Emissions
Test Report

EUT Name: Radio Module

Model No.: FBLE

CFR 47 Part 15.247:2013 and RSS 210:2010

Prepared for:

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Revisions

Revision No.	Date MM/DD/YYYY	Reason for Change	Author
0	10/11/2013	Original Document	N/A

Statement of Compliance

Manufacturer:	Fluke Corporation. 6920 Seaway Blvd. Everett, WA 98203 U.S.A.
Requester / Applicant:	Dave Epperson
Name of Equipment:	Radio Module
Model No.	FBLE
Type of Equipment:	Intentional Radiator
Application of Regulations:	CFR 47 Part 15.247:2011 and RSS 210:2010
Test Dates:	July 31 - September 16, 2013

Guidance Document:

Emissions: ANSI C63.10-2009

Test Methods:

Emissions: ANSI C63.10-2009

The electromagnetic compatibility test and documented data described in this report has been performed and recorded by TUV Rheinland, in accordance with the standards and procedures listed herein. As the responsible authorized agent of the EMC laboratory, I hereby declare that the equipment described above has been shown to be compliant with the EMC requirements of the stated regulations and standards based on these results. If any special accessories and/or modifications were required for compliance, they are listed in the Executive Summary of this report.

This report must not be used to claim product endorsement by A2LA. This report contains data that are not covered by A2LA accreditation. This report shall not be reproduced except in full, without the written authorization of TUV Rheinland of North America.

Digitally signed by Conan Boyle
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Date: 2013.10.03 17:16:48 -07'00'

Suresh Kondapalli	October 11, 2013	Conan Boyle	October 11, 2013
Test Engineer	Date	A2LA Signatory	Date

Testing Certificate #3331.02	**US5254**	**INDUSTRY CANADA** **2932M-1**

1 Executive Summary

1.1 Scope

This report is intended to document the status of conformance with the requirements of the CFR 47 Part 15.247:2011 and RSS 210:2010 based on the results of testing performed from July 31 to September 16, 2013 on the Radio Module Model: FBLE manufactured by *Fluke Corporation.* This report only applies to the specific samples tested under the stated test conditions. It is the responsibility of the manufacturer to assure that additional production units of this model are manufactured with identical or EMI equivalent electrical and mechanical components. This report is further intended to document changes and modifications to the EUT throughout its life cycle. All documentation will be included as a supplement.

1.2 Purpose

Testing was performed to evaluate the EMC performance of the EUT in accordance with the applicable requirements, procedures, and criteria defined in the application of regulations and application of standards listed in this report.

1.3 Summary of Test Results

Table 1: Summary of Test Results

Test	Test Method ANSI C63.4	Test Parameters (from Standard)	Result
2400 MHz to 2483.5 MHz Band			
Occupied Bandwidth	CFR 47 15.247(a1), RSS Gen Sect. 4.4.1		**Complied**
Spurious Emission in Transmitted Mode	CFR47 15.209, RSS-GEN Sect.7.2.3	Class B	**Complied**
Restricted Bands of Operation	CFR47 15.205, RSS 210 Sect.2.6	Class B	**Complied**
AC Power Conducted Emission	CFR47 15.207, RSS-GEN Sect.7.2.2	N/A	**Complied**
Channel Separation	CFR47 15.247 (a1), RSS 210 Sect. A.8.1	>25 kHz	**Complied**
Number of Hopping Channels	CFR47 15.247 (a1), RSS 210 Sect. A.8.1	>15	**Complied**
Maximum Transmitted Power	CFR47 15.247 (b1), RSS 210 Sect. A.8.1	<125 mWatts	**Complied**
Average time occupancy of Channel	CFR47 15.247 (e), RSS 210 Sect. A.8.1	< 0.4 sec	**Complied**

Note: Since EUT is portable device where the end user will have the direct contact, RF Exposure/SAR test requirements are evaluated separately

1.3.1 Measured Values of Key Parameters

Test	Test Method ANSI C63.4	Measured value	Result
2400 MHz to 2483.5 MHz Band			
Occupied Bandwidth	CFR47 15.247 (a)(1) RSS Gen Sect. 4.4.1	1.520MHz (20dB) 1.322MHz (99%)	Complied
Maximum Transmitted Power	CFR47 15.247 (b) (1), RSS 210 Sect. A.8.4	-1.15 dBm (0.76 mW)	Complied
Number of Hopping Channels	CFR47 15.247 (a1), RSS GEN Sect.4.4.1	40	Complied
Channel Separation	CFR47 15.247 (a1), RSS GEN Sect.4.4.1	1.96 MHz	Complied
Channel Dwell Time	CFR47 15.247 (a1 iii), RSS 210 Sect. A.8.1(d)	1.8 msec	Complied
Spurious Emission in Transmitted Mode	CFR47 15.209, RSS-GEN Sect.7.2.3	53.06dBuV/m at 4804MHz	Complied

1.4 Special Accessories

No special accessories were necessary in order to achieve compliance.

1.5 Equipment Modifications

None

2 Laboratory Information

2.1 Accreditations & Endorsements

2.1.1 US Federal Communications Commission

TUV Rheinland of North America EMC test facilities located at 1279 Quarry Lane, Ste. A, Pleasanton, CA, 94566, and 2305 Mission College Blvd, Ste. 105, Santa Clara, CA 95054, are recognized by the Commission for performing testing services for the general public on a fee basis. These laboratory test facilities have been fully described in reports submitted to and accepted by the FCC (Pleasanton Registration No. US5254, Santa Clara Registration No. US5251). The laboratory Scopes of Accreditation include Title 47 CFR Parts 15, 18 and 90. The accreditations are updated every three years.

2.1.2 A2LA

TUV Rheinland of North America EMC test facilities are accredited by the American Association for Laboratory Accreditation (A2LA). The laboratories have been assessed and accredited by A2LA in accordance with ISO Standard 17025:2005 (Testing Certificate #3331.02). The Scope of Laboratory Accreditation includes emission and immunity testing. The accreditations are updated annually.

2.1.3 Industry Canada

Industry Canada Industrie Canada

The Pleasanton 5-meter Semi-Anechoic Chamber, Registration No. 2932M-1, has been accepted by Industry Canada to perform testing to 3 and 5 meters based on the test procedures described in ANSI C63.4-2009. The Santa Clara 10-meter Semi-Anechoic Chamber, Registration No. 2932D-1, has been accepted by Industry Canada to perform testing to 3 and 10 meters based on the test procedures described in ANSI C63.4-2009.

2.1.4 Japan – VCCI

The Voluntary Control Council for Interference by Information Technology Equipment (VCCI) is a group that consists of Information Technology Equipment (ITE) manufacturers and EMC test laboratories. The purpose of the Council is to take voluntary control measures against electromagnetic interference from Information Technology Equipment, and thereby contribute to the development of a socially beneficial and responsible state of affairs in the realm of Information Technology Equipment in Japan. TUV Rheinland of North America EMC test facilities located at 1279 Quarry Lane, Ste. A, Pleasanton, CA, 94566, and 2305 Mission College Blvd, Ste. 105, Santa Clara, CA 95054, have been assessed and approved in accordance with the Regulations for Voluntary Control Measures.

2.2 Test Facilities

All of the test facilities are located at 1279 Quarry Lane, Pleasanton, California 94566, USA. The 2305 Mission College, Santa Clara, 95054, USA location is considered a Pleasanton annex.

2.2.1 Emission Test Facility

The Semi-Anechoic chamber and AC Line Conducted measurement facility used to collect the radiated and conducted data has been constructed in accordance with ANSI C63.7:1992. The site has been measured in accordance with and verified to comply with the theoretical normalized site attenuation requirements of ANSI C63.4-2009, at a test distance of 3 and 5 meters. The site is listed with the FCC and accredited by A2LA (Testing Cert #3331.02). The 3/5-meter semi-anechoic chamber used to collect the radiated data has been verified to comply with the theoretical normalized site attenuation requirements of ANSI C63.4-2009, at a test distance of 3 meter and 5 meters. A report detailing this site can be obtained from TUV Rheinland of North America.

2.2.2 Immunity Test Facility

ESD, EFT, Surge, and PQF: These tests are performed in an environmentally controlled room with a 3.7 m x 4.8 m x 3.175 mm thick aluminum floor connected to PE ground.

For ESD testing, tabletop equipment is placed on an insulated mat with a surface resistivity of 10^9 Ohms/square on a 1.6 m x 0.8 m x 0.8 m high non-conductive table with a 3.175 mm aluminum top (Horizontal Coupling Plane). The HCP is connected to the main ground plane via a low impedance ground strap through two 470-kΩ resistors. The Vertical Coupling Plane consists of an aluminum plate 50 cm x 50 cm x 3.175 mm thick. The VCP is connected to the main ground plane via a low impedance ground strap through two 470-kΩ resistors.

For EFT, Surge, PQF, the HCP and VCP are removed.

RF Field Immunity testing is performed in a 7.3m x 4.3m x 4.1m anechoic chamber.

RF Conducted and Magnetic Field Immunity testing is performed on a 4.8m x 3.7m x 3.175mm thick aluminum ground plane.

All test areas allow a minimum distance of 1 meter from the EUT to walls or conducting objects.

2.3 Measurement Uncertainty

Two types of measurement uncertainty are expressed in this report, per *ISO Guide To The Expression Of Uncertainty In Measurement*, 1st Edition, 1995.

The Combined Standard Uncertainty is the standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities; it is equal to the positive square root of the sum of the variances or co-variances of these other quantities, weighted according to how the measurement result varies with changes in these quantities. The term *standard uncertainty* is the result of a measurement expressed as a standard deviation.

2.3.1 Sample Calculation – radiated & conducted emissions

The field strength is calculated by subtracting the Amplifier Gain and adding the Cable Loss and Antenna Correction Factor to the measured reading. The basic equation is as follows:

Field Strength (dBμV/m) = RAW - AMP + CBL + ACF

Where: RAW = Measured level before correction (dBμV)

AMP = Amplifier Gain (dB)

CBL = Cable Loss (dB)

ACF = Antenna Correction Factor (dB/m)

$$\mu V/m = 10^{\frac{dB\mu V/m}{20}}$$

Sample radiated emissions calculation @ 30 MHz

Measurement +Antenna Factor–Amplifier Gain+Cable loss=Radiated Emissions (dBuV/m)

25 dBuV/m + 17.5 dB – 20 dB + 1.0 dB = 23.5 dBuV/m

2.3.2 Measurement Uncertainty

Per CISPR 16-4-2	U_{lab}	U_{cispr}
Radiated Disturbance @ 10 meters		
30 – 1,000 MHz	2.25 dB	4.51 dB
Radiated Disturbance @ 3 meters		
30 – 1,000 MHz	2.26 dB	4.52 dB
1 – 6 GHz	2.12 dB	4.25 dB
6 – 40 GHz	2.47 dB	4.93 dB
Conducted Disturbance @ Mains Terminals		
150 kHz – 30 MHz	1.09 dB	2.18 dB
Disturbance Power		
30 MHz – 300 MHz	3.92 dB	4.3 dB

Voltech PM6000A

The estimated combined standard uncertainty for harmonic current and flicker measurements is ± 5.0%.	Per CISPR 16-4-2 Methods

2.3.3 Measurement Uncertainty Immunity

The estimated combined standard uncertainty for ESD immunity measurements is ± 8.2%.	Per IEC 61000-4-2
The estimated combined standard uncertainty for radiated immunity measurements is ± 4.10 dB.	Per IEC 61000-4-3
The estimated combined standard uncertainty for conducted immunity measurements with CDN is ± 3.66 dB	Per IEC 61000-4-6
The estimated combined standard uncertainty for power frequency magnetic field immunity is ± 2.9%.	Per IEC 61000-4-8

Thermo KeyTek EMC Pro

The estimated combined standard uncertainty for EFT fast transient immunity measurements is ± 2.6%.
The estimated combined standard uncertainty for surge immunity measurements is ± 2.6%.
The estimated combined standard uncertainty for voltage variation and interruption measurements is ± 1.74%.

The expanded uncertainty at a level of 95% confidence is obtained by multiplying the combined standard uncertainty by a coverage factor of 2. Compliance criteria are not based on measurement uncertainty.

Measurement Uncertainty – Radio Testing

The estimated combined standard uncertainty for frequency error measurements is ± 3.88 Hz
The estimated combined standard uncertainty for carrier power measurements is ± 1.59 dB.
The estimated combined standard uncertainty for adjacent channel power measurements is ± 1.47 dB.
The estimated combined standard uncertainty for modulation frequency response measurements is ± 0.46 dB.
The estimated combined standard uncertainty for transmitter conducted emission measurements is ± 4.01 dB

The expanded uncertainty at a level of 95% confidence is obtained by multiplying the combined standard uncertainty by a coverage factor of 2. Compliance criteria are not based on measurement uncertainty.

2.4 Calibration Traceability

All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Measurement method complies with ANSI/NCSL Z540-1-1994 and ISO Standard 17025:2005. Equipment calibration records are kept on file at the test facility.

3 Product Information

3.1 Product Description

The FBLE is radio is used in Fluke Portable measuring devices.

The radio module will be used in future Fluke products to provide wireless communication between a central module radio device and satellite radio devices. The protocol used will be similar to Lower Power Bluetooth but tailored to meet Fluke proprietary requirements.

3.2 Equipment Configuration

A description of the equipment configuration is given in the Test Plan Section. The EUT was tested as called for in the test standard and was configured and operated in a manner consistent with test standards. The EUT was programed to rated power and allowed to reach intended operating conditions. The placement of the EUT system components was guided by the test standard and selected to represent typical installation conditions.

In the case of EUT that can operate in more than one configuration, preliminary testing was performed to determine the configuration that produced maximum radiation.

The final configuration was selected to produce the worst case radiation for emissions testing and to place the EUT in the most susceptible state for immunity testing.

3.3 Operating Mode

A description of the operation mode is given in the Test Plan Section. In the case of an EUT that can operate in more than one state, preliminary testing was performed to determine the operating mode that produced maximum radiation.

EUT was programed to operate at > 99% duty for the purpose of testing. This operating mode was selected to produce the worst case radiation for emissions testing and to place the EUT in the most susceptible state for immunity testing.

3.4 Duty Cycle:

Duty Cycle description is provided under test plan in section 11

3.5 Unique Antenna Connector

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of CFR47 Parts 15.211, 15.213, 15.217, 15.219, or 15.221.

3.6 Results

The Radio Module has one internal antenna. The antenna is integral part of module PCB. EUT is compliant.

4 Emission Requirements – 2400 MHz to 2483.5 MHz Band

Testing was performed in accordance with CFR 47 Part 15.247: 2013 and RSS 210 Annex 8: 2010. These test methods are listed under the laboratory's A2LA Scope of Accreditation. This test measures the levels emanating from the EUT, thus evaluating the potential for the EUT to cause radio frequency interference to other electronic devices. Procedures described in Section 8 of the standard were used.

4.1 Output Power Requirements

The maximum output power requirement is the maximum equivalent isotropic radiated power delivering at the transmitting antenna under specified conditions of measurements in the presence of modulation.

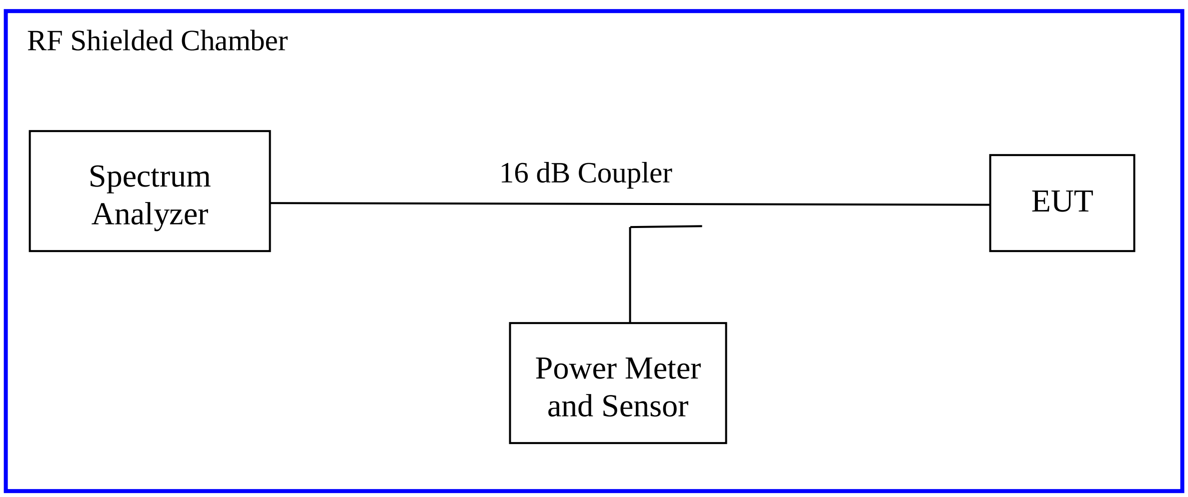
The maximum output power and harmonics shall not exceed CFR47 Part 15.247 (b1) and RSS 210 A.8.1: 2010

Frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

4.1.1 Test Method

The conducted method was used to measure the channel power output according to ANSI C63.10:2009 Section 6.10.3.1. The measurement was performed with modulation per CFR47 Part 15.247 (b 1):2013 and RSS 210 A.8.1. This test was conducted on 3 channels in each operating range. The worst mode result indicated below.

Test Setup:



4.1.2 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 2: RF Output Power at the Antenna Port – Test Results

Test Conditions: Conducted Measurement, Normal Temperature				
Antenna Type: Internal		**Power Setting:** See test plan		
Max. Antenna Gain: +3.0 dBi				
Ambient Temp.: 21 °C		**Relative Humidity:**39%		
802.15.1 Mode				
Operating Channel	**Limit [dBm]**	**[dBm]**	**Power [mWatts]**	**Margin [dB]**
2402 MHz	+20.96	-1.15	0.76	-22.11
2440 MHz	+20.96	-2.25	0.59	-23.21
2480 MHz	+20.96	-2.88	0.51	-23.24
Note: EUT has duty cycle EUT was modified to transmit continuously for test purpose. EUT normal data rate is 1 Mbps. No duty was applied.				

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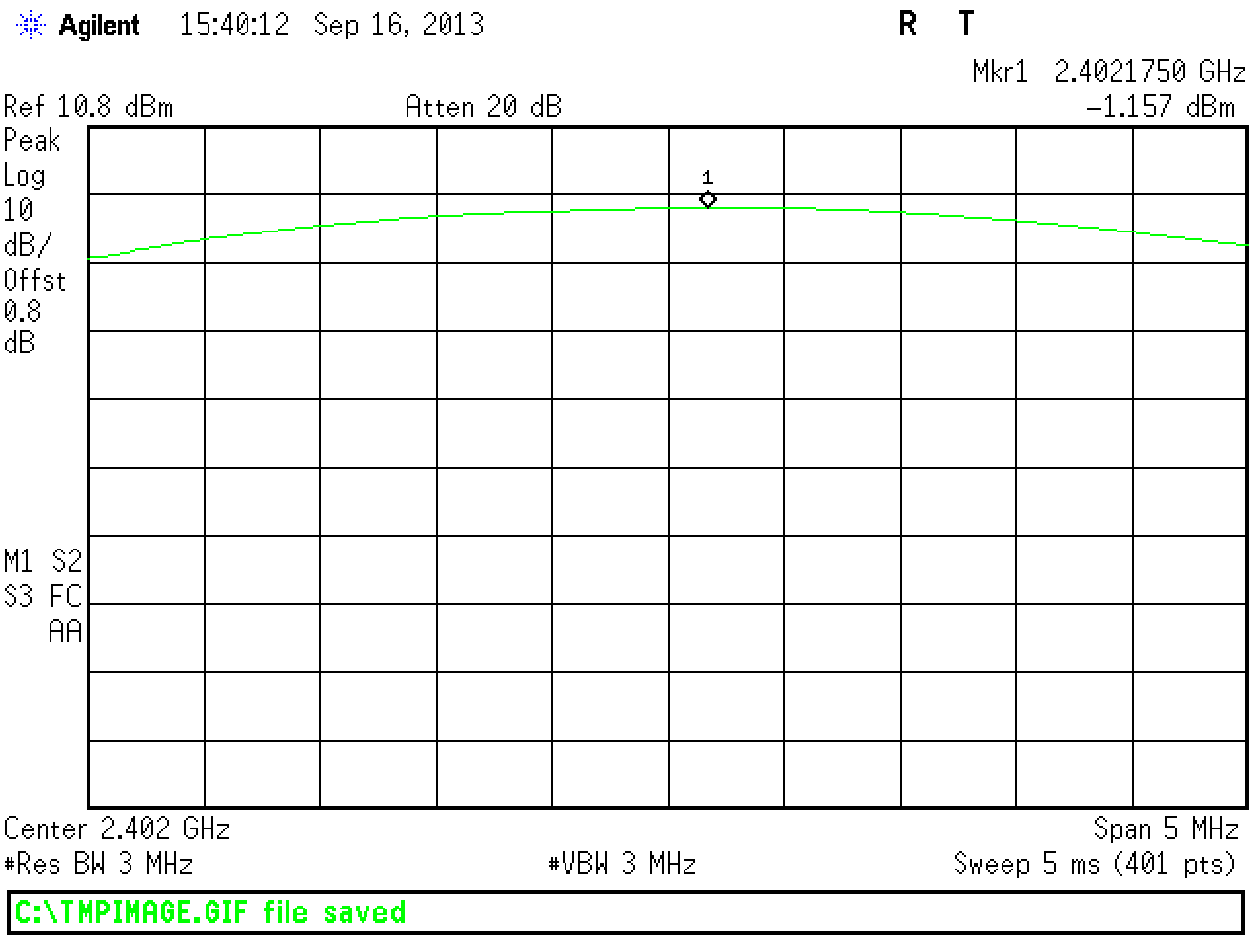


