



313 West 12800 South, Suite 311
Draper, UT 84020
(801) 260-4040

Test Report

Certification

FCC ID	R33C4EA1POEV2
Equipment Under Test	C4-EA1-POE-V2
Test Report Serial No	V043903_02
Dates of Test	February 5, 6, and 12, 2018
Report Issue Date	February 23, 2018

Test Specifications:	Applicant:
FCC Part 15, Subpart C	Control4 11734 S. Election Road Draper, UT 84020 U.S.A.



Certification of Engineering Report

This report has been prepared by VPI Laboratories, 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 of this report 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-EA1-POE-V2
FCC ID	R33C4EA1POEV2

On this 23rd day of February 2018, I, individually and for VPI Laboratories, 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 accredited the VPI Laboratories, Inc. EMC testing facilities, this report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

VPI Laboratories, Inc.



Tested by: Norman P. Hansen



Reviewed by: Joseph W. Jackson

Revision History		
Revision	Description	Date
01	Original Report Release	February 23, 2018
02	Correct Double Ridge Guide Horn used and calibration	February 27, 2018

Table of Contents

1	Client Information.....	5
1.1	Applicant.....	5
1.2	Manufacturer.....	5
2	Equipment Under Test (EUT).....	6
2.1	Identification of EUT	6
2.2	Description of EUT	6
2.3	EUT and Support Equipment	6
2.4	Interface Ports on EUT	7
2.5	Modification Incorporated/Special Accessories on EUT	7
2.6	Deviation from Test Standard	7
3	Test Specification, Methods and Procedures	8
3.1	Test Specification.....	8
3.2	Methods & Procedures.....	8
3.3	Test Procedure	12
4	Operation of EUT During Testing	13
4.1	Operating Environment.....	13
4.2	Operating Modes.....	13
4.3	EUT Exercise Software.....	13
5	Summary of Test Results	14
5.1	FCC Part 15, Subpart C	14
5.2	Result	14
6	Measurements, Examinations and Derived Results	15
6.1	General Comments.....	15
6.2	Test Results.....	15
7	Test Procedures and Test Equipment.....	31
7.1	Conducted Emissions at Mains Ports.....	31
7.2	Direct Connection at the Antenna Port Tests.....	32
7.3	Radiated Emissions	33
7.4	Equipment Calibration	34
7.5	Measurement Uncertainty	35
8	Photographs	36

1 Client Information

1.1 Applicant

Company Name	Control4 11734 S. Election Road Draper, UT 84020 U.S.A.
Contact Name	Roger Midgley
Title	Sr. Regulatory Compliance Engineer

1.2 Manufacturer

Company Name	Control4 11734 S. Election Road Draper, UT 84020 U.S.A.
Contact Name	Roger Midgley
Title	Sr. Regulatory Compliance Engineer

2 Equipment Under Test (EUT)

2.1 Identification of EUT

Brand Name	Control4
Model Number	C4-EA1-POE-V2
Hardware Version	Revision A
Serial Number	6283
Dimensions (cm)	18.0 x 12.0 x 2.75

2.2 Description of EUT

The C4-EA1-POE-V2 is a controller for Control4's home automation system. The C4-EA1-POE-V2 has two Ethernet ports, HDMI port, USB port, and 4 IR ports. The C4-EA1-POE-V2 receives power from an installer provided POE supply. An 802.15.4 transceiver is used for communication with other devices in the system. The 802.15.4 transceiver uses a Shen Zhen Cos-Link Technology Co., Ltd Model CSL-AN2400-100840-B01 with 2.0 dBi gain.

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 VPI Laboratories, Inc. report V043901.

2.3 EUT and Support Equipment

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

Brand Name Model Number Serial Number	Description	Name of Interface Ports / Interface Cables
BN: Control4 MN: C4-EA1-POE-V2 (Note 1) SN: 2376	Controller	See Section 2.4
BN: Trendnet MN: TE100-S8P SN: 0243C3A16540	Network Switch	Ethernet/Cat 5e cable (Note 2)

Notes: (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 Description/Length
Ethernet/POE	1	Cat 5e cable/7 meters
HDMI	0	HDMI cable/1.5 meters
USB	0	USB A to USB B cable/2 meters
Serial IR	0	2 conductor cables with mono jacks/2 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.

- The maximum power setting for channels 11 – 24 was set to +2. The maximum power setting for channel 25 was set at -6. These maximum settings will be incorporated in manufacturing and the user will have no access to the settings

2.6 Deviation from Test Standard

There were no deviations from the test specification.

3 Test Specification, Methods and 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 as shown in paragraphs (b) and (c) of this section, for an intentional radiator 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 μ 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 boundary between the frequency ranges.

Frequency range (MHz)	Limit (dB μ V)	
	Quasi-peak	Average
0.15 to 0.50*	66 to 56*	56 to 46*
0.50 to 5	56	46
5 to 30	60	50

*Decreases with the logarithm of the frequency.

Table 1: Limits for conducted emissions at mains ports of Class B ITE.

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

- 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 staff 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 C63.10-2013, KDB 558074 DTS Meas Guidance v04, and 47 CFR Part 15. Testing was performed at the VPI Laboratories, Inc. Wanship Upper Open Area Test Site, located at 29145 Old Lincoln Highway, Wanship, UT. VPI Laboratories, Inc. is accredited by National Voluntary Laboratory Accreditation Program (NVLAP); NVLAP Lab Code: 100272-0, which is effective until September 30, 2018. VPI Laboratories, Inc. carries FCC Accreditation Designation Number US5263.

4 Operation of EUT During Testing

4.1 Operating Environment

Power Supply	120 VAC/60 Hz to POE supply/48 VDC from POE supply to EUT
---------------------	---

4.2 Operating Modes

The transmitter was tested while in a constant transmit mode at the upper, middle, and lower channels. Channel 24 was also tested as it was the upper channel of the channels with higher power setting than channel 25. The voltage was varied as required by §15.31(e) with no change seen in transmitter characteristics.

4.3 EUT Exercise Software

Firmware version 2.10.1.544795 was used to exercise the EUT.

5 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	2400 to 2483.5	Complied
15.247(b)	Peak Output Power	2400 to 2483.5	Complied
15.247(d)	Antenna Conducted Spurious Emissions	0.009 - 25000	Complied
15.247(d)	Radiated Spurious Emissions	0.009 - 25000	Complied
15.247(e)	Peak Power Spectral Density	2400 to 2483.5	Complied

5.2 Result

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

6 Measurements, Examinations and Derived 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 Section 7 of this report.

6.2 Test Results

6.2.1 §15.203 Antenna Requirements

The EUT uses a Shen Zhen Cos-Link Technology Co., Ltd Model CSL-AN2400-100840-B01. The antenna uses a RP-SMA connector and the EUT is professionally installed. The antenna gain is 2 dBi.

Result

The EUT complied with the specification.

6.2.2 Conducted Emissions at Mains Ports Data

(Hot Lead)

Frequency (MHz)	Detector	Measured Level (dBμV)	Limit (dBμV)	Margin (dB)
0.45	Peak (Note 1)	41.6	46.9	-5.3
1.73	Peak (Note 1)	40.2	46.0	-5.8
1.98	Peak (Note 1)	41.2	46.0	-4.8
2.38	Peak (Note 1)	41.9	46.0	-4.1
2.50	Peak (Note 1)	42.5	46.0	-3.5
2.60	Peak (Note 1)	42.1	46.0	-3.9
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 limit by a margin of 3.5 dB.

