2.4GHz BTLE Radio Test Report

(DTS)

For
IW9165E-B (BLE Radio)
IW9165E-A (BLE Radio)

Supports

5/6 GHz 802.11 a/ac/ax/n Wi-Fi + Bluetooth LE v5.0 + GNSS radio

FCC ID: LDKIW9165E IC: 2461A-IW9165E

Against the following Specifications:

47 CFR 15.247

47 CFR 15.209

47 CFR 15.205

RSS-Gen issue 5

RSS-247 Issue 3

A2LA ACCREDITED
CERTIFICATE #1178.01

Cisco Systems

EMC Laboratory

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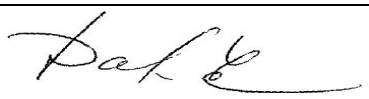
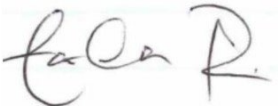
Author:	
Tested By: **Title**: Test Engineers	 Danh Le  Farida Rahmanzai
Approved By: Howard Ji **Title**: Compliance Manager	
Revision	1.0

This report replaces any previously entered test report under EDCS – This test report has been electronically authorized and archived using the CISCO Engineering Document Control system.
Test Report Template EDCS# 703456

Table of Contents

Section 1: Overview

1.1 Test Summary

Samples were assessed against the tests detailed in section 3 under the requirements of the following specifications:

Specifications
47 CFR 15.205 47 CFR 15.209 47 CFR 15.247 RSS-247 Issue 3 RSS-Gen Issue 5

Section 2: Assessment Information

2.1 General

This report contains an assessment of an apparatus against Electromagnetic Compatibility Standards based upon tests carried out on the samples submitted. The testing was performed by and for the use of Cisco systems Inc:

With regard to this assessment, the following points should be noted:

a) The results contained in this report relate only to the items tested and were obtained in the period between the date of the initial assessment and the date of issue of the report. Manufactured products will not necessarily give identical results due to production and measurement tolerances.

b) The apparatus was set up and exercised using the configuration and modes of operation defined in this report only.

c) Where relevant, the apparatus was only assessed using the susceptibility criteria defined in this report and the Test Assessment Plan (TAP).

d) All testing was performed under the following environmental conditions:

Temperature	15°C to 35°C (54°F to 95°F)
Atmospheric Pressure	860mbar to 1060mbar (25.4" to 31.3")
Humidity	10% to 75*%

*[Where applicable] For ESD testing the humidity limits used were 30% to 60% and for EFT/B tests the humidity limits used were 25% to 75%.

e) All AC testing was performed at the following supply voltage:
110V 60 Hz (+/-20%)

2.2 Units of Measurement

The units of measurements defined in the appendices are reported in specific terms, which are test dependent. Where radiated measurements are concerned these are defined at a particular distance. Basic voltage measurements are defined in units of [dBuV]

As an example, the basic calculation for all measurements is as follows:

Emission level [dBuV] = Indicated voltage level [dBuV] + Cable Loss [dB] + Other correction factors [dB]

The combinations of correction factors are dependent upon the exact test configurations [see test equipment lists for further details] and may include:-

Antenna Factors, Pre Amplifier Gain, LISN Loss, Pulse Limiter Loss and Filter Insertion Loss..

Note: to convert the results from dBuV/m to uV/m use the following formula:-

Level in uV/m = Common Antilogarithm [(X dBuV/m)/20] = Y uV/m

Measurement Uncertainty Values

voltage and power measurements	± 2 dB
conducted emissions measurements	± 1.4 dB
radiated emissions measurements	± 3.2 dB
Operating Frequency measurements	± 2.4 10-7
temperature measurements	± 0.54º.
humidity measurements	± 2.3%
DC and low Operating Frequency measurements	± 2.5%.

Where relevant measurement uncertainty levels have been estimated for tests performed on the apparatus. This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2.

Radiated emissions (expanded uncertainty, confidence interval 95%)

30 MHz – 300 MHz	± 3.8 dB
300 MHz – 1000 MHz	± 4.3 dB
1.0 GHz – 10.0 GHz	± 4.0 dB
10.0 GHz – 18.0 GHz	± 8.2 dB
18.0 GHz – 26.5 GHz	± 4.1 dB
26.5 GHz – 40.0 GHz	± 3.9 dB

Conducted emissions (expanded uncertainty, confidence interval 95%)

30 MHz – 40.0 GHz	± 0.38 dB

A product is considered to comply with a requirement if the nominal measured value is below the limit line. The product is considered to not be in compliance in case the nominal measured value is above the limit line.

2.3 Testing Dates

10-February-2023

2.4 Report Issue Date

19-April-2023

2.5 Testing facilities

This assessment was performed by:

Testing Laboratory

Cisco Systems, Inc.,
125 West Tasman Drive (Building P)
San Jose, CA 95134,
USA

Headquarters

Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134
USA

Registration Numbers for Industry Canada

Cisco System Site	Address	Site Identifier
Building P, 10m Chamber	125 West Tasman Dr San Jose, CA 95134 United States	Company #: 2461N-2
Building P, 5m Chamber	125 West Tasman Dr San Jose, CA 95134 United States	Company #: 2461N-1
Building 7, 5m Chamber	425 E. Tasman Drive San Jose, California 95134 United States	Company #: 2461N-3

Test Engineer(s)

Danh Le
Farida Rahmanzai

2.6 Equipment Assessed (EUT)

IW9165E-B with embedded 2.4GHz BLE radio module.

2.7 EUT Description

The Catalyst IW9165 Series addresses the growing need for reliable client wireless connectivity to mission-critical applications as organizations automate processes and operations. It comes with two 2x2 radios, features an industrial design, and is packed with advanced features.

The Catalyst IW9165E is designed to add ultrareliable wireless connectivity to moving vehicles and machines. Its compact form factor makes it very simple to integrate into industrial assets. It can operate in WGB or Cisco URWB mode to enable any use case and leverages the existing wireless environment.

The Catalyst IW9165E supports Cisco WGB mode, which allows it to connect to a Cisco access point infrastructure, and Universal WGB (uWGB) mode, which allows it to connect to a third-party access point infrastructure. Both of these modes help bridge the wired clients that are behind the WGB to the access point on the infrastructure side.

Low power consumption, rugged IP30 design, small form factor, and DIN rail mount capabilities make the Catalyst IW9165E an ideal wireless client for automated guided vehicle (AGV) and autonomous mobile robot (AMR) deployments. An M12 adapter and rail certifications make the Catalyst IW9165E a preferred choice for onboard train deployments as well.

IW9165E Key Features:

- Dual radio – 5GHz, 5/6GHz
- External antenna – 4 x RP-SMA
- 2x2 MIMO 2SS, Max data rate – 3.6 Gbps
- Operation Modes: CURWB or WGB
- BLE, GNSS, GPIO
- RJ45, M12 – 1 x 2.5Gbps, 1x 1 Gbps
- Dual power input – PoE-in & 24-48VDC
- Dual mounting options – DIN Rail & Wall mount
- IP30, EN50155

Bluetooth LE Radio

- 2.4 GHz BTLE Radio version 5.0
- Number of channels: 40
- Data rate supported: 1 Mbps & 2 Mbps
- Modulation: GFSK
- Advertising Channels: 37, 38 and 39

The following antennas are supported by this product series.
Please note the following antenna gain information was used during the testing.

Operating Frequency	Part Number	Antenna Type	Peak Antenna Gain (dBi)
2.4GHz	AIR-ANT2588P4M-NS=W-ANT-PNL-59-N=	2.4 GHz 8 dBi 4-Element Dual-Polarized Patch Antenna, N Female Connectors	8.0

2.8 Model/PID differences

All PIDs have identical components, PCB layout, electronics circuitries, and enclosure. The only difference is domain code selected in the software.

The model differences are described below:
IW9165E-ROW represents Worldwide PID, except for US & CAN, with ROW domain code selected.
IW9165E-B represents U.S PID with US domain code selected.
IW9165E-A represents Canada PID with Canada domain code selected.

Section 3: Result Summary

3.1 Results Summary Table(s)

RF Conducted Emissions		
Standard(s)	**Test Details / Comments**	**Result**
FCC15.247(a)(2) **RSS-247 5.2(a)**	**99%- & 6-dB Bandwidth** **FCC/RSS**: The 99% occupied bandwidth is the Operating frequency bandwidth such that, below its lower and above its upper Operating Frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission. There is no limit for 99% OBW. The 6 dB emission bandwidth is the width of the emission that is constrained by the Operating Frequencies associated with the two outermost amplitude points (upper and lower Operating Frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission. **FCC:** Systems using digital modulation techniques may operate in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands. **RSS:** DTSs include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400- 2483.5 MHz: The minimum 6dB bandwidth shall be at least 500 kHz	**Pass**
FCC15.247(b)(3) **FCC 15.247(b)(4)**	**Output Power** The maximum conducted output power is the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. **FCC:** The maximum peak conducted output power of the intentional radiator shall not exceed the following: For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt (30 dBm). As an alternative to a peak power measurement, compliance with the one-Watt limit can be based on a measurement of the maximum conducted output power. The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.	**Pass**

RF Conducted Emissions (continue)		
Standard(s)	**Test Details / Comments**	**Result**
RSS-247 5.4(d)	**Output Power (continue)** **RSS:** DTSs include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400- 2483.5 MHz: For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).	**Pass**
FCC15.247(e)/ RSS-247 5.2 (b)	**Power Spectral Density** **FCC/RSS:** The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.	**Pass**
FCC15.247(d)/ RSS-247 5.5	**Conducted Band-Edge / Out of band emissions / Spurious Emissions** **FCC/RSS:** In any 100 kHz bandwidth outside the Operating Frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio Operating Frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in FCC§15.209(a) & RSS-Gen is not required.	**Pass**

Section 4: Sample Details

Note: Each sample was evaluated to ensure that its condition was suitable to be used as a test sample prior to the commencement of testing.

4.1 Sample Details

Sample Number	Equipment Details	Serial Number	CISCO Part Number	Radio FW Version
S01	IW9165E-B with embedded 2.4GHz BLE radio module.	FOC2638BKYB	68-103412-02	QC_Image_Version_String=WLAN.HK .2.7-04509-QCAHKSWPL_Siliconz-1
S02	IW-PWRADPT-MFIT4PN Liteon AC Adaptor	LIN2631203P	341-101392-01	----

4.2 System Details

System #	Description	Samples
1	IW9165E-B with embedded Radio module, radio + ext. PS.	S01, S02

4.3 Test Mode, Modulation and Data Rate Description

Mode	Mode	Modulation	Data Rate	BW
1	BTLE continuous TX (100% DC)	GFSK	1Mbps	1MHz
2	BTLE continuous TX (100% DC)	GFSK	2Mbps	2MHz

Section 5: Modifications

5.1 Sample Modifications Performed During Assessment

No modifications were performed during assessment.

