

EMISSIONS TEST REPORT FOR A LOW POWER TRANSMITTER**I. GENERAL INFORMATION**

Requirement: Federal Communications Commissions
Test Requirements: 15.205, 15.207, 15.209, 15.247

Applicant: Invensys Controls
P.O. Box 27606
Richmond, VA 23261-7601

FCC ID:  **QI2-EMS2400**

II. DESCRIPTION OF EQUIPMENT UNDER TEST (EUT)

The EUT is a digital transmission system (DTS) operating under the requirements in FCC Part 15.247. The EUT is an RF module that will be used in various Invensys Controls power management and power meter products. The EUT follows the Zigbee protocol under IEEE 802.15.4.

A Limited Modular Approval certification application will be submitted for the EUT.

The EUT operates in the ISM band between 2.4GHz and 2.4835 GHz.

Transmitter Specification

TX Power	4.49 dBm Peak
Frequency of operation	2405-2475 MHz
Data Rate	250 kbps
6 dB bandwidth	1.73 MHz
99% bandwidth	2.44 MHz
Duty Cycle	Less than 1%
Antenna type (Permanently attached)	Inverted F printed ckt
Power source	3 VDC from converter or from host

III. TEST LOCATION

All tests were performed at:

Compliance Certification Services
561F Monterey Road
Morgan Hill, CA 95037

T.N. Cokenias
EMC Consultant/Agent for Invensys

25 March 2005

15.203 Antenna connector requirement

The antenna is permanently attached to the product. When the EUT is integrated into products, one of two antennas will be used: the inverted F on the pcb of the module, or a permanently attached monopole whip antenna.

15.204 Antenna description

Antenna description	Gain
Inverted F printed ckt antenna	3.5 dBi
externalmonopole	2 dBi

TEST DATA and TEST PROCEDURES**Radiated Emissions**

Test Requirement: 15.205, 15.247

Out of Band Measurements

Test Requirement: 15.247

Measurement Equipment Used:

Agilent E4444A PSA, 9 kHz – 26.5 GHz

Miteq NSP2600-44 Microwave pre-amplifier, 1-26.5 GHz

EMCO 3115 Double Ridged Horn antenna, 1 - 18 GHz

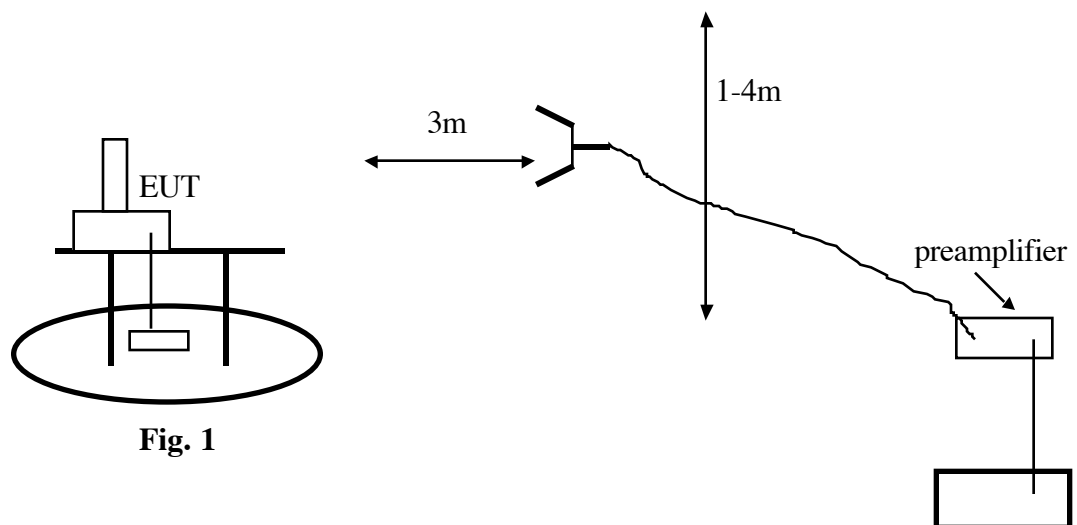
Radiated Test Set-up, 1-26 GHz

Fig. 1

Radiated emissions generated by the transmitter portion of the EUT were measured.

1. The EUT was placed on a wooden table resting on a turntable in the 5m anechoic chamber. .

The search antenna was placed 3m from the EUT. The EUT antenna was mounted in its test fixture.

2. The turntable was slowly rotated to locate the direction of maximum emission at each emission falling in the restricted bands of 15.205.

3. Radiated emissions were investigated for a LOW channel, a MID channel, and HIGH channel. Emissions were investigated to the 10th harmonic.

4. Once maximum direction was determined, the search antenna was raised and lowered in both vertical and horizontal polarizations. The maximum readings so obtained are recorded in the data listed below.

Channel	Frequency, MHz
LOW	2405
MID	2445
HIGH	2475

Test Results: Worst case results are presented. Tests were performed for three different EUT orientations, in the XY, XZ, and YZ planes.

03/03/05 High Frequency Measurement
Compliance Certification Services, Morgan Hill Open Field Site

Test Engr: William Zhuang
Project #: 05U3315-1
Company: Invensys Controls
EUT Descr.: RF Model
EUT M/N: WNM245001-1SFR
Test Target: FCC Class B
Mode Oper: Continuous Transmit

f	Measurement Frequency	Amp	Preamp Gain	Avg Lim	Average Field Strength Limit
Dist	Distance to Antenna	D Corr	Distance Correct to 3 meters	Pk Lim	Peak Field Strength Limit
Read	Analyzer Reading	Avg	Average Field Strength @ 3 m	Avg Mar	Margin vs. Average Limit
AF	Antenna Factor	Peak	Calculated Peak Field Strength	Pk Mar	Margin vs. Peak Limit
CL	Cable Loss	HPF	High Pass Filter		

