FCC Test Report

For:
Appareo Systems, LLC

Model Name:
Galeo

Product Description:
Small tracking tag that communicates with a mobile application over BLE or cellular. The DUT acquires GPS location and reports its location back to the user.

FCC ID: 2AETC-GALEO

Applied Rules and Standards:
47 CFR Part 15.247 (DTS)

REPORT #: EMC_APPAR-003-20501_15.247_BTLE_DTS

DATE: 2020-08-14

A2LA Accredited

IC recognized #
3462B-1

***CETECOM* Inc.**
411 Dixon Landing Road ◆ Milpitas, CA 95035 ◆ U.S.A.
Phone: + 1 (408) 586 6200 ◆ Fax: + 1 (408) 586 6299 ◆ E-mail: info@cetecom.com ◆ http://www.cetecom.com
CETECOM Inc. is a Delaware Corporation with Corporation number: 2905571

TABLE OF CONTENTS

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.

No deviations were ascertained.

Company	Description	Model Name
Appareo Systems, LLC	Small tracking tag that communicates with a mobile application over BLE or cellular. The DUT acquires GPS location and reports its location back to the user.	Galeo

Responsible for Testing Laboratory:

Date	Section	Name	Signature
2020-08-14	Compliance	Cindy Li (EMC Lab Manager)	Cindy Li

Responsible for the Report:

Date	Section	Name	Signature
2020-08-14	Compliance	Chin Ming Lui (Associate EMC Engineer)	Chin Ming Lui Digitally signed by: Chin Ming Lui DN: CN = Chin Ming Lui email = chinming.lui@cetecom.com C = US O = CETECOM Date: 2020.08.14 20:41:28 -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:	Cindy Li
Responsible Project Leader:	Akanksha Baskaran

2.2 Identification of the Client

Client's Name:	Appareo Systems, LLC
Street Address:	1810 NDSU Research Cir. N.
City/Zip Code	Fargo, ND 58102
Country	USA
Contact Person:	Nathan Schneck
Phone No.	(701) 356-2200
e-mail:	nschneck@appareo.com

2.3 Identification of the Manufacturer

Manufacturer's Name:	Appareo Systems, LLC
Manufacturers Address:	1810 NDSU Research Cir. N.
City/Zip Code	Fargo, ND 58102
Country	USA
Contact Person:	Nathan Schneck
Phone No.	(701) 356-2200
e-mail:	nschneck@appareo.com

3 Equipment Under Test (EUT)

3.1 EUT Specifications

Model Name:	Galeo
HW Version :	X07
SW Version :	0.4.0.373
FCC-ID :	2AETC-GALEO
FWIN:	N/A
HVIN:	N/A
PMN:	Galeo
Product Description:	Small tracking tag that communicates with a mobile application over BLE or cellular. The DUT acquires GPS location and reports its location back to the user.
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:	Bluetooth Low Energy (BLE): • Manufacturer: Nordic Semiconductor • Module: nRF52832 SoC (Software version S-132 soft device) • Technology Supported: Bluetooth 5.1 • Modes of Operation: LE 1 Mbps & LE 2 Mbps
Antenna Information as declared:	Main Antenna: • Type: Trace Antenna (Monopole) • Location: Internal • Peak Gain: -0.78 dBi • Average Gain: -4.55 dBi
Max. Peak Output Power:	Conducted Power: 12.00 dBm
Power Supply/ Rated Operating Voltage Range:	Vmin: 4.75 VDC / Vnom: 5.0 VDC / Vmax: 5.25 VDC
Operating Temperature Range	-20 °C to 60 °C
Sample Revision	☐Prototype Unit; ☐Production Unit; ■Pre-Production

3.2 EUT Sample details

EUT #	Serial Number	HW Version	SW Version	Notes/Comments
1	172	X07	0.4.0.373	Conducted Emissions
2	153510-000145	X07	0.4.0.373	Radiated and AC Conducted Emissions

3.3 Accessory Equipment (AE) details

N/A

3.4 Support Equipment (SE) details

SE #	Type	Model	Manufacturer	Serial Number
1	Test Laptop	Latitude E5430	DELL	8RW1VY1
2	USB Breakout Board	-	-	-
3	USB-C to USB-A Cable	-	-	-
4	ITE Power Supply	A1385	Flextronics	N/A

3.5 Test Sample Configuration

EUT Set-up #	Combination of SE used for test set up	Comments
1	EUT #1 + SE #1 + SE #2	Conducted Setup: The radio of the EUT was configured using Tera Term: • Single Channel (Fixed): ○ start_channel 2 → 2402 MHz, BLE Channel 0 ○ start_channel 40 → 2440 MHz, BLE Channel 19 ○ start_channel 80 → 2480 MHz, BLE Channel 39 • TX Output Power: ○ output_power pos0dBm → TX power: 0 dBm • Mode of Operation: ○ data_rate ble_1Mbit → 1 Mbit/s Bluetooth Low Energy ○ data_rate ble_2Mbit → 2 Mbit/s Bluetooth Low Energy Tera Term will not be available to the end user. The measurement equipment was connected to the 50 ohm RF port of the EUT.

2	EUT #2 + SE #3 + SE #4	Radiated Setup: The radio of the EUT was configured using Tera Term: • Single Channel (Fixed): ○ start_channel 2 → 2402 MHz, BLE Channel 0 ○ start_channel 40 → 2440 MHz, BLE Channel 19 ○ start_channel 80 → 2480 MHz, BLE Channel 39 • TX Output Power: ○ output_power pos0dBm → TX power: 0 dBm • Mode of Operation: ○ data_rate ble_1Mbit → 1 Mbit/s Bluetooth Low Energy Tera Term will not be available to the end user. The internal antenna was connected. **Note:** SE #1 and SE #2 were first utilized to configure the BLE radio
3	EUT #2 + SE #3 + SE #4	AC Conducted Setup: The radio of the EUT was configured using Tera Term: • Single Channel (Fixed): ○ start_channel 40 → 2440 MHz, BLE Channel 19 • TX Output Power: ○ output_power pos0dBm → TX power: 0 dBm • Mode of Operation: ○ data_rate ble_1Mbit → 1 Mbit/s Bluetooth Low Energy ○ data_rate ble_2Mbit → 2 Mbit/s Bluetooth Low Energy Tera Term will not be available to the end user. The internal antenna was connected. **Note:** SE #1 and SE #2 were first utilized to configure the BLE radio

3.6 Justification for Worst Case Mode of Operation

During the testing process, the EUT was tested with transmitter sets on low, mid and high channels, and test mode duty cycle of 100% for both LE 1 Mbps and LE 2 Mbps.

For radiated measurements, LE 1 Mbps was chosen for evaluation, which is the worst case operating mode supported, based on the peak power spectral density measured. All data in this report show 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 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.

This test report is to support a request for new equipment authorization under the FCC ID: 2AETC-GALEO

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	Operating Mode	Pass	NA	NP	Result
§15.247(a)(1) RSS-247 5.2(a)	Emission Bandwidth	Nominal	LE 1 Mbps LE 2 Mbps	■	☐	☐	Complies
§15.247(e) RSS-247 5.2(b)	Power Spectral Density	Nominal	LE 1 Mbps LE 2 Mbps	■	☐	☐	Complies
§15.247(b)(1) RSS-247 5.4(d)	Maximum Conducted Output Power and EIRP	Nominal	LE 1 Mbps LE 2 Mbps	■	☐	☐	Complies
§15.247(d) RSS-247 5.5	Band edge compliance Unrestricted Band Edges	Nominal	LE 1 Mbps LE 2 Mbps	■	☐	☐	Complies
§15.247; 15.209; 15.205 RSS-Gen 8.9; 8.10	Band edge compliance Restricted Band Edges	Nominal	LE 1 Mbps LE 2 Mbps	■	☐	☐	Complies
§15.247(d); §15.209 RSS-Gen 6.13	TX Spurious emissions-Radiated	Nominal	LE 1 Mbps	■	☐	☐	Complies
§15.207(a) RSS Gen 8.8	AC Conducted Emissions	Nominal	LE 1 Mbps LE 2 Mbps	■	☐	☐	Complies

Note 1: NA= Not Applicable; NP= Not Performed.
Note 2: EUT in charging state during testing

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=1.

Radiated measurement

9 kHz to 30 MHz	±2.5 dB (Magnetic Loop Antenna)
30 MHz to 1000 MHz	±2.0 dB (Biconilog Antenna)
1 GHz to 40 GHz	±2.3 dB (Horn Antenna)

Conducted measurement

150 kHz to 30 MHz	±0.7 dB (LISN)
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.

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:

07/13/2020 - 07/24/2020

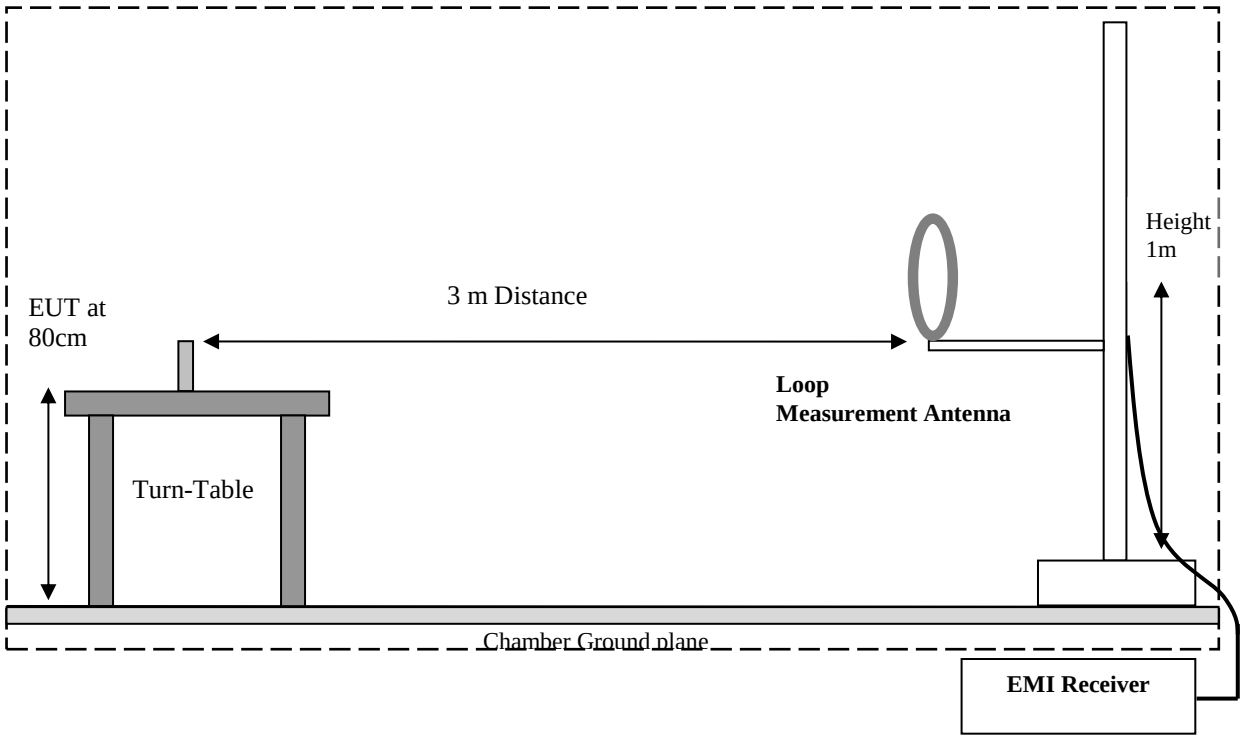
7 Measurement Procedures

7.1 Radiated Measurement

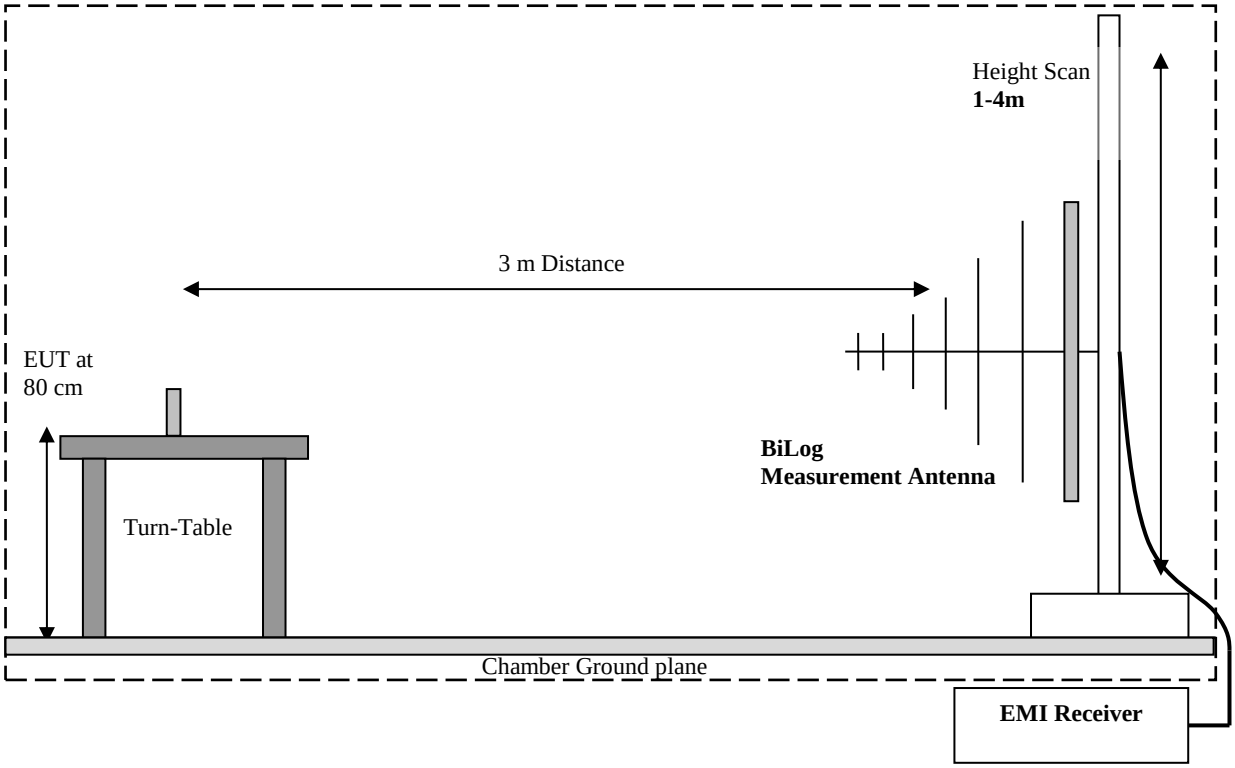
The radiated measurement is performed according to ANSI C63.10 (2013)

- 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.

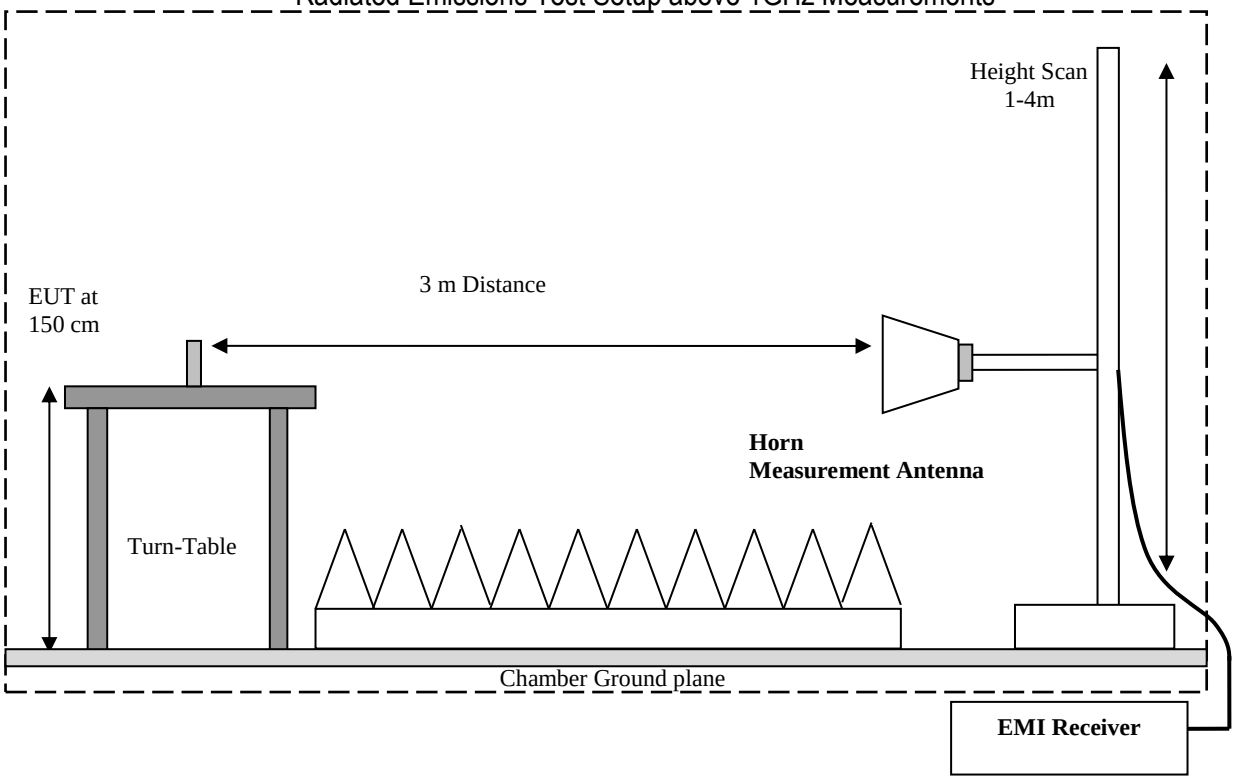
Radiated Emissions Test Setup below 30MHz Measurements



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:

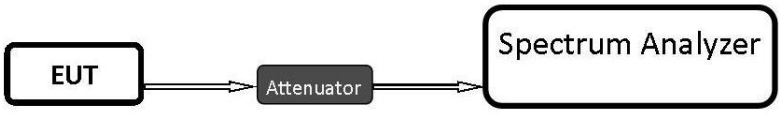
Frequency (MHz)	Measured SA (dBµV)	Cable Loss (dB)	Antenna Factor Correction (dB)	Field Strength Result (dBµV/m)
1000	80.5	3.5	14	98.0

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

8.1.3 Test conditions and setup:

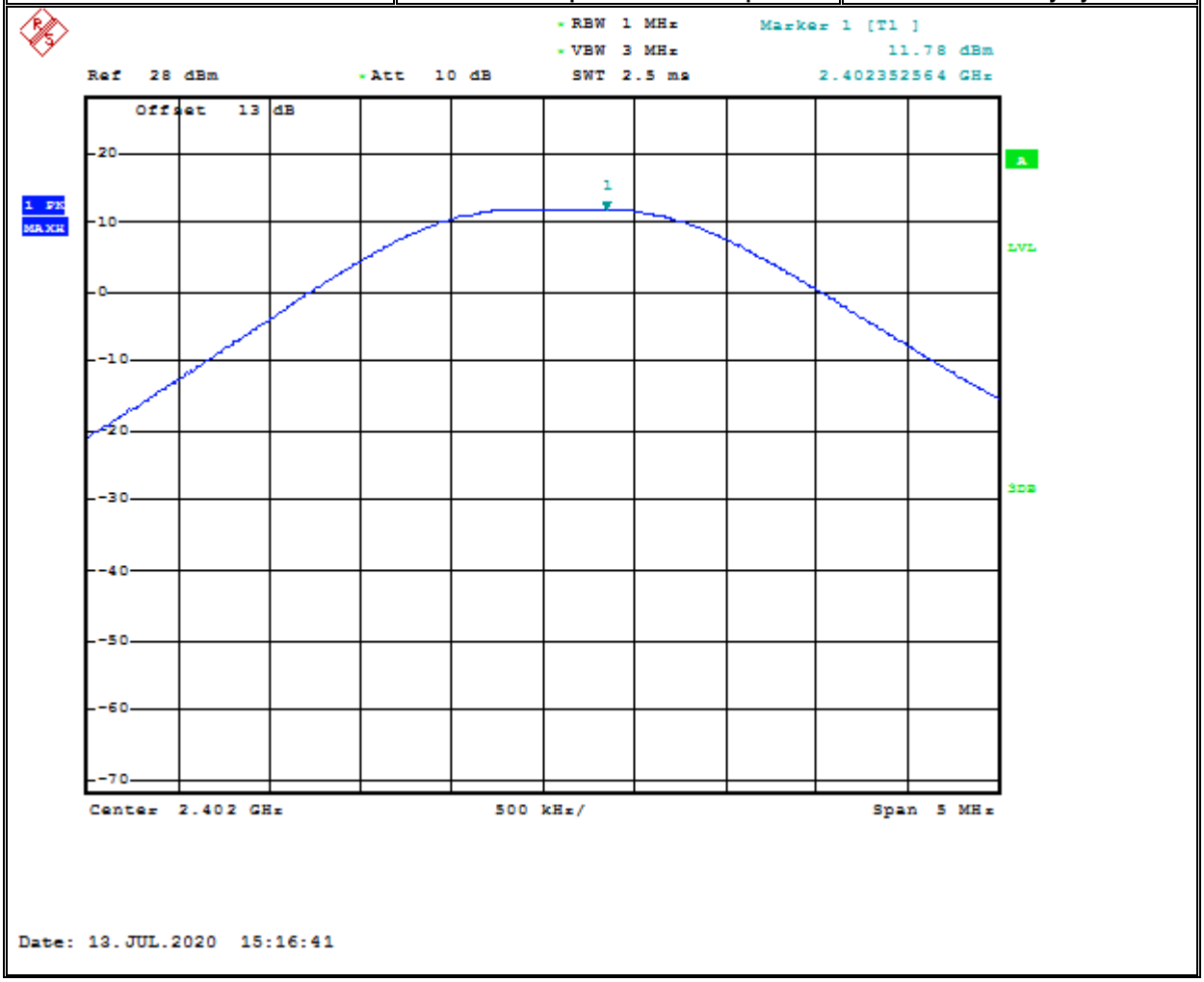
Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22.4 °C	1	BTLE fixed channel: LE 1 Mbps & LE 2 Mbps	5.0V DC	-0.78 dBi

8.1.4 Measurement result:

Plot #	EUT operating mode	Channel	Frequency (MHz)	Maximum Peak Conducted Output Power (dBm)	EIRP (dBm)	Limit (dBm)	Result
1	LE 1 Mbps	Low: 0	2402	11.78	11.00	30 (Pk) / 36 (EIRP)	Pass
2	LE 1 Mbps	Mid: 19	2440	12.00	11.22	30 (Pk) / 36 (EIRP)	Pass
3	LE 1 Mbps	High: 39	2480	11.68	10.90	30 (Pk) / 36 (EIRP)	Pass
4	LE 2 Mbps	Low: 0	2402	11.78	11.00	30 (Pk) / 36 (EIRP)	Pass
5	LE 2 Mbps	Mid: 19	2440	12.00	11.22	30 (Pk) / 36 (EIRP)	Pass
6	LE 2 Mbps	High: 39	2480	11.71	10.93	30 (Pk) / 36 (EIRP)	Pass

