FCC / ISED Test Report

For:
Geoforce Inc.

Model Name:
Geoforce GT1/GT1s and Geoforce GT0/GT0s

Product Description:
Battery Powered Asset Logistics Device

FCC ID: OWA00GT1X
IC: 10540A-00GT1X

Applied Rules and Standards:
47 CFR Part 15.247 (DTS)
RSS-247 Issue 3 (DTSs) & RSS-Gen Issue 5

REPORT #: EMC_GEOFO_038_23001_FCC_15.247_ISED_RSS_247_BTLE_DTS

DATE: 2024-05-21

A2LA Accredited

IC recognized # 3462B

***CETECOM* Inc.**
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CETECOM Inc. is a Delaware Corporation with Corporation number: 2905571

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1 Assessment

The following device was evaluated against the applicable criteria specified in FCC rules Parts 15.247 of Title 47 of the Code of Federal Regulations and the relevant ISED Canada standard RSS-247.

No deviations were ascertained.

Company Name	Product Description	Model No.
Geoforce Inc.	Battery Powered Asset Logistics Device	OWA1S52

Responsible for the Report:

Date	Section	Name	Signature
2024-05-21	Compliance	Chin Ming Lui (EMC Test Engineer)	Chin Ming Lui Digitally signed by: Chin Ming Lui DN: CN = Chin Ming Lui email = ChinMing.Lui@cetecom.com C = US O = CETECOM Inc. OU = OTA Date: 2024.05.22 15:54:00 -07'00'

2 Administrative Data

2.1 Identification of the Testing Laboratory Issuing the EMC Test Report

Company Name:	CETECOM Inc.
Department:	Compliance
Street Address:	411 Dixon Landing Road
City/Zip Code	Milpitas, CA 95035
Country	USA
Telephone:	+1 (408) 586 6200
Fax:	+1 (408) 586 6299
EMC Lab Manager:	Issa Ghanma
Responsible Project Leader:	Sangeetha Sivaraman

2.2 Identification of the Client

Client's Name:	Geoforce Inc.
Street Address:	5830 Granite Parkway, Suite 1200
City/Zip Code	Plano, TX 75024
Country	USA

2.3 Identification of the Manufacturer

Manufacturer's Name:	Same as client
Manufacturer's Address:	
City/Zip Code	
Country	

3 Equipment Under Test (EUT)

3.1 EUT Specifications

Product Description:	Battery Powered Asset Logistics Device
Model Name	Geoforce GT1/GT1s and Geoforce GT0/GT0s
HW Version :	R3
SW Version :	11.X
FCC-ID :	OWA00GT1X
IC :	10540A-00GT1X
Frequency Range / number of channels:	BLE: 2402 – 2480 MHz / 39 Channels with 2 MHz Spacing
Radio Module(s):	BLE: Nordic NRF52840 (DTS)
Mode(s) of Operation:	BLE: GFSK
Antenna Information as declared:	BLE: SMT MID Chip Antenna: 3.3 dBi
Max. Output Power (Measured):	BLE: 2.23 dBm (Peak Conducted)
Max. Output Power (Declared):	BLE: 6.0 dBm +/- 1.0 dBm EIRP
Other Radios included in the device	❖ Satcom: • Module: Discrete Licensed Geoforce Transmitter (TNB) • Frequency Range / Number of Channels: 1611.25 – 1618.75 MHz / 4 Channels with 2.5 MHz Spacing • Mode of Operation: DSSS • Modulation: BPSK ❖ GNSS: • Module: uBlox MAX-M10S (RCV Only) • Frequency Range / Number of Channels: 1575.42, 1602, 1561 MHz
Power Supply/ Rated Operating Voltage Range	3.6VDC Nominal, 3.9VDC Maximum
Operating Temperature Range	Low: -40°C Norm: 25°C High: 85 °C
Sample Revision	☐Production ☒ Pre-Production
EUT Dimensions	7.1cm x 7.1cm x 3.2cm
Weight	200 grams
EUT Diameter	☒< 60 cm ☐ Other _____
Note: The information of the EUT specifications in the table above is provided by the client except the specified Max. Output Power (Measured). Refer to following documents:	

- **Operational Description:** *GT0-GT1 Theory of Operation Description Document # HW-SP-0-0160*
- **EUT Model Declaration of Similarities:** *Declaration of Product Model Code*
- **Antenna Datasheet – BLE:** *Molex 0479480001, 2.4 GHz SMT MID Chip Antenna*
- **Antenna Datasheet – GPS-SAT:** *Tallysman Wireless TW11-0006-1, Dual Feed Patch Antenna*

3.2 EUT Sample details

EUT #	Serial Number	HW Version	SW Version	Notes/Comments
1	2-3000105	R3	11.X	Conducted Sample
2	2-3000103	R3	11.X	Radiated Sample

3.3 Accessory Equipment (AE) details

AE #	Type	Model	Manufacturer	Serial Number
1	N/A	N/A	N/A	N/A

3.4 Test Sample Configuration

EUT Set-up #	Combination of AE used for test set up	Comments
1	EUT#1	The radio of the EUT was configured to a fixed channel transmission with Nordic nRF Connect for Desktop v4.3.0 Direct Test Mode v2.2.0 software that is not available to the end user. The RF pigtail cable coming out of the EUT was connected to the 50 ohm RF port of the measurement equipment.
2	EUT#2	The radio of the EUT was configured to a fixed channel transmission with Nordic nRF Connect SDK Radio test (short-range) shell commands via PuTTY that is not available to the end user. The internal antenna was connected.

3.5 Mode of Operation Details

Mode of Operation	Description of Operating Modes	Additional Information
Op. 1	BLE Fixed Channel	A USB to UART configuration cable provided by the client was used to communicate with the EUT through Nordic nRF Connect for Desktop v4.3.0 Direct Test Mode v2.2.0, which will not be available to the end-user, to configure the radio to: • Channel mode: Single • Transmit on channel: o Low → Channel 37, 2402 MHz o Mid → Channel 17, 2440 MHz o High → Channel 39, 2480 MHz • Transmit power: 8 dBm • Physical layer: LE 1Mbps • Packet type: PRBS9 • Packet length: 37 bytes
Op. 2		A USB to UART configuration cable provided by the client was used to communicate with the EUT through Nordic nRF Connect SDK Radio test (short-range) shell commands via PuTTY, which will not be available to the end-user, to configure the radio to: • Data rate: BLE 1Mbit • Output power: +8dBm • Transmission pattern: Random • Channel: o Low → Ch. 2, 2402 MHz o Mid → Ch. 40, 2440 MHz o High → Ch. 80, 2480 MHz • Duty cycle: 50 percent

3.6 Justification for Worst Case Mode of Operation

During the testing process, the EUT was tested with transmitter set to low, mid and high fixed TX channels.

For conducted measurements:

- All measurements were performed with a peak detector.
- Using configurations through Nordic nRF DTM as described in Section 3.5 Mode of Operation Op. 1, a duty cycle of 62.4% was achieved.

For radiated measurements:

- All data in this report show the worst case between horizontal and vertical antenna polarizations and for all orientations of the EUT.
- Using Nordic nRF Connect SDK shell commands as described in Section 3.5 Mode of Operation Op. 2, the EUT was set to a maximum duty cycle of 50% during connection as declared in GT0-GT1 Theory of Operation Description.

4 Subject of Investigation

The objective of the measurements done by CETECOM Inc. was to assess the performance of the EUT according to the relevant requirements specified in FCC rules Part 15.247 of Title 47 of the Code of Federal Regulations and Radio Standard Specification RSS-247 of ISED Canada.

This test report is to support a request for new equipment authorization under the FCC ID: OWA00GT1XX, IC: 10540A-00GT1X

Testing procedures are based on 558074 D01 15.247 Meas Guidance v05r02 – "GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES" - April 2, 2019, by the Federal Communications Commission, Office of Engineering and Technology, Laboratory Division.

5 Measurement Results Summary

Test Specification	Test Case	Temperature and Voltage Conditions	Mode	Pass	NA	NP	Result
§15.247(a)(1) RSS-247 5.2(a)	Emission Bandwidth	Nominal	BTLE	■	☐	☐	Complies
§15.247(e) RSS-247 5.2(b)	Power Spectral Density	Nominal	BTLE	■	☐	☐	Complies
§15.247(b)(1) RSS-247 5.4(d)	Maximum Conducted Output Power and EIRP	Nominal	BTLE	■	☐	☐	Complies
§15.247(d) RSS-247 5.5	Non-Restricted Band Edge Compliance and Conducted Spurious Emissions	Nominal	BTLE	■	☐	☐	Complies
§15.247(d) §15.209(a) §15.205(a) RSS-Gen 6.13 RSS-Gen 8.9 RSS-Gen 8.10	Transmitter Spurious Emissions and Restricted Bands – Radiated	Nominal	BTLE	■	☐	☐	Complies
§15.207(a) RSS Gen 8.8	AC Conducted Emissions	Nominal	BTLE	☐	☐	■	Note 2

Note 1: NA= Not Applicable; NP= Not Performed.
Note 2: EUT is battery powered. Not Applicable.

6 Measurement Uncertainty

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus, with 95% confidence interval (in dB delta to result), based on a coverage factor k=2.

Radiated measurement

Measurement System		EMC 1	EMC 2
Conducted emissions (mains port)		1.12 dB	0.46 dB
Radiated emissions	(< 30 MHz)	3.66 dB	3.88 dB
	(30 MHz – 1GHz)	3.17 dB	3.34 dB
	(1 GHz – 3 GHz)	5.01 dB	4.45 dB
	(>3 GHz)	4.0 dB	4.79 dB

RF conducted measurement ±0.5 dB

According to TR 102 273 a multiplicative propagation of error is assumed for RF measurement systems. For this reason the RMS method is applied to dB values and not to linear values as appropriate for additive propagation of error. Also used: http://physics.nist.gov/cuu/Uncertainty/typeb.html. The above calculated uncertainties apply to direct application of the Substitution method. The Substitution method is always used when the EUT comes closer than 3dB to the limit.

6.1 Environmental Conditions During Testing:

The following environmental conditions were maintained during the course of testing:

- Ambient Temperature: 20-25°C
- Relative humidity: 40-60%

6.2 Dates of Testing:

2024-02-14 – 2024-04-12

6.3 Decision Rule:

Cetecom advanced follows ILAC G8:2019 chapter 4.2.1 (Simple Acceptance Rule).

Only the measured values related to their corresponding limits will be used to decide whether the equipment under test meets the requirements of the test standards listed in chapter 3. The measurement uncertainty is mentioned in this test report, See chapter 9, but is not taken into account – neither to the limits nor to the measurement results. Measurement results with a smaller margin to the corresponding limits than the measurement uncertainty have a potential risk of more than 5% that the decision might be wrong.

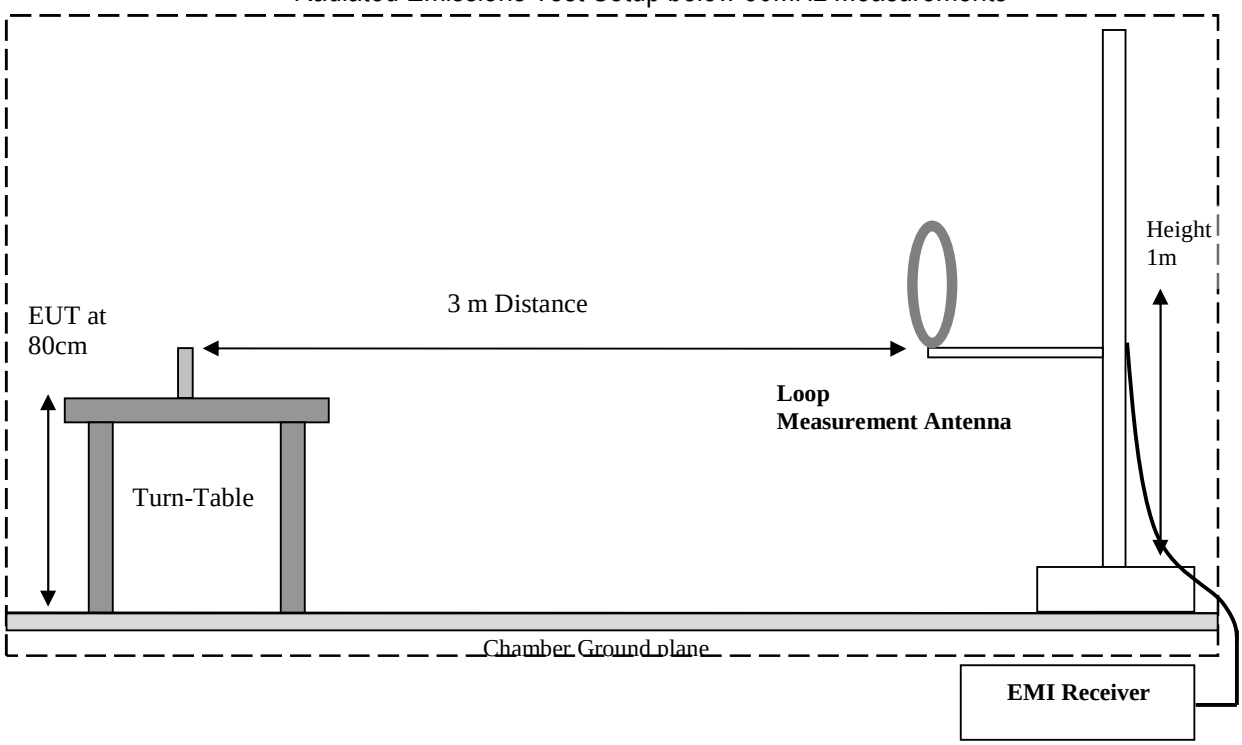
7 Measurement Procedures

7.1 Radiated Measurement

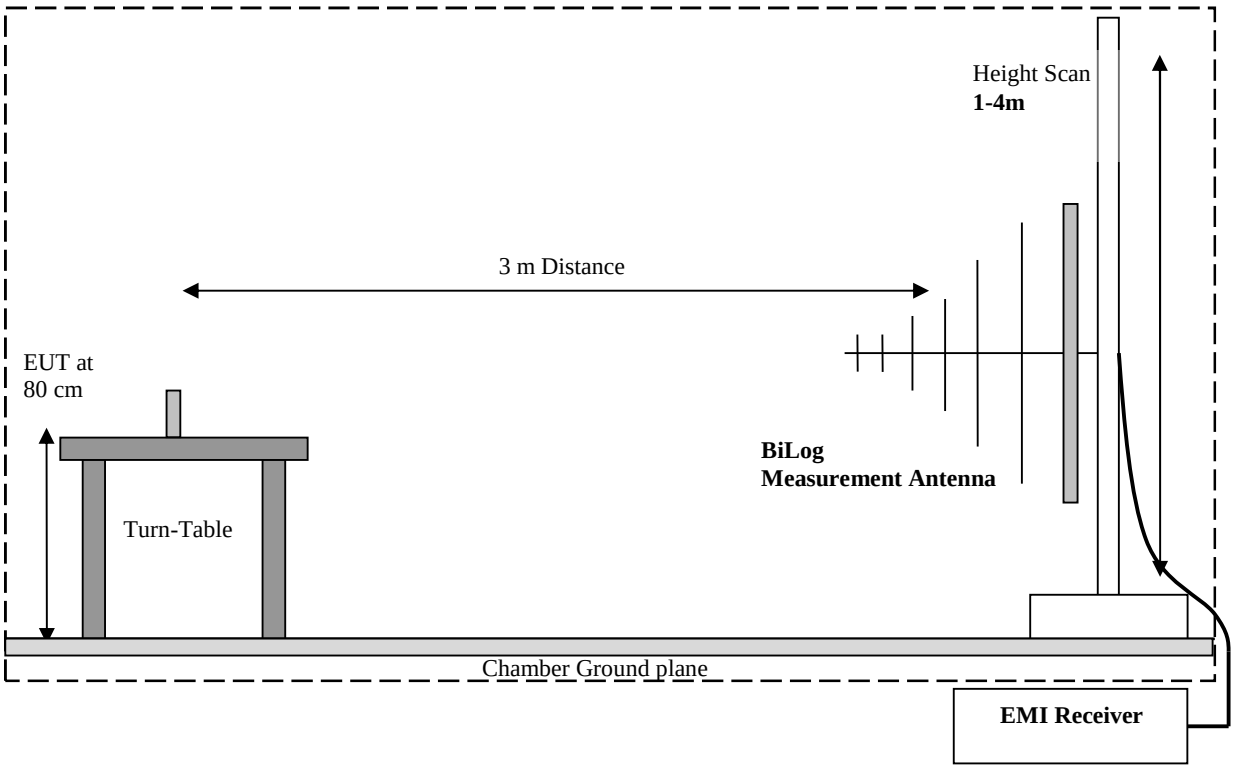
The radiated measurement is performed according to ANSI C63.10 (2013)

- The exploratory measurement is accomplished by running a matrix of 16 sweeps over the required frequency range with R&S Test-SW EMC32 for 4 positions of the turntable, two orthogonal positions of the EUT and both antenna polarizations. This procedure exceeds the requirement of the above standards to cover the 3 orthogonal axis of the EUT. A max peak detector is utilized during the exploratory measurement. The Test-SW creates an overall maximum trace for all 12 sweeps and saves the settings for each point of this trace. The maximum trace is part of the test report.
- The 10 highest emissions are selected with an automatic algorithm of EMC32 searching for peaks in the noise floor and ensuring that broadband signals are not selected multiple times.
- The maxima are then put through the final measurement and again maximized in a 90deg range of the turntable, fine search in frequency domain and height scan between 1m and 4m.
- The above procedure is repeated for all possible ways of power supply to EUT and for all supported modulations.
- In case there are no emissions above noise floor level only the maximum trace is reported as described above.
- The results are split up into up to 4 frequency ranges due to antenna bandwidth restrictions. A magnetic loop is used from 9 kHz to 30 MHz, a Biconilog antenna is used from 30 MHz to 1 GHz, and two different horn antennas are used to cover frequencies up to 40 GHz.

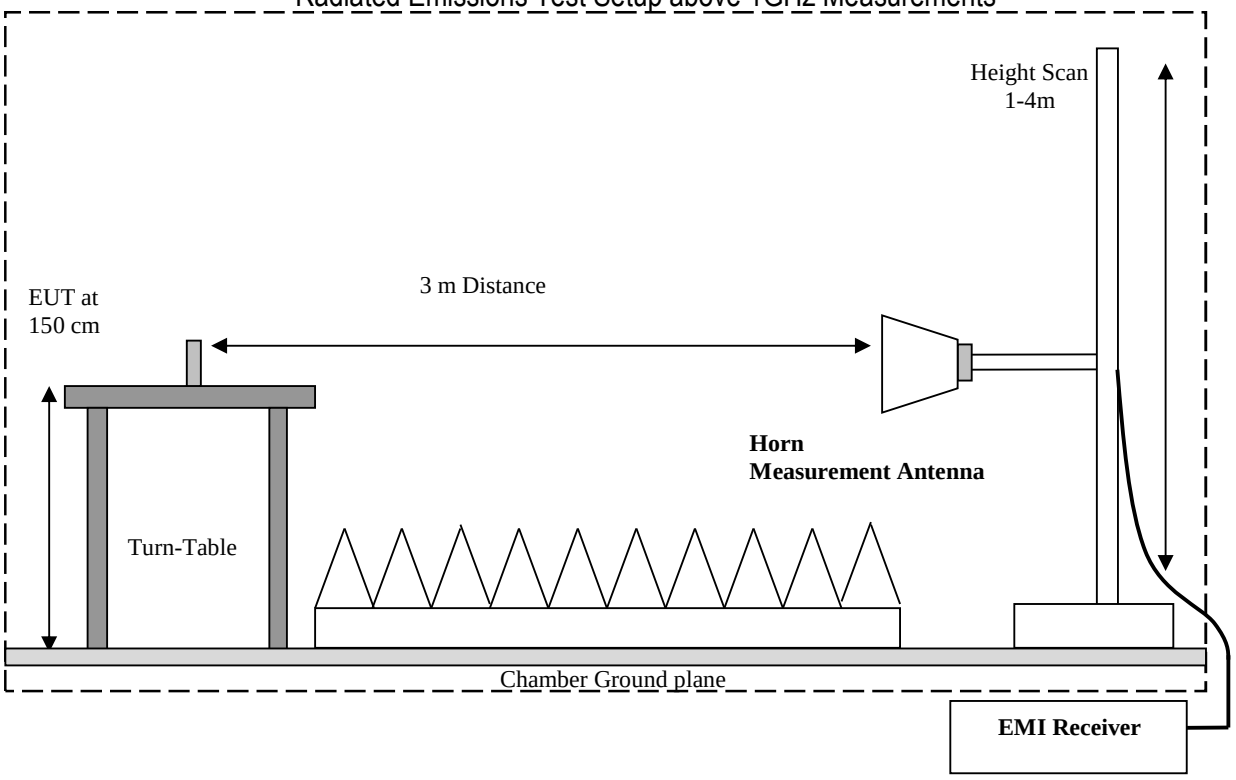
Radiated Emissions Test Setup below 30MHz Measurements



Radiated Emissions Test Setup 30MHz-1GHz Measurements



Radiated Emissions Test Setup above 1GHz Measurements



7.1.1 Sample Calculations for Field Strength Measurements

Field Strength is calculated from the Spectrum Analyzer/ Receiver readings, taking into account the following parameters:

1. Measured reading in dBµV
2. Cable Loss between the receiving antenna and SA in dB and
3. Antenna Factor in dB/m

All radiated measurement plots in this report are taken from a test SW that calculates the Field Strength based on the following equation:

FS (dBµV/m) = Measured Value on SA (dBµV) + Cable Loss (dB) + Antenna Factor (dB/m)

Example:

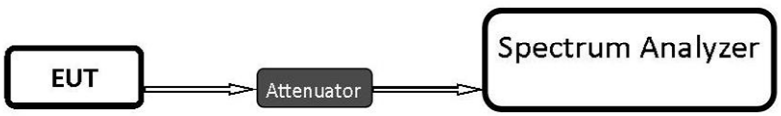
Frequency (MHz)	Measured SA (dBµV)	Cable Loss (dB)	Antenna Factor Correction (dB)	Field Strength Result (dBµV/m)
1000	80.5	3.5	14	98.0

7.2 Power Line Conducted Measurement Procedure

AC Power Line conducted emissions measurements performed according to: ANSI C63.4 (2014)

7.3 RF Conducted Measurement Procedure

Testing procedures are based on 558074 D01 15.247 Meas Guidance v05r02 – "GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES" - April 2, 2019, by the Federal Communications Commission, Office of Engineering and Technology, Laboratory Division.



