Testing Cert #1007.01

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FCC
Test Report

FCC CFR 47 Part 15.207, 15.209 and 15.247 COMPLIANCE

Stack Labs, Inc.
10054 Pasadena Ave.
Cupertino, CA 95014

Product:
Stack Hub
Model:
HUB-01AC-00Z

Contains FCC ID:	2AGFX-STACK001
Test Report Number:	1547STKmodule_247
Date of Report:	November 17, 2015

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Table of Contents

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Change History

1547STKmodule_247

Rev.	Change Description	Reason/Application	Date	Appvd.
D	Issue of report	Applies to HUB-01AC-00Z	November 17, 2015	MEB
C1	Re measured output power	Updated pages 23, 27-29	December 9, 2015	MEB

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General Information

Test Report Number:	1547STKmodule_247
Date Product Tested:	November 10-16, 2015
Date of Report:	November 25, 2015
Applicant:	Stack Labs, Inc. 10054 Pasadena Ave. Cupertino, CA 95014
Contact Person	Mr Kent S Whiting
Equipment Tested:	Stack Hub
Trade Name:	Stack
Model:	HUB-01AC-00Z
Purpose of Test:	To demonstrate the compliance of the Stack Hub, HUB-01AC-00Z, with the requirements of FCC CFR 47 Part 15 Rules and Regulations to the limits of Subpart C 15.207, 15.209 and 15.247 using the procedure stated in ANSI C63.10.
Frequency Range Investigated:	9 KHz to 24.835 GHz
Contains FCC ID:	2AGFX-STACK001
Test Site Locations:	Field Strength Measurement Facility: Atlas Compliance & Engineering, Inc. 726 Hidden Valley Road Royal Oaks, California 95076 Conducted Interference Measurement Facility: Atlas Compliance & Engineering, Inc. 1792 Little Orchard Street San Jose, California 95125
Test Personnel:	Bruce Smith EMC Engineer

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Test Equipment

The following list contains the test equipment that was utilized in making the measurements in this report.

Description _ Model	Serial	Manufacturer	Calibration Due
BiLog Antenna _ CBL6112B	2783	Chase Electronics Ltd.	5/8/17
Active Loop Antenna _ 6502	9108-2669	EMCO	12/9/15
Biconilog Antenna _ 3142	9610-1101	EMCO	5/8/17
Double Ridge Guide Horn Antenna _ 3115	9003-3340	EMCO	12/2/15
Standard Gain Horn Antenna _ 3160-09	00057143	EMCO	11/22/17
LISN _ 3825/2	9007-1683	EMCO	12/7/15
Pre amp 0.01-2000MHz _ LNA 6901	74007	Teseq	7/7/16
Pre amp 9kHz-2GHz _ CPA9231A	3259	Schaffner	10/1/17
Spectrum Analyzer 9kHz-2.4GHz _ 8594E	3543A02886	HP	1/30/16
EMI Test Receiver 9 kHz - 2500 MHz _ ESPC	DE15934 845296/0024	Rohde & Schwarz	2/19/17
EMI Test Receiver 9 kHz - 2500 MHz _ ESPC (bat)	DE14459 843820/0015	Rohde & Schwarz	2/17/17
Pre amp 1Ghz-26.5GHz _ 8449B	3008A00910	HP	2/24/17
Spectrum Analyzer 100Hz-22GHz _ 8566B	2542A13058 (IF) 2637A03426 (RF)	HP	2/18/17
Quasi-Peak Adapter _ 85650A	2521A00716	HP	2/18/17
4.8kVA AC Power Source _ 4801iL	HK511991	California Instruments	VOP
Temperature and humidity probe _ RH-20F	200-97-082591	Omega Engineering	3/31/16
Chamber – HPI160SCable 50 ft.	0002	Semflex	8/27/16
Chamber – HP190S Cable 8 ft.	0003	Semflex	9/29/16
RF Cable 75 ft. _ BM95012.900	109	Bracke Manufacturing, LLC	4/28/17

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Test Configuration

Customer:	Stack Labs, Inc.
Test Date:	November 10-16, 2015
Specification:	FCC CRF 47 Part 15.247 Limits, ANSI C63.10 Methods

HUB-01AC-00Z Oscillator Overview:

Stack Hub is the link between Stack Enabled Products, the Stack Cloud and the customer. It is the translator between the protocol of low power mesh networks, the internet and user interaction. In order to do all this it employs multiple oscillators. From the Line voltage input a Class II converter, steps down to a DC rail voltage for the Hub. This rail is fed into the Power Management IC (PMIC) that regulates the power to the rest of the system components, including all the system oscillators and clocks, it operates at 2.25MHz or less. The Core processor and its buses work off a system clock of 600MHz, it is fed by a 25MHz crystal for creation of the system clock and a 32.768kHz crystal for creation of a Real Time Clock. The transceiver used for communication with Stack Enabled Products has an onboard 32MHz Crystal and transmits at 2.4GHz. The Ethernet IC has its own 50MHz crystal for clocking.

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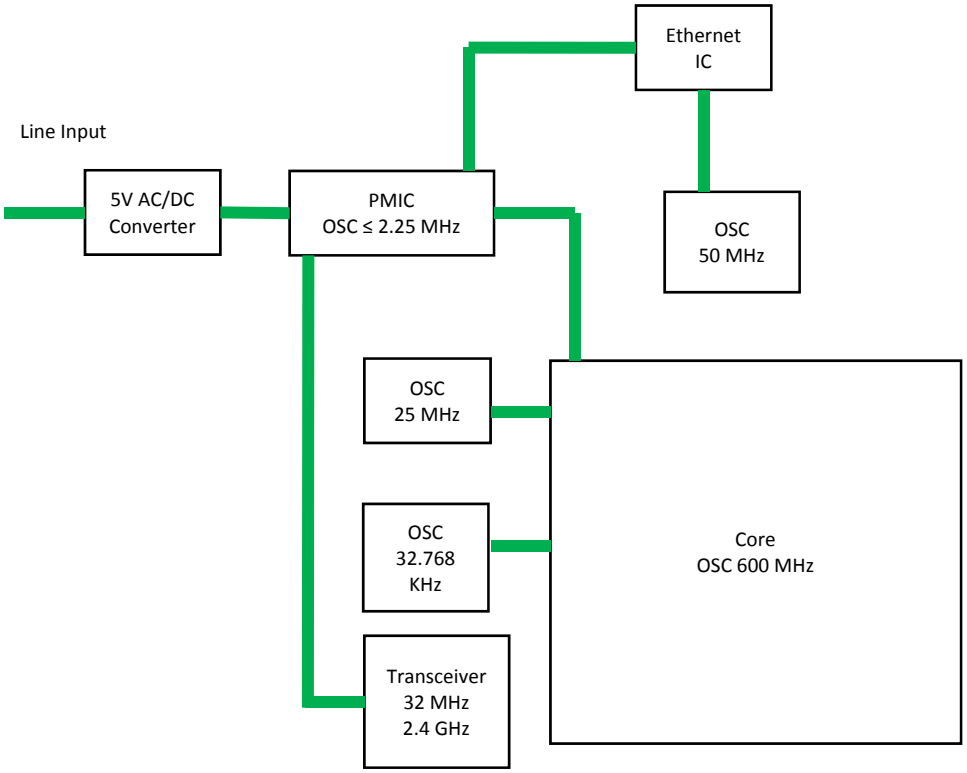
HUB-01AC-00Z Oscillator Block Diagram



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EUT Description / Note:

The EUT, HUB-01AC-00Z, a Stack Hub was powered up and in a continuous transmitting mode at full power. The EUT contains a ZigBee module and interface was through the host circuits to send commands to place it in the different operating modes. The EUT was running the Ethernet port while also running a continuous loop of MCU operations to simulate a worst case condition of operation. The power for the EUT was supplied by an AC adapter.

EUT Support Program

The EUT was tested at lowest channel, 2405 MHz, mid channel, 2445 MHz, and highest channel, 2480 MHz in a continuous transmit mode. The transmitter was at full power and 100% modulation. The EUT was operated in this mode and all data rates were tested to find worst case levels. Preliminary radiated tests were performed to identify which operating mode produced the worst case (maximum) transmit level. Using this mode the module was tested to find maximum transmit level. Tests were performed with the measurement antenna in both horizontal and vertical orientations.