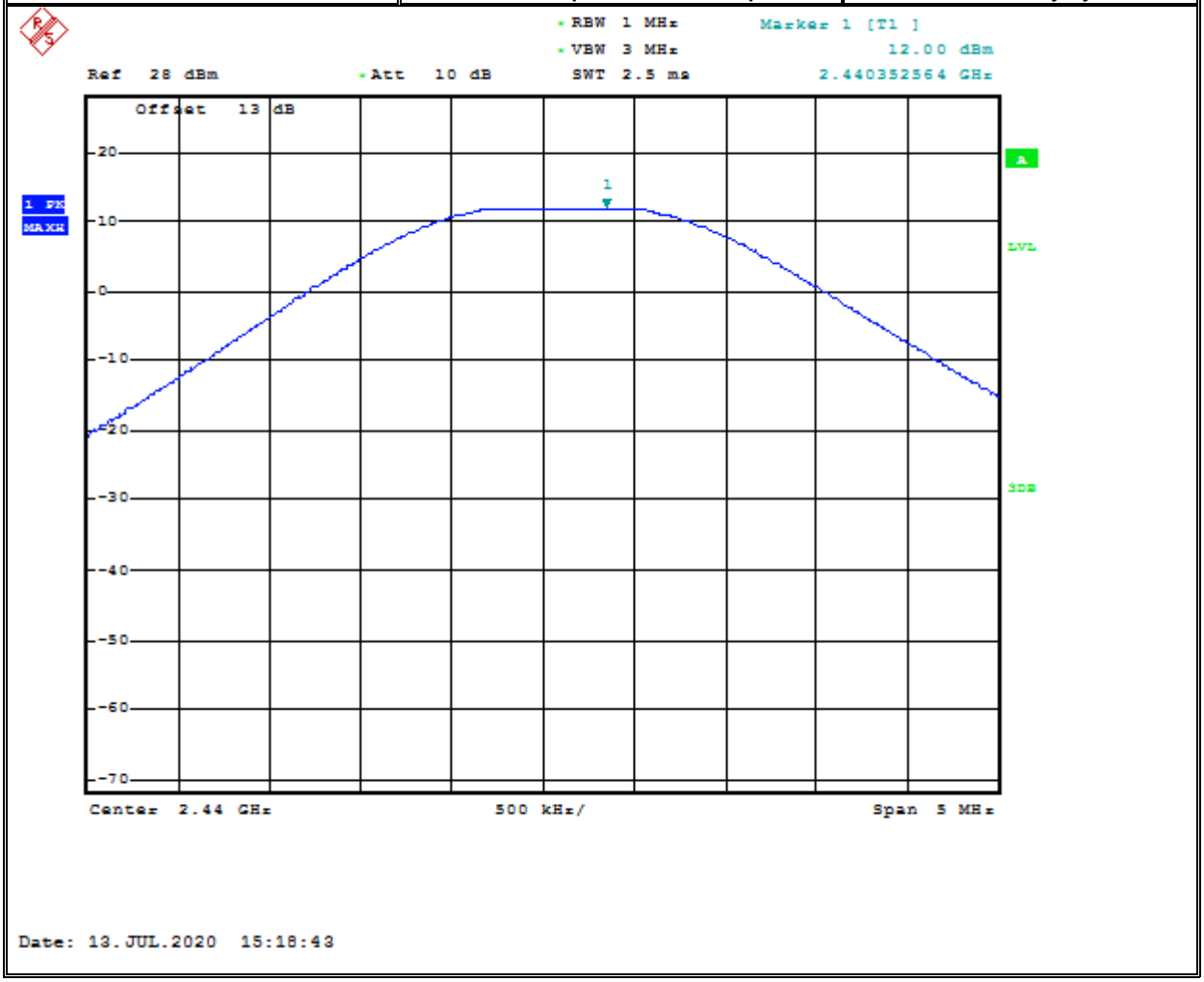
8.1.5 Measurement Plots:

Plot #1		
Low channel: 0 / 2402 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



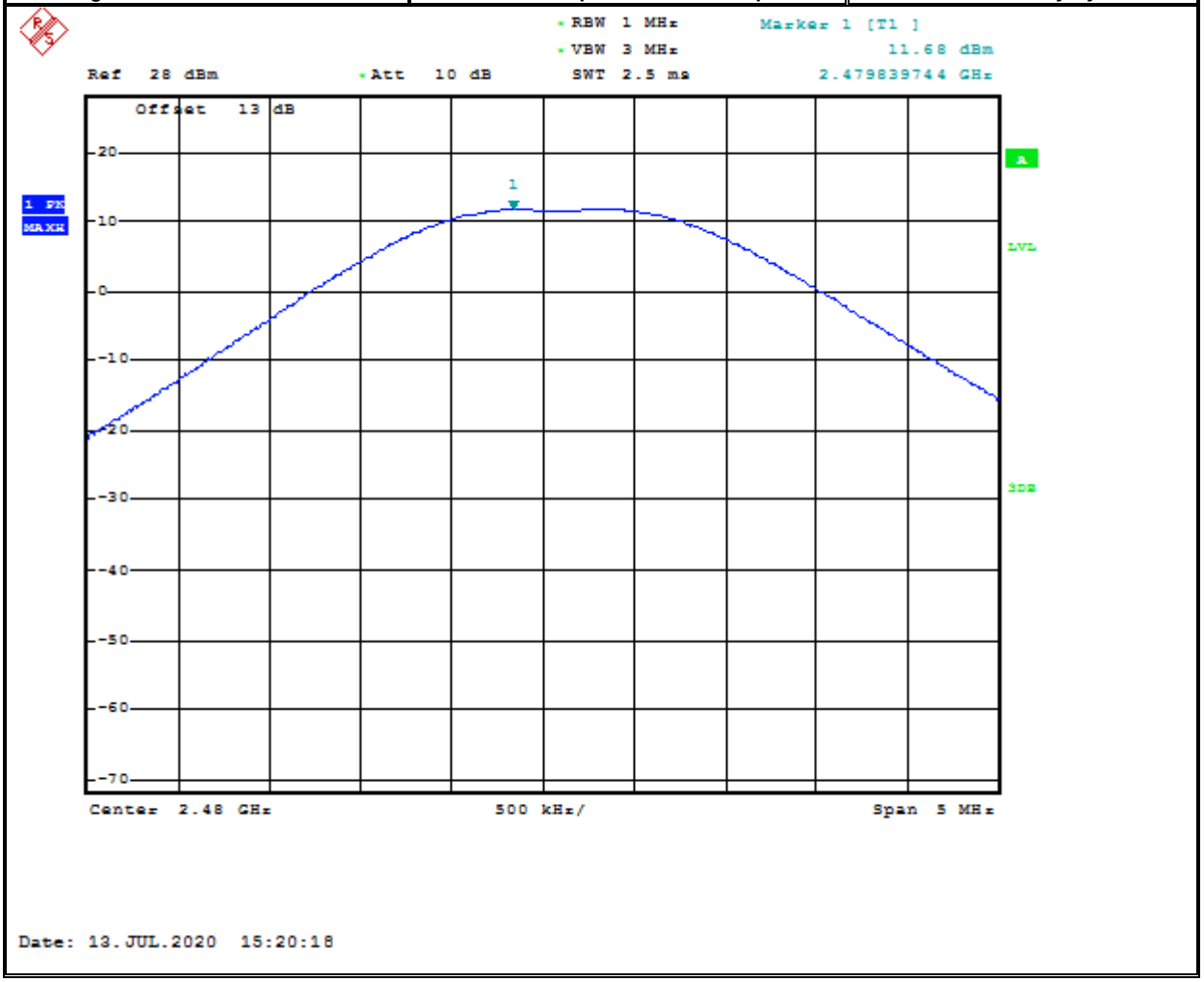
Plot #2

Mid channel: 19 / 2440 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



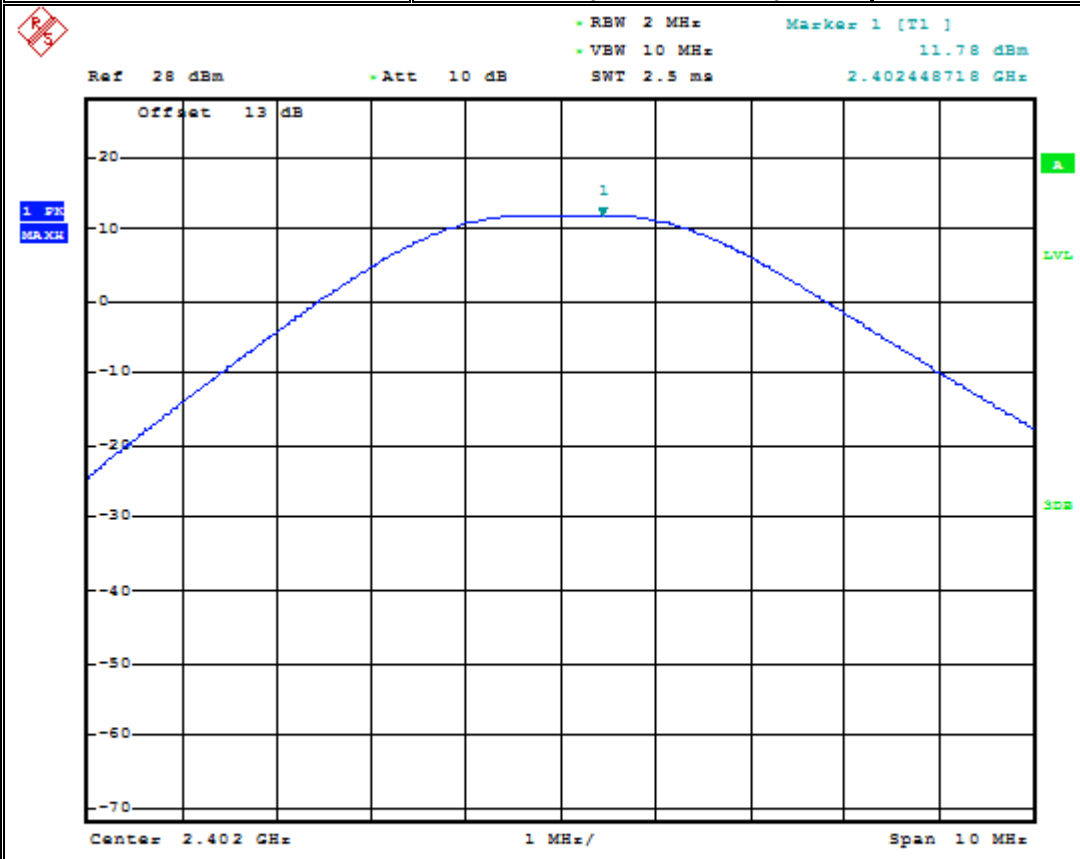
Plot #3

High channel: 39 / 2480 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



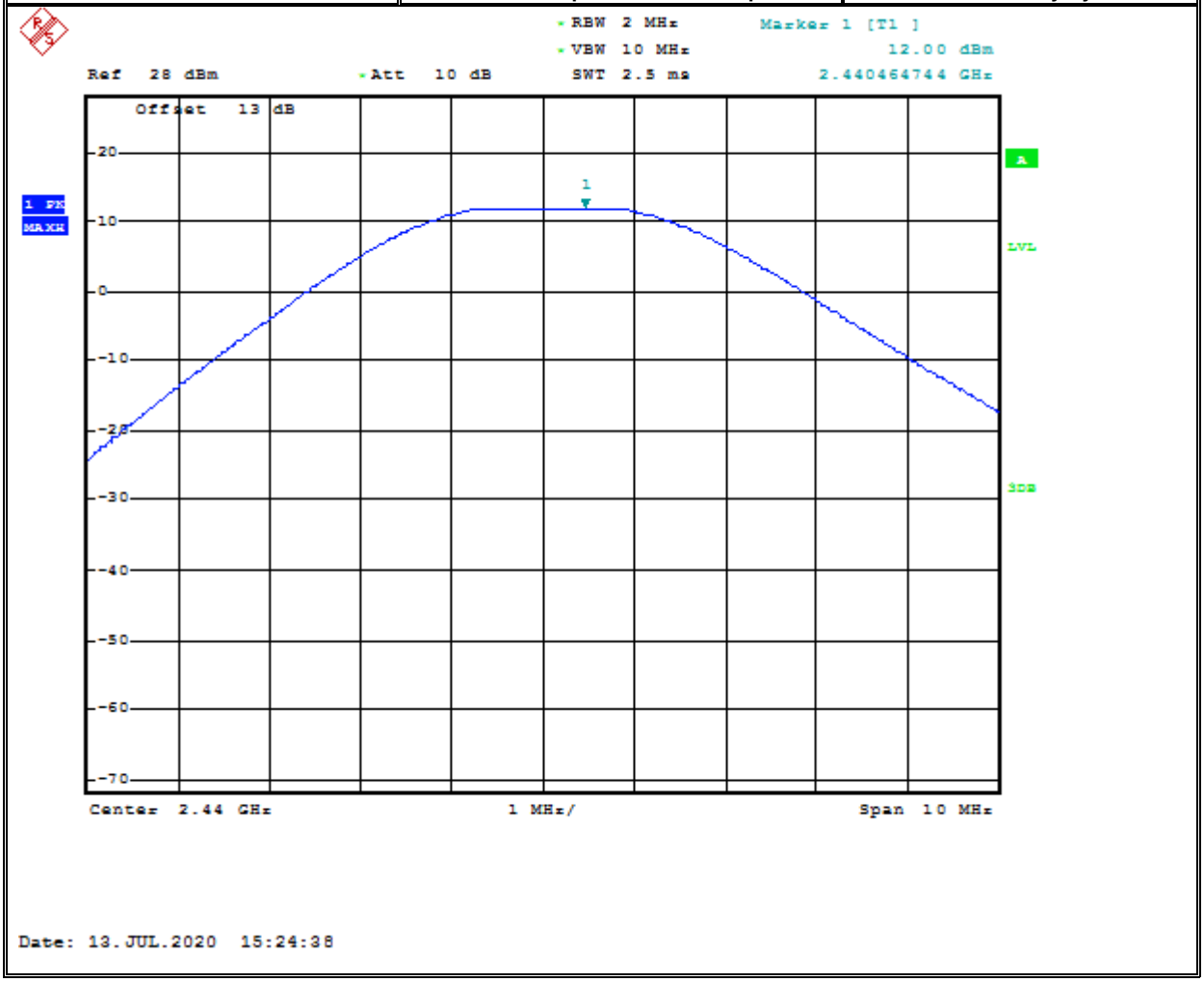
Plot #4

Low channel: 0 / 2402 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



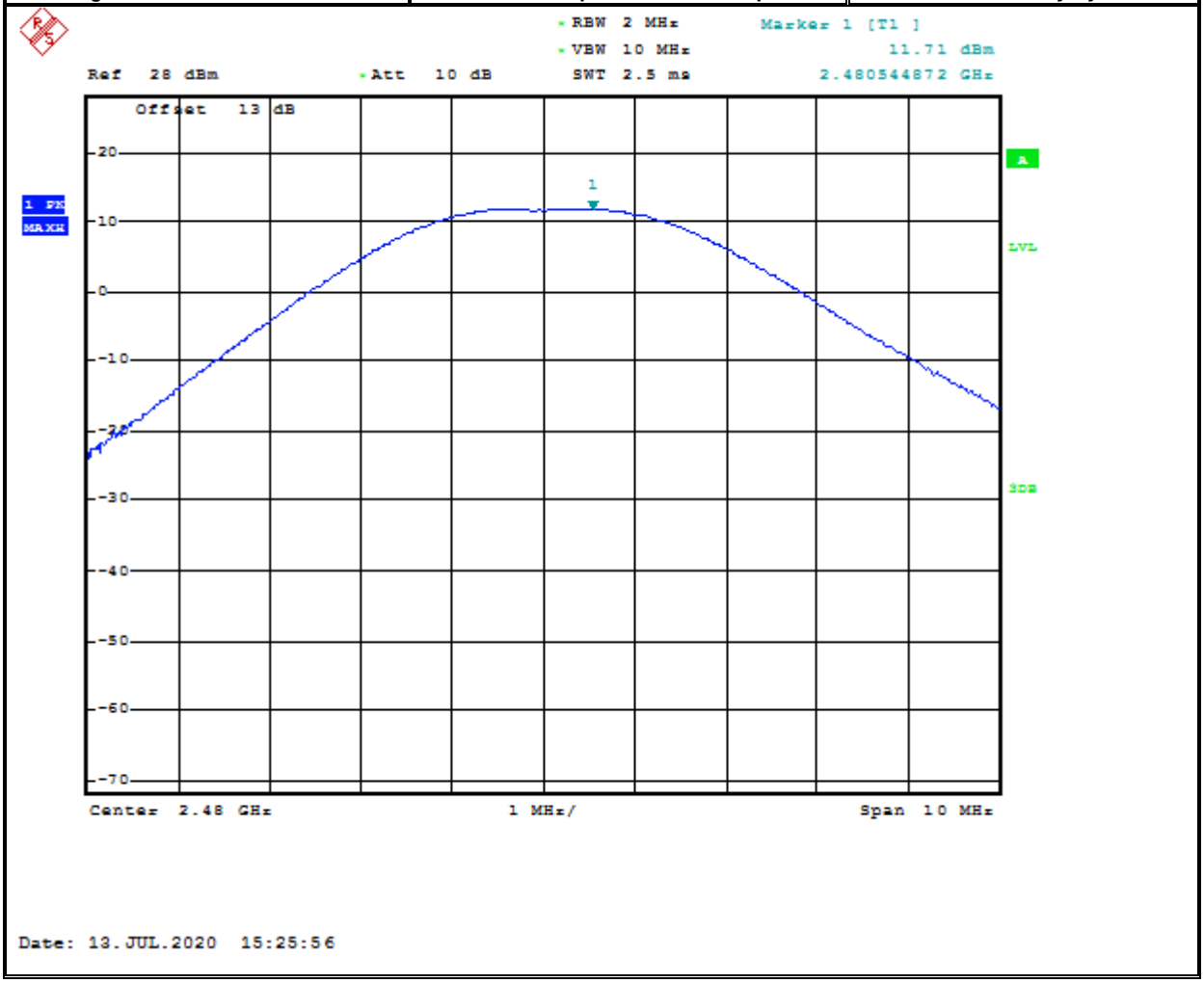
Plot #5

Mid channel: 19 / 2440 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



Plot #6

High channel: 39 / 2480 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



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)

- 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:

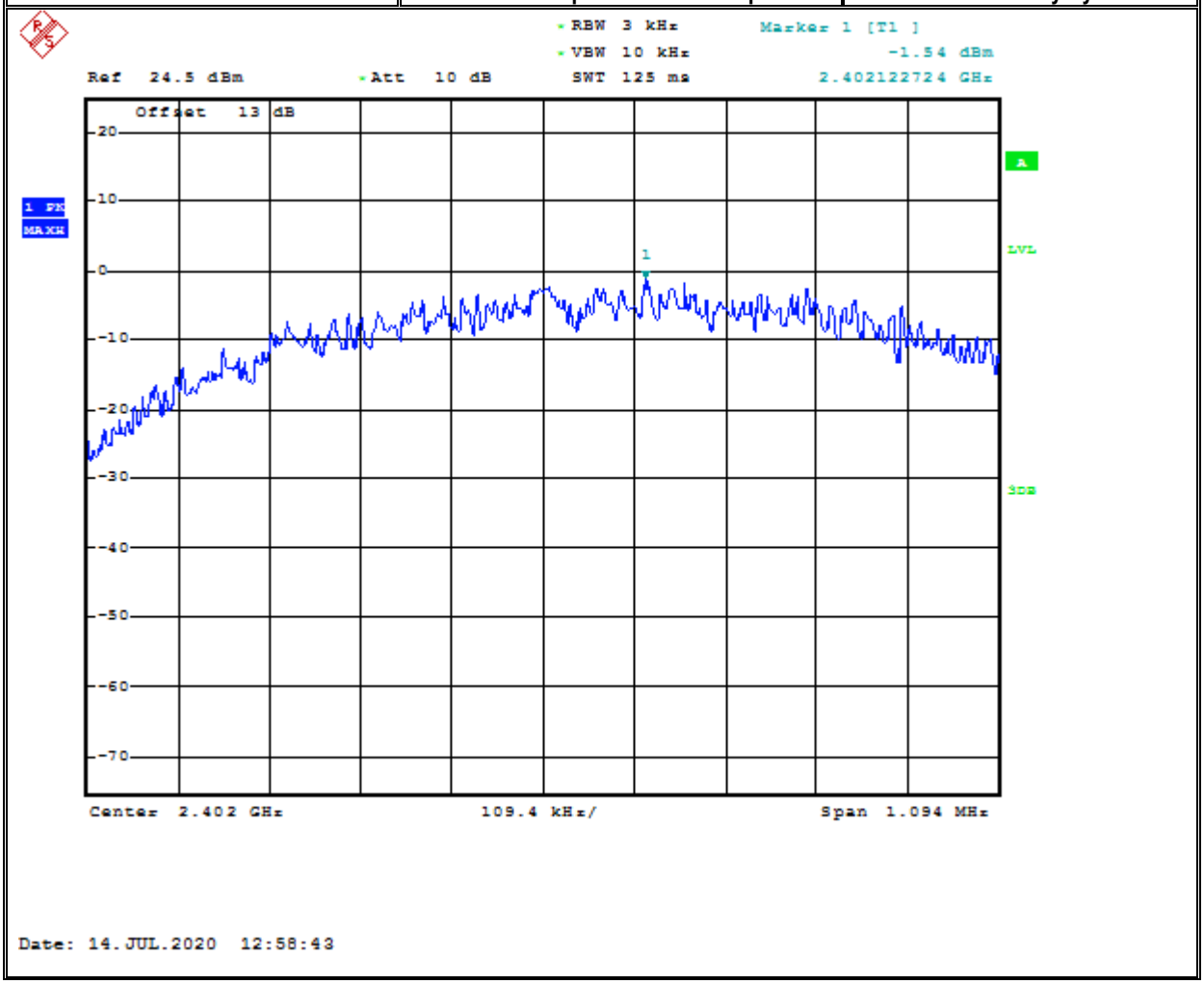
Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22.4 °C	1	BTLE fixed channel: LE 1 Mbps & LE 2 Mbps	5.0V DC	-0.78 dBi

8.2.4 Measurement result:

Plot #	EUT operating mode	Channel	Frequency (MHz)	Maximum Power Spectral Density (dBm / 3 kHz)	Limit (dBm / 3 kHz)	Result
1	LE 1 Mbps	Low: 0	2402	-1.54	8	Pass
2	LE 1 Mbps	Mid: 19	2440	-2.26	8	Pass
3	LE 1 Mbps	High: 39	2480	-2.03	8	Pass
4	LE 2 Mbps	Low: 0	2402	-3.80	8	Pass
5	LE 2 Mbps	Mid: 19	2440	-4.91	8	Pass
6	LE 2 Mbps	High: 39	2480	-5.47	8	Pass

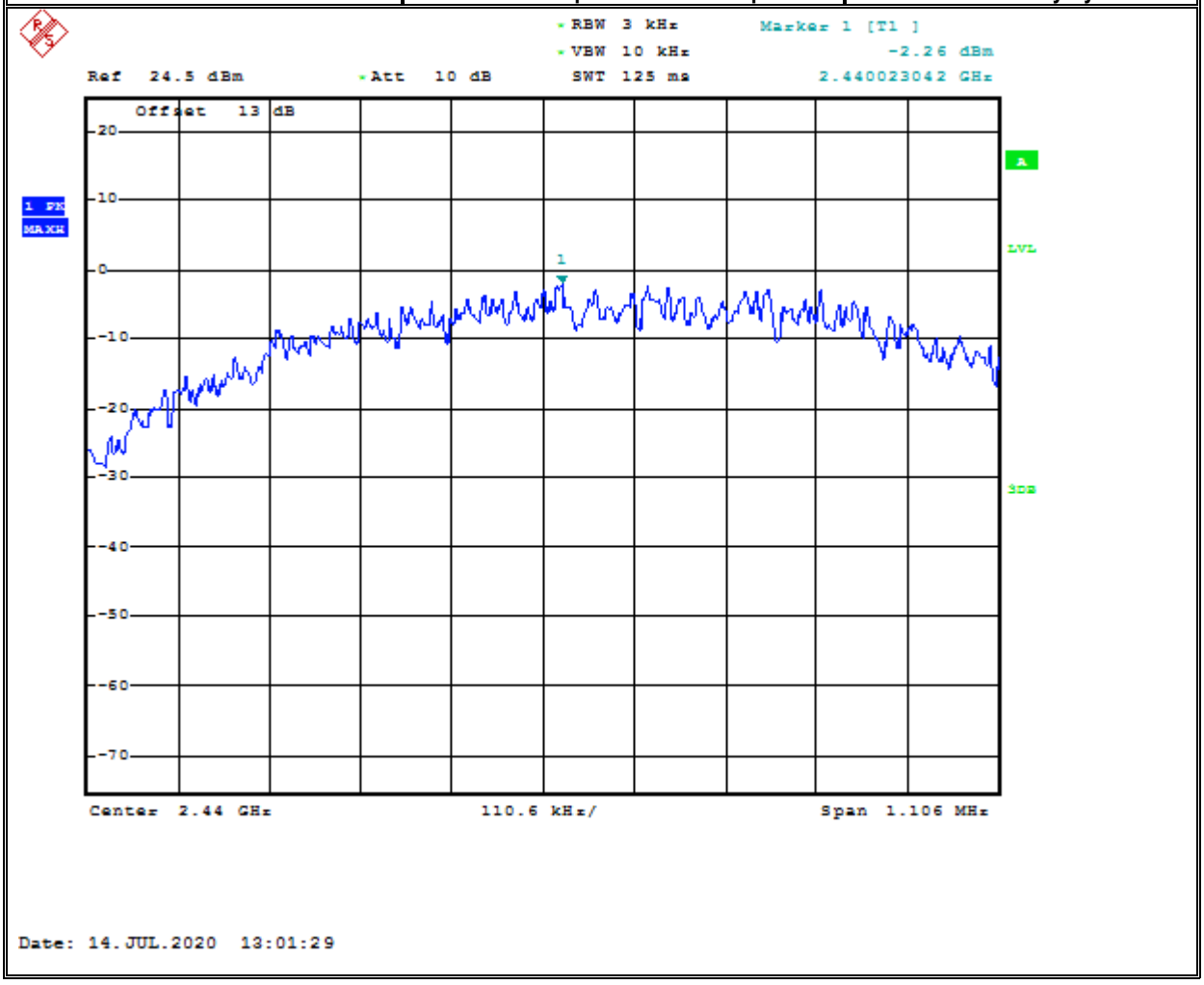
8.2.5 Measurement Plots:

Plot #1		
Low channel: 0 / 2402 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



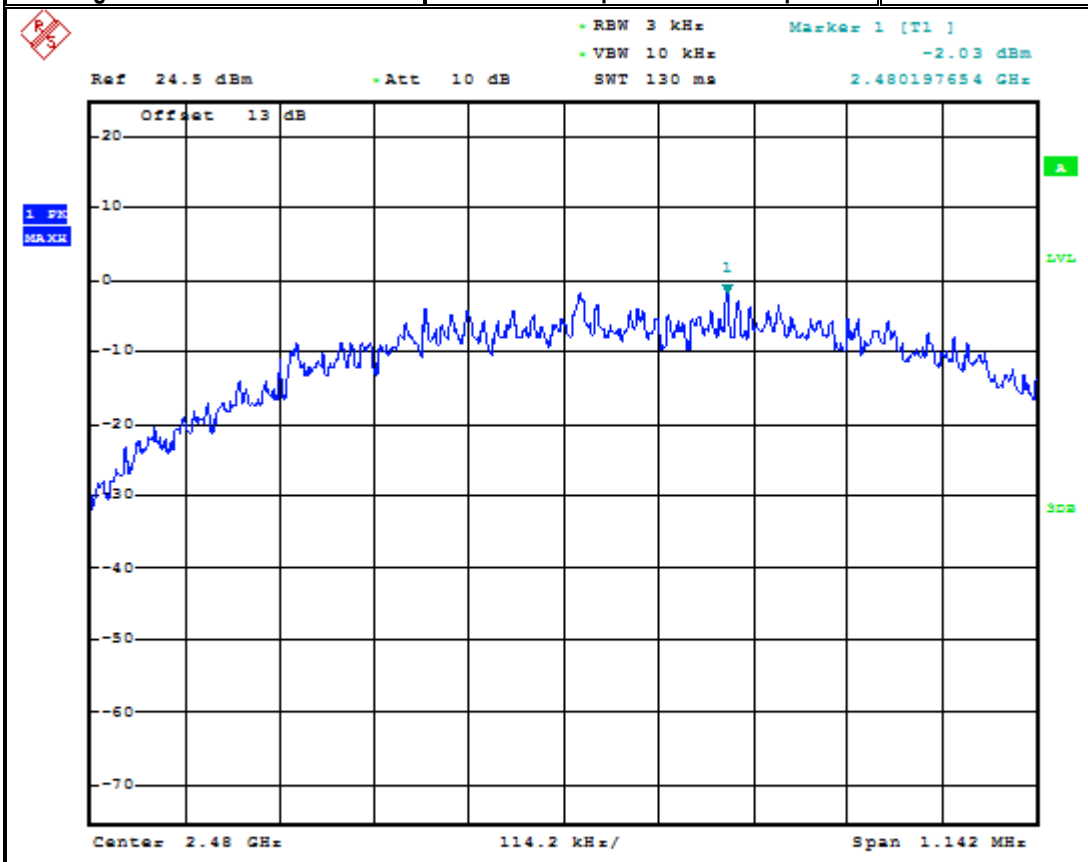
Plot #2

Mid channel: 19 / 2440 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



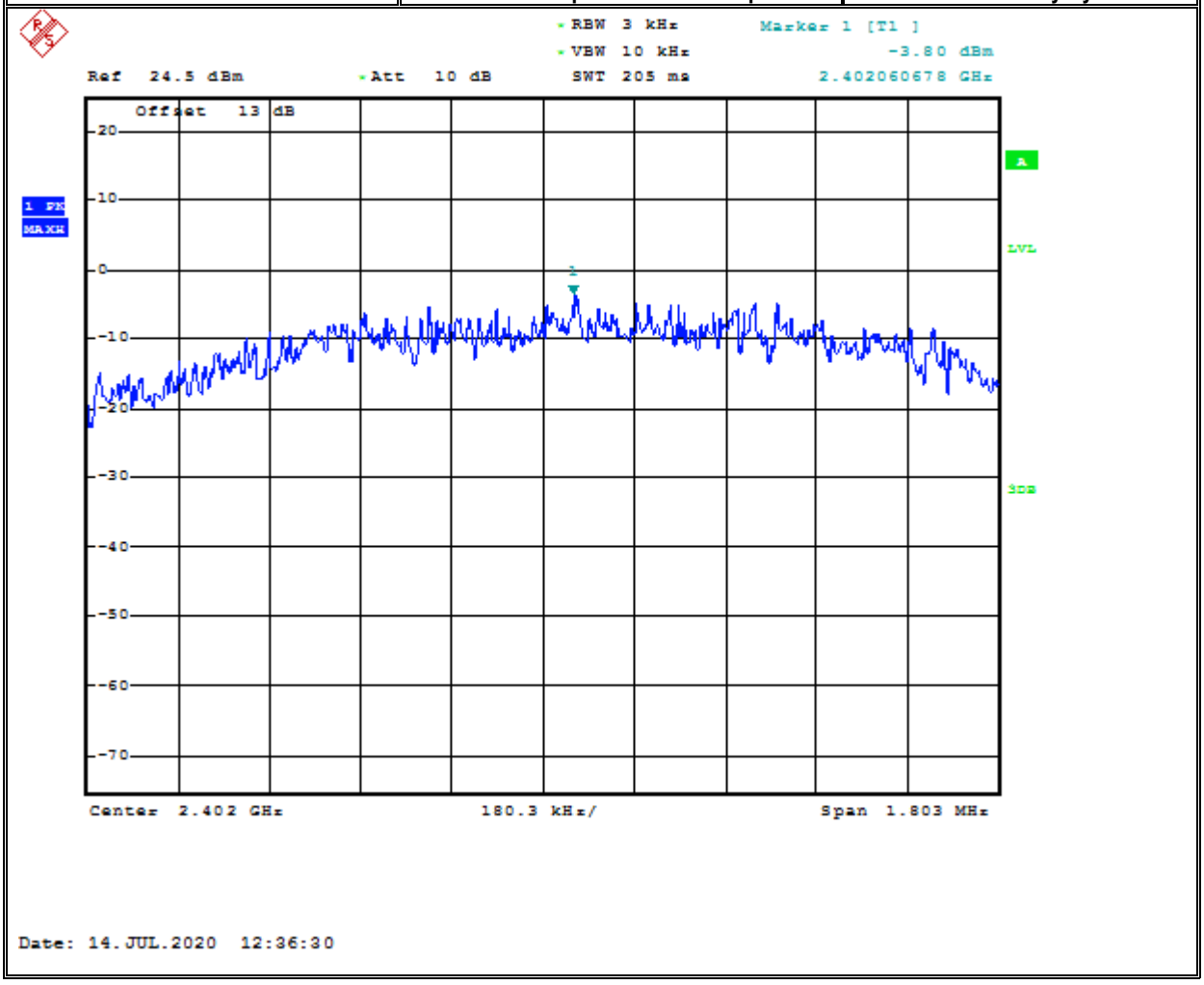
Plot #3

High channel: 39 / 2480 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



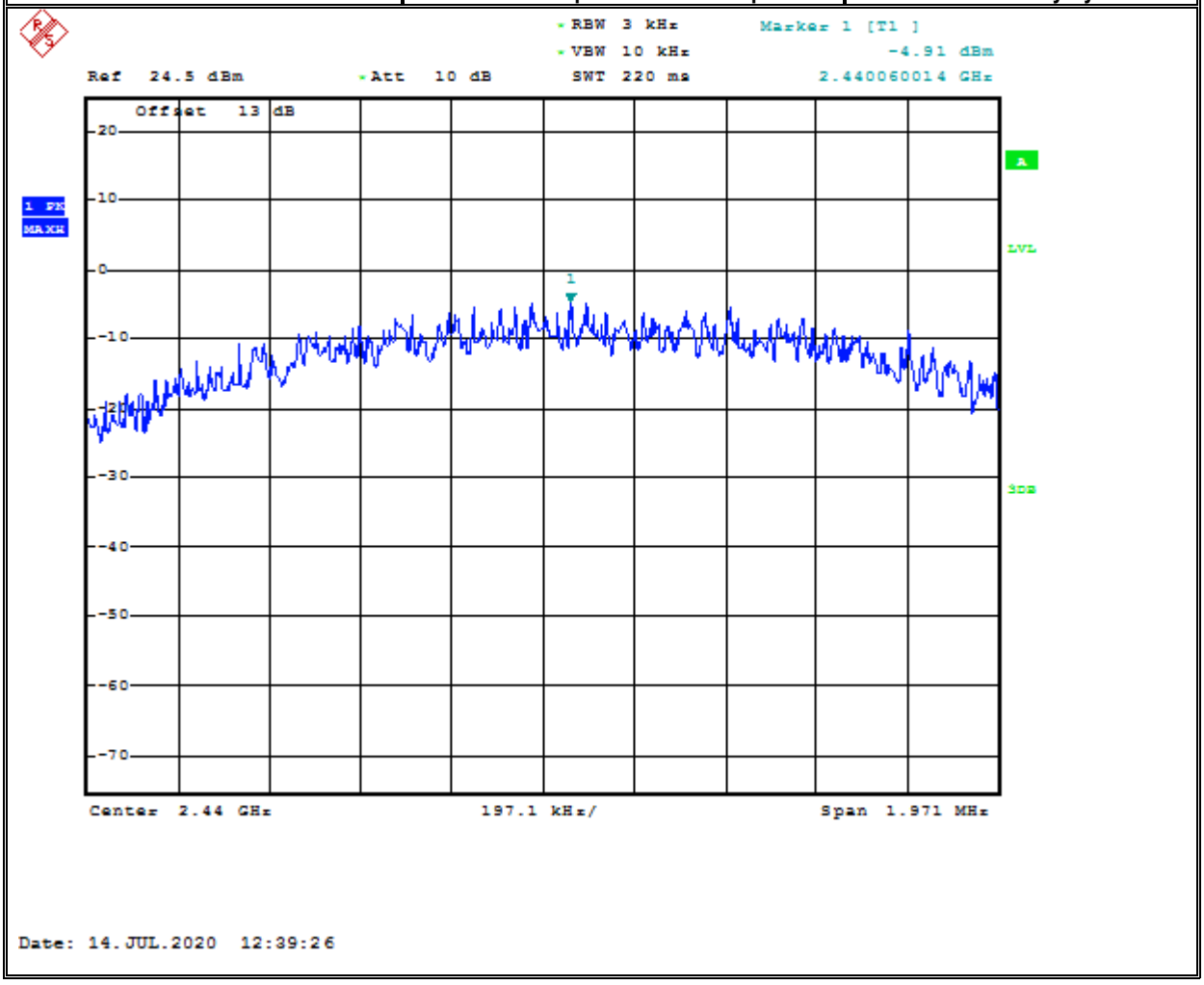
Plot #4

Low channel: 0 / 2402 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



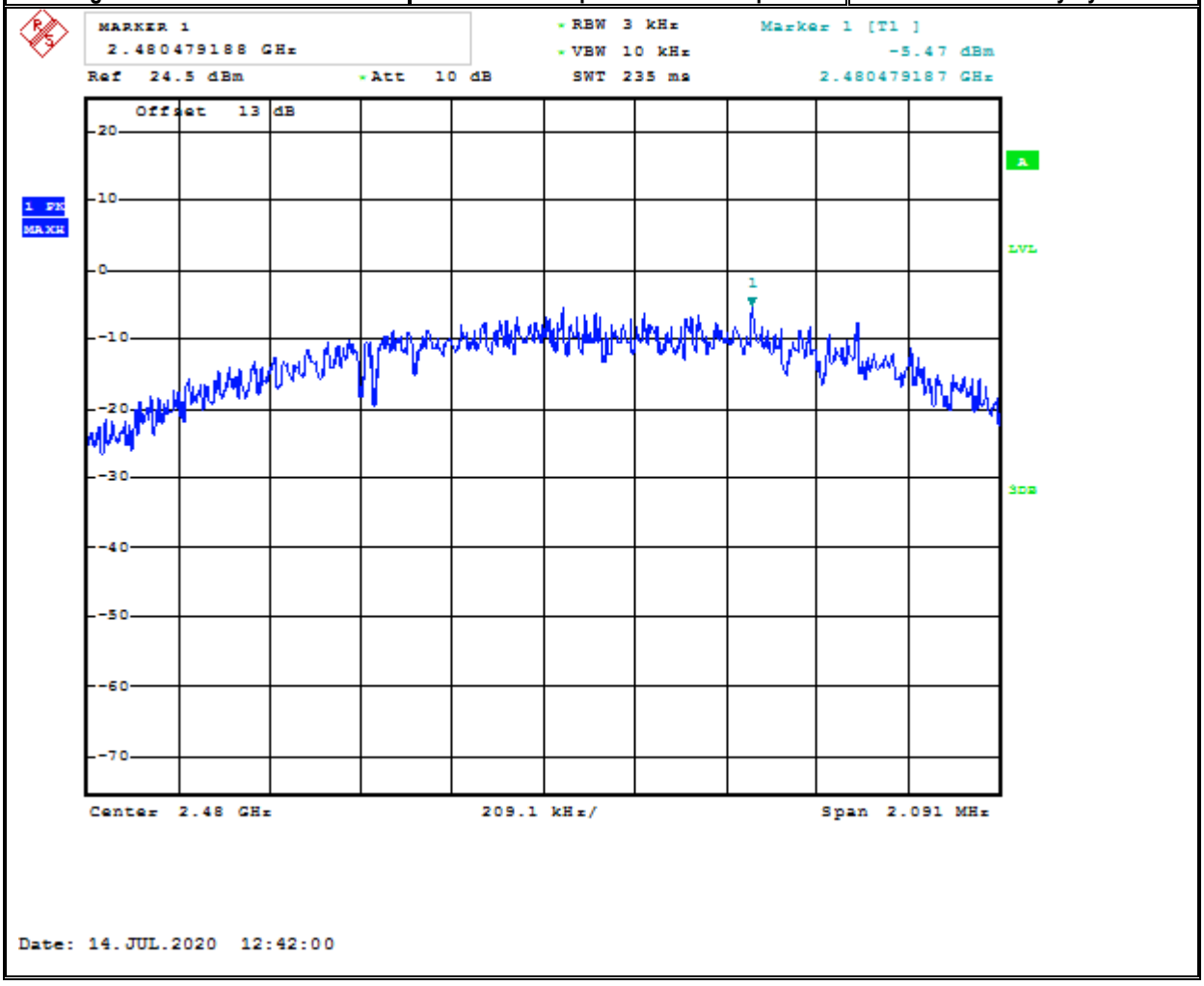
Plot #5

Mid channel: 19 / 2440 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



Plot #6

High channel: 39 / 2480 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



8.3 Duty cycle

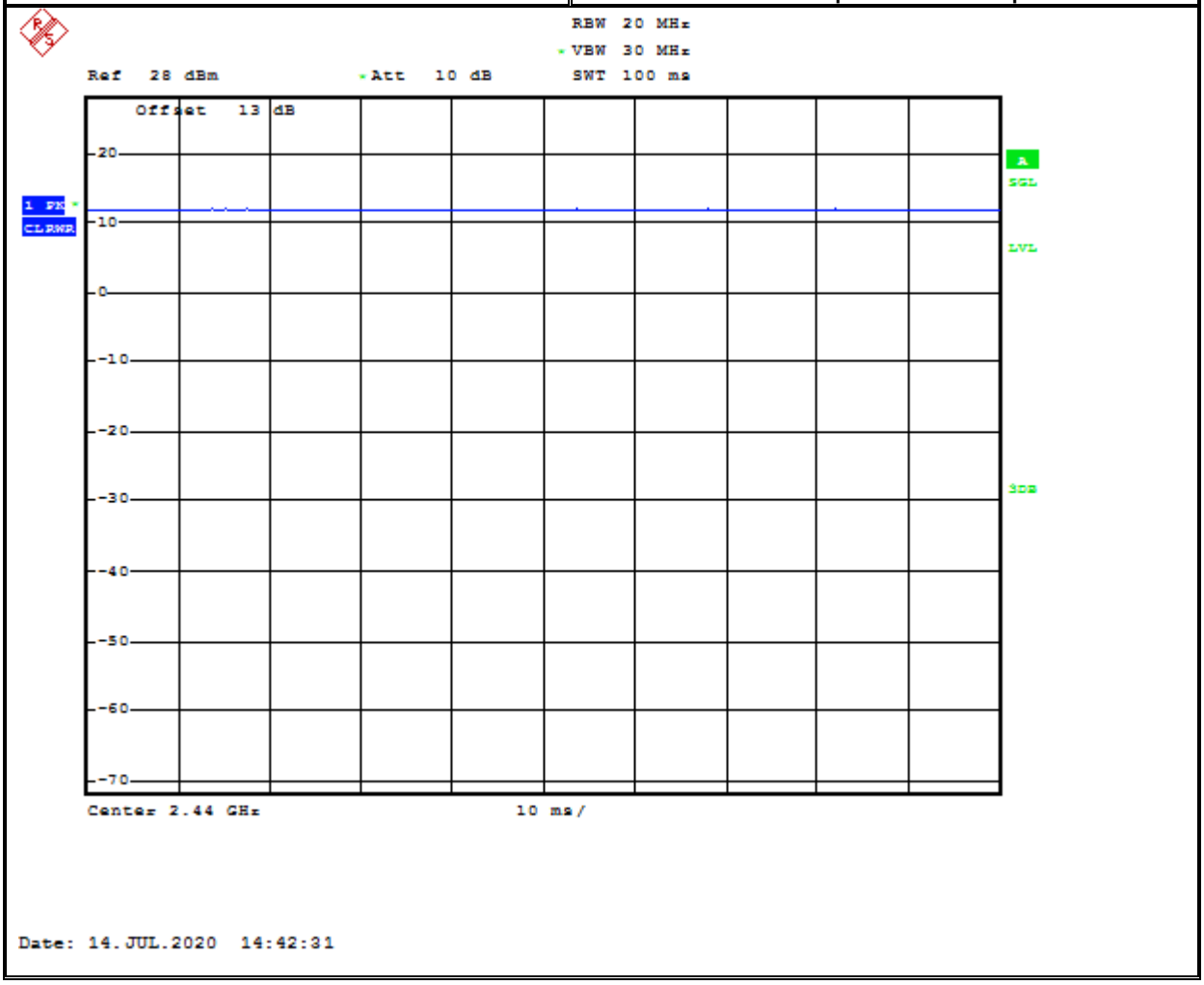
8.3.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02

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

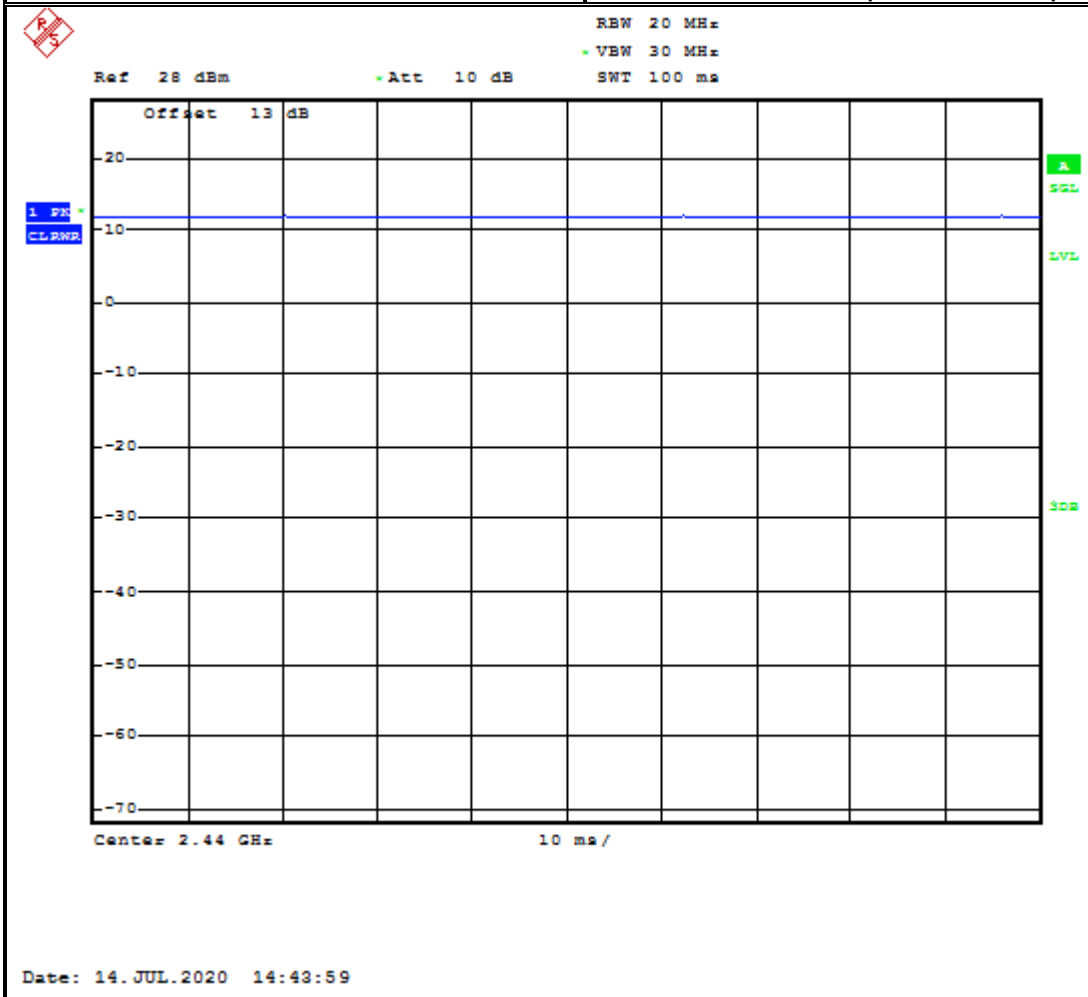
8.3.2 Measurement result

Duty cycle measurement	
Mid channel: 19 / 2440 MHz	Mode of Operation: LE 1 Mbps



- Test Mode Duty Cycle of 100%

Duty cycle measurement	
Mid channel: 19 / 2440 MHz	Mode of Operation: LE 2 Mbps



- Test Mode Duty Cycle of 100%

8.4 Band Edge Compliance

8.4.1 Measurement according to FCC 558074 D01 15.247 Meas Guidance v05r02

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

8.4.2 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)).

Spectrum Analyzer settings for restricted band:

- Peak measurements are made using a peak detector and RBW=1 MHz

8.4.3 Limits restricted band §15.247/15.209/15.205

- *PEAK LIMIT= 74 dBµV/m @3m =-21.23 dBm
- *AVG. LIMIT= 54 dBµV/m @3m =-41.23 dBm
- Start frequency & stop frequency according to frequency range specified in the restricted band table in FCC section 15.205
- Measurements with a peak detector were used to show compliance to average limits, thus showing compliance to both peak and average limits.