(Neutral Lead)

Frequency (MHz)	Detector	Measured Level (dBμV)	Limit (dBμV)	Margin (dB)
0.15	Quasi-Peak (Note 1)	51.8	56.0	-4.2
0.18	Peak (Note 1)	51.4	54.5	-3.1
0.45	Peak (Note 1)	41.0	46.9	-5.9
2.37	Peak (Note 1)	41.4	46.0	-4.6
2.63	Peak (Note 1)	41.5	46.0	-4.5
2.83	Peak (Note 1)	40.6	46.0	-5.4

Frequency (MHz)	Detector	Measured Level (dB μ V)	Limit (dB μ V)	Margin (dB)
<p>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.</p> <p>Note 2: The reference detector used for the measurements was quasi-peak and average and the data was compared to the respective limits.</p>				

Result

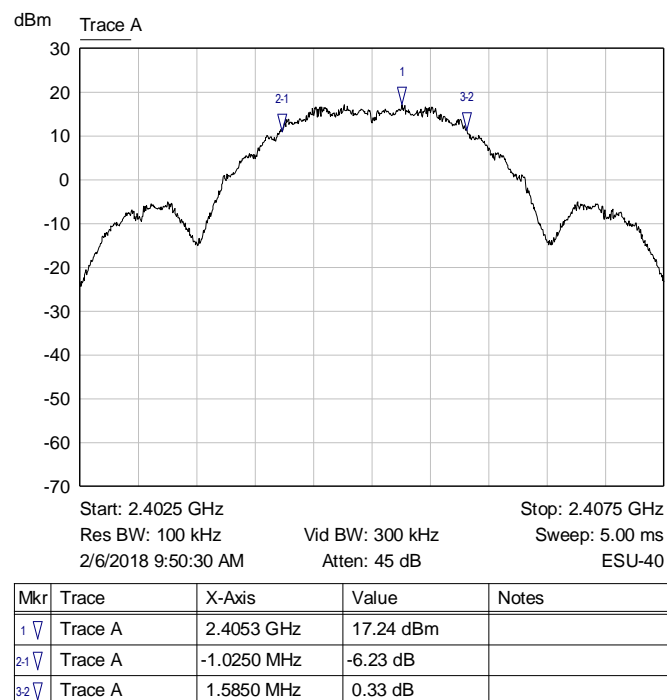
The EUT complied with the specification limit by a margin of 3.1 dB.

6.2.3 §15.247(a)(2) Emissions Bandwidth

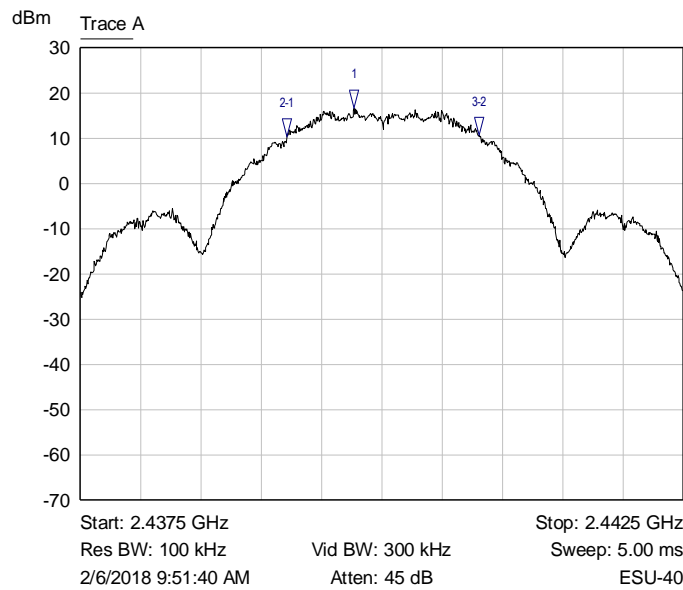
Frequency (MHz)	Emissions 6 dB bandwidth (kHz)
2405	1585.0
2440	1595.0
2470	1595.0
2475	1595.0

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).

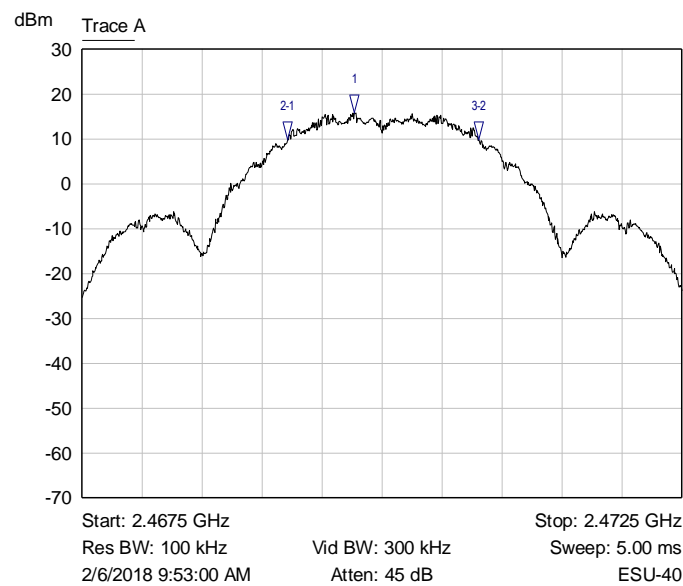


Graph 1: Lowest Channel Bandwidth (2405 MHz)



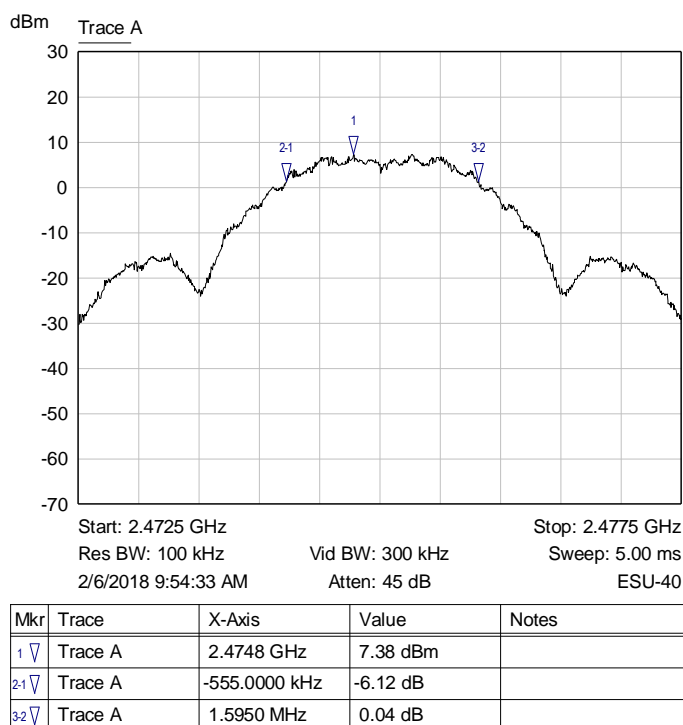
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4398 GHz	16.61 dBm	
2-1 ▽	Trace A	-560.0000 kHz	-6.34 dB	
3-2 ▽	Trace A	1.5950 MHz	0.43 dB	

Graph 2: Middle Channel Bandwidth (2440 MHz)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4698 GHz	15.86 dBm	
2-1 ▽	Trace A	-560.0000 kHz	-6.07 dB	
3-2 ▽	Trace A	1.5950 MHz	0.01 dB	

Graph 3: Channel 24 Bandwidth (2470 MHz)



Graph 4: Highest Channel Bandwidth (2475 MHz)

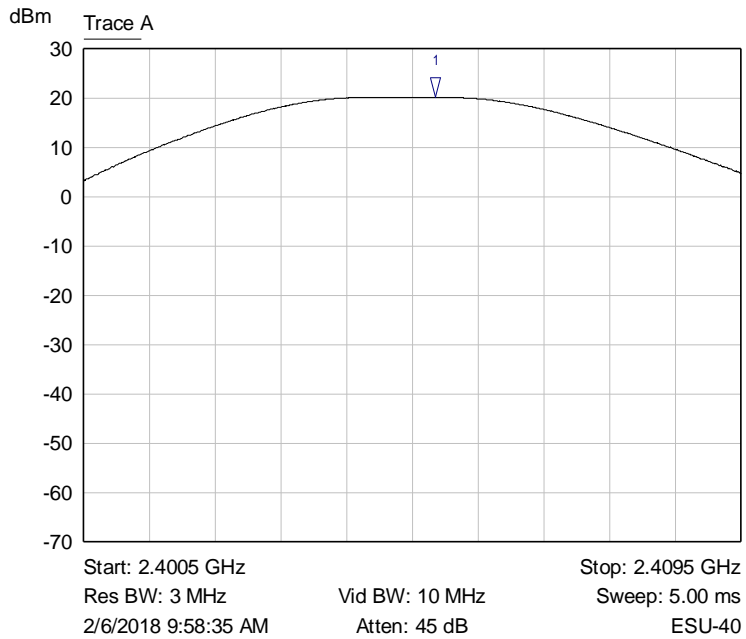
6.2.4 §15.247(b)(3) Peak Output Power

The maximum peak RF Conducted output power measured for this device was 20.21 dBm or 104.95 mW. The limit is 30 dBm or 1 Watt when using antennas with 6 dBi or less gain. The antenna has a gain of 2.0 dBi.