- Connect the equipment as shown in the above diagram.
- Adjust the settings of the SA (Rohde-Schwarz Spectrum Analyzer) to connect the EUT at the required mode of test.
- Measurements are to be performed with the EUT set to the low, middle and high channels and for worst case modulation schemes.

8 Test Result Data

8.1 Maximum Peak Conducted Output Power

8.1.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02

Spectrum Analyzer settings:

- RBW ≥ DTS bandwidth
- VBW ≥ 3 x RBW
- Span ≥ 3 x RBW
- Sweep = Auto couple
- Detector function = Peak
- Trace = Max hold
- Use peak marker function to determine the peak amplitude level

8.1.2 Limits:

Maximum Peak Output Power:

- FCC §15.247 (b)(1): 1 W
- IC RSS-247: 1 W

8.1.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22.5° C	1	Op. 1	3.6 VDC	3.3 dBi

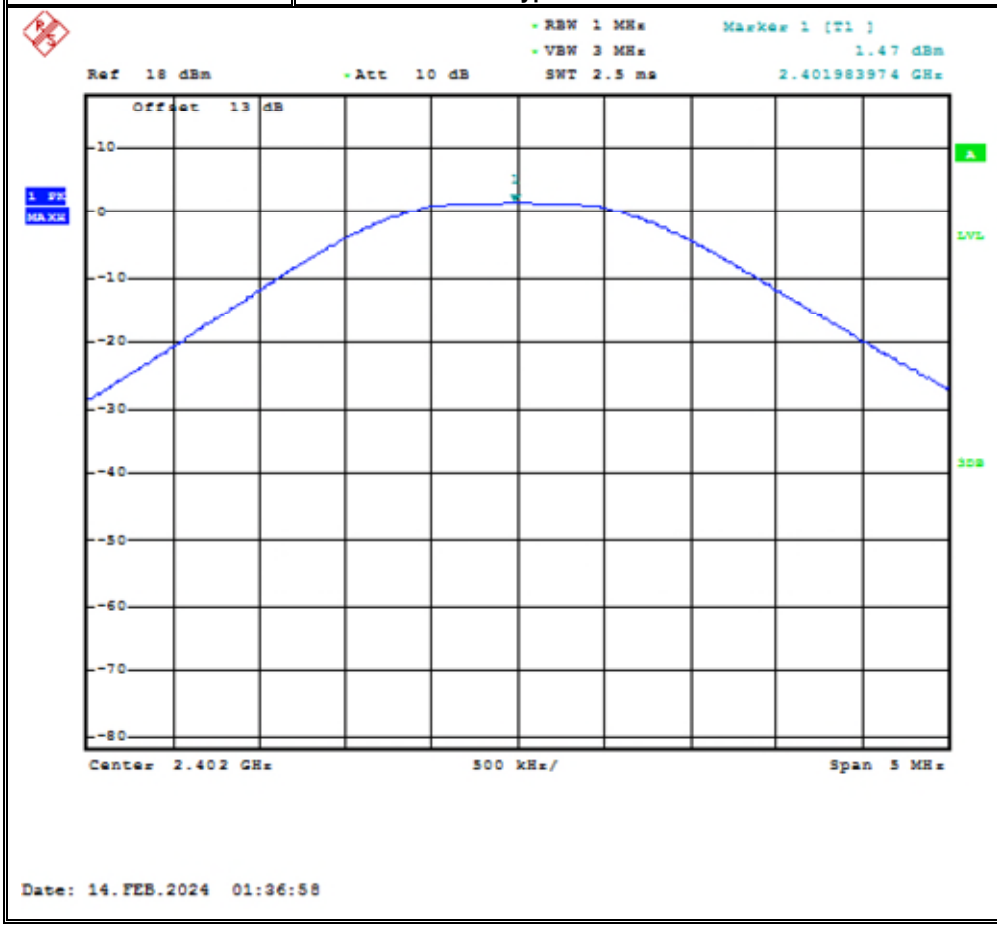
8.1.4 Measurement result:

Plot #	Frequency (MHz)	Maximum Peak Conducted Output Power (dBm)	EIRP (dBm)	Limit (dBm)	Result
1	2402	1.47	4.77	30 (Pk) / 36 (EIRP)	Pass
2	2440	1.97	5.27	30 (Pk) / 36 (EIRP)	Pass
3	2480	2.23	5.53	30 (Pk) / 36 (EIRP)	Pass

8.1.5 Measurement Plots:

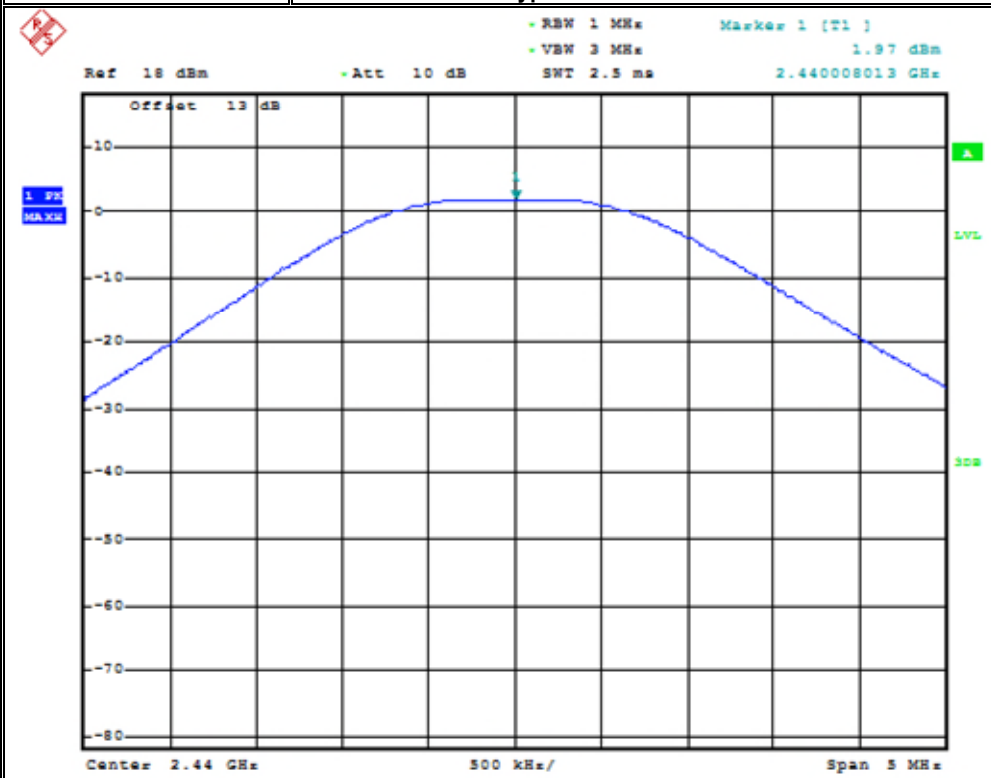
Plot #1

Low channel / 2402 MHz | **Modulation/Packet Type: BTLE**



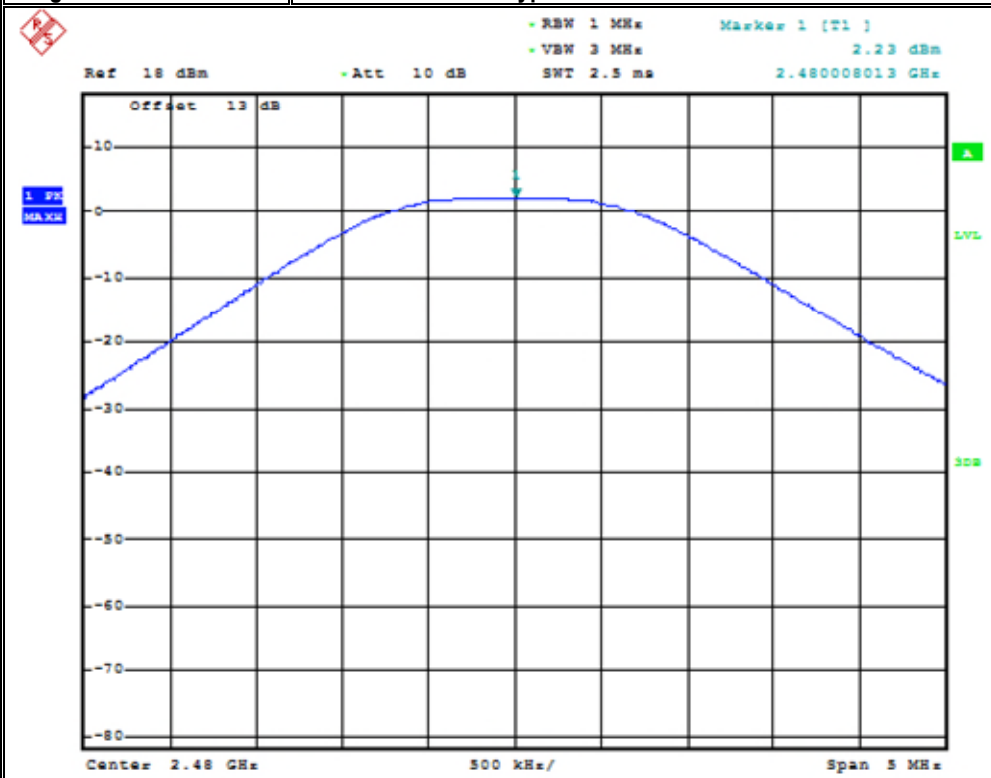
Plot #2

Mid channel 2440 MHz	Modulation/Packet Type: BTLE



Plot #3

High channel 2480 MHz	Modulation/Packet Type: BTLE



8.2 Power Spectral Density

8.2.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02

Spectrum Analyzer settings for Peak PSD method:

- Set analyzer center frequency to DTS channel center frequency
- Set the span to 1.5 x DTS bandwidth
- Set RBW to: 3 kHz ≤ RBW ≤ 100 kHz
- Set the VBW ≥ 3 x RBW
- Detector = Peak
- Sweep time = Auto couple
- Trace mode = Max hold
- Allow trace to fully stabilize
- Use the peak marker function to determine the maximum amplitude level within the RBW
- If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat

8.2.2 Limits:

FCC§15.247(e) & RSS-247 5.2(b)

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

8.2.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22.5° C	1	Op. 1	3.6 VDC	3.3 dBi

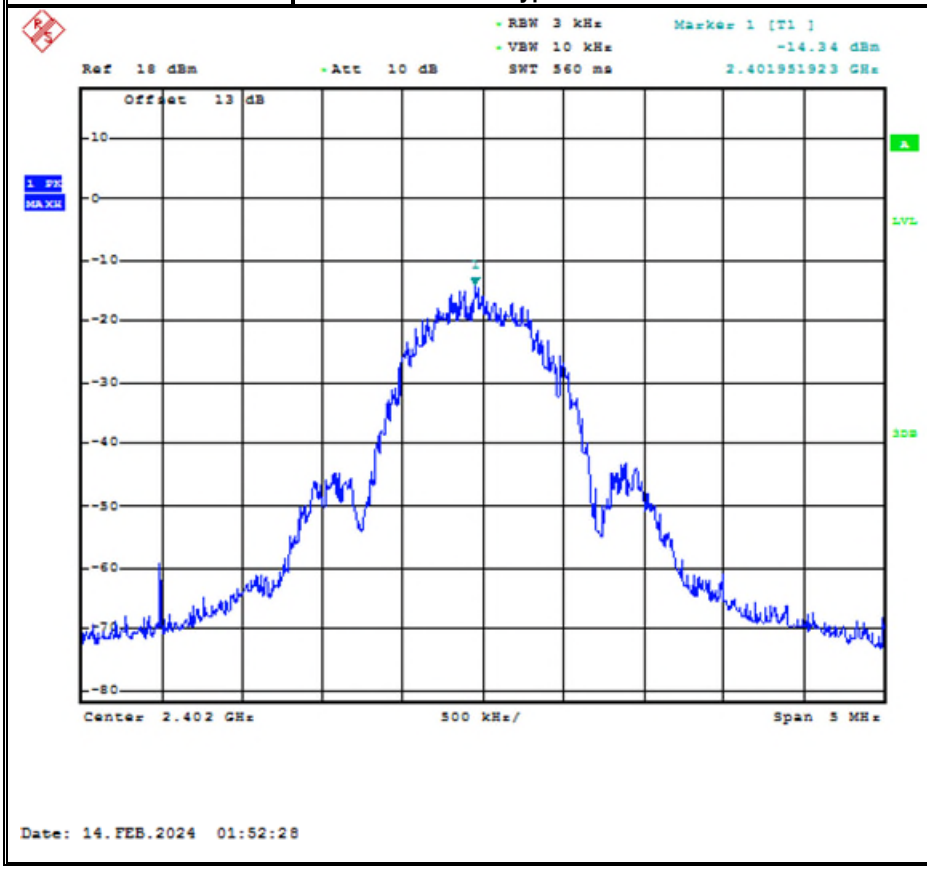
8.2.4 Measurement result:

Plot #	Frequency (MHz)	Maximum Power Spectral Density (dBm/3 kHz)	Limit (dBm / 3 kHz)	Result
1	2402	-14.34	8	Pass
2	2440	-13.91	8	Pass
3	2480	-13.62	8	Pass

