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ENGINEERING TEST REPORT # 314250 A
LSR Job #: C-2013

Compliance Testing of:
Remote Puffer

Test Date(s):
August 7, 8, 11, 12 2014

Prepared For:
Suterra
Attn: Matt Hamman
20950 NE Talus Place
Bend, OR 97701 USA

This Test Report is issued under the Authority of: Adam Alger, EMC Engineer

Signature: Date: 1-19-15

Test Report Reviewed by:	**Report by:**
Michael Hintzke, EMC Engineer	Adam Alger, EMC Engineer
Signature: Date: 8/21/14	Signature: Date: 8-18-14

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LS Research, LLC in Review

As an EMC Testing Laboratory, our Accreditation and Assessments are recognized through the following:

TESTING CERT #1255.01

A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025: 2005 with Electrical (EMC) Scope of Accreditation
A2LA Certificate Number: 1255.01

Federal Communications Commission (FCC) – USA

Listing of 3 Meter Semi-Anechoic Chamber based on Title 47 CFR – Part 2.948
FCC Registration Number: 90756

Industrie Canada Industry Canada

Canada

Industry Canada

On file, 3 Meter Semi-Anechoic Chamber based on RSS-212 – Issue 1
File Number: IC 3088-A
On file, 3 and 10 Meter OATS based on RSS-212 – Issue 1
File Number: IC 3088

U. S. Conformity Assessment Body (CAB) Validation

Validated by the European Commission as a U. S. Competent Body operating under the U. S./EU, Mutual Recognition Agreement (MRA) operating under the European Union Electromagnetic Compatibility –Council Directive 2004/108/EC (formerly 89/336/EEC, Article 10.2).
Date of Validation: January 16, 2001

Validated by the European Commission as a U.S. Notified Body operating under the U.S. /EU, Mutual Recognition Agreement (MRA) operating under the European Union Telecommunication Equipment – Council Directive 99/5/EC, Annex V.
Date of Validation: November 20, 2002
Notified Body Identification Number: 1243

1.0 Summary of Test Report

In August 2014 the Suterra Remote Puffer was tested and MEETS the following requirements:

FCC Rule Part	Test Requirements	Compliance (Yes/No)
15.247 (a)(2)	6 dB Bandwidth of a Digital Modulation System	Yes
15.247(b) & 1.1310	Maximum Output Power	Yes
15.247 (d)	Power Spectral Density of a Digital Modulation System	Yes
15.247(d)	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
15.247(c), 15.209 & 15.205	Transmitter Radiated Emissions	Yes
15.207	Power Line Conducted Emissions Measurements	Not Applicable
15.109	Receiver / Digital Device Radiated Emissions	Yes

2.0 Test Facilities

All testing was performed at:

LS Research, LLC
W66 N220 Commerce Court
Cedarburg, Wisconsin, 53012 USA

LS Research, LLC is accredited by A2LA (American Association for Laboratory Accreditation) to the requirements of ISO/IEC 17025, 2005 “General Requirements for the Competence of Calibration and Testing Laboratories”.
LS Research, LLC’s scope of accreditation includes all test methods listed herein, unless otherwise noted.

3.0 Client Information

Manufacturer Name:	Suterra, LLC
Address:	20950 NE Talus Place
Contact Person:	Matt Hamman

3.1 Equipment Under Test (EUT) Information

The following information has been supplied by the applicant.

Product Name:	Remote Puffer
Model Number:	SUT01B
Serial Number:	Radiated (14210107); RF Conducted (14210030)
FCC ID	2ACYJ-1

3.2 Product Description

EUT utilizes Bluetooth Low Energy with an integral antenna that has a peak gain of 4.7 dBi as measured over a ground plane.

3.3 Modifications Incorporated In the EUT for Compliance Purposes

None noted at time of test

3.4 Deviations & Exclusions from Test Specifications

None noted at time of test

3.5 Additional Information

EUT programmed for continuous transmit or receive on low (2402 MHz), middle (2440 MHz), and high (2480 MHz) via a TI CC Debugger connected to pin-holes on the EUT and USB cable connected to laptop running TI Smart RF Studio software. Normal mode of operation was accessible via a button press on the EUT which activated the motors in a few second intervals.

4.0 Conditions of Test

Environmental:

Temperature: 20-25º C
Relative Humidity: 30-60%
Atmospheric Pressure: 86-106 kPa

DC Power: 4 (AA type batteries) (Nominal 6 VDC to EUT)

5.0 Test Equipment

All test equipment is calibrated by a calibration laboratory accredited by A2LA to the requirements of ISO 17025. For a complete list of test equipment and calibration dates, see Appendix A. Unless otherwise noted, resolution bandwidth of measuring instrument used during testing for given frequency range, see below.

Frequency Range	Resolution Bandwidth
9 kHz – 150 kHz	200 Hz
150 kHz – 30 MHz	9 kHz
30 MHz – 1000 MHz	120 kHz
Above 1000 MHz	1 MHz

6.0 Conformance Summary

The EUT was found to MEET the requirements as described within the specification of FCC Title 47, CFR Part 15.247 and 15.109.

If some emissions are seen to be within 3 dB of their respective limits:
As these levels are within the tolerances of the test equipment and site employed, there is a possibility that this unit, or a similar unit selected out of production may not meet the required limit specification if tested by another agency.

LS Research, LLC certifies that the data contained herein was taken under conditions that meet or exceed the requirements of the test specifications. The results in this Test Report apply only to the item(s) tested on the above-specified dates. Any modifications made to the EUT subsequent to the indicated test date(s) will invalidate the data herein, and void this certification.

Appendix A – Test Equipment

LS RESEARCH LLC
Wireless Product Development
Equipment Calibration

Date: 7-Aug-2014 Type Test: RF Conducted Job #: C-2013

Prepared By: Adam Customer: Suterra Quote #: 314250

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	11/19/2013	11/19/2014	Active Calibration
2	EE 960087	44GHz EXA Spectrum Analyzer	Agilent	N9010A	MY53400296	10/27/2013	10/27/2014	Active Calibration

Project Engineer: Quality Assurance:

LS RESEARCH LLC
Wireless Product Development
Equipment Calibration

Date: 7-Aug-2014 Type Test: Radiated Emissions Job #: C-2013

Prepared By: Adam Customer: Suterra Quote #: 314250

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	8GHz MXE Spectrum Analyzer	Agilent	N9038A	MY51210138	11/19/2013	11/19/2014	Active Calibration
2	AA 960158	Double Ridge Horn Antenna	ETS Lindgren	3117	109300	6/20/2014	6/20/2015	Active Calibration
3	EE 960159	0.8 - 21GHz LNA	Mini-Circuits	ZVA-213X-S+	740411007	6/20/2014	6/20/2015	Active Calibration
4	AA 960150	Biconical Antenna	ETS	3110B	0003-3346	1/8/2014	1/8/2015	Active Calibration
5	AA 960078	Log Periodic Antenna	EMCO	93146	9701-4855	1/8/2014	1/8/2015	Active Calibration
6	AA 960081	Double Ridge Horn Antenna	EMCO	3115	6907	2/25/2014	2/25/2015	Active Calibration
7	EE 960087	44GHz EXA Spectrum Analyzer	Agilent	N9010A	MY53400296	10/27/2013	10/27/2014	Active Calibration
8	AA 960153	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-04	4/7/2014	4/7/2015	Active Calibration
9	EE 960146	Std. Gain Horn Ant. w/preamp	Adv. Micro / EMC	WLA622-4 / 3160-09	123001	9/24/2013	9/24/2014	Active Calibration

Project Engineer: Quality Assurance:

Appendix B – Test Data
B.1 – RF Conducted Emissions

Manufacturer	Suterra
Test Location	LS Research, LLC
Rule Part	FCC Part 15.247
General Measurement Procedure	FCC KDB 558074 D01 DTS Meas Guidance v03r02 ANSI C63.10-2009 Section 6.7
General Description of Measurement	A direct measurement of the transmitted signal was performed at the antenna port of the EUT via a cable connection to a spectrum analyzer. An attenuator was placed in series with the cable to protect the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings there by allowing direct measurements, without the need for any further corrections. The EUT was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source.

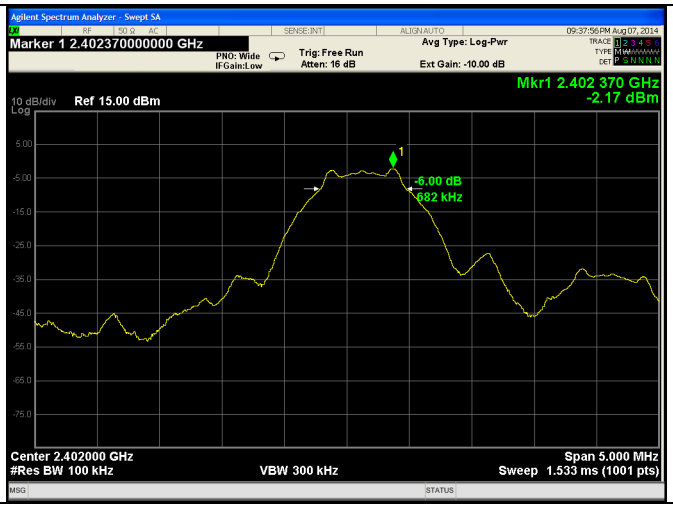
B.1.1 – RF Conducted – Fundamental Bandwidth

Manufacturer	Suterra
Date	8-7-2014
Operator	Adam A
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	FCC Part 15.247
Specific Measurement Procedure	FCC KDB 558074 Section 8.0 DTS bandwidth ANSI C63.10-2009 Section 6.9
Additional Description of Measurement	Peak detector used
Additional Notes	Continuous transmit modulated used for this test.