EUT Modifications for Compliance

There were no modifications performed on the EUT. The test results state the emission levels of the EUT in the condition as it was received on November 10, 2015.

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EUT Support Devices

Table 1 – Support Equipment Used For Test

Model:	Description:	S/N	FCC ID#
8003	U S Robotics Broadband Router	1NAWR7SE1655	NA
Inspiron 5720	Dell Laptop computer	DZ53DT1	NA

I/O Ports and Cables

Table 2 – EUT Port Termination's

I/O Port	Cable Type	Length	Connector	Termination
DC power	Shielded/Ferrite	1.5 m	DC jack	AC adapter
Ethernet	CAT 6	15 m	RJ45	Router

Table 3 – Host Port Termination's

I/O Port	Cable Type	Length	Connector	Termination
Ethernet	CAT 6	1 m	RJ45	Router

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Equipment Under Test

The photographs below show the condition of the EUT for test.

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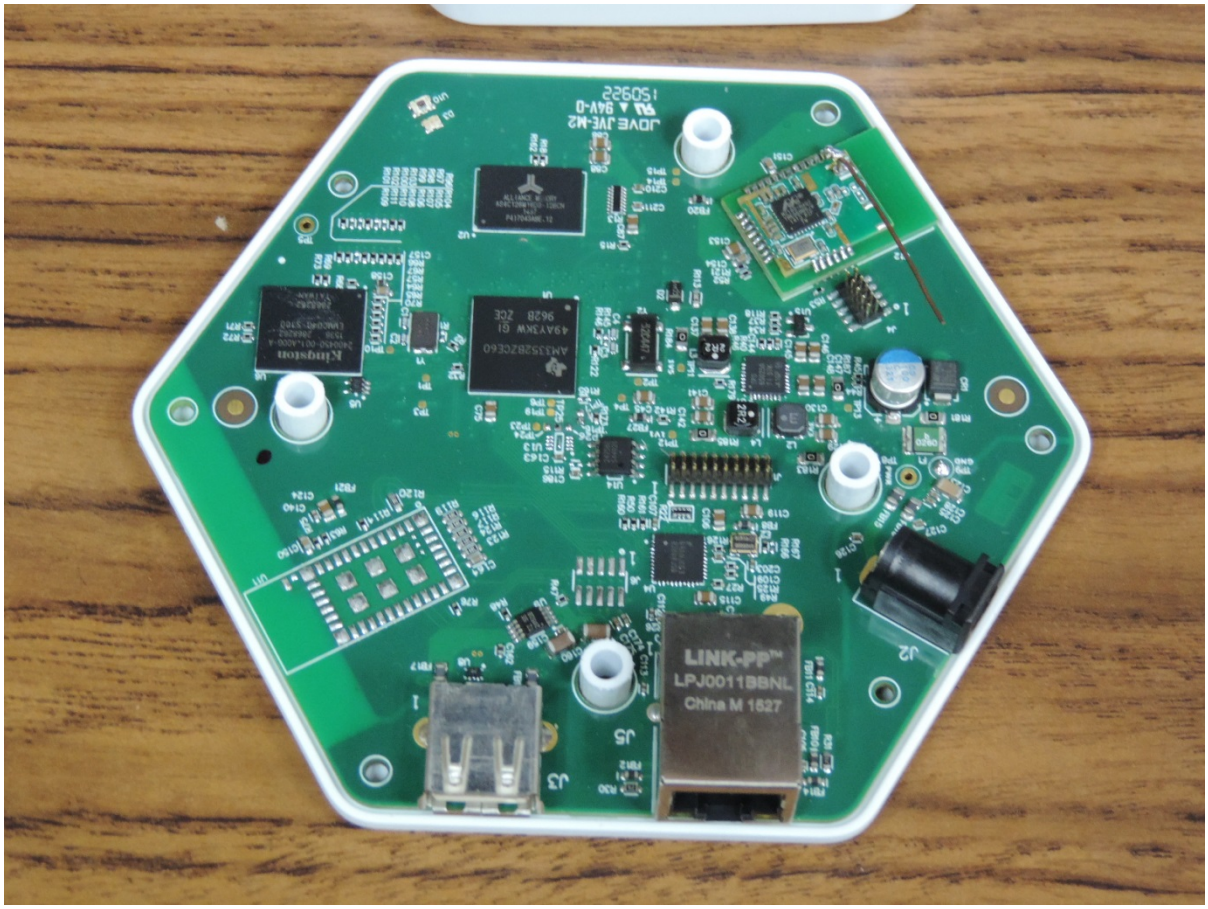

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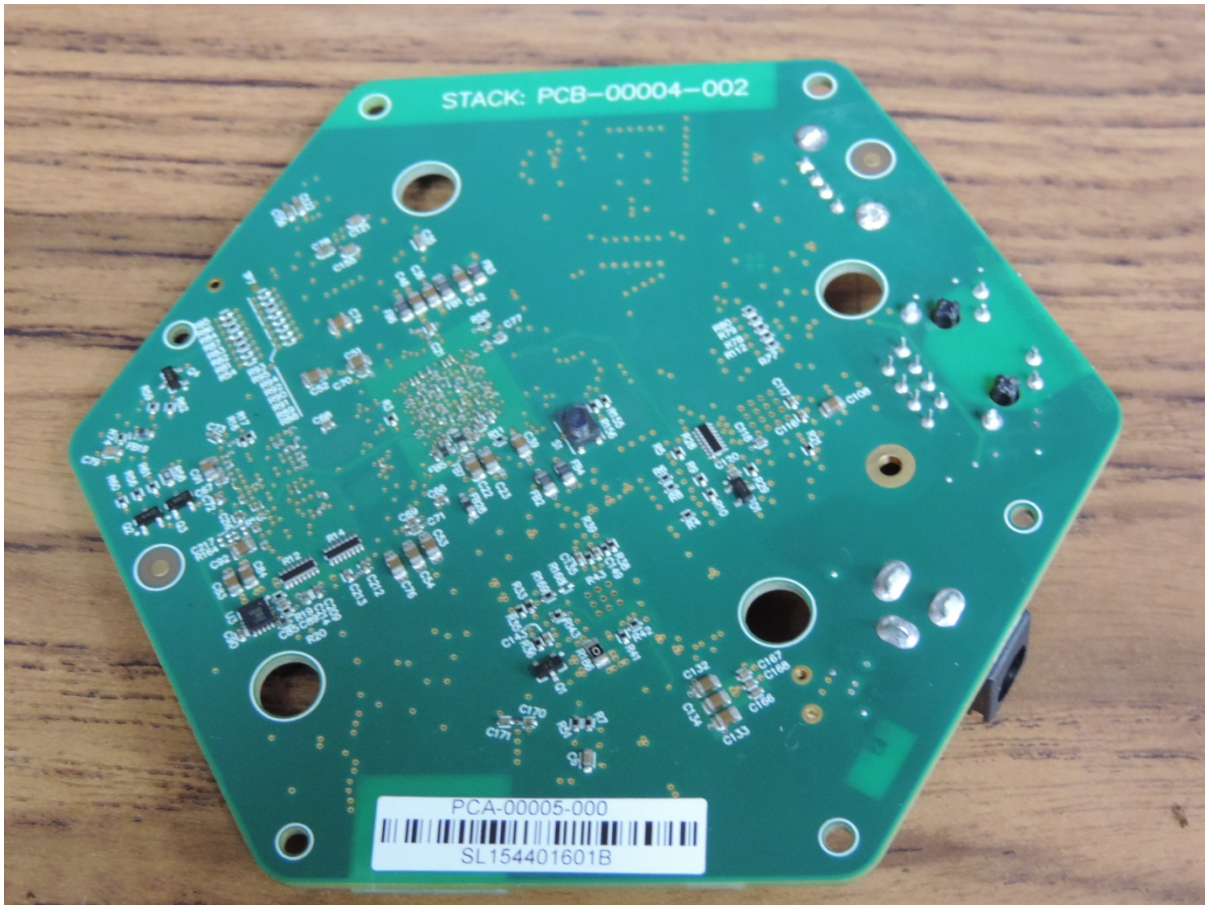

