

**Nemko-CCL, Inc.**  
1940 West Alexander Street  
Salt Lake City, UT 84119  
801-972-6146

## **Test Report**

Certification

Test Of:

C4-KC120277

FCC ID: R33C4KC

Test Specification:

FCC PART 15, Subpart C

Test Report Serial No: 211341-3.2

Applicant:  
Control4  
11734 S. Election Road, Suite 200  
Draper, UT 84020

Dates of Test: June 13 & 15, 2012 and September 17, 2012

Report Issue Date: September 25, 2012

Accredited Testing Laboratory By:



NVLAP Lab Code 100272-0

## CERTIFICATION OF ENGINEERING REPORT

This report has been prepared by Nemko-CCL, Inc. to document compliance of the device described below with the requirements of Federal Communications Commission (FCC) Part 15, Subpart C. This report may be reproduced in full; partial reproduction may only be made with the written consent of the laboratory. The results in this report apply only to the sample tested.

- Applicant: Control4
- Manufacturer: Control4
- Brand Name: Control4
- Model Number: C4-KC120277
- FCC ID Number: R33C4KC

On this 25<sup>th</sup> day of September 2012, I, individually and for Nemko-CCL, Inc., certify that the statements made in this engineering report are true, complete, and correct to the best of my knowledge, and are made in good faith.

Although NVLAP has recognized that the Nemko-CCL, Inc. EMC testing facilities are in good standing, this report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Nemko-CCL, Inc.



Tested by: Norman P. Hansen  
Test Technician



Reviewed by: Thomas C. Jackson  
General Manager

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## **SECTION 1.0 CLIENT INFORMATION**

### **1.1 Applicant:**

Company Name: Control4  
11734 S. Election Road, Suite 200  
Draper, UT 84020

Contact Name: Roger Midgley  
Title: Sr. Regulatory Compliance Engineer

### **1.2 Manufacturer:**

Company Name: Control4  
11734 S. Election Road, Suite 200  
Draper, UT 84020

Contact Name: Roger Midgley  
Title: Sr. Regulatory Compliance Engineer

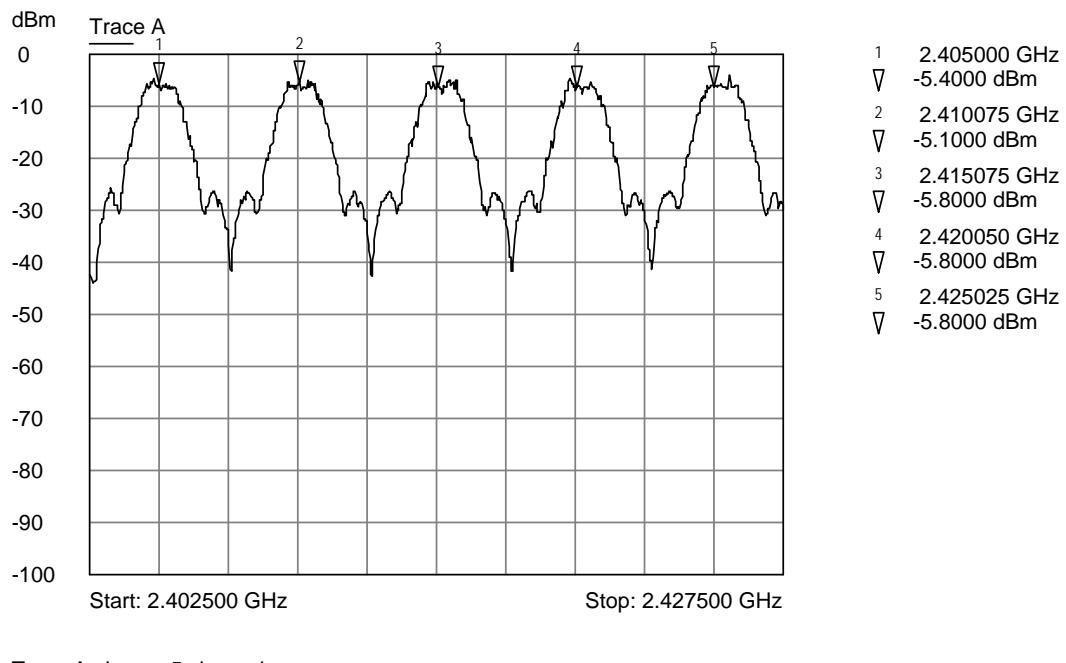
**SECTION 2.0 EQUIPMENT UNDER TEST (EUT)****2.1 Identification of EUT:**

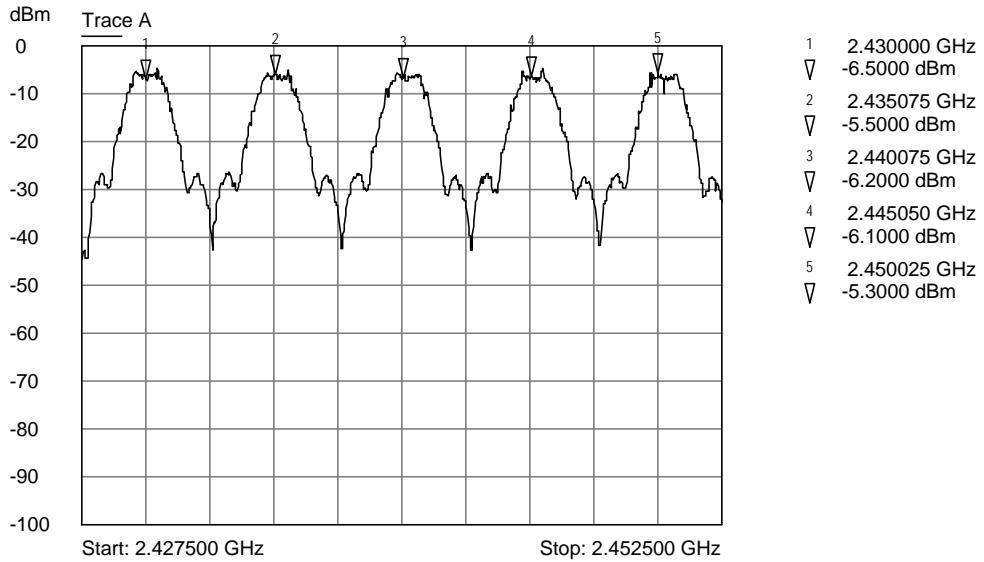
Brand Name: Control4  
Model Number: C4-KC120277  
Serial Number: None  
Dimensions: 4.5 cm x 10.5 cm x 2.9 cm

**2.2 Description of EUT:**

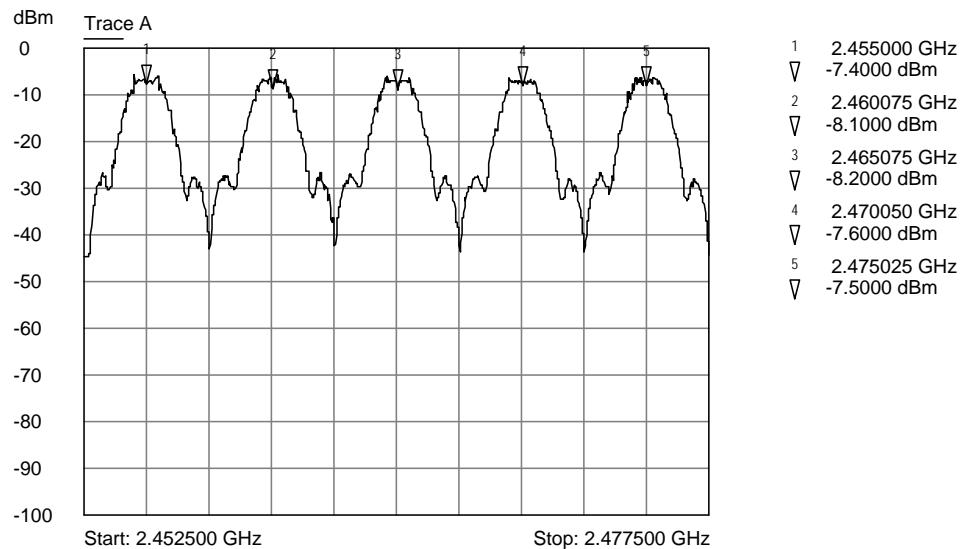
The C4-KC120277 is a programmable keypad for use in Control4 home automation systems. The home control system is interfaced via an 802.15.4 transceiver. The device is powered by the AC mains.

The C4-KC120277 transceiver operates using 15 channels, spaced 5 MHz apart, in the 2400 MHz to 2483.5 MHz frequency band. The C4-KC120277 transceiver uses a trace antenna on the PCB. Testing was performed at the upper channel (2475 MHz), the middle channel (2440 MHz), and the lower channel (2405 MHz). See the plots of the channels below.





Trace A Middle 5 channels



Trace A Upper 5 channels

This report covers the circuitry of the devices subject to FCC Part 15, Subpart C. The circuitry of the device subject to FCC Part 15, Subpart B has been tested and found to comply. See Nemko-CCL report #211341-2.

**2.3 EUT and Support Equipment:**

The EUT and support equipment used during the test are listed below:

Brand Name	FCC ID Number or Compliance	Description	Name of Interface Ports / Interface Cables
BN: Control4 MN: C4-KC120277 (Note 1) SN: None	R33C4KC	Programmable Keypad	See Section 2.4

Note: (1) EUT

**2.4 Interface Ports on EUT:**

Name of Port	No. of Ports Fitted to EUT	Cable Descriptions/Length
AC In	1	3 conductors in power cord/1.3 meters

**2.5 Modification Incorporated/Special Accessories on EUT:**

The following modifications were made to the EUT by the Client during testing to comply with the specification. This report is not complete without an accompanying signed attestation that the product will have all of the documented modifications incorporated into the product when manufactured and placed on the market.

1. The transmit power setting was set at +1.

**SECTION 3.0 TEST SPECIFICATION, METHODS & PROCEDURES****3.1 Test Specification:**

Title: FCC PART 15, Subpart C (47 CFR 15)  
15.203, 15.207, and 15.247

Limits and methods of measurement of radio interference characteristics of radio frequency devices

Purpose of Test: The tests were performed to demonstrate initial compliance

**3.2 Methods & Procedures:****3.2.1 §15.203 Antenna Requirement**

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of Sections 15.211, 15.213, 15.217, 15.219, or 15.221. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with Section 15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this Part are not exceeded.

**3.2.2 §15.207 Conducted Limits**

(a) Except for Class A digital devices, for equipment that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50  $\mu$ H/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the band edges.

Frequency of Emission (MHz)	Conducted Limit (dB $\mu$ V)	
	Quasi-peak	Average
0.15 – 0.5*	66 to 56*	56 to 46*
0.5 – 5	56	46
5 - 30	60	50

\*Decreases with the logarithm of the frequency.

### **3.2.3 §15.247 Operation within the bands 902 – 928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz**

(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400 – 2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

(i) For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

(ii) Frequency hopping systems operating in the 5725-5850 MHz band shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

(iii) Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 non-overlapping channels. The average time of occupancy on any

channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 non-overlapping channels are used.

(2) Systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

(b) The maximum peak output power of the intentional radiator shall not exceed the following:

(1) For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

(2) For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

(3) For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725 – 5850 MHz bands: 1 watt. As an alternative to a peak power measurement, compliance with the Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

(4) The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(c) Operation with directional antenna gains greater than 6 dBi.

(1) Fixed point-to-point operation:

(i) Systems operating in the 2400-2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

(ii) Systems operating in the 5725-5850 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi without any corresponding reduction in transmitter peak output power.

(iii) Fixed, point-to-point operation, as used in paragraphs (b)(4)(i) and (b)(4)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

(2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400-2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:

(i) Different information must be transmitted to each receiver.

(ii) If the transmitter employs an antenna system that emits multiple directional beams but does not emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna /antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:

(A) The directional gain shall be calculated as the sum of  $10 \log$  (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.

(B) A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient

evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.

(iii) If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.

(iv) Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.

(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

(e) For digitally modulated 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. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The digital modulation operation of the hybrid system, with the frequency hopping turned off, shall comply with the power density requirements of paragraph (d) of this section.

(g) Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the

transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

(h) The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.

(i) Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines. See § 1.1307(b)(1) of this Chapter.

Note: Spread spectrum systems are sharing these bands on a noninterference basis with systems supporting critical Government requirements that have been allocated the usage of these bands, secondary only to ISM equipment operated under the provisions of Part 18 of this Chapter. Many of these Government systems are airborne radiolocation systems that emit a high EIRP which can cause interference to other users. Also, investigations of the effect of spread spectrum interference to U. S. Government operations in the 902-928 MHz band may require a future decrease in the power limits allowed for spread spectrum operation.

### **3.3 Test Procedure**

The testing was performed according to the procedures in ANSI C63.4: 2003 and FCC KDB 558074, Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247. Testing was performed at Nemko-CCL, Inc. Wanship open area test site #2, located at 29145 Old Lincoln Highway, Wanship, UT. This site has been registered with the FCC, and was renewed February 15, 2012 (90504). This registration is valid for three years.

