# FCC PART 15, SUBPART C
# IC RSS-210, ISSUE 8, DECEMBER 2010

## TEST AND MEASUREMENT REPORT

For

# Tigo Energy, Inc.

420 Blossom Hill Road,

Los Gatos, CA 95032, USA

**FCC ID: XMYSILICONAIR2**
**IC: 11021A-SILICONAIR2**

| **Report Type:** | **Product Type:** |
|---|---|
| Original Report | Zigbee Module |

| | |
|---|---|
| **Prepared By:** | Isaac Aguilar<br>Test Engineer |
| **Report Number:** | R1409027-247 |
| **Report Date:** | 2014-10-24 |
| **Reviewed By:** | Bo Li<br>RF Lead |

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# DOCUMENT REVISION HISTORY

| Revision Number | Report Number | Description of Revision | Date of Revision |
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| 0 | R1409027-247 | Original Report | 2014-10-24 |

# 1 General Description

## 1.1 Product Description for Equipment Under Test (EUT)

This test and measurement report was prepared on behalf of *Tigo Energy* and their product model: *SILICONAIR2, FCC ID: XMYSILICONAIR2; IC: 11021A-SILICONAIR2* or the "EUT" (Equipment under Test) as referred to in this report. The EUT is a Zigbee 802.15.4 RF module operates in 2.4 GHz.

## 1.2 Mechanical Description of EUT

The EUT measures approximately 11 cm (L) x 7 cm (W) x 2 cm (H) and weighs 150 g.

*The test data gathered are from typical production sample, serial number: 001-00230-00 assigned by Client.*

## 1.3 Objective

This report is prepared on behalf of *Tigo Energy* in accordance with Part 2, Subpart J, and Part 15, Subparts B and C of the Federal Communication Commissions rules and IC RSS-210.

The objective is to determine compliance with FCC Part 15.247 and RSS-210 rules for Output Power, Antenna Requirements, 6 dB& 99% Bandwidth, power spectral density, 100 kHz Bandwidth of Band Edges Measurement, Spurious Emissions, Conducted and Radiated Spurious Emissions.

## 1.4 Related Submittal(s)/Grant(s)

N/A

## 1.5 Test Methodology

All measurements contained in this report were conducted in accordance with ANSI C63.4-2009, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the range of 9 kHz to 40 GHz and FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247

## 1.6 Measurement Uncertainty

All measurements involve certain levels of uncertainties, especially in the field of EMC. The factors contributing to uncertainties are spectrum analyzer, cable loss, antenna factor calibration, antenna directivity, antenna factor variation with height, antenna phase center variation, antenna factor frequency interpolation, measurement distance variation, site imperfections, mismatch (average), and system repeatability.

The following calculation follows the procedures as set forth in clause 7.2.3, ETSI TR 100 028-1 V1.4.1 (2001-12), the expression of Uncertainty in Radiated RF Testing is in accordance to ISO/IEC 17025 and TR 100 028-1 V1.4.1 (2001-12).

The expanded Measurement Uncertainty value having a confidence factor of 95%, is within a range of 5.48 dB.

This means that the value of conducted RF carrier power test will be within +/- 2.74 dB of the measuring radiated emissions power versus the expected value.

The expected value is defined as the power at the antenna of the Transmitter under Test.

## 1.7 Test Facility

Bay area compliance Laboratories Corp. (BACL) is:
1- An independent Commercial Test Laboratory accredited to **ISO 17025: 2005** by **A2LA**, in the fields of: Electromagnetic Compatibility & Telecommunications covering Emissions, Immunity, Radio, RF Exposure, Safety and Telecom. This includes NEBS (Network Equipment Building System), Wireless RF, Telecommunications Terminal Equipment (TTE); Network Equipment; Information Technology Equipment (ITE); Medical Electrical Equipment; Industrial, Commercial, and Medical Test Equipment; Professional Audio and Video Equipment; Electronic (Digital) Products; Industrial and Scientific Instruments; Cabled Distribution Systems and Energy Efficiency Lighting.

2- An ENERGY STAR Recognized Laboratory, for the LM80 Testing, a wide variety of Luminares and Computers.

3- A NIST Designated Phase-I and Phase-II CAB including: ACMA (Australian Communication and Media Authority), BSMI (Bureau of Standards, Metrology and Inspection of Taiwan), IDA (Infocomm Development Authority of Singapore), IC(Industry Canada), Korea ( Ministry of Communications Radio Research Laboratory), NCC (Formerly DGT; Directorate General of Telecommunication of Chinese Taipei) OFTA (Office of the Telecommunications Authority of Hong Kong), Vietnam, VCCI - Voluntary Control Council for Interference of Japan and a designated EU CAB (Conformity Assessment Body) (Notified Body) for the EMC and R&TTE Directives.

4- A Product Certification Body accredited to **ISO Guide 65: 1996** by **A2LA** to certify:
1- Unlicensed, Licensed radio frequency devices and Telephone Terminal Equipment for the FCC. Scope A1, A2, A3, A4, B1, B2, B3, B4 & C.
2. Radio Standards Specifications (RSS) in the Category I Equipment Standards List and All Broadcasting Technical Standards (BETS) in Category I Equipment Standards List for Industry Canada.
3. Radio Communication Equipment for Singapore.
4. Radio Equipment Specifications, GMDSS Marine Radio Equipment Specifications, and Fixed Network Equipment Specifications for Hong Kong.
5. Japan MIC Telecommunication Business Law (A1, A2) and Radio Law (B1, B2 and B3).
6. Audio/Video, Battery Charging Systems, Computers, Displays, Enterprise Servers, Imaging Equipment, Set-Top Boxes, Telephony, Televisions, Ceiling Fans, CFLs (Including GU24s),Decorative Light Strings, Integral LED Lamps, Luminaires, Residential Ventilating Fans.

The test site used by BACL Corp. to collect radiated and conducted emissions measurement data is located at its facility in Sunnyvale, California, USA.

The test site at BACL Corp. has been fully described in reports submitted to the Federal Communication Commission (FCC) and Voluntary Control Council for Interference (VCCI). The details of these reports have been found to be in compliance with the requirements of Section 2.948 of the FCC Rules on February 11 and December 10, 1997, and Article 8 of the VCCI regulations on December 25, 1997. The test site also complies with the test methods and procedures set forth in CISPR 22:2008 §10.4 for measurements below 1 GHz and §10.6 for measurements above 1 GHz as well as ANSI C63.4-2009, ANSI C63.4-2009, TIA/EIA-603 & CISPR 24:2010.

The Federal Communications Commission and Voluntary Control Council for Interference have the reports on file and they are listed under FCC registration number: 90464 and VCCI Registration No.: A-0027. The test site has been approved by the FCC and VCCI for public use and is listed in the FCC Public Access Link (PAL) database.

Additionally, BACL Corp. is an American Association for Laboratory Accreditation (A2LA) accredited laboratory (Lab Code 3297-02). The current scope of accreditations can be found at

http://www.a2la.org/scopepdf/3297-02.pdf?CFID=1132286&CFTOKEN=e42a3240dac3f6ba-6DE17DCB-1851-9E57-477422F667031258&jsessionid=8430d44f1f47cf2996124343c704b367816b

# 2 System Test Configuration

## 2.1 Justification

The EUT was configured for testing according to ANSI C63.4-2009 and FCC KDB 558074 D01 DTS Meas Guidance v03r02.

The EUT was tested in a testing mode to represent worst-case results during the final qualification test.

The worst-case data rates are determined to be as follows for each mode based upon investigation by measuring the average power, peak power and PPSD across all data rates bandwidths, and modulations.

## 2.2 EUT Exercise Software

The test utility used was *Tera Term*, provided by *Tigo Energy*, and was verified by Isaac Aguilar to comply with the standard requirements being tested against.

## 2.3 Special Equipment

Tigo Energy MM2ES Programming JIG was used to operate the EUT.

## 2.4 Equipment Modifications

No modifications were made to the equipment.

## 2.5 Local Support Equipment

| Manufacturer | Description | Model | Serial Number |
|---|---|---|---|
| Dell | Laptop | E6410 | FFXR4Q1 |

## 2.6 EUT Internal Configuration Details

| Manufacturer | Description | Model | Serial Number |
|---|---|---|---|
| Tigo Energy | Radio | Tigo-COMM-02 | 1000251-1120 |

## 2.7 Interface Ports and Cables

| Cable Description | Length (m) | To | From |
|---|---|---|---|
| USB | < 1 | MM2ES Programming JIG | Laptop |

## 2.8 Power Supply List and Details

N/A

# 3 Summary of Test Results

Results reported relate only to the product tested.

| FCC & IC Rules | Description of Test | Results |
|---|---|---|
| FCC §2.1091<br>IC RSS-102 | RF Exposure | Compliant |
| FCC §15.203<br>IC RSS-Gen §7.1.2 | Antenna Requirements | Compliant |
| FCC §15.207(a)<br>IC RSS-Gen §7.2.4 | AC Line Conducted Emissions | Compliant |
| FCC §15.247(d)<br>IC RSS-210 §A8.5 | Spurious Emissions at Antenna Port | Compliant |
| FCC §5.209, §15.247(d)<br>IC RSS-210 §A8.5 | Spurious Radiated Emissions | Compliant |
| FCC §15.247(a)(2)<br>IC RSS-210 §A8.2 | 6 dB & 99% Emission Bandwidth | Compliant |
| FCC §15.247(b)(3)<br>IC RSS-210 §A8.4 | Output Power | Compliant |
| FCC §15.247(d)<br>IC RSS-210 §A8.5 | Band Edge | Compliant |
| FCC §15.247(e)<br>IC RSS-210 §A8.2(b) | Power Spectral Density | Compliant |

# 4 FCC §15.247 (i), §2.1091 & IC RSS-102 – RF Exposure

## 4.1 Applicable Standards

According to FCC §15.247(i) and §1.1307(b)(1), 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 level in excess of the Commission's guidelines.

Limits for General Population/Uncontrolled Exposure

| Frequency Range (MHz) | Electric Field Strength (V/m) | Magnetic Field Strength (A/m) | Power Density ($mW/cm^2$) | Averaging Time (minutes) |
|---|---|---|---|---|
| Limits for General Population/Uncontrolled Exposure | | | | |
| 0.3-1.34 | 614 | 1.63 | * (100) | 30 |
| 1.34-30 | 824/f | 2.19/f | * ($180/f^2$) | 30 |
| 30-300 | 27.5 | 0.073 | 0.2 | 30 |
| 300-1500 | / | / | f/1500 | 30 |
| 1500-100,000 | / | / | 1.0 | 30 |

f = frequency in MHz
* = Plane-wave equivalent power density

Before equipment certification is granted, the procedure of IC RSS-102 must be followed concerning the exposure of humans to RF fields.