Frequency (MHz)	Measured Output Power (dBm)	Output Power (mW)
2405	20.21	104.95
2440	19.81	95.72
2470	19.32	85.51
2475	10.93	12.39

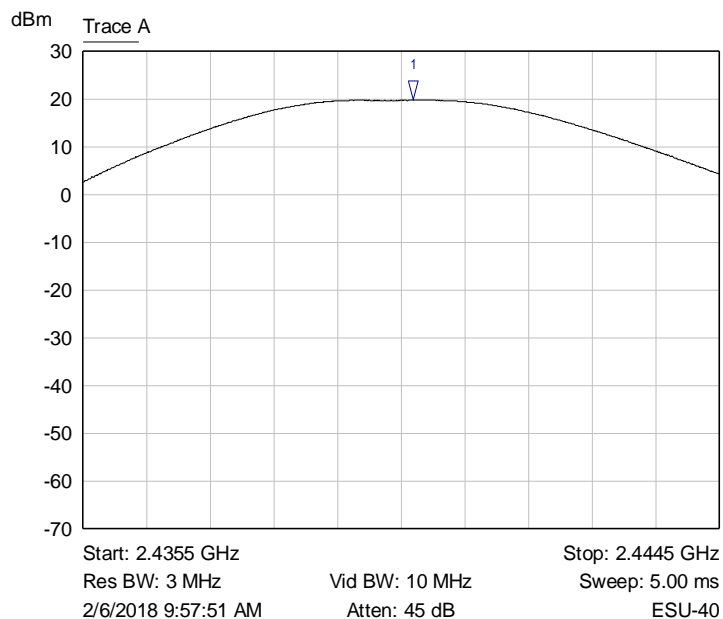
Result

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).



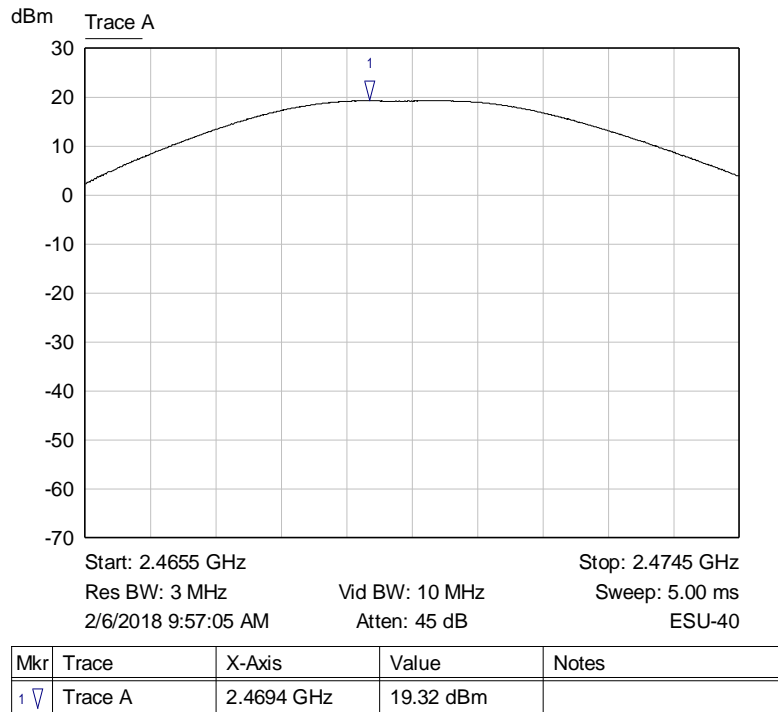
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4053 GHz	20.21 dBm	

Graph 5: Lowest Channel Output Power Plot (2405 MHz)

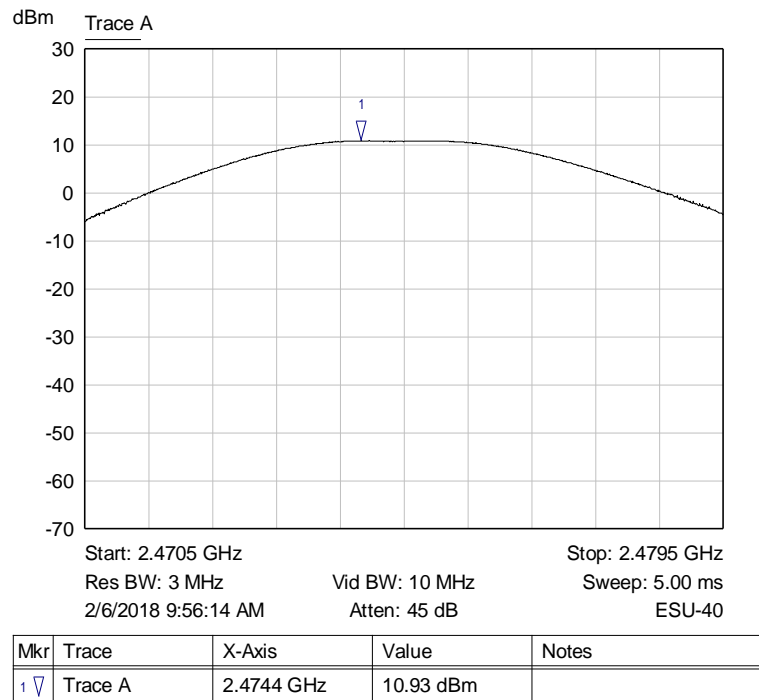


Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4402 GHz	19.81 dBm	

Graph 6: Middle Channel Output Power (2440 MHz)



Graph 7: Channel 24 Output Power (2470 MHz)



Graph 8: Highest Channel Output Power Plot (2475 MHz)

6.2.5 §15.247(d) Spurious Emissions

Conducted Spurious Emissions

The frequency range from the lowest frequency generated or 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, channel 24, and upper frequency. Shown below are 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 power measured from Channel 11 to Channel 24 was 14.85 dBm; therefore, the criteria is $14.85 - 20 = -2.76$ dBm. Channel 25 had a maximum power of 7.38 dBm; therefore, the criteria is $7.38 - 20 = -12.62$.

Result

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

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4810.0	-43.9	-2.8	-41.1
7215.0	-47.9	-2.8	-45.1
9620.0	-48.5	-2.8	-45.7
12025.0	-47.9	-2.8	-45.1
14430.0	-48.50	-2.8	-45.7
16835.0	-47.6	-2.8	-44.8
19240.0	-47.5	-2.8	-44.7
21645.0	-48.2	-2.8	-45.4
24050.0	-48.3	-2.8	-45.5

Table 2: Transmitting on the Lowest Channel (2405 MHz)

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4880.0	-44.6	-2.8	-41.8
7320.0	-48.3	-2.8	-45.5
9760.0	-48.6	-2.8	-45.8
12200.0	-48.7	-2.8	-45.9
14640.0	-48.2	-2.8	-45.4
17080.0	-48.7	-2.8	-45.9
19520.0	-47.9	-2.8	-45.1

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
21960.0	-48.3	-2.8	-45.5
24400.0	-47.0	-2.8	-44.2

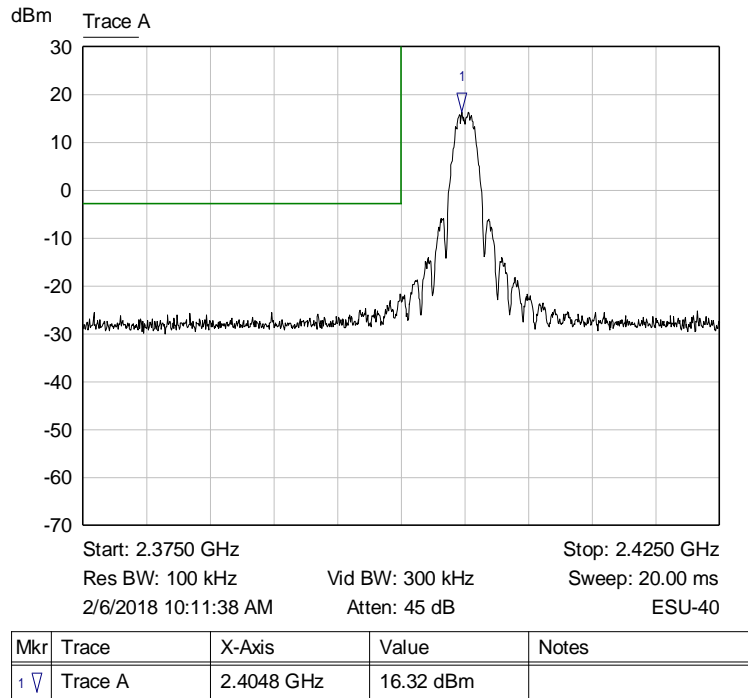
Table 3: Transmitting on the Middle Channel (2440 MHz)

