FCC / ISED Test Report

For:
Hendrickson USA, L.L.C., DBA Hendrickson Brake and Wheel-End Group

Model Name:
B-40699

Product Description:
Wheel End Sensor with Tire Pressure Monitoring and Bluetooth Radio

FCC ID: 2BMOAWES
ISED: 33452-WES

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

REPORT: EMC_HENDR_002_24001_FCC_15_247_BLE_Rev1

DATE: 2025-03-26

A2LA Accredited

IC recognized # 3462B

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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.
Hendrickson USA, L.L.C., DBA Hendrickson Brake and Wheel-End Group	Wheel End Sensor with Tire Pressure Monitoring and Bluetooth Radio	B-40699

Report Reviewer:

Date	Section	Name	Signature
2025-03-26	Compliance	Alvin, Ilarina (Senior Manager Regulatory Services)	Alvin ILARINA Digitally signed by Alvin ILARINA Date: 2025.03.27 16:20:13 -07'00'

Responsible for the Report:

Date	Section	Name	Signature
2025-03-26	Compliance	Art Thammanavarat (Senior EMC Engineer)	Art Thammanavarat Digitally signed by: Art Thammanavarat DN: CN = Art Thammanavarat email = art.thammanavarat@cetecom.com C = AD Date: 2025.03.26 14:31:47 -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 Engineer:	Art Thammanavarat
Responsible Project Leader:	Hao Shane

2.2 Identification of the Client

Applicant's Name:	Hendrickson USA, L.L.C., DBA Hendrickson Brake and Wheel-End Group
Street Address:	9260 Pleasantwood Ave NW
City/Zip Code	North Canton Ohio 44720
Country	USA

2.3 Identification of the Manufacturer

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

3 Equipment Under Test (EUT)

3.1 EUT Specifications

Product Description:	Wheel End sensor with tire pressure monitoring and Bluetooth radio
Model Name:	B-40699
Marketing Name:	WATCHMAN™ or TIREMAAX®
HW Version:	V4.2E
SW Version:	V1.0.1
FCC-ID:	2BMOAWES
ISED:	33452-WES
Frequency Range / number of channels:	Nominal band: 2400 MHz – 2483.5 MHz Center to center: 2402 MHz (ch 0) – 2480 MHz (ch 39), 40 channels
Radio Information as declared:	**Bluetooth Modules** **Brandl Name**: Texas Instruments Incorporated **Model Number:** CC2650MODA **FCC:** ZAT26M1 **ISED**: 451H-26M1 **Wireless Technologies** **Bluetooth**
Antenna Information as declared:	Type: PCB Trace Location: Internal Peak Gain: +5 dBi gain
Power Supply/ Rated Operating Voltage Range	3VDC
Operating Temperature Range	Low: -40ºC Norm: 25ºC High: 85ºC
Sample Revision	☐Production ☒ Pre-Production
EUT Dimensions	113mm x 113mm x 31mm
Weight	129 grams
EUT Diameter	☒< 60 cm ☐ Other _____
Note: The information of the EUT specifications in the table above is provided by the client.	

3.2 EUT Sample details

EUT #	Serial Number	HW Version	SW Version	Notes/Comments
1	N/A	V4.2E	V1.0.1	Radiated Emissions / Conducted Emissions

3.3 Accessory Equipment (AE) details

AE #	Type	Model	Manufacturer	Serial Number	Comments
1	Laptop	P135G	Dell	12243628947	Support laptop provided by Cetecom to exercise device.

3.4 Test Sample Configuration

EUT Set-up #	Combination of AE used for test set up	Comments
1	EUT#1+AE#1	The client provides a USB cable to communicate with the device and sends commands for configuring the BLE radios into a specific test mode. This test mode configuration, designed for worst-case scenarios, is not intended for end-user application and is outlined as follows: • EUT powered by 3Vdc • Radiated RF measurements were performed with EUT configured via customer provided using BTool and instructions • The EUT connected to support laptop to exercise device.

3.5 Mode of Operation

Mode of Operation	Description of Operating modes	Additional Information
Op. 1	BLE	BLE was tested on Low, Mid, and High channels at the maximum allowed power setting.

3.6 Justification for Mode of Operation

During the testing process, the EUT was tested with transmitter sets on low, mid and high channels, and highest possible duty cycle. For radiated measurements, all data in this report shows the worst case between horizontal and vertical antenna polarizations and for all orientations of the EUT.

4 Subject of Investigation

The objective of the measurements done by CETECOM Inc. was to evaluate the compliance of the EUT against the relevant requirements specified in section 1.

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	Op. 1	■	☐	☐	Complies
§15.247(e) RSS-247 5.2(b)	Power Spectral Density	Nominal	Op. 1	■	☐	☐	Complies
§15.247(b)(1) RSS-247 5.4(d)	Maximum Conducted Output Power and EIRP	Nominal	Op. 1	■	☐	☐	Complies
§15.247(d) RSS-247 5.5	Band edge compliance Unrestricted Band Edges	Nominal	Op. 1	■	☐	☐	Complies
§15.247; 15.209; 15.205 RSS-Gen 8.9; 8.10	Band edge compliance Restricted Band Edges	Nominal	Op. 1	■	☐	☐	Complies
§15.247(d); §15.209 RSS-Gen 6.13	TX Radiated Spurious Emissions	Nominal	Op. 1	■	☐	☐	Complies
§15.207(a) RSS Gen 8.8	AC Conducted Emissions	Nominal	-	☐	■	☐	Note 1 Note 2

Note 1: NA= Not Applicable; NP= Not Performed.
Note 2: The EUT does not utilize power from public mains, hence testing for AC line conducted emissions is not applicable in this case.

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 Lab 1	EMC Lab 2
Conducted emissions (mains port)	150 kHz – 30 MHz	2.47 dB	N/A
Radiated emissions	9 kHz – 30 MHz	2.68 dB	2.53 dB
	30 – 100 MHz	4.39 dB	3.85 dB
	100 MHz – 1 GHz	5.65 dB	5.24 dB
	1 – 6 GHz	5.0 dB	4.88 dB
	6 – 18 GHz	4.76 dB	4.58 dB
	18 – 40 GHz	4.65 dB	4.61 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:

2024-10-23 – 2024-10-24

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.

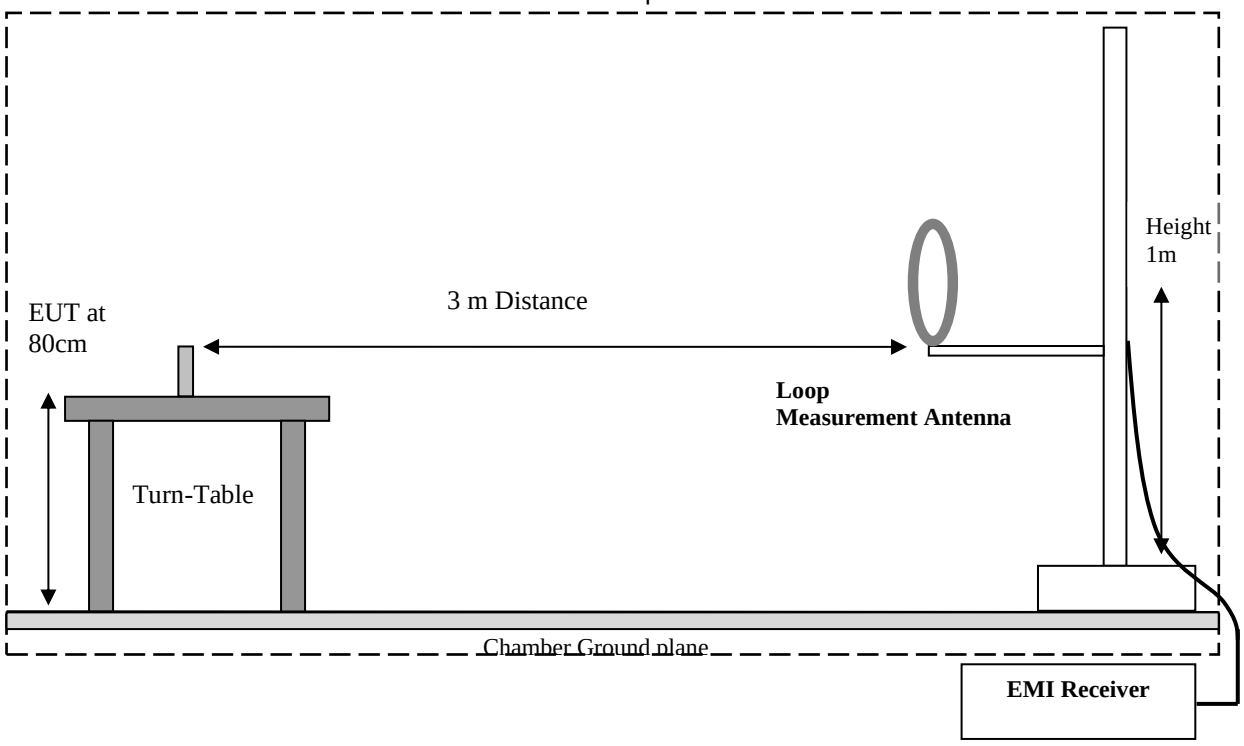
7 Measurement Procedures

7.1 Radiated Measurement

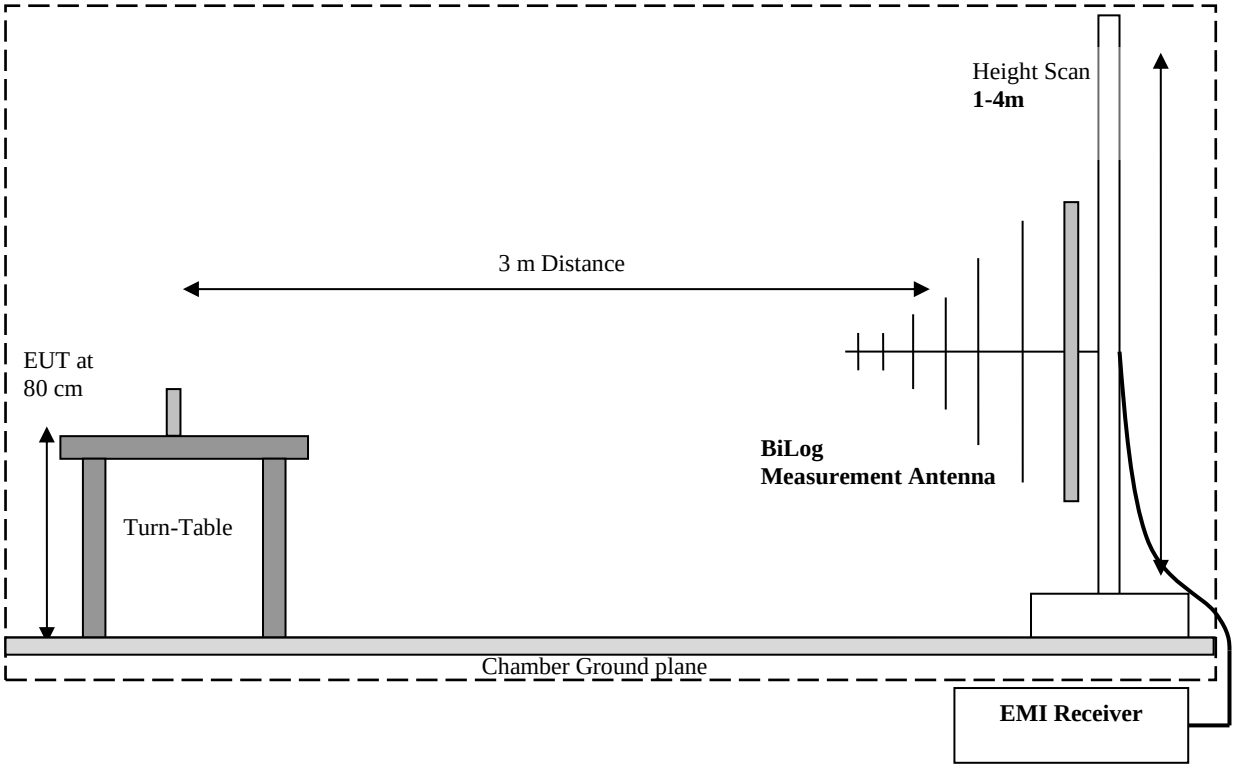
The radiated measurement is performed according to ANSI C63.10 (2013)

- 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.

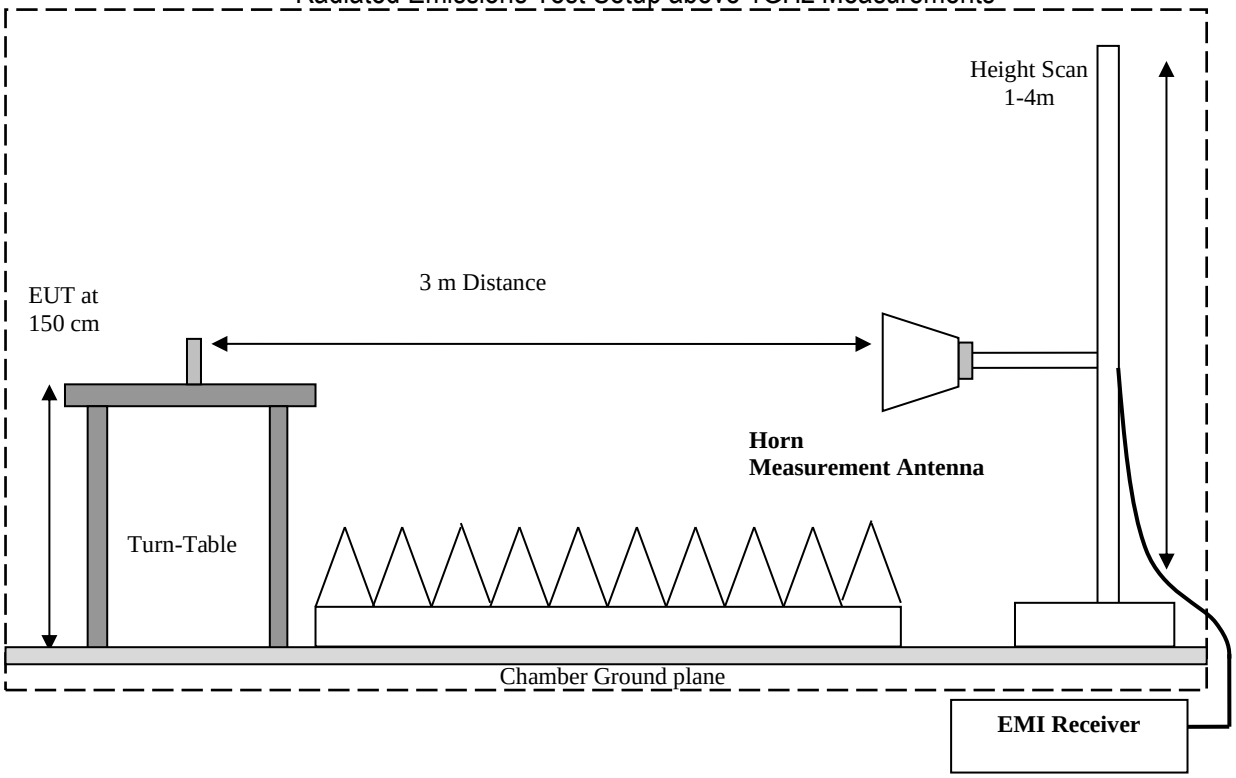
Radiated Emissions Test Setup below 30MHz Measurements



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:

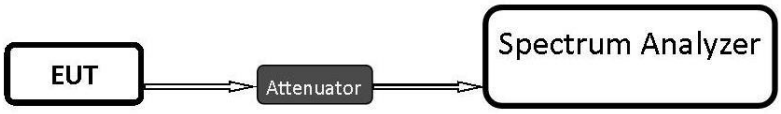
Frequency (MHz)	Measured SA (dBµV)	Cable Loss (dB)	Antenna Factor Correction (dB)	Field Strength Result (dBµV/m)
1000	80.5	3.5	14	98.0

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 Emission Bandwidth 6dB and 99% Occupied Bandwidth

8.1.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02, and ANSI C63.10 Clause 11.

Spectrum Analyzer settings:

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.

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.

8.1.2 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.

8.1.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22 °C	1	Op. 1	nominal

8.1.4 Measurement result:

Plot #	Channel	PHY	99% Occupied Bandwidth (MHz)	Limit (MHz)	Result
1	0	LE 1M	1.095000	-	For info only
2	19	LE 1M	1.080000	-	For info only
3	39	LE 1M	1.095000	-	For info only
4	0	LE 2M	2.090000	-	For info only
5	19	LE 2M	2.050000	-	For info only
6	39	LE 2M	2.080000	-	For info only

Note 1: The test results and plots are generated by the R&S WMS32 software, which automatically performs the measurements.