Nemko-CCL, Inc. is accredited by National Voluntary Laboratory Accreditation Program (NVLAP); NVLAP Lab Code: 100272-0, which is effective until September 30, 2013.

## **SECTION 4.0 OPERATION OF EUT DURING TESTING**

### **4.1 Operating Environment:**

Power Supply: 120/277 VAC  
AC Mains Frequency: 60 Hz

### **4.2 Operating Modes:**

The transmitter was tested while in a constant transmit mode at the desired frequency, using either the upper, middle, or lower channel. The voltage to the transmitter was varied as required by §15.31(e) with no change seen in the transmitter characteristics.

### **4.3 EUT Exercise Software:**

Control4 software was used to exercise the transmitter.

**SECTION 5.0 SUMMARY OF TEST RESULTS****5.1 FCC Part 15, Subpart C****5.1.1 Summary of Tests:**

Section	Environmental Phenomena	Frequency Range (MHz)	Result
15.203	Antenna Requirements	Structural requirement	Complied
15.207	Conducted Disturbance at Mains Ports	0.15 to 30	Complied
15.247(a)	Bandwidth Requirement	2405 – 2475	Complied
15.247(b)	Peak Output Power	2405 – 2475	Complied
15.247(c)	Operation with Directional Gains Greater than 6 dBi	2400 – 2483.5	Not Applicable
15.247(d)	Spurious Emissions	0.1 – 24750	Complied
15.247(e)	Peak Power Spectral Density	2405 – 2475	Complied
15.247(f)	Hybrid System Requirements	2400 – 2483.5	Not Applicable
15.247(g)	Frequency Hopping Channel Usage	2400 – 2438.5	Not Applicable
15.247(h)	Frequency Hopping Intelligence	2400 – 2483.5	Not Applicable
15.247(i)	RF Energy Exposure	2400 – 2483.5	Complied

**5.2 Result**

In the configuration tested, the EUT complied with the requirements of the specification.

**SECTION 6.0 MEASUREMENTS, EXAMINATIONS AND DERIVED RESULTS****6.1 General Comments:**

This section contains the test results only. Measurements were made following the guidance of FCC KDB 558074, Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247. A list of the test equipment used during the measurements can be found in Appendix 1 of this report.

**6.2 Test Results:****6.2.1 §15.203 Antenna Requirements**

The EUT uses a 1.6 dBi trace antenna on the PCB that is not user replaceable.

**6.2.2 §15.207 Conducted Disturbance at the AC Mains Ports****6.2.2.1 Operating from 120 VAC**

Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dB $\mu$ V)	Limit (dB $\mu$ V)	Margin (dB)
0.16	Hot Lead	Quasi-Peak (Note 2)	55.5	65.5	-10.0
0.16	Hot Lead	Average (Note 2)	40.0	55.5	-15.5
0.18	Hot Lead	Quasi-Peak (Note 2)	53.3	64.5	-11.2
0.18	Hot Lead	Average (Note 2)	38.5	54.5	-16.0
0.24	Hot Lead	Quasi-Peak (Note 2)	50.6	62.0	-11.4
0.24	Hot Lead	Average (Note 2)	31.0	52.0	-21.0
0.32	Hot Lead	Quasi-Peak (Note 2)	47.6	59.8	-12.2
0.32	Hot Lead	Average (Note 2)	31.1	49.8	-18.7
0.44	Hot Lead	Quasi-Peak (Note 2)	49.5	57.1	-7.6
0.44	Hot Lead	Average (Note 2)	35.2	47.1	-11.9
0.52	Hot Lead	Peak (Note 1)	41.1	46.0	-4.9
0.16	Neutral Lead	Quasi-Peak (Note 2)	54.5	65.5	-11.0
0.16	Neutral Lead	Average (Note 2)	32.6	55.5	-22.9

Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dB $\mu$ V)	Limit (dB $\mu$ V)	Margin (dB)
0.19	Neutral Lead	Quasi-Peak (Note 2)	53.2	63.9	-10.7
0.19	Neutral Lead	Average (Note 2)	34.4	53.9	-19.5
0.26	Neutral Lead	Quasi-Peak (Note 2)	50.0	61.4	-6.2
0.26	Neutral Lead	Average (Note 2)	29.4	51.4	-22.0
0.34	Neutral Lead	Quasi-Peak (Note 1)	44.7	49.2	-4.5
0.45	Neutral Lead	Quasi-Peak (Note 2)	49.0	56.9	-7.9
0.45	Neutral Lead	Average (Note 2)	30.9	46.9	-16.0
0.55	Neutral Lead	Peak (Note 1)	41.3	46.0	-4.7

Note 1: The reference detector used for the measurements was Quasi-Peak or Peak and the data was compared to the average limit; therefore, the EUT was deemed to meet both the average and quasi-peak limits.

Note 2: The reference detector used for the measurements was quasi-peak and average and the data was compared to the respective limits.

## RESULT

The EUT complied with the specification by 4.5 dB.

### 6.2.2.2 Operating from 277 VAC

Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dB $\mu$ V)	Limit (dB $\mu$ V)	Margin (dB)
0.21	Hot Lead	Peak (Note 1)	49.6	53.1	-3.5
0.33	Hot Lead	Peak (Note 1)	45.8	49.6	-3.8
0.44	Hot Lead	Quasi-Peak (Note 2)	43.8	57.1	-13.3
0.44	Hot Lead	Average (Note 2)	26.0	47.1	-21.1
0.50	Hot Lead	Peak (Note 1)	38.6	46.0	-7.4
0.61	Hot Lead	Peak (Note 1)	36.0	46.0	-10.0
0.91	Hot Lead	Peak (Note 1)	33.8	46.0	-12.2
0.17	Neutral Lead	Peak (Note 1)	50.6	55.0	-4.4
0.23	Neutral Lead	Peak (Note 1)	48.9	52.5	-3.6

Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dB $\mu$ V)	Limit (dB $\mu$ V)	Margin (dB)
0.27	Neutral Lead	Peak (Note 1)	45.0	51.2	-6.2
0.43	Neutral Lead	Quasi-Peak (Note 2)	43.1	57.2	-14.1
0.43	Neutral Lead	Average (Note 2)	28.0	47.2	-19.2
0.60	Neutral Lead	Peak (Note 1)	35.4	46.0	-10.6
0.88	Neutral Lead	Peak (Note 1)	36.4	46.0	-9.6

Note 1: The reference detector used for the measurements was Quasi-Peak or Peak and the data was compared to the average limit; therefore, the EUT was deemed to meet both the average and quasi-peak limits.

Note 2: The reference detector used for the measurements was quasi-peak and average and the data was compared to the respective limits.

## RESULT

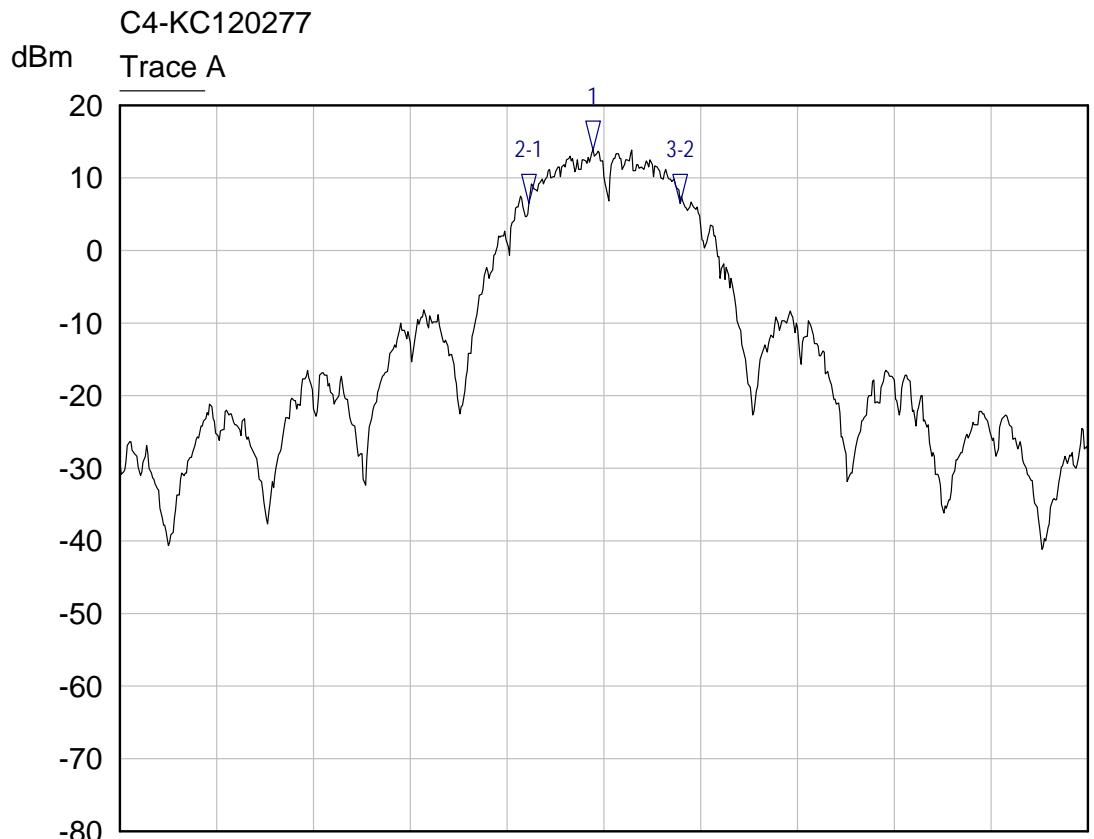
The EUT complied with the specification by 3.5 dB.

### 6.2.3 §15.247(a)(2) Emission Bandwidth

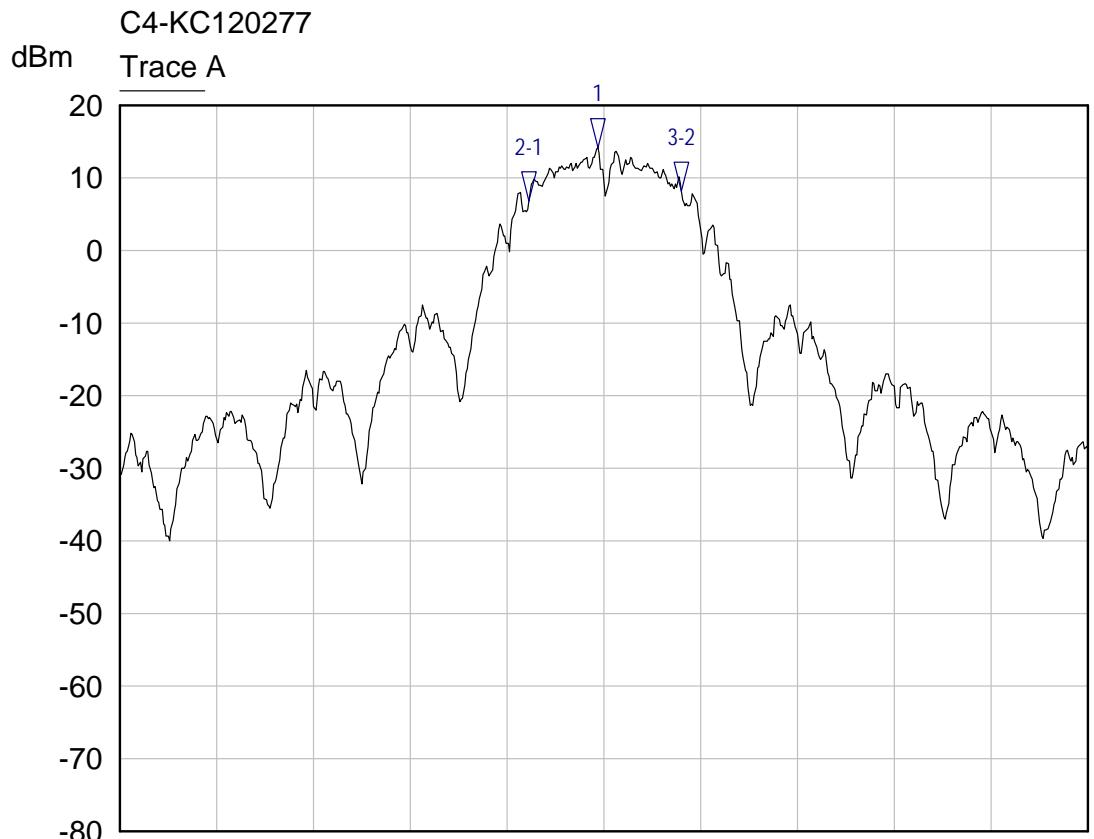
Frequency (MHz)	Emission 6 dB Bandwidth (kHz)
2405	1554.5
2440	1570.5
2475	1538.5