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4940.0	-40.9	-2.8	-38.1
7410.0	-48.2	-2.8	-45.4
9880.0	-49.0	-2.8	-46.2
12350.0	-46.9	-2.8	-44.1
14820.0	-48.3	-2.8	-45.5
17290.0	-48.3	-2.8	-45.5
19760.0	-48.6	-2.8	-45.8
22230.0	-48.0	-2.8	-45.2
24700.0	-47.7	-2.8	-44.9

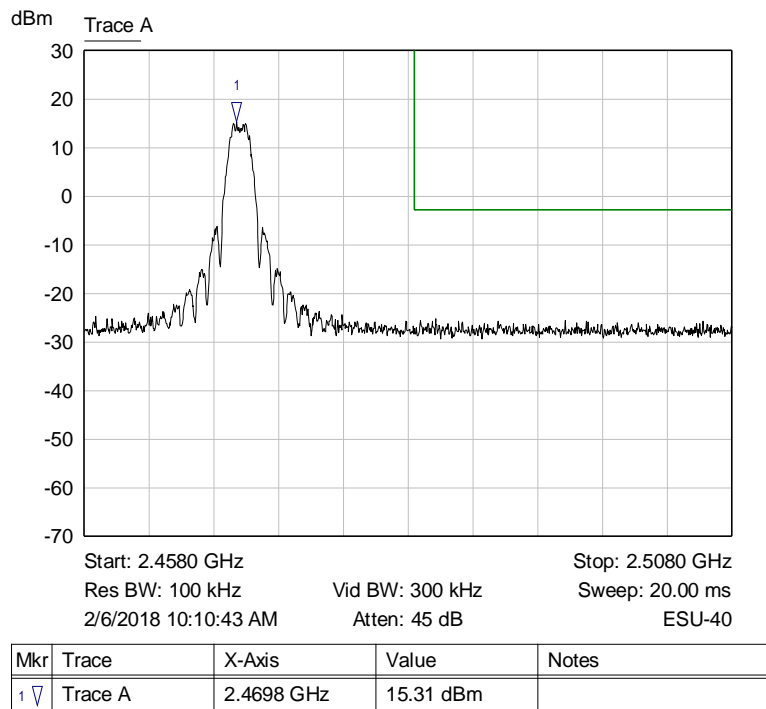
Table 4: Transmitting on the Channel 24 (2470 MHz)

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
4950.0	-47.2	-12.6	-34.6
7425.0	-48.6	-12.6	-36.0
9900.0	-49.1	-12.6	-36.5
12375.0	-48.6	-12.6	-36.0
14850.0	-48.5	-12.6	-35.9
17325.0	-47.8	-12.6	-35.2
19800.0	-48.2	-12.6	-35.6
22275.0	-48.3	-12.6	-35.7
24750.0	-48.3	-12.6	-35.7

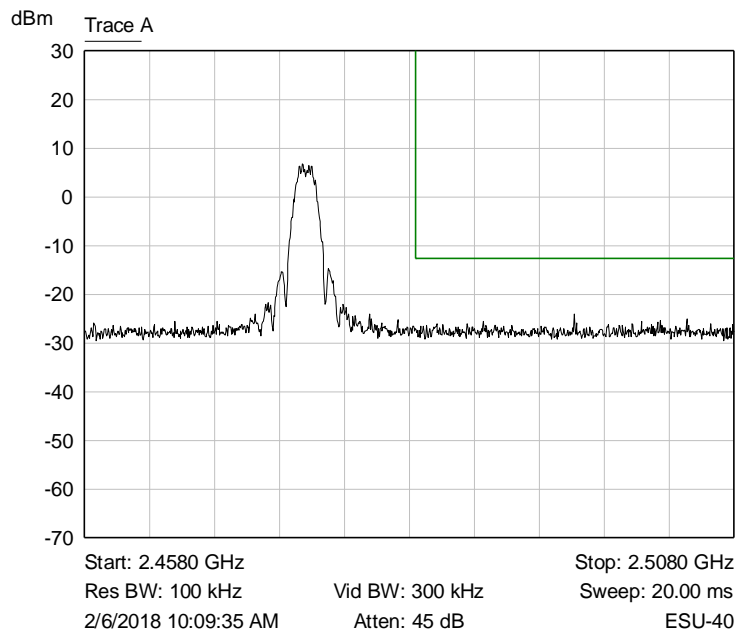
Table 5: Transmitting on the Highest Channel (2475 MHz)



Graph 9: Lower Band Edge Plot (2405 MHz)



Graph 10: Upper Band Edge Plot (2470 MHz)



Graph 11: Upper Band Edge Plot (2475 MHz)

Radiated Spurious Emissions in the Restricted Bands of §15.205

The frequency range from the lowest frequency generated or used in the device to the tenth harmonic of the highest fundamental emission 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 18.0 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. All testing was done with a power setting of +2, including channel 25. Plots of the band edges are also shown. The band edge plots were done with the maximum allowed power setting for the frequency transmitting, -6 for channel 25 and +2 for all other channels.

Result

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

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4810.0	Peak	Vertical	14.7	39.8	54.5	74.0	-19.5
4810.0	Average	Vertical	7.2	39.8	47.0	54.0	-7.0
4810.0	Peak	Horizontal	11.1	39.8	50.9	74.0	-23.1
4810.0	Average	Horizontal	4.2	39.8	44.0	54.0	-10.0
7320.0	Peak	Vertical	15.0	44.6	59.6	74.0	-14.4
7320.0	Average	Vertical	6.1	44.6	50.7	54.0	-3.3

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
7320.0	Peak	Horizontal	9.8	44.6	54.4	74.0	-19.6
7320.0	Average	Horizontal	1.9	44.6	46.5	54.0	-7.5
12025.0	Peak	Vertical	4.3	50.4	54.7	74.0	-19.3
12025.0	Average	Vertical	-5.7	50.4	44.7	54.0	-9.3
12025.0	Peak	Horizontal	2.0	50.4	52.4	74.0	-21.6
12025.0	Average	Vertical	-9.8	50.4	40.6	54.0	-13.4
14430.0	Peak	Vertical	1.7	54.0	55.7	74.0	-18.3
14430.0	Average	Vertical	-9.7	54.0	44.3	54.0	-9.7
14430.0	Peak	Horizontal	1.5	54.0	55.5	74.0	-18.5
14430.0	Average	Vertical	-10.4	54.0	43.6	54.0	-10.4

Table 6: Transmitting at the Lowest Frequency

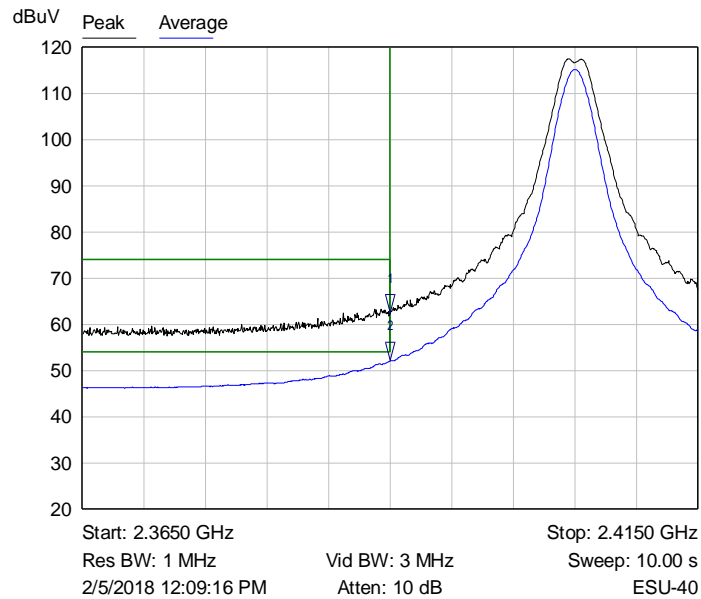
Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4880.0	Peak	Vertical	15.0	40.0	55.0	74.0	-19.0
4880.0	Average	Vertical	7.8	40.0	47.8	54.0	-6.2
4880.0	Peak	Horizontal	10.6	40.0	50.6	74.0	-23.4
4880.0	Average	Horizontal	4.3	40.0	44.3	54.0	-9.7
7320.0	Peak	Vertical	9.7	45.0	54.7	74.0	-19.3
7320.0	Average	Vertical	0.7	45.0	45.7	54.0	-8.3
7320.0	Peak	Horizontal	7.6	45.0	52.6	74.0	-21.4
7320.0	Average	Horizontal	-3.4	45.0	41.6	54.0	-12.4
12200.0	Peak	Vertical	4.7	50.3	55.0	74.0	-19.0
12200.0	Average	Vertical	-5.1	50.3	45.2	54.0	-8.8
12200.0	Peak	Horizontal	2.6	50.3	52.9	74.0	-21.1
12200.0	Average	Vertical	-7.9	50.3	42.4	54.0	-11.6
14640.0	Peak	Vertical	2.0	53.7	55.7	74.0	-18.3
14640.0	Average	Vertical	-10.4	53.7	43.3	54.0	-10.7
14640.0	Peak	Horizontal	1.5	53.7	55.2	74.0	-18.8
14640.0	Average	Vertical	-10.4	53.7	43.3	54.0	-10.7

