LS Research, LLC
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ENGINEERING TEST REPORT # 307455 TX R6

Compliance Testing of:
2.4 GHz RF Module (VS Module)
Model CWD1016

Test Date(s):
December 11,12,16,20, 2007
January 9 & 1, 2008

Prepared For:
Crestron Electronics, Inc
Attn: Tom Mans
15 Volvo Drive
Rockleigh, NJ 07647

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 is issued under the Authority of:
Brian E. Petted, VP of Engineering

Signature: Date: January 23, 2008

Test Report Reviewed by:	**Tested by:**
Teresa A. White, Quality Manager	Laura Bott EMC Engineer
Signature: Teresa A. White	Signature: Laura M Bott
Date: January 23, 2008	Date: January 23, 2008

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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:	• Commercial, Industrial or Business • Residential

1.2 NORMATIVE REFERENCES

Publication	Year	Title
47 CFR, Parts 0-15 (FCC)	2007	Code of Federal Regulations - Telecommunications
ANSI C63.4	2003	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 201: 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.

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.

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1 CLIENT INFORMATION

Manufacturer Name:	Crestron Electronics Inc.
Address:	15 Volvo Drive Rockleigh, NJ 07647
Contact Person:	Tom Mans Phone: 201.750.7004 Email: tmans@crestron.com

2.2 EQUIPMENT UNDER TEST (EUT) INFORMATION

The following information has been supplied by the applicant.

Product Name:	2.4 GHz RF Module (V2 Module)
Model Number:	CWD1016
Serial Number:	N/A

2.3 ASSOCIATED ANTENNA DESCRIPTION

Johanson Technology 2.45 GHz chip antenna, P/N 2450AT18A100.
Peak Gain = 0.5 dBi
Average Gain = -0.5 dBi

2.4 EUT'S TECHNICAL SPECIFICATIONS

Additional Information:

Frequency Range (in MHz)	2400-2483.5
RF Power in Watts	.100
Conducted Output Power (in dBm)	20 dBm
Field Strength (and at what distance)	121.03 dBµV/m @ 1meter
Occupied Bandwidth (99% BW)	2708 kHz
Type of Modulation	OQPSK
Emission Designator	G1D1M58
EIRP (in mW)	80.91 mW
Transmitter Spurious (worst case)	67.78 dBµV/m
Frequency Tolerance %, Hz, ppm	100 ppm
Microprocessor Model # (if applicable)	N/A
Antenna Information	
Detachable/non-detachable	Non-detachable
Type	chip
Gain (in dBi)	0.5 dBi
EUT will be operated under FCC Rule Part(s)	Title 47 CFR 15.247 and 15.207 IC: RSS_GEN and RSS-210
Modular Filing	☒ Yes ☐ No

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: 2 & 4%
- Standard used for evaluation: OET 65
- Measurement Distance: 1 m
- RF Value: 1.426 ☒ V/m ☐ A/m ☐ W/m^2
  ☒ Measured ☐ Computed ☐ Calculated

2.5 PRODUCT DESCRIPTION

This module is to be used in Crestron's line of home automation products. The module will be placed in wall mounted keypads. The module contains a RF transceiver, RF power amplifier, host processor, and integrated antenna. The radio operates in the 2.4-2.4835 GHz ISM band. The RF transceiver is the Ember EM2420.

EXHIBIT 3. EUT OPERATING CONDITIONS & CONFIGURATIONS DURING TESTS

3.1 CLIMATE TEST CONDITIONS

Temperature:	20-25°C
Humidity:	30-60%
Pressure:	86-106 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
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.		

3.3 MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES

☐ **None** ☒ **Yes (explain below)**

Power was reduced on channel 16 (from -1 to -10), to meet upper band edge compliance.

3.4 DEVIATIONS & EXCLUSIONS FROM TEST SPECIFICATIONS

☒ **None** ☐ **Yes (explain below)**

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 (2007), 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.

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 Transmit and Receive modes, and final testing was performed using CW transmit mode, using power as provided by a variable DC voltage supply. The unit has the capability to operate on 16 channels, controllable via laptop PC using the Hyper Terminal.

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 (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 from 30 MHz to 1 GHz were performed on the EUT in a 3 meter Semi-Anechoic, FCC listed Chamber and 1 GHz to 25 GHz was measured at a 1m separation distance in a mini chamber. The radiated RF emission levels were manually noted at the various fixed degree turntable azimuths 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 from the ground plane, 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 three orthogonal axis during the investigations to find the highest emission levels.

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 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 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 (2007), Annex 8 (section 8.2). The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

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 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	-
960-24,000	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

Relaxation Correction Factor

A 20 dB relaxation factor was available to use (detailed in Appendix C); however, it was only utilized in the band edge measurements.

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:	Crestron Electronics, Inc						
Date(s) of Test:	December 12, 2007						
Test Engineer(s):	Laura Bott						
Voltage:	5 VDC						
Operation Mode:	continuous transmit, modulated						
Environmental Conditions in the Lab:	Temperature: 20 – 25° C Relative Humidity: 30 – 60 %						
EUT Power:		Single Phase 110 VAC		3 Phase ___VAC			
		Battery	√	Other: 5 VDC power source			
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	

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

Frequency (MHz)	Height (m)	Azimuth (degree)	Quasi Peak Reading (dBµV/m)	Quasi Peak Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
170.8	1	0	24.2	43.5	19.3	Horizontal	Vertical
257.5	1	0	30.8	46	15.2	Vertical	Vertical
158.5	1	0	24.8	43.5	18.7	Vertical	Side
292.3	1	0	33	46	13	Horizontal	Side
254.2	1	0	30.1	46	15.9	Horizontal	Flat
208.2	1	0	31.7	43.5	11.8	Vertical	Flat
878.5	1	0	36.2	46	9.8	Vertical	Flat
969	1	0	37.5	54	16.5	Horizontal	Flat
774	1	0	34.5	46	11.5	Horizontal	Vertical
620	1	0	32	46	14	Vertical	Vertical
753	1	0	33.8	46	12.2	Vertical	Side
948	1	0	37.1	46	8.9	Horizontal	Side

RADIATED (SPURRIOUS) EMISSIONS DATA CHART *(continued)*

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 ERP (dBµV/m)	15.247 Limit (dBµV/m)	Margin (dB)
2405	H/S	1	24	120.6	134.7	13.67
4810	H/S	1.14	154	48.09	63.5	15.41
7215	H/V	1.03	214	67.78	100	32.22
9620	H/S	1	120	54.93	100	45.07
12025	H/S	1	120	49.58	63.5	13.92
14430				*Note 3	101	
16835				*Note 3	101	
19240				*Note 3	74	
21645				*Note 3	111	
24050				*Note 3	111	

