

TEST REPORT

Report Number: 102314980MPK-006

Project Number: G102314980

October 28, 2015

Testing performed on
Earlens Light Driven Hearing Aid
(Processor with Light Tip)
Model Numbers: PREL1& LTEL1

FCC ID: 2AGDU-EL1

IC: 20825-EL1

to

FCC Part 15 Subpart C (15.247)
Industry Canada RSS-247, Issue 1

For

EarLens Corporation

Test Performed by:
Intertek
1365 Adams Court
Menlo Park, CA 94025 USA

Test Authorized by:
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Minh Ly

Date: October 28, 2015

Reviewed by:



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Date: October 28, 2015

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Report No. 102314980MPK-006

Equipment Under Test:	Earlens Light Driven Hearing Aid (Processor with Light Tip)
Model Tested:	PREL1 & LTEL1
Serial Numbers:	EL1 15090002 EL1 15090006 EL1 15090008
Applicant:	EarLens Corporation
Contact:	Vince Kapral
Address:	EarLens Corporation 4045 Campbell Ave #A Menlo Park, CA 94025
Country	USA
Tel. Number:	(650) 743-1360
Email:	Vkapral@earlenscorp.com
Applicable Regulation:	FCC Part 15 Subpart C (15.247) Industry Canada RSS-247, Issue 1
Date of Test:	October 14 to October 19, 2015

We attest to the accuracy of this report:



Minh Ly
Project Engineer



Krishna K Vemuri
EMC Senior Staff Engineer

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1.0 Summary of Tests

Test	Reference FCC	Reference Industry Canada	Result
RF Output Power	15.247(b)(3)	RSS-247, 5.4	Complies
6 dB Bandwidth	15.247(a)(2)	RSS-247, 5.2	Complies
Power Density	15.247(e)	RSS-247, 5.2	Complies
Out of Band Antenna Conducted Emission	15.247(d)	RSS-247, 5.5	Complies
Transmitter Radiated Emissions	15.247(d), 15.209, 15.205	RSS-247, 5.5	Complies
AC Line Conducted Emission	15.207	RSS-GEN	Not applicable ¹
Antenna Requirement	15.203	RSS-GEN	Complies (Internal Antenna)
RF Exposure	15.247(i), 2.1093(d)	RSS-102	Complies *

¹ EUT is battery operated.

* Compliance with the SAR requirements is considered without testing because the RF power of channel is below SAR Test Exclusion Threshold. The SAR Test Exclusion Threshold (TET in mW) was calculated according to the KDB 447498, sec 4.3.1.1) using formula:

$$TET = 3 \times d / \sqrt{f_{(GHz)}}$$

where d = 5 mm – is the minimum test separation distance. At f = 2.45 GHz, TET = 9.6 mW (10 mW if rounded).

EUT receive date: September 14, 2015

EUT receive condition: The pre-production version of the EUT was received in good condition with no apparent damage. As declared by the Applicant, it is identical to the production units.

Test start date: October 14, 2015

Test completion date: October 19, 2015

The test results in this report pertain only to the item tested.

2.0 General Information

2.1 Product Description

The EUT is a EarLens Light Driven Hearing Aid.

The EarLens Light Driven Hearing Aid consists of Processor (model: PREL1), Light Tip (model: LTEL1), Lens (model: TLEL1) and Charger (model: CHEL101).

This test report covers only the Bluetooth radio of the Processor with Light Tip.

For more information, see user's manual provided by the manufacturer.

Information about the 2.4 GHz radio is presented below:

Applicant	EarLens Corporation
Model Numbers	PREL1& LTEL1
FCC Identifier	2AGDU-EL1
IC Identifier	20825-EL1
Type of transmission	Digital Transmission System (DTS)
Rated RF Output	-2.95 dBm (0.507 mW)
Frequency Range	2402 – 2480 MHz
Type of modulation/data rate	GFSK 1Mb/s
Number of Channel(s)	40
Antenna(s) & Gain	PCB antenna, Gain: -3 dBi
Applicant & Address	EarLens Corporation 4045 Campbell Ave #A Menlo Park, CA 94025, USA

2.2 Related Submittal(s) Grants

None.

2.3 Test Facility

The test site used to collect the radiated data is site 1 (10-m semi-anechoic chamber). This test facility and site measurement data have been fully placed on file with the FCC, IC and A2LA accredited.

2.4 Test Methodology

Antenna conducted measurements were performed according to the FCC documents “Guidance for Performing Compliance Measurement on Digital Transmission Systems (DTS) Operating under §15.247” (KDB 558074), and RSS-247, RSS-GEN, and

Radiated emissions and AC mains conducted emissions measurements were performed according to the procedures in ANSI C63.10. Radiated tests were performed at an antenna to EUT distance of 3 meters, unless stated otherwise in the "Data Sheet" of this report.

2.5 Measurement Uncertainty

Compliance with the limits was based on the results of the measurements and doesn't take into account the measurement uncertainty.

Estimated Measurement Uncertainty

Measurement	Expanded Uncertainty (k=2)		
	0.15 MHz – 1 GHz	1 GHz – 2.5 GHz	> 2.5 GHz
RF Power and Power Density – antenna conducted	-	0.7 dB	-
Unwanted emissions - antenna conducted	1.1 dB	1.3 dB	1.9 dB
Bandwidth – antenna conducted	-	30 Hz	-
Radiated emissions	4.2 dB	3.4 dB	4.4 dB
AC mains conducted emissions	2.4 dB	-	-

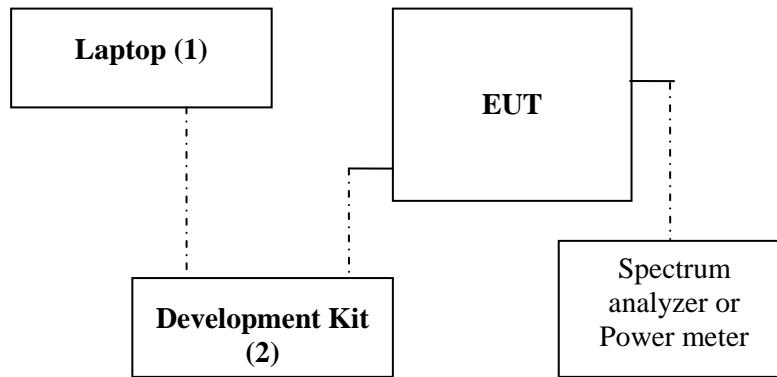
3.0 System Test Configuration

3.1 Support Equipment

Item #	Description	Model No./ Part No.	Serial No.
1	Dell Laptop	Vostro	Not listed
2	Development Kit	Not Listed	Not Listed

3.2 Block Diagram of Test Setup

Antenna was removed and co-axial connector with a cable was installed for Conducted Measurements.
Internal antenna was used for Radiated Measurements.



Note: A 1.8VDC power supply was used to power the EUT during Conducted testing and EUT was tested in Battery mode during Radiated testing.

S = Shielded	F = With Ferrite
U = Unshielded	m = Length in Meters

3.3 Justification

For radiated emission measurements the EUT is placed on a non-conductive table. The EUT is programmed to transmit full power at low/mid/high channel.

3.4 Software Exercise Program

The EUT exercise program used during radiated and conducted testing was provided by Earlens Corporation.

3.5 Mode of Operation during Test

During transmitter testing, the transmitter was setup to transmit at maximum RF power on low, middle and high frequencies/channels.

3.5 Modifications Required for Compliance

Intertek installed no modifications during compliance testing in order to bring the product into compliance.

3.6 Additions, Deviations and Exclusions from Standards

No additions, deviations or exclusions from the standard were made.

4.0 Measurement Results

4.1 6-dB Bandwidth and Occupied Bandwidth FCC Rule: 15.247(a)(2); RSS-247 5.2 and RSS-GEN;

4.1.1 Requirement

The minimum 6-dB bandwidth shall be at least 500 kHz

4.1.2 Procedure

The Procedure described in the FCC Publication 558074 was used.

The antenna port of the EUT was connected to the input of a spectrum analyzer (SA). For each RF output channel investigated, the spectrum analyzer center frequency was set to the channel carrier. A PEAK output reading was taken, a DISPLAY line was drawn 6 dB lower than PEAK level. The 6-dB bandwidth was determined from where the channel output spectrum intersected the display line.

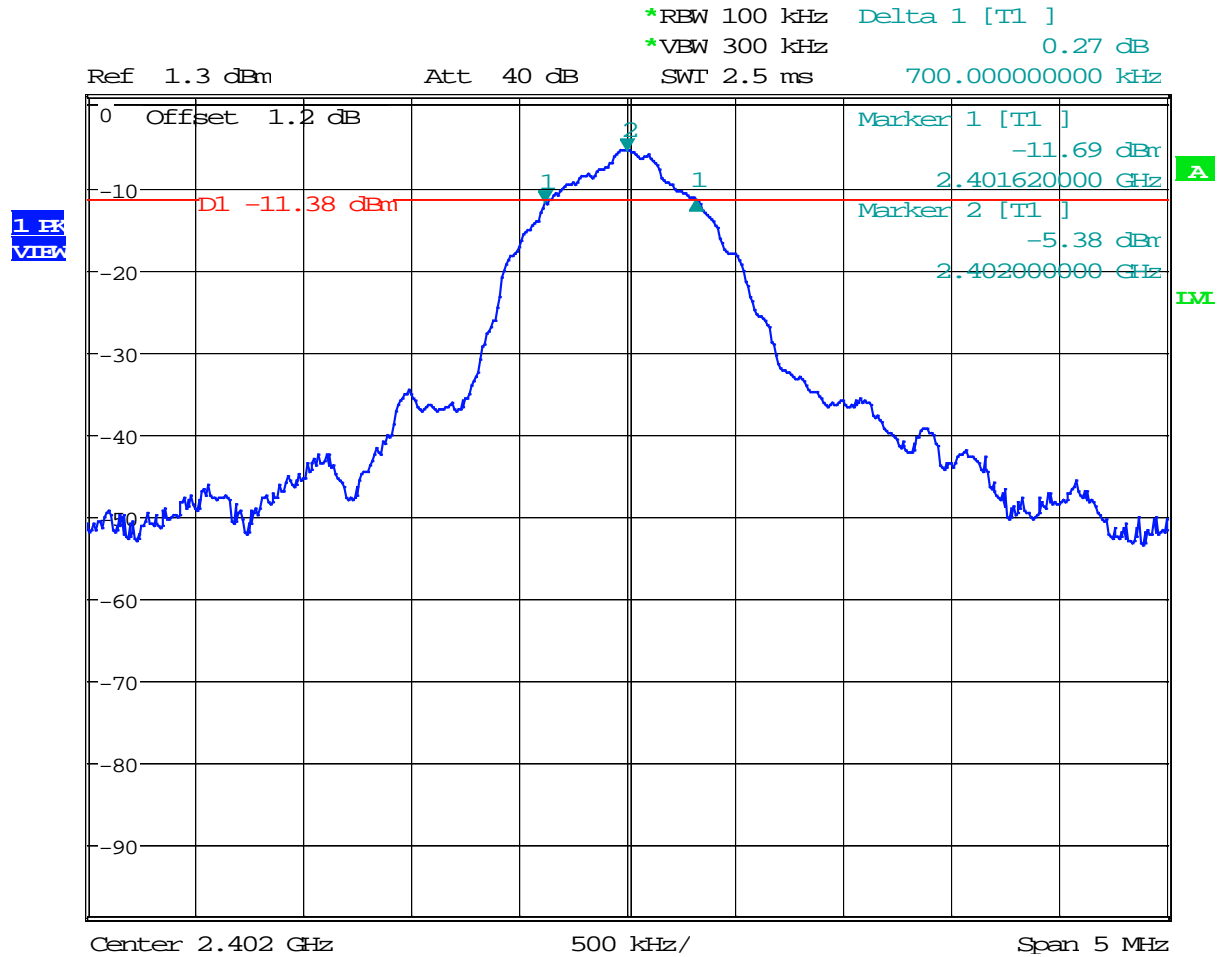
The occupied bandwidth was measured using the built-in spectrum analyzer function for 99% power bandwidth measurement.