Table 7: Transmitting at the Middle Frequency

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4950.0	Peak	Vertical	15.0	40.2	55.2	74.0	-18.8
4950.0	Average	Vertical	7.8	40.2	48.0	54.0	-6.0
4950.0	Peak	Horizontal	10.6	40.2	50.8	74.0	-23.2
4950.0	Average	Horizontal	2.4	40.2	42.6	54.0	-11.4
7425.0	Peak	Vertical	11.4	45.3	56.7	74.0	-17.3
7425.0	Average	Vertical	2.8	45.3	48.1	54.0	-5.9
7425.0	Peak	Horizontal	7.8	45.3	53.1	74.0	-20.9
7425.0	Average	Horizontal	-2.8	45.3	42.5	54.0	-11.5
12375.0	Peak	Vertical	3.0	50.2	53.2	74.0	-20.8
12375.0	Average	Vertical	-7.0	50.2	43.2	54.0	-10.8
12375.0	Peak	Horizontal	2.1	50.2	52.3	74.0	-21.7
12375.0	Average	Vertical	-9.4	50.2	40.8	54.0	-13.2
14850.0	Peak	Vertical	2.0	53.1	55.1	74.0	-18.9
14850.0	Average	Vertical	-10.3	53.1	42.8	54.0	-11.2
14850.0	Peak	Horizontal	1.8	53.1	54.9	74.0	-19.1
14850.0	Average	Vertical	-10.0	53.1	43.1	54.0	-10.9

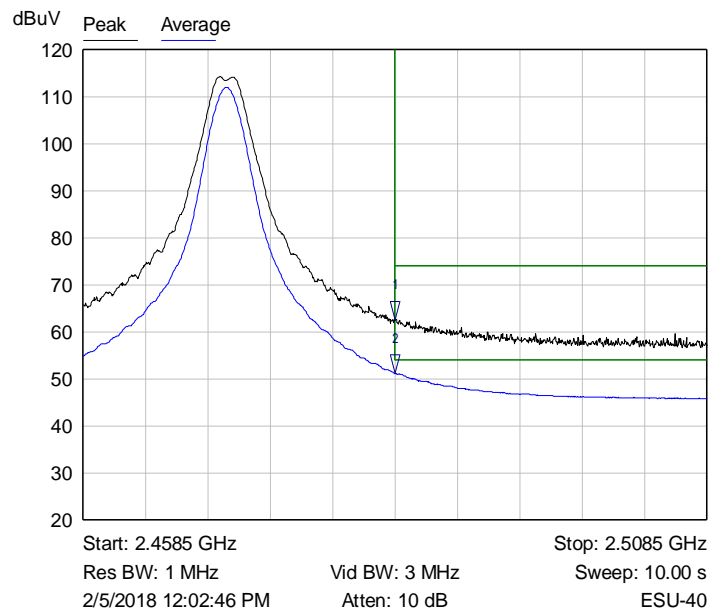
Table 8: Transmitting at the Highest Frequency

No other emissions were seen in the restricted bands.



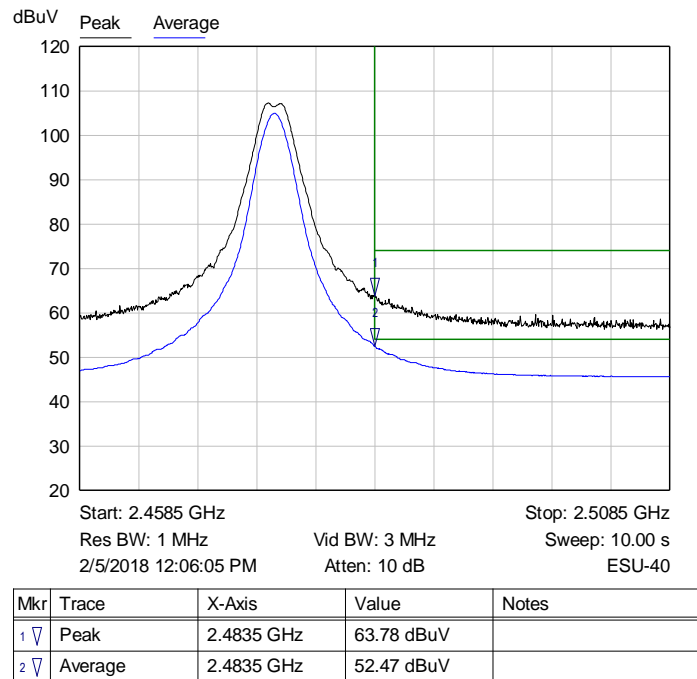
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.3900 GHz	62.53 dBuV	
2 ▽	Average	2.3900 GHz	52.13 dBuV	

Graph 12: Radiated Lower Band Edge Plot (2405 MHz)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Peak	2.4835 GHz	62.50 dBuV	
2 ▽	Average	2.4835 GHz	51.14 dBuV	

Graph 13: Radiated Upper Band Edge Plot (2470 MHz)



Graph 14: Radiated Upper Band Edge Plot (2475 MHz)

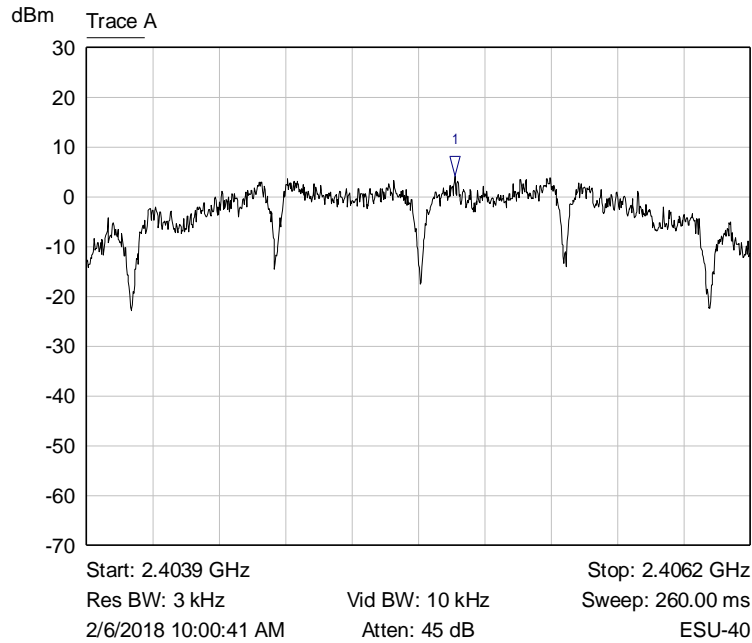
6.2.6 §15.247(e) Peak Power Spectral Density

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. Results of this testing are summarized.

