

Report on the FCC and IC Testing of: Apple Inc. Model: A2159

In accordance with FCC 47 CFR Part 15C and
Industry Canada RSS-247 and Industry Canada
RSS-GEN

Prepared for: Apple Inc.
One Apple Park Way
Cupertino, California 95014, USA

FCC ID: BCGA2159

IC: 579C-A2159

COMMERCIAL-IN-CONFIDENCE

Document Number: 75945152-11 | Issue: 02



Add value.
Inspire trust.

SIGNATURE

NAME	JOB TITLE	RESPONSIBLE FOR	ISSUE DATE
Philip Harrison	Senior Engineer	Authorised Signatory	27 June 2019

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD document control rules.

ENGINEERING STATEMENT

The measurements shown in this report were made in accordance with the procedures described on test pages. All reported testing was carried out on a sample equipment to demonstrate limited compliance with FCC 47 CFR Part 15C and Industry Canada RSS-247 and Industry Canada RSS-GEN. The sample tested was found to comply with the requirements defined in the applied rules.

SIGNATURE

NAME	JOB TITLE	RESPONSIBLE FOR	ISSUE DATE
Matthew Russell	RF Team Leader	Testing	27 June 2019
Mehadi Choudhury	Engineer	Testing	27 June 2019
George Porter / Daniel Bishop	Assistant Engineers	Testing	27 June 2019
Cristian Onaca / Malik Mohammed / Jay Balendraraiah	Shift Technicians	Testing	27 June 2019

FCC Accreditation

90987 Octagon House, Fareham Test Laboratory

Industry Canada Accreditation

IC2932B-1 Octagon House, Fareham Test Laboratory

EXECUTIVE SUMMARY

A sample of this product was tested and found to be compliant with FCC 47 CFR Part 15C: 2017, Industry Canada RSS-247: Issue 2 (2017-02) and Industry Canada RSS-GEN: Issue 5 (2018-04).



DISCLAIMER AND COPYRIGHT

This non-binding report has been prepared by TÜV SÜD with all reasonable skill and care. The document is confidential to the potential Client and TÜV SÜD. No part of this document may be reproduced without the prior written approval of TÜV SÜD. © 2019 TÜV SÜD. This report relates only to the actual item/items tested.

ACCREDITATION

Our UKAS Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our UKAS Accreditation. Results of tests not covered by our UKAS Accreditation Schedule are marked NUA (Not UKAS Accredited).

TÜV SÜD
is a trading name of TÜV SÜD Ltd
Registered in Scotland at East Kilbride,
Glasgow G75 0QF, United Kingdom
Registered number: SC215164

TÜV SÜD Ltd is a
TÜV SÜD Group Company

Phone: +44 (0) 1489 558100
Fax: +44 (0) 1489 558101
www.tuv-sud.co.uk

TÜV SÜD
Octagon House
Concorde Way
Fareham
Hampshire PO15 5RL
United Kingdom



Contents

1 Report Summary2

1.1 Report Modification Record.....2

1.2 Introduction.....2

1.3 Brief Summary of Results3

1.4 Product Information5

1.5 Deviations from the Standard.....7

1.6 EUT Modification Record8

1.7 Test Location9

2 Test Details 10

2.1 Maximum Conducted Output Power 10

2.2 Power Spectral Density 13

2.3 Emission Bandwidth 27

2.4 Authorised Band Edges 41

2.5 Restricted Band Edges..... 46

2.6 Spurious Radiated Emissions 54

3 Measurement Uncertainty 74



1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	09 May 2019
2	Removed Set-Up Photos	27 June 2019

Table 1

1.2 Introduction

Applicant	Apple Inc.
Manufacturer	Apple Inc.
Model Number(s)	A2159
Serial Number(s)	C02Y4006L59F, C02Y400PL5FL, C02Y5001L5G8
Hardware Version(s)	REV 1.0
Software Version(s)	18F65, 18F74
Number of Samples Tested	2
Test Specification/Issue/Date	FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN: 2016 and Issue 2 (2017-02) and Issue 4 (2014-11)
Order Number	0540175066
Date	21-February-2019
Date of Receipt of EUT	06-February-2019
Start of Test	06-March-2019
Finish of Test	24-April-2019
Name of Engineer(s)	Matthew Russell, Mehadi Choudhury, Malik Mohammed, George Porter, Cristian Onaca, Jay Balendrarajah, Daniel Bishop.
Related Document(s)	ANSI C63.10 (2013)



1.3 Brief Summary of Results

A brief summary of the tests carried out in accordance with FCC 47 CFR Part 15C and Industry Canada RSS-247 and Industry Canada RSS-GEN is shown below.

Section	Specification Clause	Test Description	Result	Comments/Base Standard
Configuration and Mode: Bluetooth LE (iPA) - LE1M				
2.1	15.247 (b), 5.4 and 6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013)
2.2	15.247 (e), 5.2 and 6.12	Power Spectral Density	Pass	ANSI C63.10 (2013)
2.3	15.247 (a)(2), 5.2 and 6.6	Emission Bandwidth	Pass	ANSI C63.10 (2013)
2.4	15.247 (d), 5.5 and N/A	Authorised Band Edges	Pass	ANSI C63.10 (2013)
2.5	15.205 N/A and 8.10	Restricted Band Edges	Pass	ANSI C63.10 (2013)
2.6	15.247 (d), 15.205, 5.5 and 6.13	Spurious Radiated Emissions	Pass	ANSI C63.10 (2013)
Configuration and Mode: Bluetooth LE (iPA) - LE2M				
2.1	15.247 (b), 5.4 and 6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013)
2.2	15.247 (e), 5.2 and 6.12	Power Spectral Density	Pass	ANSI C63.10 (2013)
2.3	15.247 (a)(2), 5.2 and 6.6	Emission Bandwidth	Pass	ANSI C63.10 (2013)
2.4	15.247 (d), 5.5 and N/A	Authorised Band Edges	Pass	ANSI C63.10 (2013)
2.5	15.205 N/A and 8.10	Restricted Band Edges	Pass	ANSI C63.10 (2013)



Configuration and Mode: Bluetooth (ePA) – HDR4/HDR8				
2.1	15.247 (b), 5.4 and 6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013)
2.2	15.247 (e), 5.2 and 6.12	Power Spectral Density	Pass	ANSI C63.10 (2013)
2.3	15.247 (a)(2), 5.2 and 6.6	Emission Bandwidth	Pass	ANSI C63.10 (2013)
2.4	15.247 (d), 5.5 and N/A	Authorised Band Edges	Pass	ANSI C63.10 (2013)
2.5	15.205 N/A and 8.10	Restricted Band Edges	Pass	ANSI C63.10 (2013)
2.6	15.247 (d), 15.205, 5.5 and 6.13	Spurious Radiated Emissions	Pass	ANSI C63.10 (2013)
Configuration and Mode: Bluetooth (iPA) – HDR4/HDR8				
2.1	15.247 (b), 5.4 and 6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013)
2.2	15.247 (e), 5.2 and 6.12	Power Spectral Density	Pass	ANSI C63.10 (2013)
2.3	15.247 (a)(2), 5.2 and 6.6	Emission Bandwidth	Pass	ANSI C63.10 (2013)

Table 2



1.4 Product Information

1.4.1 Technical Description

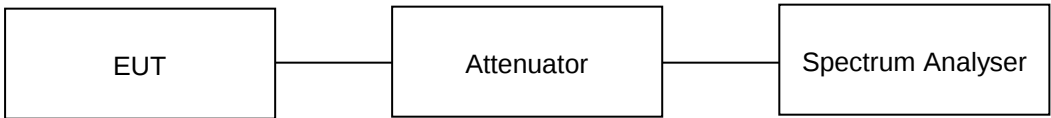
The Equipment Under Test (EUT) was a laptop computer with Bluetooth, Bluetooth Low Energy and 802.11 a/b/g/n/ac capabilities in the 2.4GHz and 5GHz bands.

1.4.2 Details of Antenna Assembly and Cable Loss

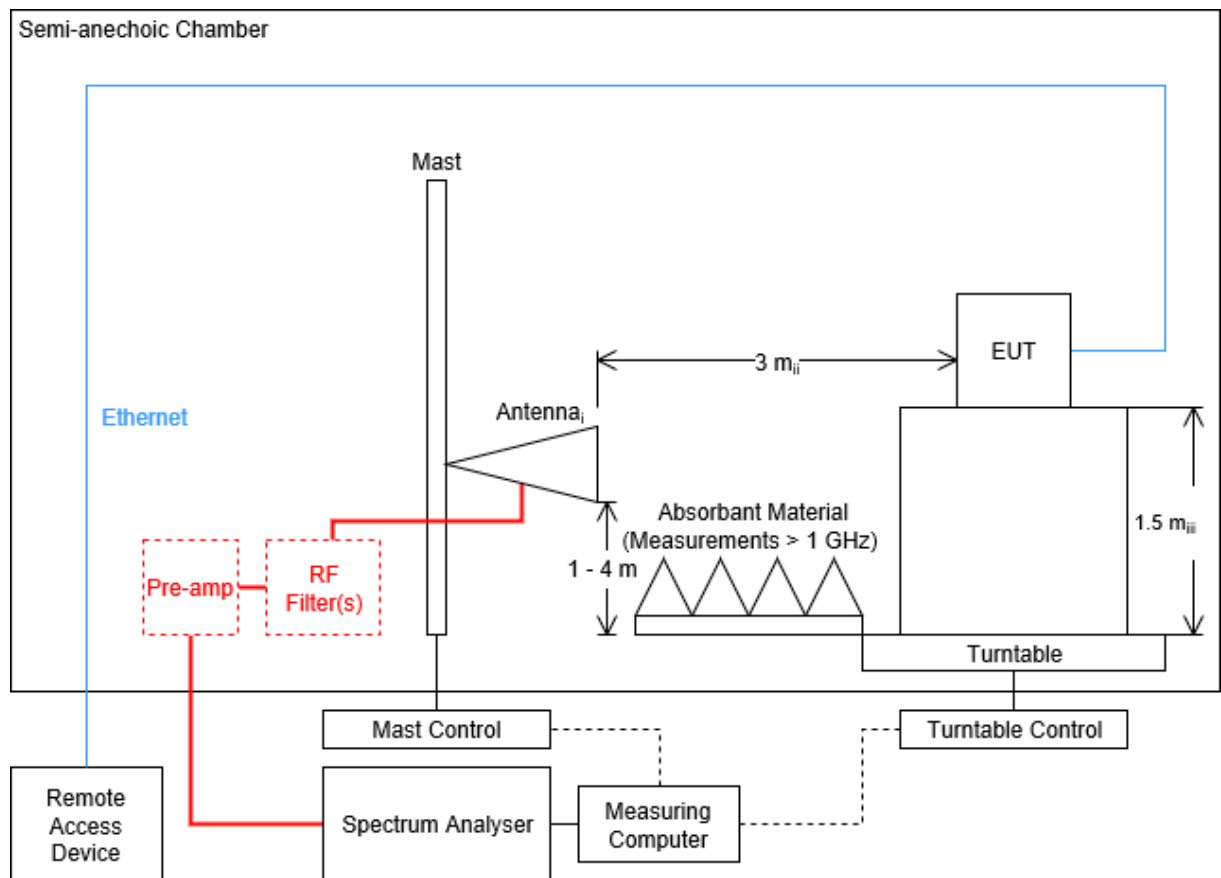
Detailed below are the antenna gains for each port as declared by the manufacturer. Also given are the declared losses of internal test cables fitted to provide a means of conducted antenna port testing.

Frequency (MHz)	Peak Gain (dBi)	Conducted Cable Loss (dB)
2400 – 2480	1.91	0.7

1.4.3 Conducted Test Setup Diagram(s)



1.4.4 Radiated Test Setup Diagram(s)



- i Antenna is boresighted for measurements > 1 GHz.
- ii Distance from antenna to EUT is 1 m for measurements > 18 GHz.
- iii Height of EUT above the ground plane is 0.8 m for measurements < 1 GHz.



1.4.5 EUT Configuration and Rationale for Radiated Spurious Emissions

The EUT was powered and charging from 120V, 60Hz via its USB type C power adaptor.

The spare USB type C port on the device, was connected (via a Belkin F2CU040 USB-C to Ethernet adapter) to another laptop computer located outside the test chamber which was used to remotely control the unit.

A set of wired Ear Pods were connected to the EUT

The Bluetooth transmitter was enabled. as detailed in section 2.8

1.5 Deviations from the Standard

No deviations from the applicable test standard were made during testing.



1.6 EUT Modification Record

The table below details modifications made to the EUT during the test programme.
The modifications incorporated during each test are recorded on the appropriate test pages.

Modification State	Description of Modification still fitted to EUT	Modification Fitted By	Date Modification Fitted
Serial Number: C02Y4006L59F			
0	As supplied by the customer	Not Applicable	Not Applicable
Serial Number: C02Y400PL5FL			
0	As supplied by the customer	Not Applicable	Not Applicable
Serial Number: C02Y5001L5G8			
0	As supplied by the customer	Not Applicable	Not Applicable

Table 3



1.7 Test Location

TÜV SÜD conducted the following tests at our Fareham Test Laboratory.

Test Name	Name of Engineer(s)	Accreditation
Configuration and Mode: Bluetooth LE (iPA) - LE1M / LE2M		
Maximum Conducted Output Power	Matthew Russell	UKAS
Power Spectral Density	Matthew Russell	UKAS
Emission Bandwidth	Mehadi Choudury	UKAS
Authorised Band Edges	Malik Mohammed, George Porter, Cristian Onaca, Jay Balendrarajah, Daniel Bishop.	UKAS
Restricted Band Edges		UKAS
Spurious Radiated Emissions		UKAS
Configuration and Mode: Bluetooth (iPA) – HDR4/HDR8		
Maximum Conducted Output Power	Mehadi Choudhury	UKAS
Power Spectral Density	Mehadi Choudhury	UKAS
Emission Bandwidth	Mehadi Choudhury	UKAS
Configuration and Mode: Bluetooth (ePA) – HDR4/HDR8		
Maximum Conducted Output Power	Mehadi Choudhury	UKAS
Power Spectral Density	Mehadi Choudhury	UKAS
Emission Bandwidth	Mehadi Choudhury	UKAS
Authorised Band Edges	Malik Mohammed, George Porter, Cristian Onaca, Jay Balendrarajah, Daniel Bishop.	UKAS
Restricted Band Edges		UKAS
Spurious Radiated Emissions		UKAS

Table 4

Office Address:

Octagon House
 Concorde Way
 Segensworth North
 Fareham
 Hampshire
 PO15 5RL
 United Kingdom



2 Test Details

2.1 Maximum Conducted Output Power

2.1.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (b)(1)
Industry Canada RSS-247, Clause 5.4
Industry Canada RSS-GEN, Clause 6.12

2.1.2 Equipment Under Test and Modification State

A2159, S/N: C02Y5001L5G8 - Modification State 0

2.1.3 Date of Test

19-March-2019

2.1.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 11.9.1.1.

2.1.5 Environmental Conditions

Ambient Temperature 21.2 °C
Relative Humidity 35.6 %

2.1.6 Test Results

Bluetooth LE (iPA) - LE1M

Frequency (MHz)	Output Power	
	dBm	mW
2440	6.53	4.50
2480	6.79	4.78
2402	6.49	4.46

Table 5 - Maximum Conducted Output Power Results

Bluetooth LE (iPA) - LE2M

Frequency (MHz)	Output Power	
	dBm	mW
2440	6.90	4.90
2480	6.69	4.67
2402	6.49	4.46

Table 6 - Maximum Conducted Output Power Results



Bluetooth (ePA) - HDR4

Frequency (MHz)	Maximum Output Power	
	dBm	mW
2404	9.96	9.91
2441	9.85	9.66
2478	9.74	9.42

Table 7 - Maximum Conducted Output Power Results

Bluetooth (ePA) - HDR8

Frequency (MHz)	Maximum Output Power	
	dBm	mW
2404	9.70	9.33
2441	9.45	8.81
2478	9.89	9.75

Table 8 - Maximum Conducted Output Power Results

Bluetooth (iPA) - HDR4

Frequency (MHz)	Maximum Output Power	
	dBm	mW
2404	5.32	3.40
2441	5.41	3.48
2478	5.33	3.41

Table 9 - Maximum Conducted Output Power Results

Bluetooth (iPA) - HDR8

Frequency (MHz)	Maximum Output Power	
	dBm	mW
2404	5.13	3.26
2441	5.16	3.28
2478	5.13	3.22

Table 10 - Maximum Conducted Output Power Results

Note: The device has a peak antenna gain of 1.91dBi, which would result in a peak EIRP of 11.87dBm (15.38mW) when operating in (ePA) HDR4 mode.



FCC 47 CFR Part 15, Limit Clause 15.247 (b)(3)

For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands: 1 Watt.

Industry Canada RSS-247, Limit Clause 5.4 (d)

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

2.1.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 3.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
EXA	Keysight Technologies	N9010B	4969	24	21-Dec-2019
Network Analyser	Keysight Technologies	E5063A	5018	12	04-May-2019
Electronic Calibration Module	Keysight Technologies	85093C	5188	12	25-Apr-2019
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 11

O/P Mon – Output Monitored Using Calibrated Equipment



2.2 Power Spectral Density

2.2.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.247 (e), 5.2 and 6.12

2.2.2 Equipment Under Test and Modification State

A2159, S/N: C02Y5001L5G8 - Modification State 0

2.2.3 Date of Test

20-March-2019 to 18-April-2019

2.2.4 Test Method

The EUT was connected to a spectrum analyser via a cable and attenuator. The span was adjusted to display the entire fundamental on screen. Due to the swept peak detector and the number of sweep points used, this was deemed an acceptable alternative to the 1.5 x DTS bandwidth specified in ANSI C63.10, section 11.10.2 b).

Using a peak detector and max hold trace with an RBW of 3 kHz and VBW of 9.1 kHz, the marker was used to determine the peak PSD and this result was recorded in the tables below.

Results are recorded in dBm/3 kHz.