## RESULT

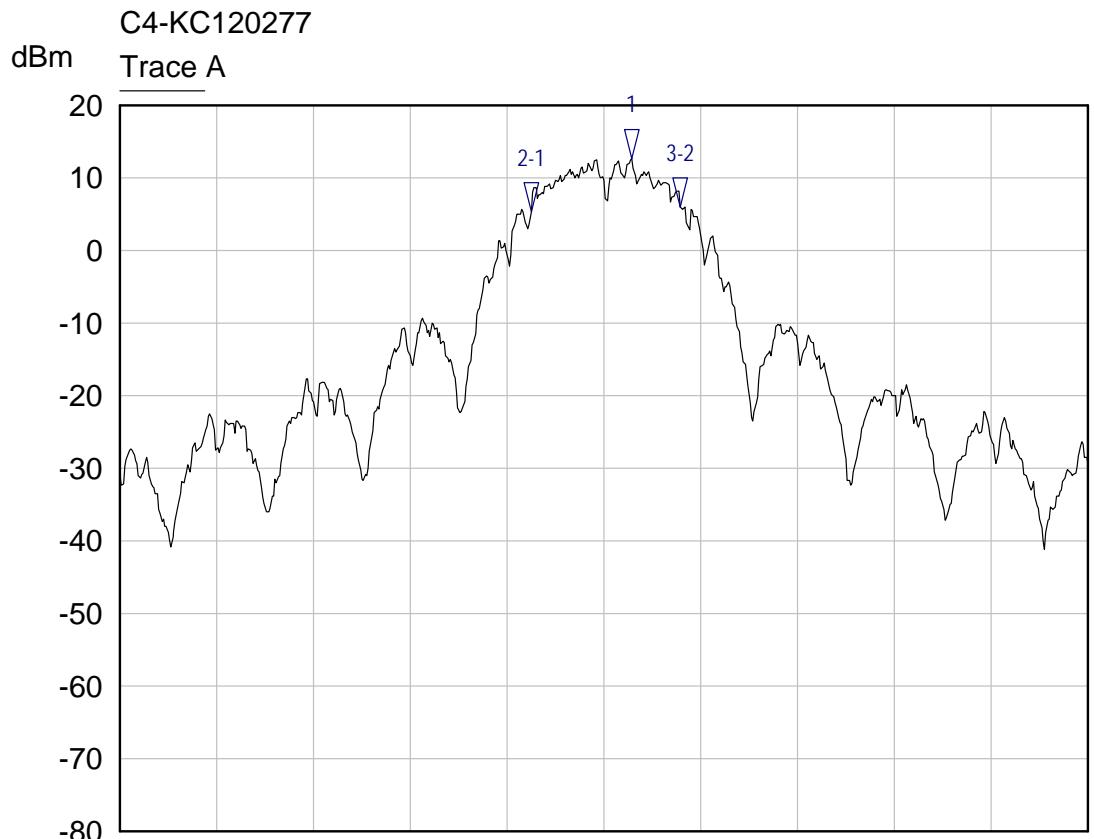
In the configuration tested, the 6 dB bandwidth was greater than 500 kHz; therefore, the EUT complied with the requirements of the specification (see spectrum analyzer plots below).



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4049 GHz	13.89 dBm	
2-1 ▽	Trace A	-657.0513 kHz	-7.31 dB	
3-2 ▽	Trace A	1.5545 MHz	-0.13 dB	



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4399 GHz	14.22 dBm	
2-1▽	Trace A	-705.1282 kHz	-7.31 dB	
3-2▽	Trace A	1.5705 MHz	1.18 dB	



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4753 GHz	12.71 dBm	
2-1 ▽	Trace A	-1.0417 MHz	-7.43 dB	
3-2 ▽	Trace A	1.5385 MHz	0.77 dB	

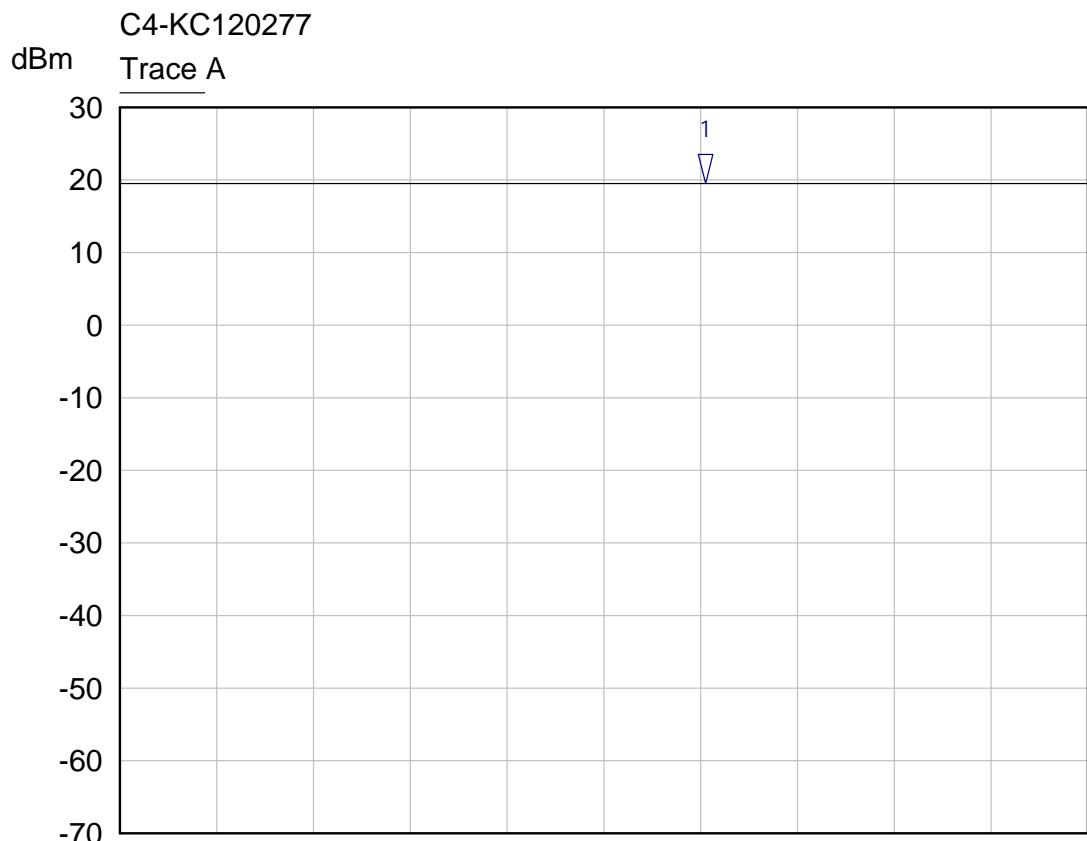
**6.2.4 §15.247(b)(3) Peak Output Power**

The maximum peak RF Conducted output power measured for this device was 88.51 mW or 19.47 dBm. The limit is 30 dBm or 1 Watt when using antennas with 6 dBi or less gain. The antenna has a gain of 1.16 dBi.

Frequency (MHz)	Measured Output Power (dBm)	Measured Output Power (mW)
2405	19.47	88.51
2440	18.74	74.82
2475	17.70	58.88

**RESULT**

In the configuration tested, the RF peak output power was less than 1 Watt; therefore, the EUT complied with the requirements of the specification (see spectrum analyzer plots below).



Start: 0 s

Stop: 5.0000 ms

Res BW: 3 MHz

Vid BW: 10 MHz

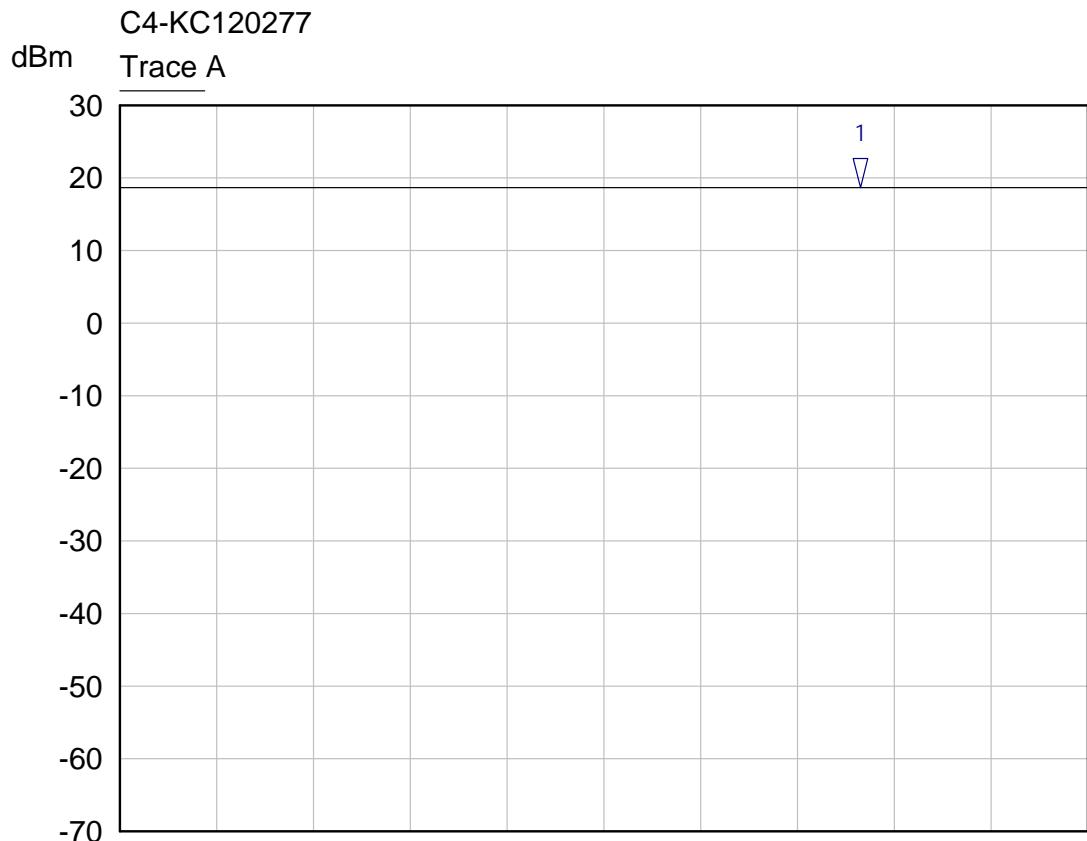
Sweep: 5.00 ms

6/15/2012 10:06:12 AM

CF: 2.404340 GHz

ESU-40

Mkr	Trace	X-Axis	Value	Notes
1	Trace A	3.0250 ms	19.47 dBm	



Start: 0 s

Stop: 5.0000 ms

Res BW: 3 MHz

Vid BW: 10 MHz

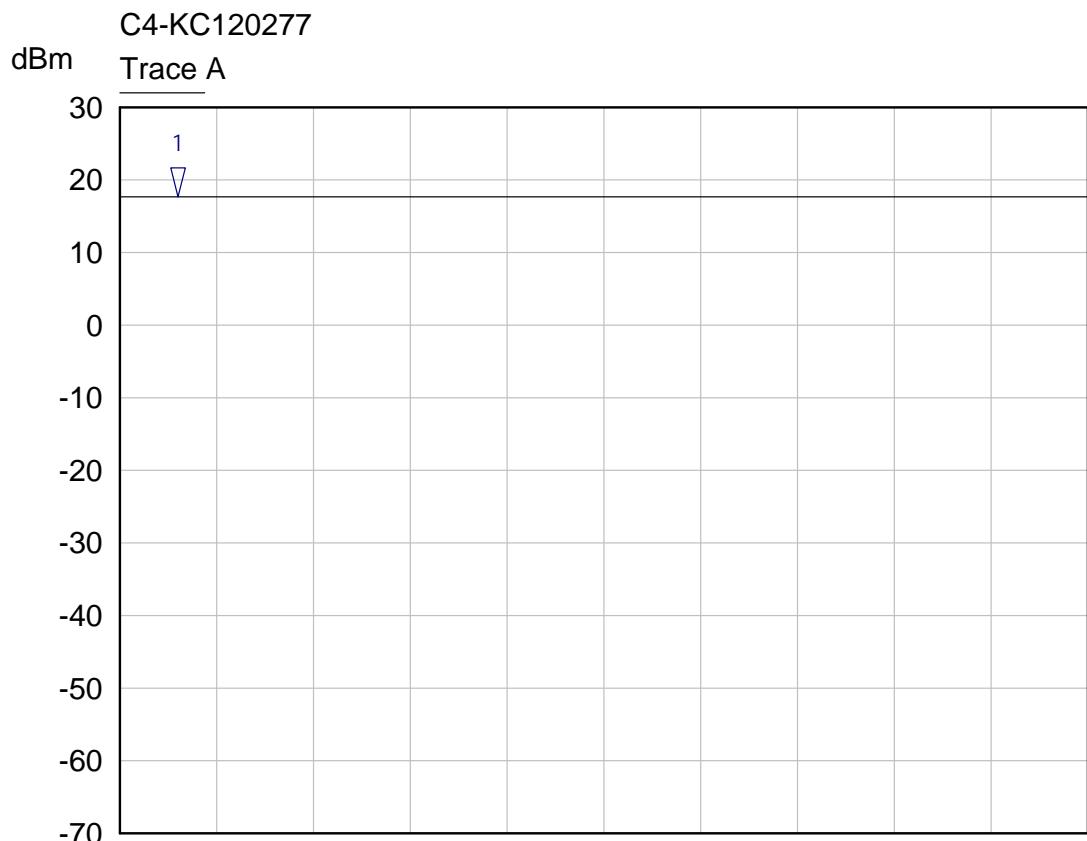
Sweep: 5.00 ms

6/15/2012 10:25:14 AM

CF: 2.440000 GHz

ESU-40

Mkr	Trace	X-Axis	Value	Notes
1 V	Trace A	3.8250 ms	18.74 dBm	



Start: 0 s

Stop: 5.0000 ms

Res BW: 3 MHz

Vid BW: 10 MHz

Sweep: 5.00 ms

6/15/2012 10:37:17 AM

CF: 2.474330 GHz

ESU-40

Mkr	Trace	X-Axis	Value	Notes
1	Trace A	300.0000 us	17.70 dBm	

**6.2.5 §15.247(d) Spurious Emissions****6.2.5.1 Conducted Spurious Emissions**

The frequency range from the lowest frequency used in the device to the tenth harmonic of the highest fundamental frequency was investigated to measure any antenna-conducted emissions. The tables show the measurement data from spurious emissions noted across the frequency range when transmitting at the lowest frequency, middle frequency, and upper frequency. Shown after the tables, are band edge plots with the EUT tuned to the upper and lower channels. These demonstrate compliance with the provisions of this section at the band edges.