According to IC RSS-102 Issue 2 section 4.1, RF limits used for general public will be applied to the EUT.

| Frequency Range (MHz) | Electric Field (V/m rms) | Magnetic Field (A/m rms) | Power Density ($W/m^2$) | Time Averaging (min) |
|---|---|---|---|---|
| 0.003 - 1 | 280 | 2.19 | - | 6 |
| 1 - 10 | 280 / f | 2.19 / f | - | 6 |
| 10 - 30 | 28 | 2.19 / f | - | 6 |
| 30 – 300 | 28 | 0.073 | 2* | 6 |
| 300 – 1 500 | $1.585\ f^{0.5}$ | $0.0042\ f^{0.5}$ | f / 150 | 6 |
| 1 500 – 15 000 | 61.4 | 0.163 | 10 | 6 |
| 15 000 – 150 000 | 61.4 | 0.163 | 10 | $616000 / f^{1.2}$ |
| 150 000- 300 000 | $0.158\ f^{0.5}$ | $4.21 \times 10\ -4\ f^{0.5}$ | $6.67 \times 10^{-5}\ f$ | $616000 / f^{1.2}$ |

**Note:** *f* is frequency in MHz
* = Power density limit is applicable at frequencies greater than 100 MHz

## 4.2 MPE Prediction

Predication of MPE limit at a given distance, Equation from OET Bulletin 65, Edition 97-01

$$S = PG/4\pi R^2$$

Where: S = power density
P = power input to antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

## 4.3 MPE Results

| | |
|---|---|
| Maximum peak output power at antenna input terminal (dBm): | 3.24 |
| Maximum peak output power at antenna input terminal (mW): | 2.10 |
| Prediction distance (cm): | 20 |
| Prediction frequency (MHz): | 2480 |
| Maximum Antenna Gain, typical (dBi): | 2.0 |
| Maximum Antenna Gain (numeric): | 1.58 |
| Power density of prediction frequency at 20.0 cm ($mW/cm^2$): | 0.000665 |
| Power density of prediction frequency at 20.0 cm ($W/m^2$): | 0.00665 |
| MPE limit for uncontrolled exposure at prediction frequency ($mW/cm^2$): | 1.0 |
| MPE limit for uncontrolled exposure at prediction frequency ($W/m^2$): | 10 |

The device is compliant with the requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is $6.65 \times 10^{-4}$ mW/ $cm^2$ (0.00665 W/ $m^2$). Limit is 1.0 $mW/cm^2$ (10 $W/m^2$).

# 5 FCC §15.203 & IC RSS-Gen §7.1.2 - Antenna Requirements

## 5.1 Applicable Standards

According to FCC §15.203, 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.

And according to FCC §15.247 (b) (4), if transmitting antennas of directional gain greater than 6 dBi are used the power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

According to IC RSS-Gen §7.1.2: Transmitter Antenna

A transmitter can only be sold or operated with antennas with which it was certified. A transmitter may be certified with multiple antenna types. An antenna type comprises antennas having similar in-band and out-of-band radiation patterns. Testing shall be performed using the highest-gain antenna of each combination of transmitter and antenna type for which certification is being sought, with the transmitter output power set at the maximum level. Any antenna of the same type and having equal or lesser gain as an antenna that had been successfully tested for certification with the transmitter, will also be considered certified with the transmitter, and may be used and marketed with the transmitter. The manufacturer shall include with the application for certification a list of acceptable antenna types to be used with the transmitter.

When a measurement at the antenna connector is used to determine RF output power, the effective gain of the device's antenna shall be stated, based on measurement or on data from the antenna manufacturer. Any antenna gain in excess of 6 dBi (6 dB above isotropic gain) shall be added to the measured RF output power before using the power limits specified in RSS-210 or RSS-310 for devices of RF output powers of 10 mW or less. For devices of output powers greater than 10 mW, except devices subject to RSS-210 Annex 8 (Frequency Hopping and Digital Modulation Systems Operating in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz Bands) or RSS-210 Annex 9 (Local Area Network Devices), the total antenna gain shall be added to the measured RF output power before using the specified power limits. For devices subject to RSS-210 Annex 8 or Annex 9, the antenna gain shall not be added.

## 5.2 Antenna List

| Manufacturers | Antenna Type/Pattern | Antenna Gain (dBi) @ 2.4 GHz |
|---|---|---|
| Tigo Energy | Intergral | 2.0 |

Please refer EUT photos.

# 6 FCC §15.207 & IC RSS-Gen §7.2.4 - AC Line Conducted Emissions

## 6.1 Applicable Standards

As per FCC §15.207 and IC RSS-Gen §7.2.4 Conducted limits:

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 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 boundary between the frequencies ranges.

| Frequency of Emission (MHz) | Conducted Limit (dBuV) | |
|---|---|---|
| | 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.*

## 6.2 Test Setup

The measurement was performed at shield room, using the setup per ANSI C63.4-2009 measurement procedure. The specification used was FCC §15.207 and IC RSS-Gen §7.2.4 limits.

External I/O cables were draped along the edge of the test table and bundle when necessary.

The AC/DC power adapter of the EUT was connected with LISN-1 which provided 120 V / 60 Hz AC power.

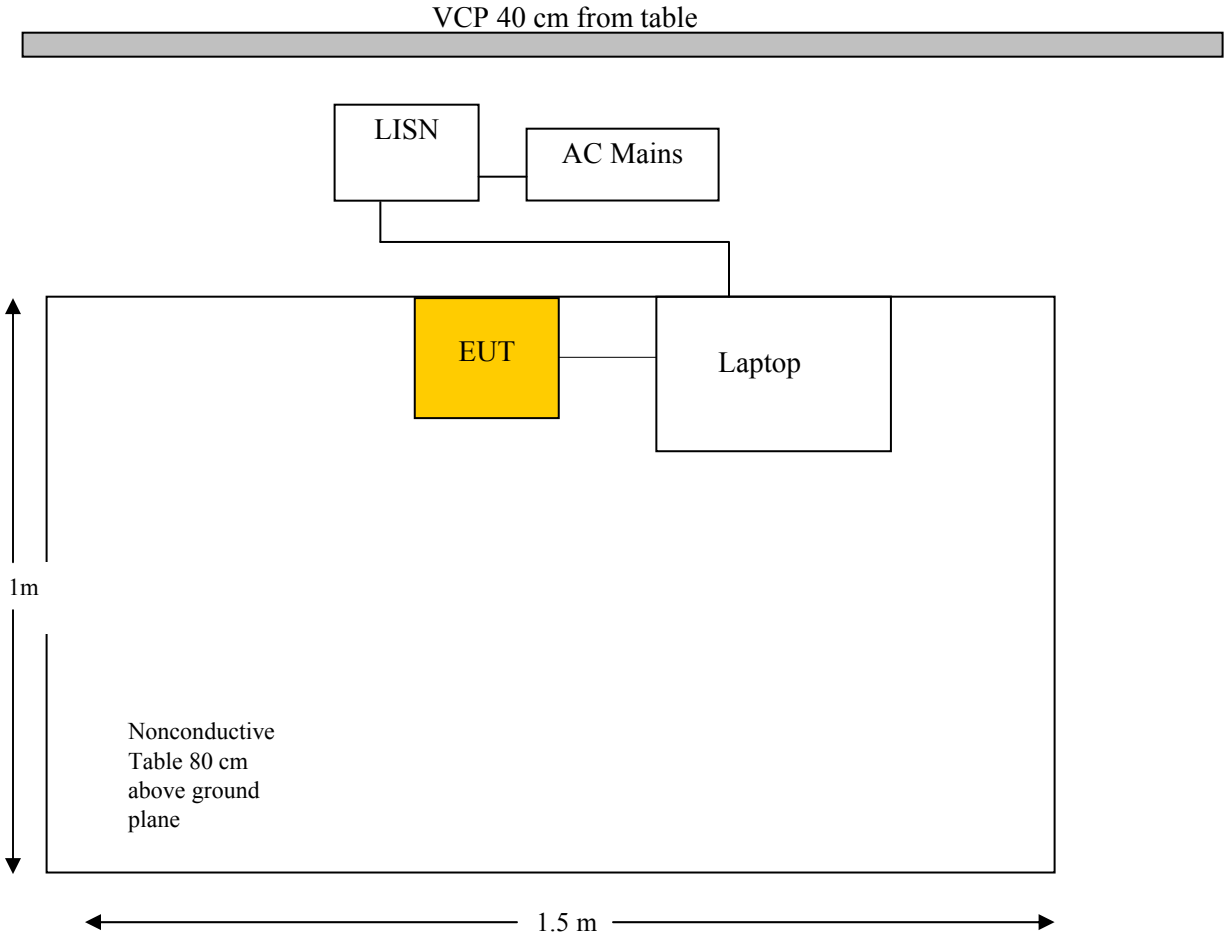
## 6.3 Test Procedure

During the conducted emissions test, the power cord of the EUT host system was connected to the mains outlet of the LISN-2.

Maximizing procedure was performed on the six (6) highest emissions of the EUT.

All data was recorded in the peak detection mode, quasi-peak and average. Quasi-Peak readings are distinguished with a “QP.” Average readings are distinguished with an “Ave”.

## 6.4 Test Setup Block Diagram




## 6.5 Corrected Amplitude & Margin Calculation

The Corrected Amplitude (CA) is calculated by adding the Cable Loss (CL), the Attenuator Factor (Atten) to indicated Amplitude (Ai) reading. The basic equation is as follows:

CA = Ai + CL + Atten

For example, a corrected amplitude of 46.2 dBuV = Indicated Reading (32.5 dBuV) + Cable Loss (3.7 dB) + Attenuator (10 dB)

The "**Margin**" column of the following data tables indicates the degree of compliance within the applicable limit. For example, a margin of -7 dB means the emission is 7 dB below the maximum limit. The equation for margin calculation is as follows:

Margin = Corrected Amplitude - Limit

## 6.6 Test Equipment List and Details

| Manufacturer | Description | Model No. | Serial No. | Calibration Date | Calibration Interval |
|---|---|---|---|---|---|
| Rhode & Shwarz | EMI Test Receiver | 100338 | N/A | 2014-01-20 | 1 year |
| Sunol Sciences | LISN | 9252-50-R-24-N | 511213 | 2014-06-25 | 1 year |

***Statement of Traceability: BACL Corp.*** *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

## 6.7 Test Environmental Conditions

| | |
|---|---|
| **Temperature:** | 24 °C |
| **Relative Humidity:** | 45 % |
| **ATM Pressure:** | 101.64 kPa |