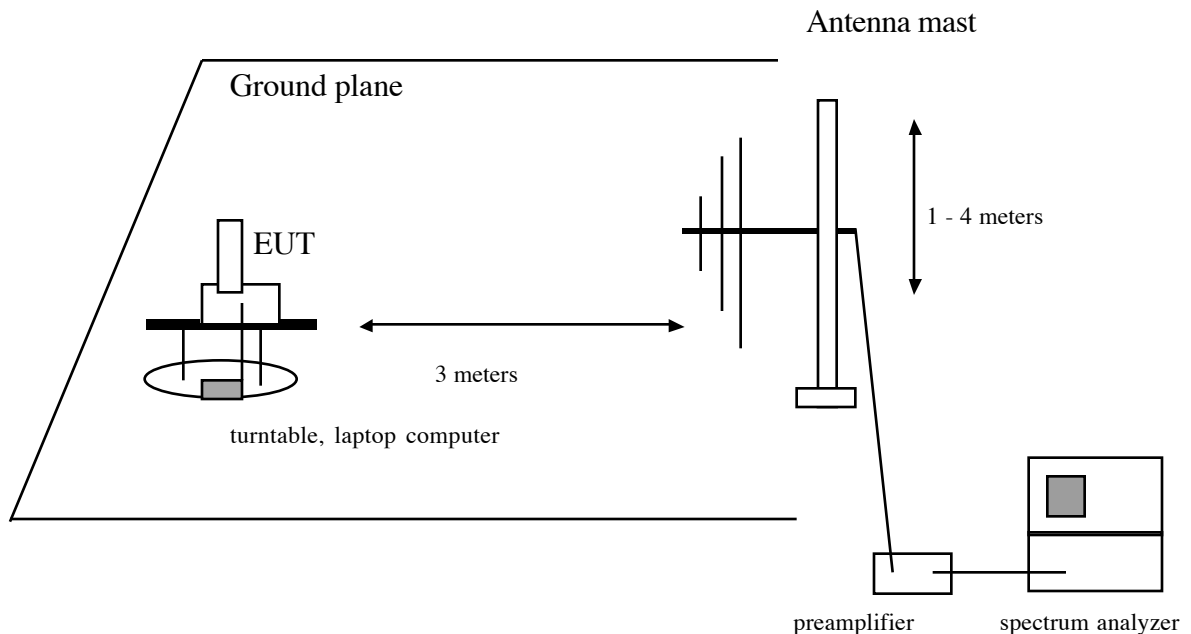
f GHz	Dist (m)	Read Pk dBuV	Read Avg. dBuV	AF dB/m	CL dB	Amp dB	D Corr dB	Filtr dB	Peak dBuV/m	Avg dBuV/m	Pk Lim dBuV/m	Avg Lim dBuV/m	Pk Mar dB	Avg Mar dB	Notes (V/H)
XZ High Ch. 2475MHz															
4.950	3.0	53.8	42.7	33.0	3.3	-39.8	0.0	0.6	50.9	39.8	74.0	54.0	-23.1	-14.2	V
4.950	3.0	58.8	47.3	33.0	3.3	-39.8	0.0	0.6	55.9	44.5	74.0	54.0	-18.1	-9.5	H
YZ High Ch. 2475MHz															
4.950	3.0	59.1	47.1	33.0	3.3	-39.8	0.0	0.6	56.3	44.3	74.0	54.0	-17.7	-9.7	V
4.950	3.0	58.5	46.9	33.0	3.3	-39.8	0.0	0.6	55.7	44.1	74.0	54.0	-18.3	-9.9	H
XY High Ch. 2475MHz															
4.950	3.0	58.8	47.3	33.0	3.3	-39.8	0.0	0.6	55.9	44.5	74.0	54.0	-18.1	-9.5	V
4.950	3.0	51.1	40.4	33.0	3.3	-39.8	0.0	0.6	48.3	37.5	74.0	54.0	-25.7	-16.5	H
XY Mid Ch. 2445MHz															
4.890	3.0	54.8	43.5	32.9	3.3	-39.7	0.0	0.6	51.9	40.7	74.0	54.0	-22.1	-13.3	V
4.890	3.0	49.3	39.0	32.9	3.3	-39.7	0.0	0.6	46.5	36.1	74.0	54.0	-27.5	-17.9	H
7.335	3.0	45.0	34.0	35.9	3.9	-40.3	0.0	0.6	45.1	34.1	74.0	54.0	-28.9	-19.9	H
7.335	3.0	46.4	36.2	35.9	3.9	-40.3	0.0	0.6	46.6	36.3	74.0	54.0	-27.4	-17.7	V
XZ Mid Ch. 2445MHz															
4.890	3.0	50.8	40.2	32.9	3.3	-39.7	0.0	0.6	47.9	37.3	74.0	54.0	-26.1	-16.7	V
4.890	3.0	53.9	42.8	32.9	3.3	-39.7	0.0	0.6	51.1	40.0	74.0	54.0	-22.9	-14.0	H
7.335	3.0	47.0	36.7	35.9	3.9	-40.3	0.0	0.6	47.2	36.8	74.0	54.0	-26.8	-17.2	H
7.335	3.0	44.6	33.8	35.9	3.9	-40.3	0.0	0.6	44.7	34.0	74.0	54.0	-29.3	-20.0	V
YZ Mid Ch. 2445MHz															
4.890	3.0	52.5	41.6	32.9	3.3	-39.7	0.0	0.6	49.6	38.7	74.0	54.0	-24.4	-15.3	V
4.890	3.0	53.0	41.9	32.9	3.3	-39.7	0.0	0.6	50.2	39.0	74.0	54.0	-23.8	-15.0	H
7.335	3.0	48.0	36.6	35.9	3.9	-40.3	0.0	0.6	48.1	36.7	74.0	54.0	-25.9	-17.3	H
7.335	3.0	45.8	35.4	35.9	3.9	-40.3	0.0	0.6	46.0	35.5	74.0	54.0	-28.0	-18.5	V
YZ Low Ch. 2405MHz															
4.810	3.0	51.6	40.5	32.9	3.2	-39.5	0.0	0.6	48.8	37.7	74.0	54.0	-25.2	-16.3	V
4.810	3.0	52.7	41.8	32.9	3.2	-39.5	0.0	0.6	49.8	38.9	74.0	54.0	-24.2	-15.1	H
7.215	3.0	51.1	40.7	35.7	3.9	-40.4	0.0	0.6	50.9	40.5	74.0	54.0	-23.1	-13.5	H
7.215	3.0	51.5	40.5	35.7	3.9	-40.4	0.0	0.6	51.4	40.3	74.0	54.0	-22.6	-13.7	V
XZ Low Ch. 2405MHz															
4.810	3.0	51.1	40.8	32.9	3.2	-39.5	0.0	0.6	48.2	37.9	74.0	54.0	-25.8	-16.1	V
4.810	3.0	55.0	43.4	32.9	3.2	-39.5	0.0	0.6	52.1	40.5	74.0	54.0	-21.9	-13.5	H
7.215	3.0	48.0	37.5	35.7	3.9	-40.4	0.0	0.6	47.8	37.4	74.0	54.0	-26.2	-16.7	H
7.215	3.0	48.6	38.4	35.7	3.9	-40.4	0.0	0.6	48.5	38.2	74.0	54.0	-25.5	-15.8	V
XY Low Ch. 2405MHz															
4.810	3.0	52.1	41.2	32.9	3.2	-39.5	0.0	0.6	49.3	38.3	74.0	54.0	-24.7	-15.7	V
4.810	3.0	47.9	38.1	32.9	3.2	-39.5	0.0	0.6	45.1	35.3	74.0	54.0	-28.9	-18.7	H
7.215	3.0	49.3	38.9	35.7	3.9	-40.4	0.0	0.6	49.1	38.8	74.0	54.0	-24.9	-15.2	H
7.215	3.0	50.5	39.7	35.7	3.9	-40.4	0.0	0.6	50.3	39.6	74.0	54.0	-23.7	-14.4	V

Radiated Emissions
Test Requirement: 15.109

Measurement Equipment Used:

HP 8568 Spectrum Analyzer, 30-1000 MHz
 HP 8447D Pre-amplifier, .1 - 1300 MHz
 Schaffner/Chase CBL6112B Bilog Antenna, 30 - 2000 MHz

Radiated Test Set-up, 30 - 1000 MHz

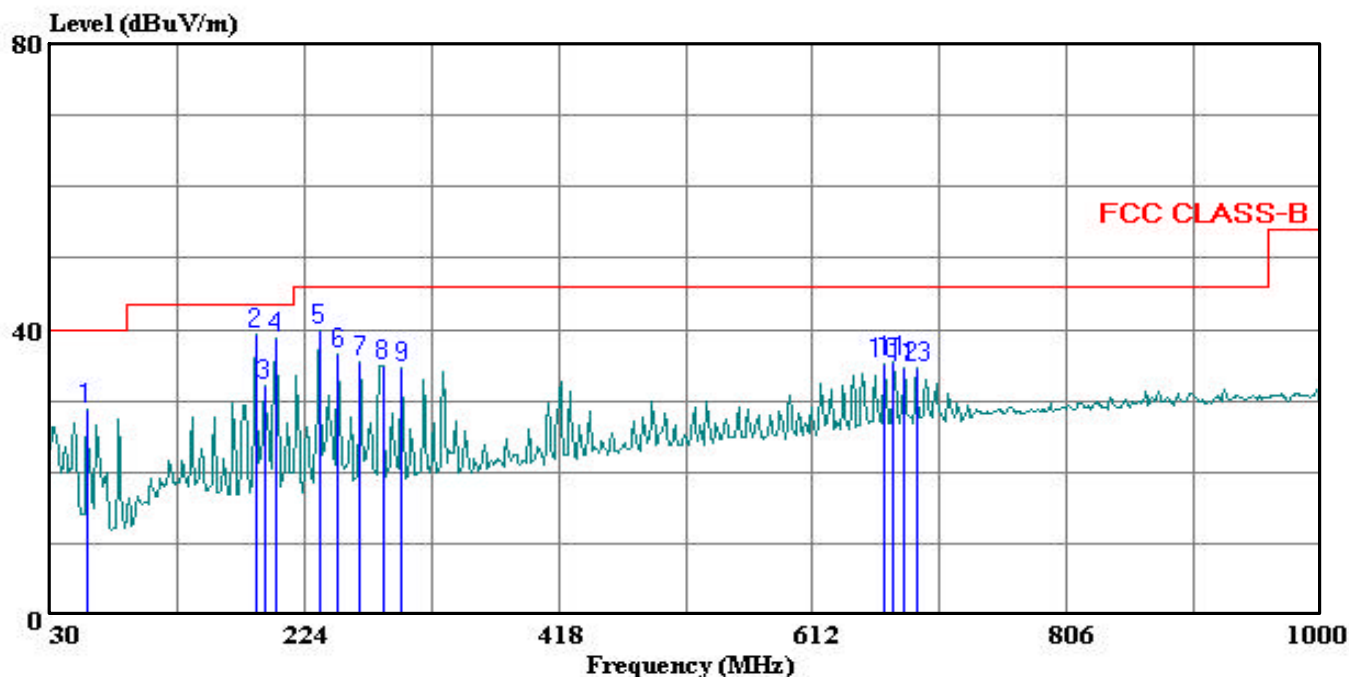


Radiated emissions generated by the digital portion of the EUT were measured.