2.2.5 Environmental Conditions

Ambient Temperature 24.3 °C to 24.6 °C
Relative Humidity 31.7% to 34.9 %

2.2.6 Test Results

Bluetooth LE (iPA) - LE1M

Modulation/Packet Type: GFSK/DH1

Frequency (MHz)	Power Spectral Density (dBm)
2402	-10.36
2440	-10.68
2480	-10.61

Table 12 - Power Spectral Density

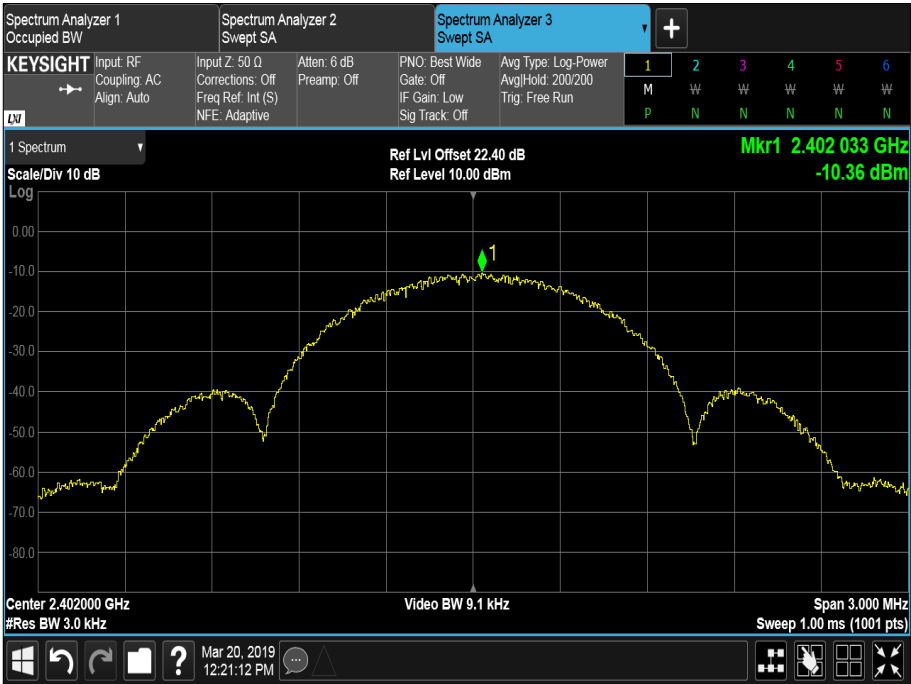


Figure 1 - 2402 MHz, Power Spectral Density

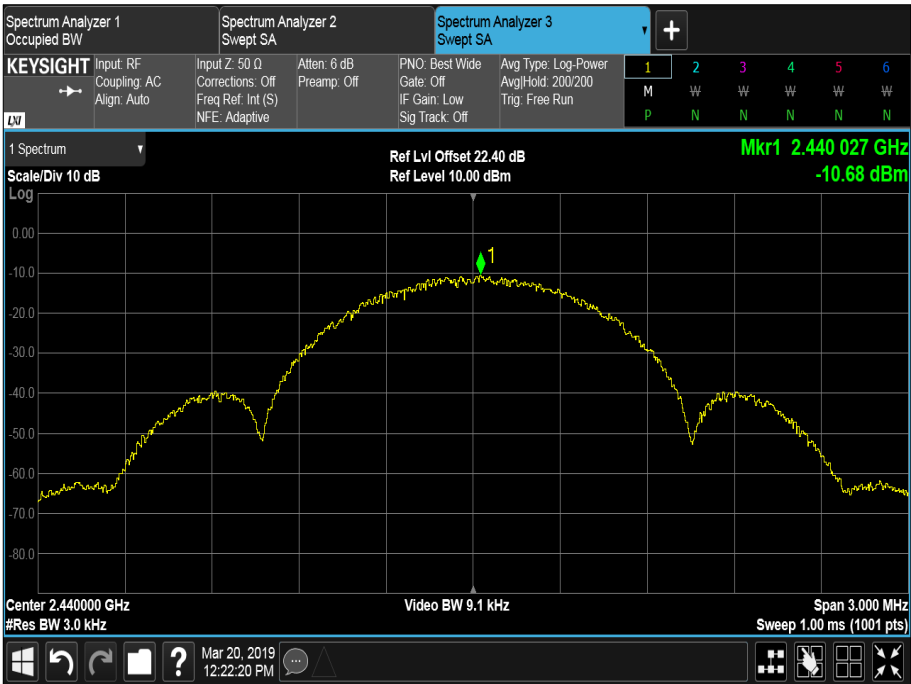


Figure 2 - 2440 MHz, Power Spectral Density

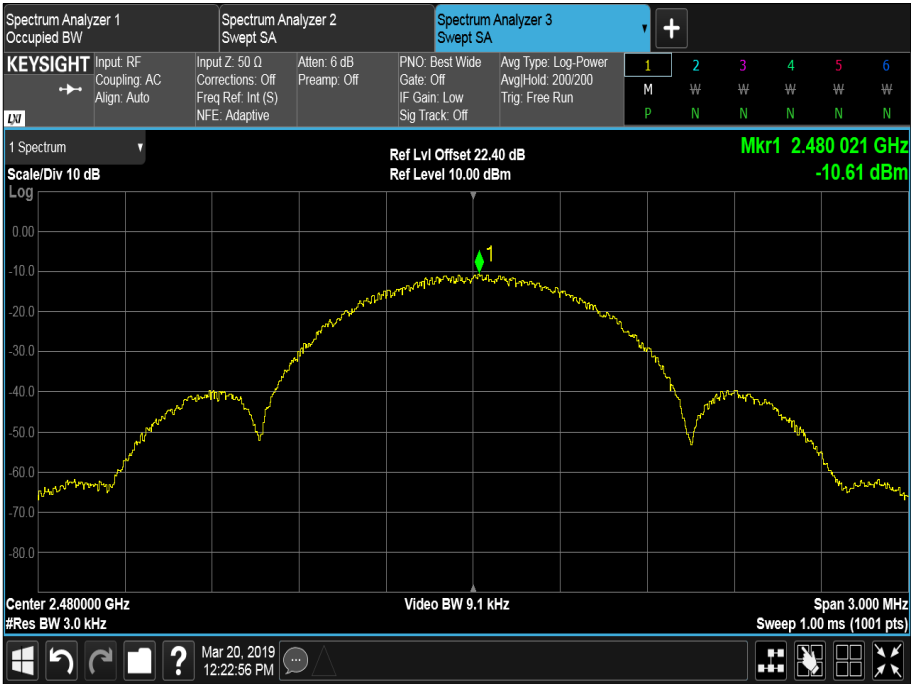


Figure 3 - 2480 MHz, Power Spectral Density



Bluetooth LE (iPA) - LE2M

Modulation/Packet Type: GFSK/DH1

Frequency (MHz)	Power Spectral Density (dBm)
2402	-11.20
2440	-11.84
2480	-11.25

Table 13 - Power Spectral Density

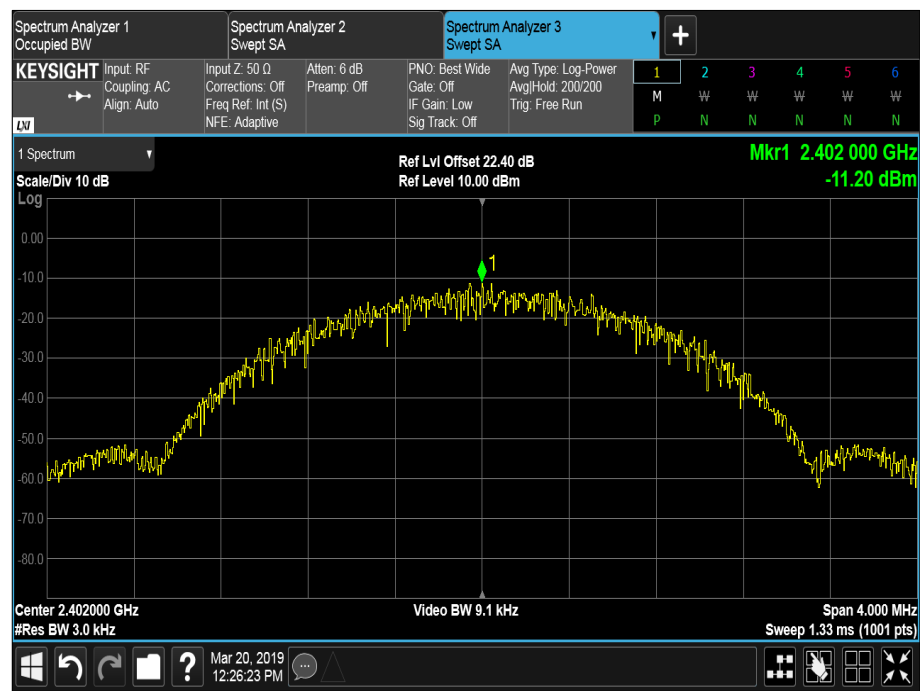


Figure 4 - 2402 MHz, Power Spectral Density

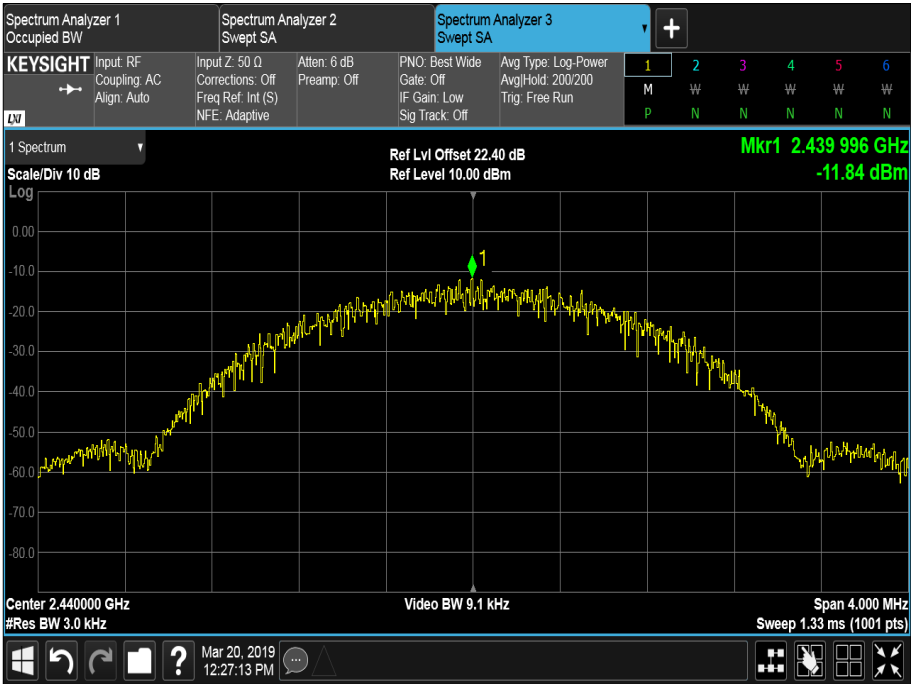


Figure 5 - 2440 MHz, Power Spectral Density

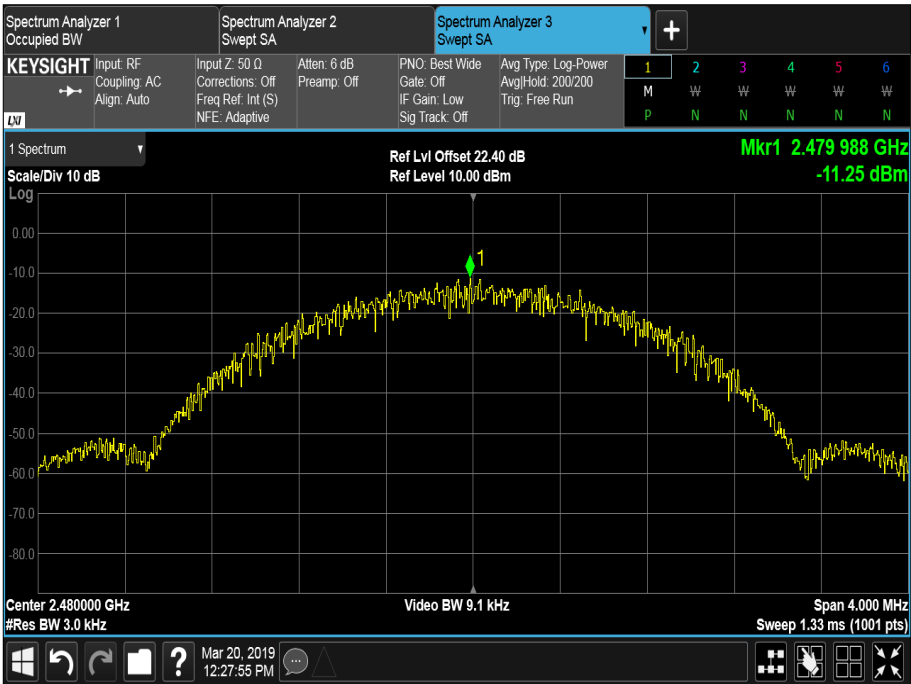


Figure 6 - 2480 MHz, Power Spectral Density



Bluetooth (ePA) – HDR4

Modulation/Packet Type: 4DH5

Frequency (MHz)	Power Spectral Density (dBm)
2404	1.75
2441	1.96
2478	0.97

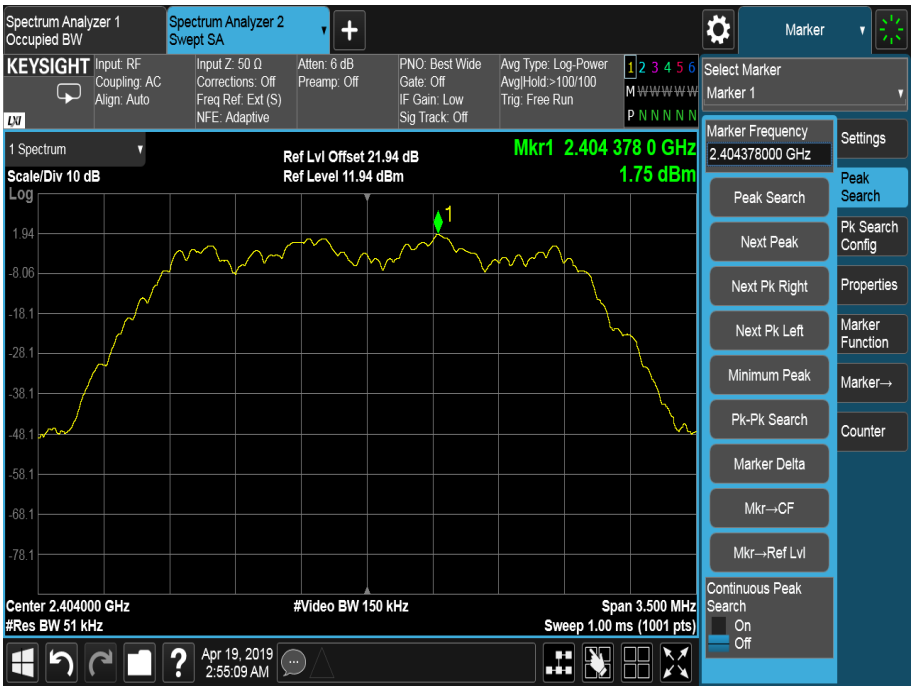


Figure 7 - 2404 MHz, Power Spectral Density

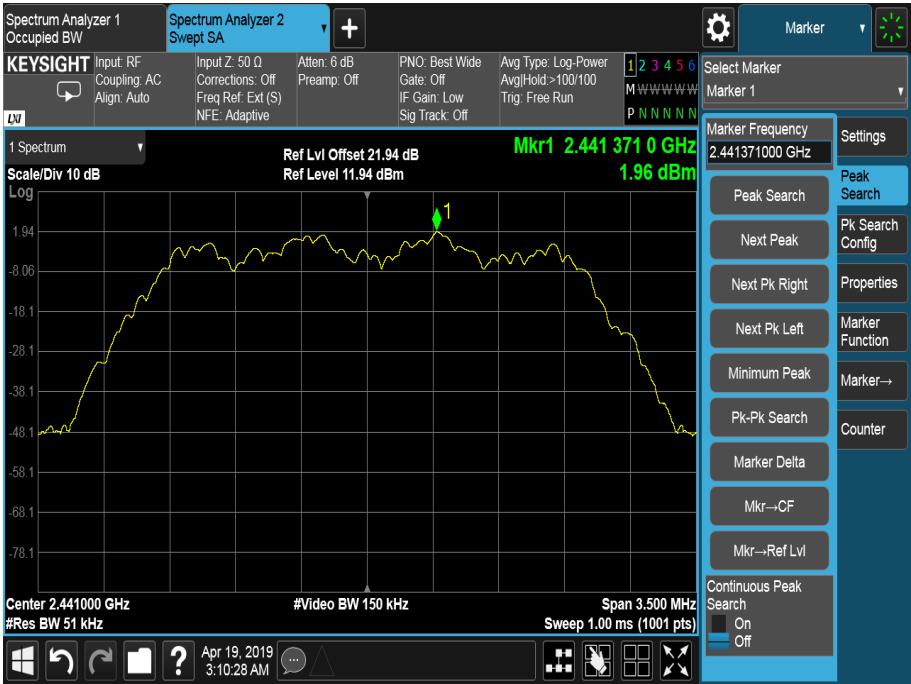


Figure 8 - 2441 MHz, Power Spectral Density

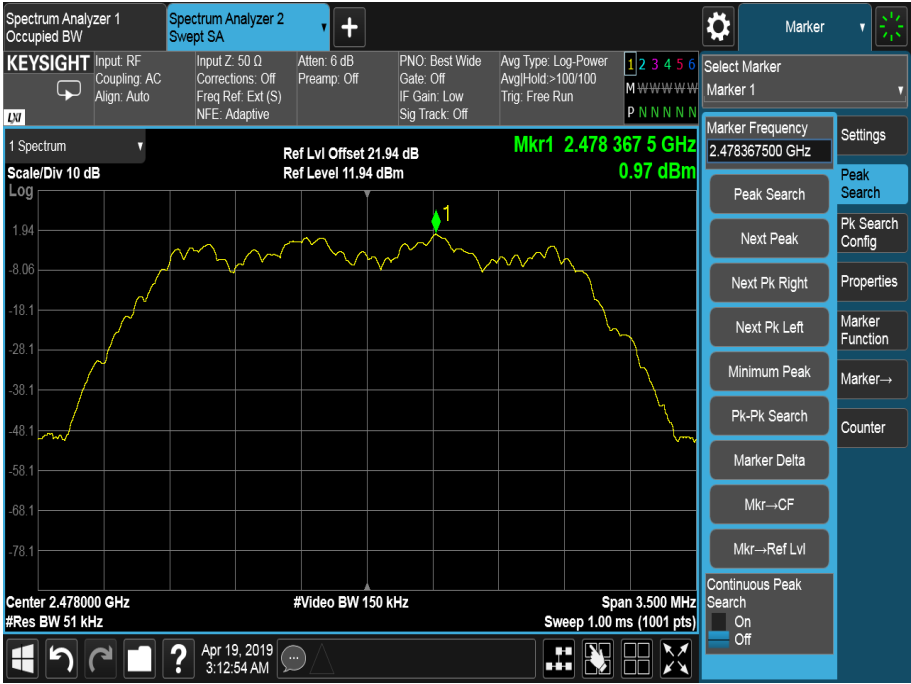


Figure 9 - 2478 MHz, Power Spectral Density



Bluetooth (ePA) – HDR8

Modulation/Packet Type: 8DH5

Frequency (MHz)	Power Spectral Density (dBm)
2404	-0.09
2441	-0.23
2478	-0.45

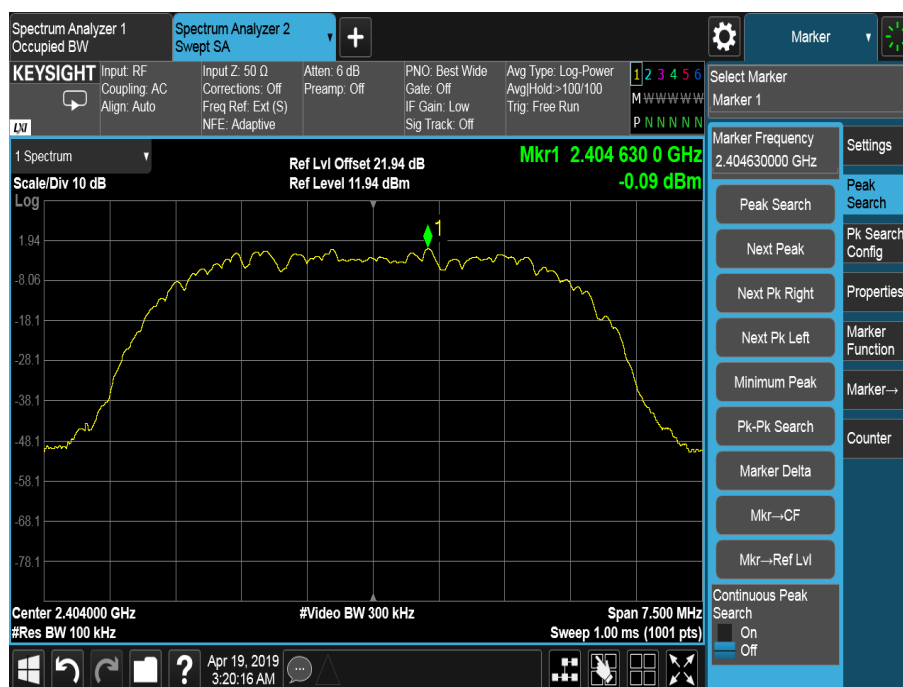


Figure 10 - 2404 MHz, Power Spectral Density

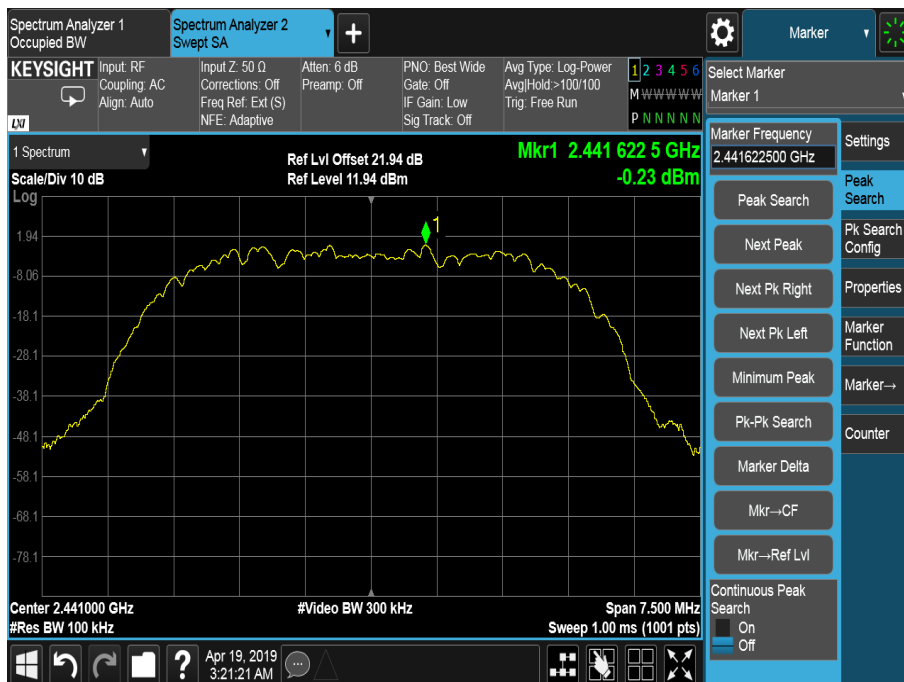


Figure 11 - 2441 MHz, Power Spectral Density

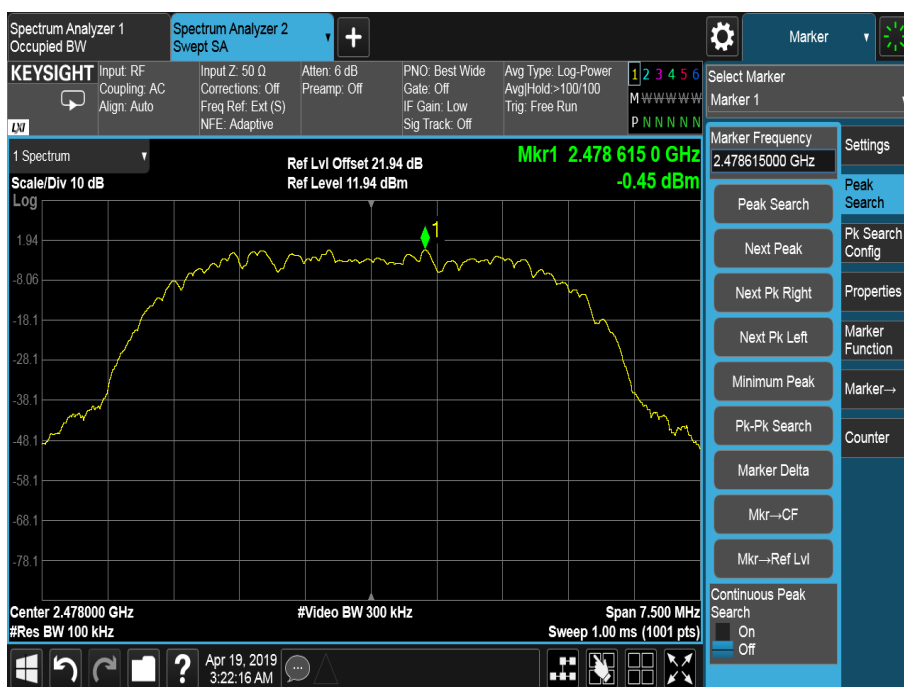


Figure 12 - 2478 MHz, Power Spectral Density



Bluetooth (iPA) – HDR4

Modulation/Packet Type: 4DH5

Frequency (MHz)	Power Spectral Density (dBm)
2404	-3.13
2441	-3.10
2478	-3.53

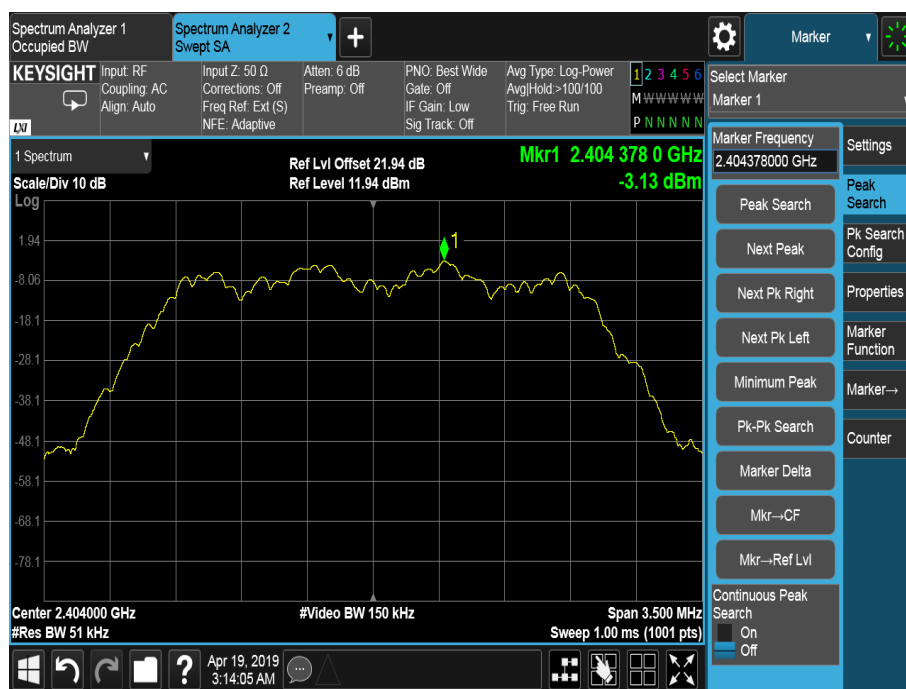


Figure 13 - 2404 MHz, Power Spectral Density



Figure 14 - 2441 MHz, Power Spectral Density



Figure 15 - 2478 MHz, Power Spectral Density



Bluetooth (iPA) – HDR8

Modulation/Packet Type: 8DH5

Frequency (MHz)	Power Spectral Density (dBm)
2404	-4.71
2441	-4.70
2478	-5.10

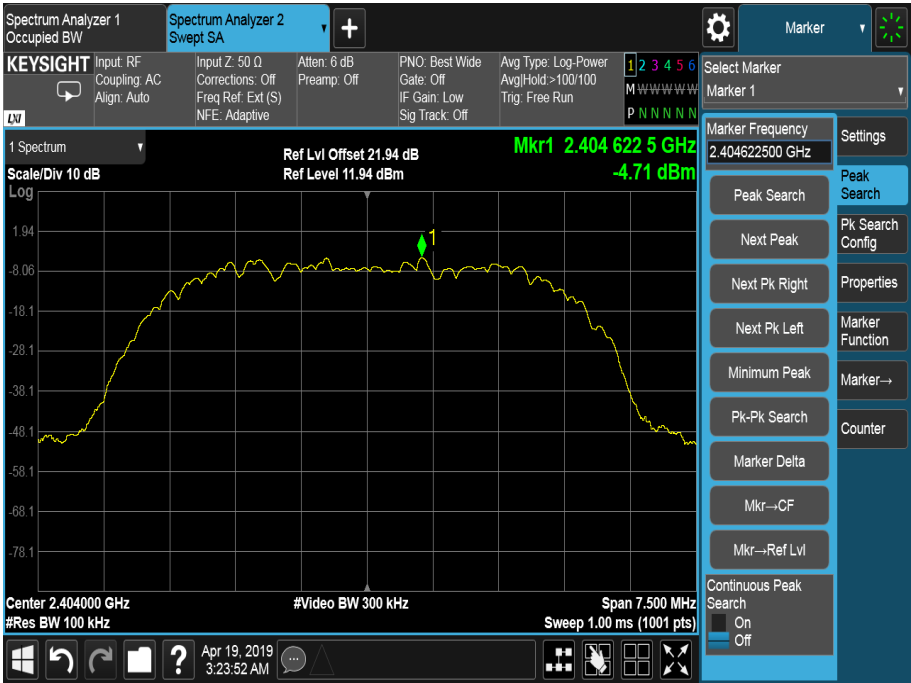


Figure 16 - 2404 MHz, Power Spectral Density

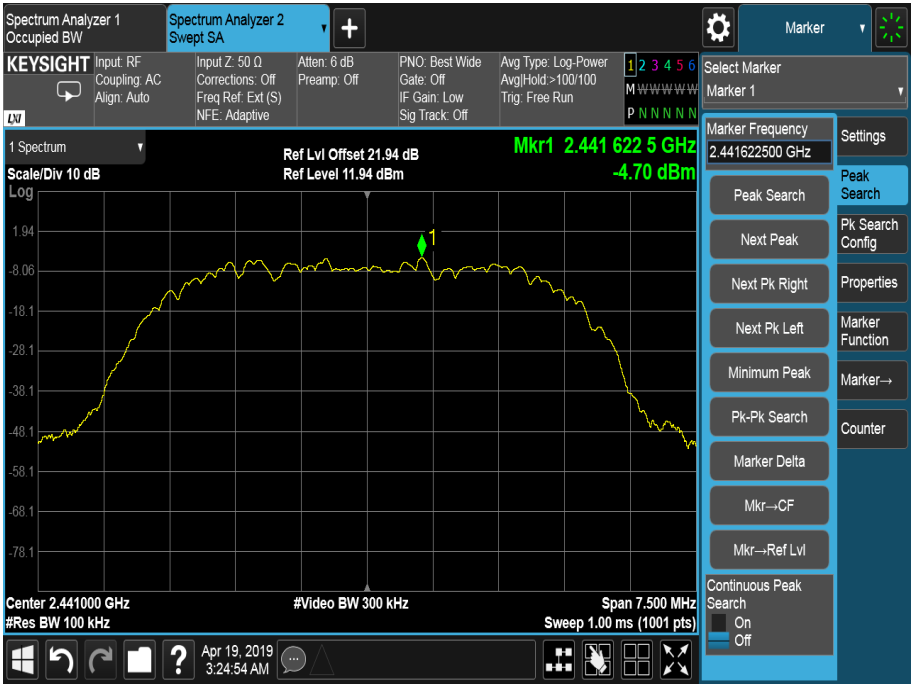


Figure 17 - 2441 MHz, Power Spectral Density

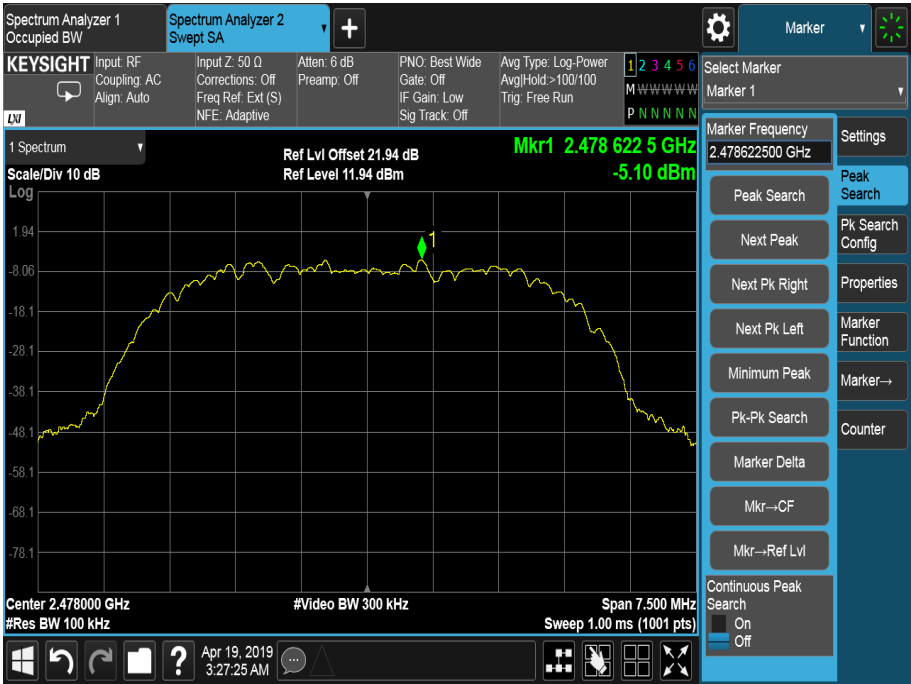


Figure 18 - 2478 MHz, Power Spectral Density



FCC 47 CFR Part 15, Limit Clause 15.247 (e)

The 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.