8.2.5 Measurement Plots:

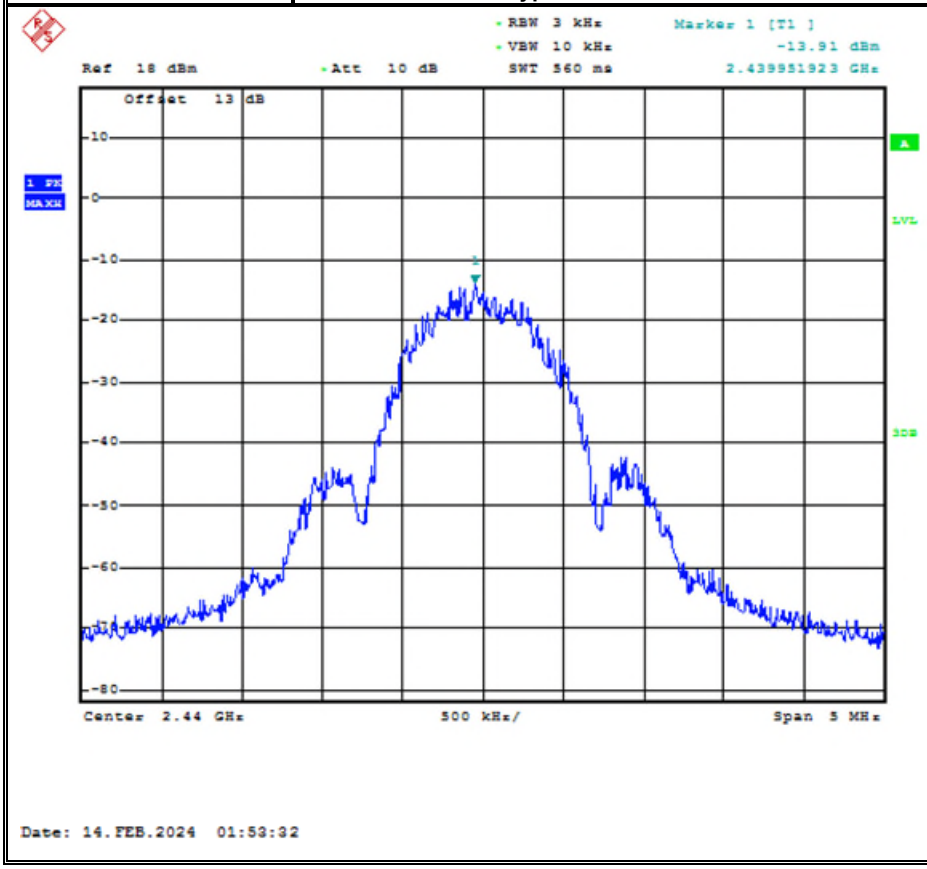
Plot #1

Low channel / 2402 MHz | **Modulation/Packet Type: BTLE**



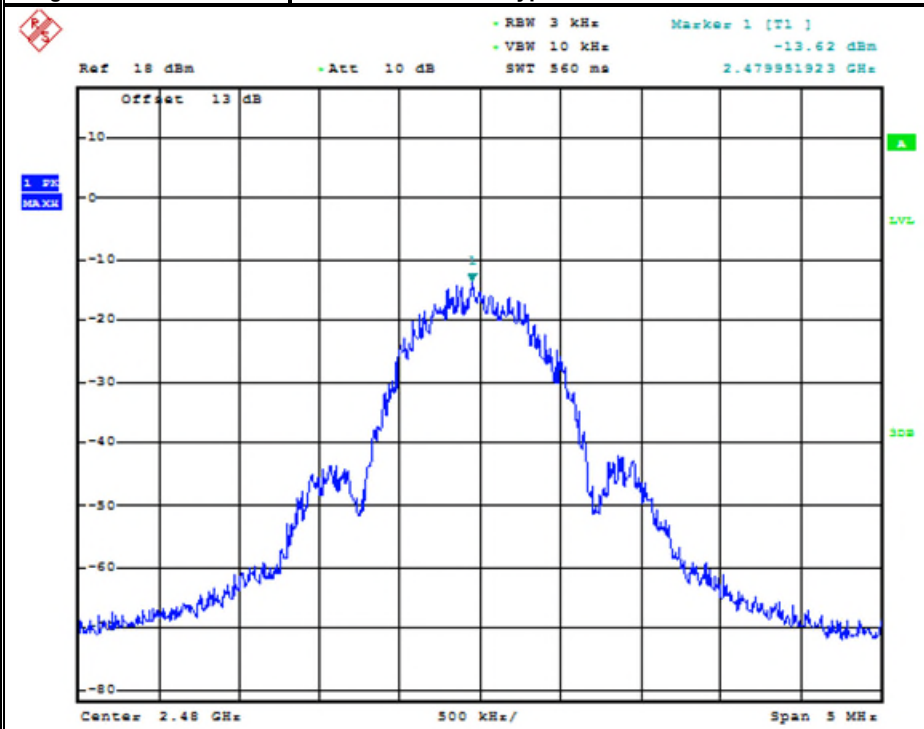
Plot #2

Mid channel 2441 MHz | **Modulation/Packet Type: BTLE**



Plot #3

High channel 2480 MHz | **Modulation/Packet Type: BTLE**



8.3 Duty cycle

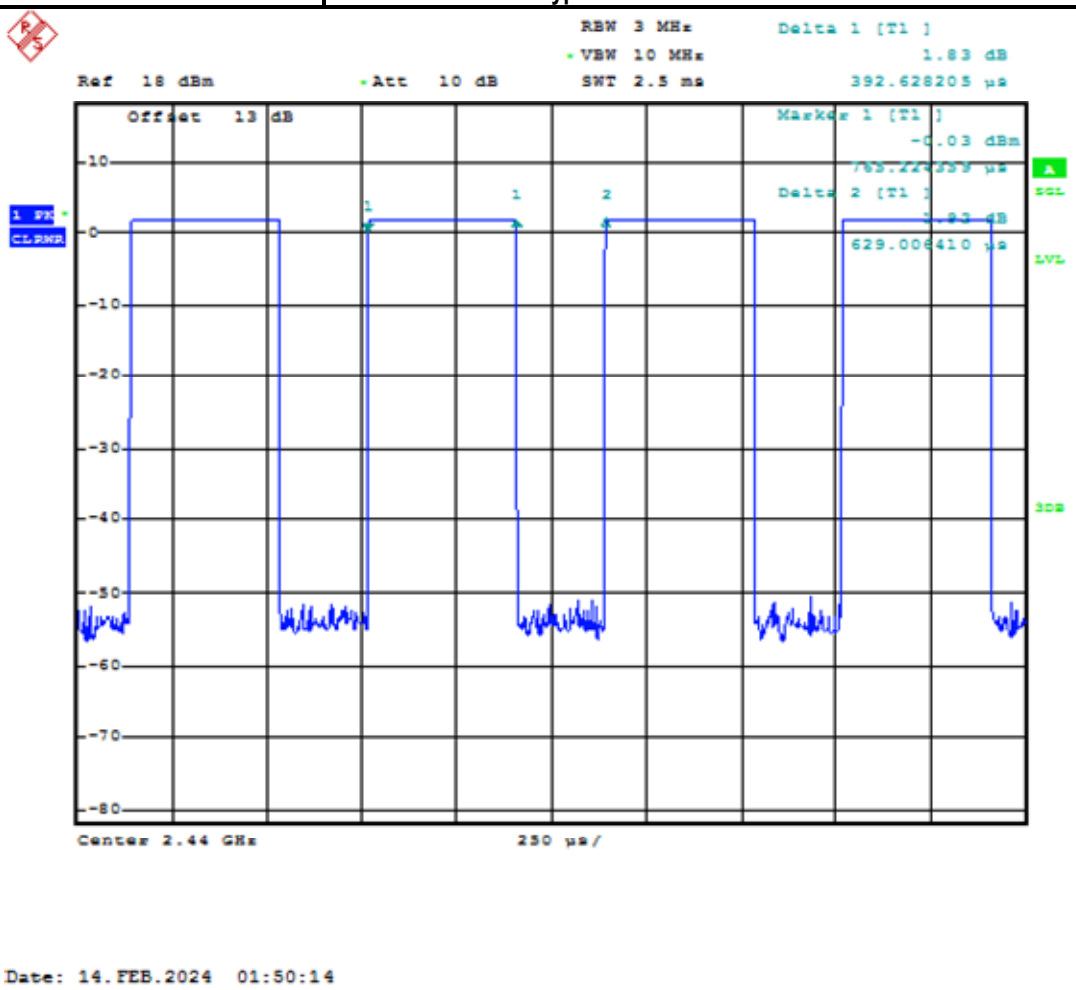
8.3.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02

Spectrum Analyzer settings:

- Set the center frequency and of the instrument to the center frequency of the transmission
- Zero span
- Set RBW >=OBW if possible; otherwise, set RBW to the largest available value
- Detector = Peak or average

8.3.2 Measurement result

Duty cycle measurement	
Mid channel / 2440 MHz	Modulation/Packet Type: BTLE



Duty cycle = 62.4%
Duty cycle correction factor = 10*log(1/0.624) = 2.05 dB

8.4 Emission Bandwidth 6dB and 99% Occupied Bandwidth

8.4.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02

Spectrum Analyzer settings:

6dB (DTS) Bandwidth:

- Set RBW = 100 kHz
- Set the video bandwidth (VBW) ≥ 3 x RBW
- Detector = Peak
- Trace mode = Max hold
- Sweep = Auto couple
- Allow the trace to stabilize
- Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

99% Occupied Bandwidth:

- Set frequency = nominal EUT channel center frequency
- Set Span = 1.5 x to 5.0 x OBW
- Set RBW = 1% to 5% of OBW
- Set the video bandwidth (VBW) ≈ 3 x RBW
- Detector = Peak
- Trace mode = Max hold
- Sweep = Auto couple
- Allow the trace to stabilize
- Use the 99% power bandwidth function of the instrument (if available) and report the measured bandwidth
- If the instrument does not have a 99% power bandwidth function, then the trace data points are recovered and directly summed in linear power terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached; that frequency is recorded as the lower frequency. The process is repeated until 99.5% of the total is reached; that frequency is recorded as the upper frequency. The 99% power bandwidth is the difference between these two frequencies.

8.4.2 Limits:

FCC §15.247(a)(2) and RSS-247 5.2(a)

- Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

8.4.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22.5° C	1	Op. 1	3.6 VDC

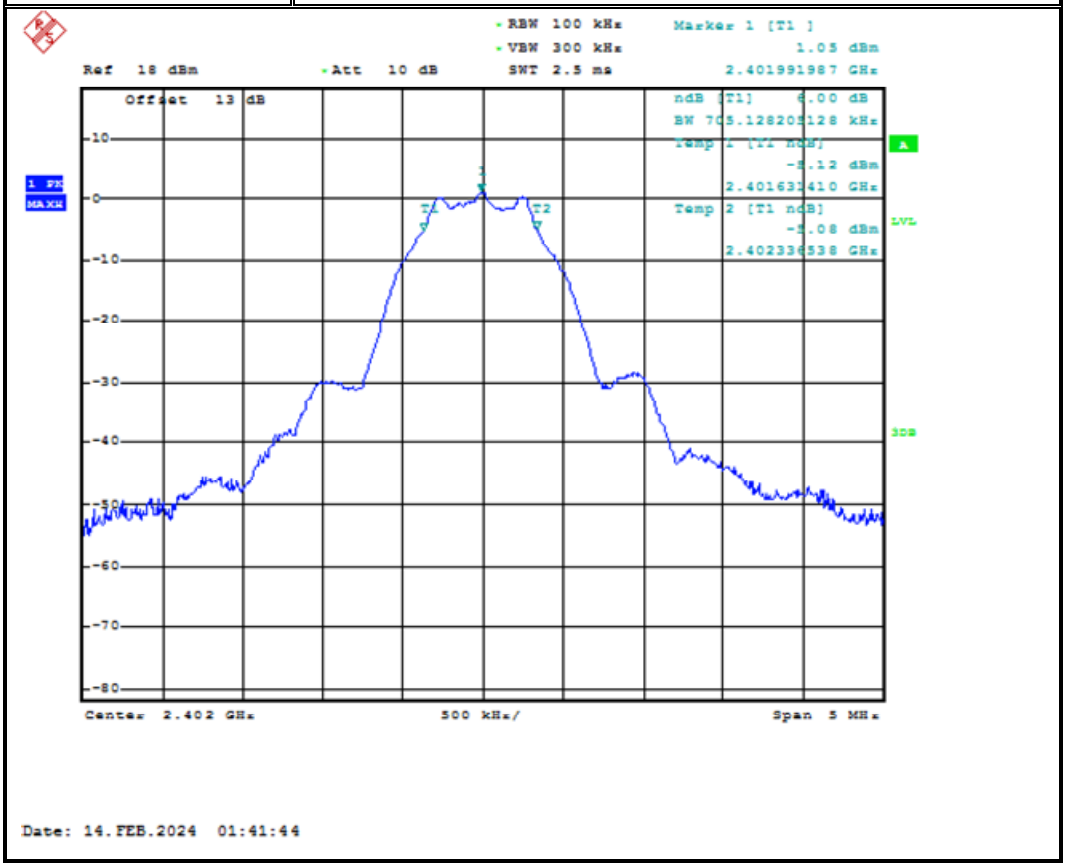
8.4.4 Measurement result:

Plot #	Frequency (MHz)	6dB Emissions Bandwidth (MHz)	Limit (MHz)	Result
1	2402	0.7051	> 0.5	Pass
2	2440	0.7051	> 0.5	Pass
3	2480	0.7051	> 0.5	Pass

Plot #	Frequency (MHz)	99% Occupied Bandwidth (MHz)	Limit (MHz)	Result
4	2402	1.0576	> 0.5	Pass
5	2440	1.0576	> 0.5	Pass
6	2480	1.0576	> 0.5	Pass

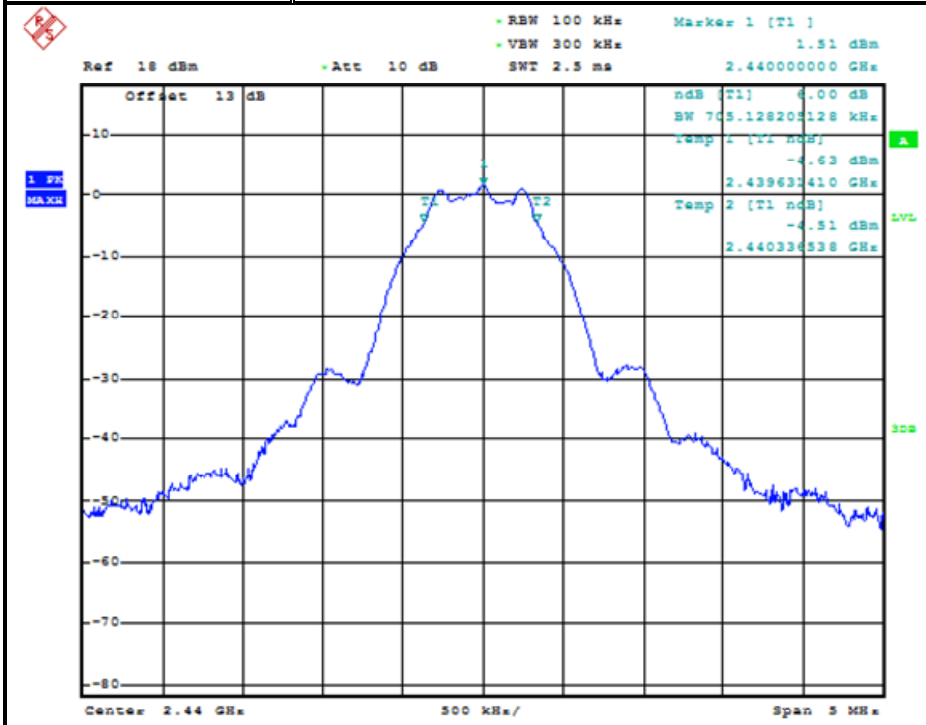
8.4.5 Measurement Plots:

Plot #1	
Low channel / 2402 MHz	Mode: BTLE



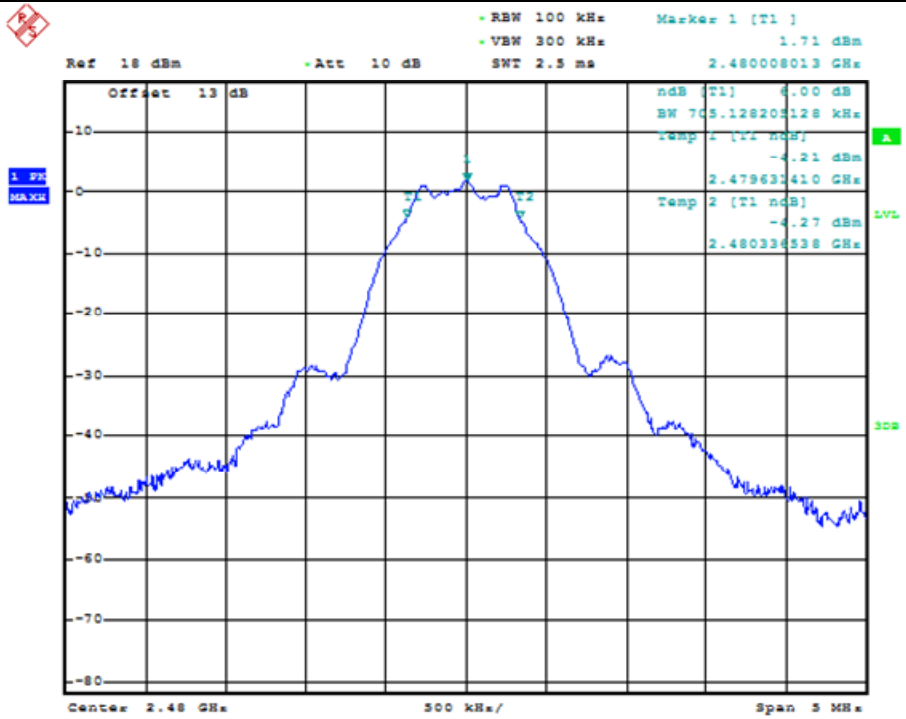
Plot #2

Mid channel / 2440 MHz	Mode: BTLE



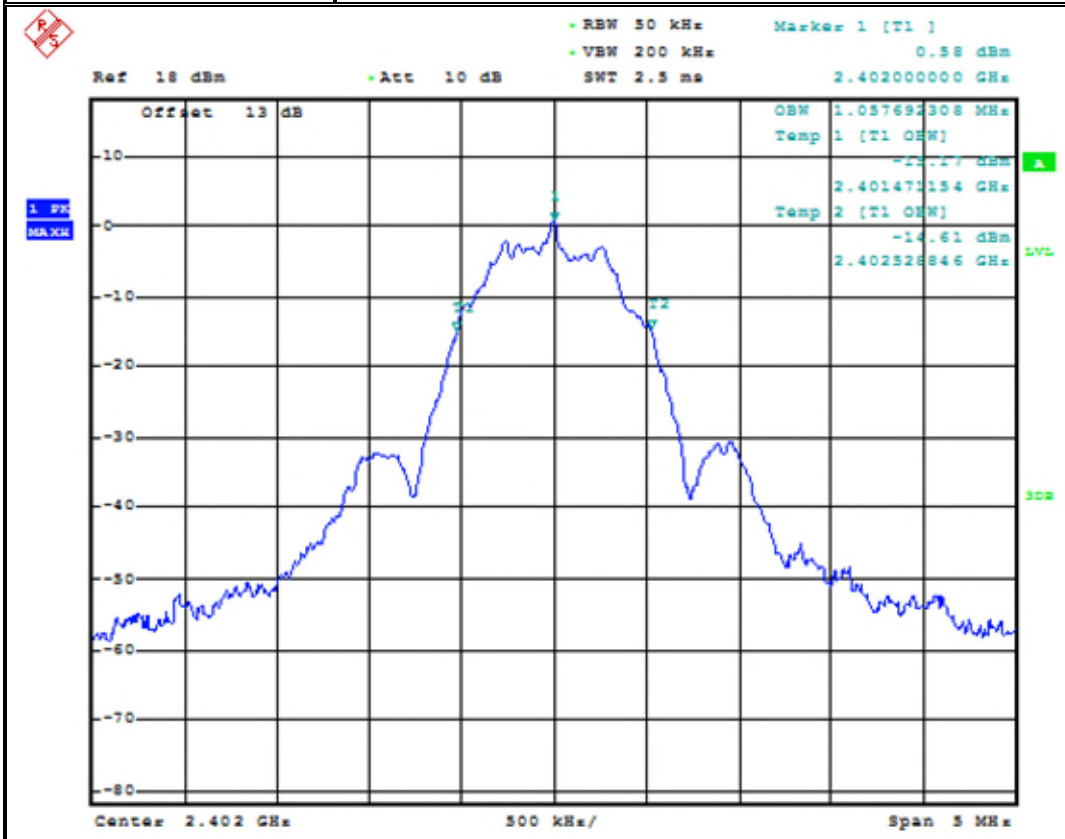
Plot #3

High channel / 2480 MHz	Mode: BTLE



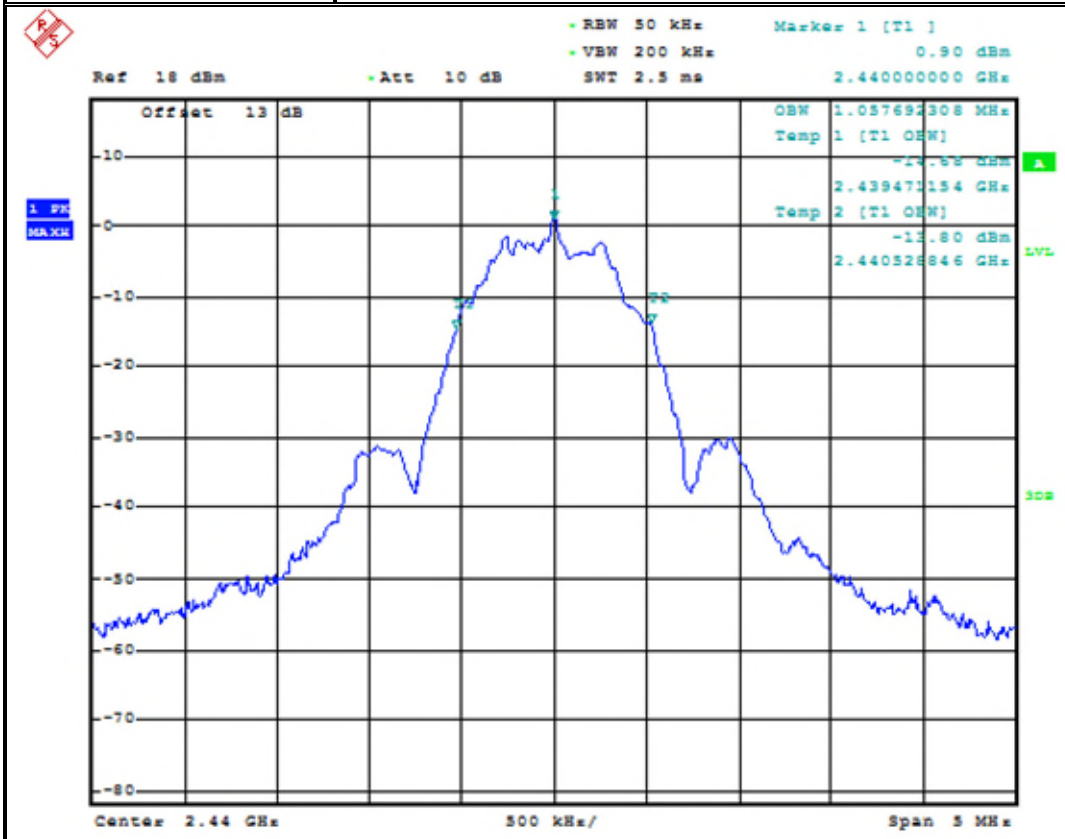
Plot #4

Low channel / 2402 MHz	Mode: BTLE



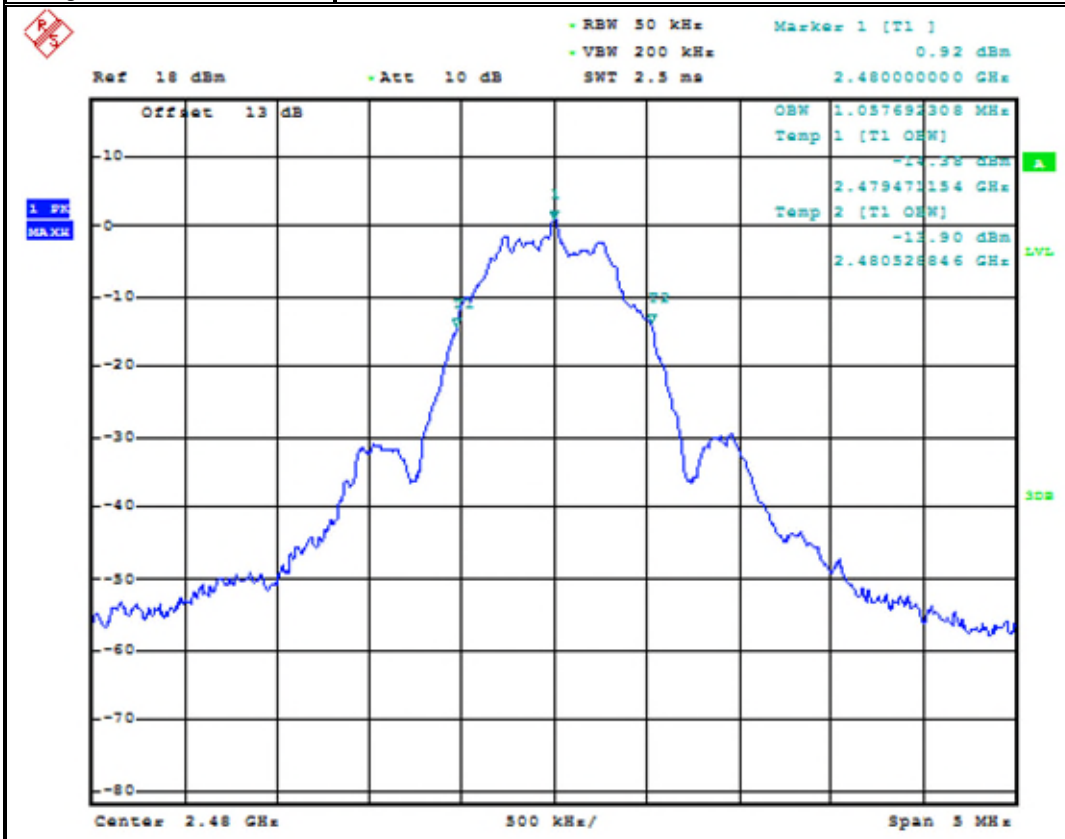
Plot #5

Mid channel / 2440 MHz	Mode: BTLE



Plot #6

High channel / 2480 MHz	Mode: BTLE



8.5 Non-Restricted Band Edge Compliance and Conducted Spurious Emissions

8.5.1 Emissions in Non-Restricted Frequency Bands

Measurement according to ANSI C63.10 Section 6.10:

- Set the center frequency and span to encompass frequency range to be measured
- RBW = 100 kHz
- VBW ≥ 3 x RBW
- Sweep Time: Auto couple
- Detector = Peak
- Trace = Max hold
- Allow trace to fully stabilize
- Use the peak marker function to determine the maximum amplitude level
- Set the marker on the emission at the band edge, or on the highest modulation product outside of the band, if this level is greater than that at the band edge

8.5.2 Limits: Non-restricted Band

FCC §15.247(d)

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

RSS-247 5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 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.

