum transceiver operating in the 2400 – 2483.5 MHz ISM band. The system is based on the IEEE 802.15.4 standard, with channels spaced at 5 MHz intervals. The system operates at a chip rate of 2 Mcps, a symbol rate of 62.5 Ksps, and a bit rate of 250 Kbps. O-QPSK modulation is used with 16-ary orthogonal symbols. It transmits with a maximum power of 50 milliwatts (+17 dBm) into a surface mounted “chip” antenna with a nominal average gain of 2 dBi.

The radio is based upon a single chip radio transceiver, the Ember EM2420. Frequency determination is by virtue of a 16 MHz reference crystal which is connected to the radio chip. Various frequencies are possible by programming inputs to the internal phase locked loop circuitry. The channels thus programmed are controlled by firmware installed in the on-board microcontroller.

This system utilizes a fixed frequency within the 2400 to 2483.5 MHz ISM Band. The band plan allows for 16 channels. The highest channel centered at 2480 MHz is blocked to prevent interference with a protected band, thus, the radio uses only the lower 15 channels of the 16 channel band plan.

The receiver is a low-IF receiver. The received RF signal is amplified by a low noise amplifier and down-converted in quadrature (I and Q) to the intermediate frequency (IF) of 2 MHz. At the IF, the complex I/Q signal is filtered and amplified, and then digitized by the ADCs. Automatic gain control, final channel filtering, dispreading, symbol correlation, and byte synchronization are performed digitally.

6. Test Requirements

The above mentioned tests were performed in order to determine the compliance of the Eaton Corporation's Model Number "*Home Heartbeat Water Valve*" transmitters with limits contained in various provisions of Title 47 CFR, FCC Part 15 (DTS), including:

15.31	15.247a	15.247d
15.205	15.247b	15.247e
15.207	15.247c	

7. Summary of Test Report

DECLARATION OF CONFORMITY

The Eaton Corporation's Model Number "*Home Heartbeat Water Valve*" transmitter was found to **MEET** the requirements as described within the specification of Title 47 CFR FCC, Part 15.247 (DTS), and Industry Canada RSS-210, Annex 8, Section 8.2 for a Direct Sequence Spread Spectrum Transmitter.

8. Radiated Emissions Test

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 continuous transmit modulated mode for this portion of the testing, using 120 VAC power as provided by the Mains. The unit has the capability to operate on 15 channels. During the testing, the channel and mode selection was accomplished by reprogramming the EUT using the PCB programming/test pads on the circuit board, along with a lap-top computer, interface fixture and a terminal program.

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 (Ch:0, 2405 MHz), middle (Ch 7, 2440 MHz) and high (Ch E, 2475 MHz) to comply with FCC Part 15.35. The channels and operating modes were changed by reprogramming the EUT.

The EUT is typically installed either in vertical orientation or in horizontal orientation.

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 for measurements below 1 GHz, and at 1 meter from the EUT for measurements above 1 GHz. 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 0.3 meter separation, using a standard gain Horn Antenna and pre-amplifier.

The EUT was rotated along two orthogonal axis of vertical and horizontal during the investigations to find the highest emission levels.

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 E4407B Spectrum Analyzer and an EMCO Horn Antenna were used. From 18 GHz to 25 GHz, the HP E4407B Spectrum Analyzer with a standard gain horn, and preamp were used.

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, Annex 8, section 8.2]. The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

CALCULATION OF RADIATED EMISSIONS LIMITS

The maximum peak output power of an intentional radiator in the 2400-2483.5 MHz band, as specified in 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 Class B limits for an unintentional radiator. 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 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

Sample conversion from field strength μV/m to dBμV/m:

$dB\mu V/m = 20 \log_{10} (100)$

= 40 dBμV/m (from 30-88 MHz)

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

960 MHz to 10,000 MHz

500μV/m or 54.0 dB/μV/m at 3 meters

54.0 + 9.5 = 63.5 dB/μV/m at 1 meter

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

960 MHz to 10,000 MHz

500μV/m or 54.0 dB/μV/m at 3 meters

54.0 + 20 = 74 dB/μV/m at 0.3 meters

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:	Eaton Corporation							
Date(s) of Test:	March 13TH through 27TH, 2006							
Test Engineer(s):		Tom Smith	√	Abtin Spantman		Ken Boston		
Model #:	Home Heartbeat Water Valve							
Serial #:	Pre-production Samples							
Voltage:	120 VAC, 60 Hz							
Operation Mode:	Normal operation and continuous transmit							
EUT Power:	√	Single Phase 120VAC				3 Phase ___VAC		
		Battery:				Other:		
EUT Placement:	√	80cm non-conductive table				10cm Spacers		
EUT Test Location:	√	3 Meter Semi-Anechoic FCC Listed Chamber				3/10m OATS		
Measurements:		Pre-Compliance		Preliminary	√	Final		
Detectors Used:		Peak	√	Quasi-Peak	√	Average		

Environmental Conditions in the Lab:
Temperature: 20 – 25°C
Relative Humidity: 30 – 60 %

Test Equipment Used:
EMI Measurement Instrument: HP8546A and Agilent E4407B
Log Periodic Antenna: EMCO #93146
Horn Antenna: EMCO #3115
Biconical Antenna: EMCO 93110
Pre-Amp: Advanced Microwave WHA6224
Standard Gain Horn: EMCO 3160-09

The following table depicts the level of significant spurious radiated RF emissions found:

Frequency (MHz)	Ant./EUT Polarity	Channel	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.205 Limit (dBμV/m)	Margin (dB)
37.8	V / V	All	1.00	0	25.1	40.0	14.9
44.6	V / V	All	1.00	0	25.1	40.0	14.9
124.4	V / V	All	1.00	0	22.5	43.0	20.5
135.3	V / V	All	1.00	0	27.1	43.0	15.9
171.7	V / V	All	1.00	0	23.9	43.0	19.1

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 0:

Frequency (MHz)	Ant./EUT Polarity	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
2405	H / H	1.10	215	118.6	125.2	6.6
4810	H / H	1.25	15	47.0	54.0	7.0
7215	V / H	1.00	190	54.6	108.1	53.5
9620	V / V	1.00	0	44.2	108.1	63.9
12025	H / V	1.00	55	34.5	63.5	29.0
14430				(Note 3)	63.5	
16835				(Note 3)	108.1	
19240				(Note 3)	74.0	
21645				(Note 3)	118.6	
24050				(Note 3)	118.6	

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 7:

Frequency (MHz)	Ant./EUT Polarity	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
2440	H / H	1.05	215	117.0	125.2	8.2
4880	H / H	1.55	345	44.0	54.0	10.0
7320	V / H	1.00	190	53.1	63.5	10.4
9760	V / V	1.00	0	47.0	106.5	59.5
12200	H / V	1.00	0	33.4	63.5	30.1
14640				(Note 3)	106.5	
17080				(Note 3)	106.5	
19520				(Note 3)	74.0	
21960				(Note 3)	117.0	
24400				(Note 3)	117.0	

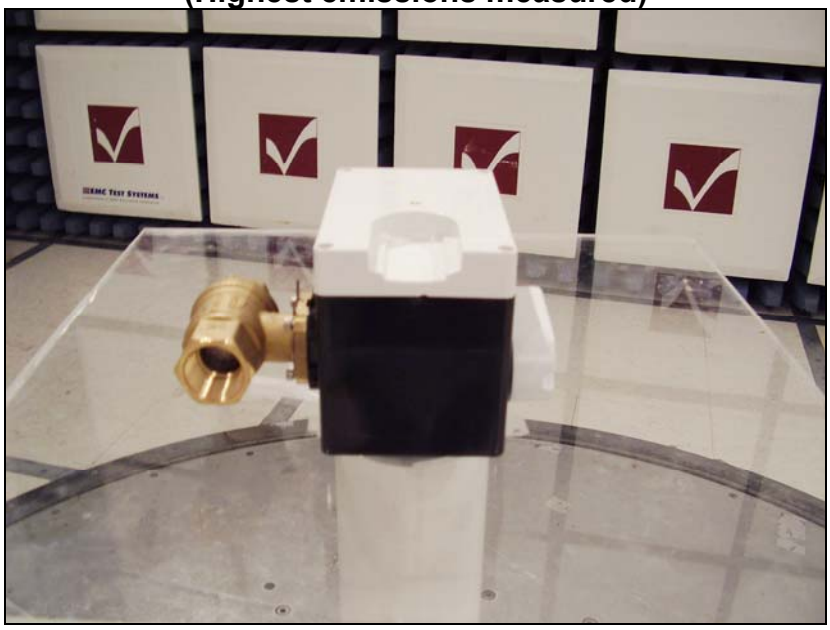
The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel E:

Frequency (MHz)	Ant./EUT Polarity	Height (meters)	Azimuth (0° - 360°)	Measured EFI (dBμV/m)	15.247 Limit (dBμV/m)	Margin (dB)
2475	H / H	1.05	210	117.3	125.2	7.9
4950	H / H	1.35	30	43.7	54.0	10.3
7425	V / H	1.00	175	52.7	63.5	10.8
9900	V / V	1.00	0	46.8	106.8	60.0
12375	H / V	1.00	195	40.3	63.5	23.2
14850				(Note 3)	106.8	
17325				(Note 3)	106.8	
19800				(Note 3)	74.0	
22275				(Note 3)	74.0	
24750				(Note 3)	117.3	

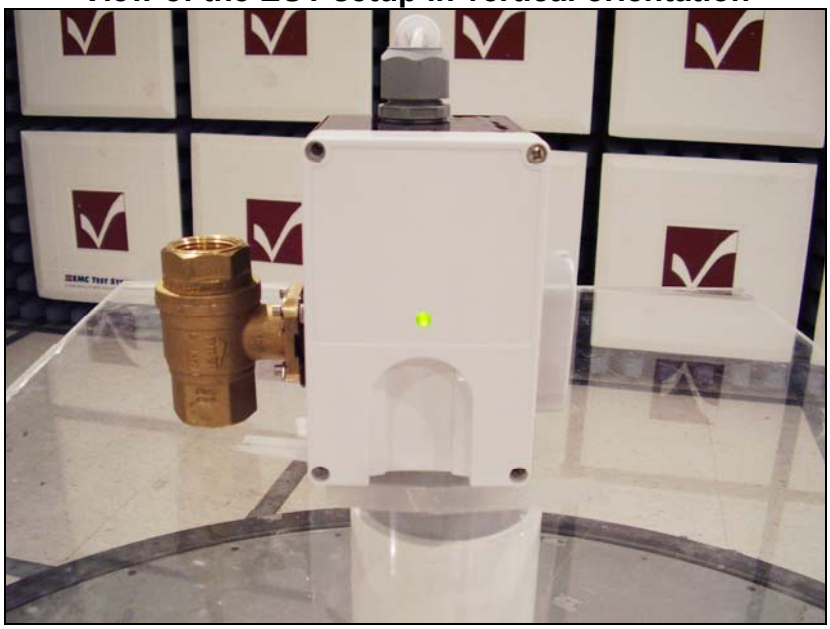
Notes:

1) A Quasi-Peak Detector was used in measurements below 1 GHz, and a Peak as well as an Average Detector was used in measurements above 1 GHz. Only the results from the Average detector are published in the table above. The peak detector was used to ensure the peak emissions did not exceed 20 dB above the limits.
2) Measurements above 5 GHz were made at 1 meters of separation from the EUT, and at 0.3 m separation for frequencies between 18 – 25 GHz.
3) Measurement at receiver system noise floor.
4) For measurements of the fundamental power, because of spectral bandwidth, the receiver was set to RBW=VBW=3 MHz. The reported measurement is from an Average detector.
5) A relaxation of the limit is NOT invoked based on the average duty factor of the transmitter on-air-time, as it was not needed for this product at the time of testing. Justification appears in appendix D, and is included in the appendix sections, as reference only, incase the need should arise in the future.

View of the EUT setup in Horizontal orientation
(Highest emissions measured)

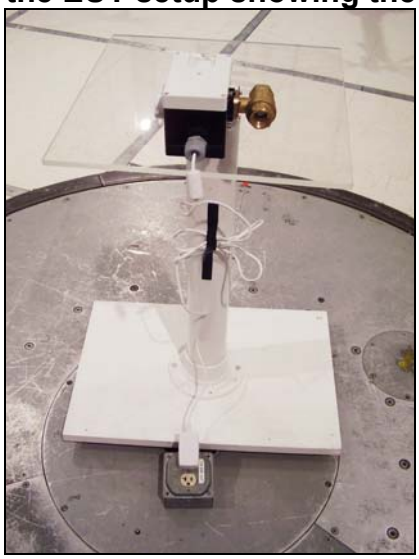


View of the EUT setup in vertical orientation



Front View of the EUT setup on the test pedestal

Rear View of the EUT setup showing the wire draping

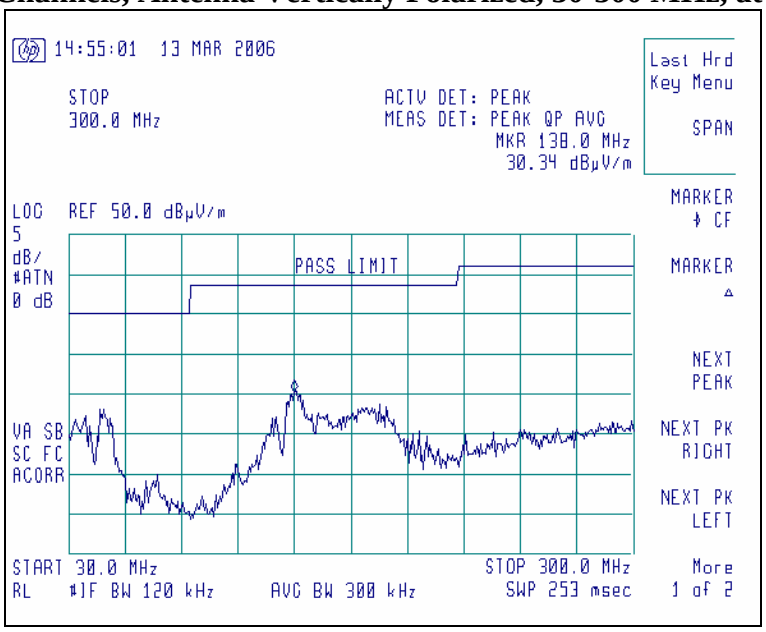


Screen Captures of Radiated RF Emissions:

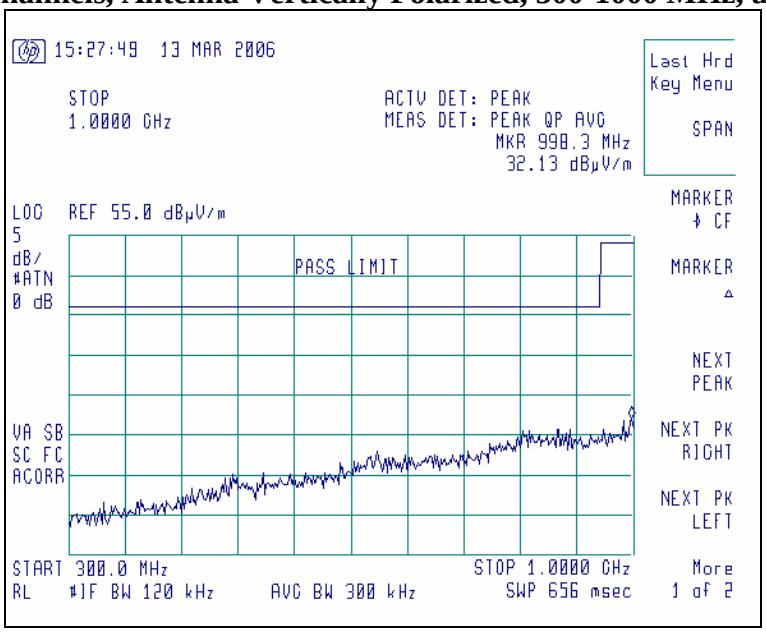
Please note these screen captures represent Peak Emissions. For radiated emission measurements, we utilize a Quasi-Peak detector function when measuring frequencies below 1 GHz, and an Average detector function when measuring frequencies above 1 GHz.

The signature scans shown here are from worst-case emissions, as measured on channels 0, 7, or E, with the sense and EUT antennas both in vertical polarity for worst case presentations.

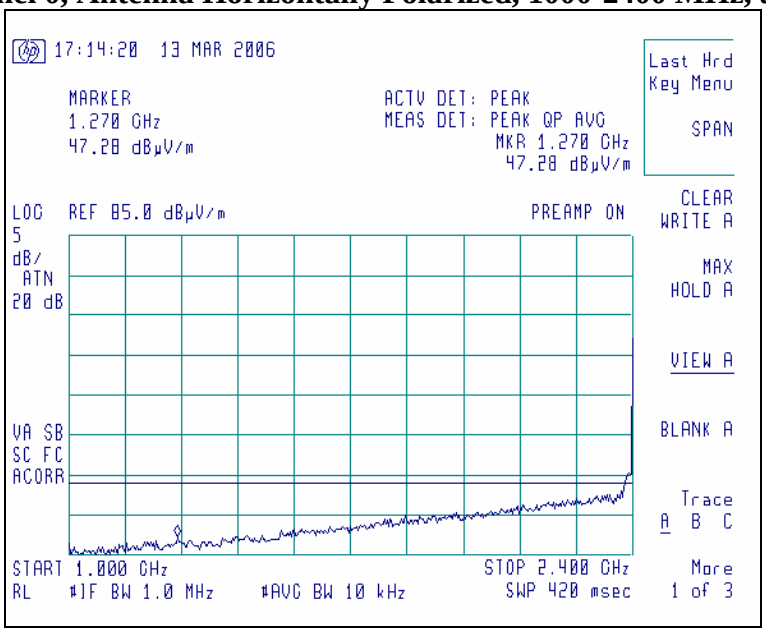
All Channels, Antenna Vertically Polarized, 30-300 MHz, at 3m.