Industry Canada RSS-247, Limit Clause 5.2(b)

The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission

2.2.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 3.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	16-Apr-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Network Analyser	Rohde & Schwarz	ZVA 40	3548	12	17-Oct-2019
Calibration Unit	Rohde & Schwarz	ZV-Z54	4368	12	22-Oct-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	16-Apr-2019
EXA	Keysight Technologies	N9010B	4969	24	21-Dec-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Cable (40GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
Cable (40GHz)	Rosenberger	LU1-001-2000	4393	-	O/P Mon
Network Analyser	Keysight Technologies	E5063A	5018	12	04-May-2019
Cable (18GHz)	Rosenberger	LU7-036-2000	5039	-	O/P Mon
Electronic Calibration Module	Keysight Technologies	85093C	5188	12	25-Apr-2019
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 14

O/P Mon – Output Monitored using calibrated equipment



2.3 Emission Bandwidth

2.3.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.247 (a)(2), 5.2 and 6.6

2.3.2 Equipment Under Test and Modification State

A2159, S/N: C02Y400PL5FL - Modification State 0

2.3.3 Date of Test

05-March-2019 & 19-April-2019

2.3.4 Test Method

This test was performed in accordance with ANSI C63.10, clause 11.8.1.

2.3.5 Environmental Conditions

Ambient Temperature 22.0 °C to 24.6 °C

Relative Humidity 31.7 % to 44.0 %

2.3.6 Test Results

Bluetooth LE (iPA) - LE1M

Modulation/Packet Type: GFSK/DH1

Frequency (MHz)	6 dB Bandwidth (MHz)	99% Occupied Bandwidth (MHz)
2402	710.0	1.071
2440	708.6	1.070
2480	708.7	1.070

Table 15

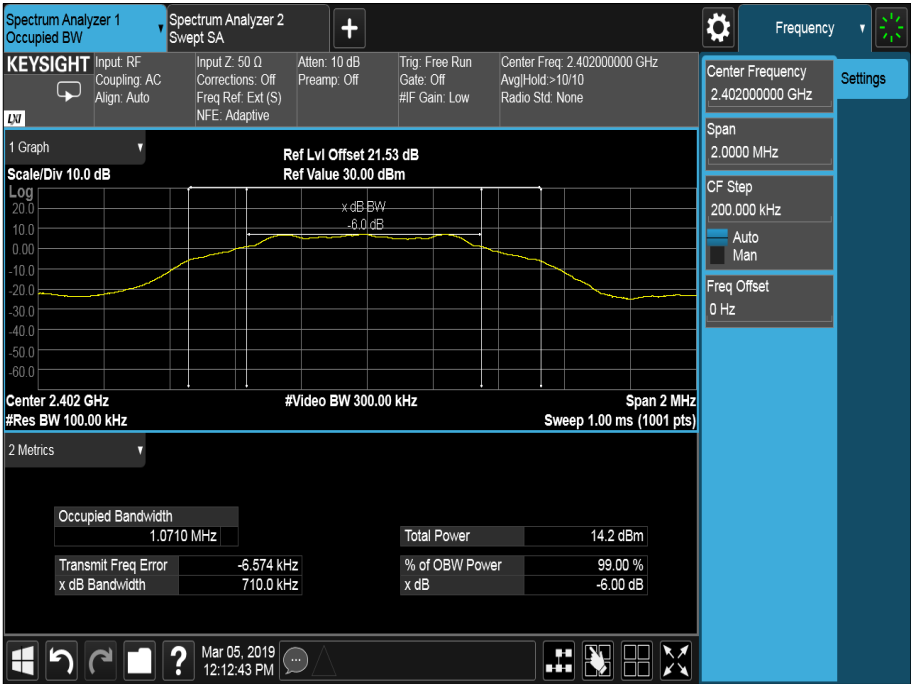


Figure 19 - 2402 MHz

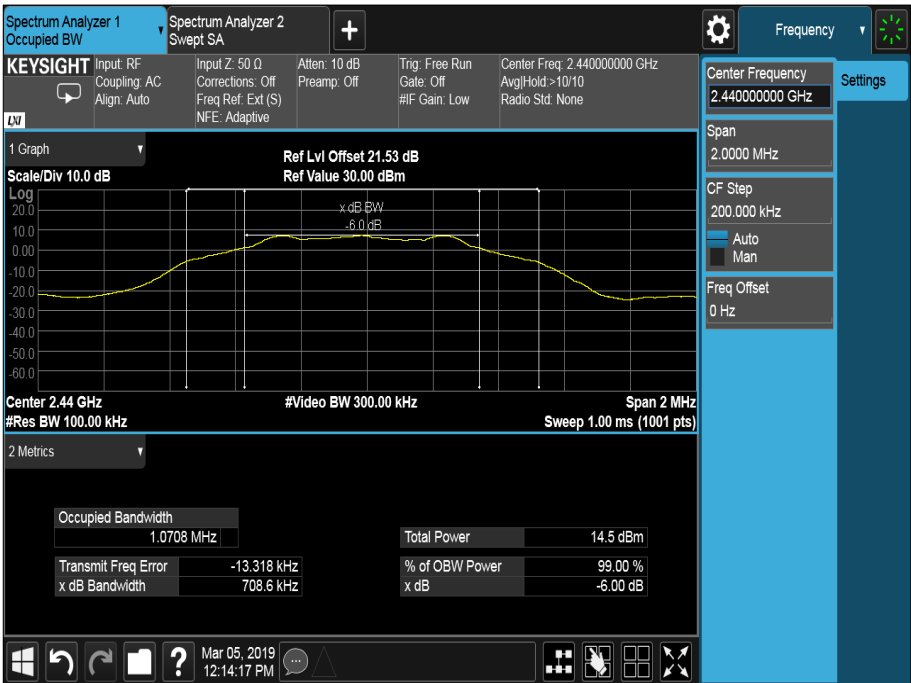


Figure 20 - 2440 MHz

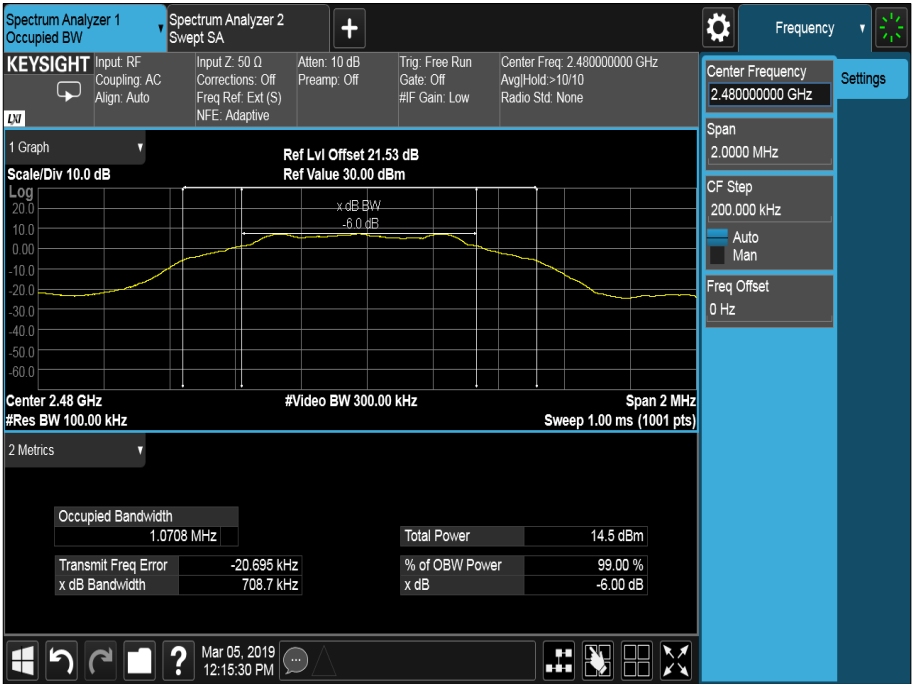


Figure 21 - 2480 MHz



Bluetooth LE (iPA) - LE2M

Modulation/Packet Type: GFSK/DH1

Frequency (MHz)	6 dB Bandwidth (MHz)	99% Occupied Bandwidth (MHz)
2402	1.254	2.056
2480	1.252	2.057
2480	1.252	2.057

Table 16



Figure 22 - 2402 MHz



Figure 23 - 2480 MHz



Figure 24 - 2480 MHz



Bluetooth (ePA) – HDR4

Modulation/Packet Type: 4DH5

Frequency (MHz)	6 dB Bandwidth (MHz)	99% Occupied Bandwidth (MHz)
2404	2.101	2.322
2441	2.101	2.323
2478	2.102	2.323

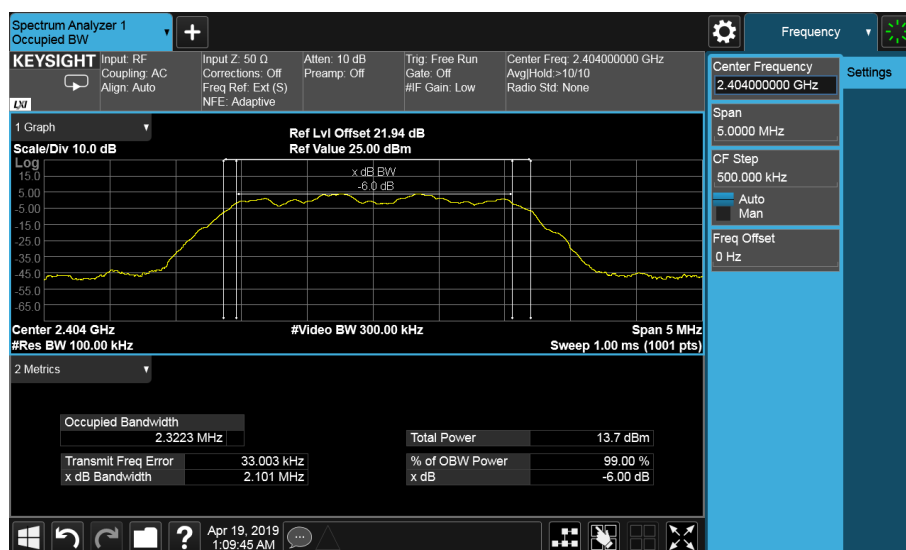


Figure 25 - 2404 MHz

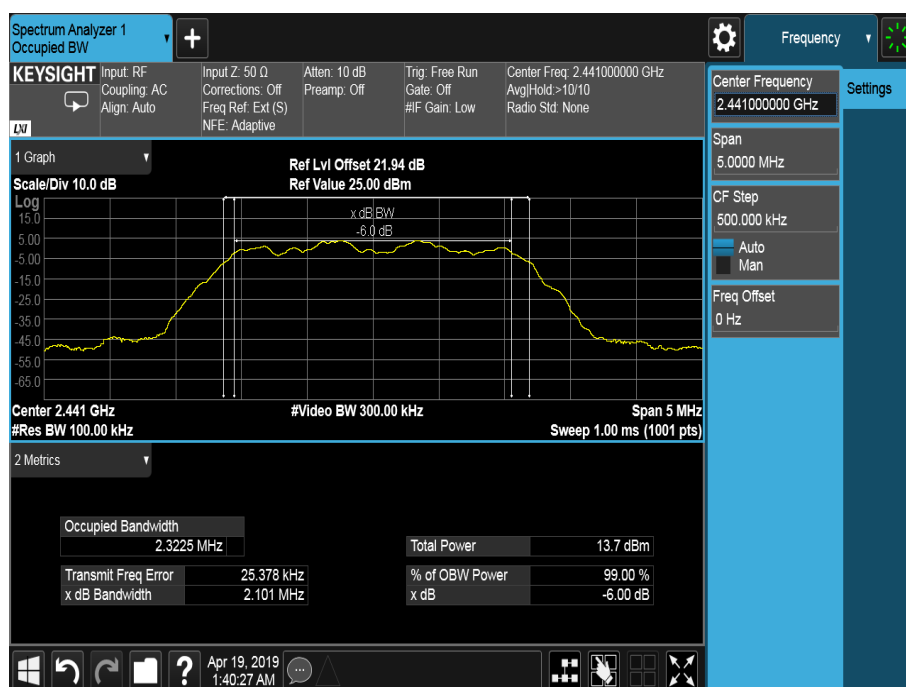


Figure 26 - 2441 MHz

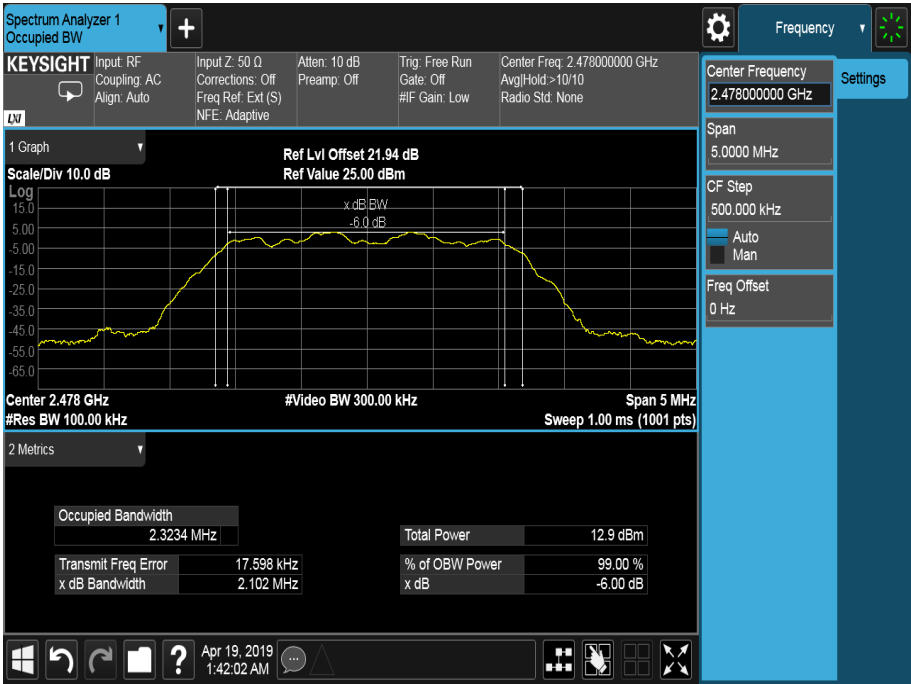


Figure 27 - 2478 MHz



Bluetooth (ePA) – HDR8

Modulation/Packet Type: 8DH5

Frequency (MHz)	6 dB Bandwidth (MHz)	99% Occupied Bandwidth (MHz)
2404	4.083	4.784
2441	4.070	4.777
2478	4.063	4.779