1. The EUT was placed on a wooden table resting on a turntable in the 5m chamber. The search antenna was placed 3m from the EUT. The EUT antenna was mounted vertically as per normal installation. The EUT was set to transmit continuously on the MID channel.
2. The turntable was slowly rotated to locate the direction of maximum emission at each emission falling in the restricted bands of 15.205.
3. Once maximum direction was determined, the search antenna was raised and lowered in both vertical and horizontal polarizations. The maximum readings so obtained are recorded in the data listed below.

Test Results: Worst case results are presented. Tests were performed for three different EUT orientations, in the XY, XZ, and YZ planes..

Data#: 12 File#: Tom030305.EMI Date: 03-03-2005 Time: 10:53:46



(Aux ATC)

Trace: 11

Ref Trace:

Condition: FCC CLASS-B VERTICAL
Test Operator: : William Zhuang
Project #: : 05U3315-1
Company: : INVENSYS CONTROLS
EUT: : RF Module
Model No : WNM245001-1SFR int. ant.
Configuration: : EUT only
Target of Test: : FCC Class B
Mode of Operation: Continous Transmit

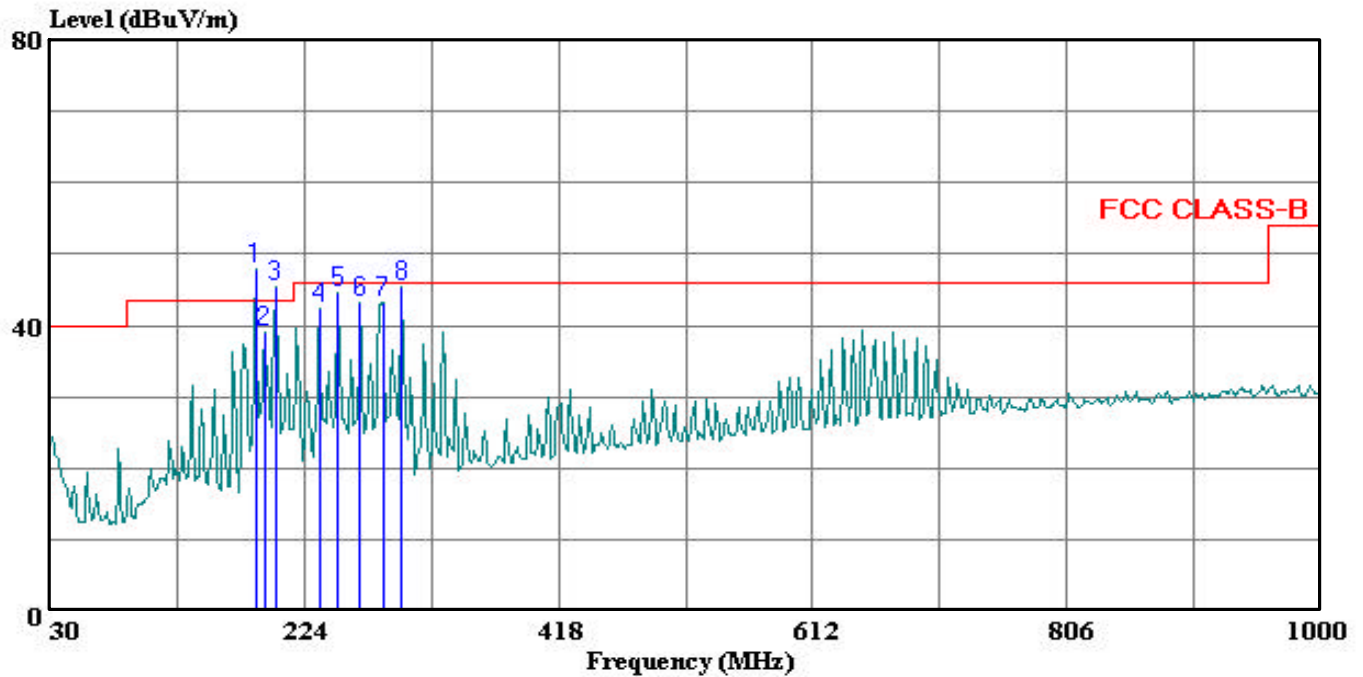
Page: 1

	Freq	Read Level	Factor	Level	Limit Line	Over Limit	Remark
	MHz	dBuV	dB	dBuV/m	dBuV/m	dB	
1	58.130	48.16	-19.28	28.88	40.00	-11.12	Peak
2	187.140	54.21	-14.80	39.41	43.50	-4.09	Peak
3	193.930	46.24	-14.11	32.13	43.50	-11.37	Peak
4	201.690	52.08	-13.32	38.76	43.50	-4.74	Peak
5	235.640	54.28	-14.32	39.96	46.00	-6.04	Peak
6	250.190	50.35	-13.68	36.67	46.00	-9.33	Peak
7	266.680	48.58	-13.12	35.46	46.00	-10.54	Peak
8	284.140	47.51	-12.50	35.01	46.00	-10.99	Peak
9	298.690	46.58	-11.88	34.70	46.00	-11.30	Peak

Data#: 12 File#: Tom030305.EMI Date: 03-03-2005 Time: 10:53:46
Page: 2

	Freq	Read Level	Factor	Level	Limit Line	Over Limit	Remark
	MHz	dBuV	dB	dBuV/m	dBuV/m	dB	
10	667.290	39.05	-3.81	35.24	46.00	-10.76	Peak
11	674.080	39.10	-3.69	35.41	46.00	-10.59	Peak
12	681.840	38.19	-3.45	34.74	46.00	-11.26	Peak
13	691.540	37.85	-3.34	34.51	46.00	-11.49	Peak

Data#: 10 File#: Tom030305.EMI Date: 03-03-2005 Time: 10:47:19



(Audix ATC)

Trace: 9

Ref Trace:

Condition: FCC CLASS-B HORIZONTAL
Test Operator: : William Zhuang
Project #: : 05U3315-1
Company: : INVENSYS CONTROLS
EUT: : RF Module
Model No : WNM245001-1SFR int. ant.
Configuration: : EUT only
Target of Test: : FCC Class B
Mode of Operation: Continous Transmit
: Freq. 184 MHz and 200 MHz are radio
: -20dBc PLL

Page: 1

		Read		Limit	Over	
	Freq	Level	Factor	Level	Line	Limit Remark
	MHz	dBuV	dB	dBuV/m	dBuV/m	dB
1 *	187.140	62.62	-14.80	47.82	43.50	4.32 Peak
2	193.930	53.11	-14.11	39.00	43.50	-4.50 Peak
3 *	201.690	58.63	-13.32	45.31	43.50	1.81 Peak
4	235.640	56.79	-14.32	42.47	46.00	-3.53 Peak
5	250.190	58.20	-13.68	44.52	46.00	-1.48 Peak
6	266.680	56.41	-13.12	43.29	46.00	-2.71 Peak
7	284.140	55.79	-12.50	43.29	46.00	-2.71 Peak

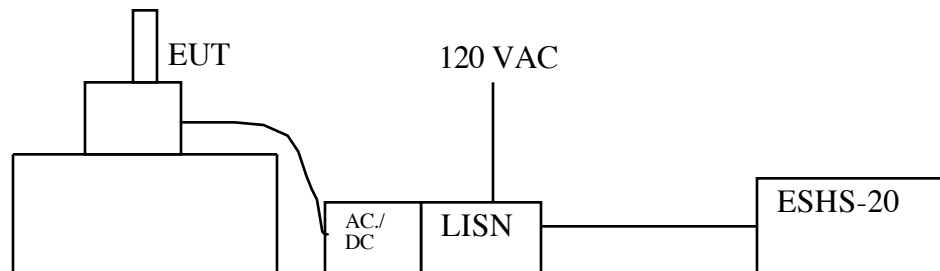
Data#: 10 File#: Tom030305.EMI Date: 03-03-2005 Time: 10:47:19
Page: 2

	Freq	Read Level	Factor	Level	Limit Line	Over Limit	Remark
	MHz	dBuV	dB	dBuV/m	dBuV/m	dB	
8	298.690	57.19	-11.88	45.31	46.00	-0.69	Peak

AC Line Conducted Emissions
Test Requirement: 15.107, 15.207

Measurement Equipment Used:

Rohde & Schwarz EMI Receiver ESHS-20
Fischer Custom Communication LISN, FCC-LISN-50/250-25-2