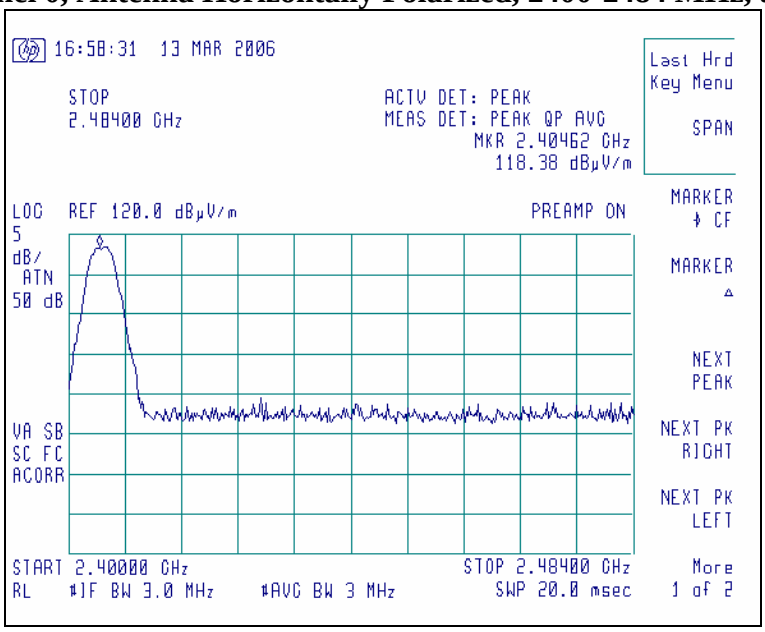
All Channels, Antenna Vertically Polarized, 300-1000 MHz, at 3m.



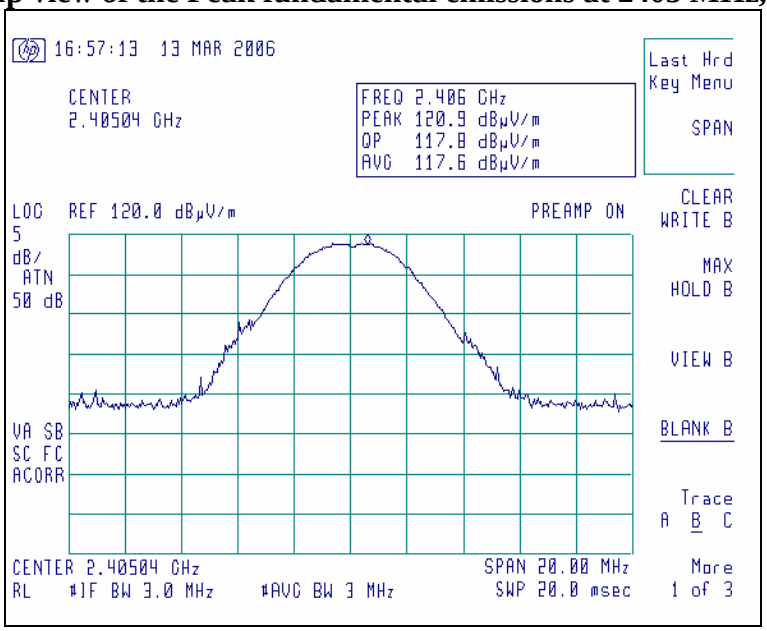
Channel 0, Antenna Horizontally Polarized, 1000-2400 MHz, at 3m.



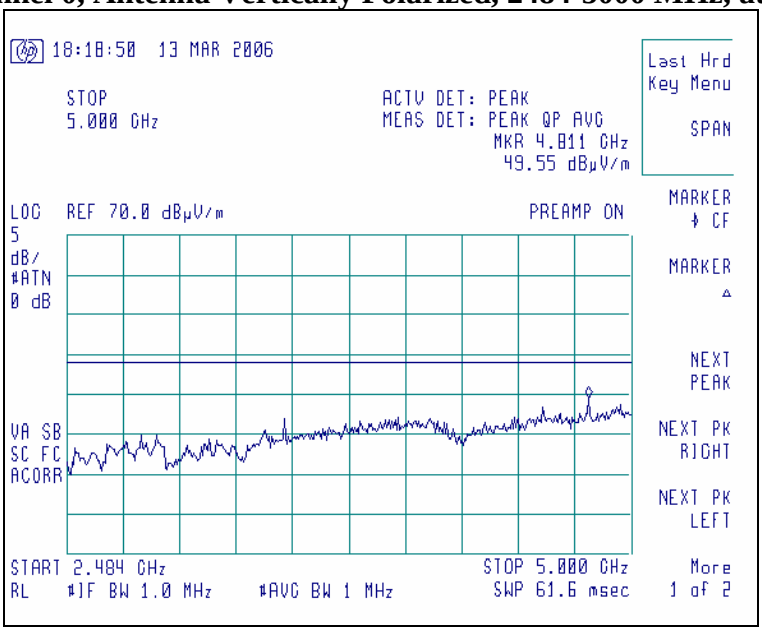
Channel 0, Antenna Horizontally Polarized, 2400-2484 MHz, at 3m.



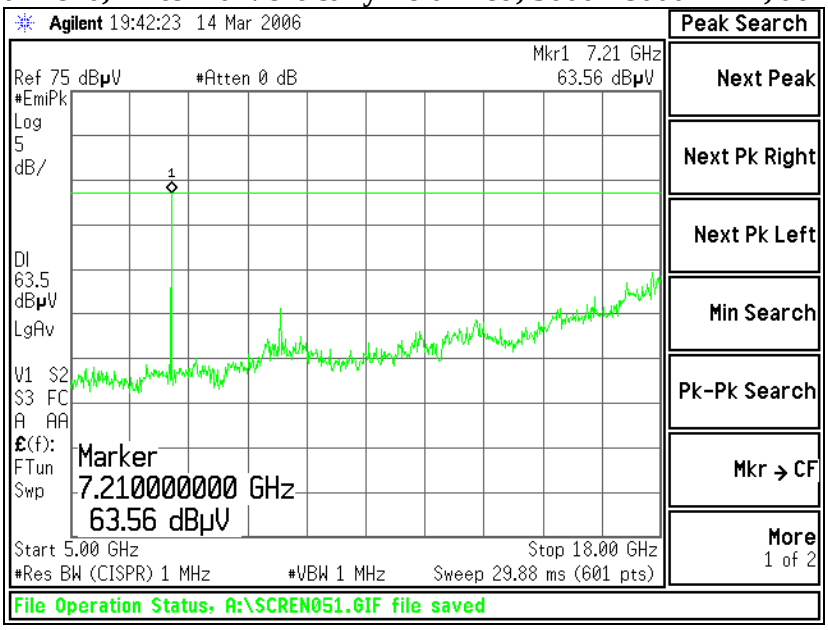
Channel 0, Antenna Horizontally Polarized,
Close up view of the Peak fundamental emissions at 2405 MHz, at 3m.



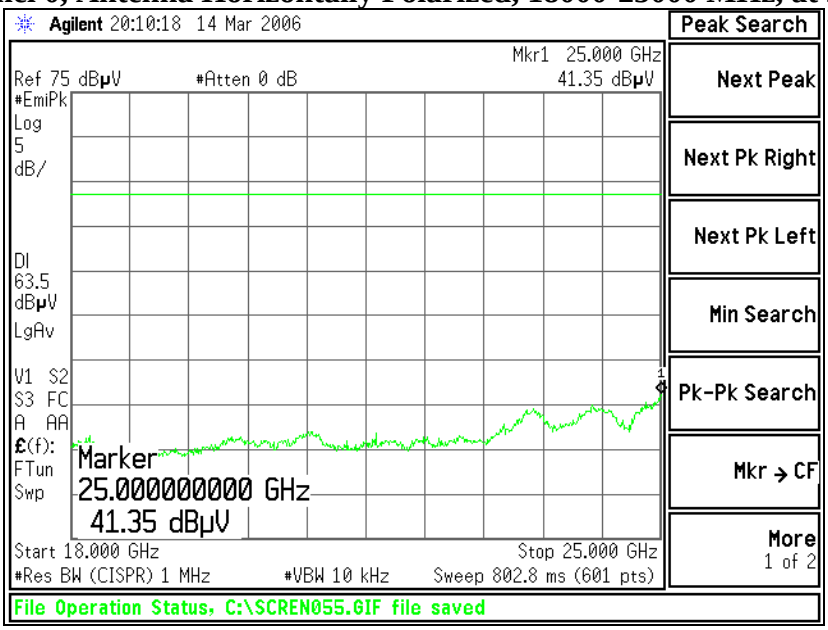
Channel 0, Antenna Vertically Polarized, 2484-5000 MHz, at 1m.