Plot #	Channel	PHY	6dB Emissions Bandwidth (MHz)	Limit (MHz)	Result
7	0	LE 1M	0.740260	> 0.5	Pass
8	19	LE 1M	0.727273	> 0.5	Pass
9	39	LE 1M	0.727273	> 0.5	Pass
10	0	LE 2M	1.506494	> 0.5	Pass
11	19	LE 2M	1.454546	> 0.5	Pass
12	39	LE 2M	1.428572	> 0.5	Pass

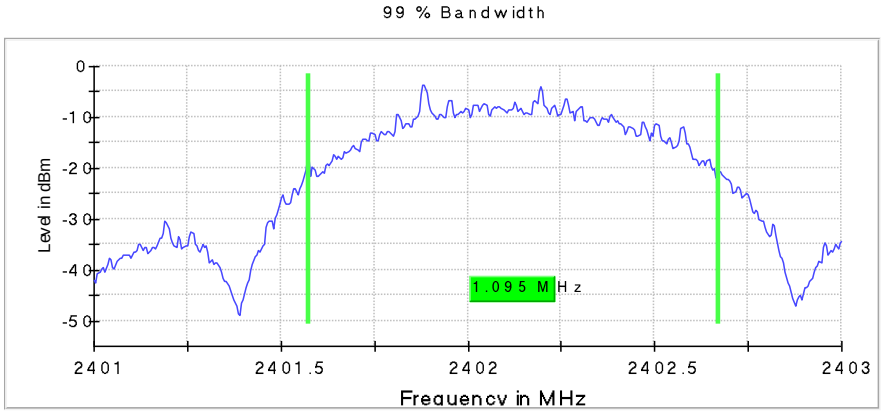
Note 1: The test results and plots are generated by the R&S WMS32 software, which automatically performs the measurements.

8.1.5 Measurement Plots: 99% OBW

Plot #1	
2402 MHz	Mode: BTLE 1M

99 % Bandwidth

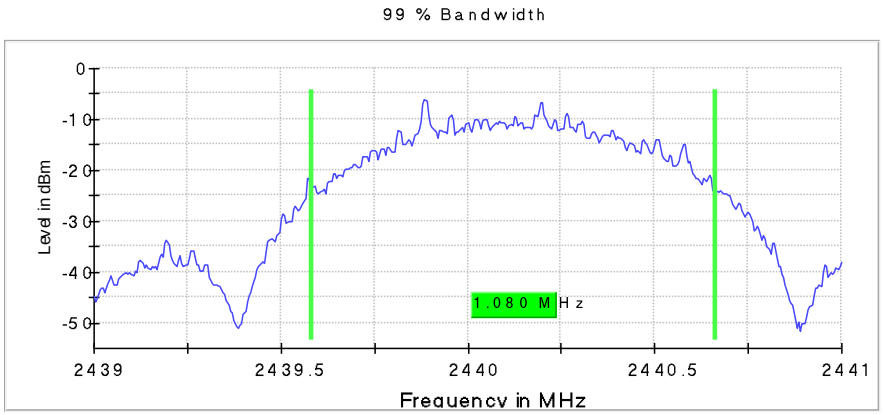
DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2402.000000	1.095000	---	---	2401.575000	2402.670000



Plot #2	
2440 MHz	Mode: BTLE 1M

99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2440.000000	1.080000	---	---	2439.585000	2440.665000

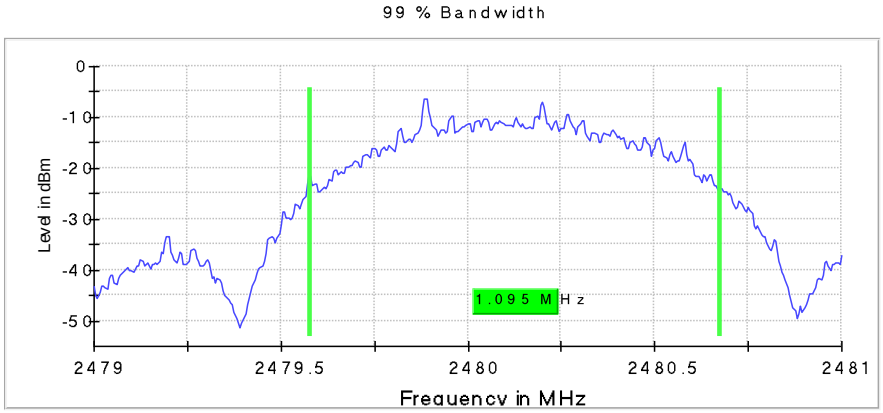


Plot #3

2480 MHz	Mode: BTLE 1M

99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2480.000000	1.095000	---	---	2479.580000	2480.675000

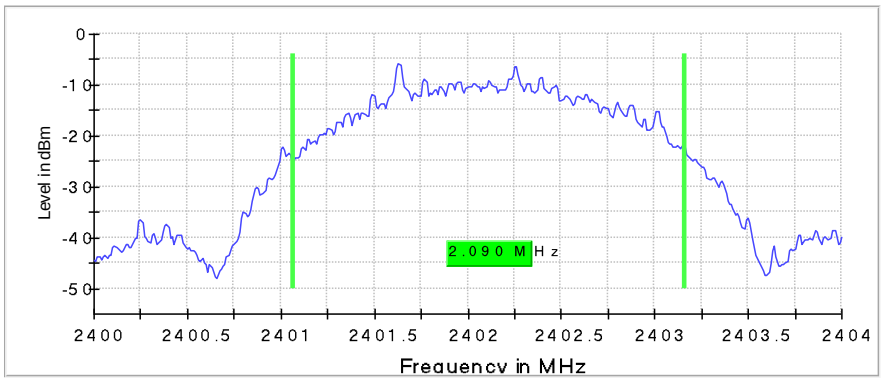


Plot #4

2402 MHz	Mode: BTLE 2M

99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2402.000000	2.090000	---	---	2401.070000	2403.160000

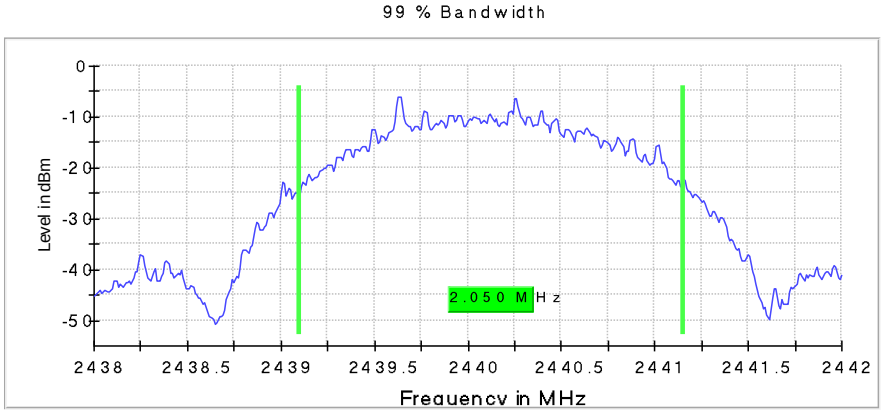


Plot #5

2440 MHz	Mode: BTLE 2M

99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2440.000000	2.050000	---	---	2439.100000	2441.150000

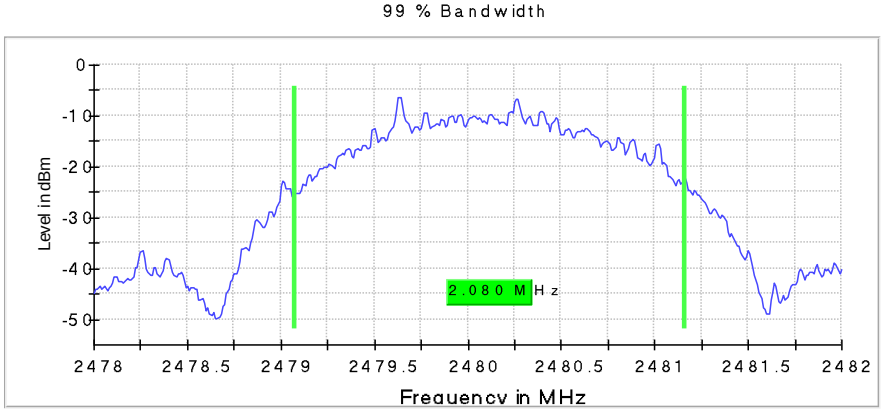


Plot #6

2480 MHz	Mode: BTLE 2M

99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2480.000000	2.080000	---	---	2479.080000	2481.160000

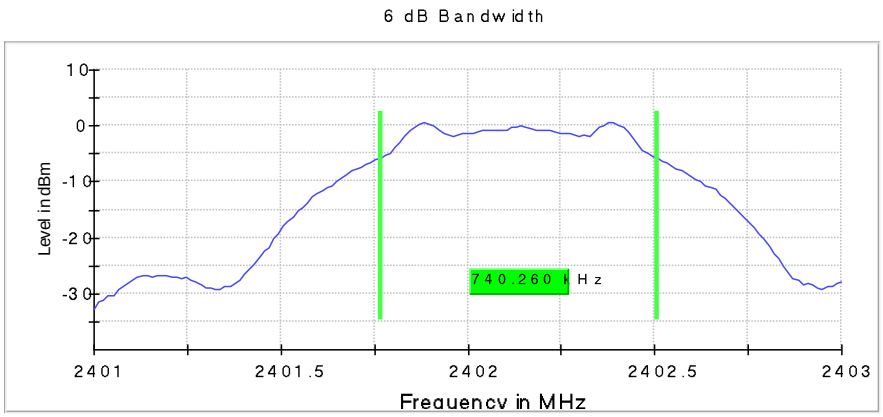


8.1.6 Measurement Plots: 6dB BW

Plot #7	
2402 MHz	Mode: BTLE 1M

6 dB Bandwidth

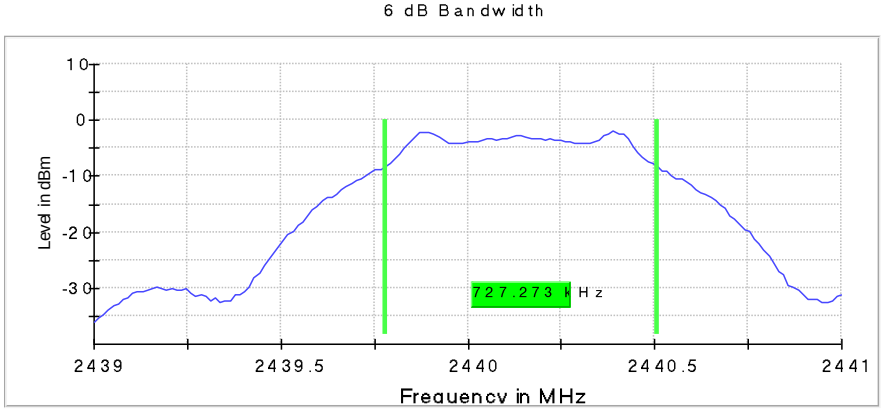
DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2402.000000	0.740260	0.500000	---	2401.766234	2402.506494



Plot #8	
2440 MHz	Mode: BTLE 1M

6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2440.000000	0.727273	0.500000	---	2439.779221	2440.506494

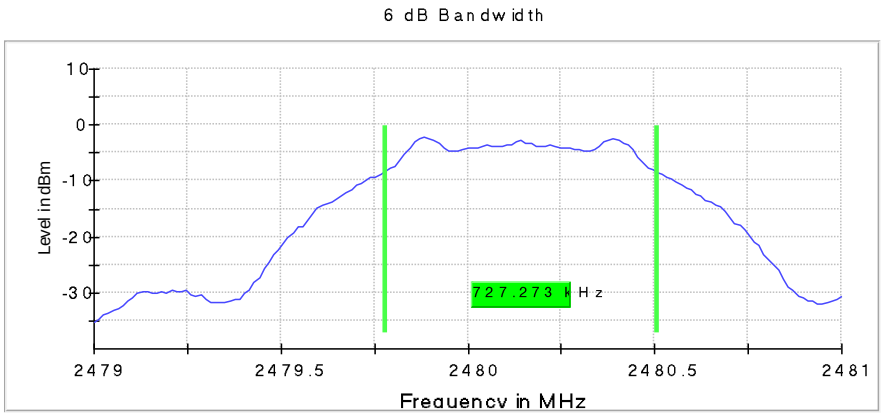


Plot #9

2480 MHz	Mode: BTLE M

6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2480.000000	0.727273	0.500000	---	2479.779221	2480.506494

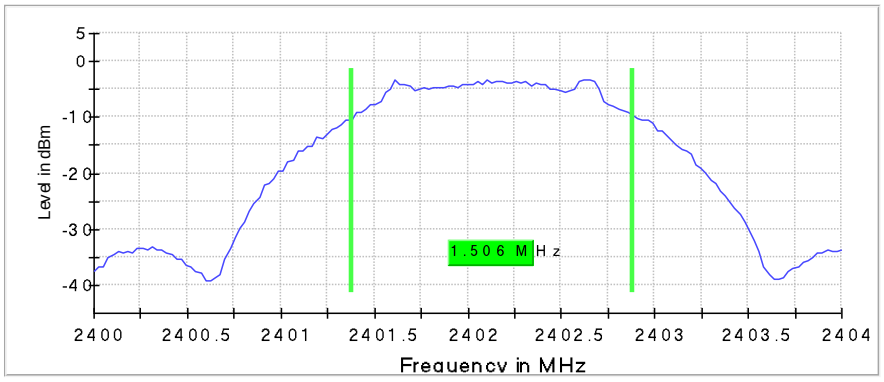


Plot #10

2402 MHz	Mode: BTLE 2M

6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2402.000000	1.506494	0.500000	---	2401.376623	2402.883117

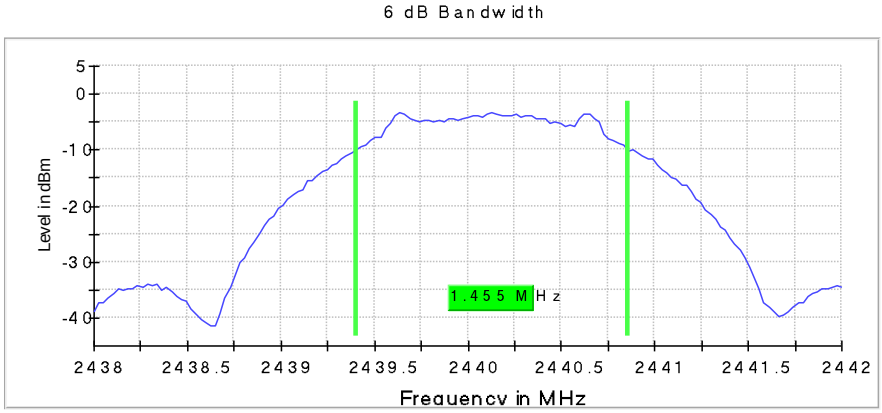


Plot #11

2440 MHz	Mode: BTLE 2M

6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2440.000000	1.454546	0.500000	---	2439.402597	2440.857143

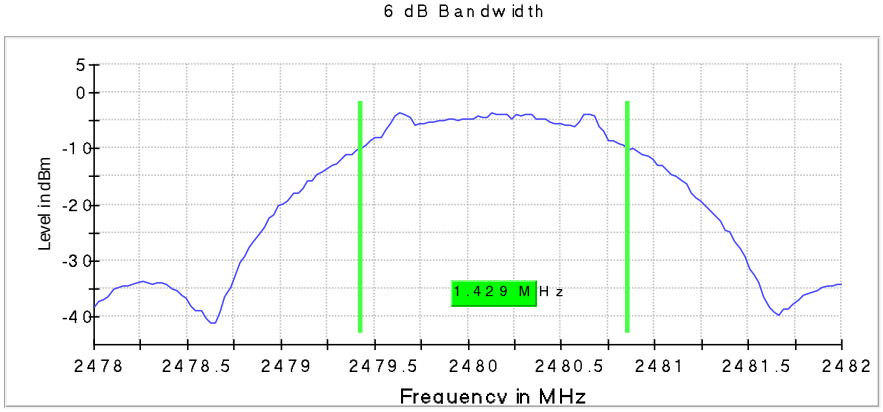


Plot #12

2480 MHz	Mode: BTLE 2M

6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2480.000000	1.428572	0.500000	---	2479.428571	2480.857143



8.2 Maximum Peak Conducted Output Power

8.2.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02, and ANSI C63.10 Clause 11.