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 ERP (dBµV/m)	15.247 Limit (dBµV/m)	Margin (dB)
2440	H/S	1	154	121.03	134.7	14.1
4880	H/S	1.21	236	41.1	63.5	22.4
7320	H/F	1	175	53.68	63.5	9.82
9760	H/S	1	233	55	101	46
12200				*Note 3	63.5	
14640				*Note 3	100	
17080				*Note 3	100	
19520				*Note 3	74	
21960				*Note 3	110	
24400				*Note 3	110	

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

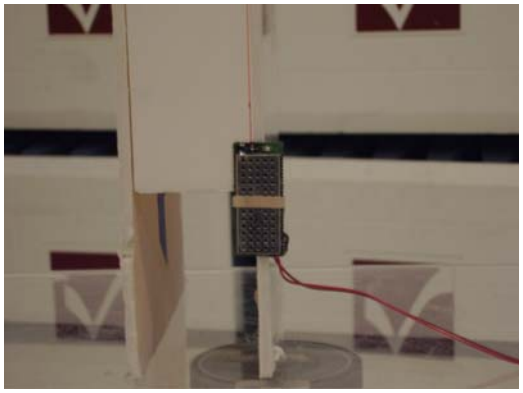
Frequency (MHz)	Ant/EUT Polarity	Height (meters)	Azimuth (0°-360°)	Measured ERP (dBµV/m)	15.247 Limit (dBµV/m)	Margin (dB)
2480	H/S	1	348	118.85	134.7	15.85
4960	H/S	114	141	42.4	63.5	21.1
7440	H/S	1	179	43.8	63.5	19.7
9920	H/S	1	14	45	98	53
12400				*Note 3	63.5	
14880				*Note 3	98	
17360				*Note 3	98	
19840				*Note 3	74	
22320				*Note 3	74	
24800				*Note 3	108	

Notes:

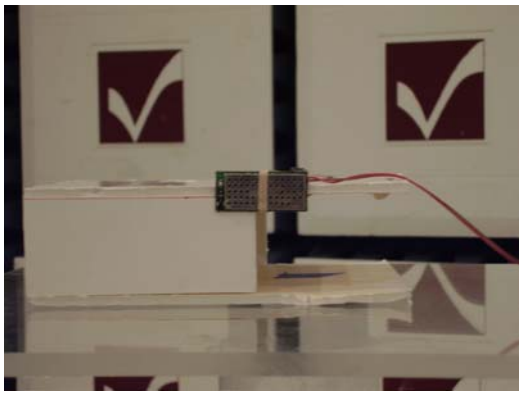
1) A Quasi-Peak Detector was used in measurements below 1 GHz, and a Peak as well as an Average Detector was used in measurements above 1 GHz. Of the measurements taken at frequencies higher than 1 GHz, the results from the Average detector are reflected in the above table. The peak detector was used to ensure the peak emissions did not exceed 20 dB above the limits.
2) Measurements for frequencies 1-18 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=3 MHz, VBW=50 MHz.

5.7 Test Setup Photo(s) – Radiated Emissions Test

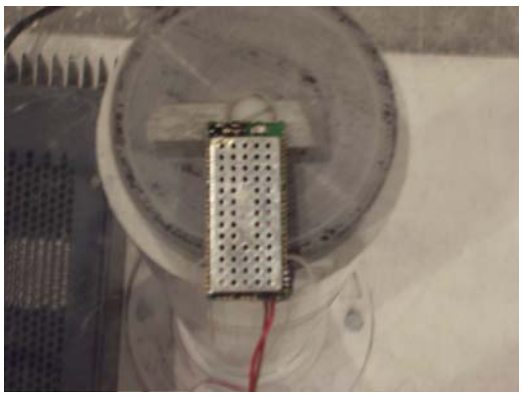
Vertical Orientation



Side Orientation



Flat Orientation

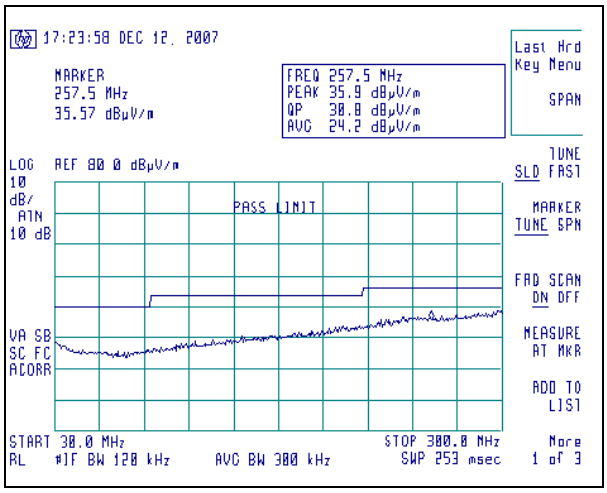


5.8 Screen Captures - Radiated Emissions Testing

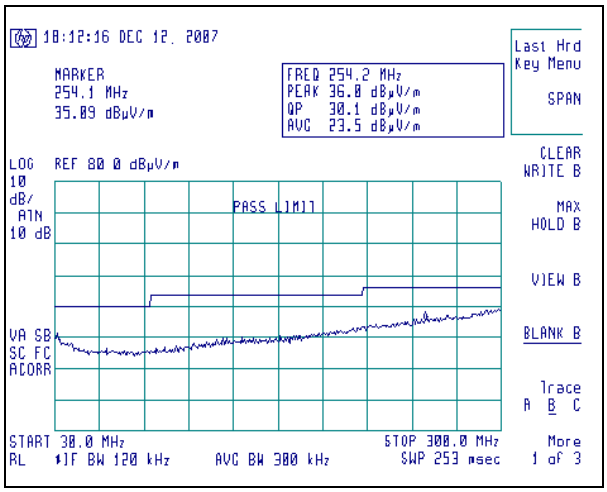
These screen captures represent Peak Emissions. For radiated emission measurements, a Quasi-Peak detector function is utilized when measuring frequencies below 1 GHz, and an Average detector function is utilized when measuring frequencies above 1 GHz.