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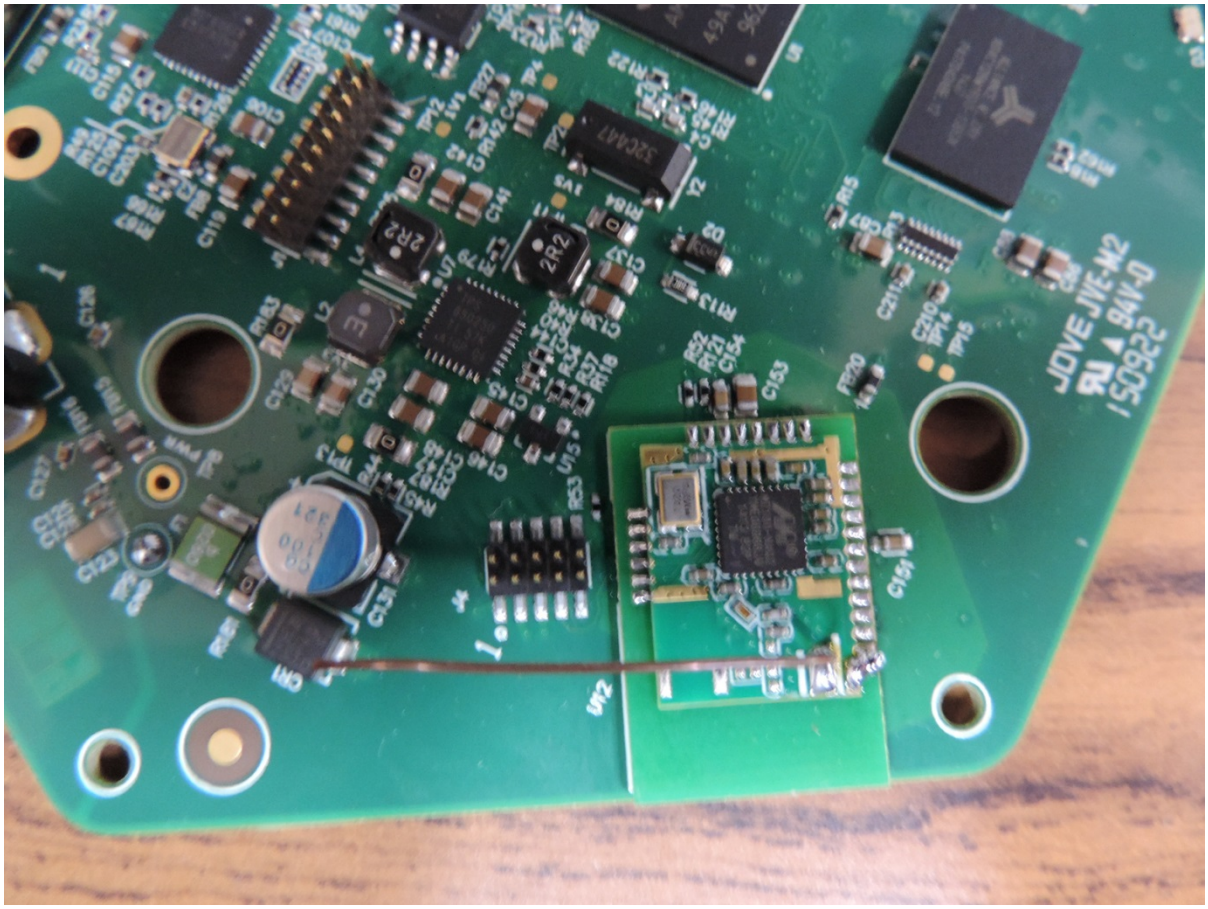

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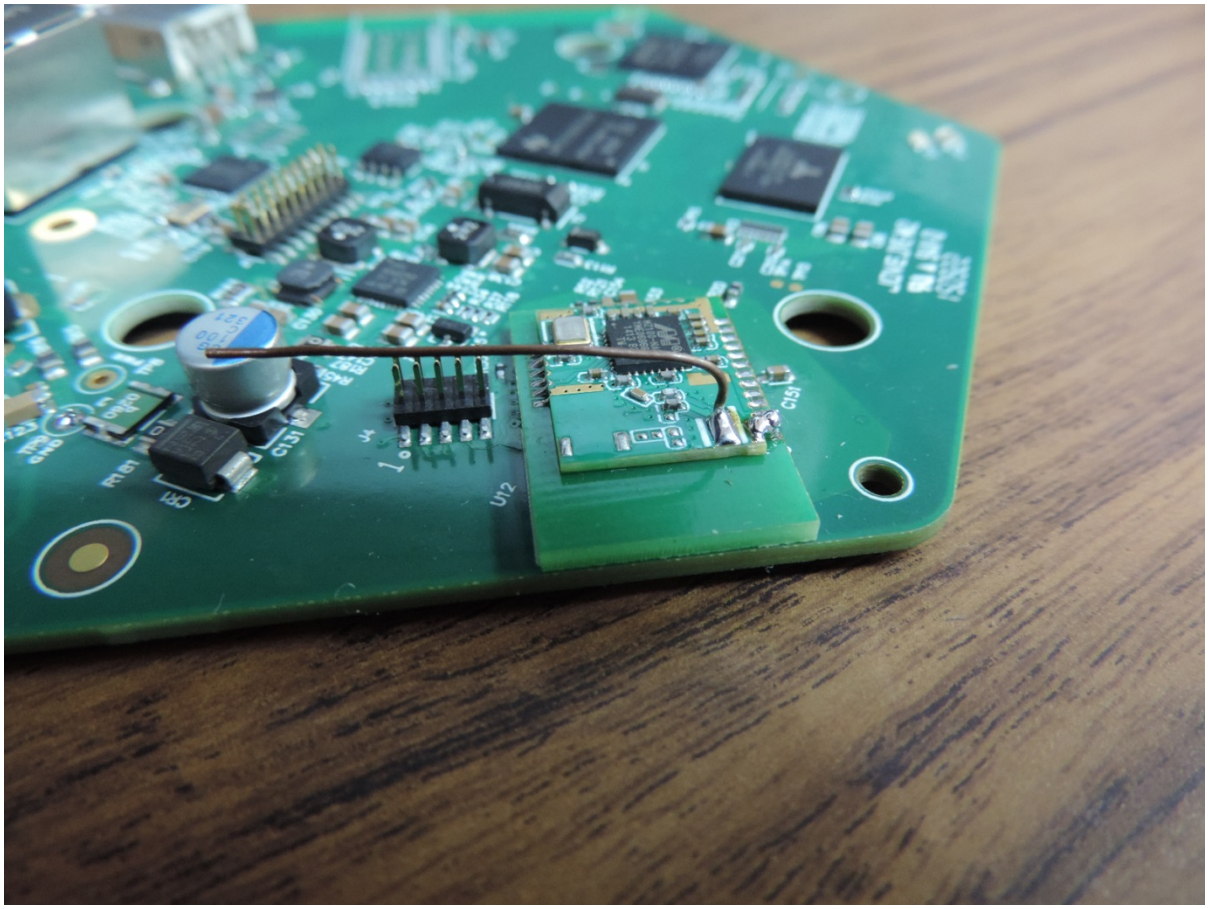

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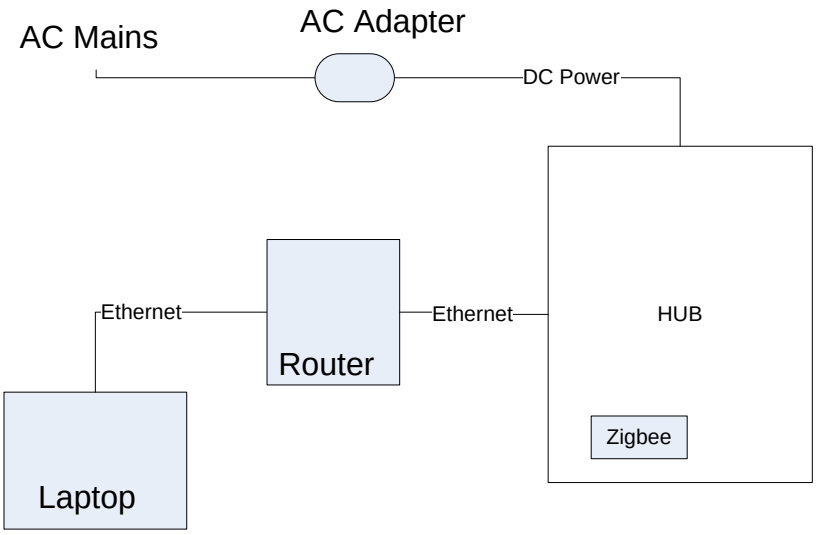
Equipment Block Diagram

Following is the block diagram of the test setup. Refer to TEST CONFIGURATION pages for port connections and information.