(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			

8.4.4 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input	Antenna Gain
22.4 °C	1	BTLE fixed channel: LE 1 Mbps & LE 2 Mbps	5.0V DC	-0.78 dBi

8.4.5 Measurement result:

Plot #	EUT operating mode	Band Edge	Band Edge Delta (dBc)	Limit (dBc)	Result
1	LE 1 Mbps	Lower, Non-restricted	-54.98	-20	Pass
2	LE 2 Mbps	Lower, Non-restricted	-33.87	-20	Pass

Plot #	EUT operating mode	Band Edge	Measured Peak Value (dBm)	Corrected by Duty Cycle (dB) Note	Corrected by Antenna Gain (dBm)	Limit (dBm)	Result
3	LE 1 Mbps	Lower Restricted Peak	-42.81	N/A	-43.59	-21.23 Peak	Pass
4	LE 1 Mbps	Lower Restricted AVG	-51.24	0	-52.02	-41.23 AVG	Pass
5	LE 1 Mbps	Upper Restricted Peak	-40.18	N/A	-40.96	-21.23 Peak	Pass
6	LE 1 Mbps	Upper Restricted AVG	-49.00	0	-49.78	-41.23 AVG	Pass
7	LE 2 Mbps	Lower Restricted Peak	-42.54	N/A	-43.32	-21.23 Peak	Pass
8	LE 2 Mbps	Lower Restricted AVG	-52.11	0	-52.89	-41.23 AVG	Pass
9	LE 2 Mbps	Upper Restricted Peak	-27.64	N/A	-28.42	-21.23 Peak	Pass
10	LE 2 Mbps	Upper Restricted AVG	-43.98	0	-44.76	-41.23 AVG	Pass

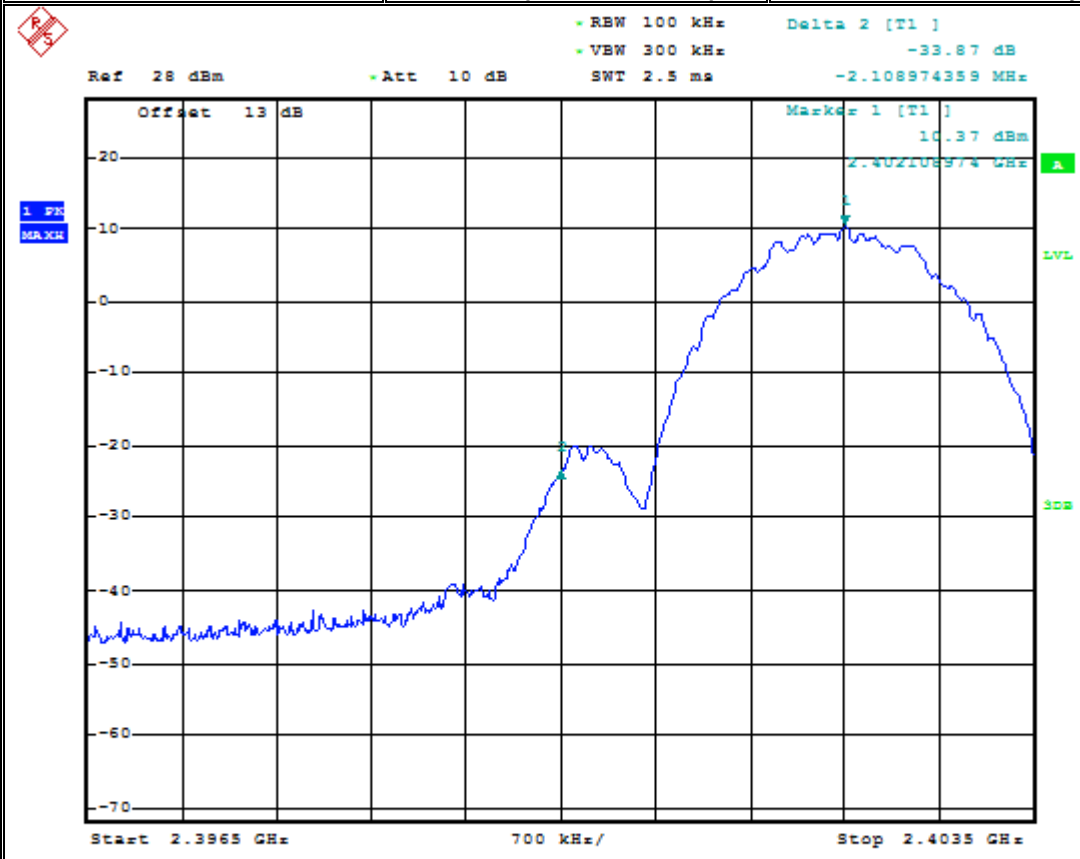
Note:
LE 1 Mbps → EUT operating at Test Mode duty cycle of 100%
LE 2 Mbps → EUT operating at Test Mode duty cycle of 100%

8.4.6 Measurement Plots:

Plot #1		
Low channel: 0 / 2402 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle

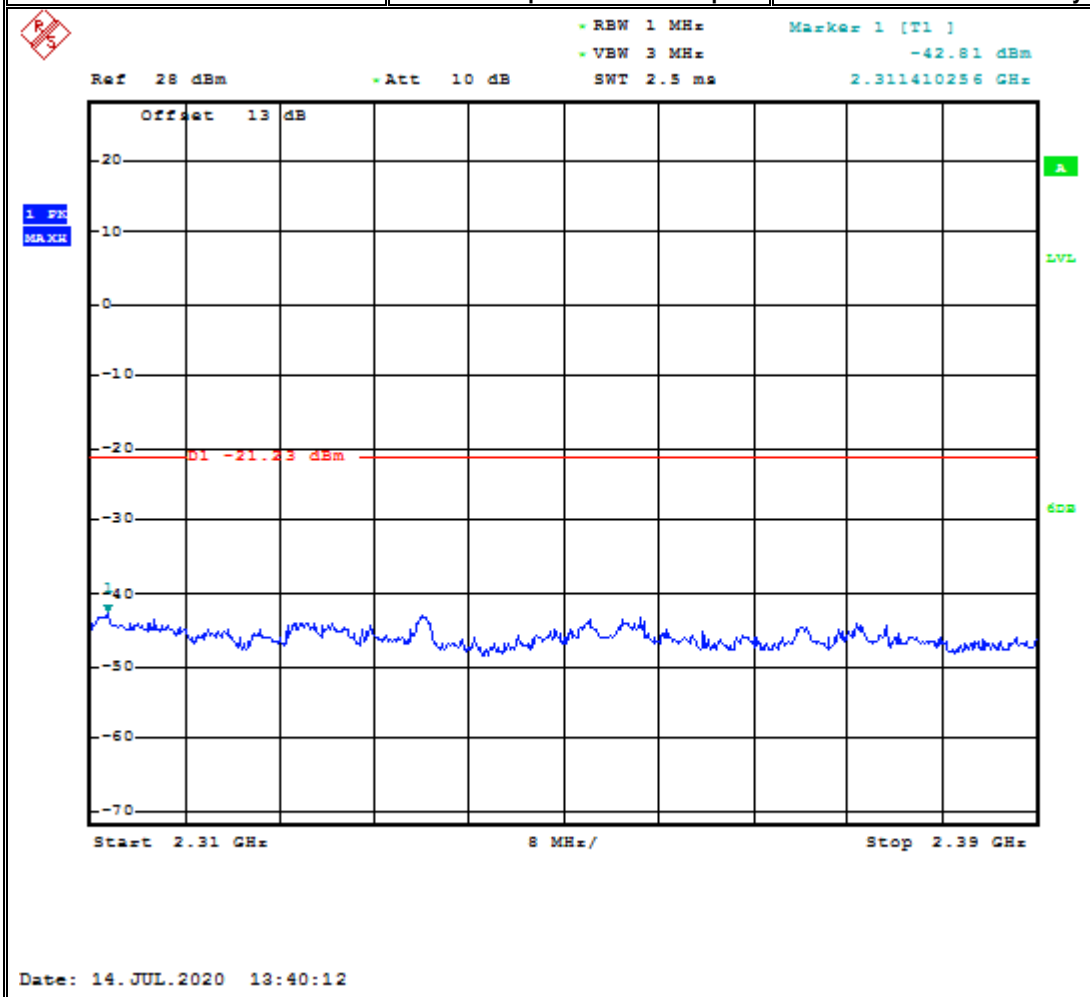
Plot #2

Low channel: 0 / 2402 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



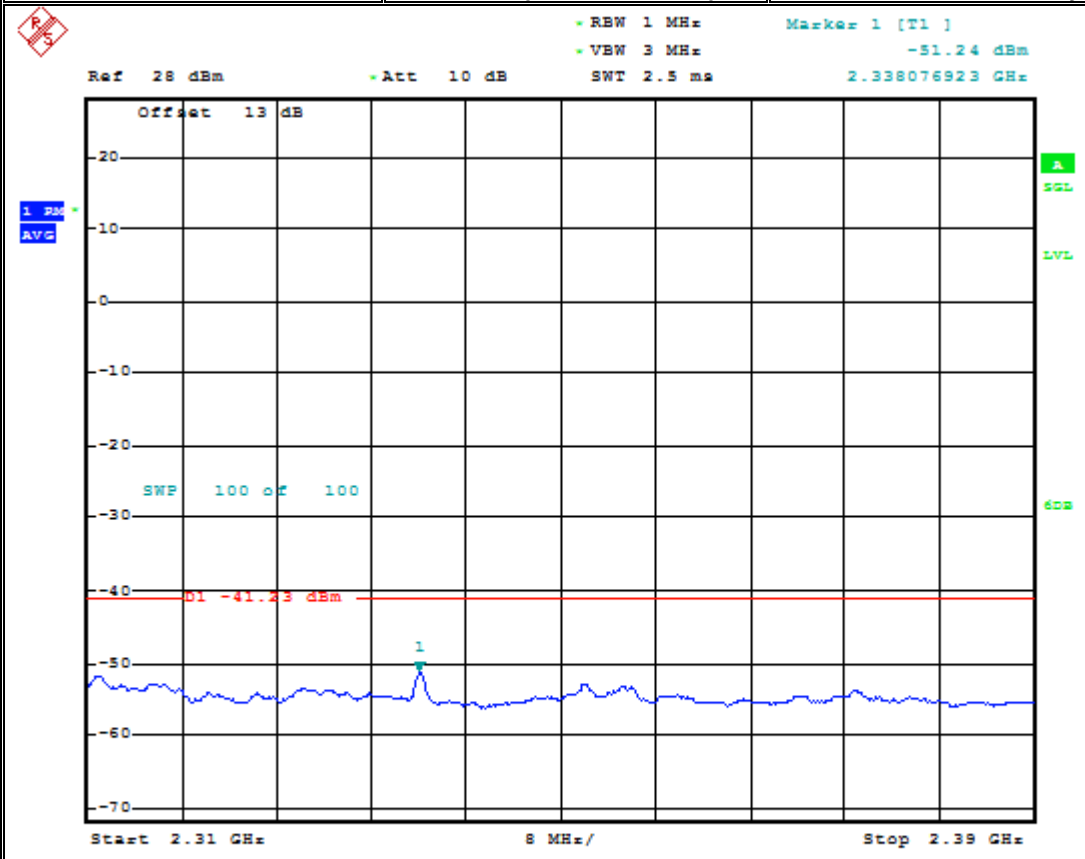
Plot #3

Low channel: 0 / 2402 MHz Peak	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



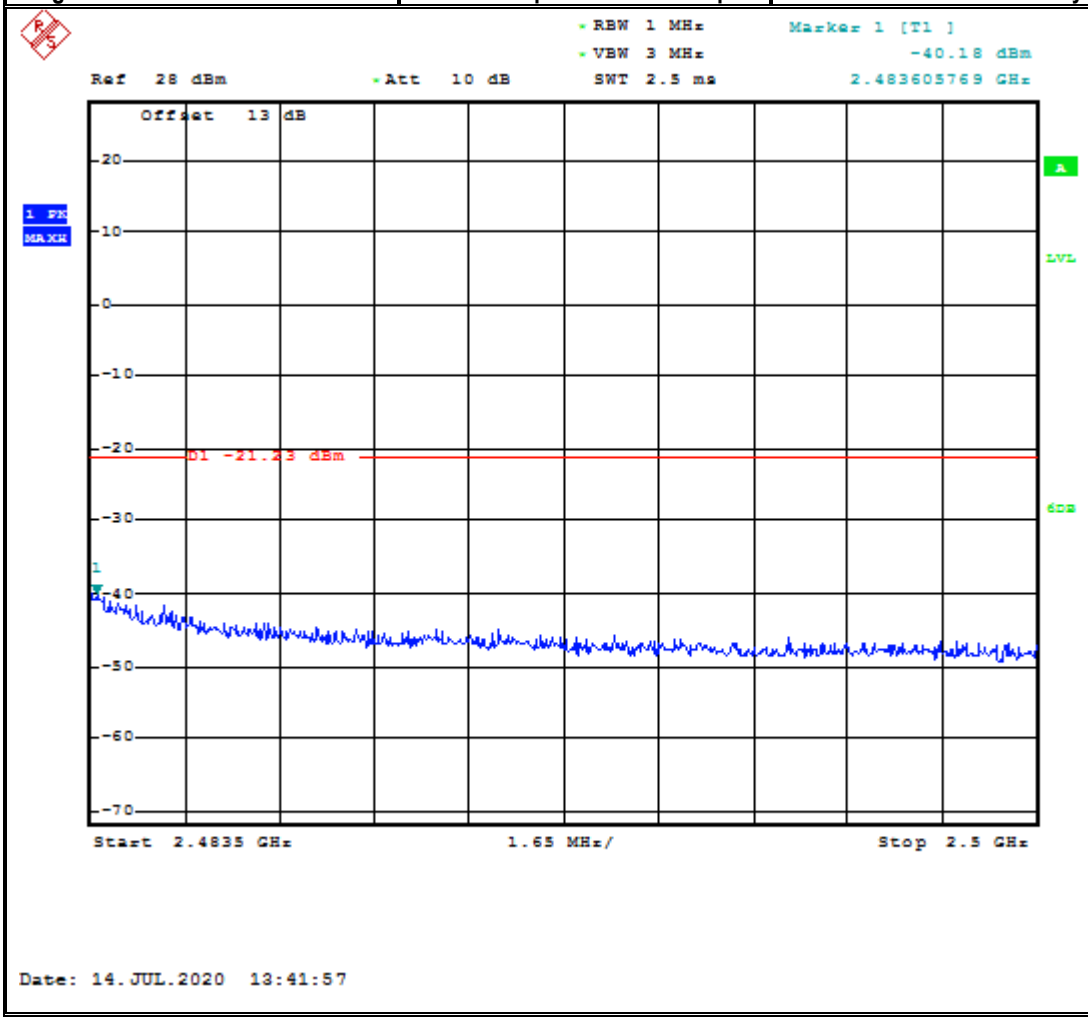
Plot #4

Low channel: 0 / 2402 MHz AVG	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



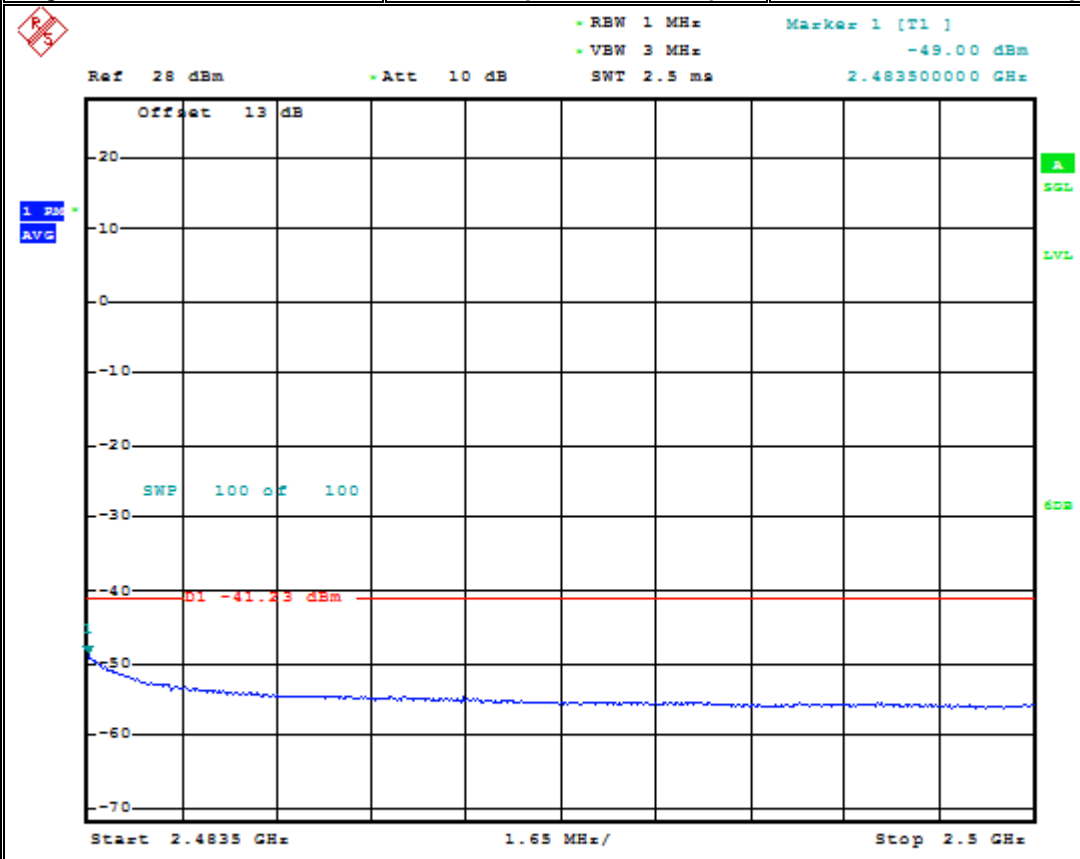
Plot #5

High channel: 39 / 2480 MHz Peak	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



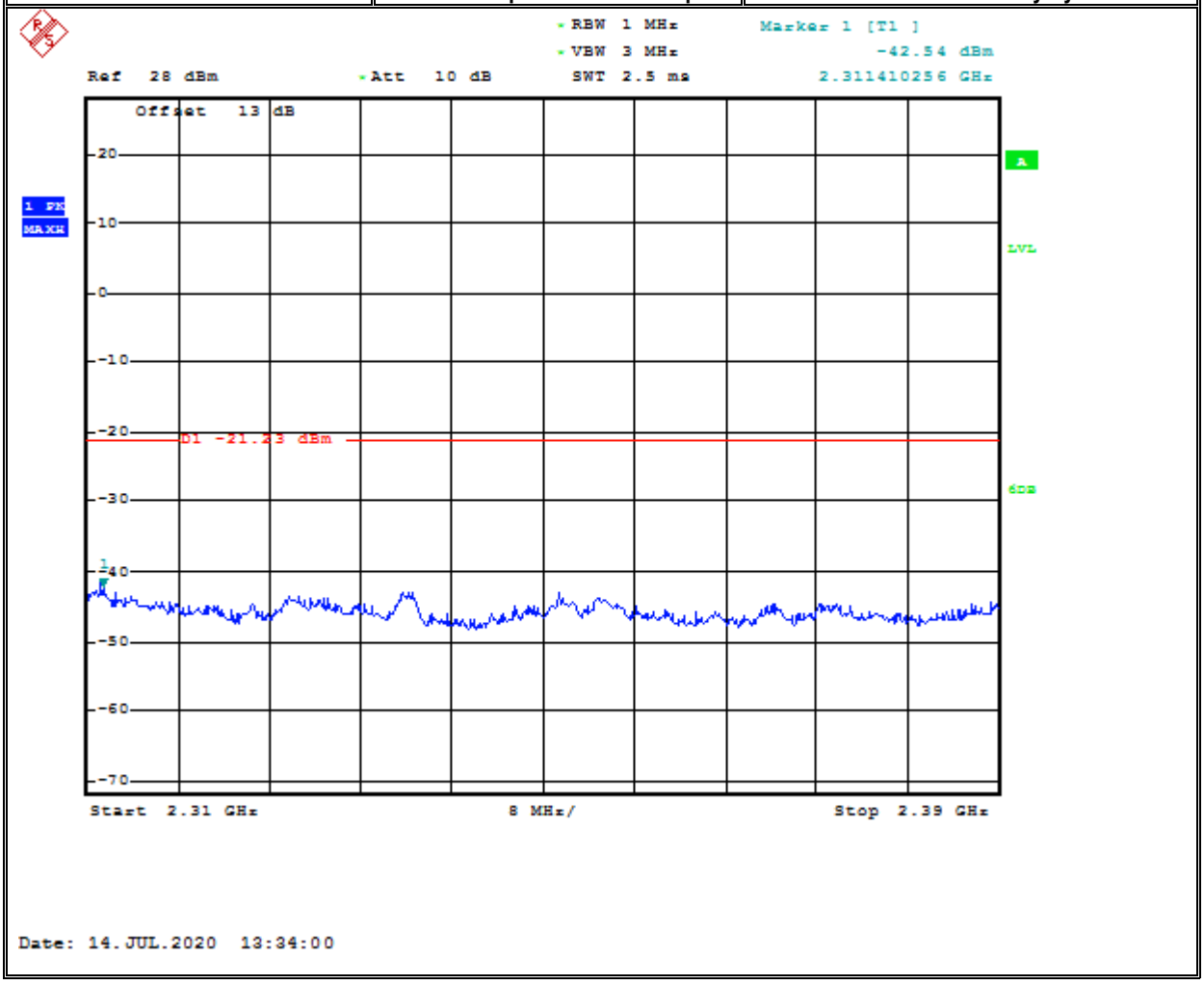
Plot #6

High channel: 39 / 2480 MHz AVG	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



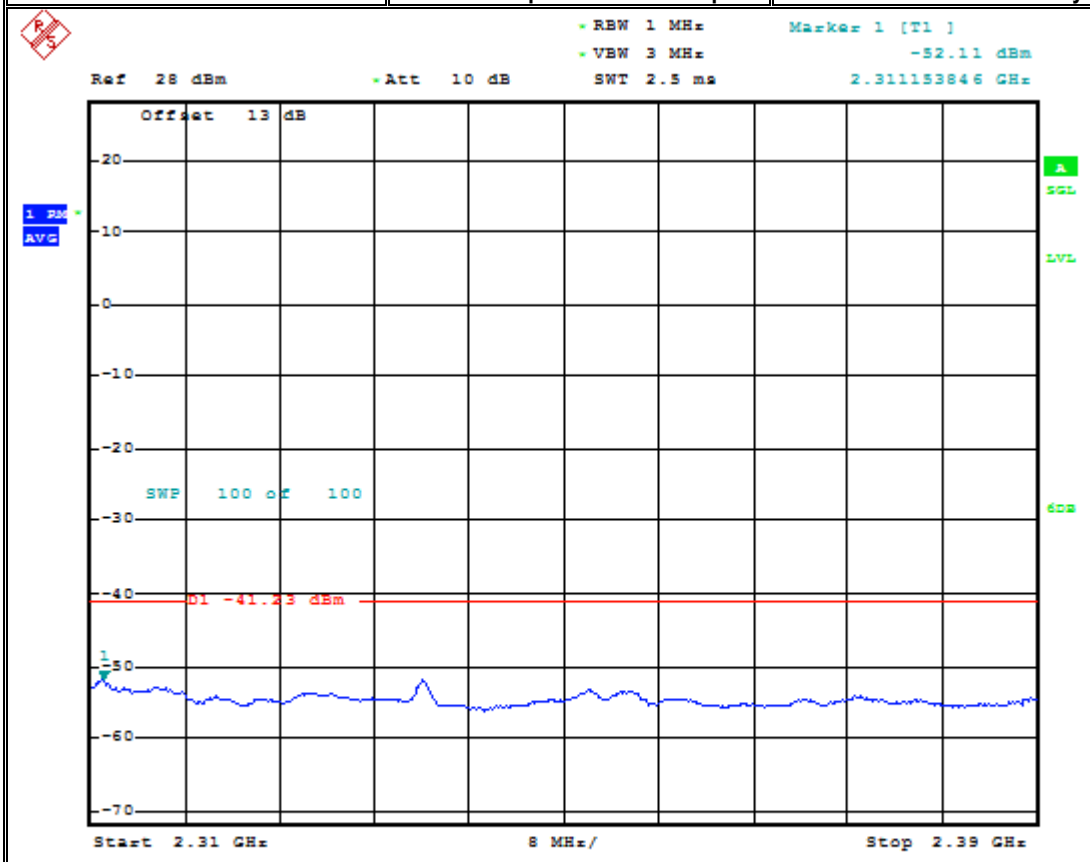
Plot #7

Low channel: 0 / 2402 MHz Peak	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