4.1.3 Test Result

Frequency (MHz)	6-dB bandwidth MHz	Plot	99% Bandwidth MHz	Plot
2402	0.700	1.1	1.052	1.4
2440	0.680	1.2	1.048	1.5
2480	0.688	1.3	1.068	1.6

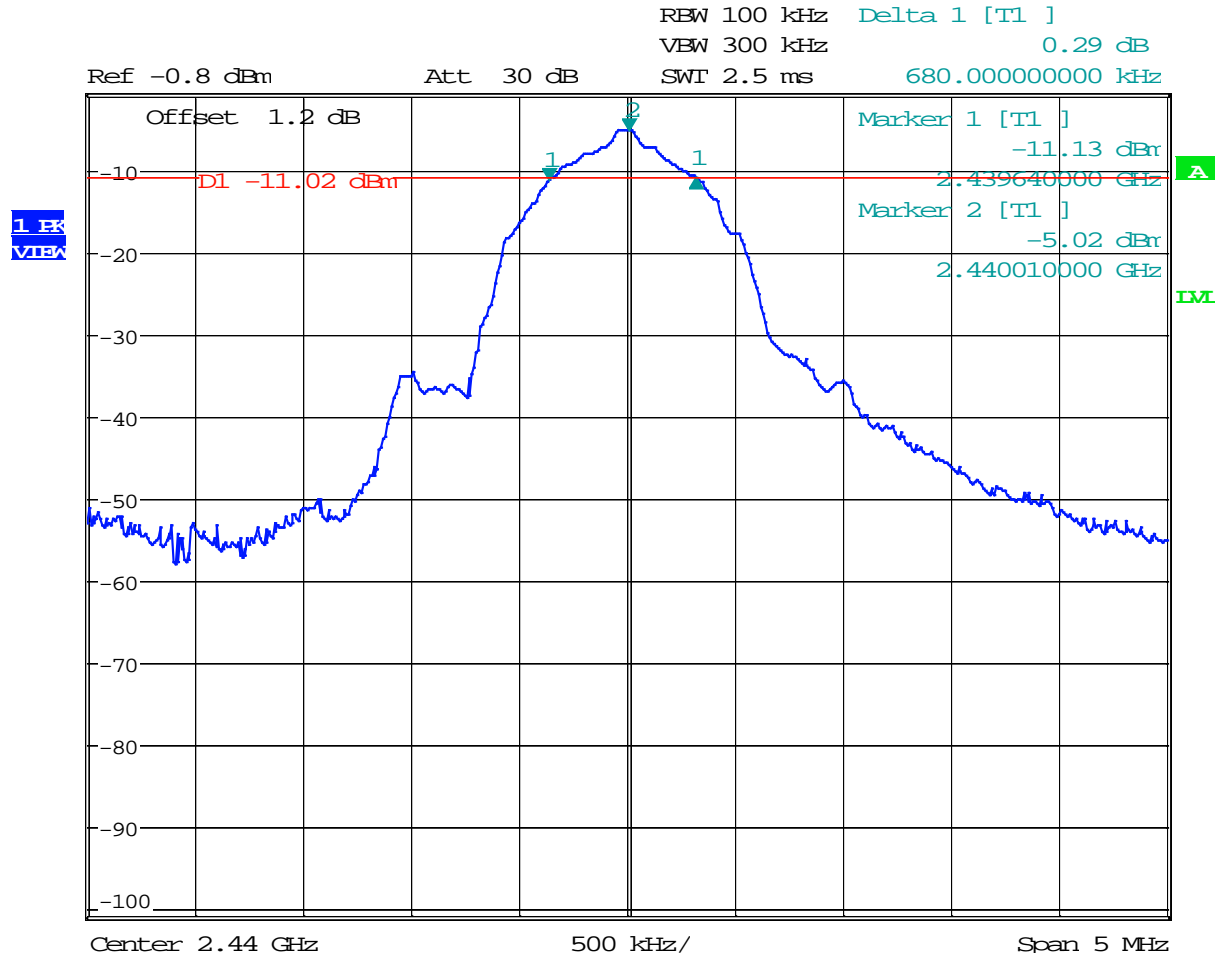
Results	Complies
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Plot 1. 1 - 6dB Bandwidth