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

Channel 0, Antenna Vertically Polarized, 30-300 MHz, at 3m

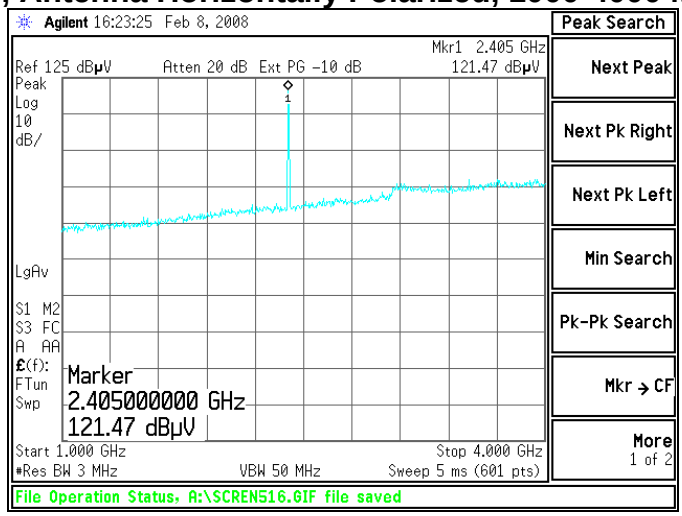


Channel 0, Antenna Vertically Polarized, 300-1000 MHz, at 3m

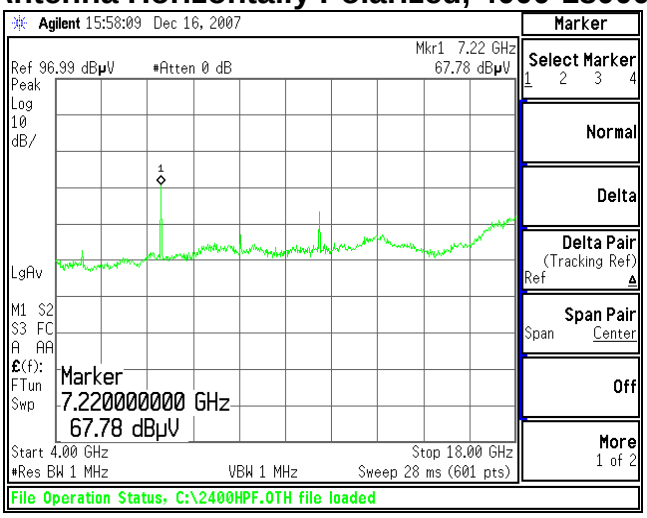


Screen Captures - Radiated Emissions Testing *(continued)*

Channel 0, Antenna Horizontally Polarized, 1000-4000 MHz, at 1m



Channel 0, Antenna Horizontally Polarized, 4000-18000 MHz, at 1m



Screen Captures - Radiated Emissions Testing *(continued)*

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

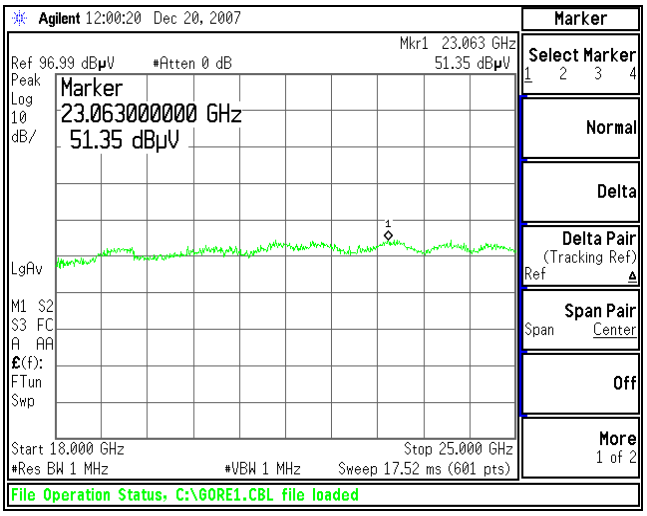


EXHIBIT 6. CONDUCTED EMISSIONS TEST, AC POWER LINE: 15.207

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, 2007, Issue 7). 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 50Ω (ohm), 50/250 μH 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 50Ω (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

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.

6.4 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.			

6.5 *TEST DATA CHART CONDUCTED EMISSION*

Frequency Range inspected: 150 KHz to 30 MHz

Test Standard: FCC 15.207 Class B

Manufacturer:	Crestron V2							
Date(s) of Test:	January 14, 2008							
Test Engineer(s):		Ken Boston	√	Laura Bott		Ryan Urness		Aidi Zainal
Model #:	CWD1016							
Serial #:	N/A							
Voltage:	5 VDC							
Operation Mode:	CW Modulated							
Test Location:		Chamber			√	Other: Shielded Room		
EUT Placed On:		40 cm from vertical ground pla				10 cm spacers		
	√	80 cm above ground plane				Other:		
Measurements:		Pre-Compliance		Preliminary		√	Final	
Detectors Used:		Peak	√	Quasi-Peak		√	Average	

		Quasi-Peak			Average		
Frequency (MHz)	Line	Q-Peak Reading (dBµV/m)	Q-Peak Limit (dBµV/m)	Quasi-Peak Margin (dB)	Average Reading (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)
0.142	L1	57.200	66.455	9.255	27.600	56.455	28.855
0.322	L1	47.400	59.670	12.270	19.200	49.670	30.470
0.359	L1	46.900	58.760	11.860	18.700	48.760	30.060
0.142	L2	54.700	66.455	11.755	27.600	56.455	28.855
0.319	L2	46.800	59.742	12.942	19.800	49.742	29.942
0.357	L2	46.600	58.811	12.211	18.900	48.811	29.911
0.372	L2	46.400	58.458	12.058	19.300	48.458	29.158
0.376	L2	46.000	58.369	12.369	19.300	48.369	29.069

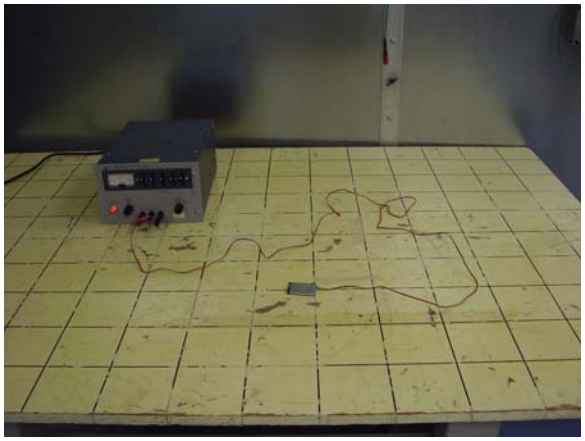
Notes:

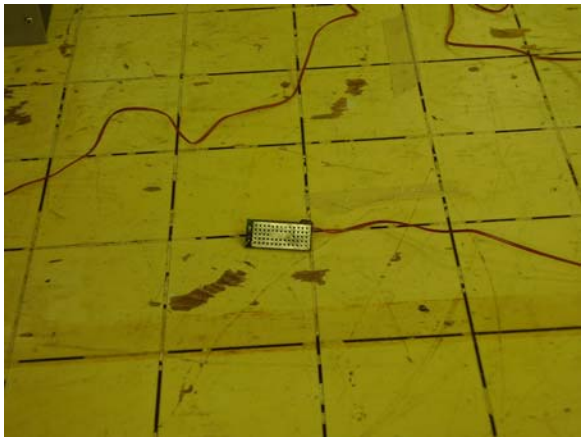
1) The emissions listed are characteristic of the power supply used, and did not change by the EUT.