Test Procedure

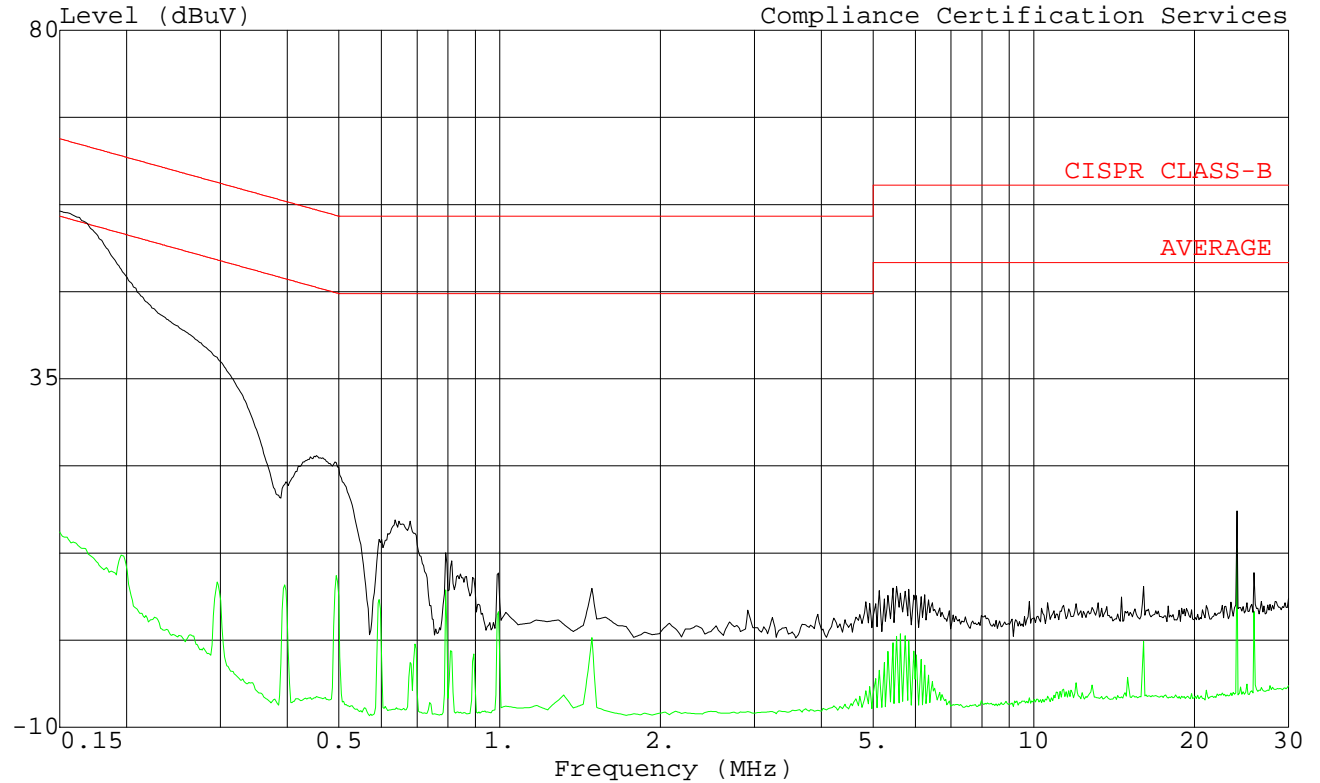
1. The EUT was placed on a wooden table 40 cm from a vertical ground plane and approximately 80 cm above the horizontal ground plane on the floor. The EUT was set to transmit in normally at MID channel (2445 MHz). The EUT AC/DC power supply was connected to the power output receptacle of the LISN
2. Line conducted data was recorded for both NEUTRAL and HOT lines.

Test Results

PASS. Refer to data sheets below.

Data#: 7 File#: 05U3315.EMI

Date: 03-02-2005 Time: 15:12:38



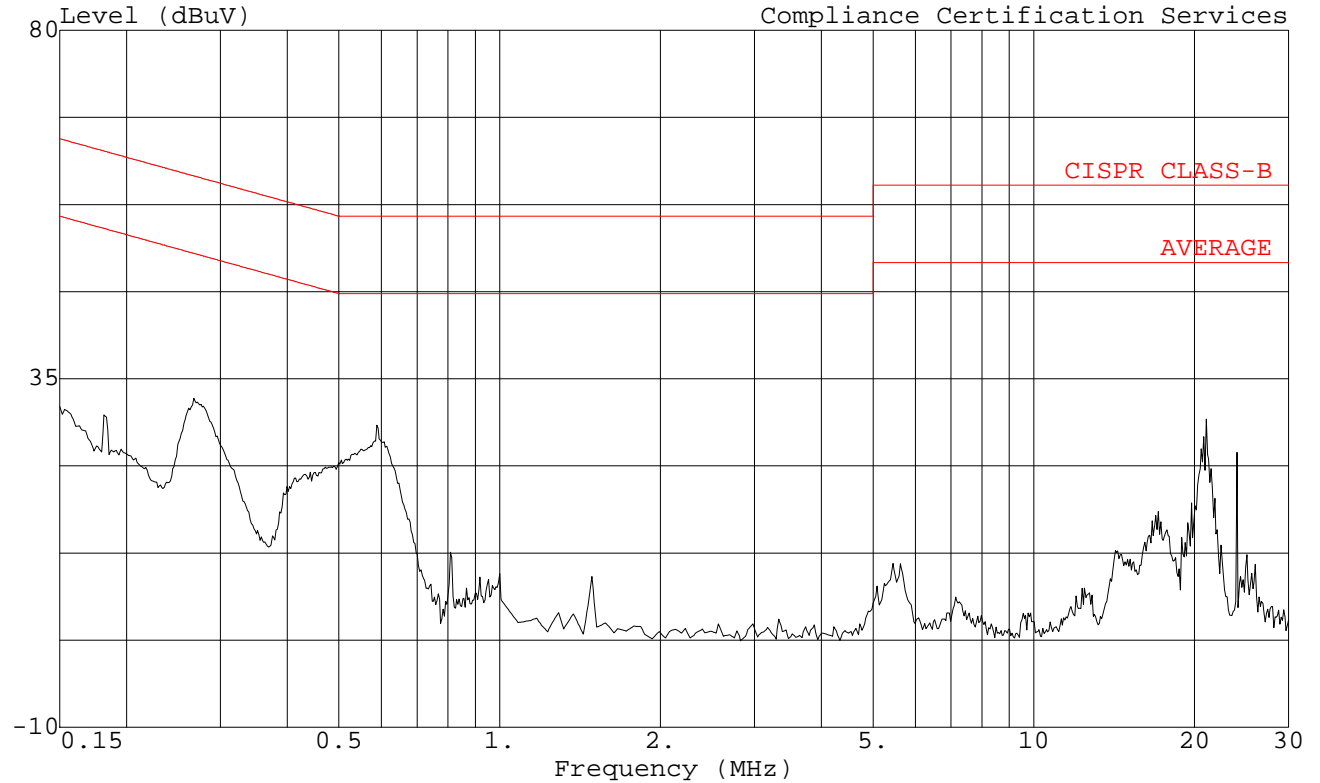
Trace: 5

Ref Trace:

Project No. : 05U315-1
Test Engr : Thanh Nguyen
Company : INVENSYS CONTROLS
EUT : Thermostat
Model No. : EMST101
Test Config.: EUT only
Type of Test: FCC Class B
Mode of Op. : 115VAC, 60HZ
AC Mains : L1: Peak(Black); Average (Green)

Data#: 42 File#: 05U3315.EMI

Date: 03-02-2005 Time: 16:30:52



Trace:

Ref Trace:

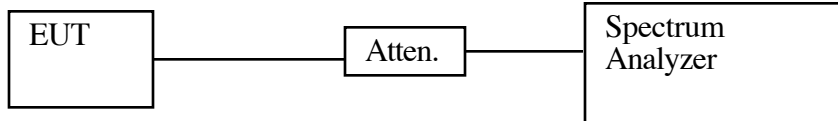
Project No. : 05U3315-2
Test Engr : Thanh Nguyen
Company : INVENSYS CONTROLS
EUT : Load Control Meter
Model No. : iL00V99400
Test Config.: EUT only
Type of Test: FCC Class B
Mode of Op. : 220VAC, 60HZ
AC Mains : L2: Peak(Black)

6dB Bandwidth for DTS
Test Requirement: 15.247**Measurement Equipment Used:**

Agilent E4444A PSA, 9 kHz – 26.5 GHz

10 dB Coaxial Attenuator

2ft test coaxial cable from antenna connector (test purposes only)