Channel 0, Antenna Vertically Polarized, 5000-18000 MHz, at 1m.



Channel 0, Antenna Horizontally Polarized, 18000-25000 MHz, at 30cm.

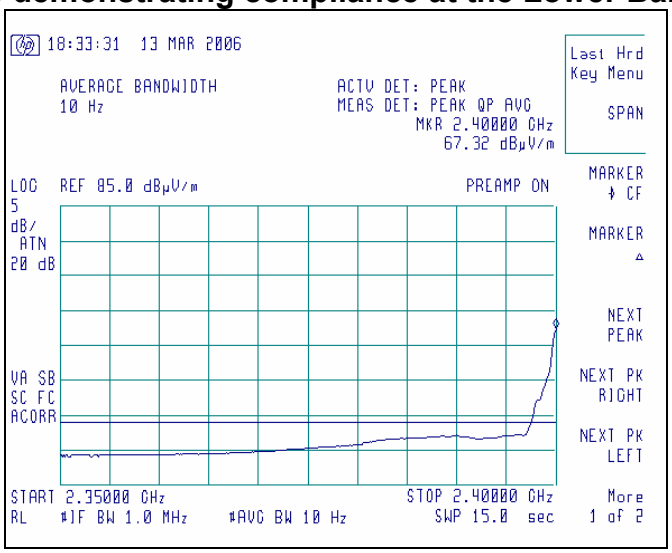


9. Band-Edge Measurements

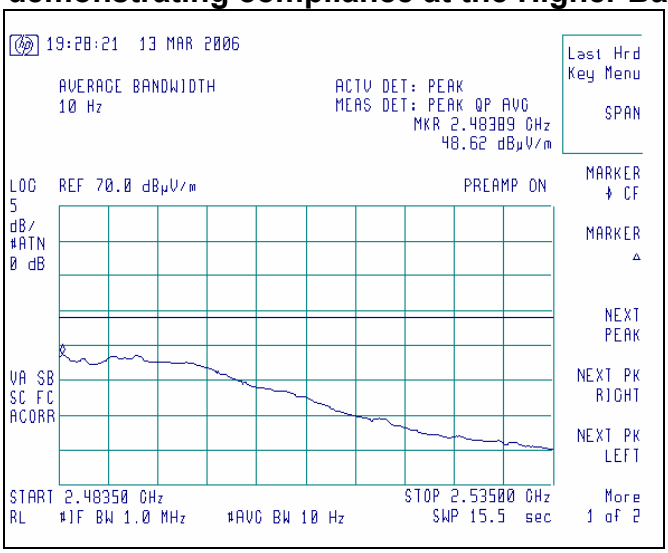
FCC 15.209(b) and 15.247(d) require a measurement of spurious emission levels to be at least 20 dB lower than the fundamental emission level, in particular at the band-edges where the intentional radiator operates. The following screen captures demonstrate compliance of the intentional radiator at the 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 = -20dBc with respect to the fundamental level.
The Upper Band-Edge limit, in this case, would be = +54 dBµV/m at 3m.

Screen Capture demonstrating compliance at the Lower Band-Edge, at 3m.



Screen Capture demonstrating compliance at the Higher Band-Edge, at 3m.

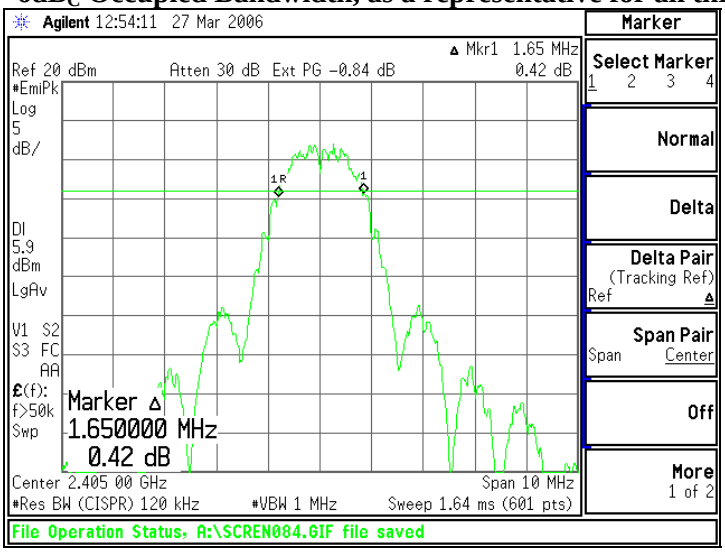


10. Occupied Bandwidth

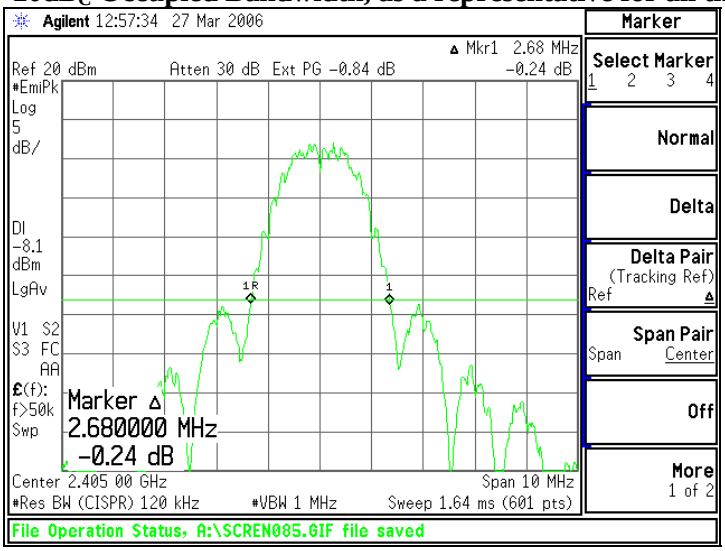
The 20 dB bandwidth requirement found in FCC Part 15.247(a)(2) requires a minimum -6dBc occupied bandwidth of 500 kHz. For this portion of the tests, a direct measurement of the transmitted signal was performed at the antenna port of the EUT, via a cable connection to the HP E4407B spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, there by 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 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.

Channel	Center Frequency (MHz)	- 6 dBc BW (kHz)	- 6 dBc BW Limit (kHz)	- 20 dBc BW (kHz)
0	2405	1650	500	2680
7	2440	1630	500	2680
E	2475	1630	500	2700

Channel 00, -6dB$_C$ Occupied Bandwidth, as a representative for all three channels



Channel 00, -20dB$_C$ Occupied Bandwidth, as a representative for all three channels



11. Conducted RF Emissions Test on AC Power Line

Test Setup

The Conducted Emissions test was performed at LS Research, LLC in Cedarburg, Wisconsin. 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). The EUT was placed on a non-conductive pedestal, with a height of 80 cm above the reference ground plane. The EUT's power cable was plugged into a 50Ω (ohm), 50/250 μH Line Impedance Stabilization Network (LISN). The AC power supply of 120V was provided 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 50Ω (ohm) load when switched to either L1 (line) or L2 (neutral).

Test Procedure

The EUT was investigated in continuous modulated transmit mode for this portion of the testing. The resulting emissions were similar across all three channels, and only the data from the middle channel is presented here as a good representative. 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.

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 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.

Calculation of Conducted Emissions Limits

The following table describes the Class B limits for an unintentional radiator. These limits are obtained from Title 47 CFR, Part 15.107 (a) for Conducted Emissions.

Frequency (MHz)	Quasi-Peak Limit (dBµV)	Average Limit (dBµV)
0.15 – 0.5	66 – 56 *	56 - 46
0.5 – 5.0	56	46
5.0 – 30.0	60	50

* Decreases with the logarithm of the frequency.