Figure 1: Maximum Transmitted Power, 2402 MHz

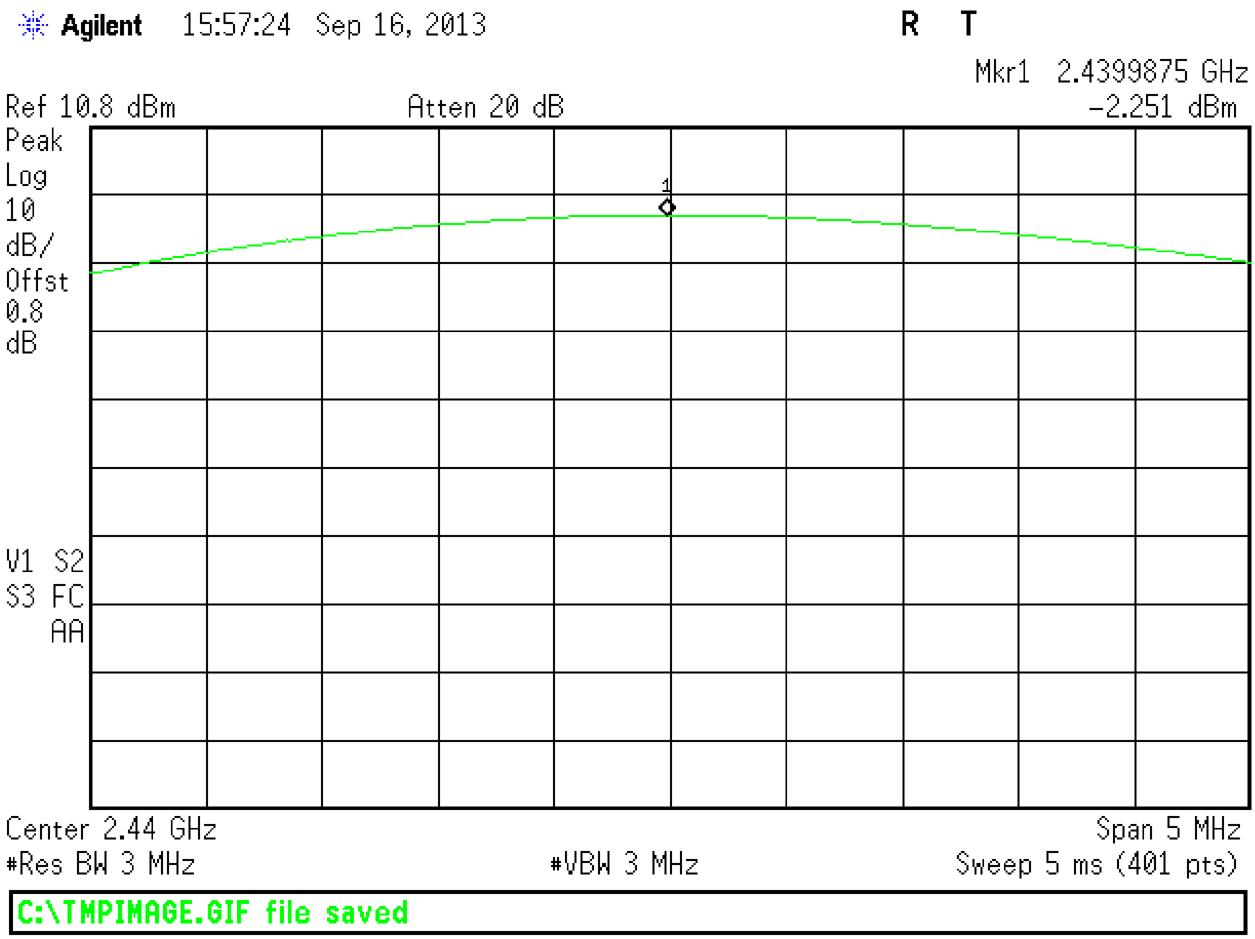


Figure 2: Maximum Transmitted Power, 2440 MHz

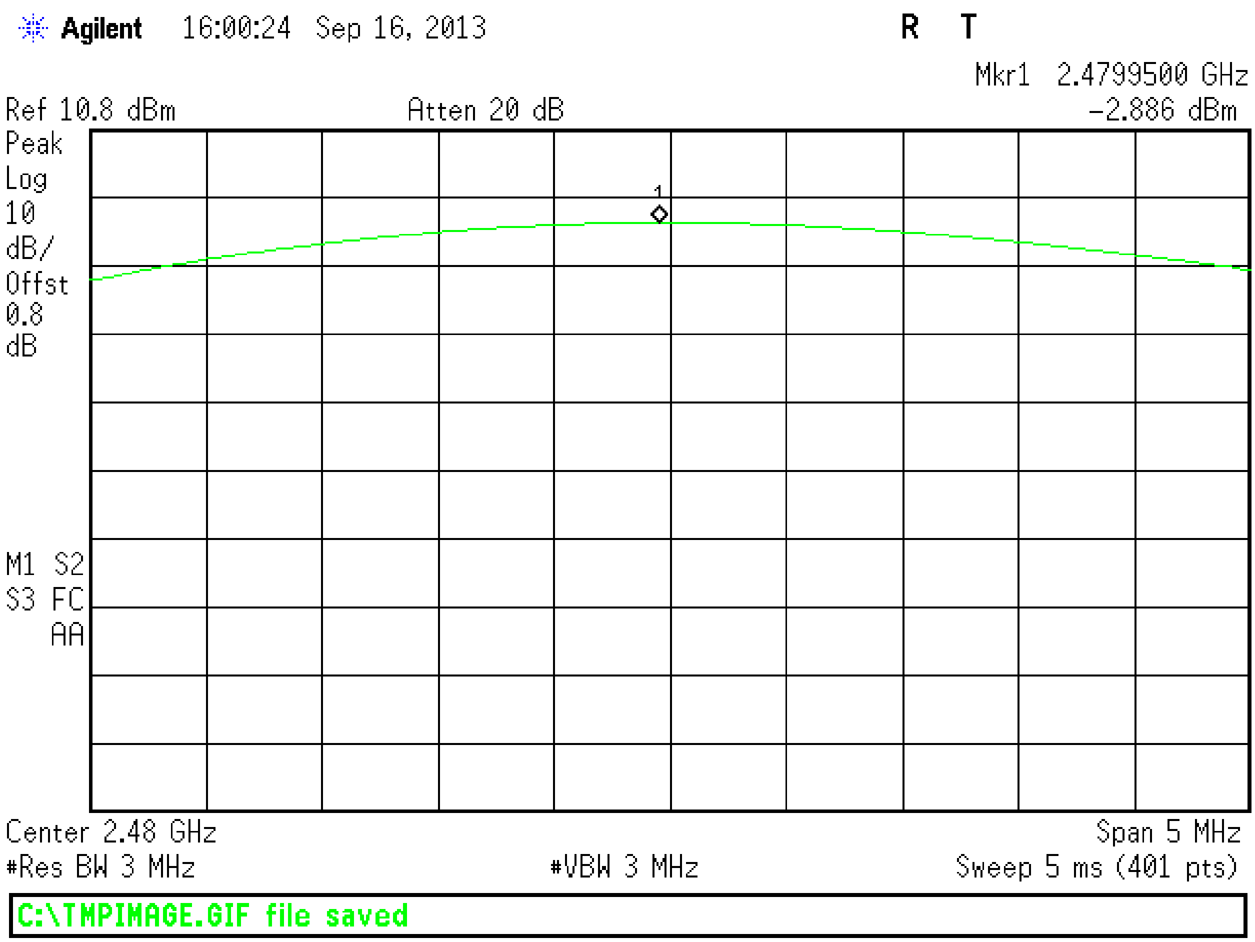


Figure 3: Maximum Transmitted Power, 2480 MHz, 1 Mbps

4.2 20 dB Bandwidth

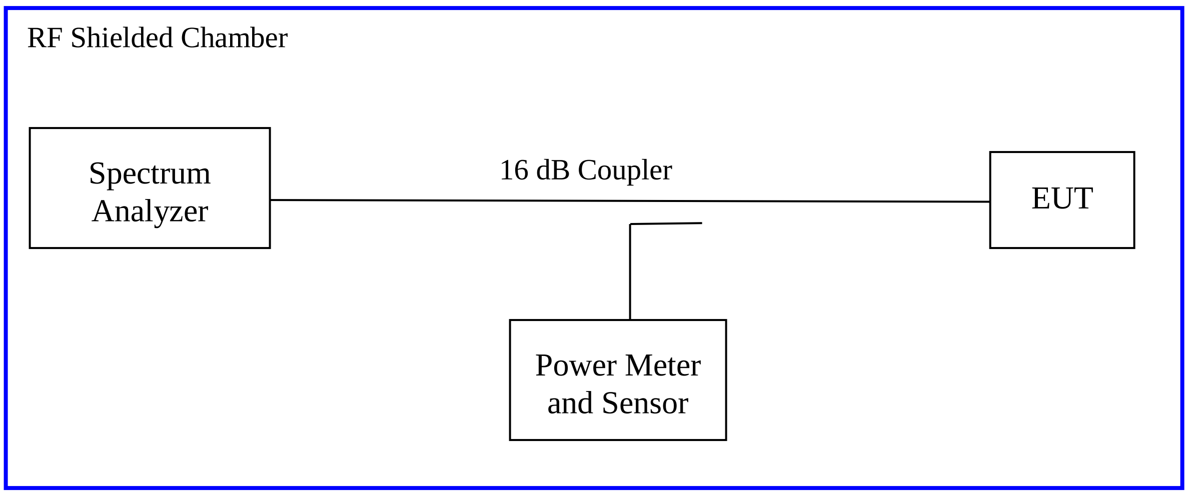
The occupied bandwidth is measured at an amplitude level reduced from the reference level by a specified ratio. The reference level is the level of the highest amplitude signal observed from the transmitter at the fundamental frequency.

20 dB bandwidth was performed by coupling the output of the EUT to the input of a spectrum analyzer.

4.2.1 Test Method

The conducted method was used to measure the 20 dB bandwidth. The measurement was performed with modulation per CFR47 15.247(a) (1) 2013 and RSS Gen Sect. 4.4.1:2010. Initial investigation was performed at different data rates. The worst sample result indicated below.

Test Setup:



4.2.2 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 3: 20 dB Bandwidth – Test Results

Test Conditions: Conducted Measurement, Normal Temperature and Voltage only			
Antenna Type: Internal		**Power Setting:** See test plan	
Max. Antenna Gain: +3.0 dBi		**Signal State:** Modulated	
Ambient Temp.: 21 °C		**Relative Humidity:**33%	
Bandwidth (MHz) for 802.15.1			
Freq. (MHz)	**20dB BW MHz**	**Occupied BW (99%) MHz**	**Results**
2402	1.480	1.322	Pass
2440	1.520	1.322	Pass
2480	1.285	1.132	Pass
Notes: None			

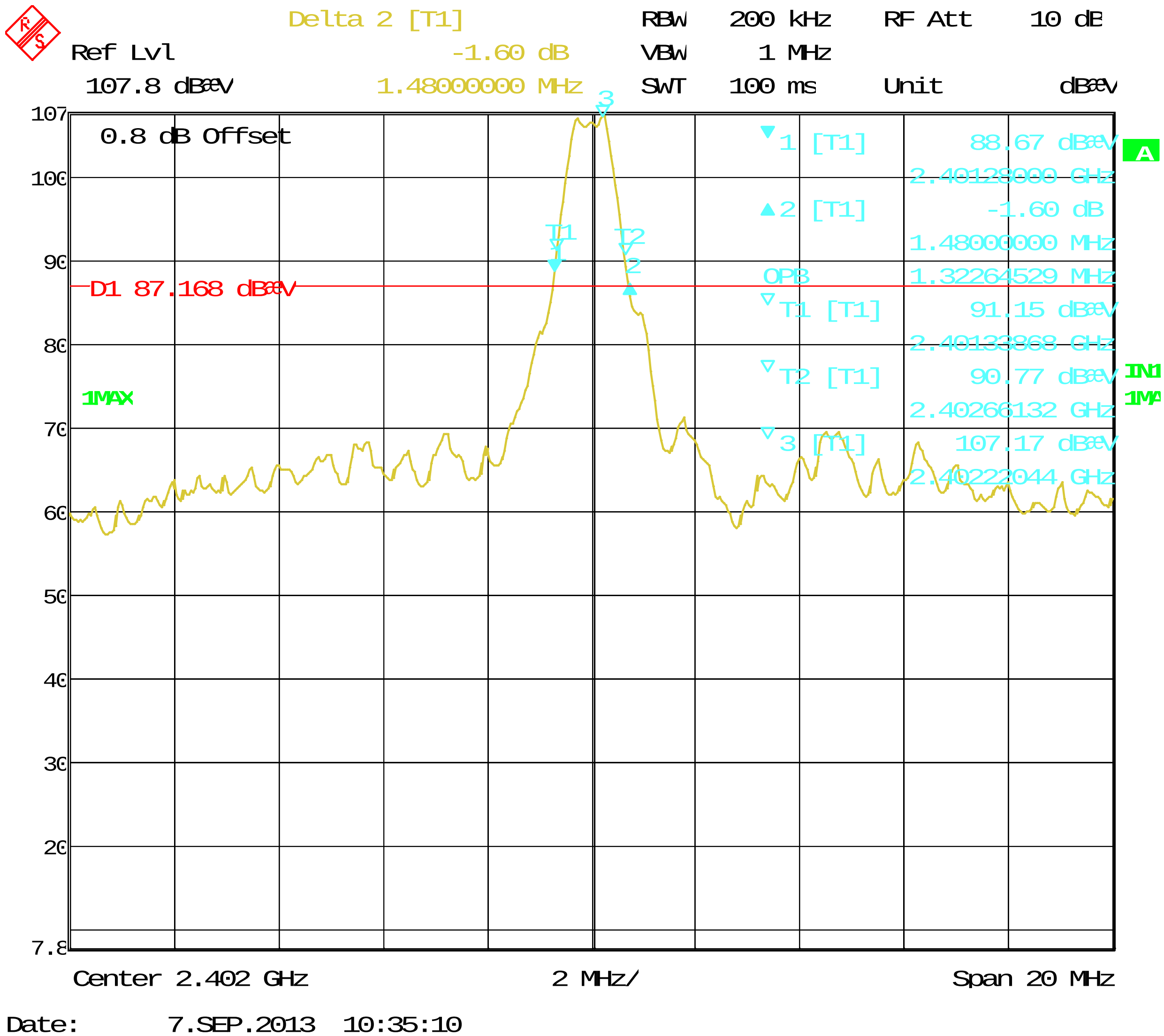


Figure 4: 20 dB Bandwidth at – Operating Channel 2402 MHz

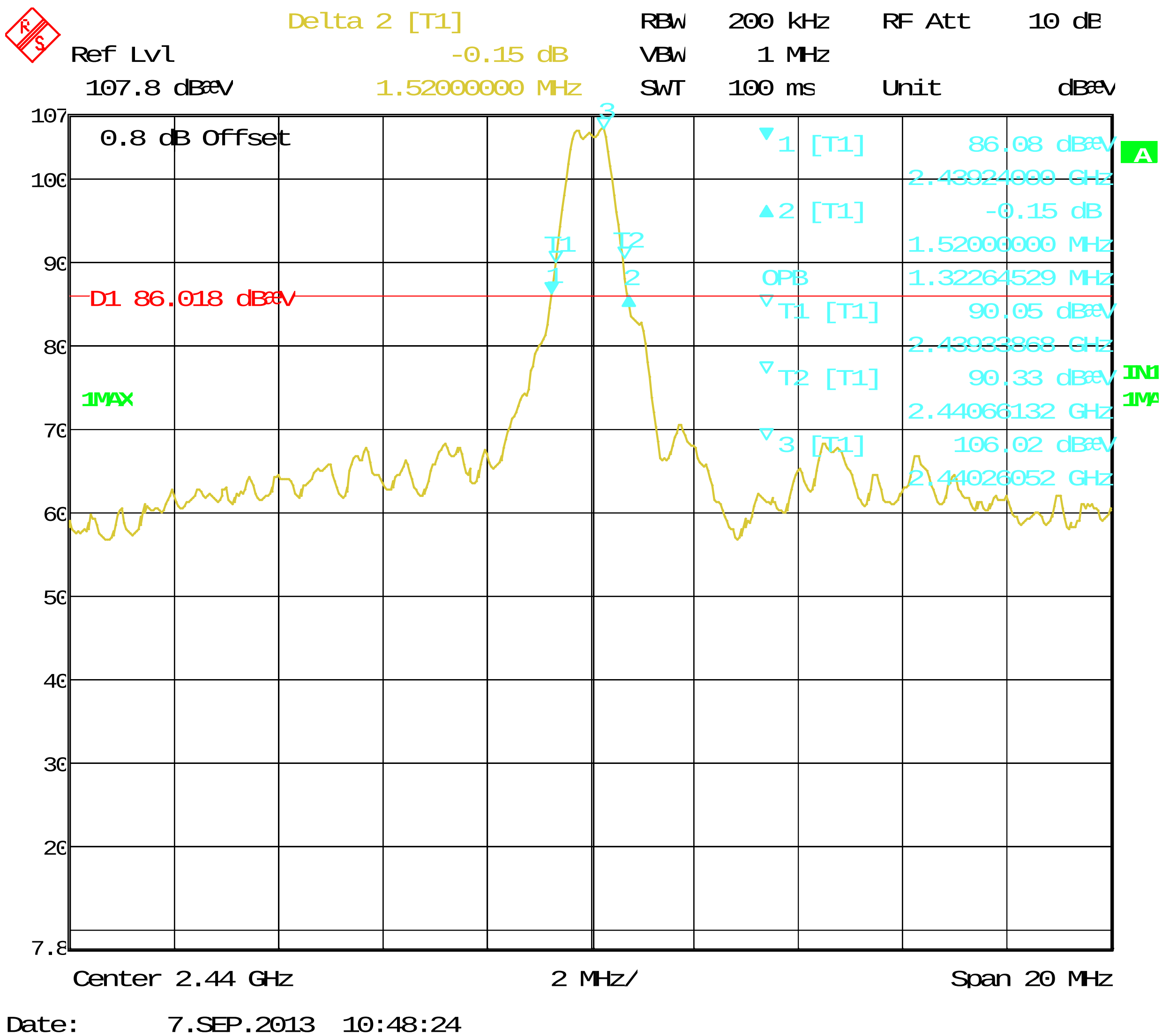
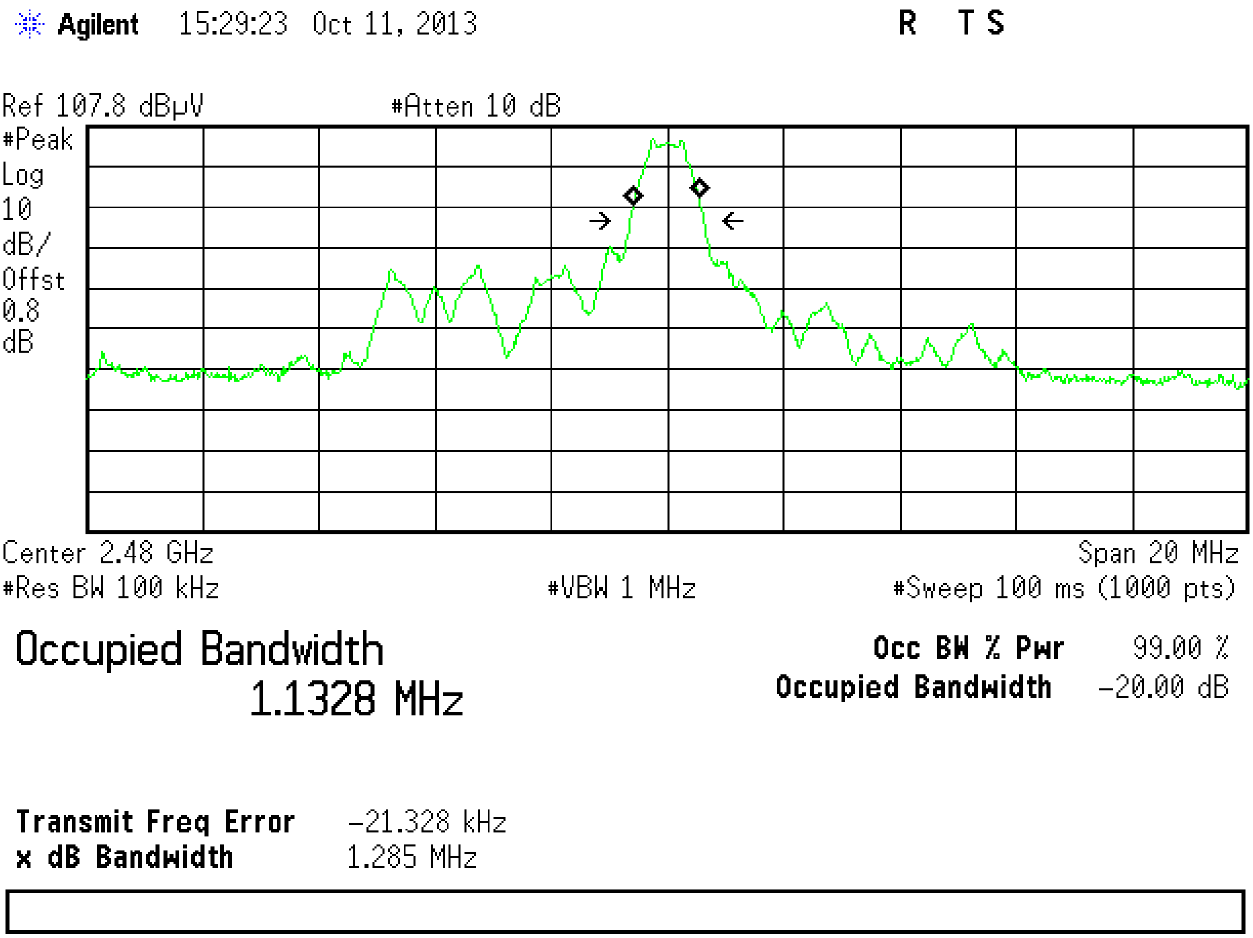


Figure 5: 20 dB Bandwidth at – Operating Channel 2440 MHz


Agilent 15:29:23 Oct 11, 2013
R T S
Ref 107.8 dBμV
#Atten 10 dB
#Peak
Log
10
dB/
Offst
0.8
dB
Center 2.48 GHz
Span 20 MHz
#Res BW 100 kHz
#VBW 1 MHz
#Sweep 100 ms (1000 pts)
Occupied Bandwidth
1.1328 MHz
Occ BW % Pwr 99.00 %
Occupied Bandwidth -20.00 dB
Transmit Freq Error -21.328 kHz
x dB Bandwidth 1.285 MHz

4.3 Number of Hopping Channels

The setup was identical to RF output power measurement.