Figure 1 – Test Setup Diagram



EUT:
HUB

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Test Setup (Radiated Emissions)

The photographs below show the test setup for radiated emission testing.

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Test Setup (Radiated Emissions)

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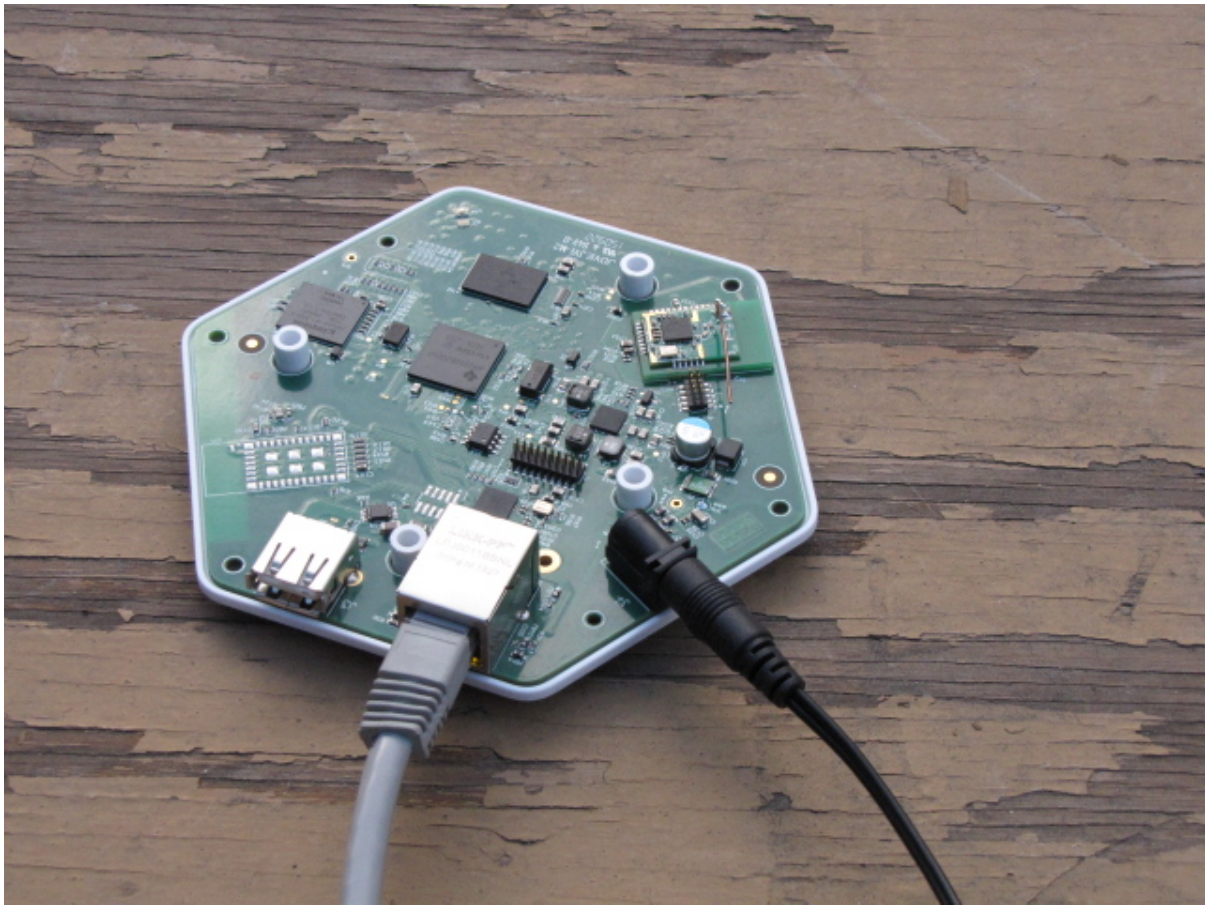

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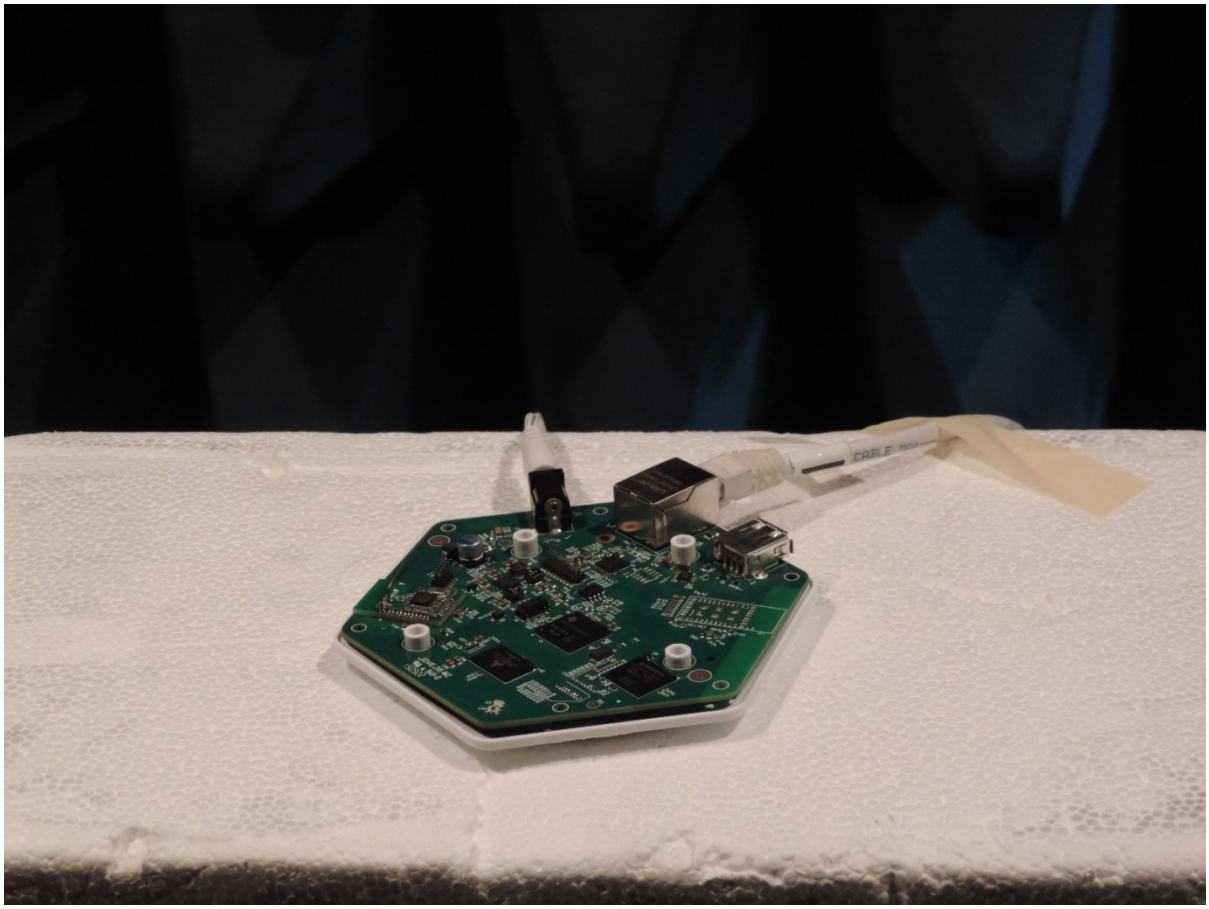