Appendix A: RF Conducted Test Results

Target Maximum Channel Power

The following table details the maximum supported Total Channel Power for the operating mode.

	Maximum Channel Power (dBm)		
	Operating Frequency(MHz)		
Operating Mode	2402	2440	2480
BTLE	-----	-----	4.66

A.1 Duty Cycle

Ref. ANSI C63.10: 2013, Clause 11.6
B. Duty Cycle (x), Transmission Duration (T) and Maximum Power Control Level

Preferably, all measurements of maximum conducted (average) output power will be performed with the EUT transmitting continuously (i.e., with a duty cycle of greater than or equal to 98%). When continuous operation cannot be realized, then the use of sweep triggering/signal gating techniques can be used to ensure that measurements are made only during transmissions at the maximum power control level. Such sweep triggering/signal gating techniques will require knowledge of the minimum transmission duration (T) over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation. Sweep triggering/signal gating techniques can then be used if the measurement/sweep time of the analyzer can be set such that it does not exceed T at any time that data are being acquired (i.e., no transmitter OFF-time is to be considered).

When continuous transmission cannot be achieved and sweep triggering/signal gating cannot be implemented, alternate procedures are provided that can be used to measure the average power; however, they will require an additional measurement of the transmitter duty cycle. Within this guidance document, the duty cycle refers to the fraction of time over which the transmitter is on and is transmitting at its maximum power control level. The duty cycle is constant if variations are less than ± 2 percent, otherwise the duty cycle is considered to be non-constant.

A.1.1 Duty Cycle Test Method

Ref. ANSI C63.10: 2013, Clause 11.6 (b)

Measurements of duty cycle and transmission duration shall be performed using the following technique:

(b) The zero-span mode on a spectrum analyzer or EMI receiver if the response time and spacing between bins on the sweep are sufficient to permit accurate measurements of the on and off times of the transmitted signal.

1) Set the center Operating Frequency of the instrument to the center Operating Frequency of the transmission.
2) Set RBW ≥ OBW if possible; otherwise, set RBW to the largest available value.
3) Set VBW ≥ RBW. Set detector = peak or average.
4) The zero-span measurement method shall not be used unless both RBW and VBW are > 50/T and the number of sweep points across duration T exceeds 100. (For example, if VBW and/or RBW are limited to 3 MHz, then the zero-span method of measuring duty cycle shall not be used if T ≤ 16.7 microseconds.)

Duty Cycle Correction Factor and Duty Cycle Percentage can be derived by using the following formulas:

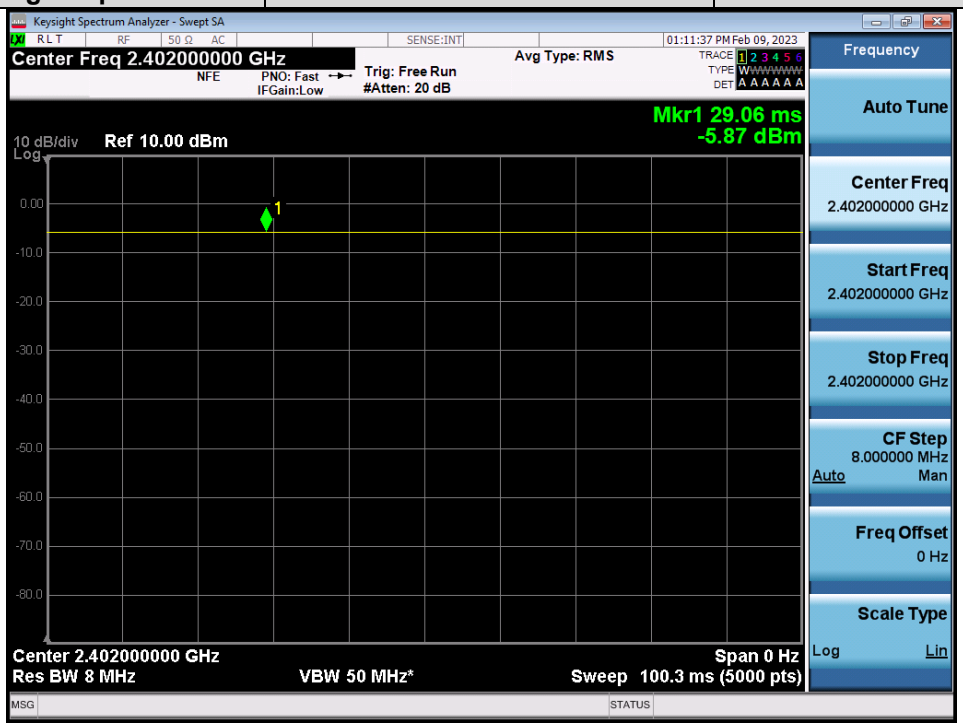
DCCF = 10 log **(**1/ (TXon / TXon + TXoff)**)**
DC % = (TXon / TXon + TXoff) * 100

A.1.2 Duty Cycle Data Table

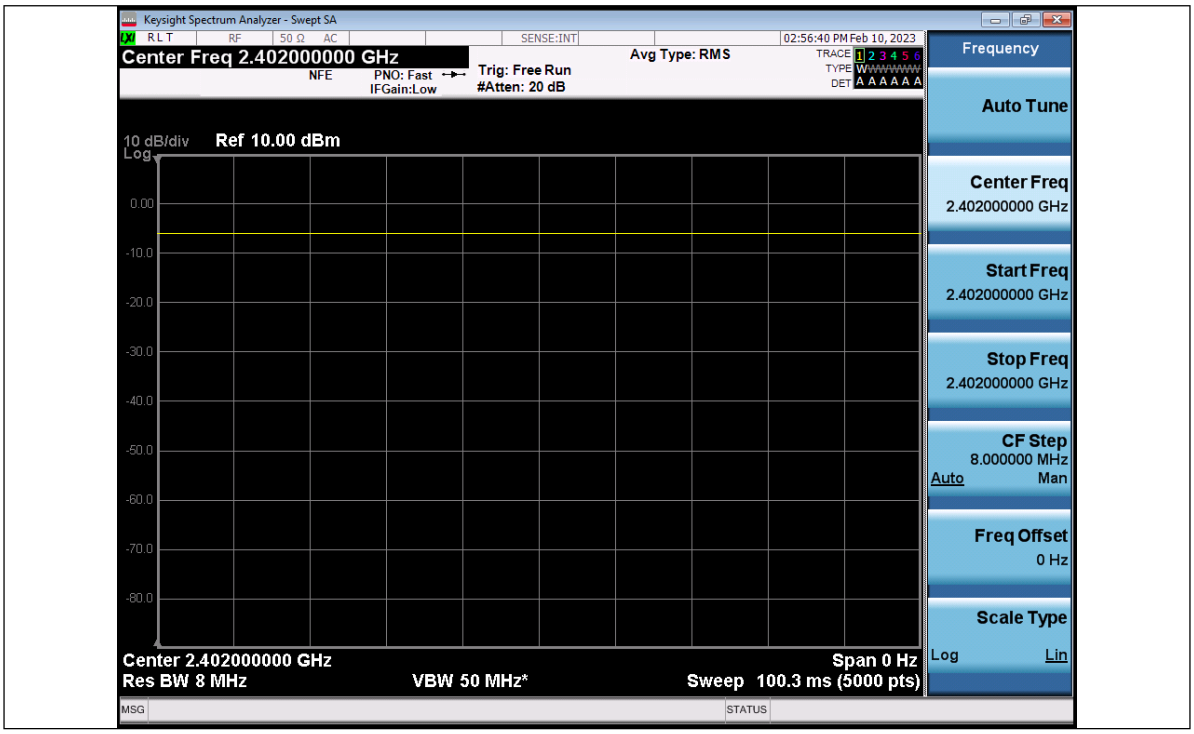
Mode	Data Rate	On-time (ms)	Total on+off Time (ms)	Duty Cycle (%)	Correction Factor (dB)
BTLE	1	--	--	100	--
BTLE	2	--	--	100	--

A.1.3 Duty Cycle Graphical Test results

Operating Freq:: 2402 MHz	Mode: BTLE	Data Rate= 1 Mbps



Operating Freq:: 2402 MHz	Mode: BTLE	Data Rate= 2 Mbps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50 Ω AC
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02:56:40 PM Feb 10, 2023
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NFE
PNO: Fast
IFGain:Low
Trig: Free Run
#Atten: 20 dB
Avg Type: RMS
TRACE 1 2 3 4 5 6
TYPE WWWWW
DET A A A A A
10 dB/div
Log
Ref 10.00 dBm
0.00
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
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Res BW 8 MHz
VBW 50 MHz*
Span 0 Hz
Sweep 100.3 ms (5000 pts)
MSG
STATUS
Frequency
Auto Tune
Center Freq
2.402000000 GHz
Start Freq
2.402000000 GHz
Stop Freq
2.402000000 GHz
CF Step
8.000000 MHz
Auto
Man
Freq Offset
0 Hz
Scale Type
Log
Lin

A.2 99% Occupied Bandwidth and 6 dB Bandwidth

The 99% occupied bandwidth is the Operating Frequency bandwidth such that, below its lower and above its upper Operating Frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission. There is no limit for 99% OBW.

The 6 dB emission bandwidth is defined as the Operating Frequency range between two points, one above and one below the carrier Operating Frequency, at which the spectral density of the emission is attenuated 6 dB below the maximum in-band spectral density of the modulated signal.

A.2.1 Limit

FCC 15.247(a) (2); RSS-247 5.2(a)

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

A.2.2 Test Procedure

Ref. ANSI C63.10: 2013, Clause 11.8.2 Option 2

99% BW and EBW (6dB) Test Procedure
1. The radio is configured in the continuous transmitting mode. 2. Allow the trace to stabilize. 3. Setting the x-dB bandwidth mode to -6dB and OBW power function to 99% within the measurement set up function. 4. Select the automatic OBW measurement function of an instrument to perform bandwidth measurement. 5. Capture graphs and record pertinent measurement data.