Spectrum Analyzer settings according to mentioned ANSI, sec.11.9.1.1:

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

8.2.2 Limits:

Maximum Peak Output Power:

- FCC §15.247 (b)(3): 1 W (30 dBm)
- IC RSS-247 5.4(d): 1 W (30 dBm)

8.2.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22 °C	1	Op. 1	nominal	5 dBi *

Note *: Details regarding the antenna gain are provided by the applicant.

8.2.4 Measurement result:

Plot #	Channel	PHY	Maximum Peak Conducted Output Power (dBm)	EIRP (dBm)	Limit (dBm)	Result
1	0	LE 1M	1	6	30 (PK) / 36 (EIRP)	Pass
2	19	LE 1M	-1.6	3.4	30 (PK) / 36 (EIRP)	Pass
3	39	LE 1M	-1.8	3.2	30 (PK) / 36 (EIRP)	Pass
4	0	LE 2M	-1.2	3.8	30 (PK) / 36 (EIRP)	Pass
5	19	LE 2M	-1.5	3.5	30 (PK) / 36 (EIRP)	Pass
6	39	LE 2M	-1.6	3.4	30 (PK) / 36 (EIRP)	Pass

Note *: Results based on calculation utilizing antenna gain information provided by applicant.
Note 2: The test results and plots are generated by the R&S WMS32 software, which automatically performs the measurements.
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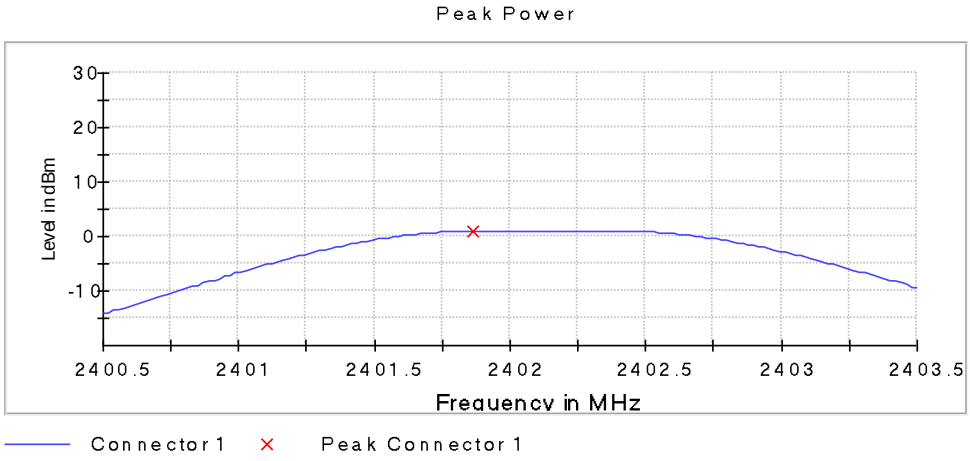
8.2.5 Measurement Plots:

Plot #1

Result

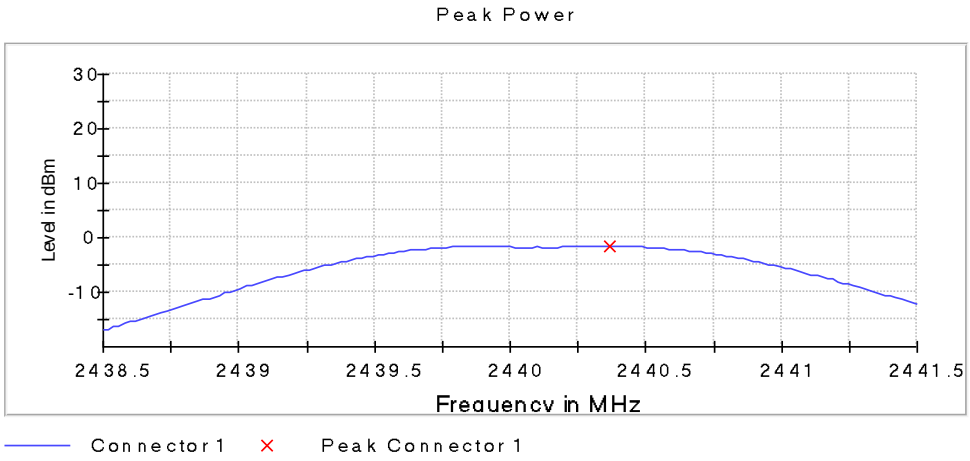
DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2402.000000	1.0	30.0	PASS



Plot #2

Result

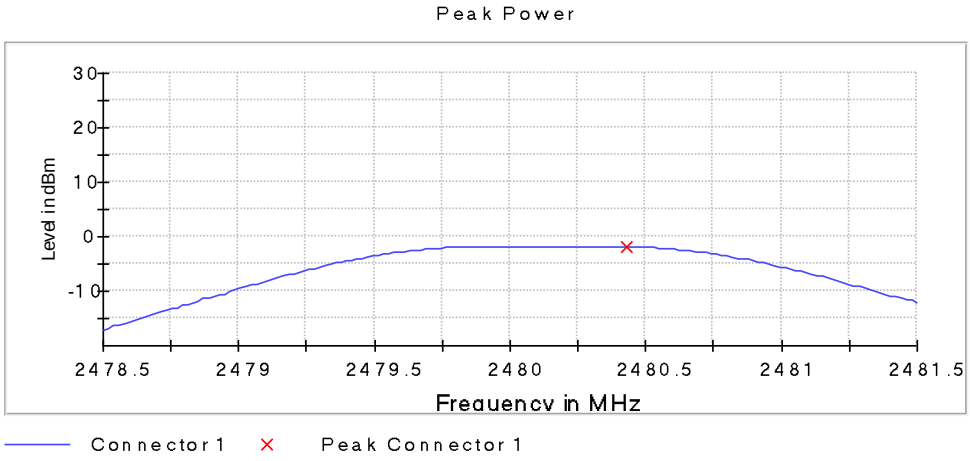
DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2440.000000	-1.6	30.0	PASS



Plot #3

Result

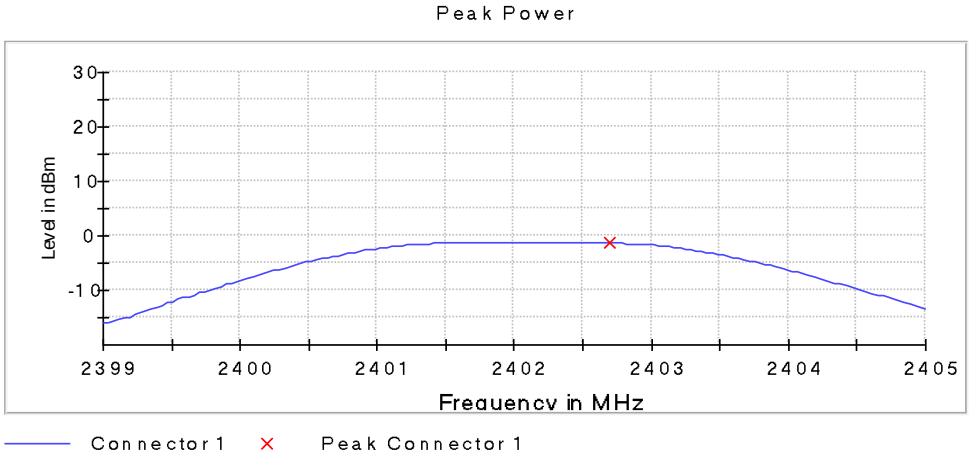
DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2480.000000	-1.8	30.0	PASS



Plot #4

Result

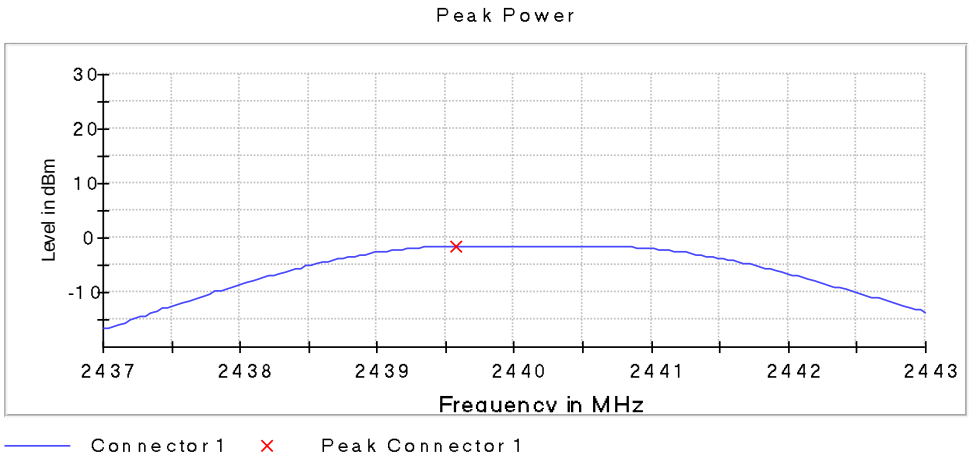
DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2402.000000	-1.2	30.0	PASS



Plot #5

Result

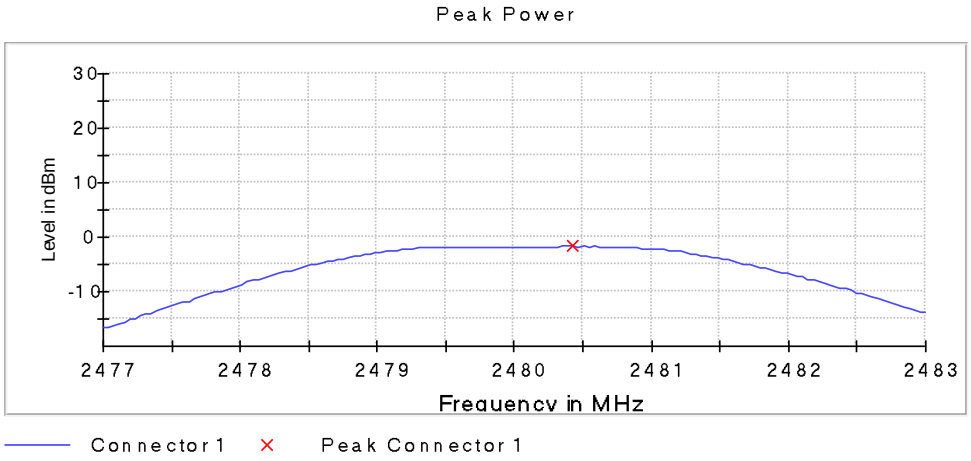
DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2440.000000	-1.5	30.0	PASS



Plot #6

Result

DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2480.000000	-1.6	30.0	PASS



8.3 Power Spectral Density

8.3.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02, and ANSI C63.10 Clause 11.

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

8.3.2 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.

8.3.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22 °C	1	Op. 1	nominal

8.3.4 Measurement result:

Plot #	Channel	PHY	Maximum Power Spectral Density (dBm/3 kHz)	Limit (dBm / 3 kHz)	Result
1	0	LE 1M	-3.464	8	Pass
2	19	LE 1M	-6.142	8	Pass
3	39	LE 1M	-6.384	8	Pass
4	0	LE 2M	-8.404	8	Pass
5	19	LE 2M	-8.765	8	Pass
6	39	LE 2M	-9.002	8	Pass

Note 1: The test results and plots are generated by the R&S WMS32 software, which automatically performs the measurements.
Note 2: The plots presented below represent the worst-case test results measured.

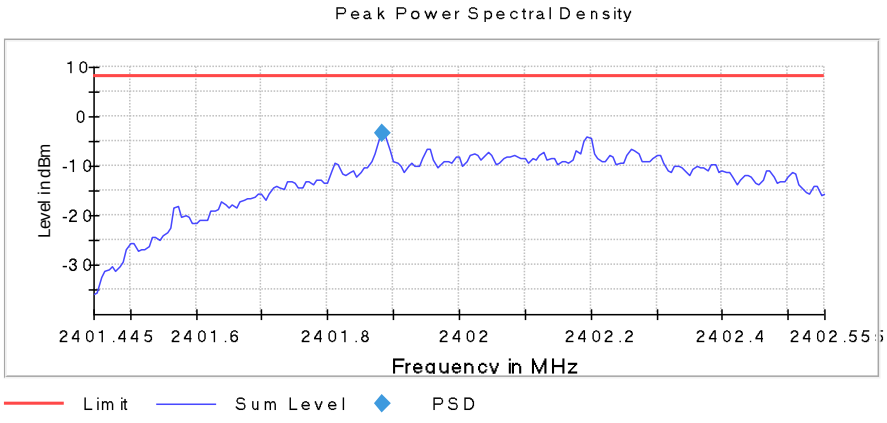
8.3.5 Measurement Plots:

Plot #1

Low channel / 2402 MHz	Modulation/Packet Type: BTLE 1M

Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2402.000000	2401.883409	-3.464	8.0	PASS

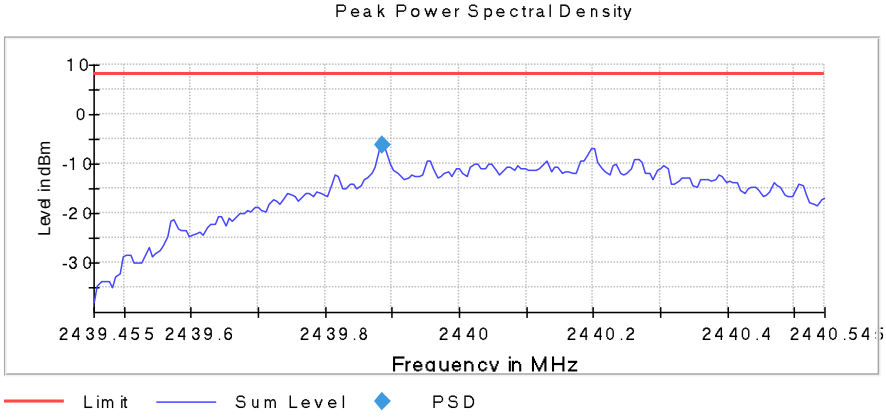


Plot #2

Mid channel 2441 MHz	Modulation/Packet Type: BTLE 1M

Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2440.000000	2439.885455	-6.142	8.0	PASS

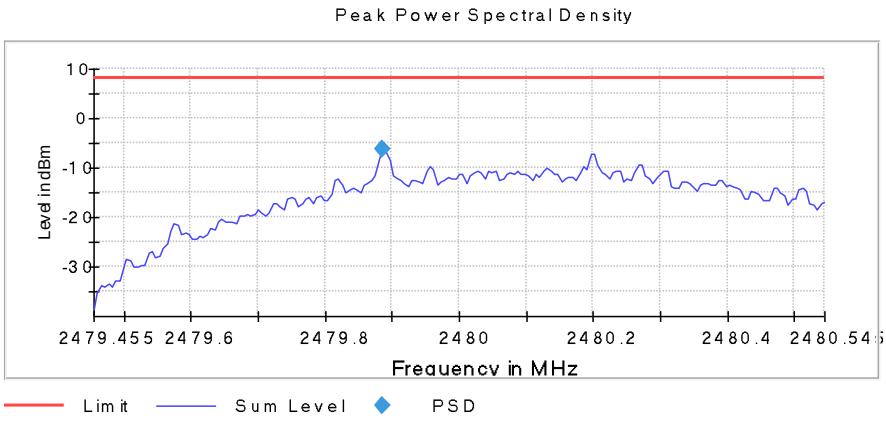


Plot #3

High channel 2480 MHz | **Modulation/Packet Type: BTLE 1M**

Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2480.000000	2479.885455	-6.384	8.0	PASS

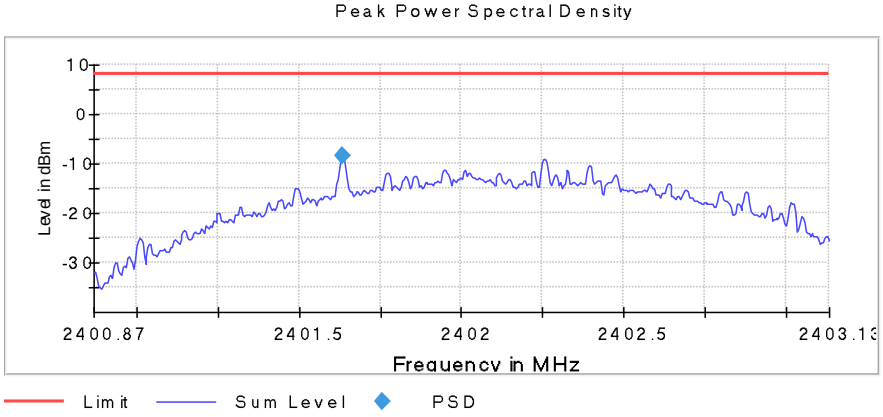


Plot #4

Low channel / 2402 MHz | **Modulation/Packet Type: BTLE 2M**

Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2402.000000	2401.633922	-8.404	8.0	PASS