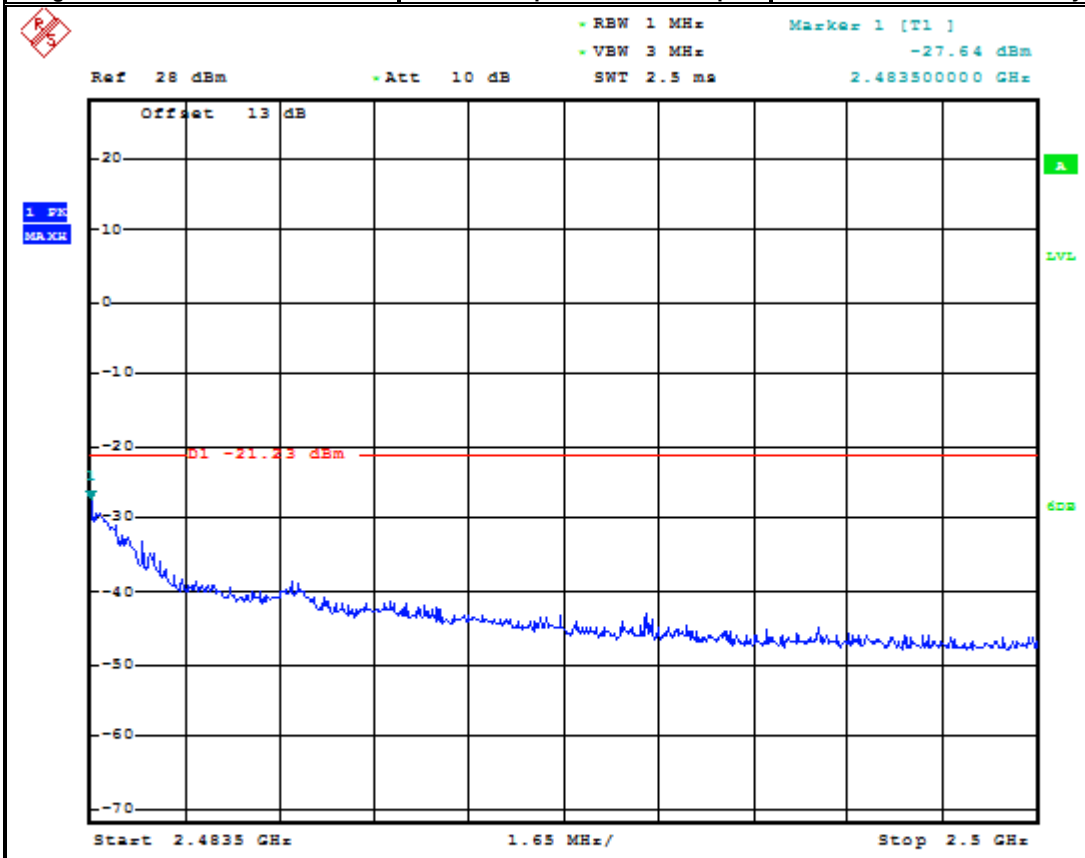
Plot #8

Low channel: 0 / 2402 MHz AVG	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



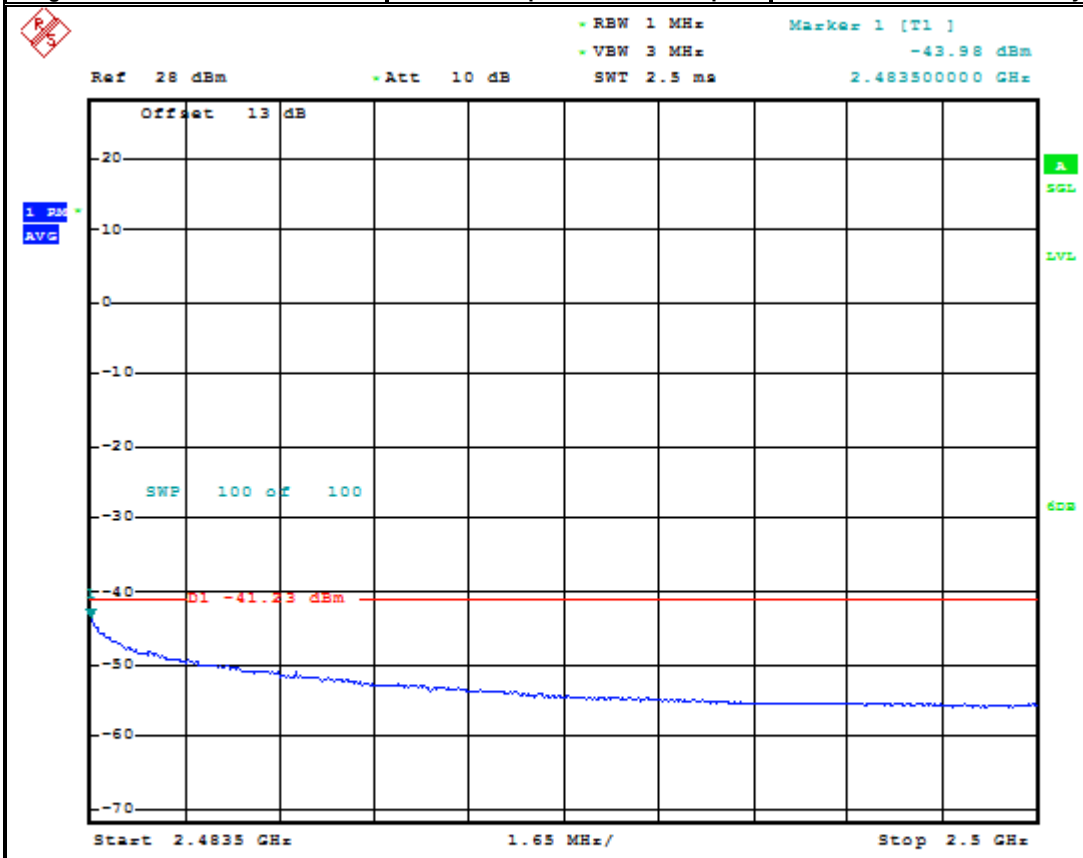
Plot #9

High channel: 39 / 2480 MHz Peak	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



Plot #10

High channel: 39 / 2480 MHz AVG	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



8.5 Emission Bandwidth 6dB and 99% Occupied Bandwidth

8.5.1 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.

8.5.2 Limits:

FCC §15.247(a)(2)

- 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.

8.5.3 Test conditions and setup:

Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22.4 °C	1	BTLE fixed channel: LE 1 Mbps & LE 2 Mbps	5.0V DC

8.5.4 Measurement result:

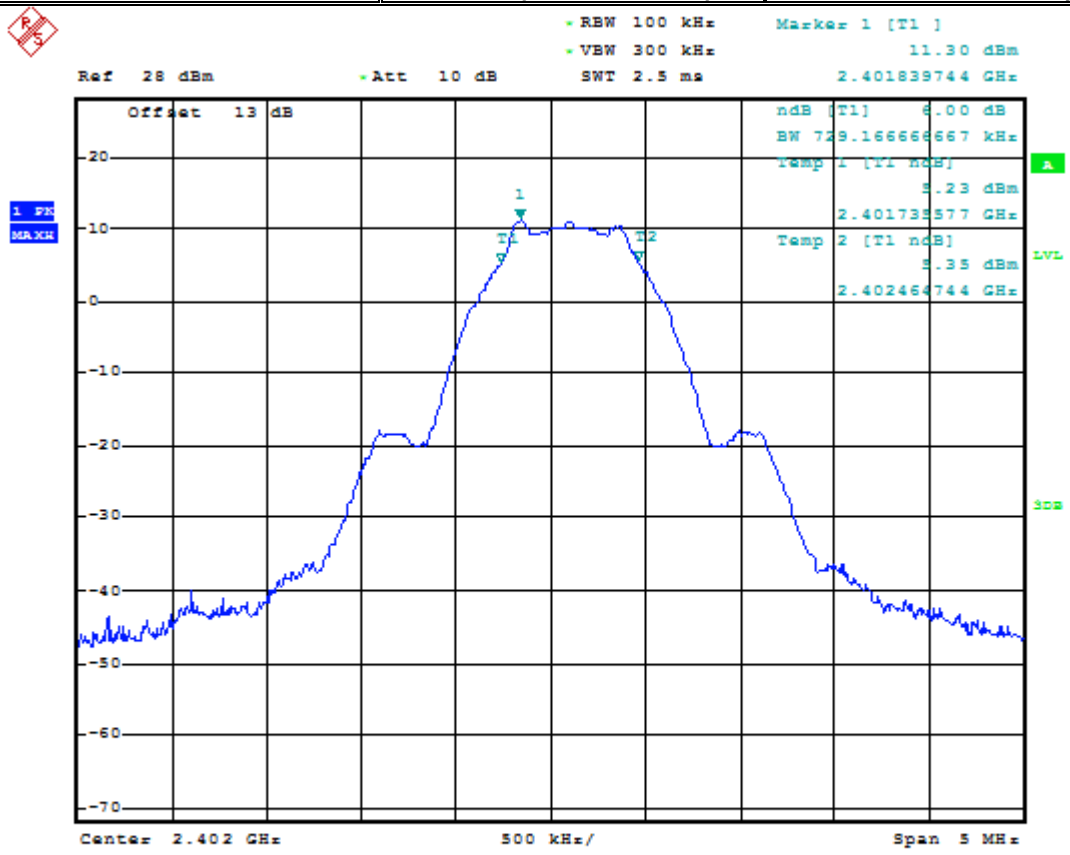
Plot #	EUT Operating Mode	Channel	Frequency (MHz)	6dB Emissions Bandwidth (MHz)	Limit (MHz)	Result
1	LE 1 Mbps	Low: 0	2402	0.7292	> 0.5	Pass
2	LE 1 Mbps	Mid: 19	2440	0.7372	> 0.5	Pass
3	LE 1 Mbps	High: 39	2480	0.7612	> 0.5	Pass
4	LE 2 Mbps	Low: 0	2402	1.2019	> 0.5	Pass
5	LE 2 Mbps	Mid: 19	2440	1.3141	> 0.5	Pass
6	LE 2 Mbps	High: 39	2480	1.3942	> 0.5	Pass

Plot #	EUT Operating Mode	Channel	Frequency (MHz)	99% Occupied Bandwidth (MHz)	Limit (MHz)	Result
7	LE 1 Mbps	Low: 0	2402	1.0497	> 0.5	Pass
8	LE 1 Mbps	Mid: 19	2440	1.0657	> 0.5	Pass
9	LE 1 Mbps	High: 39	2480	1.0737	> 0.5	Pass
10	LE 2 Mbps	Low: 0	2402	2.0994	> 0.5	Pass
11	LE 2 Mbps	Mid: 19	2440	2.0994	> 0.5	Pass
12	LE 2 Mbps	High: 39	2480	2.0994	> 0.5	Pass

8.5.5 Measurement Plots:

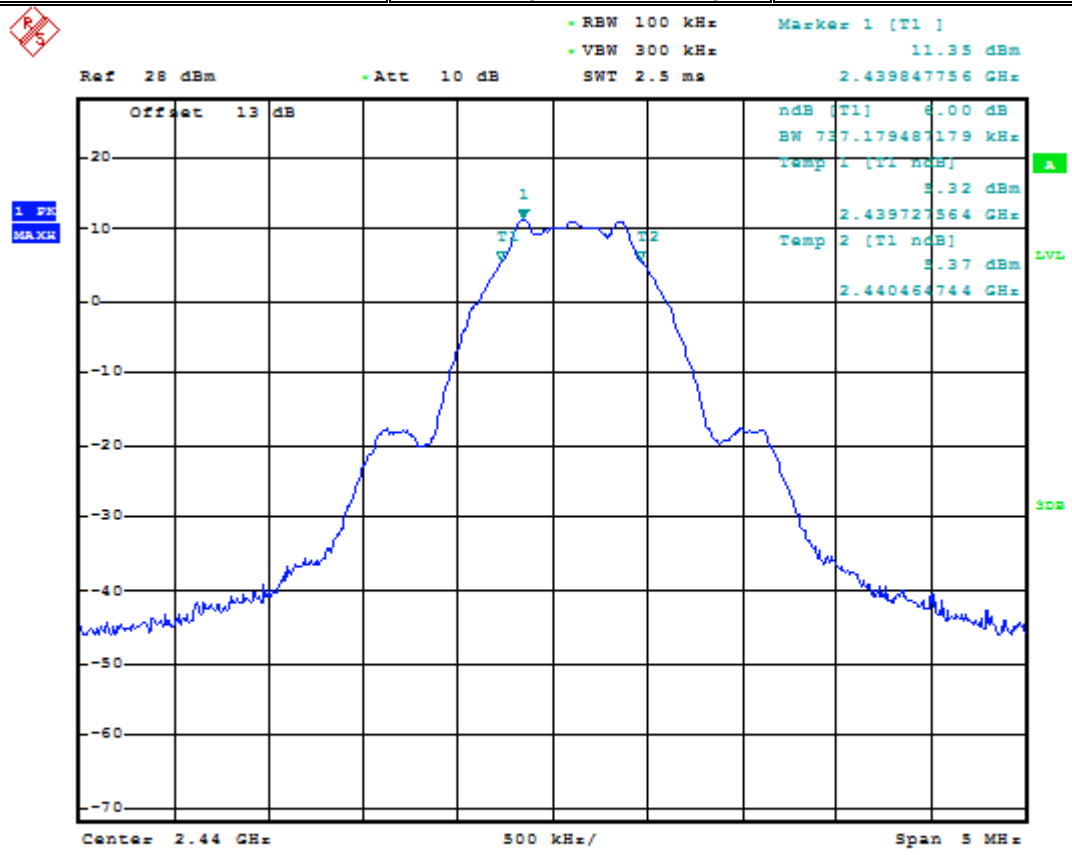
6 dB Emission Bandwidth

Plot #1		
Low channel: 0 / 2402 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



