Nemko-CCL, Inc.

1940 West Alexander Street
Salt Lake City, UT 84119
801-972-6146

Test Report

Certification

Test Of: C4-4SF120

FCC ID: R33C44SF

Test Specifications:

FCC PART 15, Subpart C

Test Report Serial No: 230754-1.1

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

Dates of Test: November 15, 2012 and January 24, 2013

Issue Date: February 20, 2013

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: C4-4SF120
- FCC ID: R33C44SF

On this 20th day of February 2013, 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:	C4-4SF120
Serial Number:	None
Dimensions:	10.2 cm x 6.0 cm x 3.8 cm
Country of Manufacture:	China

2.2 Description of EUT:

The C4-4SF120 is a wall box mounted fan controller with a Zigbee transceiver for use in Control4 home automation systems. The C4-4SF120 is powered by the AC mains and has a load line for the fan and an auxiliary line for connection of the C4-KA auxiliary keypad assembly. The C4-4SF120 uses a trace on the PCB for the antenna. The C4-4SF120 Zigbee transceiver uses 15 channels in the 2400 to 2483.5 MHz frequency range. See the table of frequencies below.

Channel	Frequency (MHz)	Channel	Frequency (MHz)	Channel	Frequency (MHz)	Channel	Frequency (MHz)
11	2405	15	2425	19	2445	23	2465
12	2410	16	2430	20	2450	24	2470
13	2415	17	2435	21	2455	25	2475
14	2420	18	2440	22	2460		

This report covers the circuitry of the devices subject to FCC Part 15, Subpart C. The circuitry of the device subject to FCC Subpart B was found to be compliant and is covered in Nemko-CCL, Inc. report 223046-6.

2.3 EUT and Support Equipment:

The FCC ID numbers for all the EUT and support equipment used during the test are listed below:

Brand Name Model Number Serial No.	FCC ID Number	Description	Name of Interface Ports / Interface Cables
BN: Control4 MN: C4-4SF120 (Note 1) SN: None	R33C44SF	Fan Speed Controller	See Section 2.4
BN: Minka-Aire MN: AC536 SN: None	None	Ceiling Fan	AC power/3 conductor cable (Note 2)
BN: Control4 MN: C4-KA SN: None	Verification	Auxiliary Keypad	Interface/2 conductors (Note 2)

Note: (1) EUT.
(2) Interface port connected to EUT (See Section 2.4)

The support equipment listed above was not modified in order to achieve compliance with this standard.

2.4 Interface Ports on EUT:

Name of Ports	No. of Ports Fitted to EUT	Cable Descriptions/Length
AC Power	1	3 conductors/1 meter
Load	1	Single conductor/20 cm extended 3 meters to fan assembly
Auxiliary	1	Single conductor/20 cm

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 +2, the power setting to be incorporated in firmware by the manufacturer.

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 μH/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 (dBµV)	
	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.

<u>3.2.3 §15.247 Operation within the bands 902 – 928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz</u>

(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.

3.2.3 Test Procedure

The testing was performed according to the procedures in ANSI C63.4: 2003 and 47 CFR Part 15 and using the guidance found in KDB 558074, Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247, dated 10/04/2012. Testing was performed at the 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 VAC
AC Mains Frequency: 60 Hz

4.2 Operating Modes:

The transceiver was tested while in a constant transmit mode at the upper, middle, and lower channels.

4.3 EUT Exercise Software:

Control4 software was used to exercise the transmitters.

SECTION 5.0 SUMMARY OF TEST RESULTS

5.1 FCC Part 15, Subpart C

The C4-4SF120 Zigbee transceiver was subjected to each of the tests shown in the summary table below.

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	2400 – 2483.5	Complied
15.247(b)	Peak Output Power	2400 – 2483.5	Complied
15.247(c)	Spurious Emissions	0.1 - 24750	Complied
15.247(d)	Peak Power Spectral Density	2400 – 2483.5	Complied
15.247(e)	Reserved Paragraph	N/A	Not Applicable
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

5.2 Result

In the configuration tested, the Zigbee transceiver complied with the requirements of the specification.

SECTION 6.0 MEASUREMENTS AND RESULTS

6.1 General Comments:

This section contains the test results only. Details of the test methods used and 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 antenna is a trace on the PCB and is not user replaceable.

RESULT

The EUT complied with the specification.

6.2.2 §15.207 Conducted Disturbance at the AC Mains Ports

Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dBμV)	Limit (dBμV)	Margin (dB)
0.17	Hot Lead	Quasi-Peak (Note 1)	51.7	55.0	-3.3
0.20	Hot Lead	Quasi-Peak (Note 1)	49.6	53.6	-4.0
0.26	Hot Lead	Quasi-Peak (Note 2)	48.8	61.4	-12.6
0.26	Hot Lead	Average (Note 2)	42.0	51.4	-9.4
0.30	Hot Lead	Quasi-Peak (Note 2)	48.7	60.3	-11.6
0.30	Hot Lead	Average (Note 2)	39.4	50.3	-10.9
0.42	Hot Lead	Quasi-Peak (Note 2)	52.4	57.4	-5.0
0.42	Hot Lead	Average (Note 2)	44.7	47.4	-2.7
0.57	Hot Lead	Quasi-Peak (Note 2)	46.0	56.0	-10.0
0.57	Hot Lead	Average (Note 2)	37.4	46.0	-8.6
0.17	Neutral Lead	Quasi-Peak (Note 2)	53.4	65.2	-11.8
0.17	Neutral Lead	Average (Note 2)	45.3	55.2	-9.9
0.20	Neutral Lead	Quasi-Peak (Note 2)	51.0	63.6	-12.6

Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dBμV)	Limit (dBμV)	Margin (dB)
0.20	Neutral Lead	Average (Note 2)	41.7	53.6	-11.9
0.26	Neutral Lead	Quasi-Peak (Note 2)	50.1	61.4	-11.3
0.26	Neutral Lead	Average (Note 2)	42.6	51.4	-8.8
0.43	Neutral Lead	Quasi-Peak (Note 2)	54.2	57.3	-3.1
0.43	Neutral Lead	Average (Note 2)	45.9	47.3	-1.4
0.51	Neutral Lead	Quasi-Peak (Note 2)	48.7	56.0	-7.3
0.51	Neutral Lead	Average (Note 2)	37.3	46.0	-8.7
1.55	Neutral Lead	Quasi-Peak (Note 2)	44.8	56.0	-11.2
1.55	Neutral Lead	Average (Note 2)	33.9	46.0	-12.1

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

In the configuration tested, the EUT complied with the specification by 1.4 dB.

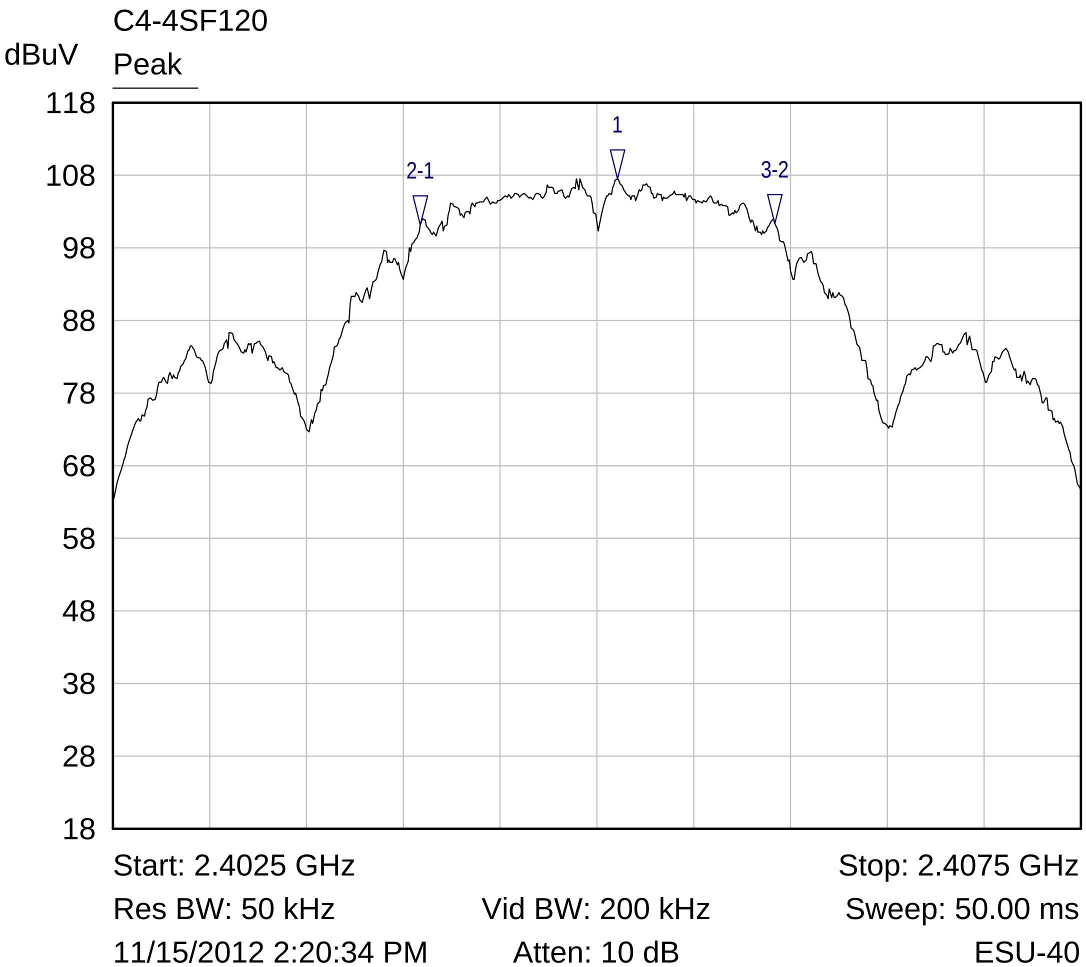
6.2.3 §15.247(a)(2) Emission Bandwidth

Frequency (MHz)	Emission 6 dB bandwidth (MHz)
2405	1.835
2440	1.819
2475	1.715

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).

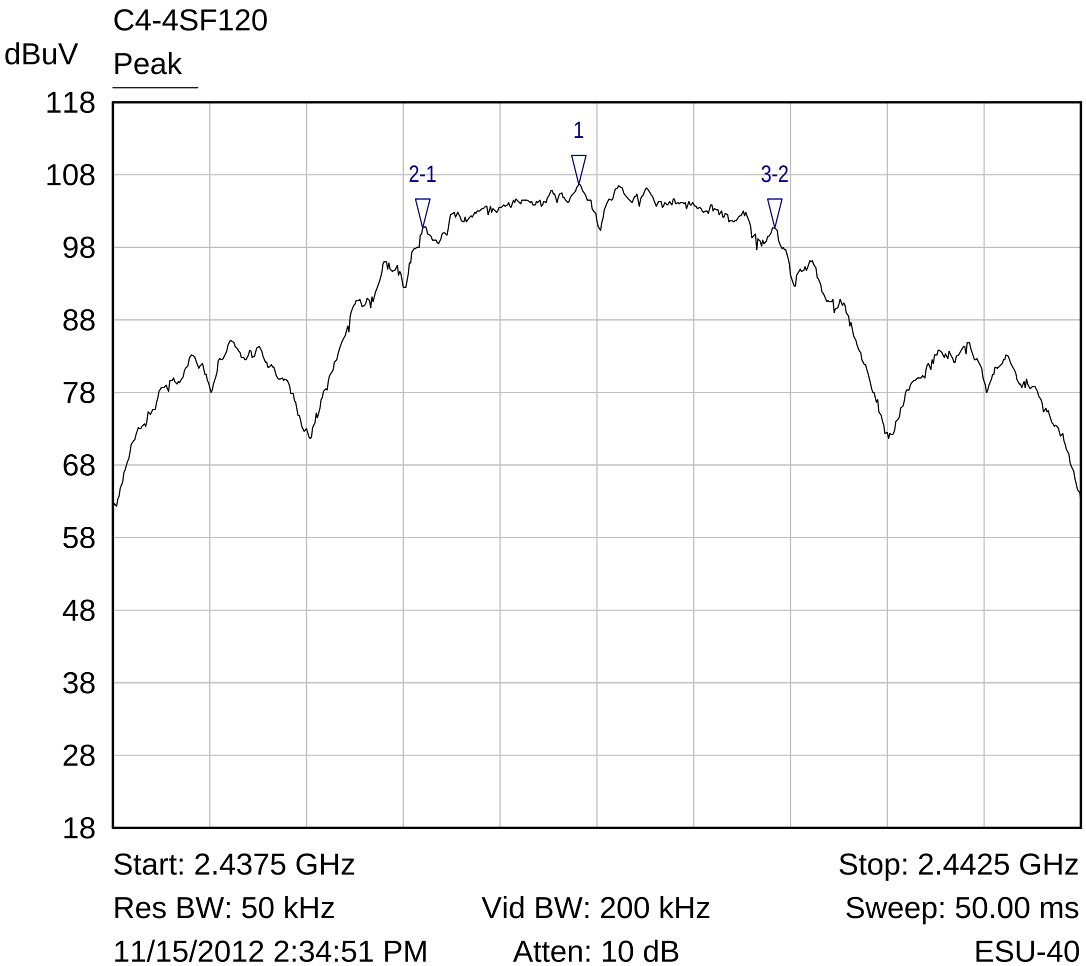
Lowest Channel 6 dB Bandwidth



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Peak	2.4051 GHz	107.54 dBuV	
2-1 ∇	Peak	-1.0176 MHz	-6.40 dB	
3-2 ∇	Peak	1.8349 MHz	0.26 dB	

