

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



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Document Number: 75945152-10 | Issue: 02

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 Balendrarajah	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).



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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	3
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-February-2019
Finish of Test	19-March-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) KDB 662911 D01 v02r02



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 (ePA) - DH5/2DH5/3DH5				
2.1	15.247 (b), 5.4 and 6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013) KDB 662911 D01 v02r02
2.2	15.247 (a)(1) and 5.1	Frequency Hopping Systems - Average Time of Occupancy	Pass	ANSI C63.10 (2013)
2.3	15.247 (a)(1) and 5.1	Frequency Hopping Systems - Channel Separation	Pass	ANSI C63.10 (2013)
2.4	15.247 (a)(1) and 5.1	Frequency Hopping Systems - Number of Hopping Channels	Pass	ANSI C63.10 (2013)
2.5	15.247 (a)(1) and 5.1	Frequency Hopping Systems - 20 dB Bandwidth	Pass	ANSI C63.10 (2013)
2.6	15.247 (d), 5.5 and N/A	Authorised Band Edges	Pass	ANSI C63.10 (2013)
2.7	15.205 N/A and 8.10	Restricted Band Edges	Pass	ANSI C63.10 (2013)
2.8	15.247 (d), 15.205, 5.5 and 6.13	Spurious Radiated Emissions	Pass	ANSI C63.10 (2013)
Configuration and Mode: Bluetooth (iPA) - DH5/2DH5/3DH5				
2.1	15.247 (b), 5.4 and 6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013) KDB 662911 D01 v02r02
2.3	15.247 (a)(1) and 5.1	Frequency Hopping Systems - Channel Separation	Pass	ANSI C63.10 (2013)
2.5	15.247 (a)(1) and 5.1	Frequency Hopping Systems - 20 dB Bandwidth	Pass	ANSI C63.10 (2013)
2.6	15.247 (d), 5.5 and N/A	Authorised Band Edges	Pass	ANSI C63.10 (2013)
2.7	15.205 N/A and 8.10	Restricted Band Edges	Pass	ANSI C63.10 (2013)
2.8	15.247 (d), 15.205, 5.5 and 6.13	Spurious Radiated Emissions	Pass	ANSI C63.10 (2013)



1.4 Product Information

1.4.1 Technical Description

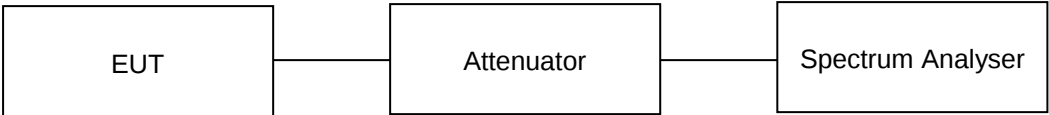
The Equipment Under Test (EUT) was a laptop computer with Bluetooth, Bluetooth Low Energy and 802.11 a/b/g/n/ac capabilities in the 2.4GHz and 5GHz bands.

1.4.2 Details of Antenna Assembly and Cable Loss

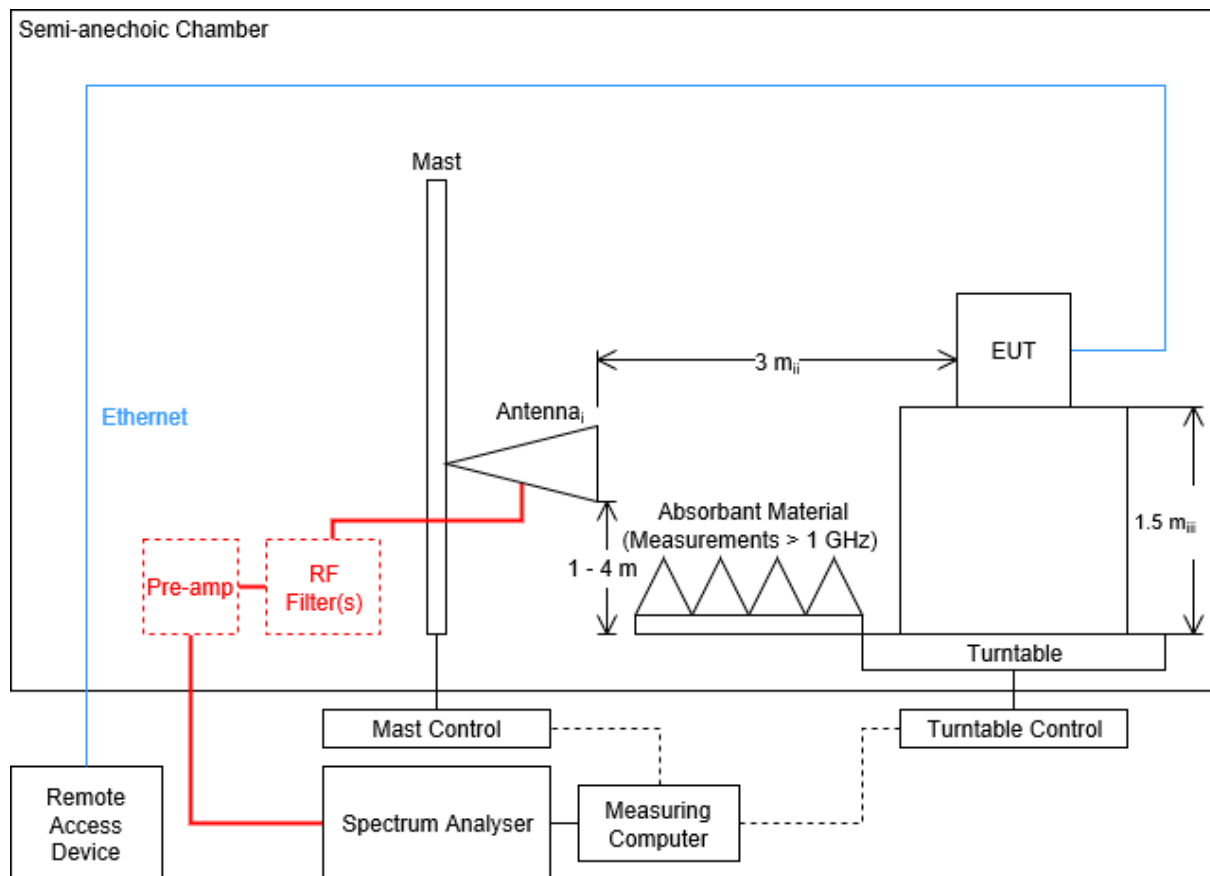
Detailed below are the antenna gains for each port as declared by the manufacturer. Also given are the declared losses of internal test cables fitted to provide a means of conducted antenna port testing.

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 2

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 (iPA/ePA)		
Maximum Conducted Output Power	Matthew Russell	UKAS
Frequency Hopping Systems - Average Time of Occupancy	Mehadi Choudury	UKAS
Frequency Hopping Systems - Channel Separation	Mehadi Choudury	UKAS
Frequency Hopping Systems - Number of Hopping Channels	Mehadi Choudury	UKAS
Frequency Hopping Systems - 20 dB 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

Table 3

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

18-March-2019 to 19-March-2019

2.1.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 7.8.5.

2.1.5 Environmental Conditions

Ambient Temperature 21.2 °C
Relative Humidity 35.6 %

2.1.6 Test Results

Bluetooth (ePA) - DH5/2DH5/3DH5

Testing was performed on the modulation/packet type with the highest conducted output power. This modulation/packet type was GFSK/DH5.

Frequency (MHz)	Maximum Output Power	
	dBm	mW
2402	18.3	67.92
2441	18.37	68.71
2480	18.47	70.31

Table 4 - Maximum Conducted Output Power Results

Note: The device has a peak antenna gain of 1.91dBi, which results in a peak EIRP of 20.38dBm (109.14mW)

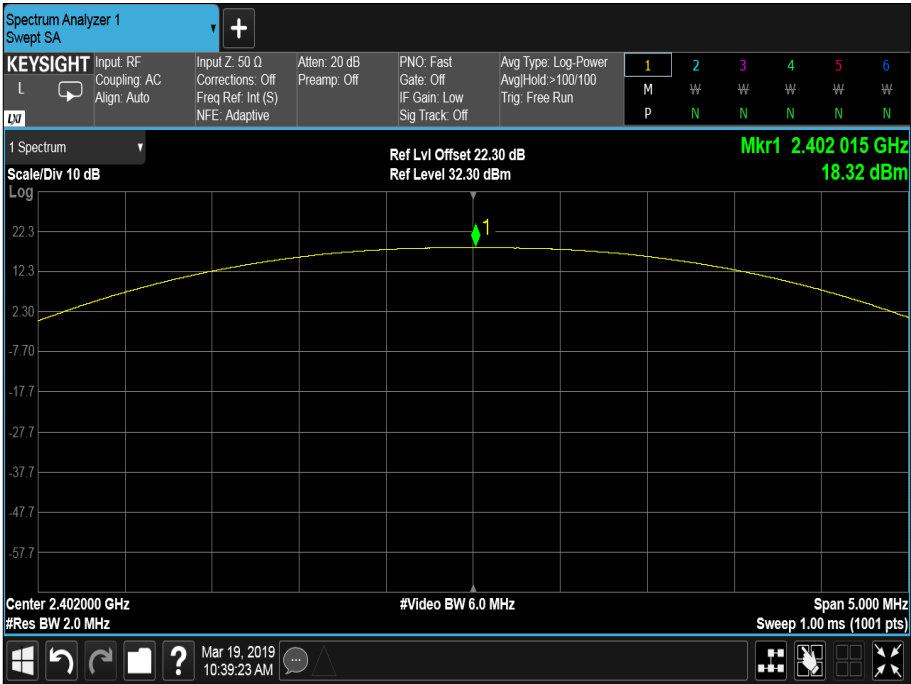


Figure 1 - 2402 MHz - Maximum Output Power

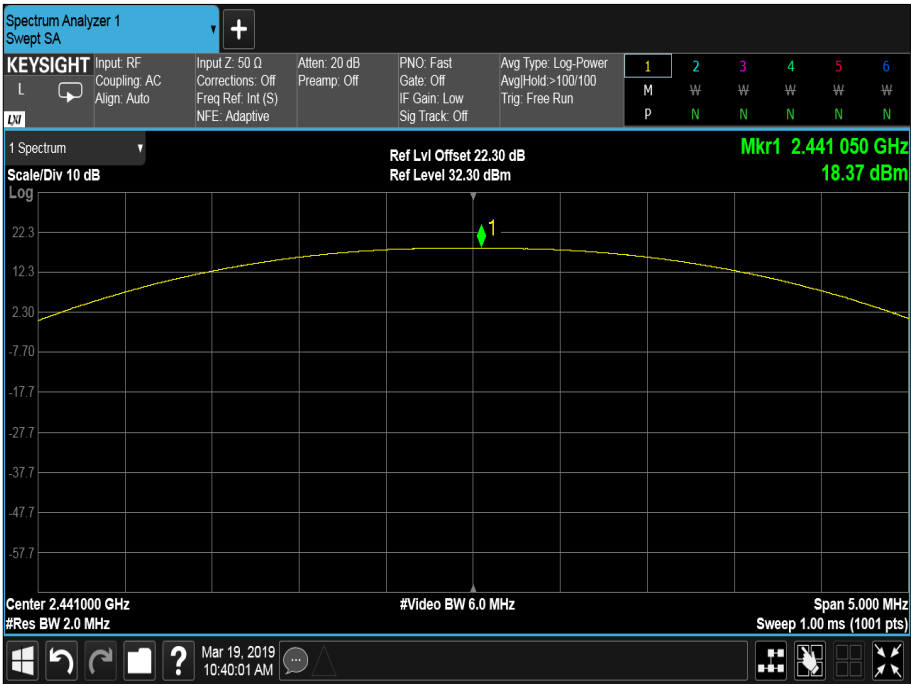


Figure 2 - 2441 MHz - Maximum Output Power

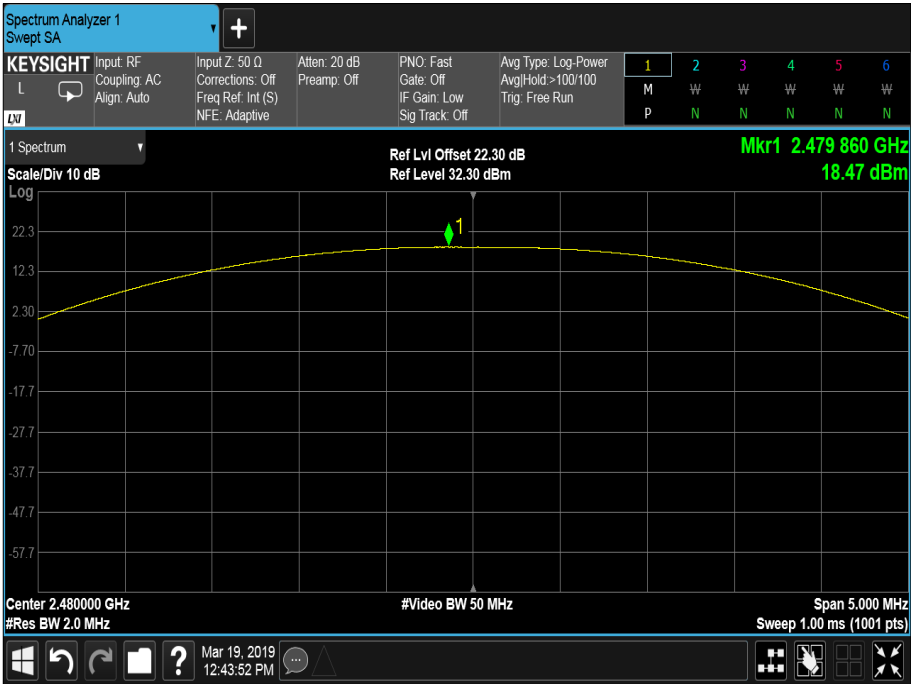


Figure 3 - 2480 MHz - Maximum Output Power



FCC 47 CFR Part 15, Limit Clause 15.247 (b)(1)

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non overlapping hopping channels, and all frequency hopping systems in the 5725-5850MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

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

For FHSs operating in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1.0 W if the hopset uses 75 or more hopping channel; the maximum peak conducted output power shall not exceed 0.125 W if the hopset uses less than 75 hopping channel. The e.i.r.p. shall not exceed 4 W except as provided in section 5.4(e) of the specification.

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

For FHSs operating in the band 902-928 MHz, the maximum peak conducted output power shall not exceed 1.0 W, and the e.i.r.p. shall not exceed 4 W if the hopset uses 50 or more hopping channels; the maximum peak conducted output power shall not exceed 0.25 W and the e.i.r.p. shall not exceed 1 W if the hopset uses less than 50 hopping channels.



Bluetooth (iPA) - DH5/2DH5/3DH5

Testing was performed on the modulation/packet type with the highest conducted output power. This modulation/packet type was GFSK/DH5.

Frequency (MHz)	Maximum Output Power	
	dBm	mW
2402	11.90	15.49
2441	11.84	15.28
2480	11.89	15.45

Table 5 - Maximum Conducted Output Power Results

Note: The device has a peak antenna gain of 1.91dBi, which results in a peak EIRP of 13.81dBm (24.04mW)