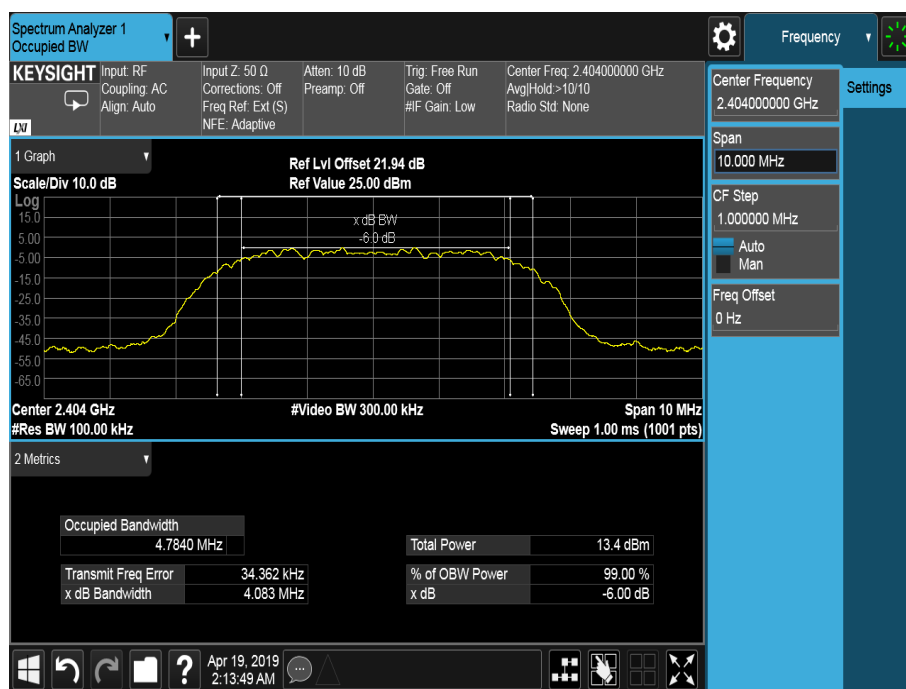


Figure 28 - 2404 MHz

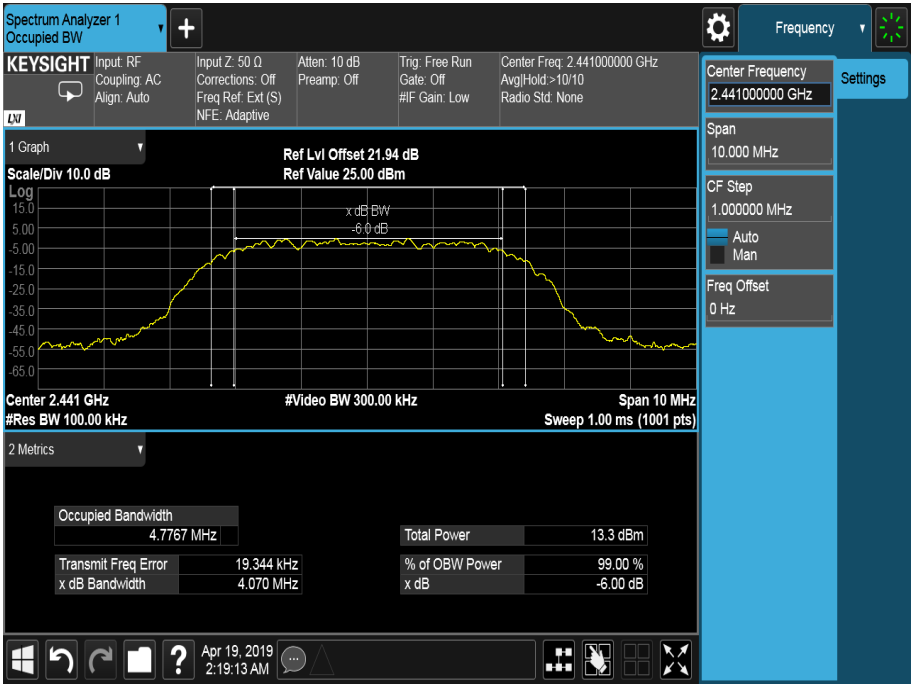


Figure 29 - 2441 MHz

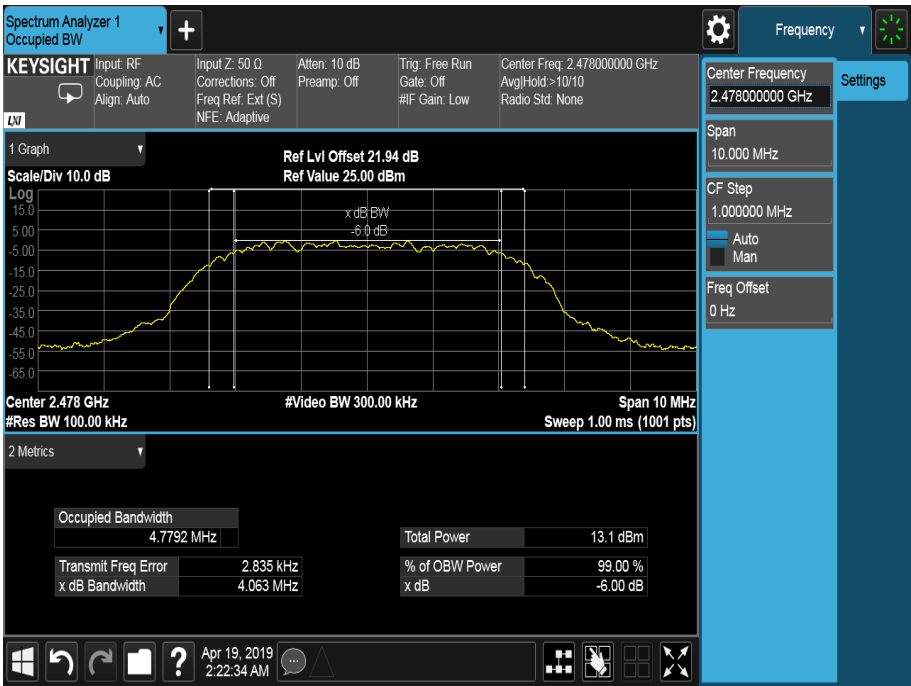


Figure 30 - 2478 MHz



Bluetooth (iPA) – HDR4

Modulation/Packet Type: 4DH5

Frequency (MHz)	6 dB Bandwidth (MHz)	99% Occupied Bandwidth (MHz)
2404	2.101	2.323
2441	2.098	2.324
2478	2.099	2.324

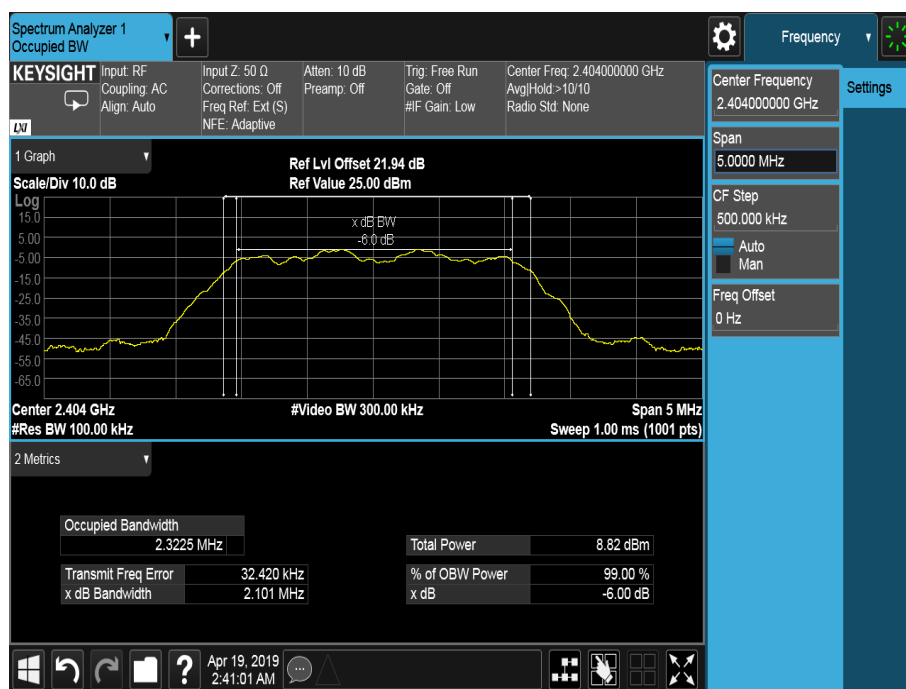


Figure 31 - 2404 MHz

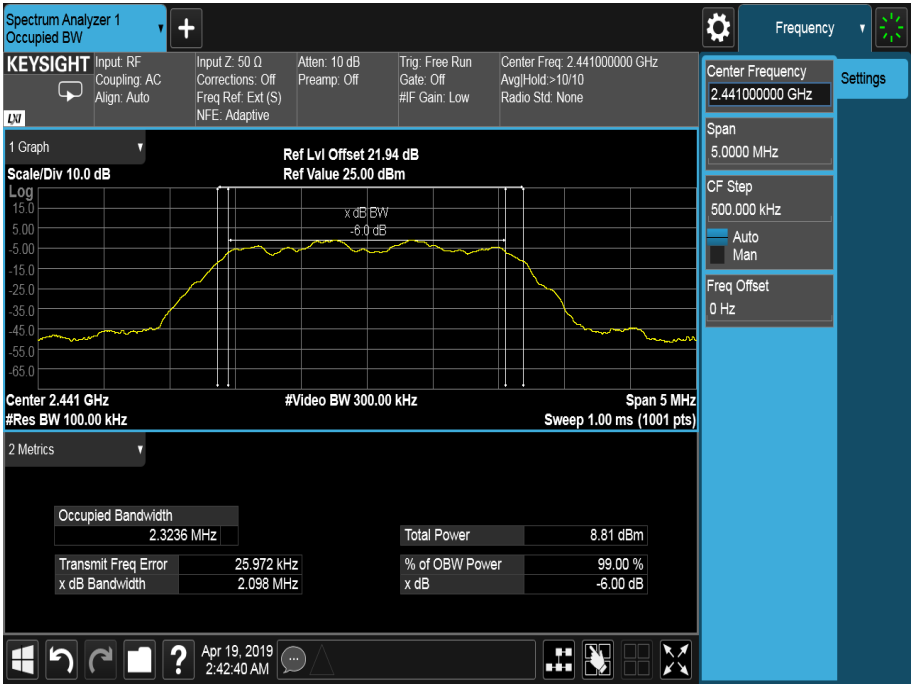


Figure 32 - 2441 MHz

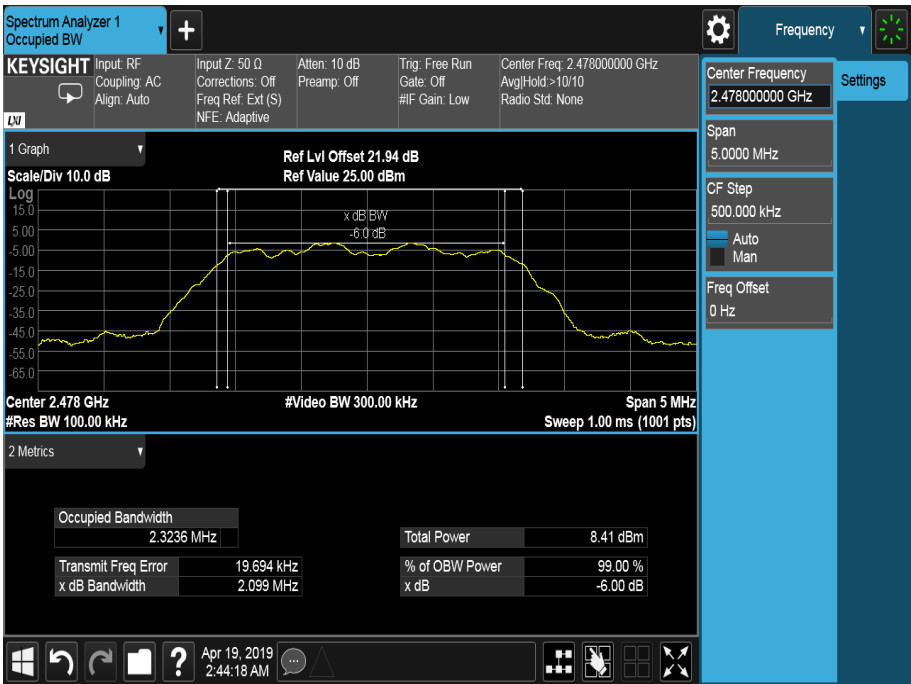


Figure 33 - 2478 MHz



Bluetooth (iPA) – HDR8

Modulation/Packet Type: 8DH5

Frequency (MHz)	6 dB Bandwidth (MHz)	99% Occupied Bandwidth (MHz)
2404	4.080	4.778
2441	4.072	4.779
2478	4.075	4.778



Figure 34 - 2404 MHz

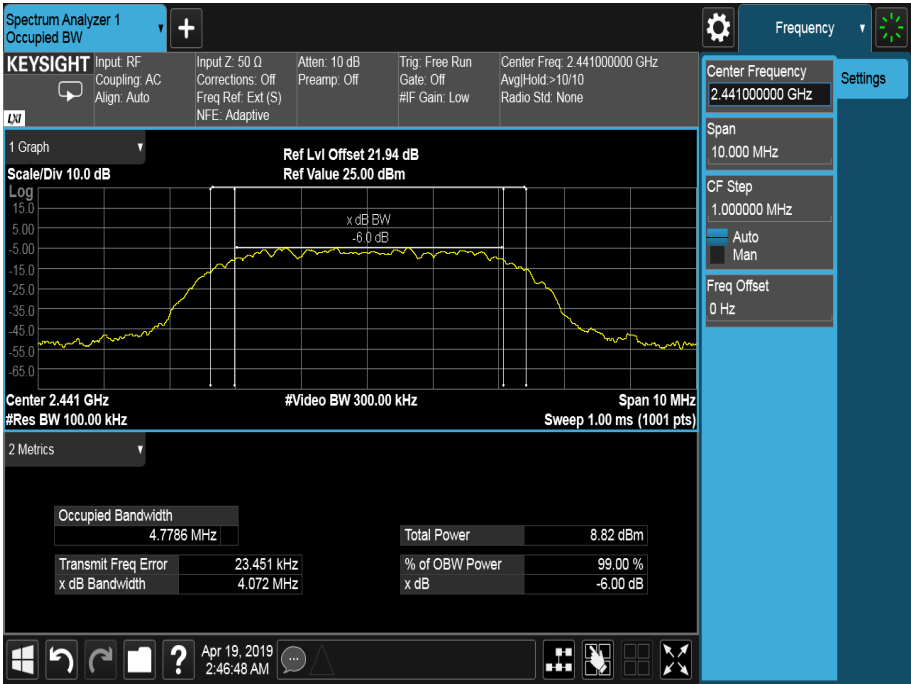


Figure 35 - 2441 MHz

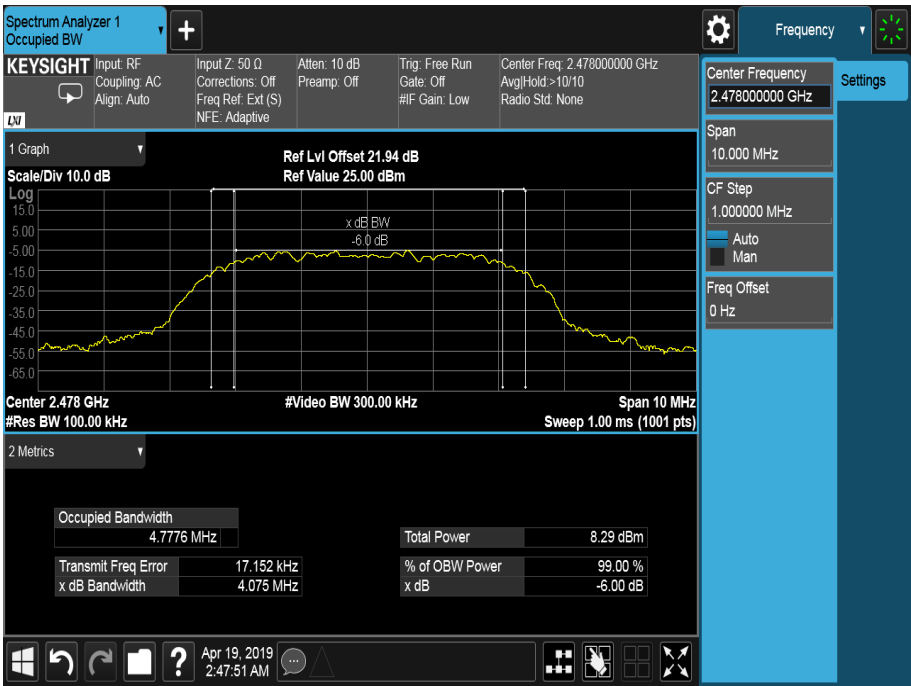


Figure 36 - 2478 MHz

FCC 47 CFR Part 15, Limit Clause 15.247(a)(2) and Industry Canada RSS-247, Clause 5.2(a)

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



2.3.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 3

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	16-Apr-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Network Analyser	Rohde & Schwarz	ZVA 40	3548	12	17-Oct-2019
Calibration Unit	Rohde & Schwarz	ZV-Z54	4368	12	22-Oct-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	16-Apr-2019
EXA	Keysight Technologies	N9010B	4969	24	21-Dec-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Cable (40GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
Cable (40GHz)	Rosenberger	LU1-001-2000	4393	-	O/P Mon
Network Analyser	Keysight Technologies	E5063A	5018	12	04-May-2019
Cable (18GHz)	Rosenberger	LU7-036-2000	5039	-	O/P Mon
Electronic Calibration Module	Keysight Technologies	85093C	5188	12	25-Apr-2019
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 17

O/P Mon – Output Monitored Using Calibrated Equipment



2.4 Authorised Band Edges

2.4.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.247 (d), 5.5 and N/A

2.4.2 Equipment Under Test and Modification State

A2159, S/N: C02Y4006L59F - Modification State 0

2.4.3 Date of Test

16-Feb-2019 to 16-March-2019

2.4.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 6.10.4.