99% BW and EBW (6dB) Test parameters
Span =Wide enough to capture the entire emission bandwidth RBW =100 kHz VBW ≥ 3 x RBW Detector =Peak Trace = Max. Hold Sweep = Auto couple

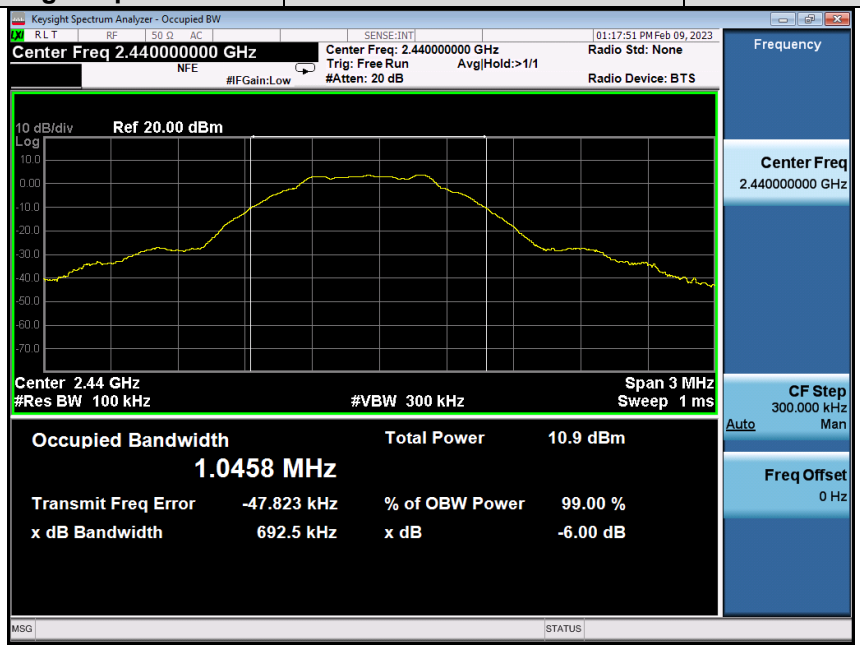
A.2.3 99% and 6dB Occupied Bandwidth Data Table

Operating Frequency (MHz)	Data Rate (Mbps)	99% BW (MHz)	6dB BW (MHz)	6dB BW Limit (kHz)	Result
2402	1	1.045	0.696	≥ 500	Pass
2440	1	1.046	0.693	≥ 500	Pass
2480	1	1.046	0.694	≥ 500	Pass
2402	2	2.064	1.348	≥ 500	Pass
2440	2	2.074	1.346	≥ 500	Pass
2480	2	2.076	1.345	≥ 500	Pass

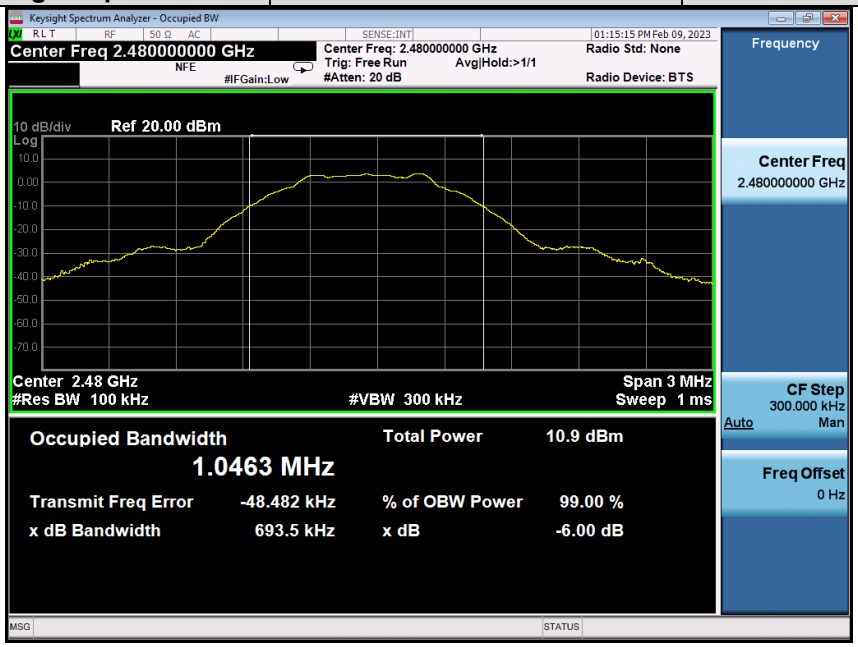
A.2.4 99% and 6dB Occupied Bandwidth Graphical Test Results

Operating Freq: 2402 MHz	Mode: BTLE	Data Rate: 1 Mpbs

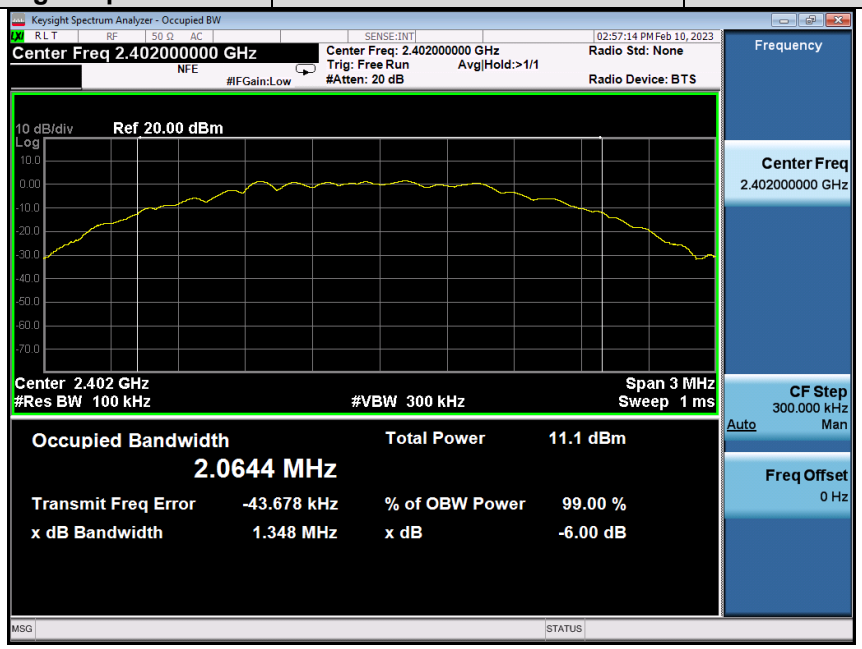
Operating Freq: 2440 MHz	Mode: BTLE	Data Rate: 1 Mbps



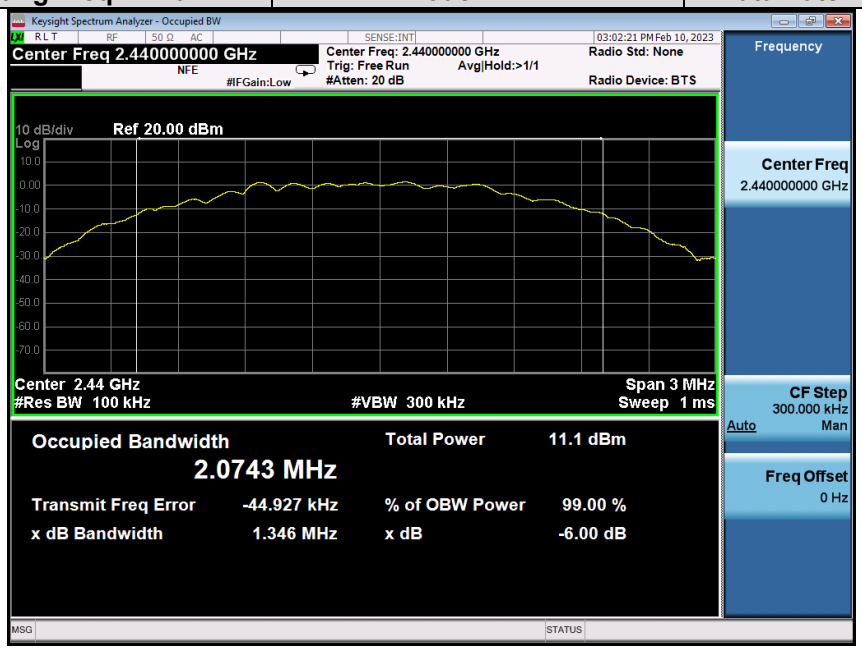
Operating Freq: 2480 MHz	Mode: BTLE	Data Rate: 1 Mbps



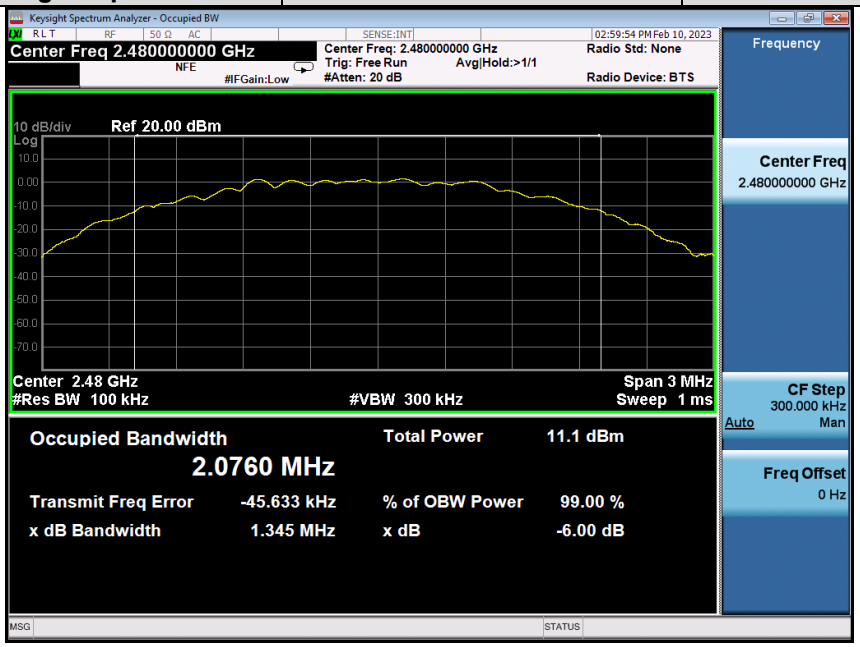
Operating Freq: 2402 MHz	Mode: BTLE	Data Rate: 2 Mpbs



Operating Freq: 2440 MHz	Mode: BTLE	Data Rate: 2 Mbps



Operating Freq: 2480 MHz	Mode: BTLE	Data Rate: 2 Mbps



A.3 Maximum Peak Conducted Output power.

The maximum conducted output power is the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level.

A.3.1 Limits

FCC 15.247 (b)(3):
The maximum peak conducted output power of the intentional radiator shall not exceed the following:
For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt (30 dBm).

FCC 15.247 (b)(4):
The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

RSS-247 (5.4) (d):
DTSs include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400- 2483.5 MHz:

For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).

A.3.2 Test Procedure

Ref. ANSI C63.10:2013 Clause 11.9.1.1 (RBW ≥ DTS Bandwidth)

Max. Peak Conducted Output Power Test Procedure
1. Set the radio in the transmitting mode. 2. Center Operating Frequency of interest. 3. Allow trace to stabilize. 4. Use peak marker or peak-search function to determine the peak amplitude level. 5. Capture graphs and record pertinent measurement data.