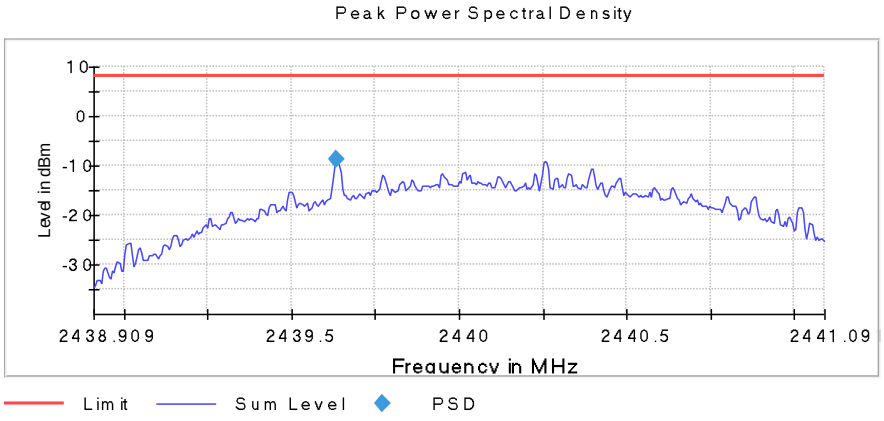


Plot #5

Mid channel 2441 MHz	Modulation/Packet Type: BTLE 2M

Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2440.000000	2439.634545	-8.765	8.0	PASS

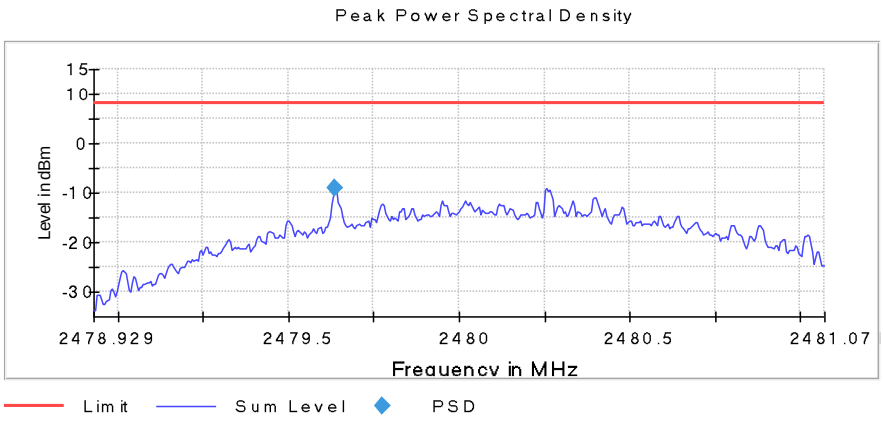


Plot #6

High channel 2480 MHz	Modulation/Packet Type: BTLE 2M

Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2480.000000	2479.635714	-9.002	8.0	PASS



8.4 Duty cycle

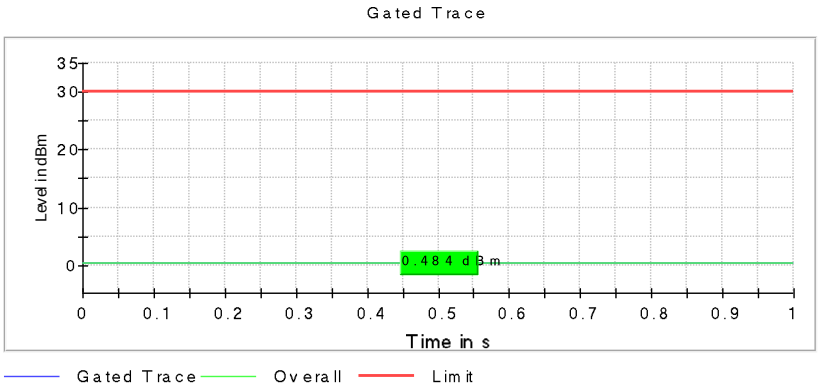
8.4.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02, and ANSI C63.10 Clause 11.

8.4.2 Measurement result

Test according to FCC title 47 part 15 §15.247(b), KDB 558074 D01 DTS Meas Guidance v05r02 and ANSI C63.10-2013, section 11.6.

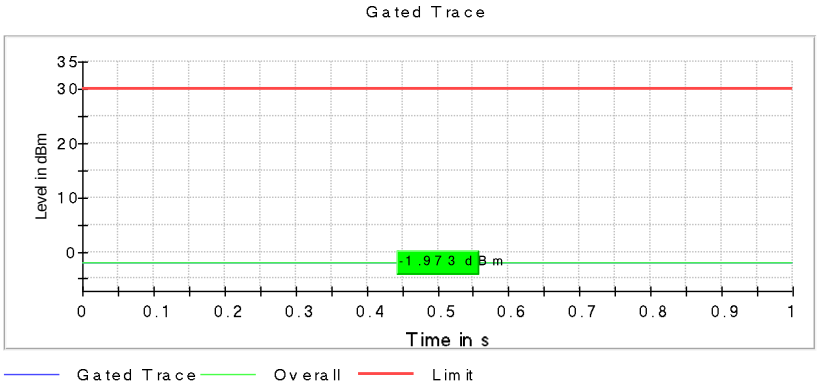
Duty cycle (2402 MHz; 10.000 dBm; 1 MHz)

DUT Frequency (MHz)	Gated RMS (dBm)	Limit Max (dBm)	Gated EIRP (dBm)	DutyCycle (%)	Result
2402.000000	0.5	30.0	0.5	100.000	PASS



Duty cycle (2402 MHz; 10.000 dBm; 2 MHz)

DUT Frequency (MHz)	Gated RMS (dBm)	Limit Max (dBm)	Gated EIRP (dBm)	DutyCycle (%)	Result
2402.000000	-2.0	30.0	-2.0	100.000	PASS



8.5 Non-restricted Band Edge Compliance

8.5.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02, and ANSI C63.10 Clause 11.

Spectrum Analyzer settings for band edge:

- 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)).

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- 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 30dB instead of 20dB.

Spectrum Analyzer settings for restricted band:

- Peak measurements are made using a peak detector and RBW=100 kHz

8.5.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22 °C	1	Op. 1	nominal

8.5.4 Measurement result: band edge (conducted)

Test #	EUT operating mode	PHY	Band Edge	Level (dBm)	Band Edge Delta (dBm)	Limit (dBm)	Result
1	Op. 1	LE 1M	Lower, Non-restricted (conducted)	-2.2	-54.8	-22.2	Pass
2	Op. 1	LE 2M	Lower, Non-restricted (conducted)	-3.4	-38.0	-23.4	Pass

Note 1: The test results and plots are generated by the R&S WMS32 software, which automatically performs the measurements.
\

8.5.5 Measurement Plots (Non-restricted Band Edge)

Plot #1

Low channel / 2402 MHz	Modulation/Packet Type: BTLE 1M

Result

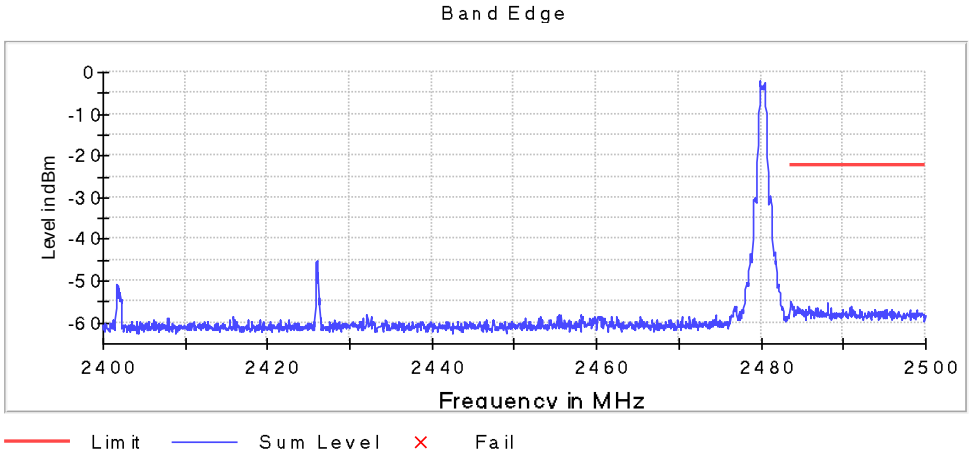
DUT Frequency (MHz)	Result
2480.000000	PASS

Inband Peak

Frequency (MHz)	Level (dBm)
2479.914412	-2.2

Measurements

Frequency (MHz)	Level (dBm)	Margin (dB)	Limit (dBm)	Result
2483.658654	-54.8	32.6	-22.2	PASS
2483.605769	-55.1	32.9	-22.2	PASS
2488.100962	-55.2	33.0	-22.2	PASS
2483.764423	-55.5	33.3	-22.2	PASS
2483.552885	-55.6	33.3	-22.2	PASS
2483.711538	-55.8	33.6	-22.2	PASS
2485.826923	-56.0	33.8	-22.2	PASS
2483.817308	-56.0	33.8	-22.2	PASS
2491.009615	-56.2	34.0	-22.2	PASS
2484.451923	-56.2	34.0	-22.2	PASS
2483.923077	-56.2	34.0	-22.2	PASS
2484.399038	-56.3	34.1	-22.2	PASS
2484.663462	-56.3	34.1	-22.2	PASS
2486.567308	-56.5	34.3	-22.2	PASS
2488.524038	-56.5	34.3	-22.2	PASS



Plot #2

Low channel / 2402 MHz | **Modulation/Packet Type: BTLE 2M**

Result

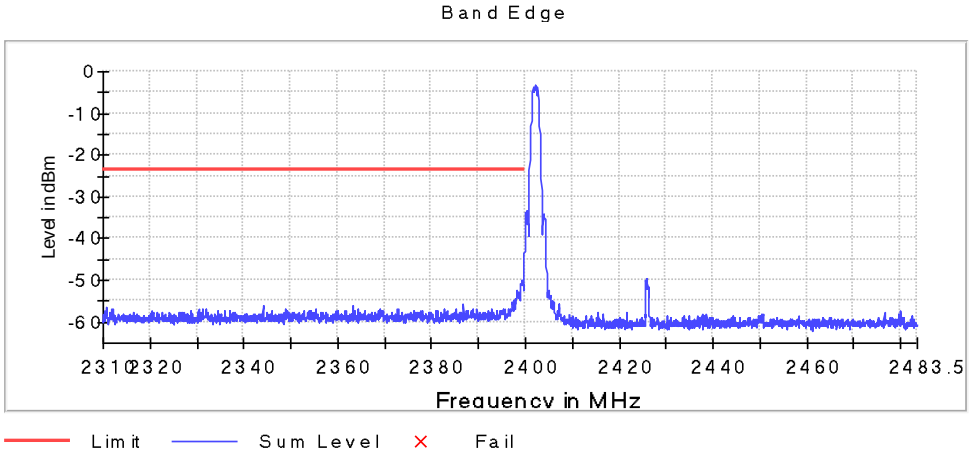
DUT Frequency (MHz)	Result
2402.000000	PASS

Inband Peak

Frequency (MHz)	Level (dBm)
2402.161176	-3.4

Measurements

Frequency (MHz)	Level (dBm)	Margin (dB)	Limit (dBm)	Result
2399.950000	-38.0	14.6	-23.4	PASS
2399.900000	-39.2	15.8	-23.4	PASS
2399.850000	-42.9	19.5	-23.4	PASS
2399.800000	-43.6	20.2	-23.4	PASS
2399.750000	-46.7	23.3	-23.4	PASS
2399.700000	-47.5	24.1	-23.4	PASS
2399.650000	-48.0	24.7	-23.4	PASS
2399.250000	-50.1	26.7	-23.4	PASS
2399.600000	-50.1	26.7	-23.4	PASS
2399.200000	-50.3	26.9	-23.4	PASS
2399.350000	-50.3	26.9	-23.4	PASS
2399.400000	-50.4	27.0	-23.4	PASS
2399.050000	-50.6	27.3	-23.4	PASS
2399.150000	-50.9	27.5	-23.4	PASS
2399.300000	-50.9	27.6	-23.4	PASS



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

- 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 & RSS-Gen 8.9

- 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 / (29.5)	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

FCC §15.205 & RSS-Gen 8.10

- 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			

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

8.6.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22° C	2	Op. 1	Battery

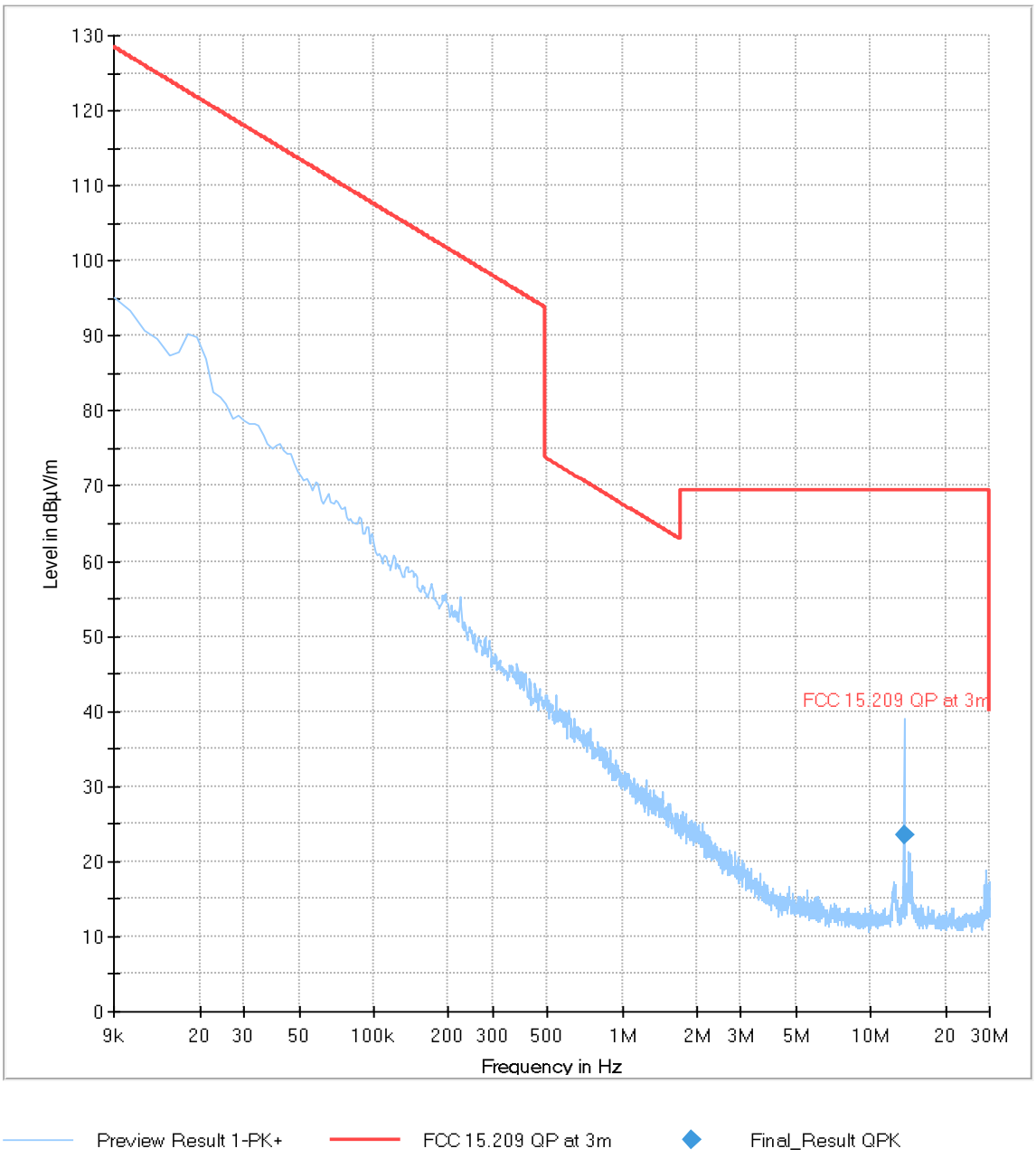
8.6.4 Measurement result:

Plot #	Channel #	Scan Frequency	Limit	Result
1-5	Low	9 kHz – 26 GHz	See section 8.6.2	Pass
6-10	Mid	9 kHz – 26 GHz	See section 8.6.2	Pass
11-15	High	9 kHz – 26 GHz	See section 8.6.2	Pass
16	High	Upper Restricted Band Edge	See section 8.6.2	Pass

8.6.5 Measurement Plots:

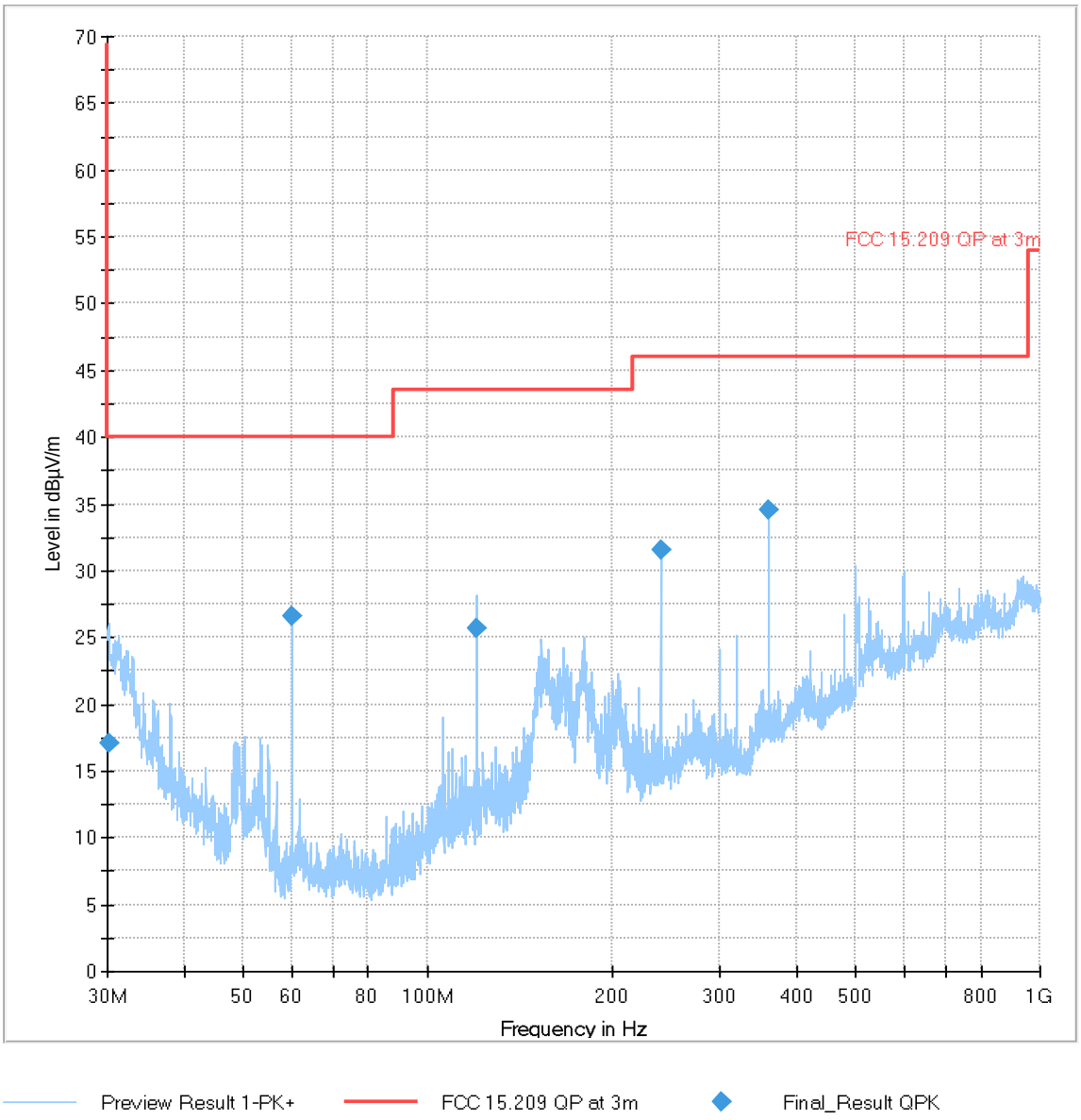
Plot # 1

Frequency (MHz)	QuasiPeak (dBµV/m)	DET 2 (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
13.559	23.55	---	69.50	45.95	500.0	9.0	120.0	H	188.0	5.5	



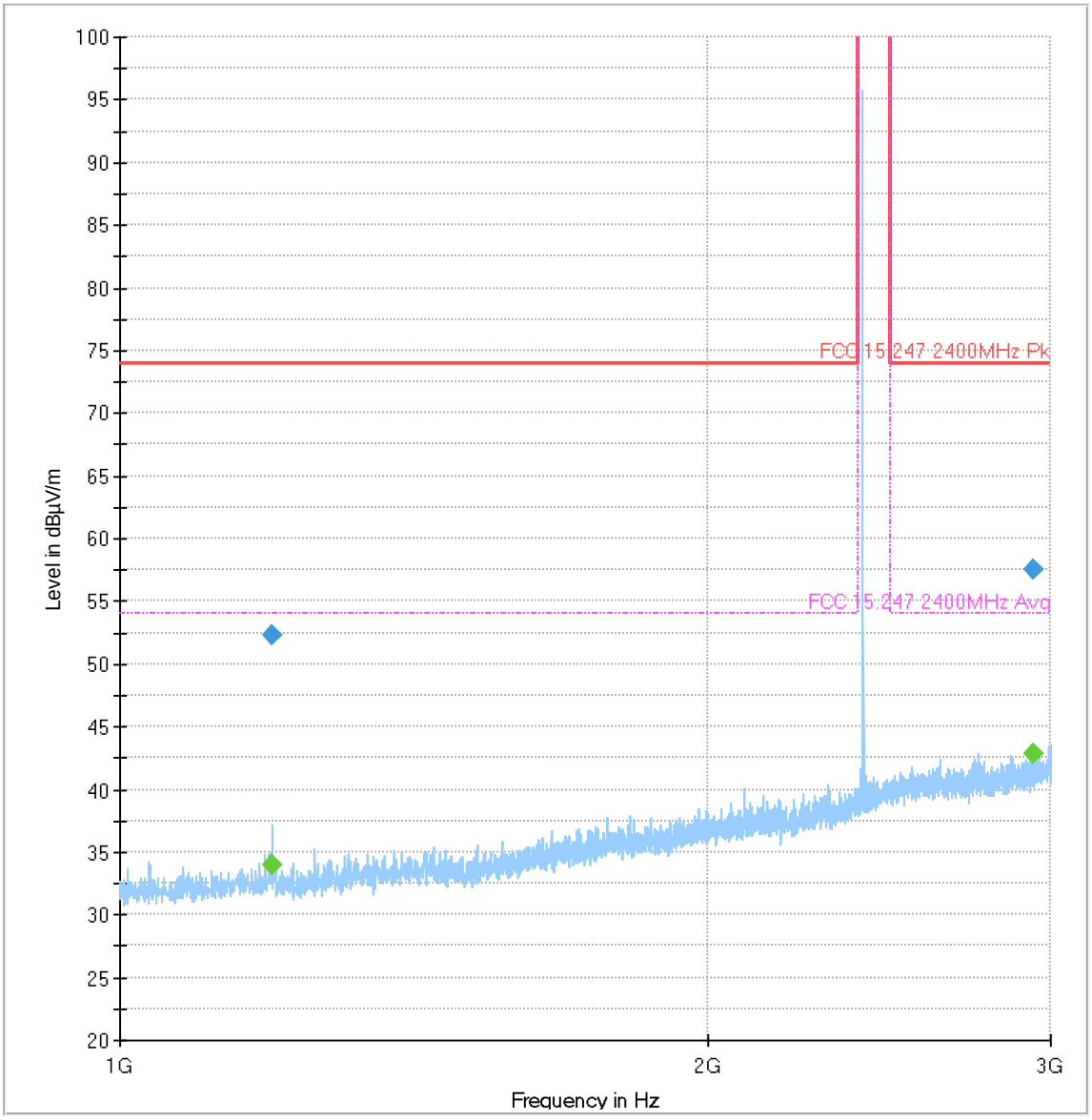
Plot # 2

Frequency (MHz)	QuasiPeak (dBµV/m)	DET 2 (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
30.128	17.12	---	40.00	22.88	500.0	120.0	184.0	V	6.0	-12.3	
59.993	26.57	---	40.00	13.43	500.0	120.0	163.0	V	7.0	-21.6	
119.980	25.64	---	43.50	17.86	500.0	120.0	264.0	H	145.0	-20.4	
240.005	31.57	---	46.02	14.46	500.0	120.0	172.0	H	245.0	-15.3	
360.004	34.55	---	46.02	11.47	500.0	120.0	137.0	H	163.0	-11.0	



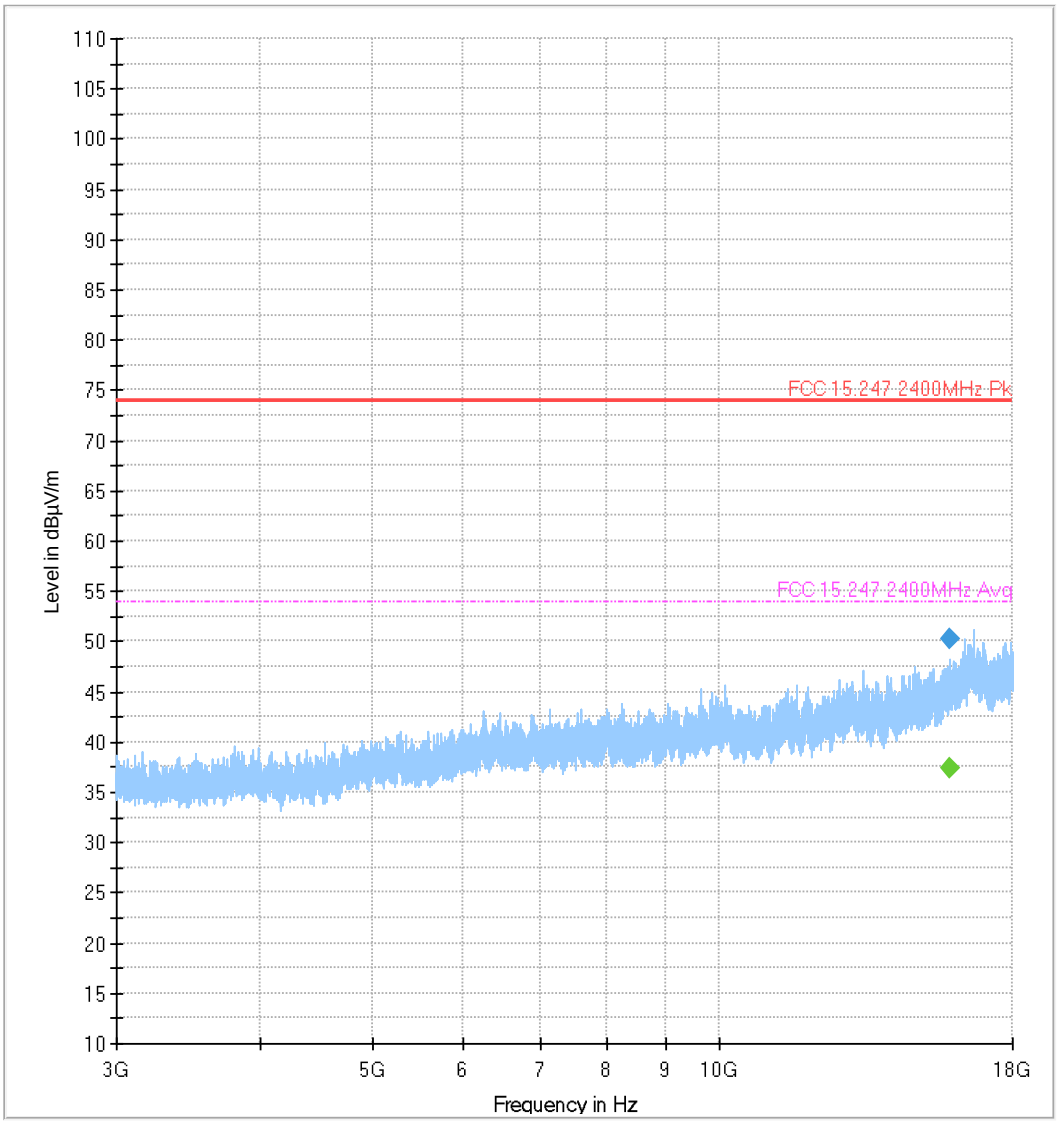
Plot # 3

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)	Comment
1196.500	52.36	---	74.00	21.64	500.0	1000.0	280.0	V	183.0	29.1	
1196.500	---	33.93	54.00	20.07	500.0	1000.0	280.0	V	183.0	29.1	
2941.500	57.49	---	74.00	16.51	500.0	1000.0	325.0	V	92.0	35.9	
2941.500	---	42.84	54.00	11.16	500.0	1000.0	325.0	V	92.0	35.9	

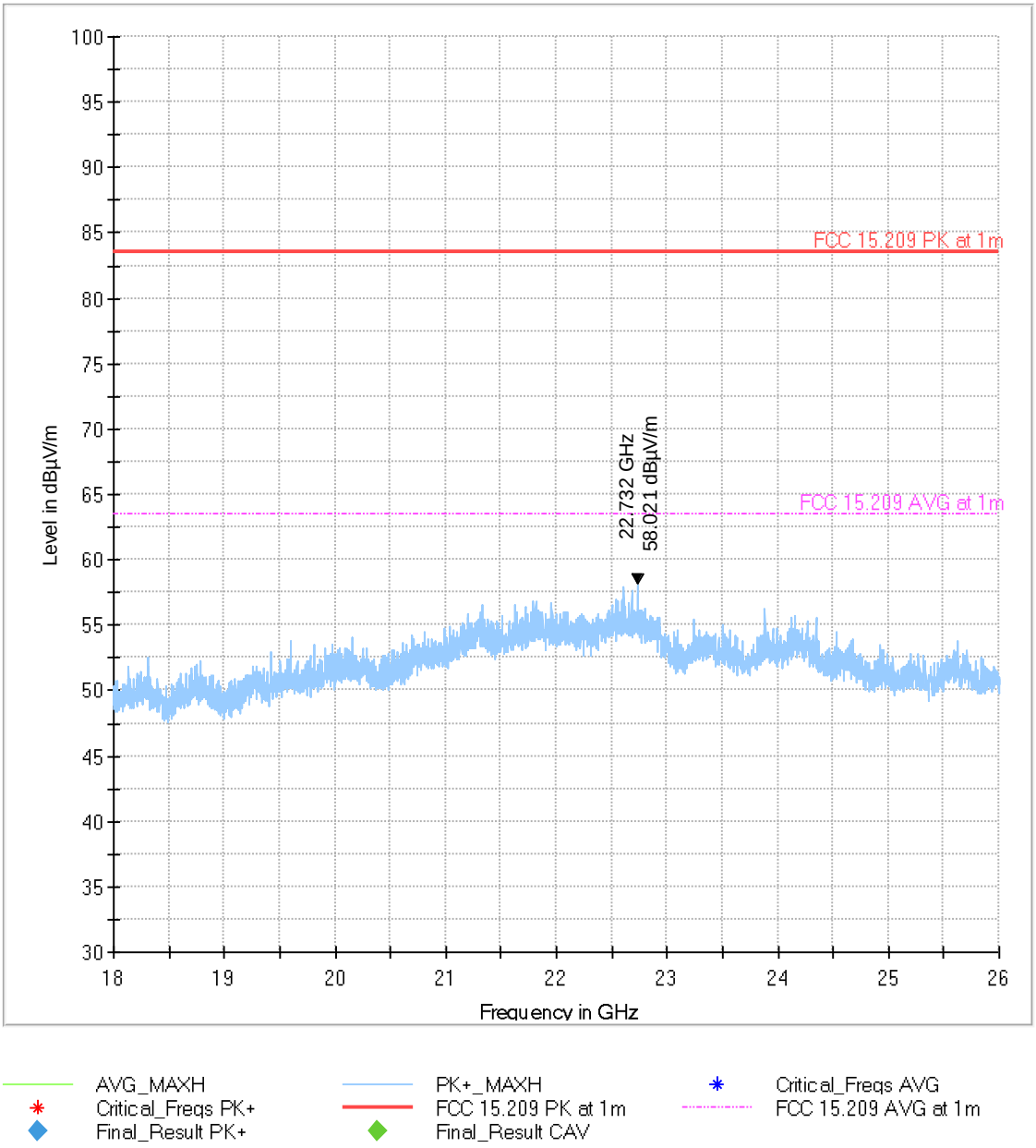


Plot # 4

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)	Comment
15884.250	50.27	---	74.00	23.73	500.0	1000.0	357.0	V	250.0	10.8	
15884.250	---	37.30	54.00	16.70	500.0	1000.0	357.0	V	250.0	10.8	