6dB BW

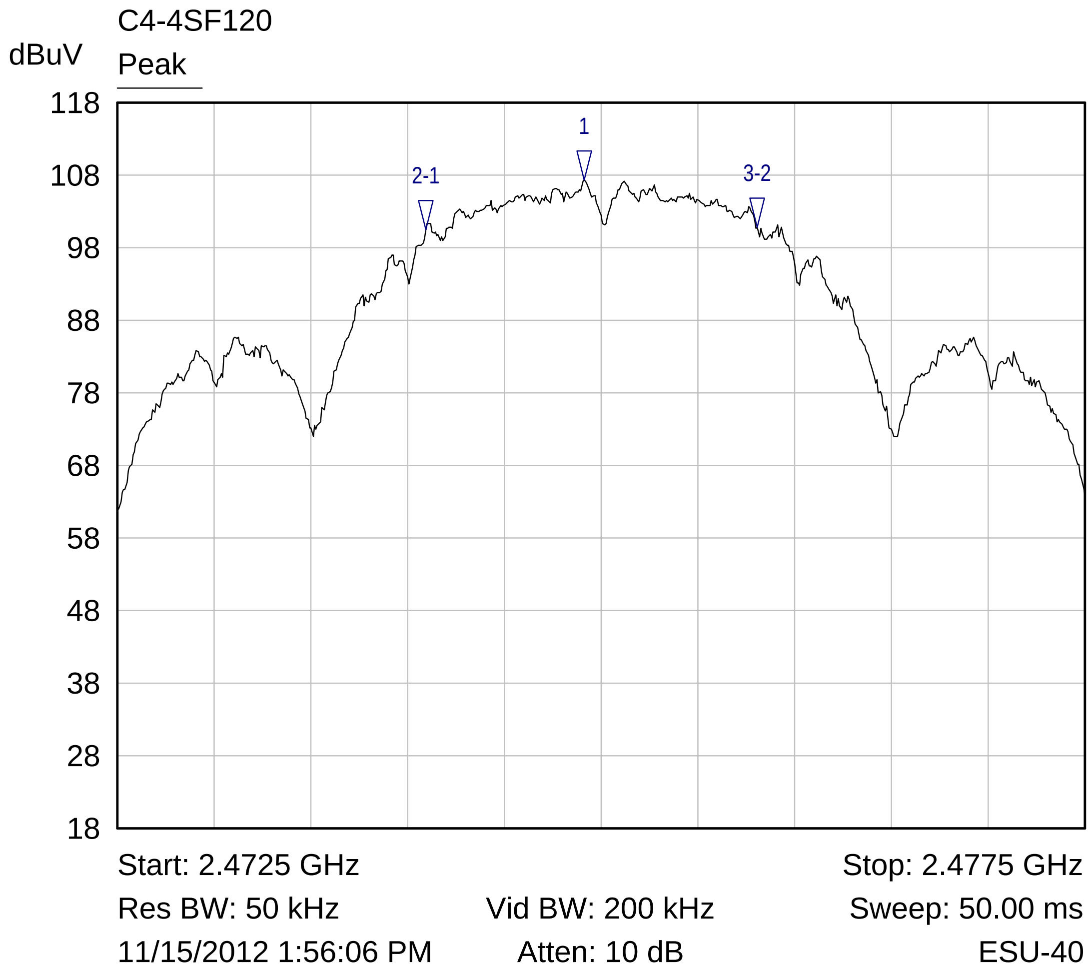
Middle Channel 6 dB Bandwidth



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4399 GHz	106.71 dBuV	
2-1 ▽	Peak	-801.2821 kHz	-6.08 dB	
3-2 ▽	Peak	1.8189 MHz	0.04 dB	

6 dB BW

Highest Channel 6 dB Bandwidth



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Peak	2.4749 GHz	107.28 dBuV	
2-1 ∇	Peak	-817.3077 kHz	-6.75 dB	
3-2 ∇	Peak	1.7147 MHz	0.26 dB	

6 dB BW

6.2.4 §15.247(b)(3) Peak Output Power

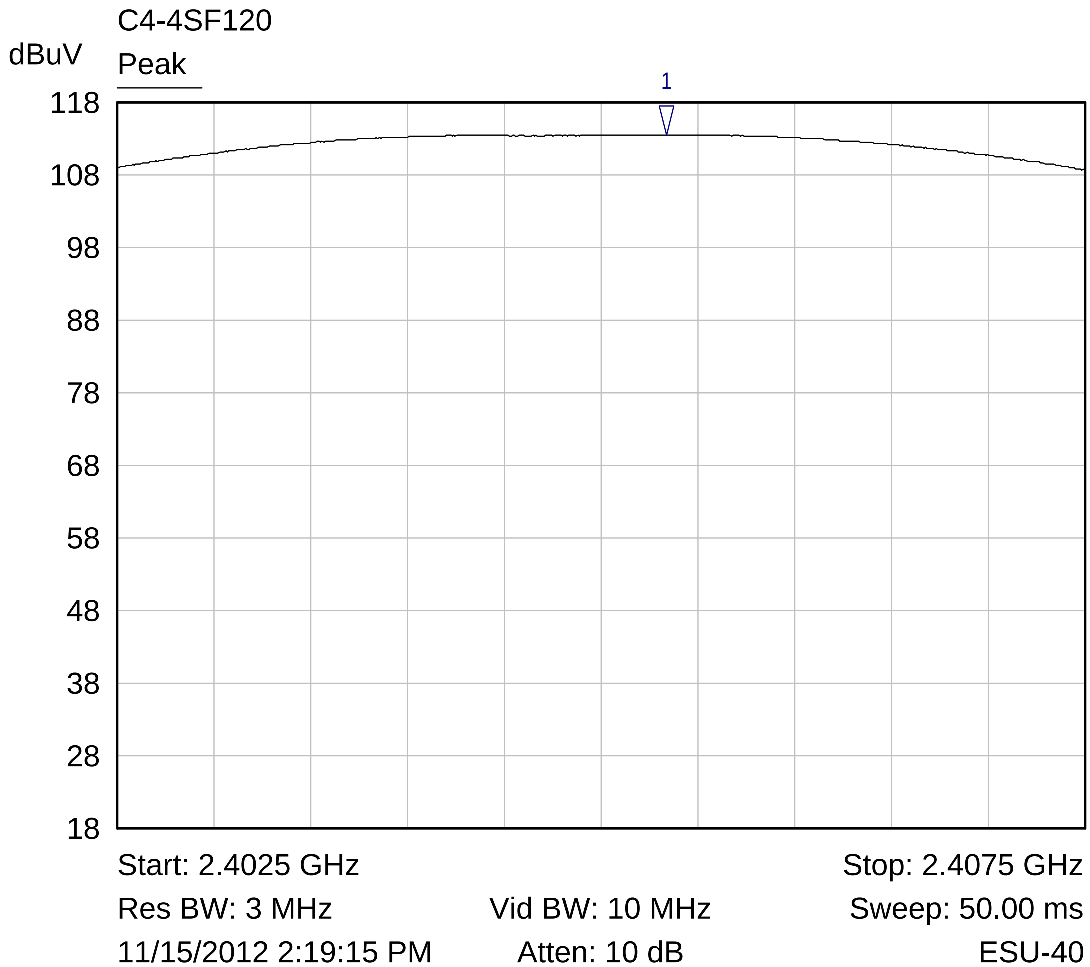
The maximum peak RF output power for this device was 57.81 mW. The maximum peak RF output power was calculated using equation 1.3.1 of KDB 412172 (eirp = $(E \times d)^2 / 30$) to get EIRP in Watts, then Watts was converted to dBm, following the guidance of KDB 558074 paragraph 2.0, the antenna gain in dBi was subtracted to get the maximum transmitter output power in dBm. The limit is 30 dBm (1 Watt) when using antennas with 6 dBi or less gain. Parameters used in the calculations are antenna gain equals 0.7 dBi and a measurement distance (d) of 3 meters. E is the measured field strength in V/m.

Frequency (MHz)	Measured Field Strength (dBµV/m)	Peak RF Output Power to Antenna (dBm)	Peak RF Output Power to Antenna (mW)
2405	113.55	17.62	57.81
2440	113.25	17.32	53.95
2475	112.93	17.00	50.12

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).