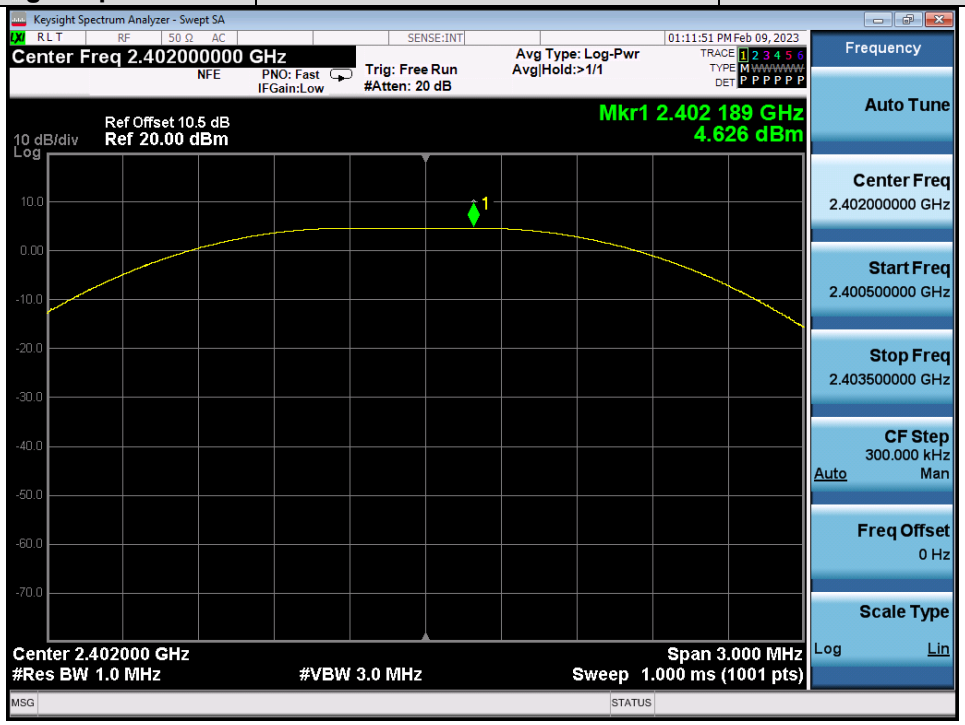
Test parameters
BW ≥ the DTS bandwidth VBW ≥ 3 x RBW Span ≥ 3 times the DTS bandwidth Detector = Peak Trace Mode = Max. Hold Sweep time = Auto

A.3.3 Max. Conducted Output Power & EIRP Data Table

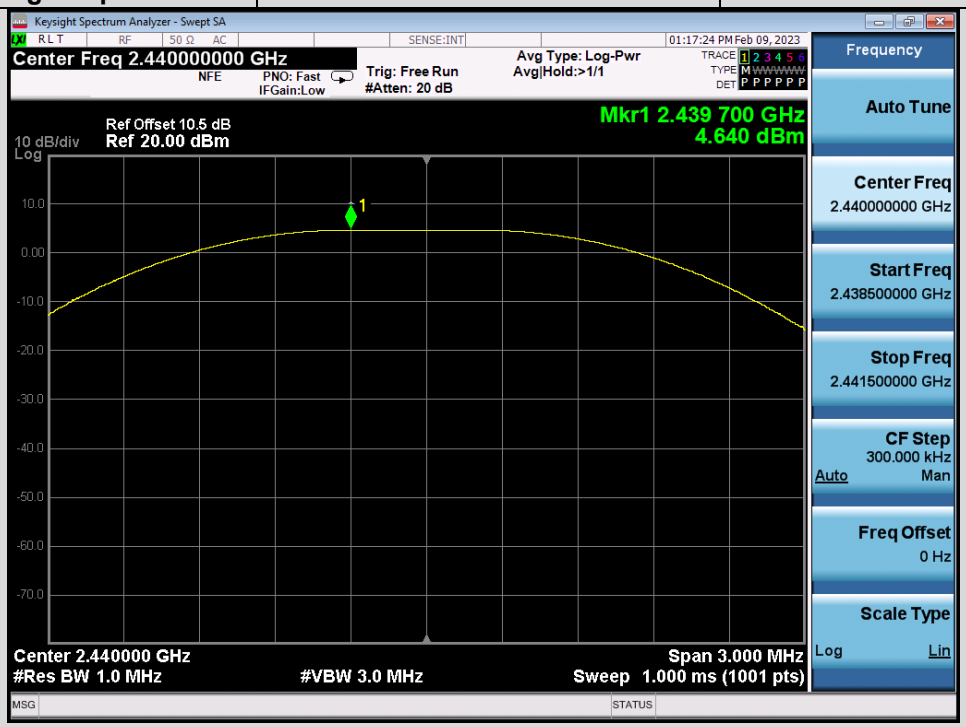
Operating Frequency (MHz)	Mode	Data Rate (Mbps)	Correlated Antenna Gain (dBi)	Tx Conducted Output Power (dBm)	EIRP (dBm)	Conducted Limit (dBm)	EIRP Limit (dBm)	Result
2402	BTLE	1	8.0	4.63	12.63	30	36	Pass
2440	BTLE	1	8.0	4.64	12.64	30	36	Pass
2480	BTLE	1	8.0	4.66	12.66	30	36	Pass
2402	BTLE	2	8.0	4.51	12.51	30	36	Pass
2440	BTLE	2	8.0	4.49	12.49	30	36	Pass
2480	BTLE	2	8.0	4.53	12.53	30	36	Pass

A.3.4 Max. Peak Conducted Output Power Graphical Test Results

Maximum Peak Conducted Output Power		
Operating Freq: 2402 MHz	Mode: BTLE	Data Rate: 1 Mbps

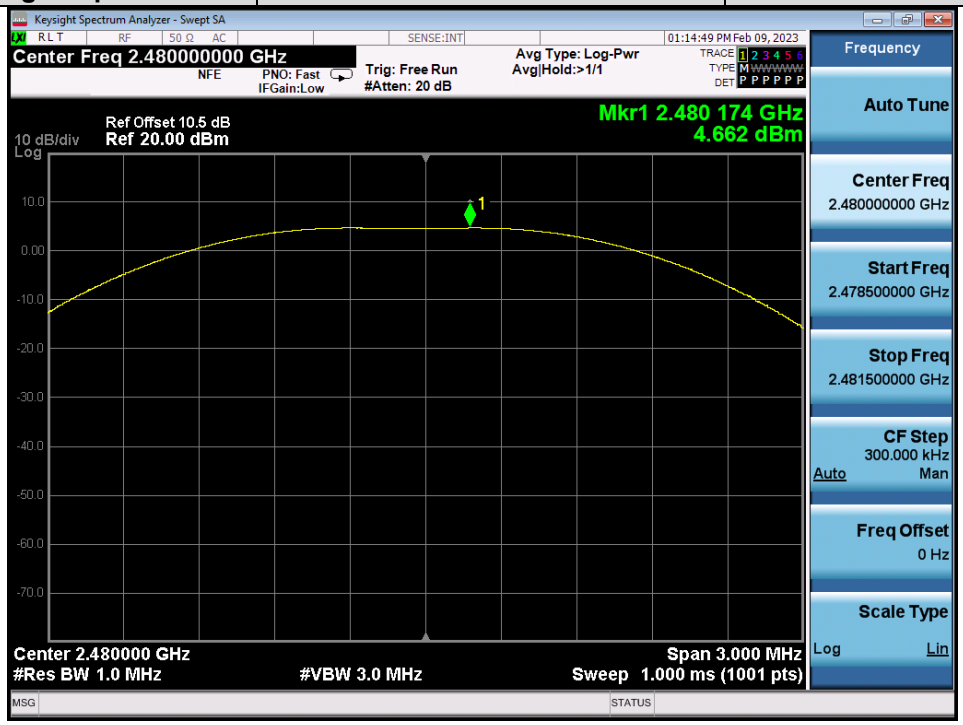


Operating Freq: 2440 MHz	Mode: BTLE	Data Rate: 1 Mbps

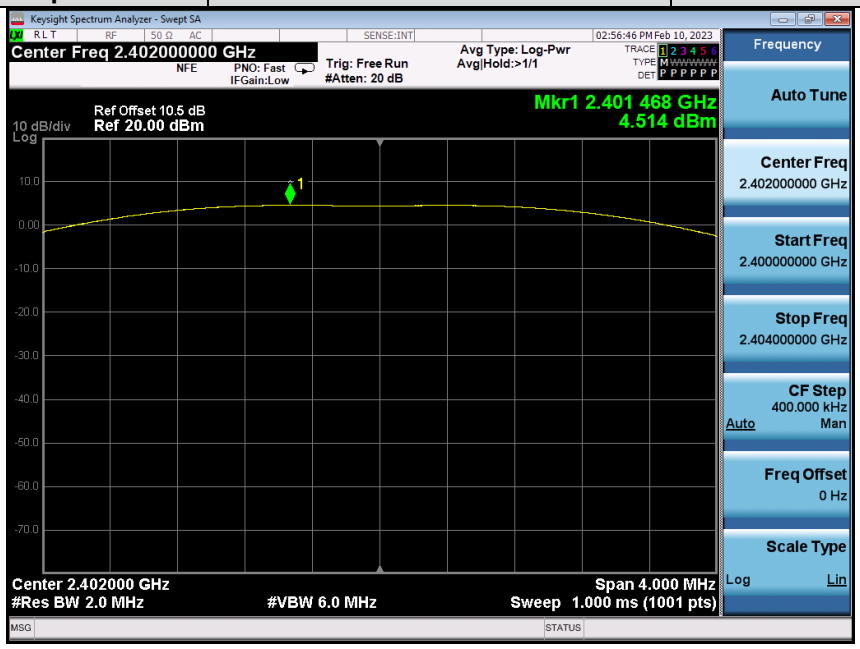


Maximum Peak Conducted Output Power

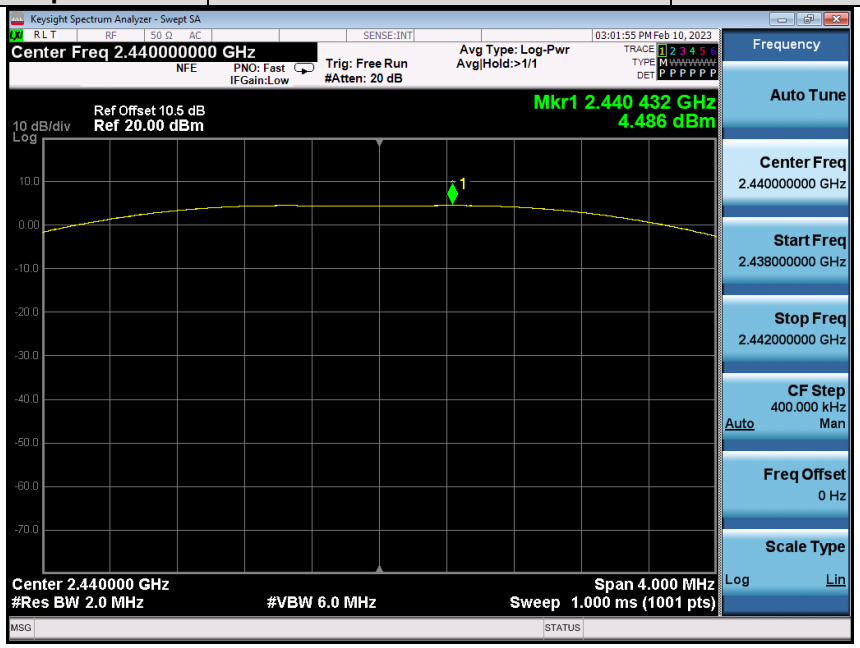
Operating Freq: 2480 MHz	Mode: BTLE	Data Rate: 1 Mbps