As per FCC 15.247 (a) (1) (iii) Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

4.3.1 Results

Number measured in the frequency band 2400 -2483.5 MHz was 40

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

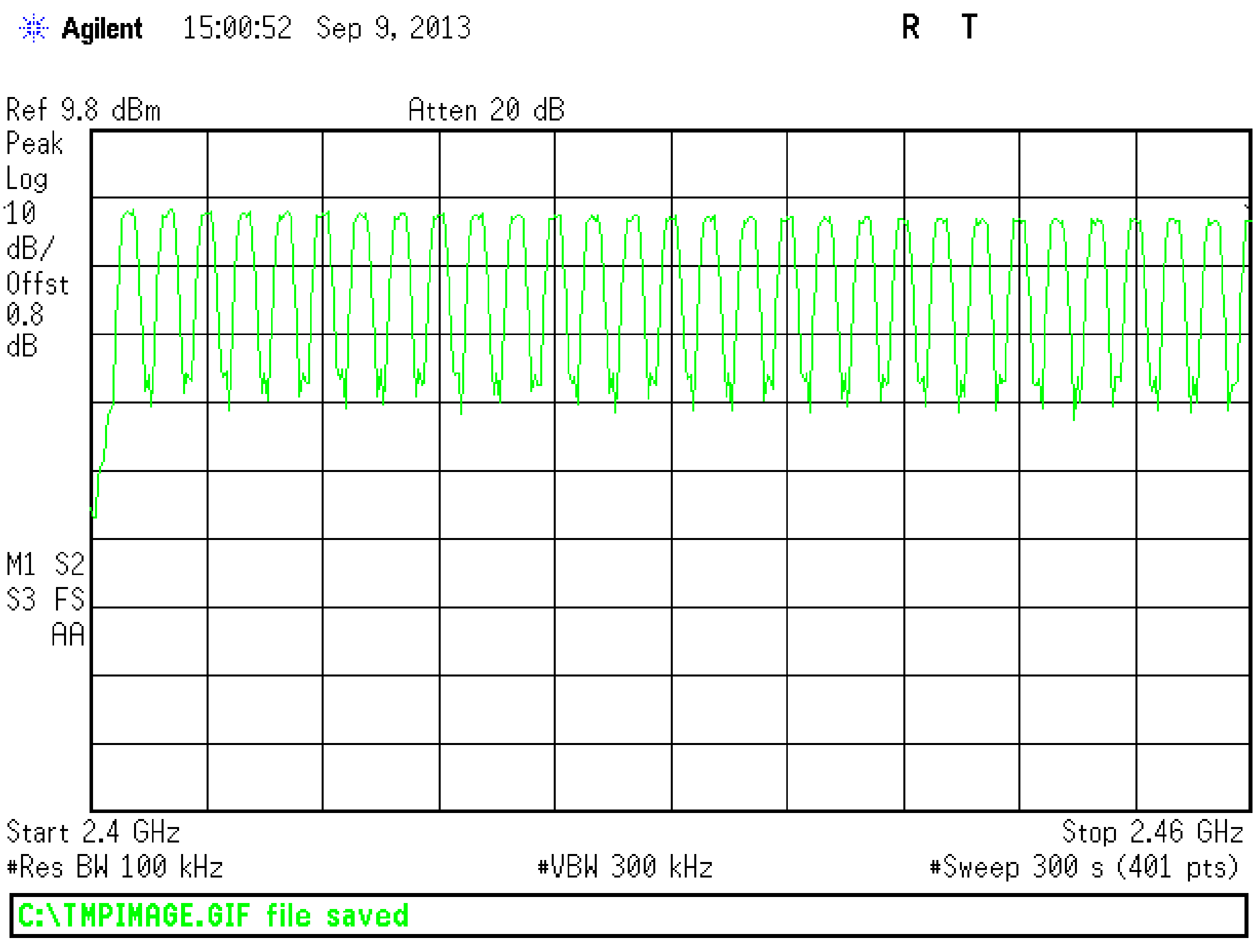


Figure 6: Number channels Operating 2400 -2483.5 MHz plot1

Number of Channels 2400 to 2460 MHz: 29 (Plot 1)

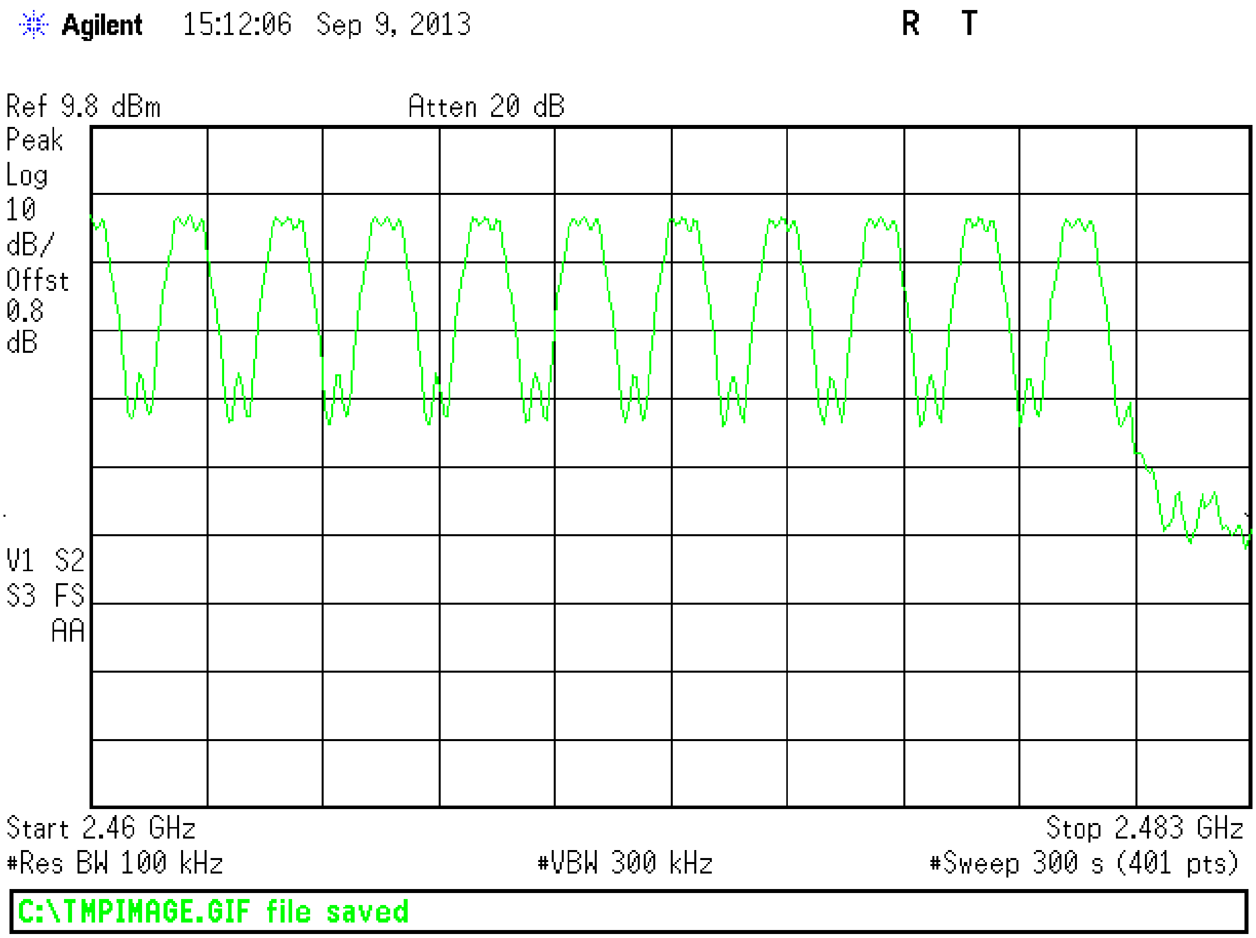


Figure 7: Number channels Operating 2400 -2483.5 MHz, plot 2

Number of Channels 2460 to 2483.5 MHz: 11 (Plot 2, includes the channel split between graphs)

Total number of Channels used: 40

4.4 Channels Separation

The setup was identical to RF output power measurement.

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

4.4.1 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Measured Channel separation > 25 kHz meets the requirements additionally meets following

Minimum Channel Separation				
Operating Channel (MHz)	**Hopping Separation (kHz)**	**Two-Third of Separation (kHz)**	**Two-Third of 20 dB Bandwidth Limit (kHz)**	**Result**
2440	1962.5	1308.3	> 850	Pass

Measured Channel separation: 1.9625 MHz - See Plot #9
1.9875 MHz - See Plot #10

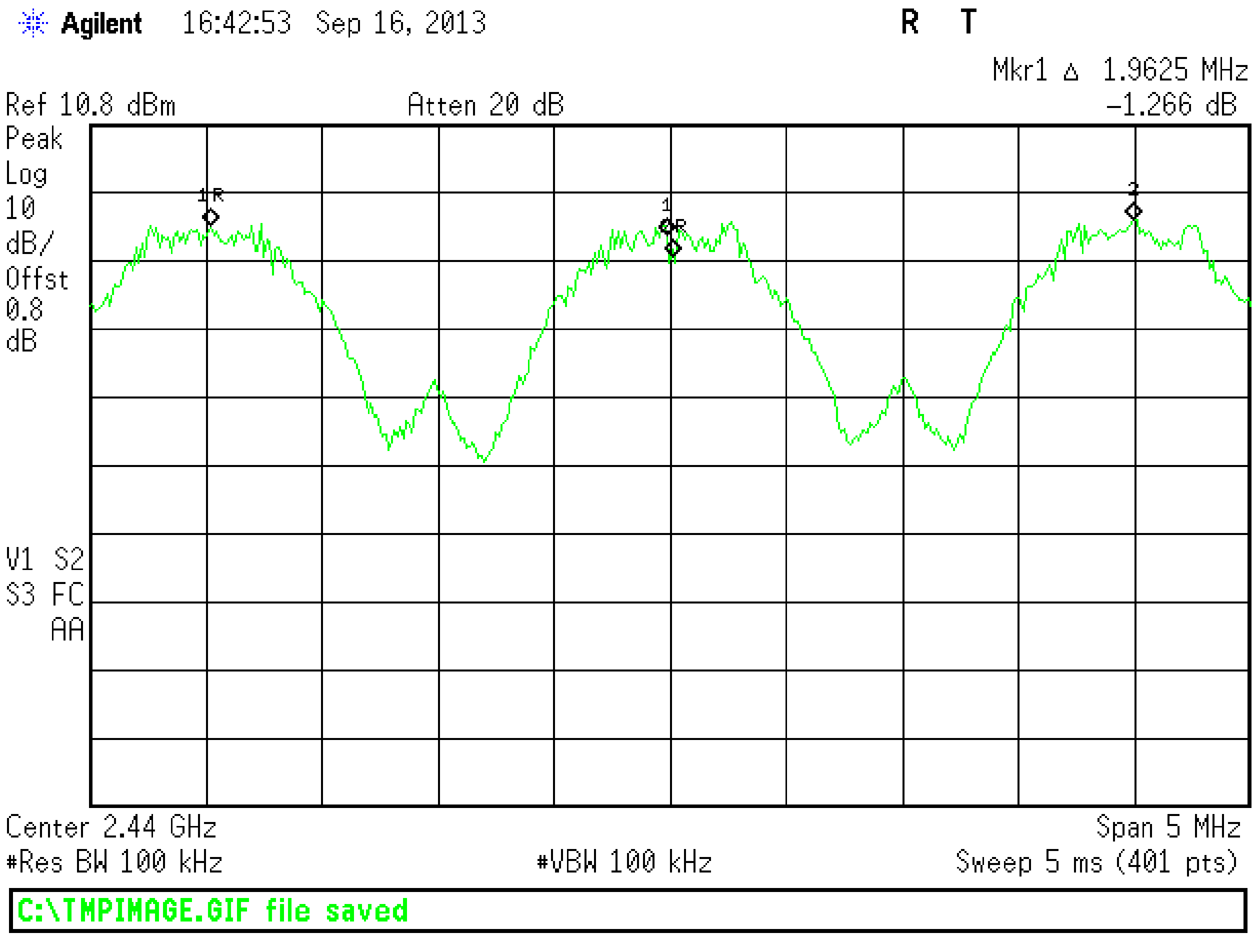


Figure 8: Channel Sepeation, plot 1

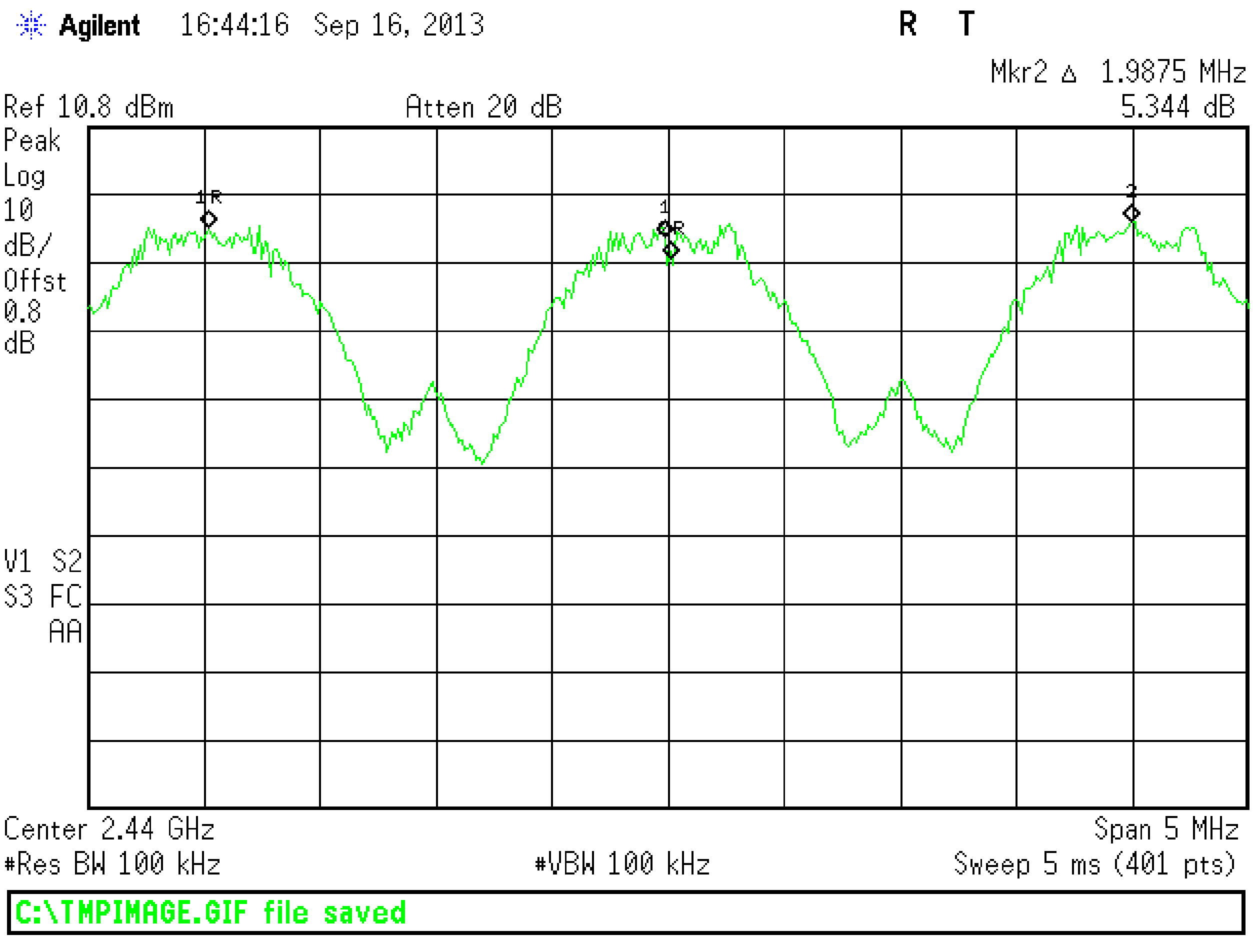


Figure 9: Channel Sepeation, plot 2

4.5 Channel Dwell time

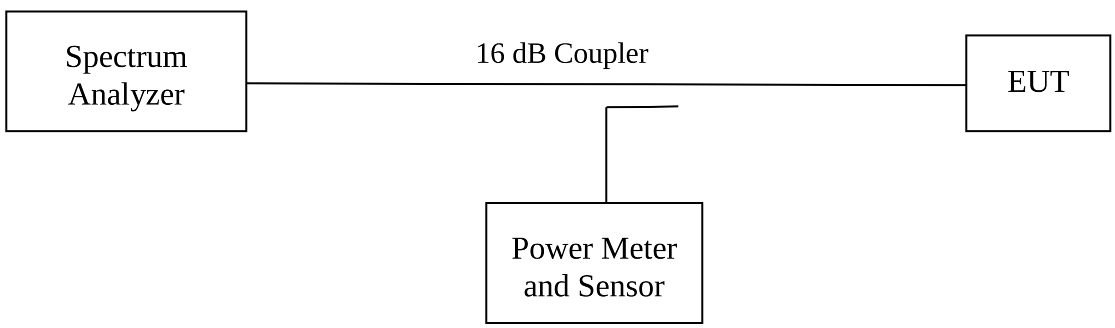
The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

4.5.1 Test Method

The conducted method was used to measure the channel dwell time per ANSI C63.10:2009 Section 6.11.2

The measurement was performed with modulation per CFR47 Part 15.247 (a) (1) (iii) and RSS 210 A8.1 (d) . The worst sample result indicated below.

Test Setup:



4.5.2 Results

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 4: Channel dwell time – Test Results

Test Conditions: Conducted Measurement, Normal Temperature and Voltage Only				
Antenna Type: Internal			**Power Setting:** See test plan	
Max. Antenna Gain: +3.0 dBi			**Signal State:** Modulated	
Ambient Temp.: 21 °C			**Relative Humidity:** 39%	
Freq. (MHz)	**Mode**	**Channel Dwell time**	**Limit [Sec]**	**Result**
2440	1 Mbps	0.111 secs	0.4	Pass

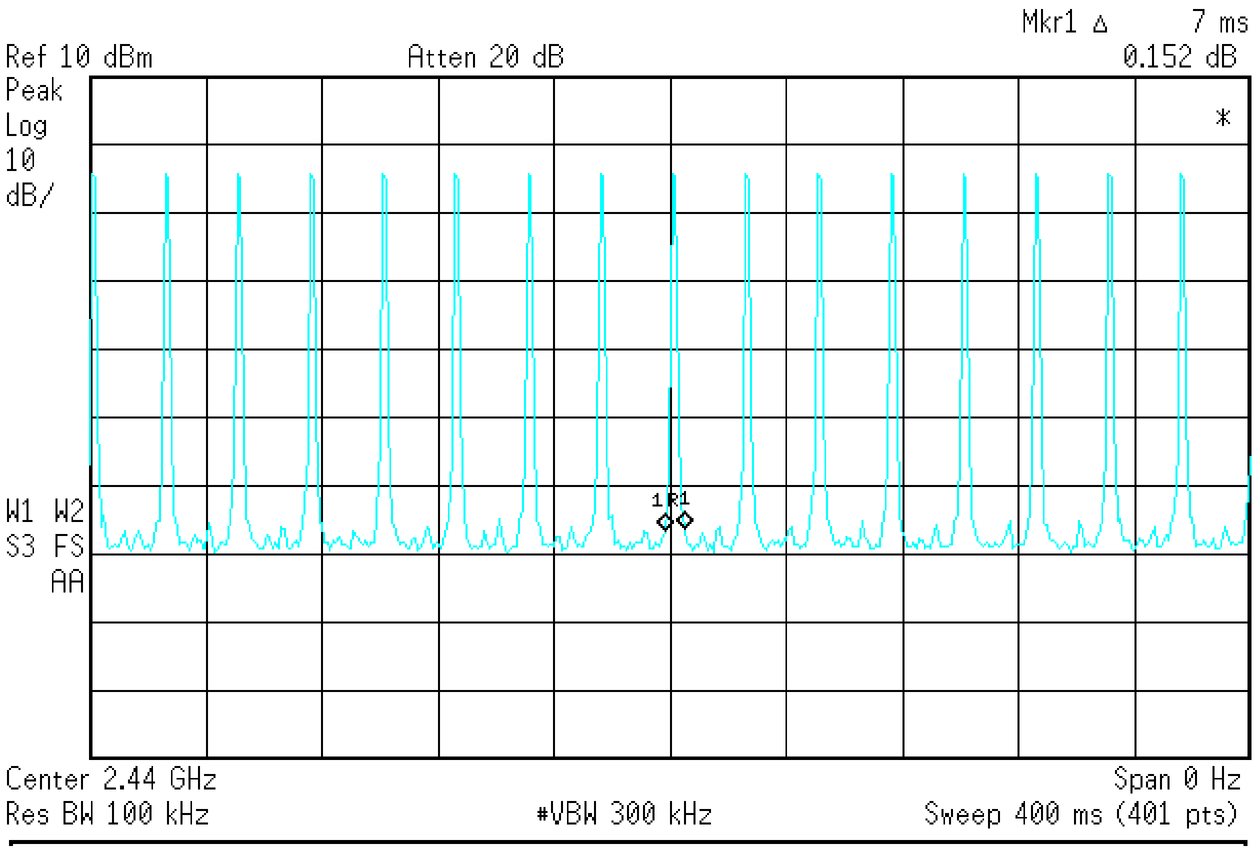


Figure 10: Channel Occupancy time

In this plot:

Time of Occupancy for each Hop: 7 ms

Number of Hops in 400 ms = 16

Total Time of Occupancy for Each Channel 16 x 7 = 112 ms in 400 ms

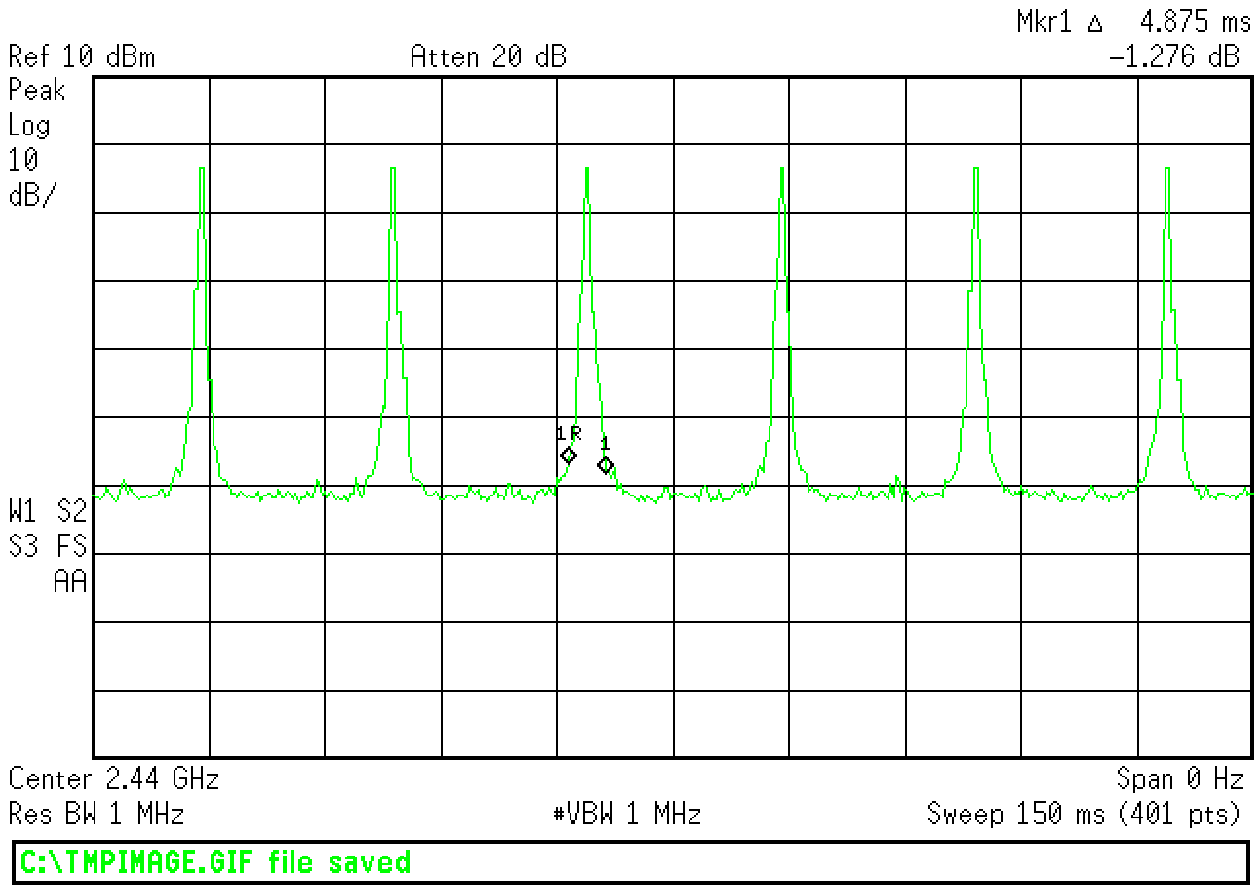


Figure 11: Channel Occupancy time -150ms

In this plot:

Hop Time = 4.875 ms

Number of Hops: 6

Channel Occupancy Time = 29.95 ms in 150 ms

Channel occupancy Time in 400 ms = 117 ms

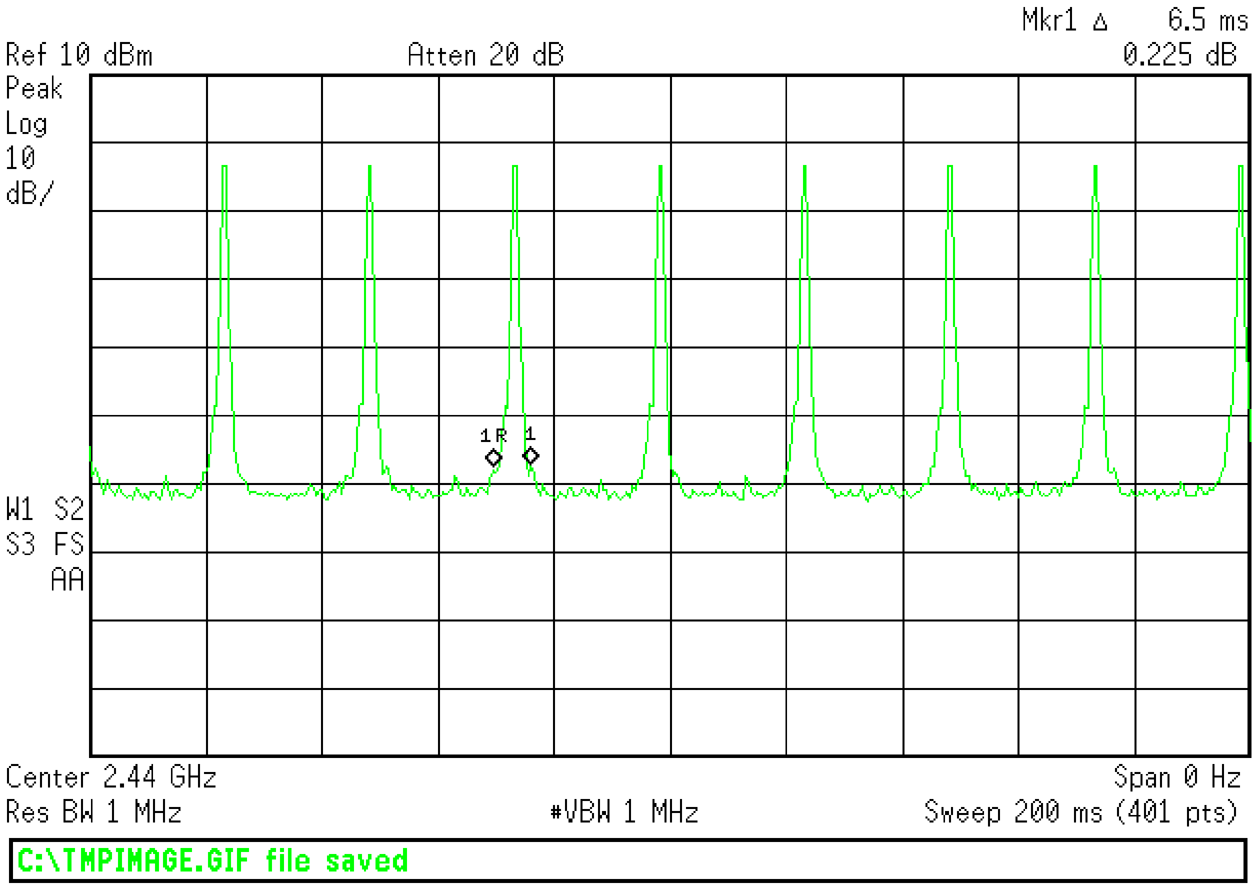


Figure 12: Channel Occupancy time -200ms

Hop Time = 6.5ms

Number of Hops = 8

Channel Occupancy Time = 52 ms in 200 ms

Channel Occpancy Time in 400 ms = 104 ms

Average Occpancy Time in all 3 Measurements: 111 ms

Average Channel is Occupancy less than the limit 400 ms

4.6 Out of Band Emission requirements

The setup was identical to RF output power measurement. Intentional radiators operating under the alternative provisions to the general emission limits, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If the frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

Any frequency outside the band of 2400 MHz to 2483.5 MHz, the power output level must be below 20 dB from the in-band transmitting signal; CFR 47 Part 15.215, 15.247(d) and RSS 210 A8.5

4.6.1 Results

The Out of band emission was performed on the conducted test Sample.

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 5: Band Edge Requirements – Test Results

Test Conditions: Conducted Measurement, Normal Temperature and Voltage only				
Antenna Type: Internal			**Power Setting:** See test plan	
Max. Antenna Gain: +3.0 dBi			**Signal State:** Modulated	
Ambient Temp.: 21 °C			**Relative Humidity:**39%	
-20 dB Band Edge Results				
Operating Freq.	**Mode**	**Limit (dBm)**	**Measured Value (dBm)**	**Result**
2402 MHz	1Mbps	-21.39	-28.38	Pass
2440 MHz	1Mbps	-21.65	-32.56	Pass
2480 MHz	1Mbps	-22.71	-24.89	Pass
Note: The stated limits for 30 dBr are relative to each individual output per KDB 662911 Method.				

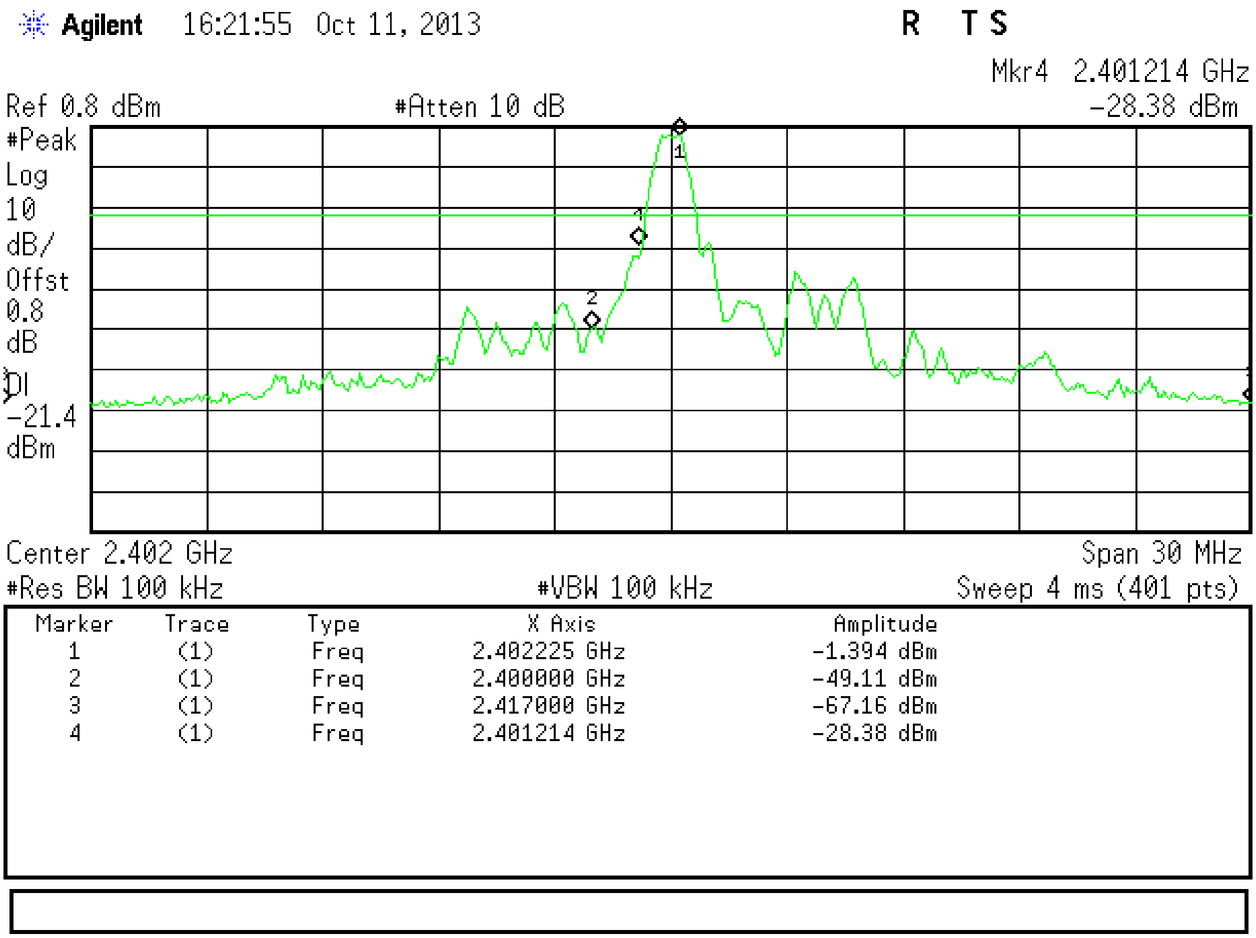


Figure 13: Band Edge Requirement at Operating Channel 2402 MHz

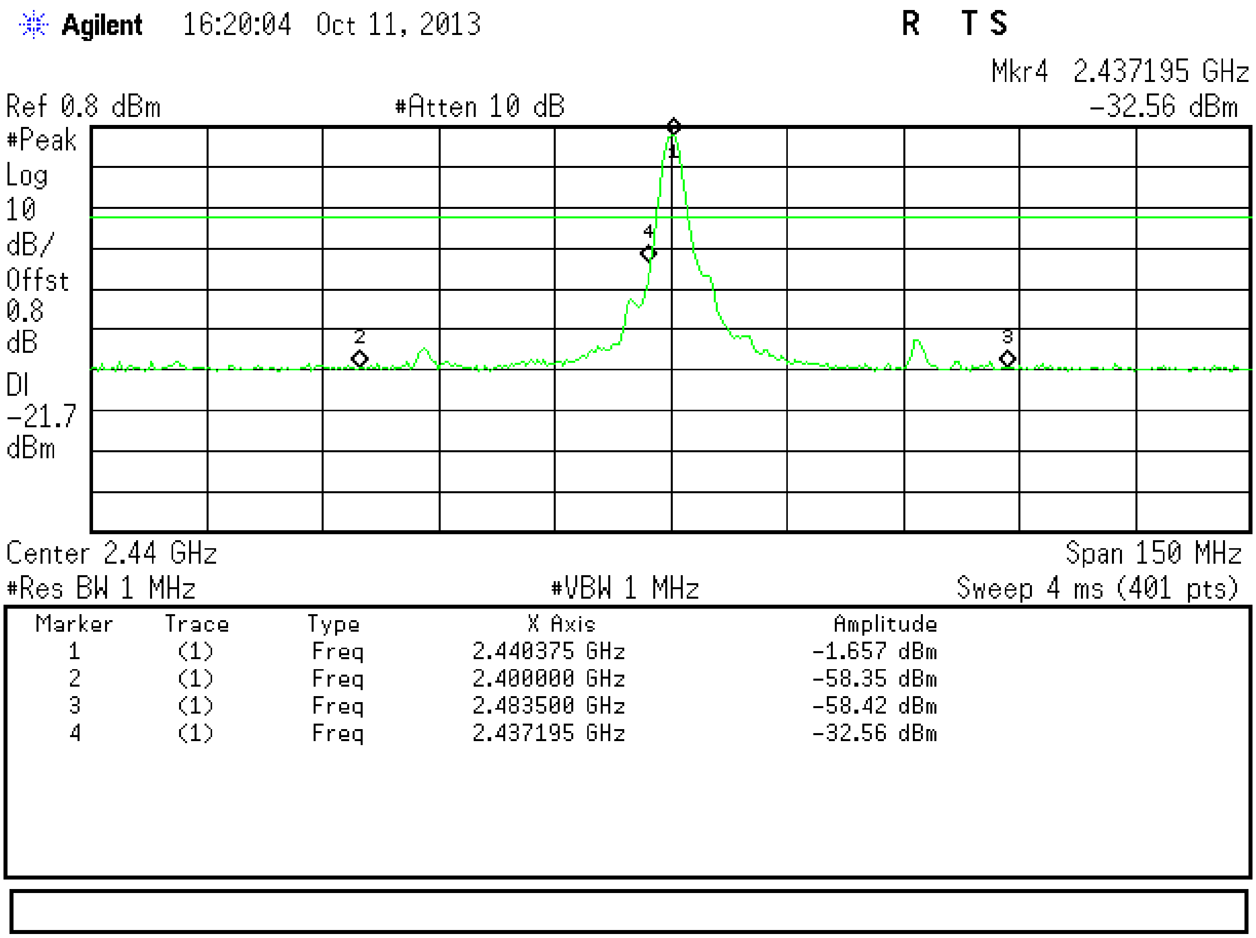


Figure 14: Band Edge Requirement at Operating Channel 2440 MHz

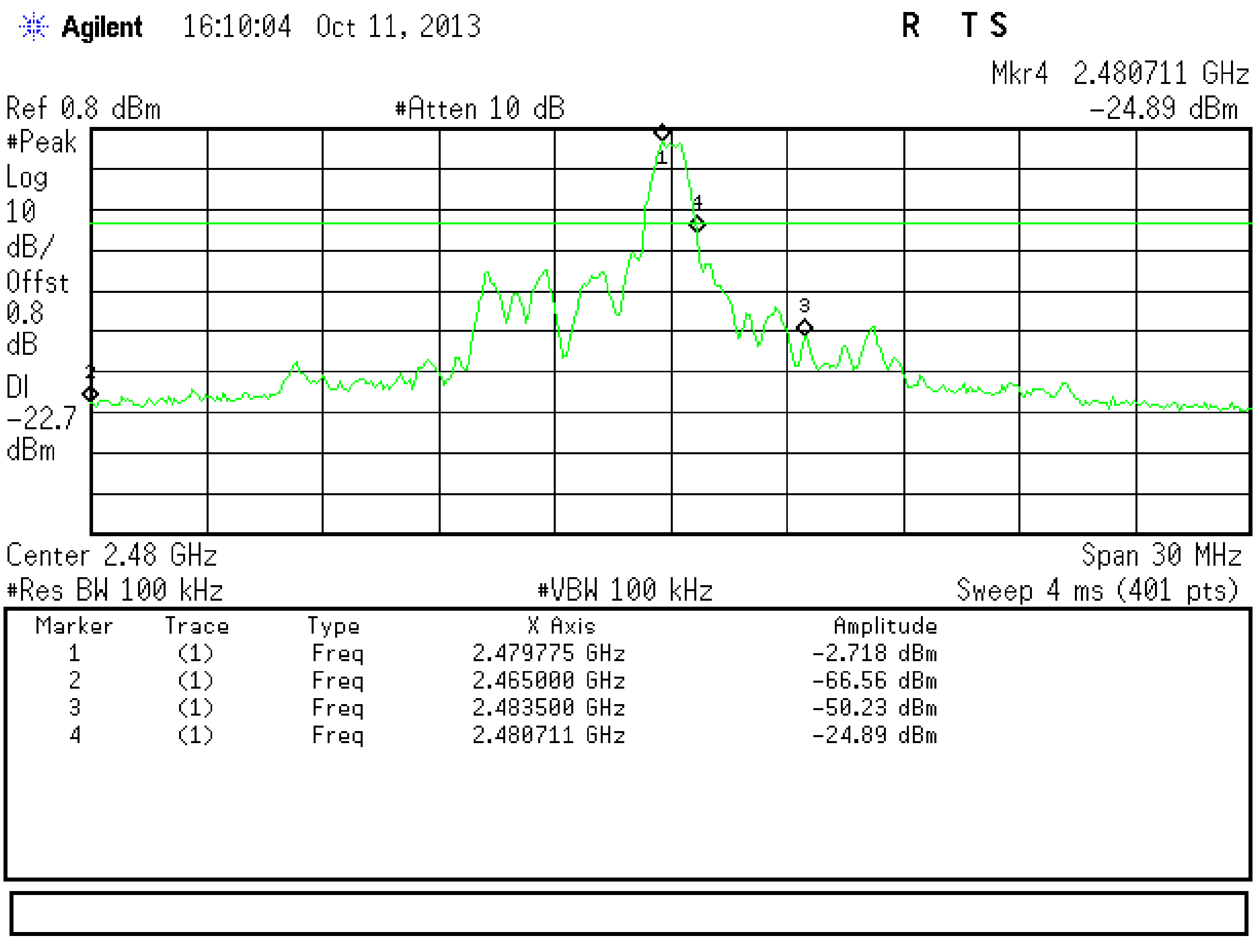


Figure 15: Band Edge Requirement at Operating Channel 2480 MHz

Table 6: Out-of-Band Conducted Emission – Test Results

Operating Freq.	Mode	Result
2402 MHz	1 Mbps	Pass
2442 MHz	1 Mbps	Pass
2480 MHz	1 Mbps	Pass