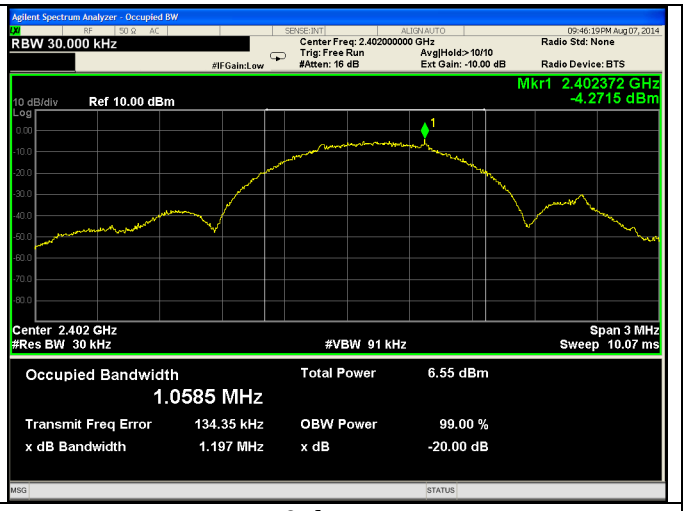
Table

Frequency (MHz)	6 dB DTS BW (kHz)	20 dB BW (MHz)
2402	682	1.197
2440	678	1.213
2480	683	1.212

Low Channel – 2402 MHz



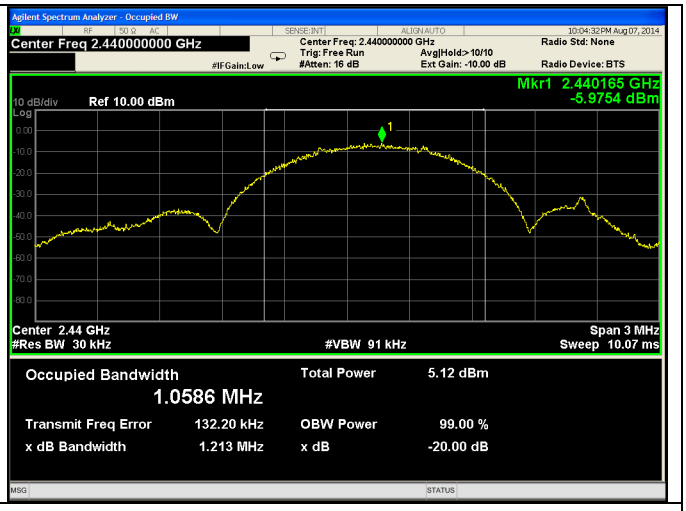
6 dB DTS BW



20 dB BW

Mid Channel – 2440 MHz

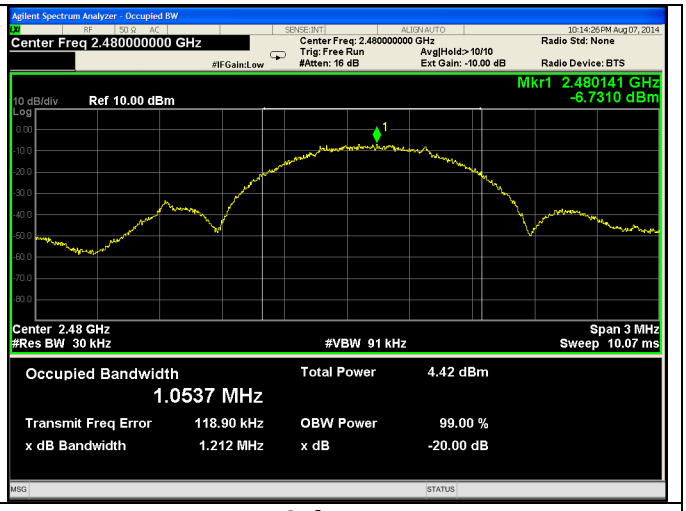
6 dB DTS BW



20 dB BW

High Channel – 2480 MHz

6 dB DTS BW



20 dB BW

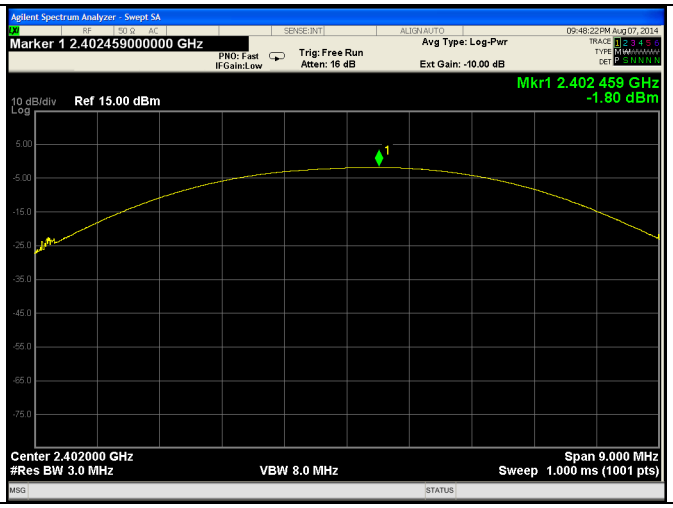
B.1.2 – RF Conducted – Fundamental Power and Spectral Density

Manufacturer	Suterra
Date	8-7-2014
Operator	Adam A
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	15.247
Specific Measurement Procedure	FCC KDB 558074 Section 9.1.1 – Maximum peak conducted output power FCC KDB 558074 Section 10.2 – Peak PSD
Additional Description of Measurement	3 kHz resolution bandwidth used for Peak Power Spectral Density measurement
Additional Notes	Sample Calculation: Margin (dB) = Limit – Measured level Continuous transmit modulated used for this test.

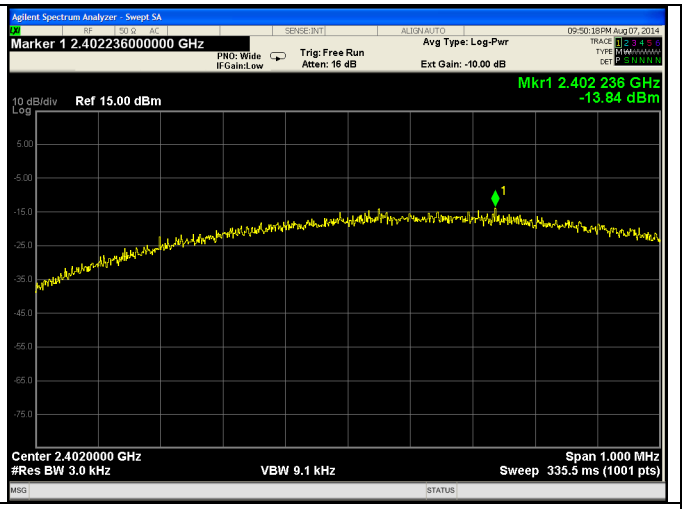
Table

Frequency (MHz)	Power (dBm)	PKPSD (dBm)	PSD Limit (dBm)	PSD Margin (dB)
2402	-1.80	-13.84	8	21.84
2440	-2.40	-15.61	8	23.61
2480	-3.16	-15.74	8	23.74