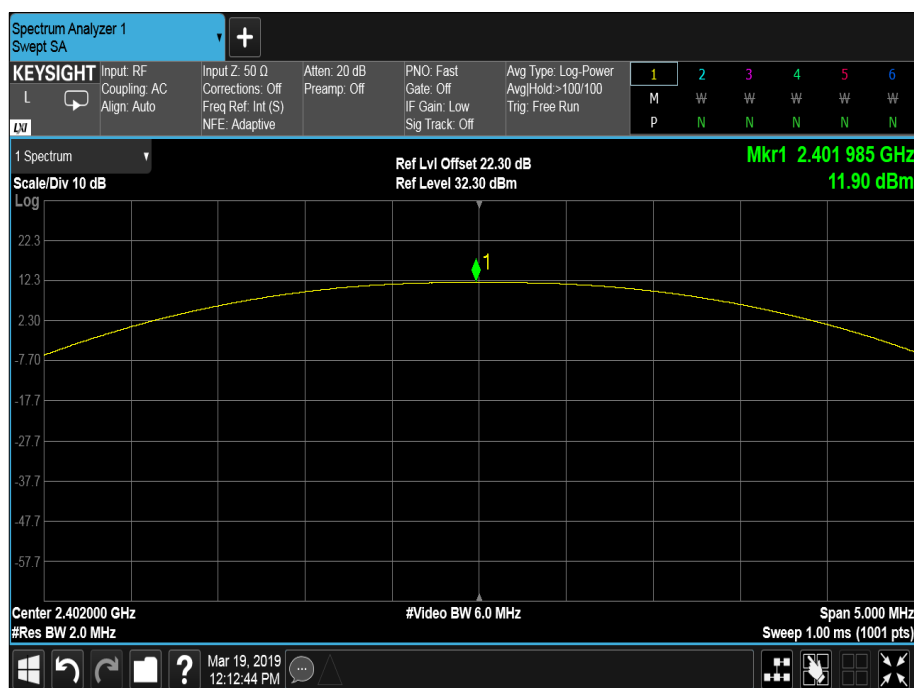


Figure 4 - 2402 MHz - Maximum Output Power

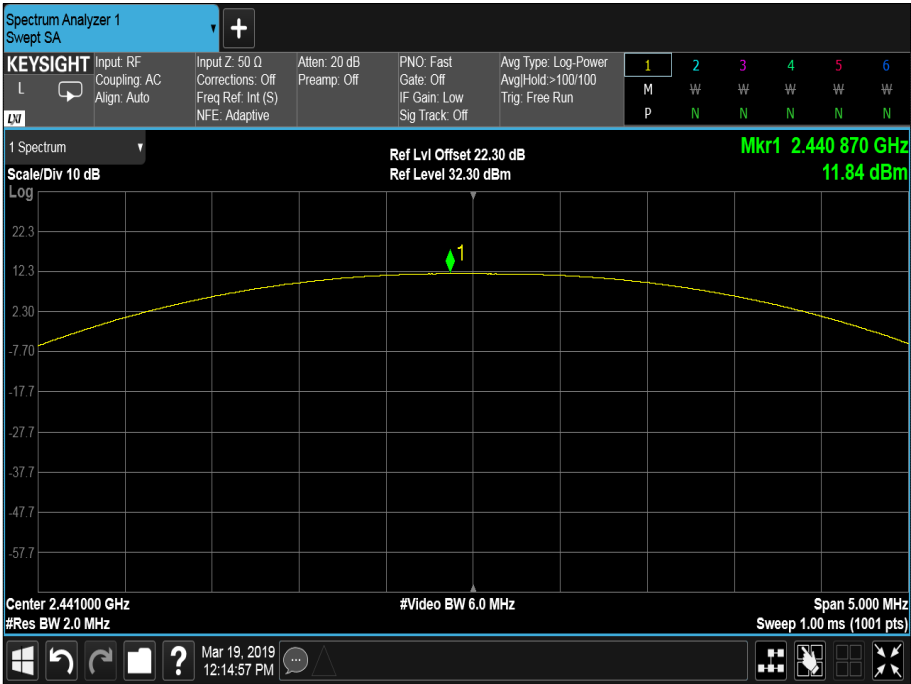


Figure 5 - 2441 MHz - Maximum Output Power

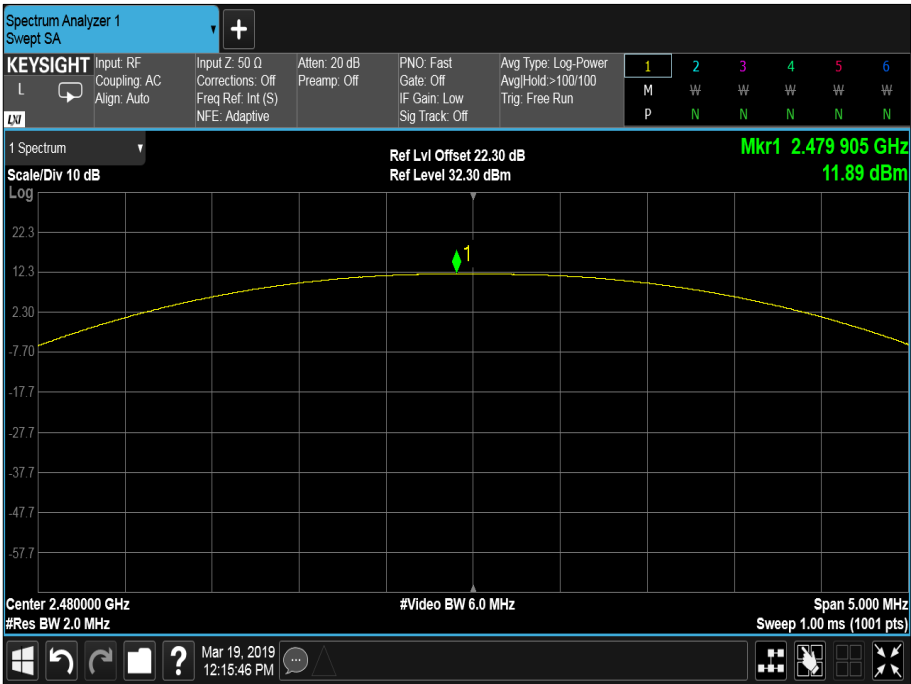


Figure 6 - 2480 MHz - Maximum Output Power



FCC 47 CFR Part 15, Limit Clause 15.247 (b)(1)

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non overlapping hopping channels, and all frequency hopping systems in the 5725-5850MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

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

For FHSs operating in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1.0 W if the hopset uses 75 or more hopping channel; the maximum peak conducted output power shall not exceed 0.125 W if the hopset uses less than 75 hopping channel. 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 6

O/P Mon – Output Monitored Using Calibrated Equipment



2.2 Frequency Hopping Systems - Average Time of Occupancy

2.2.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (a)(1)
Industry Canada RSS-247, Clause 5.1

2.2.2 Equipment Under Test and Modification State

A2159, S/N: C02Y400PL5FL - Modification State 0

2.2.3 Date of Test

05-March-2019

2.2.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 7.8.4.

Testing has been limited to ePA mode only, the lower power provided by iPA having been deemed to have no impact on the hopping sequence or this test.

2.2.5 Environmental Conditions

Ambient Temperature 22.0 °C
Relative Humidity 44.0 %

2.2.6 Test Results

Bluetooth (ePA) - DH5/2DH5/3DH5

Packet Type	Dwell Time (ms)	Number of Transmissions	Average Occupancy Time (ms)
DH5	2.858	109	311.552
2DH5	2.880	96	276.48
3DH5	2.880	106	305.28

Table 7

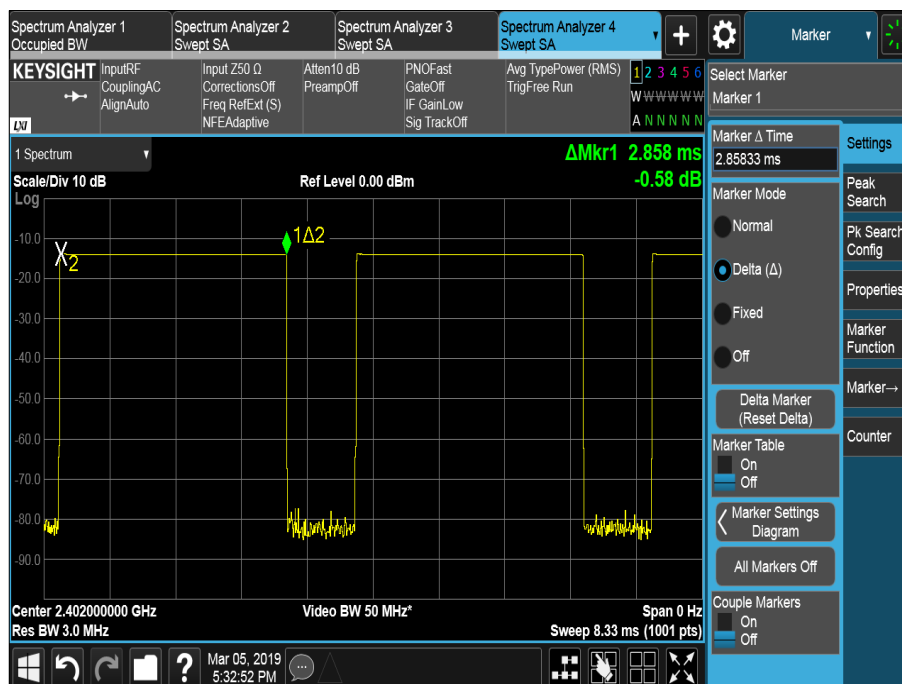


Figure 7 - DH5, Dwell Time

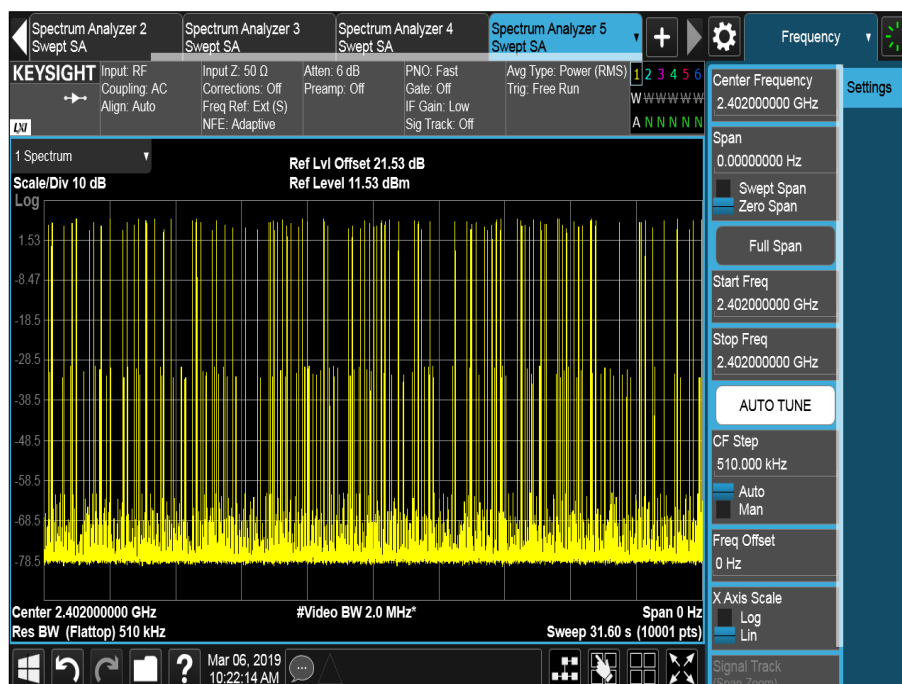


Figure 8 - DH5, Total Average Time of Occupancy

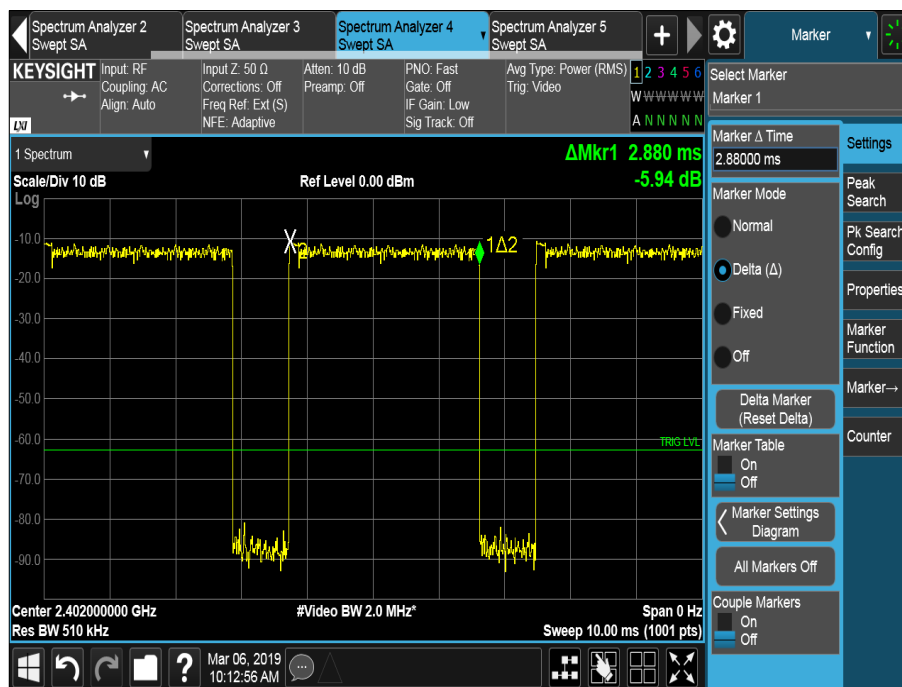


Figure 9 - 2DH5, Dwell Time

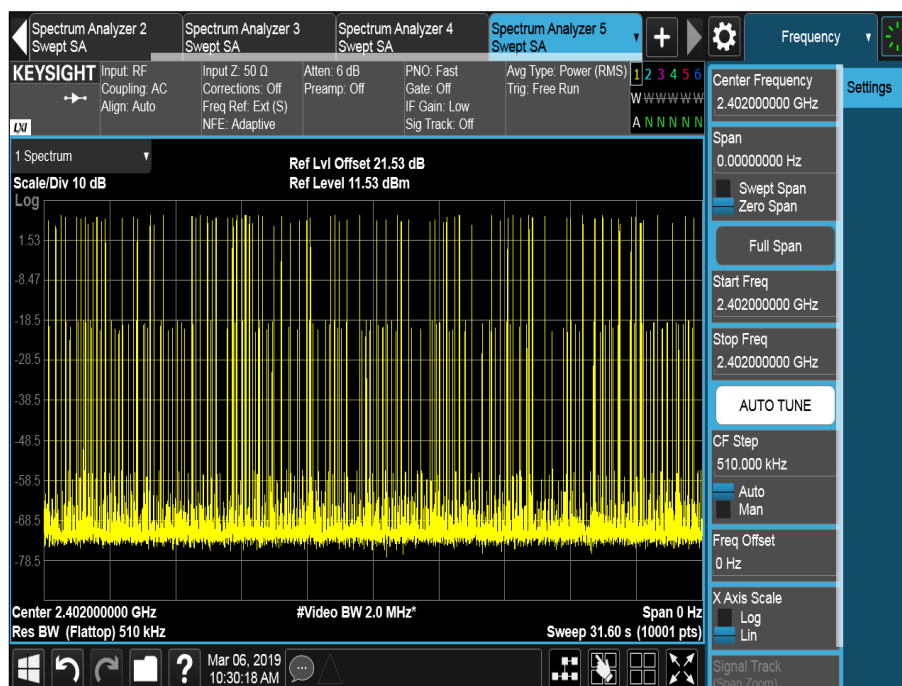


Figure 10 - 2DH5, Total Average Time of Occupancy

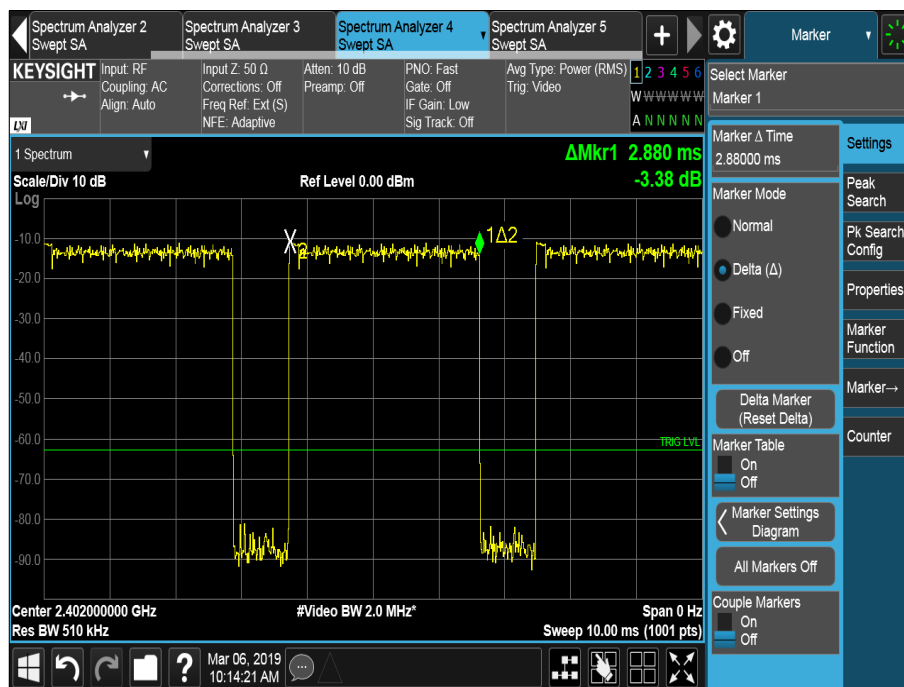


Figure 11 - 3DH5, Dwell Time

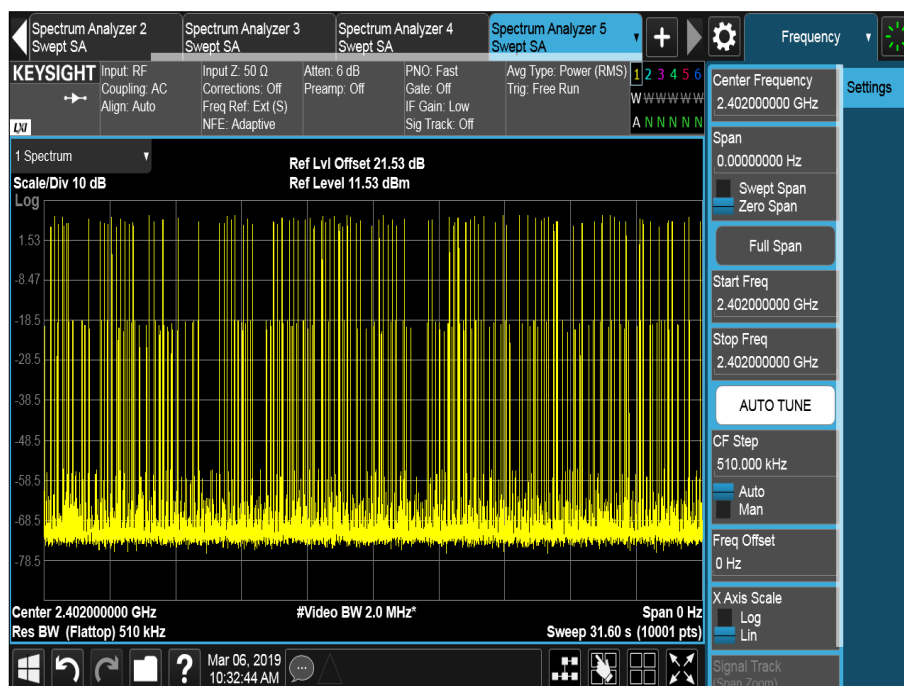


Figure 12 - 3DH5, Total Average Time of Occupancy



FCC 47 CFR Part 15, Limit Clause 15.247 (a)(1)(iii)

Frequency hopping systems operating in the band 2400-2483.5 MHz shall use at least 15 hopping channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Transmissions on particular hopping frequencies may be avoided or suppressed provided that a minimum of 15 hopping channels are used.