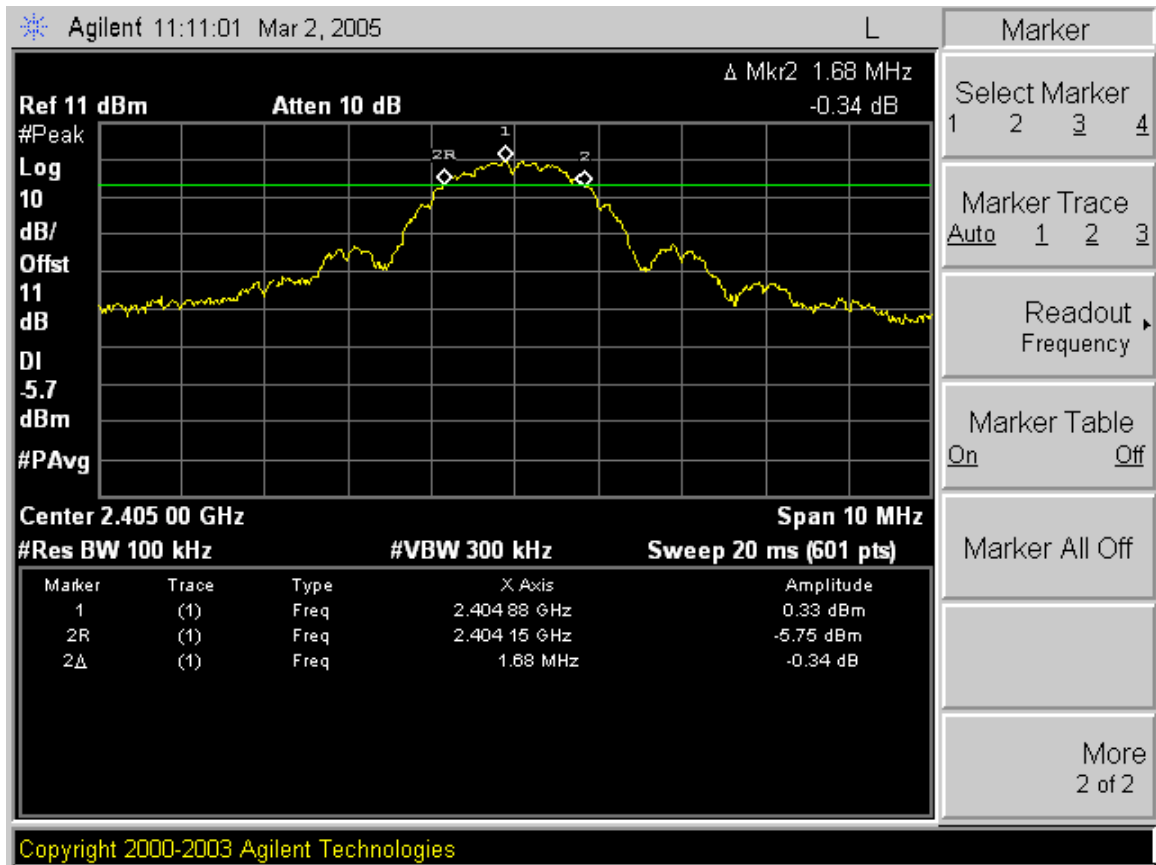
**Test Procedures**

A modified EUT with a coaxial cable attached to the radio antenna port was configured on a test bench. The cable's SMA connector was connected to the spectrum analyzer. The EUT transmission was continuous at 2405 MHz (LOW channel). While the transmitter broadcast a steady stream of digital data, the analyzer OCC BW function was used to capture the envelope of the transmission occupied bandwidth.

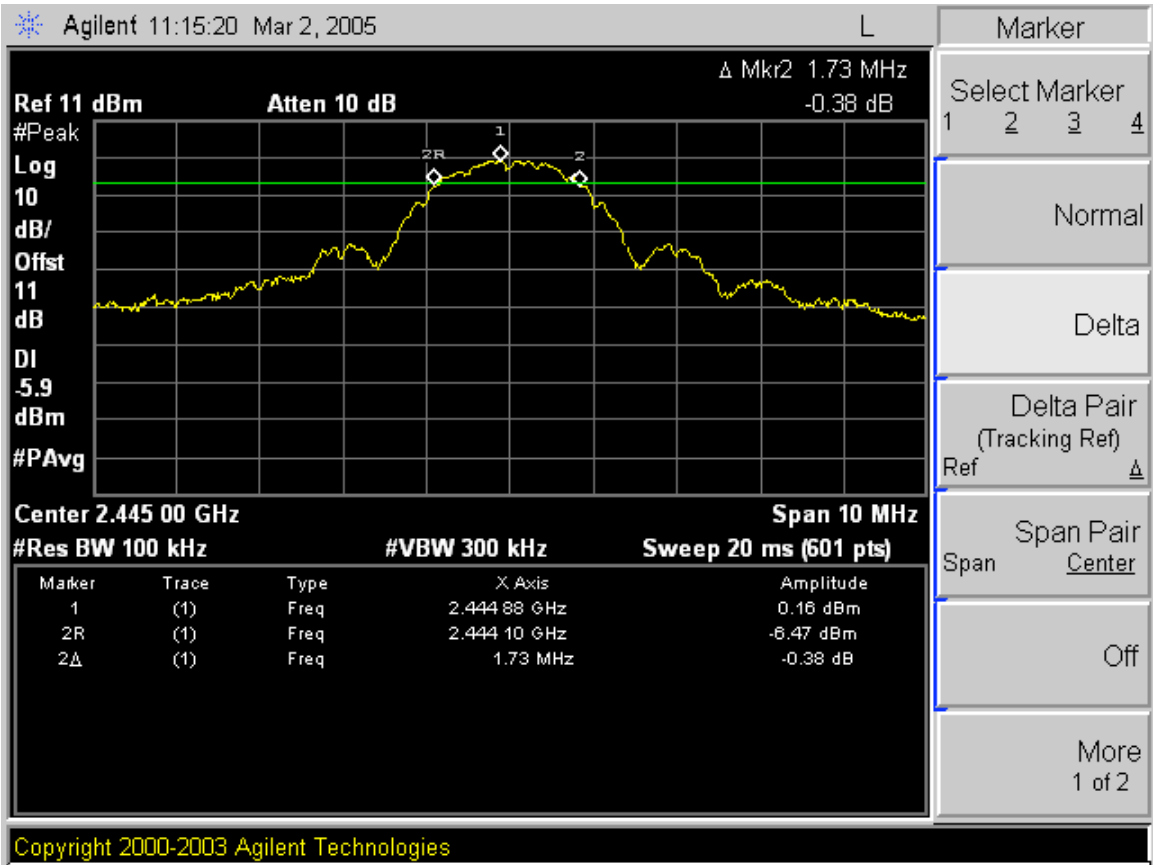
Test was repeated for MID and HIGH channels.

Channel	Frequency, MHz
LOW	2405
MID	2445
HIGH	2475

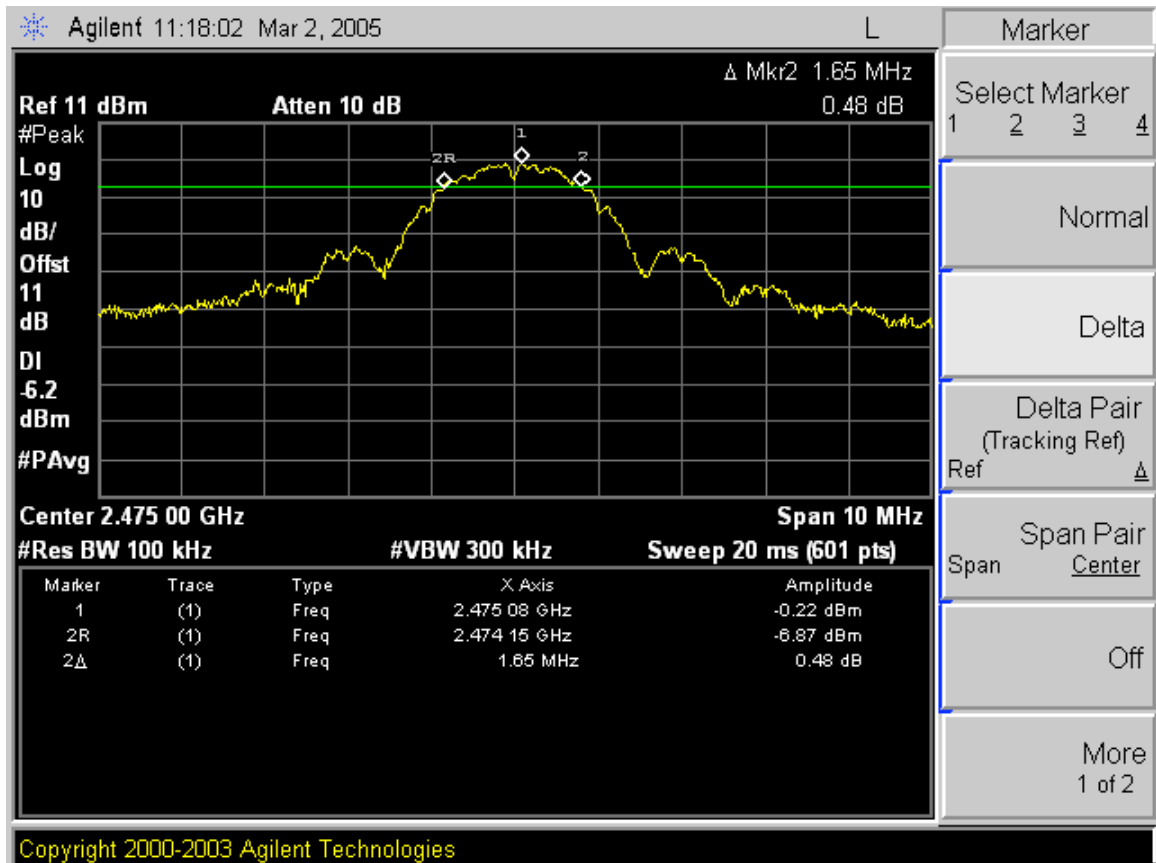
Test Results: Measured approximately 1.73MHz, 6 dB BW. Refer to data sheets below.