The emissions must be attenuated 20 dB below the highest power level measured within the authorized band as measured with a 100 kHz RBW; the highest level measured was 16.9 dBm; therefore, the criteria is  $16.9 - 20.0 = -3.1$  dBm.

**RESULT**

Conducted spurious emissions were attenuated 20 dB or more from the fundamental; therefore, the EUT complies with the specification.

**Transmitting on the Lowest Channel (2.405 GHz)**

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)
4810.0	-51.9	-3.1
7215.0	-49.8	-3.1
9620.0	-62.7	-3.1
12025.0	-55.7	-3.1
14430.0	-65.1	-3.1
16835.0	-64.0	-3.1
19240.0	-62.5	-3.1
21645.0	-63.5	-3.1
24050.0	-62.3	-3.1

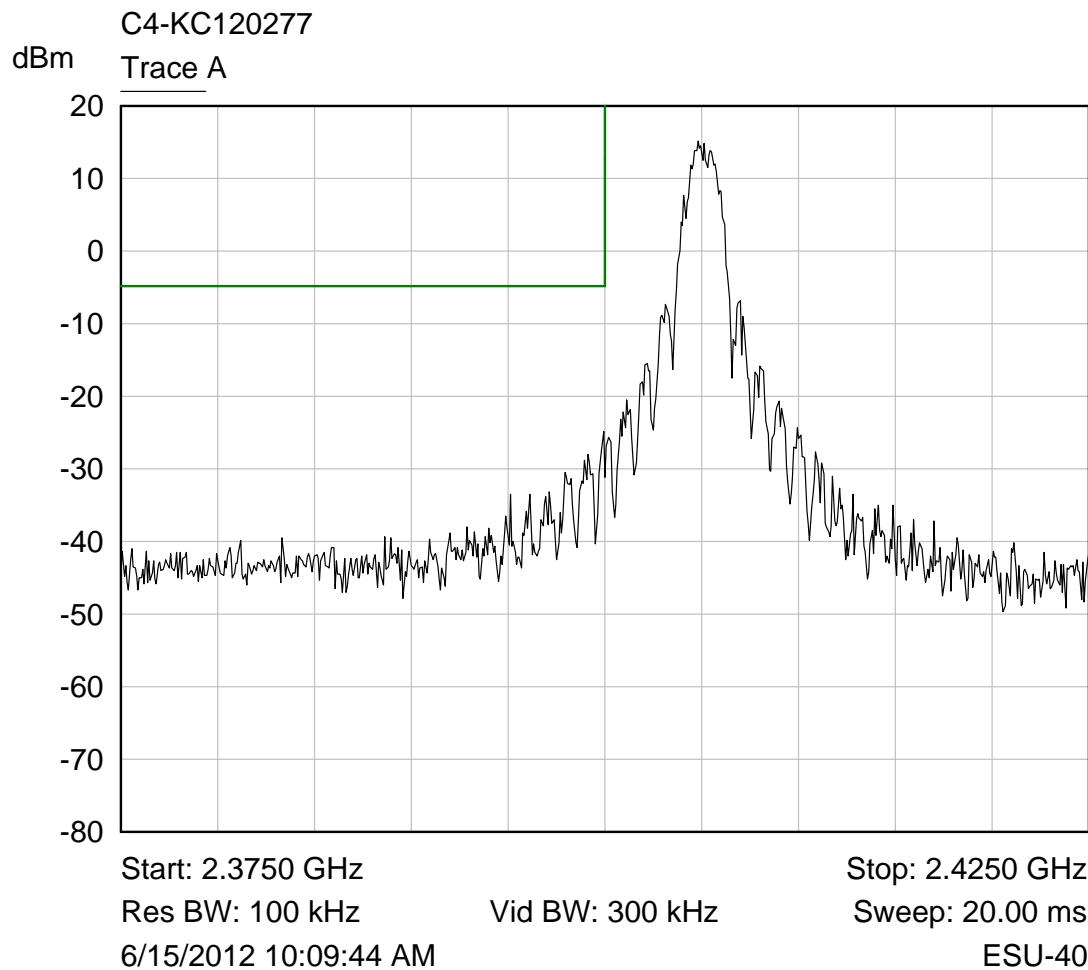
## Transmitting on the Middle Channel (2.440 GHz)

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)
4880.0	-48.6	-3.1
7320.0	-49.9	-3.1
9760.0	-66.0	-3.1
12200.0	-54.3	-3.1
14640.0	-65.8	-3.1
17080.0	-64.8	-3.1
19520.0	-64.5	-3.1
21960.0	-64.7	-3.1
24400.0	-63.2	-3.1

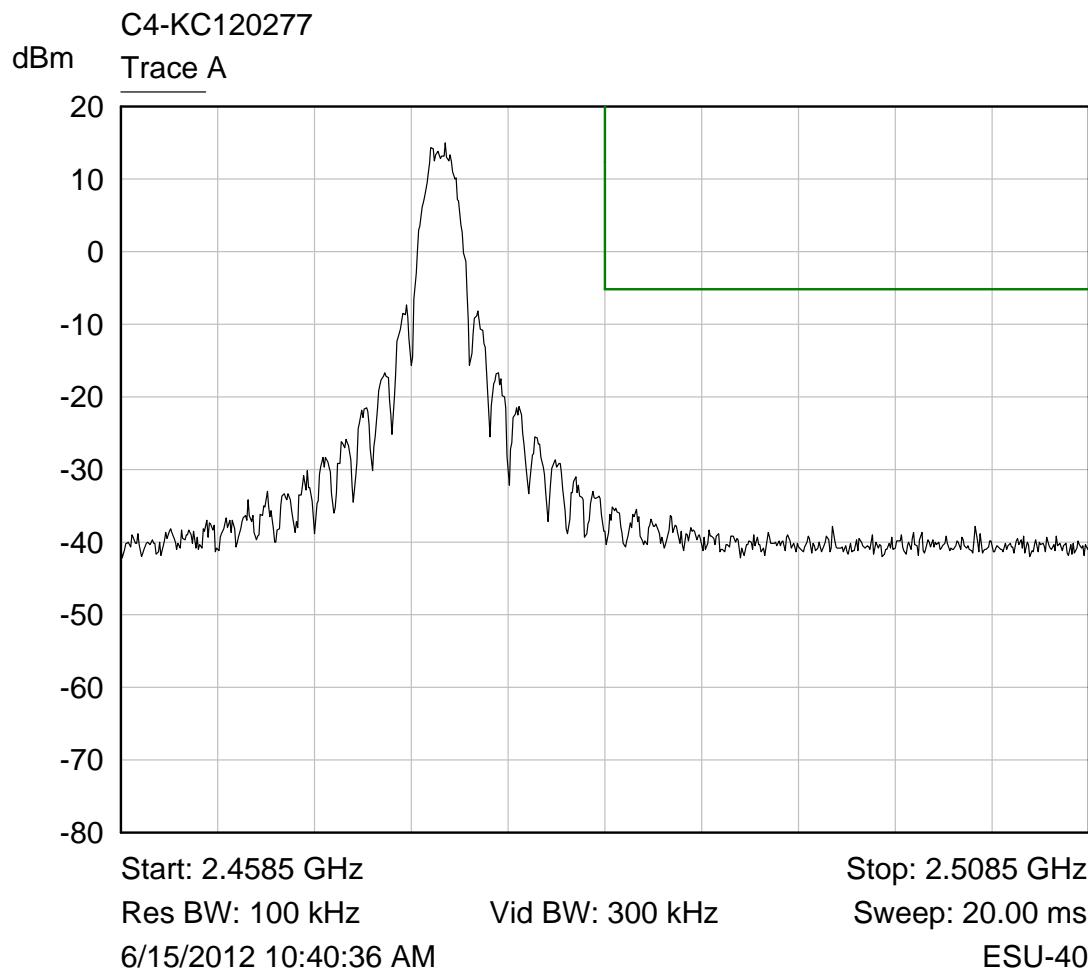
## Transmitting on the Highest Channel (2.475 GHz)

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)
4950.0	-54.1	-3.1
7425.0	-51.9	-3.1
9900.0	-67.4	-3.1
12375.0	-57.2	-3.1
14850.0	-65.1	-3.1
17325.0	-64.1	-3.1
19800.0	-62.9	-3.1
22275.0	-64.1	-3.1
24750.0	-61.6	-3.1

## Lower Band Edge Plot



## Upper Band Edge



### **6.2.5.2 Radiated Emissions**

The frequency range from the lowest frequency used in the device to the tenth harmonic of the highest fundamental frequency was investigated to measure any radiated emissions in the restricted bands. The following tables show measurements of any emission that fell into the restricted bands of §15.205. The tables show the worst-case emission measured from the EUT. For frequencies above 12.5 GHz, a measurement distance of 1 meter was used. The noise floor was a minimum of 6 dB below the limit. The emissions in the restricted bands must meet the limits specified in §15.209. Tabular data for each of the spurious emissions is shown below for each of the units. Plots of the band edges are also shown.

#### **Average Factor**

The EUT operates at a maximum duty cycle of 42.06% when using the EmberZNet protocol. A correction factor of -7.5 dB will be applied to the average detection measurements. For details of the duty cycle calculation, see Appendix 3.

#### **RESULT**

All emissions in the restricted bands of §15.205 met the limits specified in §15.209; therefore, the EUT complies with the specification.

##### **Transmitting at the Lowest Frequency (2405 MHz)**

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
4810.0	Peak	Vertical	24.7	37.7	0.0	62.4	74.0	-11.6
4810.0	Average	Vertical	17.9	37.7	-7.5	48.1	54.0	-5.9
4810.0	Peak	Horizontal	18.8	37.7	0.0	56.5	74.0	-17.5
4810.0	Average	Horizontal	11.6	37.7	-7.5	41.8	54.0	-12.2
7215.0	Peak	Vertical	24.9	42.1	0.0	67.0	74.0	-7.0
7215.0	Average	Vertical	17.7	42.1	-7.5	52.3	54.0	-1.7
7215.0	Peak	Horizontal	23.1	42.1	0.0	65.2	74.0	-8.8
7215.0	Average	Horizontal	15.4	42.1	-7.5	50.0	54.0	-4.0
12025.0	Peak	Vertical	12.5	47.2	0.0	59.7	74.0	-14.3
12025.0	Average	Vertical	0.9	47.2	-7.5	40.6	54.0	-13.4

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
12025.0	Peak	Horizontal	12.8	47.2	0.0	60.0	74.0	-14.0
12025.0	Average	Horizontal	0.0	47.2	-7.5	39.7	54.0	-14.3
14430.0	Average	Horizontal	11.7	50.8	0.0	55.0	74.0	-19.0
14430.0	Average	Horizontal	-0.7	50.8	-7.5	42.6	54.0	-11.4
14430.0	Average	Horizontal	11.8	50.8	0.0	62.6	74.0	-11.4
14430.0	Average	Horizontal	-0.7	50.8	-7.5	42.6	54.0	-11.4

Transmitting at the Middle Frequency (2440 MHz)