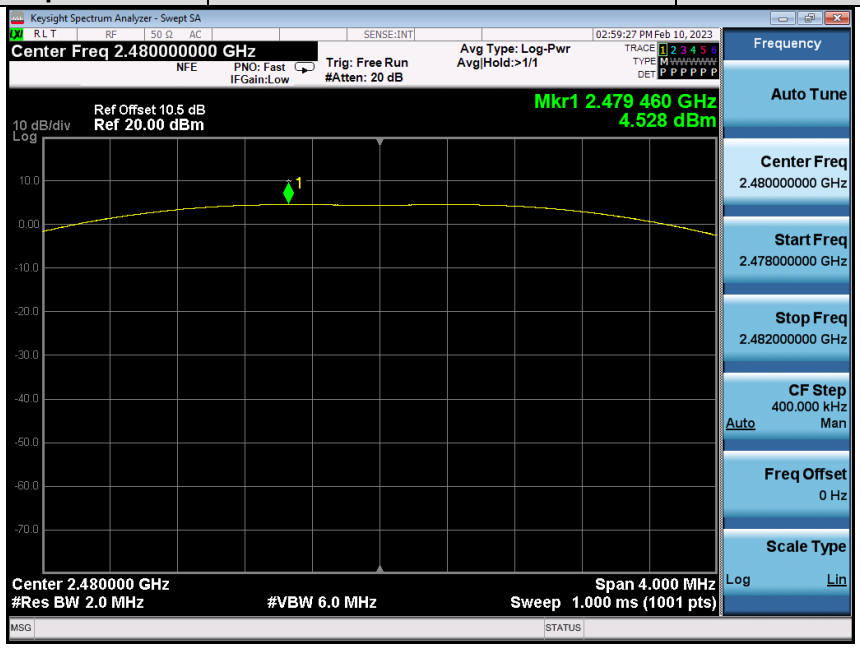
Maximum Peak Conducted Output Power		
Operating Freq: 2402 MHz	Mode: BTLE	Data Rate: 2 Mbps



Operating Freq: 2440 MHz	Mode: BTLE	Data Rate: 2 Mbps



Maximum Peak Conducted Output Power		
Operating Freq: 2480 MHz	Mode: BTLE	Data Rate: 2 Mbps



A.4 Power Spectral Density

The Power Spectral Density is the total energy output per unit bandwidth from a pulse or sequence of pulses for which the transmit power is at its maximum level, divided by the total duration of the pulses, This total time does not include the time between pulses during which the transmit power is off or below its maximum level.

A.4.1 Limits

FCC 15.247(e)/ RSS-247 5.2(b)
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

A.4.2 Test Procedure

Ref. ANSI C63.10:2013, Clause 11.10.2 Method PKPSD (peak PSD)

Power Spectral Density Test Procedure
1. Set the radio in the continuous transmitting mode. 2. Center Operating Frequencyof interest. 3. Allow trace to stabilize. 4. Use peak marker or peak-search function to determine the peak amplitude level with the RBW. 5. Capture graphs and record pertinent measurement data.

Power Spectral Density Test parameters
Span ≥ 1.5 times the DTS bandwidth 3 kHz ≥ RBW ≤ 100 kHz VBW ≥ 3 x RBW Detector = Peak Trace Mode = Max. Hold Sweep time = auto

A.4.3 Power Spectral Density Data Table

Operating Frequency (MHz)	Mode	Data Rate (Mbps)	Tx PSD (dBm/3KHz)	PSD Limit	Result
2402	BLE	1	-11.12	8	Pass
2440	BLE	1	-11.05	8	Pass
2480	BLE	1	-11.05	8	Pass
2402	BTLE	2	-13.20	8	Pass
2440	BTLE	2	-13.23	8	Pass
2480	BTLE	2	-13.19	8	Pass

Note: correction factors (ext. attenuation + cable loss) are compensated in the offset function of the Spectrum Analyzer.

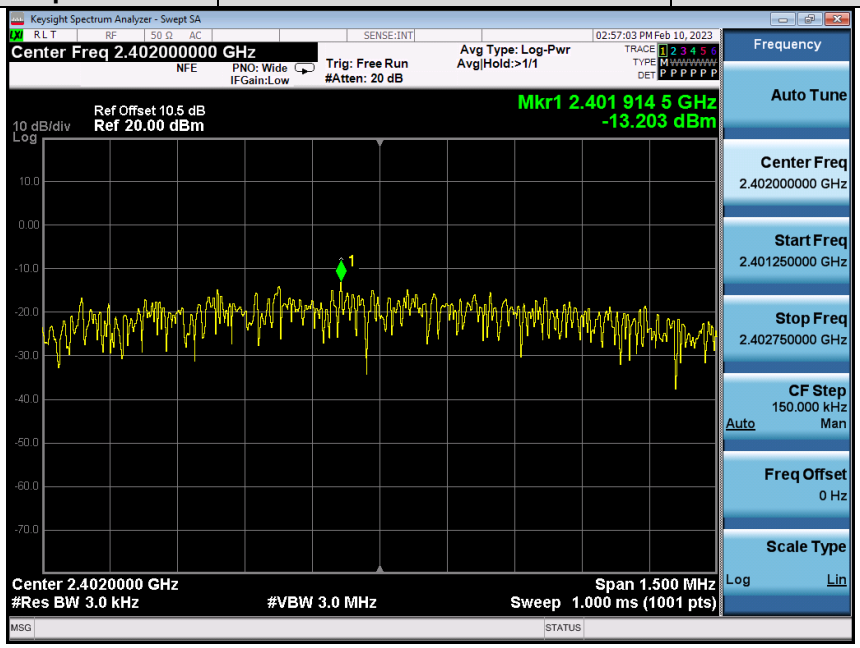
A.4.4 Power Spectral Density Graphical Test Results

Power Spectral Density		
Operating Freq: 2402 MHz	Mode: BTLE	Data Rate: 1 Mbps

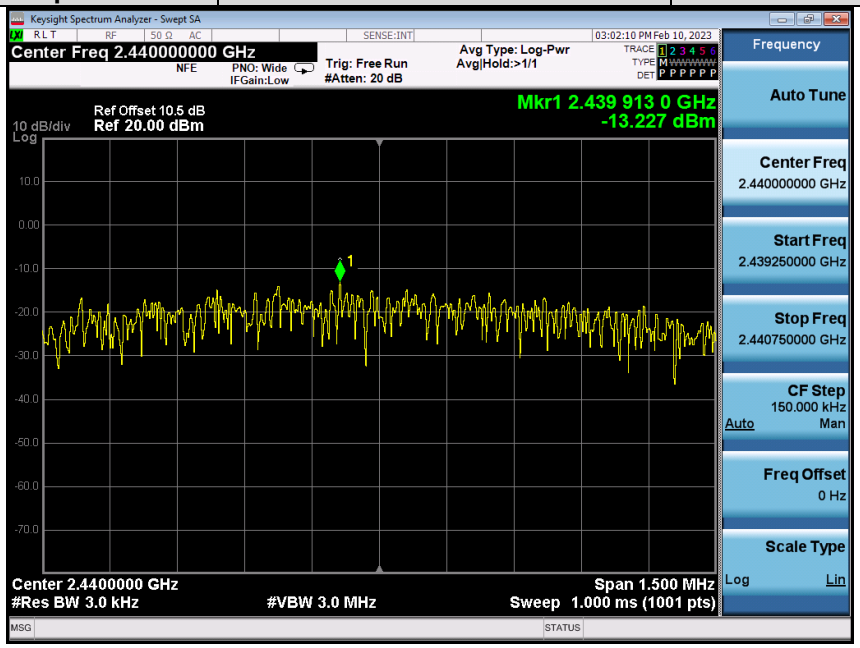
Operating Freq: 2440 MHz	Mode: BTLE	Data Rate: 1 Mbps

Power Spectral Density		
Operating Freq: 2480 MHz	Mode: BTLE	Data Rate: 1 Mbps

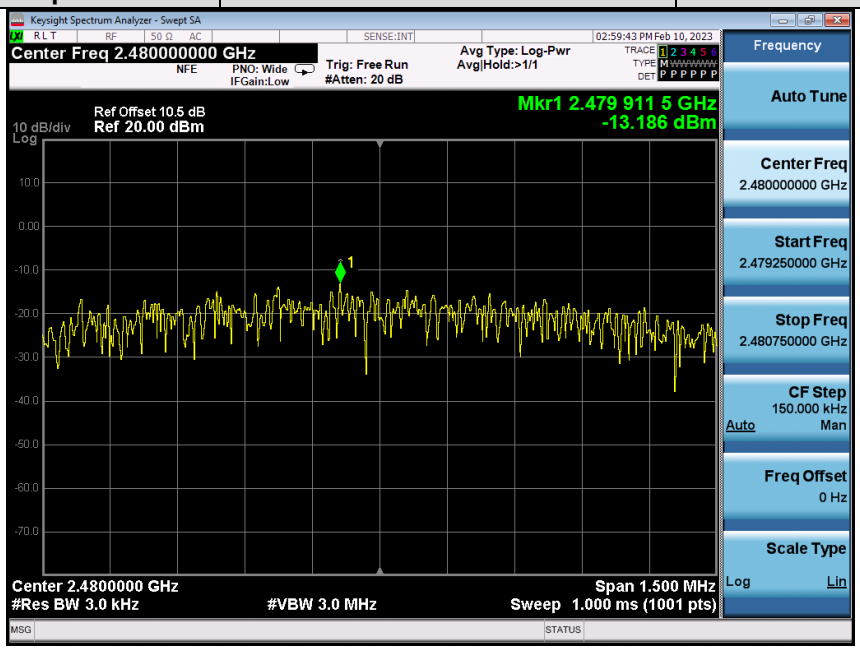
Power Spectral Density		
Operating Freq: 2402 MHz	Mode: BTLE	Data Rate: 2 Mbps



Operating Freq: 2440 MHz	Mode: BTLE	Data Rate: 2 Mbps



Power Spectral Density		
Operating Freq: 2480 MHz	Mode: BTLE	Data Rate: 2 Mbps



A.5 Conducted Band Edge within Restricted bands and non-Restricted bands

Non-Restricted Bands

FCC 15.247(d)
Emissions which fall outside of the operating Frequency band and restricted bands, the radio Operating Frequency power that is produced by the intentional radiator shall comply with the limits in applicable FCC part 15.247 (d). Attenuation below the general limits specified in FCC§15.209(a) is not required.