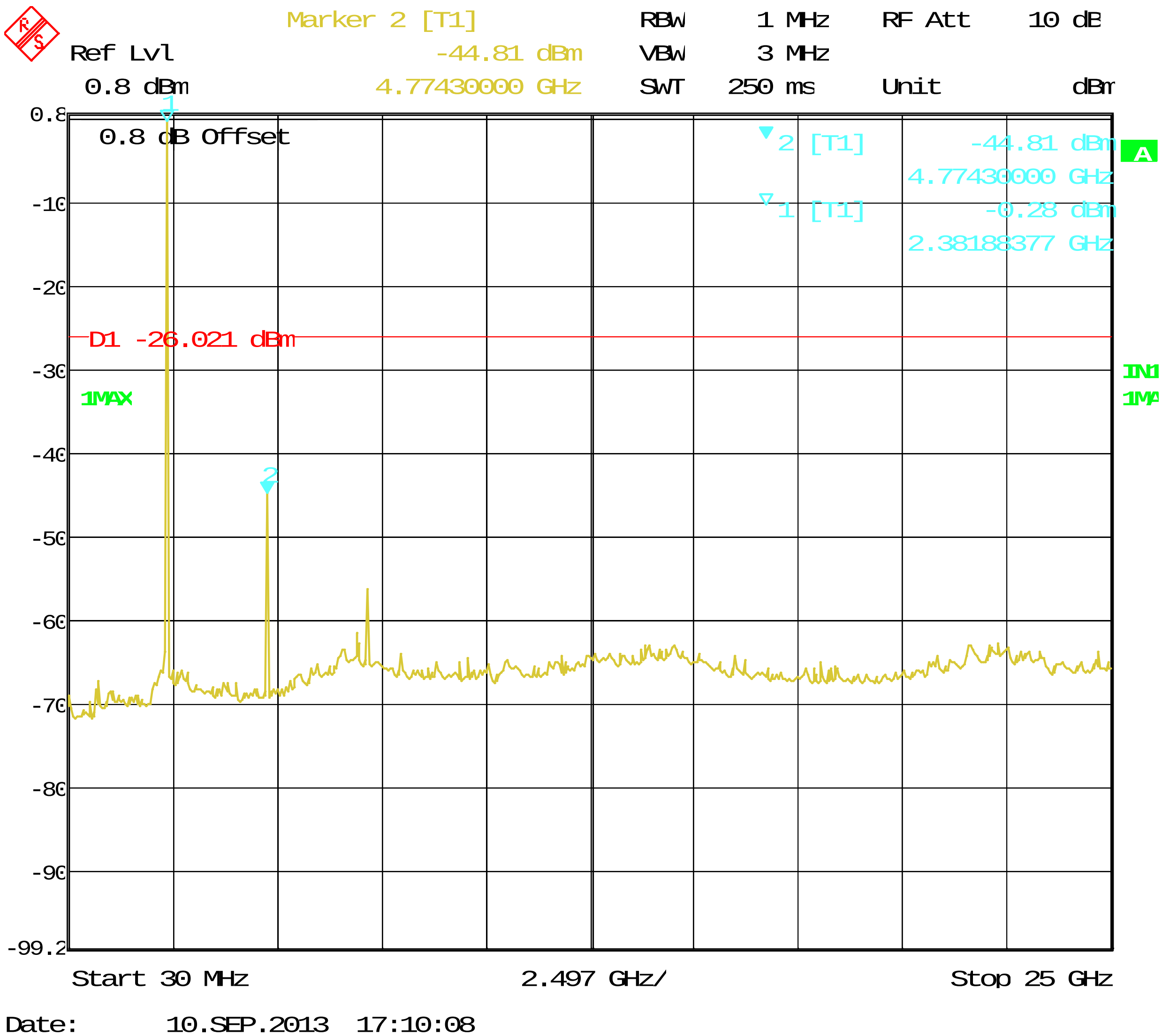


Figure 16: Out of band emissions at Operating Channel 2402 MHz

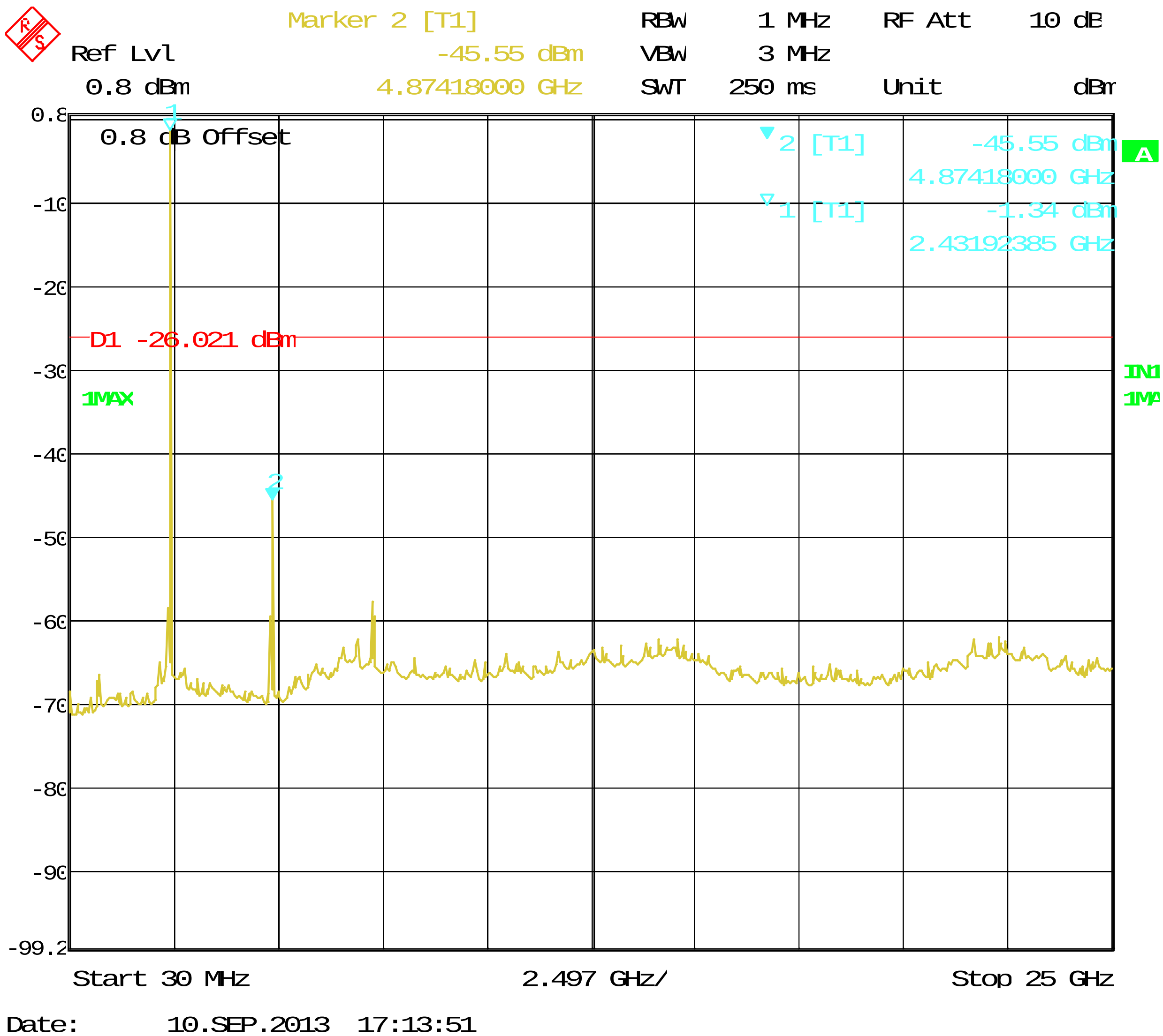


Figure 17: Out of band emissions at Operating Channel 2440MHz

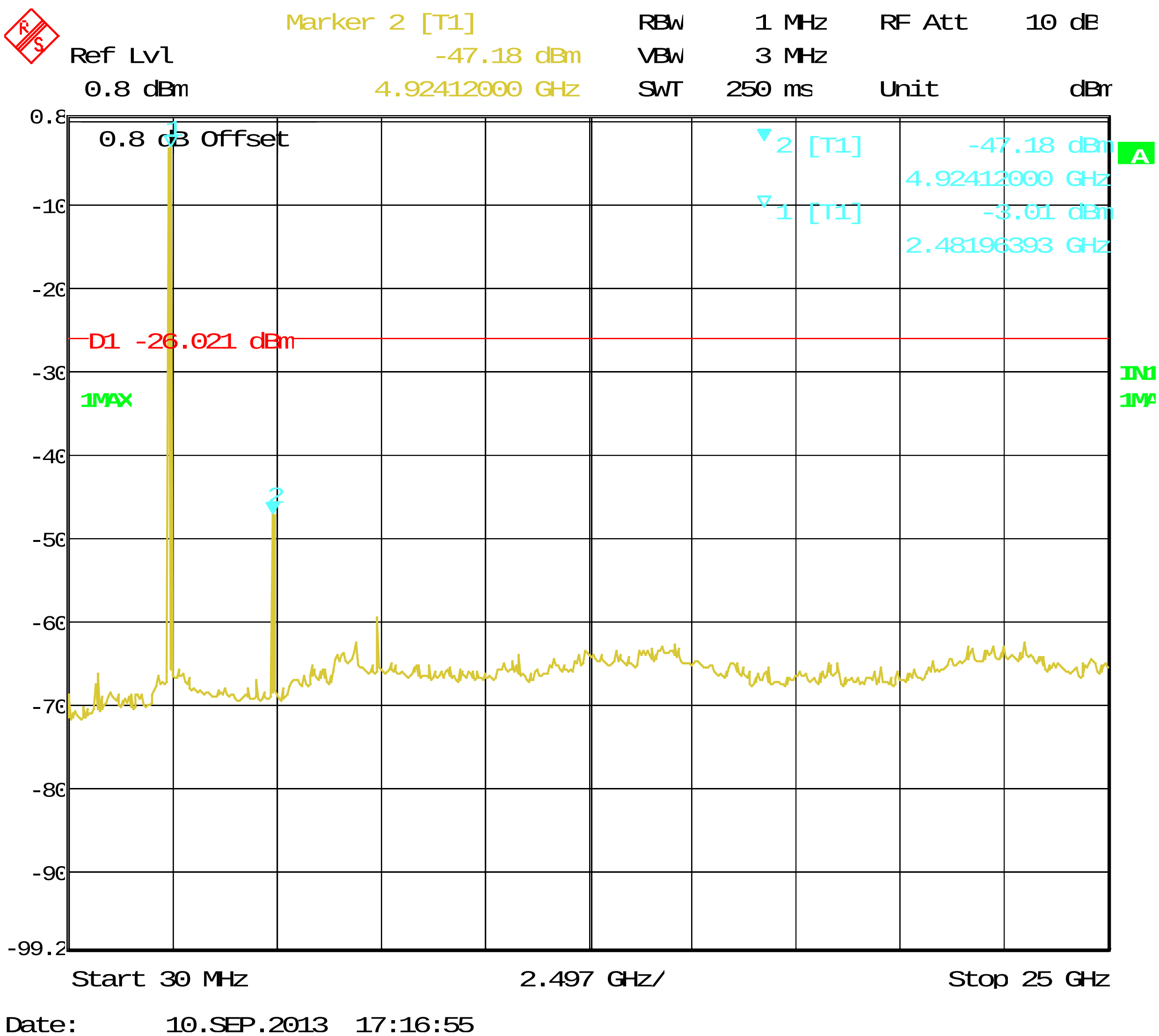


Figure 18: Out of band emissions at Operating Channel 2480 MHz

4.7 Transmitter Spurious Emissions

Transmitter spurious emissions are emissions outside the frequency range of the equipment when the equipment is in transmitting mode; per requirement of CFR47 15.205, 15.209, 15.247(d), RSS 210 Sect. A.8.5

4.7.1 Test Methodology

4.7.1.1 Preliminary Test

A test program that controls instrumentation and data logging was used to automate the preliminary RF emission test procedure. The frequency range of interest was divided into sub-ranges to yield a frequency resolution of approximately 120 kHz and provide a reading at each frequency for no more than 12° of turntable rotation. For each frequency sub-range the turntable was rotated 360° while peak emission data was recorded and plotted over the frequency range of interest in horizontal and vertical antenna polarization's.

Preliminary emission profile testing was performed inside the anechoic chamber. The EUT was placed on a 1.0m x 1.5m non-conductive table 80cm above the floor. The EUT was positioned as shown in the setup photographs. The receiving antenna was placed at a distance of 3m at a fixed height of 1m. Measurement equipment was located outside of the chamber. A video camera was placed inside the chamber to view the EUT.

4.7.1.2 Final Test

For each frequency measured, the peak emission was maximized by manipulating the receiving antenna from 1 to 4 meters above the ground plane and placing it at the position that produced the maximum signal strength reading. The turntable was then rotated through 360° while observing the peak signal and placing the EUT at the position that produced maximum radiation. The six highest emissions relative to the limit were measured unless such emissions were more than 20 dB below the limit. If less than six emissions are within 20 dB of the limit, than the noise level of the receiver is measured at frequencies where emissions are expected. Multiples of all oscillator and microprocessor frequencies were also checked.

Final testing was performed on an NSA compliant test site. The EUT was placed on a 1.0m x 1.5m non-conductive table 80cm above the ground plane. The placement of EUT and cables were the same as for preliminary testing and is shown in the setup photographs.

The final scans performed on the worst axis, Y-Axis, for three operating channels: 2402 MHz, 2440 MHz, and 2480 MHz at 1 Mbit/s.

4.7.1.3 Deviations

None.

4.7.2 Transmitter Spurious Emission Limit

The spurious emissions of the transmitter shall not exceed the values in CFR47 Part 15.205, 15.209: 2011 and RSS 210 A1.1.2 2010.

Frequency (MHz)	Field strength (microvolts/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

All harmonics and spurious emission which are outside of the restricted band shall be 20 dB below the in-band emission.

4.7.3 Test Results

The final measurement data was taken under the worst case operating modes, configurations, and/or cable positions. It also reflects the results including any modifications and/or special accessories listed in Sections 1.4 and Test Plan.

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 7: Transmit Spurious Emission at Band Edge Requirements

Test Conditions: Radiated Measurement, at 3 meters								
Antenna Type: Internal				**Power Setting:** See test plan				
Max. Antenna Gain: +3.0 dBi				**Signal State:** Modulated at 99%				
Ambient Temp.: 22 °C				**Relative Humidity:**34%				
Band Edge Results								
Operating Channel MHz	**Polarity**	**Peak Field Strength Measured dBuV**	**Peak Limit dBuV**	**Margin dB**	**Avg Field Strength Measured dBuV**	**Avg Limit dBuV**	**Margin dB**	**Result**
2402	H	56.77	74.0	-17.23	44.86	54.00	-9.14	Pass
2402	V	56.88	74.0	-17.12	44.88	54.00	-9.12	Pass
2480	H	58.08	74.0	-15.92	44.84	54.00	-9.16	Pass
2480	V	58.12	74.0	-15.88	44.57	54.00	-9.43	Pass

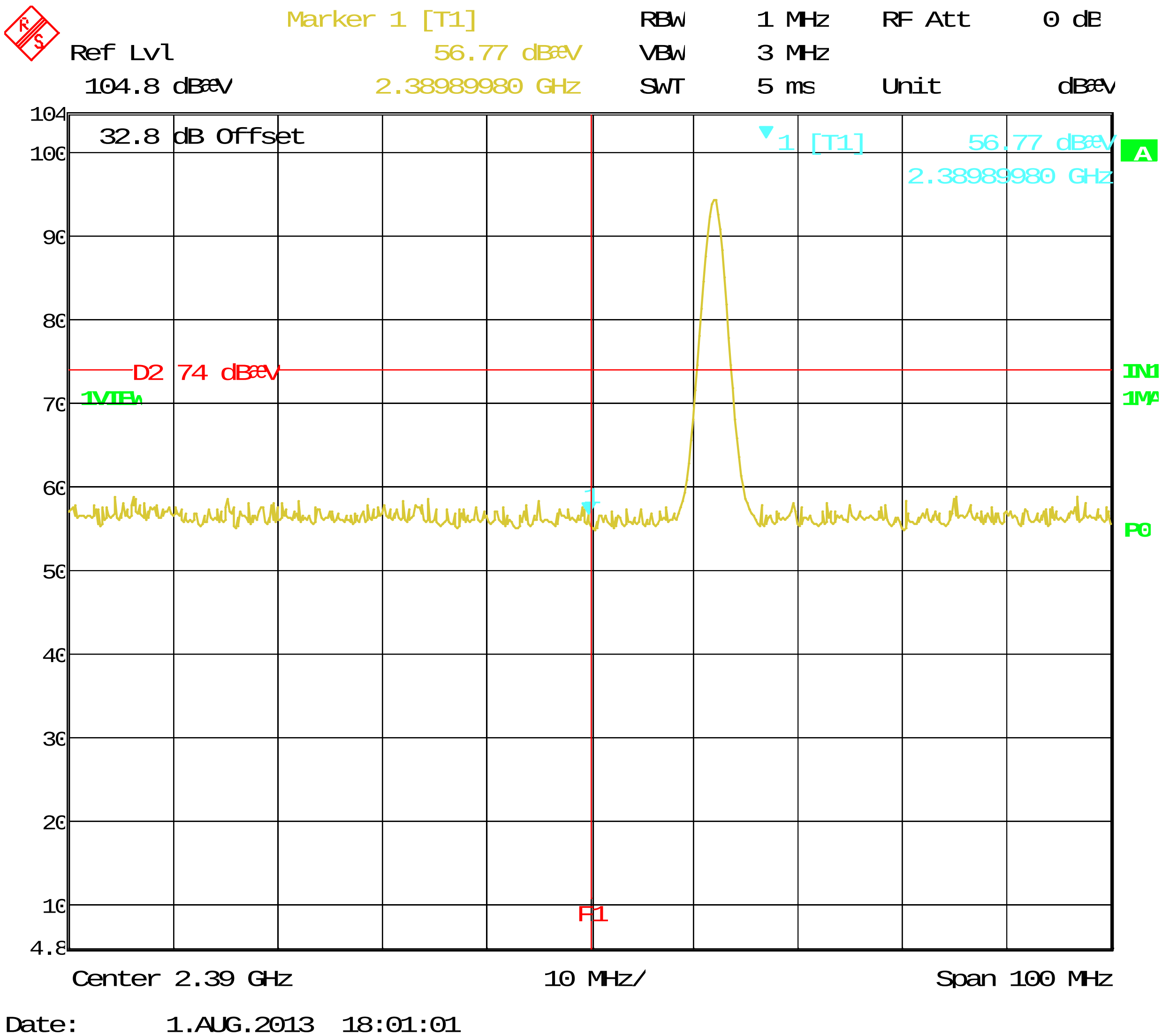


Figure 19: Radiated Emission at the Edge for Channel 2402 MHz at 1Mbps – Horizontal (Peak)

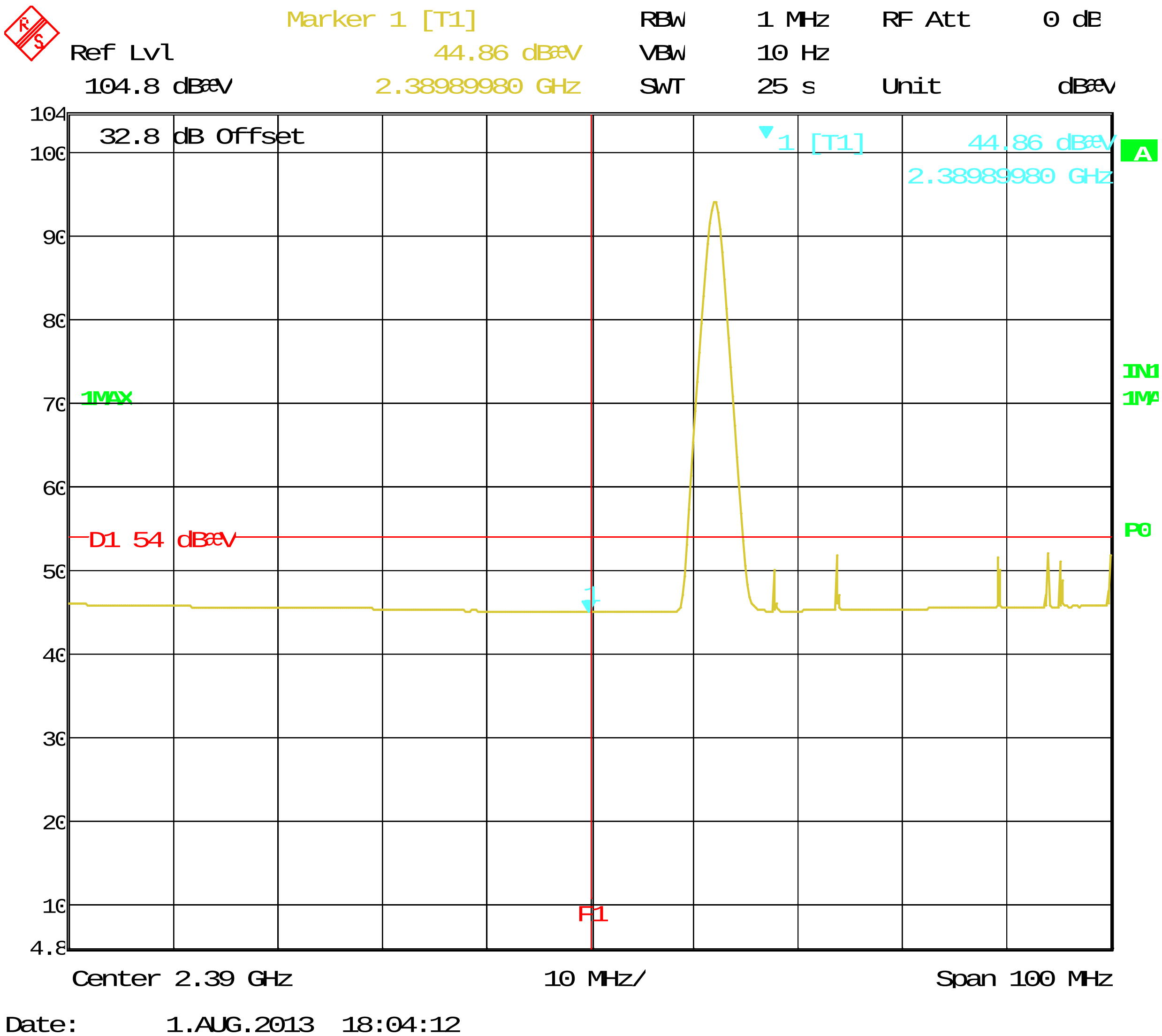


Figure 20: Radiated Emission at the Edge for Channel 2402 MHz at 1Mbps – Horizontal (Avg)

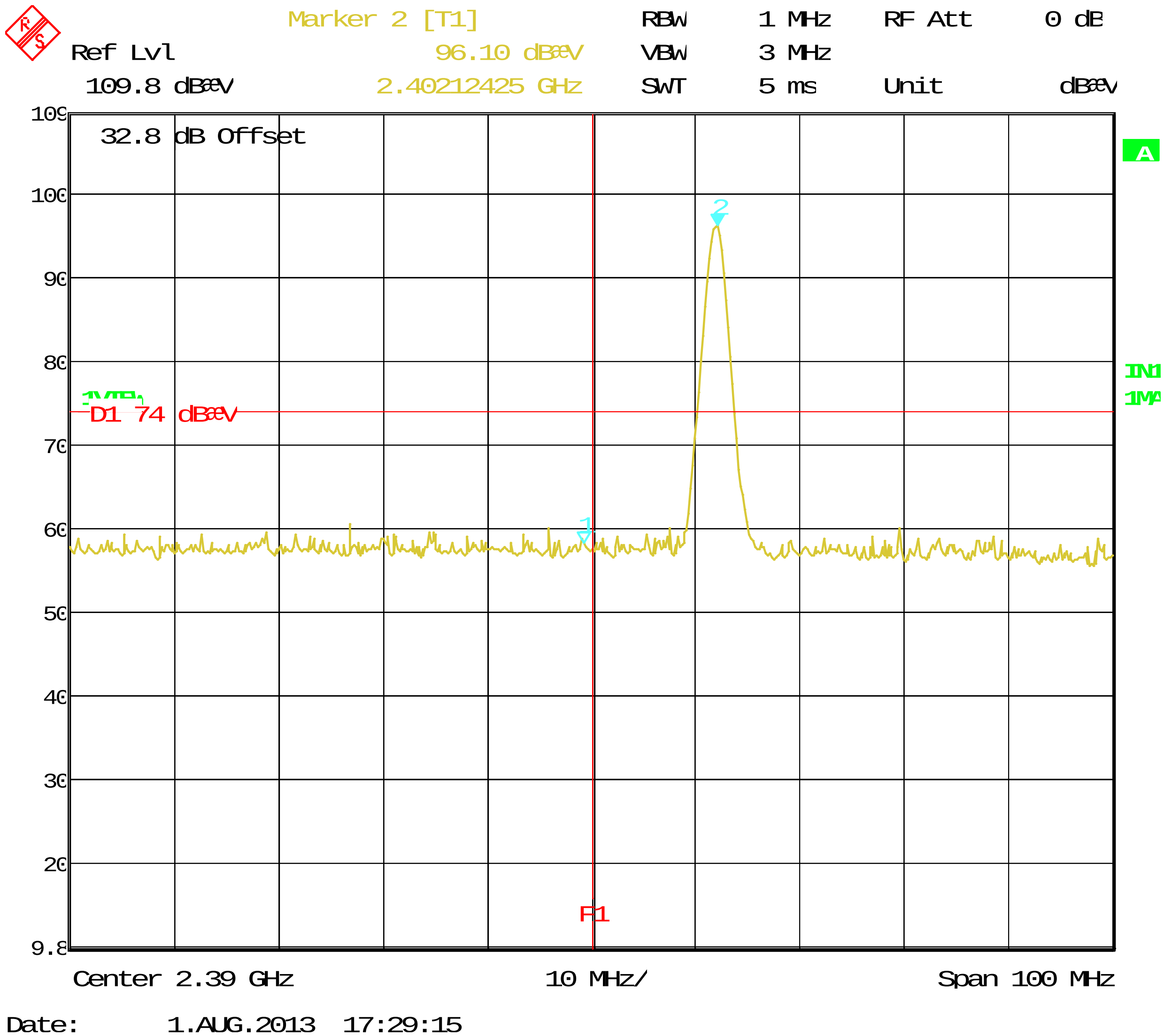


Figure 21: Radiated Emission at the Edge for Channel 2402 MHz at 1Mbps – Vertical (Pk)