*The testing was performed by Isaac Aguilar on 2014-09-19 in 5 m chamber 3.*

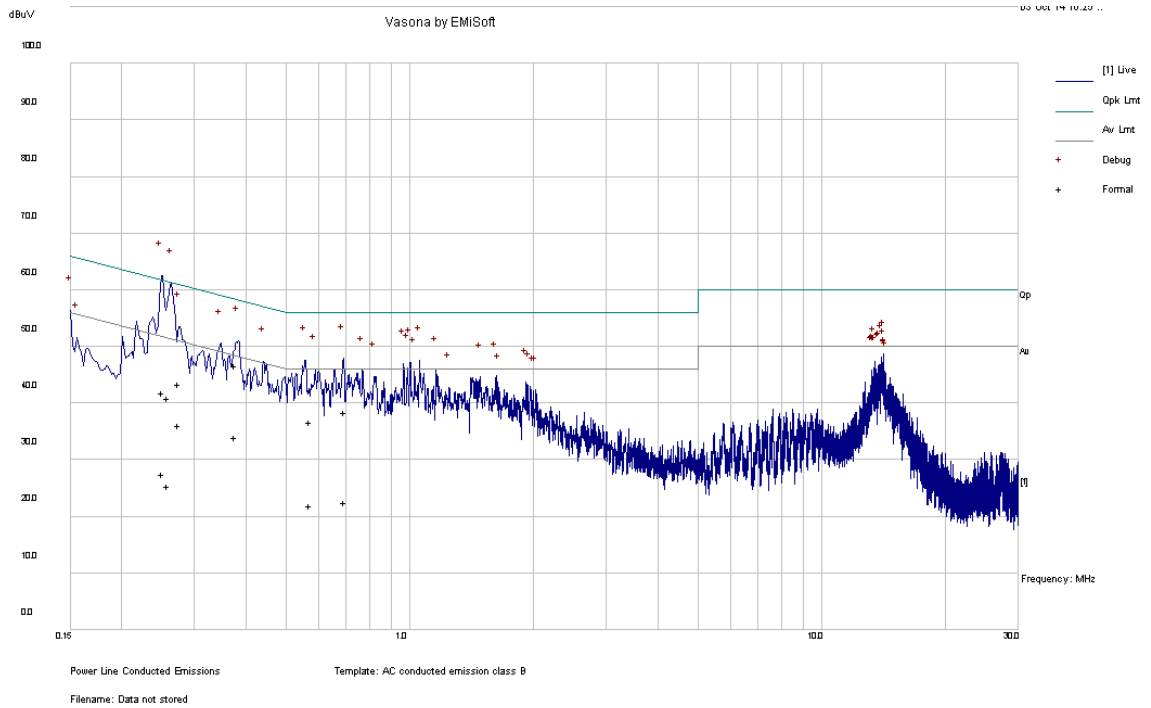
## 6.8 Summary of Test Results

According to the recorded data in following table, the EUT complied with the FCC and IC standard's conducted emissions limits, with the margin reading of:

| Connection: AC/DC adapter connected to 120 V/60 Hz, AC | | | |
|---|---|---|---|
| **Margin (dB)** | **Frequency (MHz)** | **Conductor Mode (Line/Neutral)** | **Range (MHz)** |
| -5.95 | 0.312924 | Neutral | 0.15-30 |

## 6.9 Conducted Emissions Test Plots and Data

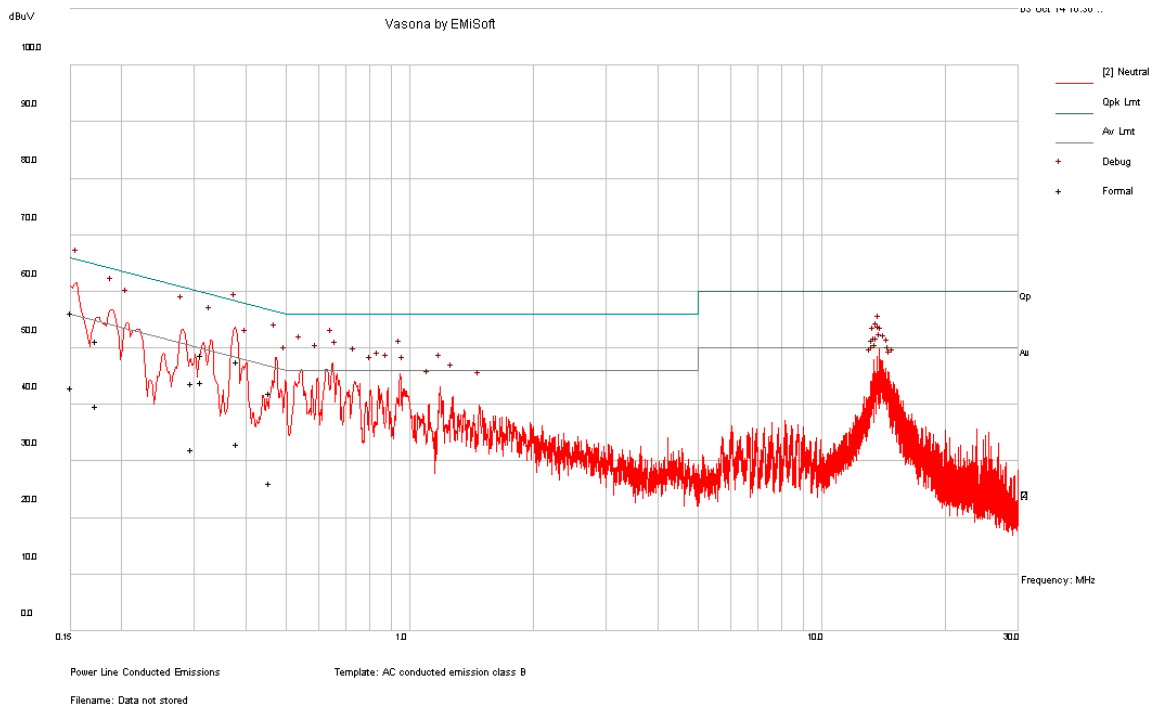
**120 V, 60 Hz – Line, AC/DC Adaptor**




| Frequency (MHz) | Corrected Amplitude (dBµV) | Conductor (Line/Neutral) | Limit (dBµV) | Margin (dB) | Detector (QP/Ave) |
|---|---|---|---|---|---|
| 0.259546 | 40.89 | Line | 61.45 | -20.56 | QP |
| 0.252204 | 41.94 | Line | 61.68 | -19.75 | QP |
| 0.37849 | 46.60 | Line | 58.31 | -11.72 | QP |
| 0.275475 | 43.46 | Line | 60.95 | -17.50 | QP |
| 0.696744 | 38.43 | Line | 56 | -17.57 | QP |
| 0.572699 | 36.72 | Line | 56 | -19.28 | QP |

| Frequency (MHz) | Corrected Amplitude (dBµV) | Conductor (Line/Neutral) | Limit (dBµV) | Margin (dB) | Detector (QP/Peak) |
|---|---|---|---|---|---|
| 0.259546 | 25.31 | Line | 51.45 | -26.14 | Ave |
| 0.252204 | 27.54 | Line | 51.68 | -24.14 | Ave |
| 0.37849 | 33.92 | Line | 48.31 | -14.39 | Ave |
| 0.275475 | 36.11 | Line | 50.95 | -14.84 | Ave |
| 0.696744 | 22.59 | Line | 46 | -23.41 | Ave |
| 0.572699 | 21.94 | Line | 46 | -24.06 | Ave |

## 120 V, 60 Hz – Neutral, AC/DC Adaptor




| Frequency (MHz) | Corrected Amplitude (dBµV) | Conductor (Line/Neutral) | Limit (dBµV) | Margin (dB) | Detector (QP/Ave) |
|---|---|---|---|---|---|
| 0.151025 | 56.22 | Neutral | 65.94 | -9.72 | QP |
| 0.382487 | 47.62 | Neutral | 58.23 | -10.61 | QP |
| 0.173714 | 51.33 | Neutral | 64.78 | -13.45 | QP |
| 0.296839 | 43.77 | Neutral | 60.33 | -16.56 | QP |
| 0.312924 | 48.85 | Neutral | 59.89 | -11.04 | QP |
| 0.457774 | 42.11 | Neutral | 56.73 | -14.62 | QP |

| Frequency (MHz) | Corrected Amplitude (dBµV) | Conductor (Line/Neutral) | Limit (dBµV) | Margin (dB) | Detector (QP/Peak) |
|---|---|---|---|---|---|
| 0.151025 | 42.99 | Neutral | 55.94 | -12.95 | Ave |
| 0.382487 | 33.08 | Neutral | 48.23 | -15.14 | Ave |
| 0.173714 | 39.79 | Neutral | 54.78 | -14.99 | Ave |
| 0.296839 | 32.02 | Neutral | 50.33 | -18.31 | Ave |
| 0.312924 | 43.94 | Neutral | 49.89 | -5.95 | Ave |
| 0.457774 | 26.18 | Neutral | 46.73 | -20.55 | Ave |

# 7 FCC §15.247(d) & IC RSS-210 §A8.5 - Spurious Emissions at Antenna Terminals

## 7.1 Applicable Standards

For FCC §15.247(d) and IC RSS-210 §A8.5 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.

## 7.2 Measurement Procedure

The measurements are based on FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 section 11: Emissions in non-restricted frequency bands.

## 7.3 Test Equipment List and Details

| Manufacturer | Description | Model | Serial Number | Calibration Date | Calibration Cycle |
|---|---|---|---|---|---|
| Agilent | Spectrum Analyzer | E4440A | US42221841 | 2014-04-09 | 1 year |

***Statement of Traceability: BACL Corp.*** *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

## 7.4 Test Environmental Conditions

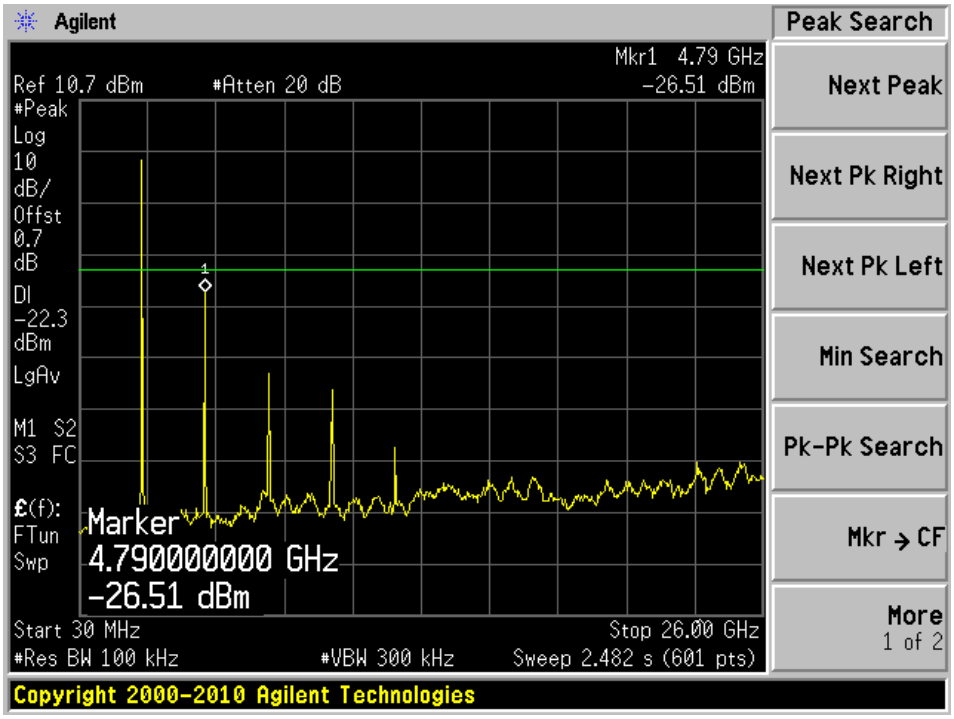
| | |
|---|---|
| **Temperature:** | 25 °C |
| **Relative Humidity:** | 46 % |
| **ATM Pressure:** | 101.68 kPa |