Industry Canada RSS-247, Limit Clause 5.1 (d)

The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds, multiplied by the number of hopping channels employed.

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
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
Cable (18GHz)	Rosenberger	LU7-036-2000	5039	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 8

O/P Mon - Output Monitored Using Calibrated Equipment



2.3 Frequency Hopping Systems - Channel Separation

2.3.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.247 (a)(1) and 5.1

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 & 22-March-2019

2.3.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 7.8.2.

2.3.5 Environmental Conditions

Ambient Temperature 22.0 °C

Relative Humidity 44.0 %

2.3.6 Test Results

Bluetooth (ePA) - DH5/2DH5/3DH5

Modulation	Channel Separation (MHz)
GFSK	0.999
$\pi/4$ DQPSK	0.999
8-DPSK	0.999

Table 9

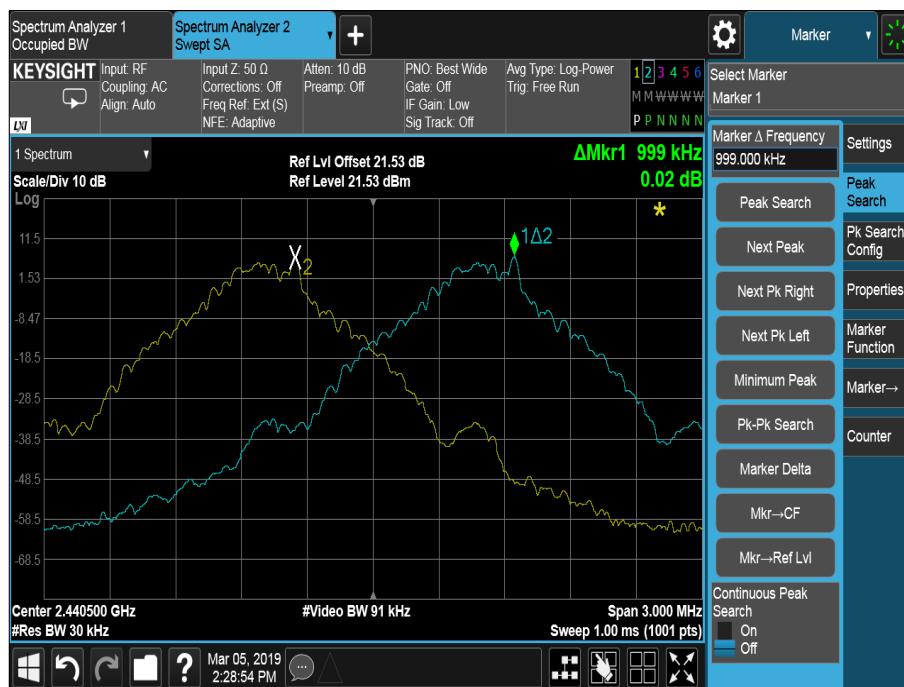


Figure 13 - GFSK



Figure 14 - $\pi/4$ DQPSK



Figure 15 - 8-DPSK



FCC 47 CFR Part 15, Limit Clause 15.247 (a)(1)

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater.

Alternatively, frequency hopping systems operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 0.125 W.

Industry Canada RSS-247, Limit Clause 5.1 (b)

FHSs shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, FHSs operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.



Bluetooth (iPA) - DH5/2DH5/3DH5

Modulation	Channel Separation (MHz)
GFSK	0.999
$\pi/4$ DQPSK	0.999
8-DPSK	0.999

Table 10



Figure 16 - GFSK



Figure 17 - $\pi/4$ DQPSK



Figure 18 - 8-DPSK



FCC 47 CFR Part 15, Limit Clause 15.247 (a)(1)

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater.

Alternatively, frequency hopping systems operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 0.125 W.

Industry Canada RSS-247, Limit Clause 5.1 (b)

FHSs shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, FHSs operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

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
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
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 11



2.4 Frequency Hopping Systems - Number of Hopping Channels

2.4.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and Industry Canada RSS-GEN, Clause 15.247 (a)(1) and 5.1

2.4.2 Equipment Under Test and Modification State

A2159, S/N: C02Y400PL5FL - Modification State 0

2.4.3 Date of Test

05-March-2019

2.4.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 7.8.3.

Testing has been limited to DH5 (ePA) mode only, as this was deemed to be worst case.

2.4.5 Environmental Conditions

Ambient Temperature 22.0 °C
Relative Humidity 44.0 %

2.4.6 Test Results

Bluetooth (ePA) - DH5

Number of Hopping Channels:79

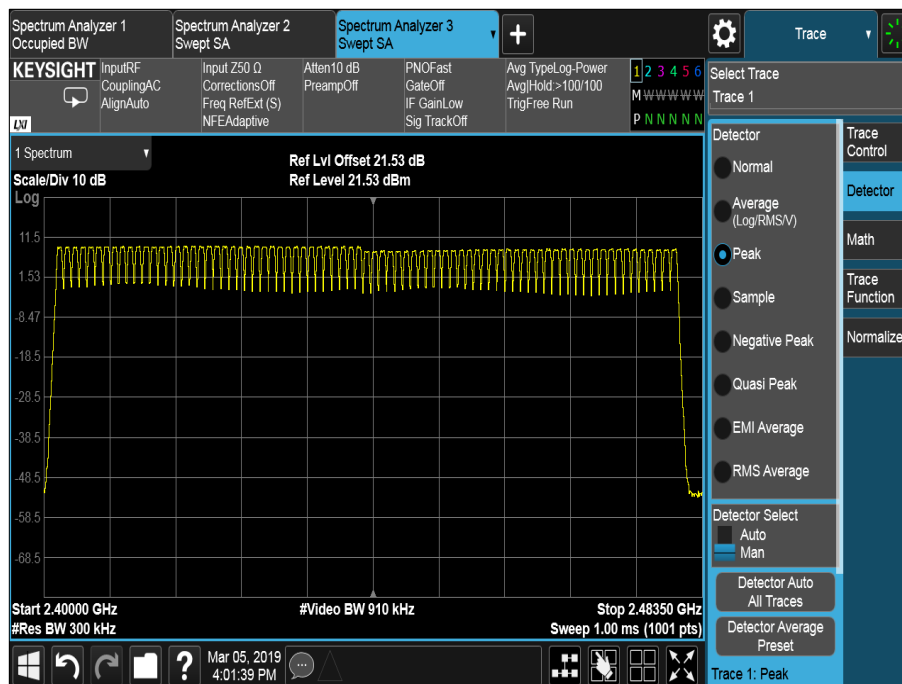


Figure 19 - Measurement Frequency Range: 2400 MHz to 2483.5 MHz



2.4.7 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
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
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 12



2.5 Frequency Hopping Systems - 20 dB Bandwidth

2.5.1 Specification Reference

FCC 47 CFR Part 15C, Industry Canada RSS-247 and
Industry Canada RSS-GEN, Clause 15.247 (a)(1) and 5.1

2.5.2 Equipment Under Test and Modification State

A2159, S/N: C02Y400PL5FL - Modification State 0

2.5.3 Date of Test

05-March-2019

2.5.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 6.9.2

2.5.5 Environmental Conditions

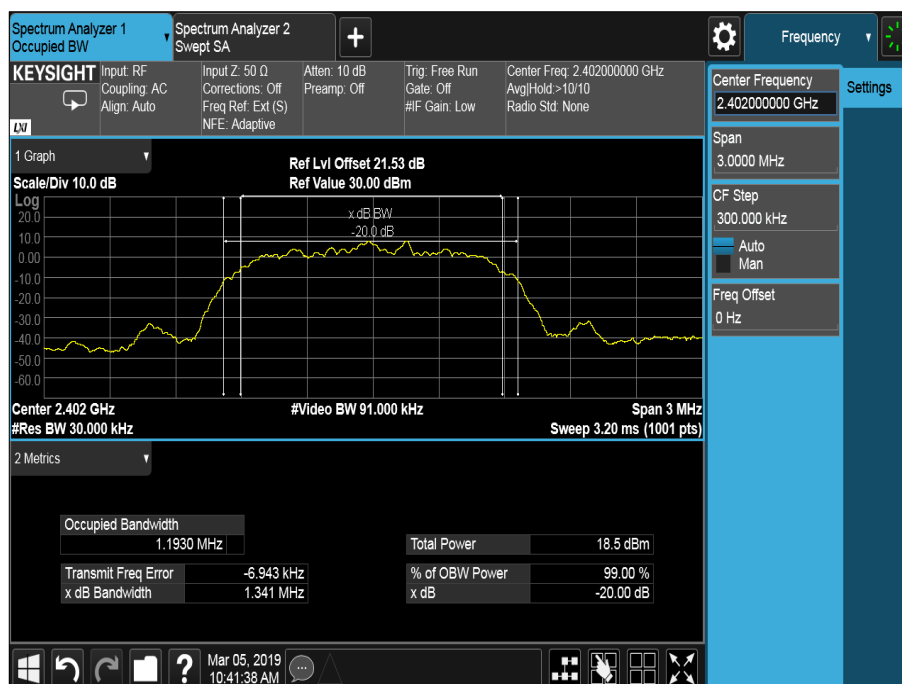
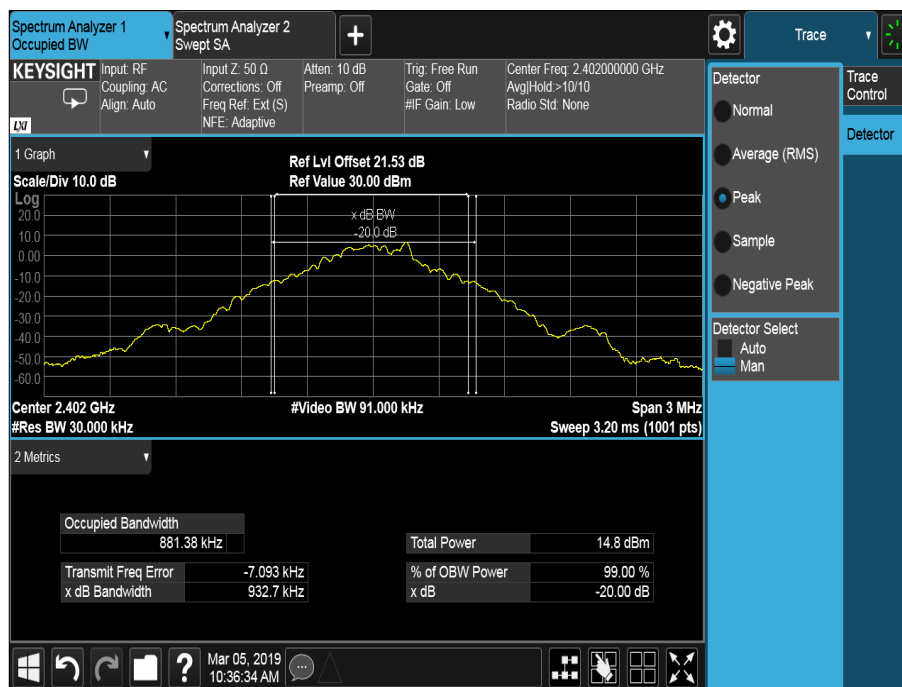
Ambient Temperature 22.0 °C
Relative Humidity 44.0 - 53.0 %

2.5.6 Test Results

Bluetooth (ePA) - DH5/2DH5/3DH5

Frequency (MHz)	20 dB Bandwidth (kHz)		
	GFSK	$\pi/4$ DQPSK	8-DPSK
2402	932.7	1341.0	1300.0
2441	932.6	1341.0	1299.0
2480	931.9	1341.0	1300.0