2.4.5 Environmental Conditions

Ambient Temperature 22.9 - 23.3 °C

Relative Humidity 30.7 - 34.8 %

2.4.6 Test Results

Bluetooth LE (iPA) - LE1M

Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
GFSK	DH1	2402	2400.0	-62.67

Table 18

Bluetooth LE (iPA) - LE2M

Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
GFSK	DH1	2402	2400.0	-39.99

Table 19

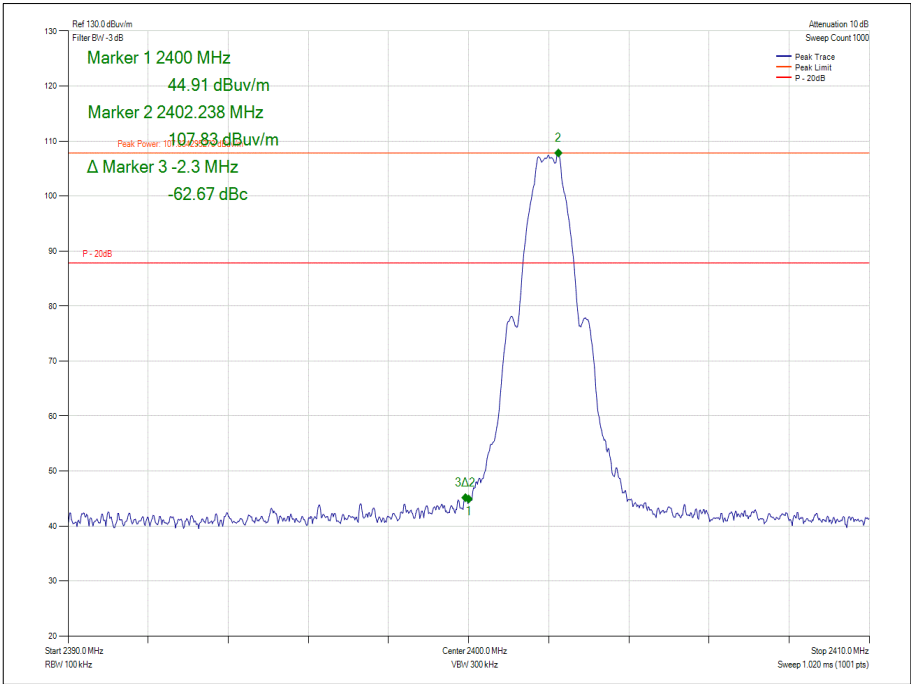


Figure 37 - GFSK/LE1M - 2402 MHz – Band Edge Frequency 2400.0 MHz

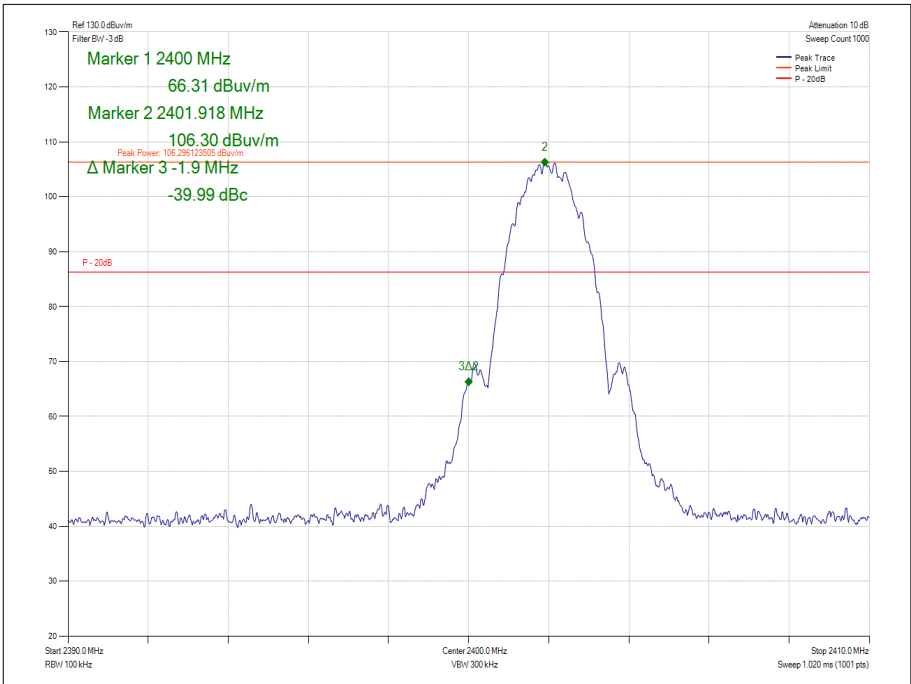


Figure 38 - GFSK/LE2M - 2402 MHz - Band Edge Frequency 2400.0 MHz



Bluetooth (ePA)

Mode	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
HDR4	2404	2399.0	-50.25
HDR8	2404	2399.9	-47.20

Table 20

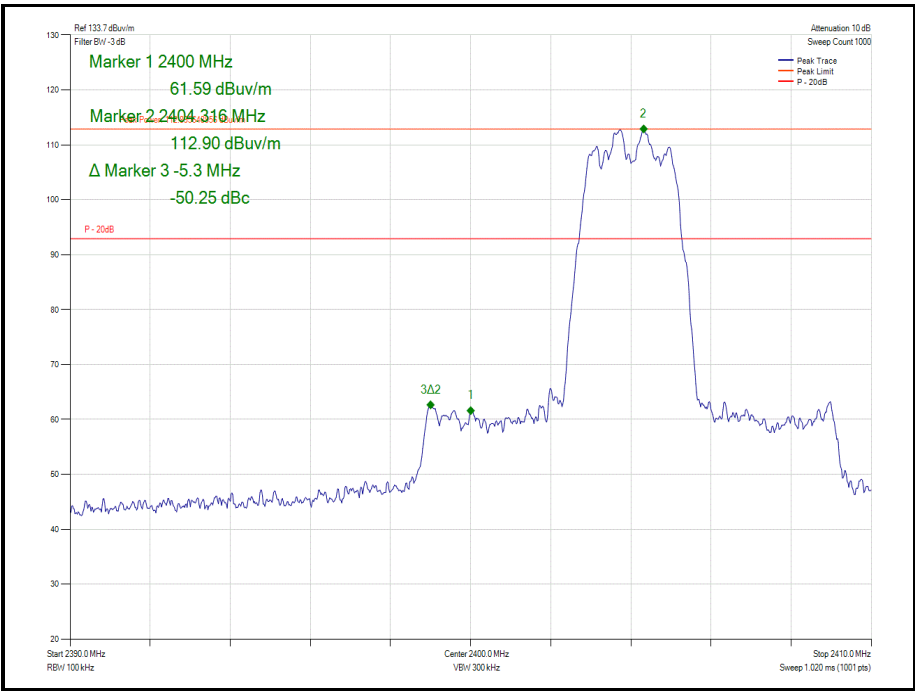


Figure 39 – HDR4 - 2404 MHz - Band Edge Frequency 2400 MHz

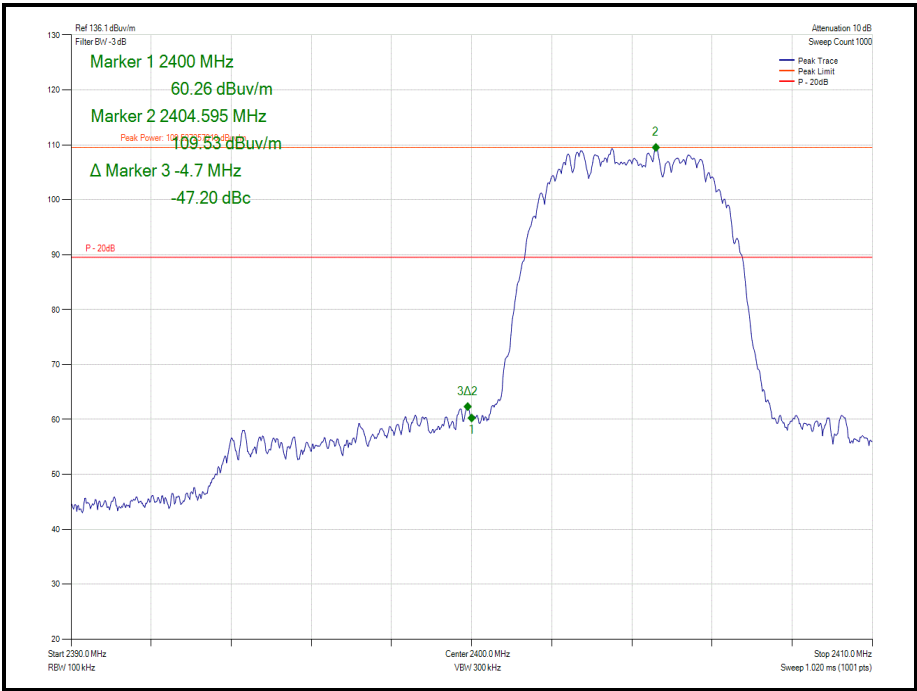


Figure 40 - HDR 8 - 2404 MHz - Band Edge Frequency 2400 MHz



FCC 47 CFR Part 15, Limit Clause 15.247 (d)

20 dB below the fundamental measured in a 100 kHz bandwidth using a peak detector. If the transmitter complies with the conducted power limits, based on the use of RMS averaging over a time interval, the attenuation required shall be 30 dB below the fundamental instead of 20 dB.

Industry Canada RSS-247, Limit Clause 5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under Section 5.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

2.4.7 Test Location and Test Equipment Used

This test was carried out in EMC Chamber 11

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Hygrometer	Rotronic	Hygropalm	2404	12	26-Apr-2019
Double Ridge Broadband Horn Antenna	Schwarzbeck	BBHA 9120 B	4848	12	12-Feb-2019
EMI Test Receiver	Rohde & Schwarz	ESW44	5084	12	12-Sep-2019
8m N-Type RF Cable	Teledyne	PR90-088-8MTR	5095	12	04-Oct-2019
Cable (18GHz)	Rosenberger	LU7-071-2000	5107	12	05-Oct-2019
Screened Room (11)	Rainford	Rainford	5136	36	01-Nov-2021
Mast	Maturo	TAM 4.0-P	5158	-	TU
Mast and Turntable Controller	Maturo	Maturo NCD	5159	-	TU
Turntable	Maturo	TT 15WF	5160	-	TU
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 21

TU - Traceability Unscheduled



2.5 Restricted Band Edges

2.5.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.205 N/A and 8.10

2.5.2 Equipment Under Test and Modification State

A2159, S/N: C02Y4006L59F - Modification State 0

2.5.3 Date of Test

16-Feb-2019 to 16-March-2019

2.5.4 Test Method

This test was performed in accordance with ANSI C63.10, clause 6.10.5.

Plots for average measurements were taken in accordance with ANSI C63.10 clause 4.1.4.2.3. These are shown for information purposes and were used to determine the worst-case measurement point. Final average measurements were then taken in accordance with ANSI C63.10 clause 4.1.4.2.2. to obtain the measurement result recorded in the test results tables.

The following conversion can be applied to convert from dBμV/m to μV/m:
 $10^{\frac{\text{Field Strength in dB}\mu\text{V/m}}{20}}$

2.5.5 Environmental Conditions

Ambient Temperature 23.1 - 23.3 °C
Relative Humidity 34.7 - 34.8 %

2.5.6 Test Results

Bluetooth LE (iPA) - LE1M

Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Peak Level (dBμV/m)	Average Level (dBμV/m)
GFSK	DH1	2402	2390.0	53.71	42.41
GFSK	DH1	2480	2483.5	52.42	42.26

Table 22

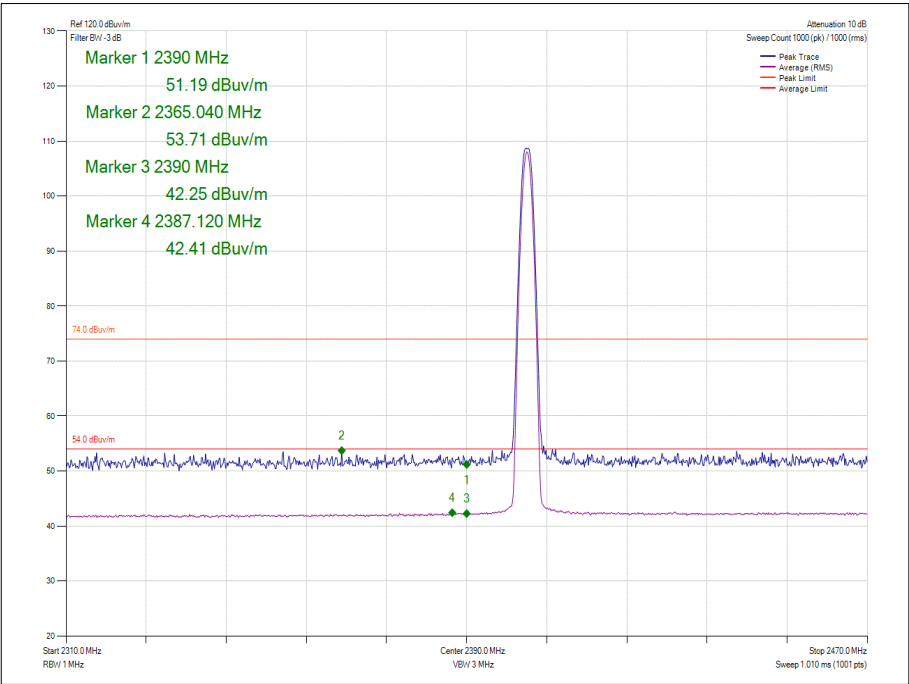


Figure 41 - GFSK/DH1 - 2402 MHz - Band Edge Frequency 2390.0 MHz

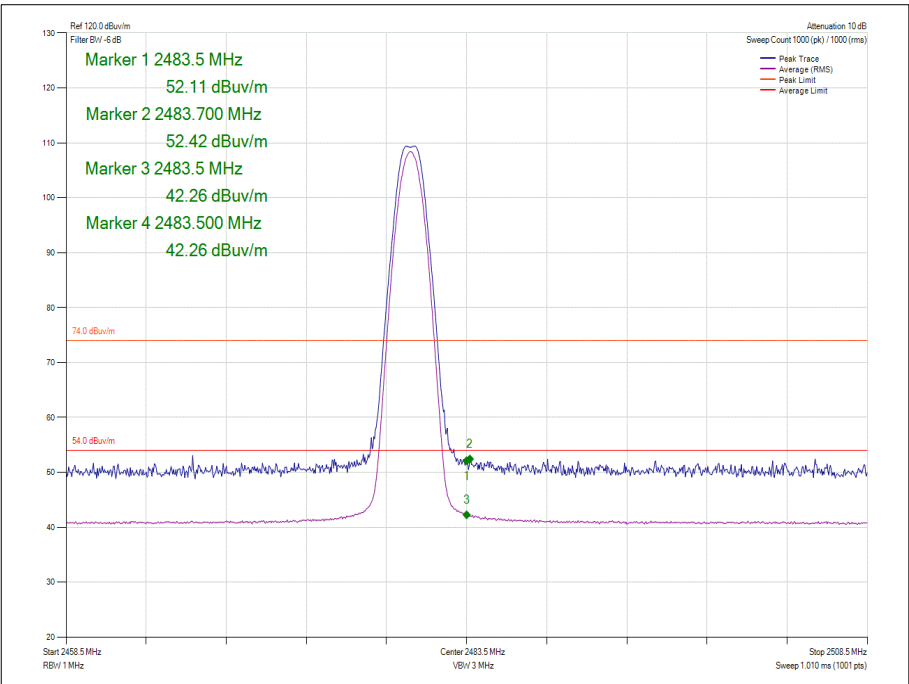


Figure 42 - GFSK/DH1 - 2480 MHz - Band Edge Frequency 2483.5 MHz



Bluetooth LE (iPA) - LE2M

Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Peak Level (dBμV/m)	Average Level (dBμV/m)
GFSK	DH1	2402	2390.0	53.75	42.36
GFSK	DH1	2480	2483.5	54.06	44.23

Table 23

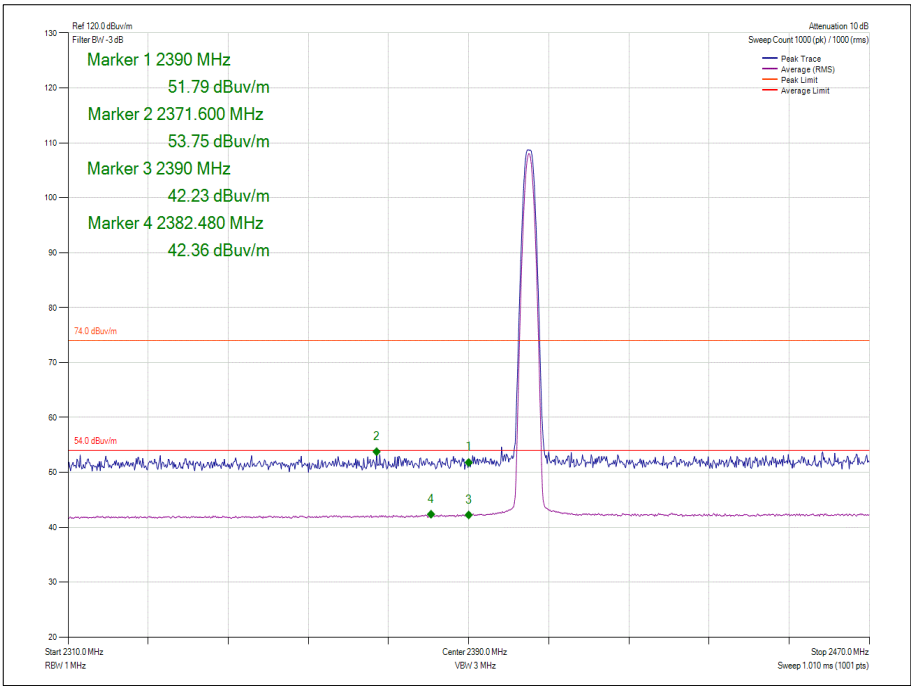


Figure 43 - GFSK/DH1 - 2402 MHz - Band Edge Frequency 2390.0 MHz

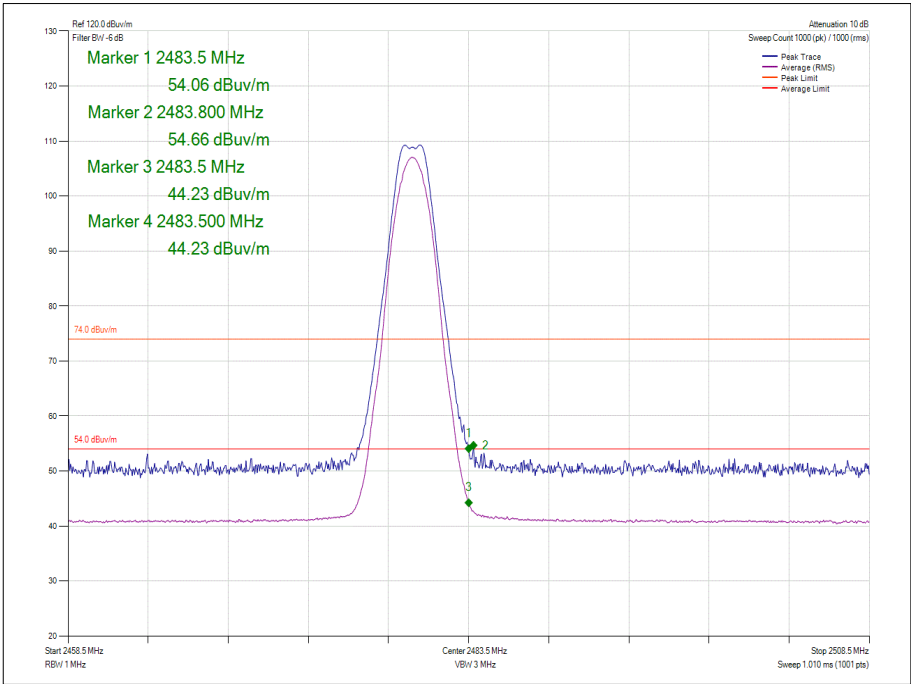


Figure 44 - GFSK/DH1 - 2480 MHz - Band Edge Frequency 2483.5 MHz



Bluetooth (ePA)

Mode	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Peak Level (dBµV/m)	Average Level (dBµV/m)
HDR4	2404	2390	55.13	42.1
HDR4	2478	2483.5	58.91	46.54
HDR8	2404	2390	55.54	42.5
HDR8	2478	2483.5	61.49	50.55