Plot # 5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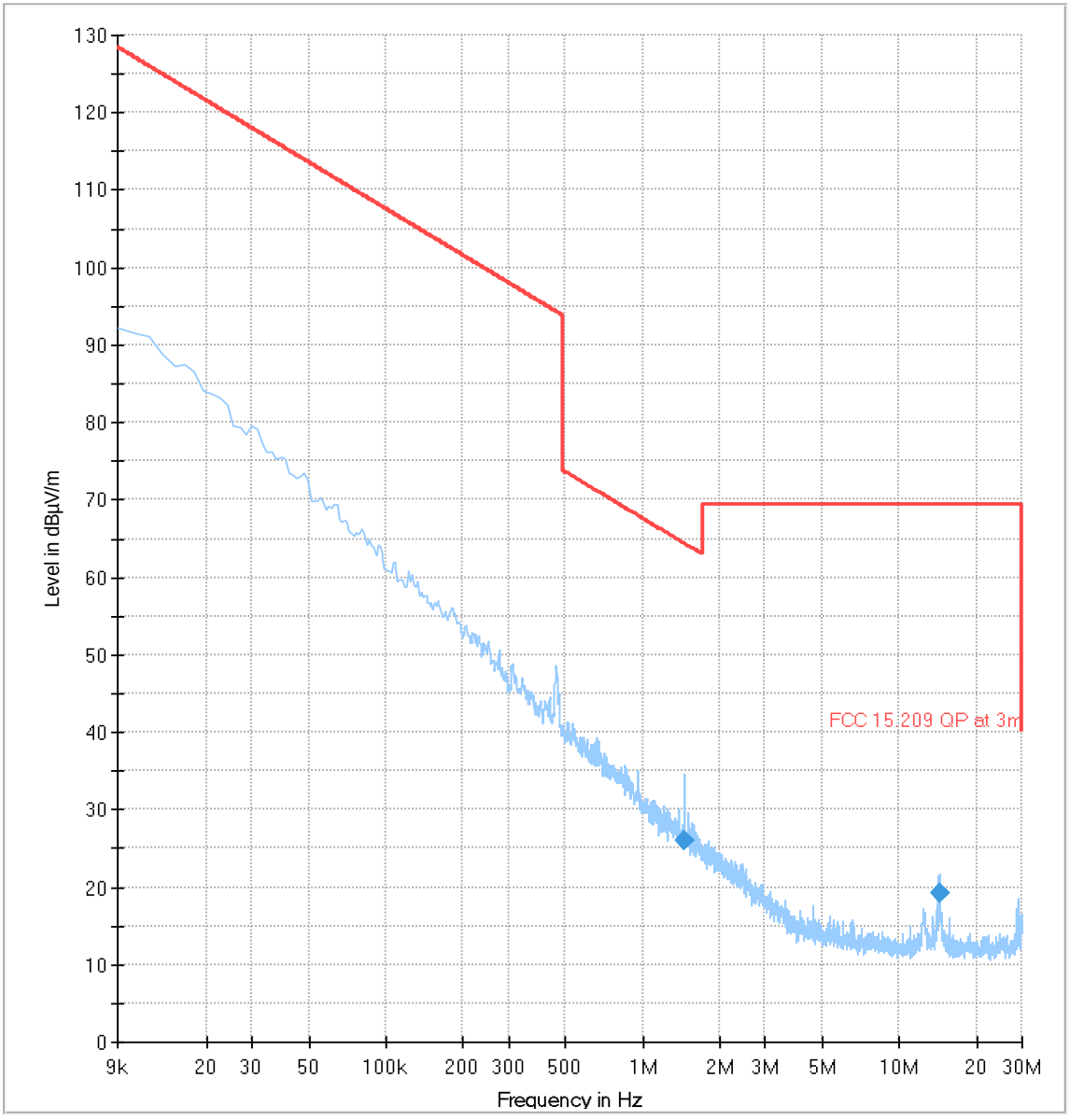
Level in dBµV/m
Frequency in GHz
FCC 15.209 PK at 1m
FCC 15.209 AVG at 1m
22.732 GHz
58.021 dBµV/m
AVG_MAXH
Critical_Freqs PK+
Final_Result PK+
PK+_MAXH
FCC 15.209 PK at 1m
Final_Result CAV
Critical_Freqs AVG
FCC 15.209 AVG at 1m

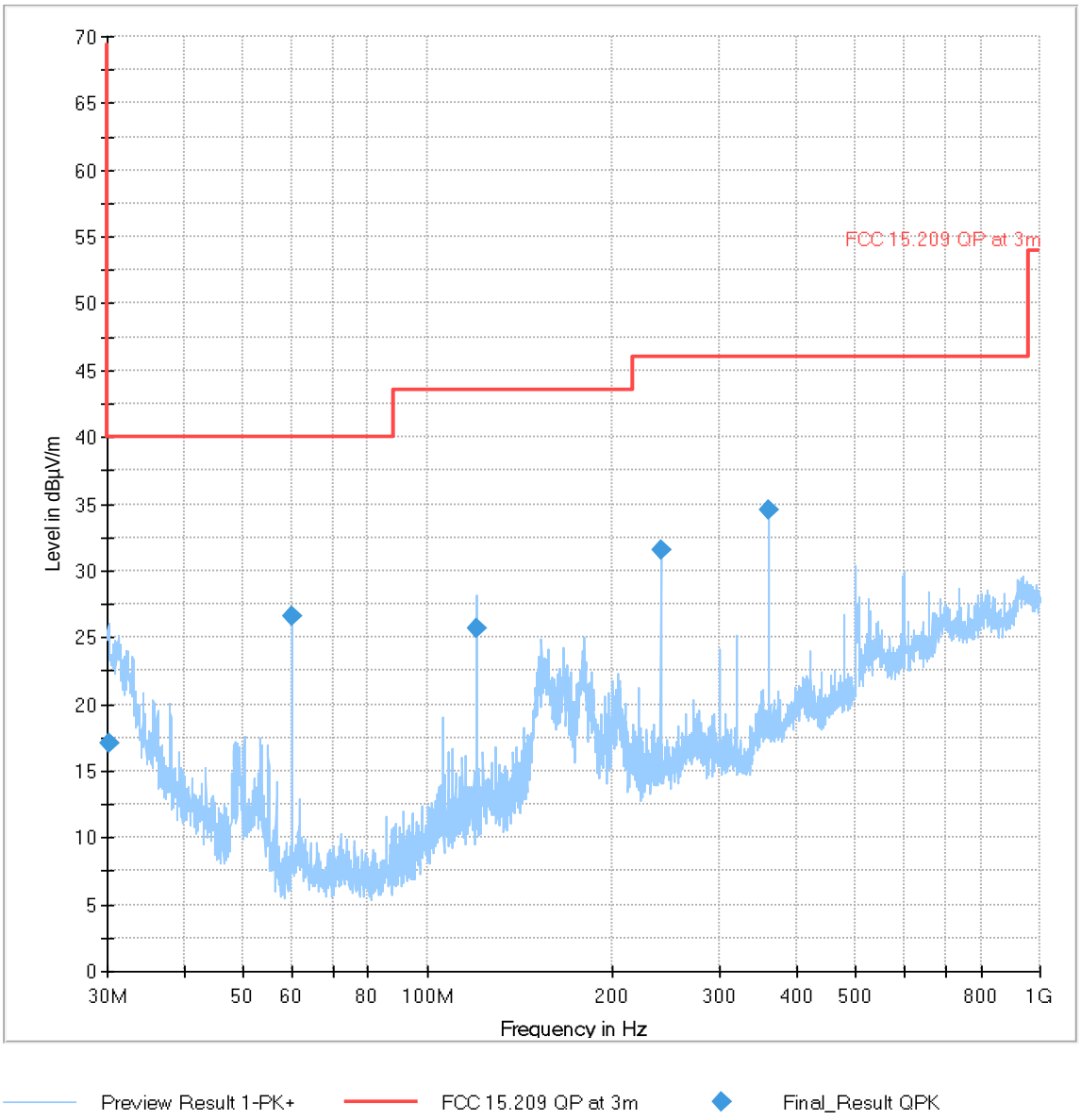
Plot # 6

Frequency (MHz)	QuasiPeak (dBµV/m)	DET 2 (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
1.455	25.91	---	64.38	38.46	500.0	9.0	120.0	H	117.0	15.1	
14.273	19.28	---	69.50	50.22	500.0	9.0	120.0	V	228.0	5.4	



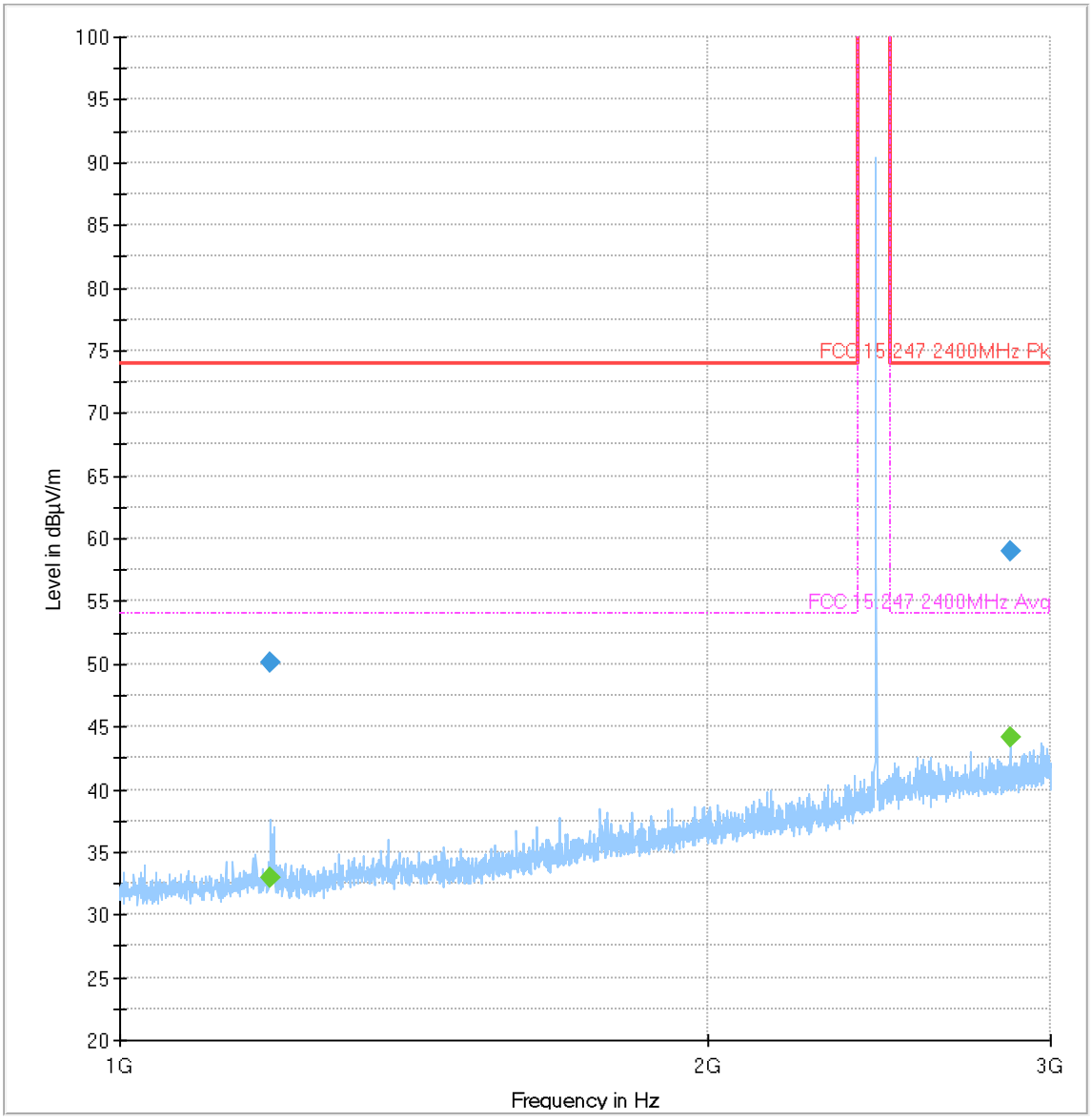
Plot # 7

Frequency (MHz)	QuasiPeak (dBµV/m)	DET 2 (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
30.128	17.12	---	40.00	22.88	500.0	120.0	184.0	V	6.0	-12.3	
59.993	26.57	---	40.00	13.43	500.0	120.0	163.0	V	7.0	-21.6	
119.980	25.64	---	43.50	17.86	500.0	120.0	264.0	H	145.0	-20.4	
240.005	31.57	---	46.02	14.46	500.0	120.0	172.0	H	245.0	-15.3	
360.004	34.55	---	46.02	11.47	500.0	120.0	137.0	H	163.0	-11.0	



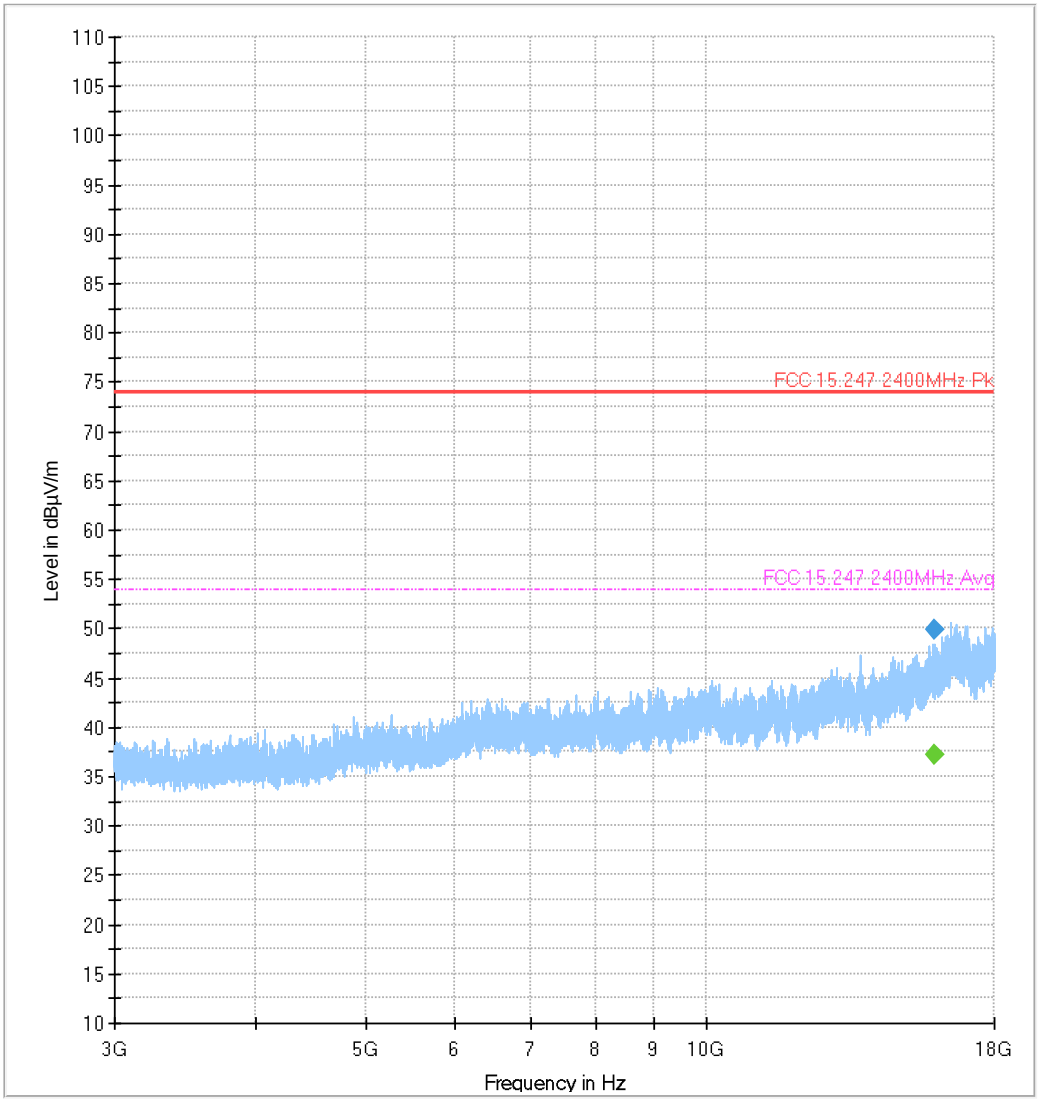
Plot # 8

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)	Comment
1194.500	50.08	---	74.00	23.92	500.0	1000.0	172.0	V	176.0	29.1	
1194.500	---	32.93	54.00	21.07	500.0	1000.0	172.0	V	176.0	29.1	
2859.000	59.05	---	74.00	14.95	500.0	1000.0	258.0	V	6.0	35.6	
2859.000	---	44.11	54.00	9.89	500.0	1000.0	258.0	V	6.0	35.6	