Table 13



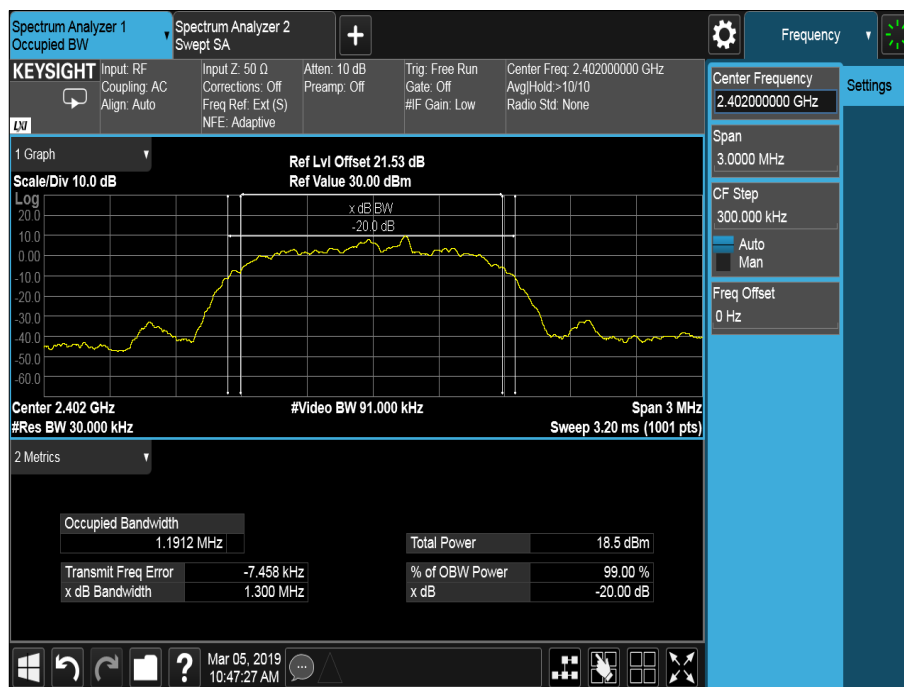


Figure 22 - 2402 MHz - 8-DPSK

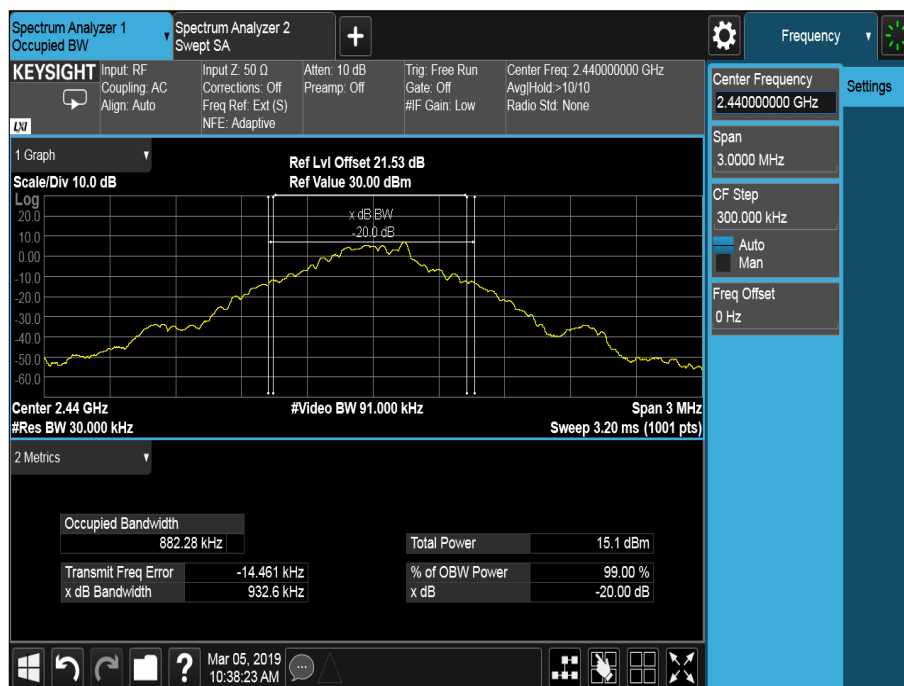


Figure 23 - 2441 MHz - GFSK



Figure 24 - 2441 MHz - $\pi/4$ DQPSK

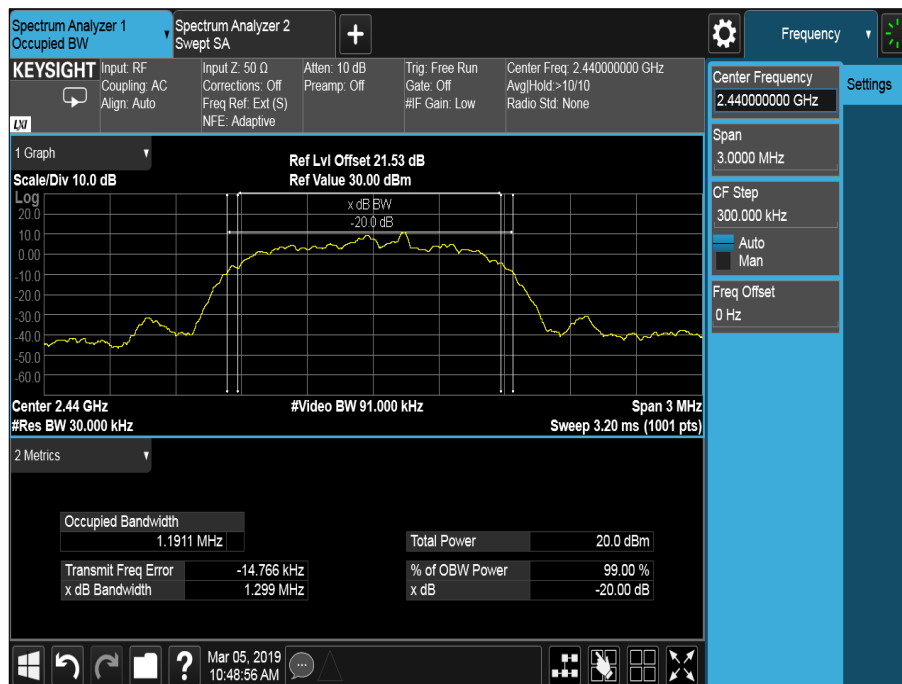


Figure 25 - 2441 MHz - 8-DPSK



Figure 26 - 2480 MHz - GFSK

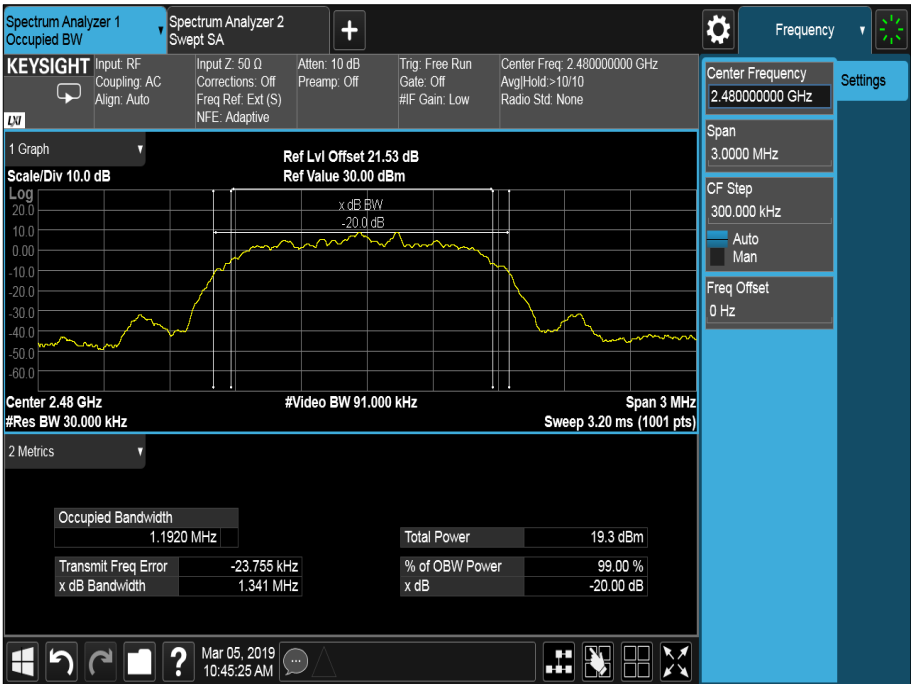


Figure 27 - 2480 MHz - $\pi/4$ DQPSK



Figure 28 - 2480 MHz - 8-DPSK



Bluetooth (iPA) - DH5/2DH5/3DH5

Frequency (MHz)	20 dB Bandwidth (kHz)		
	GFSK	$\pi/4$ DQPSK	8-DPSK
2402	923.7	1340.0	1301.0
2441	932.9	1340.0	1300.0
2480	933.2	1342.0	1301.0

Table 14



Figure 29 - 2402 MHz - GFSK



Figure 30 - 2402 MHz - $\pi/4$ DQPSK



Figure 31 - 2402 MHz - 8-DPSK



Figure 32 - 2441 MHz - GFSK

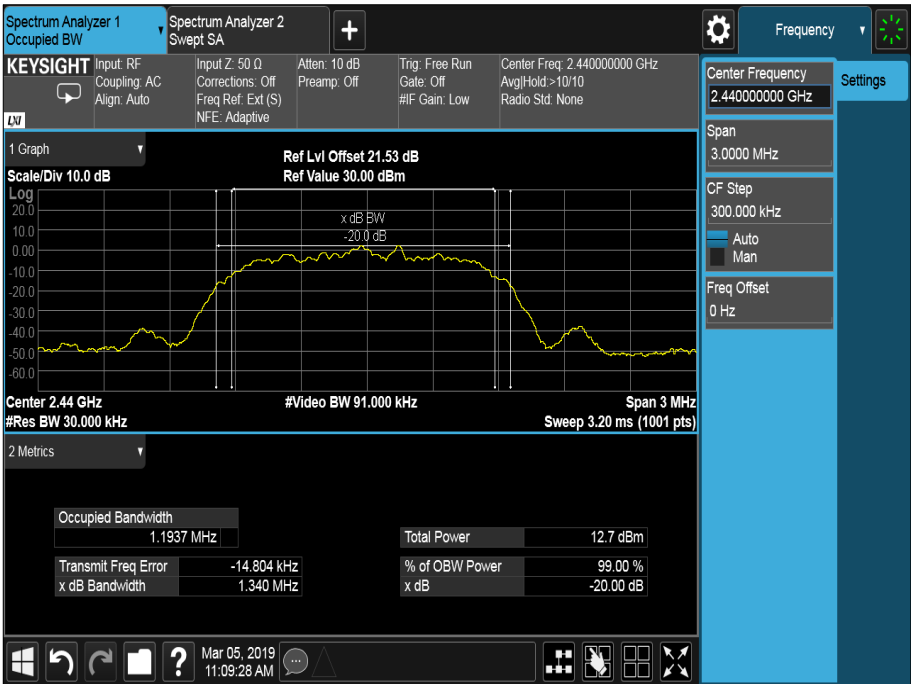


Figure 33 - 2441 MHz - $\pi/4$ DQPSK



Figure 34 - 2441 MHz - 8-DPSK



Figure 35 - 2480 MHz - GFSK



Figure 36 - 2480 MHz - $\pi/4$ DQPSK

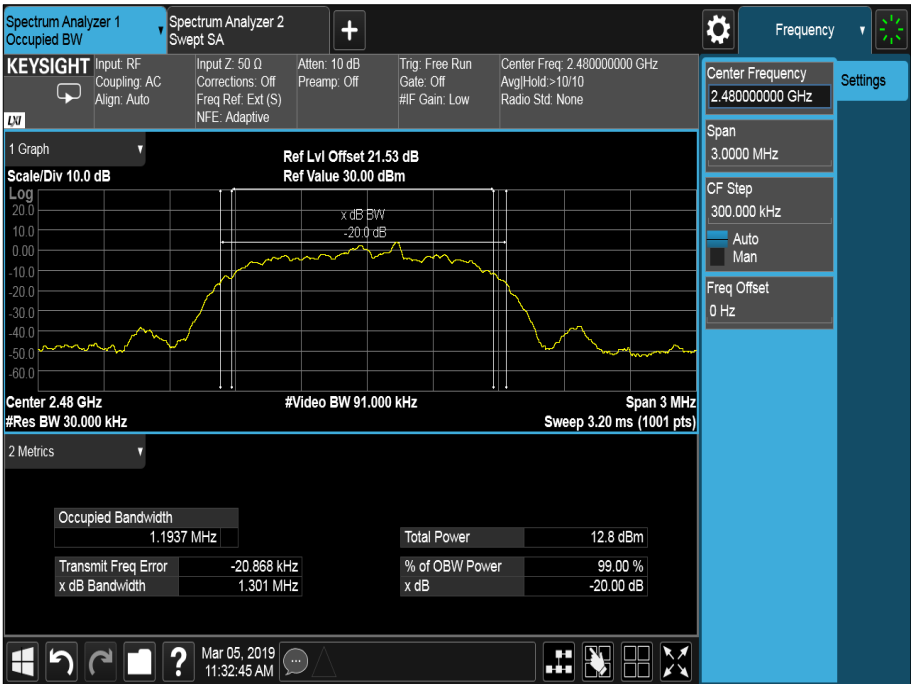


Figure 37 - 2480 MHz - 8-DPSK



FCC 47 CFR Part 15 and RSS-247 Limit Clause

None specified.



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
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
Cable (18GHz)	Rosenberger	LU7-036-2000	5039	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2019

Table 15

O/P Mon - Output Monitored Using Calibrated Equipment



2.6 Authorised Band Edges

2.6.1 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

2.6.2 Equipment Under Test and Modification State

A2159, S/N: C02Y4006L59F - Modification State 0

2.6.3 Date of Test

16-Feb-2019 to 16-March-2019

2.6.4 Test Method

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

2.6.5 Environmental Conditions

Ambient Temperature 22.9 - 23.3 °C

Relative Humidity 30.7 - 34.8 %

2.6.6 Test Results

Bluetooth (ePA) - DH5/2DH5/3DH5

Mode	Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
Static	GFSK	DH5	2402	2400.0	-65.30
Static	$\pi/4$ DQPSK	2DH5	2402	2400.0	-49.78
Static	8-DPSK	3DH5	2402	2400.0	-52.38
Hopping	GFSK	DH5	n/a	2400.0	-66.98
Hopping	$\pi/4$ DQPSK	2DH5	n/a	2400.0	-67.15
Hopping	8-DPSK	3DH5	n/a	2400.0	-69.96

Table 16

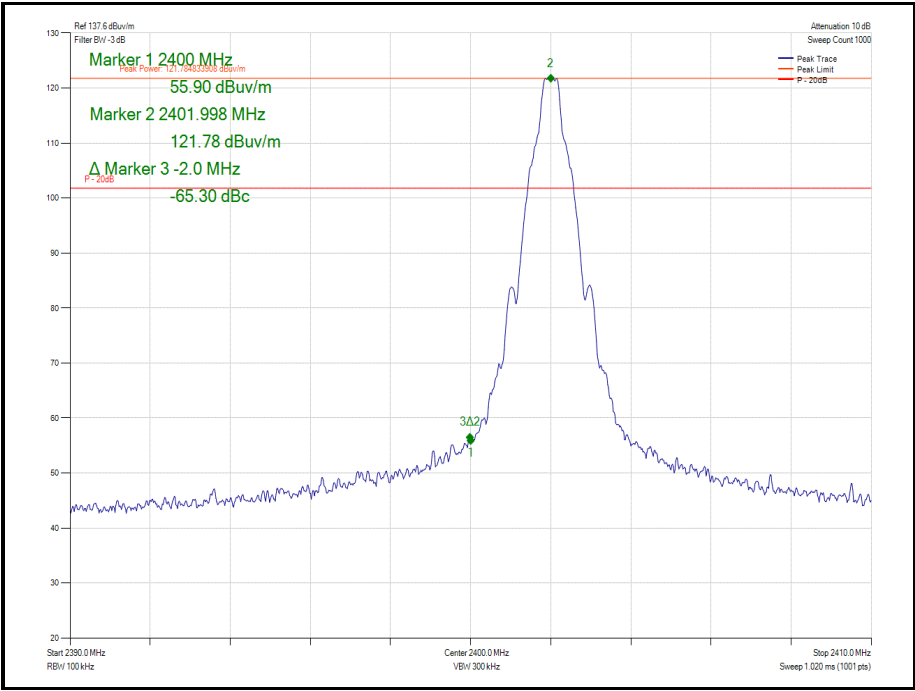


Figure 38 - Static - GFSK/DH5 - 2402 MHz – Band Edge Frequency 2400.0 MHz

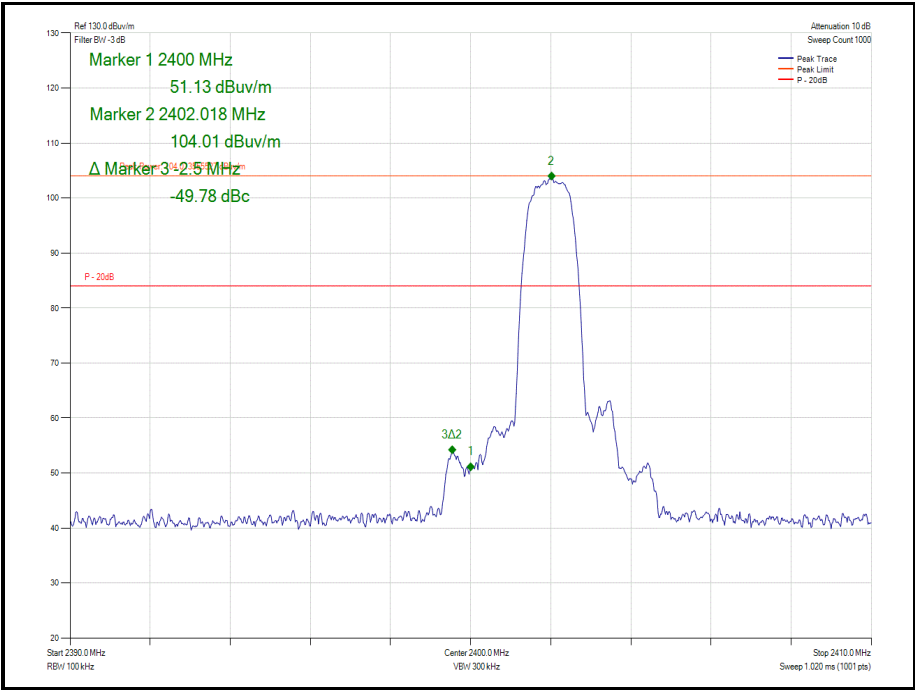
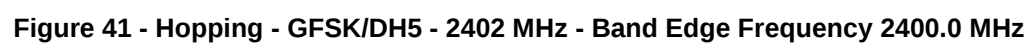


Figure 39 - Static - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz



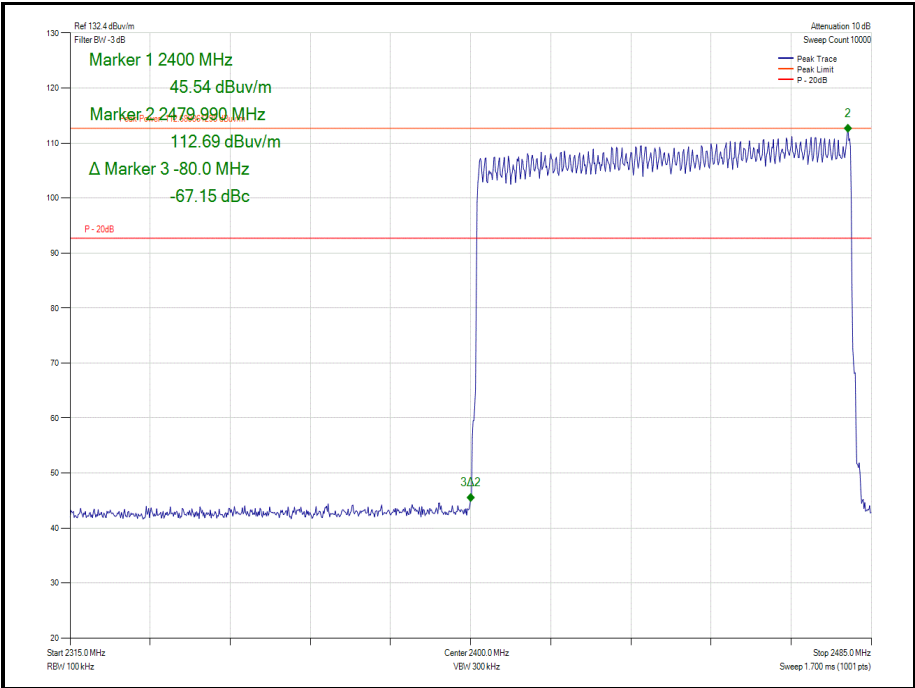


Figure 42 - Hopping - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz

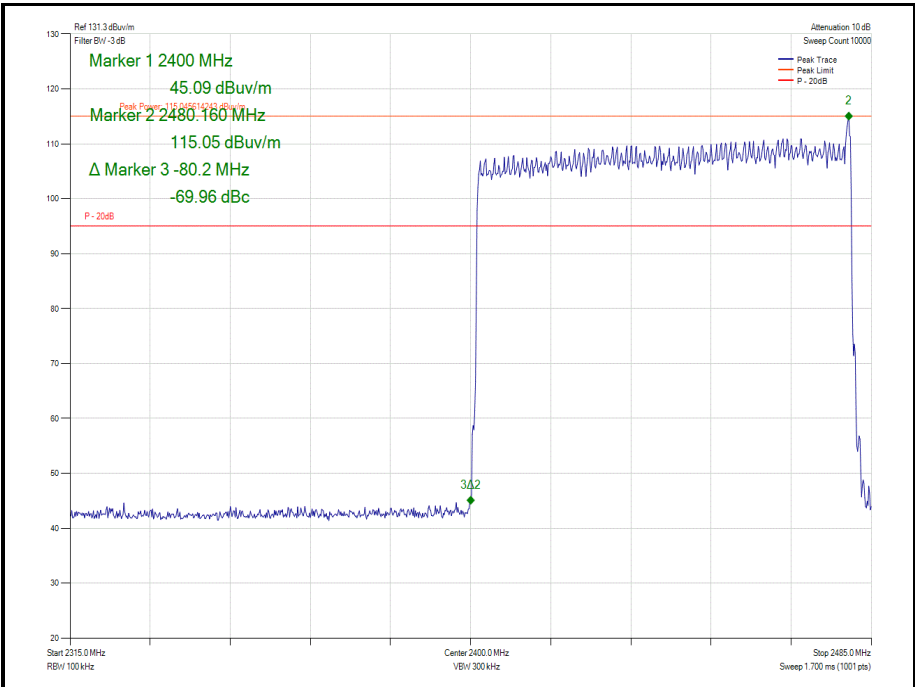


Figure 43 - Hopping - 8-DPSK/3DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz



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.