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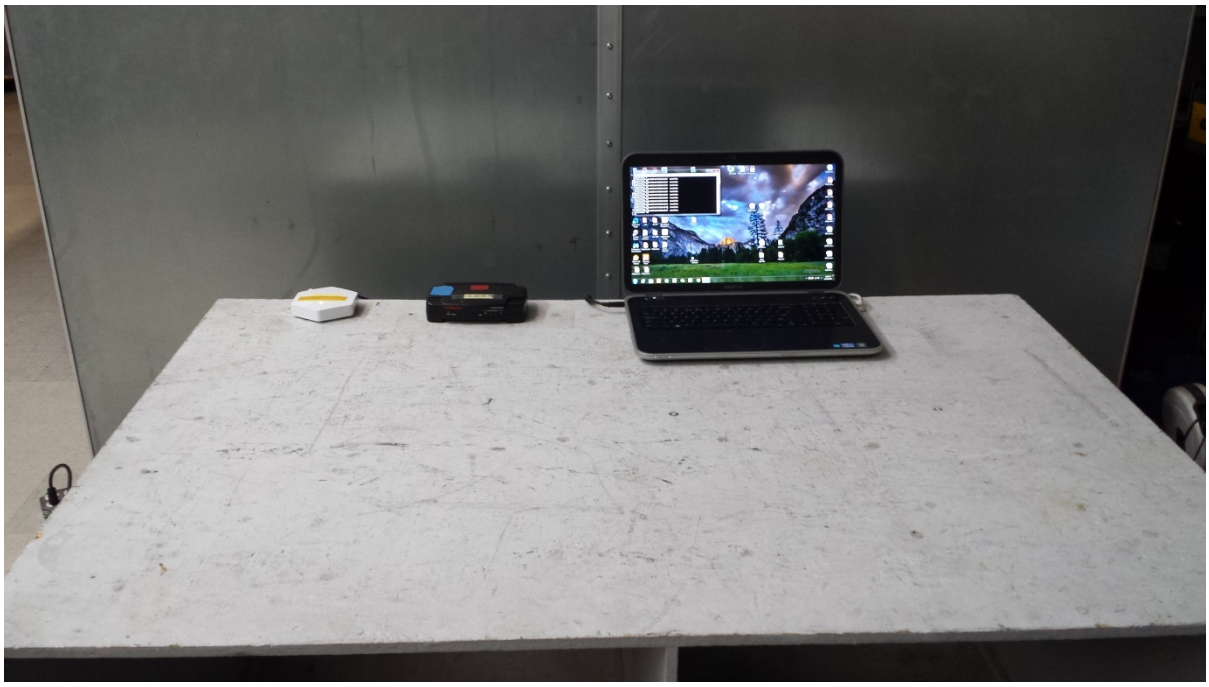
Test Setup (Conducted Emissions)

The photographs below show worst case setup for line conducted testing.



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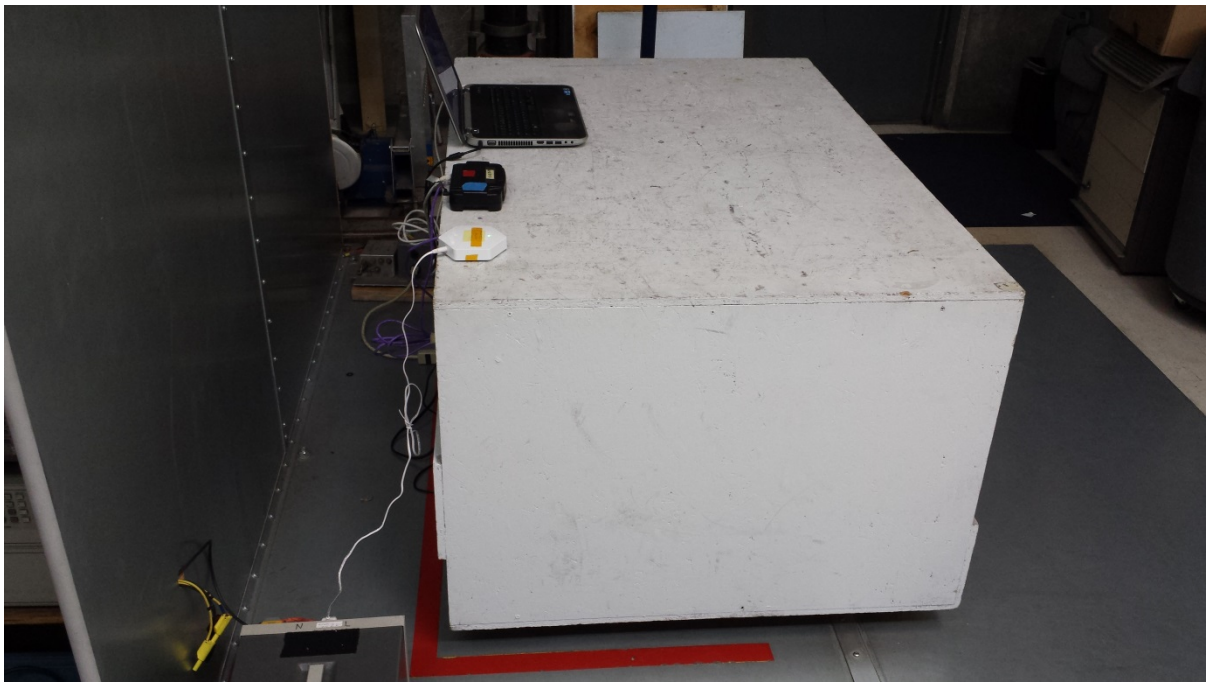

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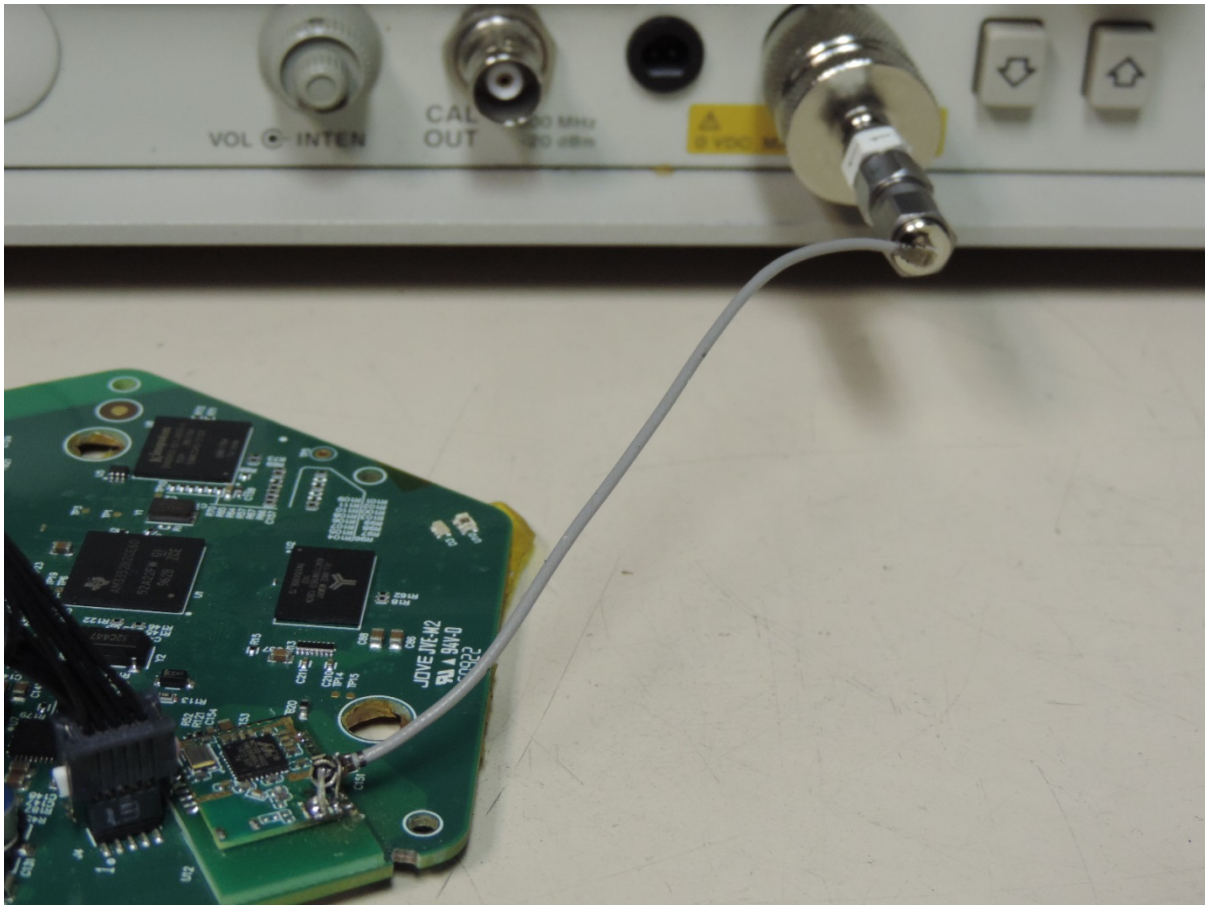
Test Setup (Conducted RF)

The photographs below show the test setup for conducted RF testing.