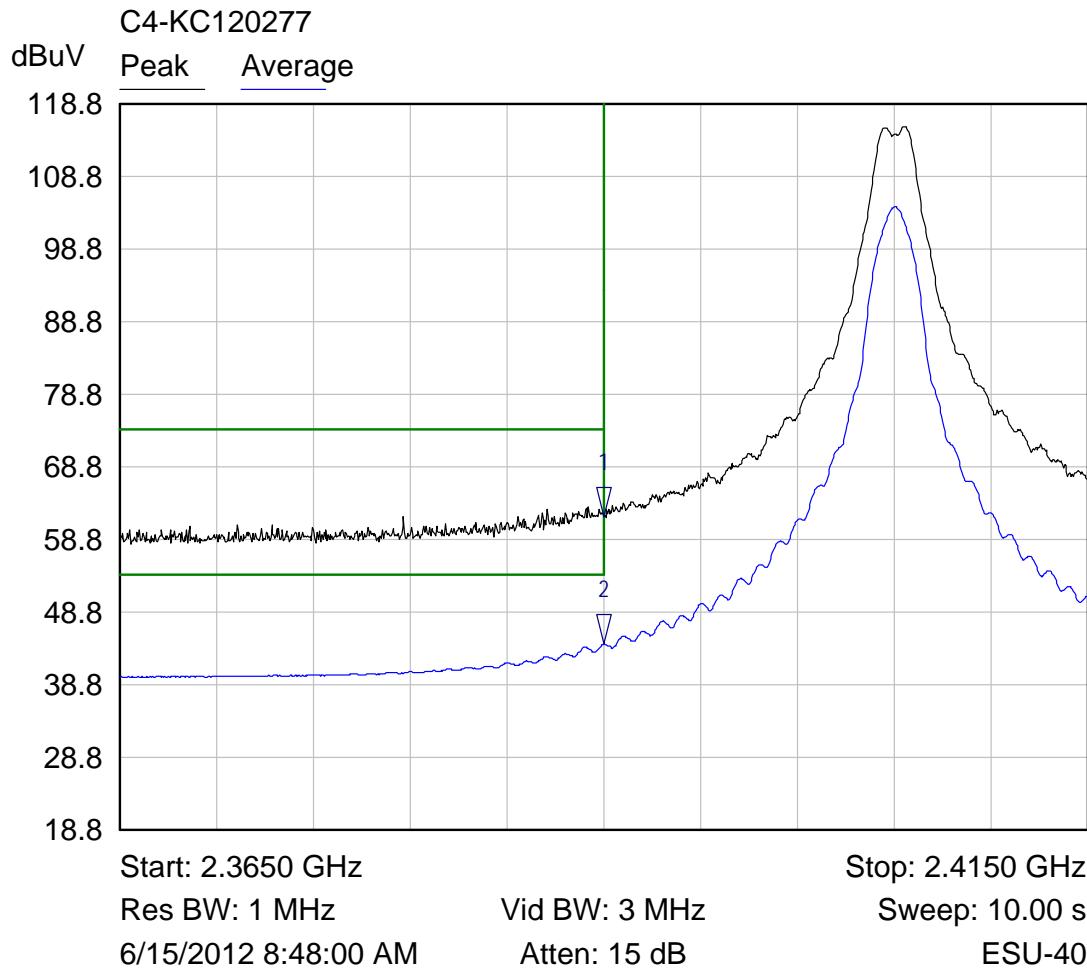
Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
4880.0	Peak	Vertical	21.4	37.9	0.0	59.3	74.0	-14.7
4880.0	Average	Vertical	15.2	37.9	-7.5	45.6	54.0	-8.4
4880.0	Peak	Horizontal	18.1	37.9	0.0	56.0	74.0	-18.0
4880.0	Average	Horizontal	10.7	37.9	-7.5	41.1	54.0	-12.9
7320.0	Peak	Vertical	18.9	42.3	0.0	61.2	74.0	-12.8
7320.0	Average	Vertical	10.4	42.3	-7.5	45.2	54.0	-8.8
7320.0	Peak	Horizontal	18.8	42.3	0.0	61.1	74.0	-12.9
7320.0	Average	Horizontal	10.8	42.3	-7.5	45.6	54.0	-8.4
12200.0	Peak	Vertical	12.2	47.1	0.0	59.3	74.0	-14.7
12200.0	Average	Vertical	-0.5	47.1	-7.5	39.1	54.0	-14.9
12200.0	Peak	Horizontal	12.2	47.1	0.0	59.3	74.0	-14.7
12200.0	Average	Horizontal	-0.6	47.1	-7.5	39.0	54.0	-15.0
14640.0	Average	Horizontal	12.6	50.5	0.0	55.6	74.0	-18.4
14640.0	Average	Horizontal	-0.2	50.5	-7.5	42.8	54.0	-11.2
14640.0	Average	Horizontal	11.8	50.5	0.0	62.3	74.0	-11.7
14640.0	Average	Horizontal	-0.3	50.5	-7.5	42.7	54.0	-11.3

## Transmitting at the Highest Frequency (2475 MHz)

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dB $\mu$ V)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)
4950.0	Peak	Vertical	24.6	38.0	0.0	58.6	74.0	-15.4
4950.0	Average	Vertical	15.8	38.0	-7.5	44.9	54.0	-9.1
4950.0	Peak	Horizontal	21.3	38.0	0.0	60.6	74.0	-13.4
4950.0	Average	Horizontal	14.1	38.0	-7.5	46.9	54.0	-7.1
7425.0	Peak	Vertical	17.5	42.6	0.0	57.5	74.0	-16.5
7425.0	Average	Vertical	9.6	42.6	-7.5	42.5	54.0	-11.5
7425.0	Peak	Horizontal	16.0	42.6	0.0	58.4	74.0	-15.6
7425.0	Average	Horizontal	7.3	42.6	-7.5	43.6	54.0	-10.4
12375.0	Peak	Vertical	11.6	47.0	0.0	48.6	74.0	-25.4
12375.0	Average	Vertical	0.0	47.0	-7.5	30.6	54.0	-23.4
12375.0	Peak	Horizontal	12.3	47.0	0.0	49.7	74.0	-24.3
12375.0	Average	Horizontal	0.0	47.0	-7.5	32.2	54.0	-21.8
14850.0	Peak	Vertical	12.3	49.8	0.0	54.6	74.0	-19.4
14850.0	Average	Vertical	-0.4	49.8	-7.5	41.9	54.0	-12.1
14850.0	Peak	Horizontal	12.2	49.8	0.0	62.0	74.0	-12.0
14850.0	Average	Horizontal	1.8	49.8	-7.5	44.1	54.0	-9.9

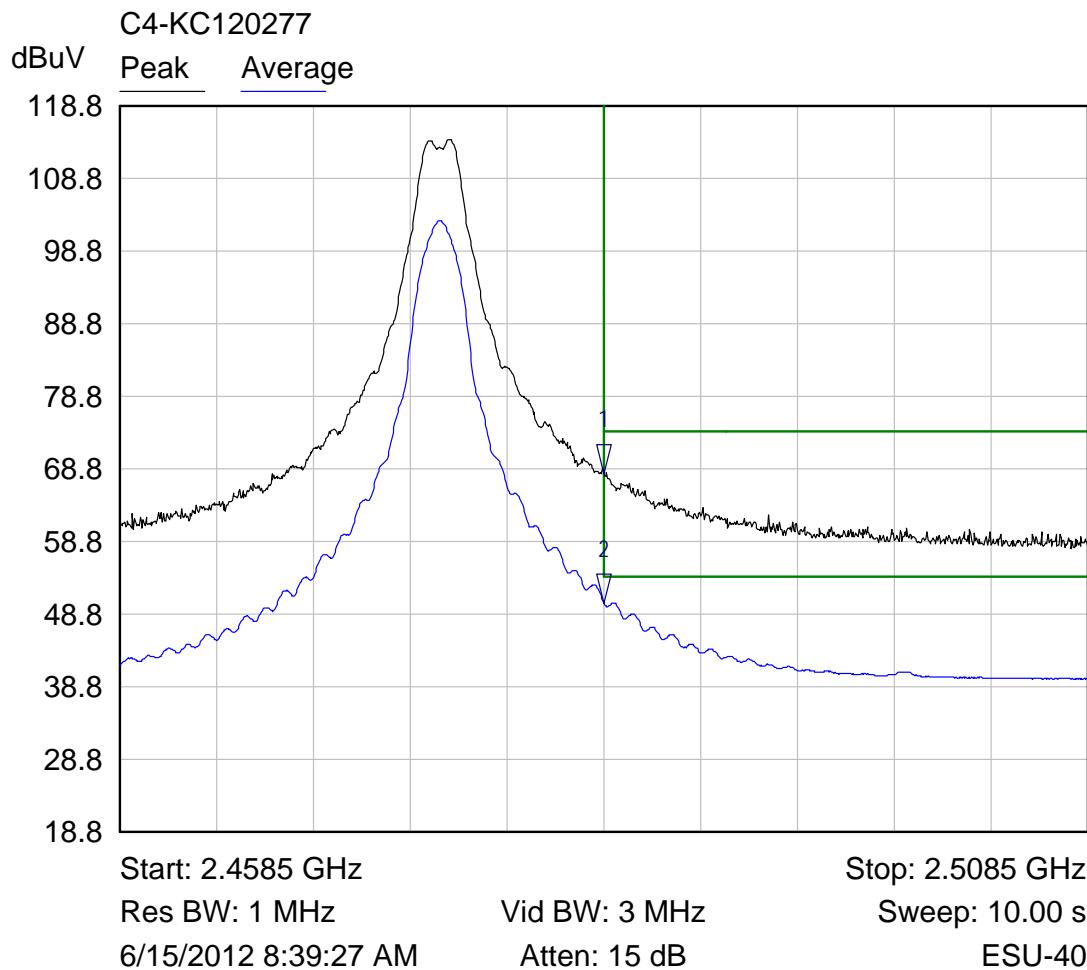
No other emissions in the restricted bands were seen above the noise floor. Noise floor was greater than 6 dB below the limit. At frequencies above 12.5 GHz, a 1 meter measurement distance was used.

## Lower Band Edge Plot



Mkr	Trace	X-Axis	Value	Notes
1	Peak	2.3900 GHz	61.99 dBuV	
2	Average	2.3900 GHz	44.41 dBuV	

## Upper Band Edge Plot



Mkr	Trace	X-Axis	Value	Notes
1	Peak	2.4835 GHz	68.21 dBuV	
2	Average	2.4835 GHz	50.28 dBuV	

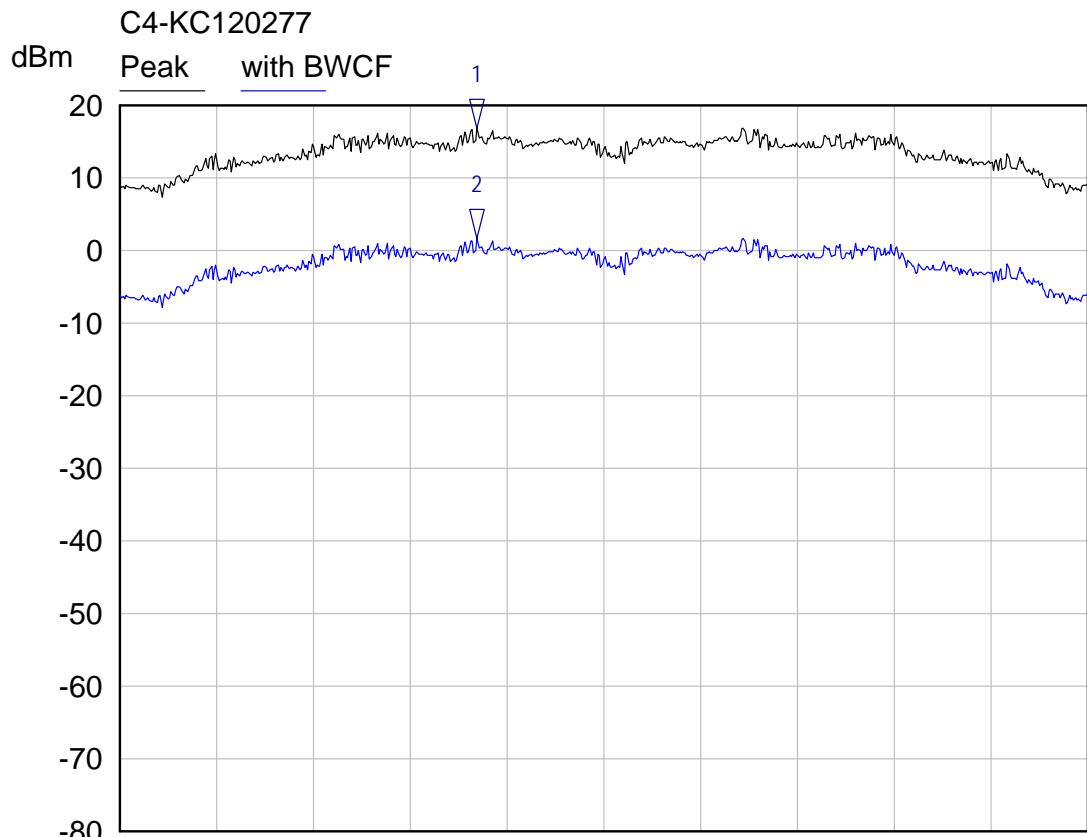
**6.2.6 §15.247(e) Peak Power Spectral Density**

The peak 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. The plots are shown below and the results of this testing are summarized in the table below.