2.6.7 Test Location and Test Equipment Used

This test was carried out in RF Chamber 11.

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	11-Mar-2020
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 17

TU - Traceability Unscheduled



2.7 Restricted Band Edges

2.7.1 Specification Reference

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

2.7.2 Equipment Under Test and Modification State

A2159, S/N: C02Y4006L59F - Modification State 0

2.7.3 Date of Test

16-Feb-2019 to 16-March-2019

2.7.4 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:
 $10^{(\text{Field Strength in dB}\mu\text{V/m}/20)}$.

2.7.5 Environmental Conditions

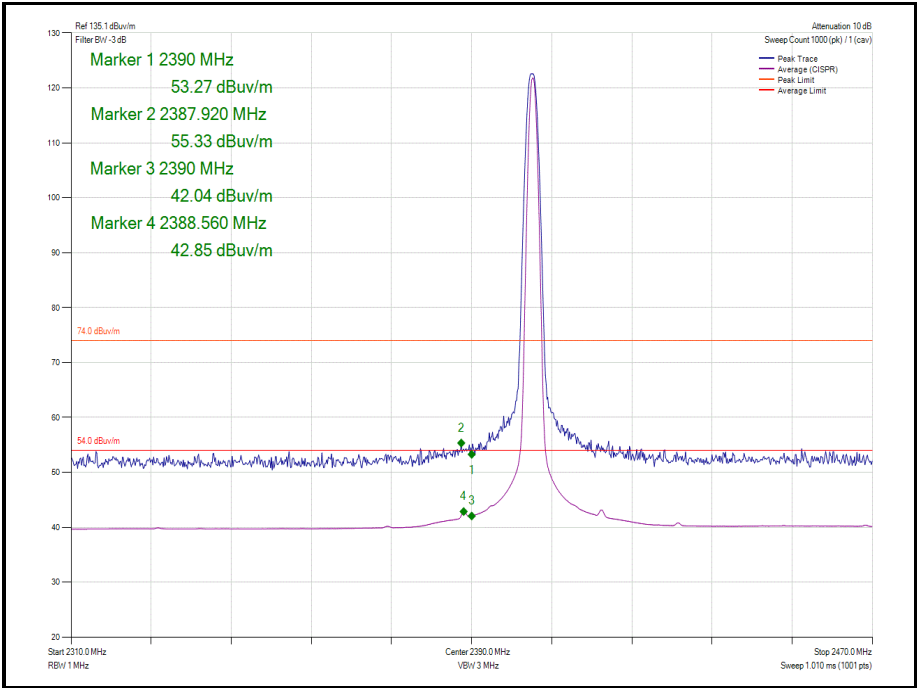
Ambient Temperature 23.1 - 23.3 °C
Relative Humidity 34.7 - 34.8 %

2.7.6 Test Results

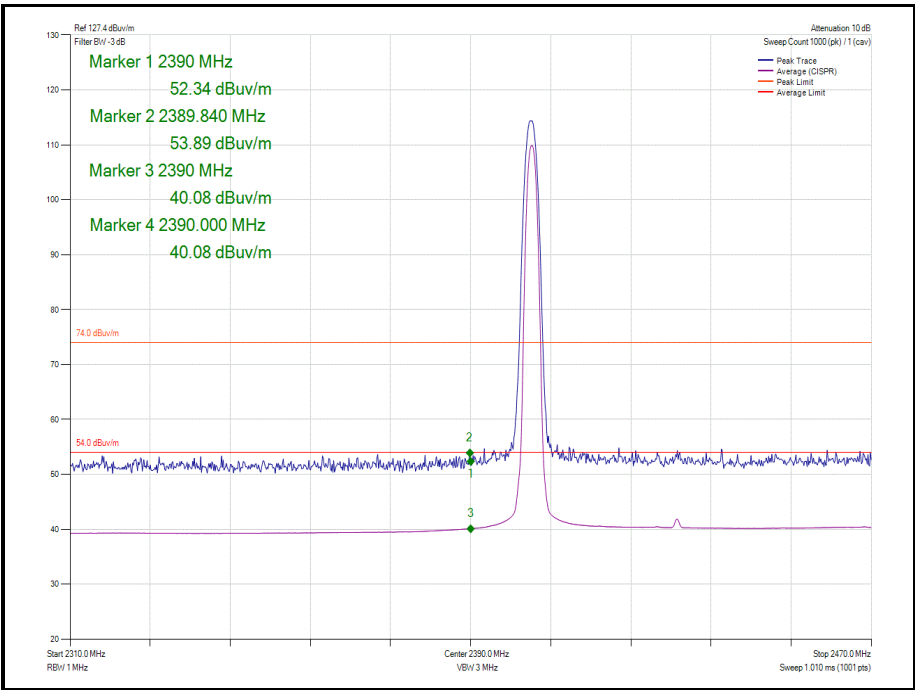
Bluetooth (ePA) - DH5/2DH5/3DH5

Mode	Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Peak Level (dBμV/m)	Average Level (dBμV/m)
Static	GFSK	DH5	2402	2390.0	55.33	42.85
Static	π/4 DQPSK	2DH5	2402	2390.0	53.89	40.08
Static	8-DPSK	3DH5	2402	2390.0	54.09	40.23
Static	GFSK	DH5	2480	2483.5	60.04	49.02
Static	π/4 DQPSK	2DH5	2480	2483.5	55.17	44.17
Static	8-DPSK	3DH5	2480	2483.5	56.69	45.58
Hopping	GFSK	DH5	n/a	2390.0	54.45	40.14
Hopping	π/4 DQPSK	2DH5	n/a	2390.0	54.71	39.75
Hopping	8-DPSK	3DH5	n/a	2390.0	54.33	39.63
Hopping	GFSK	DH5	n/a	2483.5	61.81	40.8
Hopping	π/4 DQPSK	2DH5	n/a	2483.5	60.3	40.23
Hopping	8-DPSK	3DH5	n/a	2483.5	58.19	40.12

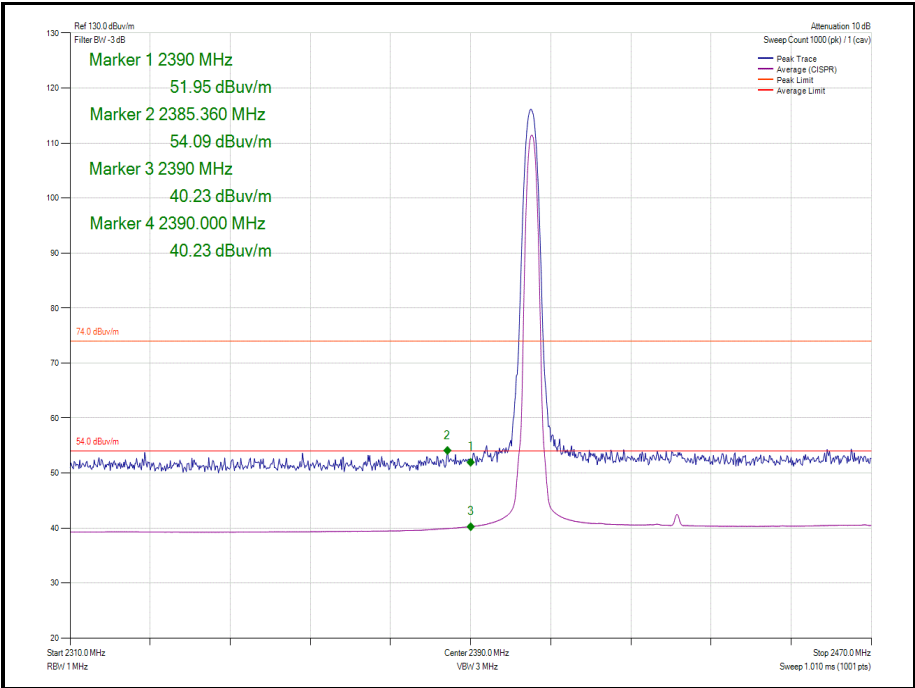
Table 18



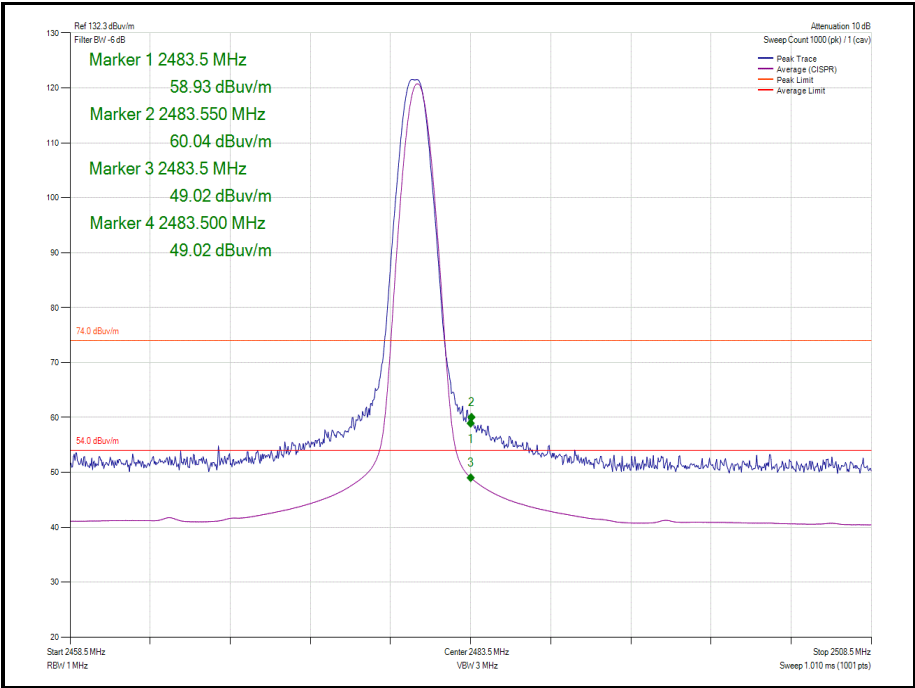
Static - GFSK/DH5 - 2402 MHz - Band Edge Frequency 2390.0 MHz



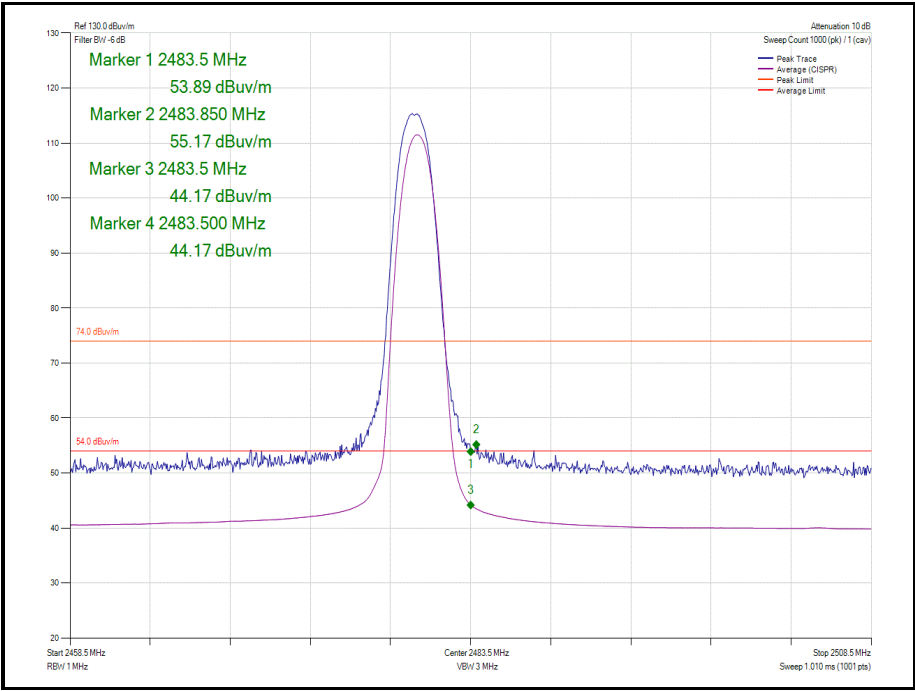
Static - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Band Edge Frequency 2390.0 MHz



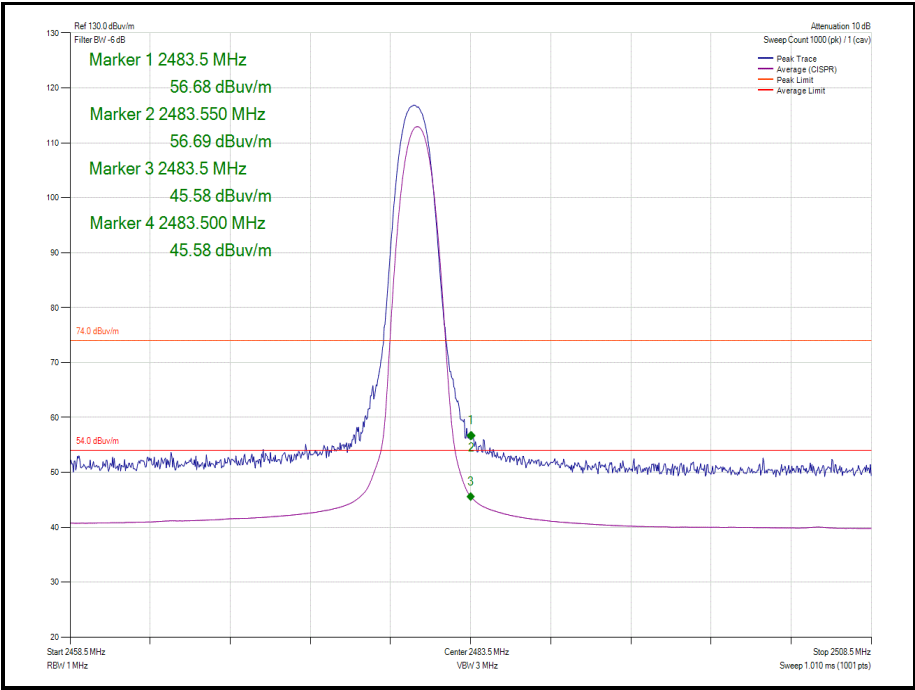
Static - 8-DPSK/3DH5 - 2402 MHz - Band Edge Frequency 2390.0 MHz



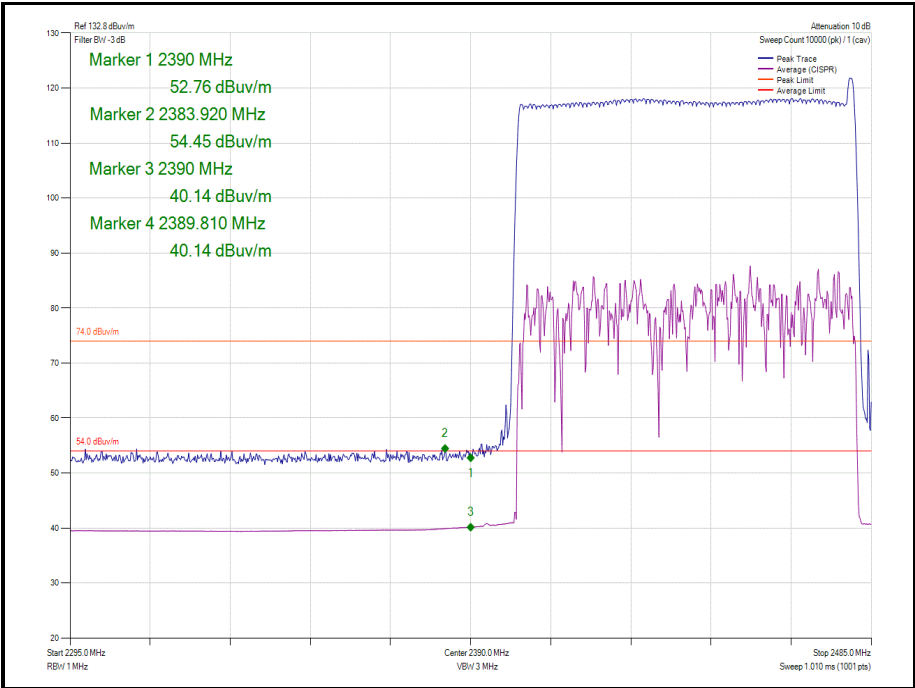
Static - GFSK/DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz



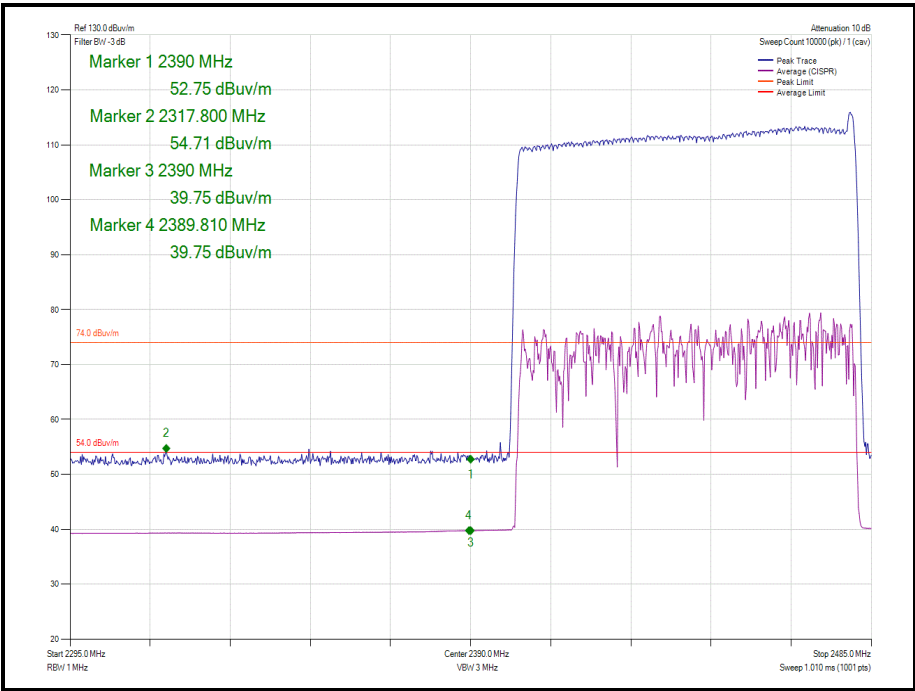
Static - $\pi/4$ DQPSK/2DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz



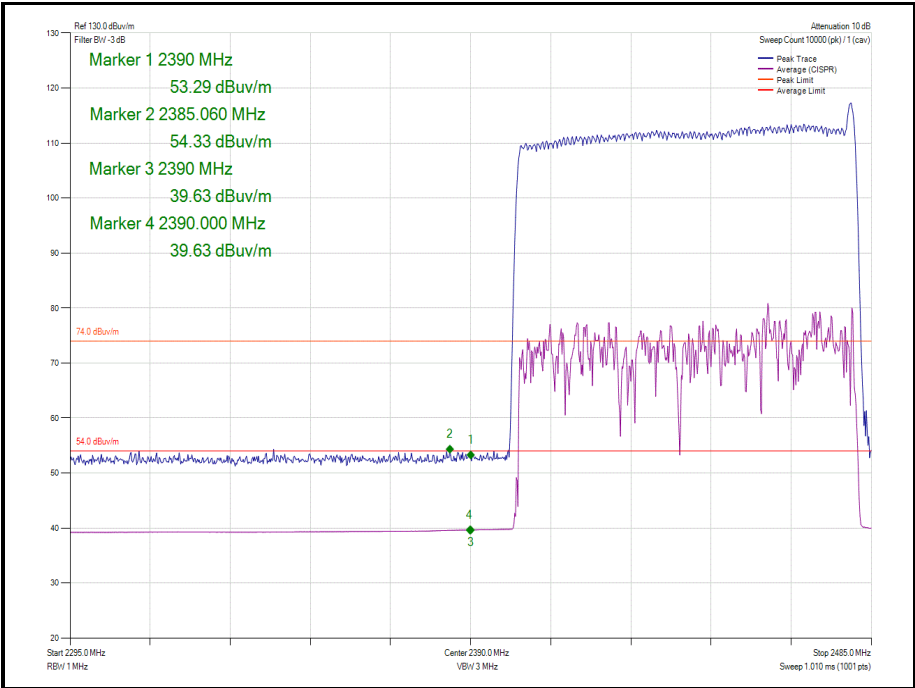
Static - GFSK/ - 2402 MHz - Band Edge Frequency 2390.0 MHz



Hopping - GFSK/DH5 - 2402 MHz - Measured Frequency 2390.0 MHz



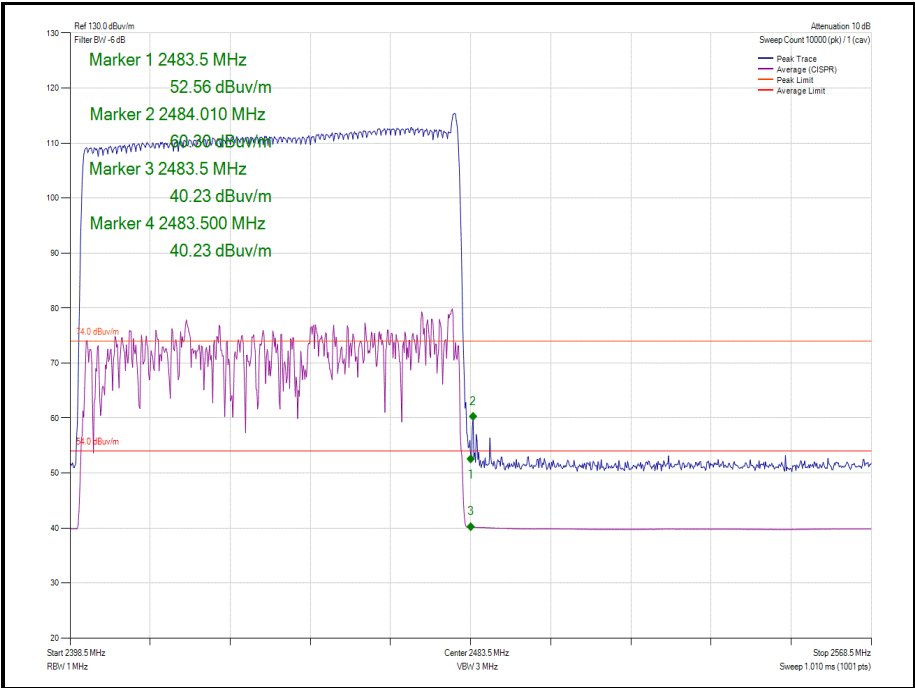
Hopping - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Measured Frequency 2390.0 MHz



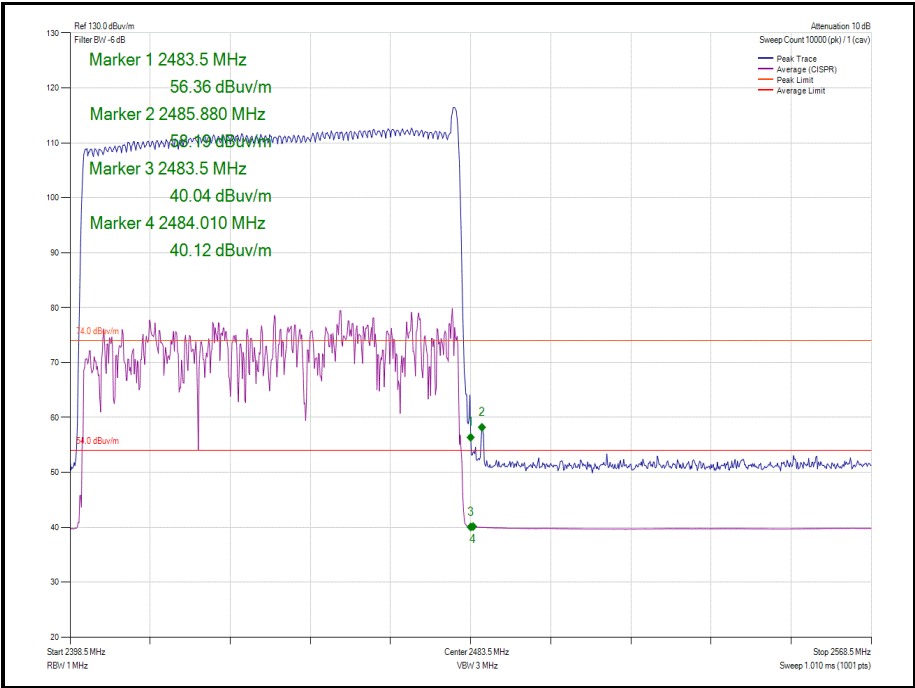
Hopping - 8-DPSK/3DH5 - 2402 MHz - Band Edge Frequency 2390.0 MHz



Hopping - GFSK/DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz



Hopping - $\pi/4$ DQPSK/2DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz



Hopping - 8-DPSK/3DH5 - 2480 MHz – Band Edge Frequency 2483.5 MHz



FCC 47 CFR Part 15, Limit Clause 15.209

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

Table 19

Industry Canada RSS-GEN, Limit Clause 8.9

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

Table 20

*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.



2.7.7 Test Location and Test Equipment Used

This test was carried out in RF 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	11-Mar-2020
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



2.8 Spurious Radiated Emissions

2.8.1 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

2.8.2 Equipment Under Test and Modification State

A2159, S/N: C02Y3006L59G - Modification State 0

2.8.3 Date of Test

06-February-2019 to 12-March-2019

2.8.4 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 on mid channel (2412 MHz) and any emissions identified then measured on bottom (2437 MHz) and top (2472 MHz).

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 dBμV/m to μV/m:

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

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

2.8.5 Environmental Conditions

Ambient Temperature 21.7 - 29.4 °C

Relative Humidity 22.5 – 45.0 %



2.8.6 Test Results

Bluetooth (ePA) - DH5

Testing was performed on the modulation and packet type which resulted in the highest conducted output power.

Frequency (MHz)	QP Level (dBμV/m)	QP Limit (dBμV/m)	QP Margin (dB)	Angle (Deg)	Height (m)	Polarity
249.986	23.47	46.0	22.53	60	103	Vertical
358.578	25.75	46.0	20.25	271	104	Vertical
463.996	18.56	46.0	27.44	259	108	Vertical
483.441	19.33	46.0	26.67	320	100	Vertical
498.381	19.36	46.0	26.64	309	104	Vertical
955.835	27.33	46.0	18.67	356	383	Vertical

Table 22 –30 MHz to 1 GHz – Radiated

Frequency (GHz)	Result (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
7.206	*	46.28	74.0	54.0	n/a	7.72

Table 23 – 2402 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
4.882	*	35.18	74.0	54.0	n/a	18.82
7.322	*	44.19	74.0	54.0	n/a	9.81

Table 24 – 2441 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
7.440	*	43.26	74.0	54.0	n/a	10.74