Frequency (MHz)	Measurement (dBm)	Criteria (dBm)
2405.0	4.12	8.0
2440.0	4.11	8.0
2470.0	3.05	8.0
2475.0	-5.04	8.0

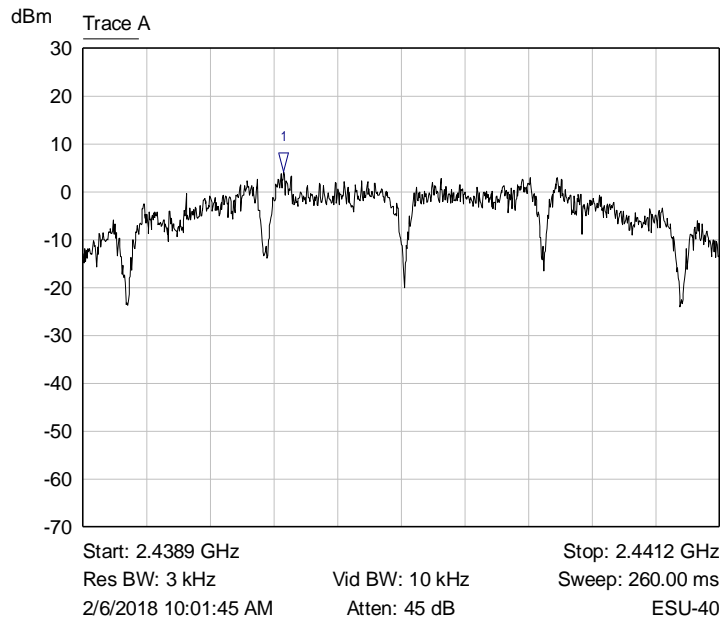
Result

The maximum peak power spectral density was less than the limit of 8 dBm; therefore, the EUT complies with the specification.



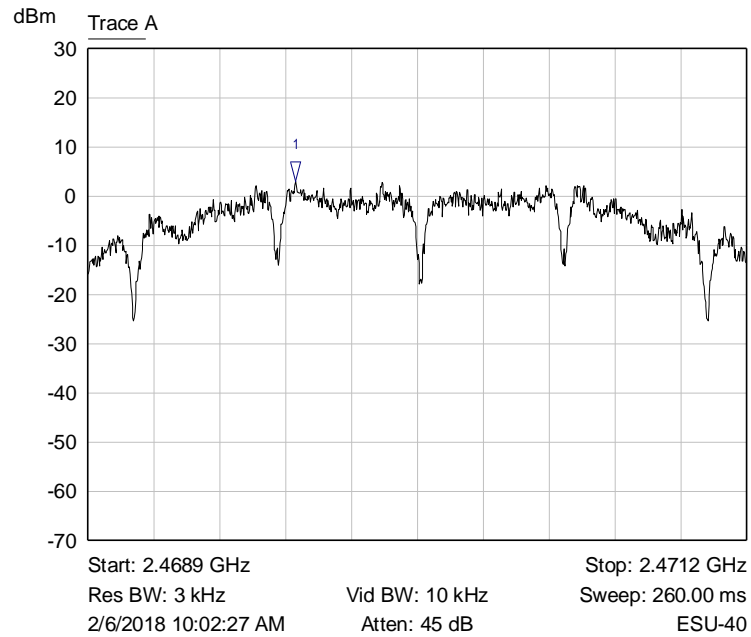
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4051 GHz	4.12 dBm	

Graph 15: Lowest Channel 3 kHz PSD Plot (2405 MHz)



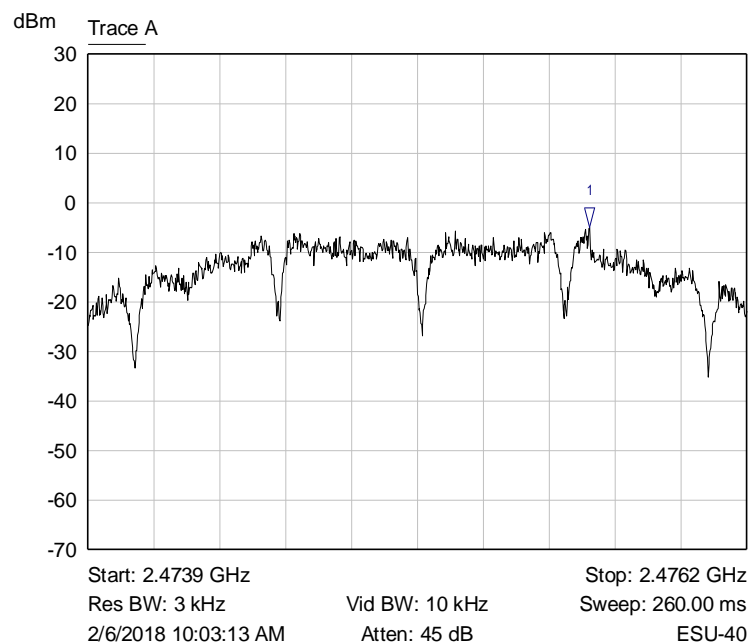
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4396 GHz	4.11 dBm	

Graph 16: Middle Channel 3 kHz PSD Plot (2440 MHz)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4696 GHz	3.05 dBm	

Graph 17: Channel 24 3 kHz PSD Plot (2470 MHz)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.4756 GHz	-5.04 dBm	

Graph 18: Highest Channel 3 kHz PSD Plot (2475 MHz)

7 Test Procedures and Test Equipment

7.1 Conducted Emissions at Mains Ports

The conducted emissions at mains and telecommunications ports from the EUT were 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 emissions at mains ports measurements are performed in a screen room using a (50 Ω /50 μ H) 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:

- Each power cord, which is terminated in a mains supply plug, shall be tested separately.
- Power cords, which are not specified by the manufacturer to be connected via a host unit, shall be tested separately.
- 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.
- Where a special connection is specified, the necessary hardware to effect the connection is supplied by the manufacturer for the testing purpose.
- 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 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	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer	Hewlett Packard	8566B	2747A05734	02/09/2018	02/09/2019
Quasi-Peak Detector	Hewlett Packard	85650A	V039474	03/16/2017	03/16/2018
LISN	VPI Labs	LISN-COMM-50	V034042	02/24/2017	02/24/2018
Conductance Cable Wanship Upper Site	VPI Labs	Cable J	V034832	01/09/2018	01/09/2019
Transient Limiter	Hewlett Packard	11947A	V033591	01/09/2018	01/09/2019
Test Software (AC)	VPI Labs	Revision 01	V035674	N/A	N/A

Table 9: List of equipment used for conducted emissions testing at mains ports.

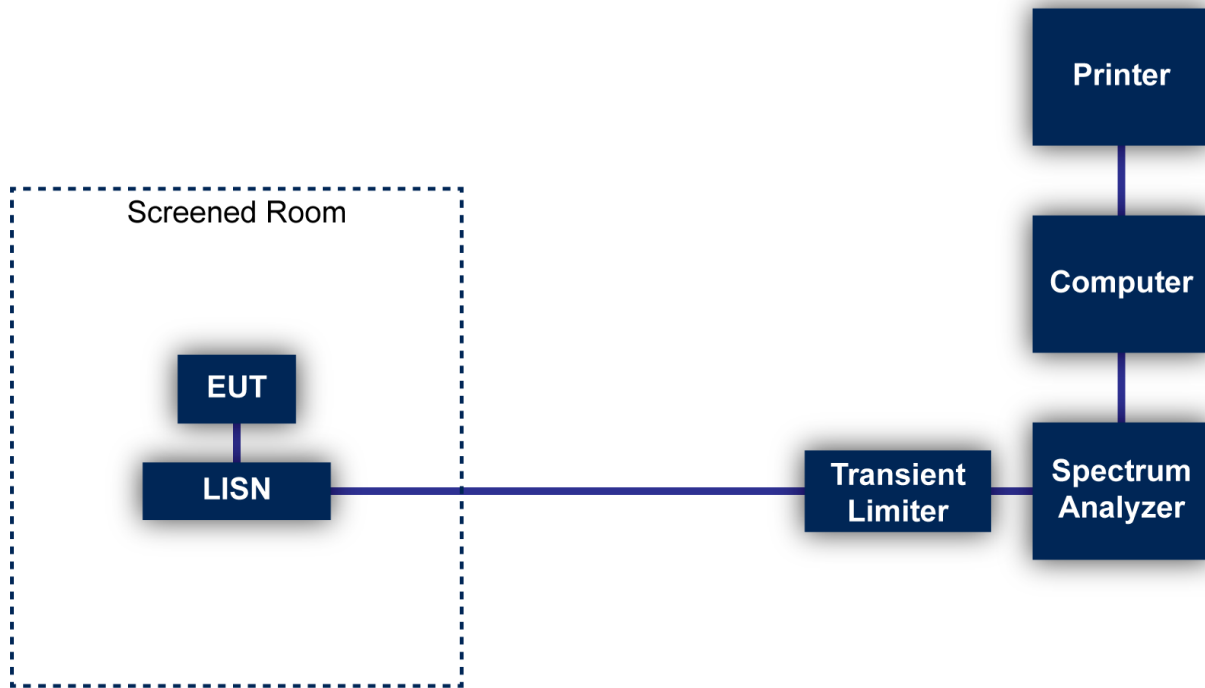


Figure 1: Conducted Emissions Test

7.2 Direct Connection at the Antenna Port Tests

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer/Receiver	Rohde & Schwarz	ESU40	V033119	06/06/2017	06/06/2018
6 dB Attenuator	Pasternack	PE7004-6	V033645	01/09/2018	01/09/2019
Low Loss Cable	N/A	N/A	V034173	01/09/2018	01/09/2019

7.2.1 Test Configuration Block Diagram



Figure 2: Direct Connection at the Antenna Port Test

7.3 Radiated Emissions

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

A preamplifier with a fixed gain of 26 dB and a power amplifier with a fixed gain of 22 dB 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 frequencies below 30 MHz, a 9 kHz resolution Bandwidth was used.