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Test Methods for Emissions

The test procedure stated in ANSI C63.10-2013 and FCC KDB 558074 was used to collect the test data. The emission data of the EUT was taken with the Rohde & Schwarz EMI Test Receiver and HP 8566B. Incorporating the application of correction factors programmed into the Test Receiver and verified for distance, antenna, cable loss, and amplifier gain, the data was reduced as shown in the Sample Calculations. These correction factors are available upon request. The corrected data was then compared to the emission limits to determine compliance.

During radiated emission testing, the EUT was placed on a nonconductive rotating table 0.8 meter above the conductive grid. The nonconductive table dimensions were 1 meter deep by 1.5 meters wide at 0.8 meter high. The EUT is centered on the tabletop and the measurement antenna was placed 10 or 3 meters from the EUT as noted in the test data.

For emissions testing, scans in the frequency range of 9 kHz to 24.835 GHz were made. Measurement bandwidths and detectors stated in ANSI C63.4 were used.

Measurements were made at a distance of 3 or 10 meters.

For conducted RF testing the procedures stated in FCC KDB 558074 was used.

Conducted Emission Testing

For the conducted emissions testing, the EMCO LISN, Model No. 3825/2, was used for the EUT. During conducted emission testing the EUT was located on a wooden test bench measuring 0.8 meter high, 1 meter deep, and 1.5 meters in width. The vertical conducting surface was 0.4 meter from the back of the test bench. The LISNs were placed on the ground plane of the test area in accordance with ANSI C63.4-2014.

The metal plane used for conducted emission testing was grounded to the earth by a heavy gage braided wire attached to the plane. All other objects were kept a minimum of 1 meter away from the EUT during the conducted test.

For conducted emissions testing a scan of the frequency band 150 kHz to 30 MHz was made stepping every 5 kHz. Each frequency was measured at a bandwidth of 10 kHz for 20 msec. All readings within 25 dB of the limits were recorded, and those emissions were then measured using the CISPR quasi-peak and average detectors at a bandwidth of 10 kHz for a 2 second measurement time. All emissions within 6 dB of the limit were examined with additional measurements to ensure compliance with the FCC 15.207 limits. The results of the conducted emissions test are shown in Tables 8 and 9 and Figures 3 and 4.

Temperature and Humidity

The ambient temperature of the actual EUT was within the range of 10° to 40° C (50° to 104° F) unless the particular equipment requirements specify testing over a different temperature range. The humidity levels were within the range of 10% to 90% relative humidity unless the EUT operating requirements call for a different level.

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Sample Calculations

An example of how the EMI Test Receiver reading is converted using correction factors is given for the emissions recorded in Table 6. These correction factors are programmed into the EMI Test Receiver and verified. For radiated emissions in dBµV/m, the EMI Test Receiver reading in dBµV is corrected by using the following formula:

33.90	Meter Reading (dBµV/m)
34.01	- Pre amp Gain (dB)
12.48	+ Cable Loss (dB)
33.12	+ Antenna Factor (dB)
45.49	= Corrected Reading (dBµV/m)

This reading is then compared to the applicable specification limits and the difference will determine compliance.

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FCC Part 15 Subpart C 15.207 and 15.209 Limits

Table 4 – Conducted Limits

Frequency MHz	Limit Quasi-Peak dBµV	Limit Average dBµV
0.15-0.50	66-56	56-46
0.50-5	56	46
5-30	60	50

NOTE:

1. The lower limit shall apply at the transition frequencies.
2. Both Quasi-Peak and Average limits for power line conducted testing must be met.
3. The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz.

Table 5 – Radiated Emission Limits, General Requirements

Frequency MHz	Field Strength µV/m	Measurement Distance Meters
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30	30	30
30 – 88	100	3
88 – 216	150	3
216 – 960	200	3
Above 960	500	3

NOTE:

1. The lower limit shall apply at the transition frequencies.
2. Distance refers to the distance in meters between the measuring instrument antenna and the closest point of any part of the device or system.
3. The level of any unwanted emissions from an intentional radiator operating under these general provisions shall not exceed the level of the fundamental emission.
4. The emission limits shown are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

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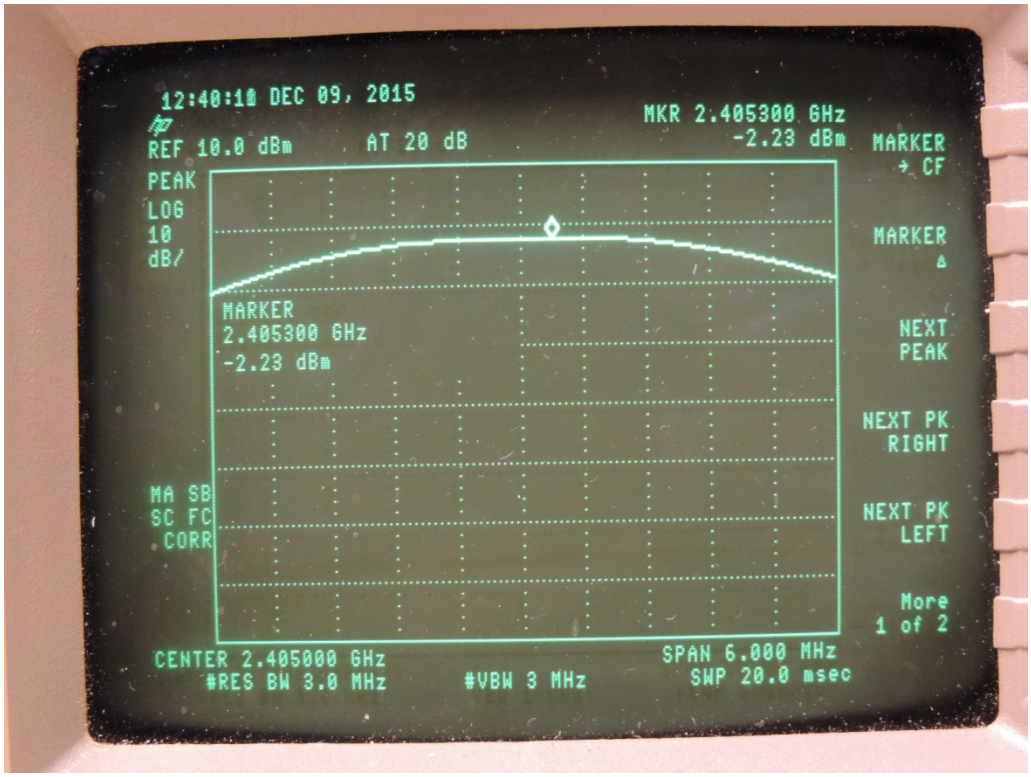
Report of Measurements Maximum Peak Output Power Data

The maximum peak output power of the intentional radiator was measured to verify the level to be equivalent to the original module levels. The level of the original modules were compared to these measurements and found to be within the expected levels.