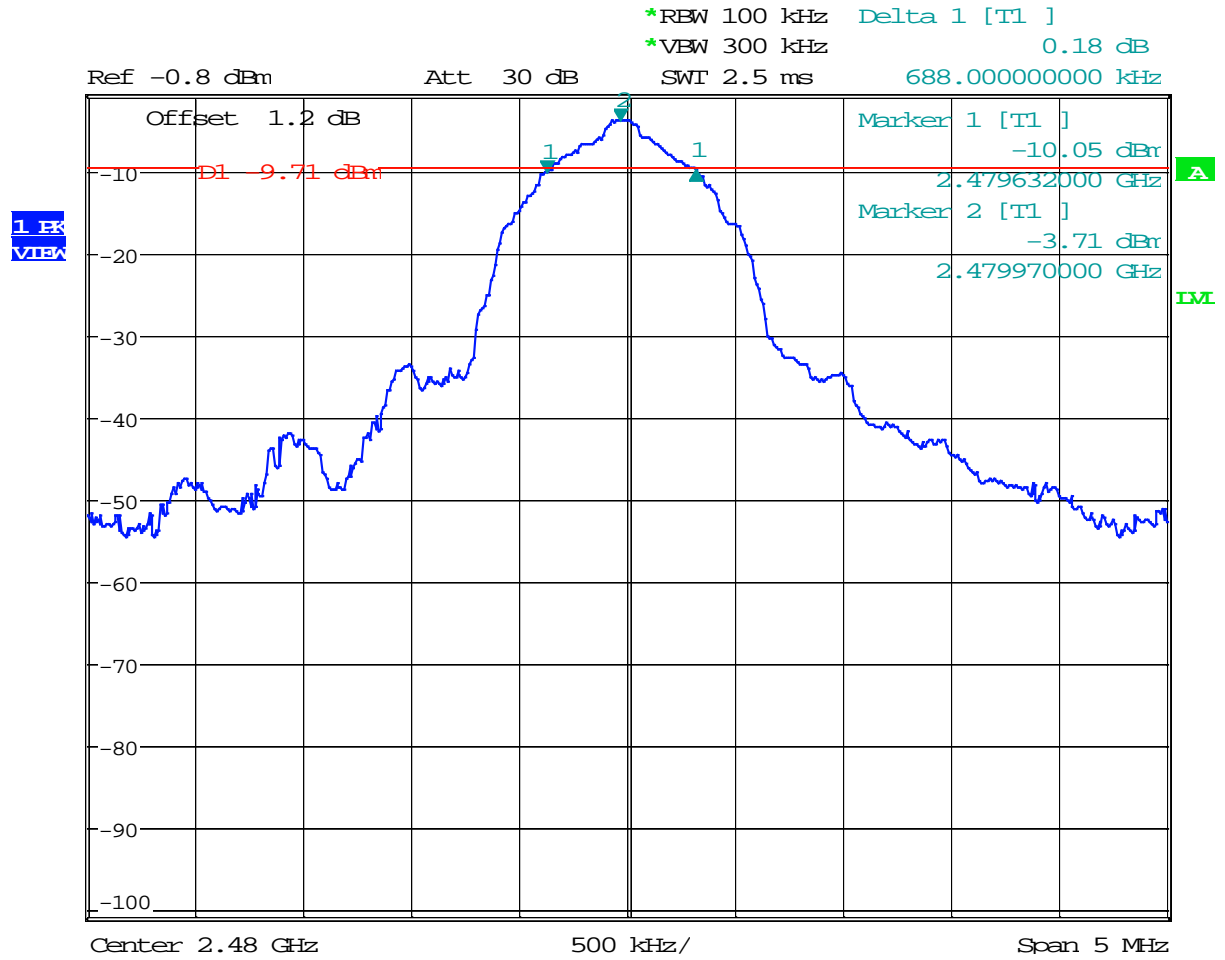
Date: 14.OCT.2015 18:45:31

Plot 1. 2 - 6dB Bandwidth



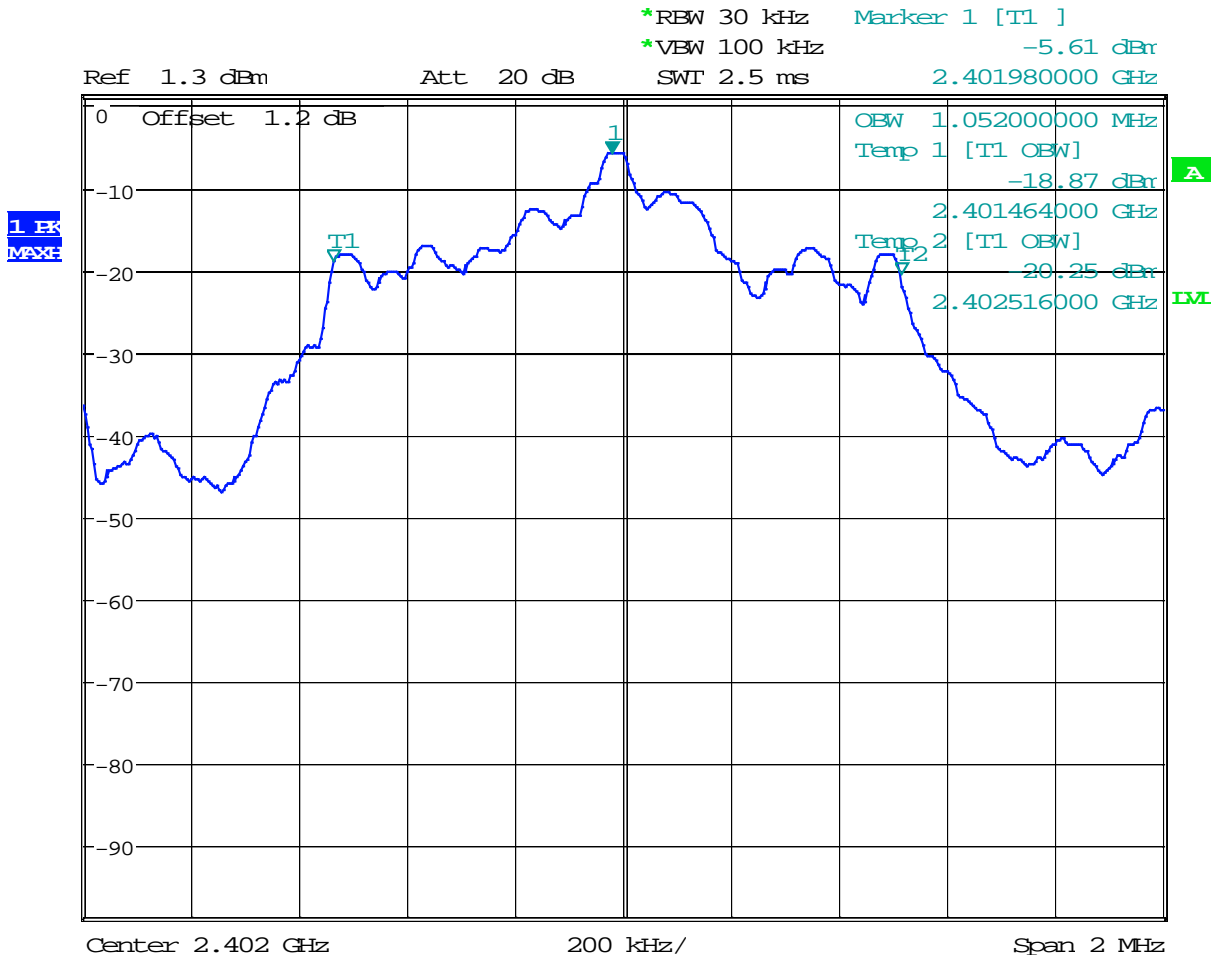
Date: 14.OCT.2015 19:24:07

Plot 1.3 - 6dB Bandwidth



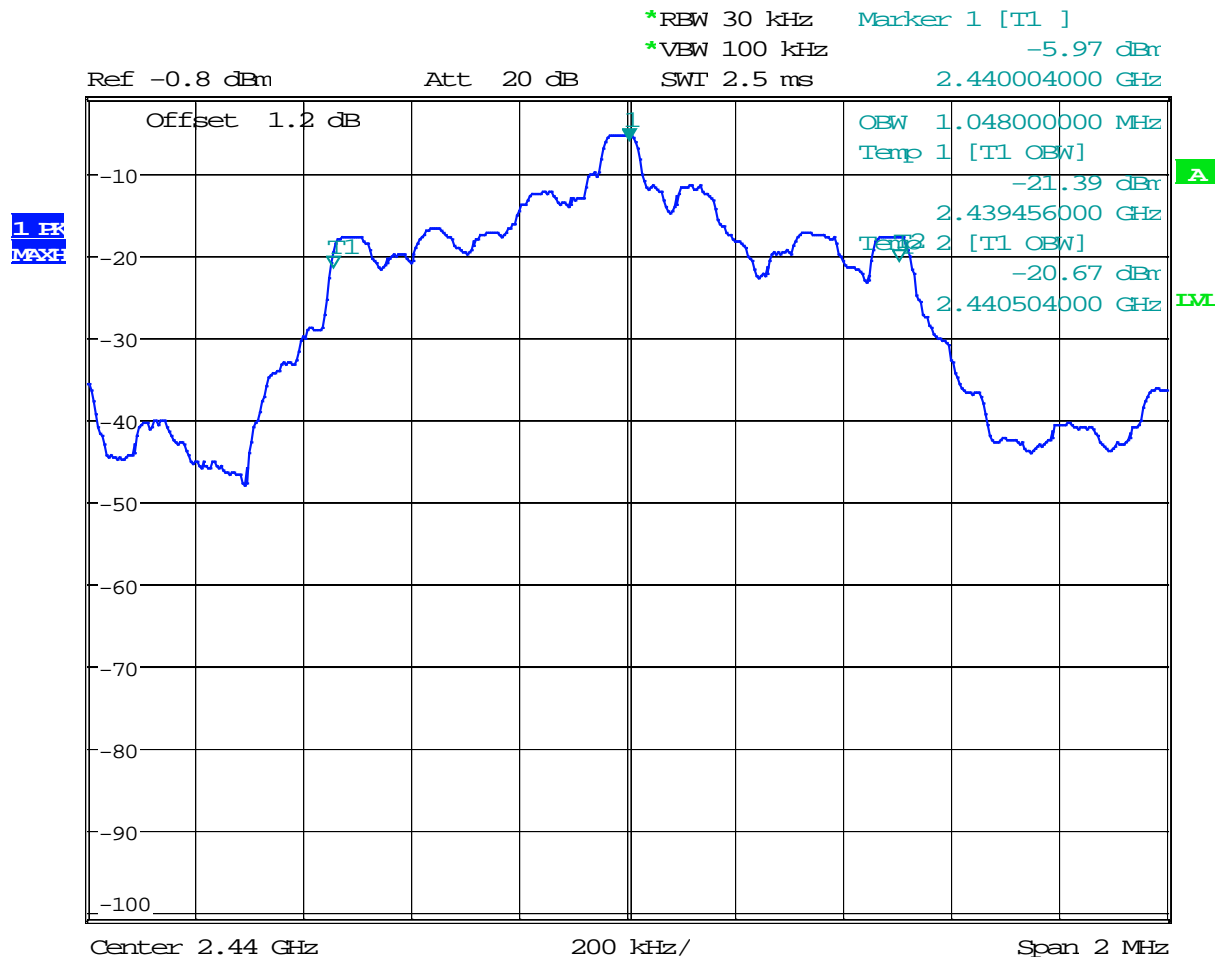
Date: 14.OCT.2015 19:47:44

Plot 1.4 - 99% Bandwidth



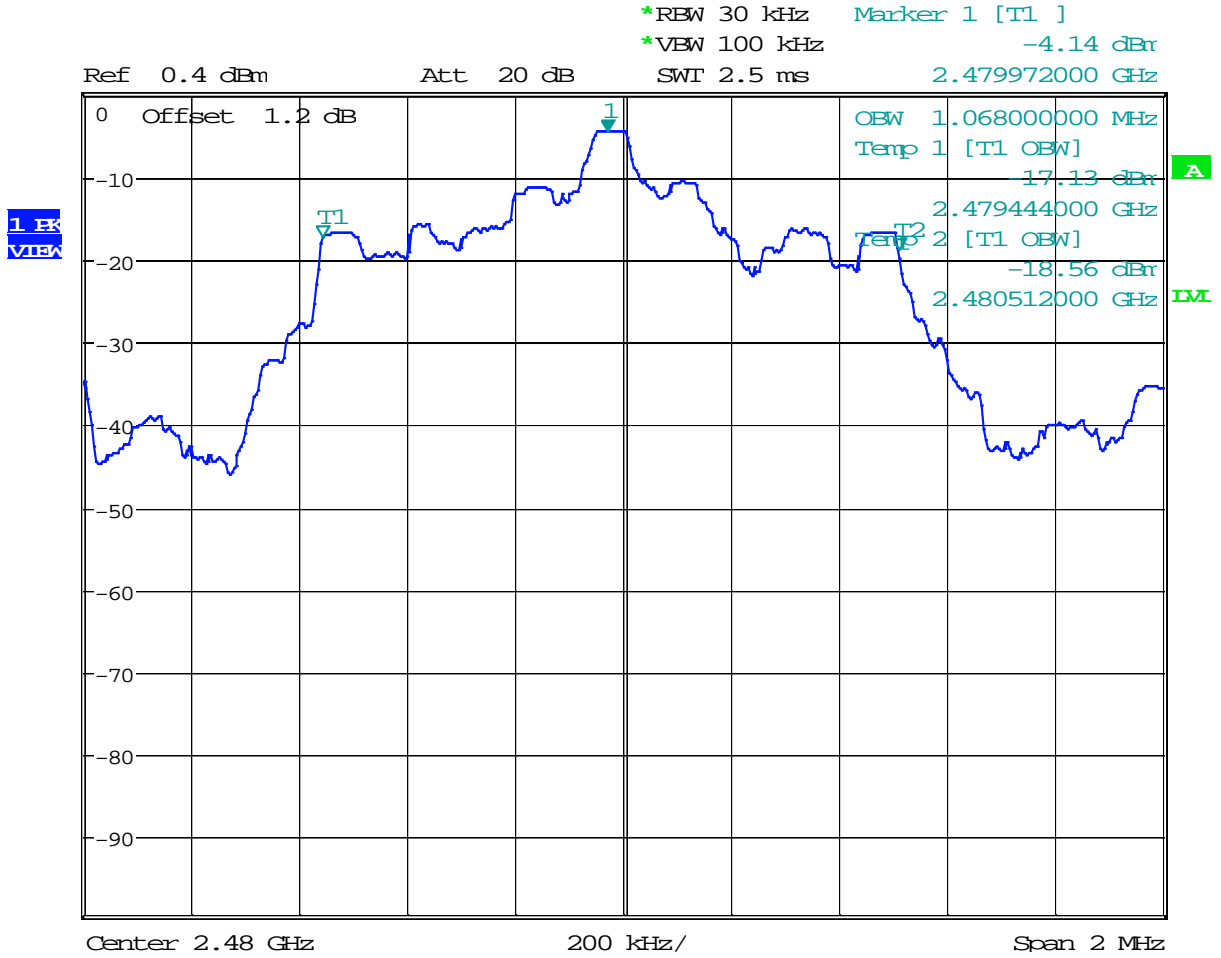
Date: 14.OCT.2015 18:52:52

Plot 1.5- 99% Bandwidth



Date: 14.OCT.2015 19:25:08

Plot 1.6- 99% Bandwidth



Date: 14.OCT.2015 19:44:55

4.2 Maximum Peak Conducted Output Power at Antenna Terminals
 FCC Rule: 15.247(b)(3); RSS-247, 5.4

4.2.1 Requirement

For antennas with gains of 6 dBi or less, maximum allowed transmitter output is 1 watt or 30 dBm. For antennas with gains greater than 6 dBi, transmitter output level must be decreased appropriately, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

4.2.2 Procedure

The antenna port of the EUT was connected to the input of a spectrum analyzer/power meter to measure the Maximum Conducted Transmitter Output Power.

The procedure described in FCC Publication 558074, was used. Specifically, section 9.1.1 for Maximum Peak Conducted Output Power, with the spectrum analyzer’s peak detector and Resolution Bandwidth $RBW > DTS$ Bandwidth.