*The testing was performed by Isaac Aguilar from 2014-09-19 at RF site.*

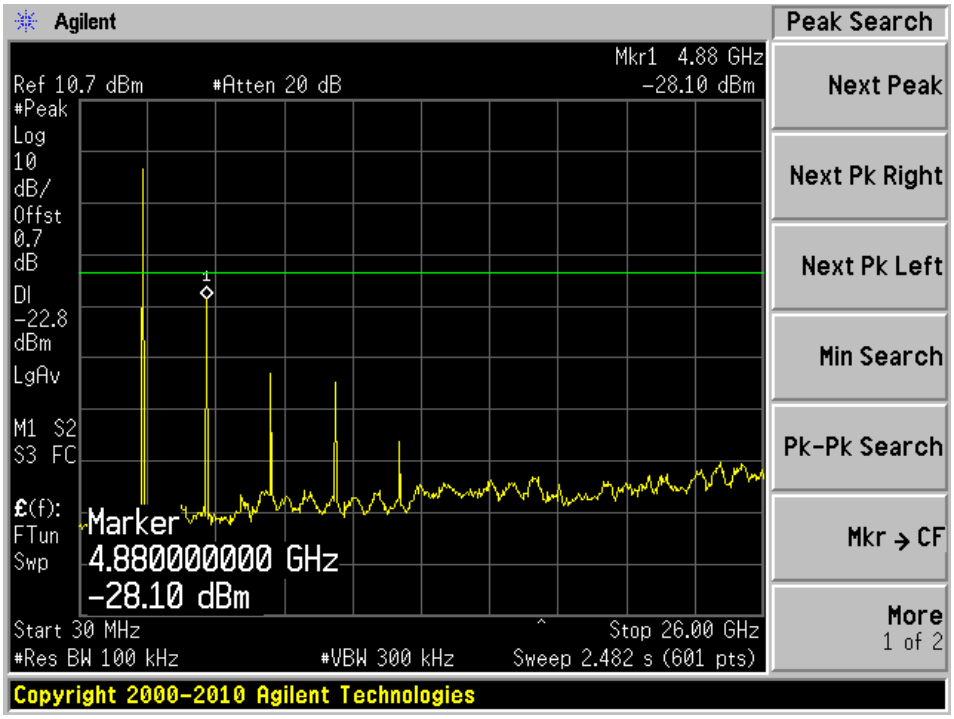
## 7.5 Test Results

Please refer to the following plots.

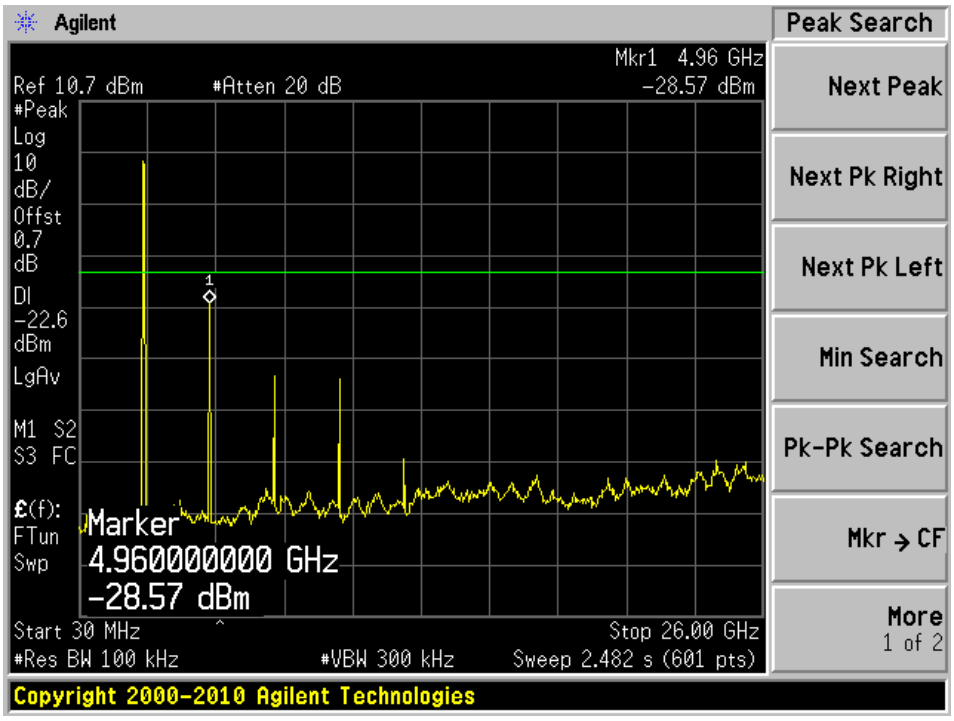
Low Channel (2405 MHz) Spurious Emissions




Middle Channel (2440 MHz) Spurious Emissions



High Channel (2480 MHz) Spurious Emissions



# 8 FCC §15.209, §15.247(d) & IC RSS-210 §A8.5 - Spurious Radiated Emissions

## 8.1 Applicable Standard

As per FCC §15.35(d): Unless otherwise specified, on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz.

As per FCC §15.209(a) and RSS-210: Except as provided elsewhere in this Subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table

| Frequency (MHz) | Field Strength (micro volts/meter) | Measurement Distance (meters) |
|---|---|---|
| 0.009 - 0.490 | 2400/F(kHz) | 300 |
| 0.490 - 1.705 | 24000/F(kHz) | 30 |
| 1.705 - 30.0 | 30 | 30 |
| 30 - 88 | 100** | 3 |
| 88 - 216 | 150** | 3 |
| 216 - 960 | 200** | 3 |
| Above 960 | 500 | 3 |

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g., Sections 15.231 and 15.241.

As Per FCC §15.205(a) except as show in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090 – 0.110 | 16.42 – 16.423 | 960 – 1240 | 4. 5 – 5. 15 |
| 0.495 – 0.505 | 16.69475 – 16.69525 | 1300 – 1427 | 5. 35 – 5. 46 |
| 2.1735 – 2.1905 | 25.5 – 25.67 | 1435 – 1626.5 | 7.25 – 7.75 |
| 4.125 – 4.128 | 37.5 – 38.25 | 1645.5 – 1646.5 | 8.025 – 8.5 |
| 4.17725 – 4.17775 | 73 – 74.6 | 1660 – 1710 | 9.0 – 9.2 |
| 4.20725 – 4.20775 | 74.8 – 75.2 | 1718.8 – 1722.2 | 9.3 – 9.5 |
| 6.215 – 6.218 | 108 – 121.94 | 2200 – 2300 | 10.6 – 12.7 |
| 6.26775 – 6.26825 | 123 – 138 | 2310 – 2390 | 13.25 – 13.4 |
| 6.31175 – 6.31225 | 149.9 – 150.05 | 2483.5 – 2500 | 14.47 – 14.5 |
| 8.291 – 8.294 | 156.52475 – 156.52525 | 2690 – 2900 | 15.35 – 16.2 |
| 8.362 – 8.366 | 156.7 – 156.9 | 3260 – 3267 | 17.7 – 21.4 |
| 8.37625 – 8.38675 | 162.0125 –167.17 | 3.332 – 3.339 | 22.01 – 23.12 |
| 8.41425 – 8.41475 | 167.72 – 173.2 | 3 3458 – 3 358 | 23.6 – 24.0 |
| 12.29 – 12.293 | 240 – 285 | 3.600 – 4.400 | 31.2 – 31.8 |
| 12.51975 – 12.52025 | 322 – 335.4 | | 36.43 – 36.5 |
| 12.57675 – 12.57725 | 399.9 – 410 | | Above 38.6 |
| 13.36 – 13.41 | 608 – 614 | | |

As per FCC §15.247 (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 §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c).

As per IC RSS-210 A8.5 Out-of-band Emissions, In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced 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 that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under Section A8.4 (4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

## 8.2 Test Setup

The radiated emissions tests were performed in the 5-meter Chamber, using the setup in accordance with ANSI C63.4-2009. The specification used was the FCC 15 Subpart C limits.

The spacing between the peripherals was 10 centimeters.

External I/O cables were draped along the edge of the test table and bundle when necessary.

## 8.3 Test Procedure

The measurements are based on FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 section 11: Emissions in non-restricted frequency bands and section 12: Emissions in restricted frequency bands. As well as ANSI C63.4: 2009 as described below:

For the radiated emissions test, the EUT host, and all support equipment power cords was connected to the AC floor outlet.

Maximizing procedure was performed on the highest emissions to ensure that the EUT complied with all installation combinations.

The EUT is set 3 meter away from the testing antenna, which is varied from 1-4 meter, and the EUT is placed on a turntable, which is 0.8 meter above ground plane, the table shall be rotated for 360 degrees to find out the highest emission. The receiving antenna should be changed the polarization both of horizontal and vertical.

The spectrum analyzer or receiver is set as:

Below 1000 MHz:

RBW = 100 kHz / VBW = 300 kHz / Sweep = Auto

Above 1000 MHz:

(1) Peak: RBW = 1MHz / VBW = 1MHz / Sweep = Auto
(2) Average: RBW = 1MHz / VBW = 10Hz / Sweep = Auto

## 8.4 Corrected Amplitude & Margin Calculation

The Corrected Amplitude (CA) is calculated by adding the Antenna Factor (AF), the Cable Loss (CL), the Attenuator Factor (Atten) and subtracting the Amplifier Gain (Ga) to indicated Amplitude (Ai) reading. The basic equation is as follows:

CA = Ai + AF + CL + Atten – Ga

For example, a corrected amplitude of 40.3 dBuV/m = Indicated Reading (32.5 dBuV) + Antenna Factor (+23.5dB) + Cable Loss (3.7 dB) + Attenuator (10 dB) - Amplifier Gain (29.4 dB)

The "**Margin**" column of the following data tables indicates the degree of compliance within the applicable limit. For example, a margin of -7 dB means the emission is 7 dB below the maximum limit. The equation for margin calculation is as follows:

Margin = Corrected Amplitude - Limit

## 8.5 Test Equipment List and Details

| Manufacturer | Description | Model | Serial Number | Calibration Date | Calibration Cycle |
|---|---|---|---|---|---|
| Rohde & Schwarz | EMI Test Reciever | ESCI | 100338 | 2014-01-20 | 1 year |
| Hp | Pre-Amp | 8447D | 2443A04374 | 2014-06-09 | 1 year |
| Sunol Sciences | Bi-Log Antenna | JB3 | A020106-3 | 2014-07-24 | 1 year |
| Agilent | Spectrum Analyzer | E4440A | US422221851 | 2014-04-09 | 1 year |
| Hp | Pre-Amp | 8449B | 3008A01103 | 2014-03-10 | 1 year |
| Micro-Tonics | Band Pass Filter | BRM50701 | 160 | N/A | N/A |
| Sunol Sciences | System Controller | SC99V | 122303-1 | N/R | N/A |
| Sunol Sciences | Horn Antenna | DRH-118 | A052704 | 2014-03-28 | 1 year |
| Wisewave | Horn Atnenna | ARH-4223-02 | 10555-01 | 2012-05-09 | 3 years |

***Statement of Traceability: BACL** attests that all calibrations have been performed per the A2LA requirements, traceable to NIST.*

## 8.6 Test Environmental Conditions

| | |
|---|---|
| **Temperature:** | 23-25 $^{o}$C |
| **Relative Humidity:** | 46-48 % |
| **ATM Pressure:** | 101.32 – 101.68 kPa |

*The testing was performed by Isaac Aguilar on 2014-09-19 thru 2014-09-23 in 5 m chamber 3.*

## 8.7 Summary of Test Results

According to the data hereinafter, the EUT complied with the FCC Title 47, Part 15C and I CRSS-210/RSS-Gen standard's radiated emissions limits, and had the worst margin of:

**30-1000 MHz:**

| Mode: Transmitting | | | |
|---|---|---|---|
| **Margin (dB)** | **Frequency (MHz)** | **Polarization (Horizontal/Vertical)** | **Channel** |
| -8.85 | 143.99 | H | Low CH |

**Above 1 GHz:**

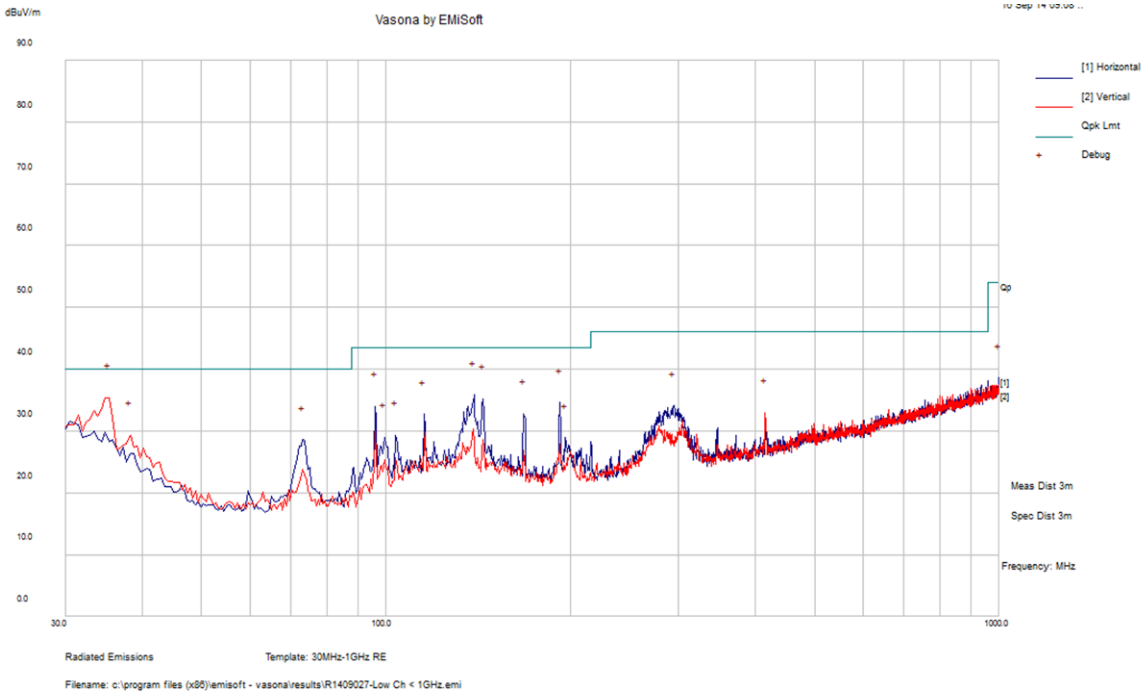
| Mode: Transmitting | | | |
|---|---|---|---|
| **Margin (dB)** | **Frequency (MHz)** | **Polarization (Horizontal/Vertical)** | **Channel** |
| -5.66 | 4879 | H | Mid CH |

## 8.8 Radiated Spurious Emissions Test Results

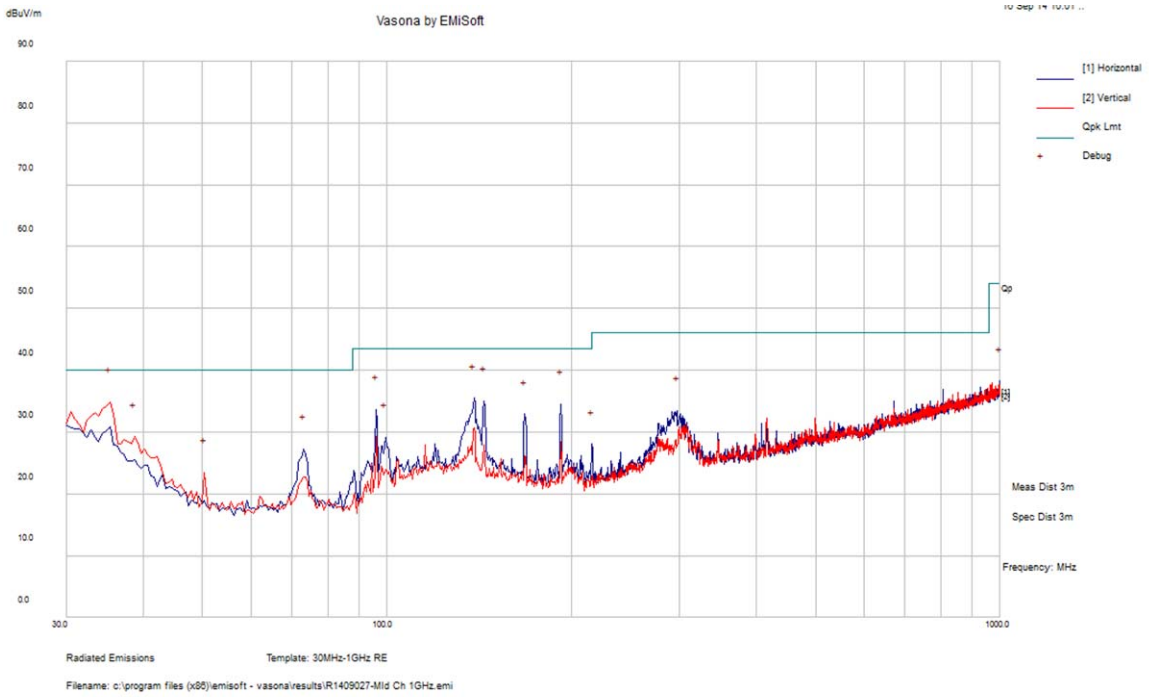
### 1) 30 MHz – 1 GHz, Measured at 3 meters

| Frequency (MHz) | Corrected Amplitude (dBµV/m) | Antenna Height (cm) | Antenna Polarity (H/V) | Turntable Azimuth (degrees) | Limit (dBµV/m) | Margin (dB) | Channel/ Freq(MHz) | Comment (PK/QP/Ave) |
|---|---|---|---|---|---|---|---|---|
| 144.00 | 34.65 | 165 | H | 0 | 43.5 | -8.85 | 1/2405 | QP |
| 143.01 | 34.63 | 188 | H | 350 | 43.5 | -8.87 | 13/2440 | QP |
| 96.00 | 32.64 | 206 | H | 342 | 40 | -10.86 | 13/2440 | QP |
| 35.14 | 28.97 | 116 | V | 69 | 43.5 | -11.03 | 1/2405 | QP |
| 192.03 | 32.33 | 179 | H | 123 | 43.5 | -11.17 | 26/2480 | QP |

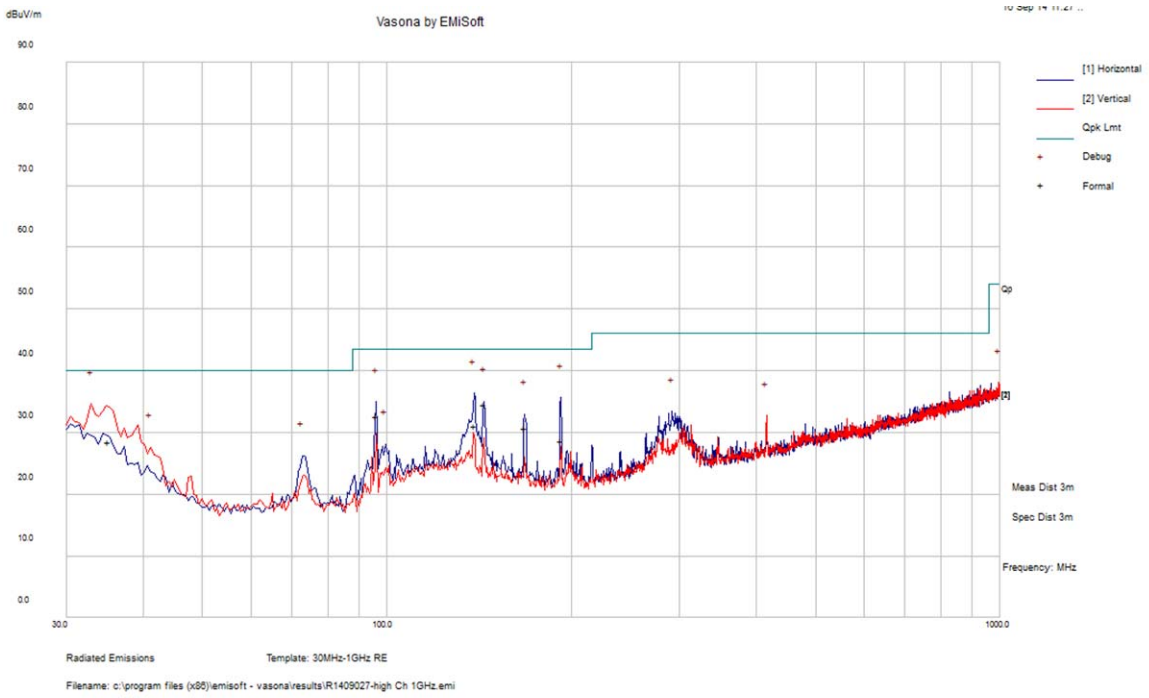
Low Channel, 2405 MHz



Middle Channel, 2440 MHz




High Channel, 2480 MHz



### 2) Above 1 GHz, Measrued at 3 meters

Note: The losses and gains are factored into spectrum analyzer before the scans.