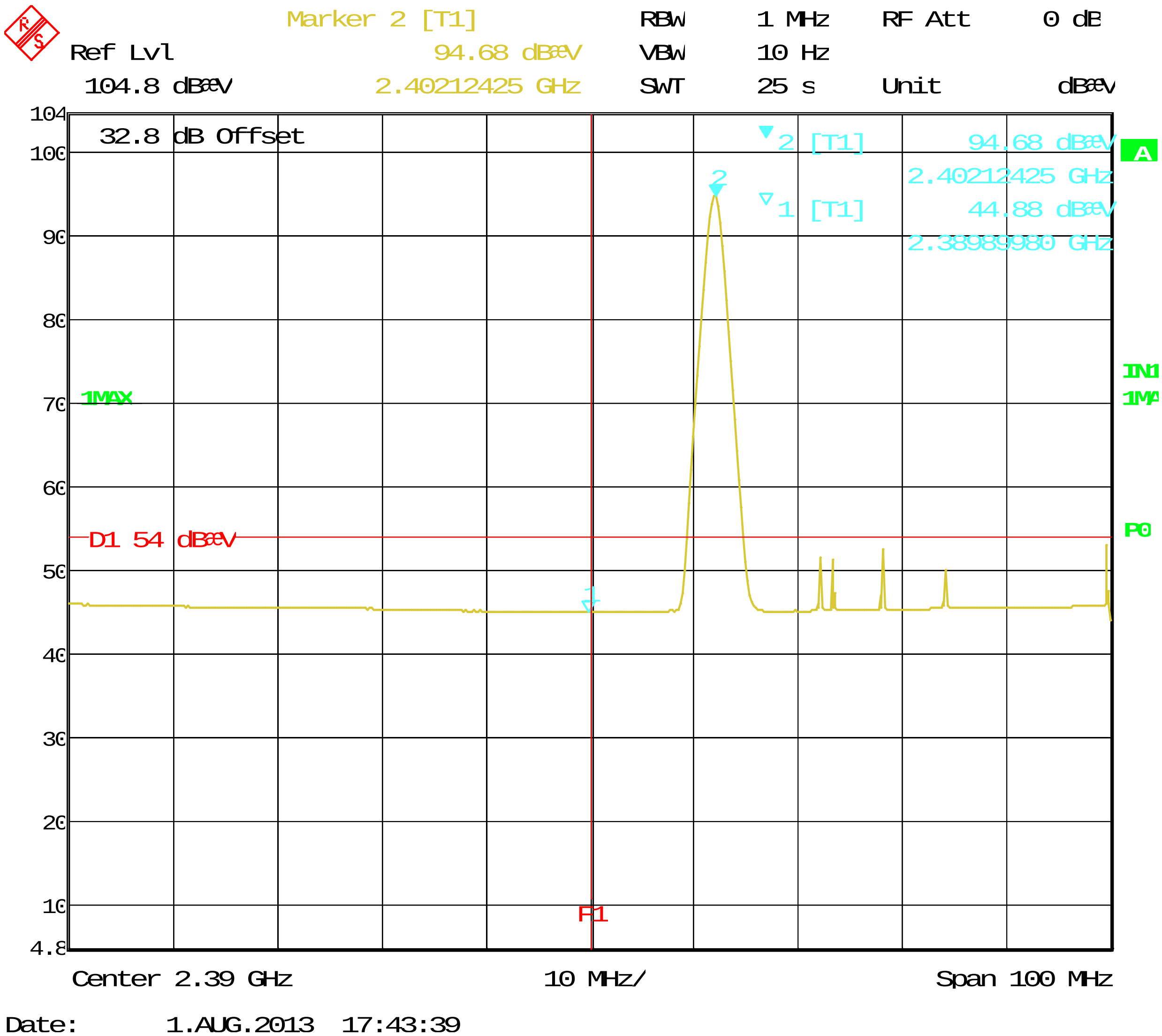


Figure 22: Radiated Emission at the Edge for Channel 2402 MHz at 1Mbps – Vertical (avg)

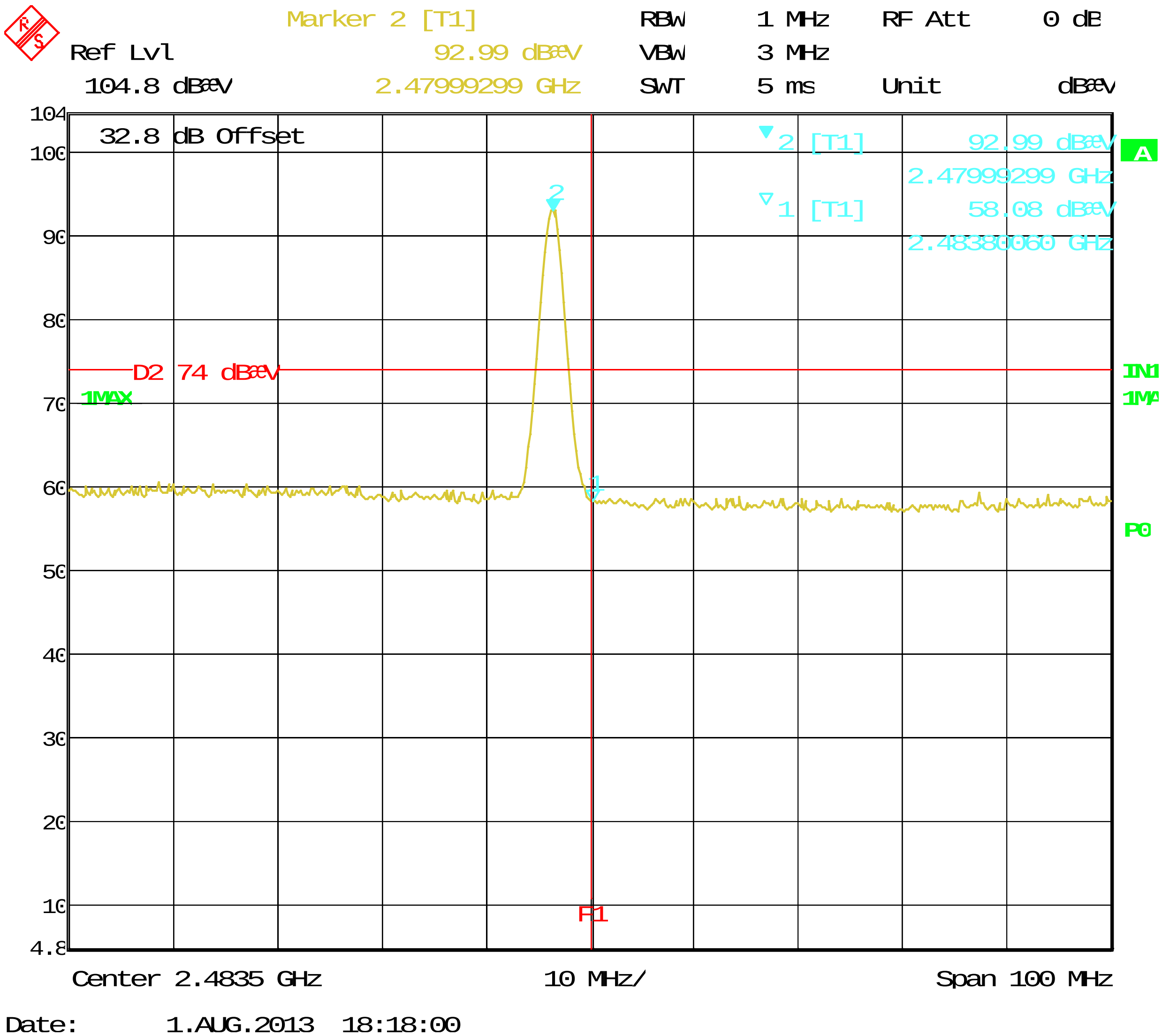


Figure 23: Radiated Emission at the Edge for Channel 2480 MHz at 1Mbps – Horizontal (Pk)

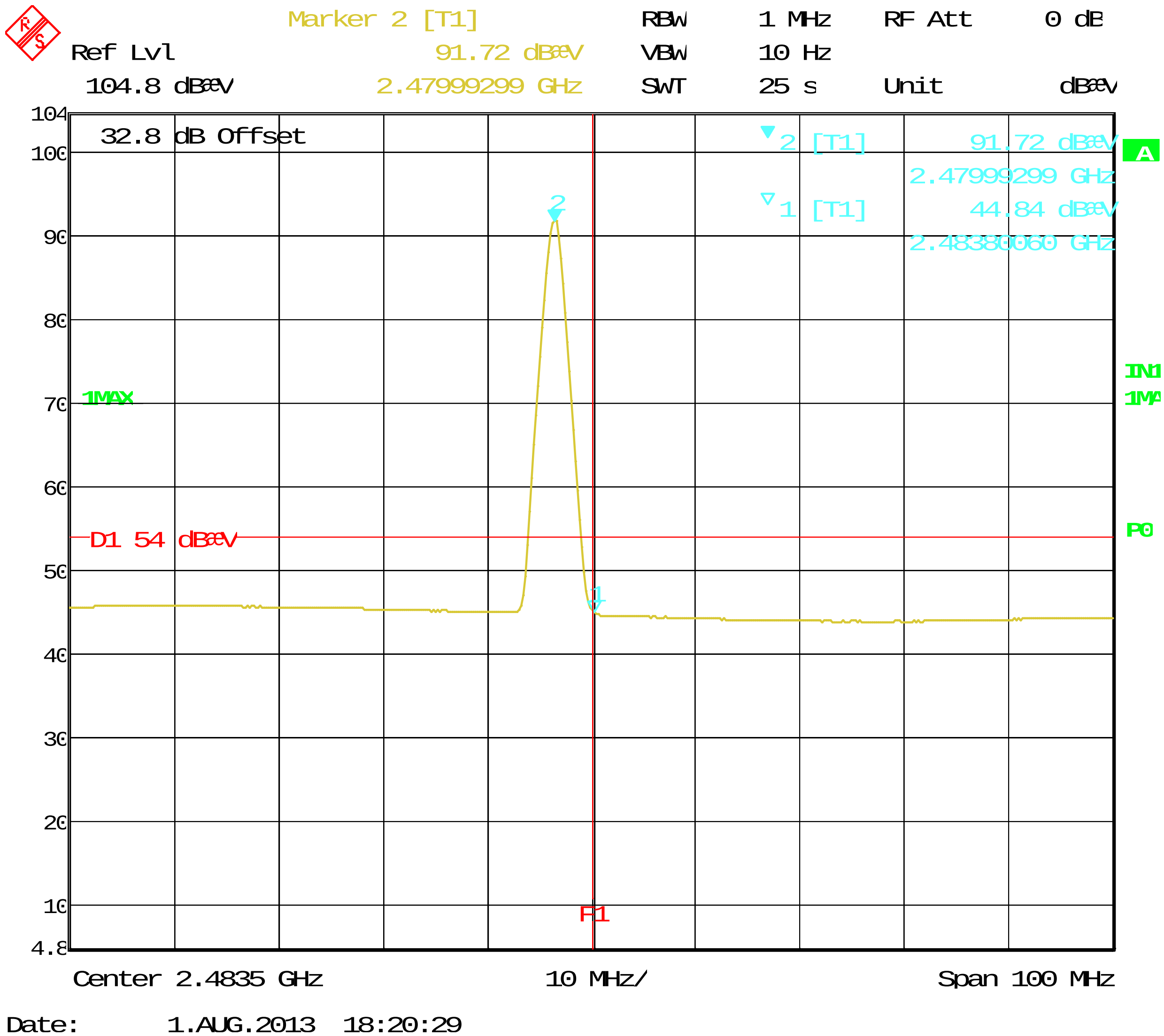


Figure 24: Radiated Emission at the Edge for Channel 2480 MHz at 1Mbps – Horizontal (Avg)

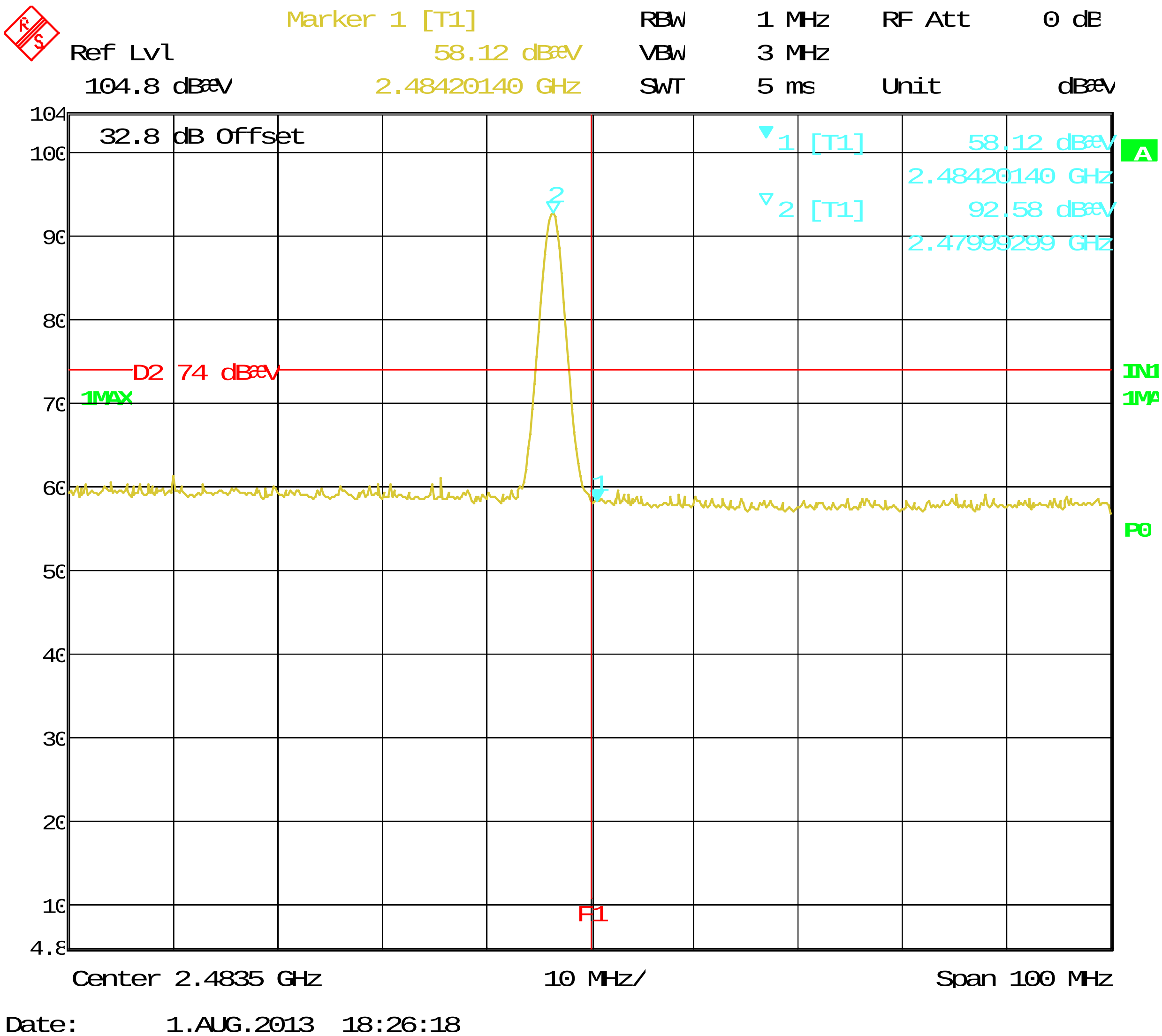


Figure 25: Radiated Emission at the Edge for Channel 2480 MHz at 1Mbps – Vertical (Pk)

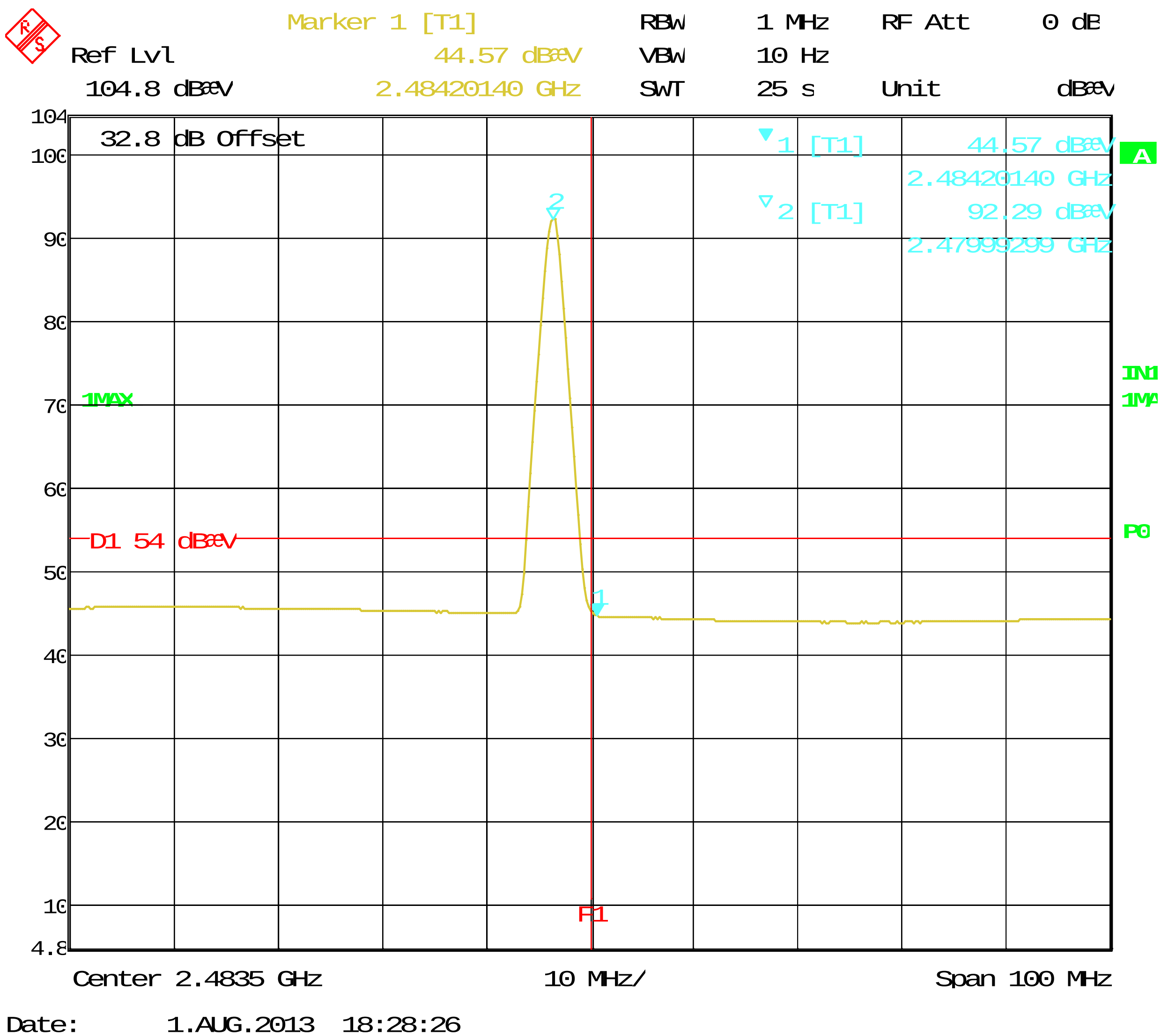


Figure 26: Radiated Emission at the Edge for Channel 2480 MHz at 1Mbps – Vertical (Avg)

Transmitter Spurious Emissions

SOP 1 Radiated Emissions		Tracking # 31362113.001 Page 1 of 8	
EUT Name	Radio Module	**Date**	July 31, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	71	**Temp / Hum out**	N/A
EUT Comfit.	Y-Axis	**Line AC / Freq**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	120KHz/300KHz
Dist/Ant Used	3m /JB3	**Performed by**	Suresh Kondapalli

Sprurious emissions 30 -1000 MHz all 3 channels combined Low, mid and High

Freq	Raw	Cable	AF	Final Level	Meas urement	Pol	Ant Hgt	Azt	Limit	Margin	Result
MHz	dBuV /m	dB	dB	dBuV/ m	QP	-	cm	Deg	dBuV	dB	
30.00	22.09	0.59	-5.44	17.24	QP	H	375	56	40	-22.76	Pass
36.65	21.89	0.65	-10.81	11.74	QP	V	120	188	40	-28.26	Pass
982.96	23.45	3.87	-3.40	23.92	QP	H	266	42	54	-30.08	Pass
35.64	21.93	0.64	-9.92	12.65	QP	V	132	4	40	-27.35	Pass
39.33	22.07	0.67	-12.90	9.84	QP	H	334	106	40	-30.16	Pass
121.56	22.17	1.24	-13.20	10.21	QP	V	105	84	43.5	-33.29	Pass
978.25	23.65	3.87	-3.49	24.03	QP	V	123	54	54	-29.97	Pass
30.63	21.96	0.6	-6.00	16.56	QP	V	262	306	40	-23.44	Pass
34.18	22.00	0.63	-8.77	13.87	QP	V	393	144	40	-26.13	Pass
198.57	22.56	1.61	-13.82	10.35	QP	H	290	215	43.5	-33.15	Pass
928.61	23	3.75	-4.14	22.61	QP	V	213	332	46	-23.39	Pass

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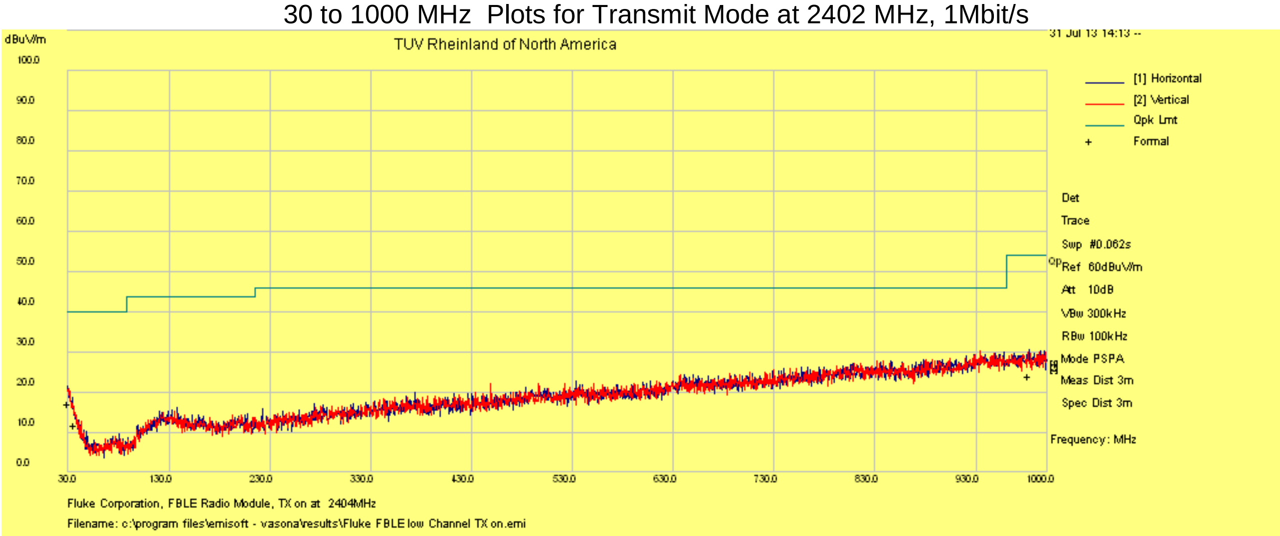
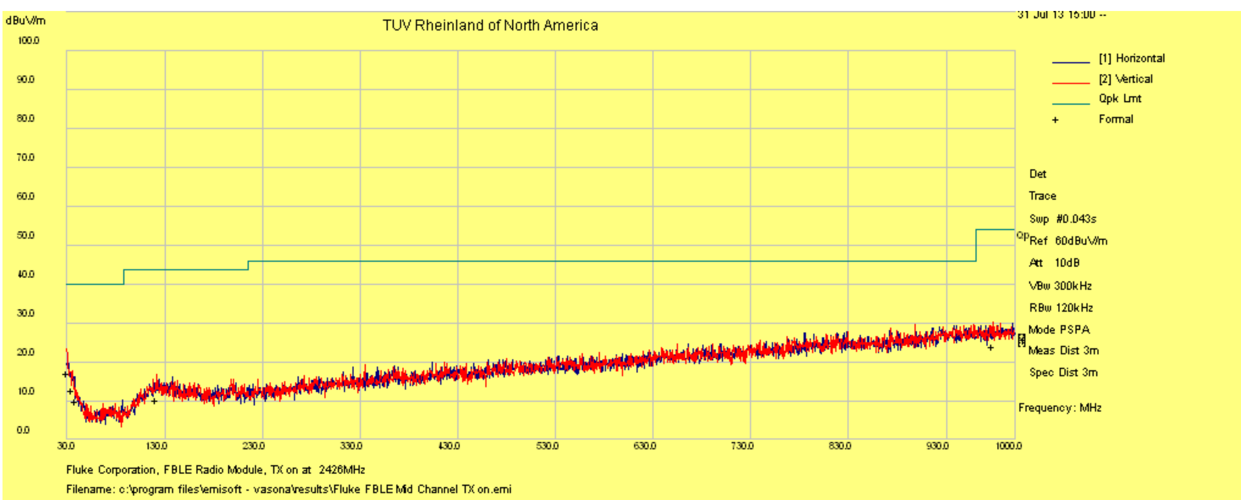
EUT Name	Radio Module	**Date**	July 31, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	71	**Temp / Hum out**	N/A
EUT Config.	Y-Axis,	**Line AC**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	120KHz/300KHz
Dist/Ant Used	3m – JB3	**Performed by**	Suresh Kondapalli