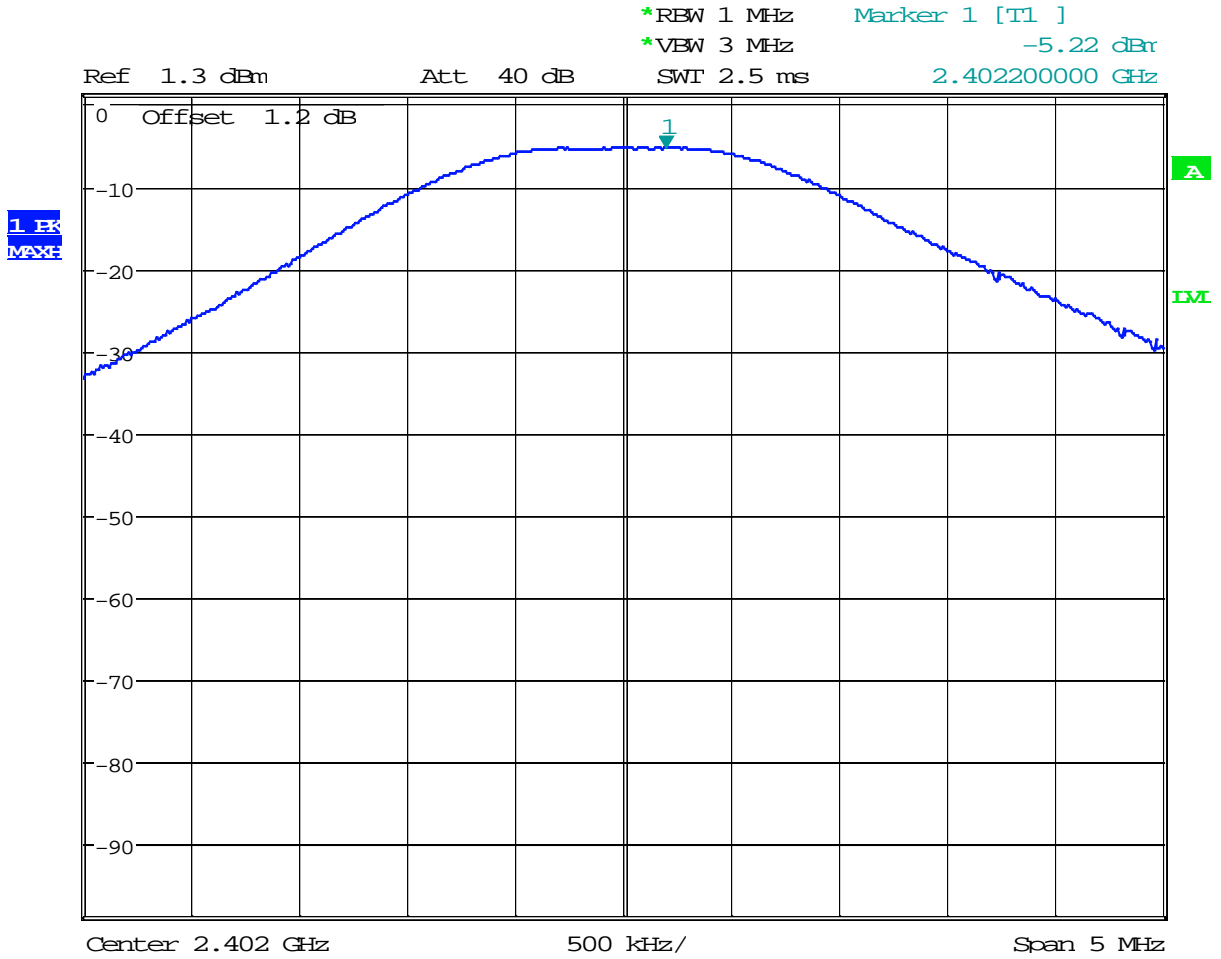
4.3.3 Test Result

Refer to the following plots 2.1 – 2.3 for the test details.

Frequency, MHz	Conducted Power (peak), dBm	Conducted Power (peak), mW	Plot
2402	-5.22	0.301	2.1
2440	-4.81	0.331	2.2
2480	-2.95	0.508	2.3

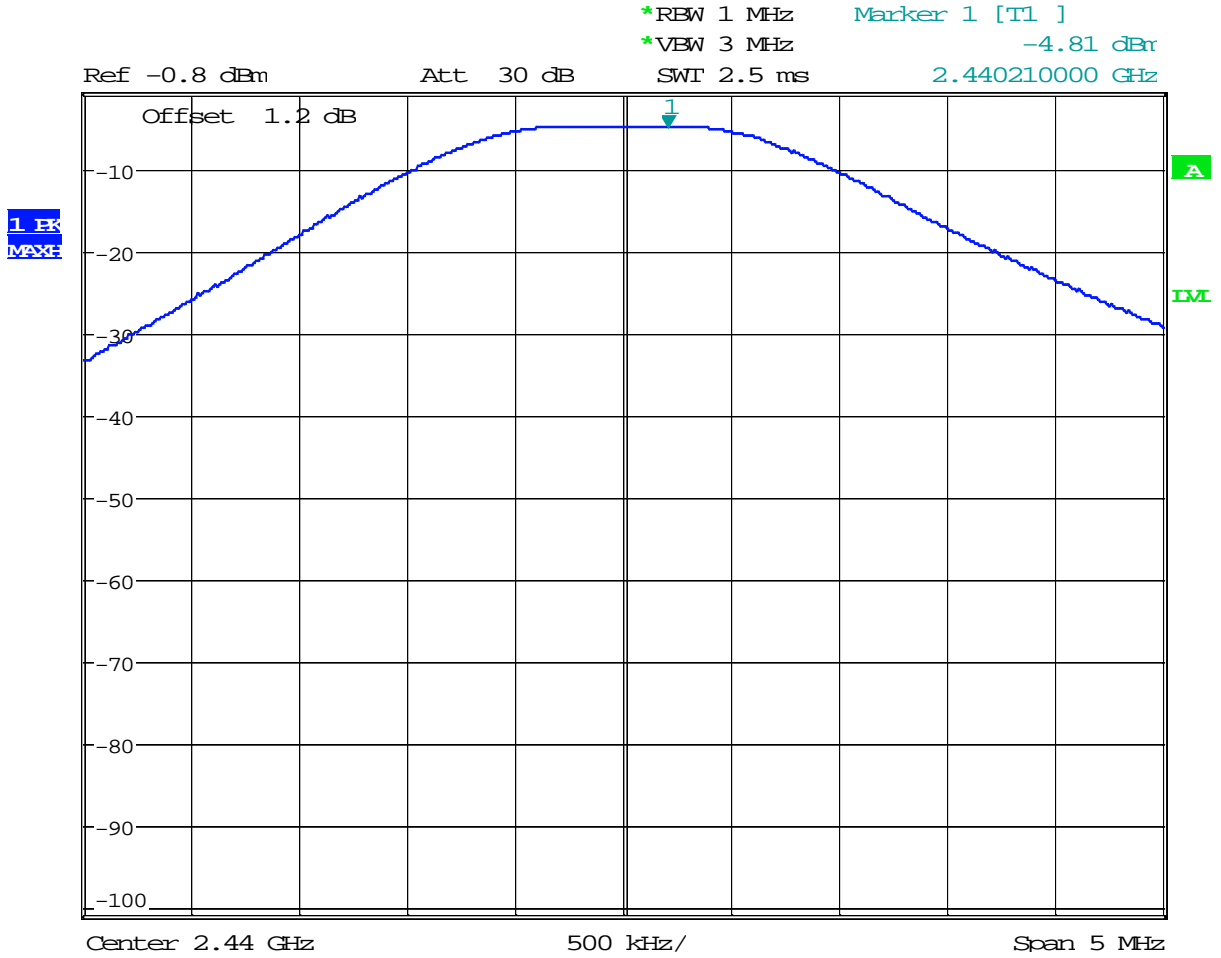
Results	Complies
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Plot 2.1



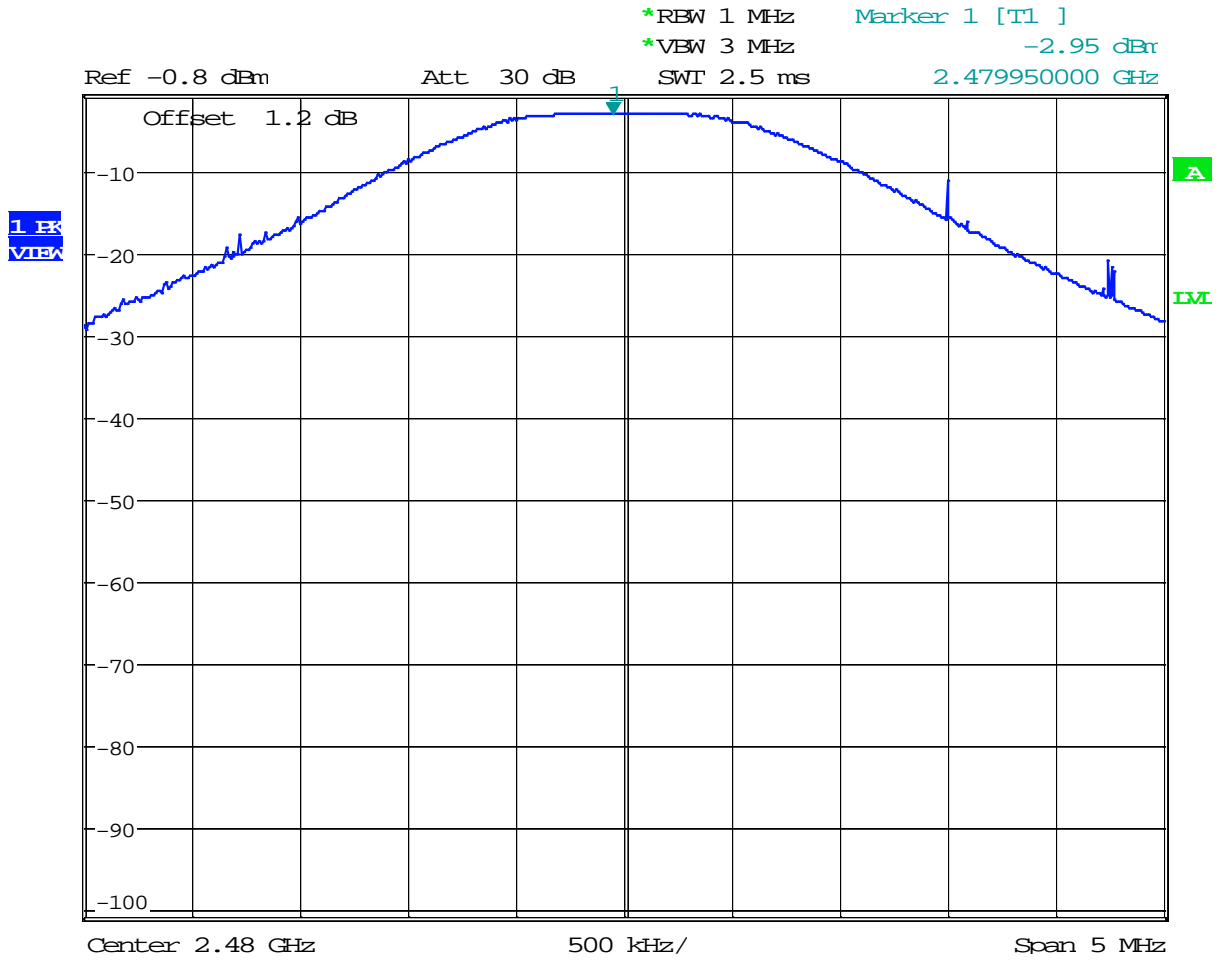
Date: 14.OCT.2015 18:49:36

Plot 2. 2



Date: 14.OCT.2015 19:27:38

Plot 2.3



Date: 14.OCT.2015 19:58:22

4.3 Maximum Power Spectral Density
FCC: 15.247 (e); RSS-247, 5.2

4.3.1 Requirement

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna should not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

4.3.2 Procedure

The antenna port of the EUT was connected to the input of a spectrum analyzer to measure the Transmitter Power Density (PSD).