8.5.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna gain
22.5 °C	1	Op. 1	3.6 VDC	3.3 dBi

8.5.4 Measurement result:

Fundamental Signal at 100 kHz RBW

Plot #	Frequency (MHz)	Fundamental Signal at 100 kHz RBW (dBm)
1	2402	1.03
2	2440	1.49
3	2480	1.70

Non-Restricted Band Edge

Plot #	EUT operating mode	Band Edge	Band Edge Delta (dBc)	Limit (dBc)	Result
4	Op. 1	Lower, non-restricted	50.39	> 20	Pass

Non-Restricted Conducted Spurious Emissions

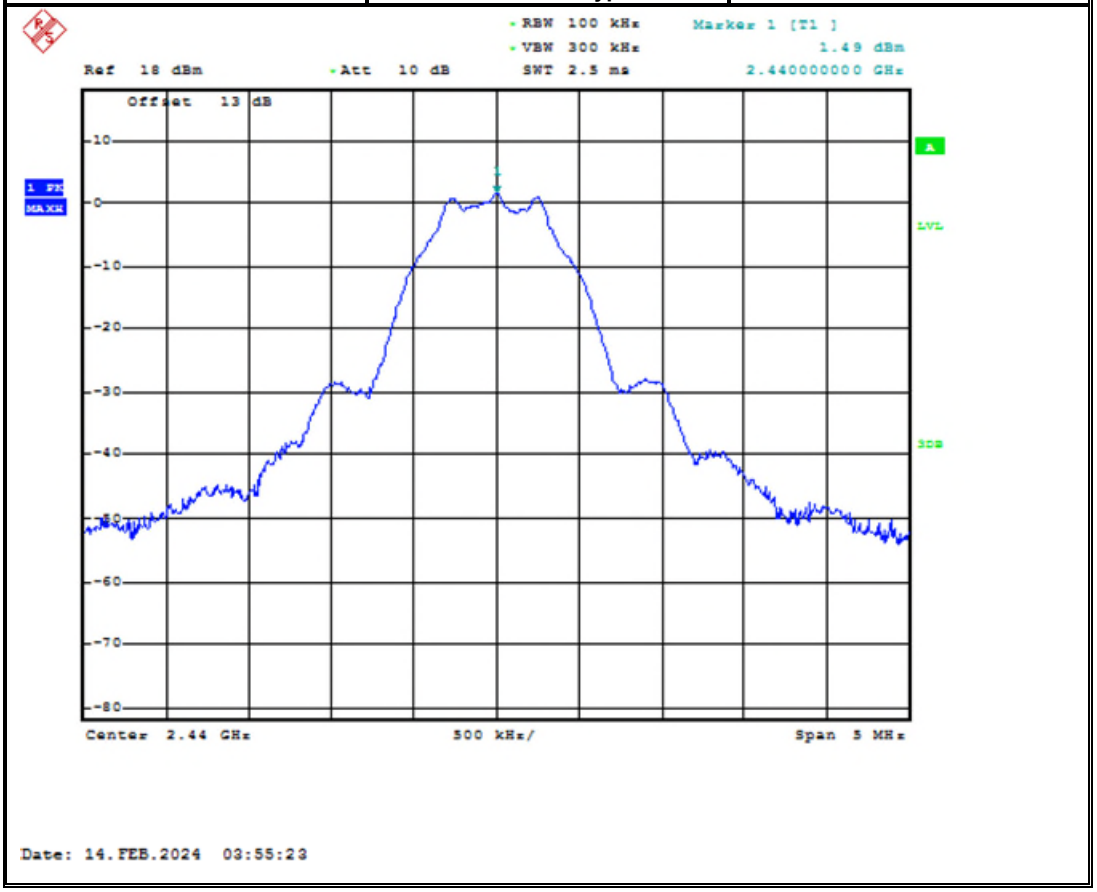
Plot #	Frequency (MHz)	EUT Operating Mode	Frequency range	Measured Lowest Margin (dBc)	Limit (dBc)	Result
5 – 9	2402	Op. 1	30 MHz – 26 GHz	52.21	> 20	Pass
10 – 14	2440			56.20	> 20	Pass
15 – 19	2480			56.57	> 20	Pass

Note: Measured Lowest Margin (dBc) = Fundamental Signal (dBm) – Highest Spurious Emission (dBm)

8.5.5 Measurement Plots:

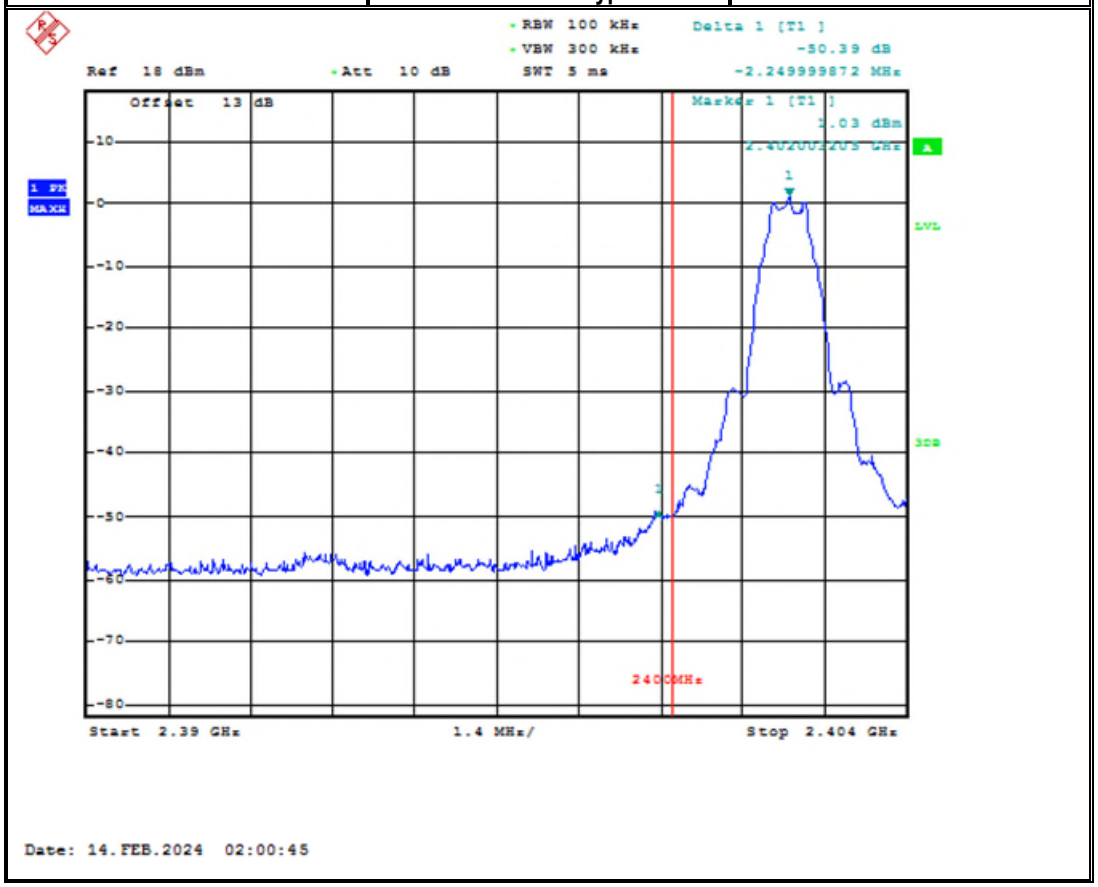
Plot #1 Fundamental Signal at 100 kHz		
Low channel / 2402 MHz	Modulation/Packet Type: BTLE	Peak Detector

Plot #2 Fundamental Signal at 100 kHz RBW		
Mid channel / 2440 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**

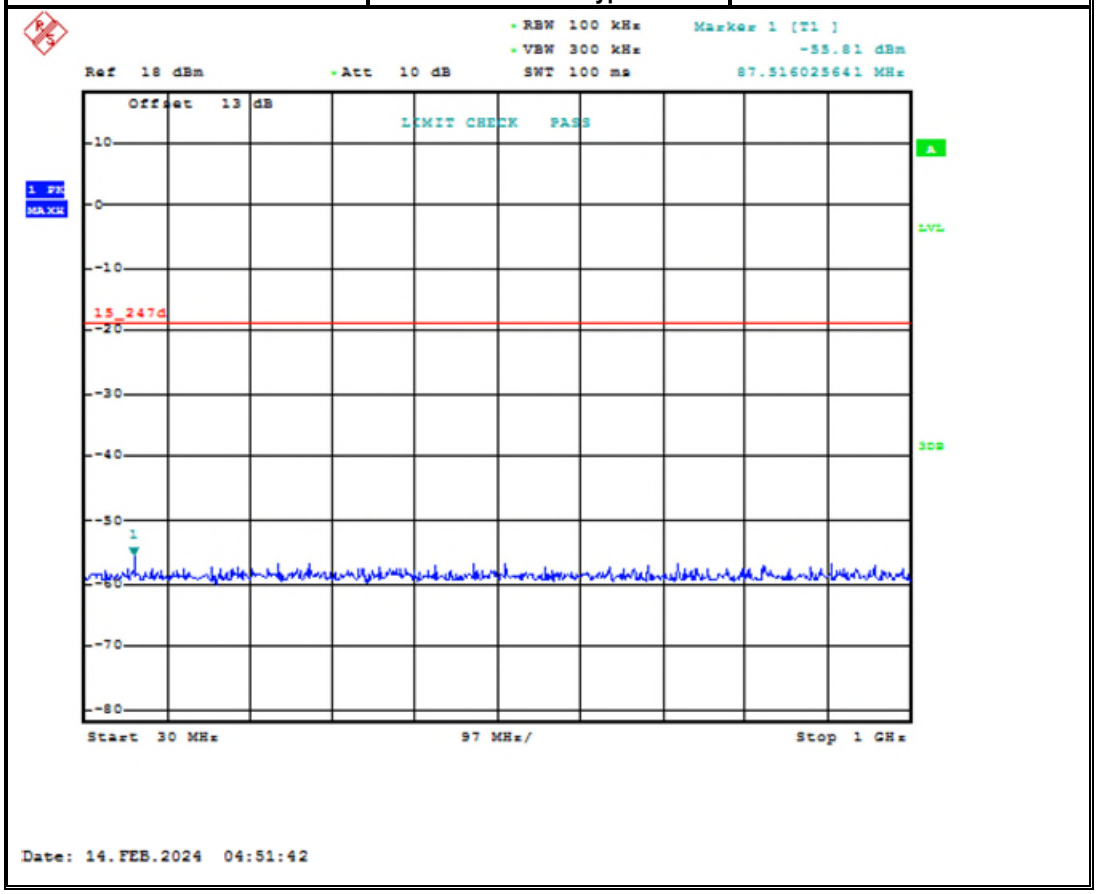


Plot #3 Fundamental Signal at 100 kHz RBW		
High channel / 2480 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**

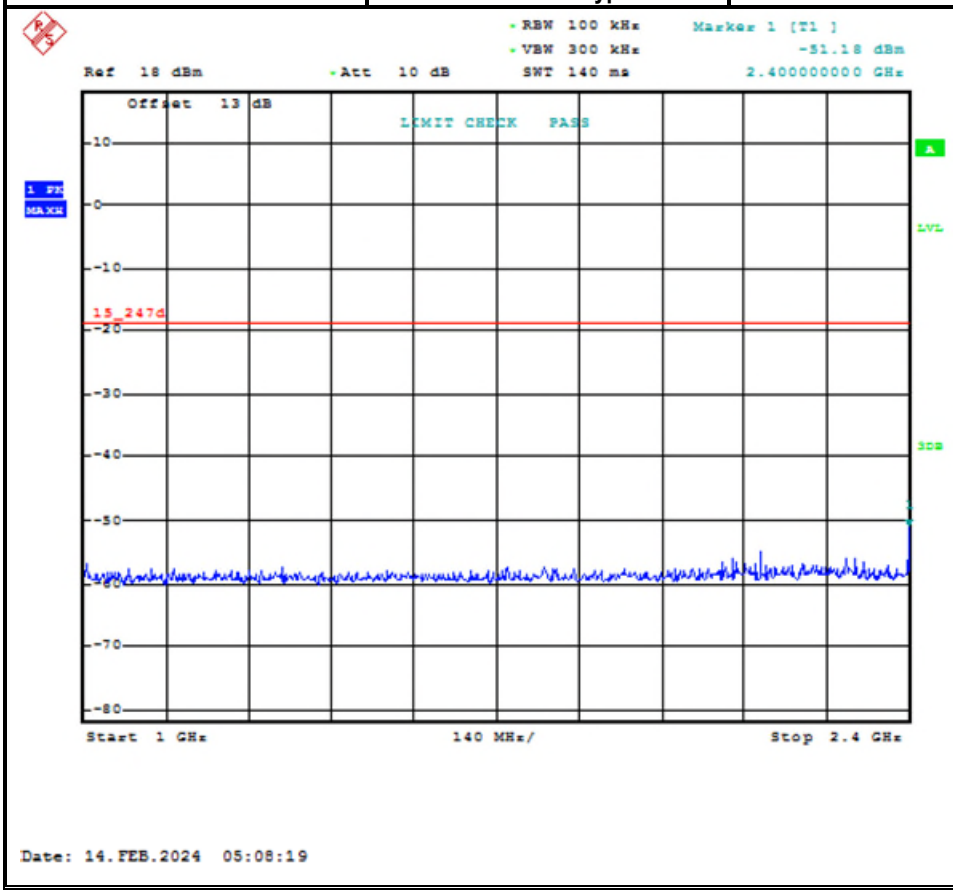
Plot #4 Lower Non-Restricted Band Edge		
Low channel / 2402 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



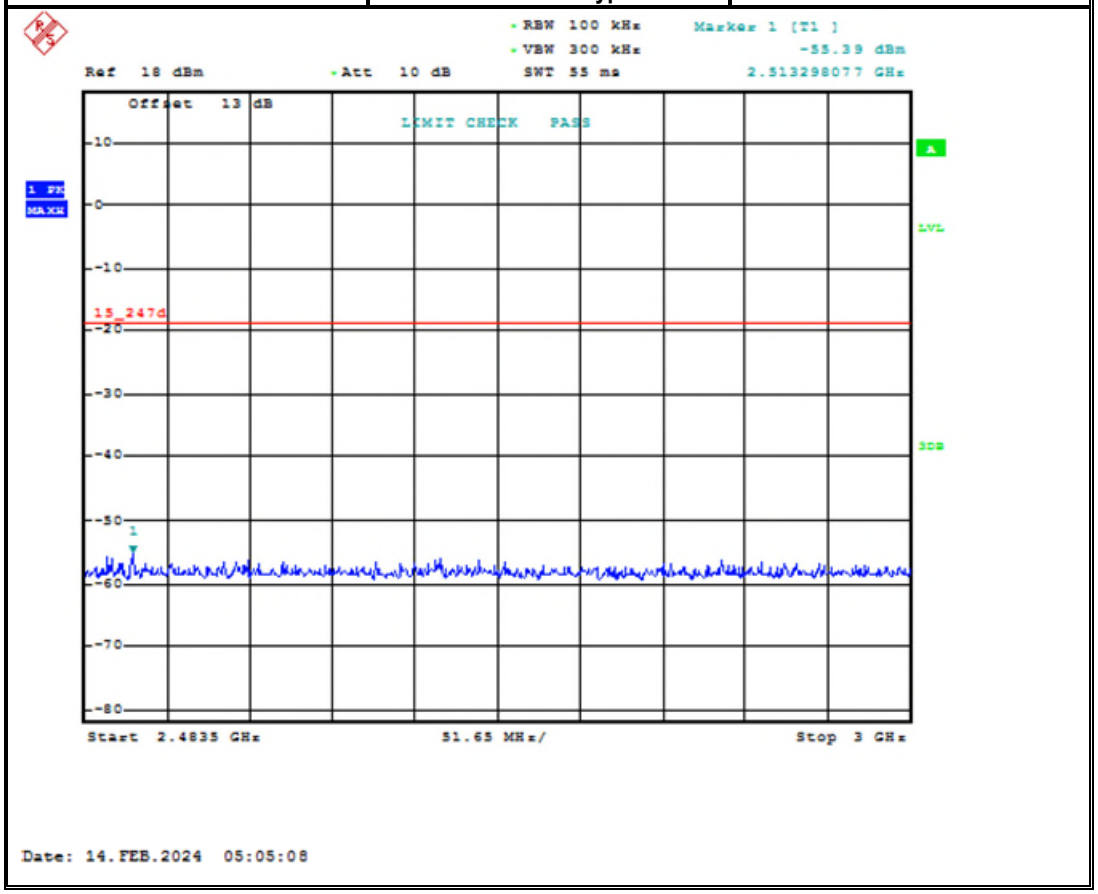
Plot #5 Conducted Spurious Emissions: 30 MHz – 1 GHz		
Low channel / 2402 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



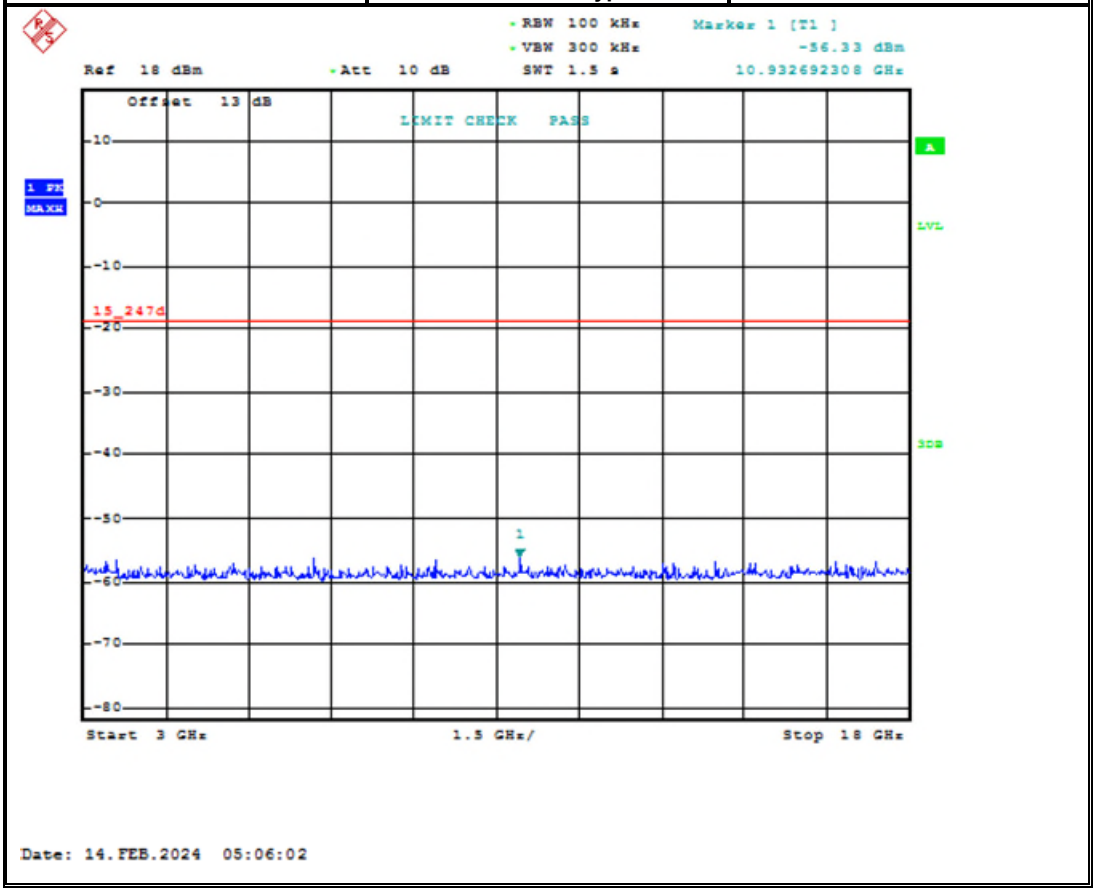
Plot #6 Conducted Spurious Emissions: 1 – 2.4 GHz		
Low channel / 2402 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