Table 25 - 2480 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

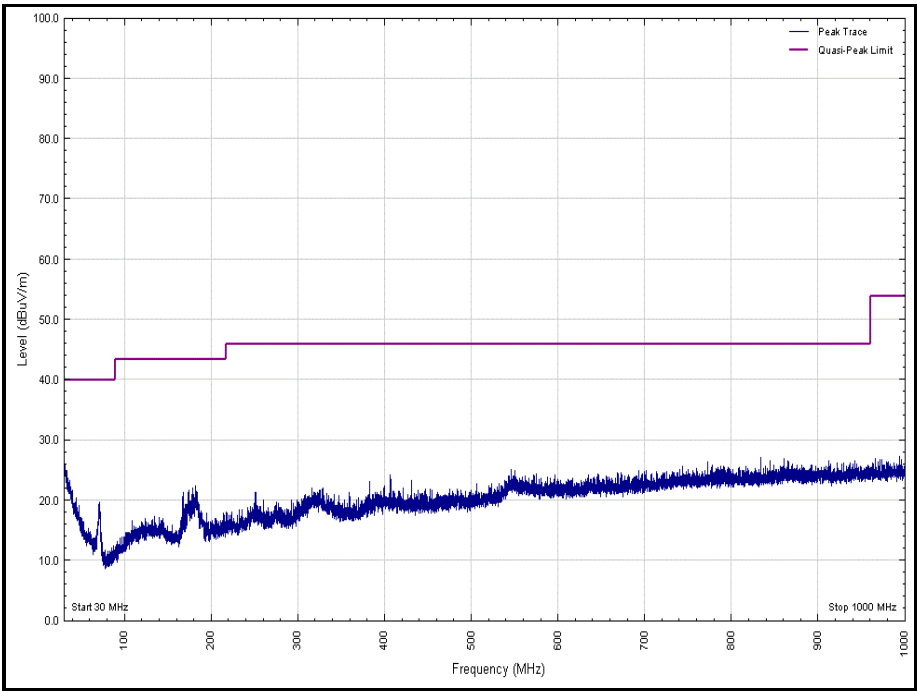


Figure 44 - 30 MHz to 1 GHz
Polarity: Horizontal

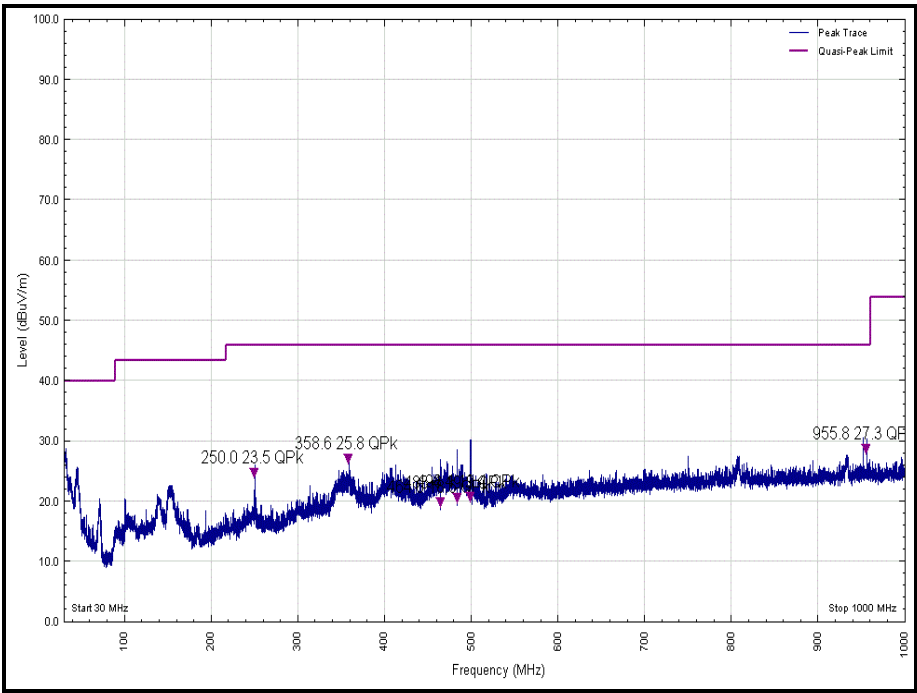


Figure 45 - 30 MHz to 1 GHz
Polarity: Vertical

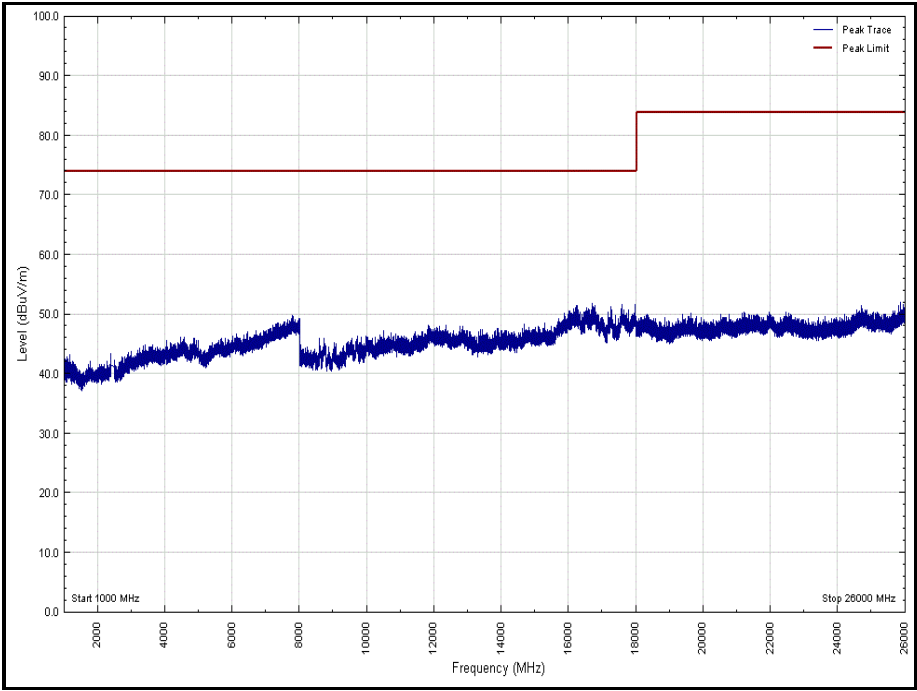


Figure 46 - 2402 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Horizontal

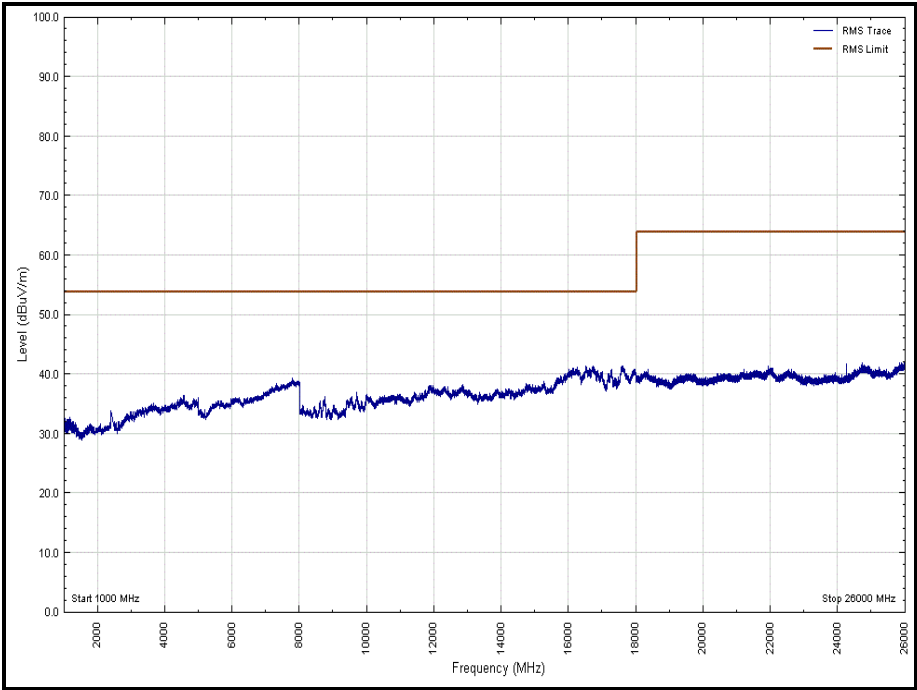


Figure 47 - 2402 MHz - 1 GHz to 26 GHz (Average)
Polarity: Horizontal

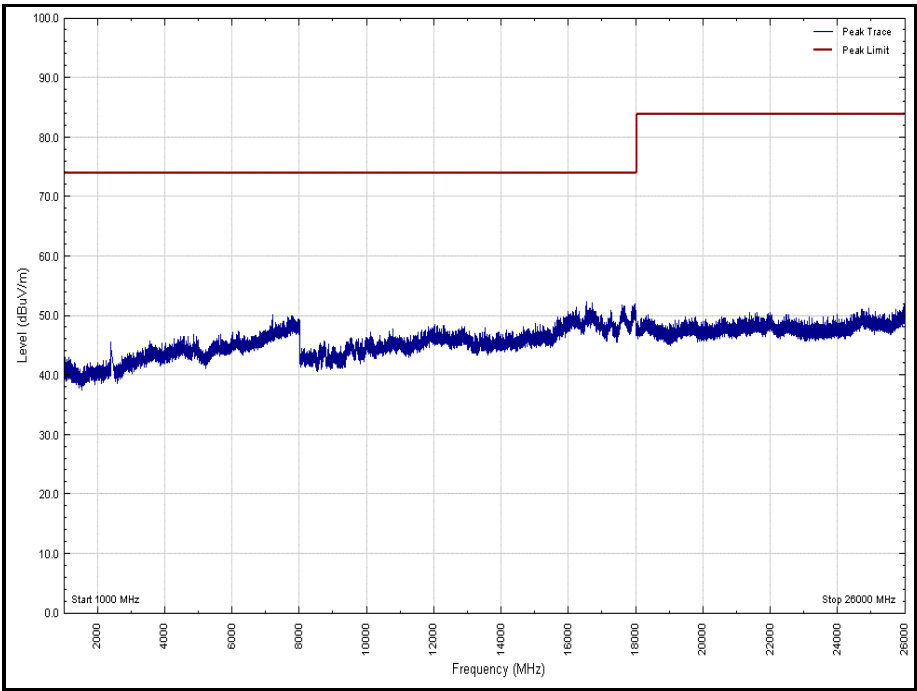


Figure 48 – 2402 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Vertical

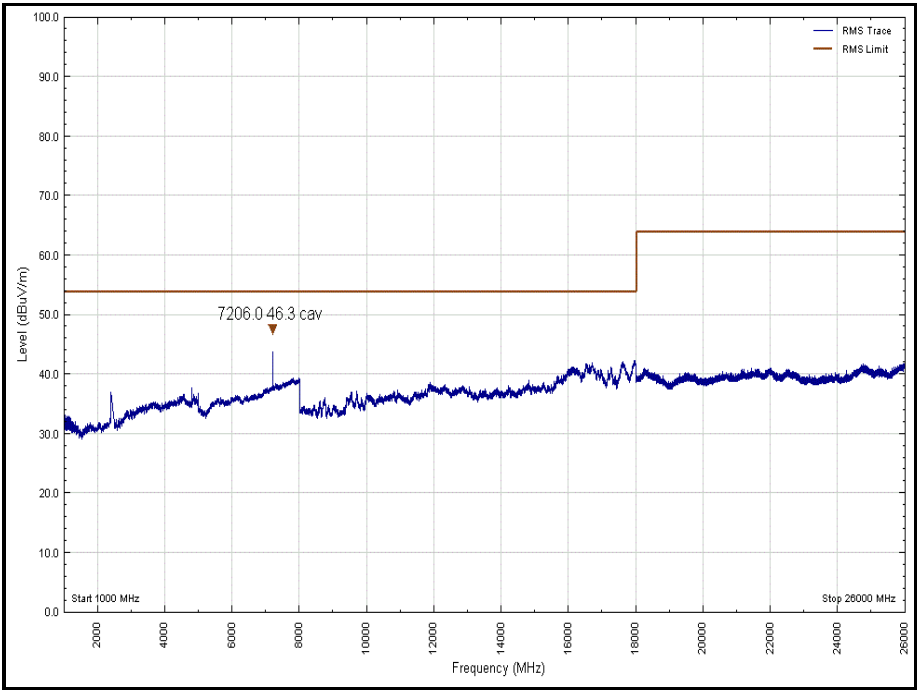


Figure 49 - 2402 MHz - 1 GHz to 26 GHz (Average)
Polarity: Vertical

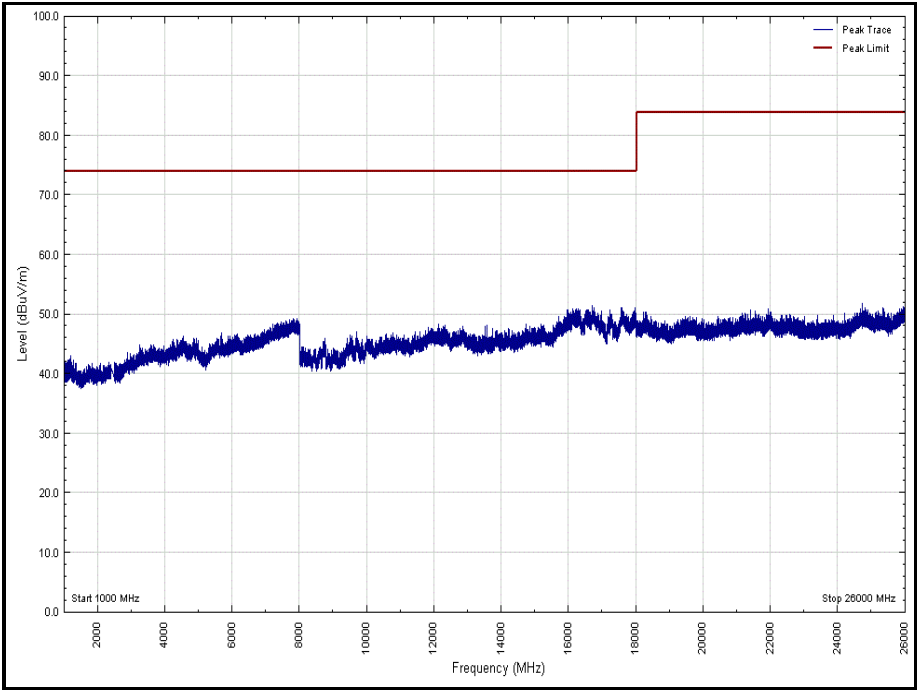


Figure 50 - 2441 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Peak)

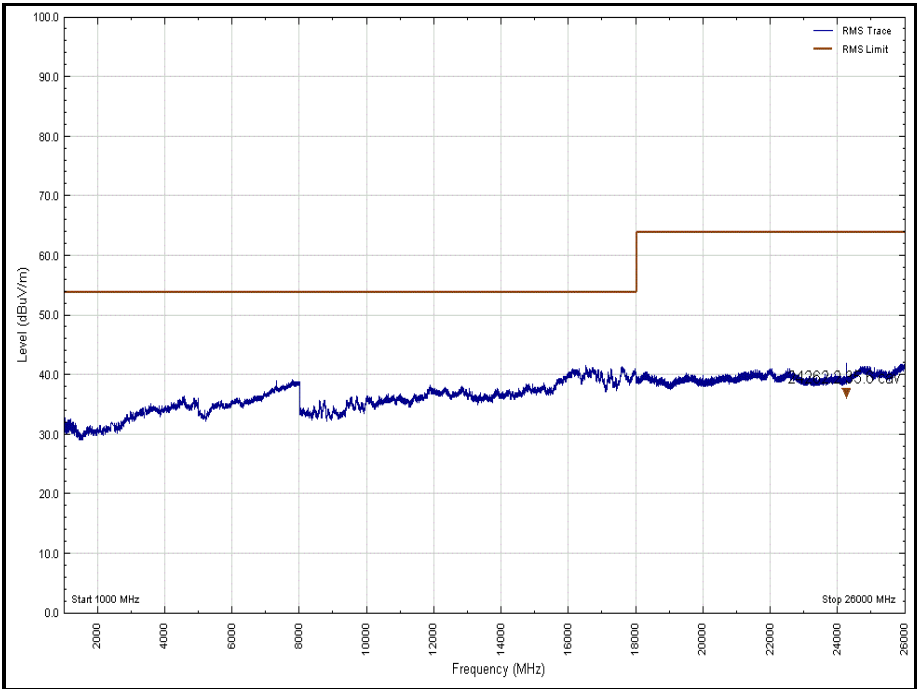


Figure 51 - 2441 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Average)

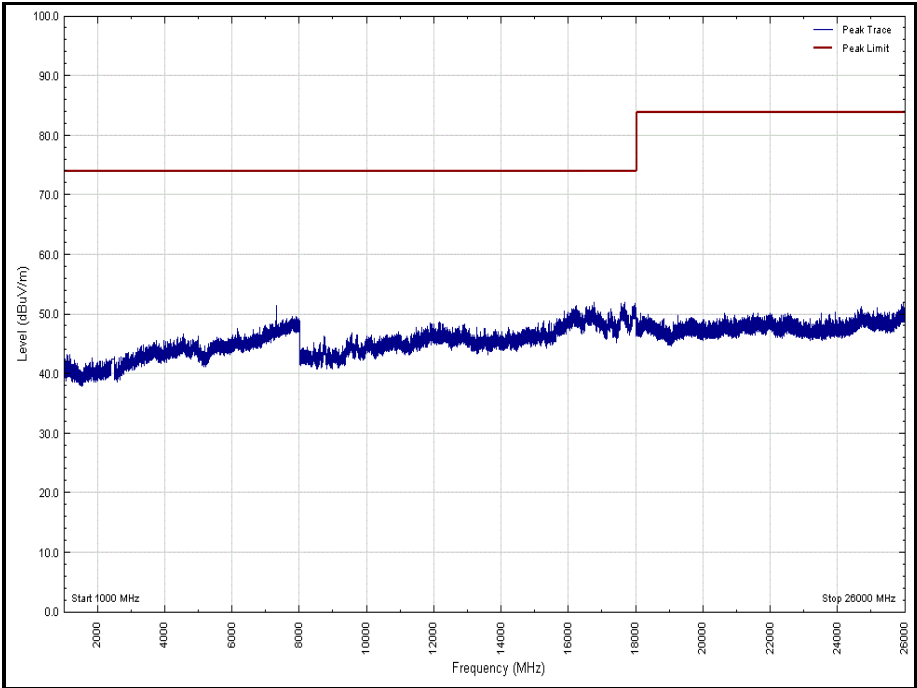


Figure 52 - 2441 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Peak)

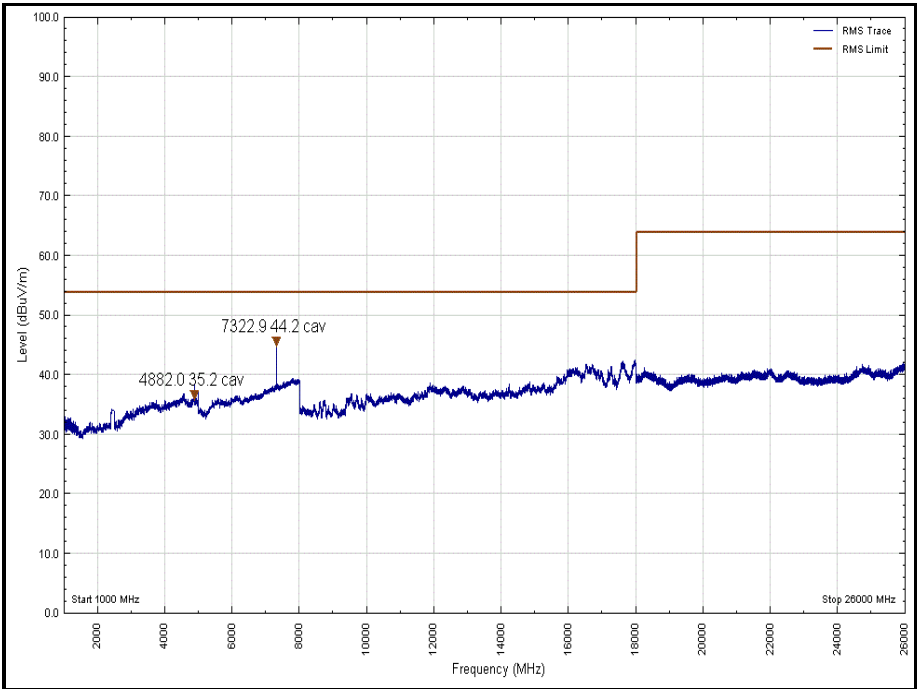


Figure 53 – 2441 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Average)

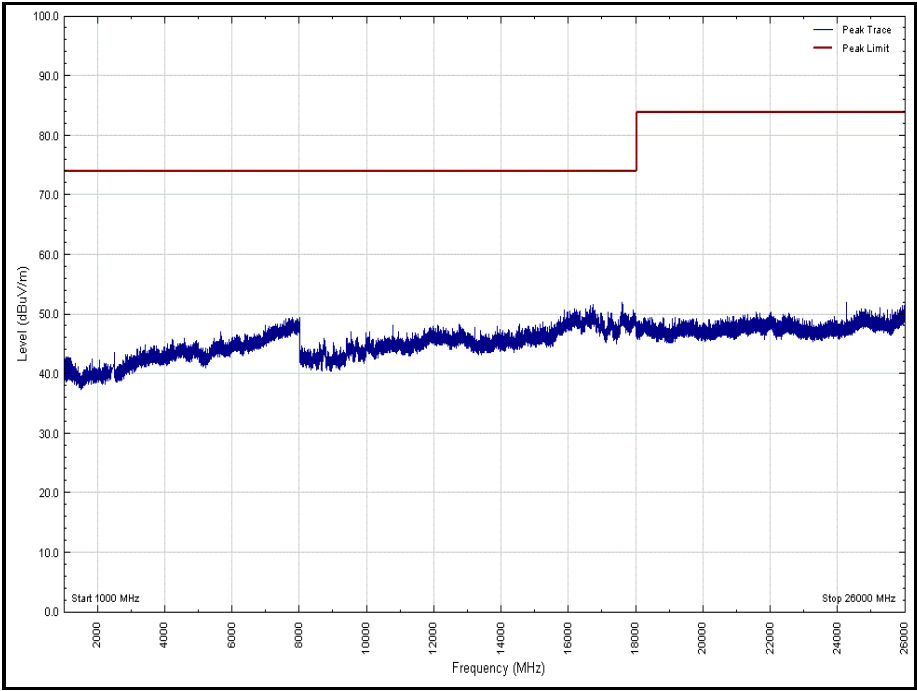


Figure 54 - 2472 MHz 1 GHz to 26 GHz
Polarity: Horizontal (Peak)

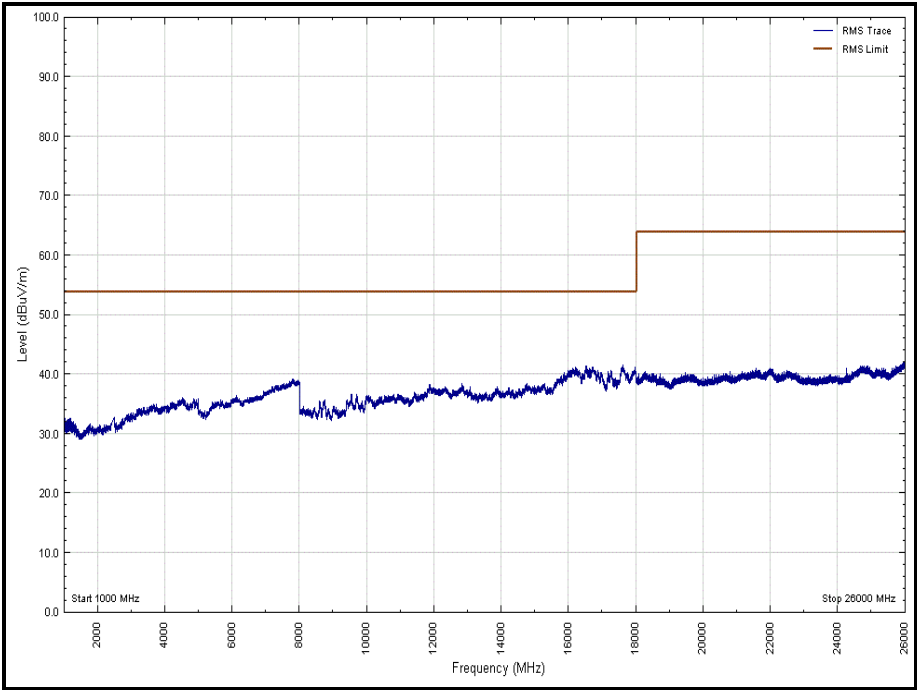


Figure 55 - 2472 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Average)