Table 24

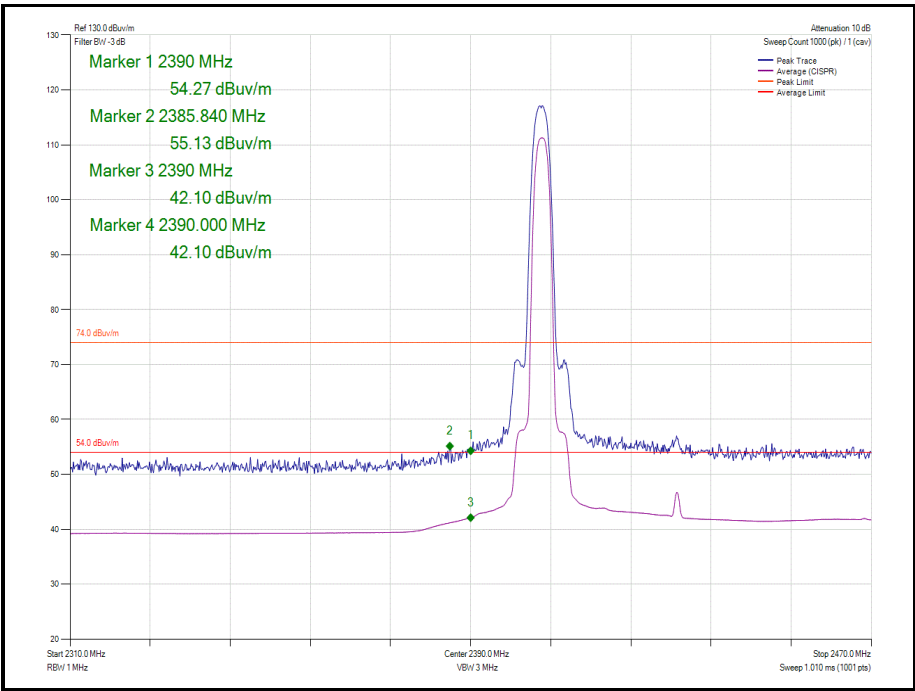


Figure 45 – HDR4 - 2404 MHz - Band Edge Frequency 2390 MHz

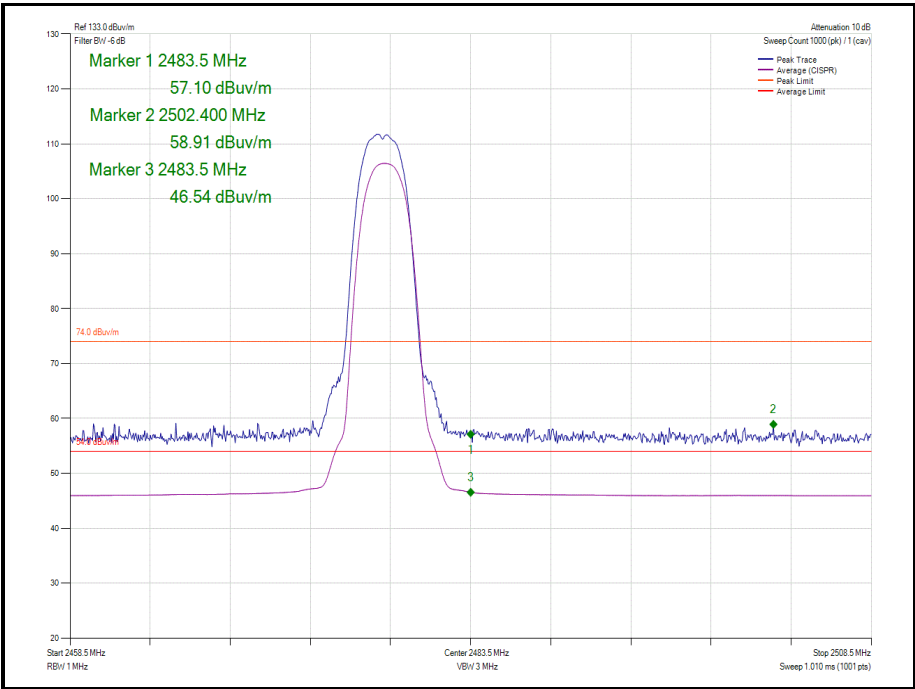


Figure 46 – HDR4 - 2478 MHz - Band Edge Frequency 2483.5 MHz

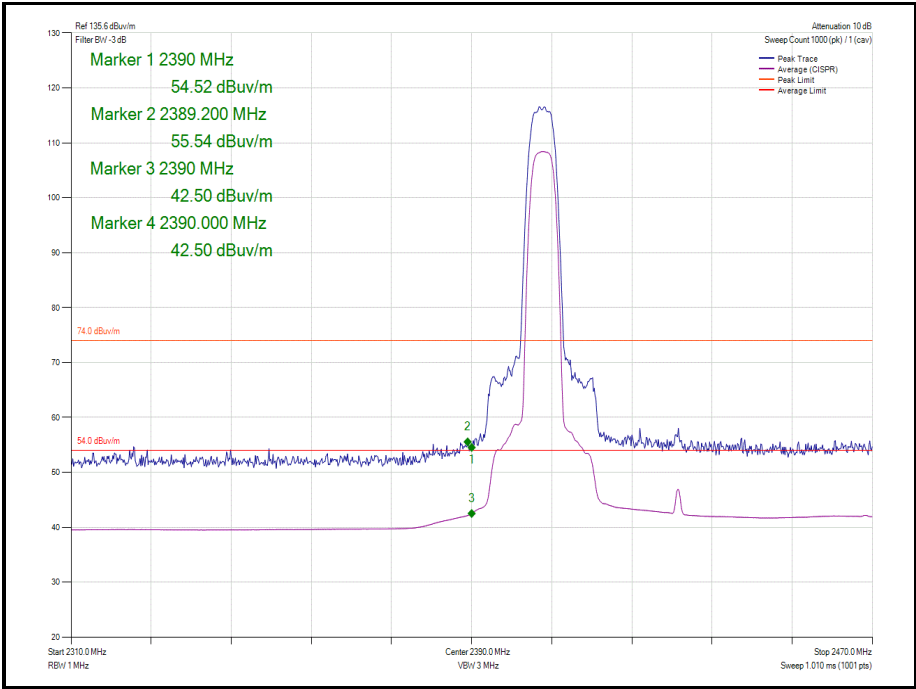


Figure 47 – HDR8 - 2404 MHz - Band Edge Frequency 2390 MHz

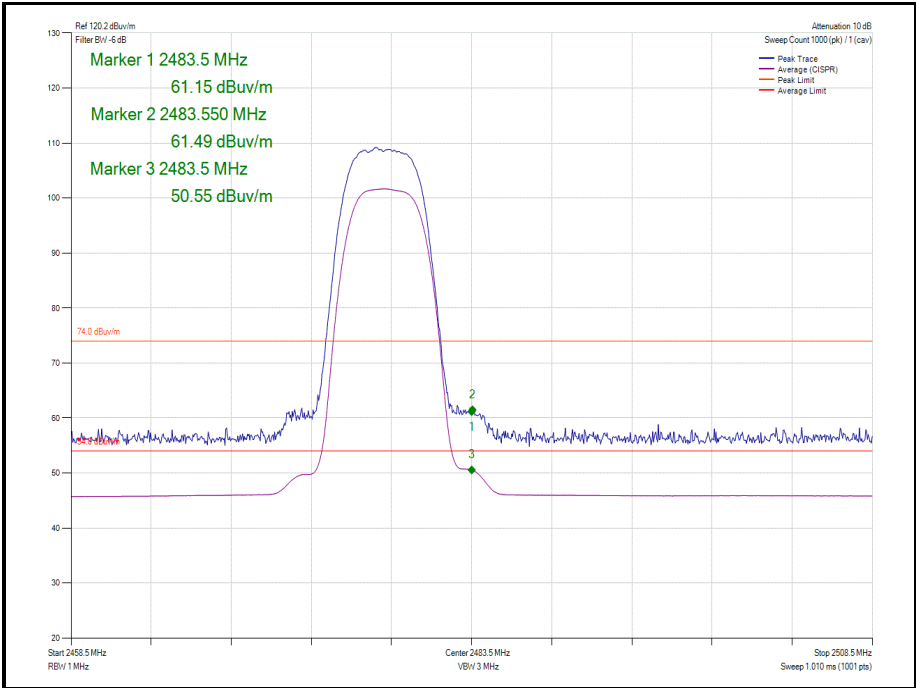


Figure 48 - HDR8 - 2478 MHz - Band Edge Frequency 2483.5 MHz



FCC 47 CFR Part 15, Limit Clause 15.209

Frequency (MHz)	Field Strength ($\mu\text{V/m}$ at 3 m)
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

Table 25

Industry Canada RSS-GEN, Limit Clause 8.9

Frequency (MHz)	Field Strength ($\mu\text{V/m}$ at 3 metres)
30-88	100
88-216	150
216-960	200
Above 960*	500

Table 26

*Unless otherwise specified, for all frequencies greater than 1 GHz, the radiated emission limits for licence-exempt radio apparatus stated in applicable RSSs (including RSS-Gen) are based on measurements using a linear average detector function having a minimum resolution bandwidth of 1 MHz. If an average limit is specified for the EUT, then the peak emission shall also be measured with instrumentation properly adjusted for such factors as pulse desensitization to ensure the peak emission is less than 20 dB above the average limit.

2.5.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 3.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Hygromer	Rotronic	Hygropalm	2404	12	26-Apr-2019
Double Ridge Broadband Horn Antenna	Schwarzbeck	BBHA 9120 B	4848	12	12-Feb-2019
EMI Test Receiver	Rohde & Schwarz	ESW44	5084	12	12-Sep-2019
8m N-Type RF Cable	Teledyne	PR90-088-8MTR	5095	12	04-Oct-2019
Cable (18GHz)	Rosenberger	LU7-071-2000	5107	12	05-Oct-2019
Screened Room (11)	Rainford	Rainford	5136	36	01-Nov-2021
Mast	Maturo	TAM 4.0-P	5158	-	TU
Mast and Turntable Controller	Maturo	Maturo NCD	5159	-	TU
Turntable	Maturo	TT 15WF	5160	-	TU

Table 27

TU - Traceability Unscheduled



2.6 Spurious Radiated Emissions

2.6.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.247 (d), 15.205, 5.5 and 6.13

2.6.2 Equipment Under Test and Modification State

A2159, S/N: C02Y3006L59G - Modification State 0

2.6.3 Date of Test

06-February-2019 to 24-April-2019

2.6.4 Test Method

Testing was performed in accordance with ANSI C63.10 clause 6.3, 6.5 and 6.6.

In the 30MHz to 1GHz range, pre-scans were only performed in LE (iPA) mode on mid channel (2412 MHz) with any emissions identified, then measured on bottom (2437 MHz) and top (2472 MHz) channel. Pre-tests on other modes, having been shown to have minimal impact on the emissions profile of the unit below 1GHz.

Measurements in the 1 – 26GHz range, were performed in LE1M and HDR4 (ePA) modes, as these were deemed to be worst case.

The plots shown are the characterization of the EUT. The limits on the plots represent the most stringent case for restricted bands, (54/74 dBuV/m @ 3m and 64/84 dBuV/m @ 1m) when compared to 20 dBc outside restricted bands. The limits shown have been used as a threshold to determine where further measurements are necessary. Where results are within 10 dB of the limits shown on the plots, further investigation was carried out and reported in results tables.

The following conversion can be applied to convert from dBuV/m to uV/m:

$10^{(\text{Field Strength in dB}\mu\text{V/m}/20)}$.

$10^{(\text{Field Strength in dB}\mu\text{V/m}/20)}$.

2.6.5 Environmental Conditions

Ambient Temperature 21.7 - 29.4 °C

Relative Humidity 22.5 – 45.0 %



2.6.6 Test Results

Frequency (MHz)	QP Level (dB μ V/m)	QP Limit (dB μ V/m)	QP Margin (dB)	Angle (Deg)	Height(m)	Polarity
249.980	29.08	46.0	16.92	145	109	Horizontal
249.985	29.4	46.0	16.6	153	103	Horizontal
249.996	29.46	46.0	16.54	137	118	Horizontal
406.347	27.1	46.0	18.9	340	272	Horizontal

Table 28 –30 MHz to 1 GHz – Radiated

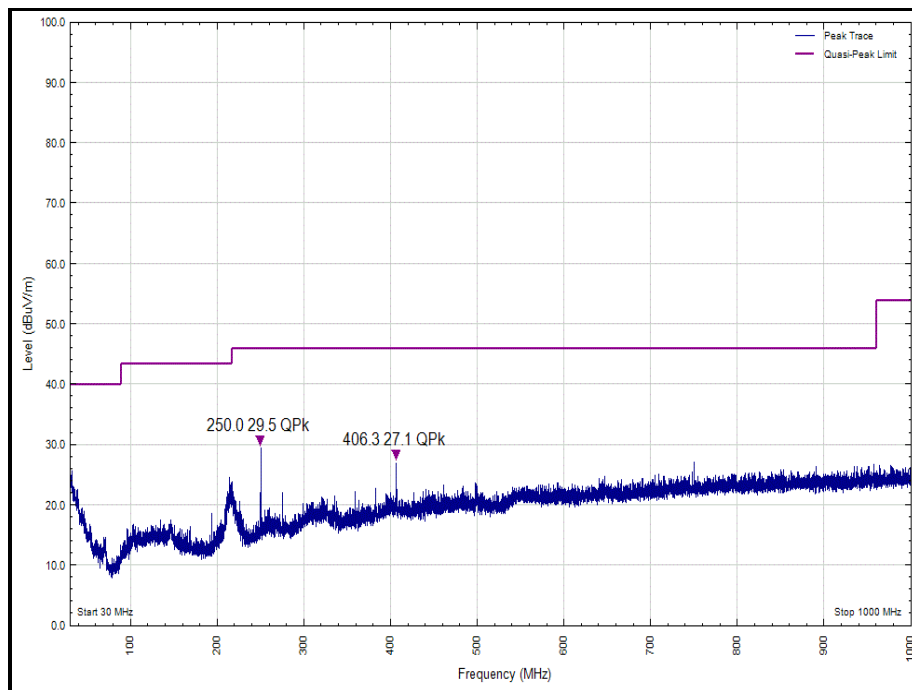


Figure 49 - 30 MHz to 1 GHz
 Polarity: Horizontal

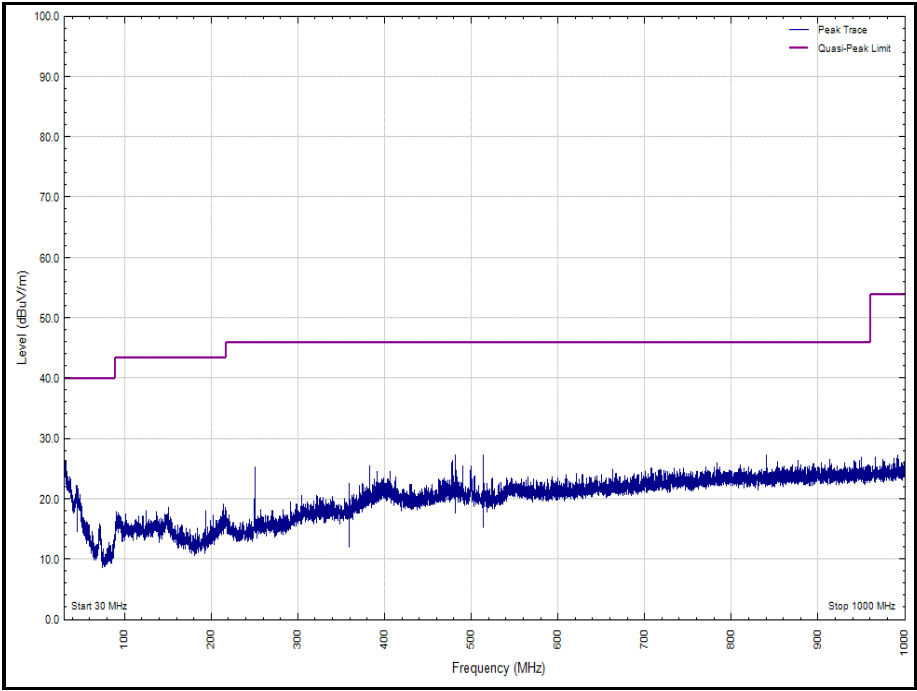


Figure 50 - 30 MHz to 1 GHz
Polarity: Vertical



Bluetooth LE (iPA) - LE1M

Frequency (GHz)	Result (µV/m)		Limit (µV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
4.803	*	37.32	74.0	54.0	n/a	16.68

Table 29 – 2402 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (µV/m)		Limit (µV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
*						

Table 30 – 2441 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (µV/m)		Limit (µV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
8110.003	*	33.62	74.0	54.0	n/a	20.38

Table 31 - 2480 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

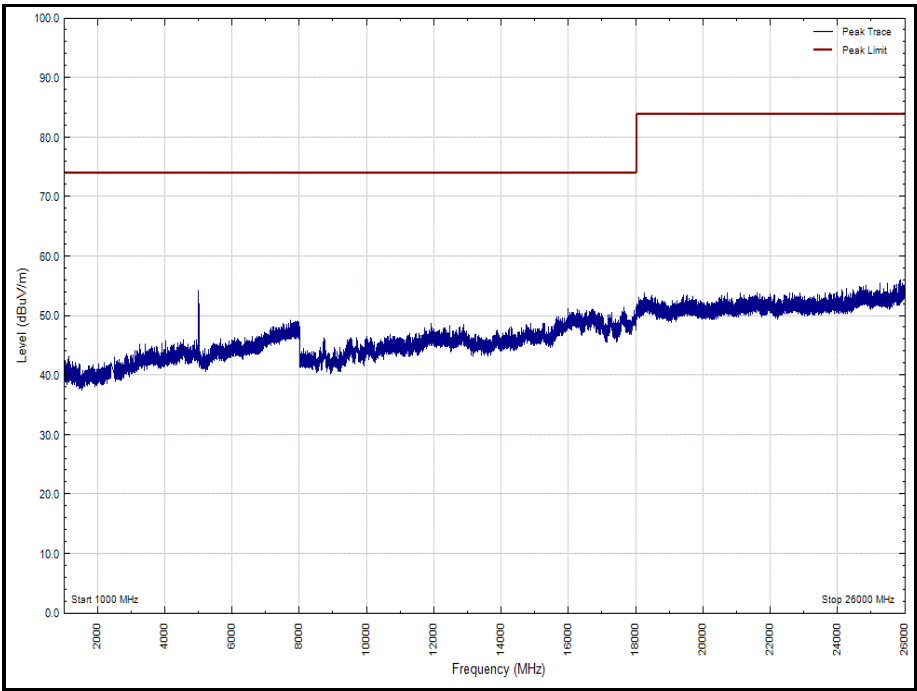


Figure 51 - 2402 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Horizontal

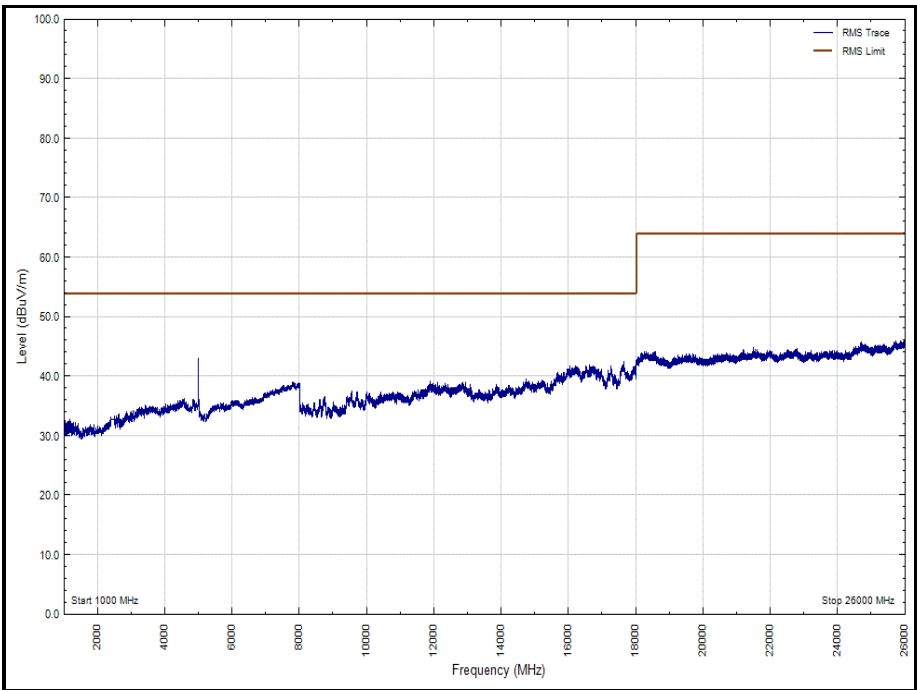


Figure 52 - 2402 MHz - 1 GHz to 26 GHz (Average)
Polarity: Horizontal

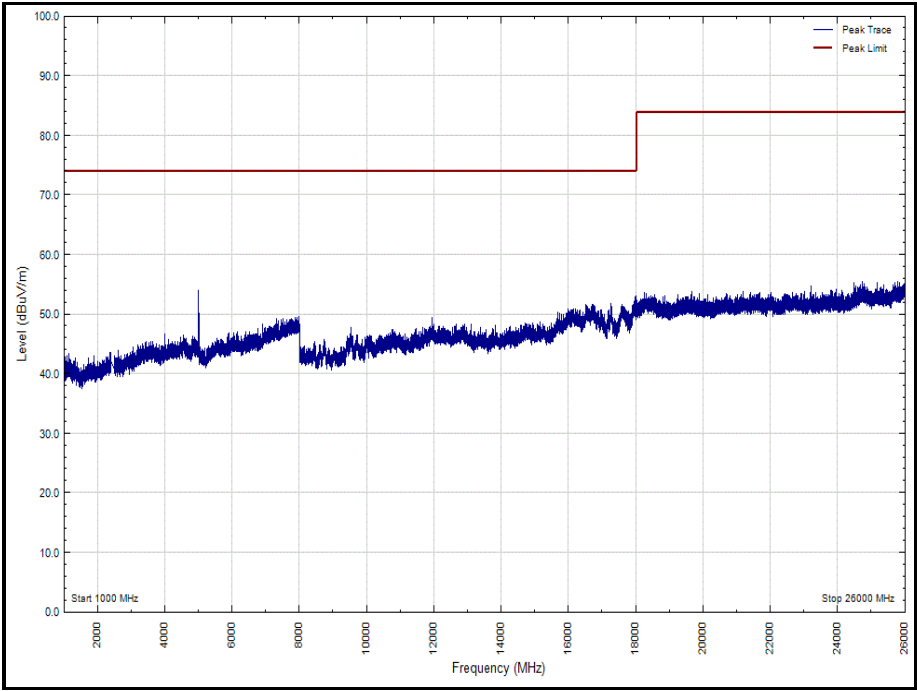


Figure 53 – 2402 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Vertical

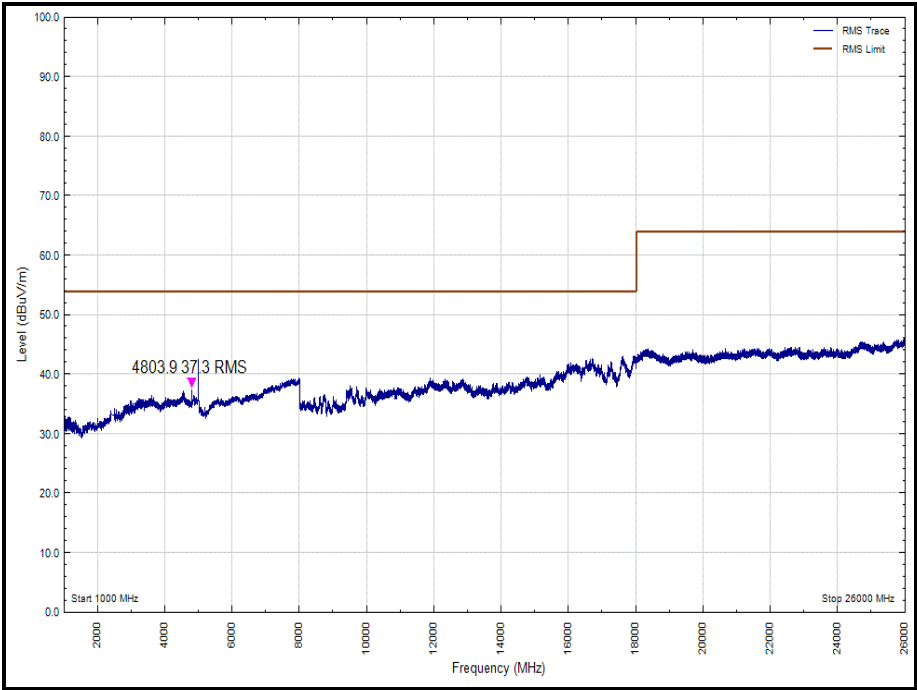


Figure 54 - 2402 MHz - 1 GHz to 26 GHz (Average)
Polarity: Vertical

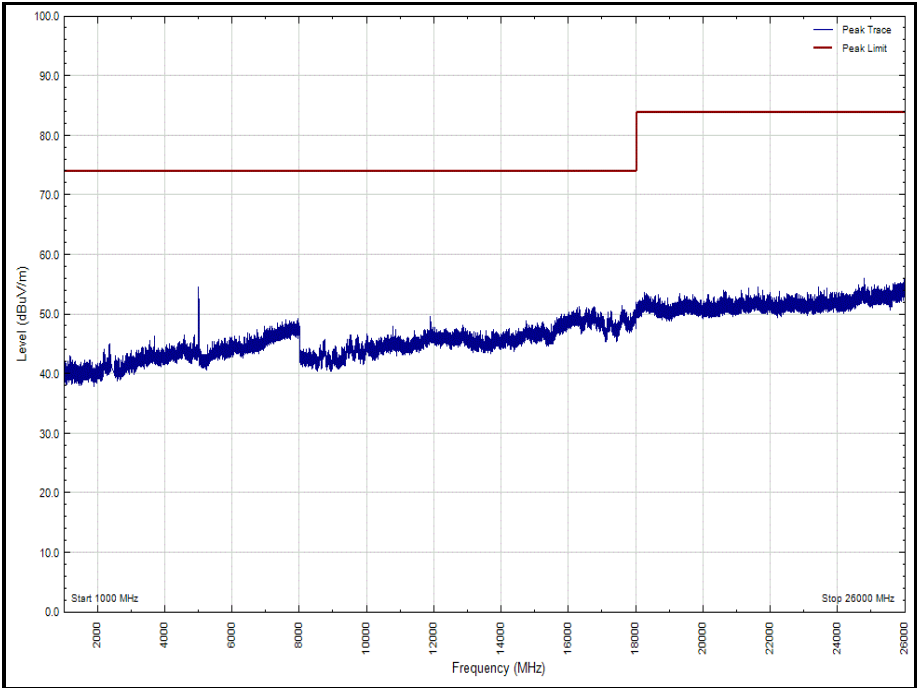


Figure 55 - 2440 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Peak)