A loop antenna was used to measure frequencies below 30 MHz. A biconilog antenna was used to measure the frequency range of 30 to 1000 MHz, at a distance of 3 meters from the EUT. The readings obtained by these antennas are correlated to the levels obtained with a tuned dipole antenna by adding antenna factors. A double-ridged guide antenna was used to measure the emissions at frequencies above 1000 MHz at a distance of 3 and/or 1 meter from the EUT.

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 emissions. 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. For frequencies above 1000 MHz, the EUT is placed on a table 1.5 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 emissions testing 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	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer/Receiver	Rohde & Schwarz	ESU40	V033119	06/06/2017	06/06/2018
Spectrum Analyzer	Hewlett Packard	8566B	2747A05734	02/09/2018	02/09/2019
Quasi-Peak Detector	Hewlett Packard	85650A	V039474	03/16/2017	03/16/2018
Loop Antenna	EMCO	6502	V034216	01/25/2017	01/25/2019
Biconilog Antenna	EMCO	3142E-PA	V035736	06/24/2016	06/24/2018
Double Ridged Guide Antenna	EMCO	3115	V034194	03/08/2017	03/08/2019
Standard Gain Horn	ETS-Lindgren	3160-09	V034223	ICO	ICO
High Frequency Amplifier	Miteq	AFS4-001018000-35-10P-4	V033997	01/09/2018	01/09/2019
2.4 GHz Notch Filter	Micro-Tronics	BRM50702-03	V034213	01/09/2018	01/09/2019
6' High Frequency Cable	Microcoax	UFB197C-0-0720-000000	V033638	01/09/2018	01/09/2019

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
20' High Frequency Cable	Microcoax	UFB197C-1-3120-000000	V033979	01/09/2018	01/09/2019
3 Meter Radiated Emissions Cable Wanship Upper Site	Microcoax	UFB205A-0-4700-000000	V033639	01/09/2018	01/09/2019
Test Software (FCC)	VPI Labs	Revision 01	V035673	N/A	N/A

Table 10: List of equipment used for radiated emissions testing.

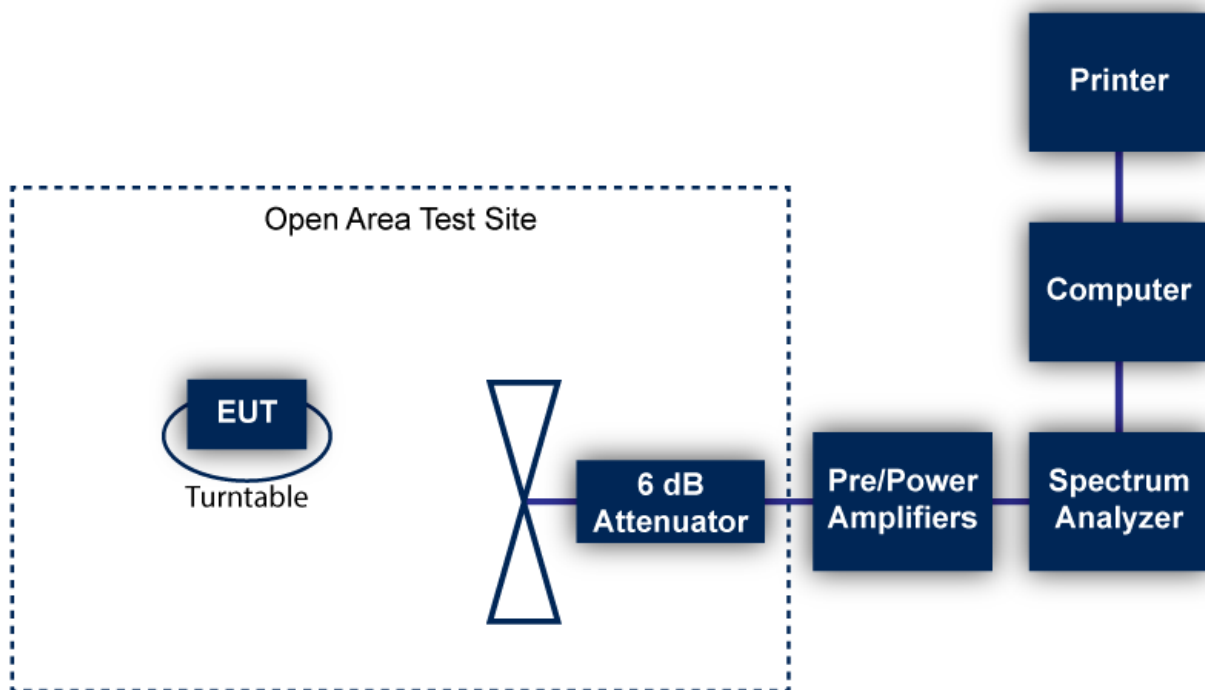


Figure 3: Radiated Emissions Test

7.4 Equipment Calibration

All applicable equipment is calibrated using either an independent calibration laboratory or VPI Laboratories, Inc. personnel at intervals defined in ANSI C63.4:2014 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.

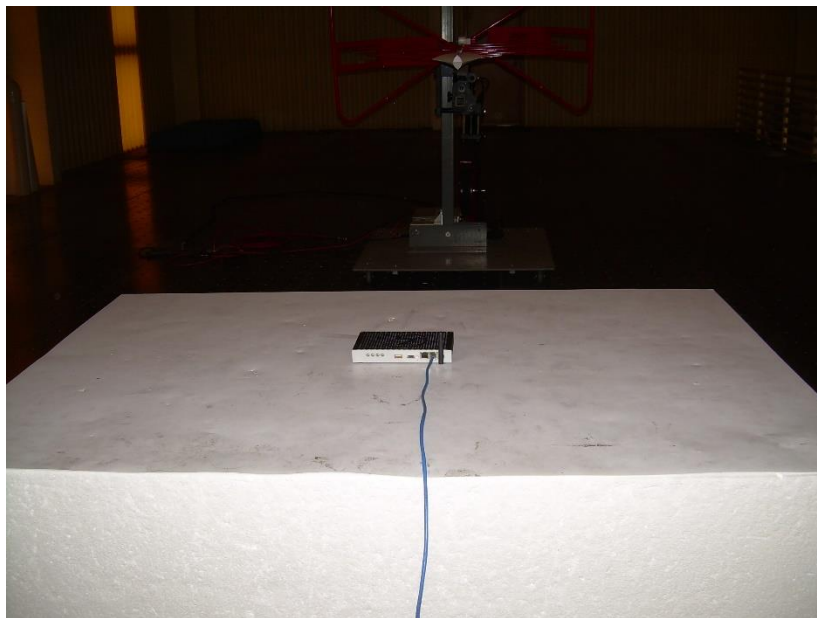
7.5 Measurement Uncertainty

Test	Uncertainty (\pm dB)	Confidence (%)
Conducted Emissions	2.8	95
Radiated Emission (9 kHz to 30 MHz)	3.3	95
Radiated Emissions (30 MHz to 1 GHz)	3.4	95
Radiated Emissions (1 GHz to 18 GHz)	5.0	95
Radiated Emissions (18 GHz to 40 GHz)	4.1	95