Low Channel – 2402 MHz

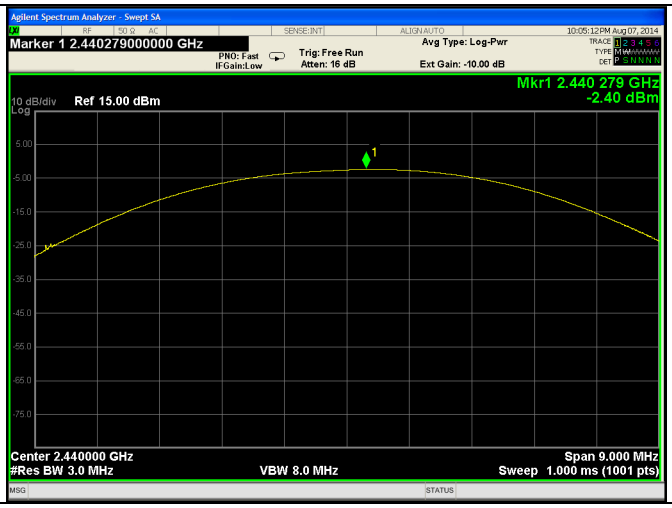


Peak Output Power

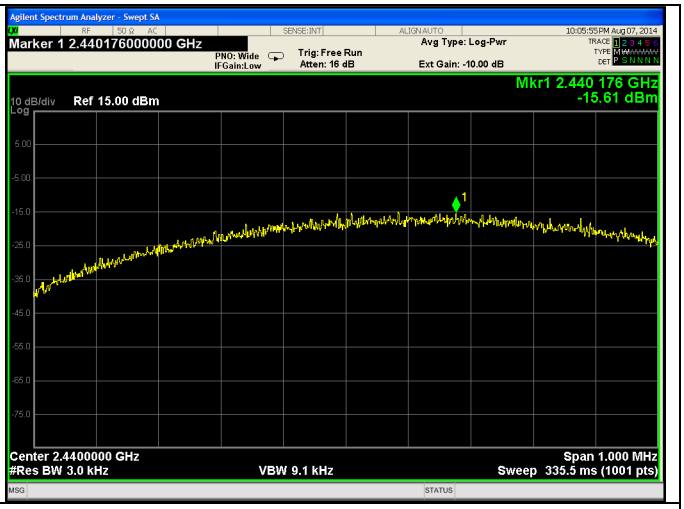


Peak Power Spectral Density

Mid Channel – 2440 MHz

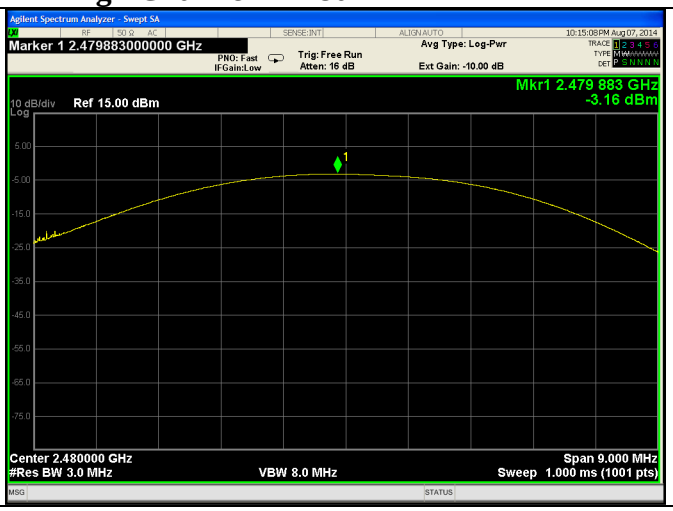


Peak Output Power

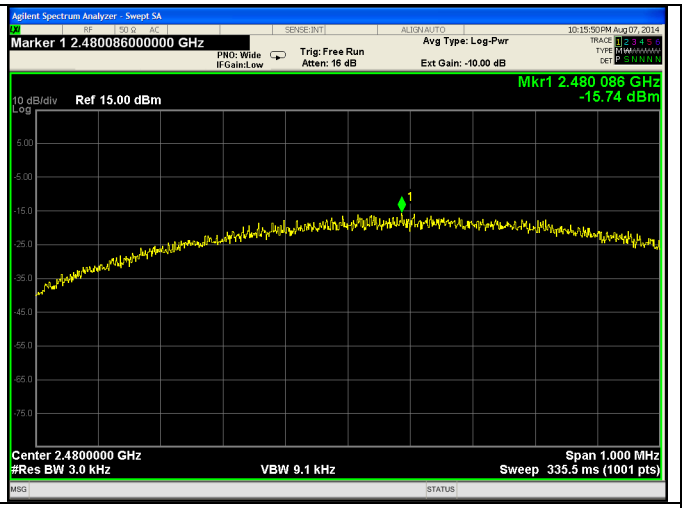


Peak Power Spectral Density

High Channel – 2480 MHz



Peak Output Power



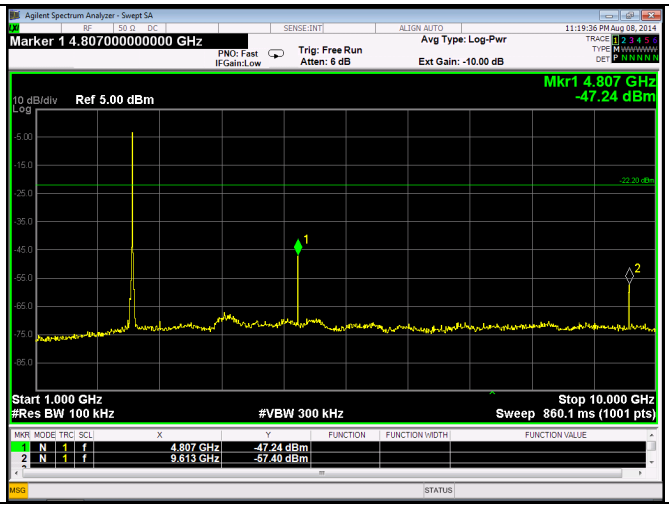
Peak Power Spectral Density

B.1.3 – RF Conducted – Spurious Emissions

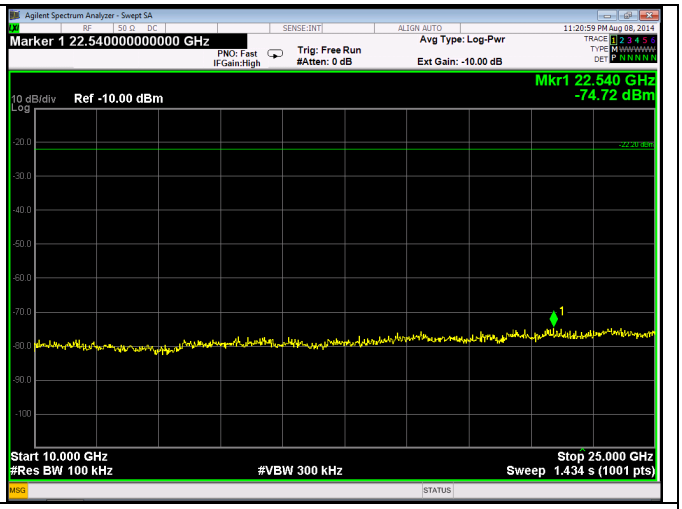
Manufacturer	Suterra
Date	8-7 and 8-8 2014
Operator	Adam A
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	15.247
Specific Measurement Procedure	FCC KDB 558074 Section 11.0 – Emissions in non-restricted frequency bands
Additional Description of Measurement	RF Conducted Measurement
Additional Notes	No Emissions found to be within 15 dB of limit Continuous transmit modulated used for this test.