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.

6.6 Test Setup Photo(s) – Conducted Emissions Test



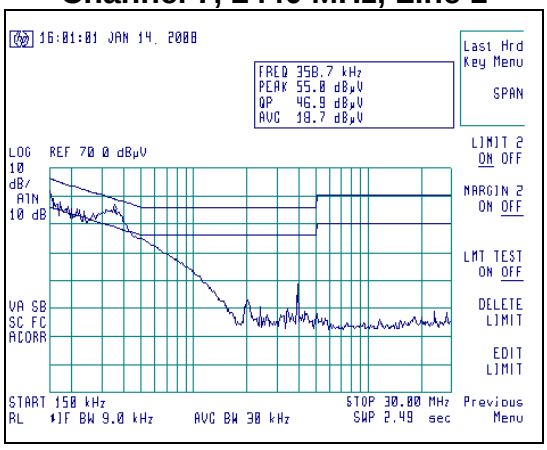


6.7 Screen Captures – Conducted Emissions Test

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.

The signature scans shown here are from channel 7, chosen as a good representative of channels.

Channel 7, 2440 MHz, Line 1



Channel 7, 2440 MHz, Line 2

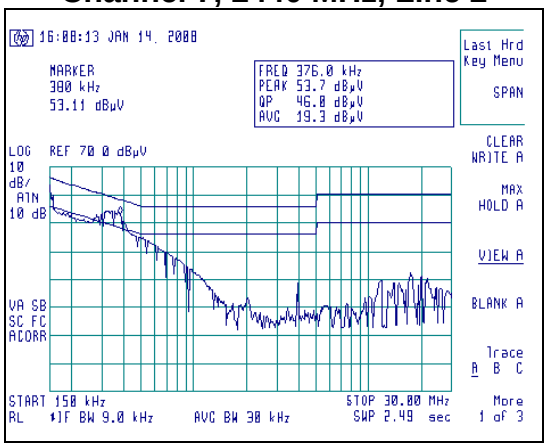


EXHIBIT 7. OCCUPIED BANDWIDTH: 15.247(a)(2)

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 (2003) 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=100 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 E4446A spectrum analyzer. The correction factors for the cable loss were loaded on the analyzer. A Hewlett Packard model E4446A 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. 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 1580 kHz, which is above the minimum of 500 kHz.

7.3 Test Data

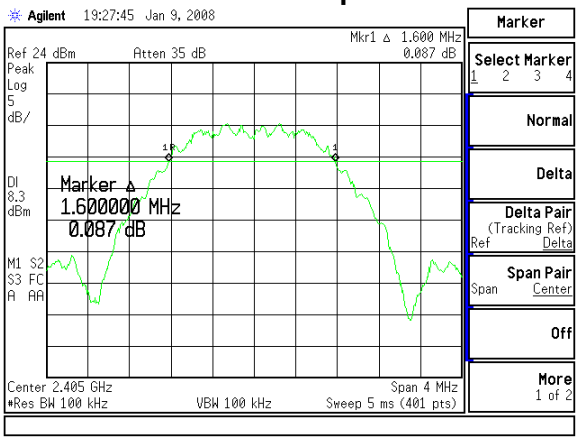
Channel	Center Frequency (MHz)	Measured -6 dBc Occupied Bandwidth (kHz)	Minimum -6 dBc Limit (kHz)	Measured -20 dBc Occupied Bandwidth (kHz)
0	2405	1600	500	2667
7	2440	1600	500	2708
16	2480	1600	500	2680

7.4 Test Equipment List

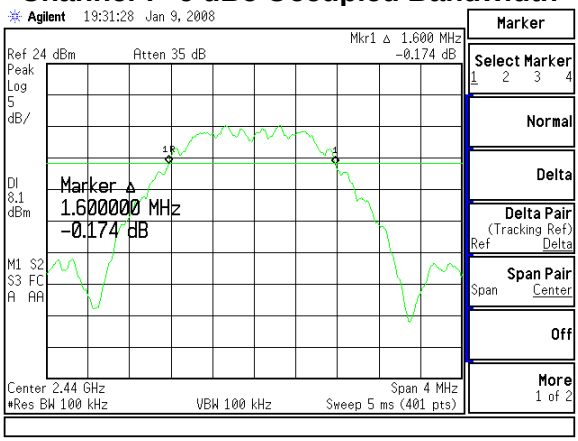
Test Equipment	Manufacturer	Model No.	Serial No.
Spectrum Analyzer	Agilent	E4407B	US39160256
Spectrum Analyzer	Agilent	E4446A	US45300564