RSS-Gen 8.10

(c) Unwanted emissions that do not fall within the restricted Operating Frequency bands listed in table 7 shall comply either with the limits specified in the applicable RSS-247 Sect.5.5 or with those specified in table 5 and table 6.

Restricted Bands

FCC 15.205
Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the Operating Frequency bands listed in restricted bands table.

RSS-Gen 8.10
Restricted Operating Frequency bands, identified in table 7, are designated primarily for safety-of-life services (distress calling and certain aeronautical activities), certain satellite downlinks, radio astronomy and some government use. Except where otherwise indicated, the following conditions related to the restricted Operating Frequency bands apply:

(b) Unwanted emissions that fall into restricted Operating Frequency bands listed in table 7 shall comply with the limits specified in table 5 and table 6.

A.5.1 Restricted Bands Tables

FCC 15.205 Restricted Bands Table			
MHz	**MHz**	**MHz**	**GHz**
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
[1]0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2690-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			
RSS-Gen Restricted Bands Table 7			
MHz	**MHz**	**MHz**	**GHz**
0.090-0.110	12.57675-12.57725	399.9-410	7250-7750
0.495 - 0.505	13.36-13.41	608-614	8025-8500
2.1735-2.1905	16.42-16.423	960-1427	9.0-9.2
3.020-3.026	16.69475-16.69525	1435-1626.5	9.3-9.5
4.125-4.128	16.80425-16.80475	1645.5-1646.5	10.6-12.7
4.17725-4.17775	25.5-25.67	1660-1710	13.25-13.4
4.20725-4.20775	37.5-38.25	1718.8-1722.2	14.47-14.5
5.677-5.683	73-74.6	2200-2300	15.35-16.2
6.215-6.218	74.8-75.2	2310-2390	17.7-21.4
6.26775-6.26825	108-138	2483.5-2500	22.01-23.12
6.31175-6.31225	149.9 - 150.05	2655-2900	23.6-24.0
8.291-8.294	156.52475-156.52525	3260-3267	31.2-31.8
8.362-8.366	156.7-156.9	3332-3339	36.43-36.5
8.37625-8.38675	162.0125 - 167.17	3345.8-3358	Above 38.6
8.41425-8.41475	167.72 - 173.2	3500-4400	*
12.29-12.293	240-285	4500-5150	

A.5.2 Limits

A.5.2.1 Non-Restricted Band Limits

FCC 15.247(d)
In any 100 kHz bandwidth outside the Operating Frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio Operating Frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in FCC§15.209(a) is not required.

RSS-247 5.5
In any 100 kHz bandwidth outside the Operating Frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or radiated measurement, provided that the transmitter demonstrates compliance with peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

A.5.2.2 Restricted Band Limits

FCC 15.247 (d)
In addition, radiated emissions which fall in the restricted bands, as defined in FCC §15.205(a), must also comply with the radiated emission limits specified in Sec. 15.209(a).

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(b) Unwanted emissions that fall into restricted Operating Frequency bands listed in table 7 shall comply with the limits specified in table 5 and table 6.

FCC§15.209(a) Limit Table / RSS-Gen 8.9 Table 5

Operating Frequency(MHz)	Field strength (uV/meter)	Field strength (dBuV/meter)	Measurement distance (meters)
30-88	100**	40 Qp	3
88-216	150**	43.5 Qp	3
216-960	200**	46 Qp	3
Above 960	500	54 Av / 74 Pk	3

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

A.5.3 Test Procedure

Band Edge within non-Restricted band

Ref. ANSI C63.10:2013, Clause 11.11.2

Set the Reference Level
Test Procedure
1. Turn on the operating channel/Operating Frequency that is closest to the lower band edge 2. Set the radio in the transmitting mode 3. Allow trace to fully stabilize 4. Use the peak marker function to determine the maximum PSD level of the fundamental signal. Record this level. 5. Set the display line 20 dB below the record level in step 4. **Note:** The maximum PSD level can be used to establish the reference level
Test parameters
Span ≥ 1.5 times the DTS bandwidth. Reference level ≥ 10 dB headroom between max. spectrum level and the reference level Int. Attenuation ≥ 10 dB or Auto whichever greater RBW = 100 kHz VBW ≥ 3 x RBW Detector = Peak Sweep time = auto Trace mode = max-hold

Ref. ANSI C63.10:2013, Clause 11.11.3

Emission Level Measurement
Test Procedure
1. Turn on the operating channel/Operating Frequency that is closest to the lower band edge 2. Set the radio in the transmitting mode 3. Allow trace to fully stabilize 4. Use the peak marker function to determine the maximum PSD level outside of the authorized Operating Frequency band (excluding restricted Operating Frequency bands). Record this level. 5 Compare the level recorded in step 4 to the 20 dB limit to determine compliance.
Test parameters
Span = Wide enough to encompass Operating Frequency range to be measured from the band-edge extended out to the out of band domain (excluding restricted bands). Reference level ≥ 10 dB headroom between max. spectrum level and the reference level Int. Attenuation ≥ 10 dB or Auto whichever greater RBW = 100 kHz VBW ≥ 3 x RBW Detector = Peak Sweep time = auto Trace mode = max-hold

Band Edge within Restricted band

Ref. ANSI C63.10:2013, Clause 11.13.3

Identified the maximum PSD Level
Test Procedure
1. Turn on the operating channel/Operating Frequency that is closest to the band edge 2. Set the radio in the transmitting mode 3. Allow trace to fully stabilize 4. Use the peak marker function to determine the maximum PSD within the restricted band closest to the band edge and within 2MHz of an authorized band edge whichever greater. **Note:** Once the maximum PSD level is identified, perform peak and average measurement.
Test parameters
Span ≥ 1.5 times the DTS bandwidth. Reference level ≥ 10 dB headroom between max. spectrum level and the reference level Int. Attenuation ≥ 10 dB or Auto whichever greater RBW = 100 kHz VBW ≥ 3 x RBW Detector = Peak Sweep time = auto Trace mode = max-hold

Ref. ANSI C63.10:2013, Clause 11.13.3.2 (Peak) / Clause 11.13.3.4 (Average followed by DCC)

Emission Level Measurement
Test Procedure for measurement using Peak detector
1. Center Operating Frequency at the identified Operating Frequency with the maximum PSD level within the closest restricted band and within 2MHz of an authorized band edge whichever greater. 2. Allow trace to fully stabilize 3. Compute the power by integrating the spectrum over 1 MHz using the analyzer's band **power measurement function** with band limits set equal to the emission Operating Frequency(***f*** emission) ± 0.5 MHz 4. Add duty cycle correction factor to the result. DCCF = 10 log (1/D), where D is duty cycle.
Test parameters for Peak measurement
Span = 2 MHz RBW = 100 kHz VBW ≥ 3 x RBW Detector = Peak Sweep time = auto Trace mode = max-hold
Test parameters for Average measurement
Span = 2 MHz RBW = 100 kHz VBW ≥ 3 x RBW Detector = RMS

Sweep time = auto Trace mode = average Trace count ≥ 100

A.5.4 Band Edge Recorded Data Table

Lower Band Edge within non-Restricted Band						
Operating Frequency (MHz)	**Mode**	**Data Rate (Mbps)**	**Measured Emission Operating frequency (MHz)**	**Measured Emission Level (dBm)**	**Limit -20dBc (dBm)**	**Results**
2402	BLE	1	2399.9	-46.86	-16.20	Pass
2402	BLE	2	2399.9	-29.89	-18.50	Pass

***Note**: correction factors (ext. attenuation + cable loss) are compensated in the offset function of the Spectrum Analyzer.*

Upper Band Edge within Restricted Band									
Operating Frequency (MHz)	**Mode**	**Data Rate (Mbps)**	**DCCF (dB)**	**Ant. G (dBi)**	**Restricted Band (MHz)**	**Maximum Emission Level @ Operating Freq: (dBm @ MHz)**	**Calculate E.I.R.P Level (dBm)**	**Limits (dBm)**	**Results**
2480	BLE	1	0	8.0	2483.5-2500	-44.15@2483.5	-36.15	-21.2	Pass
2480	BLE	1	0	8.0	2483.5-2500	-53.61@2483.5	-45.61	-41.2*	Pass
2480	BLE	2	0	8.0	2483.5-2500	-40.4@2483.5	-32.4	-21.2	Pass
2480	BLE	2	0	8.0	2483.5-2500	-50.0@2483.5*	-42*	-41.2*	Pass

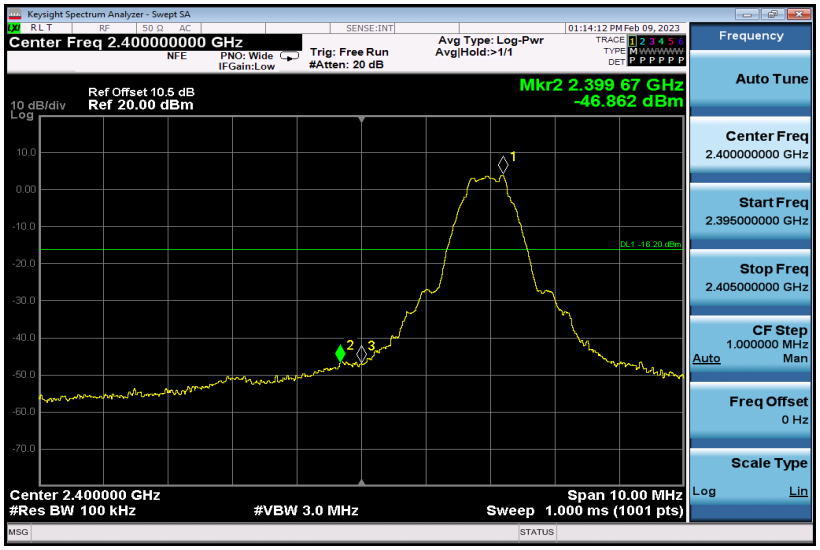
***Note1**: correction factors (ext. attenuation + cable loss) are compensated in the offset function of the Spectrum Analyzer.*
***Note2:** The readings with * at the end represent either measurements in average or average limit.*