Plots start next page

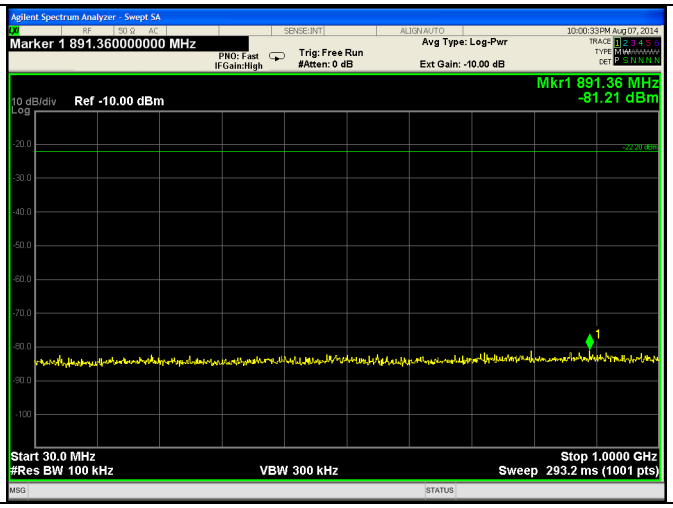
Low Channel – 2402 MHz



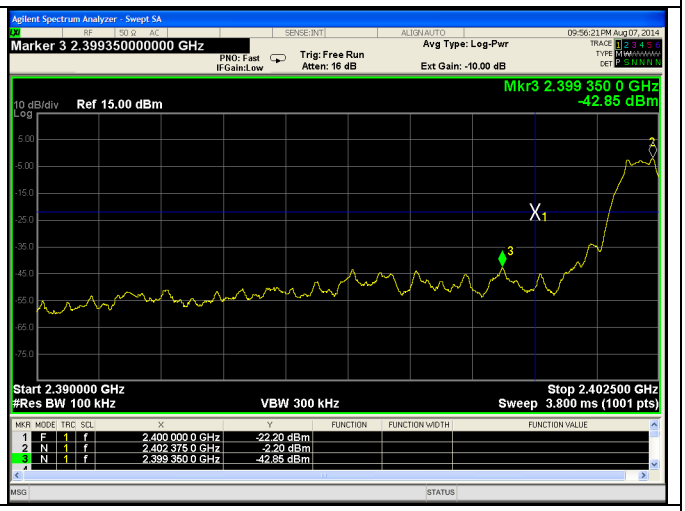
1 - 10 GHz



10-25 GHz

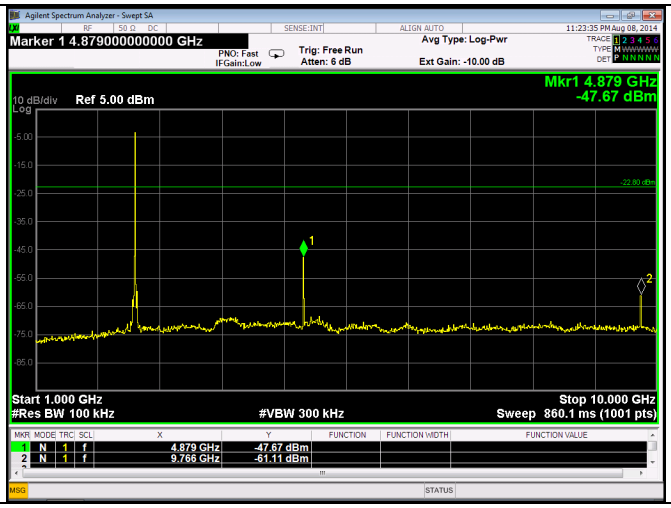


30-1000 MHz

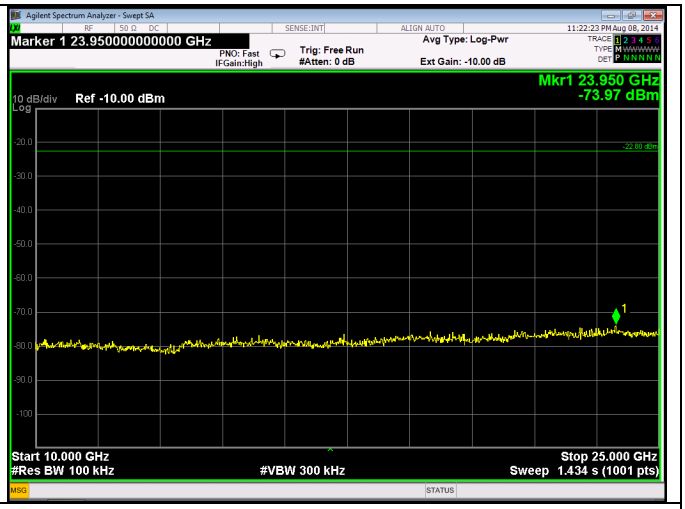


Band-Edge

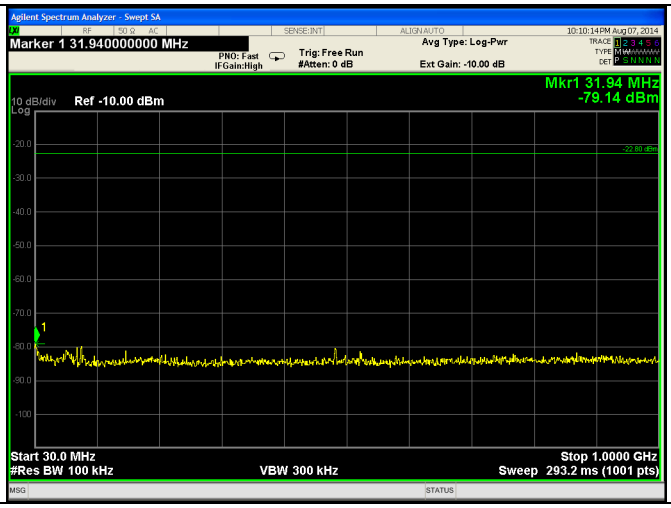
Mid Channel – 2440 MHz



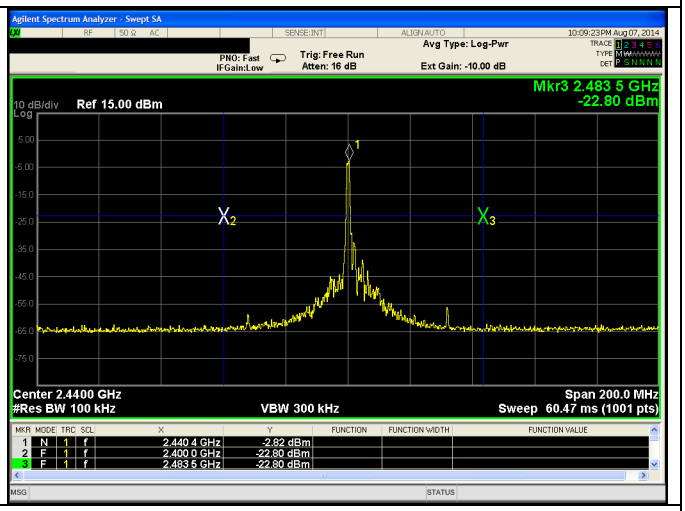
1 - 10 GHz



10-25 GHz

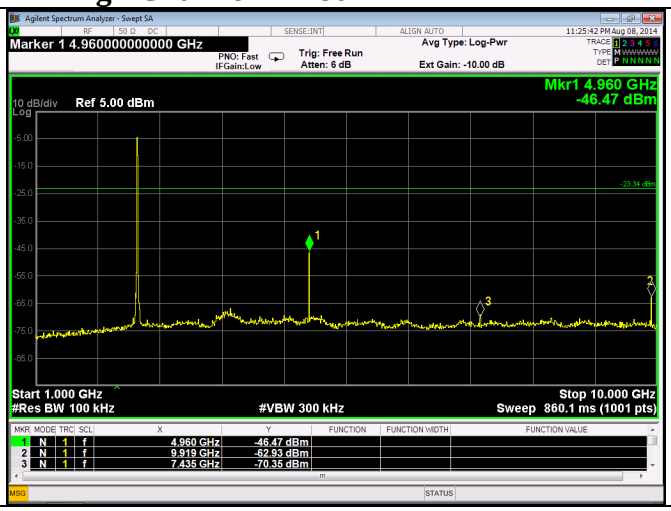


30-1000 MHz

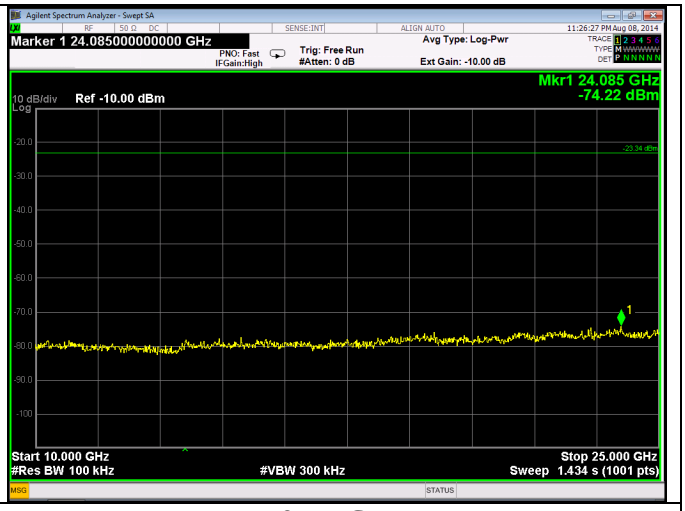


Band-Edge

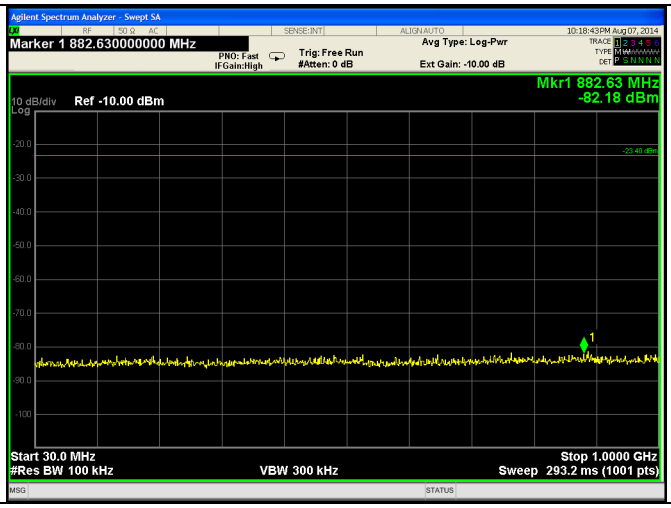
High Channel – 2480 MHz



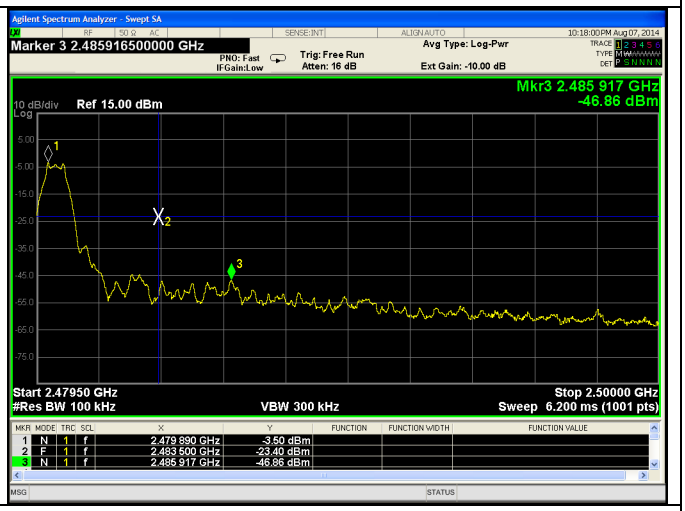
1 - 10 GHz



10-25 GHz



30-1000 MHz



Band-Edge

B.2 – Radiated Emissions

Rule Part(s)	FCC: 15.247 / 15.205 / 15.209			
Measurement Procedure	ANSI C63.4 - 2003 ANSI C63.10 – 2009 FCC KDB 558074 D01 DTS Meas Guidance v03r02			
Test Location	LS Research, LLC - FCC Listed 3 meter Semi-Anechoic Chamber			
Test Distance	See data section			
EUT Placement	80 cm height non-conductive table above reference ground plane			
Frequency Range of Measurement	Biconical: 30-200 MHz	Log Periodic Dipole Array: 200-1000 MHz	Double-Ridged Waveguide Horn: 1-18 GHz	Standard Gain Horn: 18-25 GHz
Measurement Detectors	30-1000MHz RBW: 120 kHz VBW: At least 300 kHz		1 - 40 GHz: RBW : 1MHz VBW: At least 3 (MHz) Peak 10 Hz Average	
Description of Measurement	1) The antenna, cable, pre-amp, and other necessary measurement system correction factors are loaded onto the EMI receiver / spectrum analyzer when the measurements are preformed. The data is gathered and reported as the corrected values. 2) The EUT is placed on a non-conductive pedestal centered on a turn-table in the test location with the antenna at the test distance from the EUT 3) Maximum radiated RF emissions are determined by rotation of azimuth and scanning the sense antenna between 1 and 4 meters in height using both horizontal and vertical antenna polarities. Maximized levels are manually noted at degree values of azimuth and at sense antenna height.			
Example Calculations	Reported Measurement data = Raw receiver measurement + Antenna Correction Factor + Cable factor (dB) - amplification factor (when applicable) + Additional factor (when applicable)			

FCC Part 15.209 Limits:

Frequency (MHz)	3 m Limit (µV/m)	3 m Limit (dBµV/m)	Type
30-88	100	40.0	Quasi-Peak
88-216	150	43.5	Quasi-Peak
216-960	200	46.0	Quasi-Peak
Above 960	500	54.0	Average (>1 GHz)

B.2.1 – Radiated Band-Edge Restricted Bands

Manufacturer	Suterra
Date	8-7-2014
Operator	Adam A
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	15.247/ 15.205 / 15.209
Measurement Procedure	ANSI C63.4 - 2003 ANSI C63.10 - 2009 FCC KDB 558074
Test Distance	3 meter (1-4 GHz)
EUT Placement	80 cm height non-conductive table centered on turn-table
Detectors	Peak; RBW 1MHz VBW 3 MHz (10Hz VBW for average measurements)
Additional Notes	1) Tested in the worst case of continuous transmit modulated mode with EUT maximized in three orientations at maximum power. 2) EUT maximized in azimuth and antenna height with maximum results reported.

Example Calculation:

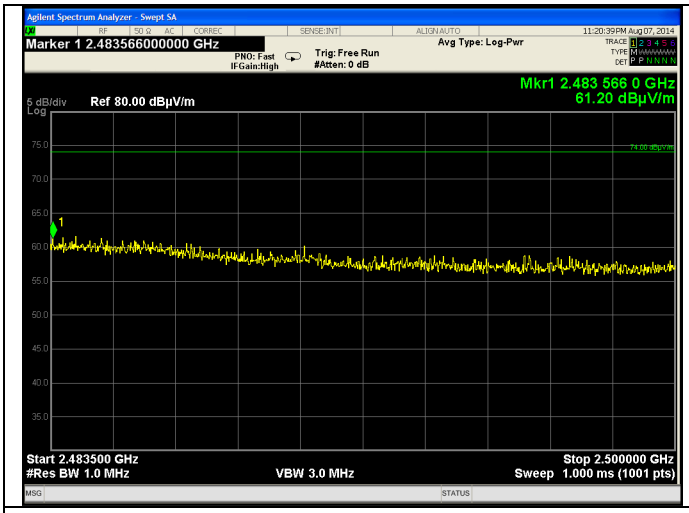
FCC 15.209 Peak Limit @ 3 meter (dBµV/m) – Peak Reading (dBµV/m) = Peak Margin

FCC 15.209 Average Limit @ 3 meter (dBµV/m) –Average Reading (dBµV/m) = Average Margin

Data Table

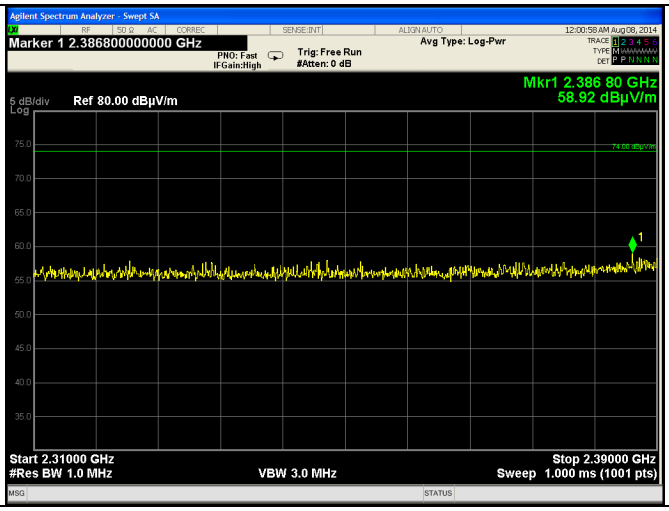
Transmit Channel	Frequency (MHz)	EUT orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Avg Limit (dBµV/m)	Avg Margin (dB)
Low	2389.5	Flat	Horizontal	123	261	58.92	39.65	74	15.1	54	14.4
High	2483.5	Vertical	Horizontal	103	331	61.20	48.16		12.8		5.8

Plots

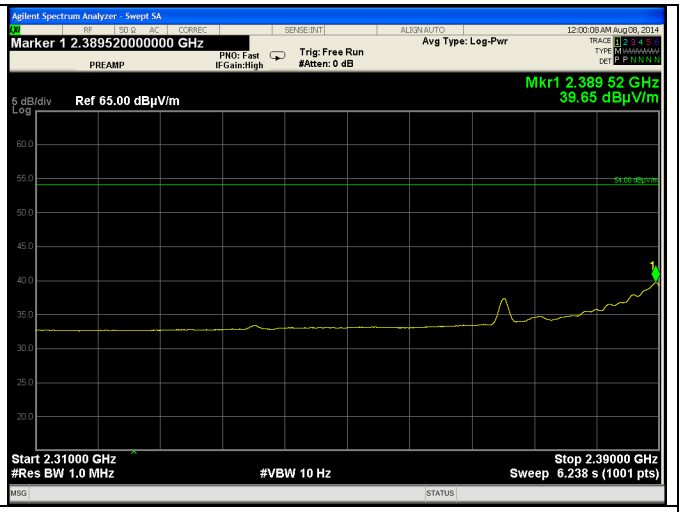


High Channel (2480MHz) - Upper Band-edge Peak

High Channel (2480MHz) - Upper Band-edge Average



Low Channel (2405 MHz) – Lower Band-edge Peak



Low Channel (205 MHz) – Lower Band-edge Average

B.2.2 – Radiated Transmitter Emissions in Restricted and Non-Restricted Bands

Manufacturer	Suterra
Date	8-7,8,12 - 2014
Operator	Adam A
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	15.247/ 15.205 / 15.209
Measurement Procedure	ANSI C63.4 - 2003 ANSI C63.10 - 2009
Test Distance	3 meter 4-25 GHz
EUT Placement	80 cm height non-conductive table centered on turn-table
Detectors	Peak; RBW 1 MHz, 3 MHz VBW
Additional Notes	1) Tested in continuous transmit modulated mode with EUT in three orientations at maximum power. 2) PLEASE SEE APPENDIX E FOR DUTY CYCLE CALCULATIONS.