Sample calculation for the limits in the 0.15 to 0.5 MHz:

$$\text{Limit} = -19.12 \left(\text{Log}_{10} \left(F[\text{MHz}] / 0.15 [\text{MHz}] \right) \right) + 66.0 \text{ dB}\mu\text{V}$$

For a frequency of 200 kHz for example:

$$\text{Quasi-Peak Limit (F = 200kHz)} = -19.12 \left(\text{Log}_{10} \left(0.2[\text{MHz}] / 0.15 [\text{MHz}] \right) \right) + 66.0 \text{ dB}\mu\text{V}$$

$$\text{Quasi-Peak Limit (F = 200kHz)} = 63.6 \text{ dB}\mu\text{V}$$

$$\text{Average Limit (F=200kHz)} = -19.12 \left(\text{Log}_{10}(0.2[\text{MHz}]/0.15[\text{MHz}]) \right) + 56.0 \text{ dB}\mu\text{V}$$

$$\text{Average Limit (F = 200 kHz)} = 53.6 \text{ dB}\mu\text{V}$$

Measurement of Electromagnetic Conducted Emission

Frequency Range inspected: 150 KHz to 30 MHz

Test Standard: FCC 15.207 Class B

Manufacturer:	Eaton Corporation					
Date(s) of Test:	March 13TH through 27TH, 2006					
Test Engineer:		Tom Smith	√	Abtin Spantman		Ken Boston
Model #:	Home Heartbeat Water Valve					
Serial #:	Pre-production Samples					
Voltage:	120 VAC, 60 Hz					
Operation Mode:	Normal operation and continuous transmit					
Test Location:		Other				Chamber
EUT Placed On:	√	40cm from Vertical Ground Plane				10cm Spacers
	√	80cm above Ground Plane				Other:
Measurements:		Pre-Compliance		Preliminary	√	Final
Detectors Used:		Peak	√	Quasi-Peak	√	Average

Environmental Conditions in the Lab:

Temperature: 20 – 25° C

Atmospheric Pressure: 86 kPa – 106 kPa

Relative Humidity: 30 – 60%

Test Equipment Utilized:

EMI Receiver: HP 8546A

LISN: EMCO 3816/2NM

Transient Limiter: HP 119474A

		QUASI-PEAK			AVERAGE		
Frequency (MHz)	Line	Q-Peak Measurement (dBµV)	Q-Peak Limit (dBµ V)	Quasi-Peak Margin (dB)	Average Measurement (dBµV)	Average Limit (dBµ V)	Average Margin (dB)
0.180	L1	48.2	64.5	16.3	35.4	54.5	19.1
0.214	L1	43.2	63.0	19.8	30.9	53.0	22.1
0.250	L1	39.5	61.8	22.3	29.2	51.8	22.6
0.290	L1	36.1	60.5	24.4	27.3	50.5	23.2
0.345	L1	39.0	59.1	20.1	36.7	49.1	12.4
0.180	L2	47.9	64.5	16.6	34.4	54.5	20.1
0.215	L2	42.2	63.0	20.8	29.6	53.0	23.4
0.250	L2	39.0	61.8	22.8	29.4	51.8	22.4
0.290	L2	36.4	60.5	24.1	28.7	50.5	21.8
0.345	L2	33.2	59.1	25.9	26.3	49.1	22.8

Notes:

1) The EUTs exhibited similar emissions in transmit and receive modes, and across the Low, Middle and High channels tested. The data presented is from the middle channel, chosen as a good representative for all.

2) All other emissions were better than 20 dB below the limits.

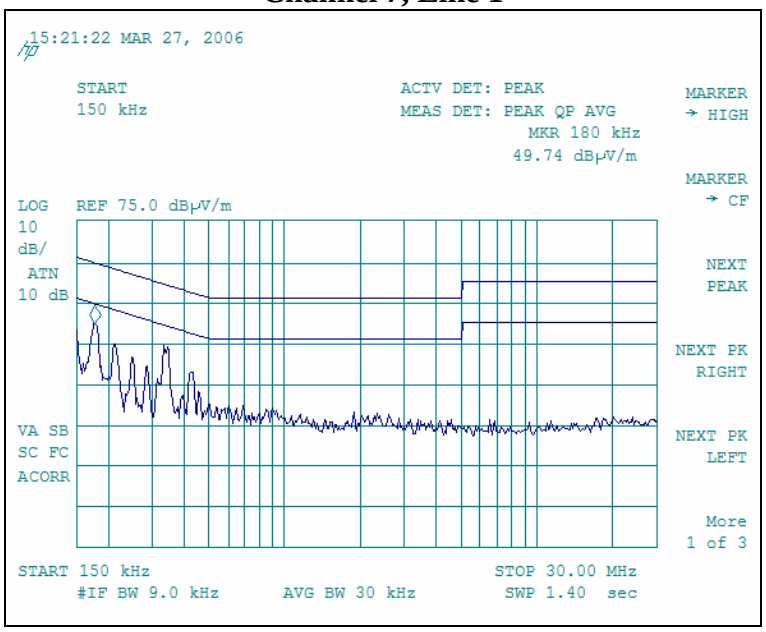
View of the EUT setup on the test pedestal, during the measurements of RF emissions onto AC Mains.

Screen Captures of Conducted AC Mains Emissions:

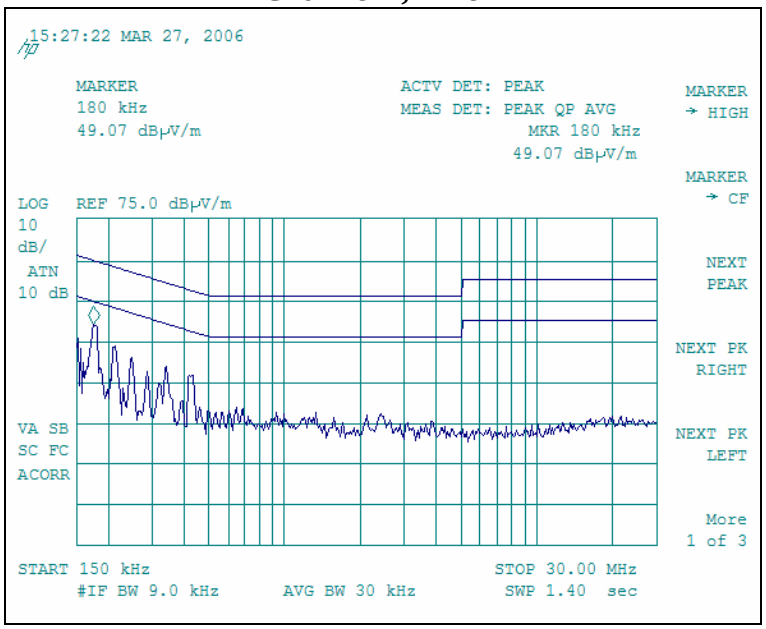
Please note these screen captures represent Peak Emissions. For conducted emission measurements, we utilize both a Quasi-Peak detector function as well as the Average detector function for measurements. The emissions must meet both the Quasi-peak limit and the Average limit as described in 47 CFR 15.207.

The signature scans shown here are from the middle channel (7), chosen as being a good representative of channels.

Channel 7, Line 1



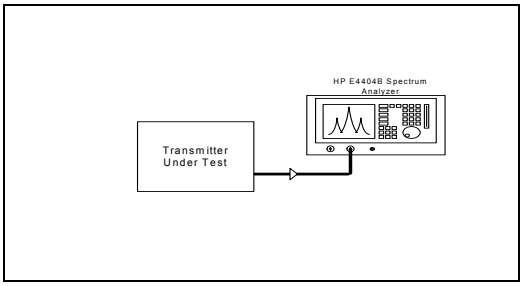
Channel 7, Line 2



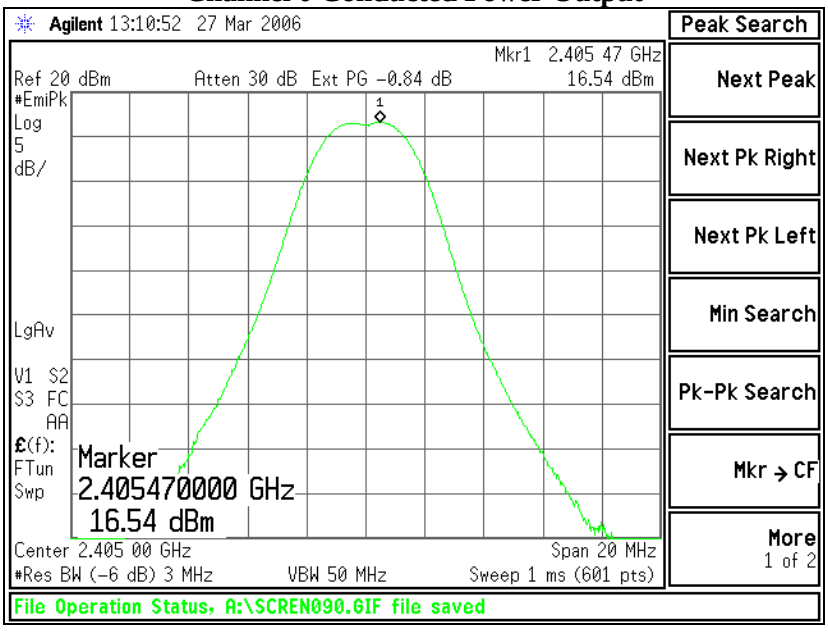
12. Power Output 15.247(b)

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable for the spectrum analyzer. The loss from the cable was added on the analyzer as gain offset settings, there by allowing direct readings of the measurements made without the need for any further corrections. 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 resolution and video bandwidths set to 3 MHz, and a span of 20 MHz, with measurements from a peak detector presented in the chart below.