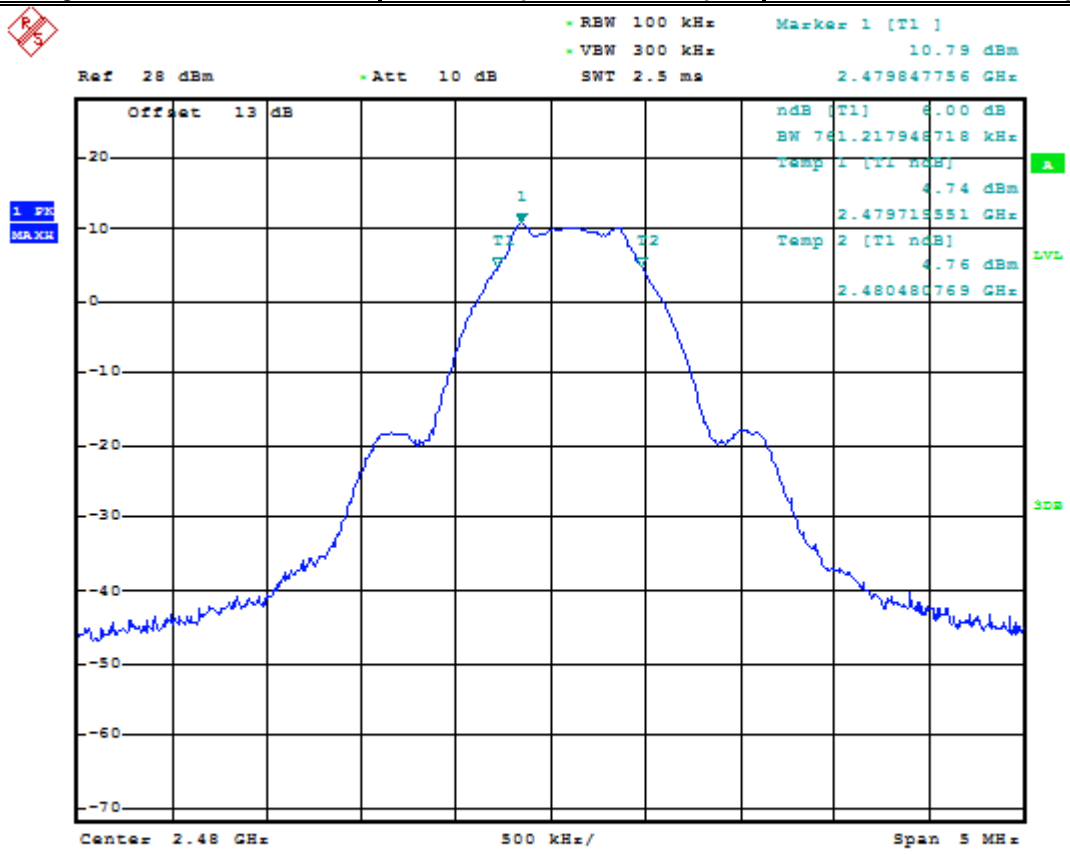
Plot #2

Mid channel: 19 / 2440 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



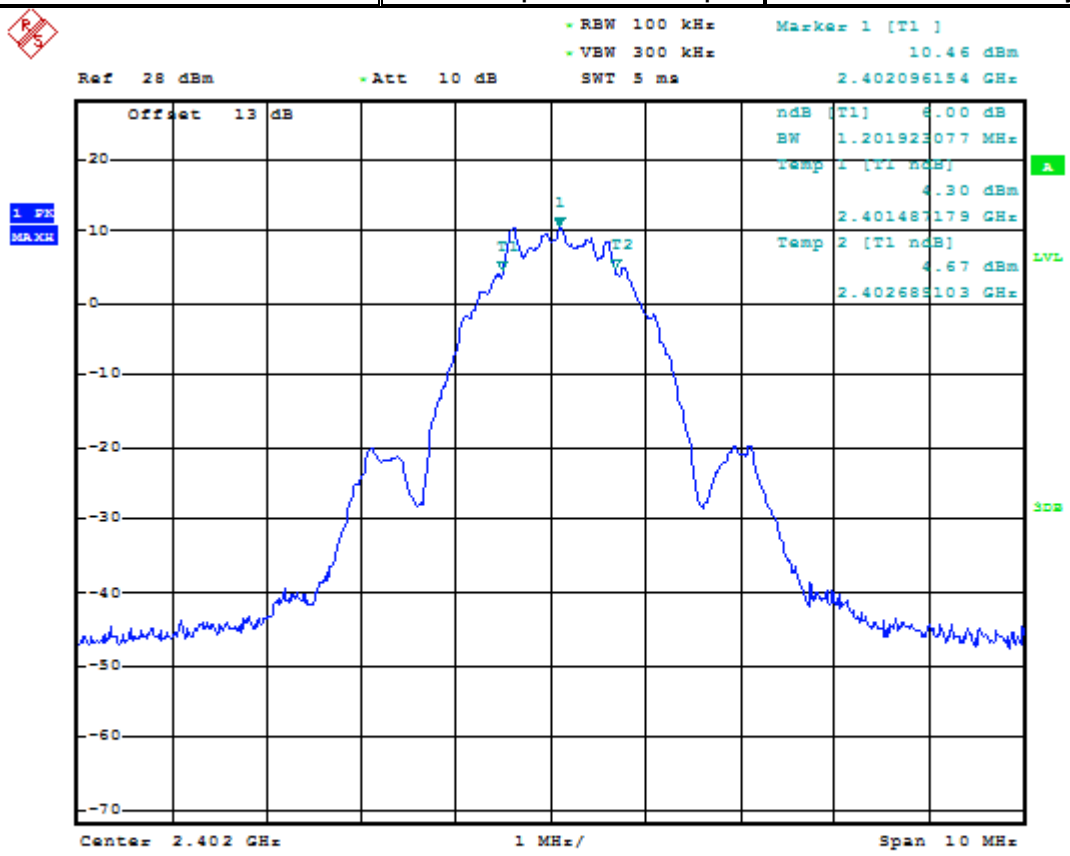
Plot #3

High channel: 39 / 2480 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



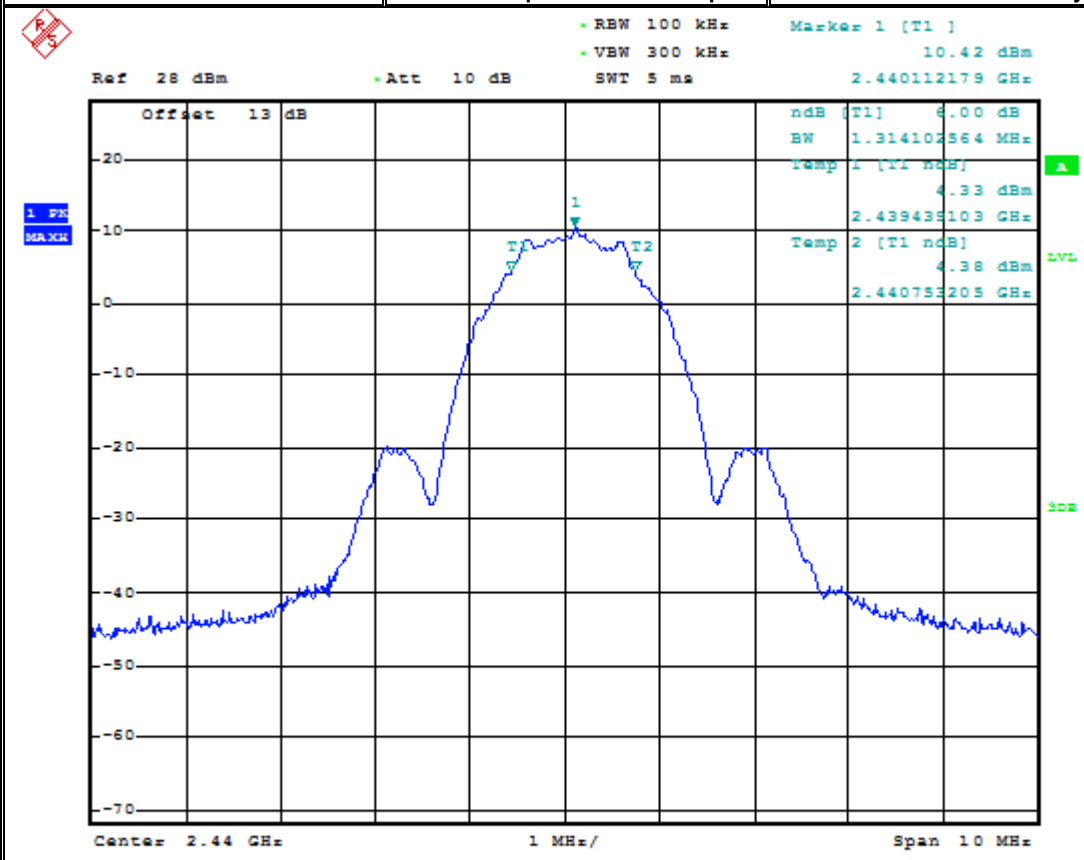
Plot #4

Low channel: 0 / 2402 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



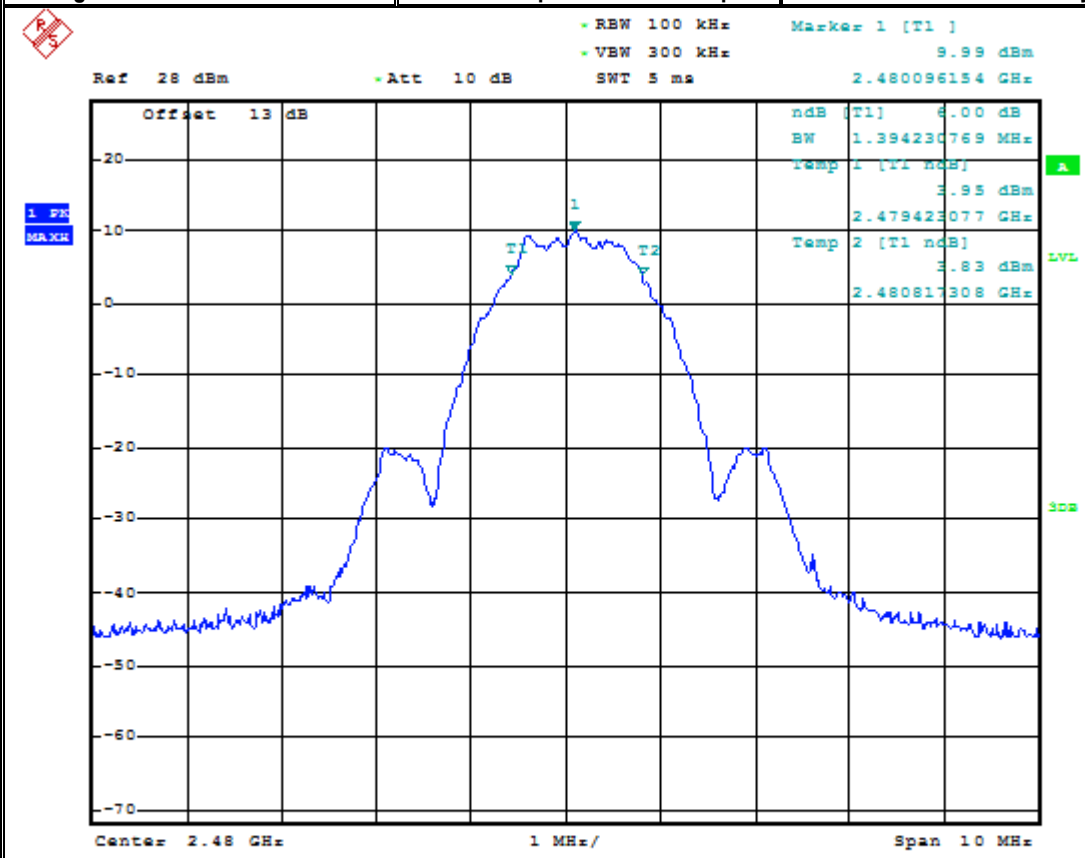
Plot #5

Mid channel: 19 / 2440 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



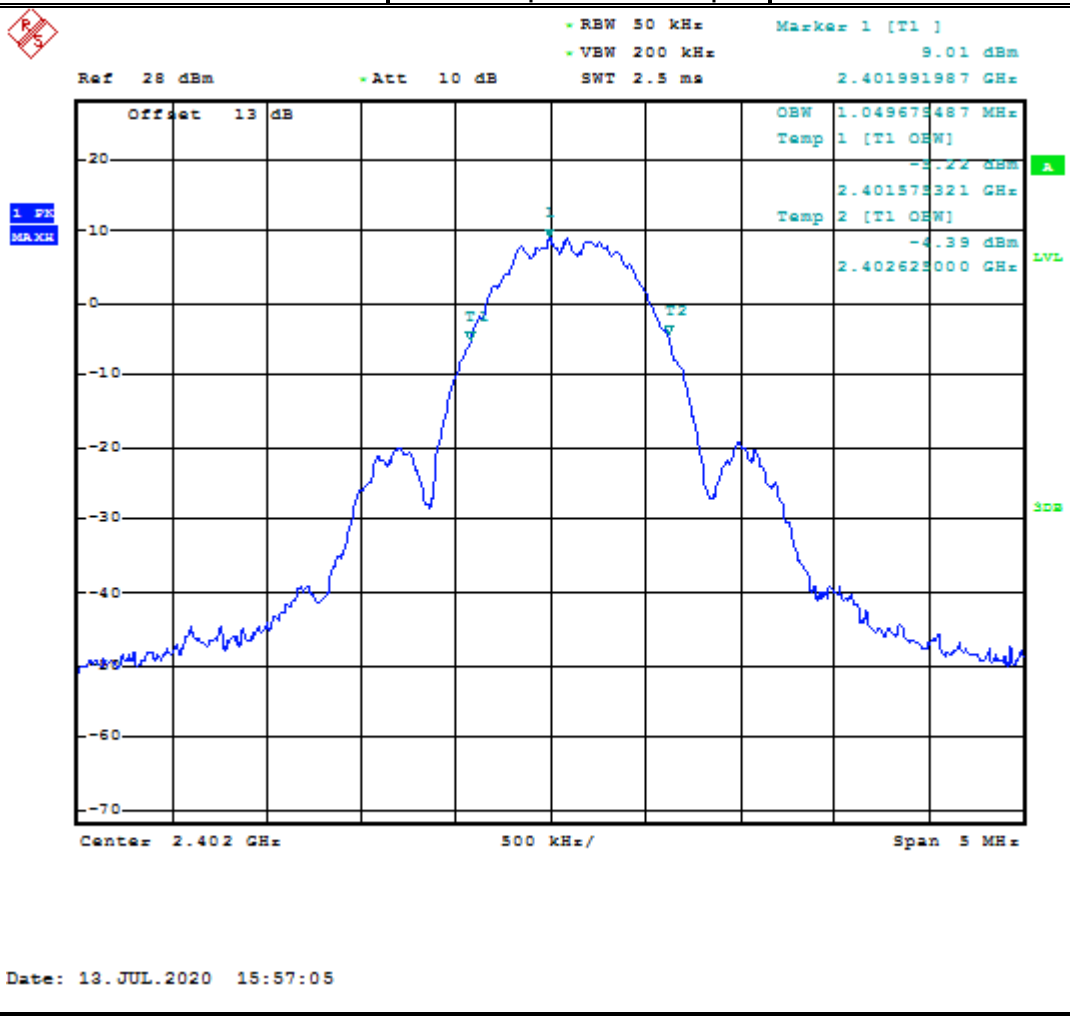
Plot #6

High Channel: 39 / 2480 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



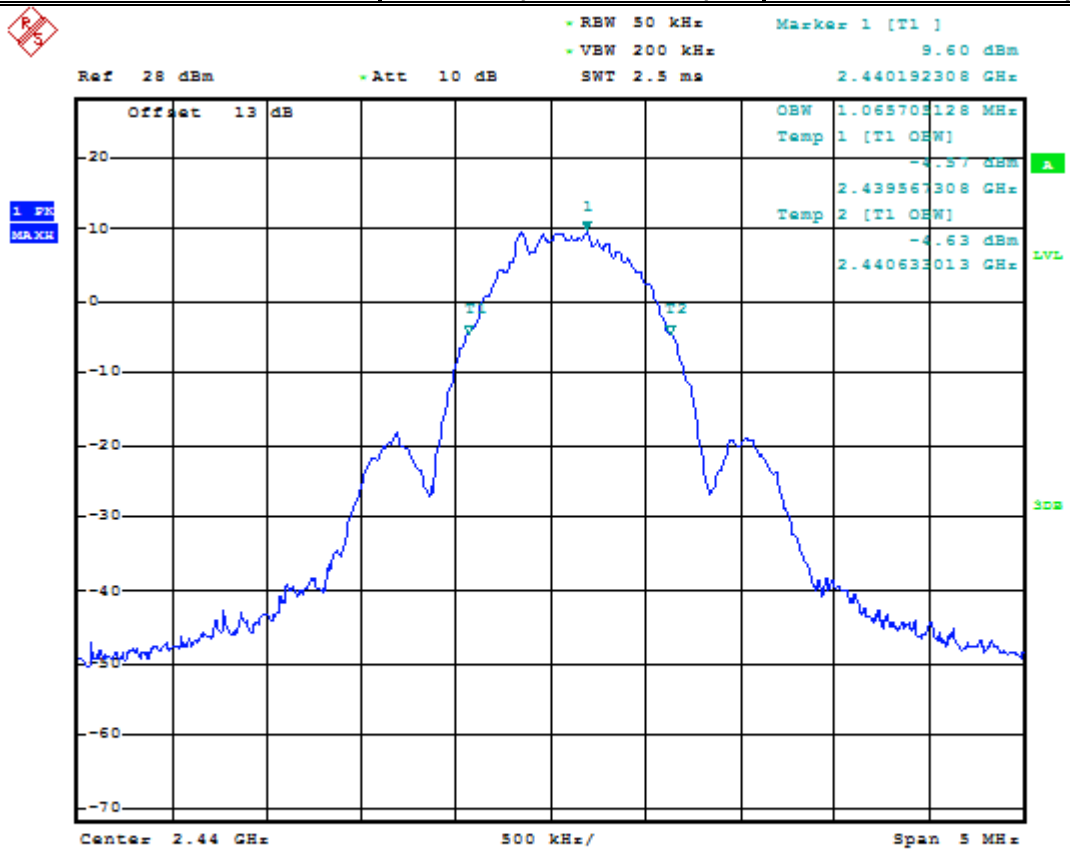
99% Occupied Bandwidth

Plot #7		
Low Channel: 0 / 2402 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



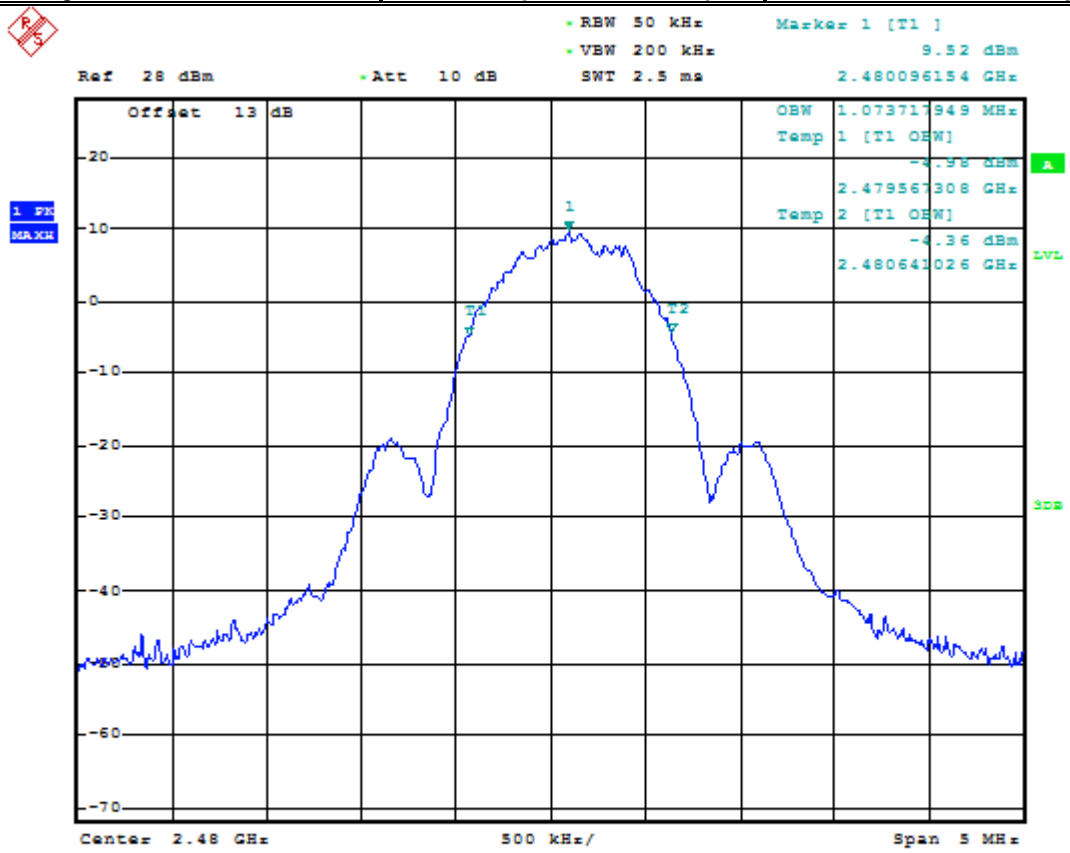
Plot #8

Mid Channel: 19 / 2440 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



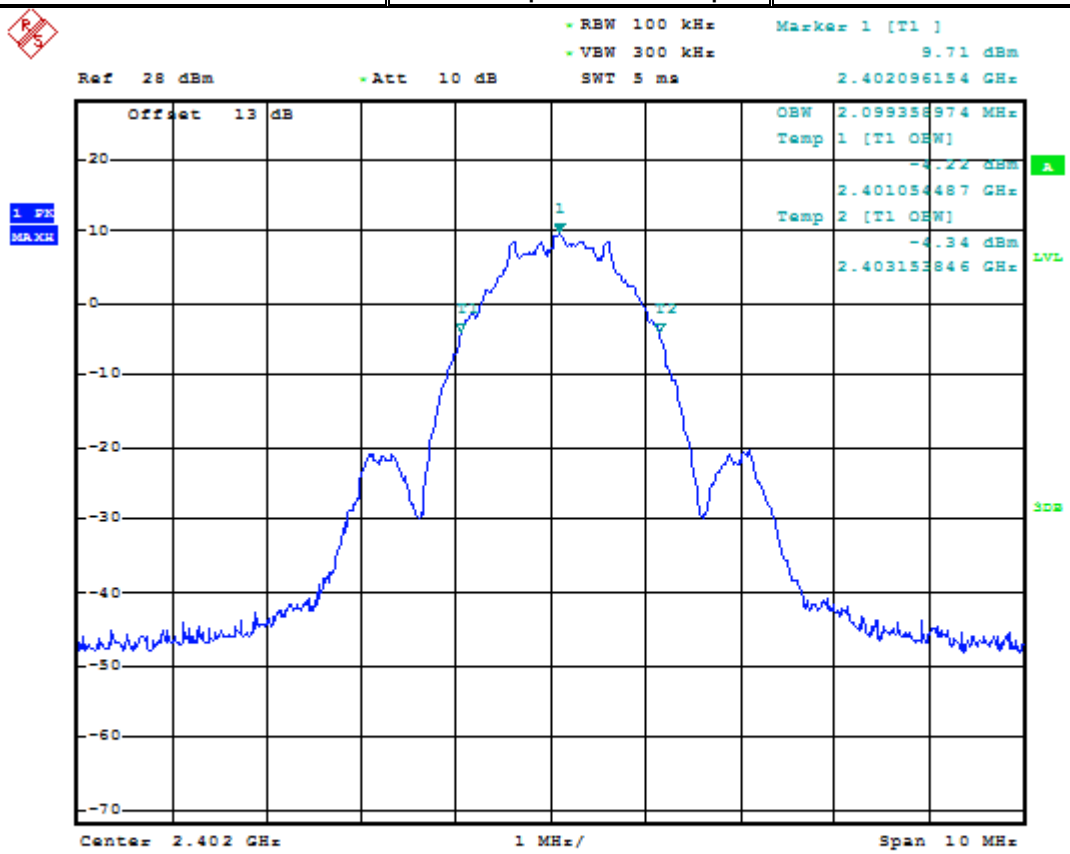
Plot #9

High Channel 39 / 2480 MHz	Mode of Operation: LE 1 Mbps	100% Test Mode Duty Cycle



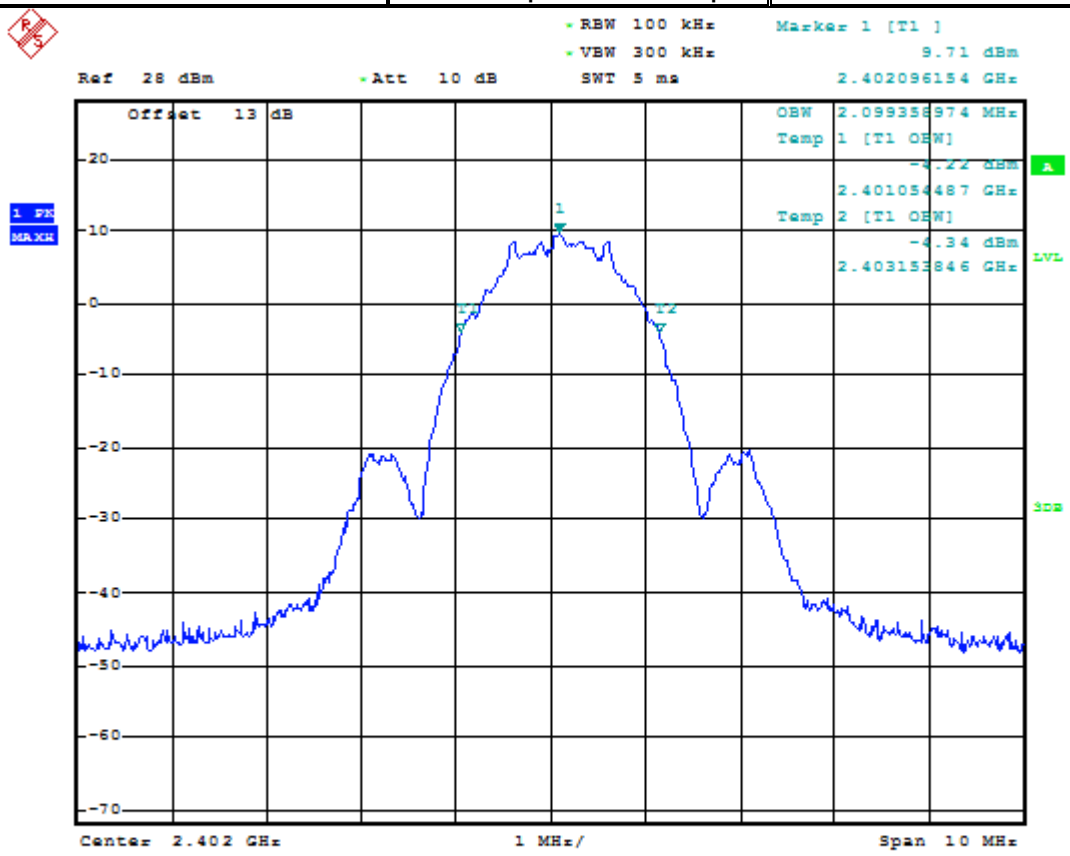
Plot #10

Low Channel 0 / 2402 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



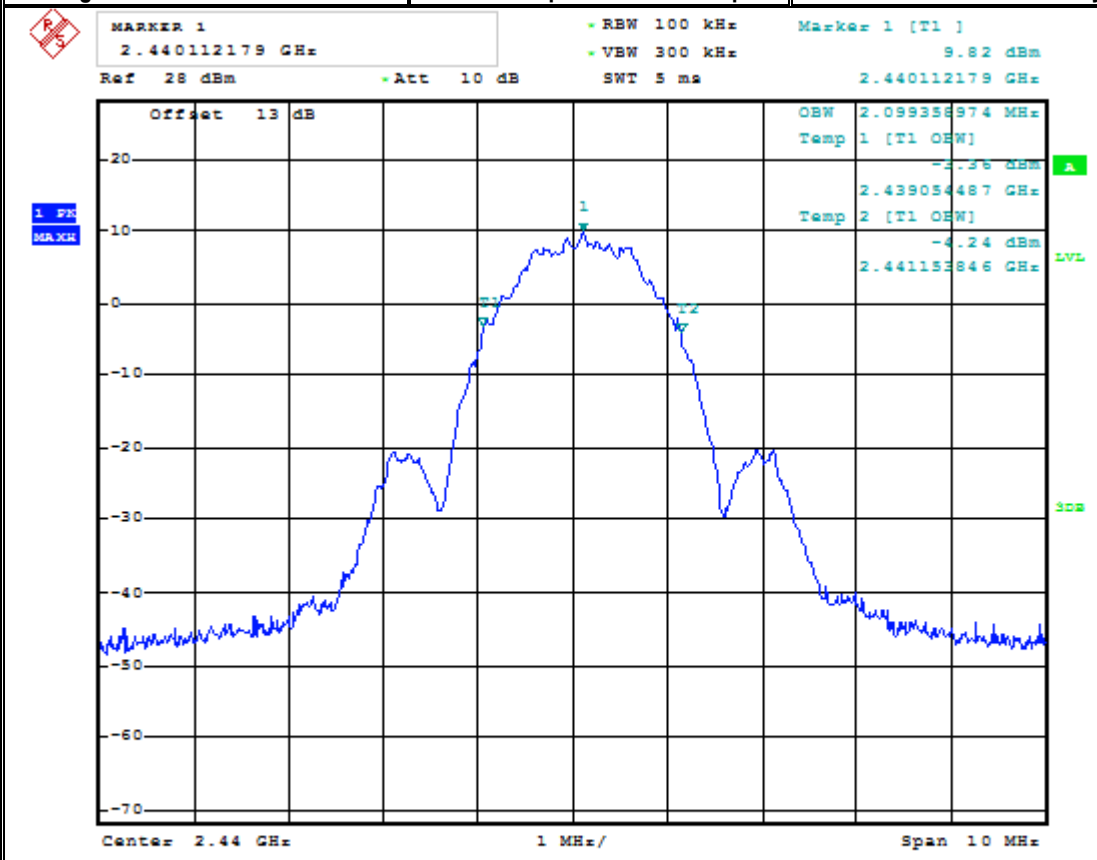
Plot #11

Mid Channel: 19 / 2440 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



Plot #12

High Channel: 39 / 2480 MHz	Mode of Operation: LE 2 Mbps	100% Test Mode Duty Cycle



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

- 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

- 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:

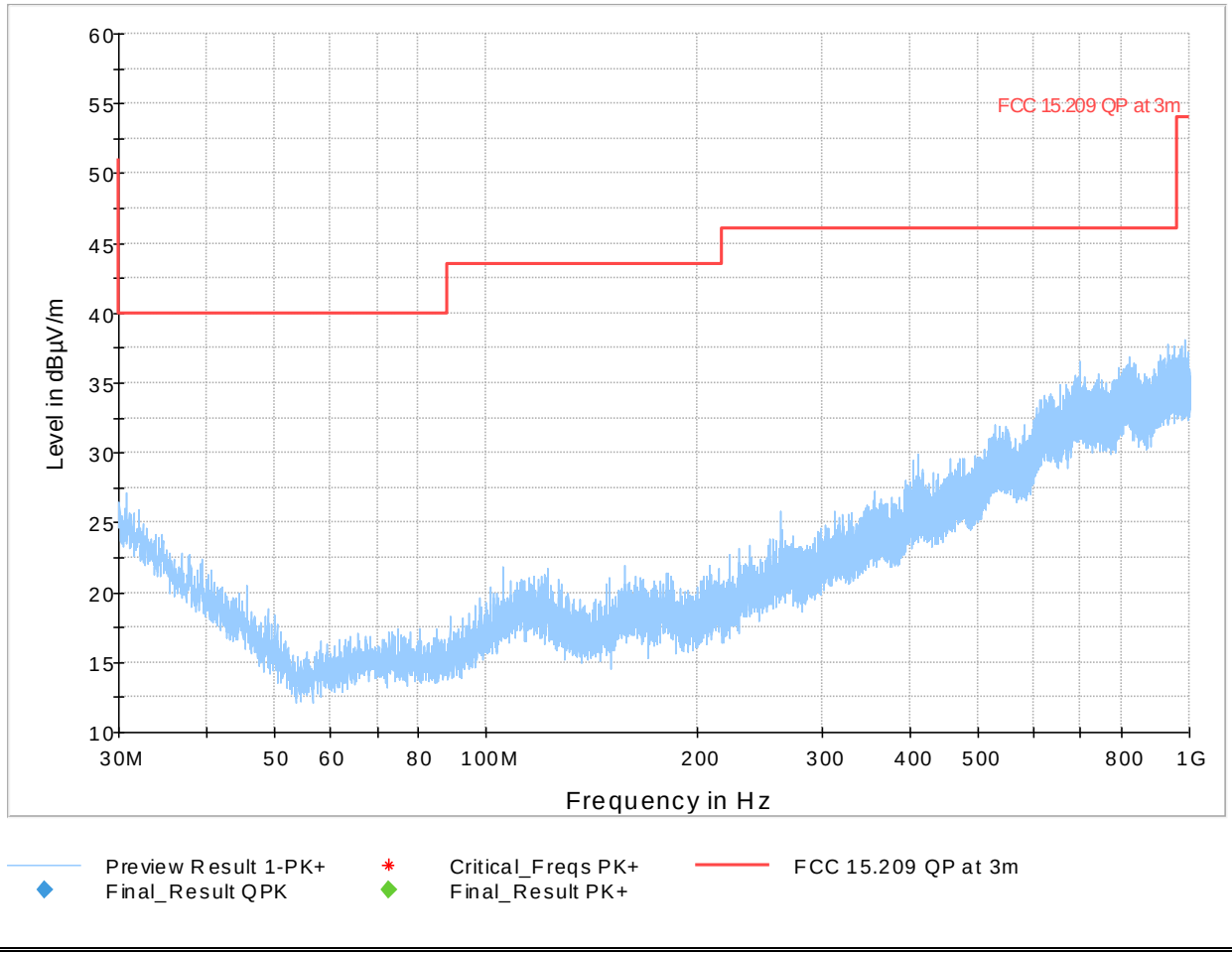
Ambient Temperature	EUT Set-Up #	EUT operating mode	Power Input
22.4 °C	2	Bluetooth LE 1 Mbps	120V AC to 5.0 VDC