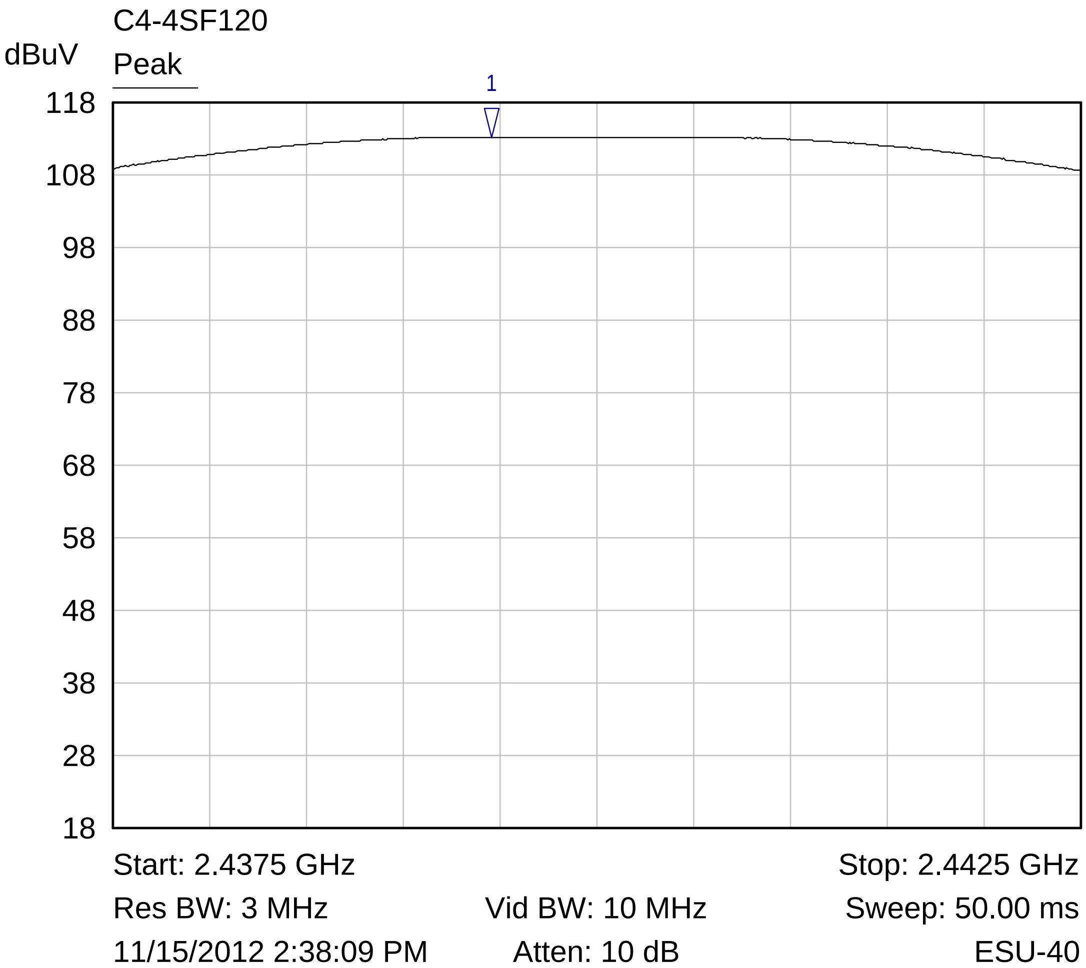
Lowest Channel Output Power Plot



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4053 GHz	113.55 dBuV	

output power

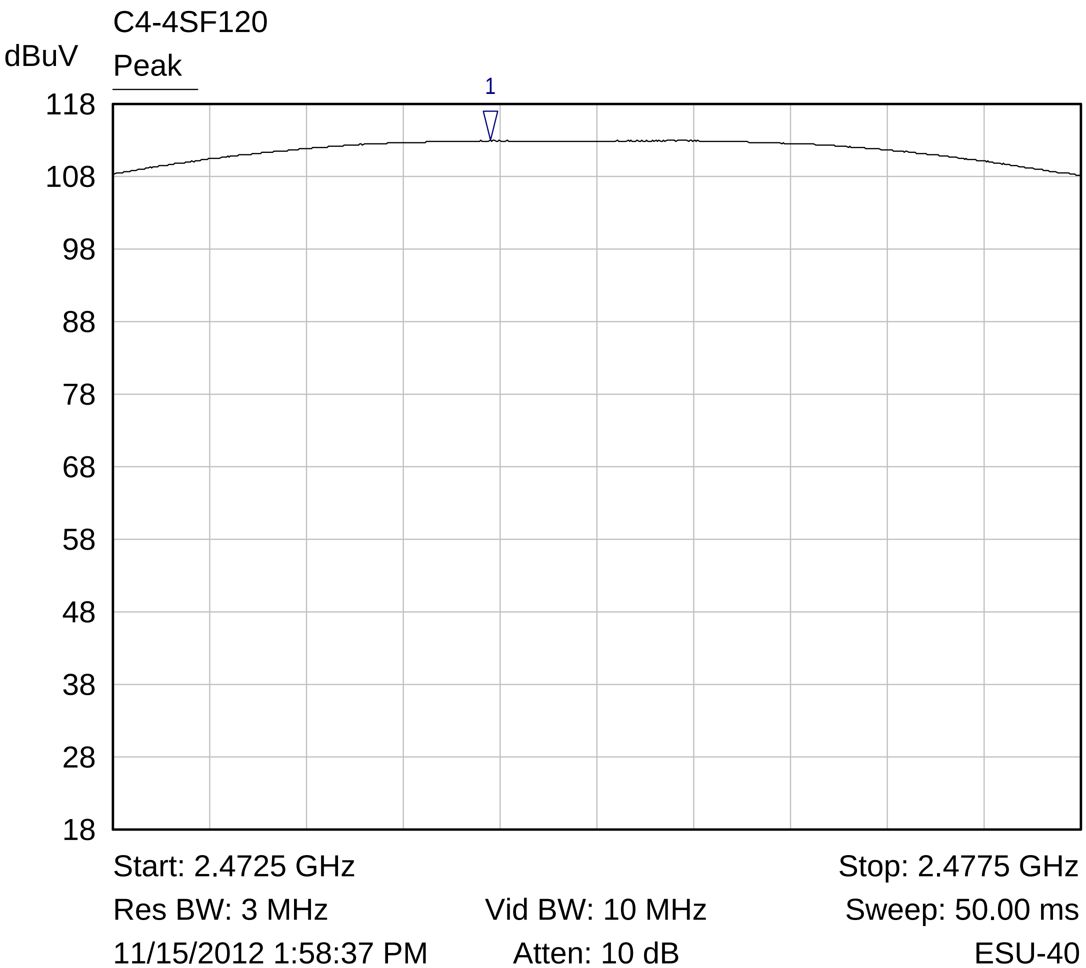
Middle Channel Output Power Plot



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4395 GHz	113.25 dBuV	

output power

Highest Channel Output Power Plot



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4744 GHz	112.93 dBuV	

output power

6.2.5 §15.247(c) Spurious Emissions

6.2.5.2 Radiated 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 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. Spurious emissions not within the restricted bands must be attenuated 20 dB from the maximum measured fundamental emission. 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 of emissions exhibiting the same characteristics as the fundamental frequency. For details of the duty cycle calculation, see Appendix 3.

RESULT

All emissions, even those outside 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 (dBμV)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4810.0	Peak	Vertical	22.2	37.7	0.0	59.9	74.0	-14.1
4810.0	Average	Vertical	16.0	37.7	-7.5	46.2	54.0	-7.8
4810.0	Peak	Horizontal	22.8	37.7	0.0	60.5	74.0	-13.5
4810.0	Average	Horizontal	16.8	37.7	-7.5	47.0	54.0	-7.0
7215.0	Peak	Vertical	25.3	42.1	0.0	67.4	74.0	-6.6
7215.0	Average	Vertical	18.8	42.1	-7.5	53.4	54.0	-0.6
7215.0	Peak	Horizontal	22.1	42.1	0.0	64.2	74.0	-9.8
7215.0	Average	Horizontal	15.4	42.1	-7.5	50.0	54.0	-4.0
9620.0	Peak	Vertical	1.3	44.7	0.0	46.0	74.0	-28.0
9620.0	Average	Vertical	-11.5	44.7	-7.5	25.7	54.0	-28.3
9620.0	Peak	Horizontal	1.2	44.7	0.0	45.9	74.0	-28.1

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
9620.0	Average	Horizontal	-11.6	44.7	-7.5	25.6	54.0	-28.4
12025.0	Peak	Vertical	3.4	47.2	0.0	43.1	74.0	-30.9
12025.0	Average	Vertical	-5.6	47.2	-7.5	34.1	54.0	-19.9
12025.0	Peak	Horizontal	4.5	47.2	0.0	51.7	74.0	-22.3
12025.0	Average	Horizontal	-4.4	47.2	-7.5	35.3	54.0	-18.7
14430.0	Peak	Vertical	5.3	50.8	0.0	56.1	74.0	-17.9
14430.0	Average	Vertical	-2.6	50.8	-7.5	40.7	54.0	-13.3
14430.0	Peak	Horizontal	2.6	50.8	0.0	53.4	74.0	-20.6
14430.0	Average	Horizontal	-5.9	50.8	-7.5	37.4	54.0	-16.6
16835.0	Peak	Vertical	2.5	49.8	0.0	52.3	74.0	-21.7
16835.0	Average	Vertical	-5.9	49.8	-7.5	36.4	54.0	-17.6
16835.0	Peak	Horizontal	4.0	49.8	0.0	53.8	74.0	-20.2
16835.0	Average	Horizontal	-6.0	49.8	-7.5	36.3	54.0	-17.7

Transmitting at the Middle Frequency (2440 MHz)

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
4880.0	Peak	Vertical	19.7	37.9	0.0	57.6	74.0	-16.4
4880.0	Average	Vertical	13.4	37.9	-7.5	43.8	54.0	-10.2
4880.0	Peak	Horizontal	20.9	37.9	0.0	58.8	74.0	-15.2
4880.0	Average	Horizontal	14.7	37.9	-7.5	45.1	54.0	-8.9
7320.0	Peak	Vertical	19.0	42.3	0.0	61.3	74.0	-12.7
7320.0	Average	Vertical	12.2	42.3	-7.5	47.0	54.0	-7.0
7320.0	Peak	Horizontal	20.8	42.3	0.0	63.1	74.0	-10.9
7320.0	Average	Horizontal	14.2	42.3	-7.5	49.0	54.0	-5.0
9760.0	Peak	Vertical	3.9	44.8	0.0	48.7	74.0	-25.3
9760.0	Average	Vertical	-5.7	44.8	-7.5	31.6	54.0	-22.4
9760.0	Peak	Horizontal	4.1	44.8	0.0	48.9	74.0	-25.1
9760.0	Average	Horizontal	-3.5	44.8	-7.5	33.8	54.0	-20.2
12200.0	Peak	Vertical	4.0	47.1	0.0	43.6	74.0	-30.4
12200.0	Average	Vertical	-4.6	47.1	-7.5	35.0	54.0	-19.0
12200.0	Peak	Horizontal	5.9	47.1	0.0	53.0	74.0	-21.0

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
12200.0	Average	Horizontal	-4.4	47.1	-7.5	35.2	54.0	-18.8
14640.0	Peak	Vertical	-1.0	50.5	0.0	49.5	74.0	-24.5
14640.0	Average	Vertical	-12.3	50.5	-7.5	30.7	54.0	-23.3
14640.0	Peak	Horizontal	-0.4	50.5	0.0	50.1	74.0	-23.9
14640.0	Average	Horizontal	-12.0	50.5	-7.5	31.0	54.0	-23.0
17080.0	Peak	Vertical	-0.4	51.3	0.0	50.9	74.0	-23.1
17080.0	Average	Vertical	-10.6	51.3	-7.5	33.2	54.0	-20.8
17080.0	Peak	Horizontal	2.6	51.3	0.0	53.9	74.0	-20.1
17080.0	Average	Horizontal	-6.0	51.3	-7.5	37.8	54.0	-16.2

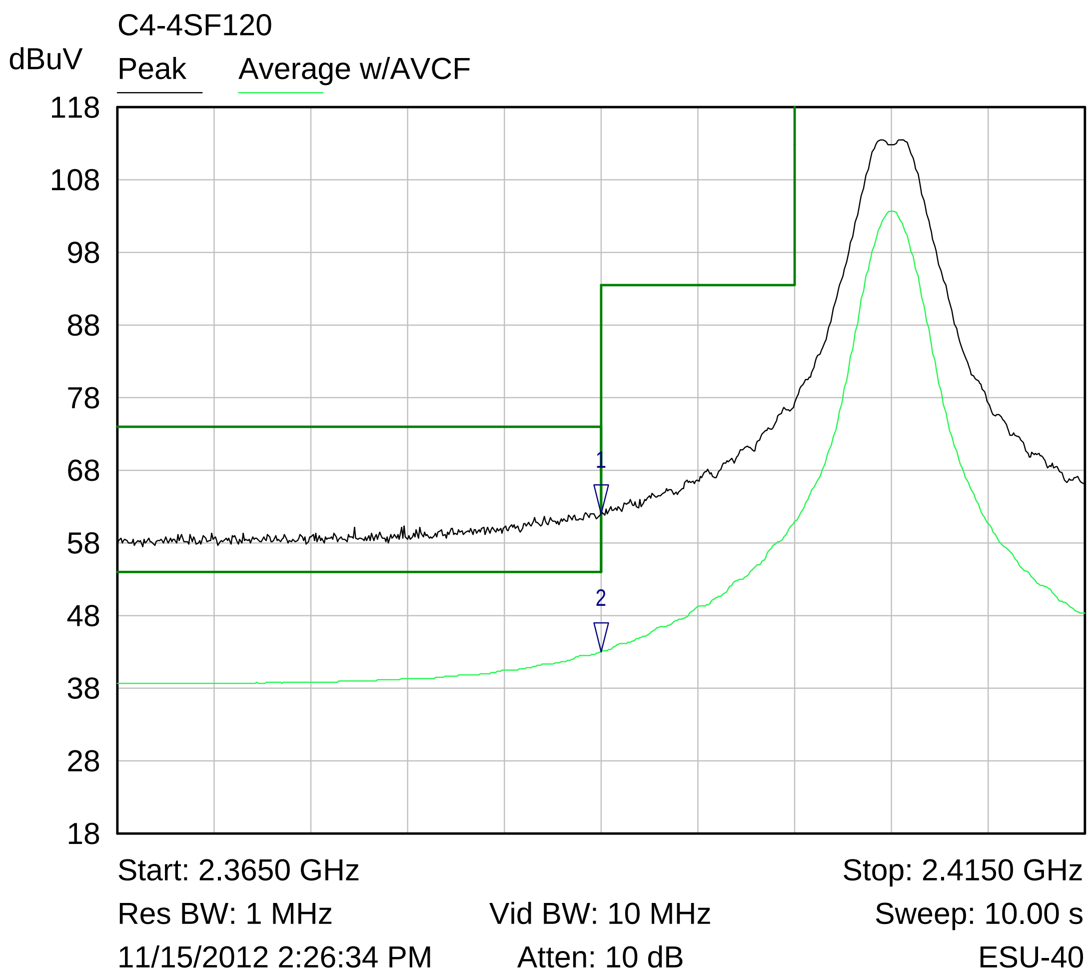
Transmitting at the Highest Frequency (2475 MHz)