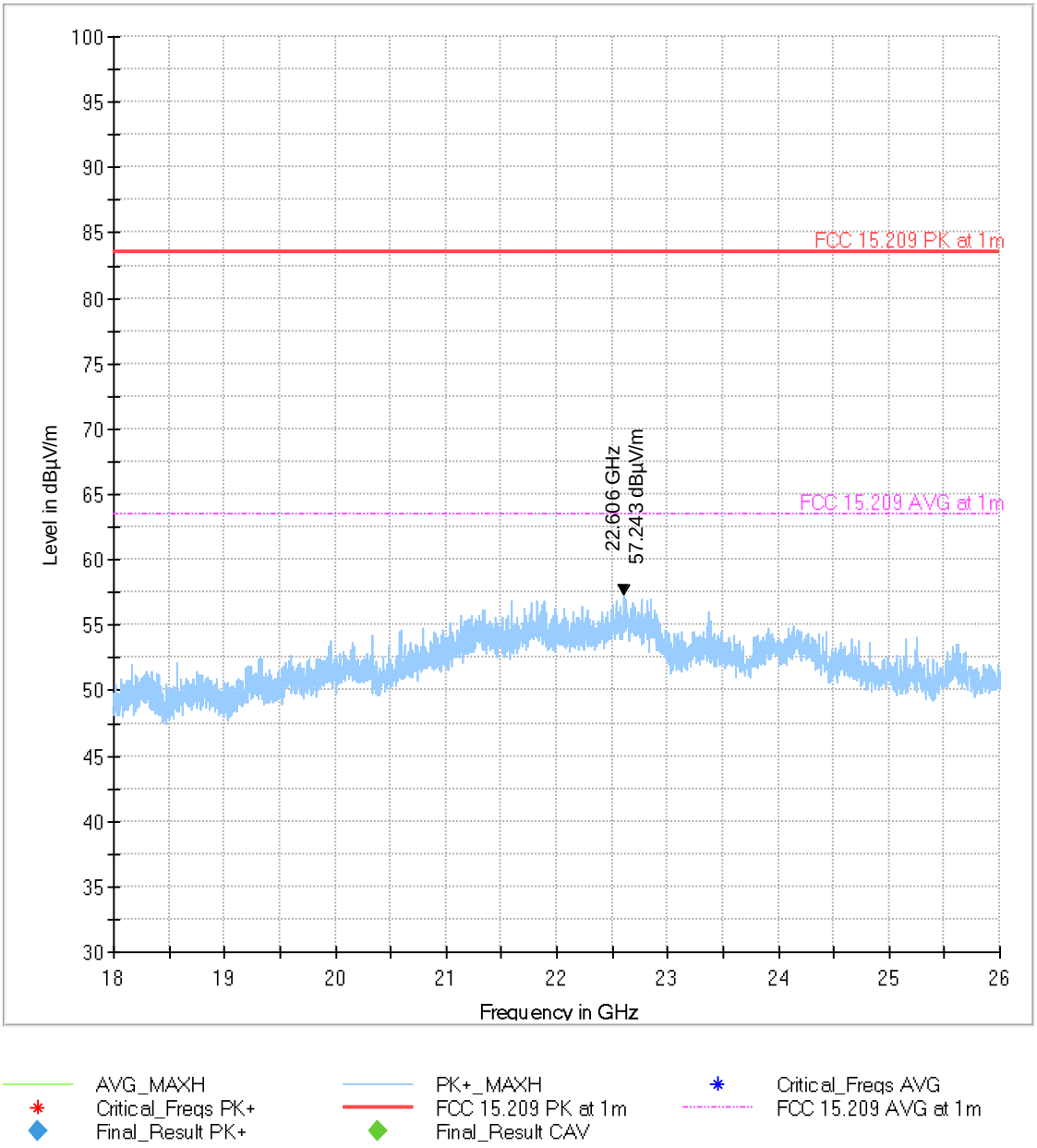


Plot # 9

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)	Comment
15934.750	49.94	---	74.00	24.06	500.0	1000.0	306.0	V	20.0	10.9	
15934.750	---	37.27	54.00	16.73	500.0	1000.0	306.0	V	20.0	10.9	



Plot # 10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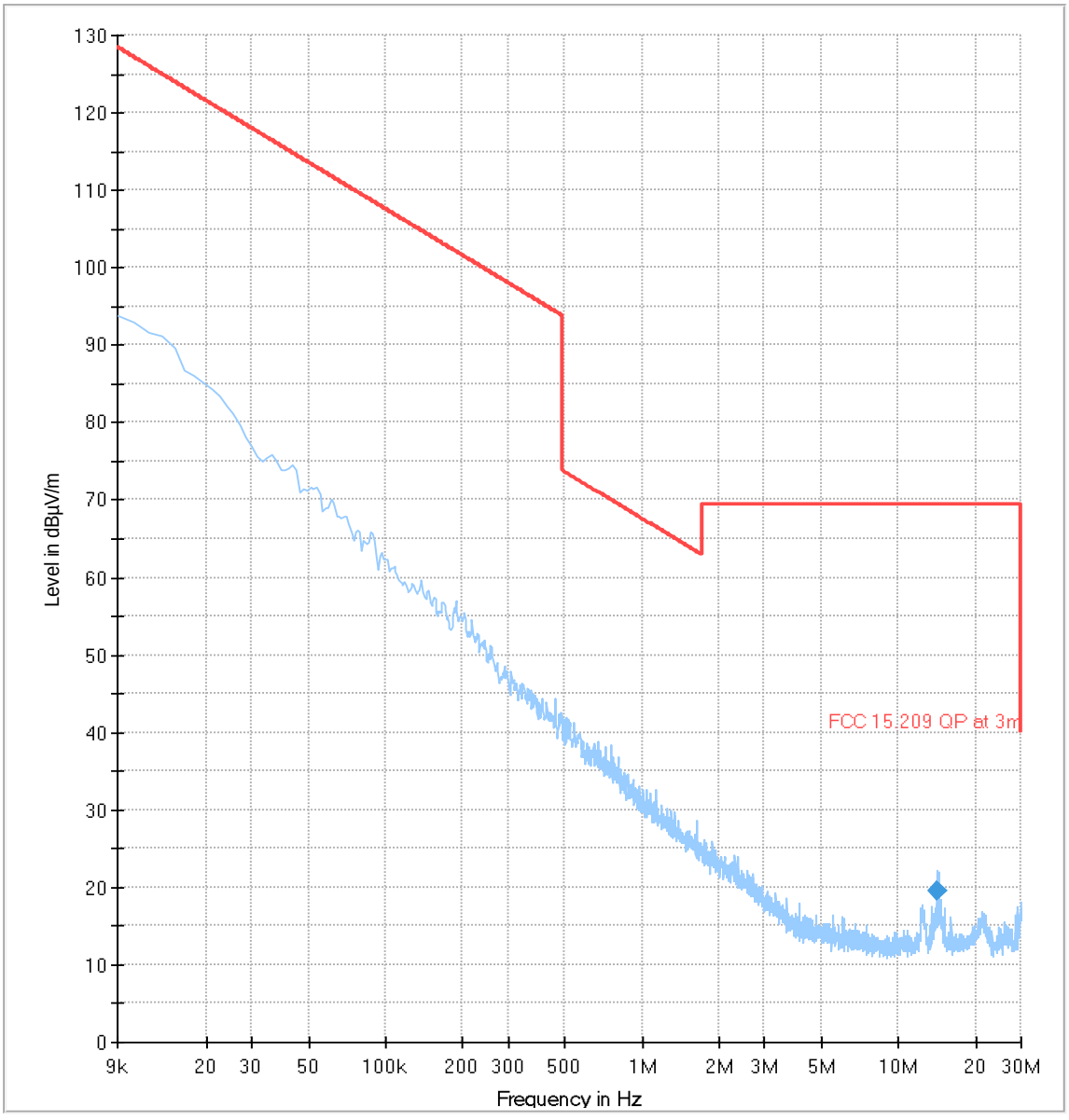
Level in dBµV/m
Frequency in GHz
FCC 15.209 PK at 1m
FCC 15.209 AVG at 1m
22.606 GHz
57.243 dBµV/m
AVG_MAXH
Critical_Freqs PK+
Final_Result PK+
PK+_MAXH
FCC 15.209 PK at 1m
Final_Result CAV
Critical_Freqs AVG
FCC 15.209 AVG at 1m

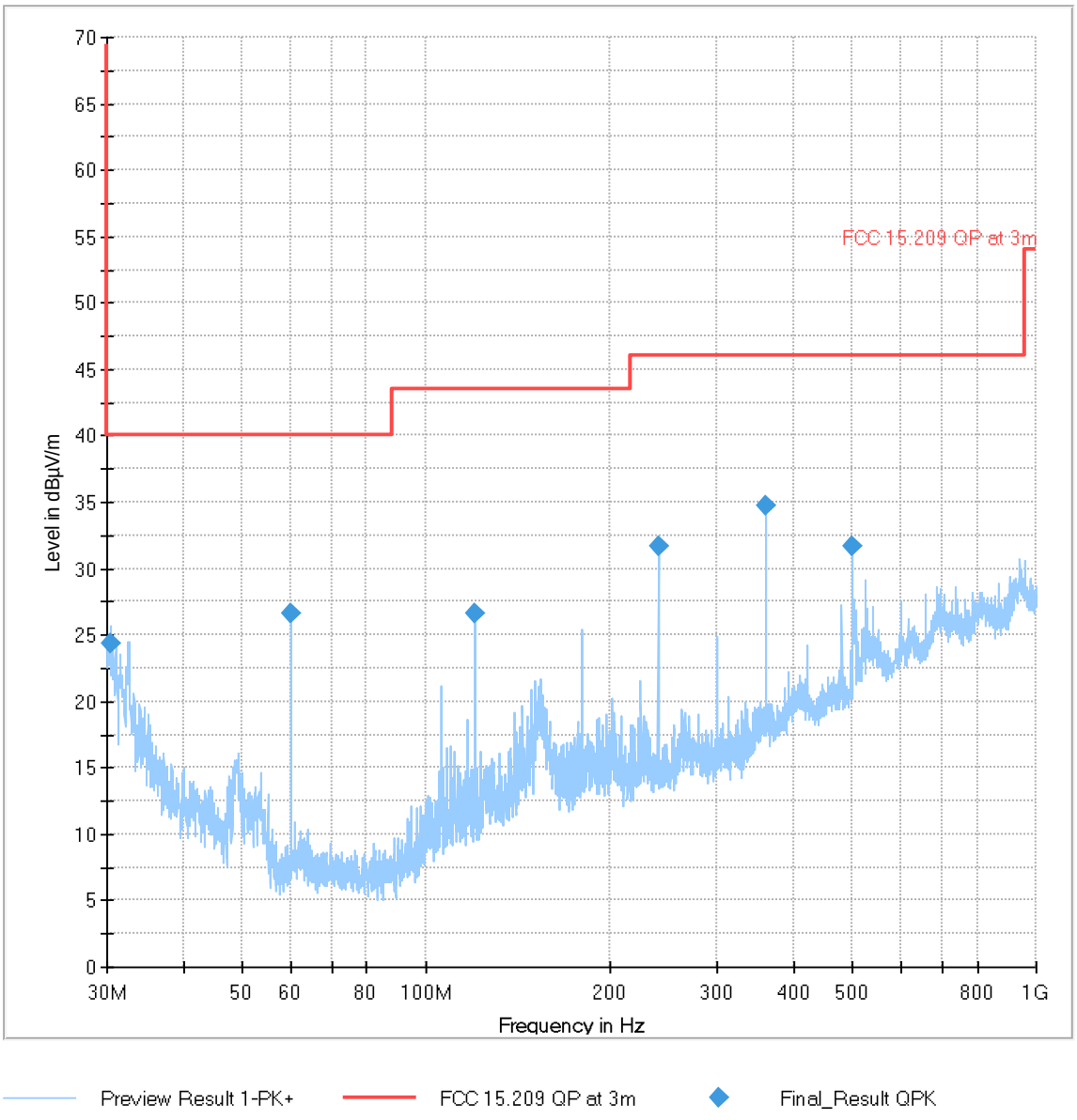
Plot # 11

Frequency (MHz)	QuasiPeak (dBµV/m)	DET 2 (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
14.151	19.49	---	69.50	50.01	500.0	9.0	120.0	H	6.0	5.4	



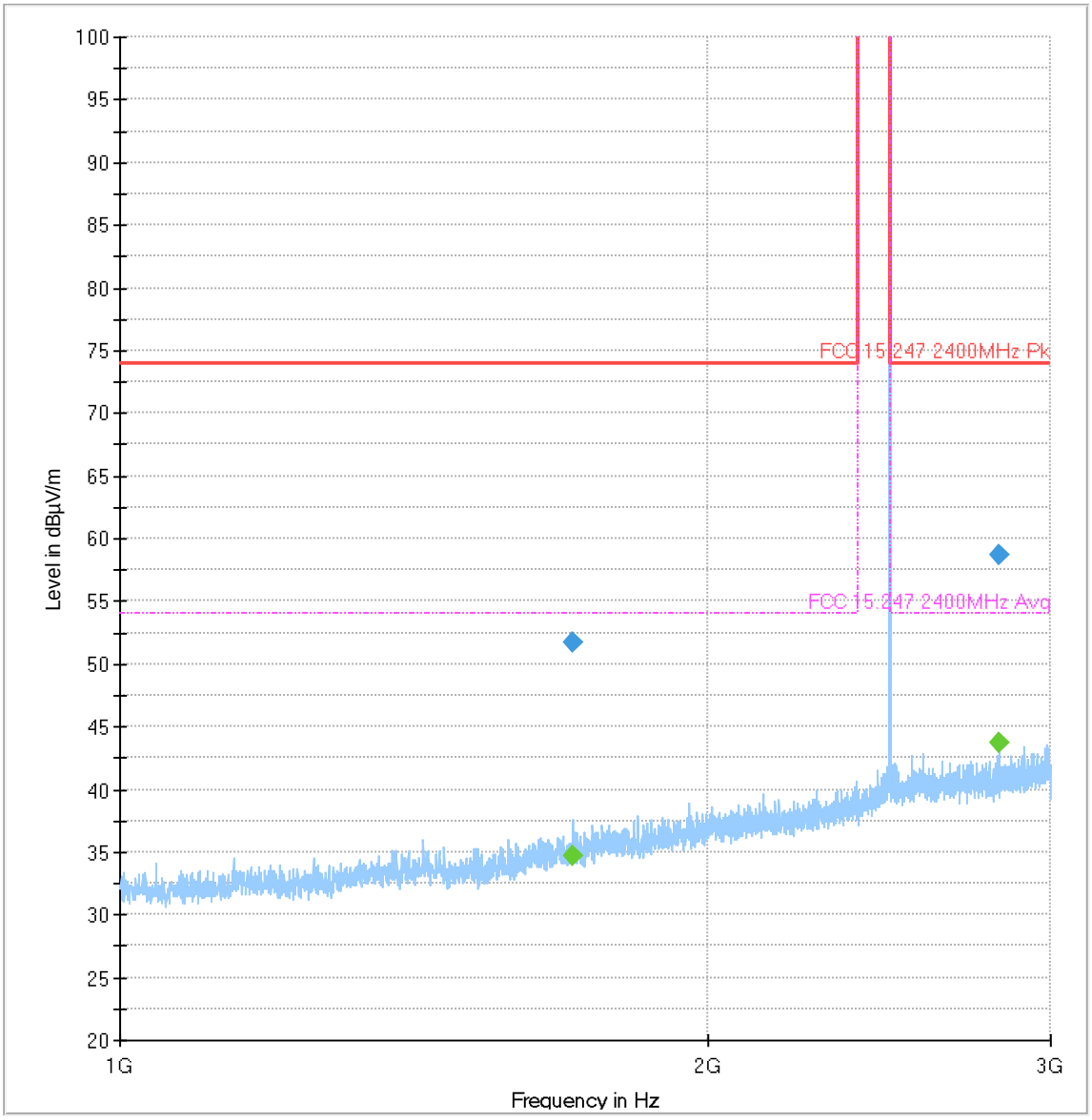
Plot # 12

Frequency (MHz)	QuasiPeak (dBµV/m)	DET 2 (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
30.357	24.35	---	40.00	15.65	500.0	120.0	111.0	V	167.0	-12.3	
59.993	26.59	---	40.00	13.41	500.0	120.0	105.0	V	38.0	-21.6	
119.980	26.59	---	43.50	16.91	500.0	120.0	175.0	H	91.0	-20.4	
240.005	31.71	---	46.02	14.31	500.0	120.0	129.0	H	257.0	-15.3	
360.004	34.69	---	46.02	11.33	500.0	120.0	199.0	H	171.0	-11.0	
500.297	31.65	---	46.02	14.37	500.0	120.0	141.0	V	293.0	-7.8	