7.5 Screen Captures - OCCUPIED BANDWIDTH

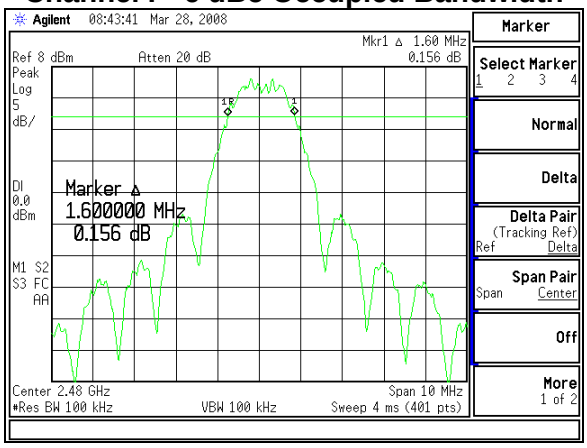
Channel 0 -6 dBc Occupied Bandwidth



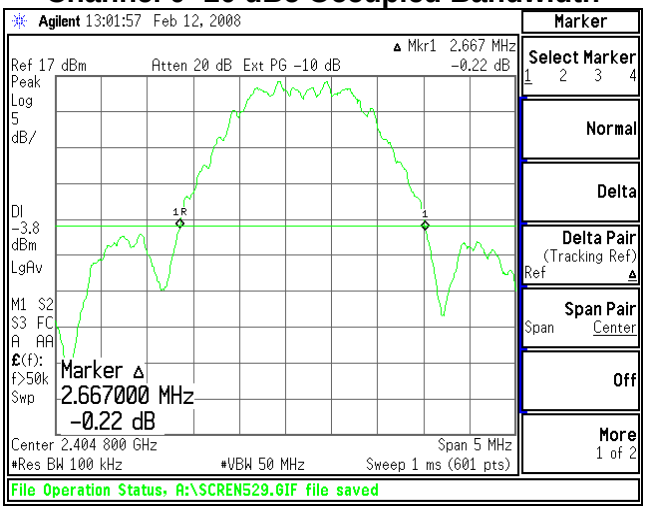
Channel 7 -6 dBc Occupied Bandwidth



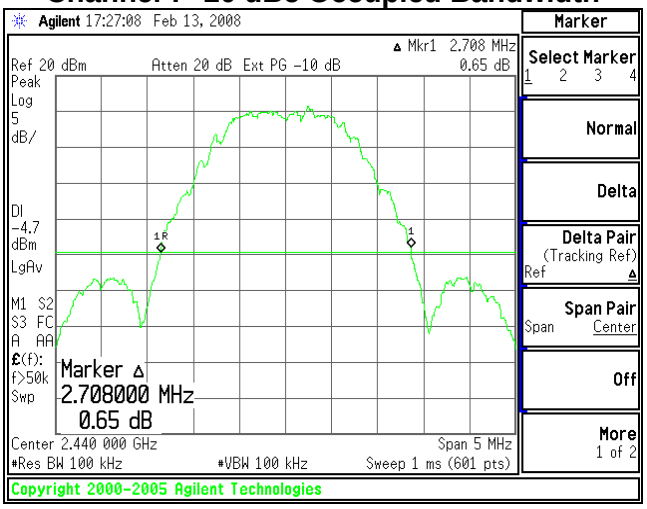
Channel F -6 dBc Occupied Bandwidth



Channel 0 -20 dBc Occupied Bandwidth



Channel 7 -20 dBc Occupied Bandwidth



Channel F -20 dBc Occupied Bandwidth

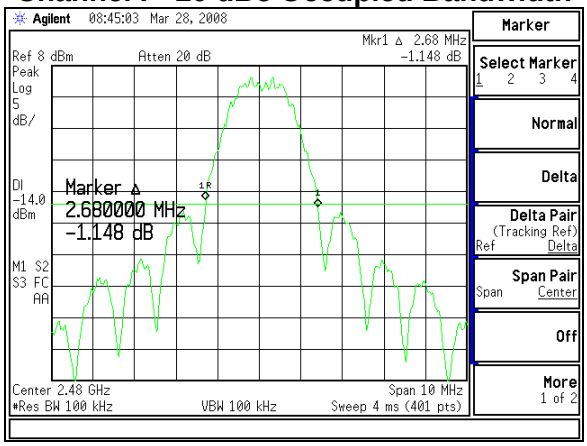


EXHIBIT 8. BAND-EDGE MEASUREMENTS

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.

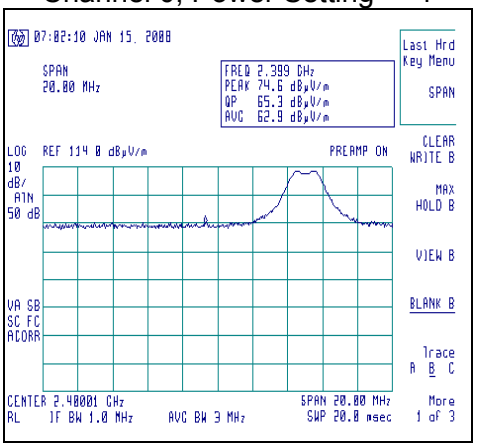
The Lower Band-Edge limit, in this case, would be -20 dBc with respect to the fundamental level.

The Upper Band-Edge limit, in this case, would be + 63.5 dBµV/m at 1m.

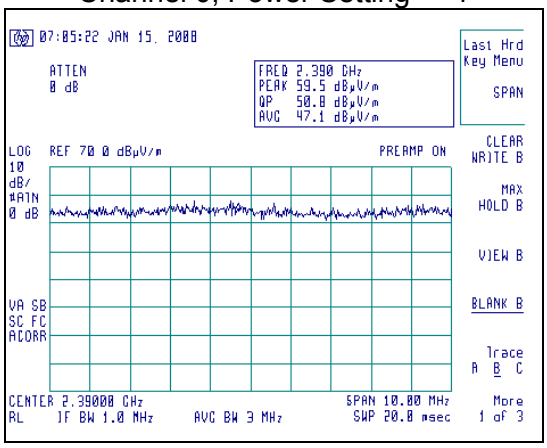
Channel	Power Setting	Frequency (MHz)	Peak (dBµV/m)	Average (dBµV/m)	Average with relaxation	Average Limit (dBµV/m)	Pass/Fail
0	-1	2440	74.6	62.9	--	103.08	Pass
0	-1	2390	59.5	47.1	--	54	Pass
E	-1	2483.5	82.3	72.96	52.96*Note 1	63.5	Pass
F	-10	2483.5	82.85	71.60	51.60*Note 1	63.5	Pass

Note 1: The 20 dB relaxation factor was applied the average readings to obtain the values in the above table.

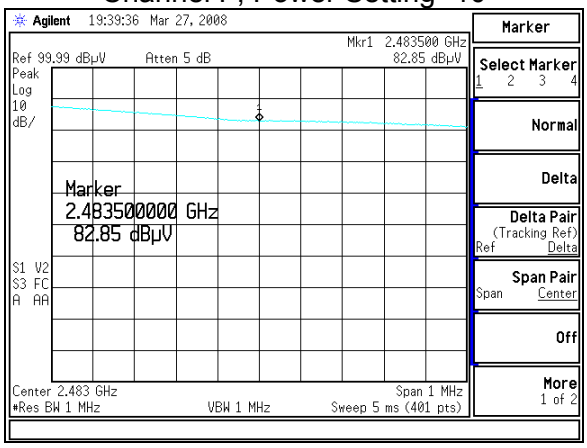
Screen Capture Demonstrating Compliance at the Lower Band-Edge
Channel 0, Power Setting = -1



Screen Capture Demonstrating Compliance at the Lower Band-Edge
Channel 0, Power Setting = -1



Screen Capture Demonstrating Compliance at the Higher Band-Edge
Channel F, Power Setting -10



Screen Capture Demonstrating Compliance at the Higher Band-Edge
Channel E, Power Setting -1

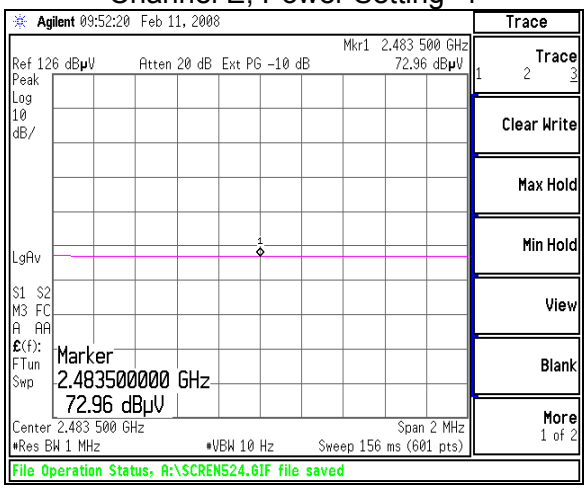


EXHIBIT 9. POWER OUTPUT (CONDUCTED): 15.247(b)

9.1 Method of Measurements

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable for the spectrum analyzer. The loss from the cable was added on the analyzer as gain offset settings, thereby allowing direct measurements without the need for any further corrections. The unit was configured to run in a continuous transmit mode. The spectrum analyzer was used with resolution and video bandwidths set to 1 MHz. Measurements from a peak detector presented in the chart below.