8 Photographs



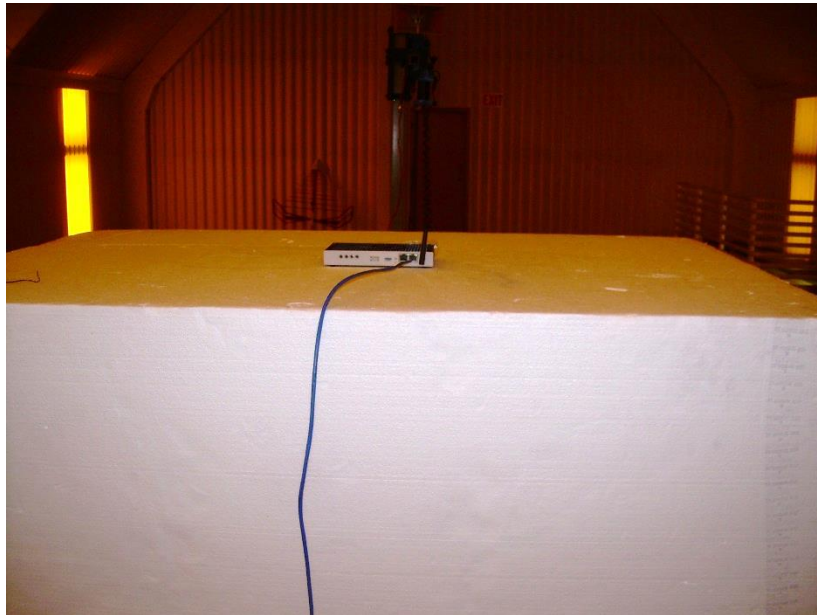
Photograph 1: Front View Radiated Emissions Below 1000 MHz Configuration



Photograph 2: Back View Radiated Emissions 30 MHz – 1000 MHz Configuration



Photograph 3: Front View Radiated Emissions Above 1000 MHz Configuration



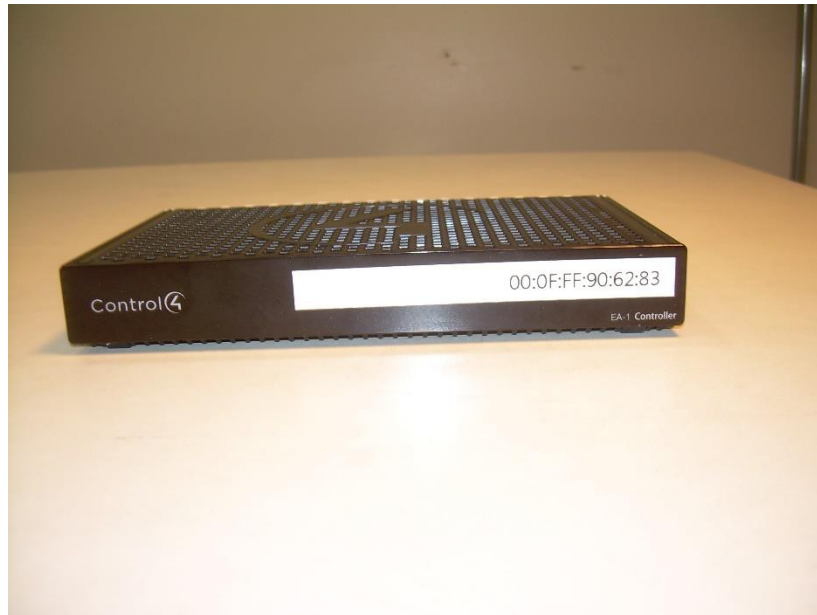
Photograph 4: Back View Radiated Emissions Above 1000 MHz Configuration



Photograph 5 – Front View Conducted Emissions Worst-Case Configuration



Photograph 6 – Back View Conducted Emissions Worst-Case Configuration



Photograph 7 - Front View of the EUT



Photograph 8 - Back View of the EUT

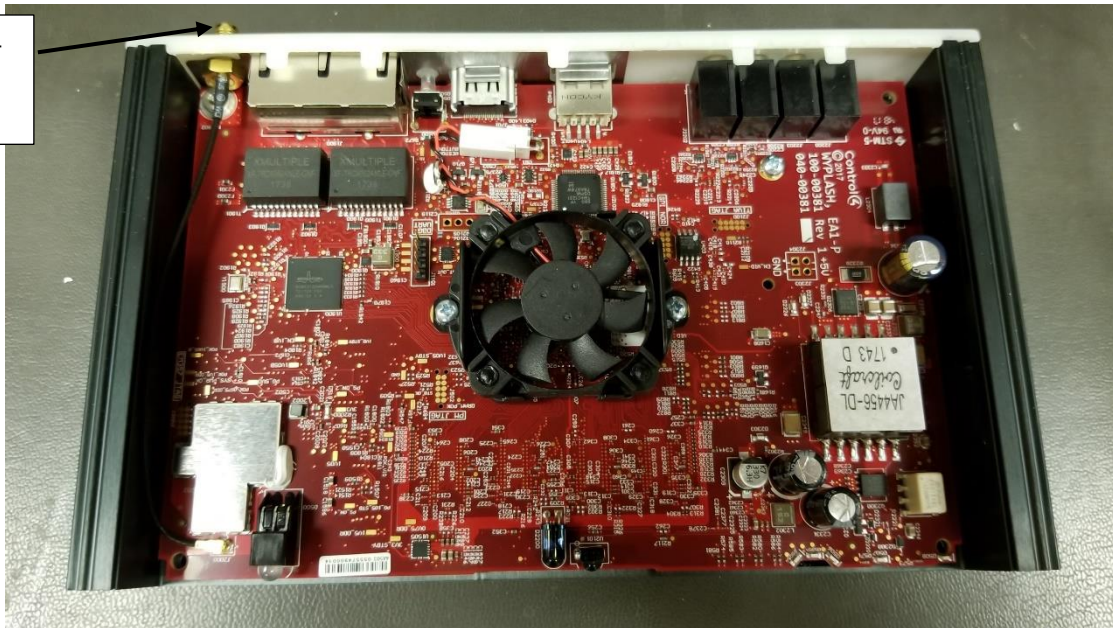


Photograph 9 – View of the Front/Right Side of the EUT

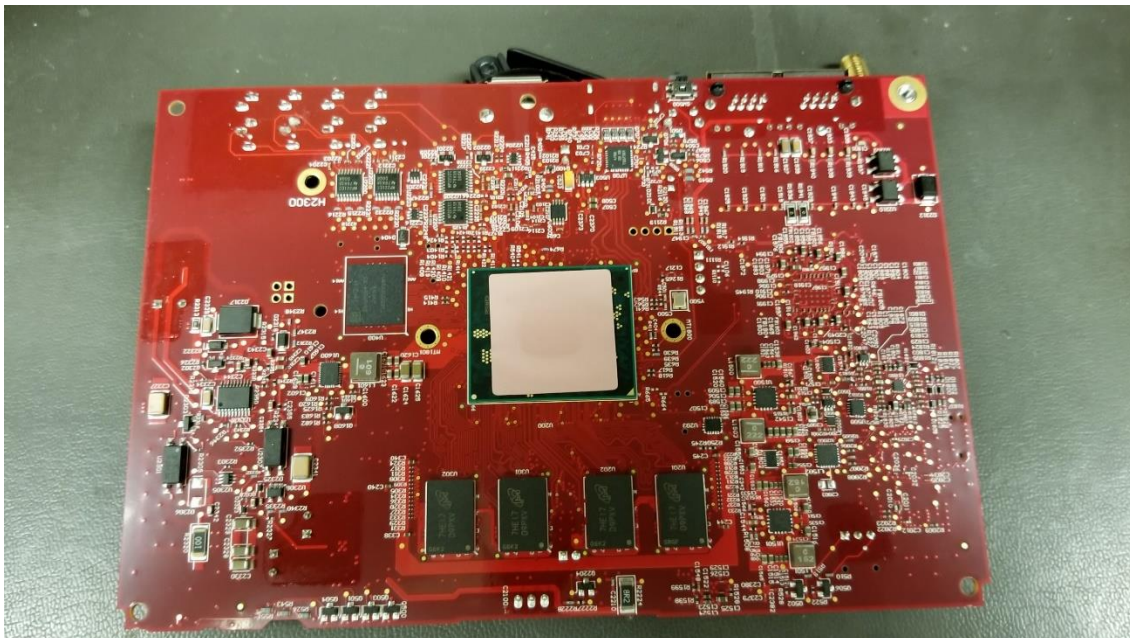


Photograph 10 – View of the Back/Left Side of the EUT

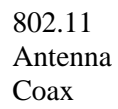
802.15.4
Antenna
Port



Photograph 11 – Top View of the PCB



Photograph 12 – Bottom View of the PCB



Photograph 14 – View of the Circuitry Under the RF Shield

--- End of Report ---