15.247 Minimum 6 dB DTS Channel Bandwidth LOW channel

15.247 Minimum 6 dB DTS Channel Bandwidth MID channel

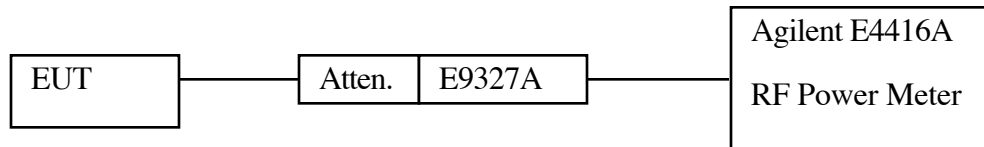


15.247 Minimum 6 dB DTS Channel Bandwidth HIGH channel



RF Power Output**Test Requirement: 15.247****Measurement Equipment Used:**

Agilent E4416A power meter
 Agilent E9327A RF sensor
 20 dB attenuator
 coaxial cable

**Test Procedures**

1. The EUT was configured on a test bench. The power meter was zeroed and calibrated. The EUT was activated.
- 2.. The power meter head was connected to the test cable and attenuator connected to the EUT antenna port. Peak power was read directly off the meter, offset adjusted for attenuator and cable loss.
3. The process in (1) and (2) was repeated for MID channel and HIGH channel.

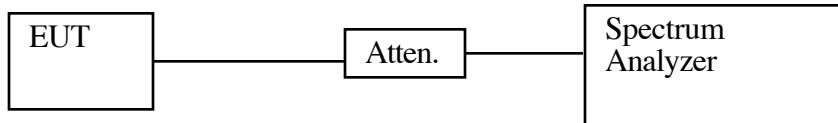
Test Results

Power level readings converted to dBm are shown below.

MODE / CHANNEL	MEASURED AVERAGE POWER (dBm)	MEASURED PEAK POWER (dBm)
Channel 2405	3.74	4.49
Channel 2445	3.54	4.29
Channel 2475	3.32	3.99

Spurious Emissions, Conducted
Test Requirement: 15.247(c)**Measurement Equipment Used:**

Agilent E4444A PSA, 9 kHz – 26.5 GHz
10 dB attenuator
low loss coaxial RF cable

**Test Procedure**

1. The EUT was configured on a test bench. The cable was connected between the EUT antenna port and the spectrum analyzer input port.

Spectrum analyzer RES BW was set to 100 kHz. While the transmitter broadcast a steady stream of digital data, the analyzer MAX HOLD function was used to capture the envelope of the transmission.

Readings were taken out to 10fo.

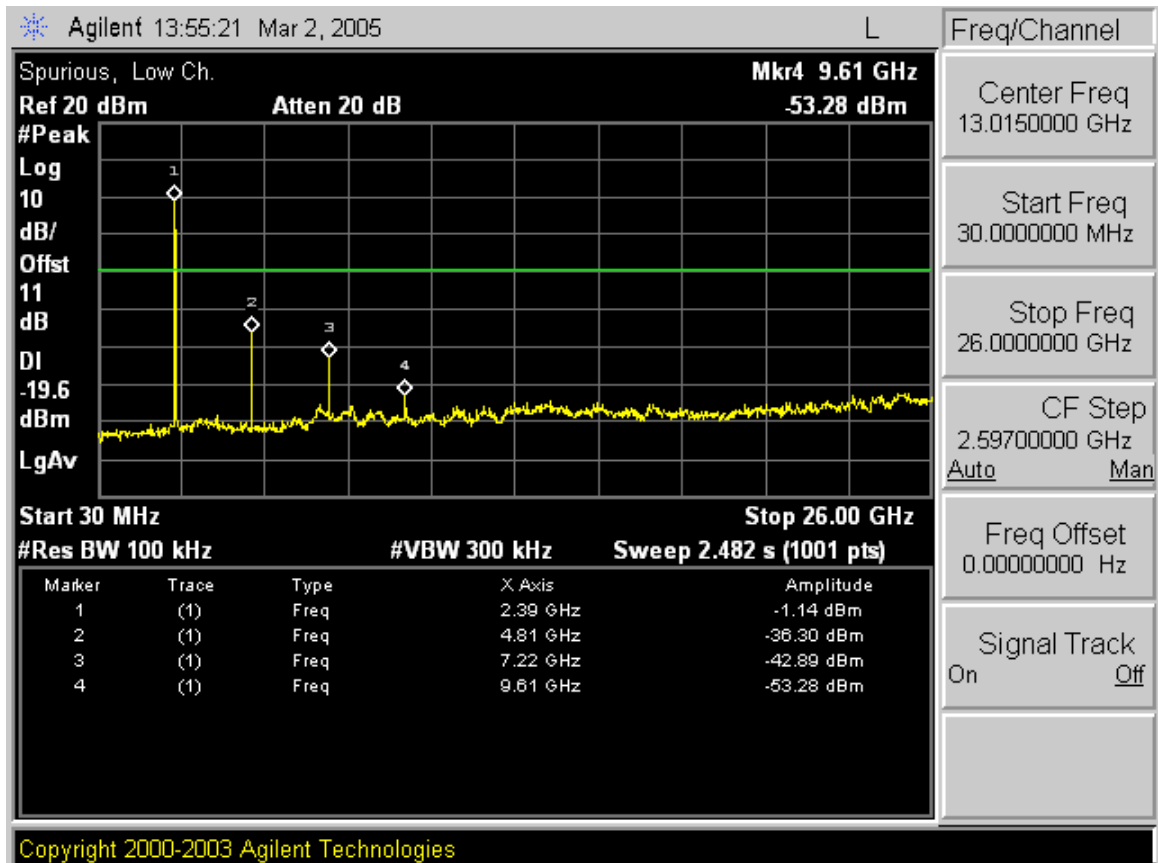
2. The process in (1) was repeated for MID channel and HIGH channel.