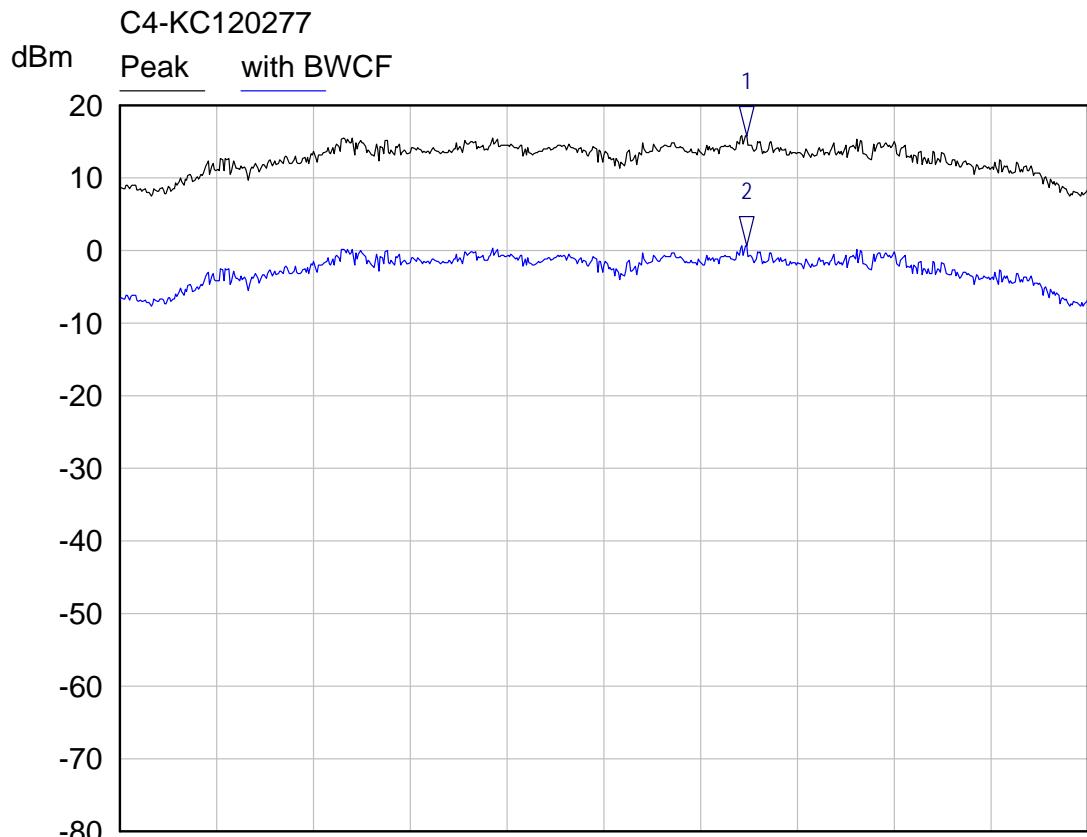
Frequency (MHz)	Measurement (dBm)	Criteria (dBm)	Margin (dBm)
2405	1.65	8.0	-6.35
2440	0.70	8.0	-7.30
2475	-0.19	8.0	-8.19

**RESULT**

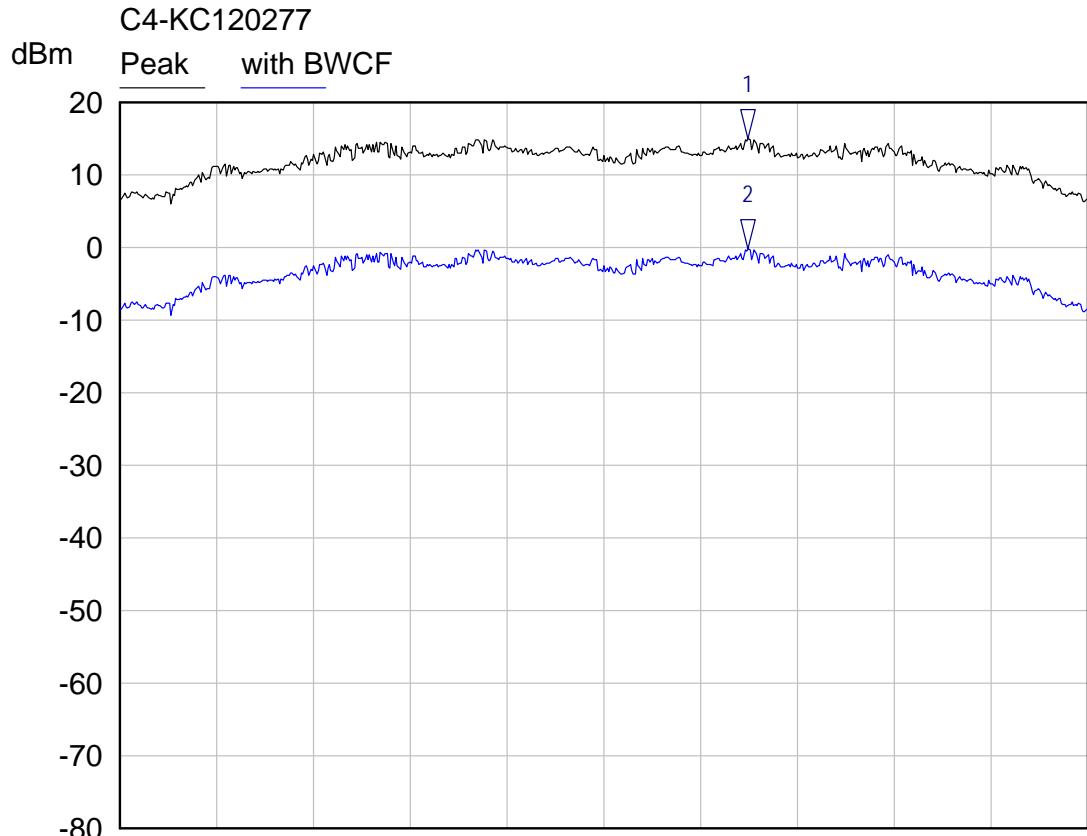
The maximum peak power spectral density was 1.65 dBm. The limit is 8 dBm. The EUT complies with the specification by 6.35 dB.



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4048 GHz	16.85 dBm	
2 ▽	with BWCF	2.4048 GHz	1.65 dBm	



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4403 GHz	15.90 dBm	
2 ▽	with BWCF	2.4403 GHz	0.70 dBm	



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4753 GHz	15.01 dBm	
2 ▽	with BWCF	2.4753 GHz	-0.19 dBm	

### **6.2.7 §15.247(i) Exposure to RF Energy**

See documents filed with the FCC for certification.

## **APPENDIX 1 TEST PROCEDURES AND TEST EQUIPMENT**

### **A1.1 Conducted Disturbance at the AC Mains**

The conducted disturbance at mains ports from the EUT was measured using a spectrum analyzer with a quasi-peak adapter for peak, quasi-peak and average readings. The quasi-peak adapter uses a bandwidth of 9 kHz, with the spectrum analyzer's resolution bandwidth set at 100 kHz, for readings in the 150 kHz to 30 MHz frequency ranges.

The conducted disturbance at mains ports measurements are performed in a screen room using a (50 Ω/50 μH) Line Impedance Stabilization Network (LISN).

Where mains flexible power cords are longer than 1 m, the excess cable is folded back and forth as far as possible so as to form a bundle not exceeding 0.4 m in length.

Where the EUT is a collection of devices with each device having its own power cord, the point of connection for the LISN is determined from the following rules:

- (a) Each power cord, which is terminated in a mains supply plug, shall be tested separately.
- (b) Power cords, which are not specified by the manufacturer to be connected via a host unit, shall be tested separately.
- (c) Power cords which are specified by the manufacturer to be connected via a host unit or other power supplying equipment shall be connected to that host unit and the power cords of that host unit connected to the LISN and tested.
- (d) Where a special connection is specified, the necessary hardware to effect the connection is supplied by the manufacturer for the testing purpose.
- (e) When testing equipment with multiple mains cords, those cords not under test are connected to an artificial mains network (AMN) different than the AMN used for the mains cord under test.

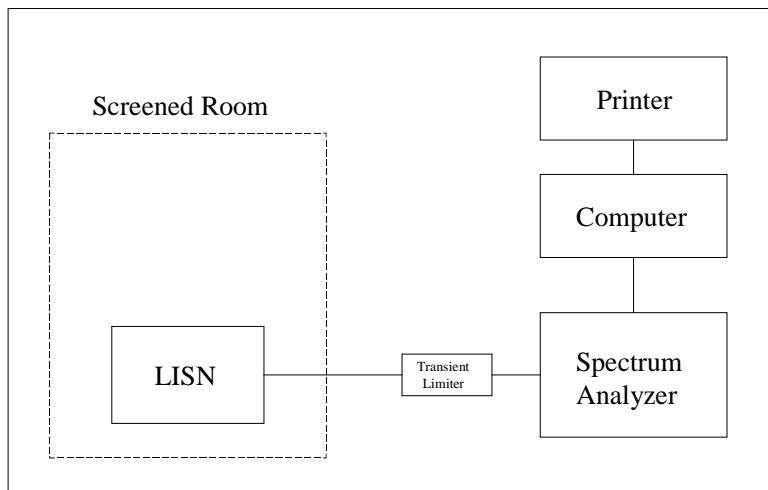
For AC mains port testing, desktop EUT are placed on a non-conducting table at least 0.8 meters from the metallic floor and placed 40 cm from the vertical coupling plane (copper plating in the wall behind EUT table). Floor standing equipment is placed directly on the earth grounded floor.

Type of Equipment	Manufacturer	Model Number	Serial Number	Date of Last Calibration	Due Date of Calibration
Wanship Open Area Test Site #2	Nemko-CCL, Inc.	N/A	N/A	11/16/2011	11/16/2012
Test Software	Nemko-CCL, Inc.	Conducted Emissions	Revision 1.2	N/A	N/A
Spectrum Analyzer	Hewlett Packard	8566B	2230A01711	01/17/2012	01/17/2013

Type of Equipment	Manufacturer	Model Number	Serial Number	Date of Last Calibration	Due Date of Calibration
Quasi-Peak Detector	Hewlett Packard	85650A	2043A00137	01/18/2012	01/18/2013
LISN	EMCO	3825/2	9305-2099	03/12/2012	03/12/2013
Conductance Cable Wanship Site #2	Nemko-CCL, Inc.	Cable J	N/A	12/14/2011	12/14/2012
Transient Limiter	Hewlett Packard	11947A	3107A02266	12/14/2011	12/14/2012

An independent calibration laboratory or Nemko-CCL Inc. personnel calibrates all the equipment listed above at intervals defined in ANSI C63.4:2003 Section 4.4 following outlined calibration procedures. All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to tractability is on file and is available for examination upon request.

#### Conducted Emissions Test Setup

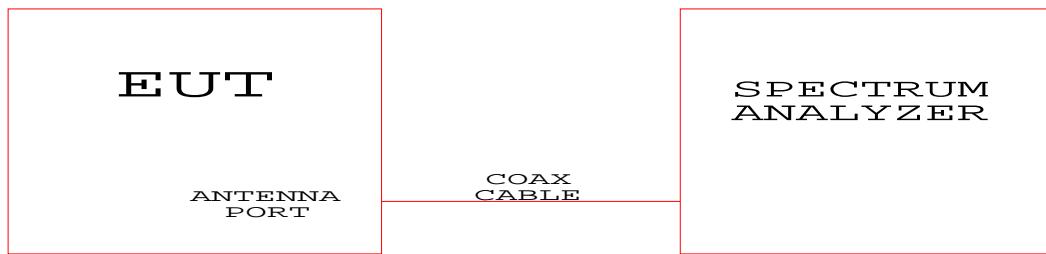


#### A1.2 Direct Connection at the Antenna Port Tests

Type of Equipment	Manufacturer	Model Number	Serial Number
Spectrum Analyzer	Hewlett Packard	8566B	2230A01711
Quasi-Peak Detector	Hewlett Packard	85650A	2043A00137
Spectrum Analyzer/Receiver	Rohde & Schwarz	ESU40	100064
Low Loss Cable (1 dB)	N/A	N/A	N/A

An independent calibration laboratory or Nemko-CCL, Inc. personnel calibrates all the equipment listed above at intervals defined in ANSI C63.4:2003 Section 4.4 following outlined calibration procedures. All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to tractability is on file and is available for examination upon request.

### Test Configuration Block Diagram



The

#### A1.3 Radiated Spurious Emissions in the Restricted Bands

The radiated emissions from the intentional radiator were measured using a spectrum analyzer with a quasi-peak adapter for peak and quasi-peak readings.

A loop antenna was used to measure emissions below 30 MHz. Emission readings more than 20 dB below the limit at any frequency may not be listed in the reported data. For frequencies between 9 kHz and 30 MHz, or the lowest frequency generated or used in the device greater than 9 kHz, and less than 30 MHz, the spectrum analyzer resolution bandwidth was set to 9 kHz and the video bandwidth was set to 30 kHz. For average measurements, the spectrum analyzer average detector was used.