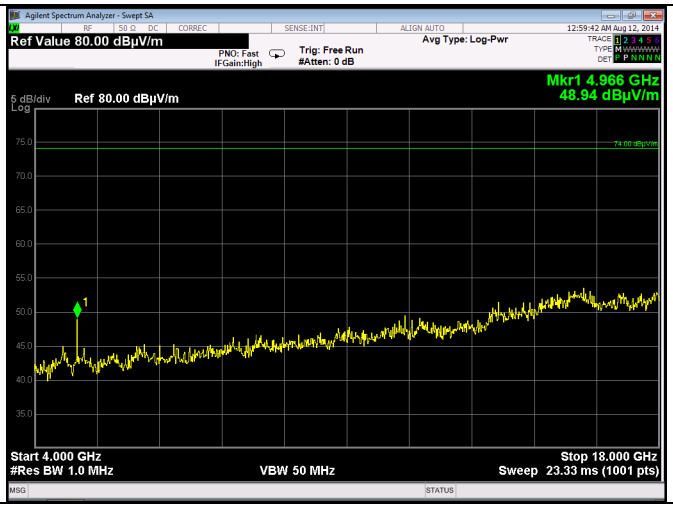
Example Calculation:
FCC 15.209 Peak Limit (dBµV/m) – Peak Reading (dBµV/m) = Margin
Peak Reading (dBµV/m) – Duty Cycle Correction (dB) = Calculated Average (dBµV/m)
FCC 15.209 Average Limit (dBµV/m) – Calculated Average (dBµV/m) = Margin

Data Table

Frequency (MHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Peak Reading (dBµV/m)	Duty Cycle (dB)	Calculated Avg (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Avg Limit (dBµV/m)	Avg Margin (dB)
(4804) Low Channel	Vertical	Vertical	109	102	54.19	14.9	39.29	74	19.8	54	14.7
		Horizontal	145	230	57.01	14.9	42.11		17.0		11.9
	Horizontal	Vertical	103	210	58.29	14.9	43.39		15.7		10.6
		Horizontal	119	354	50.80	14.9	35.90		23.2		18.1
	Flat	Vertical	100	256	54.56	14.9	39.66		19.4		14.3
		Horizontal	119	165	58.13	14.9	43.23		15.9		10.8
(4880) Mid Channel	Vertical	Vertical	107	100	53.97	14.9	39.07	74	20.0	54	14.9
		Horizontal	131	232	52.66	14.9	37.76		21.3		16.2
	Horizontal	Vertical	144	296	56.59	14.9	41.69		17.4		12.3
		Horizontal	103	100	51.73	14.9	36.83		22.3		17.2
	Flat	Vertical	100	10	51.36	14.9	36.46		22.6		17.5
		Horizontal	107	166	56.86	14.9	41.96		17.1		12.0
(4960) High Channel	Vertical	Vertical	115	101	50.21	14.9	35.31	74	23.8	54	18.7
		Horizontal	109	236	51.62	14.9	36.72		22.4		17.3
	Horizontal	Vertical	115	64	52.97	14.9	38.07		21.0		15.9
		Horizontal	102	32	50.43	14.9	35.53		23.6		18.5
	Flat	Vertical	100	112	48.90	14.9	34.00		25.1		20.0
		Horizontal	111	5	52.82	14.9	37.92		21.2		16.1

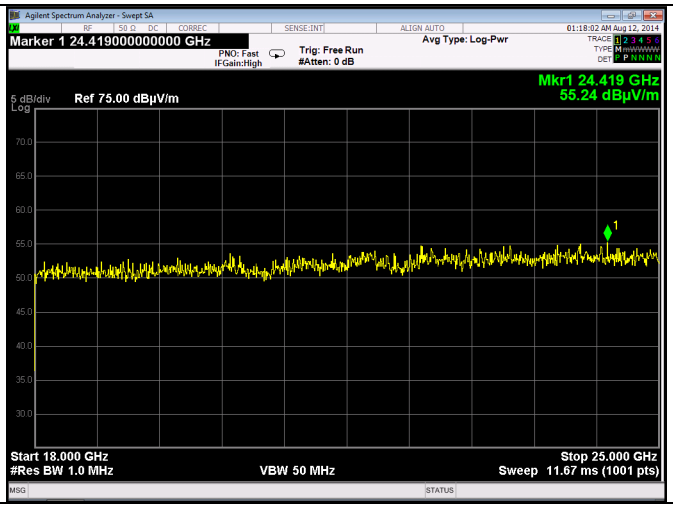
Note: See Appendix E for duty cycle calculations.

Plots

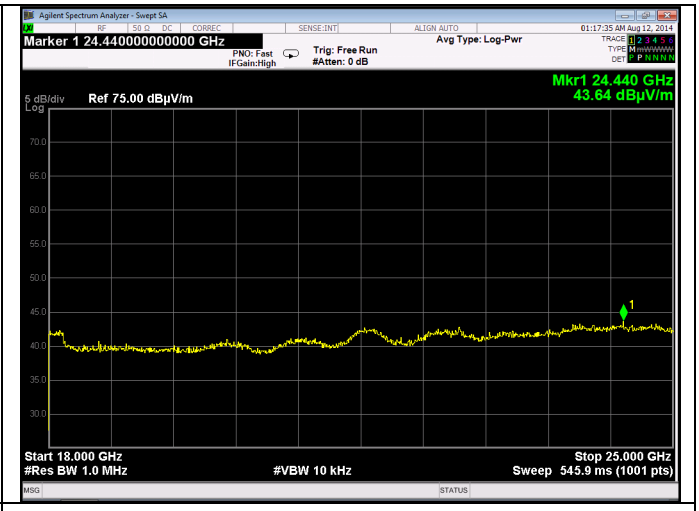


High Channel - 4-18 GHz Peak

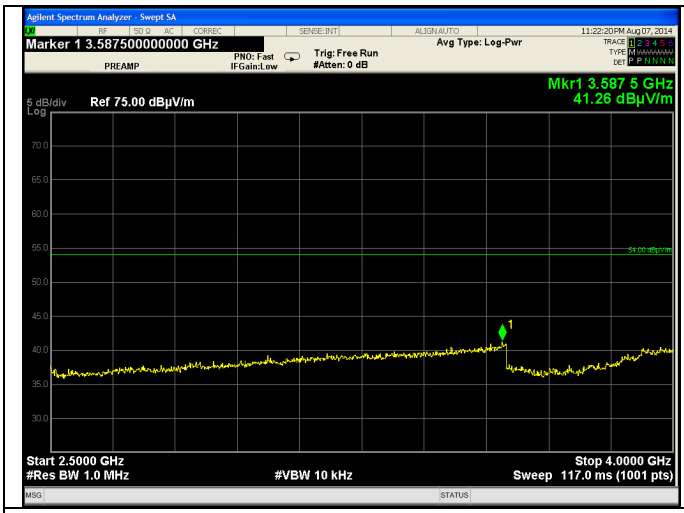
High Channel - 4-18 GHz (Reduced VBW)



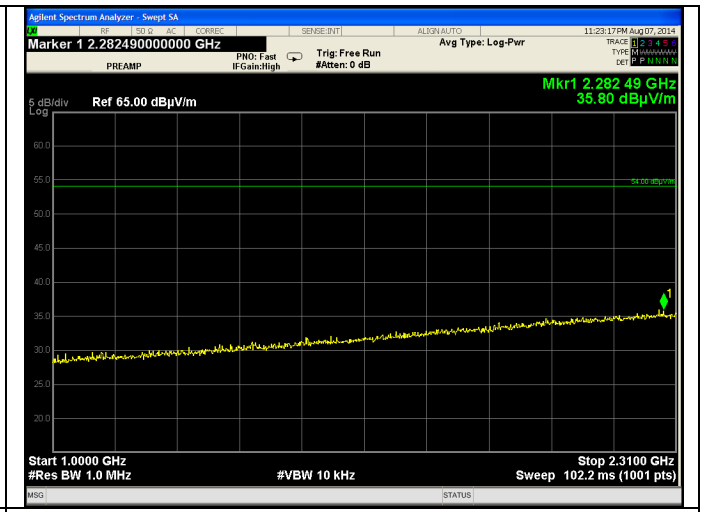
18-25 GHz Peak



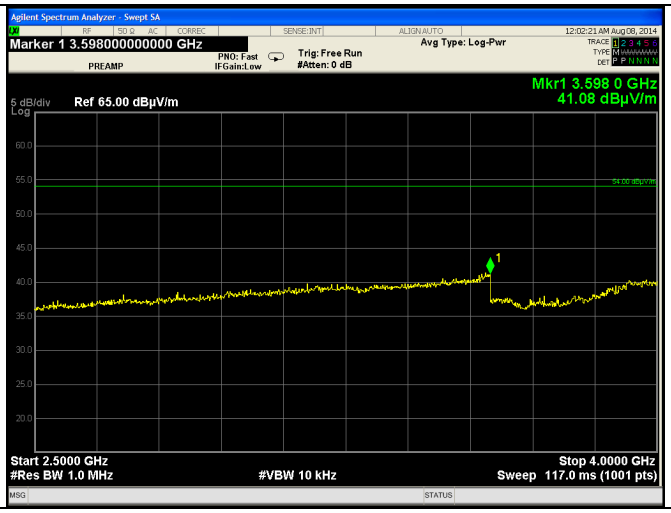
18-25 GHz (Reduced VBW)



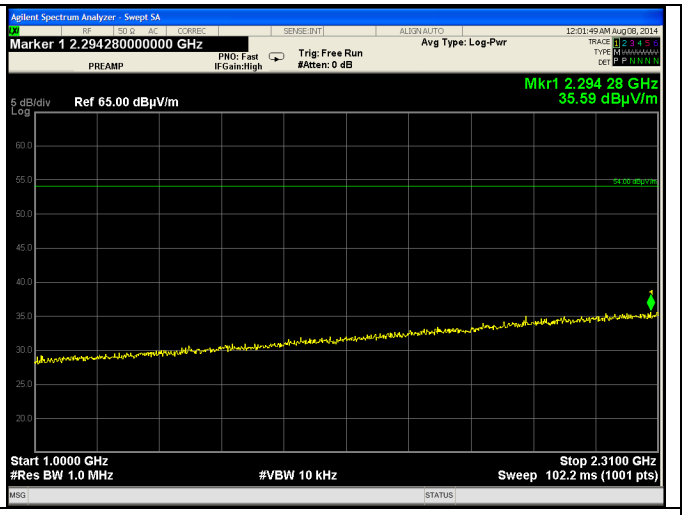
Low Channel 2.5-4 GHz (Reduced VBW)