Lowest Channel 802.15.4 – Conducted Measurement



Frequency MHz	dBm	CF	Corrected dBm	Original dBm
2405	-2.23	11.13	8.9	9.88

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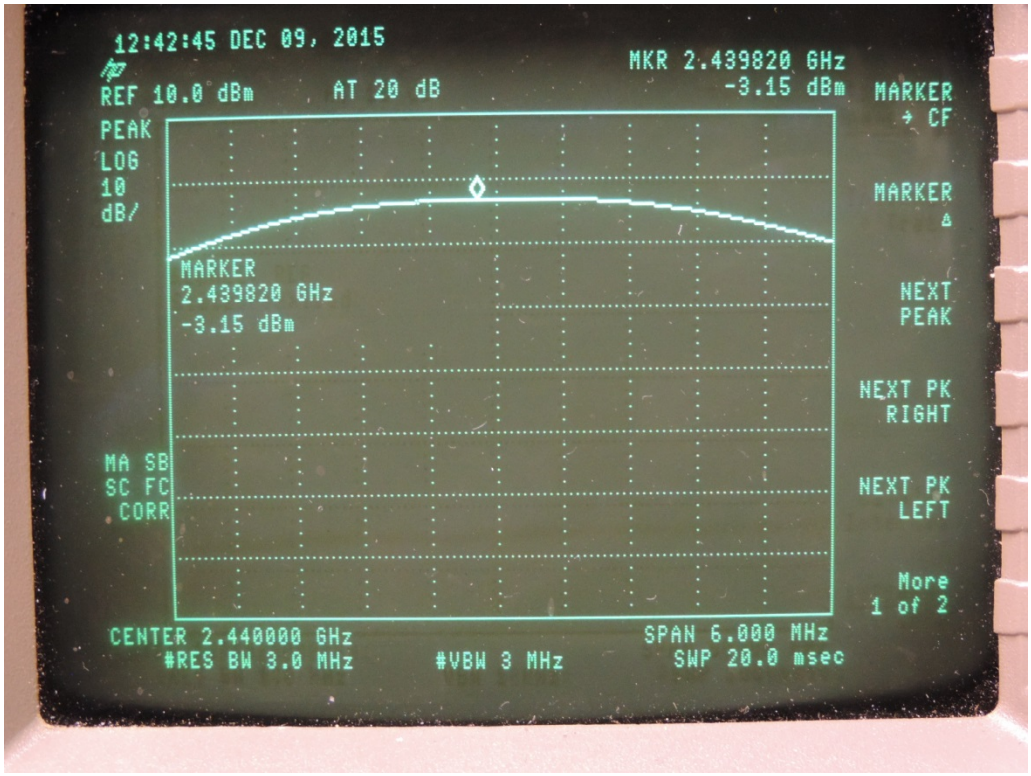
Middle Channel 802.15.4 – Conducted Measurement



Frequency MHz	dBm	CF	Corrected dBm	Original dBm
2440	-3.15	11.13	7.98	10.67

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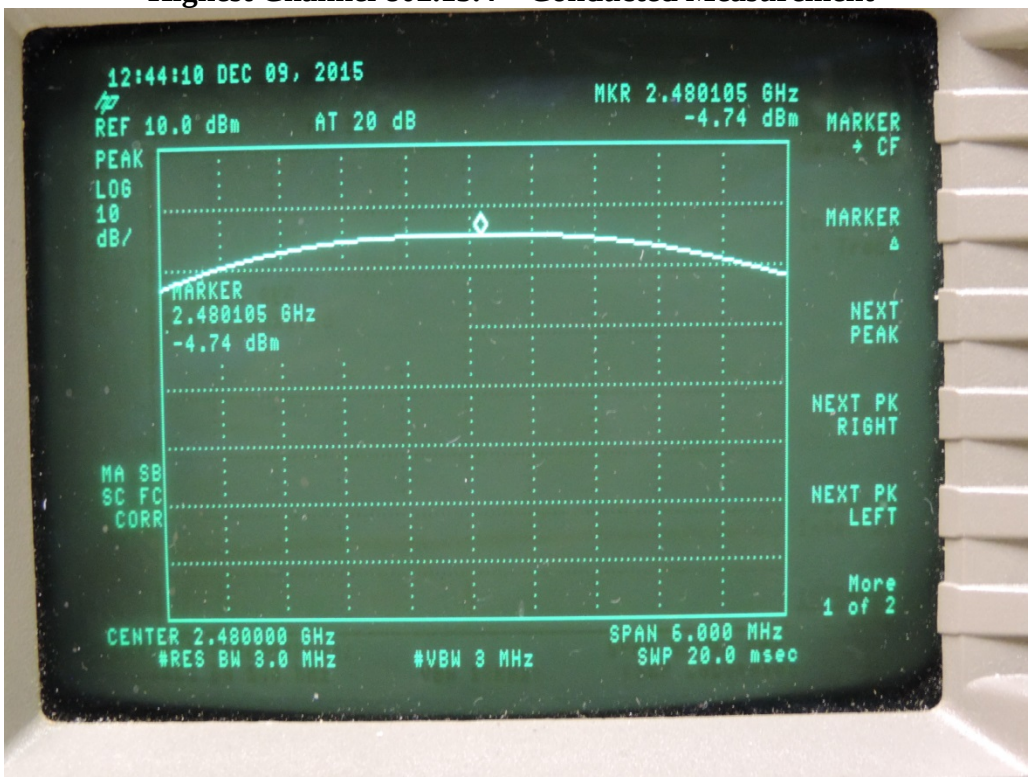
Highest Channel 802.15.4 – Conducted Measurement



Frequency MHz	dBm	CF	Corrected dBm	Original dBm
2480	-4.74	11.13	6.39	11.98

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Report of Measurements Radiated Data

Radiated emissions measurements were performed from 9 kHz to 30 MHz at 3-meter distance. The loop antenna was placed at 1-meter height and was rotated about its vertical axis. The EUT was also rotated 360 degrees in front of the measurement antenna. No emissions were observed from the EUT in this frequency range.

Measurements were performed in the frequency range of 30 MHz to 1 GHz at 10-meter distance. The Bilog antenna was searched from 1 to 4 meters in height in both horizontal and vertical orientation. The EUT was also rotated 360 degrees in front of the measurement antenna.

Measurements were performed in the frequency range of 1 GHz to 24.835 GHz at 3-meter distance. The Horn antenna was searched from 1 to 4 meters in height in both horizontal and vertical orientation. The EUT was also rotated 360 degrees in front of the measurement antenna. Only the second harmonics of the transmitter was observed, all others were baseline of the noise floor measurements. Measurements above 18 GHz were performed as exploratory at a much closer distance with the standard gain horn. No emissions were observed above the second harmonic of the fundamental frequency.

Exploratory radiated emissions measurements of the transmitter frequencies were made to determine the maximum transmit level of the EUT. All frequencies were searched for any emissions from the Zigbee module and EUT. No other emissions were observed. The transmit frequency of 2405 MHz was determined to be the highest level. With the antenna in Vertical orientation the highest level was recorded.

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Report of Measurements Maximum Unwanted Emission Levels Data

The following tables report the results of the Maximum Unwanted Emission Level measurements for the Stack Hub, HUB-01AC-00Z. These measurements were taken and compared to the general emission limits of 15.209 and the radiated emission requirements of 15.247. Final testing of the low, middle and high channels was performed to find worst case levels. The EUT was operating in the worst case condition at 2405MHz, 802.15.4.

All emissions within the restricted bands of operation were below the limits of FCC part 15.209(a).

The EUT was operated at maximum transmit power and 100% duty cycle.

The frequency range of 30 MHz to 1 GHz was scanned at a distance of 10 meters. The frequency range from 1 GHz to 18 GHz was scanned at a distance of 3 meters. Higher frequencies were scanned at a much closer distance to identify any emissions from the EUT. No emissions were observed between 9 kHz and 30 MHz and also above 5 GHz. Reported measurements above 5 GHz were the baseline levels of the measurement system.

Fundamental Frequency MHz	**PK Level dBµV/m**
2405	91.1
2405	**92.5**
2445	87.5
2445	89.4
2480	87.5
2480	88.4

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Radiated Data

Stack Labs, Inc.