Test Data

Channel	Center Frequency (MHz)	Measured Power (dBm)	Limit (dBm)	Margin (dB)	Calculated EIRP (dBm)	EIRP Limit (dBm)	Calculated EIRP (mW)
0	2405	18.58	30	11.42	19.08	36.0	80.91
7	2440	18.30	30	11.70	18.80	36.0	75.86
F	2480	9.37	30	20.63	9.87	36.0	9.71

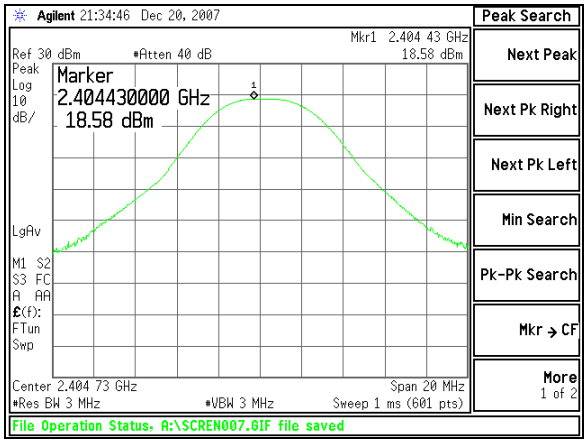
(1) EIRP Calculation:
EIRP = (Peak power at antenna terminal in dBm) + (EUT Antenna gain in dBi)
EIRP (mW) = 10^(EIRP in dBm/10)

9.3 Test Equipment List

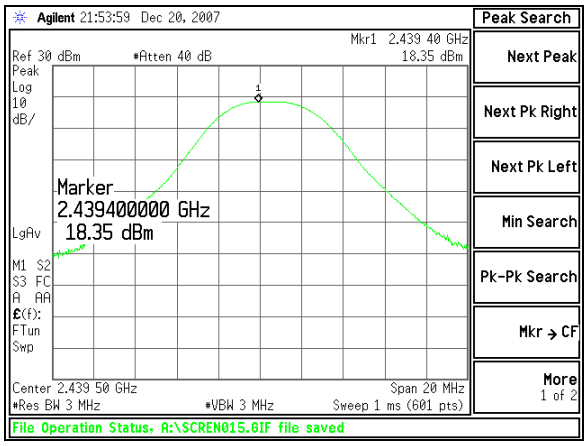
Test Equipment	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer	Agilent	E4446A	US45300564	To 44 GHz

9.4 Screen Captures – Power Output (Conducted)

Channel: 0



Channel: 7



Channel: F

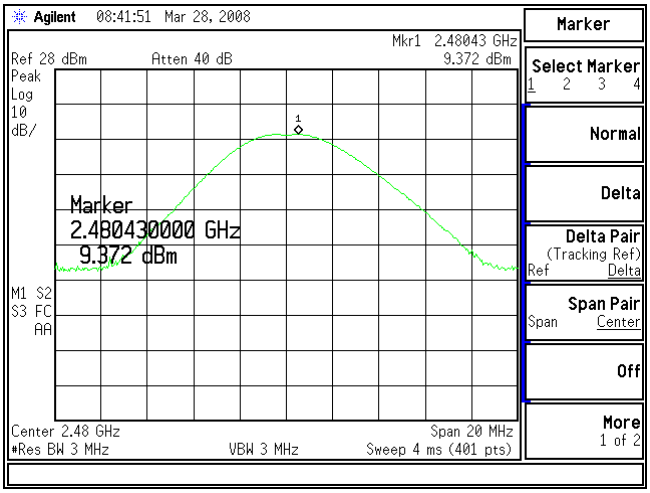


EXHIBIT 10. POWER SPECTRAL DENSITY: 15.247(e)

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 using the utility built into the HP Analyzer. The resultant density was then corrected to a 3 kHz bandwidth. The highest density was found to be no greater than 3.9 dBm, which is under the allowable limit by 4.1 dB.

10.2 Test Equipment List

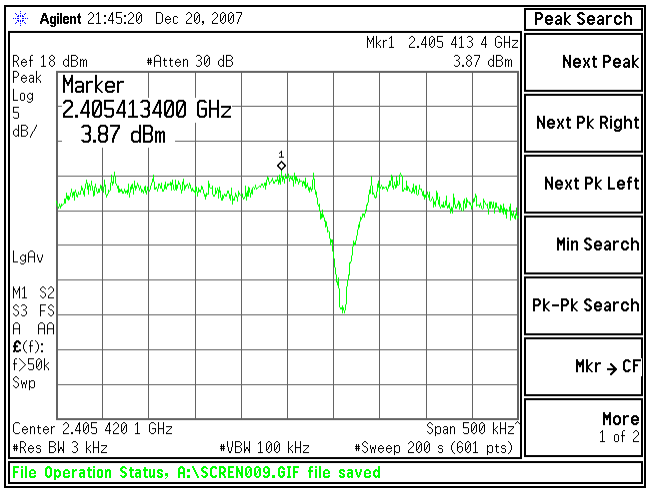
Test Equipment	Manufacturer	Model No.	Serial No.
Spectrum Analyzer	Agilent	E4446A	US45300564

10.3 Test Data

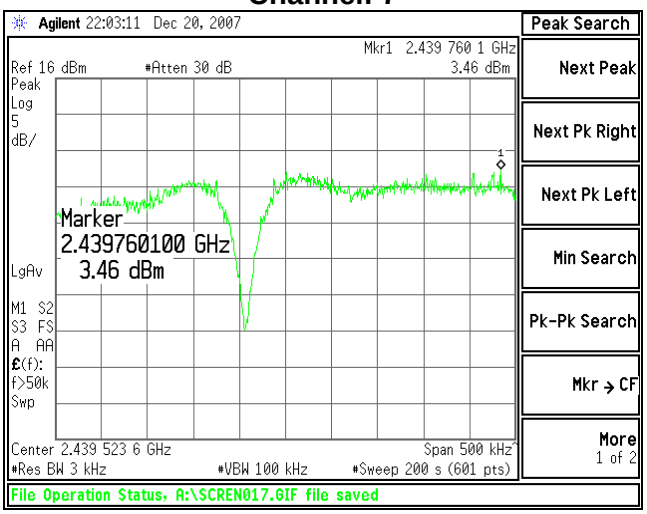
Transmitter Channel	Frequency (MHz)	RF Power Level in 3 kHz BW (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Comments Pass/Fail
0	2405	3.87	8.0	4.13	Pass
7	2440	3.46	8.0	4.54	Pass
15	2480	-4.82	8.0	12.82	Pass