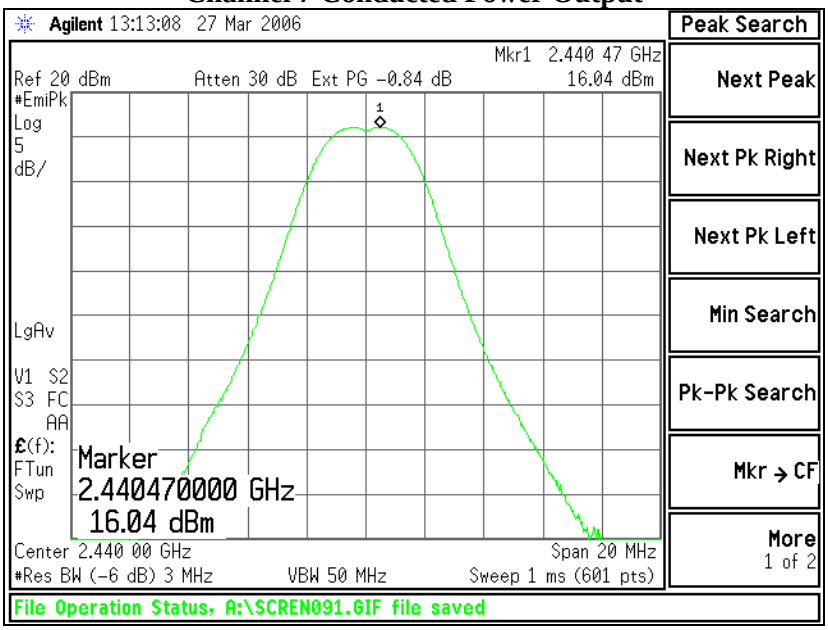
CHANNEL	CENTER FREQ (MHz)	LIMIT (dBm)	MEASURED POWER (dBm)	MARGIN (dB)
0	2405	+ 30.0	+ 16.5	13.5
7	2440	+ 30.0	+ 16.0	14.0
E	2475	+ 30.0	+ 17.0	13.0



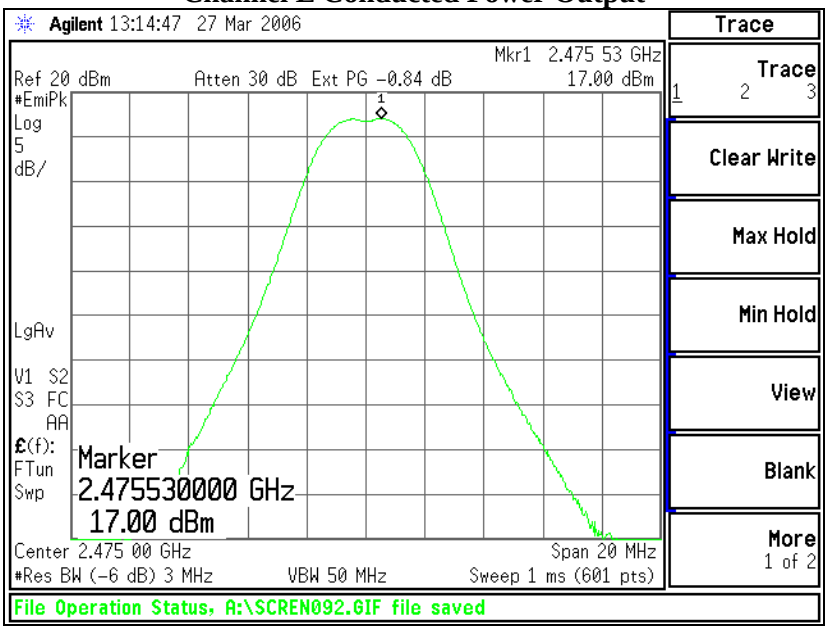
Channel 0 Conducted Power Output



Channel 7 Conducted Power Output



Channel E Conducted Power Output



13. Spurious Emissions 15.247(d)

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. The loss from the cable was added on the analyzer as gain offset settings, there by 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.

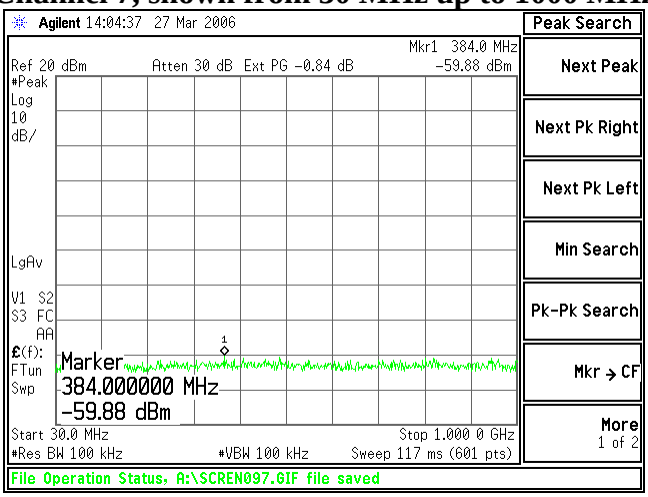
No significant emissions could be noted within -50 dBc of the fundamental level for this product.

	Channel 0	Channel 7	Channel E
Fundamental	+12.2	+12.9	+13.9
2nd Harmonic	-63.5	-49.7	-60.5
3rd Harmonic	-75.4	-75.4	-75.1
4th Harmonic	-76.3	-68.1	-75.4
5th Harmonic	-77.1	-75.1	-74.5
6th Harmonic	Note (1)	Note (1)	Note (1)
7th Harmonic	Note (1)	Note (1)	Note (1)
8th Harmonic	Note (1)	Note (1)	Note (1)
9th Harmonic	Note (1)	Note (1)	Note (1)
10th Harmonic	Note (1)	Note (1)	Note (1)

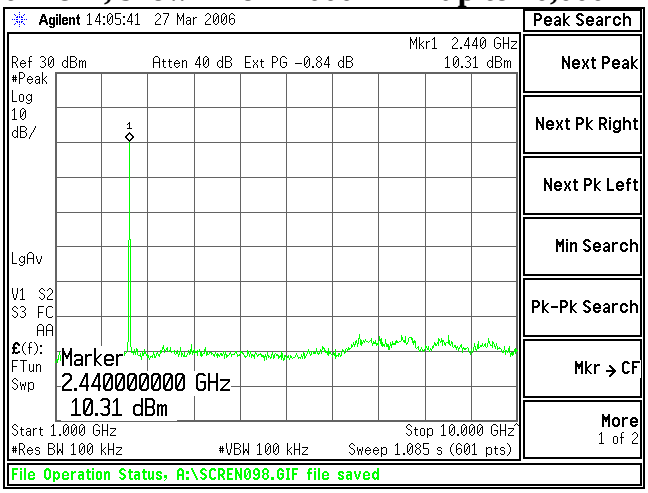
Notes:
(1) Measurement at system noise floor.

Representative plots for the middle channel are presented here, for the conducted RF spurious measurements.