| Frequency (MHz) | Corrd. Amp. (dBuV/m) | Test Antenna | | Turntable Angle (Degrees) | Limit (dBuV/m) | Margin (dB) | Comment (PK/QP/Ave. |
|---|---|---|---|---|---|---|---|
| | | Height (cm) | Pol. (V/H) | | | | |
| Low Channel, 2405 MHz | | | | | | | |
| 14160 | 59.11 | 146 | V | 228 | 74 | -14.89 | PK |
| 5665 | 51.2 | 100 | V | 225 | 74 | -22.8 | PK |
| 1609 | 63.64 | 100 | V | 71 | 74 | -10.36 | PK |
| 2064 | 53.21 | 101 | V | 188 | 74 | -20.79 | PK |
| 1886 | 52.42 | 112 | H | 98 | 74 | -21.58 | PK |
| 5383 | 52.21 | 100 | V | 172 | 74 | -21.79 | PK |
| 2406 | 50.92 | 100 | H | 79 | 74 | -23.08 | PK |
| 14160 | 48.14 | 146 | V | 228 | 54 | -5.86 | Ave. |
| 5665 | 35.5 | 100 | V | 225 | 54 | -18.5 | Ave. |
| 1609 | 40.46 | 100 | V | 71 | 54 | -13.54 | Ave. |
| 2064 | 36.81 | 101 | V | 188 | 54 | -17.19 | Ave. |
| 1886 | 37.07 | 112 | H | 98 | 54 | -16.93 | Ave. |
| 5383 | 37.74 | 100 | V | 172 | 54 | -16.26 | Ave. |
| 2406 | 39.78 | 100 | H | 79 | 54 | -14.22 | Ave. |
| Middle Channel, 2440 MHz | | | | | | | |
| 14179 | 58.57 | 189 | H | 107 | 74 | -15.43 | PK |
| 1611 | 55.34 | 158 | V | 151 | 74 | -18.66 | PK |
| 4879 | 56.55 | 100 | H | 56 | 74 | -17.45 | PK |
| 1883 | 53 | 112 | V | 177 | 74 | -21 | PK |
| 1452 | 50.64 | 138 | V | 100 | 74 | -23.36 | PK |
| 5655 | 49.37 | 211 | V | 143 | 74 | -24.63 | PK |
| 14179 | 47.92 | 189 | H | 107 | 54 | -6.08 | Ave. |
| 1611 | 33.86 | 158 | V | 151 | 54 | -20.14 | Ave. |
| 4879 | 48.34 | 100 | H | 56 | 54 | -5.66 | Ave. |
| 1883 | 37.38 | 112 | V | 177 | 54 | -16.62 | Ave. |
| 1452 | 31.54 | 138 | V | 100 | 54 | -22.46 | Ave. |
| 5655 | 35.2 | 211 | V | 143 | 54 | -18.8 | Ave. |

| Frequency (MHz) | Corrd. Amp. (dBuV/m) | Test Antenna | | Turntable Angle (Degrees) | Limit (dBuV/m) | Margin (dB) | Comment (PK/QP/Ave. |
|---|---|---|---|---|---|---|---|
| | | Height (cm) | Pol. (V/H) | | | | |
| High Channel, 2480 MHz | | | | | | | |
| 14102 | 58.46 | 234 | V | 353 | 74 | -15.54 | PK |
| 4961 | 52.09 | 138 | H | 247 | 74 | -21.91 | PK |
| 5652 | 51.46 | 213 | V | 179 | 74 | -22.54 | PK |
| 1641 | 51.2 | 101 | V | 5 | 74 | -22.8 | PK |
| 2061 | 46.41 | 100 | V | 115 | 74 | -27.59 | PK |
| 5039 | 50.48 | 142 | V | 138 | 74 | -23.52 | PK |
| 1889 | 44.46 | 143 | H | 100 | 74 | -29.54 | PK |
| 14102 | 48.03 | 234 | V | 353 | 54 | -5.97 | Ave. |
| 4961 | 42.16 | 138 | H | 247 | 54 | -11.84 | Ave. |
| 5652 | 35.92 | 213 | V | 179 | 54 | -18.08 | Ave. |
| 1641 | 30.52 | 101 | V | 5 | 54 | -23.48 | Ave. |
| 2061 | 33.52 | 100 | V | 115 | 54 | -20.48 | Ave. |
| 5039 | 34.51 | 142 | V | 138 | 54 | -19.49 | Ave. |
| 1889 | 31.87 | 143 | H | 100 | 54 | -22.13 | Ave. |

# 9 FCC§15.247(a)(2) & IC RSS-210 §A8.2 - 6 dB & 99% Emission Bandwidth

## 9.1 Applicable Standards

According to FCC §15.247(a)(2) and IC RSS-210 A8.2 (a), 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

## 9.2 Measurement Procedure

The measurements are based on FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 section 8.1: DTS bandwidth

## 9.3 Test Equipment List and Details

| Manufacturer | Description | Model | Serial Number | Calibration Date | Calibration Cycle |
|---|---|---|---|---|---|
| Agilent | Spectrum Analyzer | E4440A | US42221841 | 2014-04-09 | 1 year |

***Statement of Traceability: BACL Corp.*** *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

## 9.4 Test Environmental Conditions

| | |
|---|---|
| **Temperature:** | 26 °C |
| **Relative Humidity:** | 39 % |
| **ATM Pressure:** | 101.28 kPa |

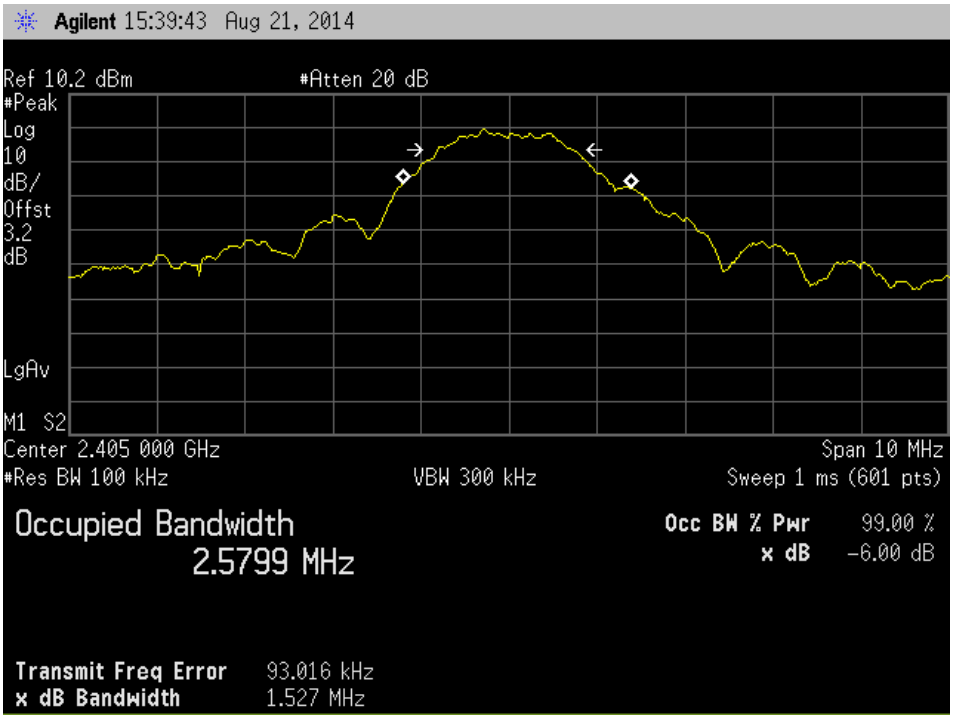
*The testing was performed by Isaac Aguilar from 2014-08-21 at RF site.*

## 9.5 Test Results

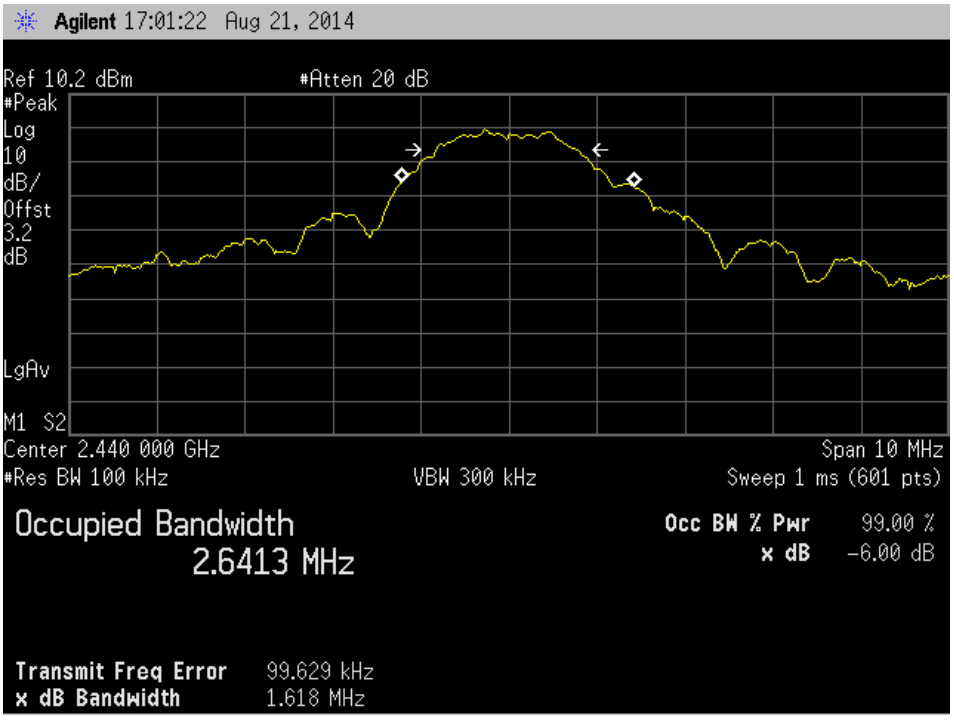
Please refer to the following table and plots

| Frequency (MHz) | 99% Emission Bandwidth (MHz) | 6 dB Emission Bandwidth (MHz) | FCC/IC Limit (MHz) | Result (Pass/Fail) |
|---|---|---|---|---|
| 2405 | 2.58 | 1.53 | > 0.500 | Pass |
| 2440 | 2.64 | 1.62 | > 0.500 | Pass |
| 2480 | 2.70 | 1.64 | > 0.500 | Pass |