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4950.0	Peak	Vertical	20.4	38.0	0.0	58.4	74.0	-15.6
4950.0	Average	Vertical	14.3	38.0	-7.5	44.8	54.0	-9.2
4950.0	Peak	Horizontal	21.9	38.0	0.0	59.9	74.0	-14.1
4950.0	Average	Horizontal	14.7	38.0	-7.5	45.2	54.0	-8.8
7425.0	Peak	Vertical	11.8	42.6	0.0	54.4	74.0	-19.6
7425.0	Average	Vertical	5.5	42.6	-7.5	40.6	54.0	-13.4
7425.0	Peak	Horizontal	15.5	42.6	0.0	58.1	74.0	-15.9
7425.0	Average	Horizontal	8.3	42.6	-7.5	43.4	54.0	-10.6
9900.0	Peak	Vertical	3.5	44.9	0.0	48.4	74.0	-25.6
9900.0	Average	Vertical	-4.8	44.9	-7.5	32.6	54.0	-21.4
9900.0	Peak	Horizontal	5.5	44.9	0.0	50.4	74.0	-23.6
9900.0	Average	Horizontal	-3.0	44.9	-7.5	34.4	54.0	-19.6
12375.0	Peak	Vertical	0.5	47.0	0.0	40.0	74.0	-34.0
12375.0	Average	Vertical	-8.1	47.0	-7.5	31.4	54.0	-22.6
12375.0	Peak	Horizontal	3.8	47.0	0.0	50.8	74.0	-23.2
12375.0	Average	Horizontal	-4.6	47.0	-7.5	34.9	54.0	-19.1
14850.0	Peak	Vertical	-0.8	49.8	0.0	49.0	74.0	-25.0
14850.0	Average	Vertical	-12.7	49.8	-7.5	29.6	54.0	-24.4
14850.0	Peak	Horizontal	0.9	49.8	0.0	50.7	74.0	-23.3

Frequency (MHz)	Detection Mode	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Averaging Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
14850.0	Average	Horizontal	-11.2	49.8	-7.5	31.1	54.0	-22.9
17325.0	Peak	Vertical	0.6	52.3	0.0	52.9	74.0	-21.1
17325.0	Average	Vertical	-11.1	52.3	-7.5	33.7	54.0	-20.3
17325.0	Peak	Horizontal	0.0	52.3	0.0	52.3	74.0	-21.7
17325.0	Average	Horizontal	-11.2	52.3	-7.5	33.6	54.0	-20.4

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.

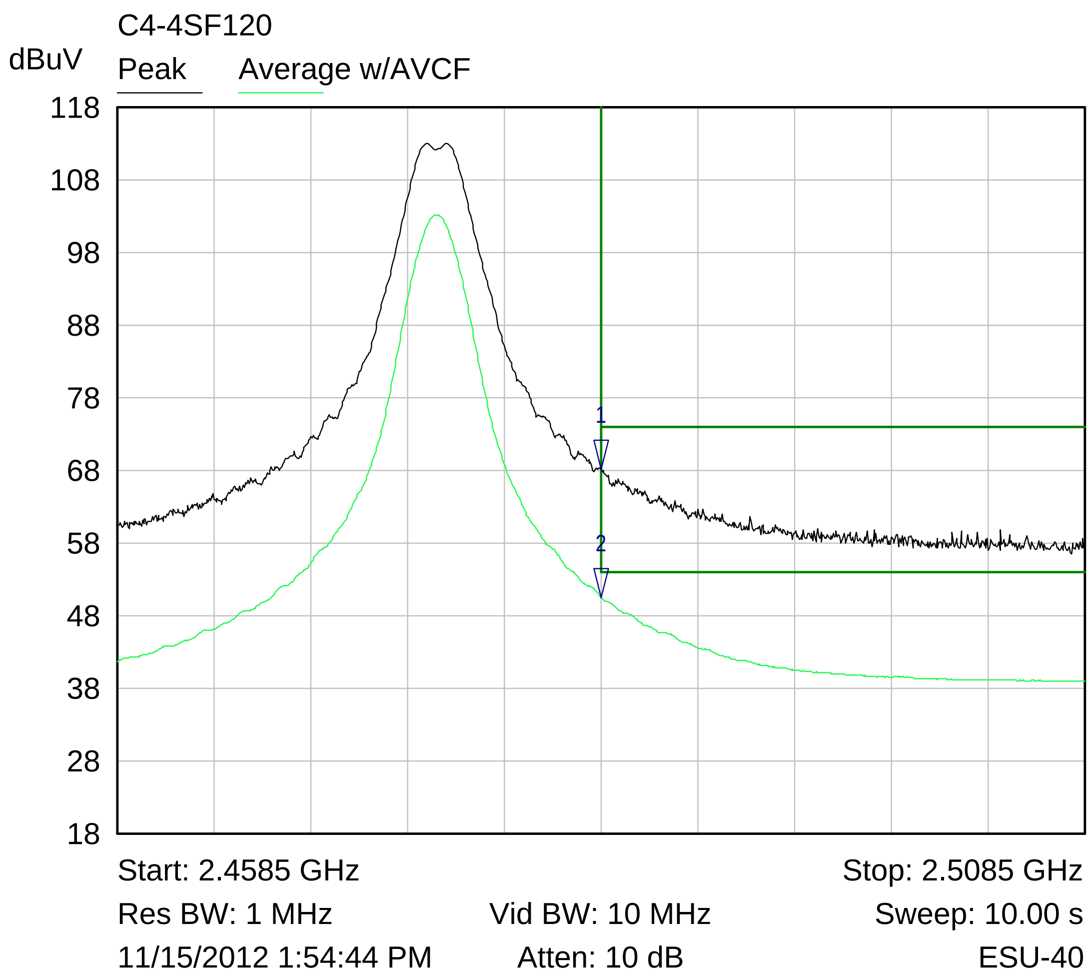
Radiated Lower Band Edge Plot



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.3900 GHz	62.04 dBuV	
2 ▽	Average w/AVCF	2.3900 GHz	43.02 dBuV	

lower band edge power level = +2

Radiated Upper Band Edge Plot



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4835 GHz	68.16 dBuV	
2 ▽	Average w/AVCF	2.4835 GHz	50.55 dBuV	

upper band edge power level = +2

6.2.6 §15.247(d) Peak Power Spectral Density

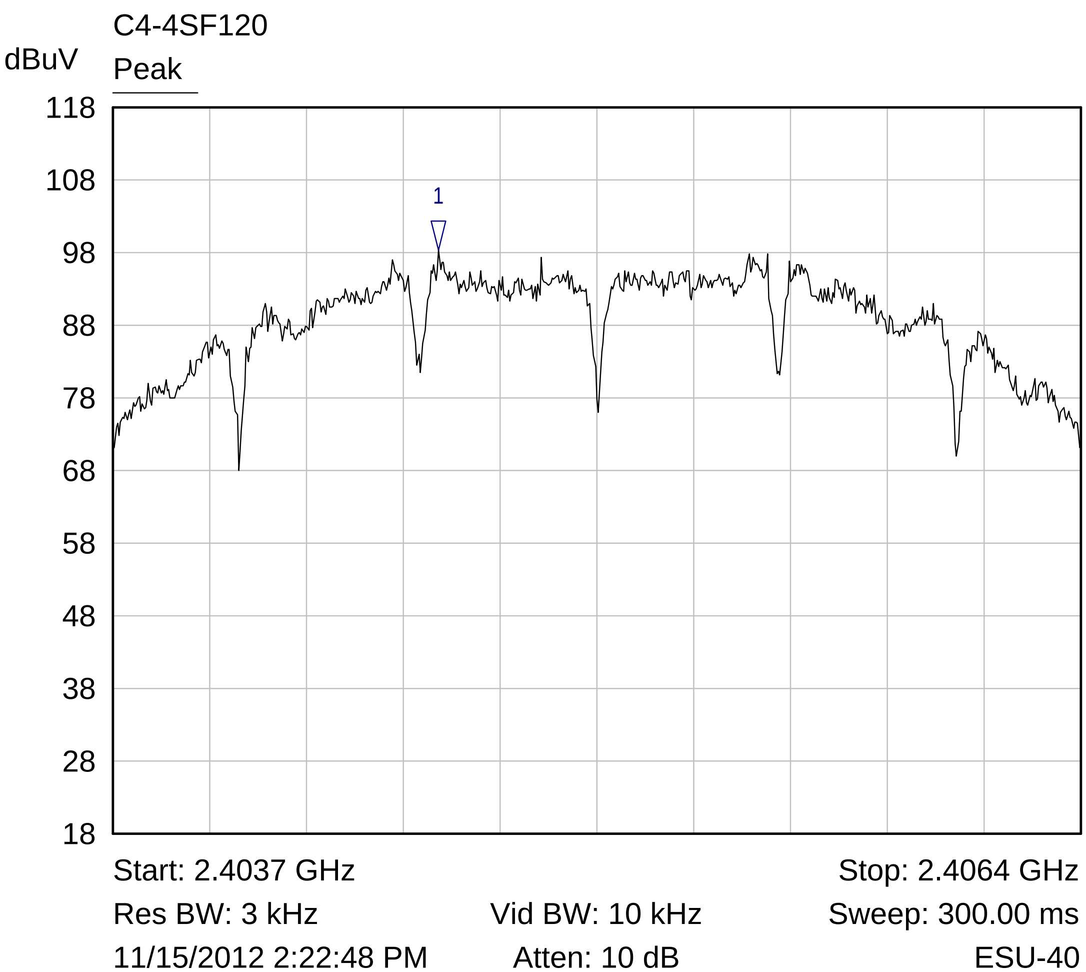
The peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. The maximum peak RF output power was calculated using equation 1.3.1 of KDB 412172 (eirp = $(E \times d)^2 / 30$) to get EIRP in Watts, then Watts was converted to dBm, following the guidance of KDB 558074 paragraph 2.0, the antenna gain in dBi was subtracted to get the maximum transmitter output power in dBm. Parameters used in the calculations are antenna gain equals 0.7 dBi and a measurement distance (d) of 3 meters. E is the measured field strength in V/m. The plots are shown below and the results of this testing are summarized in the table below.

Frequency (MHz)	Radiated Measurement (dBµV/m)	3 kHz Peak Power Spectral Density (dBm)
2405	99.28	3.35
2440	98.00	2.07
2475	97.57	1.64

RESULT

The maximum peak power spectral density was 3.35 dBm. The limit is 8 dBm. The EUT complies with the specification by 4.65 dB.