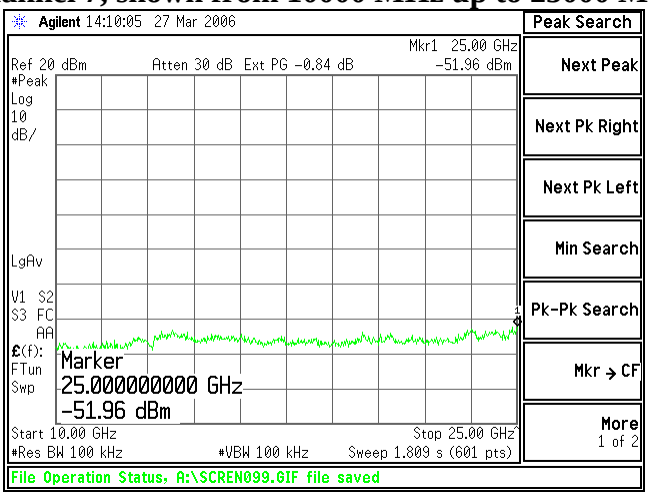
Channel 7, shown from 30 MHz up to 1000 MHz



Channel 7, shown from 1000 MHz up to 10,000 MHz



Channel 7, shown from 10000 MHz up to 25000 MHz

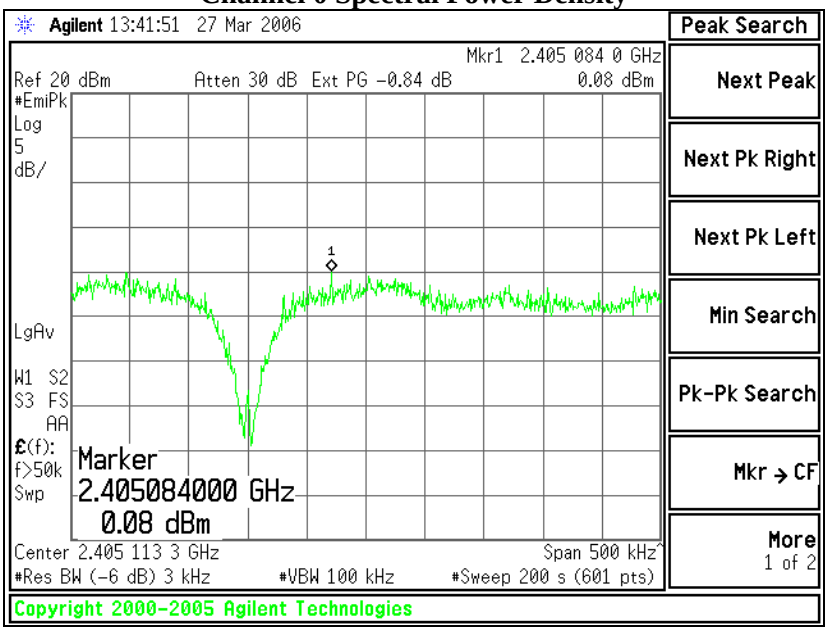


14. Spectral Density

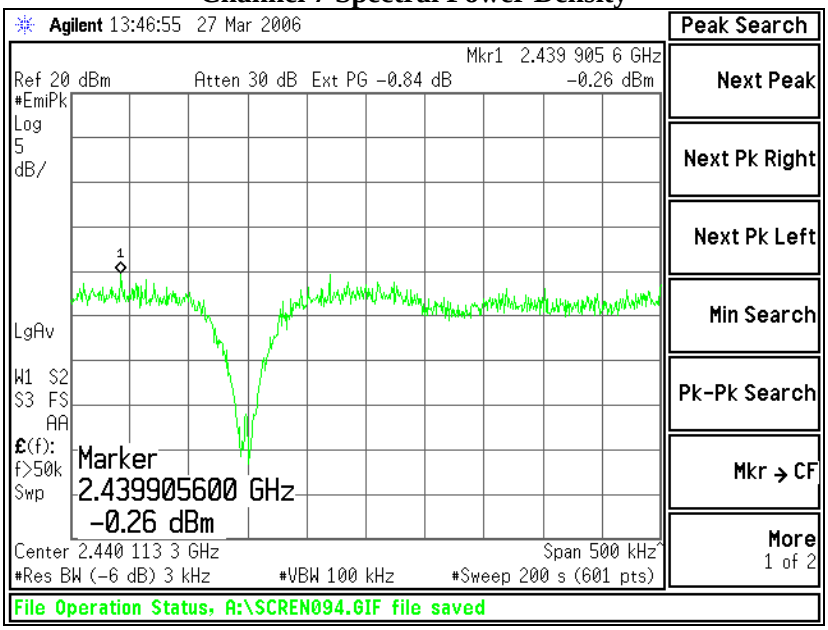
In accordance with FCC Part 15.247(e), the peak power spectral density should not exceed +8 dBm in any 3 kHz band. This measurement was performed along with the conducted power output readings performed as described in previous sections. The peak output frequency for each representative frequency was 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 +5.9 dBm, which is under the allowable limit by 2.1 dB.

Channel	Center Frequency (MHz)	Measured Power (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
0	2405	+ 0.1	+8 dBm	7.9
7	2440	- 0.3	+8 dBm	8.3
E	2475	+ 1.1	+8 dBm	6.9

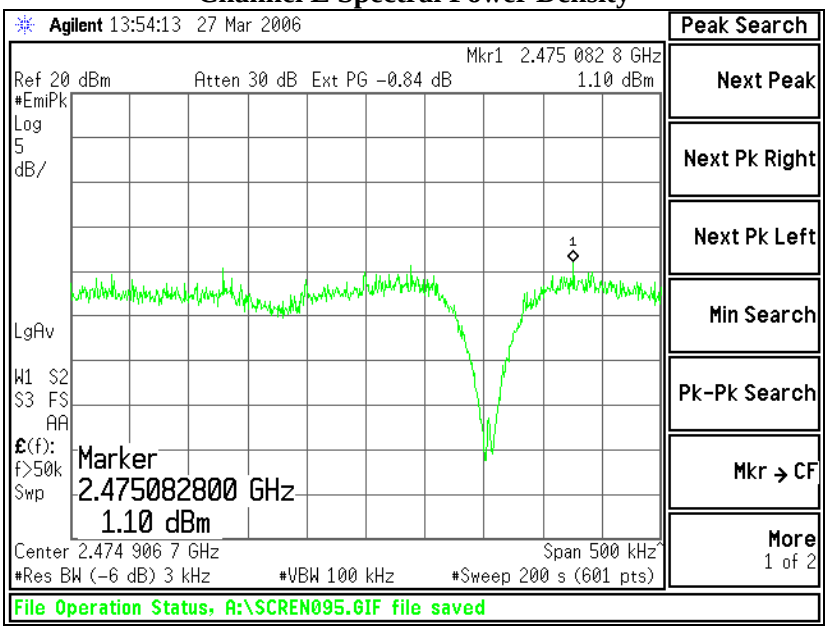
Channel 0 Spectral Power Density



Channel 7 Spectral Power Density



Channel E Spectral Power Density



15. Frequency and Power Stability over Voltage Variations

The stability of the device was examined as a function of the input voltage available to the EUT.
In this case, the EUT uses AC Mains, with a nominal voltage of 120 VAC.

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 variable AC power supply. The frequency of operation was monitored using the spectrum analyzer with RBW=VBW=1kHz, span=20kHz settings while the voltage was varied.

	AC Voltage Source		
	102 VAC	120 VAC	138 VAC
Channel 0	2405.0110 (MHz)	2405.0107 (MHz)	2405.0110 (MHz)
Channel 7	2440.0110 (MHz)	2440.0110 (MHz)	2440.0110 (MHz)
Channel E	2475.0110 (MHz)	2475.0110 (MHz)	2475.0110 (MHz)

The RF power output of the EUT was also monitored in a separate test, also using a spectrum analyzer with RBW=VBW=3MHz setting while the voltage was varied.

	AC Voltage Source		
	102 VAC	120 VAC	138 VAC
Channel 0	+ 16.4 (dBm)	+ 16.5 (dBm)	+ 16.5 (dBm)
Channel 7	+ 16.0 (dBm)	+ 16.0 (dBm)	+ 16.1 (dBm)
Channel E	+ 17.0 (dBm)	+ 17.0 (dBm)	+ 17.0 (dBm)

The power was then cycled On/Off to observe system response. No unusual response was observed during power loss, the emission characteristics were well behaved, and the system returned to the proper power-up state (standby state, not transmitting).

16. MPE Calculations

The MPE calculations are based on the Centurion Brand antenna, part number: WIC2450-U Ceramic Chip Antenna

Prediction of MPE limit at a given distance

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:	17.00	(dBm)
Maximum peak output power at antenna input terminal:	50.119	(mW)
Antenna gain(typical):	2	(dBi)
Maximum antenna gain:	1.585	(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:	0.015803	(mW/cm^2)
Maximum allowable antenna gain:	20.0	(dBi)
Margin of Compliance at 20 cm =	18.0	dB

Appendix A

Test Equipment List

Asset #	Manufacturer	Model #	Serial #	Description	Date	Due
AA960008	EMCO	3816/2NM	9701-1057	Line Impedance Stabilization Network	9-27-05	9-27-06
AA960031	HP	119474A	3107A01708	Transient Limiter	Note 1	Note 1
AA960077	EMCO	93110B	9702-2918	Biconical Antenna	9-27-05	9-27-06
AA960078	EMCO	93146	9701-4855	Log-Periodic Antenna	9-27-05	9-27-06
AA960081	EMCO	3115	6907	Double Ridge Horn Antenna	12-07-05	12-07-06
CC00221C	Agilent	E4407B	US39160256	Spectrum Analyzer	12-07-05	12-06-06
EE960004	EMCO	2090	9607-1164	Device Controller	N/A	N/A
EE960013	HP	8546A	3617A00320	Receiver RF Section	9-29-05	9-29-06
EE960014	HP	85460A	3448A00296	Receiver Pre-Selector	9-29-05	9-29-06
N/A	LSC	Cable	0011	3 Meter ½" Armored Cable	Note 1	Note 1
N/A	LSC	Cable	0038	1 Meter RG 214 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

Appendix B
Antenna Specification

The EUT uses a “Ceramic Chip” antenna, and does not have any other facilities for external or commercial antenna connections.