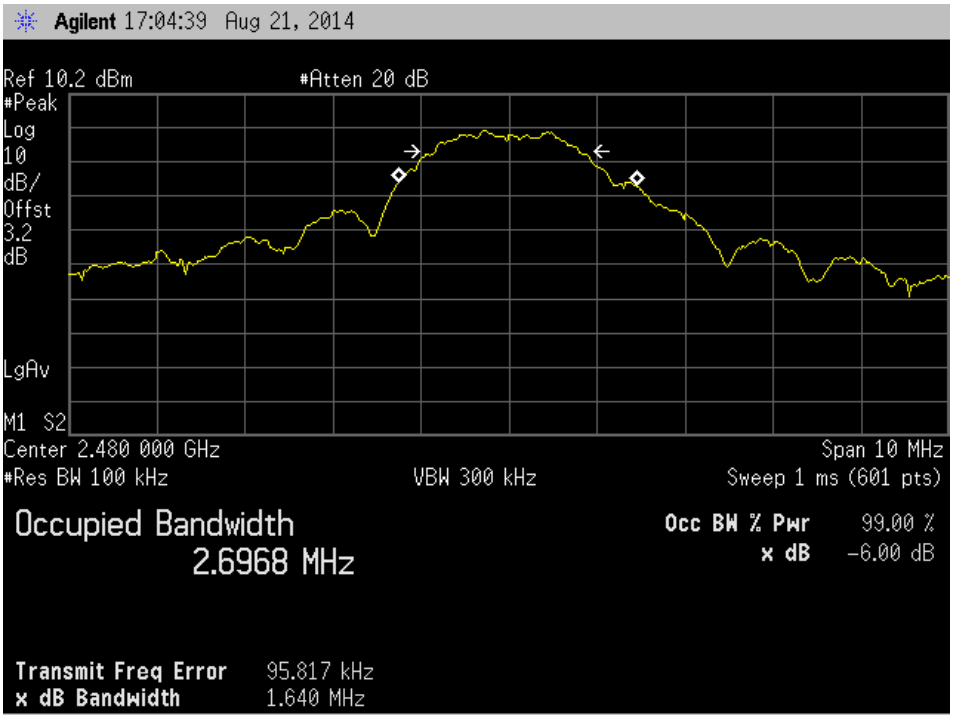
Low Channel, 2405 MHz




Middle Channel, 2440 MHz



High Channel, 2480 MHz



# 10 FCC §15.247(b) & IC RSS-210 §A8.4 - Output Power

## 10.1 Applicable Standards

According to FCC §15.247(b) and IC RSS-210 §A8.4(4) for systems using digital modulation in the 902~928 MHz, 2400~2483.5 MHz, and 5725~5850 MHz bands: 1 Watt.

## 10.2 Measurement Procedure

The measurements are based on FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 section 9.1.1: RBW ≥ DTS bandwidth.

## 10.3 Test Equipment List and Details

| Manufacturer | Description | Model | Serial Number | Calibration Date | Calibration Cycle |
|---|---|---|---|---|---|
| Agilent | Spectrum Analyzer | E4440A | US42221841 | 2014-04-09 | 1 year |

***Statement of Traceability: BACL Corp.*** *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

## 10.4 Test Environmental Conditions

| | |
|---|---|
| **Temperature:** | 26 °C |
| **Relative Humidity:** | 39 % |
| **ATM Pressure:** | 101.28 kPa |

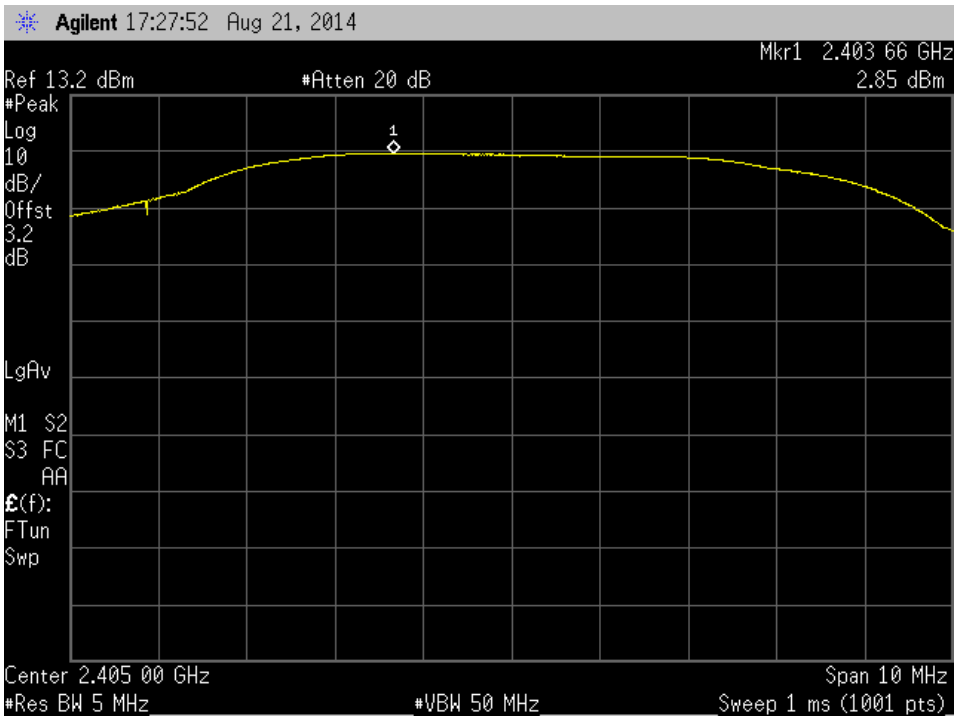
*The testing was performed by Isaac Aguilar on 2014-08-21 at RF site.*

## 10.5 Test Results

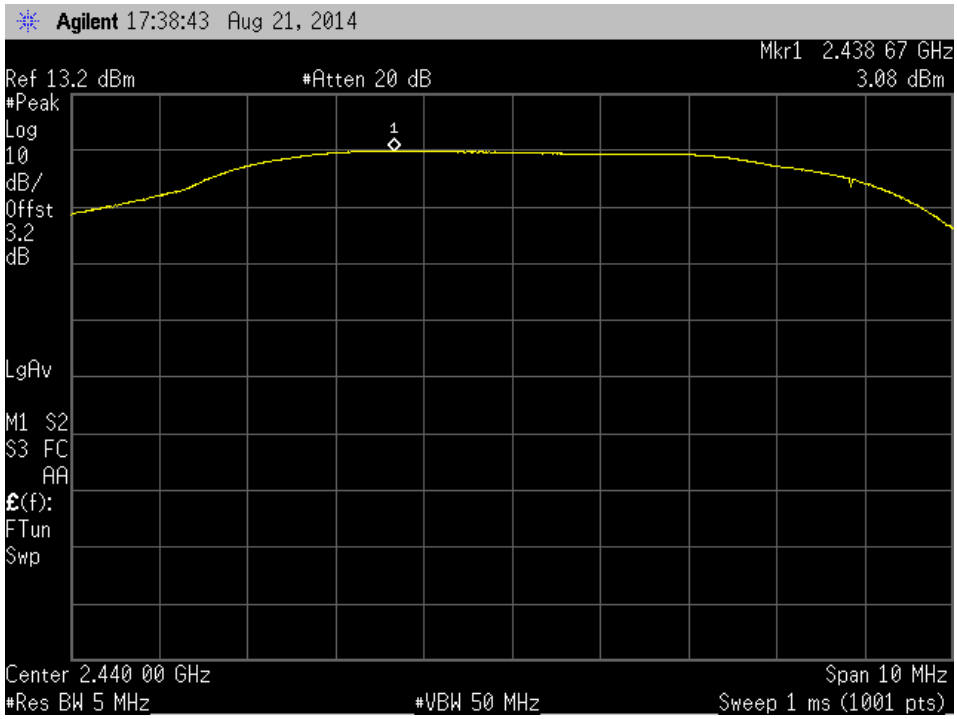
Please refer to the table and plots below:

| Frequency (MHz) | Conducted Peak Output Power (dBm) | FCC/IC Limit (dBm) | Margin (dB) | Result (Pass/Fail) |
|---|---|---|---|---|
| 2405 | 2.85 | 30 | -27.15 | Pass |
| 2440 | 3.08 | 30 | -26.92 | Pass |
| 2480 | 3.24 | 30 | -26.76 | Pass |

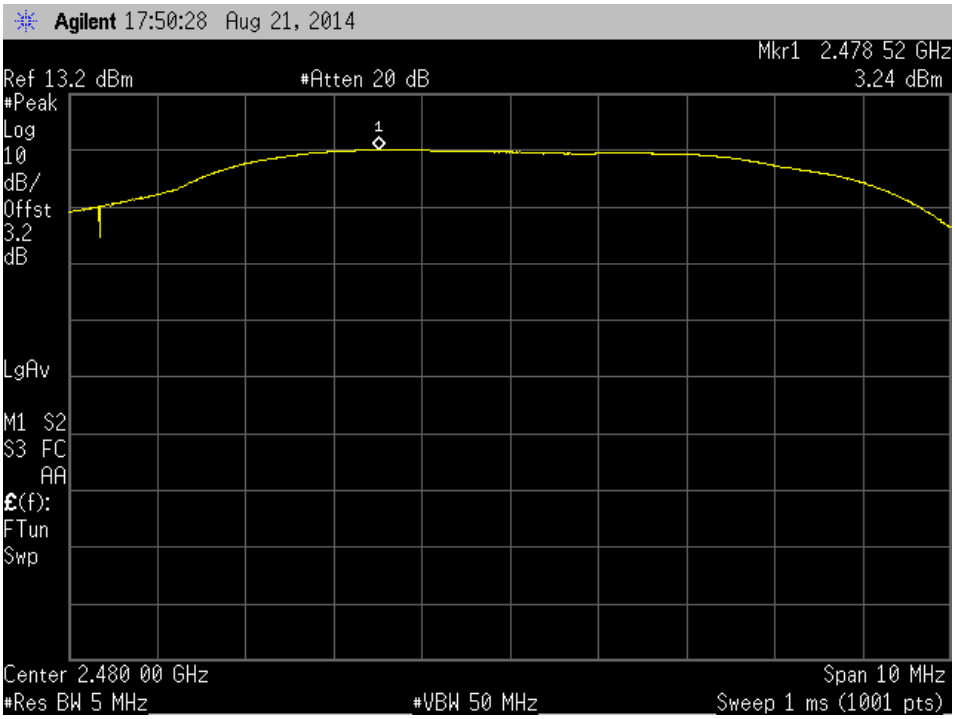
Low Channel, 2405 MHz




Middle Channel, 2440 MHz



High Channel, 2480 MHz



# 11 FCC §15.247(d) & IC RSS-210 §A8.5 - 100 kHz Bandwidth of Band Edges

## 11.1 Applicable Standard

According to FCC §15.247(d), in any 100 kHz bandwidth outside the frequency bands in which the spread spectrum 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. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emissions limits specified in §15.209(a) see §15.205(c).

According to IC Rss-210 §A8.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the radio frequency power that is produced 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 section A8.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in Tables 2 and 3 is not required.