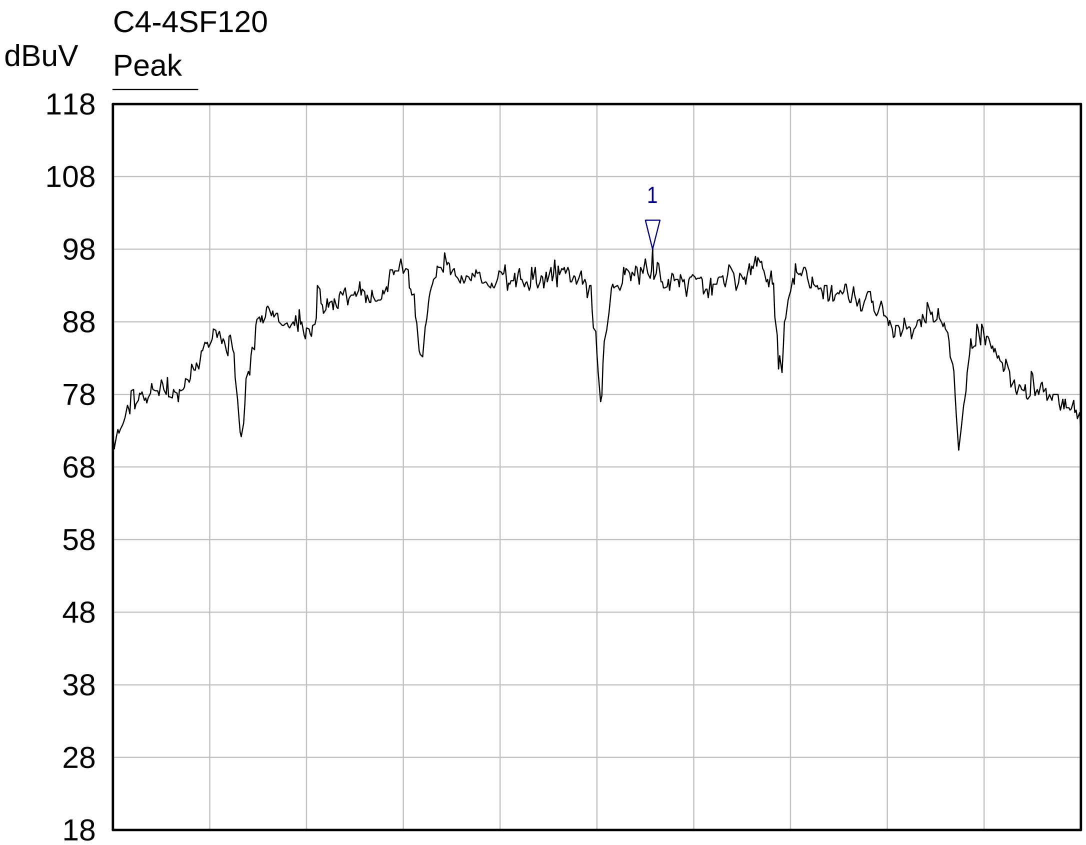
Lowest channel



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4046 GHz	98.25 dBuV	

3 kHz PSD

Middle channel

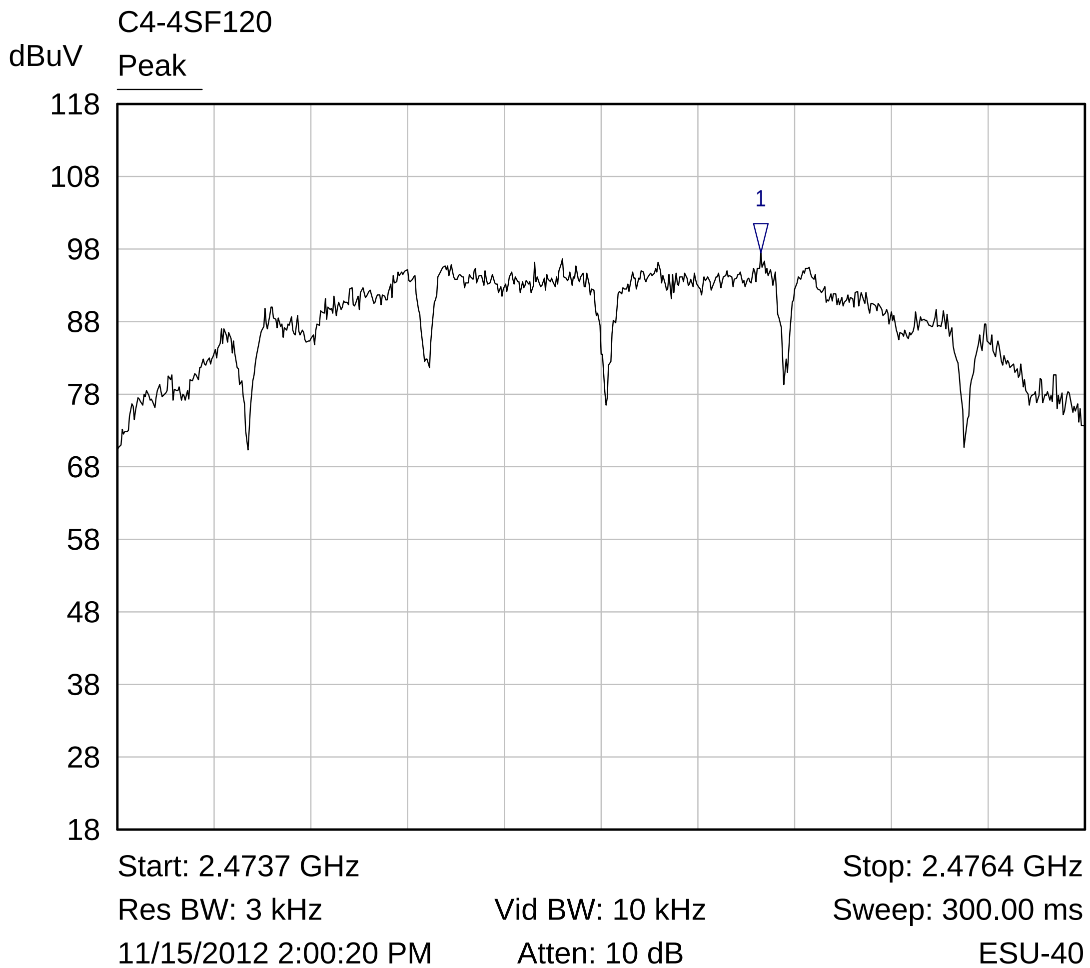


Start: 2.4387 GHz | Stop: 2.4414 GHz
Res BW: 3 kHz | Vid BW: 10 kHz | Sweep: 300.00 ms
11/15/2012 2:39:35 PM | Atten: 10 dB | ESU-40

Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4402 GHz	98.00 dBuV	

3 kHz PSD

Upper channel



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4754 GHz	97.57 dBuV	

3 kHz PSD

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.

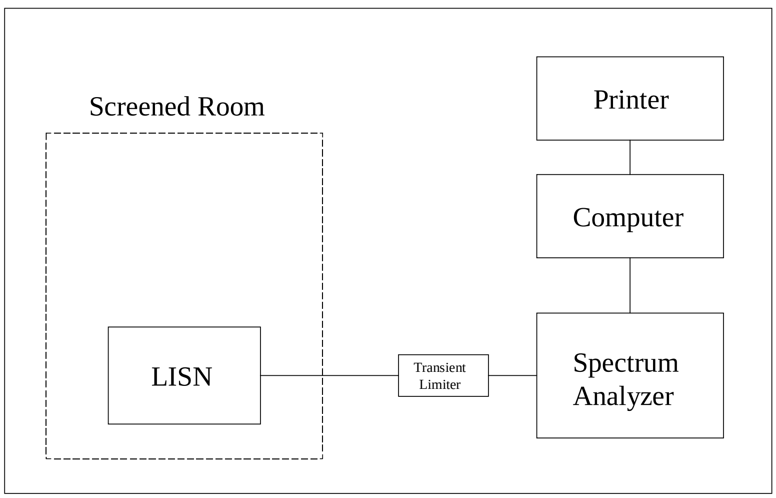
For AC mains port testing, desktop EUT are placed on a non-conducting table at least 0.8 meters from the metallic floor and placed 40 cm from the vertical coupling plane (copper plating in the wall behind EUT table). Floor standing equipment is placed directly on the earth grounded floor.

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	12/07/2012	12/07/2013
Test Software	Nemko-CCL, Inc.	Conducted Emissions	Revision 1.2	N/A	N/A
Spectrum Analyzer	Hewlett Packard	8566B	2332A02726	03/08/2012	03/08/2013
Quasi-Peak Detector	Hewlett Packard	85650A	2043A00287	03/12/2012	03/12/2013

Type of Equipment	Manufacturer	Model Number	Serial Number	Date of Last Calibration	Due Date of Calibration
LISN	EMCO	3825/2	9305-2099	03/12/2012	03/12/2013
Conductance Cable Wanship Site #2	Nemko-CCL, Inc.	Cable J	N/A	12/21/2012	12/21/2013
Transient Limiter	Hewlett Packard	11947A	3107A02266	12/21/2012	12/21/2013

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.

Conducted Emissions Test Setup



A1.2 Radiated Measurements

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 biconilog 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/or 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 EUT was varied to find the maximum radiated emission. The EUT was connected to the peripherals listed in Section 2.3 via the interconnecting cables listed in Section 2.4. A technician manually manipulated these interconnecting cables to obtain worst-case radiated disturbance. The EUT was rotated 360 degrees, and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission. Where there were 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.

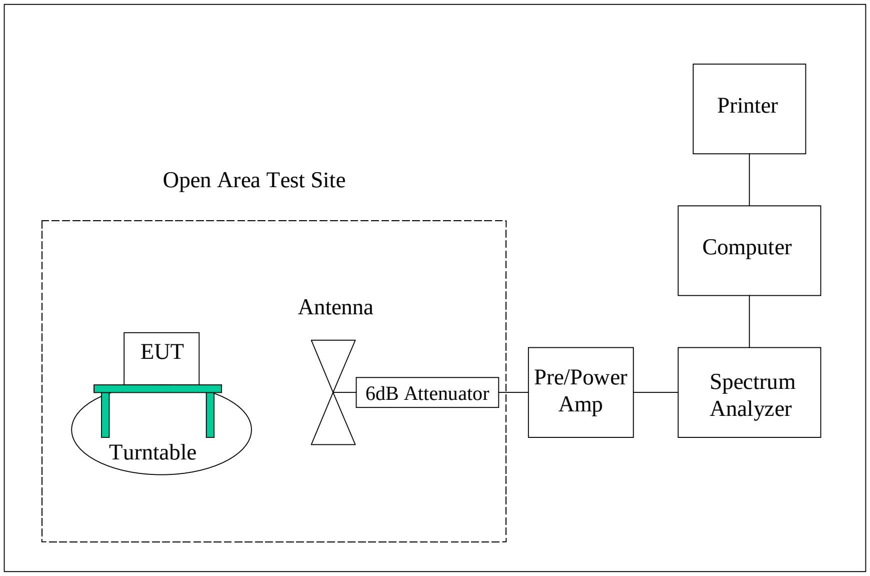
Desktop EUT are measured on a non-conducting table 0.8 meters above the ground plane. The table is placed on a turntable, which is level with the ground plane. For equipment normally placed on floors, the equipment shall be placed directly on the turntable.

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	12/07/2012	12/07/2013
Test Software	Nemko-CCL, Inc.	Radiated Emissions	Revision 1.3	N/A	N/A
Spectrum Analyzer/Receiver	Rhode & Schwarz	ESU40	100064	07/28/2012	07/28/2013
Spectrum Analyzer	Hewlett Packard	8566B	2332A02726	03/08/2012	03/08/2013
Quasi-Peak Detector	Hewlett Packard	85650A	2043A00287	03/12/2012	03/12/2013
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	EMC Test System	3160-09	0003-1197	04/10/2009	ICO
High Frequency Amplifier	Miteq	AFS4-01001800-43-10P-4	1096455	06/26/2012	06/26/2013
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
6 dB Attenuator	Hewlett Packard	8491A	32835	12/21/2012	12/21/2013

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.