10.4 Screen Captures – Power Spectral Density

Channel: 0



Channel: 7



Channel: F

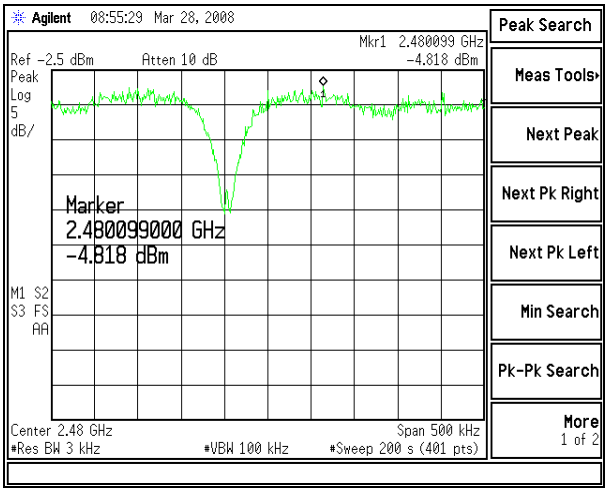


EXHIBIT 11. SPURIOUS CONDUCTED EMISSIONS: 15.247(d)

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 lease 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.

For data from the radiated measurements, please refer to section 5.6 of this report.

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 cable calibration file was loaded into the spectrum analyzer to compensate for the loss of the cable between the antenna port of the EUT to the spectrum analyzer. A Hewlett Packard model E4446A 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. 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 1	Channel 8	Channel 16
	Power in dBm		
Fundamental	14.02	12.69	-5.13
2nd Harmonic	-53.95	-53.48	-76.8
3rd Harmonic	-53.72	-46.53	Note (1)
4th Harmonic	-66.61	-72.38	Note (1)
5th Harmonic	-72.88	Note (1)	Note (1)
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)

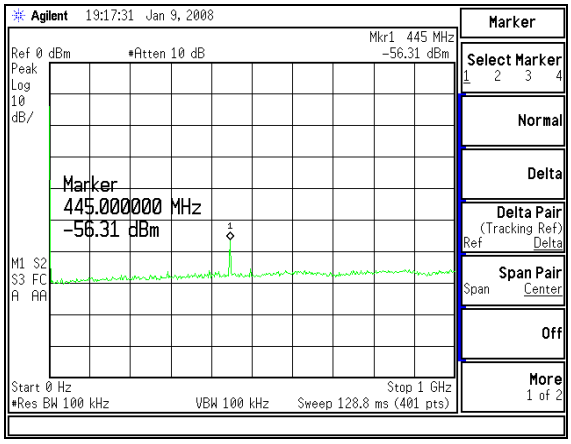
Notes:
(1) Measurement at system noise floor.

11.2 Test Equipment List

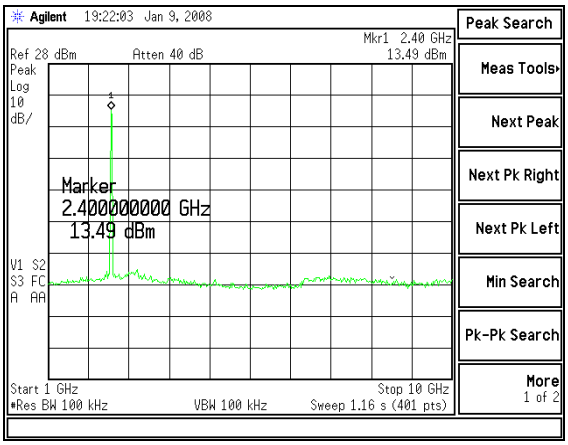
Test Equipment	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer	Agilent	E4446A	US45300564	To 44 GHz

11.3. Below, are representative plots of Conducted Spurious Emissions as measured on Channel 0.

Channel 0: 30MHz – 1000 MHz.



Channel 0: 1 GHz – 10 GHz.



Channel 0: 10 GHz – 25 GHz.

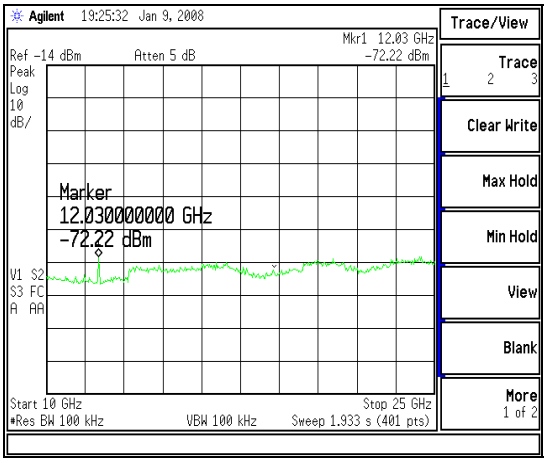


EXHIBIT 12. FREQUENCY & POWER STABILITY OVER VOLTAGE VARIATIONS

The stability of the device was examined as a function of the input voltage available to the EUT. A Spectrum Analyzer was used to measure the frequency at the appropriate frequency markers. The transmitter of the EUT placed in modulated continuous transmit mode. Power was supplied by an external bench-type variable power supply, and the frequency of operation was monitored using the spectrum analyzer.

In this case, the EUT uses a single type operates on a nominal voltage of 5.0 VDC. The test was performed to measure the stability of the frequency and power at ±15% of the nominal operating voltage: 4.25V and 5.75V.

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=10Hz settings while the voltage was varied.

	DC/AC Voltage Source		
	4.25 VDC	5 VDC	5.75 VDC
Channel 0	2404.981100 (MHz)	2404.979500 (MHz)	2404.978500 (MHz)
Channel 7	2439.980150 (MHz)	2439.979650 (MHz)	2439.978800 (MHz)
Channel F	2479.980100 (MHz)	2479.979000 (MHz)	2479.977800 (MHz)

The RF Power Output of the EUT was also monitored in a separate test, also using a Spectrum Analyzer with RBW=VBW=3 MHz setting while the voltage was varied.

	DC/AC Voltage Source		
	4.25 VDC	5 VDC	5.75 VDC
Channel 0	18.47 (dBm)	18.42 (dBm)	18.49 (dBm)
Channel 7	17.94 (dBm)	18.21 (dBm)	18.00 (dBm)
Channel F	0.522 (dBm)	0.475 (dBm)	0.48 (dBm)

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

EXHIBIT 14. MPE CALCULATIONS

The following MPE calculations are based on a 2.4 GHz ceramic chip antenna, with a measured ERP of 123.08 dBµV/m, at 1 meter, and conducted RF power of +18.58 dBm as presented to the antenna. The calculated gain of this antenna, based on the ERP measurements is -0.08 dBi.