8.6.4 Measurement result:

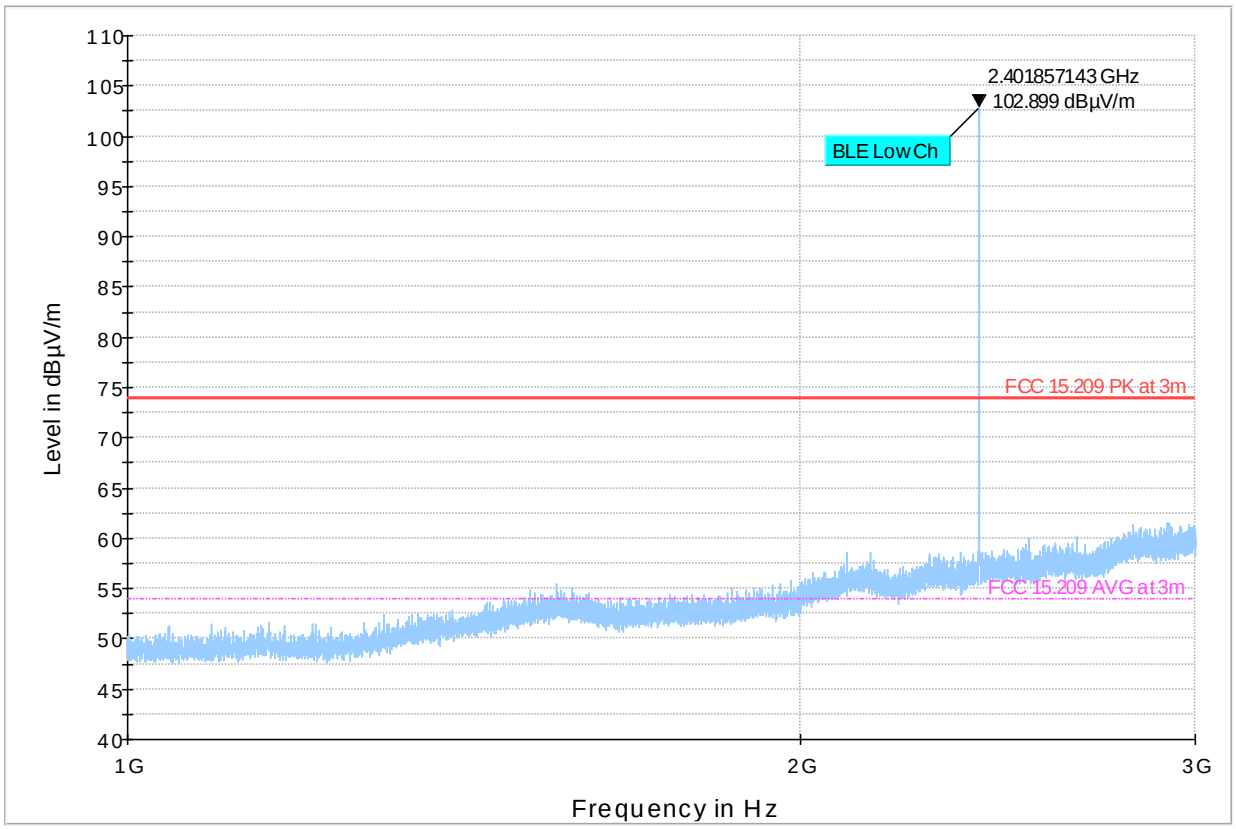
Plot #	Channel #	Scan Frequency	Limit	Result
1-3	Low: 0	30 MHz – 18 GHz	See section 8.6.2	Pass
4-8	Mid: 19	9 kHz – 26 GHz	See section 8.6.2	Pass
9-11	High: 39	30 MHz – 18 GHz	See section 8.6.2	Pass

8.6.5 Measurement Plots:

Plot #1 Radiated Emissions: 30 MHz – 1 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Low Channel: 0**	**100% Test Mode Duty Cycle**



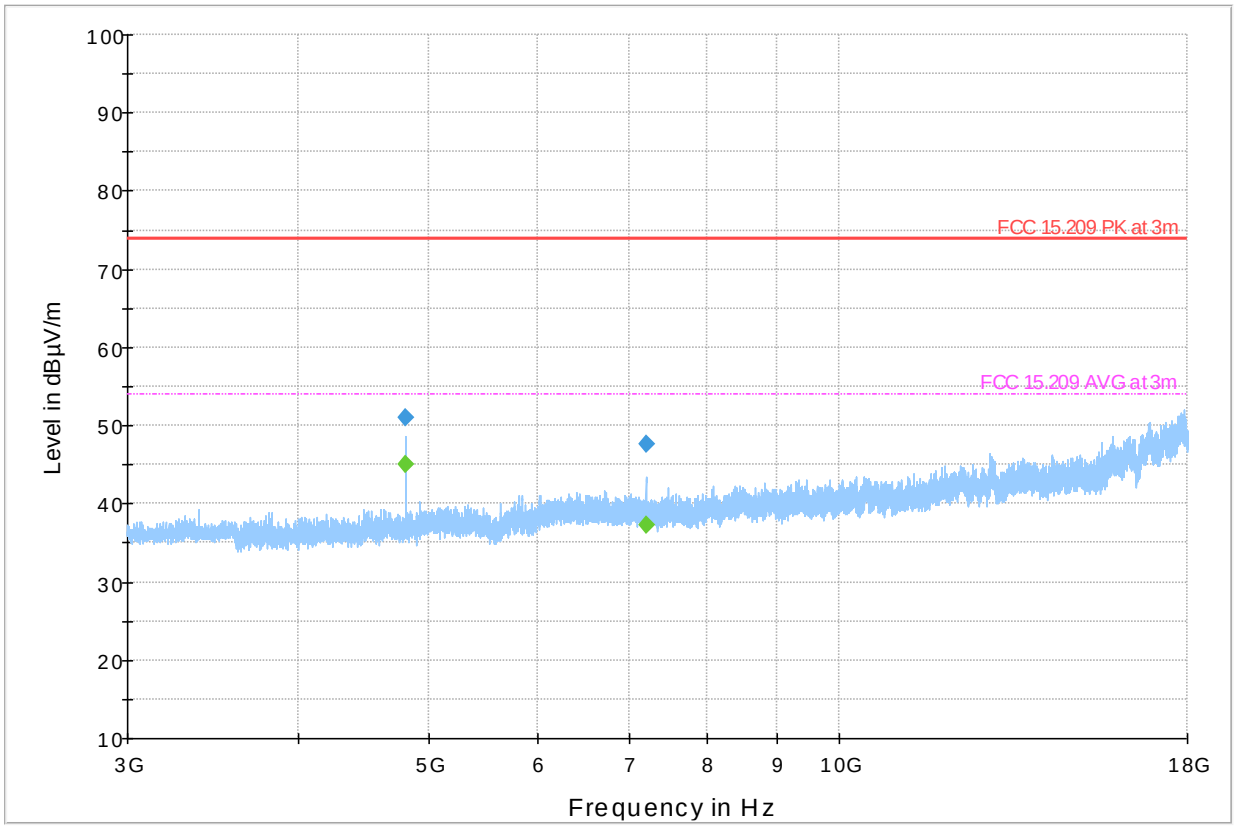
Plot #2 Radiated Emissions: 1-3 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Low Channel: 0**	**100% Test Mode Duty Cycle**



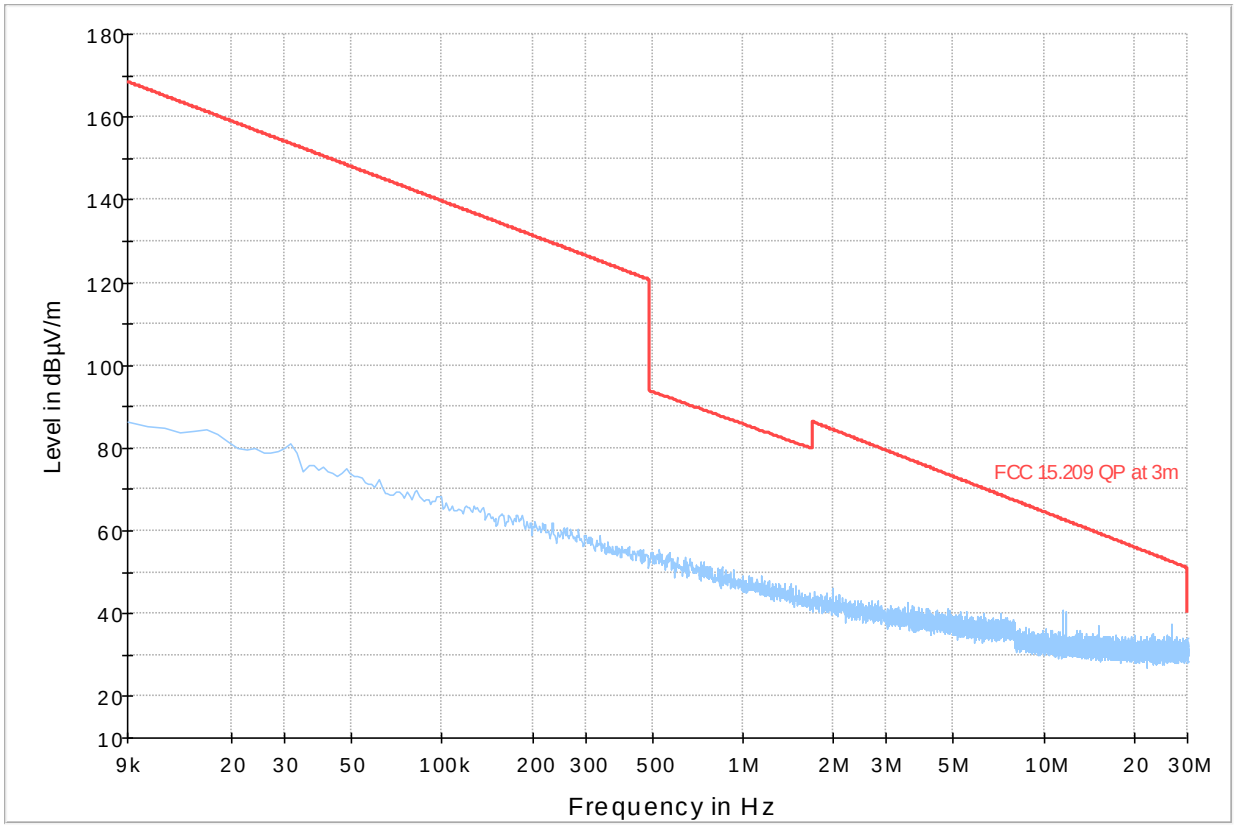
Plot #3 Radiated Emissions: 3-18 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	Low Channel: 0	100% Test Mode Duty Cycle

Final_Result

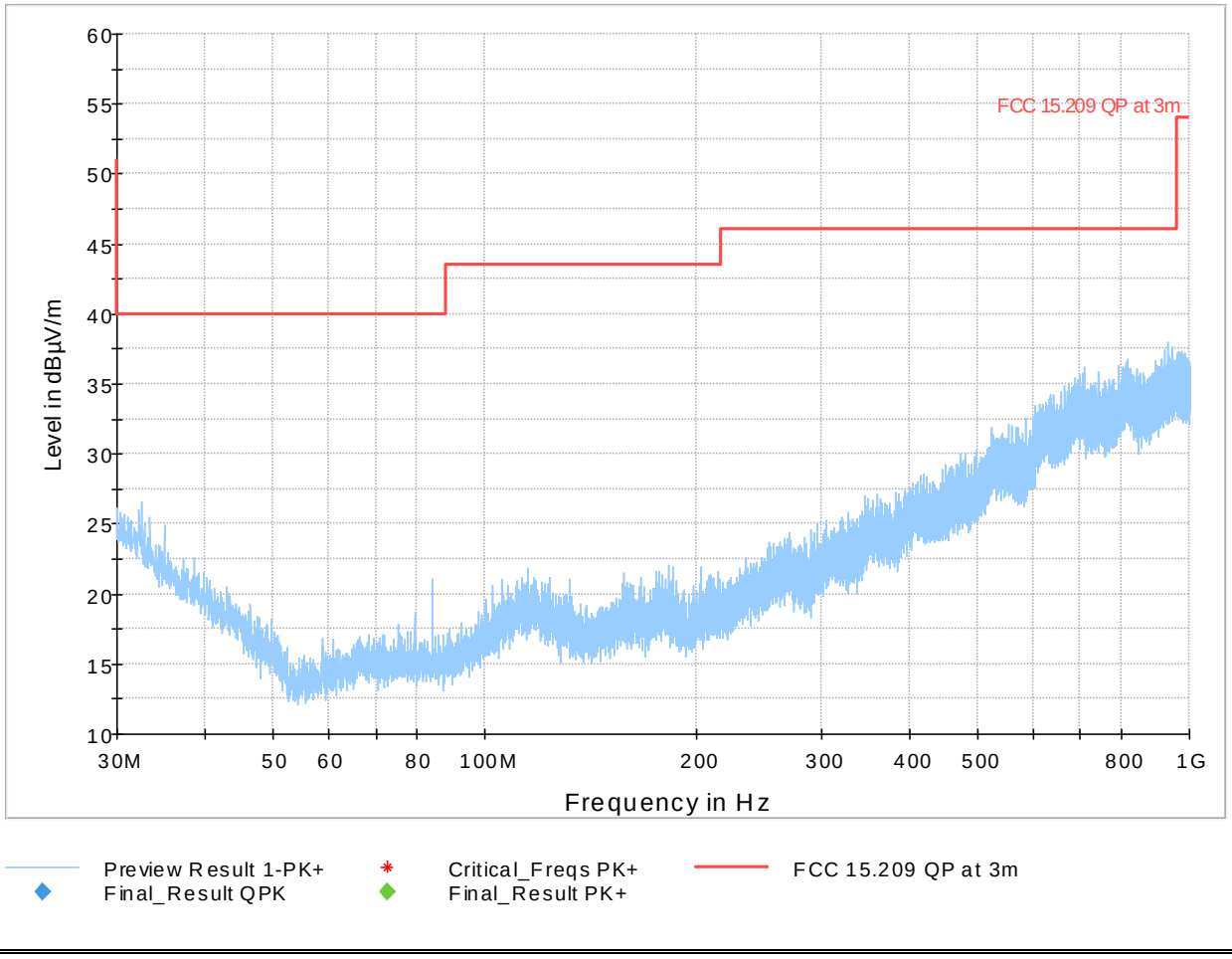
Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
4804.500	51.05	---	73.98	22.93	500.0	1000.000	140.0	H	212.0	-4.8
4804.500	---	44.95	53.98	9.03	500.0	1000.000	140.0	H	212.0	-4.8
7205.500	47.73	---	73.98	26.25	500.0	1000.000	301.0	V	230.0	-0.6
7205.500	---	37.34	53.98	16.64	500.0	1000.000	301.0	V	230.0	-0.6



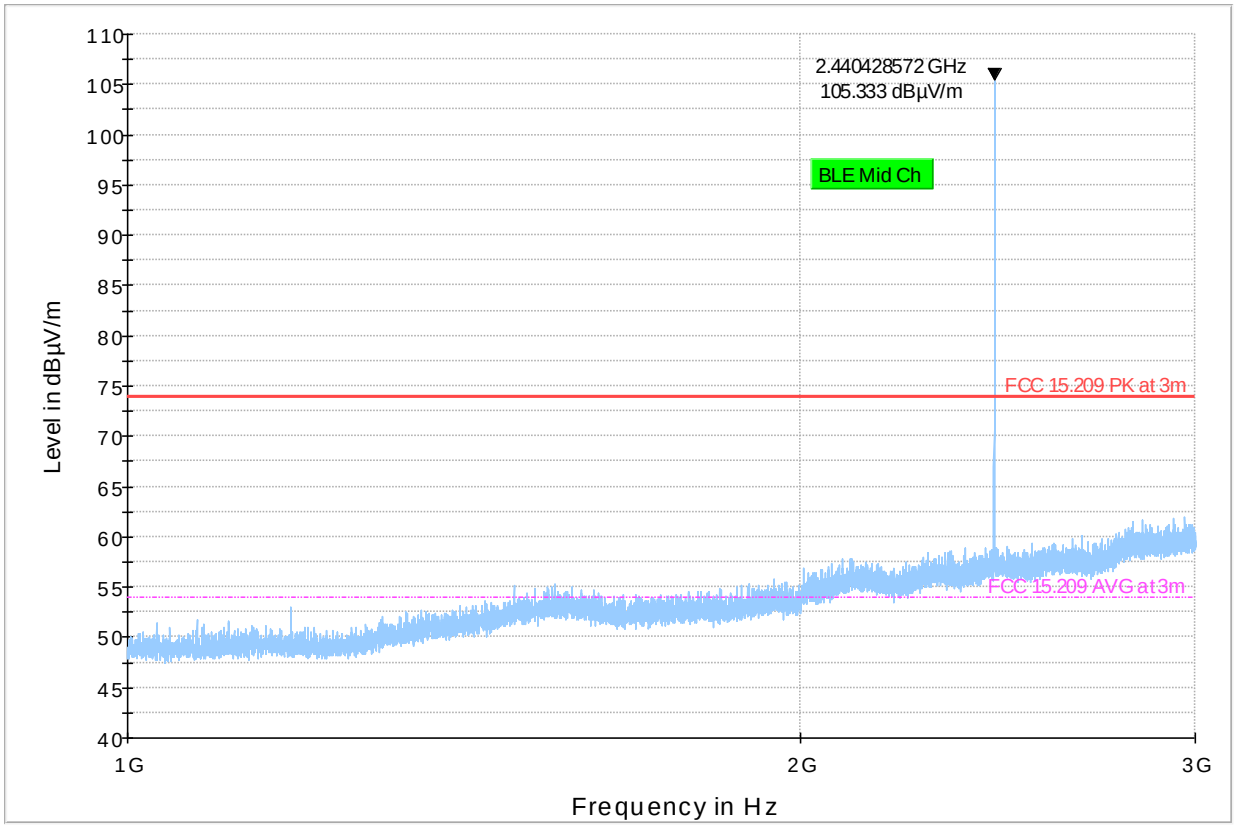
Plot #4 Radiated Emissions: 9 KHz – 30 MHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Mid Channel: 19**	**100% Test Mode Duty Cycle**



Plot #5 Radiated Emissions: 30 MHz – 1 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Mid Channel: 19**	**100% Test Mode Duty Cycle**



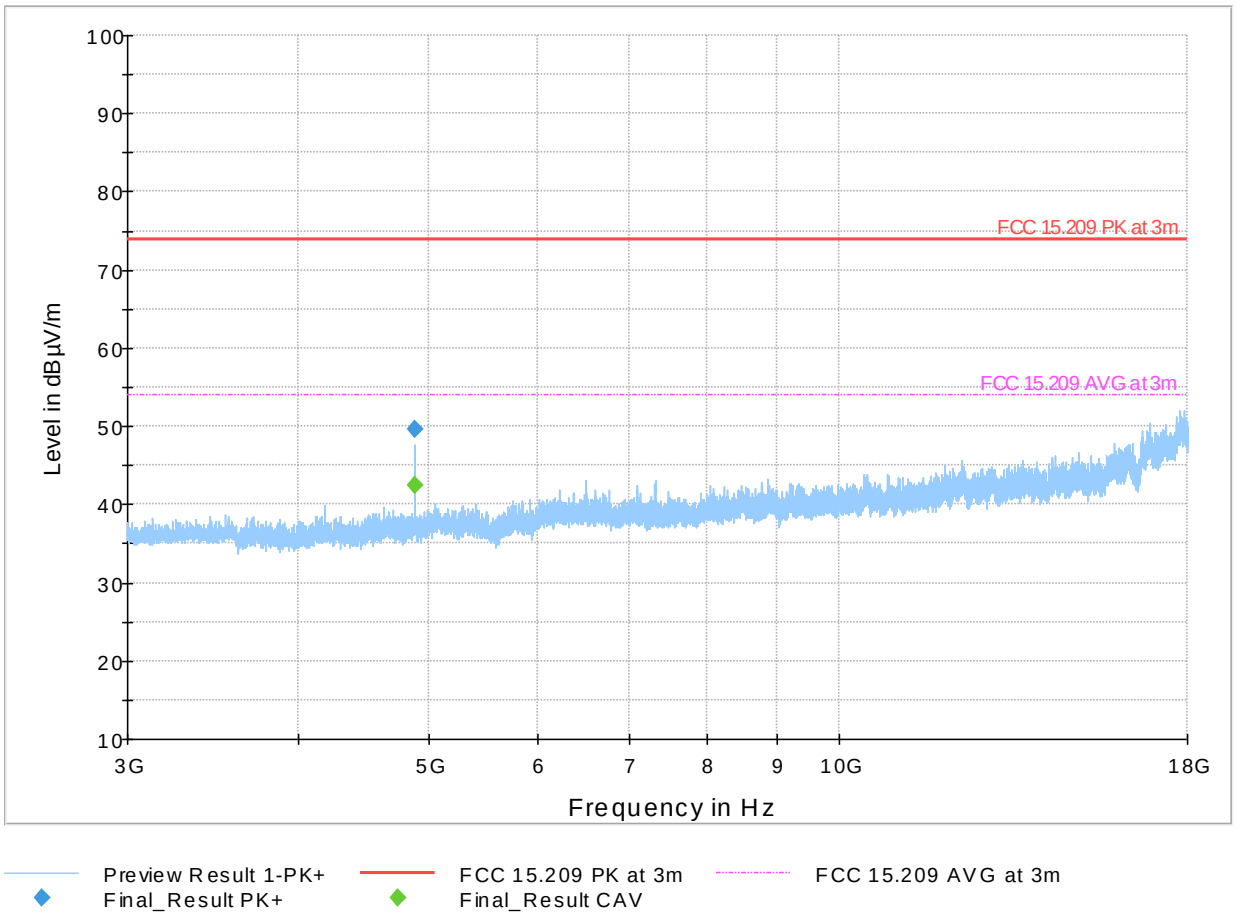
Plot #6 Radiated Emissions: 1-3 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Mid Channel: 19**	**100% Test Mode Duty Cycle**



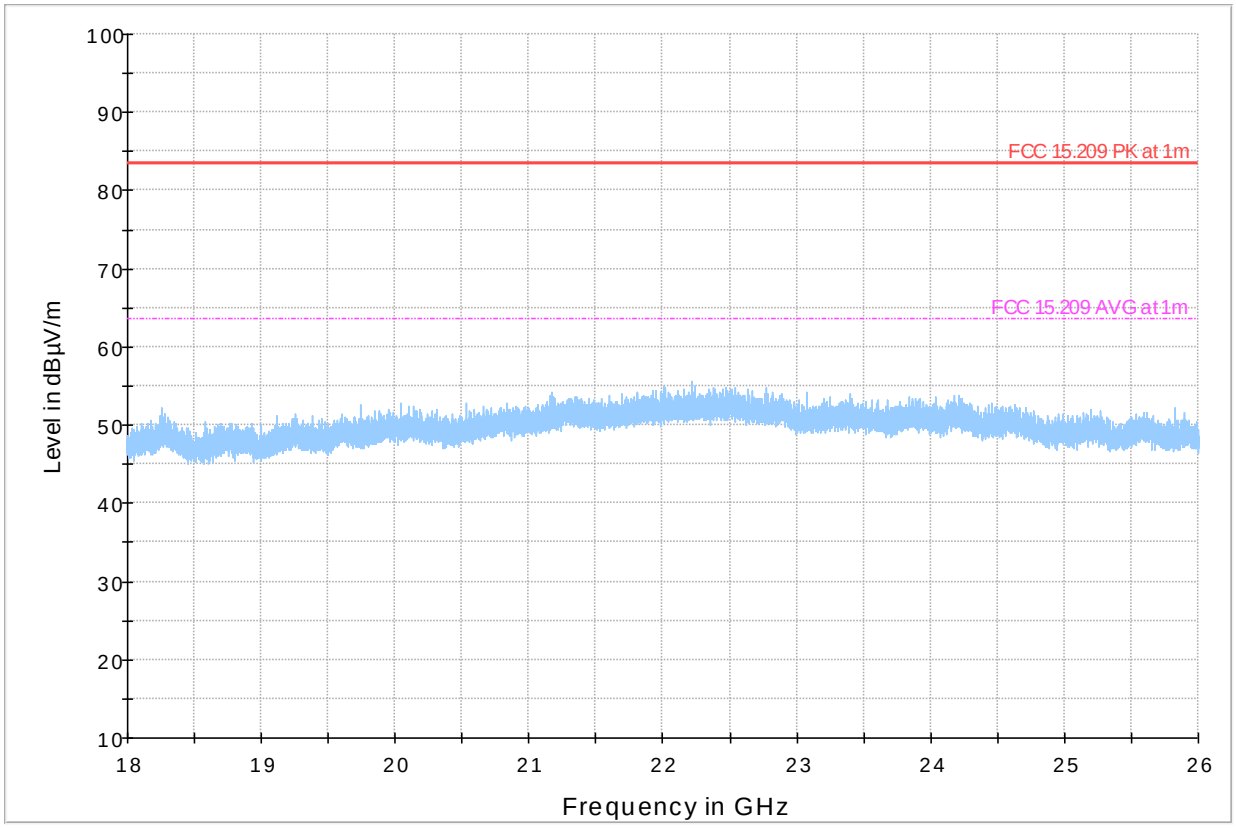
Plot #7 Radiated Emissions: 3-18 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Mid Channel: 19**	**100% Test Mode Duty Cycle**