CENTURION™ Specifications

BlueChip™

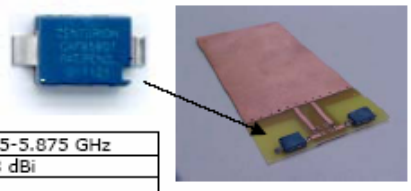
Model Number:
WIC2450-U

Internal Antenna – Surface Mount

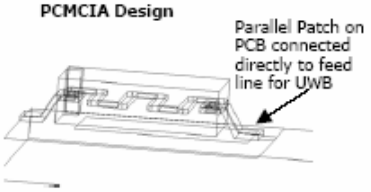
Specifications:

- Small and lightweight
- Wide bandwidth, ultra-wide band capable
- Available in tape and reel packaging
- SMT compatible

Frequency Range	2.4 – 2.5 GHz	5.15-5.875 GHz
Peak Gain	> 2 dBi	> 3 dBi
Polarization	Linear	
Nominal Impedance	50 ohms	
VSWR (Min. Performance)	<2.0:1	
Temperature Range	-40° to +85°C	
Vibration	6G RMS (9.04g2/Hz) for 15 minutes each in vertical and horizontal. No appearance or functional axis.	
Thermal Shock	Change after 4 repeated cycles of 1 hr. at +85°C and 1 hr. at -40°C. Transfer time is 5 min.	
Radiating Element Size	8 x 6 x 2.5 mm (L x W x H)	
Physical Mass	0.21 grams	
Length w/ Solder Tabs	12mm	

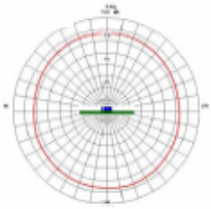


PCMCIA Design

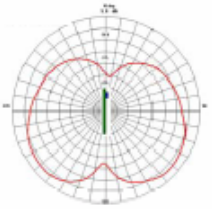


Connectors:

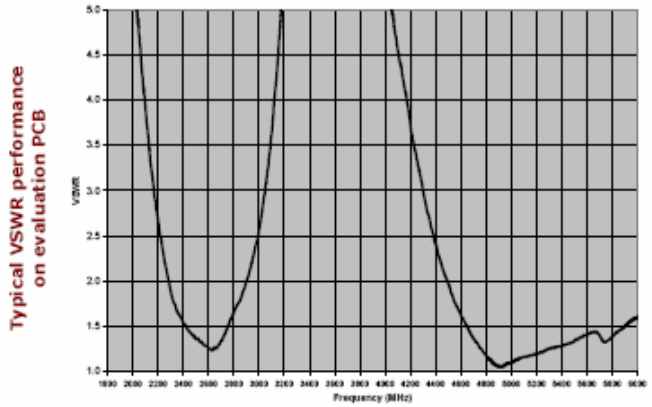
Model #	Part #	Description	Connector
WIC2450-U	CAF95901	Tape and Reel	N/A
WIC2450-U-SM	CAF95943	Single-band on eval board	SMA-female Edge-mount
WIC2452-U-SM	CAF94408	Ultrawide-band on eval board	SMA-female Edge-mount

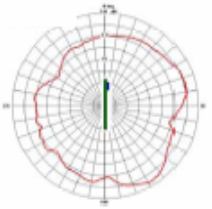


Azimuth
2.45 GHz
Free Space



Elevation phi=0
2.45 GHz
Free Space





Elevation phi=0
5.8 GHz
Free Space

Specifications subject to change without notice. WIC2450U a – 5/18/04

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QS-9000 REGISTERED ISO 9001

Appendix C

Firmware and Setup Instructions

The EUT was presented for testing with special firmware that accepted programming.
The modes were changed by reprogramming the EUT at each step. A laptop computer was used to reprogram the EUT using programming/test-pads already on the PCB, and a terminal program, set to communicate at 38400-8-N-1-N, along with a custom programming fixture as provided by the manufacturer.

Appendix D

Transmitter Duty Factor Calculations

No request for relaxation of the limits has been made, for this product, at this time.
The information presented here is for completeness only, for the family of products.
The relaxation allowance would be based on the duty cycle of the transmitter in normal operation. The relaxation may be requested up to 4 dB, if needed in the future, to be invoked when comparing measurements to the limits for radiated RF harmonic emissions, and if needed, to the band-edge limits.

The following is a description of the transmit duty cycle as presented by the manufacturer.
Worst-Case Duty factor for the transmitter "On-Time" is 62.6%, yielding a relaxation allowance of 4 dB.

IEEE 802.15.4 2.4 GHz PHY

Data Rate	250000	bits / sec	
	31250	bytes / sec	
Symbols/byte	2	sym / bytes	
Symbol Timing	62500	sym / sec	
	0.000016	sec / sym	
Byte Timing	0.000032	sec / byte	
PHY PSDU	6	bytes	4 Pramble, SPD, Length
Max Length	127	bytes	
Total Packet Length	133	bytes	
Maximum Time TX PKT	0.004256	sec	

Long Frame Scenario:

1) TX Frame — Assume Frame is Data Frame
2) Wait for ACK
3) Wait for LIFS
4) Repeat

Long InterFrame Spacing (Slotted w/ ACK)			
Long Frame	127	bytes	
Data Frame Payload	102	bytes	
ACK Frame	5	bytes	
tack	12	sym	
LIFS	40	sym	
ACK Frame	11	bytes	
Backoff Period	20	sym	
Maximum Backoff	7		Random between 0 and 7
Backoff Required	2		
Backoff Time	60	sym	

Transmit Time	
TX Time (Packet)	0.004256
TX Time (ACK)	0.000352
Total TX Time (sec)	0.004608

Off Time	
Backoff Time	0.00192
tack(minimum)	0.000192
LIFS	0.00064
Total Off Time	0.002752

Duty Cycle (On /total) 62.61% — Represents MAC only performance

MAC Constants		
maxBE	5	
aMaxFrameResponseTime	1220	symbols
aMaxFrameRetries	3	
aUnitBackoffPeriod	20	symbols
macAckWaitDuration	54	symbols
macBattLifeExtPeriods	6	Backoff periods
macMaxCSMABackoffs	4	
macMinBE	3	
aMinLIFSPeriod	40	symbols
aMinSIFSPeriod	12	symbols
aMinCAPLength	440	symbols
NB	0	
CW	2	
BE	3	

Short InterFrame Spacing (Slotted w/ ACK)			
Short Frame	18	bytes	
Data Frame Payload	18	bytes	
ACK Frame	5	bytes	
tack	12	sym	
SIFS	12	sym	
ACK Frame	11	bytes	
Backoff Period	20	sym	
Maximum Backoff	7		Random between 0 and 7
Backoff Required	2		
Backoff Time	60	sym	

Transmit Time	
TX Time (Packet)	0.000768
TX Time (ACK)	0.000352
Total TX Time (sec)	0.00112

Off Time	
Backoff Time	0.00192
tack(minimum)	0.000192
SIFS	0.000192
Total Off Time	0.002304

Duty Cycle (On /total) 32.71%

Network Based Calculation

Long InterFrame Spacing (Slotted w/ ACK)			
Long Frame	127	bytes	
Data Frame Payload	102	bytes	
ACK Frame	5	bytes	
tack	12	sym	
LIFS	625	sym	Single hop data indicates 10 ms interpacket spacing
ACK Frame	11	bytes	
Backoff Period	20	sym	
Maximum Backoff	7		Random between 0 and 7
Backoff Required	2		
Backoff Time	60	sym	

Transmit Time	
TX Time (Packet)	0.004256
TX Time (ACK)	0.000352
Total TX Time (sec)	0.004608

Off Time	
Backoff Time	0.00192
tack(minimum)	0.000192
LIFS	0.01
Total Off Time	0.012112

Duty Cycle (On /total) 27.56% Calculated Network Performance

Alternative calculation

Max radio throughput	250000	bps	
Measured throughput single hop	66816	bps	Max test network results 44544 (packet payload)

Duty Cycle 26.73% Measured Network Performance

Use for FCC Calculations	27%