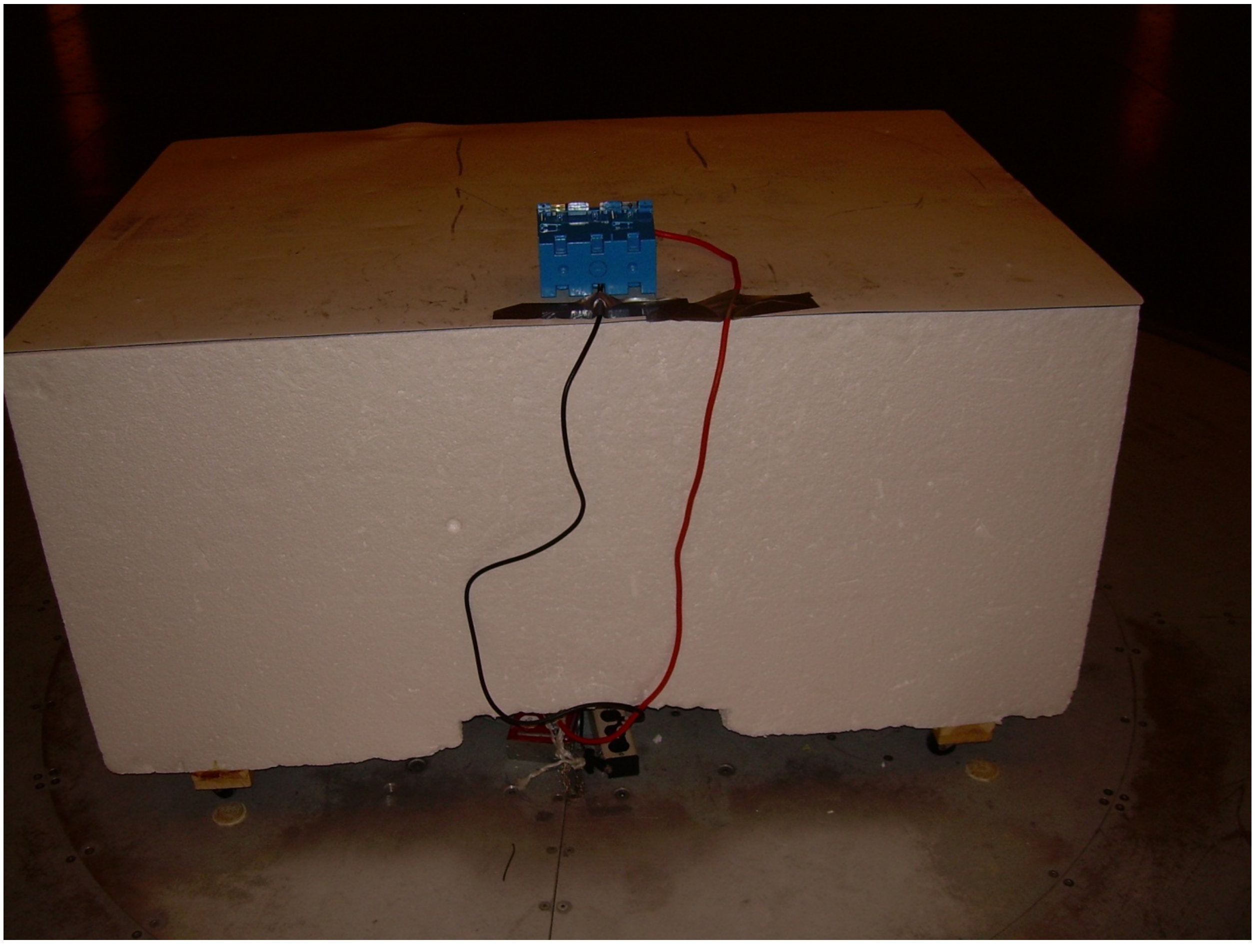
Radiated Emissions Test Setup



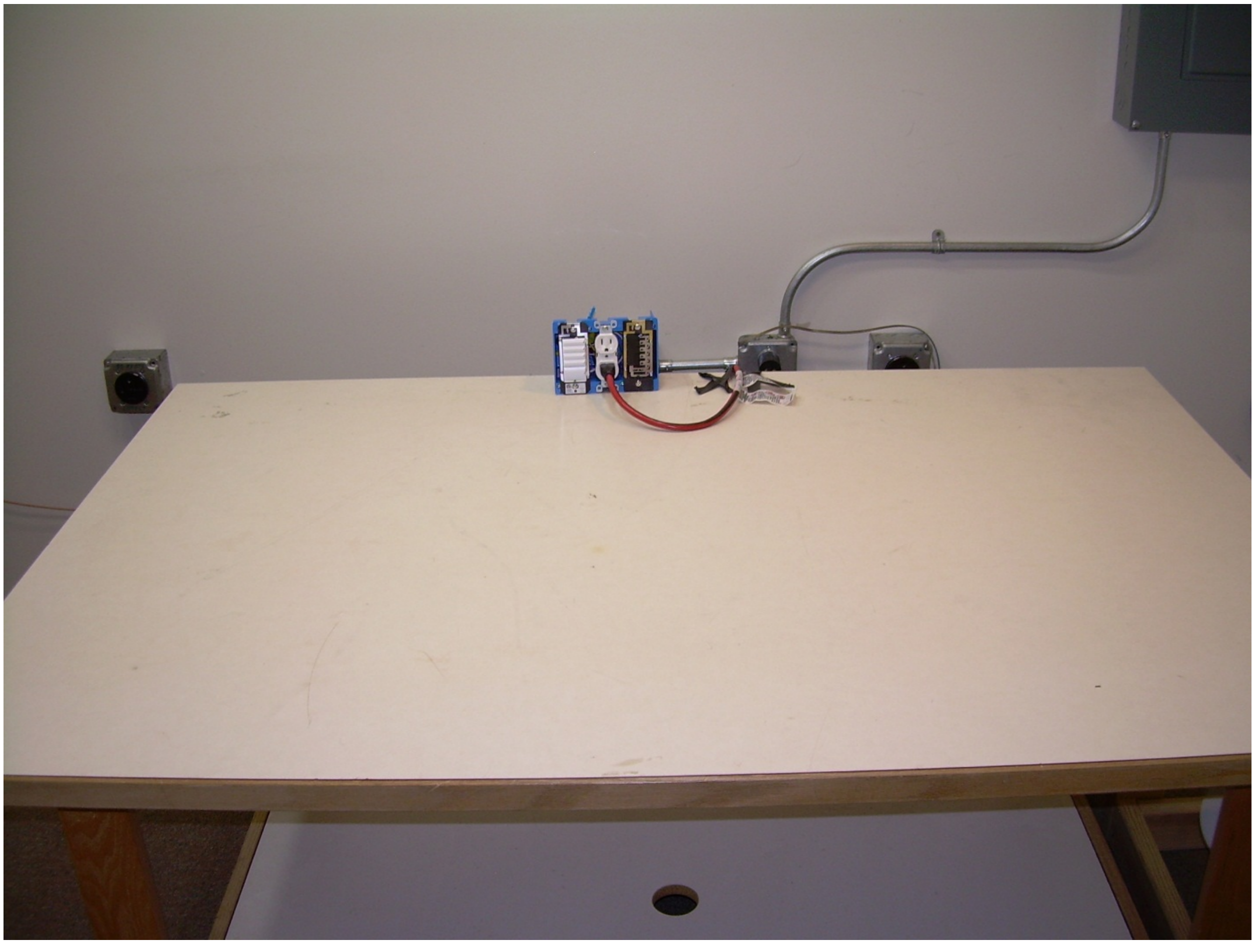
APPENDIX 2 PHOTOGRAPHS

Photograph 1 – Front View Radiated Disturbance Worst Case Configuration

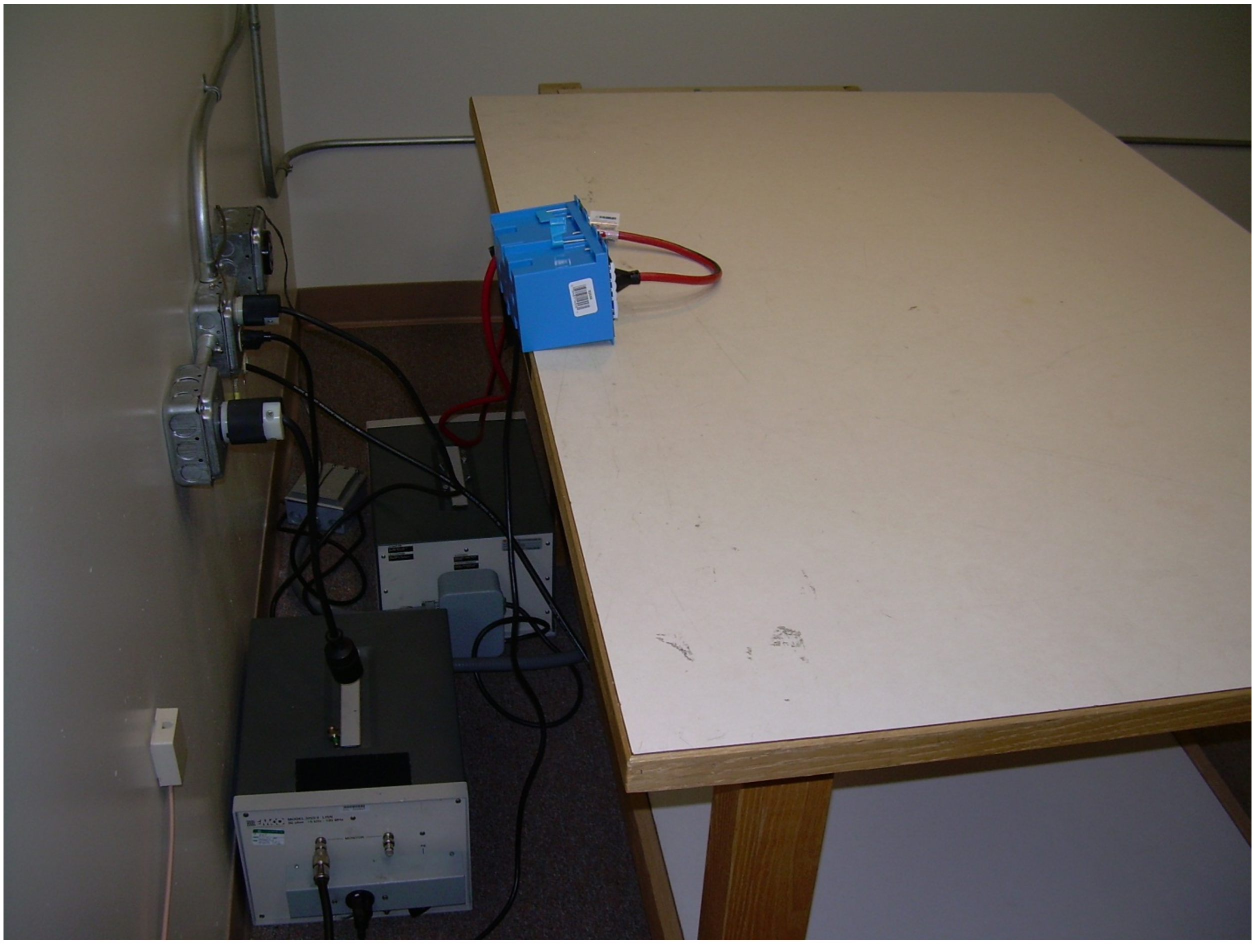
Photograph 2 – Back View Radiated Disturbance Worst Case Configuration



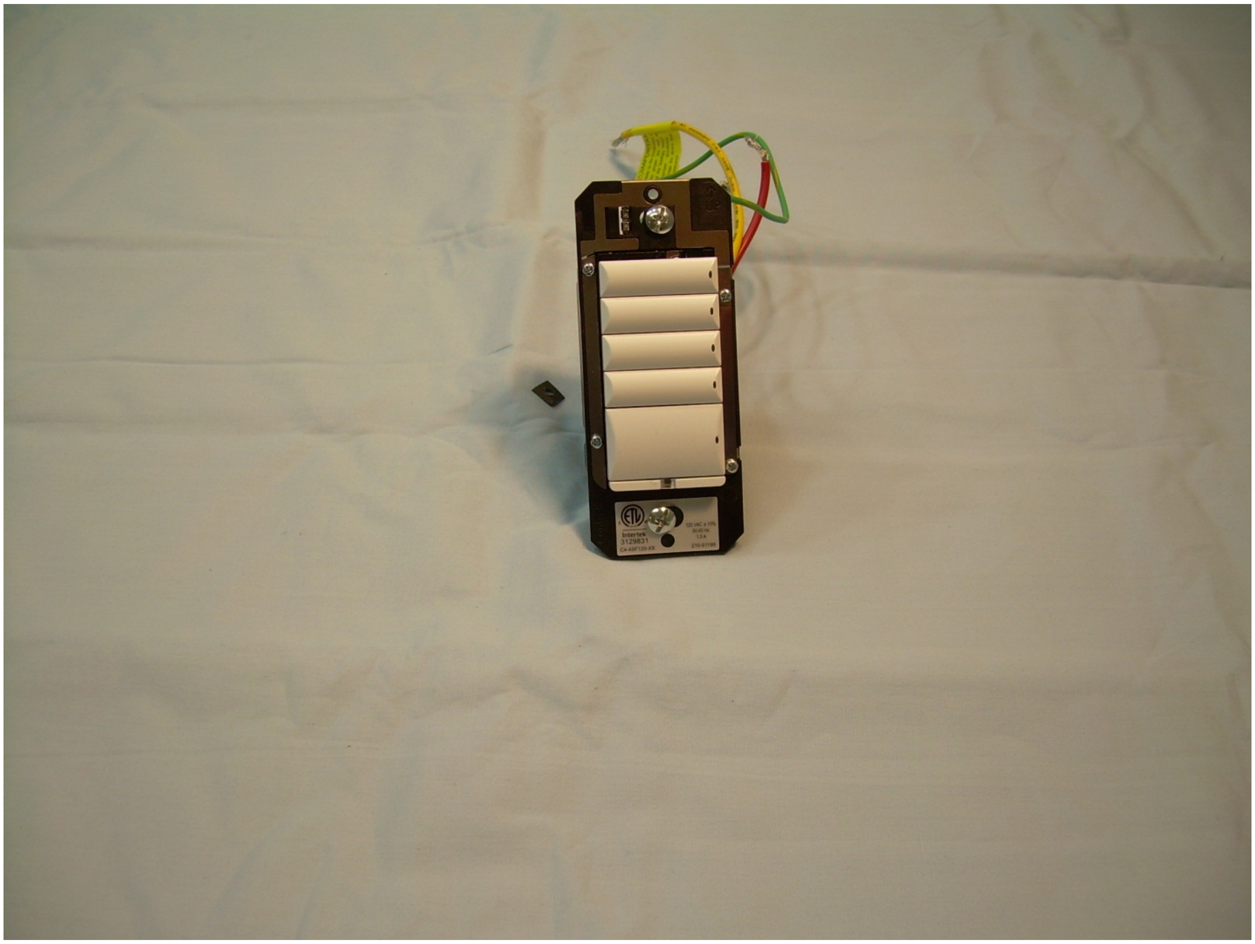
Photograph 3 – Front View Conducted Disturbance Worst Case Configuration