Channel	Frequency, MHz
LOW	2405
MID	2445
HIGH	2475

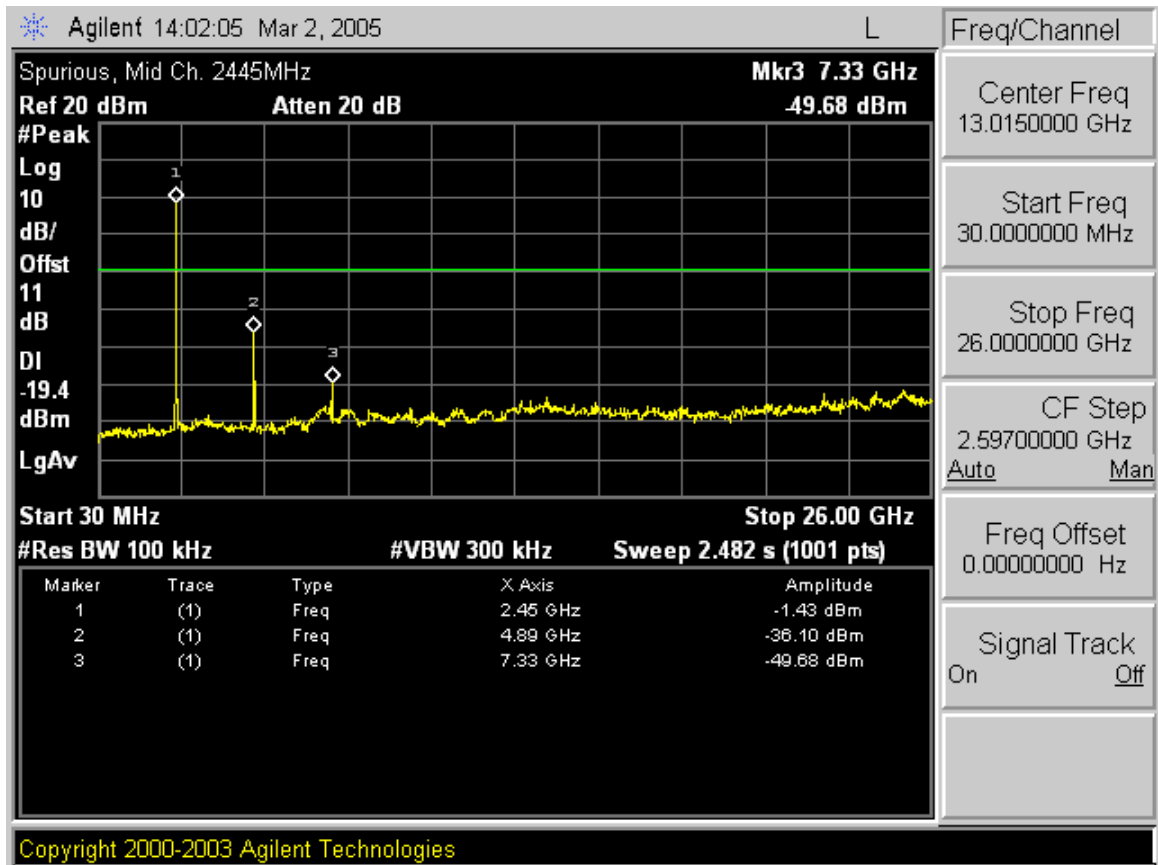
Test Results

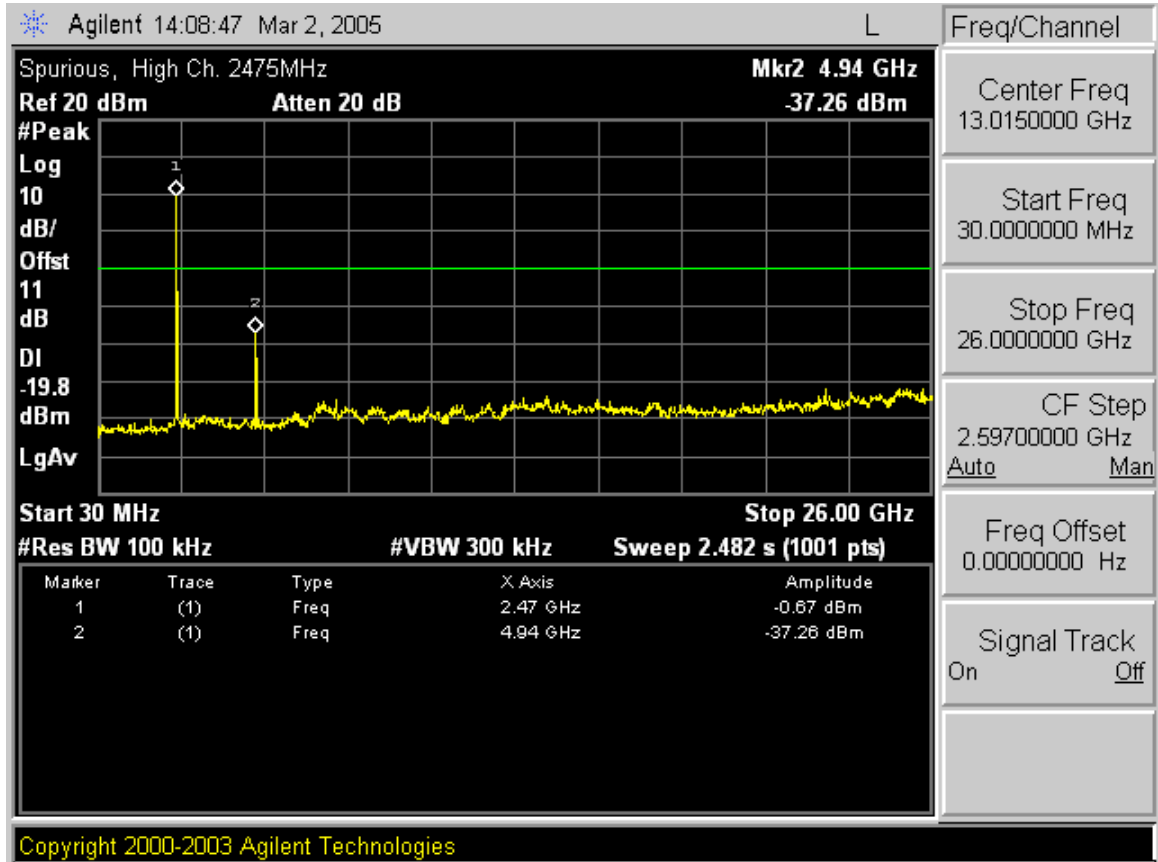
Refer to attached data sheets. Data shows out of band emissions are suppressed well below the -20 dBc minimum required by the Rules.

Antenna Port Conducted Spurious Emissions LOW Channel



Antenna Port Conducted Spurious Emissions MID channel



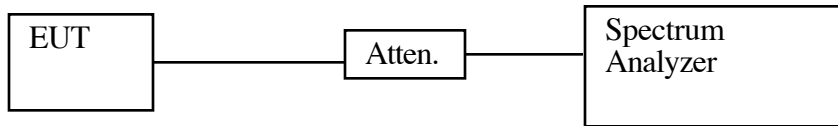
Antenna Port Conducted Spurious Emissions HIGH channel

Power Spectral Density**Test Requirement: 15.247(d)****Measurement Equipment Used:**

Agilent E4444A PSA, 9 kHz – 26.5 GHz

10 dB coaxial attenuator

low loss coaxial RF cable connected on EUT pcb at antenna connection

**Test Procedure**

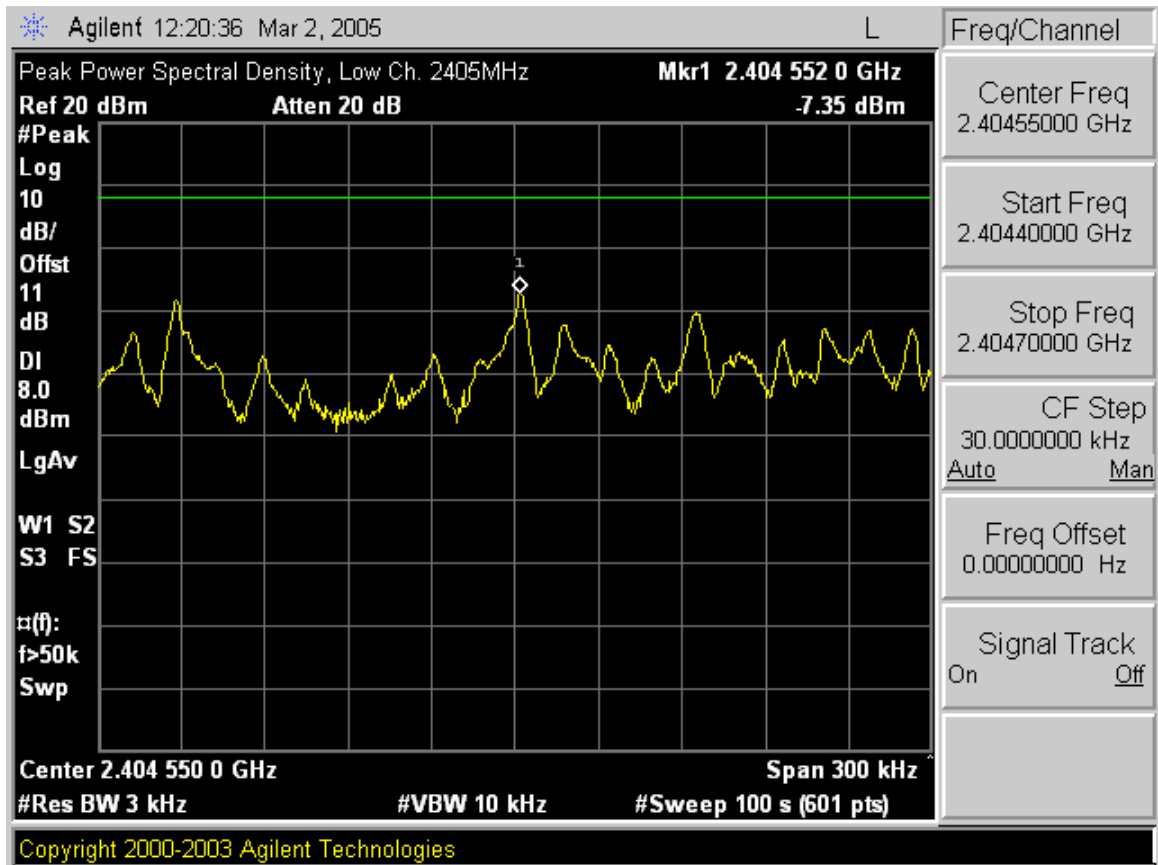
For the LOW channel, the emission peak was set to the center of the display. The SPAN was set to 300 kHz, the RES BW and VID BW were set to 3 kHz, and SWEEP TIME was set to 100 seconds. The maximum trace was recorded and compared to the 8 dBm limit.