For frequencies above 30 MHz, an amplifier and preamplifier were used to increase the sensitivity of the measuring instrumentation. The quasi-peak adapter uses a bandwidth of 120 kHz, with the spectrum analyzer's resolution bandwidth set at 1 MHz, for readings in the 30 to 1000 MHz frequency ranges. For peak emissions above 1000 MHz the spectrum analyzer's resolution bandwidth was set to 1 MHz and the video bandwidth was set to 3 MHz. For average measurements above 1000 MHz the spectrum analyzer's resolution bandwidth was set to 1 MHz and the average detector of the analyzer was used.

A biconic log antenna was used to measure the frequency range of 30 to 1000 MHz and a Double Ridge Guide Horn antenna was used to measure the frequency range of 1 GHz to 18 GHz, and a Pyramidal Horn antenna was used to measure the frequency range of 18 GHz to 25 GHz, at a distance of 3 meters and 1 meter from the EUT. The readings obtained by the antenna are correlated to the levels obtained with a tuned dipole antenna by adding antenna factors.

The configuration of the intentional radiator was varied to find the maximum radiated emission. The intentional radiator was connected to the peripherals listed in Section 2.4 via the interconnecting cables listed in Section 2.5. These interconnecting cables were manipulated manually by a technician to obtain worst case radiated emissions. The intentional radiator was rotated 360 degrees, and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission. Where there are multiple interface ports all of the same type, cables are either placed on all of the ports or cables added to these ports until the emissions do not increase by more than 2 dB.

Desktop intentional radiators are measured on a non-conducting table 0.8 meters above the ground plane. The table is placed on a turntable which is level with the ground plane. The turntable has slip rings, which supply AC power to the intentional radiator. For equipment normally placed on floors, the equipment shall be placed directly on the turntable.

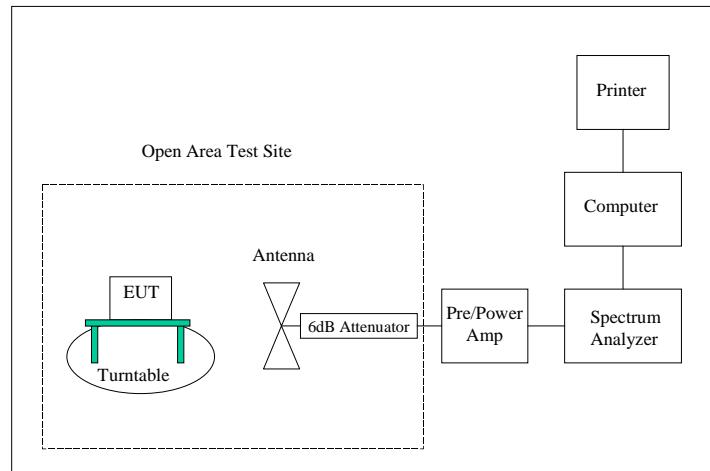
For radiated emission testing at 30 MHz or above that is performed at distances closer than the specified distance, an inverse proportionality factor of 20 dB per decade is used to normalize the measured data for determining compliance.

Type of Equipment	Manufacturer	Model Number	Serial Number	Date of Last Calibration	Due Date of Calibration
Wanship Open Area Test Site #2	Nemko-CCL, Inc.	N/A	N/A	11/16/2011	11/16/2012
Test Software	Nemko-CCL, Inc.	Radiated Emissions	Revision 1.3	N/A	N/A
Spectrum Analyzer/Receiver	Rohde & Schwarz	1302.6005.40	100064	07/28/2012	07/28/2013
Spectrum Analyzer	Hewlett Packard	8566B	2230A01711	01/17/2012	01/17/2013
Quasi-Peak Detector	Hewlett Packard	85650A	2043A00137	01/18/2012	01/18/2013
Loop Antenna	EMCO	6502	2011	03/11/2011	03/11/2013
Biconilog Antenna	EMCO	3142	9601-1009	04/21/2011	04/21/2013
Double Ridged Guide Antenna	EMCO	3115	9604-4779	03/10/2011	03/10/2013
Pyramidal Standard Gain Horn Antenna	ETS	3160-009	003-1197	04/04/2009	ICO
2.4 GHz Filter	Microtronics	HPM50111-03	001	06/26/2012	06/26/2013
High Frequency Amplifier	Miteq	AFS4-01001800-43-10P-4	1096455	06/26/2012	06/26/2013

Type of Equipment	Manufacturer	Model Number	Serial Number	Date of Last Calibration	Due Date of Calibration
6' High Frequency Cable	Microcoax	UFB197C-0-0720-000000	1296	05/14/2012	05/14/2013
20' High Frequency Cable	Microcoax	UFB197C-1-3120-000000	1297	05/14/2012	05/14/2013
3 Meter Radiated Emissions Cable Wanship Site #2	Microcoax	UFB205A-0-4700-000000	1295	05/10/2011	05/10/2013
Pre/Power-Amplifier	Hewlett Packard	8447F	3113A05161	08/27/2012	08/27/2013

An independent calibration laboratory or Nemko-CCL, Inc. personnel calibrates all the equipment listed above at intervals defined in ANSI C63.4:2003 Section 4.4 following outlined calibration procedures. All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to tractability is on file and is available for examination upon request.

Radiated Emissions Test Setup

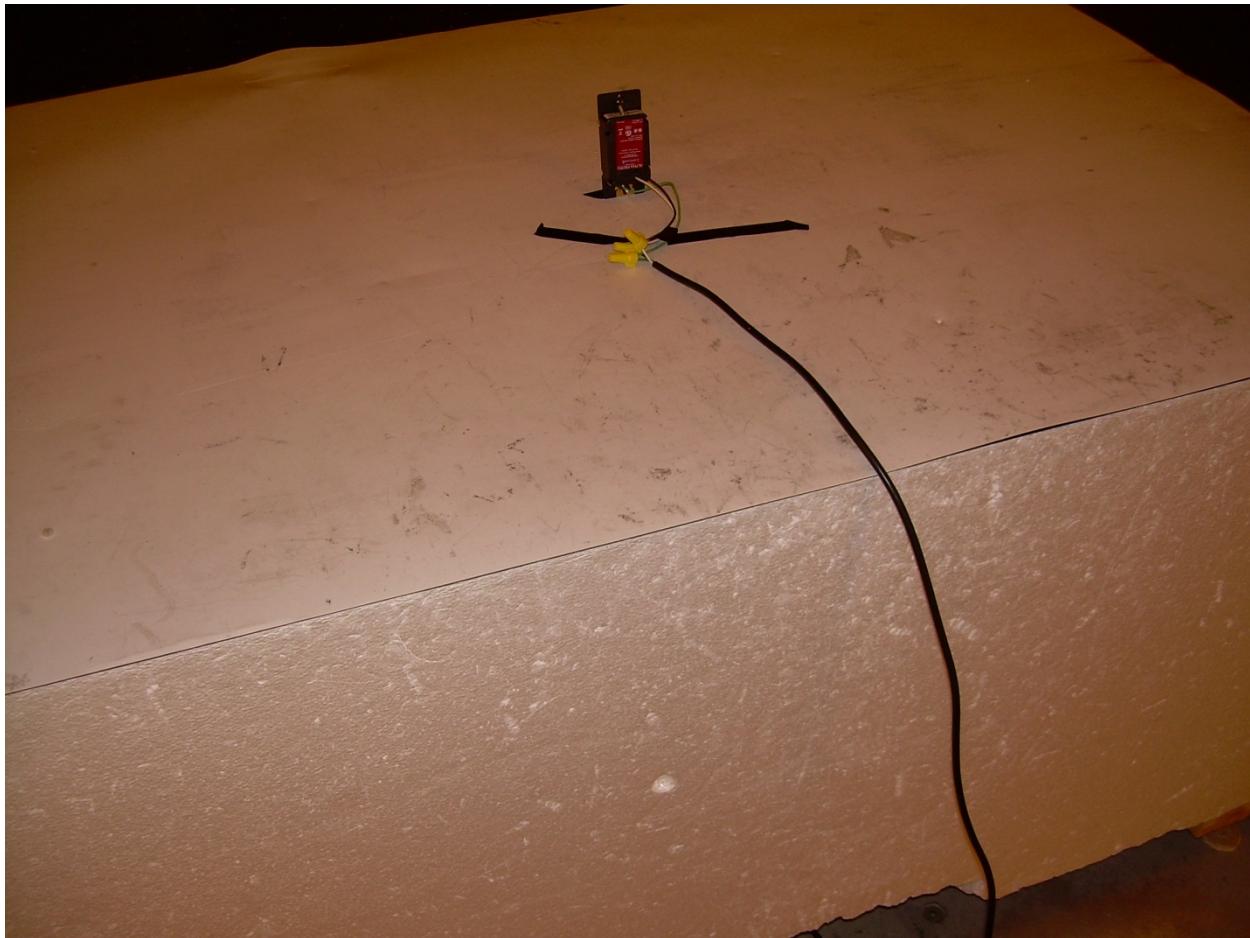


**APPENDIX 2 PHOTOGRAPHS**

Photograph 1 – Front View Radiated Disturbance Worst Case Configuration



Photograph 2 – Back View Radiated Disturbance Worst Case Configuration



Photograph 3 – Front View Conducted Disturbance Worst Case Configuration



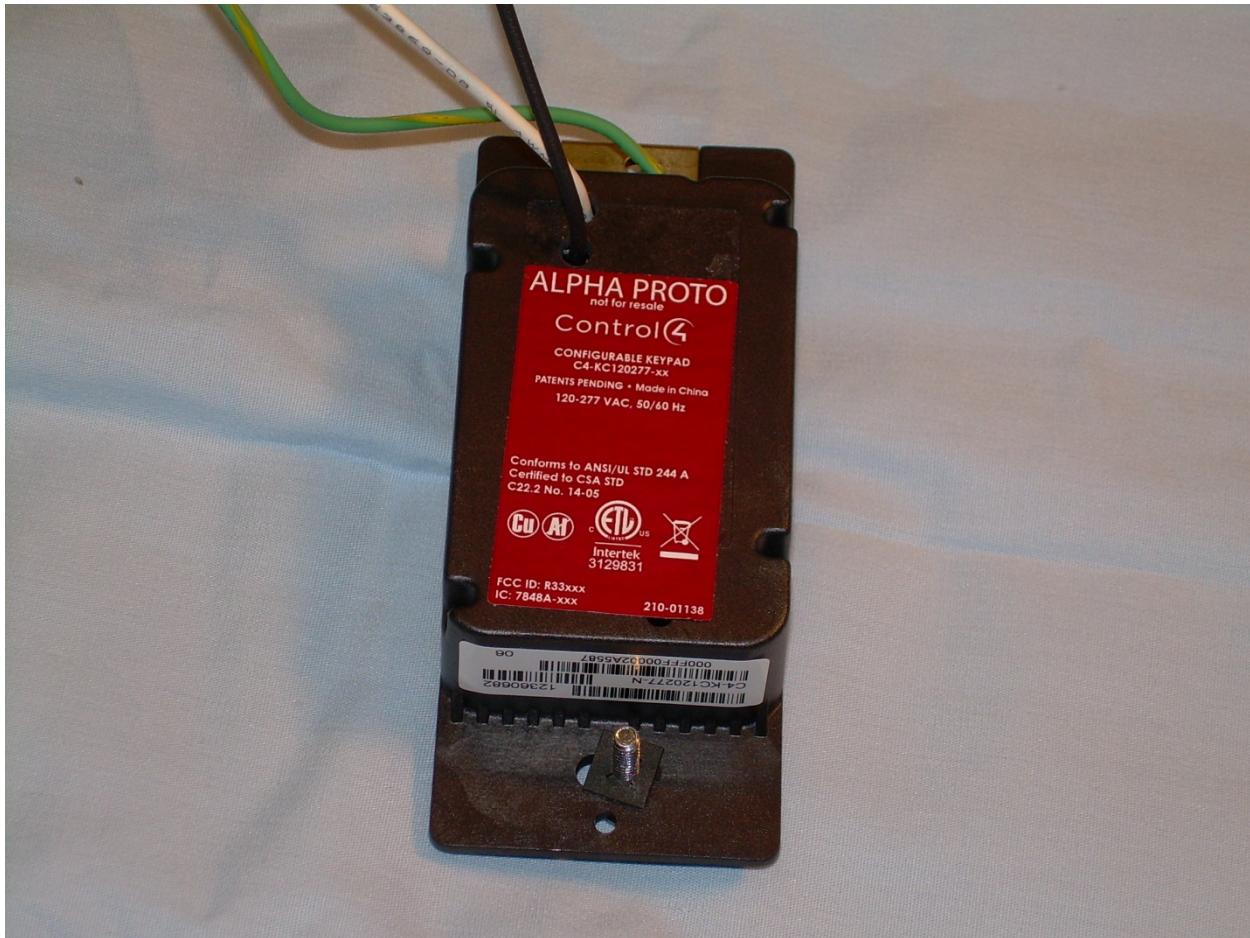
Photograph 4 – Back View Conducted Disturbance Worst Case Configuration