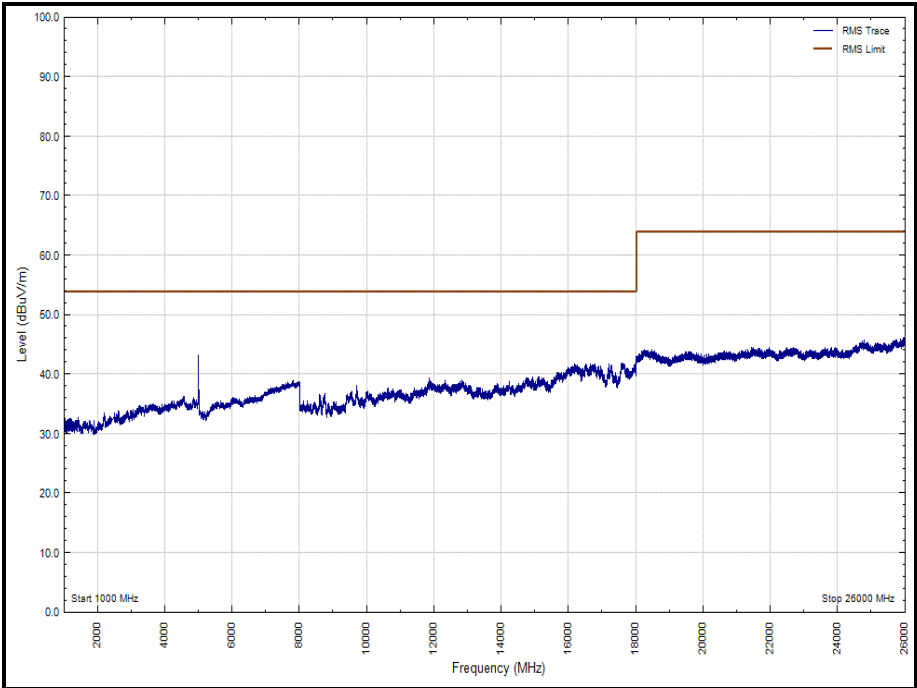


Figure 56 - 2440 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Average)

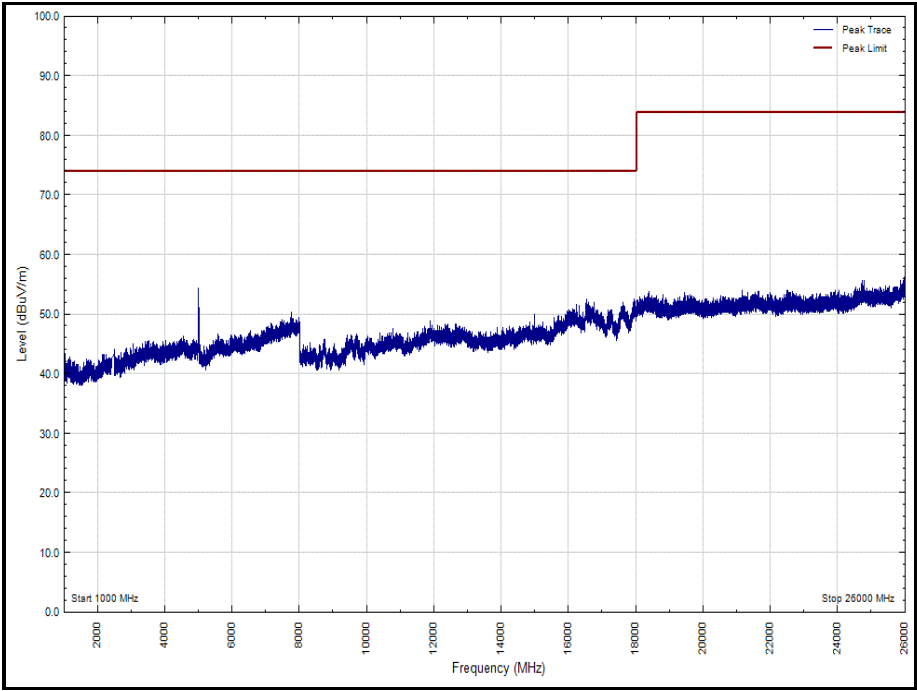


Figure 57 - 2440 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Peak)

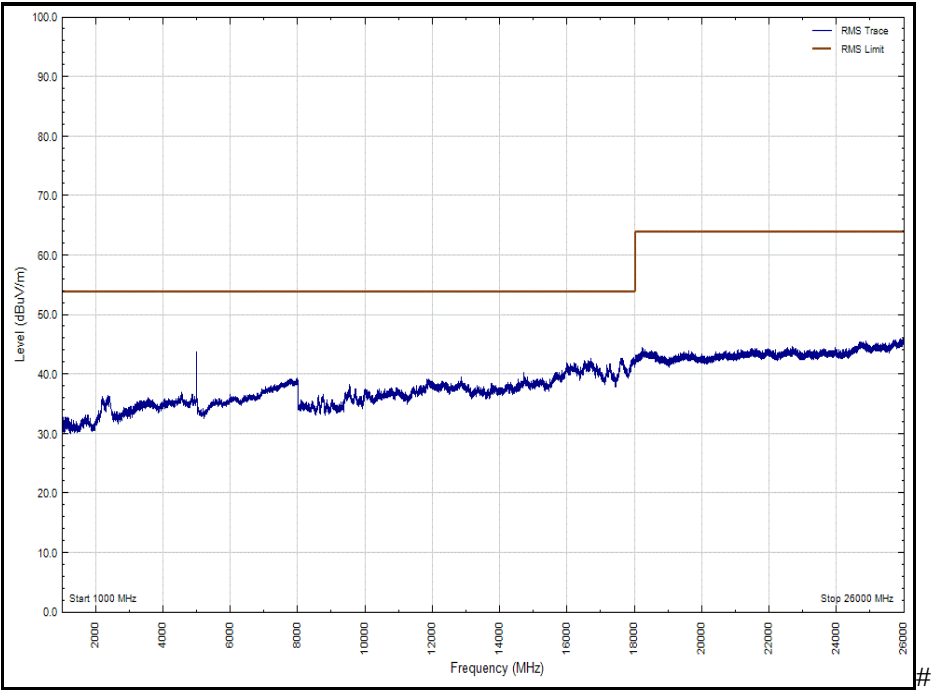


Figure 58 – 2440 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Average)

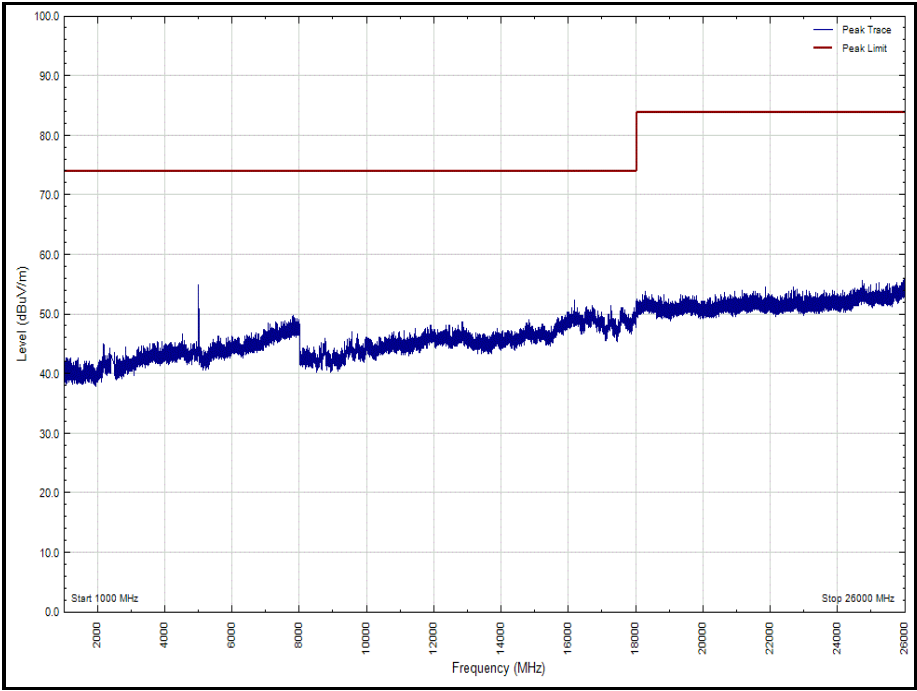


Figure 59 - 2480 MHz 1 GHz to 26 GHz
Polarity: Horizontal (Peak)

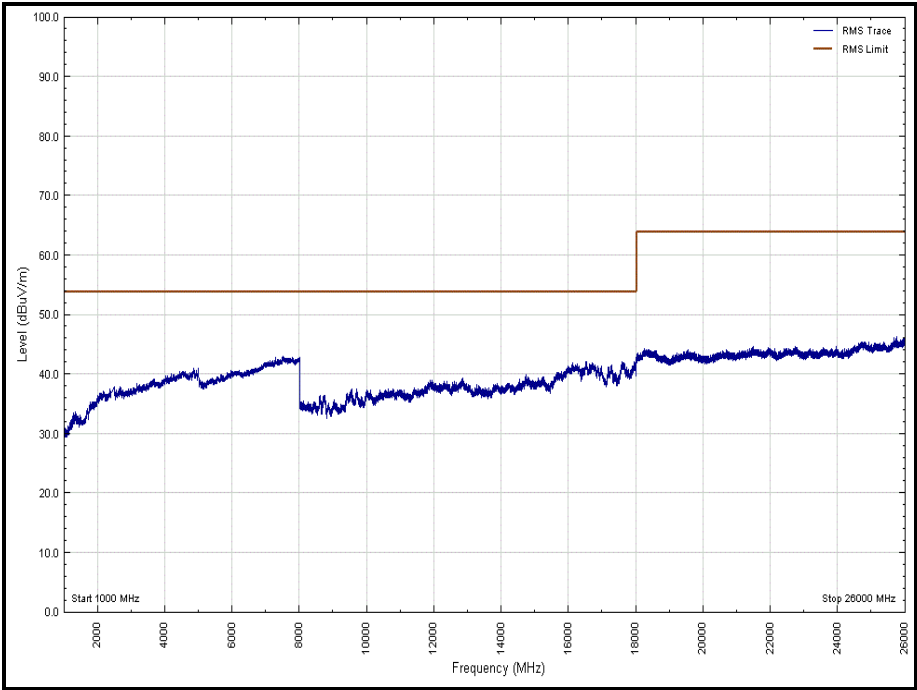


Figure 60 - 2480 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Average)

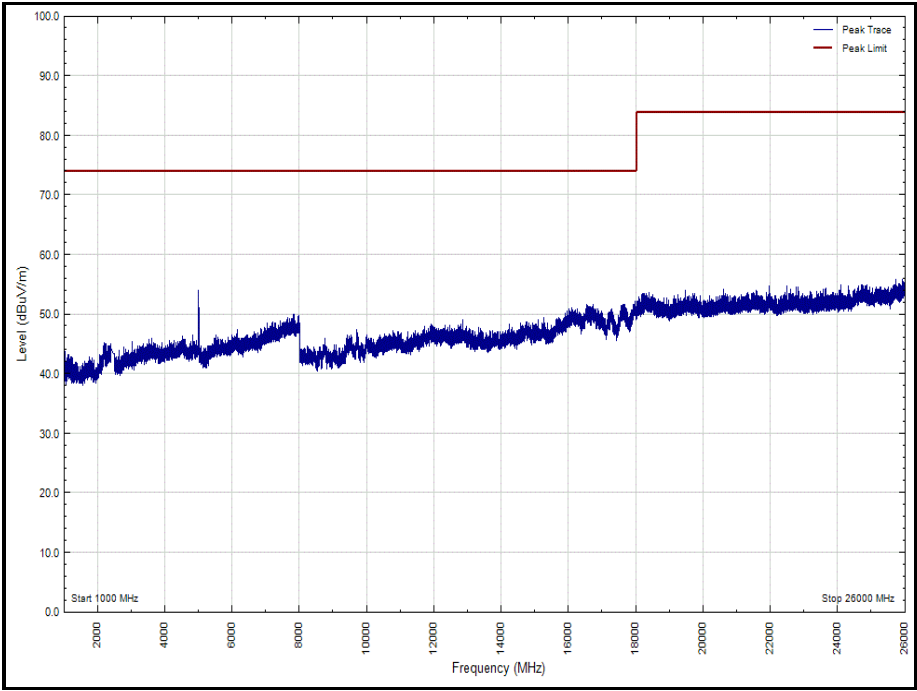


Figure 61 - 2480 MHz 1 GHz to 26 GHz
Polarity: Vertical (Peak)

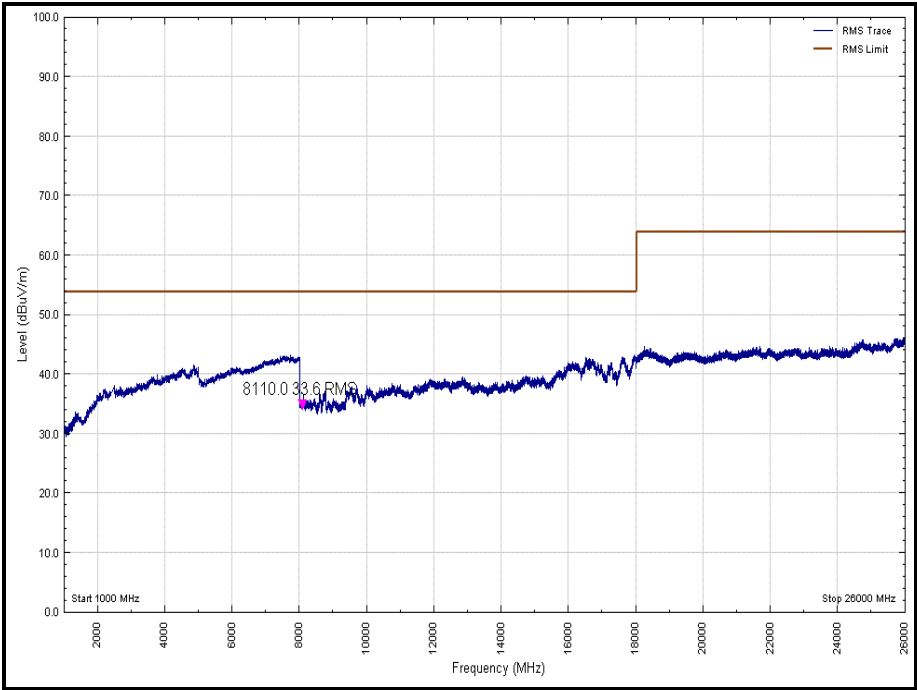


Figure 62 - 2480 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Average)



Bluetooth (ePA) – HDR4

Frequency (GHz)	Result (μV/m)		Limit (μV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
*						

Table 32 – 2404 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (μV/m)		Limit (μV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
*						

Table 33 – 2441 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (μV/m)		Limit (μV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
*						