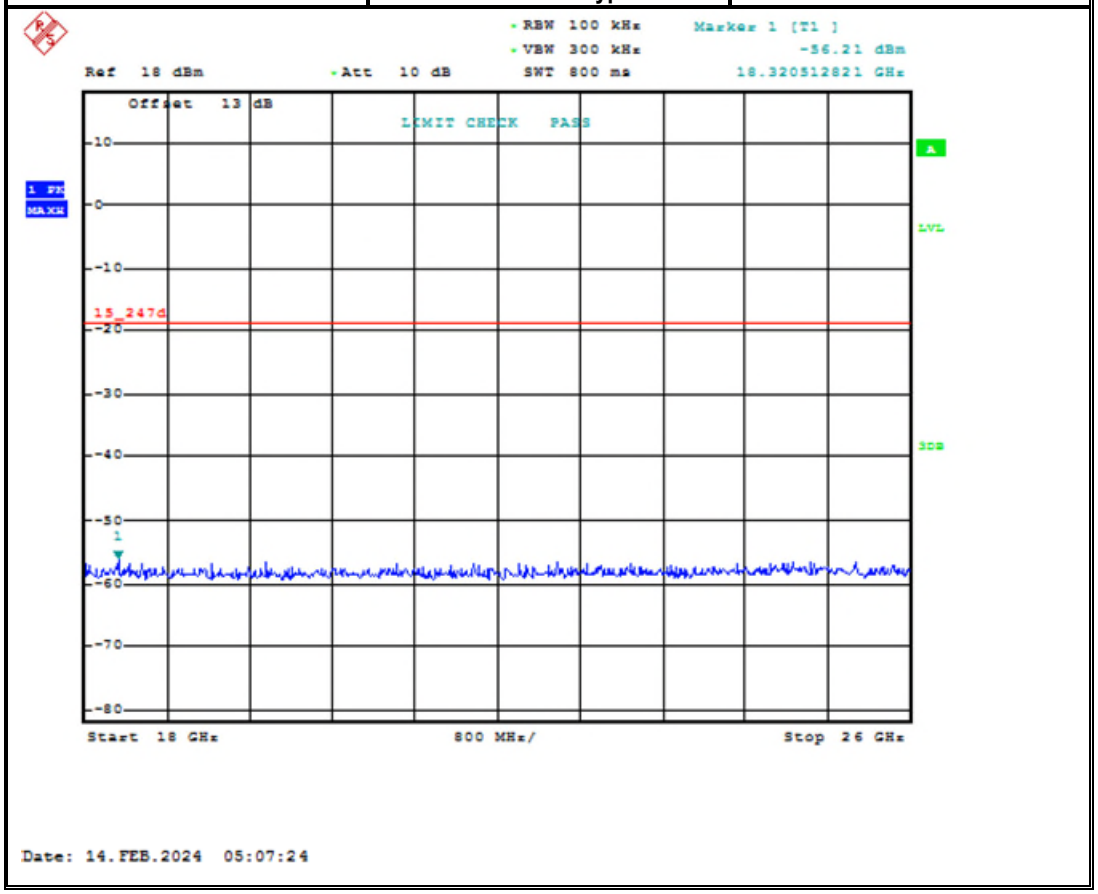
Plot #7 Conducted Spurious Emissions: 2.4835 – 3 GHz		
Low channel / 2402 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



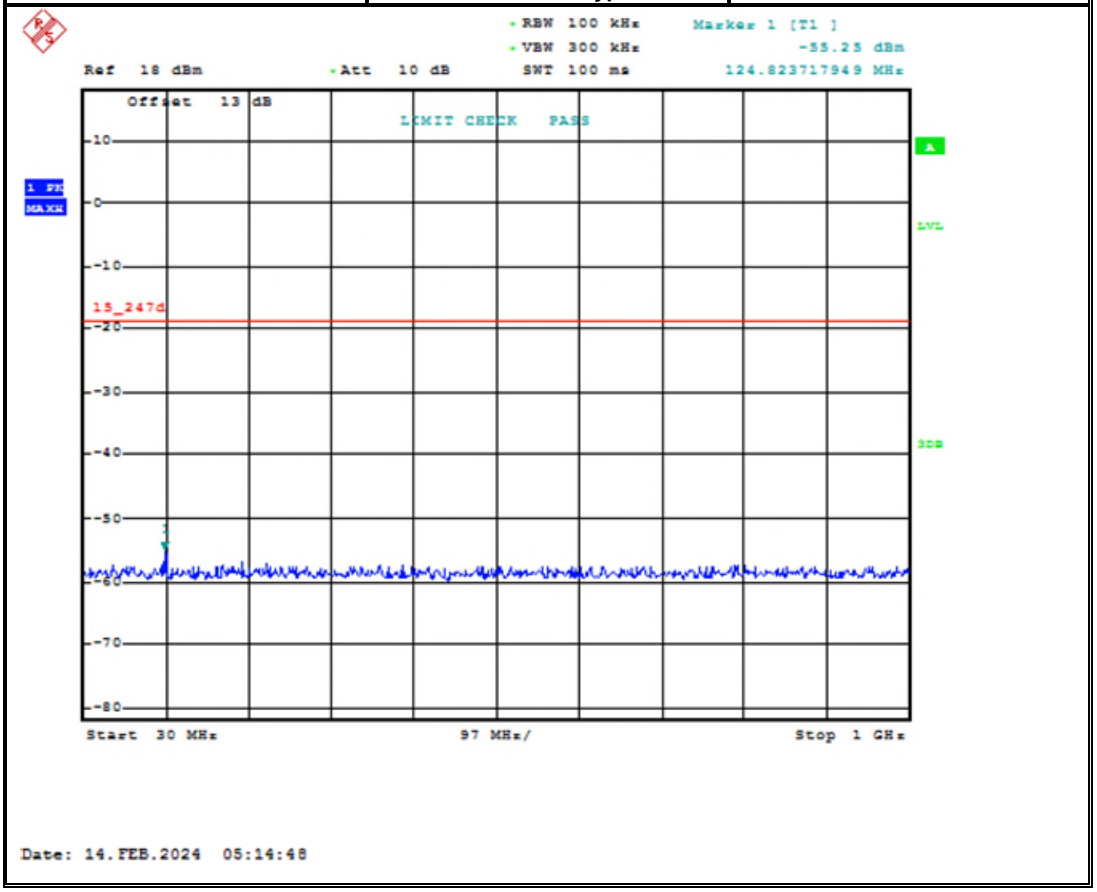
Plot #8 Conducted Spurious Emissions: 3 – 18 GHz		
Low channel / 2402 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



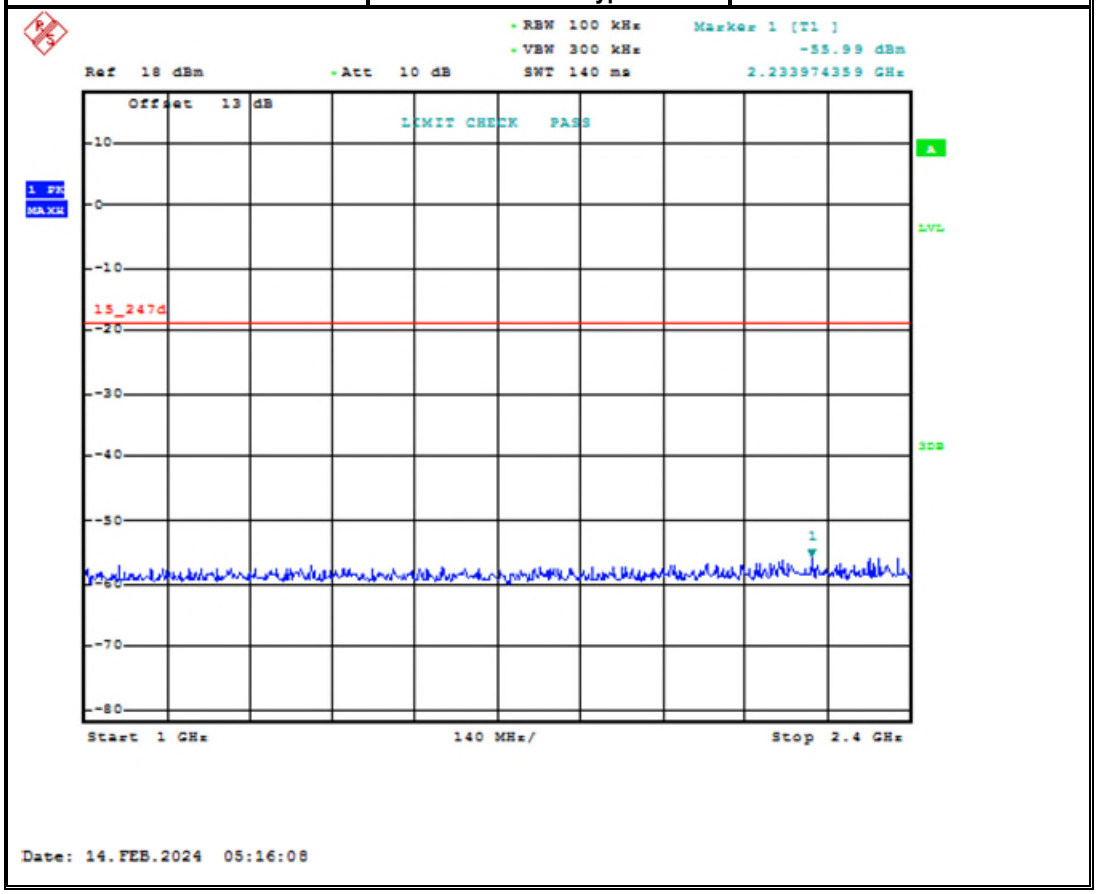
Plot #9 Conducted Spurious Emissions: 18 – 26 GHz		
Low channel / 2402 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



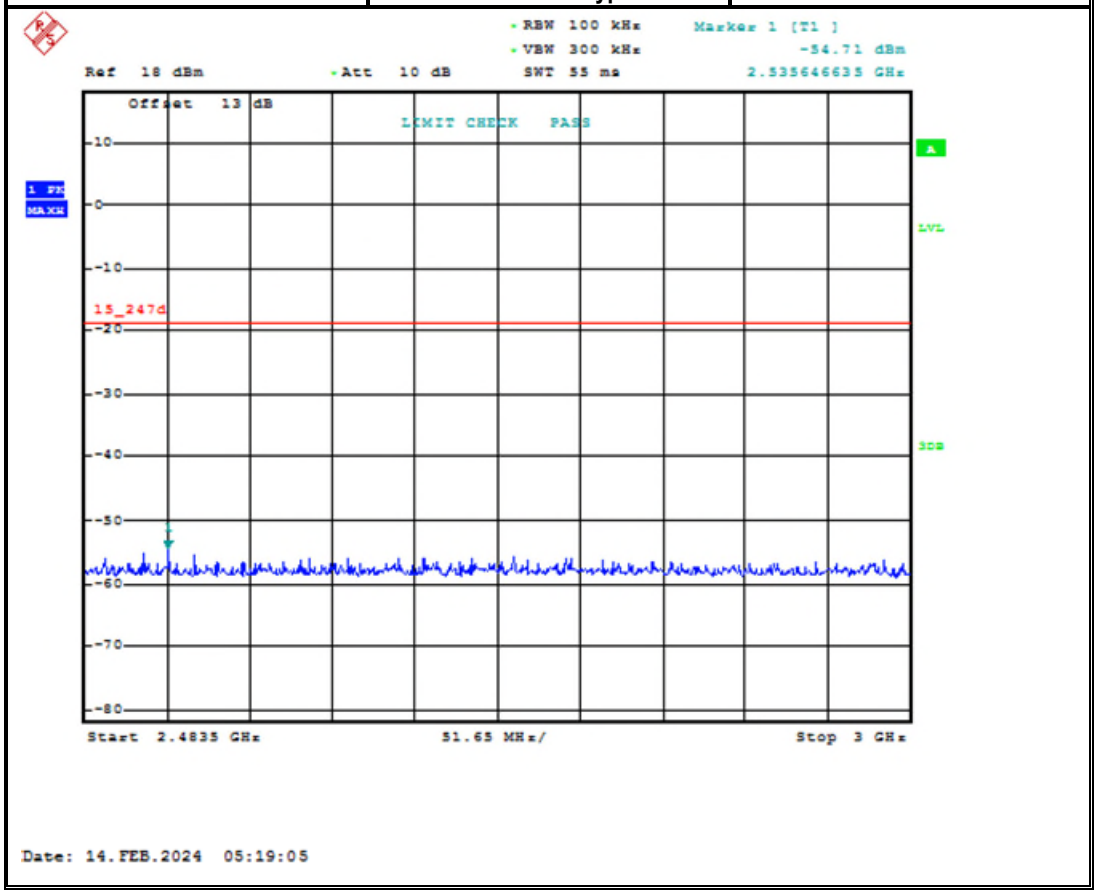
Plot #10 Conducted Spurious Emissions: 30 MHz – 1 GHz		
Mid channel / 2440 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



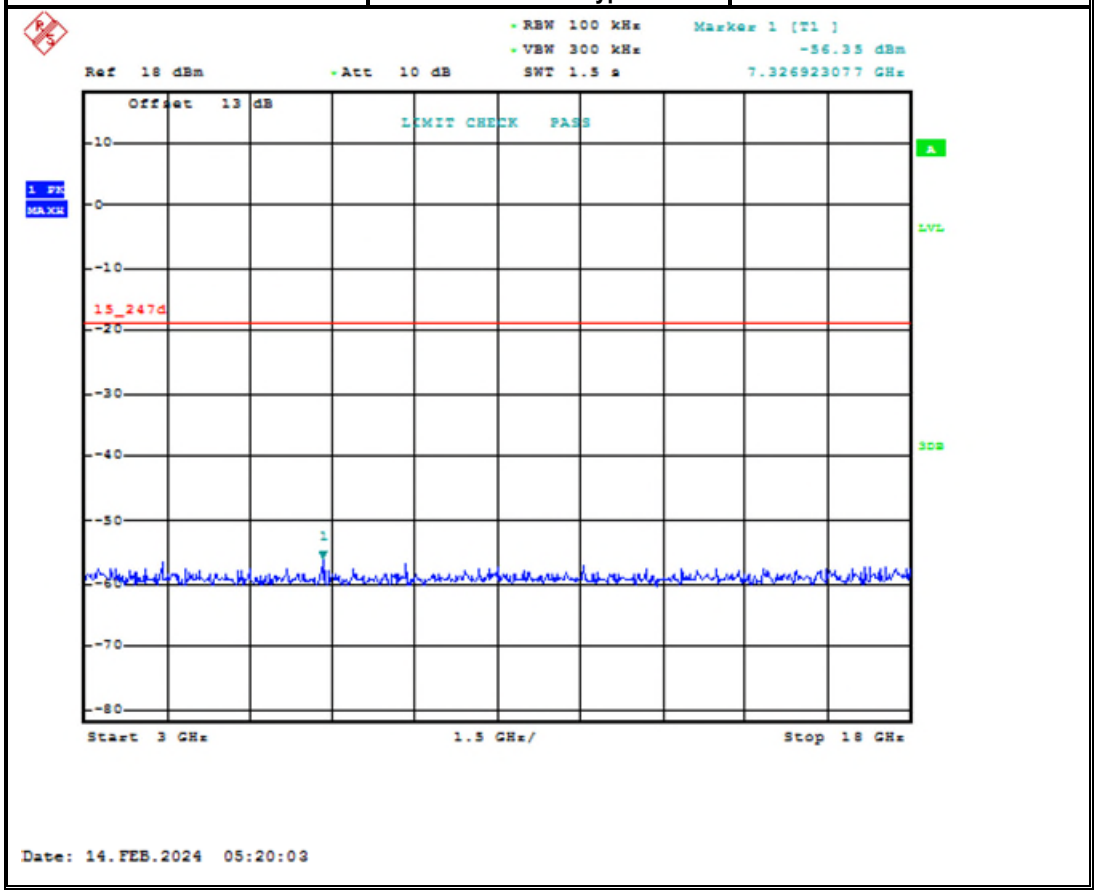
Plot #11 Conducted Spurious Emissions: 1 – 2.4 GHz		
Mid channel / 2440 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



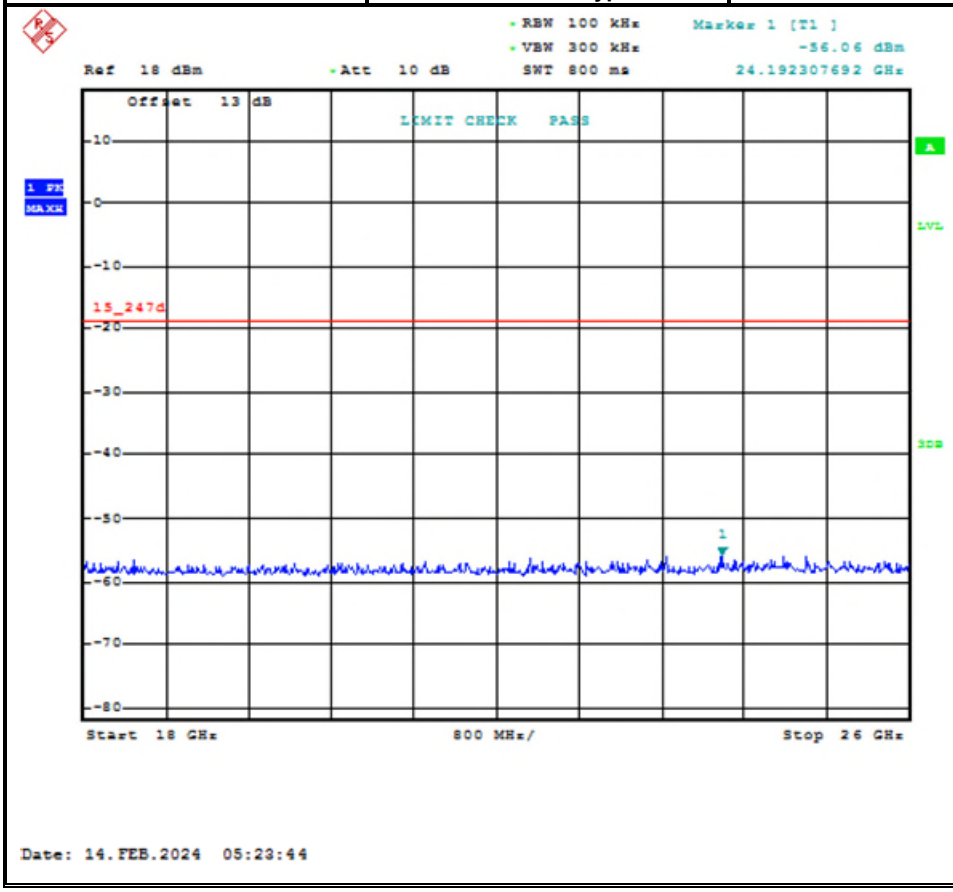
Plot #12 Conducted Spurious Emissions: 2.4835 – 3 GHz		
Mid channel / 2440 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