Photograph 5 – Front View of the EUT



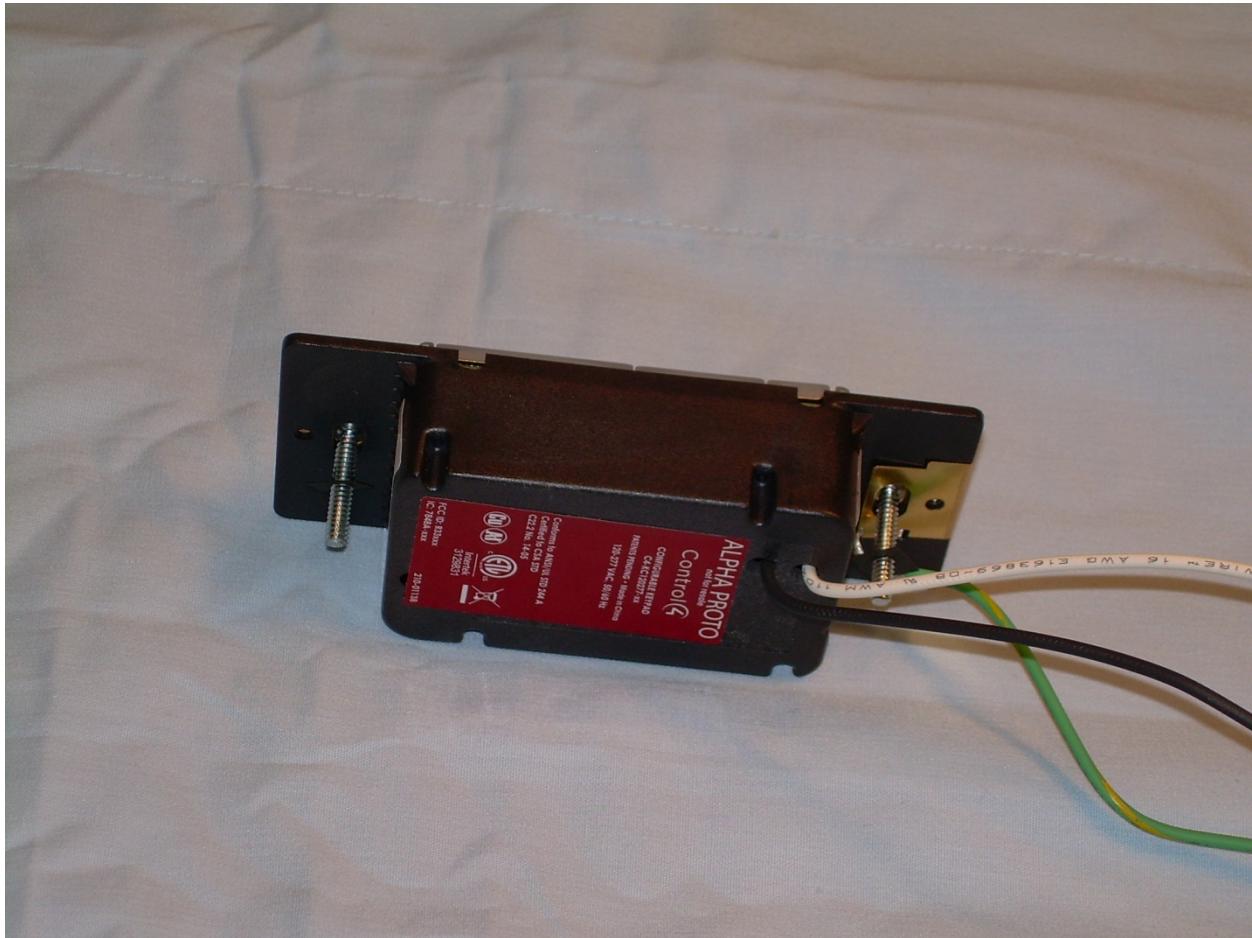
Photograph 6 – Back View of the EUT



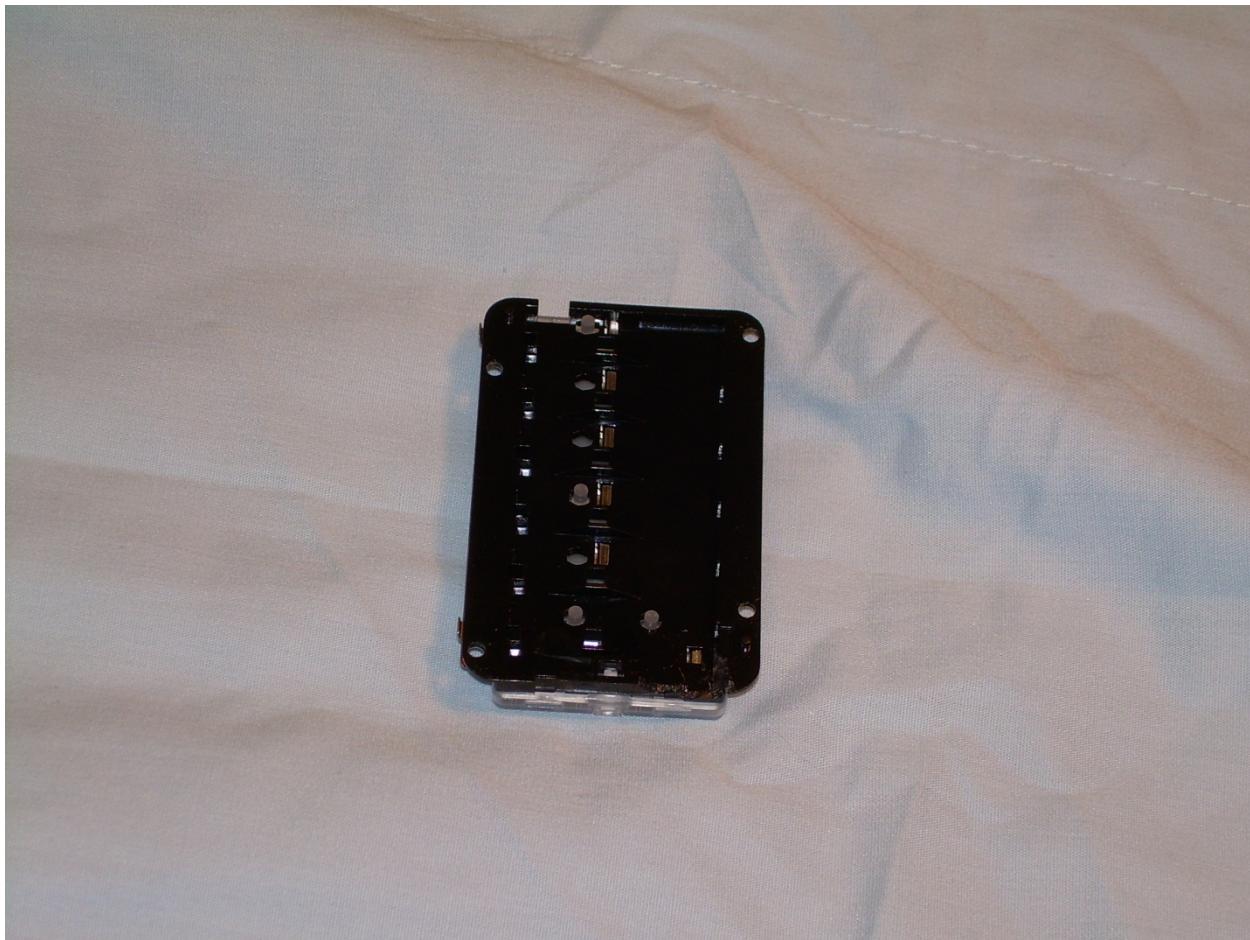
Photograph 7 – Front View of the EUT with Faceplate Removed



Photograph 8 – Side View of the EUT



Photograph 9 – View of the Back of the Front Button Assembly



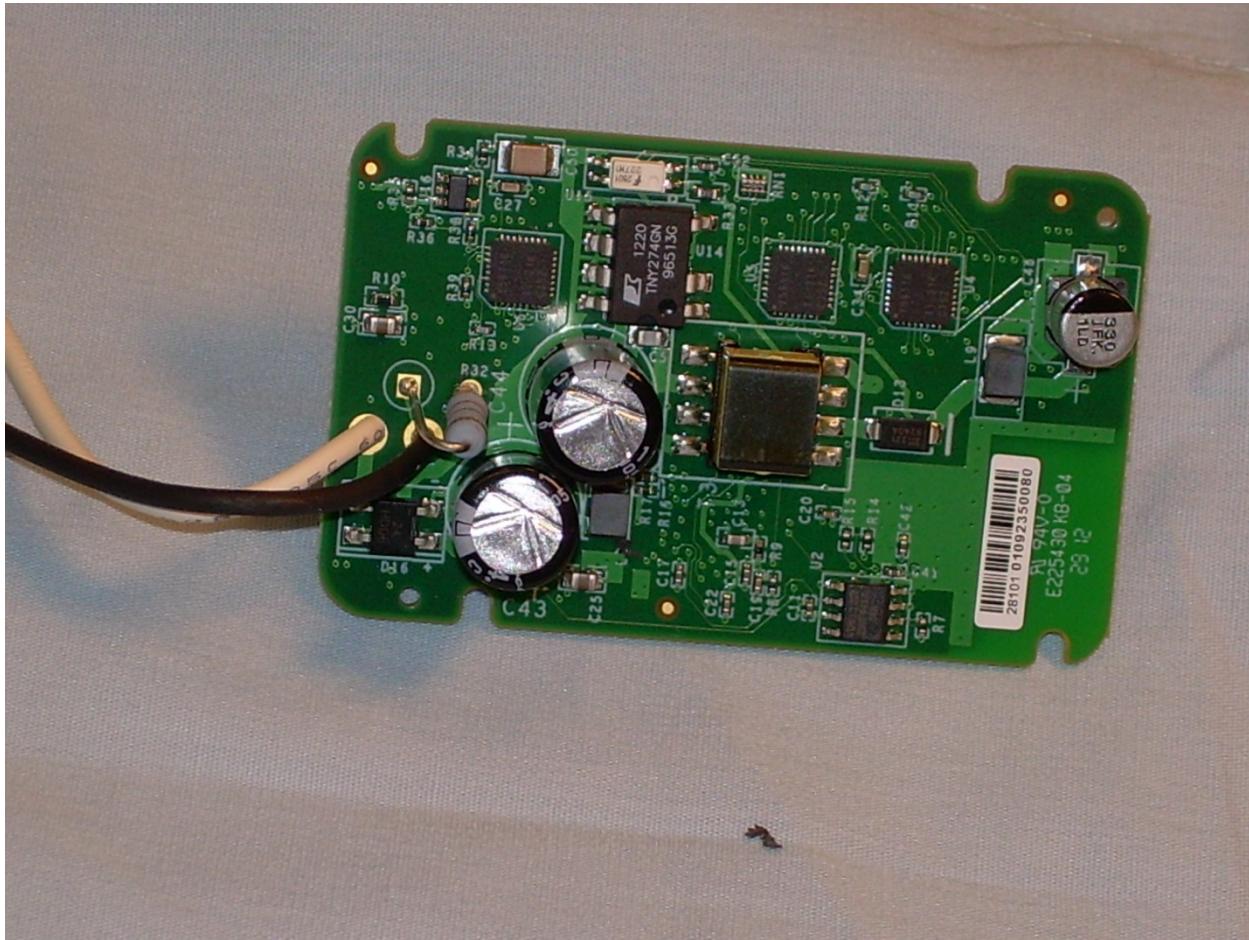
Photograph 10 – View of the Front of the EUT with the Button Assembly Removed



### Photograph 11 – View of the Front Side of the PCB



Photograph 12 – View of the Back Side of the PCB



## APPENDIX 3 TRANSMITTER DUTY CYCLE CALCULATIONS

### ***IEEE 802.15.4-2003 2.4 GHz PHY Constants***

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
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) RX ACK
- 4) CPU Processing of ACK
- 5) Wait for Backoff
- 6) Repeat 1)

### ***MAC-Level Calculation (LIFS)***

<b><u>Long InterFrame Spacing (Slotted w/ ACK)</u></b>		
Long Frame	127	bytes
Data Frame Payload	102	bytes
ACK Frame	5	bytes
tack	12	sym
LIFS	40	sym
Backoff Period	20	sym
Maximum Backoff	31	Random between 0 and 31
Backoff Required	2	
Backoff Time	300	Average at 15
<b><u>Transmit Time</u></b>		
TX Time (Packet)	0.004256	
Total TX Time (sec)	0.004256	
<b><u>NOT Transmit time (RX or Idle)</u></b>		
Wait for ACK (tack)	0.000192	
RX Time (ACK)	0.000352	
Backoff Time (tbo)	0.0048	
CPU Processing (tcpu)	0.0002	
CCA Assessment (tcca)	0.000128	
Turn Around Time (RX to TX)	0.000192	
Total Off Time (sec)	0.005864	
<b>Total Time (ttotal)</b>	<b>0.01012</b>	<b>(0.004256 + 0.005864) MAC TX Duty Cycle (On/Total) = 42.06</b>

$$\text{Average Factor} = 20 \log (0.004256 / 0.01012) = -7.52$$