The procedure described in FCC Publication 558074 was used. Specifically, section 10.2, Peak PSD, with peak detector and max hold trace mode. Spectrum analyzer resolution bandwidth was set to 3 kHz and span to at least 1.5 times the DTS (6 dB) channel bandwidth.

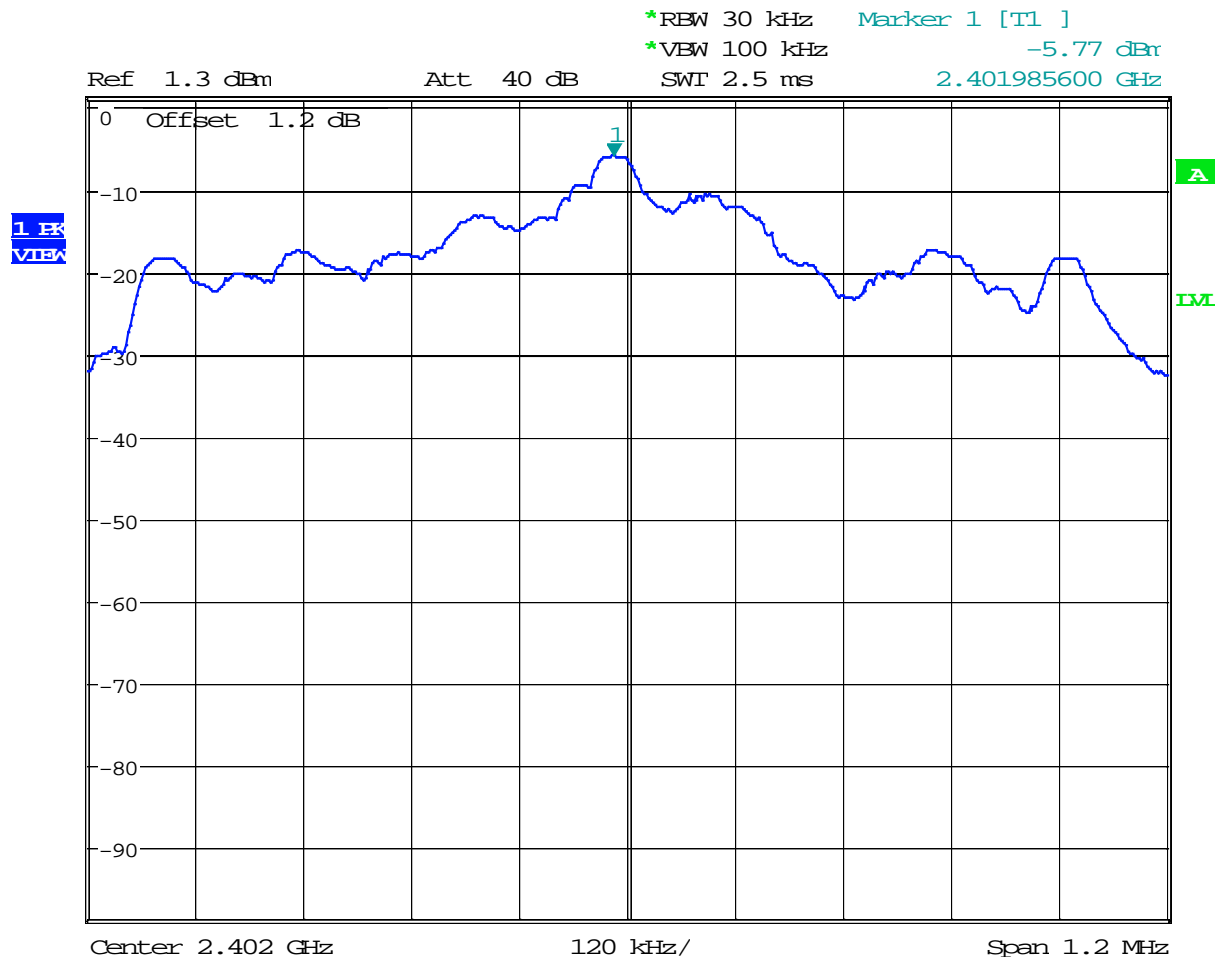
4.3.3 Test Result

Refer to the following plots for the test result

Frequency, MHz	Maximum Power Spectral Density, dBm	Maximum Power Spectral Density Limit, dBm	Margin, dB	Plot
2402	-5.77	8.0	-13.77	3.1
2440	-5.41	8.0	-13.41	3.2
2480	-4.36	8.0	-12.36	3.3

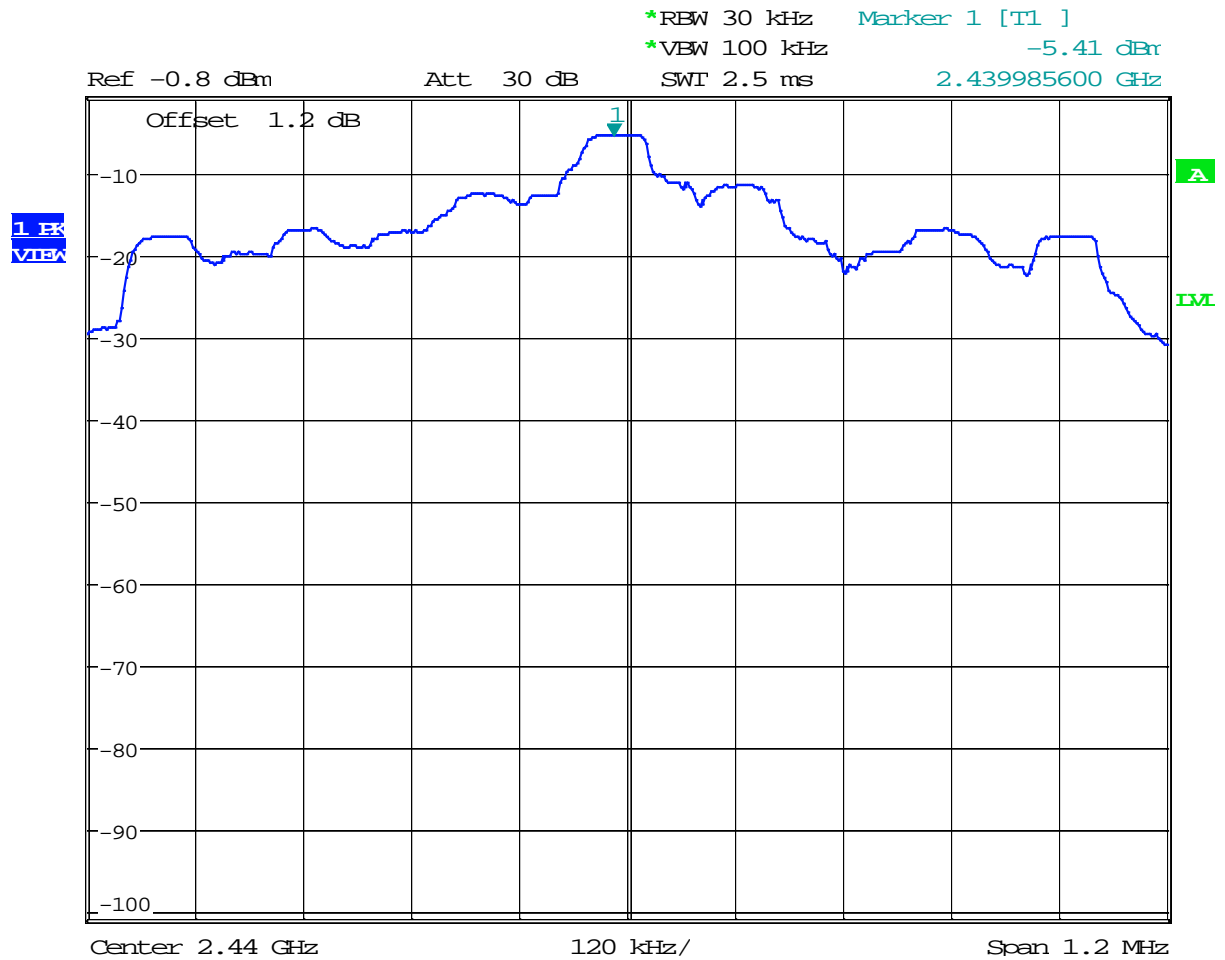
Results	Complies
----------------	-----------------

Plot 3. 1



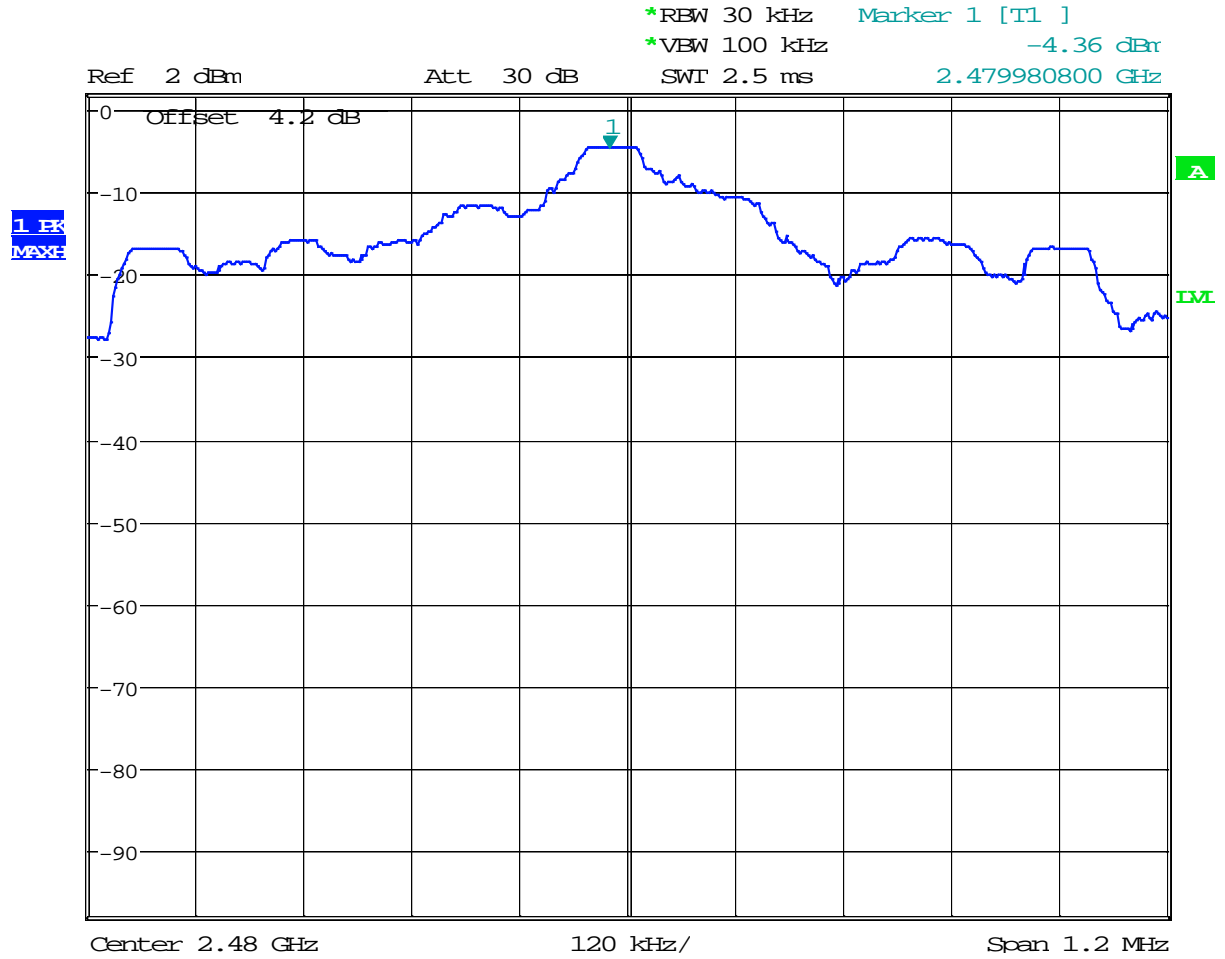
Date: 14.OCT.2015 18:57:05

Plot 3.2



Date: 14.OCT.2015 19:26:45

Plot 3.3



Date: 15.OCT.2015 20:28:37

4.4 Unwanted Conducted Emissions FCC: 15.247(d); RSS-247, 5.5;

4.4.1 Requirement

In any 100 kHz bandwidth outside the EUT pass-band, the RF power shall be below the maximum in-band 100 kHz emissions by at least 20 dB (if peak power of in-band emission is measured) or 30 dB (if average power of in-band emission is measured).