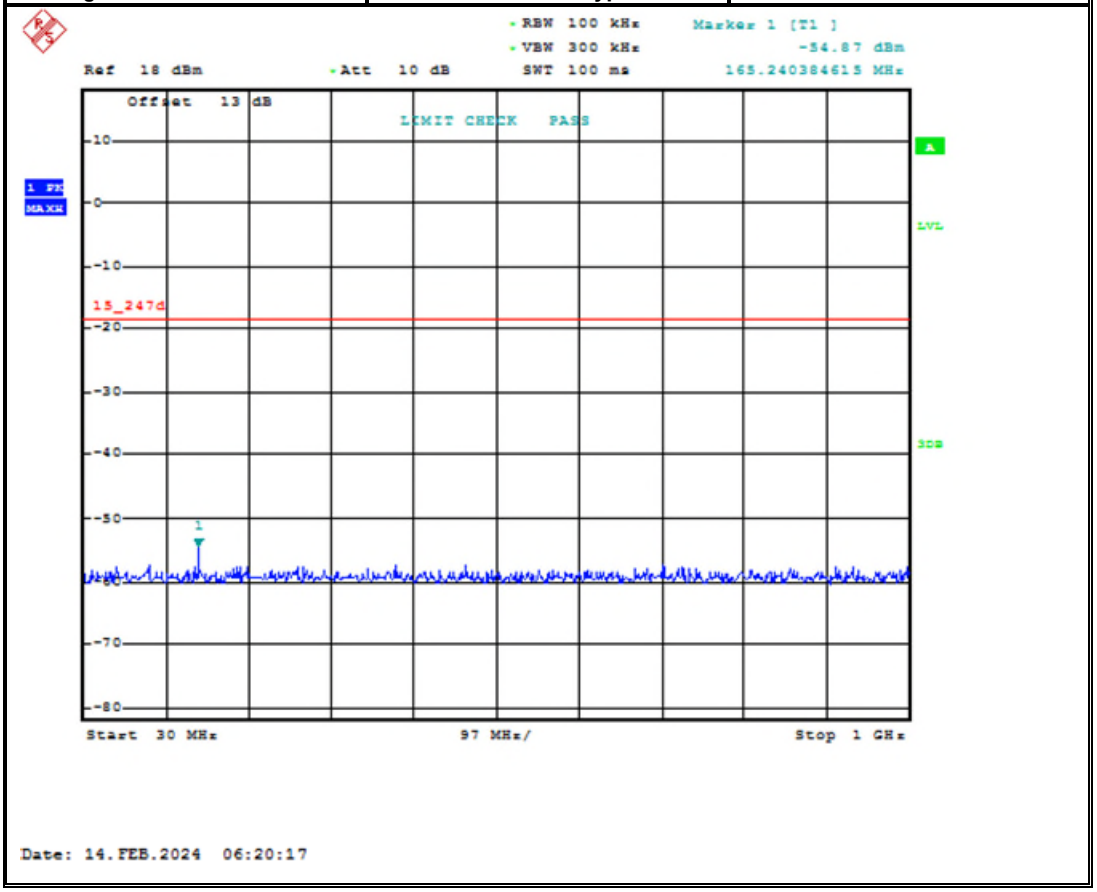
Plot #13 Conducted Spurious Emissions: 3 – 18 GHz		
Mid channel / 2440 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



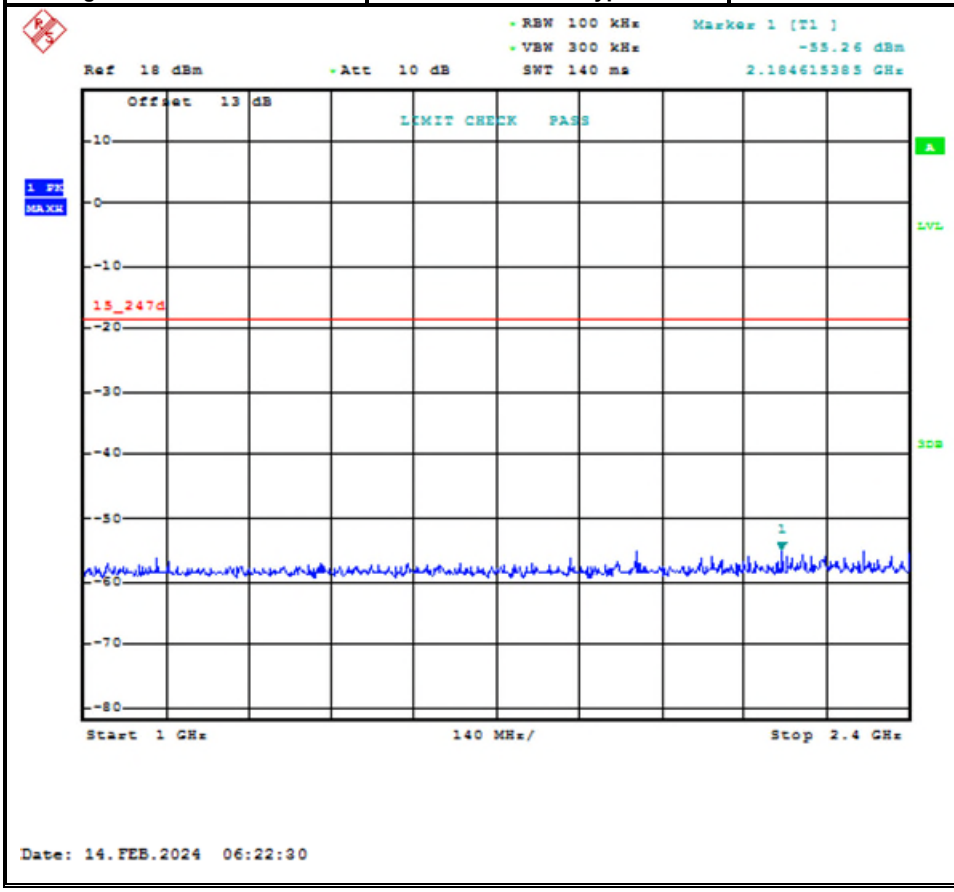
Plot #14 Conducted Spurious Emissions: 18 – 26 GHz		
Mid channel / 2440 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



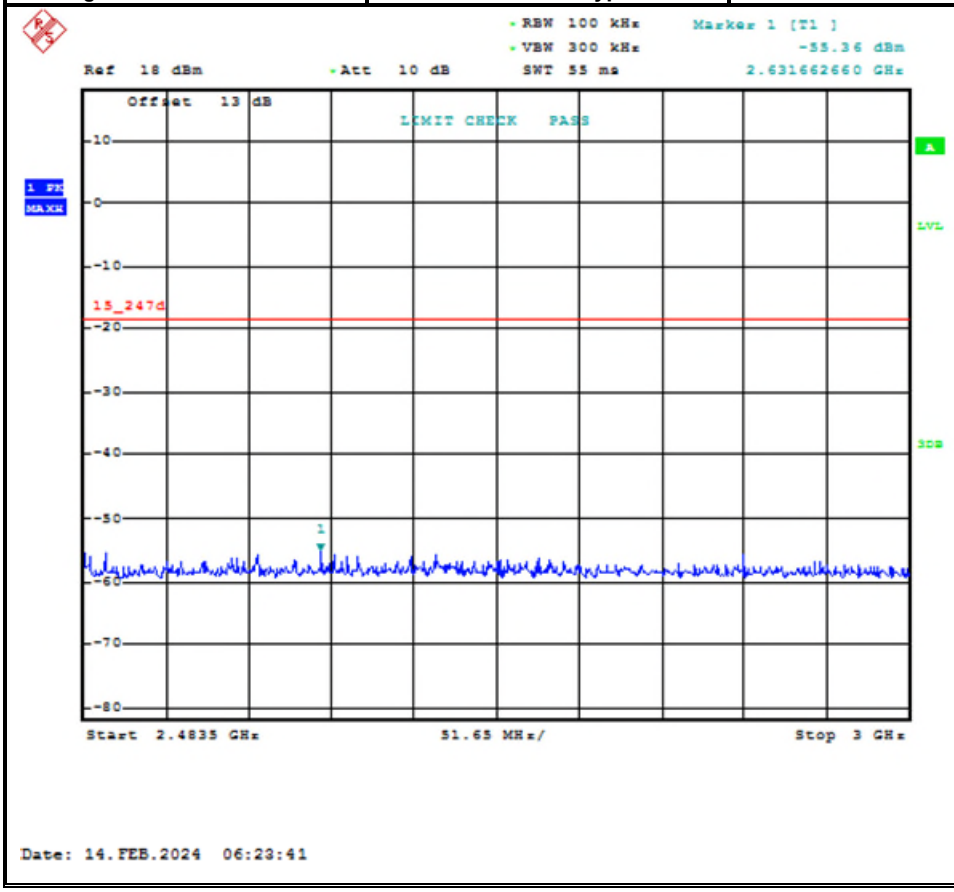
Plot #15 Conducted Spurious Emissions: 30 MHz – 1 GHz		
High channel / 2480 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



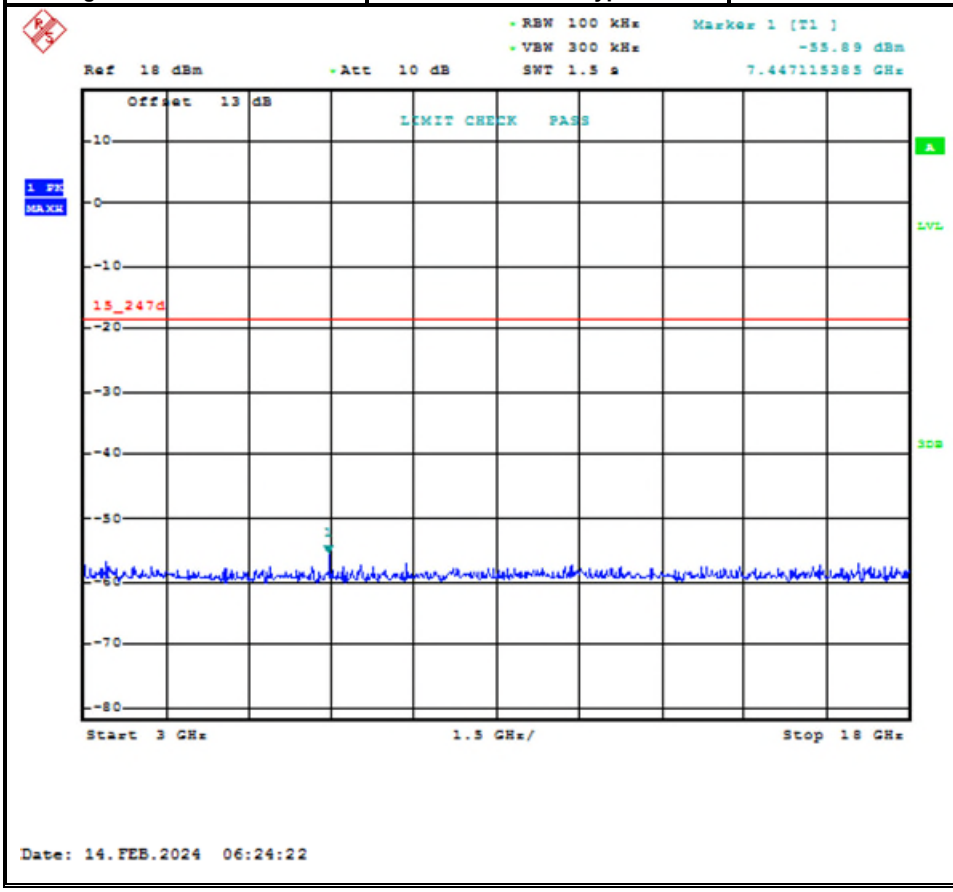
Plot #16 Conducted Spurious Emissions: 1 – 2.4 GHz		
High channel / 2480 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



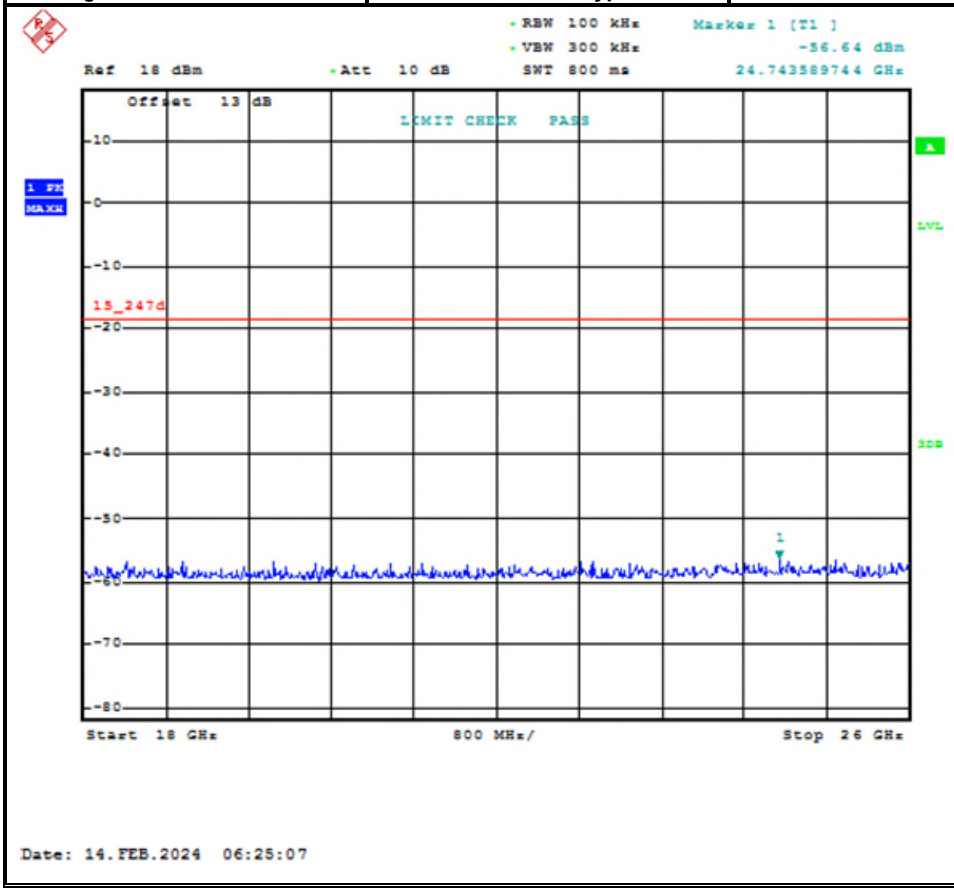
Plot #17 Conducted Spurious Emissions: 2.4835 – 3 GHz		
High channel / 2480 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



Plot #18 Conducted Spurious Emissions: 3 – 18 GHz		
High channel / 2480 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



Plot #19 Conducted Spurious Emissions: 18 – 26 GHz		
High channel / 2480 MHz	**Modulation/Packet Type: BTLE**	**Peak Detector**



8.6 Radiated Transmitter Spurious Emissions and Restricted Bands

8.6.1 Measurement according to ANSI C63.10 (2013)

Spectrum Analyzer Settings:

- Frequency = 9 KHz – 30 MHz
- RBW = 9 KHz
- Detector: Peak

- Frequency = 30 MHz – 1 GHz
- Detector = Peak / Quasi-Peak
- RBW= 120 KHz (<1GHz)

- Frequency > 1 GHz
- Detector = Peak / Average
- RBW = 1 MHz

- Radiated spurious emissions shall be measured for the transmit frequencies, transmit power, and data rate for the lowest, middle and highest channel in each frequency band of operation and for the highest gain antenna for each antenna type, and using the appropriate parameters and test requirements.
- The highest (or worst-case) data rate shall be recorded for each measurement.
- For testing frequencies below 30 MHz at distance other than the specified in the standard, the limit conversion is calculated by using the FCC materials for the ANSI 63 committee issued on January, 27 1991.

8.6.2 Limits:

FCC §15.247(d)

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

FCC §15.209(a)

Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency of emission (MHz)	Field strength (µV/m)	Measurement Distance (m)	Field strength @ 3m (dBµV/m)
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	40 dBµV/m
88–216	150 **	3	43.5 dBµV/m
216–960	200 **	3	46 dBµV/m
Above 960	500	3	54 dBµV/m

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

*PEAK LIMIT= 74 dBµV/m
*AVG. LIMIT= 54 dBµV/m

RSS-Gen 8.9

Except where otherwise indicated in the applicable RSS, radiated emissions shall comply with the field strength limits shown in table 5 and table 6. Additionally, the level of any transmitter unwanted emission shall not exceed the level of the transmitter's fundamental emission.

Table 5 – General field strength limits at frequencies above 30 MHz

Frequency (MHz)	Field strength (µV/m at 3 m)
30 – 88	100
88 – 216	150
216 – 960	200
Above 960	500

Table 6 – General field strength limits at frequencies below 30 MHz

Frequency	Magnetic field strength (H-Field) (µA/m)	Measurement Distance (m)
9 – 490 kHz	6.37/F (F in kHz)	300
490 – 1705 kHz	63.7/F (F in kHz)	30
1.705 – 30 MHz	0.08	30

Note 1: The emission limits for the ranges 9-90 kHz and 110-490 kHz are based on measurements employing a linear average detector.

*PEAK LIMIT= 74 dBµV/m
*AVG. LIMIT= 54 dBµV/m

FCC §15.205(a)

Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	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 8.10

Except where otherwise indicated, the following conditions related to the restricted frequency bands apply:

MHz	MHz	GHz
0.090-0.110	149.9-150.05	9.0-9.2
0.495-0.505	156.52475-156.52525	9.3-9.5
2.1735-2.1905	156.7-156.9	10.6-12.7
3.020-3.026	162.0125-167.17	13.25-13.4
4.125-4.128	167.72-173.2	14.47-14.5
4.17725-4.17775	240-285	15.35-16.2
4.20725-4.20775	322-335.4	17.7-21.4
5.677-5.683	399.9-410	22.01-23.12
6.215-6.218	608-614	23.6-24.0
6.26775-6.26825	960-1427	31.2-31.8
6.31175-6.31225	1435-1626.5	36.43-36.5
8.291-8.294	1645.5-1646.5	Above 38.6
8.362-8.366	1660-1710	
8.37625-8.38675	1718.8-1722.2	
8.41425-8.41475	2200-2300	
12.29-12.293	2310-2390	
12.51975-12.52025	2483.5-2500	
12.57675-12.57725	2690-2900	
13.36-13.41	3260-3267	
16.42-16.423	3332-3339	
16.69475-16.69525	3345.8-3358	
16.80425-16.80475	3500-4400	
25.5-25.67	4500-5150	
37.5-38.25	5350-5460	
73-74.6	7250-7750	
74.8-75.2	8025-8500	
108-138	--	

8.6.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22.5° C	2	Op. 2	3.6 VDC

8.6.4 Measurement result:

Restricted Radiated Spurious Emissions

Plot #	Channel #	Scan Frequency	Limit	Result
1 – 3	Low	30 MHz – 18 GHz	See section 8.7.2	Pass
4 – 8	Mid	9 kHz – 26 GHz	See section 8.7.2	Pass
9 – 11	High	30 MHz – 18 GHz	See section 8.7.2	Pass

Restricted Band Edge

Plot #	EUT operating mode	Band Edge	Measured value (dBµV/m)	Limit (dBuV/m)	Result
12	Op. 1	Upper restricted Peak	42.789	See section 8.7.2	Pass
		Upper restricted AVG	29.022		Pass