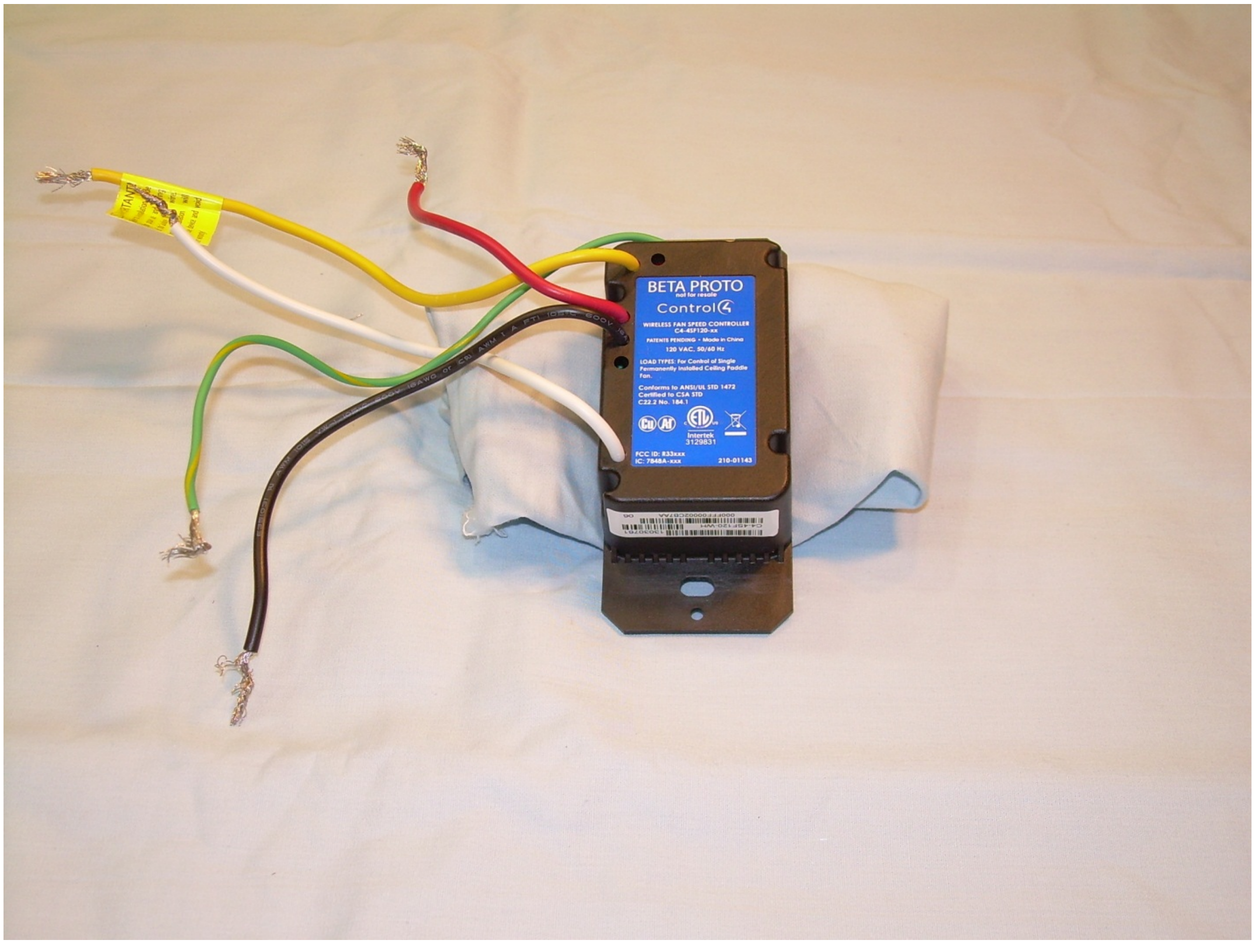
Photograph 4 – Back View Conducted Disturbance Worst Case Configuration