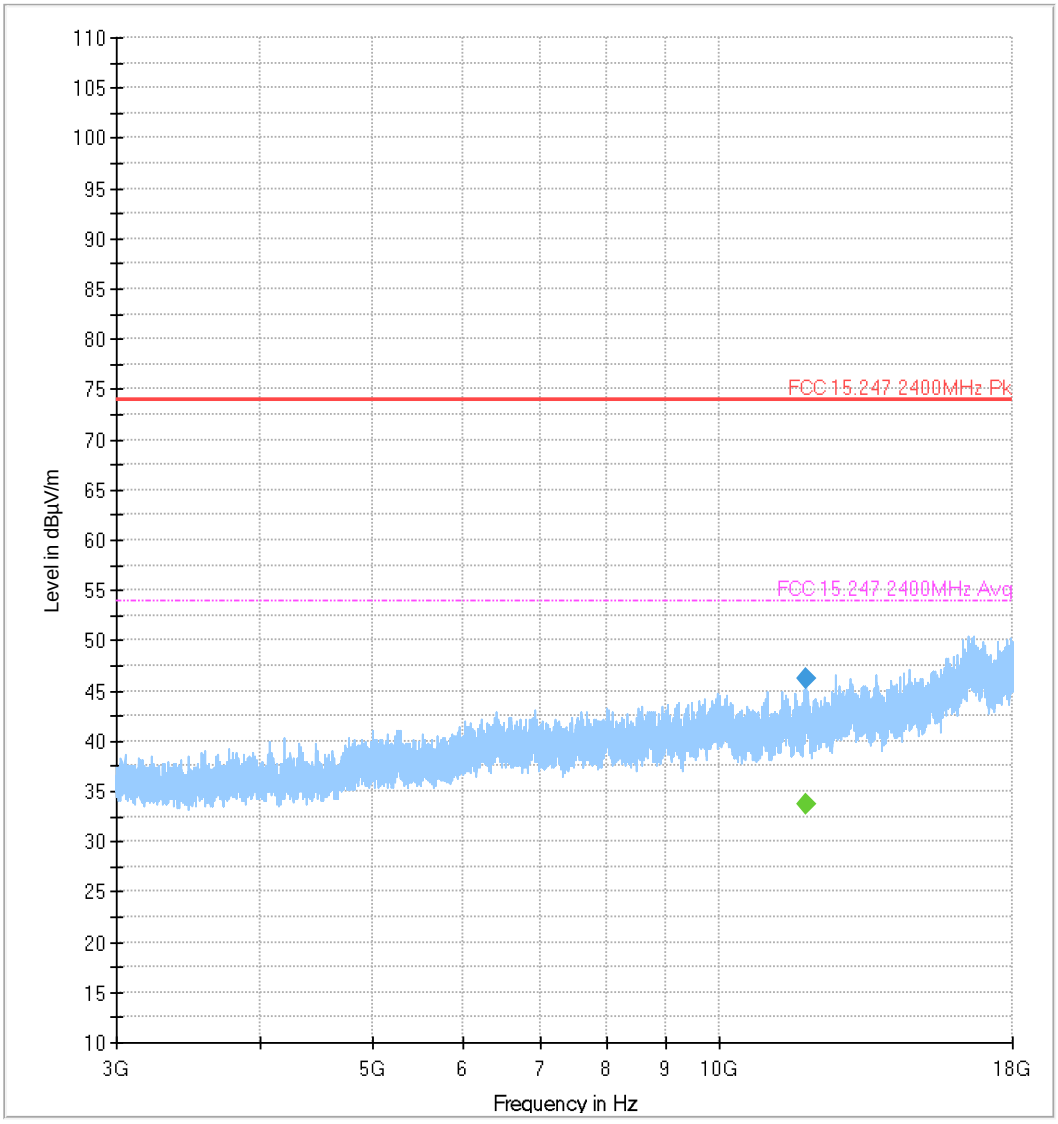
Plot # 13

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)	Comment
1707.500	51.78	---	74.00	22.22	500.0	1000.0	107.0	V	279.0	30.9	
1707.500	---	34.73	54.00	19.27	500.0	1000.0	107.0	V	279.0	30.9	
2824.000	58.72	---	74.00	15.28	500.0	1000.0	223.0	V	131.0	35.5	
2824.000	---	43.70	54.00	10.30	500.0	1000.0	223.0	V	131.0	35.5	

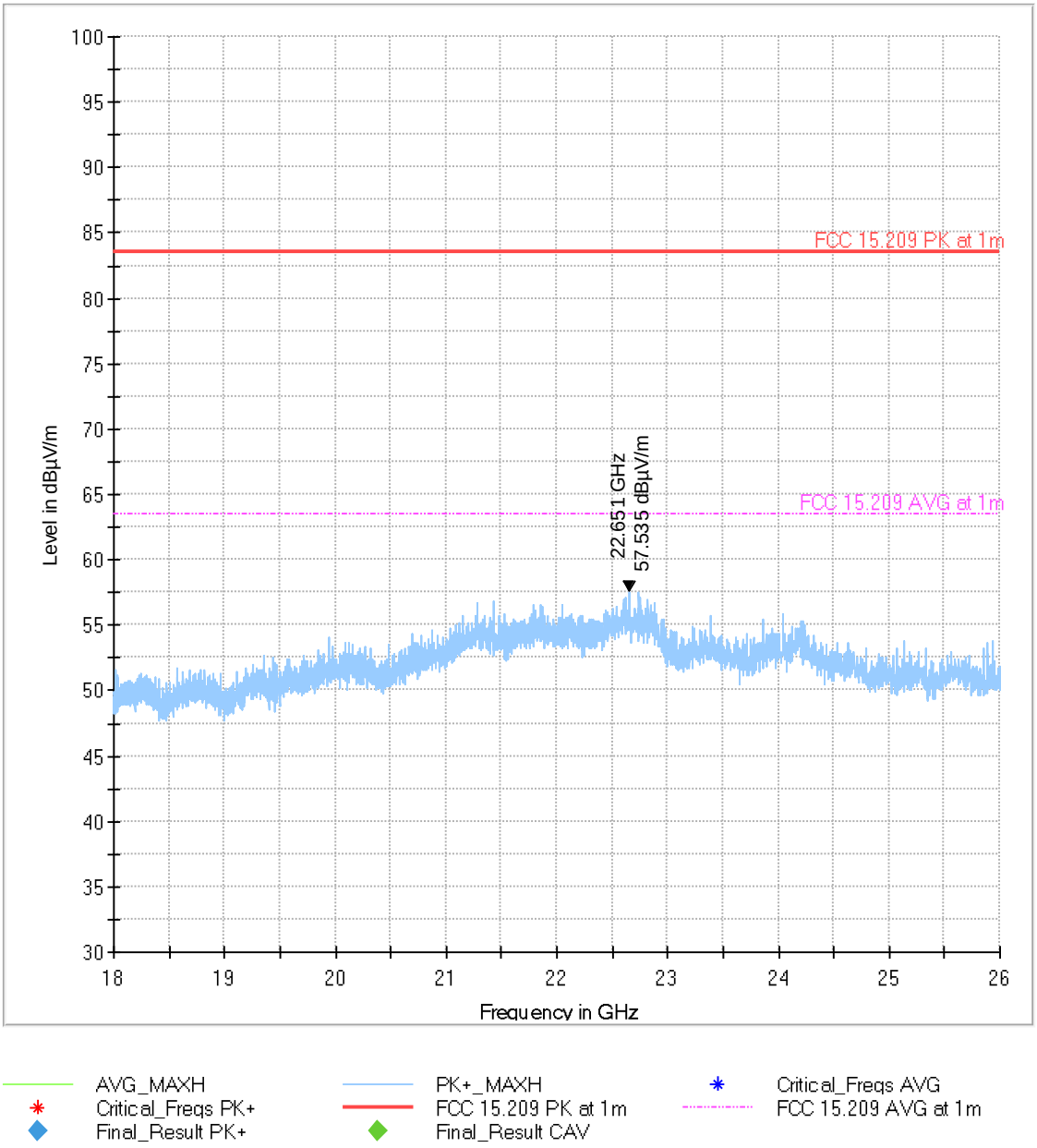


Plot # 14

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)	Comment
11919.250	46.29	---	74.00	27.71	500.0	1000.0	125.0	V	60.0	6.2	
11919.250	---	33.66	54.00	20.34	500.0	1000.0	125.0	V	60.0	6.2	



Plot # 15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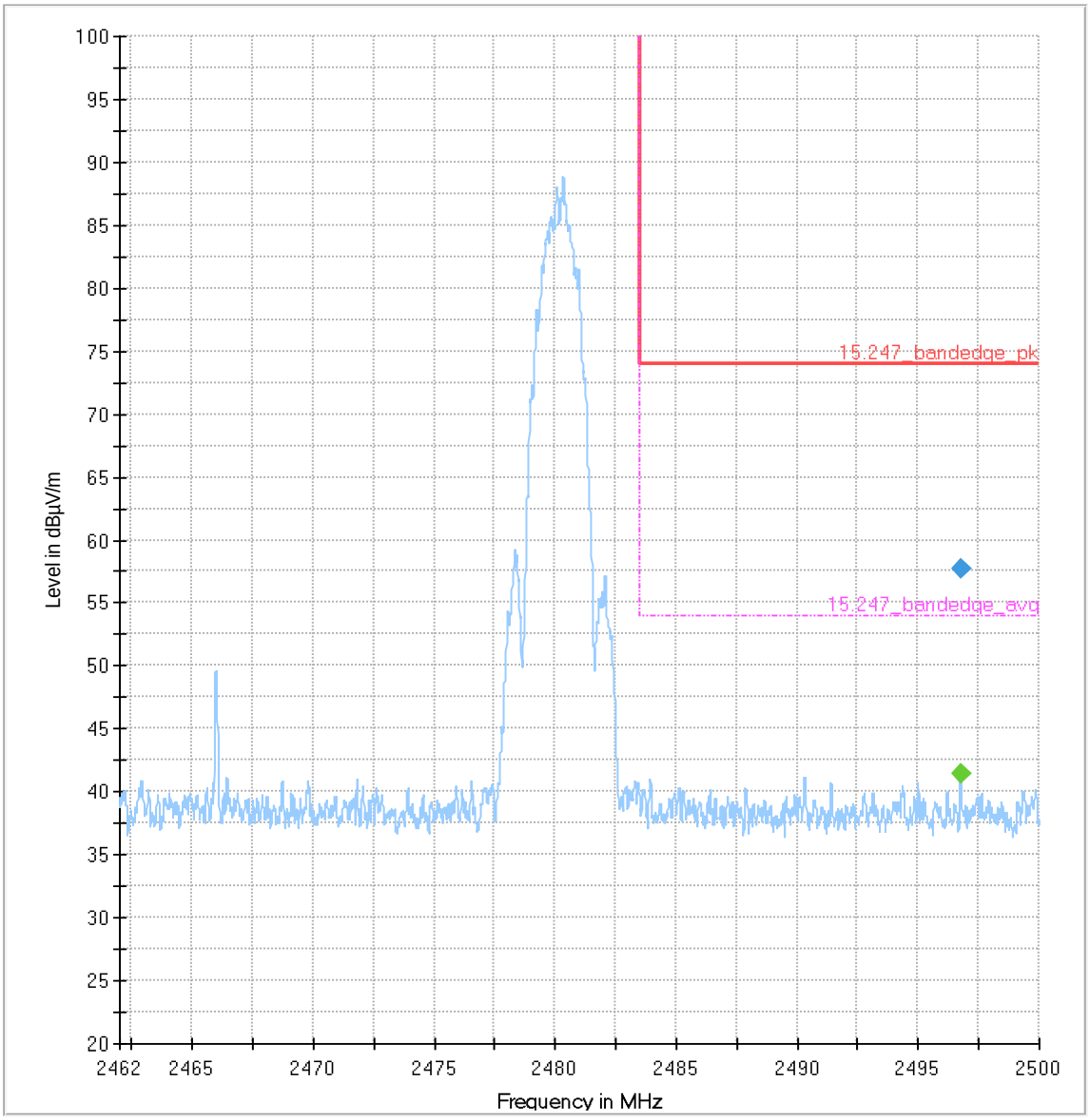
Level in dBµV/m
Frequency in GHz
FCC 15.209 PK at 1m
FCC 15.209 AVG at 1m
22.651 GHz
57.535 dBµV/m
AVG_MAXH
Critical_Freqs PK+
Final_Result PK+
PK+_MAXH
FCC 15.209 PK at 1m
Final_Result CAV
Critical_Freqs AVG
FCC 15.209 AVG at 1m

Plot # 16

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)	Comment
2496.751	---	41.45	54.00	12.55	500.0	1000.0	235.0	V	297.0	34.3	
2496.751	57.68	---	74.00	16.32	500.0	1000.0	235.0	V	297.0	34.3	



9 Test setup photos

Setup photos are included in supporting file name: "EMC_HENDR_002_24001_FCC_15_247_BLE_Photos"

10 Test Equipment And Ancillaries Used For Testing

Equipment Type	Manufacturer	Model	Serial #	Calibration Cycle	Last Calibration Date
Active Monopole	Com-Power Corp.	AM-741R	10200112	3 Years	11/09/2023
PASSIVE LOOP ANTENNA	ETS LINDGREN	6512	000164698	3 Years	09/06/2023
BILOG ANTENNA	ETS.LINDGREN	3142E	00166067	3 Years	08/01/2024
HORN ANTENNA	EMCO	3115	00035114	3 Years	09/13/2023
HORN ANTENNA	ETS.LINDGREN	3117	00215984	3 Years	10/26/2023
HORN ANTENNA	ETS LINDGREN	3116C-PA	00166821	3 Years	10/26/2023
TEST RECEIVER	ROHDE & SCHWARZ	ESW44	103143	2 Years	09/12/2024
DIGITAL THERMOMETER	CONTROL COMPANY	4410,90080-03	230713059	3 Years	10/18/2023
Multimeter	Fluke	115	56090717MV	3 Years	09/26/2023
Software	EMC32	Version 11.40.00	-	-	-

Equipment Type	Manufacturer	Model	Serial #	Calibration Cycle	Last Calibration Date
Spectrum Analyzer	ROHDE & SCHWARZ	FSU	200302	3 Years	01/30/2026
Switch	ROHDE & SCHWARZ	OSP 120	100083	3 Years	12/31/2024
Temperature Chamber	TESTEQUITY	123H	230159	-	N/A
Software	WMS32	12.00.01			

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
2025-02-12	EMC_HENDR_002_24001_FCC_15_247_BLE	Initial Version	Art Thammanavarat
2025-03-26	EMC_HENDR_002_24001_FCC_15_247_BLE_Rev1	Report Revise 1. Section 8.1.5 & 8.1.6: Added Plots. 2. Section 8.2.1: Updated statement. 3. Section 8.2.5: Added plots. 4. Section 8.3.5: Added plots. 5. Section 8.5.4: Updated Table. 6. Section 8.5.5: Added plots. 7. Section 10: Updated table.	Art Thammanavarat

<<< The End >>>