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)

4.4.2 Procedure

A spectrum analyzer was connected to the antenna port of the transmitter. Analyzer Resolution Bandwidth was set to 100 kHz. For each channel investigated, the in-band and unwanted peak emission measurements (with max hold) were performed. For the wideband scan, Spectrum Analyzer setting of number of points 30000 was used.

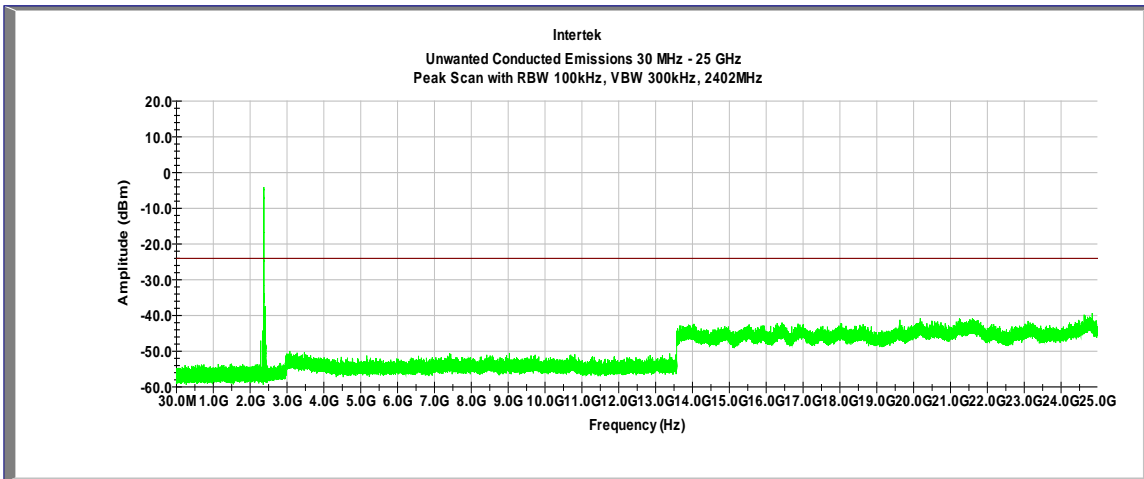
The unwanted emissions were measured from 30 MHz to 25 GHz.

4.4.3 Test Result

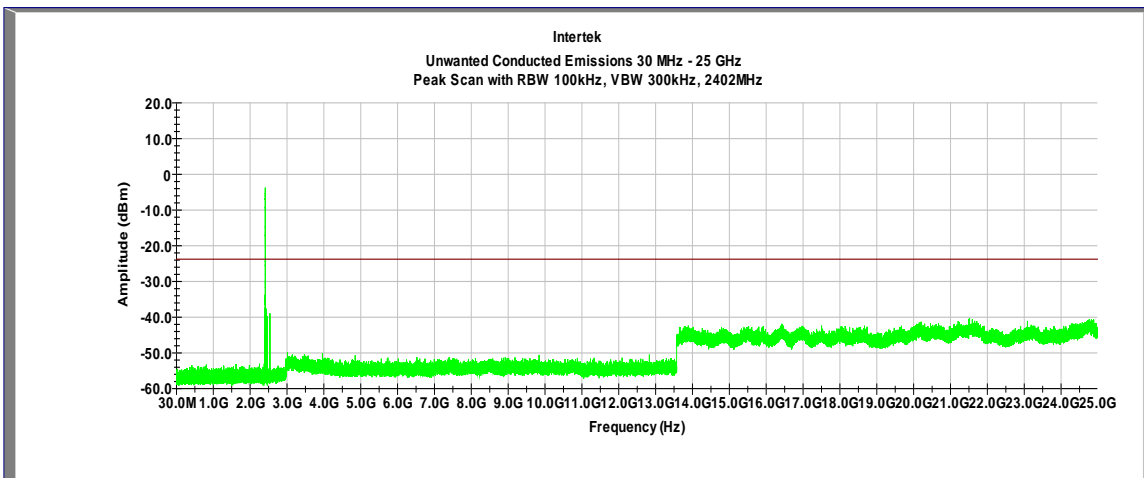
Refer to the following plots 4.1 – 4.3 for unwanted conducted emissions. The plot shows -20dB attenuation limit line.

Results	Complies
----------------	-----------------

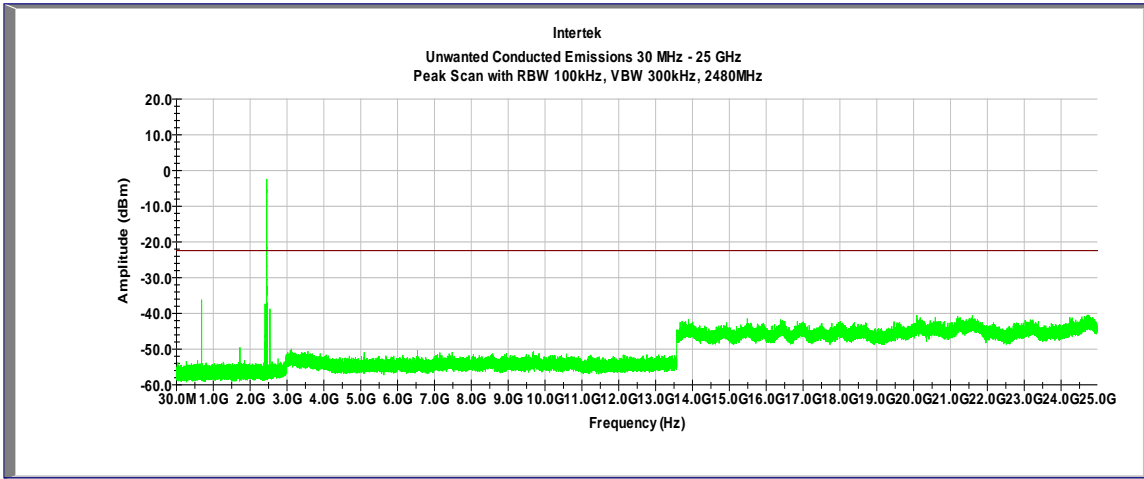
Plot 4.1 Tx @ Low Channel, 2402 MHz



Plot 4.2 Tx @ Mid Channel, 2440 MHz



Plot 4.3 Tx @ High Channel, 2480 MHz



4.5 Transmitter Radiated Emissions FCC Rules: 15.247(d), 15.209, 15.205; RSS-247;

4.5.1 Requirement

Radiated emissions which fall in the restricted bands, as defined in §15.205(a), must comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

In any 100 kHz bandwidth outside the EUT pass-band, the RF power shall be below the maximum in-band 100 kHz emissions by at least 20 dB (if peak power of in-band emission is measured) or 30 dB (if average power of in-band emission is measured).

4.5.2 Procedure

Radiated emission measurements were performed from 30 MHz to 25 GHz according to the procedure described in ANSI C64.10. Spectrum Analyzer Resolution Bandwidth is 100 kHz or greater for frequencies 30 MHz to 1000 MHz, 1 MHz for frequencies above 1000 MHz. Above 1000 MHz Peak and Average measurements were performed.

The EUT is placed on a plastic turntable that is 80 cm in height for below 1000MHz and 1.5m in height for above 1GHz. If the EUT attaches to peripherals, they are connected and operational (as typical as possible). During testing, all cables were manipulated to produce worst-case emissions. The signal is maximized through rotation. The antenna height and polarization are varied during the search for maximum signal level. The antenna height is varied from 1 to 4 meters.

Radiated emissions are taken at 3 meters for frequencies above 1 GHz and at 10 meters for frequencies below 1 GHz.

Guidance for Performing Compliance Measurements on DTS Operating under §15.247 refers to ANSI C63.10. In sec. 7.5 of ANSI C63.10 the procedure for determining the average value of pulsed emissions is described.

Following this procedure, the Peak Field Strength (FS_{peak}) is measured and the Duty Cycle Correction Factor (δ) is applied. The Duty Cycle is defined as transmitter time-on (t) in T=100 ms interval.

$$\delta = t/T \text{ or in decibels } \delta(\text{dB}) = 20 \text{ Log } \delta$$
$$FS_{\text{average}} [\text{in dB}(\mu\text{V/m})] = FS_{\text{peak}} [\text{in dB}(\mu\text{V/m})] + \delta(\text{dB})$$

Measurements made from 1 GHz to 18GHz had a 2.4-2.5GHz notch filter in place. A preamp was used from 30MHz to 26GHz.

All measurements were made with a Peak Detector and compared to QP limits for 30MHz – 1GHz and Average limits for 1GHz – 26GHz.

Data is included of the worst-case configuration (the configuration which resulted in the highest emission levels).

4.5.3 Field Strength Calculation

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

$FS = RA + AF + CF - AG$; if measurement is performed at a distance other than specified in the rule, a Distance Correction Factor (DCF) shall be added.

Where FS = Field Strength in dB(μ V/m)

RA = Receiver Amplitude (including preamplifier) in dB(μ V); AF = Antenna Factor in dB(1/m)

CF = Cable Attenuation Factor in dB; AG = Amplifier Gain in dB

Assume a receiver reading of 52.0 dB(μ V) is obtained. The antennas factor of 7.4 dB(1/m) and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving field strength of 32 dB(μ V/m). This value in dB(μ V/m) was converted to its corresponding level in μ V/m.

RA = 52.0 dB(μ V)

AF = 7.4 dB(1/m)

CF = 1.6 dB

AG = 29.0 dB

$FS = 52.0 + 7.4 + 1.6 - 29.0 = 32$ dB(μ V/m).

Level in μ V/m = Common Antilogarithm $[(32 \text{ dB}\mu\text{V/m})/20] = 39.8 \mu\text{V/m}$.