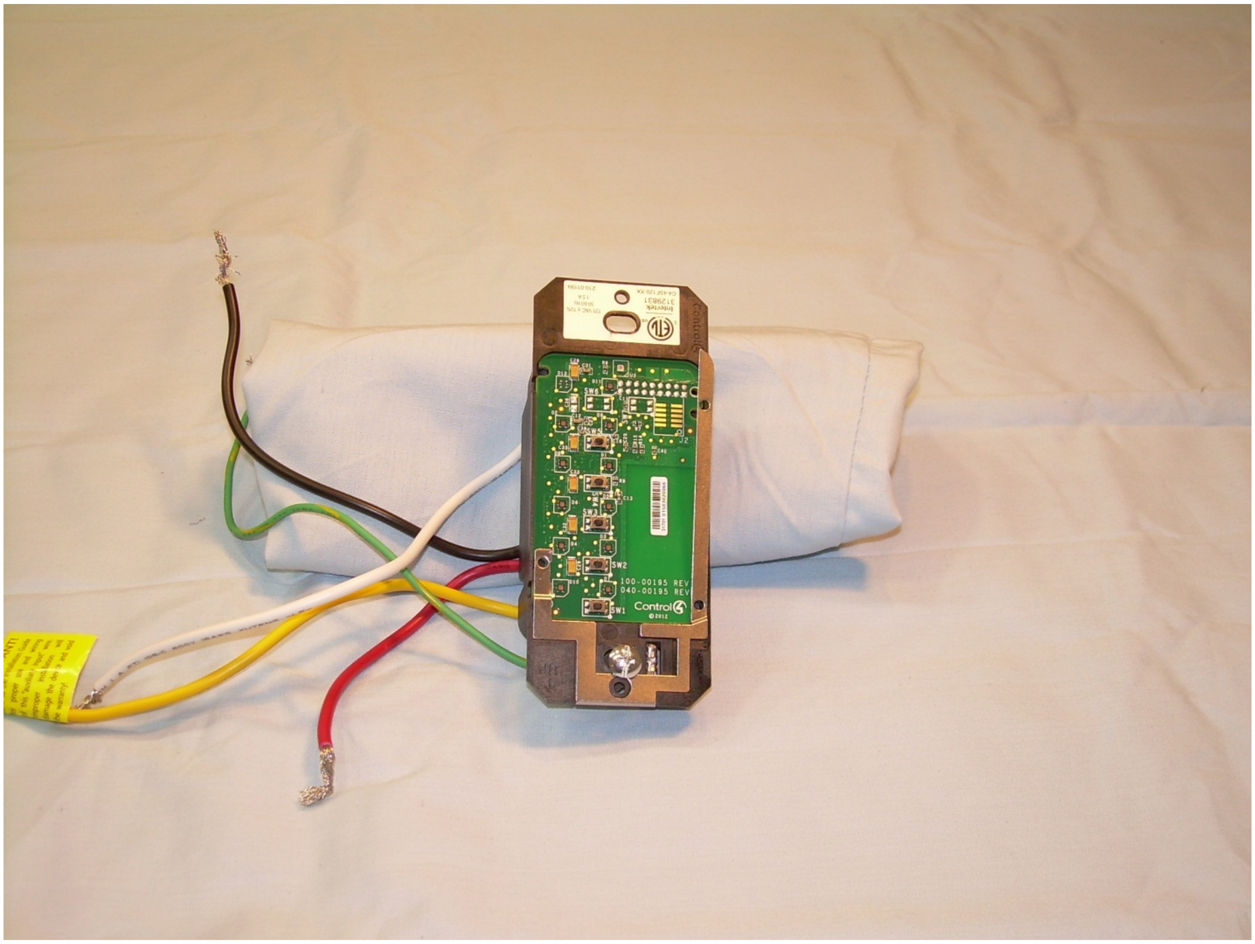
Photograph 5 – Front View of the EUT



Photograph 6 – Back View of the EUT

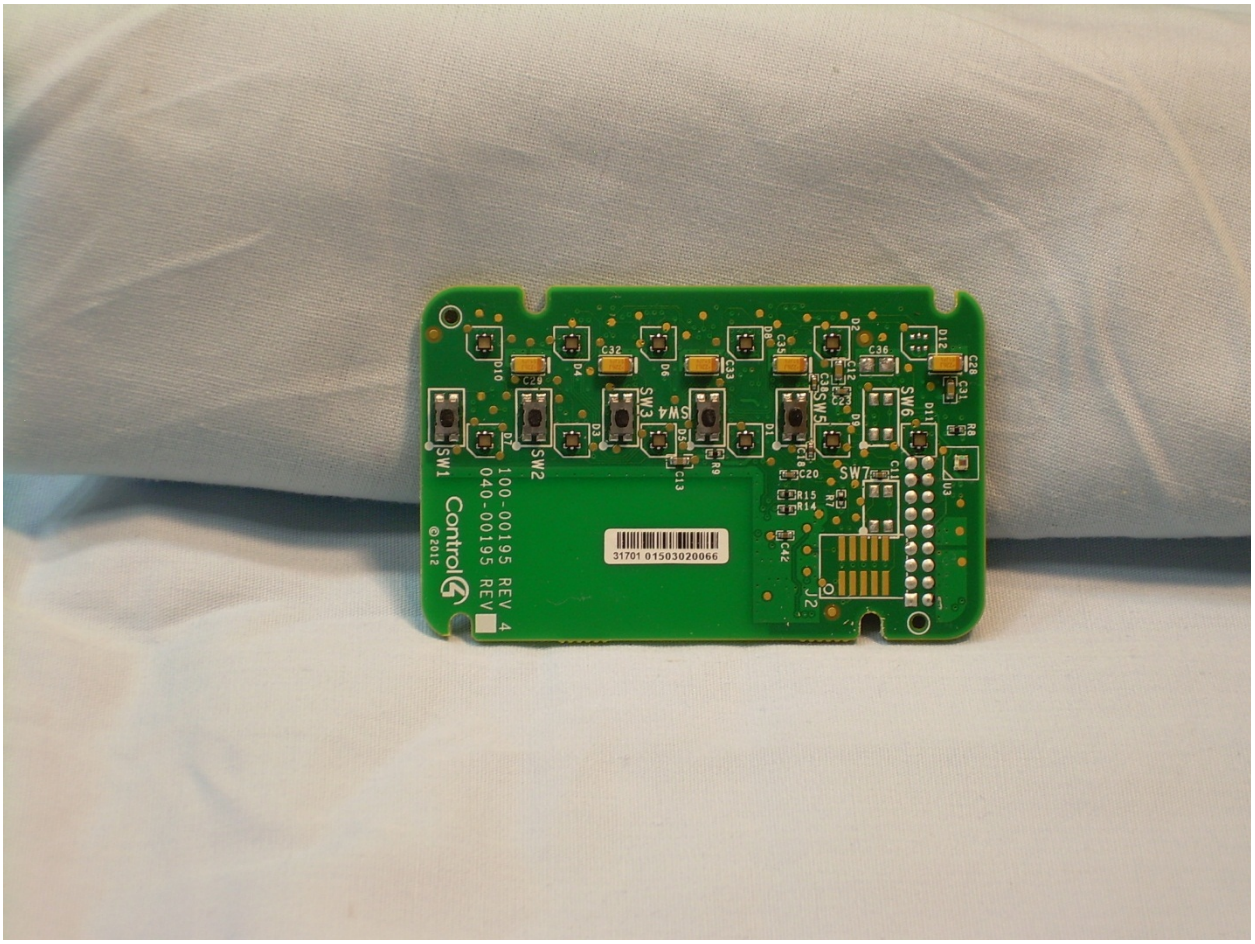


Photograph 7 – View with Front Cover and Buttons Removed

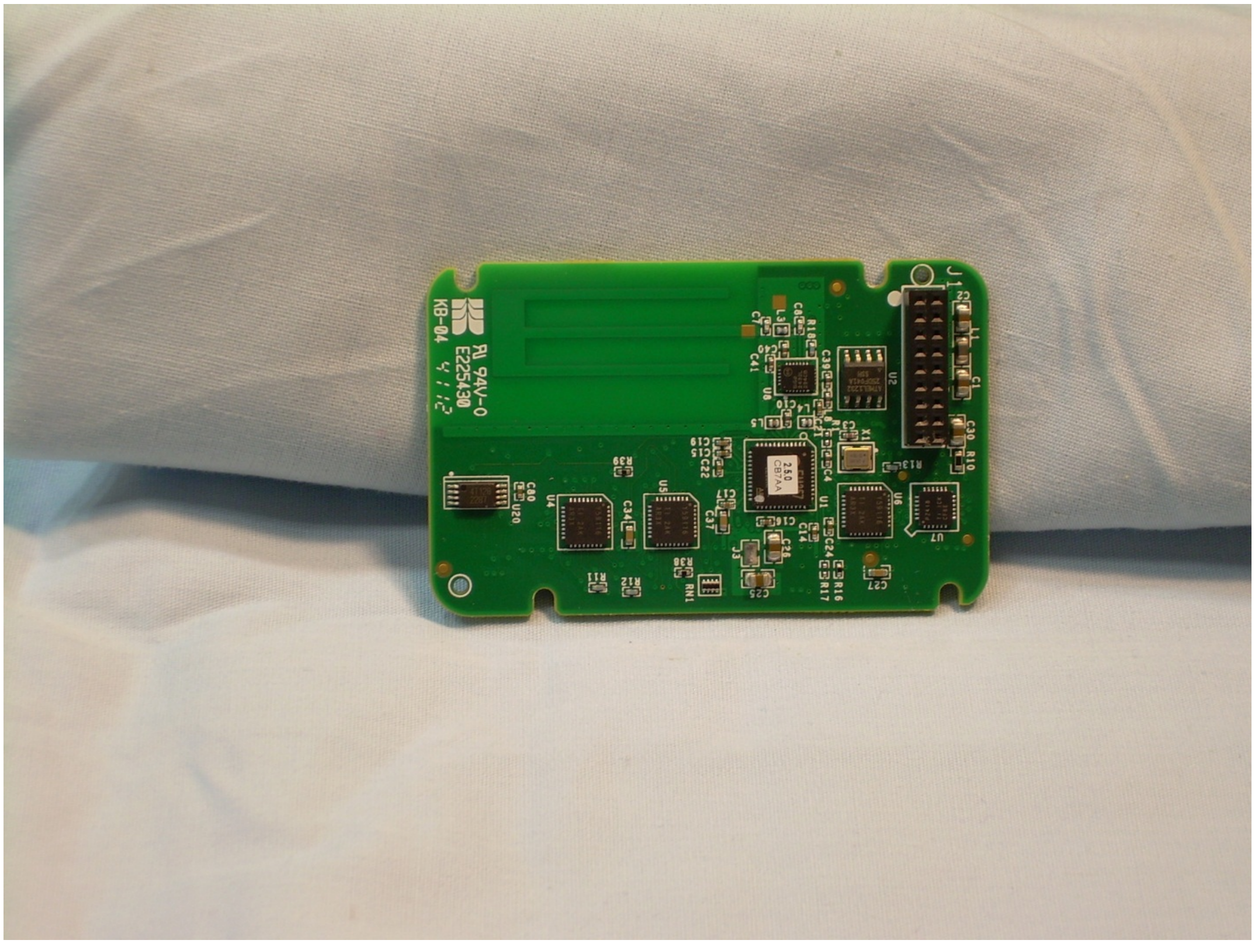


Photograph 8 – Back View of the Front Cover and Button Assembly

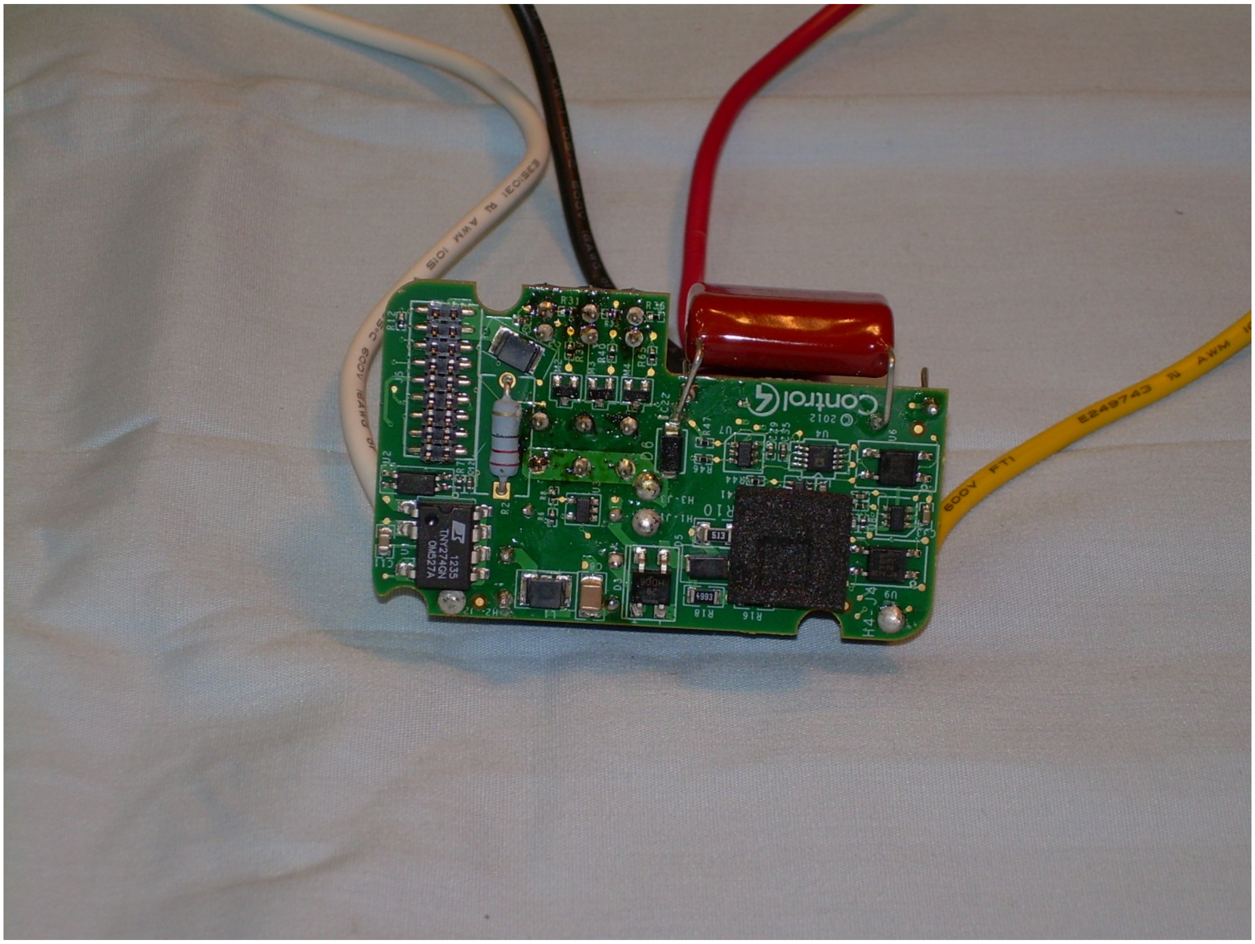
Photograph 9 – Front View of the RF/Switch PCB



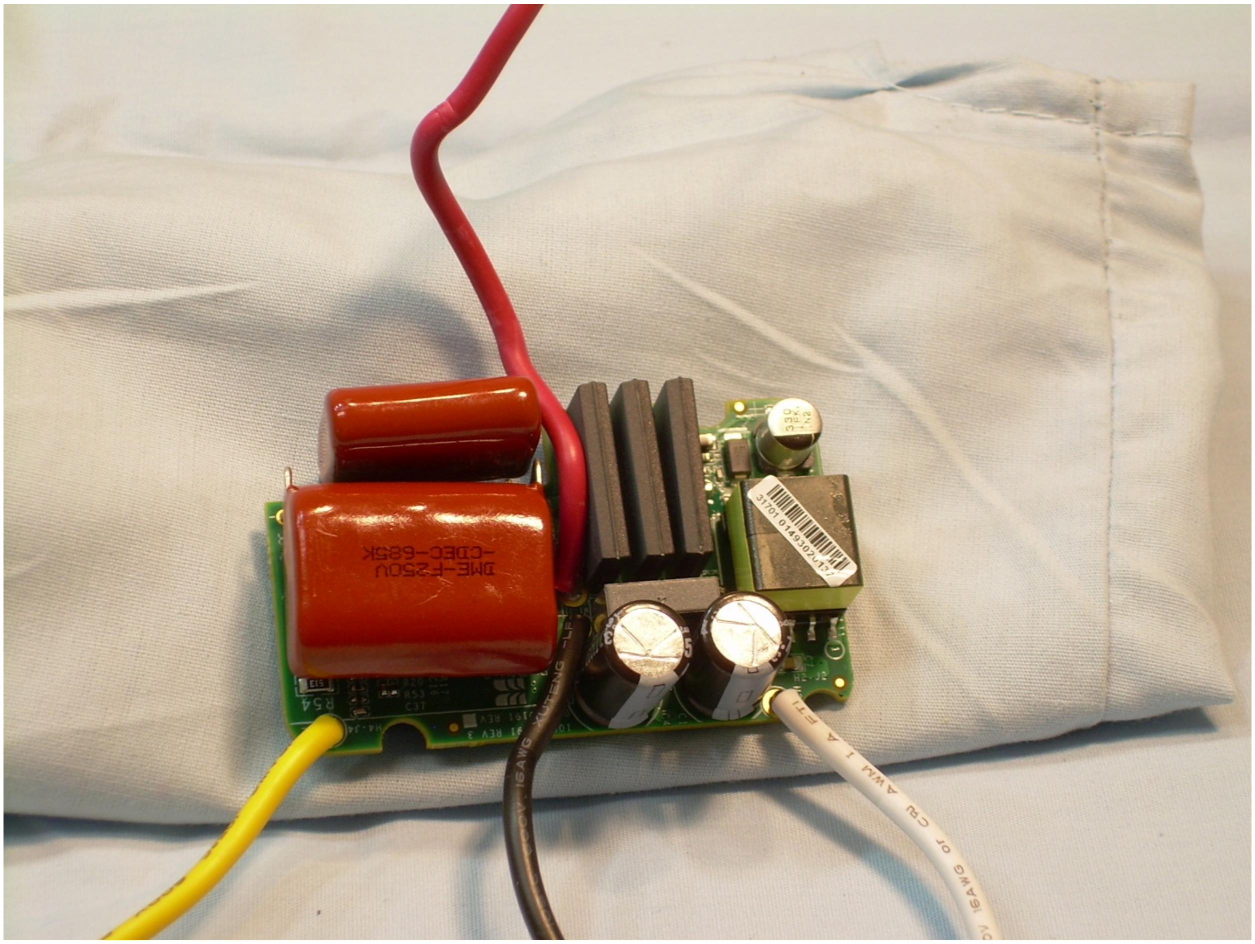
Photograph 10 – Back View of the RF/Switch PCB



Photograph 11 – Front View of the Power Supply/Load PCB



Photograph 12 – Back View of the Power Supply/Load 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	4 Preamble, SPD, Length
Max Length	127	bytes	
Total Packet Length	133	bytes	
Maximum Time TX PKT	0.004256	sec	

Long Frame Scenario:

1) TX Frame — Assume Frame is Data Frame
2) Wait for ACK
3) RX ACK
4) CPU Processing of ACK
5) Wait for Backoff
6) Repeat 1)

MAC-Level Calculation (LIFS)

Long InterFrame Spacing (Slotted w/ ACK)			
Long Frame	127	bytes	
Data Frame Payload	102	bytes	
ACK Frame	5	bytes	
tack	12	sym	
LIFS	40	sym	
Backoff Period	20	sym	
Maximum Backoff	31		Random between 0 and 31
Backoff Required	2		
Backoff Time	300	sym	Average at 15
Transmit Time			
TX Time (Packet)	0.004256		
Total TX Time (sec)	0.004256		
NOT Transmit time (RX or Idle)			
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		
Total Time (ttotal)	**0.01012**	**(0.004256 + 0.005864)**	**MAC TX Duty Cycle (On/Total) = 42.06**

Average Factor = 20 log (0.004256 / 0.01012) = -7.52