Final_Result

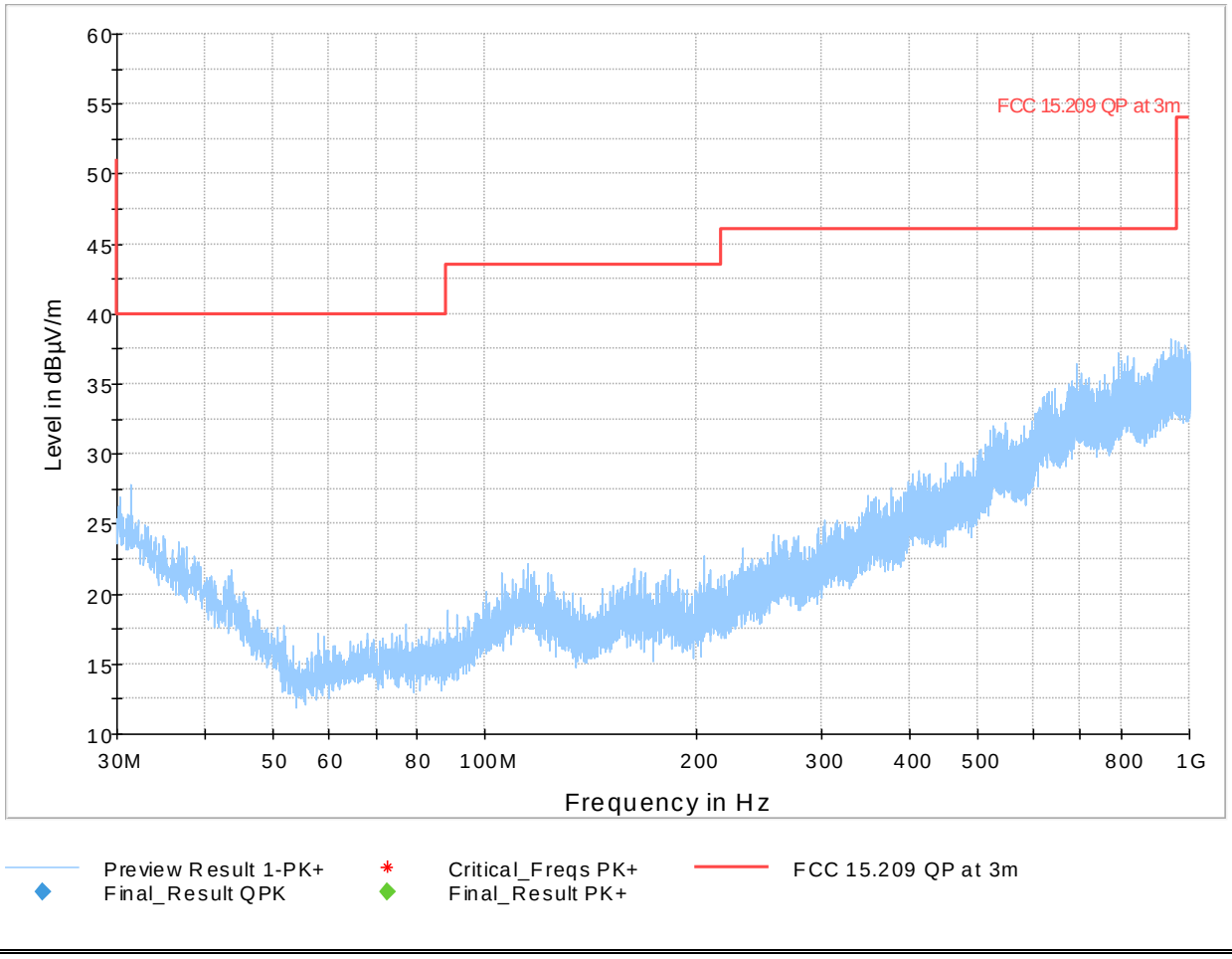
Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
4880.500	---	42.44	53.98	11.54	500.0	1000.000	186.0	V	3.0	-5.0
4880.500	49.54	---	73.98	24.44	500.0	1000.000	186.0	V	3.0	-5.0



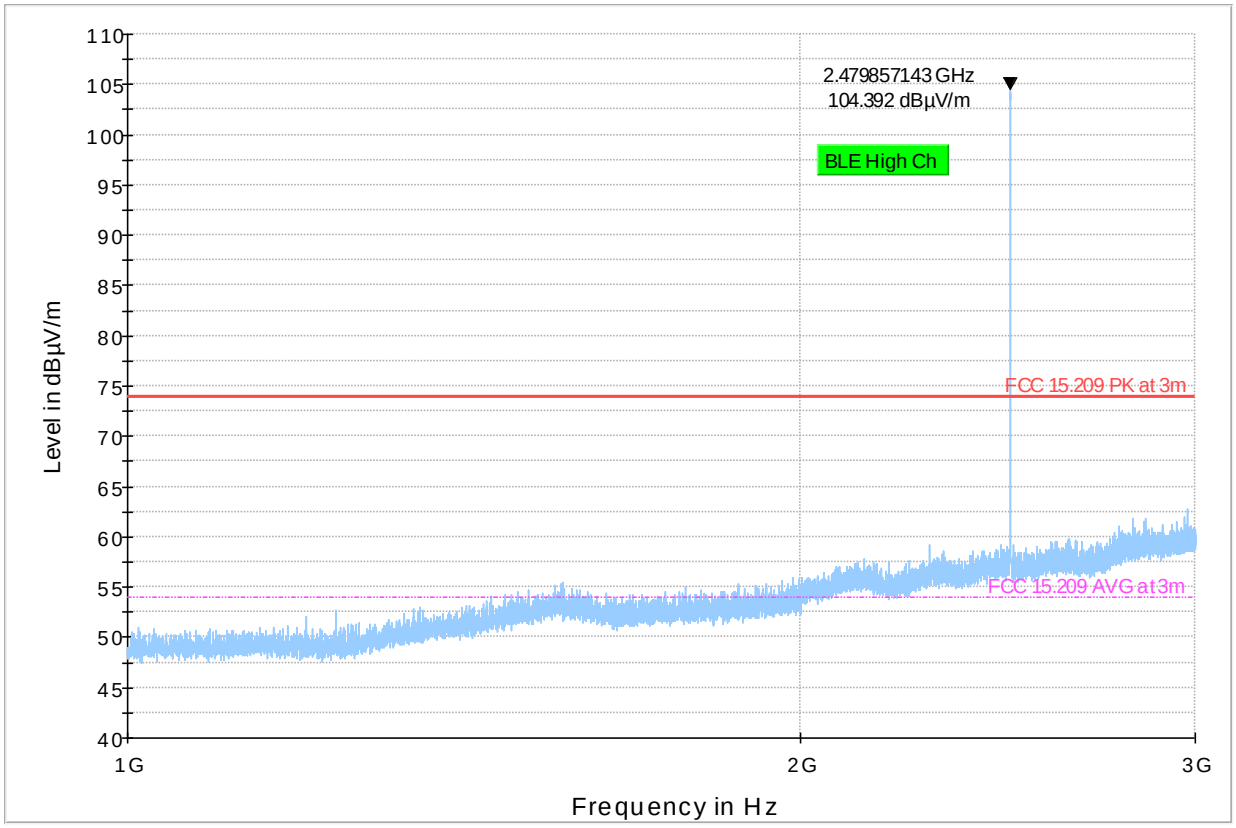
Plot #8 Radiated Emissions: 18-26 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**Mid Channel: 19**	**100% Test Mode Duty Cycle**



Plot #9 Radiated Emissions: 30 MHz – 1 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**High Channel: 39**	**100% Test Mode Duty Cycle**



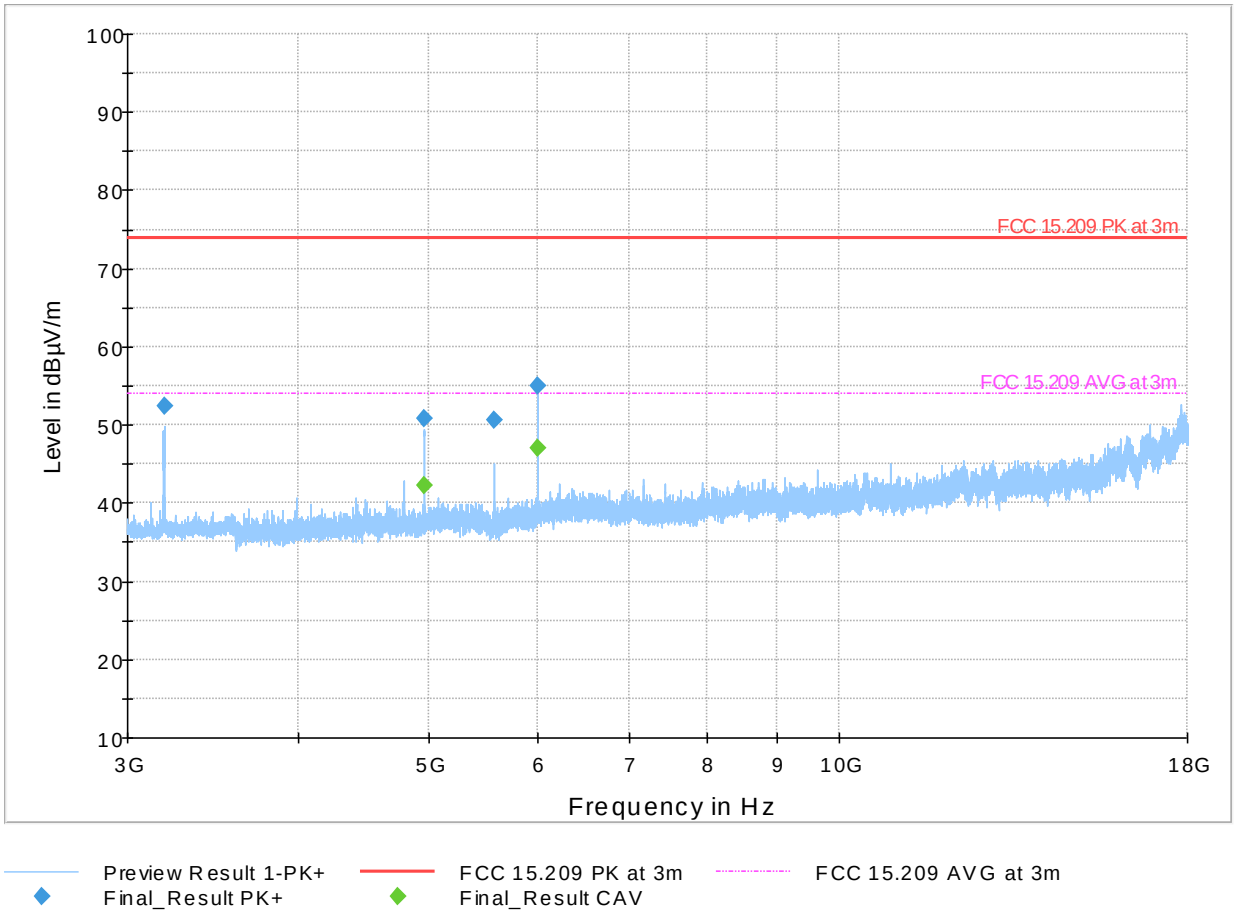
Plot #10 Radiated Emissions: 1-3 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	**High Channel: 39**	**100% Test Mode Duty Cycle**



Plot #11 Radiated Emissions: 3-18 GHz		
Mode of Operation: Bluetooth LE 1 Mbps	High Channel: 39	100% Test Mode Duty Cycle

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
3192.000	52.42	---	73.98	21.56	500.0	1000.000	162.0	V	284.0	-8.6
4959.500	50.76	---	73.98	23.22	500.0	1000.000	152.0	V	-34.0	-4.5
4959.500	---	42.19	53.98	11.79	500.0	1000.000	152.0	V	-34.0	-4.5
5580.000	50.72	---	73.98	23.26	500.0	1000.000	140.0	V	212.0	-4.5
6000.500	54.93	---	73.98	19.05	500.0	1000.000	152.0	V	236.0	-2.2
6000.500	---	46.95	53.98	7.03	500.0	1000.000	152.0	V	236.0	-2.2



8.7 AC Power Line Conducted Emissions

8.7.1 Measurement according to ANSI C63.4

Analyzer Settings:

- RBW = 9 KHz (CISPR Bandwidth)
- Detector: Peak / Average for Pre-scan
- Quasi-Peak/Average for Final Measurements

8.7.2 Limits: §15.207

FCC §15.207(a)

- Except as shown in paragraphs (b) and (c) of this section of the CFR, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table (1), as measured using a 50 μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between frequency ranges.

Frequency of emission (MHz)	Conducted limit (dBμV)	
	Quasi-peak	Average
0.15–0.5	66 to 56*	56 to 46*
0.5–5	56	46
5–30	60	50

*Decreases with the logarithm of the frequency.

8.7.3 Test conditions and setup:

Ambient Temperature (°C)	EUT Set-Up #	EUT operating mode	Power line (L1, L2, L3, N)	Power Input
22.4° C	2	BTLE fixed channel: LE 1 Mbps & LE 2 Mbps	Line & Neutral	120V AC to 5.0V DC

8.7.4 Measurement Result:

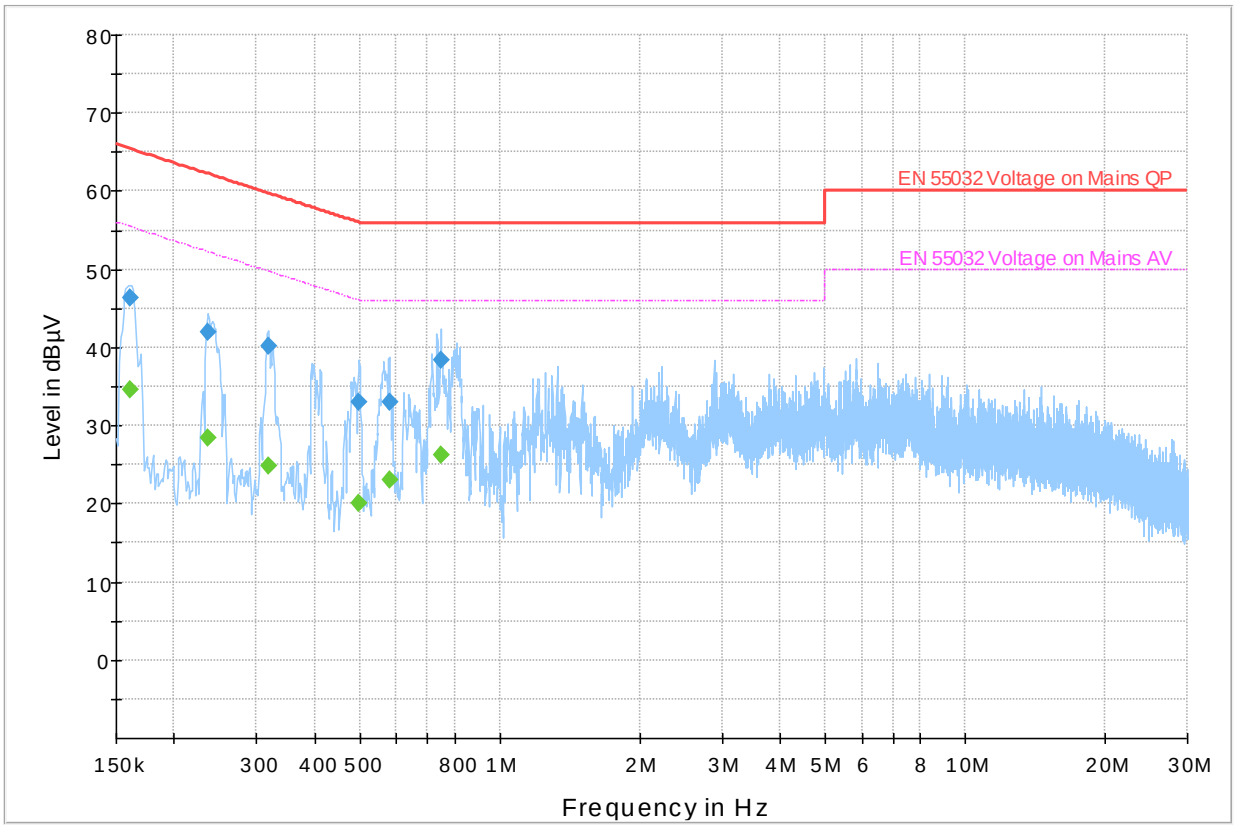
Plot #	Port	EUT Set-Up #:	EUT operating mode	Scan Frequency	Limit	Result
1	AC Mains	3	Bluetooth LE 1 Mbps	150 kHz – 30 MHz	See section 8.7.2	Pass
2	AC Mains	3	Bluetooth LE 2 Mbps	150 kHz – 30 MHz	See section 8.7.2	Pass

Plot # 1

Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
0.161	---	34.56	500.0	9.000	L1	GND	10.7	20.87	55.43
0.161	46.31	---	500.0	9.000	L1	GND	10.7	19.12	65.43
0.236	---	28.41	500.0	9.000	L1	GND	10.6	23.81	52.22
0.236	41.87	---	500.0	9.000	L1	GND	10.6	20.35	62.22
0.318	40.27	---	500.0	9.000	N	GND	10.3	19.48	59.75
0.318	---	24.92	500.0	9.000	N	GND	10.3	24.83	49.75
0.499	33.04	---	500.0	9.000	L1	GND	10.2	22.98	56.02
0.499	---	19.98	500.0	9.000	L1	GND	10.2	26.04	46.02
0.579	32.92	---	500.0	9.000	L1	GND	10.1	23.08	56.00
0.579	---	23.10	500.0	9.000	L1	GND	10.1	22.90	46.00
0.748	38.29	---	500.0	9.000	L1	GND	10.3	17.71	56.00
0.748	---	26.15	500.0	9.000	L1	GND	10.3	19.85	46.00

Disclaimer: Any measurement data within 2dB from the limit line is conditional PASS/FAIL due to measurement uncertainty considerations.



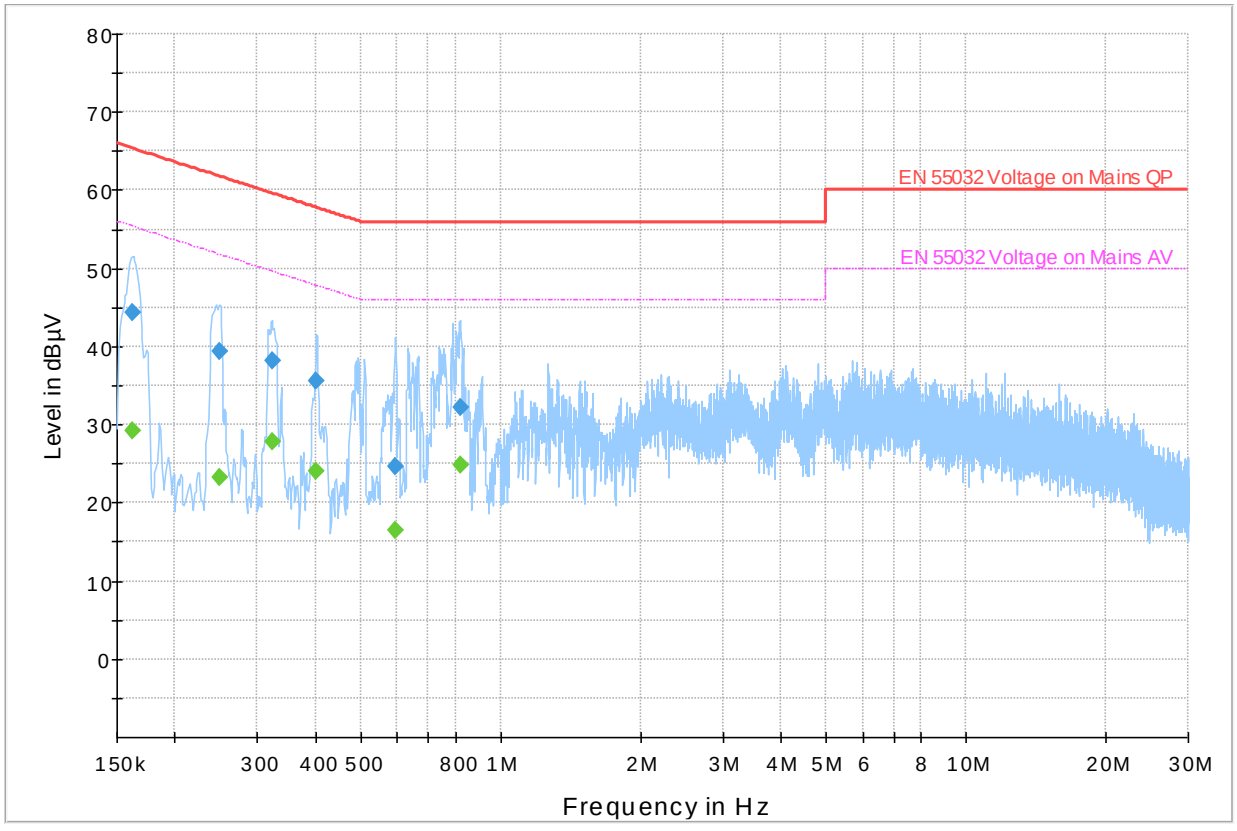
Test Date: 07/24/2020 Test Engineer: Chin Ming Lui

Plot # 2

Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
0.162	44.35	---	500.0	9.000	N	GND	10.6	21.03	65.38
0.162	---	29.24	500.0	9.000	N	GND	10.6	26.13	55.38
0.249	39.38	---	500.0	9.000	N	GND	10.6	22.40	61.79
0.249	---	23.22	500.0	9.000	N	GND	10.6	28.57	51.79
0.323	38.21	---	500.0	9.000	L1	GND	10.3	21.42	59.64
0.323	---	27.81	500.0	9.000	L1	GND	10.3	21.83	49.64
0.403	35.65	---	500.0	9.000	L1	GND	10.4	22.15	57.80
0.403	---	24.10	500.0	9.000	L1	GND	10.4	23.70	47.80
0.595	---	16.56	500.0	9.000	N	GND	10.2	29.44	46.00
0.595	24.63	---	500.0	9.000	N	GND	10.2	31.37	56.00
0.818	---	24.80	500.0	9.000	N	GND	10.3	21.20	46.00
0.818	32.15	---	500.0	9.000	N	GND	10.3	23.85	56.00

Disclaimer: Any measurement data within 2dB from the limit line is conditional PASS/FAIL due to measurement uncertainty considerations.



Test Date: 07/24/2020 Test Engineer: Chin Ming Lui

9 Test setup photos

Setup photos are included in supporting file name: "EMC_APPAR-003-20501_15.247_BTLE_DTS_Setup_Photos.pdf"

10 Test Equipment And Ancillaries Used For Testing

Item Name	Manufacturer	Model	Serial #	Calibration Cycle	Last Calibration Date
Loop Antenna	ETS Lindgren	6507	161344	3 years	10/26/2017
Biconlog Antenna	ETS Lindgren	3142E	166067	3 years	03/12/2020
Horn Antenna	ETS Lindgren	3115	35114	3 years	07/31/2017
Horn Antenna	ETS Lindgren	3117-PA	215984	3 years	01/26/2018
Horn Antenna	ETS Lindgren	3116C-PA	169535	3 years	09/24/2017
EMI Receiver	R&S	ESU40	100251	3 years	07/16/2019
Spectrum Analyzer	R&S	FSV40	101022	3 years	07/15/2019
Thermometer Humidity Monitor	Control Company	36934-164	191872028	2 years	01/10/2019

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	Report Prepared by
2020-08-14	EMC_APPAR-003-20501_15.247_BTLE_DTS	Initial Version	Chin Ming Lui

<<< The End >>>