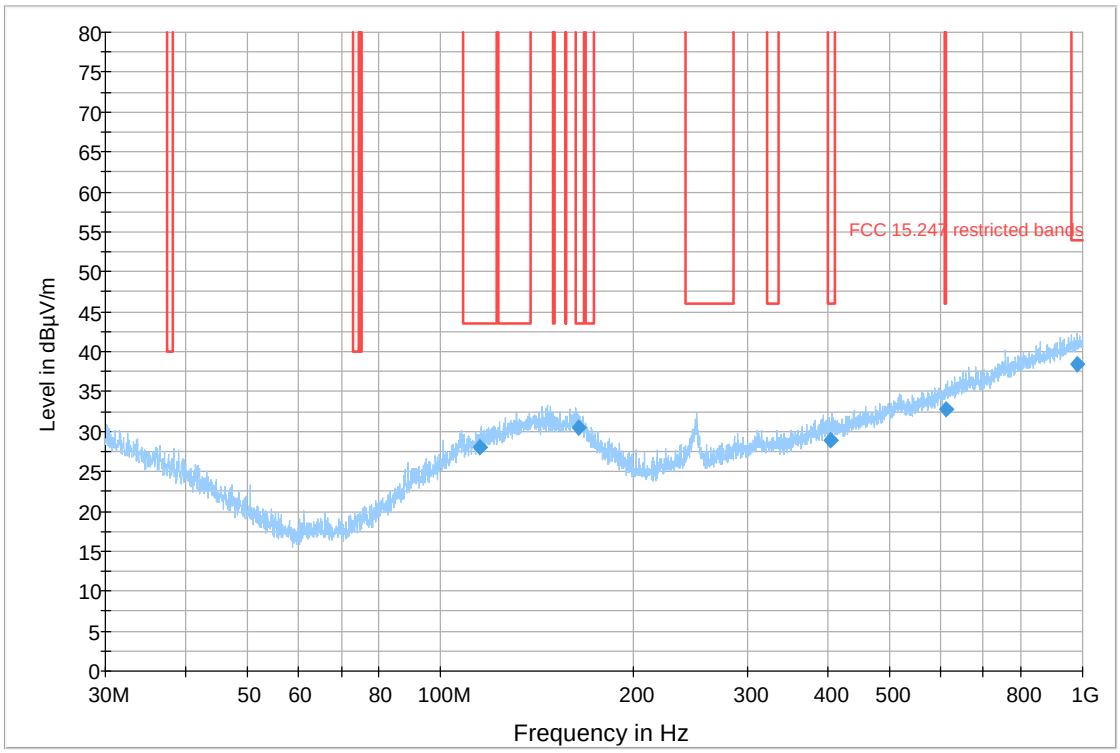
8.6.5 Measurement Plots:

Plot #1 Radiated Emissions: 30 MHz – 1 GHz

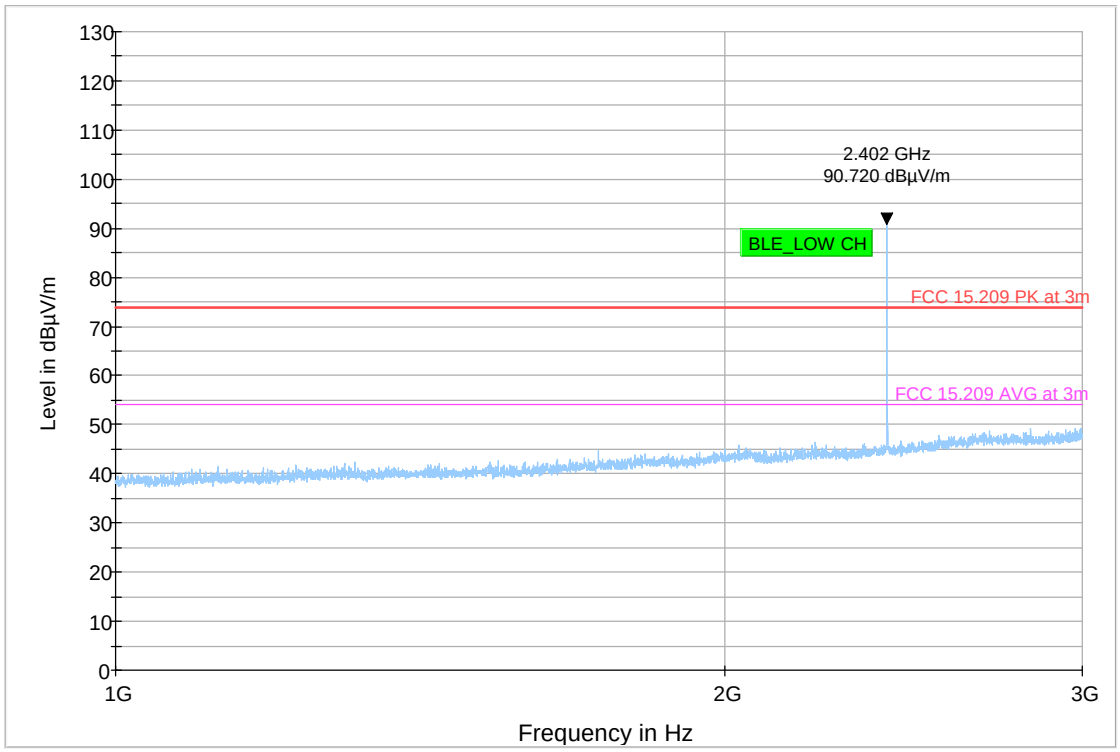
EUT Operating Mode: BLE, Fixed Channel	Channel: Low	50% Duty cycle

Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
115.254	28.097	43.50	15.40	500.0	120.000	400.0	V	222.0	-11.6
163.803	30.415	43.50	13.09	500.0	120.000	233.0	V	91.0	-9.7
404.942	28.965	46.02	17.05	500.0	120.000	250.0	H	203.0	-11.0
613.935	32.830	46.02	13.19	500.0	120.000	207.0	V	110.0	-7.7
980.535	38.476	53.98	15.50	500.0	120.000	182.0	V	285.0	-2.6



Plot #2 Radiated Emissions: 1 – 3 GHz		
EUT Operating Mode: BLE, Fixed Channel	**Channel: Low**	**50% Duty cycle**



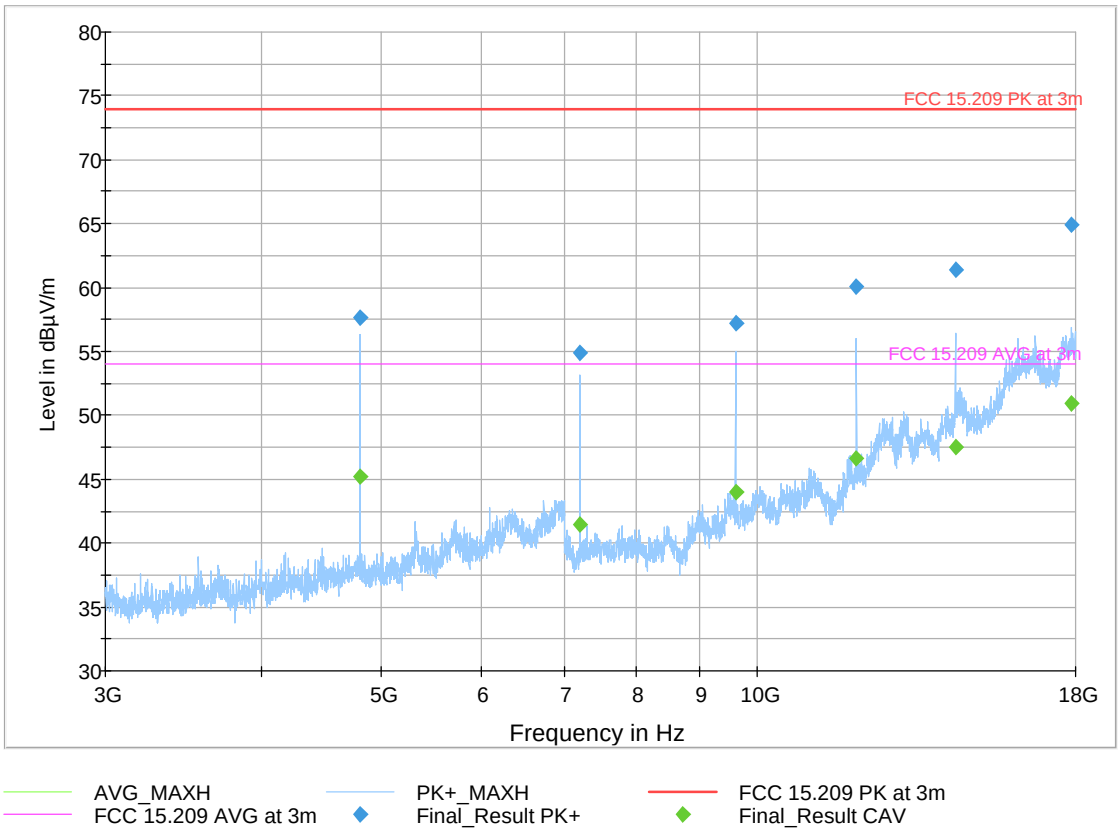
Note: The peak signal above is the transmit channel.

Plot #3 Radiated Emissions: 3 – 18 GHz

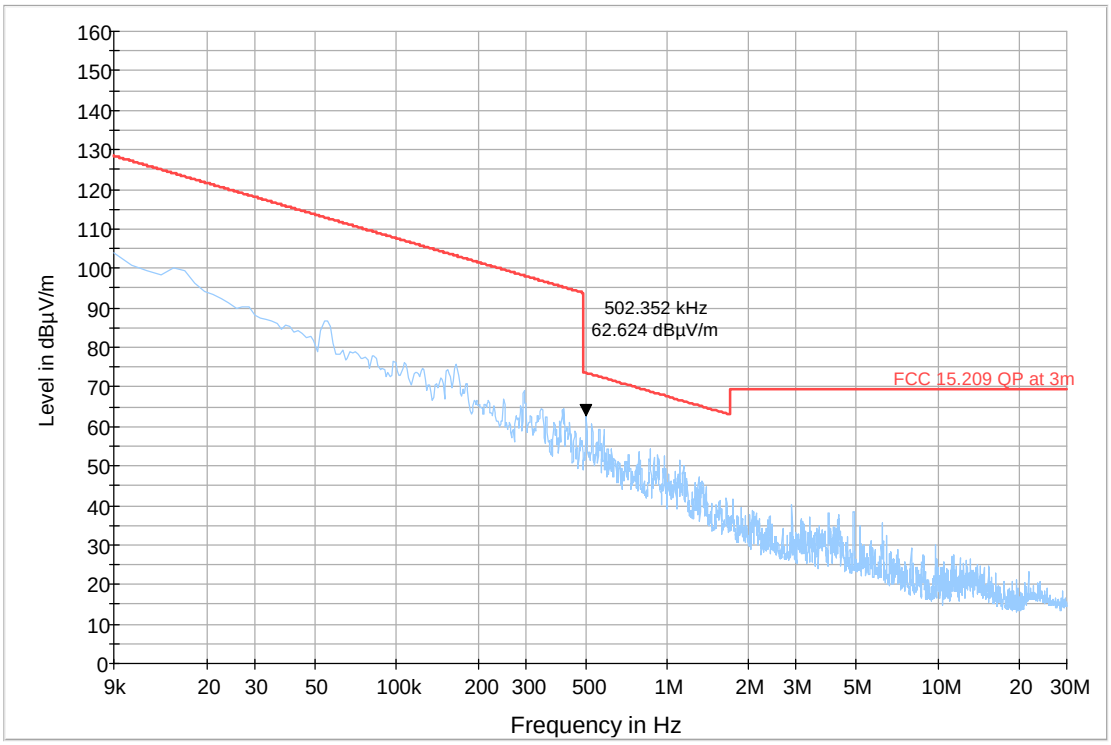
EUT Operating Mode: BLE, Fixed Channel	Channel: Low	50% Duty cycle

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
4803.422	57.627	---	73.98	16.35	500.0	1000.000	226.0	H	211.0	-3.5
4803.422	---	45.205	53.98	8.77	500.0	1000.000	226.0	H	211.0	-3.5
7205.109	54.933	---	73.98	19.05	500.0	1000.000	221.0	H	100.0	-1.5
7205.109	---	41.414	53.98	12.57	500.0	1000.000	221.0	H	100.0	-1.5
9609.005	---	44.017	53.98	9.96	500.0	1000.000	241.0	H	154.0	1.8
9609.005	57.180	---	73.98	16.80	500.0	1000.000	241.0	H	154.0	1.8
12008.688	60.094	---	73.98	13.89	500.0	1000.000	159.0	H	-9.0	5.4
12008.688	---	46.598	53.98	7.38	500.0	1000.000	159.0	H	-9.0	5.4
14413.461	61.420	---	73.98	12.56	500.0	1000.000	219.0	H	118.0	9.9
14413.461	---	47.478	53.98	6.50	500.0	1000.000	219.0	H	118.0	9.9
17859.397	---	50.925	53.98	3.05	500.0	1000.000	358.0	V	262.0	15.3
17859.397	64.905	---	73.98	9.07	500.0	1000.000	358.0	V	262.0	15.3



Plot #4 Radiated Emissions: 9 kHz – 30 MHz		
EUT Operating Mode: BLE, Fixed Channel	**Channel: Mid**	**50% Duty cycle**

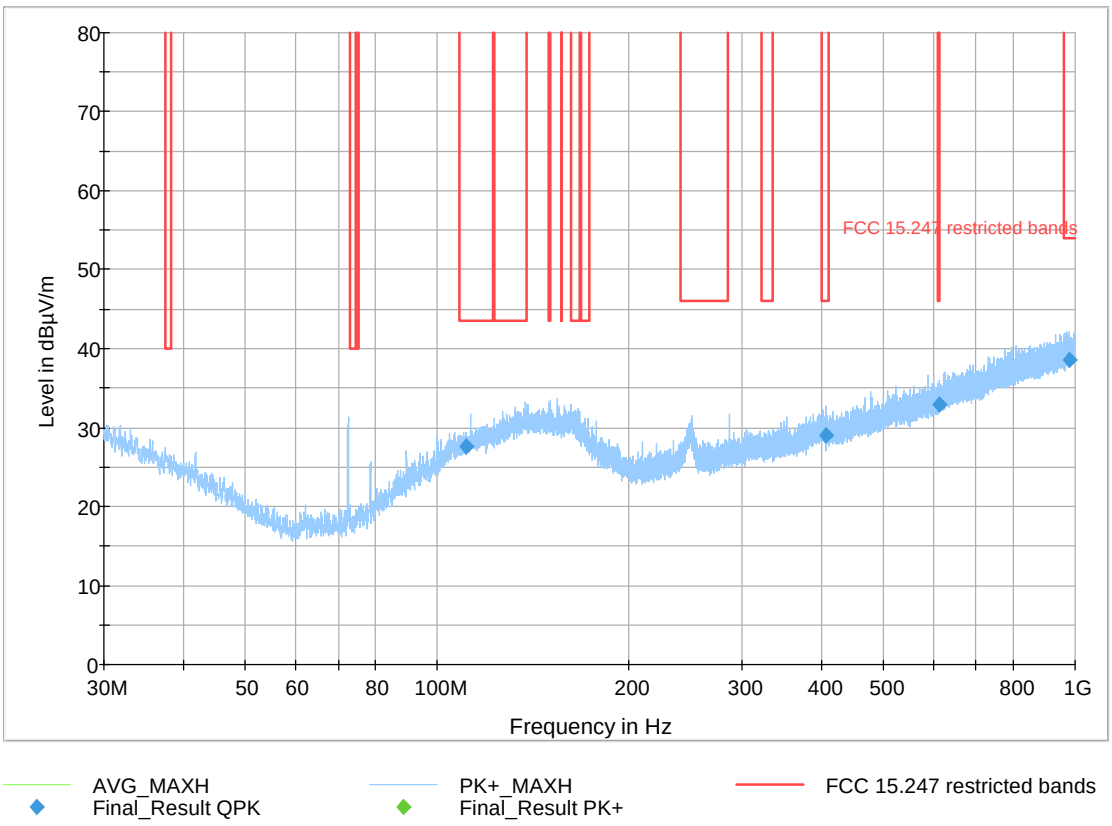


Plot #5 Radiated Emissions: 30 MHz – 1 GHz

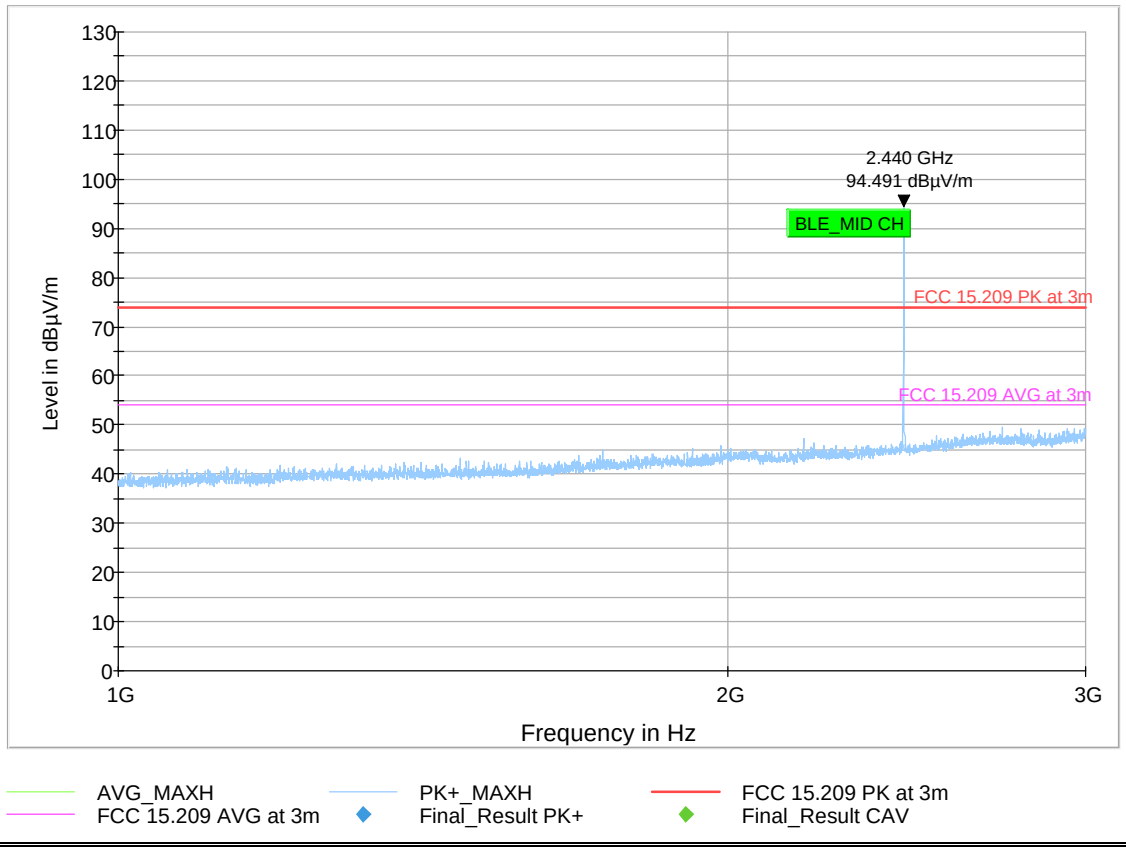
EUT Operating Mode: BLE, Fixed Channel	Channel: Mid	50% Duty cycle

Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
111.159	27.570	43.50	15.93	500.0	120.000	324.0	V	143.0	-12.1
406.739	28.969	46.02	17.05	500.0	120.000	150.0	H	11.0	-11.0
612.221	32.850	46.02	13.17	500.0	120.000	310.0	H	34.0	-7.7
111.159	27.570	53.98	15.48	500.0	120.000	224.0	V	300.0	-2.5



Plot #6 Radiated Emissions: 1 – 3 GHz		
EUT Operating Mode: BLE, Fixed Channel	**Channel: Mid**	**50% Duty cycle**



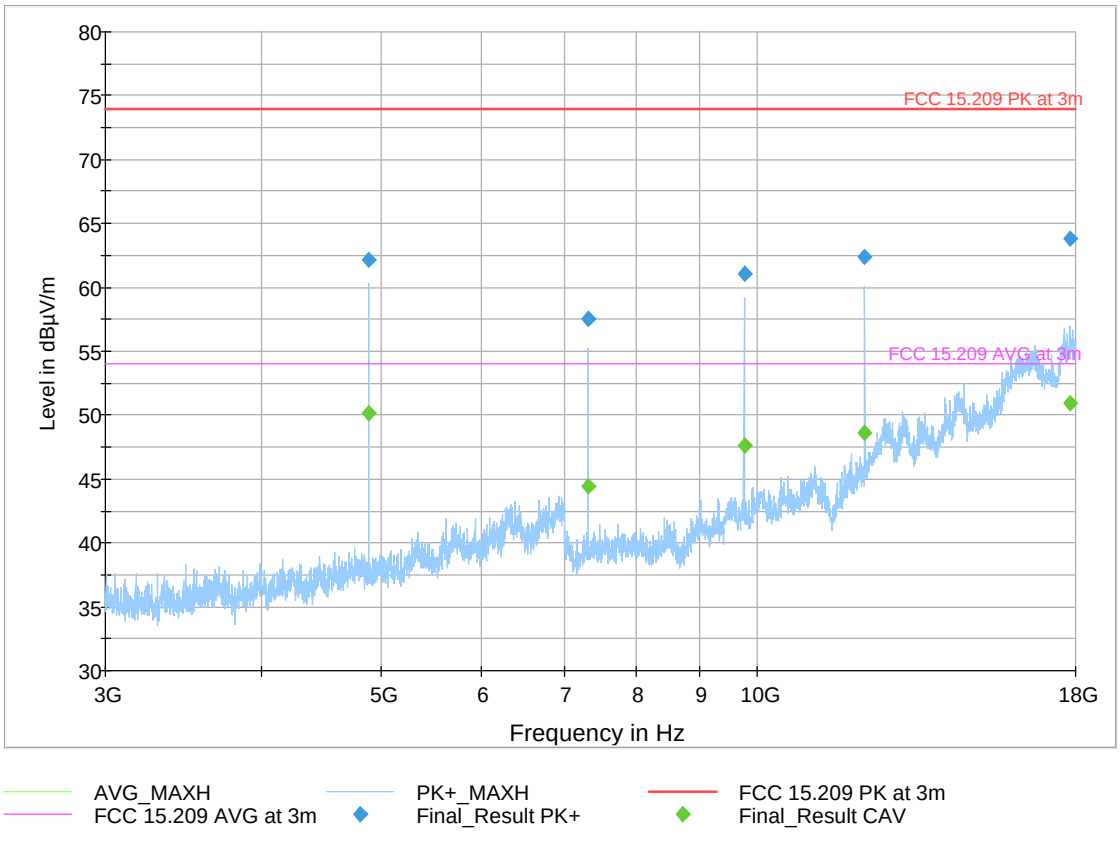
Note: The peak signal above is the transmit channel.