Table 34 - 2476 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

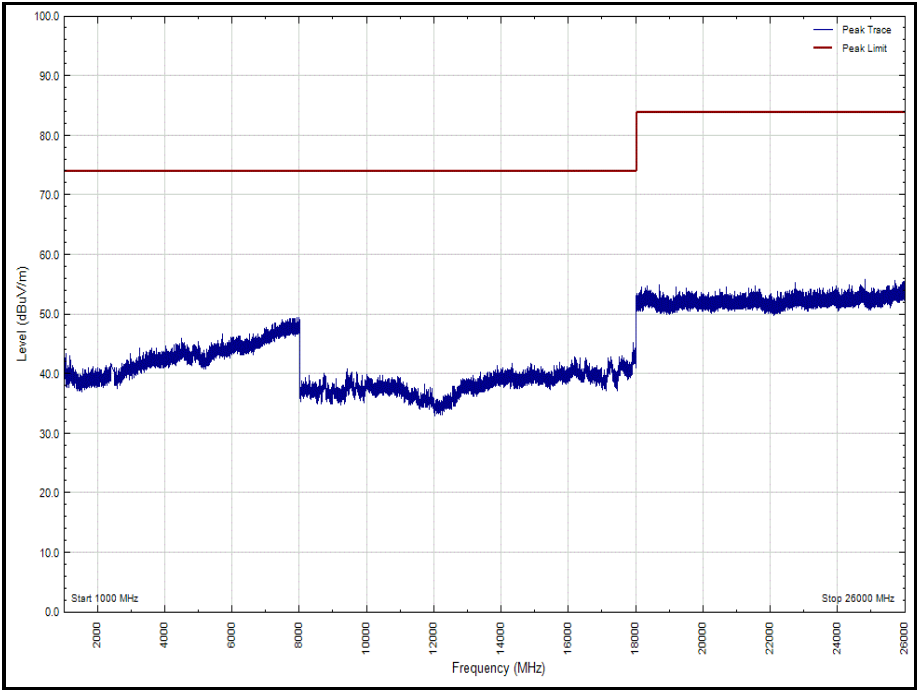


Figure 63 - 2404 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Horizontal

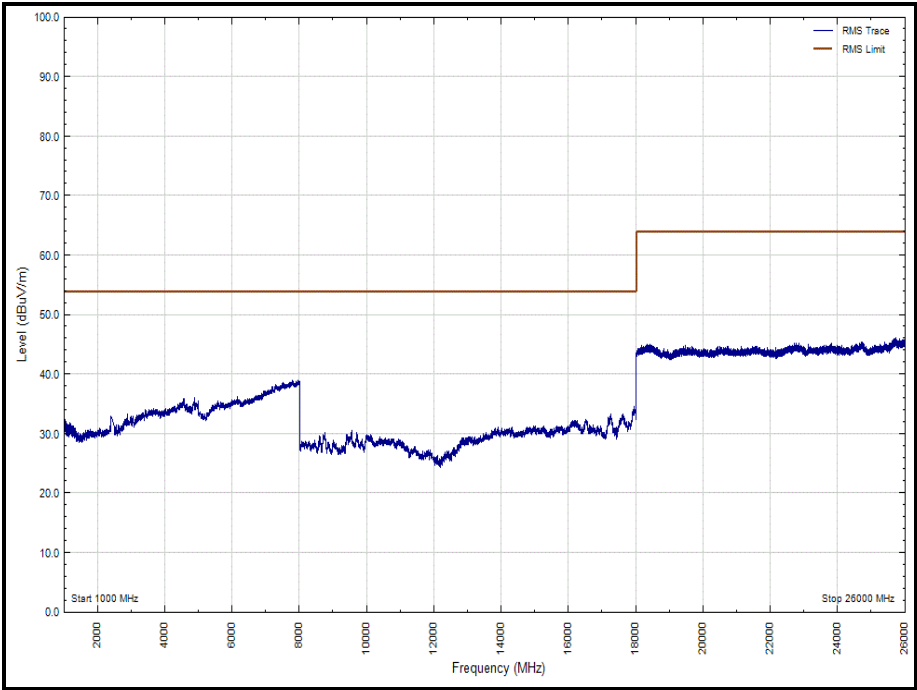


Figure 64 - 2404 MHz - 1 GHz to 26 GHz (Average)
Polarity: Horizontal

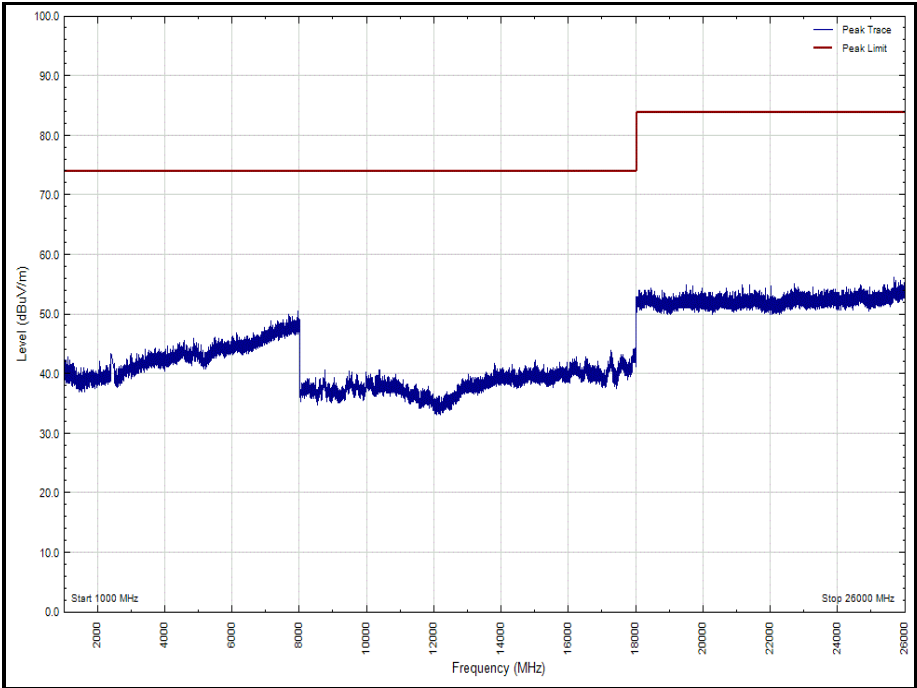


Figure 65 - 2404 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Vertical

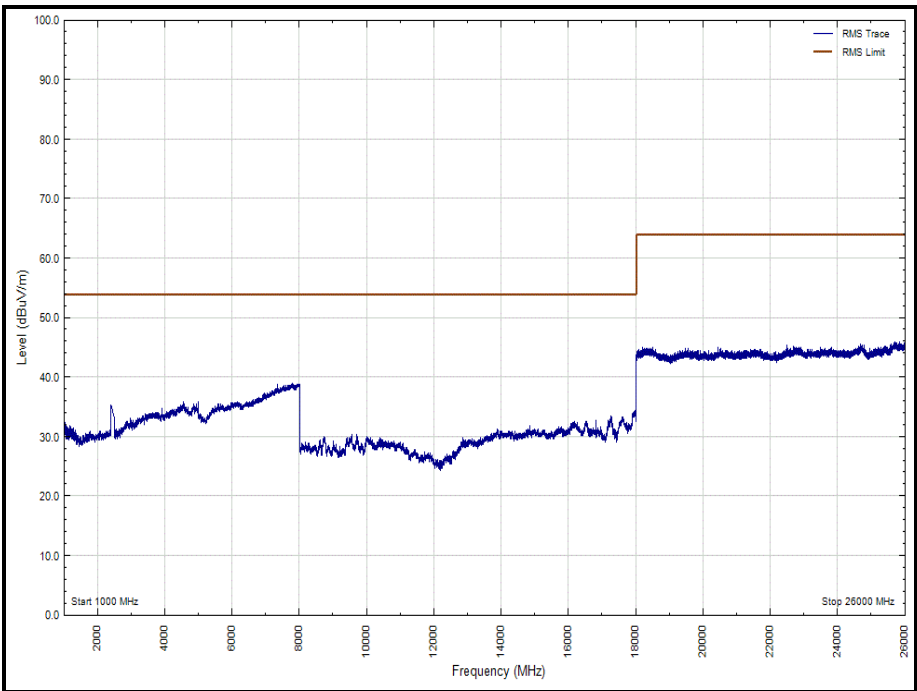


Figure 66 - 2404 MHz - 1 GHz to 26 GHz (Average)
Polarity: Vertical

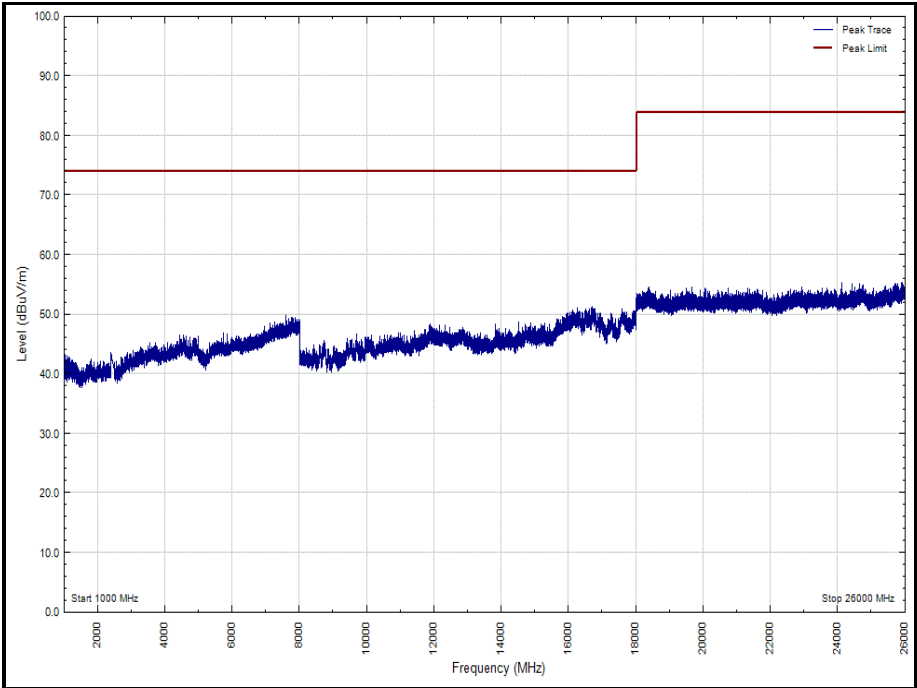


Figure 67 - 2441 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Horizontal

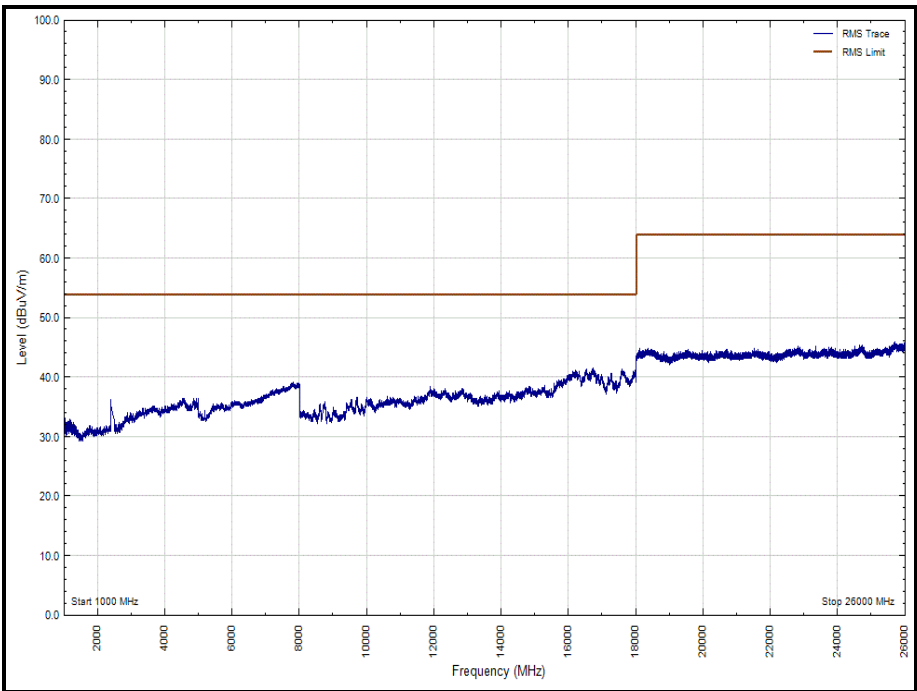


Figure 68 - 2441 MHz - 1 GHz to 26 GHz (Average)
Polarity: Horizontal

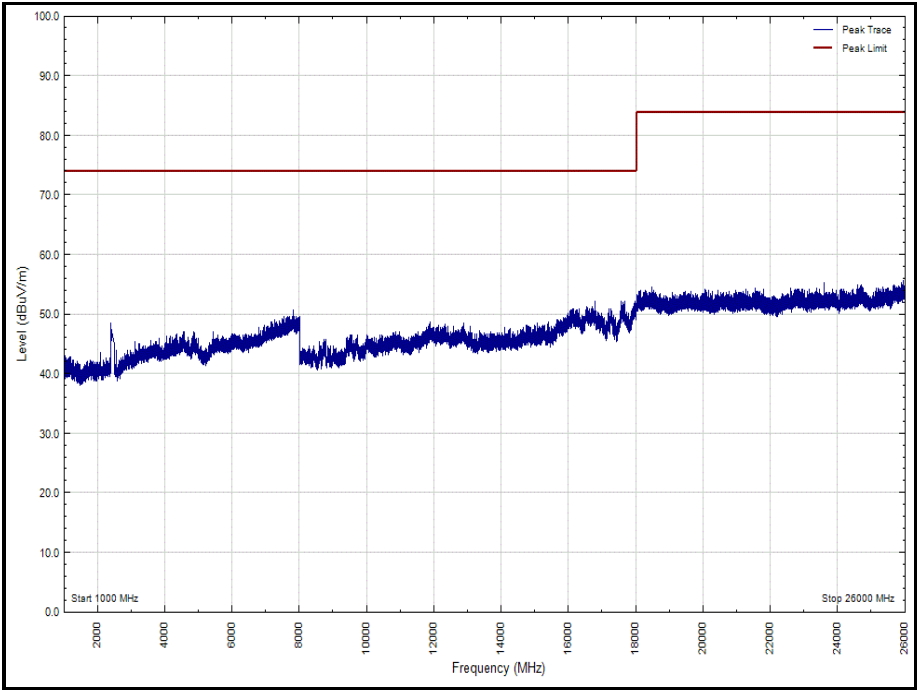


Figure 69 - 2441 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Vertical

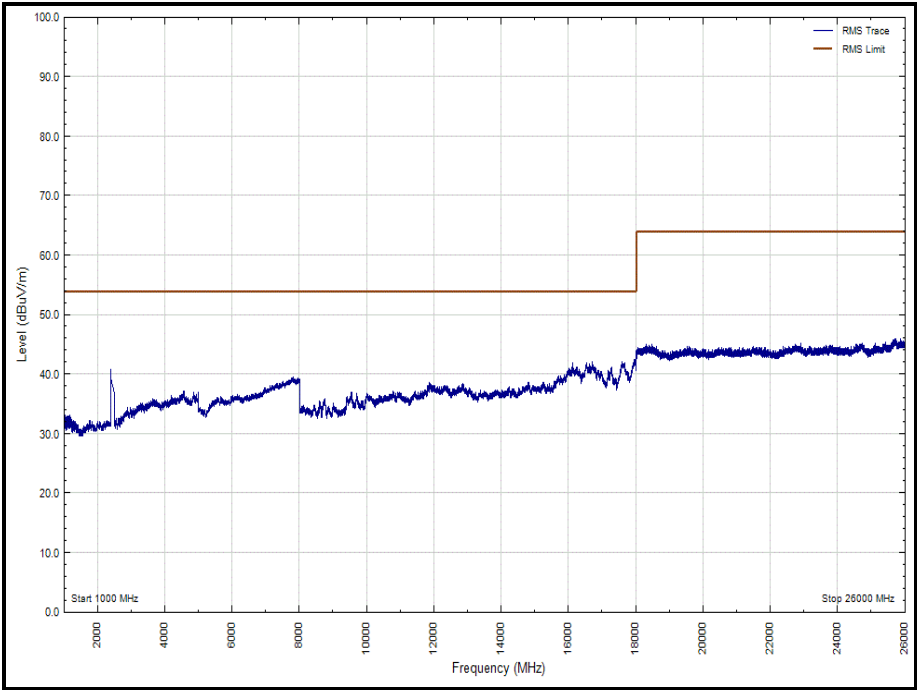


Figure 70 - 2441 MHz - 1 GHz to 26 GHz (Average)
Polarity: Vertical

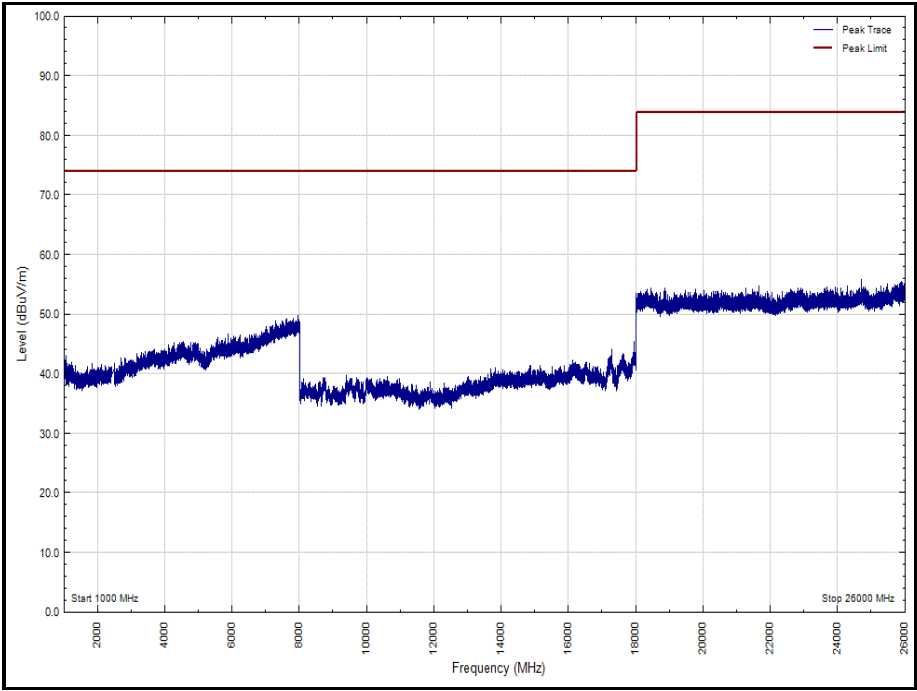


Figure 71 - 2476 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Horizontal

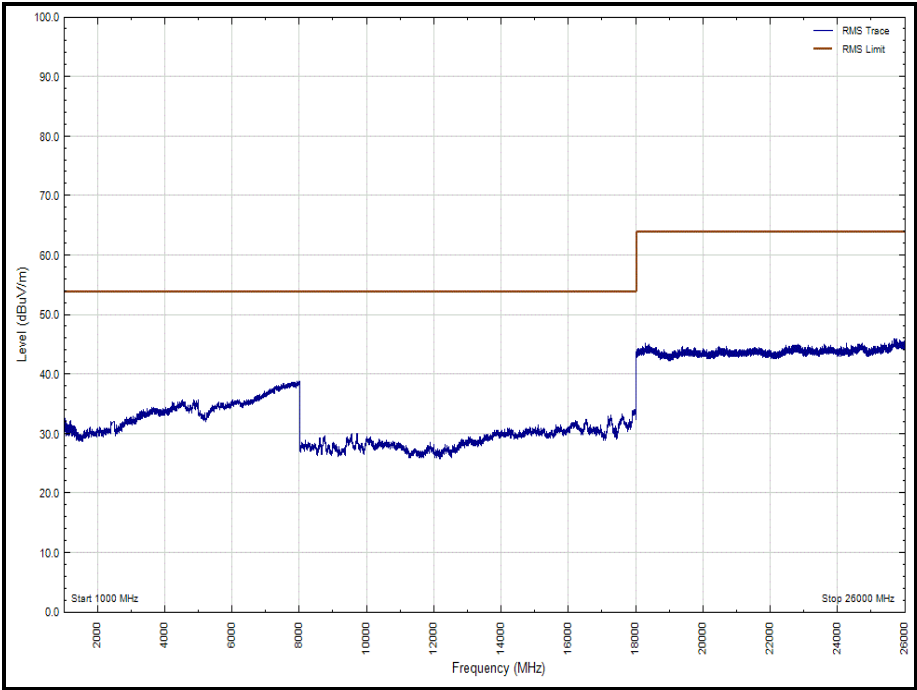


Figure 72 - 2476 MHz - 1 GHz to 26 GHz (Average)
Polarity: Horizontal

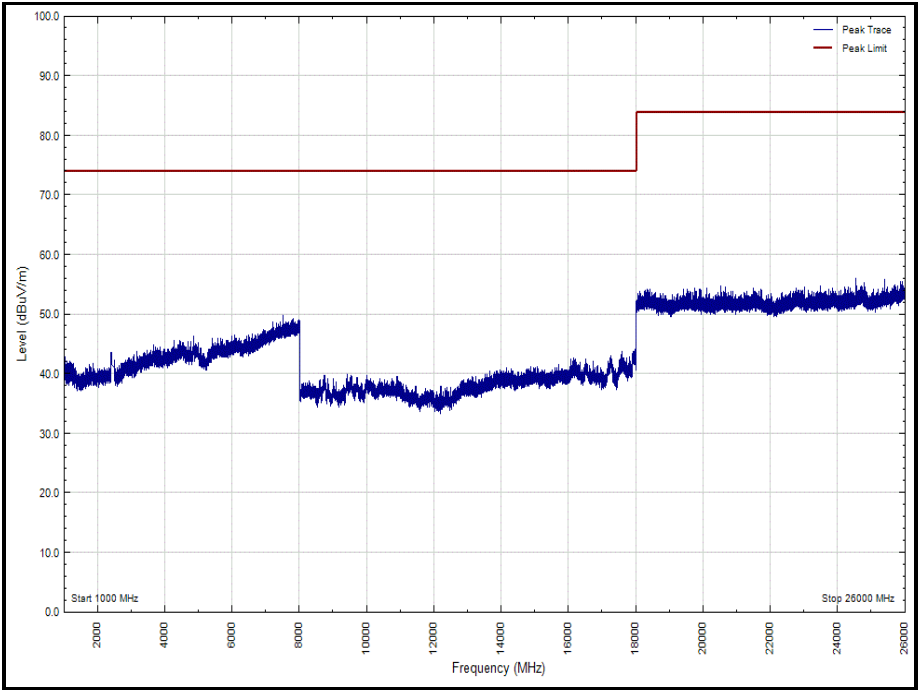


Figure 73 - 2476 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Vertical

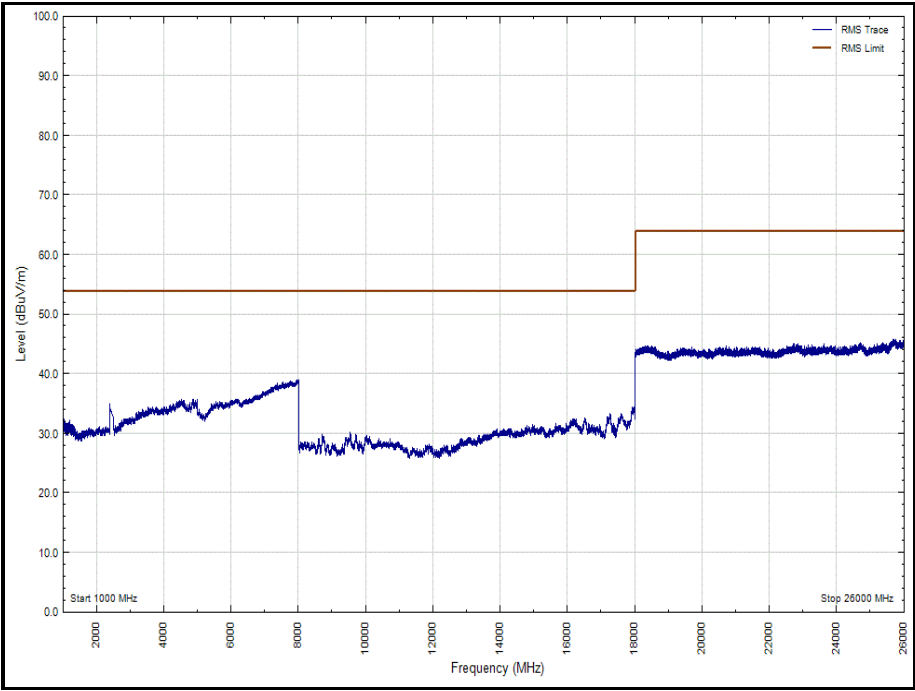


Figure 74 - 2476 MHz - 1 GHz to 26 GHz (Average)
Polarity: Vertical



FCC 47 CFR Part 15, Limit Clause 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)

Industry Canada RSS-247, Limit Clause 5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under Section 5.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.



2.6.7 Test Location and Test Equipment Used

This test was carried out in EMC Chamber 11

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Antenna 18-40GHz (Double Ridge Guide)	Link Microtek Ltd	AM180HA-K-TU2	230	24	02-May-2020
Antenna with permanent attenuator (Bilog)	Schaffner	CBL6143	287	24	15-May-2020
Filter (High Pass)	Lorch	SHP7-7000-SR	566	12	10-May-2019
Pre-Amplifier	Phase One	PS04-0086	1533	12	08-Feb-2020
Hygromer	Rotronic	Hygropalm	2404	12	26-Apr-2019
Cable 1503 2M 2.92(P)m 2.92(P)m	Rhophase	KPS-1503A-2000-KPS	4293	12	26-Oct-2019
Cable (Rx, Km-Km 2m)	Scott Cables	KPS-1501-2000-KPS	4526	6	26-Apr-2019
High Pass Filter (4GHz)	K&L Microwave	11SH10-4000/X18000-0/0	4599	12	04-Sep-2019
Double Ridged Waveguide Horn Antenna	ETS-Lindgren	3117	4722	12	05-Mar-2020
4dB Attenuator	Pasternack	PE7047-4	4935	24	28-Nov-2019
Band Reject Filter - 2.425 GHz	Wainwright	WRCGV14-2390-2400-2450-2460-50SS	5066	12	02-Oct-2019
Band Reject Filter - 2.4585 GHz	Wainwright	WRCGV14-2423.5-2433.5-2483.5-2493.5-50SS	5068	12	02-Oct-2019
EMI Test Receiver	Rohde & Schwarz	ESW44	5084	12	12-Sep-2019
8m N-Type RF Cable	Teledyne	PR90-088-8MTR	5095	12	04-Oct-2019
Cable (18GHz)	Rosenberger	LU7-071-1000	5101	12	04-Oct-2019
Cable (18GHz)	Rosenberger	LU7-071-1000	5102	12	04-Oct-2019
Cable (18GHz)	Rosenberger	LU7-071-1000	5104	12	05-Oct-2019
Cable (18GHz)	Rosenberger	LU7-071-2000	5107	12	05-Oct-2019
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 35



3 Measurement Uncertainty

For a 95% confidence level, the measurement uncertainties for defined systems are:

Test Name	Measurement Uncertainty
Spurious Radiated Emissions	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB
Restricted Band Edges	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB
Authorised Band Edges	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB
Emission Bandwidth	± 30.43 kHz
Power Spectral Density	± 3.2 dB
Maximum Conducted Output Power	± 3.2 dB

Table 36