30 to 1000 MHz Plots for Transmit Mode at 2402 MHz, 1Mbit/s



30 to 1000 MHz Plots for Transmit Mode at 2440 MHz, 1Mbit/s



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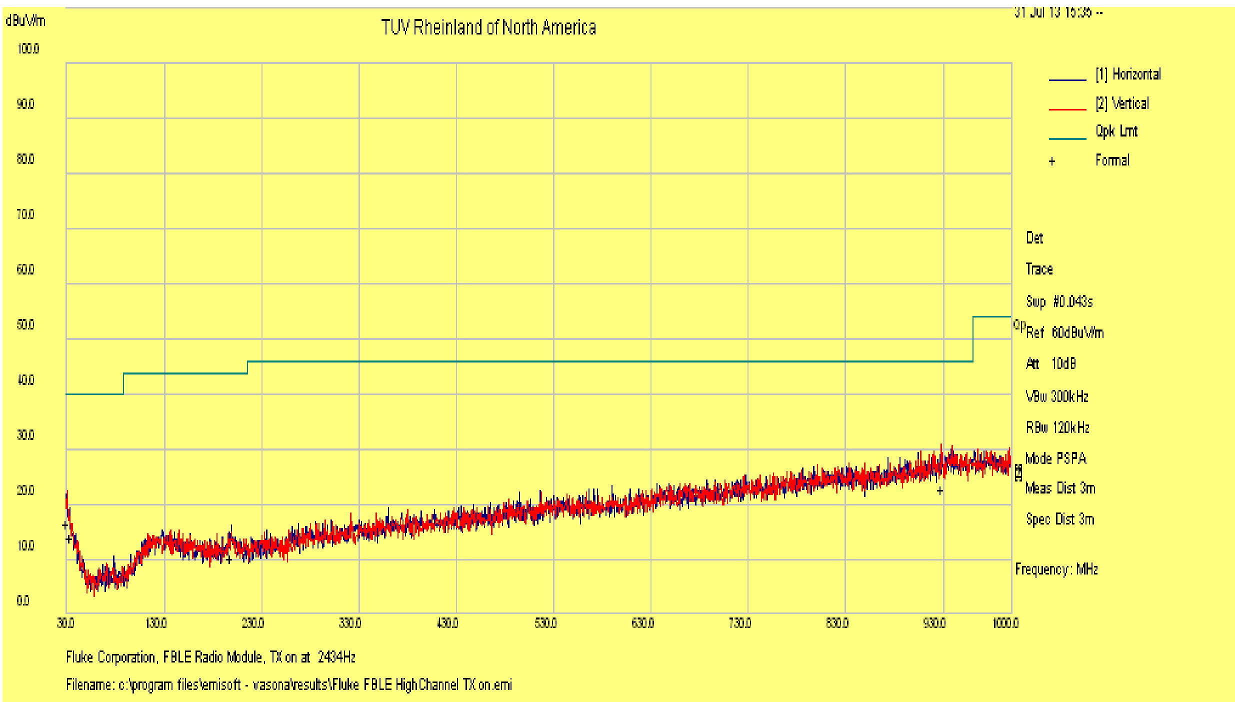
EUT Name	Radio Module	**Date**	July 31, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	71	**Temp / Hum out**	N/A
EUT Config.	Y-Axis,	**Line AC**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	120KHz/300KHz
Dist/Ant Used	3m – JB3	**Performed by**	Suresh Kondapalli

30 to 1000 MHz Plots for Transmit Mode at 2480 MHz, 1Mbit/s



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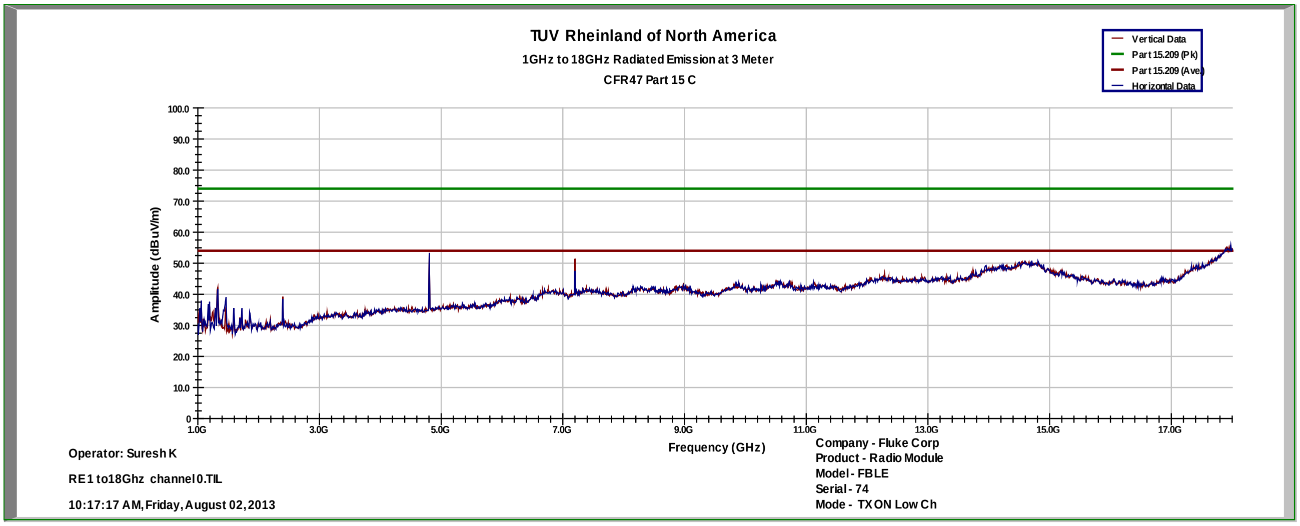
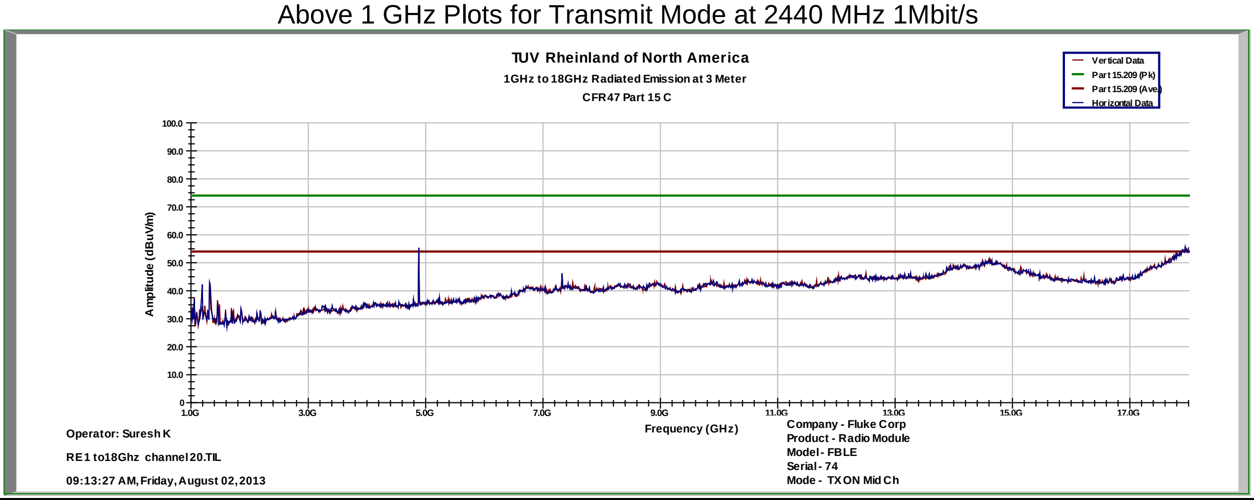
EUT Name	Radio Module	**Date**	Aug 02, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	74	**Temp / Hum out**	N/A
EUT Config.	Y-Axis, 1 Mbps	**Line AC**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	1 MHz / 3 MHz
Dist/Ant Used	3m - EMCO3115	**Performed by**	Suresh Kondapalli

Above 1 GHz Plots for Transmit Mode at 2402 MHz 1Mbit/s

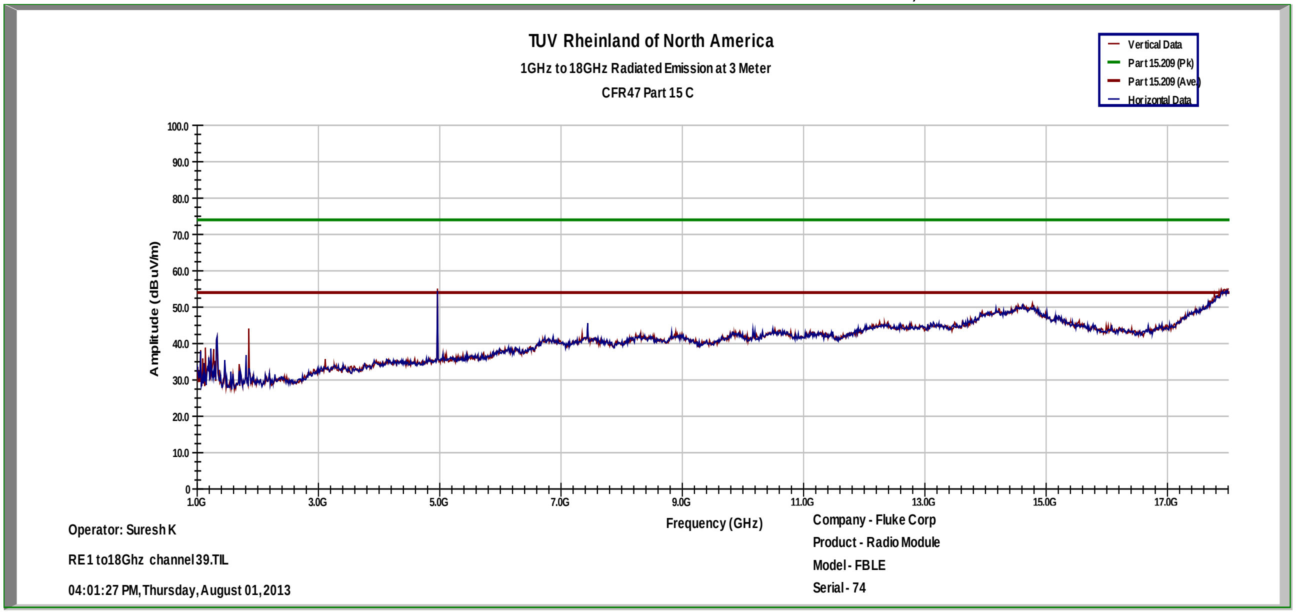


Above 1 GHz Plots for Transmit Mode at 2440 MHz 1Mbit/s



SOP 1 Radiated Emissions		Tracking # 31362113.001 Page 5 of 8	
EUT Name	Radio Module	**Date**	Aug 02, 2011
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	74	**Temp / Hum out**	N/A
EUT Config.	Y-Axis, 1 Mbps	**Line AC**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	1 MHz / 3 MHz
Dist/Ant Used	3m - EMCO3115	**Performed by**	Suresh Kondapalli

Above 1 GHz Plots for Transmit Mode at 2480 MHz, 1Mbit/s



Notes: All Emissions 18 to 26 Ghz were atleast 20 dB below the limt
1 GHz – 25 GHz Setting: RBW = 1 MHz/ VBW = 3 MHz

All emssions 18 to 26GHz were below noise floor level

SOP 1 Radiated Emissions		Tracking # 31362113.001 Page 6 of 8	
EUT Name	Radio Module	**Date**	August 01, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	74	**Temp / Hum out**	N/A
EUT Comfit.	Y-Axis	**Line AC / Freq**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	1 MHz/ 3 MHz
Dist/Ant Used	3m / EMCO3115	**Performed by**	Suresh Kondapalli

TX ON Low Channel 2402 MHz

Freq	Final Level Pk	Level Avg	Duty cycle Corr	Final Level Avg	Pol	Ant Hgt	Azt	Limit	Margin	Result
MHz	dBuV/m	dBuV/m	dB	dBuV/m	-	cm	Deg	dBuV	dB	
1195.68	42.20	25.68	-	25.68	H	119	7	53.98	-28.30	Pass
1329.41	46.87	31.61	-	31.61	V	96	55	53.98	-22.37	Pass
1329.41	41.97	27.89	-	27.89	H	117	308	53.98	-26.09	Pass
4804.03	55.66	54.31	-4.73	49.58	V	103	450	53.98	-4.40	Pass
4804.06	57.79	56.83	-4.73	53.06	H	94	337	53.98	-0.92	Pass
7206.10	51.29	46.19	-	46.19	H	112	217	53.98	-7.79	Pass
7206.13	54.09	51.36	-	51.36	V	139	424	53.98	-2.62	Pass

Spec Margin = E-Field QP - Limit, E-Field QP = FIM QP+ Total CF ± Uncertainty
Total CF= Amp Gain + Cable Loss + ANT Factor

Combined Standard Uncertainty $u_c(y)$ = ± 3.2 dB Expanded Uncertainty $U = ku_c(y)$ k = 2 for 95% confidence

Notes: Duty cycle reduction was applied only to 2nd harmonic. See test plan for details of duty cycle calculation.

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EUT Name	Radio Module	**Date**	August 01, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	74	**Temp / Hum out**	N/A
EUT Comfit.	Y-Axis	**Line AC / Freq**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	1 MHz/ 3 MHz
Dist/Ant Used	3m / EMCO3115	**Performed by**	Suresh Kondapalli

TX ON Low Channel 2440 MHz

Freq	Final Level Pk	Final Level Avg	Duty cycle Corr	Final Level	Pol	Ant Hgt	Azt	Limit	Margin	Result
MHz	dBuV/m	dBuV/m	dB	Avg	-	cm	Deg	dBuV	dB	
1194.72	41.95	25.12	-	20.39	H	130	358	53.98	-28.86	Pass
1329.51	43.24	27.80	-	23.07	V	111	21	53.98	-26.18	Pass
1329.51	42.48	28.58	-	23.85	H	126	21	53.98	-25.40	Pass
4884.03	54.20	52.65	- 4.73	47.92	V	99	466	53.98	-6.06	Pass
4884.09	57.27	56.10	- 4.73	51.37	H	93	343	53.98	-2.61	Pass
7326.10	48.26	41.28	-	36.55	V	132	292	53.98	-12.7	Pass

Spec Margin = E-Field QP - Limit, E-Field QP = FIM QP+ Total CF ± Uncertainty
Total CF= Amp Gain + Cable Loss + ANT Factor

Combined Standard Uncertainty $u_c(y)$ = ± 3.2 dB Expanded Uncertainty $U = ku_c(y)$ k = 2 for 95% confidence

Notes: Duty cycle reduction was applied only 2nd harmonic. See test plan for details duty cycle calculation

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EUT Name	Radio Module	**Date**	August 01, 2013
EUT Model	FBLE	**Temp / Hum in**	23°C / 39%rh
EUT Serial	74	**Temp / Hum out**	N/A
EUT Comfit.	Y-Axis	**Line AC / Freq**	9VDC
Standard	CFR47 Part 15 Subpart C	**RBW / VBW**	1 MHz/ 3 MHz
Dist/Ant Used	3m / EMCO3115	**Performed by**	Suresh Kondapalli

TX ON Low Channel 2480 MHz

Freq	FIM - Pk	FIM - Avg	Corrd	Final Avg Level	Pol	Ant Hgt	Azt	Limit	Margin	Result
MHz	dBuV/m	dBuV/m	dB	dBuV/m	-	cm	Deg	dBuV	dB	
1328.80	49.41	35.26	-7.61	27.65	H	111	384	53.98	-26.33	Pass
1329.09	52.49	38.84	-7.61	31.23	V	102	-59	53.98	-22.75	Pass
1344.33	51.25	42.09	-7.61	34.48	H	109	261	53.98	-19.50	Pass
1680.46	55.61	42.00	-6.23	35.77	H	125	115	53.98	-18.21	Pass
1861.09	43.04	29.70	-4.94	24.76	H	121	-1	53.98	-29.22	Pass
2016.43	44.49	33.05	-4.68	28.37	H	136	109	53.98	-25.61	Pass
3024.38	40.12	28.62	-1.17	27.45	H	127	-8	53.98	-26.53	Pass
4874.36	36.66	26.78	2.52	29.30	H	127	267	53.98	-24.68	Pass
4959.96	50.56	48.45	2.75	51.19	V	101	290	53.98	-2.79	Pass
4960.08	51.32	49.45	2.75	52.20	H	92	313	53.98	-1.78	Pass
7311.50	33.74	20.59	8.29	28.88	H	127	133	53.98	-25.10	Pass
7440.11	41.80	34.16	8.28	42.45	V	100	261	53.98	-11.53	Pass

Spec Margin = E-Field QP - Limit, E-Field QP = FIM QP+ Total CF ± Uncertainty
Total CF= Amp Gain + Cable Loss + ANT Factor

Combined Standard Uncertainty $u_c(y)$ = ± 3.2 dB Expanded Uncertainty $U = ku_c(y)$ k = 2 for 95% confidence

Notes: Worst case was observed on Y-axis, 1 Mbps. No duty cycle reduction was applied. Low, mid and high channels were evaluated for 30 MHz to 26 MHz, only worst case results are reported here.

4.7.4 Sample Calculation

The field strength is calculated by subtracting the Amplifier Gain and adding the Cable Loss and Antenna Correction Factor to the measured reading. The basic equation is as follows:

Field Strength (dBμV/m) = FIM - AMP + CBL + ACF

Where:

FIM = Field Intensity Meter (dBμV)
AMP = Amplifier Gain (dB)
CBL = Cable Loss (dB)
ACF = Antenna Correction Factor (dB/m)

$$\mu V/m = 10^{\frac{dB\mu V/m}{20}}$$

4.8 AC Conducted Emissions

Testing was performed in accordance with ANSI C63.4-2009. These test methods are listed under the laboratory's A2LA Scope of Accreditation.

This test measures the levels emanating from the EUT's AC input port, thus evaluating the potential for the EUT to cause radio frequency interference to other electronic devices.

The AC conducted emissions of equipment under test shall not exceed the values in CFR47 Part 15.207: 2011 and RSS 210: 2010.

4.8.1 Test Methodology

A test program that controls instrumentation and data logging was used to automate the AC Power Line Conducted emission test procedure. The frequency range of interest was divided into sub-ranges such as to yield a frequency resolution of 9 kHz. Each phase and neutral of the AC power line were measured with respect to ground. Measurements were performed using a set of 50μH / 50Ω LISNs.

Testing is either performed inLab 5. The setup photographs clearly identify which site was used. The vertical ground plane used in the semi-anechoic chamber is a 2m x 2m solid aluminum frame and panel, and it is bonded to the horizontal ground plane.

In the case of tabletop equipment, the EUT is placed on a 1.0m x 1.5m non-conductive table 80cm above the ground plane and 40cm from a vertical ground reference plane. The rear of the EUT was positioned flush with the backside of the table and directly over the LISNs. The power and I/O cables were routed over the edge of the table and bundled approximately 40cm from the ground plane. Support equipment was powered from a separate LISN.