The test was repeated for MID and HIGH channel.

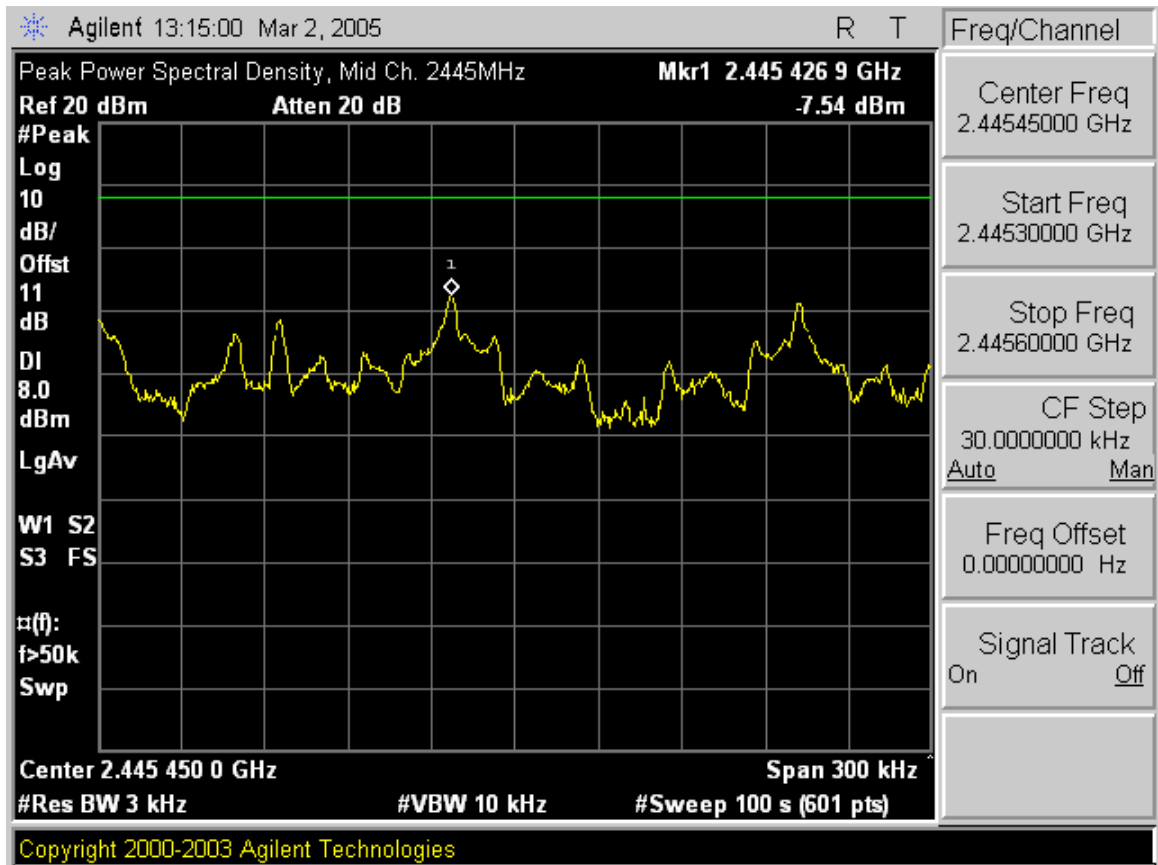
Channel	Frequency, MHz
LOW	2405
MID	2445
HIGH	2475

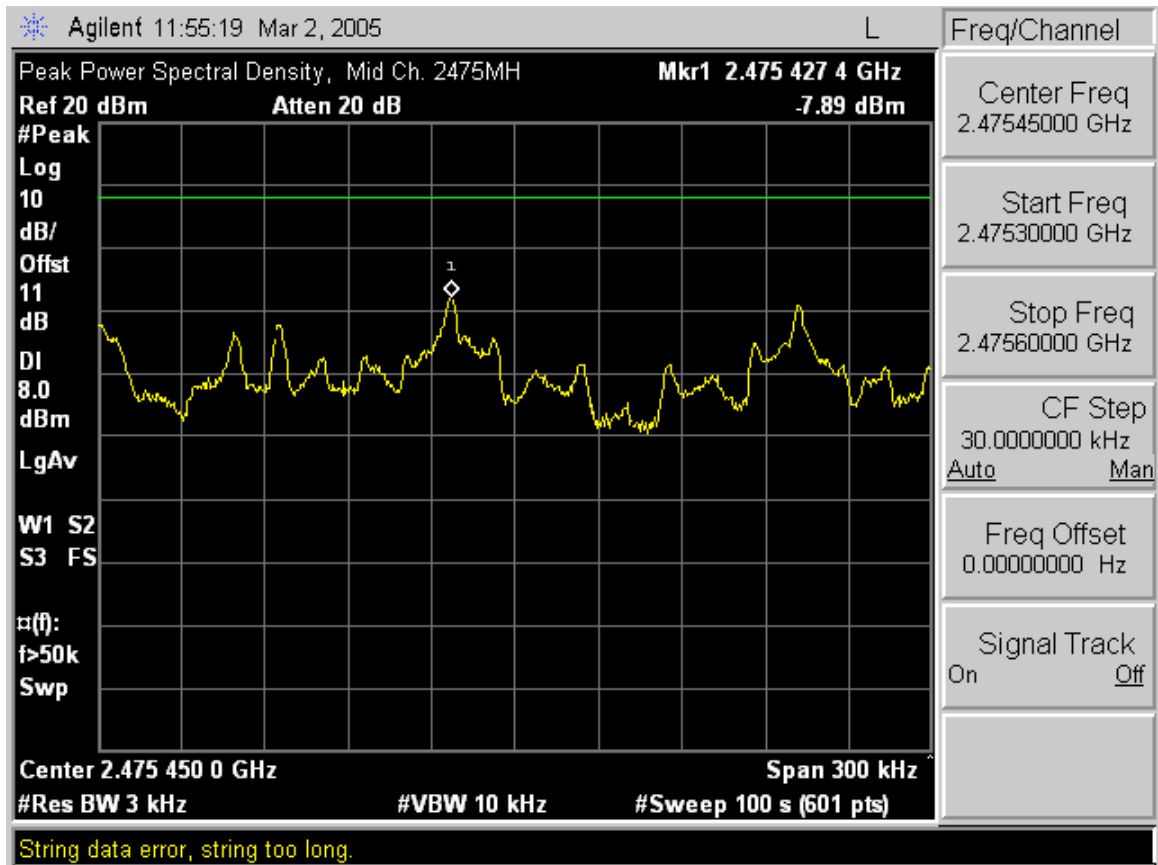
Test Results

Maximum measured PSD was -7.35 dBm. Refer to attached spectrum analyzer charts.

Power Spectral Density LOW channel

Power Spectral Density MID channel



Power Spectral Density HIGH channel

Invensys Controls							
RF Module							
FCC ID:	QI2-EMS2400						
IC:	4636A-2400						
RF Hazard Distance Calculation							
mW/cm2 from Table1:		1.00	(E: 61 V/m)				
Max RF Power	TX Antenna	MPE	MPE, inches	Comment			
P, dBm	G, dBi	Safe Distance, cm					
4.5	2.0	0.4	0.2	omni monopole			
4.5	3.5	0.7	0.3	inverted F			
Basis of Calculations:							
$E^2/3770 = S$, mW/cm2							
E , V/m = $(P_{watts} * G_{gain} * 30)^{.5} / d$, meters							
$d = ((P_{watts} * G * 30) / 3770 * S)^{.5}$		$P_{watts} * G_{gain} = 10^{(P_{dBm} - 30 + G_{dBi}) / 10}$					
NOTE: For mobile or fixed location transmitters, minimum separation distance is for FCC compliance is 20 cm, even if calculations indicate MPE distance is less							