4.5.4 Test Results

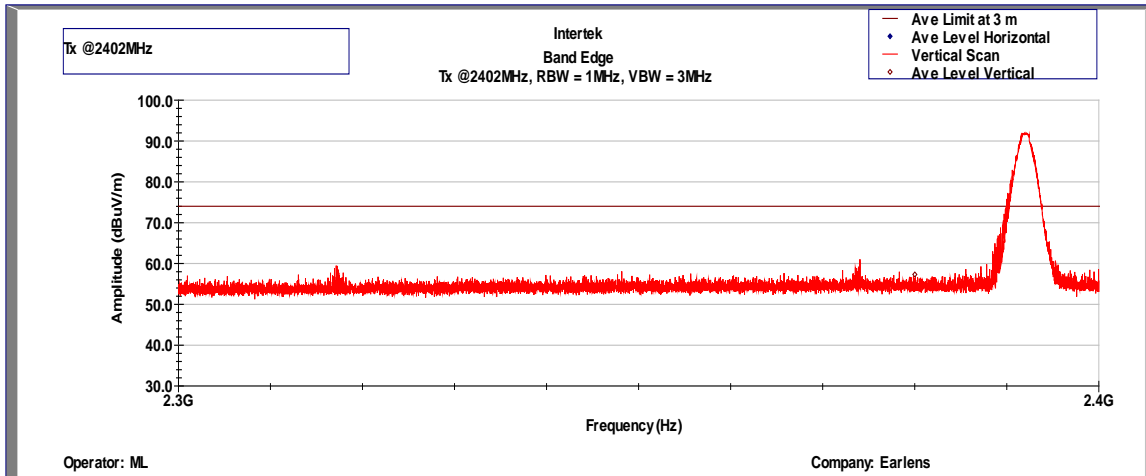
The data on the following pages list the significant emission frequencies, the limit and the margin of compliance.

Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz.

The EUT passed the test by 0.6dB

Test Results: 15.209/15.205 Restricted Band Emissions

**Out-of-Band Radiated spurious emissions at the Band-edge @ 1m distance
2310–2390 MHz**



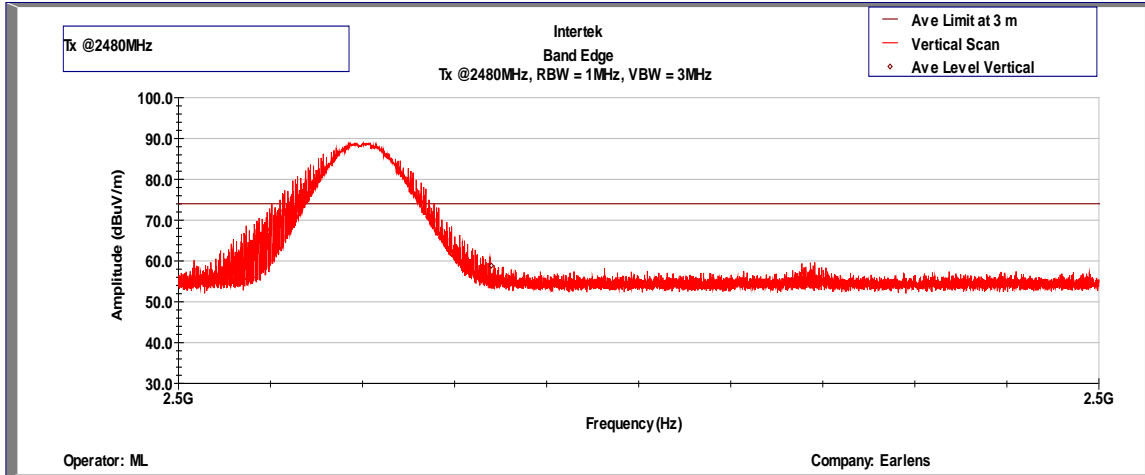
Frequency	RA @ 1 m	AF	DCF	δ (dB)*	CF + Attenuator	FS @ 3m	Detector	Limit @ 3 m	Margin
(MHz)	(dBuV/m)	(dB/m)	(dB)	(dB)	(dB)	(dBuV/m)	(Peak) / (Average)	(dBuV/m)	(dB)
Tx @ 2402MHz									
2390.00	31.5	28.0	9.5	--	7.32	57.32	Peak	74.0	-16.68
	31.5	28.0	9.5	-3.88	7.32	53.44	Average	54.0	-0.58

* δ (dB) - Duty Cycle Correction Factor. See Appendix A for Duty Cycle measurement and calculation. Duty cycle Correction Factor was applied for Average Field Strength (FS).

Note: $FS@3m = RA + AF - DCF + (CF + Attenuator)$, (Peak)

$FS@3m = RA + AF + \delta - DCF + (CF + Attenuator)$, (Average)

**Out-of-Band Radiated spurious emissions at the Band-edge @ 1m distance
2483.5–2500 MHz**



Frequency	RA @ 1 m	AF	DCF	δ (dB)*	CF + Attenuator	FS @ 3m	Detector	Limit @ 3 m	Margin
(MHz)	(dBuV/m)	(dB/m)	(dB)	(dB)	(dB)	(dBuV/m)	(Peak) / (Average)	(dBuV/m)	(dB)
Tx @ 2480MHz									
2483.5	31.2	28.1	9.5	--	7.42	57.22	Peak	74.0	-16.78
	31.2	28.1	9.5	-3.88	7.42	53.34	Average	54.0	-0.66

* δ (dB) - Duty Cycle Correction Factor. See Appendix A for Duty Cycle measurement and calculation. Duty cycle Correction Factor was applied for Average Field Strength (FS).

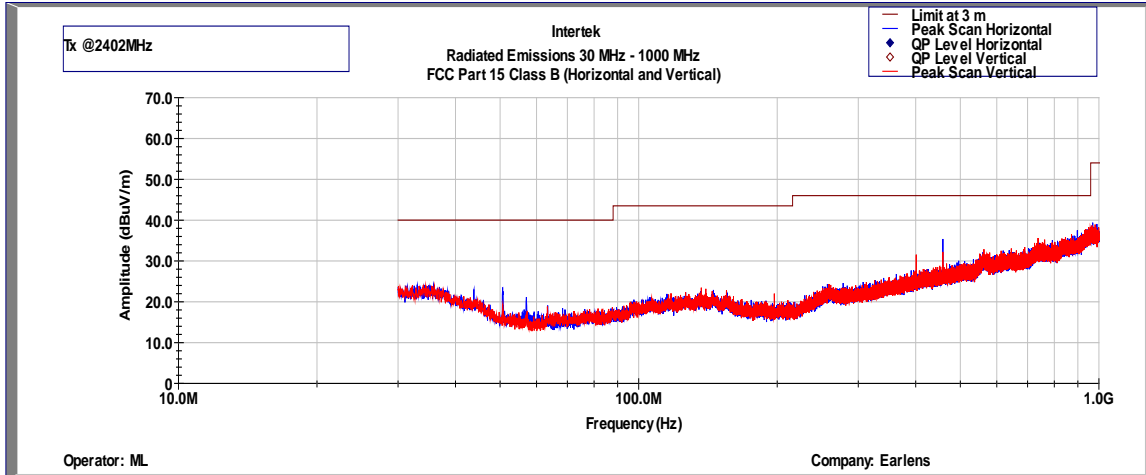
Note: FS@3m = RA + AF - DCF + (CF + Attenuator), (Peak)

FS@3m = RA + AF + δ - DCF + (CF + Attenuator), (Average)

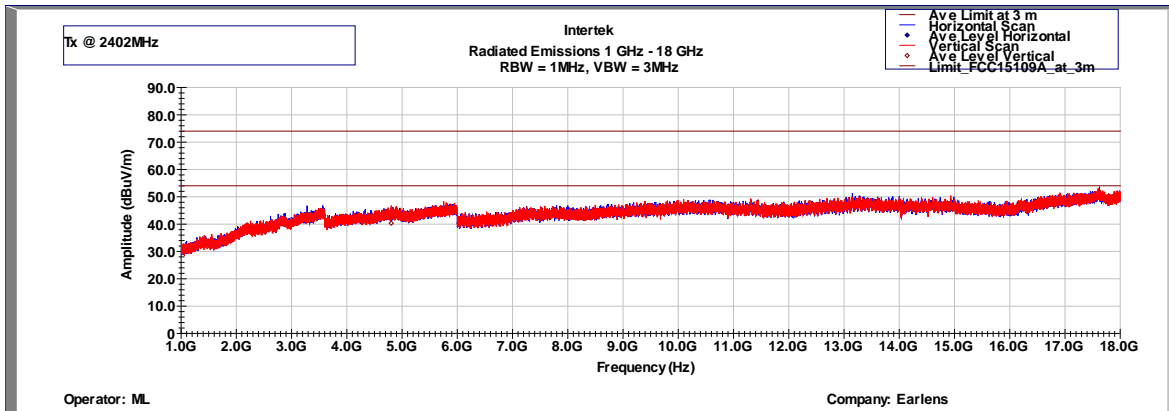
Results	Complies
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Test Results: 15.209 Radiated Spurious Emissions Low Channel, Tx at 2402MHz

Radiated Spurious Emissions 30 MHz - 1000 MHz



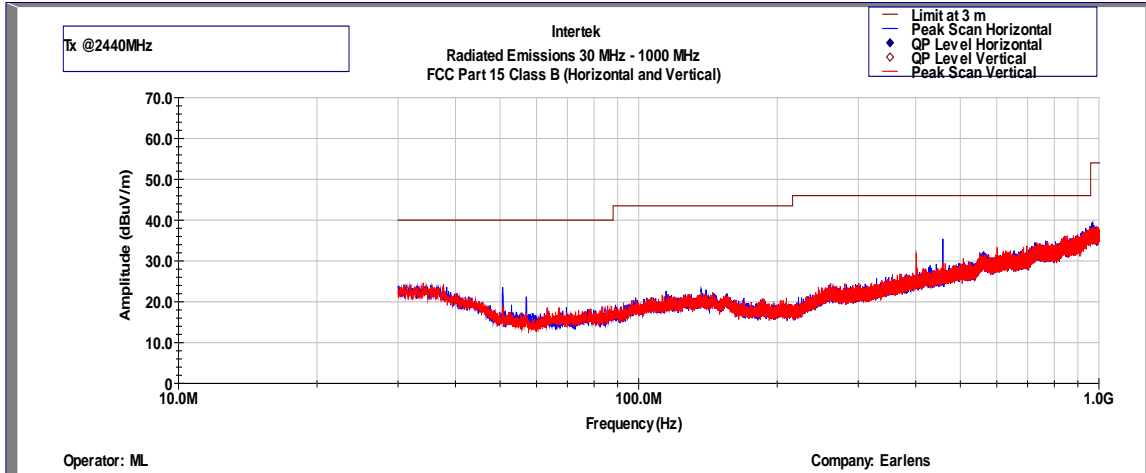
Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan



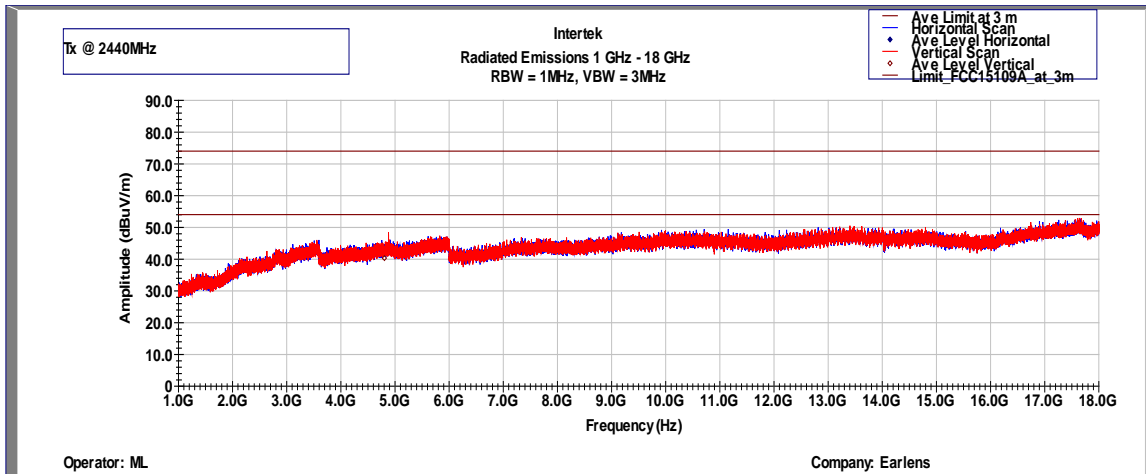
Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Test Results: 15.209 Radiated Spurious Emissions Mid Channel, Tx at 2440MHz

Radiated Spurious Emissions 30 MHz - 1000 MHz



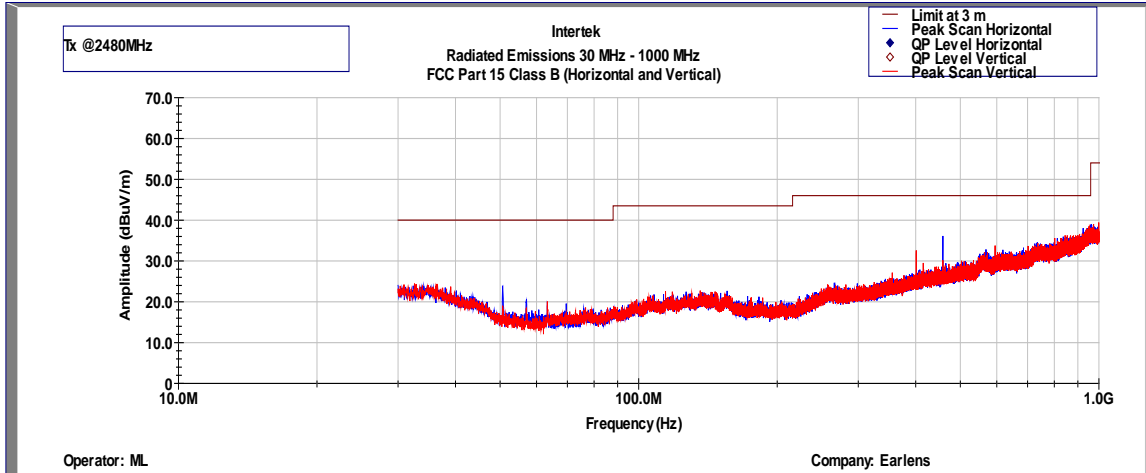
Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan



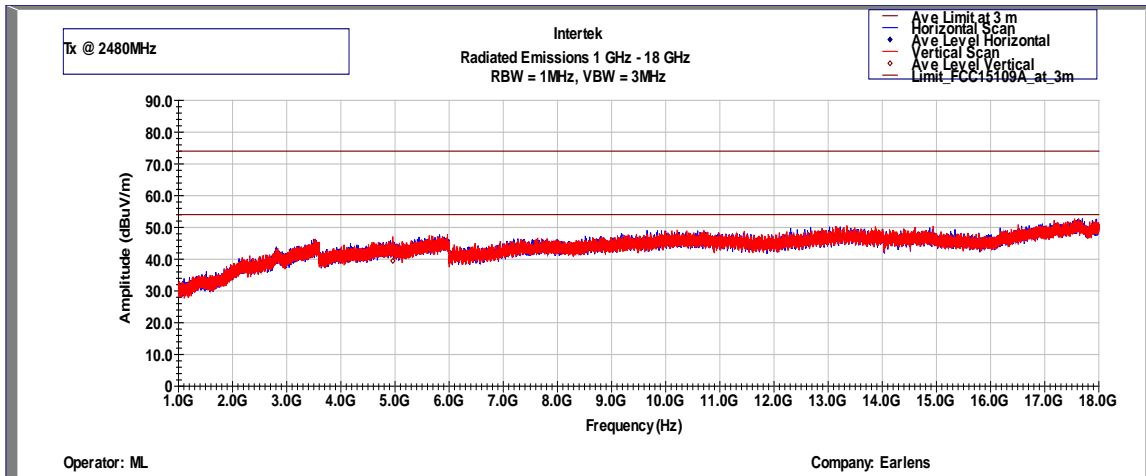
Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Test Results: 15.209 Radiated Spurious Emissions High Channel, Tx at 2480MHz

Radiated Spurious Emissions 30 MHz - 1000 MHz



Radiated Spurious Emissions 1000 - 18000 MHz, Peak Scan



Note: Radiated emission measurements were performed up to 25GHz. No Emissions were identified when scanned from 18-25 GHz

Results	Complies
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4.5.4 Test setup photographs

The following photographs show the testing configurations used.

Please refer to the attachments.

4.6 AC Line Conducted Emission
FCC: 15.207; RSS-GEN

4.6.1 Requirement

Frequency Band MHz	Class B Limit dB(μ V)		Class A Limit dB(μ V)	
	Quasi-Peak	Average	Quasi-Peak	Average
0.15-0.50	66 to 56 *	56 to 46 *	79	66
0.50-5.00	56	46	73	60
5.00-30.00	60	50	73	60

*Note: *Decreases linearly with the logarithm of the frequency
At the transition frequency the lower limit applies.*

Not Applicable. EUT is battery operated.

5.0 List of Test Equipment

Measurement equipment used for emission compliance testing utilized the equipment on the following list:

Equipment	Manufacturer	Model/Type	Asset #	Cal Int	Cal Due
Spectrum Analyzer	Rohde and Schwarz	FSU	ITS00913	12	12/16/15
EMI Receiver	Rohde and Schwarz	ESU	ITS 00961	12	06/02/16
BI-Log Antenna	Teseq	CBL 6111D	ITS 01058	12	11/21/15
Pyramidal Horn Antenna	EMCO	3160-09	ITS00571	#	#
Pre-Amplifier	Sonoma Instrument	310N	ITS 00942	12	11/26/15
Pre-Amplifier (1-18GHz)	Miteq	AMF-4D-001180-24-10P	ITS 00526	12	10/06/16
Pre-Amplifier (18-40GHz)	Miteq	JSD44-18004000-305P	ITS 00921	12	06/18/16
Horn Antenna	ETS Lindgren	3115	ITS 00982	12	11/21/15
LISN	FCC	FCC-LISN-50-50-M-H	ITS 00552	12	05/05/16

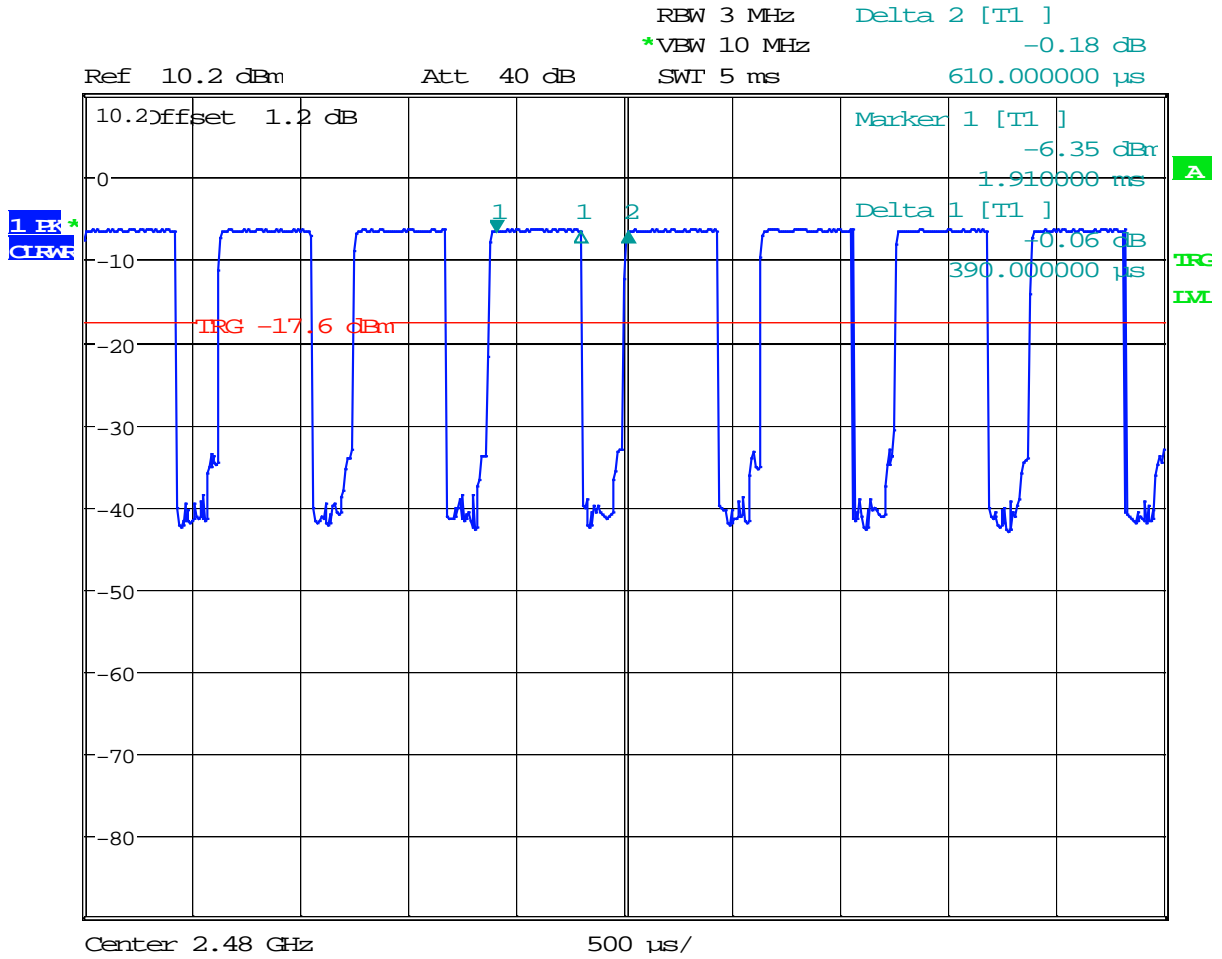
No Calibration required



6.0 Document History

Revision/ Job Number	Writer Initials	Reviewers Initials	Date	Change
1.0 / G102314980	ML	KV	October 28, 2015	Original document

Annex A - Duty Cycle Measurement



Date: 15.OCT.2015 21:02:42

Duty Cycle: $DC = 390.0 / 610.0 = 0.63$ or 63.0%

Duty Cycle Correction Factor $\delta(\text{dB}) = 20 \log (390.0 / 610.0) = -3.88\text{dB}$