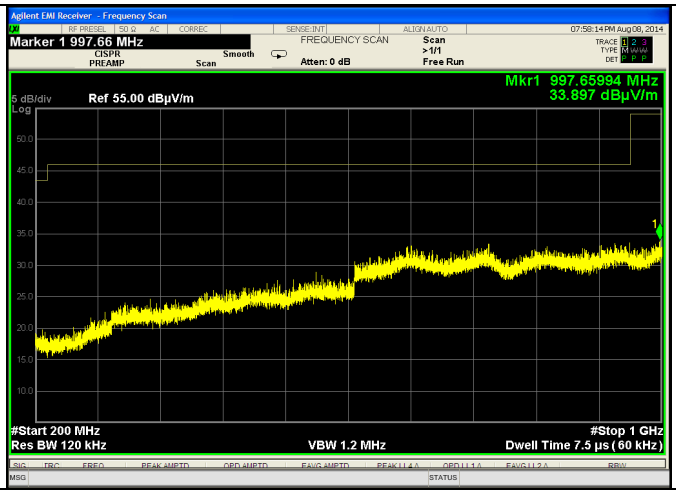
Low Channel 1-2.31 GHz (Reduced VBW)



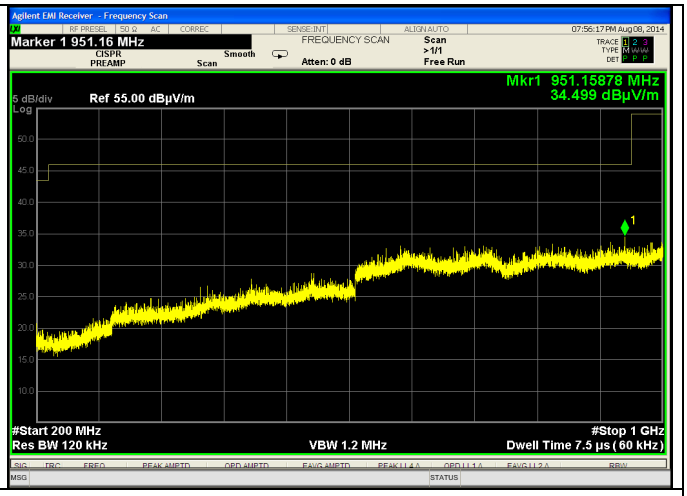
High Channel 2.5-4 GHz (Reduced VBW)



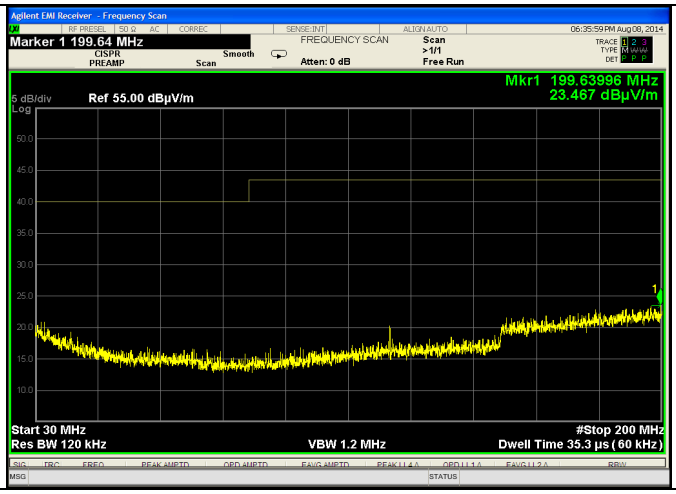
High Channel 1-2.31 GHz (Reduced VBW)



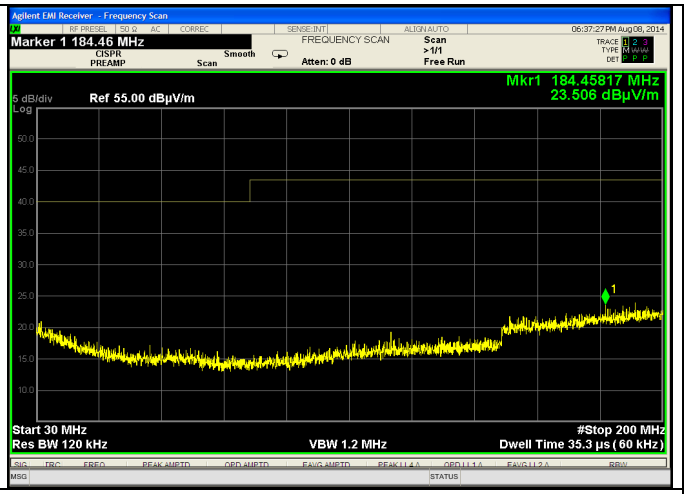
200-1000 MHz Vertical



200-1000 MHz Horizontal



30-200 MHz Vertical



30-200 MHz Horizontal

B.2.3 – Radiated Emissions Receive Mode and Normal Mode

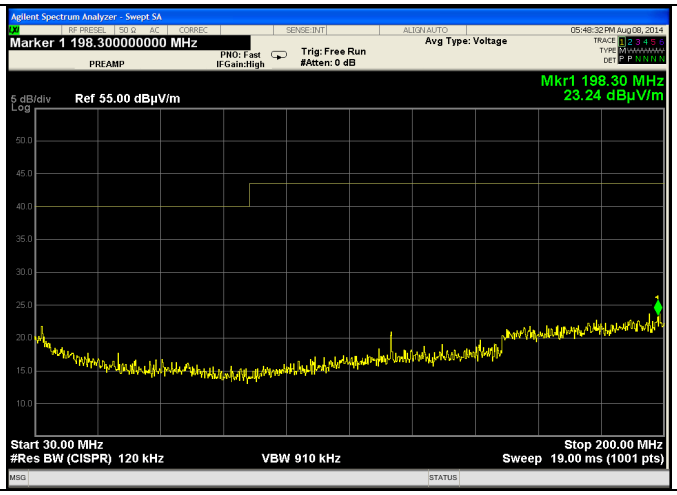
Manufacturer	Suterra
Date	8-8,11,12 -2014
Operator	Adam A
Temp. / R.H.	20 - 25º C / 30-60% R.H.
Rule Part	15.109
Measurement Procedure	ANSI C63.4 - 2003 ANSI C63.10 - 2009
Test Distance	3 meter 30-25000 MHz
EUT Placement	80 cm height non-conductive table centered on turn-table
Detectors	Peak; RBW 1 MHz (Average 10 Hz VBW) > 1 GHz < Quasi-Peak; RBW 120 kHz
Additional Notes	1) Tested in continuous receive mode with EUT in three orientations on three channels 2) Maximum results reported

Example Calculation:
Limit (dBµV/m) – Reading (dBµV/m) = Margin

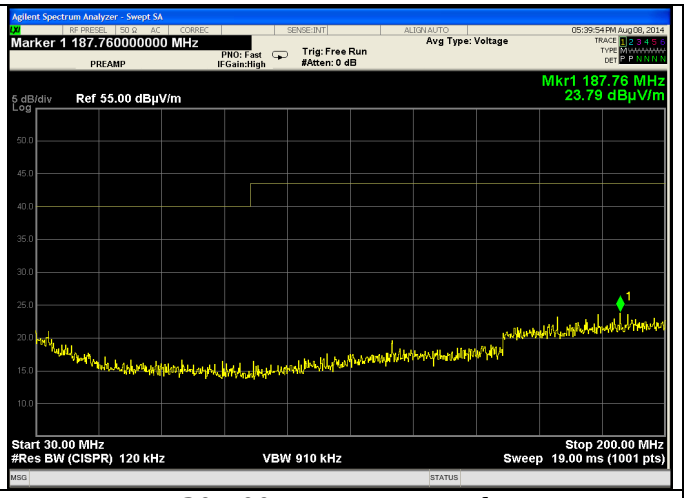
Table - Receive Mode

Frequency (MHz)	EUT orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Avg Limit (dBµV/m)	Avg Margin (dB)
(4806) Low Channel	Vertical	Vertical	NF				74		54	-
		Horizontal	133	229	44.04	33.91		29.96		20.09
	Horizontal	Vertical	106	296	45.32	36.99		28.68		17.01
		Horizontal	NF							-
	Flat	Vertical	NF							-
		Horizontal	107	169	45.70	38.08		28.30		15.92
(4882) Mid Channel	Vertical	Vertical	NF				74		54	-
		Horizontal	124	251	43.87	33.55		30.13		20.45
	Horizontal	Vertical	109	277	43.13	36.34		30.87		17.66
		Horizontal	NF							-
	Flat	Vertical	NF							-
		Horizontal	108	177	44.12	35.46		29.88		18.54
(4959) High Channel	Vertical	Vertical	NF				74		54	-
		Horizontal	NF							-
	Horizontal	Vertical	110	245	43.03	33.46		30.97		20.54
		Horizontal	NF							-
	Flat	Vertical	NF							-
		Horizontal	105	155	43.13	33.63		30.87		20.37