A.5.5 Band Edge and Band Edge within Restricted Band Graphical Test Results

Non-Restricted Band

Lower Band Edge within non-Restricted Band		
Reference Level Setting		
Operating Freq:2402 MHz	**Mode: BTLE**	**Data Rate= 1** Mbps

Emission Level Measurement (Peak)		
Operating Freq:2402 MHz	**Mode: BTLE**	**Data Rate= 1** Mbps

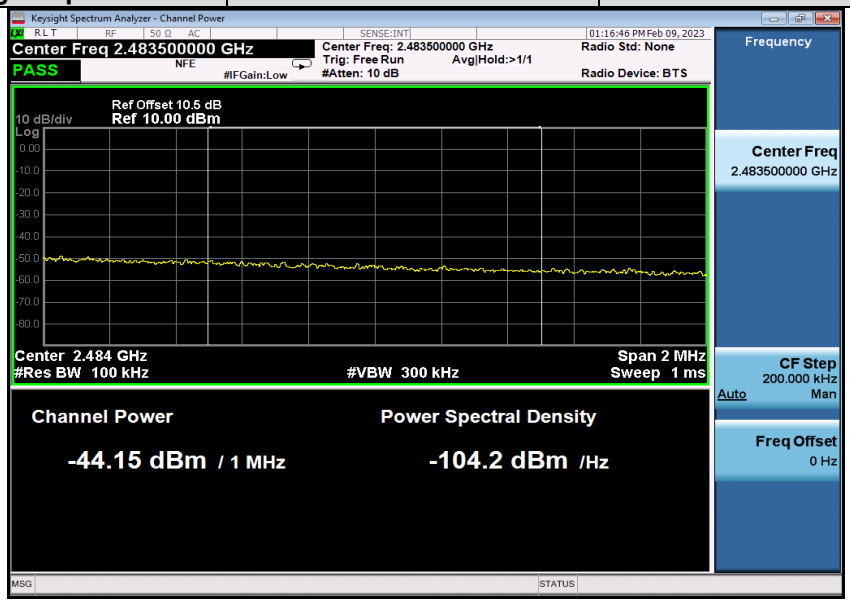


Restricted Band

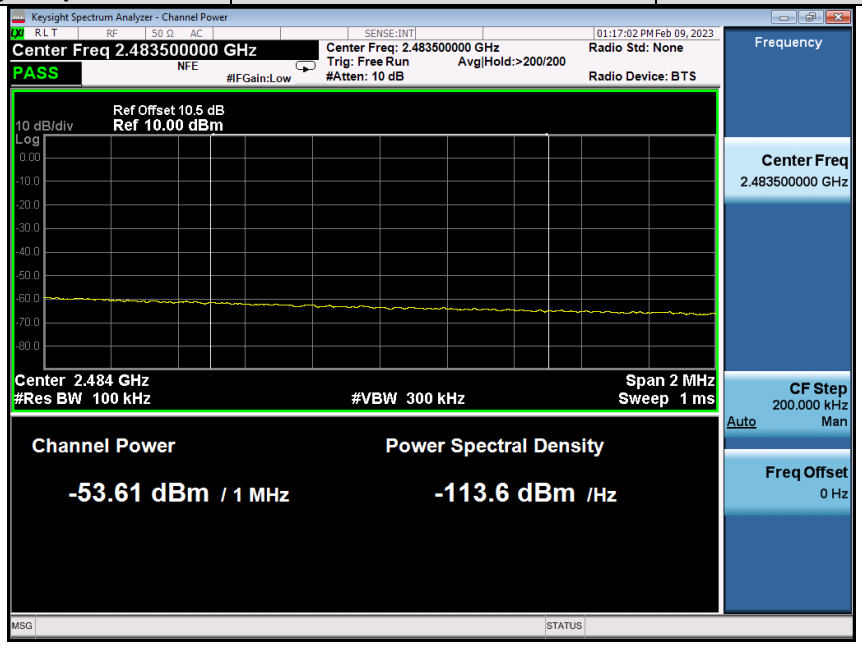
Upper Band Edge within Restricted Band		
Identified the emission		
Operating Freq:2480 MHz	Mode: BTLE	Data Rate= 1 Mbps

Emission Level Measurement (Peak)

Operating Freq:2480 MHz	Mode: BTLE	Data Rate= 1 Mbps



Upper Band Edge within Restricted Band		
Emission Level Measurement (Average)		
Operating Freq:2480 MHz	**Mode: BTLE**	**Data Rate= 1 Mbps**



Non-Restricted Band

Lower Band Edge within non-Restricted Band		
Reference Level Setting		
Operating Freq:2402 MHz	**Mode: BTLE**	**Data Rate=** 2 Mbps

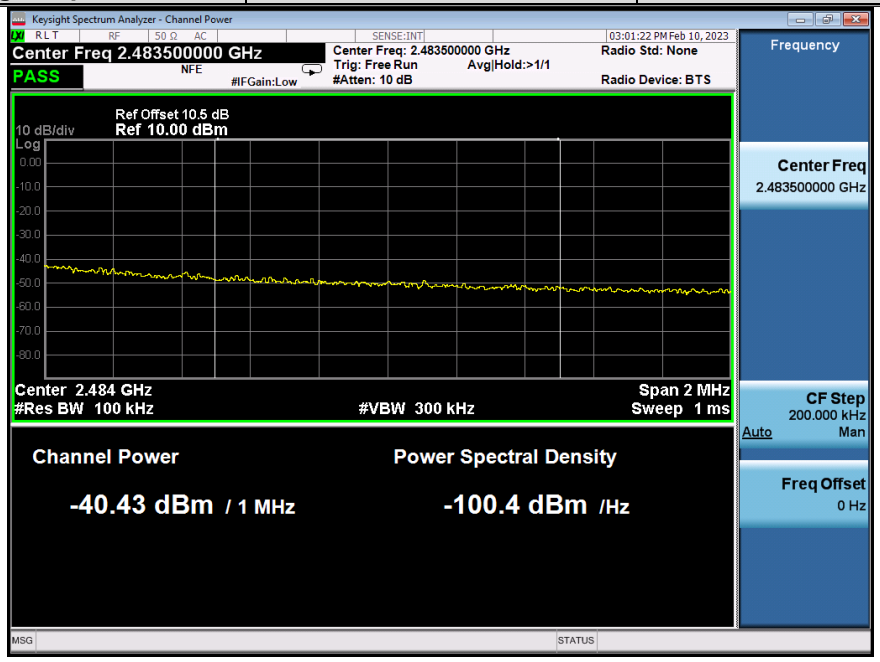
Emission Level Measurement (Peak)		
Operating Freq:2402 MHz	**Mode: BTLE**	**Data Rate=** 2 Mbps

Restricted Band

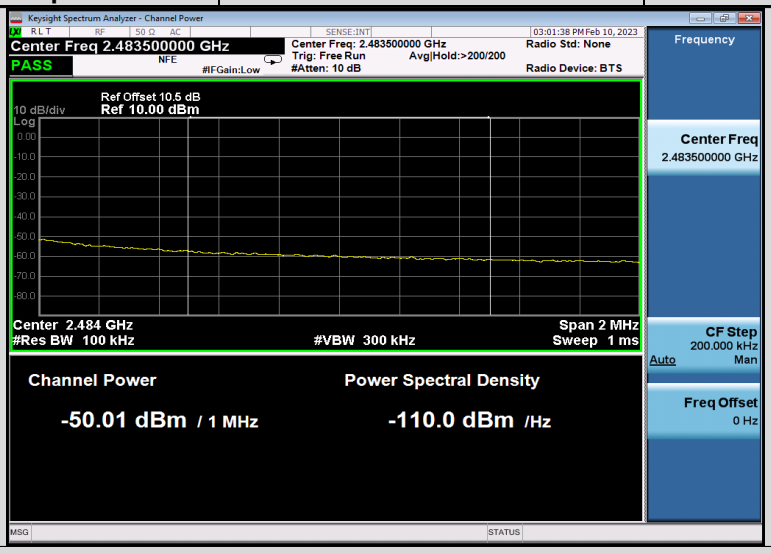
Upper Band Edge within Restricted Band		
Identified the emission		
Operating Freq:2480 MHz	Mode: BTLE	Data Rate= 2 Mbps

Emission Level Measurement (Peak)

Operating Freq:2480 MHz	Mode: BTLE	Data Rate= 2 Mbps



Upper Band Edge within Restricted Band		
Emission Level Measurement (Average)		
Operating Freq:2480 MHz	Mode: BTLE	Data Rate= 2 Mbps



Note: Upper bandedge power integration was performed with the integration band centered on the bandedge instead of starting from the bandedge. As this results in a measurement being performed closer to the fundamental with higher amplitude, worst-case compliance is shown

A.6 AC Conducted Emissions

FCC 15.207 | LP0002 (2020-07-01) (3.3)

Except when the requirements applicable to a given device state otherwise, for any radio apparatus equipped to operate from the public utility AC power supply, either directly or indirectly (such as with a battery charger), the radio frequency voltage of emissions conducted back onto the AC power lines in the frequency range of 0.15 MHz to 30 MHz shall not exceed the limits shown in the table in these sections. The more stringent limit applies at the frequency range boundaries.