Product - Stack Hub

Model - HUB-01AC-00Z

Table 6 – Radiated Data

Frequency MHz	QP Level dBµV/m	QP Limit dBµV/m	Margin dB	Azimuth, Height	Antenna, Polarization
The data below was taken at 10 meter distance.					
250.0	27.21	37.00	9.79	0, 4	BiLog, H
300.0	31.69	37.00	5.31	112, 3.8	BiLog, H
350.0	32.30	37.00	4.70	180, 3	BiLog, H
400.0	30.01	37.00	6.99	315, 2.8	BiLog, H
425.05	30.78	37.00	6.22	315, 2.1	BiLog, H
450.0	28.30	37.00	8.70	315, 2.1	BiLog, H
550.05	23.78	37.00	13.22	338, 1.8	BiLog, H
600.0	23.07	37.00	13.93	292, 1.7	BiLog, H
675.05	28.63	37.00	8.37	270, 1.5	BiLog, H
200.05	14.14	30.00	15.86	248, 1.1	BiLog, V
250.0	30.02	37.00	6.98	270, 1.1	BiLog, V
300.0	31.73	37.00	5.27	270, 1.1	BiLog, V
350.0	32.70	37.00	4.30	338, 1.5	BiLog, V
400.05	27.60	37.00	9.40	0, 1.3	BiLog, V
450.0	29.39	37.00	7.61	315, 1.1	BiLog, V
500.0	29.61	37.00	7.39	0, 1.3	BiLog, V
600.0	21.00	37.00	16.00	270, 1	BiLog, V
The data below was taken at 3 meter distance					
Emission Frequency MHz	**PK Level dBµV/m**	**PK Limit dBµV/m**	**AV Level dBµV/m**	**AV Limit dBµV/m**	**PK Margin dB**	**AV Margin dB**
Lowest Channel						
4810 H	60.8	74	50.9	54	-13.2	-3.1
4810 V	62.6	74	51.1	54	-11.4	-2.9
7215 H	41.5 BL	74	32.5 BL	54	-32.5	-21.5
7215 V	43.2 BL	74	32 BL	54	-30.8	-22
9620 H	45.8 BL	74	35.7 BL	54	-28.2	-18.3
9620 V	44.6 BL	74	35.9 BL	54	-29.4	-18.1
Middle Channel						
4890 H	60.0	74	49.9	54	-14	-4.1
4890 V	61.5	74	50.6	54	-12.5	-3.4
7335 H	43.7 BL	74	33.5 BL	54	-30.3	-20.5
7335 V	46.4 BL	74	34.1 BL	54	-27.6	-19.9
9780 H	46.4 BL	74	34.9 BL	54	-27.6	-19.1
9780 V	45.2 BL	74	35.8 BL	54	-28.8	-18.2
Highest Channel						
4960 H	51.7	74	41.4	54	-22.3	-12.6
4960 V	57.7	74	47.1	54	-16.3	-6.9
7440 H	45.2 BL	74	33.1 BL	54	-28.8	-20.9
7440 V	46.9 BL	74	33.3 BL	54	-27.1	-20.7

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9920 H	45.8 BL	74	34.8 BL	54	-28.2	-19.2
9920 V	46.4 BL	74	35.1 BL	54	-27.6	-18.9
No other emissions were observed						

Operating mode of the transmitter was 802.15.4. Only baseline noise floor was observed after the second harmonic. (BL) Note: PK – peak readings, AV – average readings, H – horizontal polarization, V – vertical polarization.

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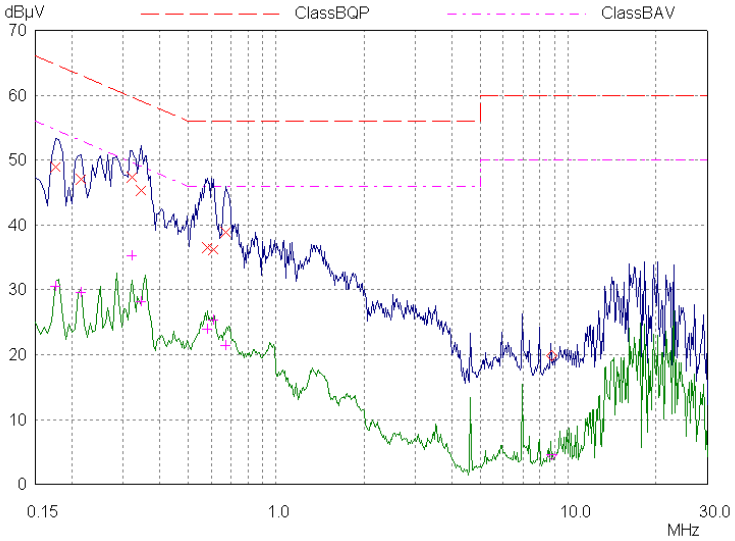
Conducted Data for 15.207 Line

Figure 2 – Line Scan



Blue Trace: Peak Measurement Green Trace: Average Measurement
Final Measurement: x = QP / + = AV at 2 second measurement time.

Table 7 – Line Scan Data

Frequency MHz	Level dBµV	Detector	Limit dBµV	Margin dB	Phase	PE
0.175	48.99	QP	64.72	15.73	L1	fl
0.215	46.97	QP	63.01	16.04	L1	fl
0.32	47.42	QP	59.71	12.29	L1	fl
0.345	45.35	QP	59.08	13.73	L1	fl
0.58	36.56	QP	56.00	19.44	L1	fl
0.61	36.12	QP	56.00	19.88	L1	fl
0.67	38.83	QP	56.00	17.17	L1	fl
0.175	30.58	AV	54.72	24.14	L1	fl
0.215	29.54	AV	53.01	23.47	L1	fl
0.32	35.25	AV	49.71	14.46	L1	fl
0.345	28.11	AV	49.08	20.97	L1	fl
0.58	23.94	AV	46.00	22.06	L1	fl
0.61	25.27	AV	46.00	20.73	L1	fl
0.67	21.42	AV	46.00	24.58	L1	fl

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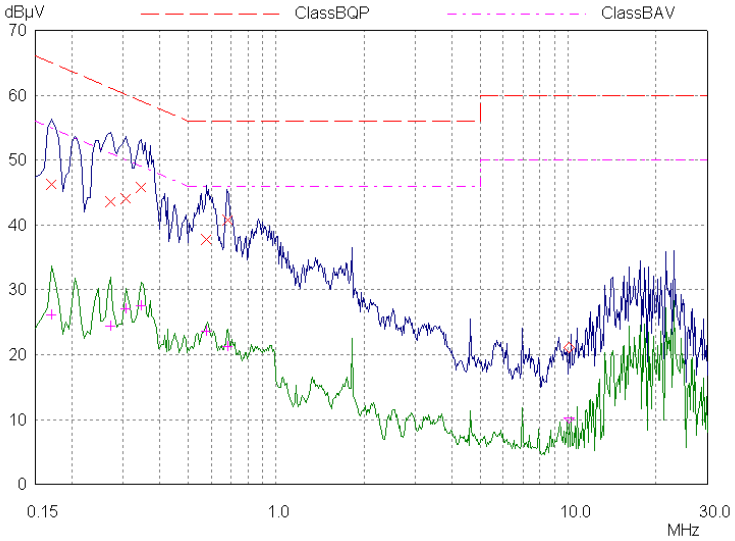
Conducted Data for 15.207 Neutral

Figure 3 – Neutral Scan



Blue Trace: Peak Measurement Green Trace: Average Measurement
Final Measurement: x = QP / + = AV at 2 second measurement time.

Table 8 – Neutral Scan Data

Frequency MHz	Level dBµV	Detector	Limit dBµV	Margin dB	Phase	PE
0.17	46.29	QP	64.96	18.67	N	fl
0.27	43.65	QP	61.12	17.47	N	fl
0.305	44.05	QP	60.11	16.06	N	fl
0.345	45.79	QP	59.08	13.29	N	fl
0.575	37.72	QP	56.00	18.28	N	fl
0.685	40.79	QP	56.00	15.21	N	fl
0.17	26.12	AV	54.96	28.84	N	fl
0.27	24.43	AV	51.12	26.69	N	fl
0.305	27.01	AV	50.11	23.10	N	fl
0.345	27.53	AV	49.08	21.55	N	fl
0.575	23.62	AV	46.00	22.38	N	fl
0.685	21.33	AV	46.00	24.67	N	fl

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COMPLIANCE VERIFICATION REPORT

TEST CERTIFICATE

APPLICANT:	Stack Labs, Inc. 10054 Pasadena Ave. Cupertino, CA 95014
Trade Name:	Stack
Model:	HUB-01AC-00Z

I HEREBY CERTIFY THAT:

The measurements shown in this report were made in accordance with the procedures indicated and that the energy emitted by this equipment, as received, was found to be within the FCC CFR 47 Part 15 Subpart C requirements. Additionally, it should be noted that the results in this report apply only to the items tested, as identified herein.

I FURTHER CERTIFY THAT:

On the basis of the measurements taken at the test site, the equipment tested is capable of operation in compliance with the requirements set forth in FCC CFR 47 Part 15.207, 15.209 and 15.247 Rules and Regulations.

On this Date: November 17, 2015

Bruce Smith
Atlas Compliance & Engineering, Inc.