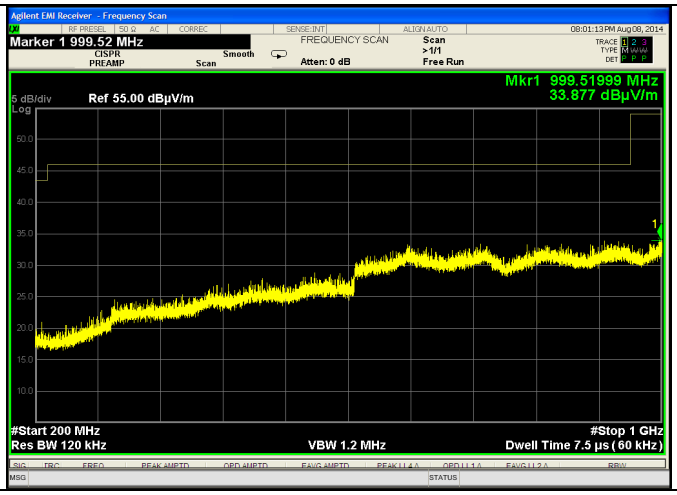
Plots - Receive Mode



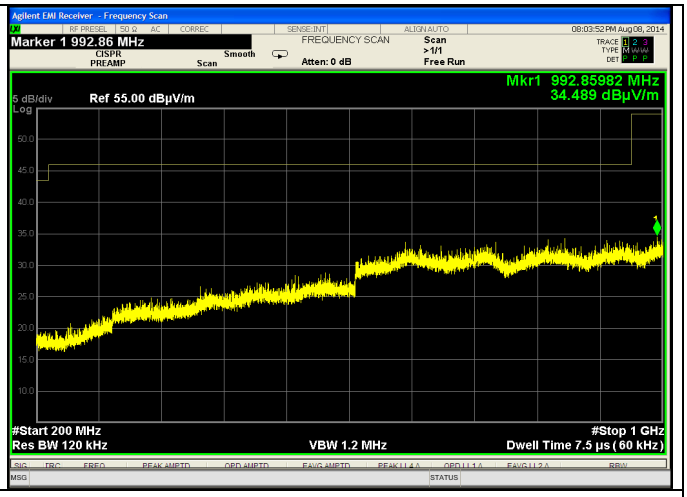
30-200 MHz Vertical



30-200 MHz Horizontal

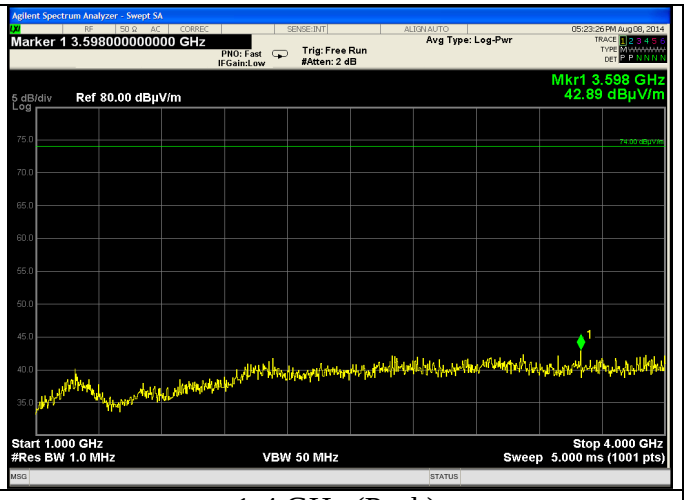


200-1000 MHz Vertical

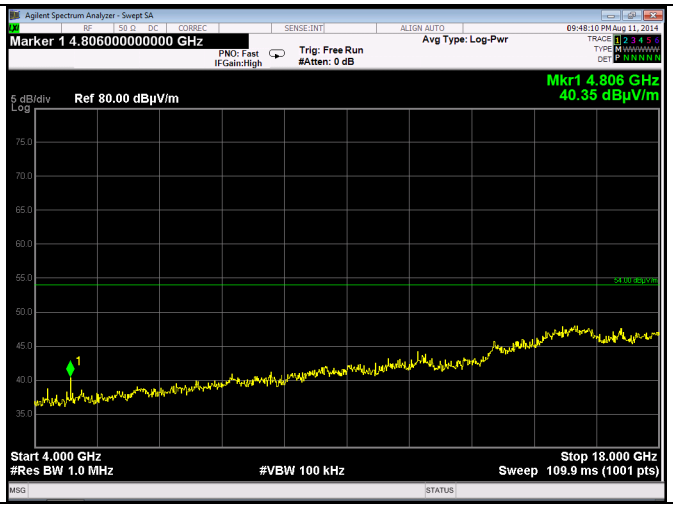


200-1000 MHz Horizontal

1-4 GHz (Reduced VBW)

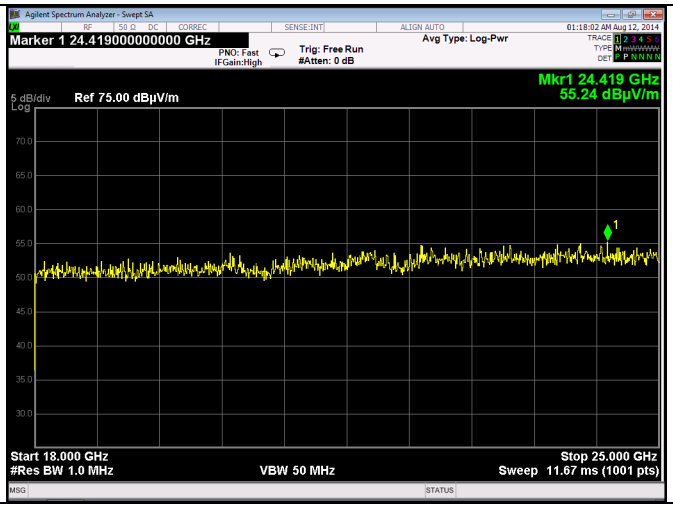


1-4 GHz (Peak)

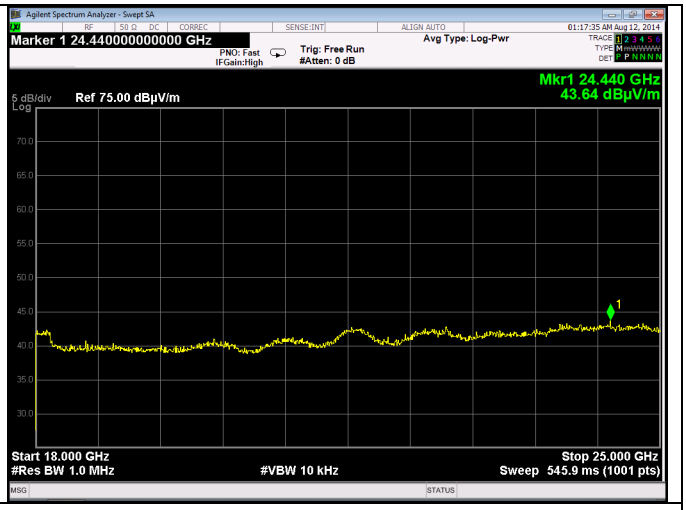


4-18 GHz (Reduced VBW)

4-18 GHz (Reduced VBW)



18-25 GHz Peak

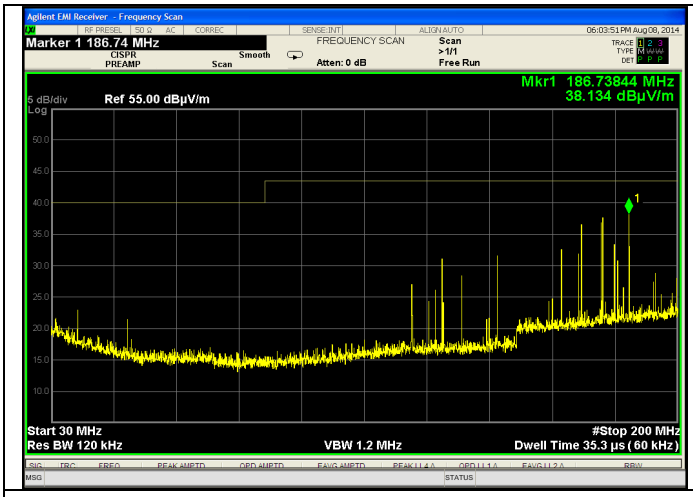


18-25 GHz (Reduced VBW)

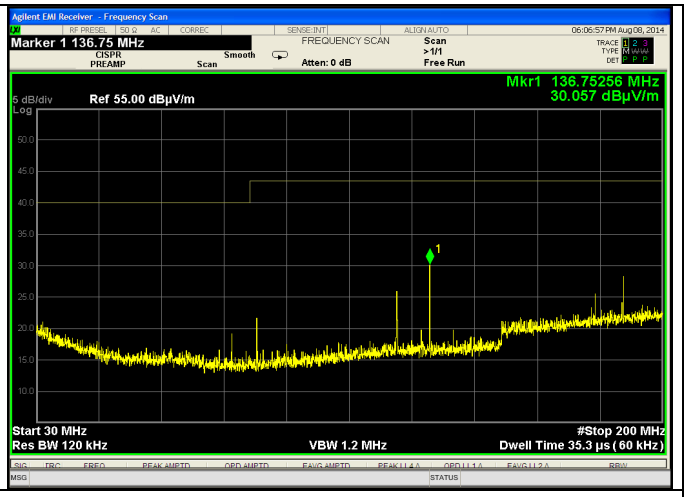
Table – Normal Mode

Frequency (MHz)	Height (cm)	Azimuth (degree)	Quasi Peak Reading (dBµV/m)	Quasi Peak Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
176.5	100	196	19.04	43.5	24.46	Vertical	Vertical
136.75	158	34	16.77	43.5	26.73	Horizontal	Vertical
761.6	143	184	31.24	46	14.76	Horizontal	Vertical
369.14	100	252	33.65	46	12.35	Vertical	Vertical

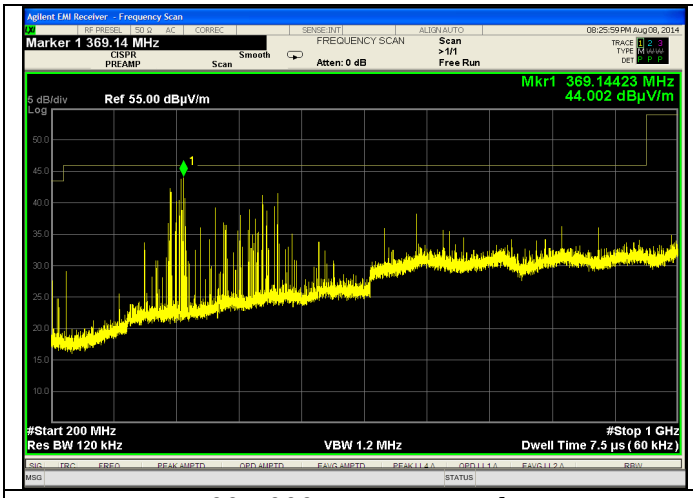
Plots – Normal Mode



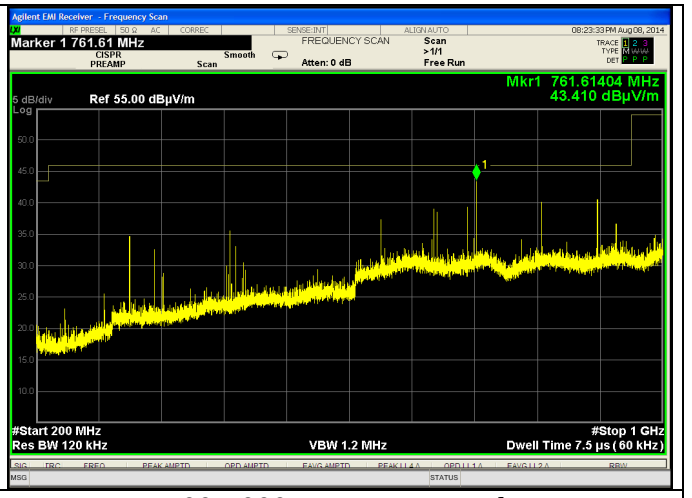
30-200 MHz Vertical



30-200 MHz Horizontal



200-1000 MHz Vertical



200-1000 MHz Horizontal

B3 – AC Mains Conducted Emissions

Test Not Applicable – EUT Battery Operated Only

Appendix C - Uncertainty Summary

This uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k=2.