## 11.2 Measurement Procedure

The measurements are based on FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 section 13: Band-edge measurements

## 11.3 Test Equipment List and Details

| Manufacturer | Description | Model | Serial Number | Calibration Date | Calibration Cycle |
|---|---|---|---|---|---|
| Agilent | Spectrum Analyzer | E4440A | US42221841 | 2014-04-09 | 1 year |

***Statement of Traceability: BACL Corp.*** *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

## 11.4 Test Environmental Conditions

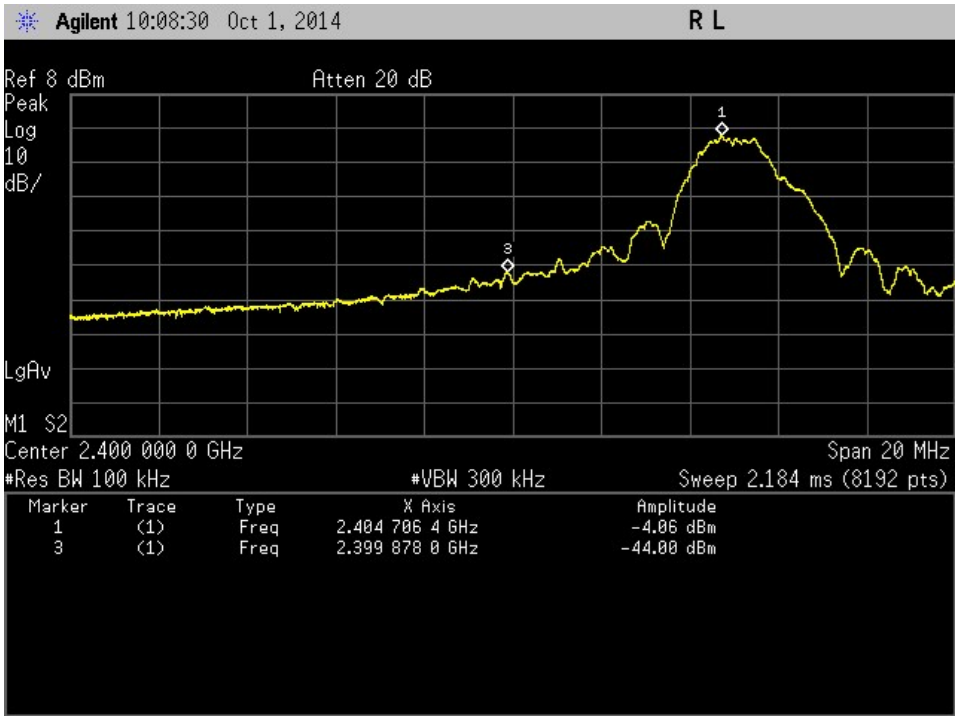
| | |
|---|---|
| **Temperature:** | 26 °C |
| **Relative Humidity:** | 39 % |
| **ATM Pressure:** | 101.28 kPa |

*The testing was performed by Isaac Aguilar on 2014-10-01 at RF site.*

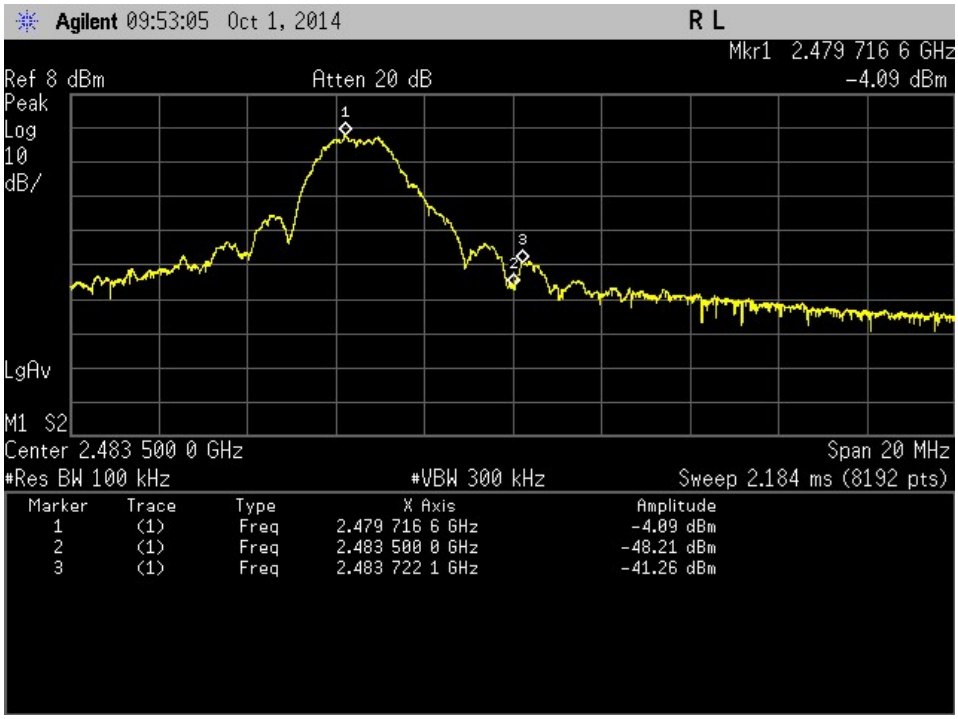
## 11.5 Test Results

Refer to the table and plot for resuts

Low Channel @ Band Edge




High Channel @ Band Edge



# 12 FCC §15.247(e) & IC RSS-210 §A8.2 (b) - Power Spectral Density

## 12.1 Applicable Standards

According to FCC §15.247(e) and RSS-210 §A8.2(b) , 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.

## 12.2 Measurement Procedure

The measurements are based on FCC KDB 558074 D01 DTS Meas Guidance v03r02: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 section 10.2: Method PKPSD (Peak PSD).

## 12.3 Test Equipment List and Details

| Manufacturer | Description | Model | Serial Number | Calibration Date | Calibration Cycle |
|---|---|---|---|---|---|
| Agilent | Spectrum Analyzer | E4440A | US42221841 | 2014-04-09 | 1 year |

***Statement of Traceability: BACL Corp.*** *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

## 12.4 Test Environmental Conditions

| | |
|---|---|
| **Temperature:** | 26 °C |
| **Relative Humidity:** | 39 % |
| **ATM Pressure:** | 101.28 kPa |

*The testing was performed by Isaac Aguilar from 2014-08-21 at RF site.*

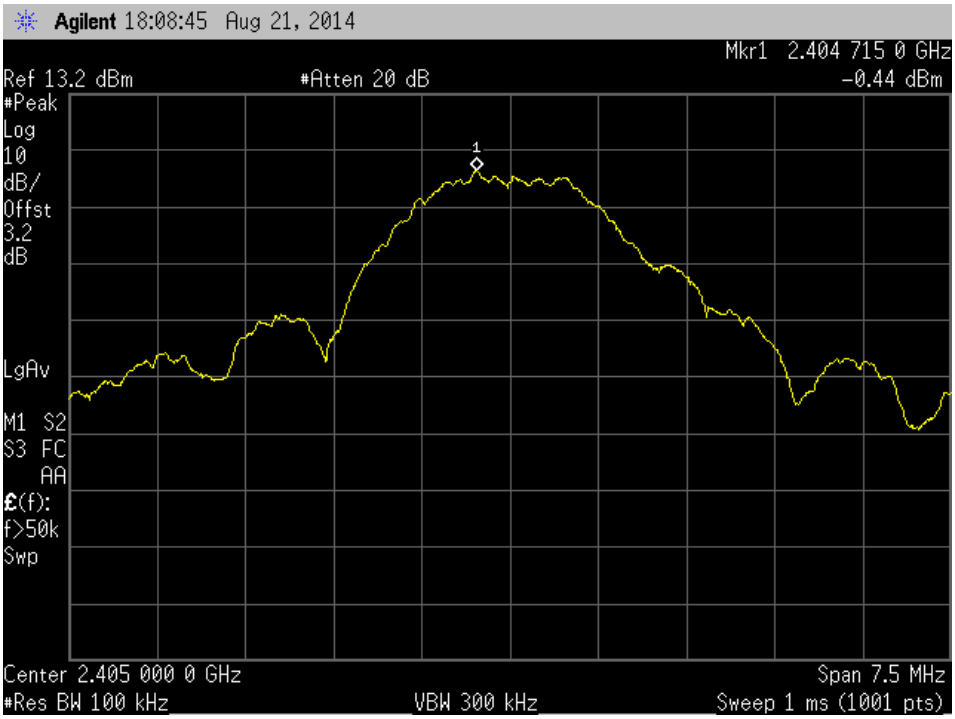
## 12.5 Test Results

Refer to the table and plots below for the test results.

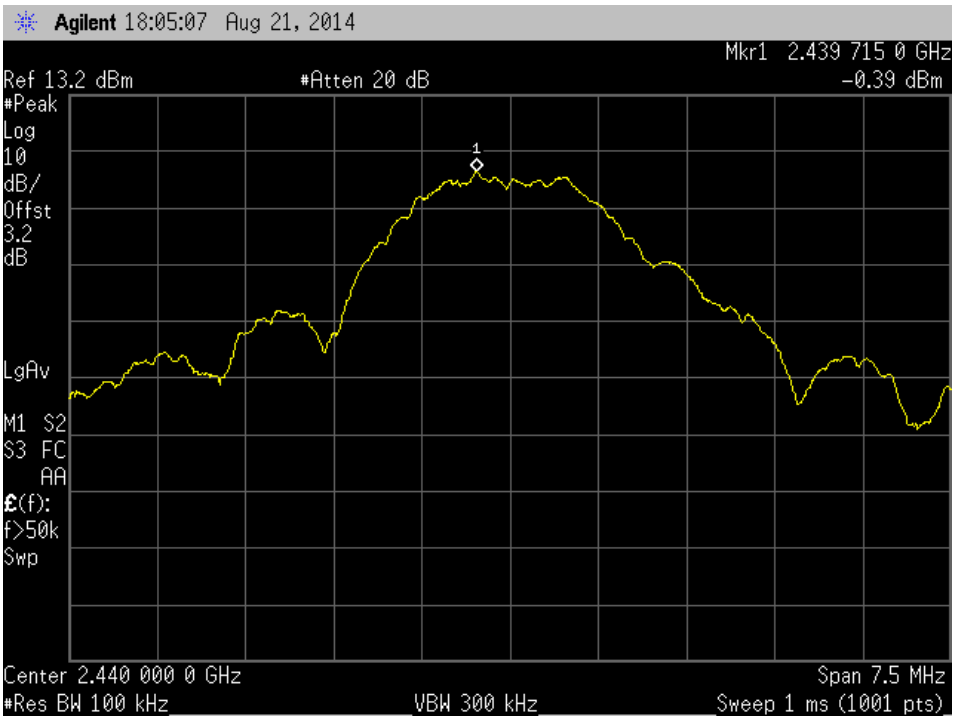
| Frequency (MHz) | Measured PSD (dBm/100 kHz) | Corrected PSD (dBm/3 kHz) | FCC/IC Limit (dBm/3 kHz) | Margin (dBm/3 kHz) | Result (Pass/Fail) |
|---|---|---|---|---|---|
| 2405 | -0.44 | -15.66 | 8 | -23.66 | Pass |
| 2440 | -0.39 | -15.61 | 8 | -23.61 | Pass |
| 2480 | -0.74 | -15.96 | 8 | -23.96 | Pass |

Correction Factor: 10*Log(100/3)=15.22 dB

Low Channel, 2405 MHz




Middle Channel, 2440 MHz



High Channel, 2480 MHz