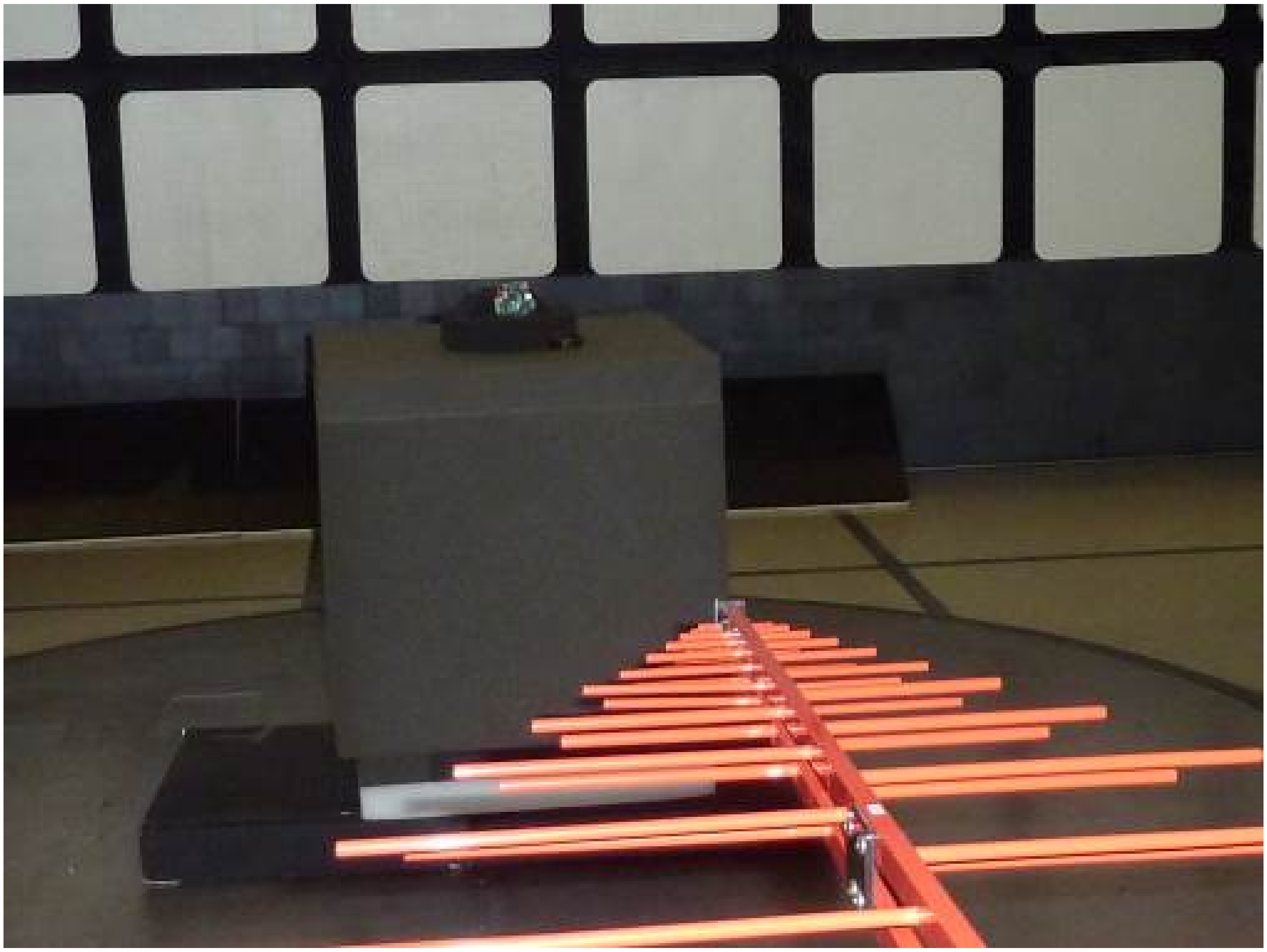
4.8.1.1 Deviations

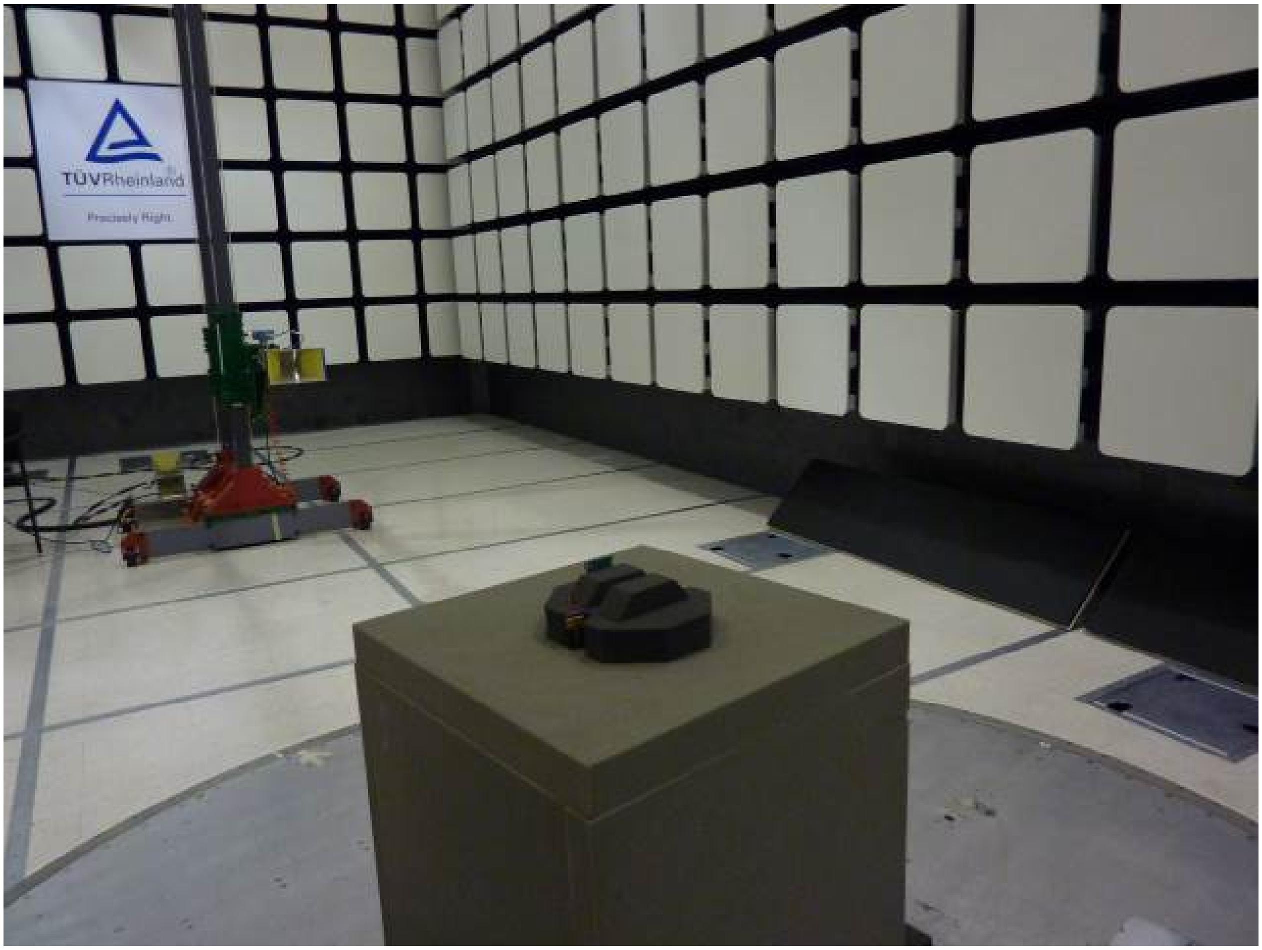
There were no deviations from this test methodology.

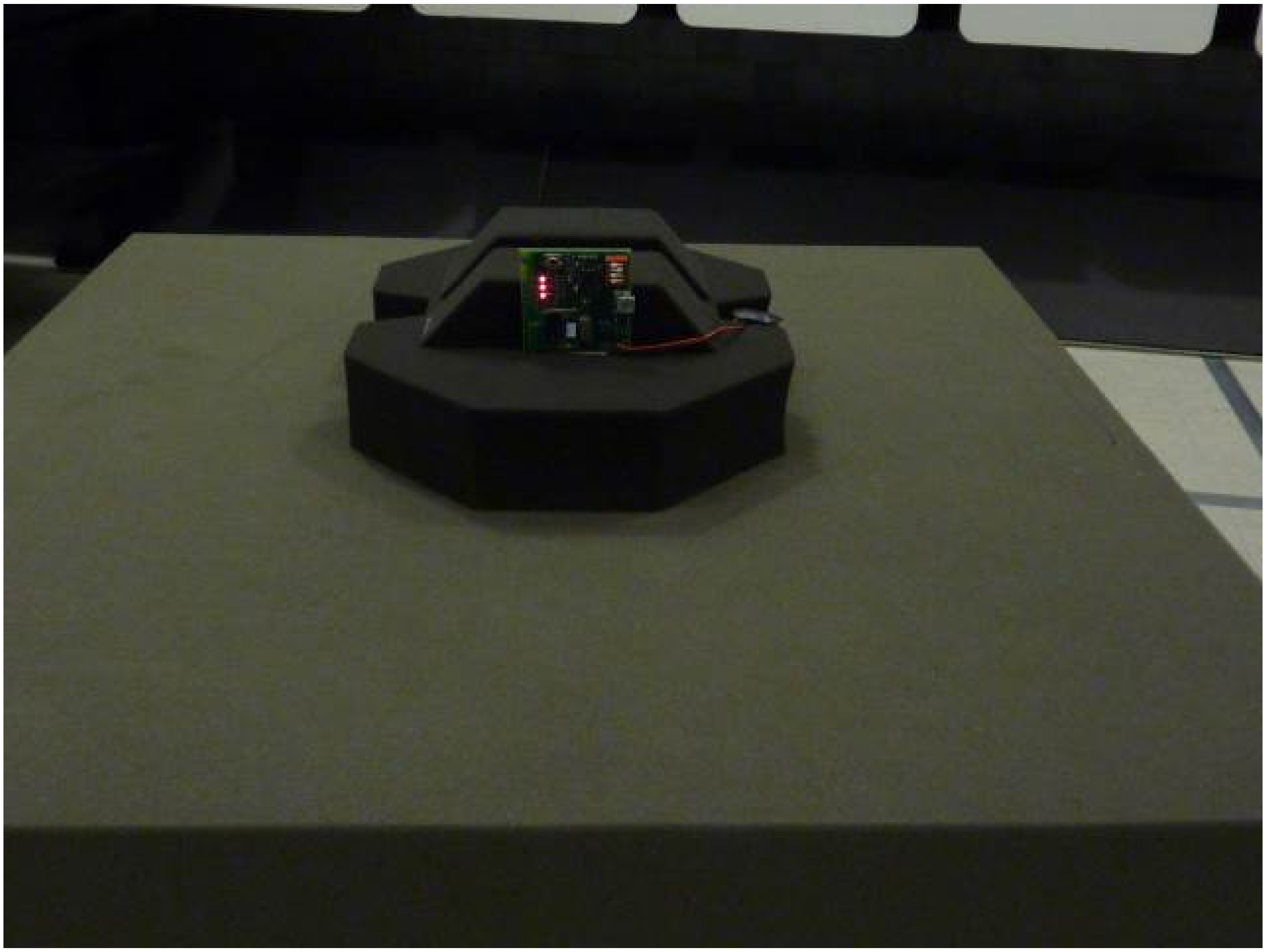
4.8.2 Test Results

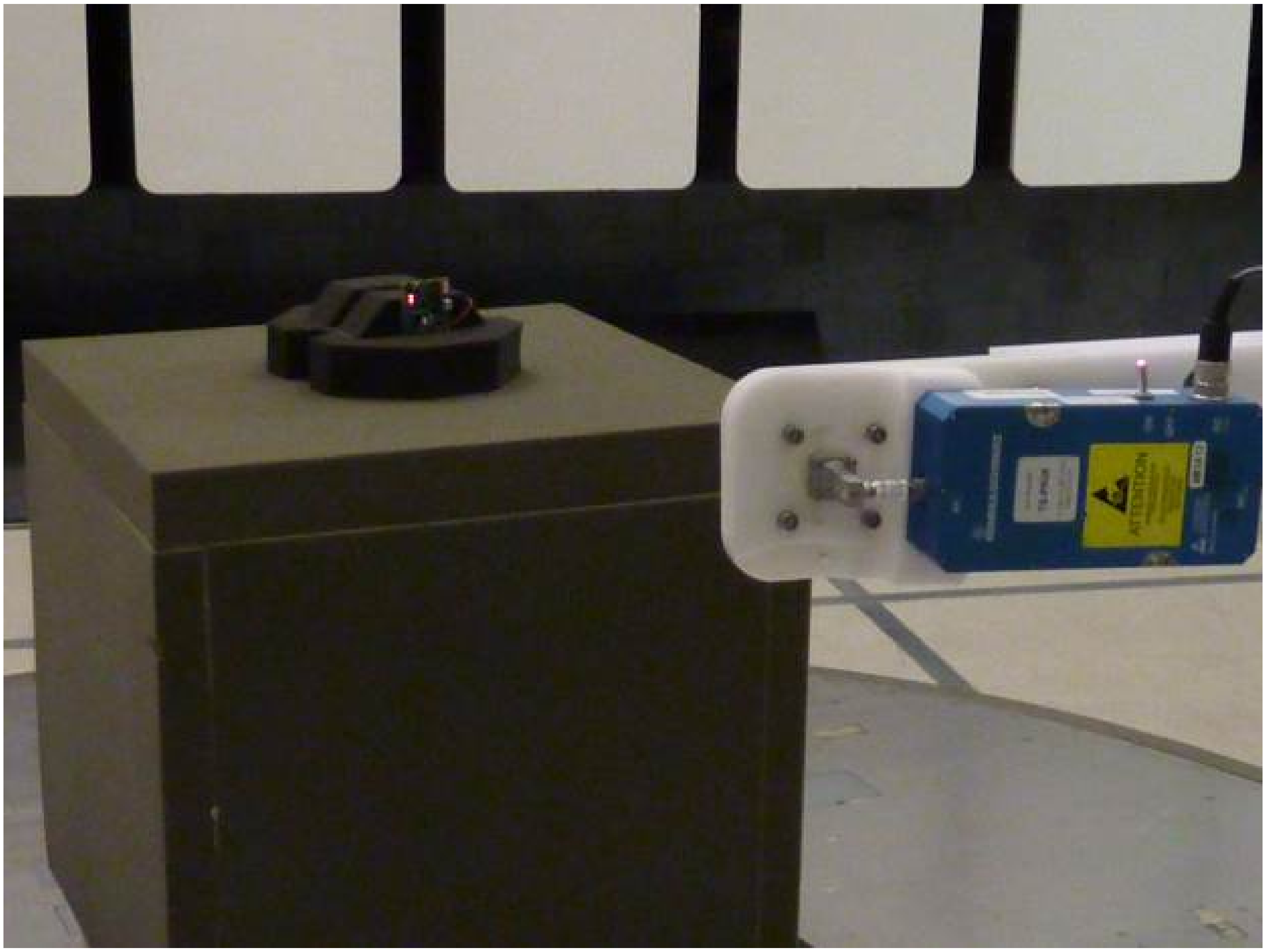
Test not applicable. EUT is powered from Host device and Host device is alkaline battery operated.

4.8.3 Test Setup Photos




TÜVRheinland
Precisely Right.





5 Test Equipment Use List

5.1 Equipment List

Equipment	Manufacturer	Model #	Serial/Inst #	Last Cal mm/dd/yy	Next Cal mm/dd/yy
Horn	EMCO	3115	9602-4676	10/05/2012	10/05/2014
Biconilog Antenna	Sunol Science	JB3	A102606	05/15/2012	05/15/2014
Passive Loop Antenna	ETS-Lindgren	6511	66507	01/24/2013	01/24/2014
EMI Receiver	Hewlett Packard	8546A	3807A00445	01/18/2013	01/18/2014
Pre-selector	Hewlett Packard	85460A	3704A00407	01/18/2013	01/18/2014
Amplifier	Hewlett Packard	8447D	2944A07996	01/16/2013	01/16/2014
Spectrum Analyzer	Rohde-Schwarz	FSL6	100169	01/16/2013	01/16/2014
Spectrum Analyzer	Rohde-Schwarz	ESIB40	832427/002	1/16/2013	1/16/2014
Amplifier	Rohde-Schwarz	TS-PR18	100019	1/16/2013	1/16/2014
Amplifier	Rohde-Schwarz	TS-PR26	100011	1/16/2013	1/16/2014
Signal Generator	Anritsu	MG3694A	42803	1/17/2013	1/17/2014
Notch Filter	Micro-Tronics	BRM50702	37	1/17/2013	1/17/2014
Notch Filter	Micro-Tronics	BRC50705	9	1/17/2013	1/17/2014
High Pass Filter (8.5 GHz)	Micro-Tronics	HPM50107	4	1/17/2013	1/17/2014
Digital Multimeter	Fluke	177	92780314	1/18/2013	1/18/2014
LISN	Com-Power	LI-215	12111	1/16/2013	1/16/2014
Spectrum Analyzer	Agilent	E4407B	SG43330468	09/06/2013	09/06/2014
Bi-log Antenna	Sunol Science	JB3	A102606	05/15/2012	05/15/2014

* Calibration of equipment past due for re-calibration will be performed expeditiously. If any equipment is found to be out of tolerance at that time, affected customers will be notified accordingly.

6 EMC Test Plan

6.1 Introduction

This section provides a description of the Equipment Under Test (EUT), configurations, operating conditions, and performance acceptance criteria. It is an overview of information provided by the manufacturer so that the test laboratory may perform the requested testing.

6.2 Customer

Table 8: Customer Information

Company Name	Fluke Corporation.
Address	6920 Seaway Blvd.
City, State, Zip	Everett, WA 98203
Country	U.S.A.
Phone	(425) 446-5928
Fax	None

Table 9: Technical Contact Information

Name	Dave Epperson
E-mail	dave.epperson@fluke.com
Phone	(425) 446-5928
Fax	(425) 446-4703

Equipment Under Test (EUT)

Table 10: EUT Specifications

EUT Specification	
Dimensions	25mm x 19mm x 2.5mm
Power	EUT is Battery Operated Input Voltage: 3.3 Vdc (9 Vdc at input of test jig) Input Current: 50 mA
Environment	Portable
Operating Temperature Range:	-10 to +50 degrees C
Multiple Feeds:	☐ Yes and how many ☒ No
Hardware Version	None
Part Number	None
RF Software Version	None
Radio Module 802.15.1 -radio module	
Operating Mode	EUT Operates on 802.11 Bluetooth Low Energy (BLE) Protocol
Transmitter Frequency Band	2.400 GHz to 2.4835 GHz
Max. Rated Power Output	See Channel Planning Table.
Power Setting @ Operating Channel	See Channel Planning Table.
Antenna Type	Internal Antenna +3.0 dBi
Modulation Type	☐ AM ☐ FM ☒ DSSS ☐ OFDM ☐Other describe:
Data Rate	1 Mbps EUT Operates on 802.11 protocol
TX/RX Chain (s)	1
Directional Gain Type	☒ Uncorrelated ☒ No Beam-Forming ☐ Other describe:
Type of Equipment	☐ Table Top ☐Wall-mount ☐ Floor standing cabinet ☒Other *Portable*

Table 11: EUT Channel Power Specifications

No.	Frequency (MHz)	802.11
1	2402	1.0 dBm
2	2440	1.0 dBm
3	2480	1.0 dBm

Note: 1.The power levels shown here are with 100% duty cycle. Duty cycle factor for a comparison with limits.
2. This report only documents frequency range 2400 - 2483.5 MHz

Duty Cycle:

Duty cycle correction factor of - 4.73dB (58%) was applied to pass transmitter spurious emissions. As per Fluke Corporation the units operates under 58% duty cycle.

The following duty cycle descrition provided by Fluke Corporation.

One of the exceptionally complicated parts of wireless technology is the actual radio that is used. Most of these radios are built by using bulk CMOS[2] technology. This creates a dilemma for designers because to make the radio stable, they need to increase the cost by adding circuitry to keep the frequency stable. Bluetooth low energy solves this for them because the packet length is sufficiently small that this heating effect is minimized. It does not need a very long packet to cause this problem. The 3-millisecond packets in Bluetooth classic are long enough to cause problems.

This very simple design decision emphasizes the level of detail that the designers of Bluetooth low energy have taken, optimizing the Link Layer specification by taking into account the physical properties of the silicon manufacturing processes used.

If the packets are never more than a few hundred microseconds in length, then no calibration of the radio or stabilization circuitry will be required. The frequency can drift for this period of time without concerns that it will drift outside the frequency drift requirements stated in the specifications. In Bluetooth low energy, the longest possible packet is 376 microseconds; this is short enough that the heating up of the silicon will not change the frequency of transmitted packets enough to drift outside the limits allowed. While in a connection, the longest possible packet is smaller at just 328 microseconds, as depicted in Figure 7–31.

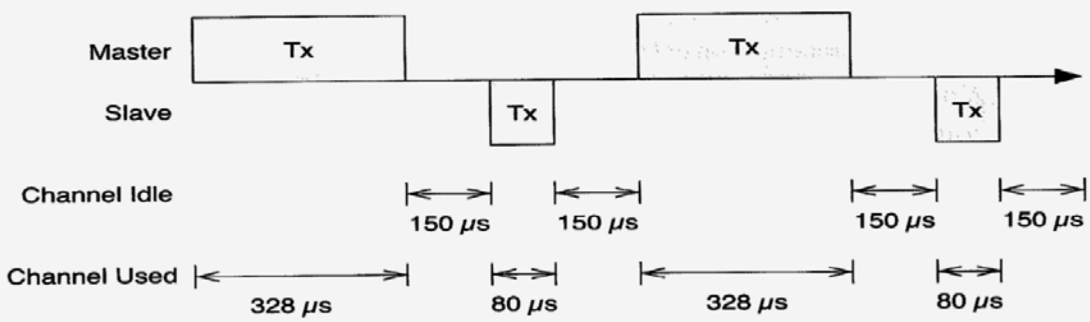


Figure 7–31 Short packets

2. Complimentary Metal on Silicon (CMOS) is used to manufacture over 95 percent of all silicon chips. It is a very low-cost technology.

Therefore, by keeping packets short, there is no need for constant calibration of the radios. This reduces peak power consumption by reducing the quantity and complexity of circuitry that is required to be powered during a packet transmission or reception.

It should also be noted that after transmitting a very long packet, a gap of 150 microseconds is required. This interpacket gap allows the silicon to cool down between packets. Thus, allowing no calibration of frequencies needed between transmitting and receiving or receiving and transmitting packets, further reducing power consumption. This means that when transmitting data in one direction on an encrypted link, the maximum duty cycle is just:

$$\frac{maximum\ size\ packet + acknowledge\ packet}{total\ time\ to\ send\ and\ acknowledge\ data}$$

$$\frac{328 + 80}{(328 + 150 + 80 + 150)} = \frac{408}{708} = \sim 58\%$$

A 58 percent duty cycle is very low for a wireless technology. Bluetooth classic has a duty cycle of 72 percent, whereas very high-speed wireless technologies will have duty cycles in the high 90 percent range. Bluetooth low energy is optimized for small discrete pieces of data being sent, not for the highest possible throughput of data.

Table 12: Interface Specifications: None

Table 13: Supported Equipment : None

Table 14: Description of Sample Used for Testing

Device	Serial Number	RF Connection	CFR47 Part 15.247
Radio Module	74	Internal Antenna	TX Emission, RX Emission
	71 66	SMA Connector (This was installed by Fluke for test purposes only)	RF Power Output, Out of Band Emission, Number of Channels, Channel Separation and Channel Occupancy Time Occupied Bandwidth

Table 15: Description of Test Configuration used for Radiated Measurement.

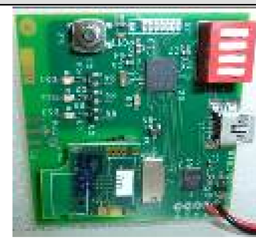
Device	Antenna	Mode	Setup Photo (X-Axis)	Setup Photo (Y-Axis)	Setup Photo (Z-Axis)
Radio Module	Internal	* Transmit * Receive	 Flat on table	 EUT set on wall laying on longer side.	 EUT Vertical
Note: Pre-scans were performed in 3 orthogonal axes and **Y-Axis was worst case.**					

Table 16: Final Test Mode for 2400 MHz to 2483.5 MHz Band

Test	802.11
Occupied Bandwidth	2402, 2440, 2480 MHz @ 1 Mbps
Output Power	2402, 2440, 2480 MHz @ 1 Mbps
Channel separation, number of channels and channel Occupancy time	2402, 2440, 2480 MHz @ 1 Mbps
Out-of-Band (-20 dBr)	2402, 2440, 2480 MHz @ 1 Mbps
Band Edge (Radiated)	2402 and 2480 MHz @ 1 Mbps
Transmitted Spurious Emission	2402, 2440, 2480 MHz @ 1 Mbps
AC Conducted Emission	Test Not Applicable

6.3 Test Specifications

Testing requirements

Table 17: Test Specifications

Emissions and Immunity	
Standard	**Requirement**
CFR 47 Part 15.247: 2013	All
RSS 210 Issue 8, 2010	All

END OF REPORT