Table of Expanded Uncertainty Values, (K=2) for Specified Measurements

Measurement Type	Particular Configuration	Uncertainty Values
Radiated Emissions	3 – Meter chamber, Biconical Antenna	4.82 dB
Radiated Emissions	3-Meter Chamber, Log Periodic Antenna	4.88 dB
Radiated Emissions	3-Meter Chamber, Horn Antenna	4.85 dB
Absolute Conducted Emissions	Agilent PSA/ESA Series	1.38 dB
AC Line Conducted Emissions	Shielded Room/EMCO LISN	3.20 dB
Temperature/Humidity	Thermo-hygrometer	0.64°/ 2.88 %RH

Appendix D - References

Publication	Year	Title
FCC CFR Parts 0-15	2014	Code of Federal Regulations – Telecommunications
ANSI C63.4	2003	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.
ANSI C63.10	2009	American National Standard for Testing Unlicensed Wireless Devices
FCC KDB 558074 D01 DTS Meas Guidance v03r02	2014	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247

Appendix E – BLE Duty Cycle Calculation

1.0 Summary

The fact that BLE is certified as a DTS (non-hopping), here is a worst-case indication for the BLE relaxation factor. The information contained in this appendix is from the Bluetooth Specification 4.0 dated June 30, 2010.

Channel dwell time cannot be incorporated into the relaxation factor as it can in Bluetooth 2.1+EDR. Shown below are the specifications for the link layer PDU (Physical Layer Protocol Data Unit) and the Inter frame spacing.

The worst case duty factor would be the interleaved concatenation of the maximum length packets and inter frame spaces. However, in the study of various sequence diagrams of the BLE protocol (particularly in the Advertising modes), this state does not really exist, there is typically 3 packets concatenated in the longest channel dwell. Also between channel dwells, there is more time allowed.

There are directed and undirected advertising events.

The worst case relaxation factor for a directed advertising event is 14.9 dB.

The worst case relaxation factor for an undirected advertising event is 20 dB.

1.1 Defining Packet Length

2.1 PACKET FORMAT

The Link Layer has only one packet format used for both advertising channel packets and data channel packets.

The packet format is shown in Figure 2.1. Each packet consists of four fields: the preamble, the Access Address, the PDU, and the CRC.

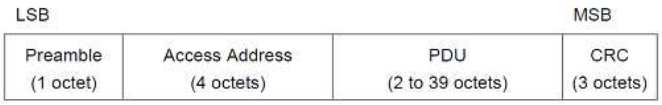


Figure 2.1: Link Layer packet format

The preamble is 1 octet and the Access Address is 4 octets. The PDU range is from 2 to a maximum of 39 octets. The CRC is 3 octets.

The Preamble is transmitted first, followed by the Access Address, followed by the PDU followed by the CRC.

The shortest packet is 80 bits in length. The longest packet is 376 bits in length.

PDU Type $b_3b_2b_1b_0$	Packet Name
0000	ADV_IND
0001	ADV_DIRECT_IND
0010	ADV_NONCONN_IND
0011	SCAN_REQ
0100	SCAN_RSP
0101	CONNECT_REQ
0110	ADV_SCAN_IND
0111-1111	Reserved

Table 2.1: Advertising channel PDU Header's PDU Type field encoding

Octets per Packet

ADV_IND = 37 octets
ADV_DIRECT_IND = 12 octets
ADV_NONCONN_IND =37 octets
SCAN_REQ = 12 octets
SCAN_RSP = 37 octets
CONNECT_REQ = 34 octets
ADV_SCAN_IND = 37 octets

Preamble (1)	Access Address (4)	PDU Header (2)	Worst Case PDU Type (37)	CRC (3)

Stated worst case length packet: 47 octets = 376 bits
Worst Case Packet Duration: 376 bits * 1 µS / bit = 376 µS

1.2 Defining Inter Frame Space

4.1 INTER FRAME SPACE

The time interval between two consecutive packets on the same channel index is called the Inter Frame Space. It is defined as the time from the end of the last bit of the previous packet to the start of the first bit of the subsequent packet. The Inter Frame Space is designated "T_IFS" and shall be 150 µs.

1.3 Defining Undirected Advertising Event

For all undirected advertising events, the time between the start of two consecutive advertising events (*T_advEvent*) is computed as follows for each advertising event:

T_advEvent = advInterval + advDelay

The a*dvInterval* shall be an integer multiple of 0.625 ms in the range of 20 ms to 10.24 s. If the advertising event type is either a scannable undirected event type or a non-connectable undirected event type, the *advInterval* shall not be less than 100 ms. If the advertising event type is a connectable undirected event type, the *advInterval* can be 20 ms or greater.

The *advDelay* is a pseudo-random value with a range of 0 ms to 10 ms generated by the Link Layer for each advertising event.

As illustrated in Figure 4.1, the advertising events are perturbed in time using the advDelay.

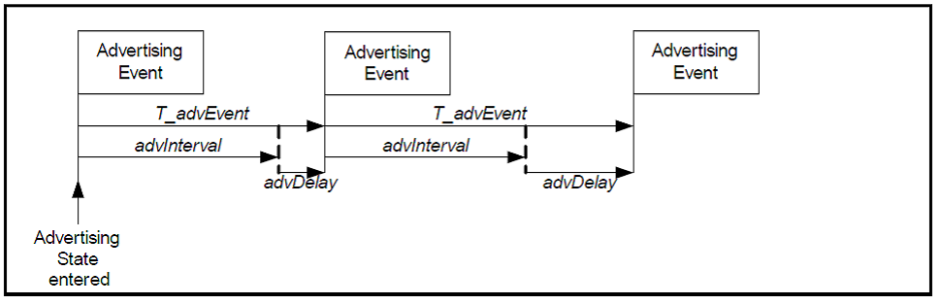


Figure 4.1: Advertising events perturbed in time using advDelay

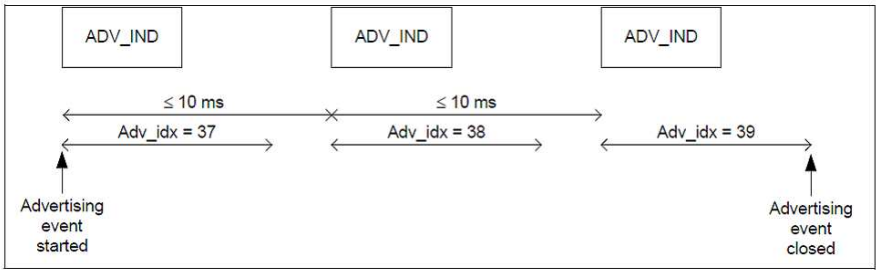


Figure F2: Connectable undirected advertising event with only advertising PDUs

1.3.1 Duty Factor for Connectable Undirected Advertising Event, per advertising channel:

ADV_IND = 376 µS duration (ON channel 37)
IFS = 150 µS (OFF)
ADV_IND = 376 µS duration (OFF channel 38)
IFS =150 µS (OFF)
ADV_IND = 376 µS duration (OFF Channel 39).
advInterval (min) = 20 mS

1.3.1.1 Straight Duty Factor

DF = 376 / (376*3+150*2+20000) =0.0175
Relaxation factor =-min (20*log10 (DF),-20 dB) =-min (-35.119,-20) = 20 dB

1.3.1.2 Duty Factor in 100mS window:

Packet Repetition Interval is (376*3) + (2*150) + 20000 microseconds =21428 microseconds
Number of Packet Repetitions per 100 mS window = 21428/100000 = 4.667 Packet Intervals
This will result in 5 packets being transmitted in a 100 mS window.

DF (rel 100 mS) = (5*376) / (100000) = 0.0188
Relaxation Factor Relative to 100 mS = - Max (20*log10 (DF (rel 100mS)),-20 dB) = -Max (-34.51 dB, -20) = 20 dB

1.4 Defining Directed Advertising Event

Duty Factor for Connectable Directed Advertising Event, per advertising channel

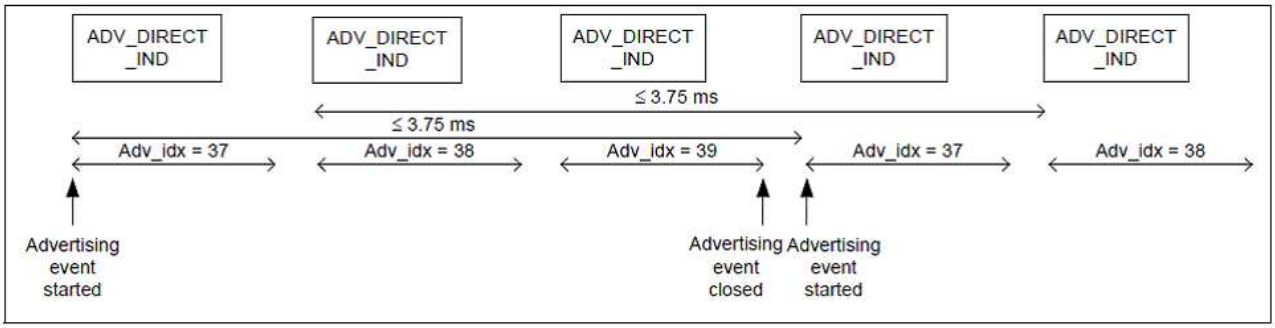


Figure F3: Connectable directed advertising event type with only advertising PDUs

1.4.1 Duty Factor for Connectable Directed Advertising Event, per advertising channel:

ADV_DIRECT_IND = 176 µS duration. (22 octets) (ON channel 37)
IFS = 150 µS (OFF)
ADV_IND = 176 µS duration (OFF channel 38)
IFS =150 µS (OFF)
ADV_IND = 176 µS duration (OFF Channel 39).
IFS=150 µS (OFF)

Time from open to close of advertising event = 3*176 + 3*150 =978 µS

1.4.1.1 Straight Duty Factor

DF = 176 / (978) = 0.179
Relaxation factor =-min (20*log10 (DF),-20 dB) =-min (-14.9,-20) = 14.9 dB

1.4.1.2 Duty Factor in 100mS window:

Number of Connectable Directed Advertising Packets, per advertising channel, per 100 mS window:
100000/978 = 102.78 packets.

Therefore, there can be 103 transmissions of packets 176 microseconds in length on one channel within a 100 mS window.
Duty Factor relative to 100 mS window: DF (rel 100 mS) = (176*103) / (100000) = 0.18128
Relaxation Factor Relative to 100 mS = - Max (20*log10 (DF (rel 100mS)),-20 dB) = -Max (-14.83 dB, -20) = 14.83 dB

END OF REPORT

Date	Version	Comments	Person
8-18-2014	V0	Initial Draft Release	Adam A
1-19-2015	V1	Final Release	Adam A