Prediction of MPE limit at a given distance

Equation from page 18 of OET Bulletin 65, Edition 97-01

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:	18.58	(dBm)
Maximum peak output power at antenna input terminal:	72.111	(mW)
Antenna gain(typical):	0.5	(dBi)
Maximum antenna gain:	1.122	(numeric)
Prediction distance:	20	(cm)
Prediction frequency:	2400	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	0.6	(mW/cm^2)
Power density at prediction frequency:	0.0161	(mW/cm^2)
Maximum allowable antenna gain:	16.214	(dBi)
Margin of Compliance at 20 cm =	15.714	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	12/04/07	12/04/08
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 ½" 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

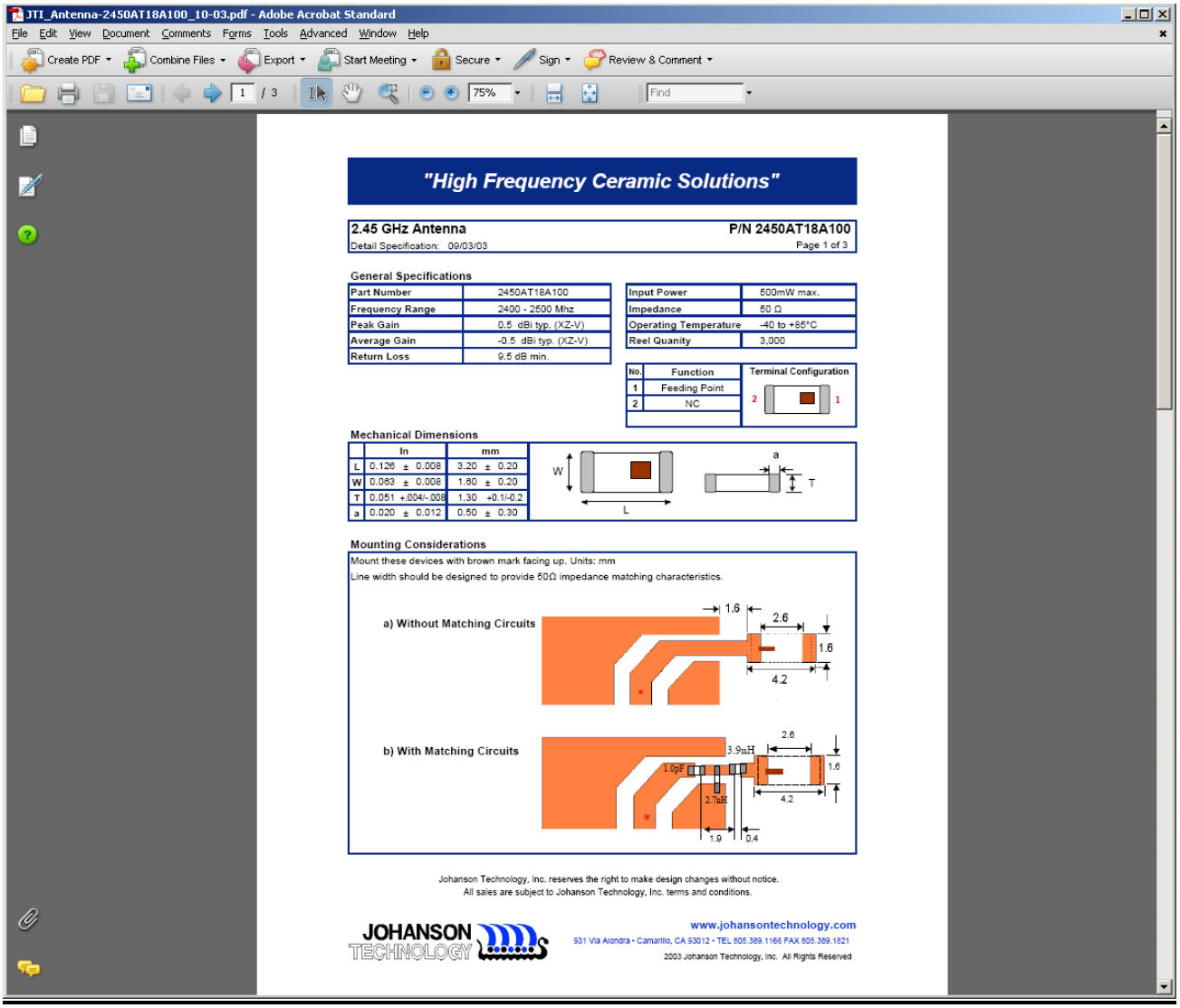
This uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k=2.

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

Appendix B

Antenna Specification(s)



JTI_Antenna-2450AT18A100_10-03.pdf - Adobe Acrobat Standard

"High Frequency Ceramic Solutions"

2.45 GHz Antenna — **P/N 2450AT18A100**

Detail Specification: 09/03/03 — Page 1 of 3

General Specifications

Part Number	2450AT18A100
Frequency Range	2400 - 2500 Mhz
Peak Gain	0.5 dBi typ. (XZ-V)
Average Gain	-0.5 dBi typ. (XZ-V)
Return Loss	9.5 dB min.

Input Power	500mW max.
Impedance	50 Ω
Operating Temperature	-40 to +85°C
Reel Quanity	3,000

No.	Function
1	Feeding Point
2	NC

Terminal Configuration: 2 — 1

Mechanical Dimensions

	In	mm
L	0.126 ± 0.008	3.20 ± 0.20
W	0.063 ± 0.008	1.60 ± 0.20
T	0.051 +.004/-.008	1.30 +0.1/-0.2
a	0.020 ± 0.012	0.50 ± 0.30

Mounting Considerations

Mount these devices with brown mark facing up. Units: mm

Line width should be designed to provide 50Ω impedance matching characteristics.

a) Without Matching Circuits

b) With Matching Circuits

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JOHANSON TECHNOLOGY

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Appendix C

Relaxation Factor Justification

According to the customer, the usage of the RF link is minimal.

The worst case transmit duty cycle is where communication is 2 ms per 0.5 s or 0.4%.

Most battery power mode applications will be a few 2 ms transmissions per day.

Typical operation (in non-battery devices) is 2 ms every 30 s or 0.007%.

In the battery power mode applications, the duty cycle relaxation factor is calculated using the equation:

Relaxation Factor = 20* log (T_{on}/100ms)
=20* log (.004/.100)
= -27.96
Therefore, 20 dB can be applied.

In non-battery devices:

Relaxation Factor = 20* log (T_{on}/100ms)
=20* log (.002/.100)
= -33.98
Therefore, 20 dB may be applied.