Plot #7 Radiated Emissions: 3 – 18 GHz

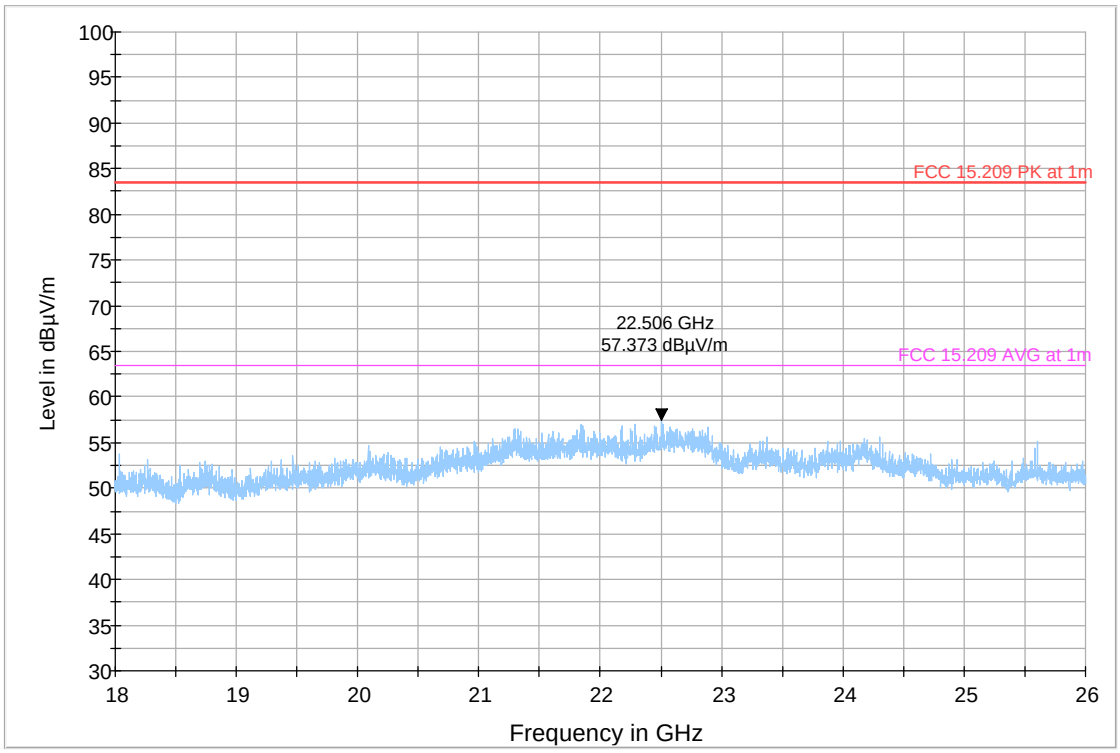
EUT Operating Mode: BLE, Fixed Channel	Channel: Mid	50% Duty cycle

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
4879.467	62.131	---	73.98	11.85	500.0	1000.000	217.0	H	211.0	-4.1
4879.467	---	50.141	53.98	3.84	500.0	1000.000	217.0	H	211.0	-4.1
7320.743	---	44.398	53.98	9.58	500.0	1000.000	217.0	H	112.0	-0.8
7320.743	57.506	---	73.98	16.47	500.0	1000.000	217.0	H	112.0	-0.8
9758.897	61.034	---	73.98	12.95	500.0	1000.000	125.0	H	98.0	2.2
9758.897	---	47.649	53.98	6.33	500.0	1000.000	125.0	H	98.0	2.2
12201.293	62.326	---	73.98	11.65	500.0	1000.000	167.0	H	-3.0	5.6
12201.293	---	48.634	53.98	5.35	500.0	1000.000	167.0	H	-3.0	5.6
17802.136	63.803	---	73.98	10.18	500.0	1000.000	363.0	H	347.0	15.0
17802.136	---	50.934	53.98	3.05	500.0	1000.000	363.0	H	347.0	15.0



Plot #8 Radiated Emissions: 18 – 26 GHz		
EUT Operating Mode: BLE, Fixed Channel	**Channel: Mid**	**50% Duty cycle**

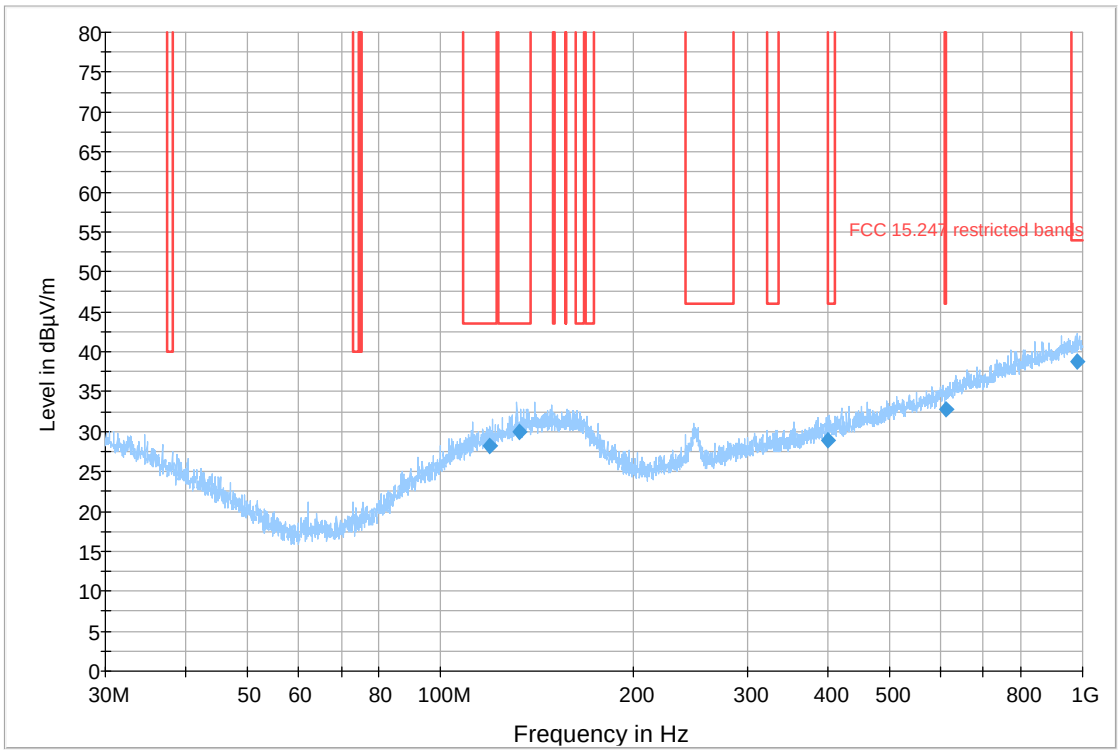


Plot #9 Radiated Emissions: 30 MHz – 1 GHz

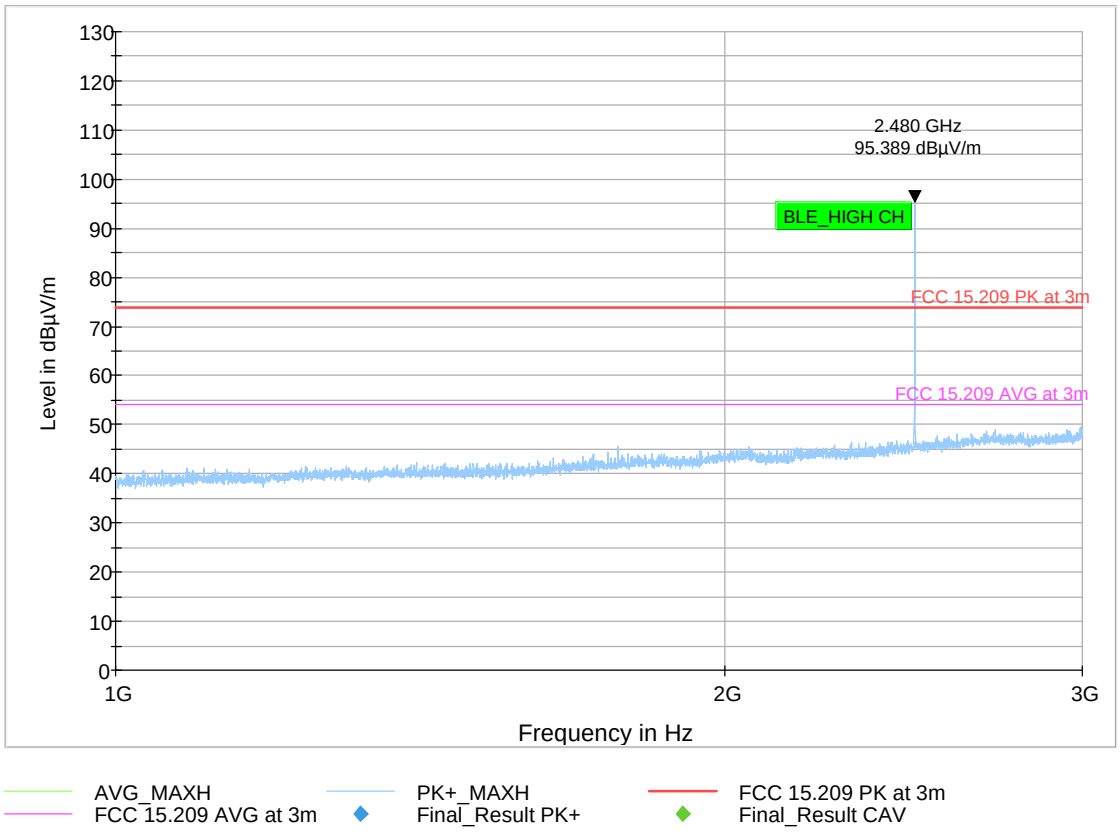
EUT Operating Mode: BLE, Fixed Channel	Channel: High	50% Duty cycle

Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
119.192	28.114	43.50	15.39	500.0	120.000	324.0	H	-45.0	-11.6
132.499	29.914	43.50	13.59	500.0	120.000	100.0	H	63.0	-10.0
401.115	28.911	46.02	17.11	500.0	120.000	392.0	H	308.0	-11.1
611.696	32.820	46.02	13.20	500.0	120.000	100.0	V	228.0	-7.7
979.871	38.848	53.98	15.13	500.0	120.000	272.0	H	16.0	-2.3



Plot #10 Radiated Emissions: 1 – 3 GHz		
EUT Operating Mode: BLE, Fixed Channel	**Channel: High**	**50% Duty cycle**



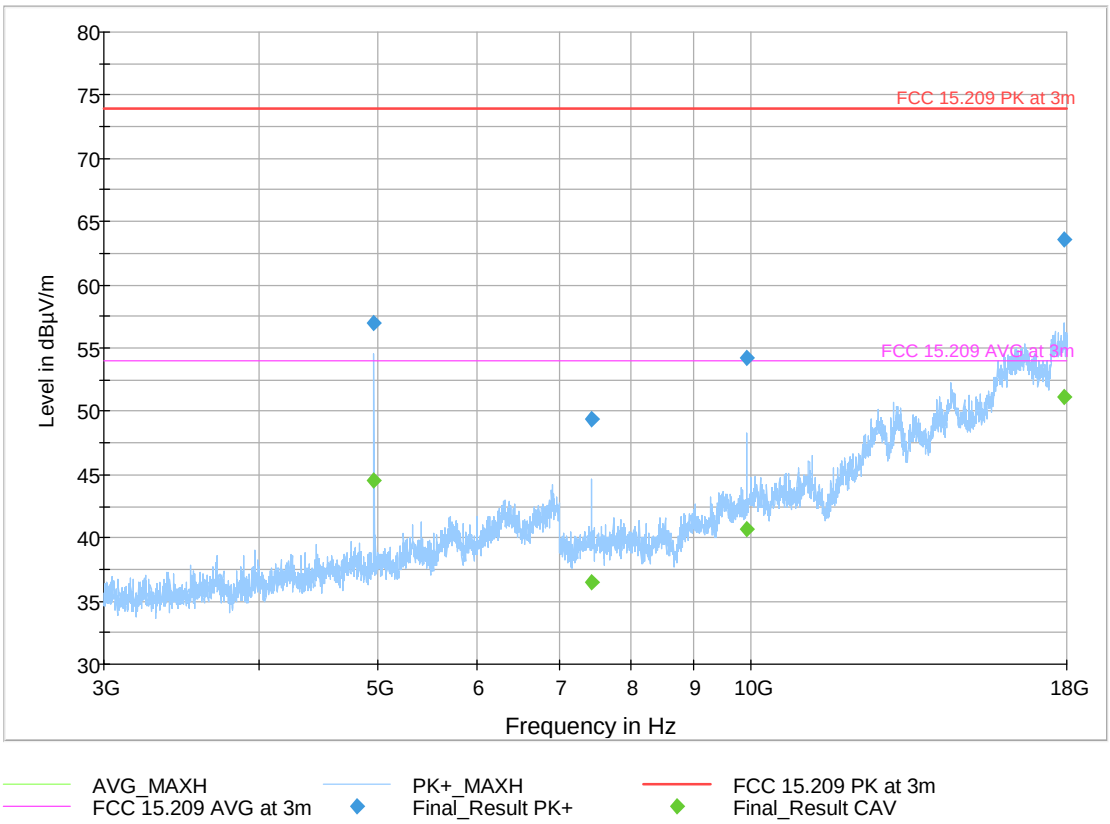
Note: The peak signal above is the transmit channel.

Plot #11 Radiated Emissions: 3 – 18 GHz

EUT Operating Mode: BLE, Fixed Channel	Channel: High	50% Duty cycle

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
4960.510	56.971	---	73.98	17.01	500.0	1000.000	265.0	H	209.0	-3.5
4960.510	---	44.483	53.98	9.50	500.0	1000.000	265.0	H	209.0	-3.5
7440.633	49.354	---	73.98	24.63	500.0	1000.000	226.0	H	254.0	-0.4
7440.633	---	36.443	53.98	17.54	500.0	1000.000	226.0	H	254.0	-0.4
9921.013	---	40.653	53.98	13.33	500.0	1000.000	125.0	V	242.0	2.9
9921.013	54.254	---	73.98	19.73	500.0	1000.000	125.0	V	242.0	2.9
17890.064	---	51.111	53.98	2.87	500.0	1000.000	275.0	V	315.0	15.4
17890.064	63.600	---	73.98	10.38	500.0	1000.000	275.0	V	315.0	15.4

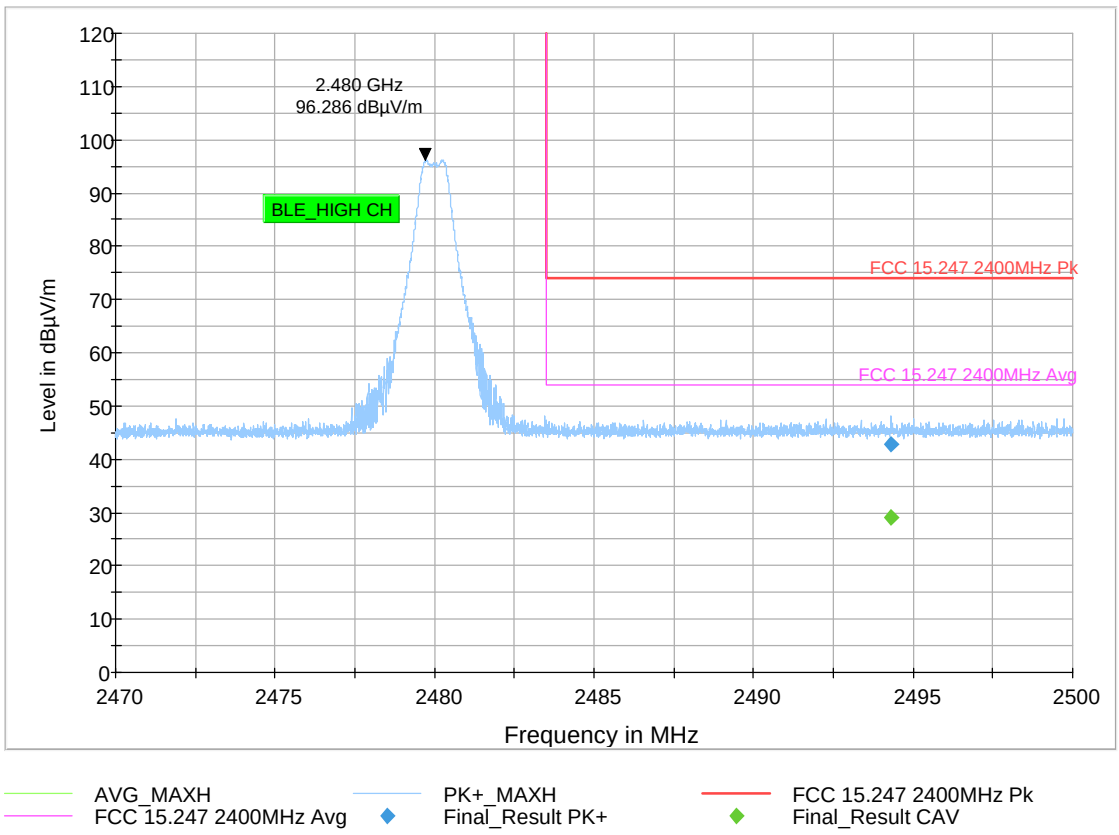


Plot #12 Upper Restricted Band Edge

EUT Operating Mode: BLE, Fixed Channel	Channel: High	50% Duty cycle

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2494.306	---	29.022	54.00	24.98	500.0	1000.000	132.0	H	76.0	5.9
2494.306	42.789	---	74.00	31.21	500.0	1000.000	132.0	H	76.0	5.9



9 Test setup photos

Setup photos are included in supporting file name:
"EMC_GEOFO_038_23001_FCC_15.247_ISED_RSS_247_BTLE_DTS_Setup_Photos.pdf"

10 Test Equipment And Ancillaries Used For Testing

Equipment Type	Manufacturer	Model	Serial #	Calibration Cycle	Last Calibration Date
Loop Antenna	ETS-LINDGREN	6512	00164698	1 Year	9/6/2023
Bilog Antenna	A.H. SYSTEMS	BiLA2G	569	2 Years	10/30/2023
Horn Antenna	EMCO	3115	00035111	2 Years	10/26/2023
Horn Antenna	ETS-LINDGREN	3117-PA	00167061	1 Year	9/25/2023
Horn Antenna	ETS-LINDGREN	3116C-PA	00166821	2 Years	11/17/2023
Signal Analyzer	Rohde & Schwarz	FSV40	101022	2 Years	9/25/2023
Spectrum Analyzer	Rohde & Schwarz	FSU26	100189	3 Years	5/27/2022
Thermometer Humidity	Control Company	4410,90080-03	230712972	2 Years	10/18/2023

Note: Equipment used meets the measurement uncertainty requirements as required per applicable standards for 95% confidence levels.
Calibration due dates, unless defined specifically, falls on the last day of the month. Items indicated "N/A" for cal status either do not specifically require calibration or is internally characterized before use.

11 History

Date	Report Name	Changes to report	Prepared by
2024-05-21	EMC_GEOFO_038_23001_FCC_15.247_ISED_RSS_247 _BTLE_DTS	Initial Version	Chin Ming Lui

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