Measurement Procedure
Accordance with ANSI C63.10:2013 section 6.2

Case Details

Test Case ID: 5088 **Test Type: Conducted Emissions**			
Product Standard	**Port Type**	**Test Details**	**Comments**
FCC CFR 15.207	DC (Indoor)	Start Freq: 0.15MHz - Stop Freq: 30MHz Power: DC Range: 150KHz to 30MHz. Class: N/A Measure: Voltage(dBuV) Detector(s): Quasi-Peak and Average 150kHz - 500kHz - 89dBuV (QP) 76(AV) 500kHz - 30MHz - 83dBuV (QP) 70(AV)	
Basic Standard	CISPR16 Series		
Overall Result	Pass		
Deviation	NA		

Subtest Details

Subtest Number: 5088-1 Subtest Date: 1/25/2023		
Engineer	Jose Huamani	
Lab Information	Bldg. P - Shield Room 1	
Subtest Results		
Subtest Title	5088-1	
Port Reference	[J] DC Input	
Measured Voltage	48VDC	
Transducer	LISN	
Subtest Result	Pass	
Comments on the above Test Results	Powered by 48VDC. DC Input port is under test.	
Environmental Conditions		
Temperature: (59 to 95) ^{oF}	72	
Humidity: (10 to 75) %	41	
Test Result File	**Start Freq [MHz]**	**Stop Freq [MHz]**
plce_150k-30m_lisn_m22e_48vdc [24-1-2023 15.53]	.15	30

Operation Mode

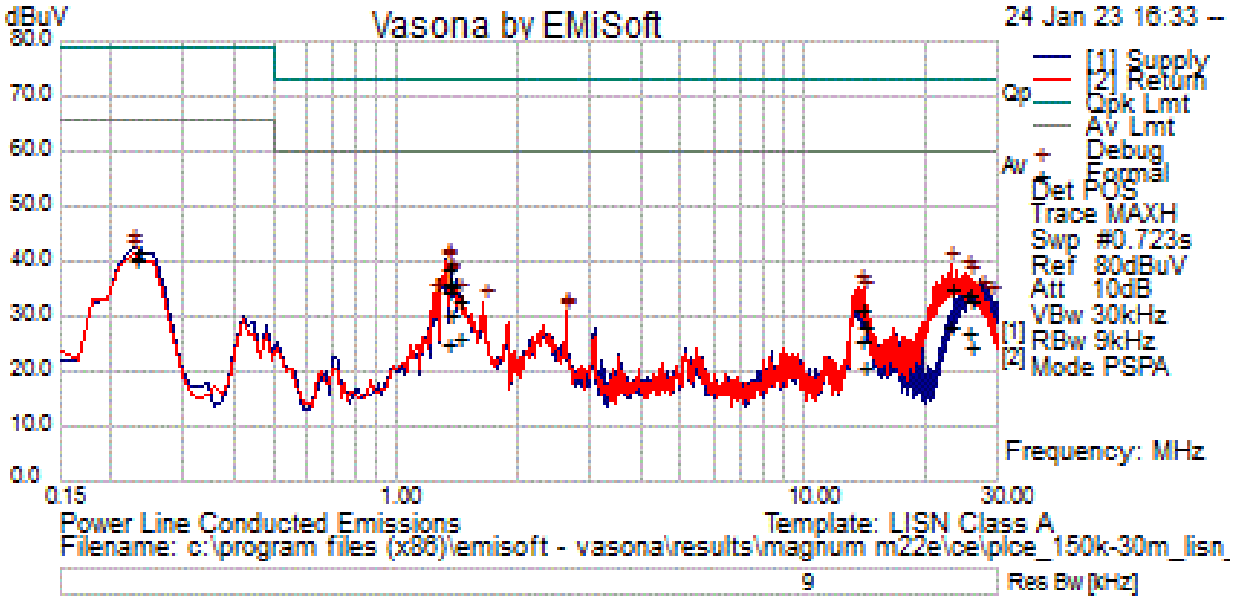
Mode#	Title	Description
1	Formal Test	EUT is set to auto-boot with Linux version 4.4.60 (root@137067b22dab) (gcc version 5.2.0 (OpenWrt GCC 5.2.0 c17576669+r49254)) #41 SMP PREEMPT Tue Oct 25 15:03:29 UTC 2022

Hardware Configuration

Config#	Title	Description
1	Mode-1 (DC Generator)	M22E powered up directly through a DC generator

Systems Details

System Number	Description	Samples	System under Test
5	IXIA Traffic Generator (Support)	1, 3, 2	No
3	Support - 2.4GHz & 5GHz Clients, Switch, and Laptop	4, 5, 8, 9	No
1	EUT - Config. 1: M22E powered up through DC Generator, without M12	1	Yes



Formal Data

No	Frequency MHz	Raw dBuV	Cable Loss	Factors dB	Level dBuV	Measurement Type	Line	Limit dBuV	Margin dB	Pass /Fail	Comments
1	1.333	16.1	19.9	.0	36.1	Average	Supply	60.0	-23.9	Pass	
2	1.333	16.1	19.9	.0	36.0	Average	Return	60.0	-24.0	Pass	
3	.231	21.7	20.1	.0	41.8	Average	Supply	66.0	-24.2	Pass	
4	.230	20.5	20.1	.0	40.6	Average	Return	66.0	-25.4	Pass	
5	1.365	10.6	19.9	.0	30.5	Average	Supply	60.0	-29.5	Pass	
6	23.014	7.5	20.5	.1	28.1	Average	Return	60.0	-31.9	Pass	
7	25.218	6.8	20.5	.2	27.4	Average	Return	60.0	-32.6	Pass	
8	1.416	6.4	19.9	.0	26.4	Average	Supply	60.0	-33.6	Pass	
9	1.333	18.9	19.9	.0	38.8	Quasi Peak	Supply	73.0	-34.2	Pass	
10	1.333	18.8	19.9	.0	38.8	Quasi Peak	Return	73.0	-34.2	Pass	
11	13.789	5.3	20.2	.1	25.7	Average	Return	60.0	-34.3	Pass	

12	1.341	5.0	19.9	.0	24.9	Average	Return	60.0	-35.1	Pass	
13	25.564	3.8	20.5	.2	24.5	Average	Supply	60.0	-35.5	Pass	
14	.231	22.0	20.1	.0	42.1	Quasi Peak	Supply	79.0	-36.9	Pass	
15	1.365	15.7	19.9	.0	35.7	Quasi Peak	Supply	73.0	-37.3	Pass	
16	23.014	14.6	20.5	.1	35.2	Quasi Peak	Return	73.0	-37.8	Pass	
17	.230	21.0	20.1	.0	41.1	Quasi Peak	Return	79.0	-37.9	Pass	
18	1.341	14.4	19.9	.0	34.4	Quasi Peak	Return	73.0	-38.6	Pass	
19	14.125	.7	20.2	.1	21.1	Average	Supply	60.0	-38.9	Pass	
20	25.218	13.3	20.5	.2	34.0	Quasi Peak	Return	73.0	-39.0	Pass	
21	1.416	13.1	19.9	.0	33.0	Quasi Peak	Supply	73.0	-40.0	Pass	
22	25.564	12.1	20.5	.2	32.8	Quasi Peak	Supply	73.0	-40.2	Pass	
23	13.789	10.9	20.2	.1	31.2	Quasi Peak	Return	73.0	-41.8	Pass	
24	14.125	7.7	20.2	.1	28.1	Quasi Peak	Supply	73.0	-44.9	Pass	

Test Equipment used for AC line Conducted emissions.

Cis-Id	Manufacturer	Model	Description	Calibrated Date	Calibration Due Date
008187	Fischer Custom Communications	FCC-450B-2.4-N	Instrumentation Limiter	2/12/2022	2/12/2023
008478	Bird	5-T-MB	5W,50 Ohm Terminator, Type BNC	6/23/2022	6/23/2023
018960	York	CNE V	Comparison Noise Emitter, 30 - 1000MHz	NA	NA
035242	Klein Tools	926-8ME	8 Meter Tape Measure	NA	NA
044022	Fischer Custom Communications	FCC-801-M2-32A	Power Line Coupling Decoupling Network	3/4/2022	3/4/2023
045982	Fischer Custom Communications	F-090527-1009-1	Line Impedance Stabilization Network	12/21/2022	12/21/2023
045983	Fischer Custom Communications	F-090527-1009-2	LISN Adapter	12/21/2022	12/21/2023
002125	FLUKE	79 II	MULTIMETER	11/18/2022	11/18/2023
058276	ROHDE & SCHWARZ	ESR3	EMI Receiver	7/29/2022	7/29/2023
058663	Vibration Research Corp	VR9500	Controller	7/18/2022	7/18/2023
062419	TTE	H785-150K-50-21378	150kHz Hi Pass Filter	2/12/2022	2/12/2023
063067	COMET	T7611-4	Temperature/Relative Humidity/Barometric Pressure Gauge/Transmitter	7/13/2022	7/13/2023

Appendix B: Photographs of Test Setups

See FCC/RSS RSE Test Setup document – EDCS-24185434

Appendix C: List of Test Equipment Used to perform the test.

Equip#	Manufacturer/ Model	Description	Last Cal	Next Due	Test Item
RF Conducted Emissions					
CIS056098	Keysight / MXA N9020A	MXA Spectrum Analyzer, 10Hz-26.5GHz	25-Jan-2023	25-Jan-2024	A.5
CIS054053	Aeroflex/INMET 40AH2W-10	SMA 10 dB Attenuator 2.92mm	28-Mar-2022	28-Mar-2023	A.5
CIS047284	HUBER + SUHNER/Sucoflex 102E	40GHz Cable K Connector	26-May-2022	26-May-2023	A.5

Appendix D: Abbreviation Key and Definitions

The following table defines abbreviations used within this test report.

Abbreviation	Description	Abbreviation	Description
EMC	Electro Magnetic Compatibility	°F	Degrees Fahrenheit
EMI	Electro Magnetic Interference	°C	Degrees Celsius
EUT	Equipment Under Test	Temp	Temperature
ITE	Information Technology Equipment	S/N	Serial Number
TAP	Test Assessment Schedule	Qty	Quantity
ESD	Electro Static Discharge	Emf	Electromotive force
EFT	Electric Fast Transient	RMS	Root mean square
EDCS	Engineering Document Control System	Qp	Quasi Peak
Config	Configuration	Av	Average
CIS#	Cisco Number (unique identification number for Cisco test equipment)	Pk	Peak
Cal	Calibration	kHz	Kilohertz ($1x10^3$)
EN	European Norm	MHz	MegaHertz ($1x10^6$)
IEC	International Electro technical Commission	GHz	Gigahertz ($1x10^9$)
CISPR	International Special Committee on Radio Interference	H	Horizontal
CDN	Coupling/Decoupling Network	V	Vertical
LISN	Line Impedance Stabilization Network	dB	decibel
PE	Protective Earth	V	Volt
GND	Ground	kV	Kilovolt ($1x10^3$)
L1	Line 1	µV	Microvolt ($1x10^{-6}$)
L2	Line2	A	Amp
L3	Line 3	µA	Micro Amp ($1x10^{-6}$)
DC	Direct Current	mS	Milli Second ($1x10^{-3}$)
RAW	Uncorrected measurement value, as indicated by the measuring device	µS	Micro Second ($1x10^{-6}$)
RF	Radio Operating Freq:uency	µS	Micro Second ($1x10^{-6}$)
SLCE	Signal Line Conducted Emissions	M	Meter
Meas dist	Measurement distance	Spec dist	Specification distance
N/A or NA	Not Applicable	SL	Signal Line (or Telecom Line)
P	Power Line	L	Live Line
N	Neutral Line	R	Return
S	Supply	AC	Alternating Current

Appendix E: Software Used to Perform Testing

EMIsoft Vasona, version 6.083

Appendix F: Test Procedures

Measurements were made in accordance with:

- ANSI C63.10:2013 Procedure for Compliance Testing of Unlicensed Wireless Devices
- RSS Gen Issue 5 General Requirements for Compliance of Radio Apparatus
- Test procedures are summarized below.

FCC part15.247 Conducted Test Procedures	EDCS # 1445042

Appendix H: Test Assessment Plan

Compliance Test Plan (Excel) EDCS# 24086914
Target Power Tables EDCS# 23409888