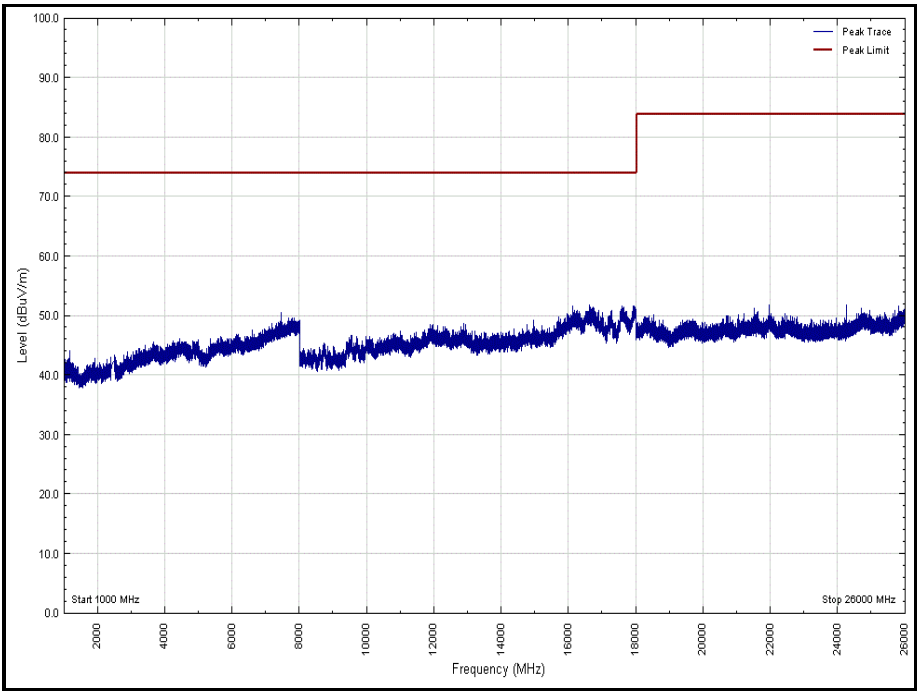


Figure 56 - 2472 MHz 1 GHz to 26 GHz
Polarity: Vertical (Peak)

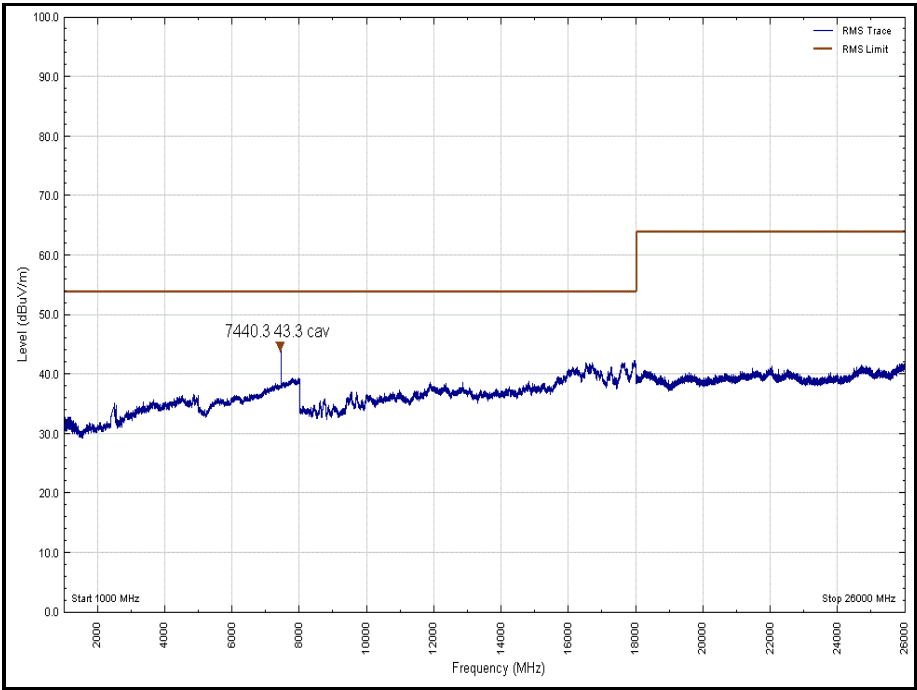


Figure 57 - 2472 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Average)



Bluetooth (iPA) - DH5

Testing was performed on the modulation and packet type which resulted in the highest conducted output power.

Frequency (MHz)	QP Level (dBuV/m)	QP Limit (dBuV/m)	QP Margin (dB)	Angle(Deg)	Height(m)	Polarity
249.971	24.32	46.0	21.68	302	117	Horizontal
274.985	12.64	46.0	33.36	123	217	Horizontal
358.537	28.24	46.0	17.76	171	104	Horizontal
486.435	20.62	46.0	25.38	186	107	Horizontal
923.465	28.25	46.0	17.75	27	110	Horizontal
952.057	19.11	46.0	26.89	27	243	Horizontal

Table 26 –30 MHz to 1 GHz – Radiated

Frequency (GHz)	Result (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
4.804	*	35.69	74.0	54.0	n/a	18.31

Table 27 – 2402 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
7.322	*	44.2	74.0	54.0	n/a	9.8
24.260	55.71	*	74.0	54.0	18.29	n/a

Table 28 – 2441 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

Frequency (GHz)	Result (dBμV/m)		Limit (dBμV/m)		Margin (dB)	
	Peak	Average	Peak	Average	Peak	Average
24.259	56.95	*	74.0	54.0	27.05	n/a

Table 29 - 2480 MHz - 1 GHz to 26 GHz – Radiated

*No emissions were detected within 10 dB of the limit

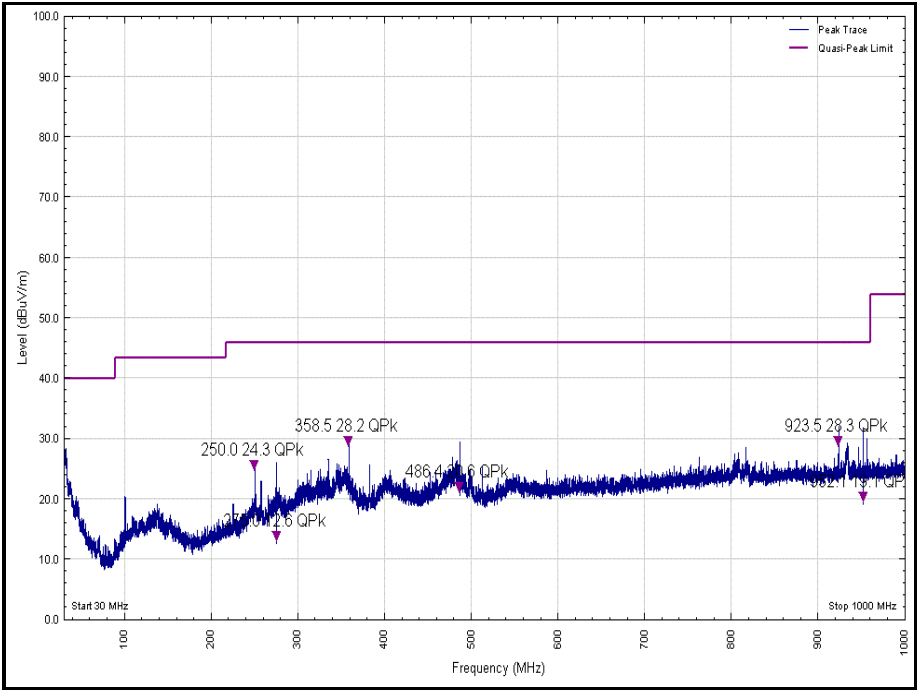


Figure 58 - 30 MHz to 1 GHz
Polarity: Horizontal

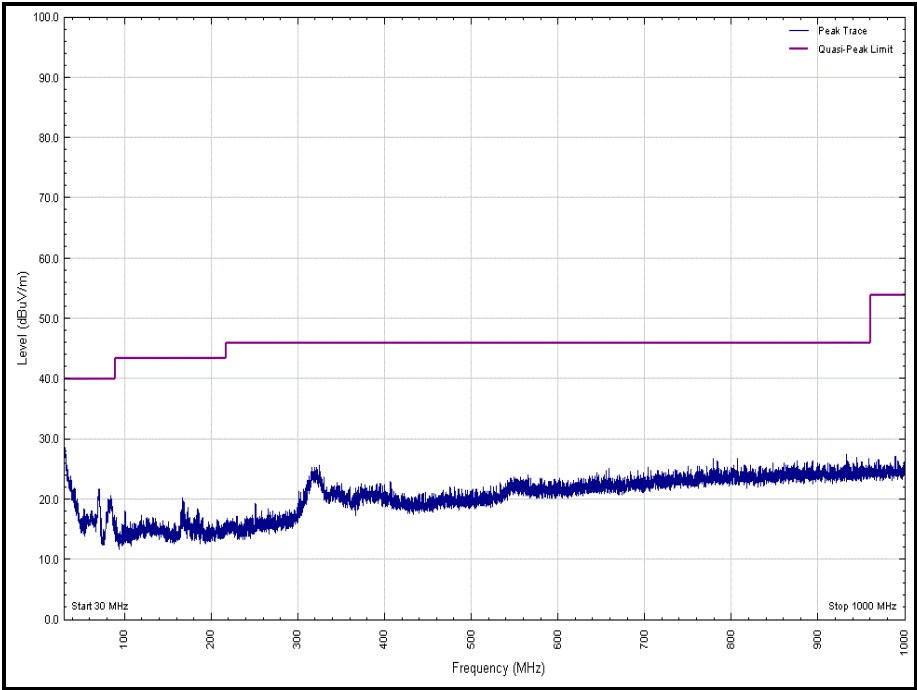


Figure 59 - 30 MHz to 1 GHz
Polarity: Vertical

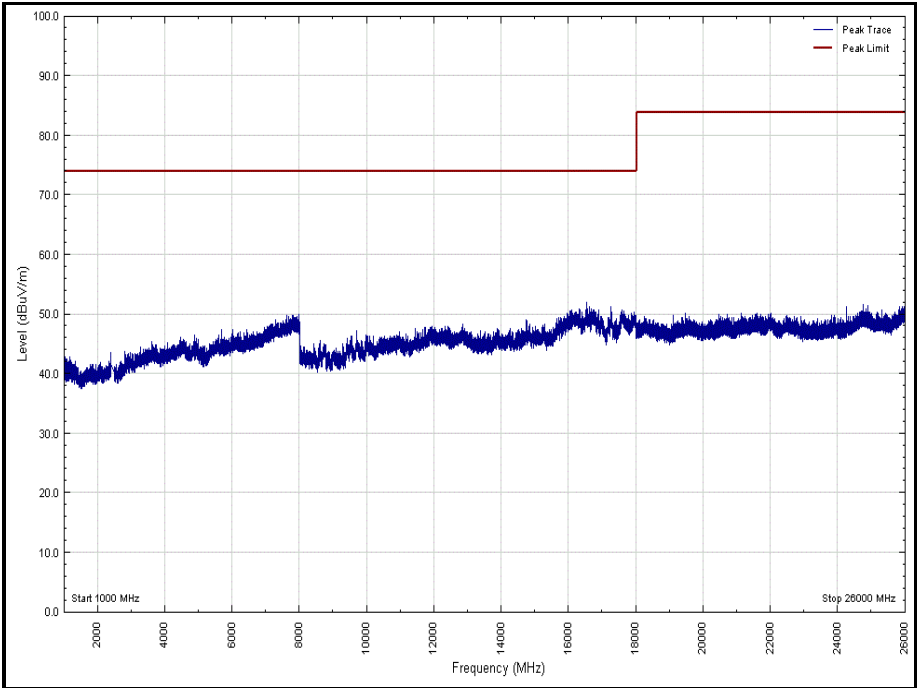


Figure 60 - 2402 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Horizontal

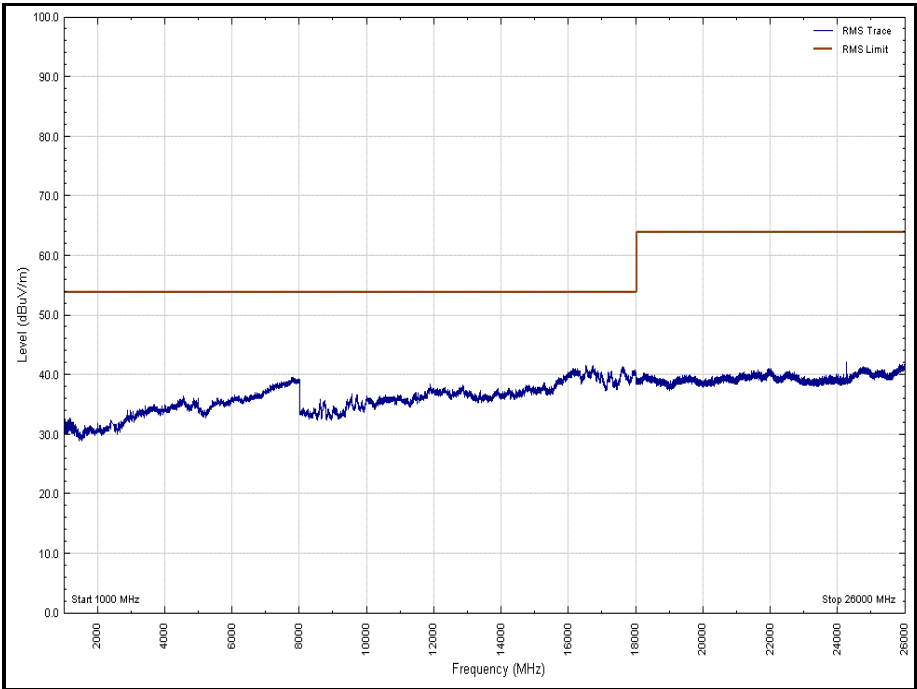


Figure 61 - 2402 MHz - 1 GHz to 26 GHz (Average)
Polarity: Horizontal

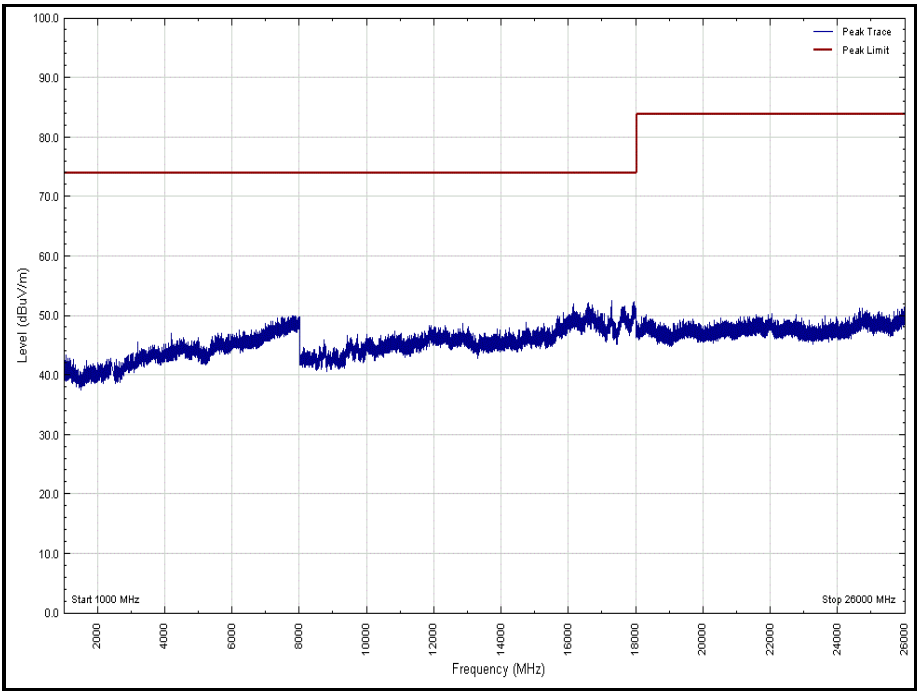


Figure 62 – 2402 MHz - 1 GHz to 26 GHz (Peak)
Polarity: Vertical

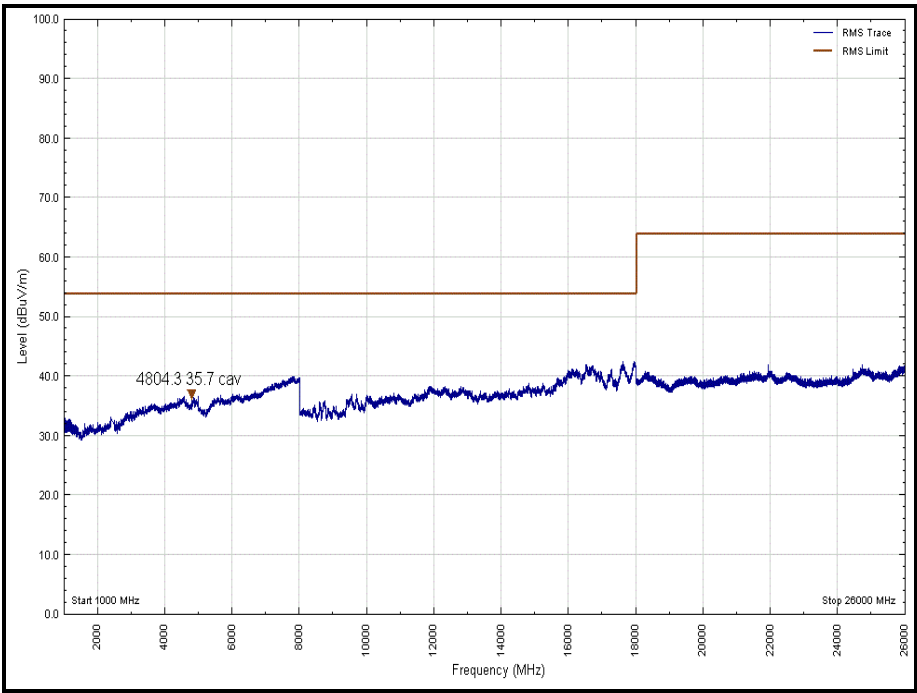
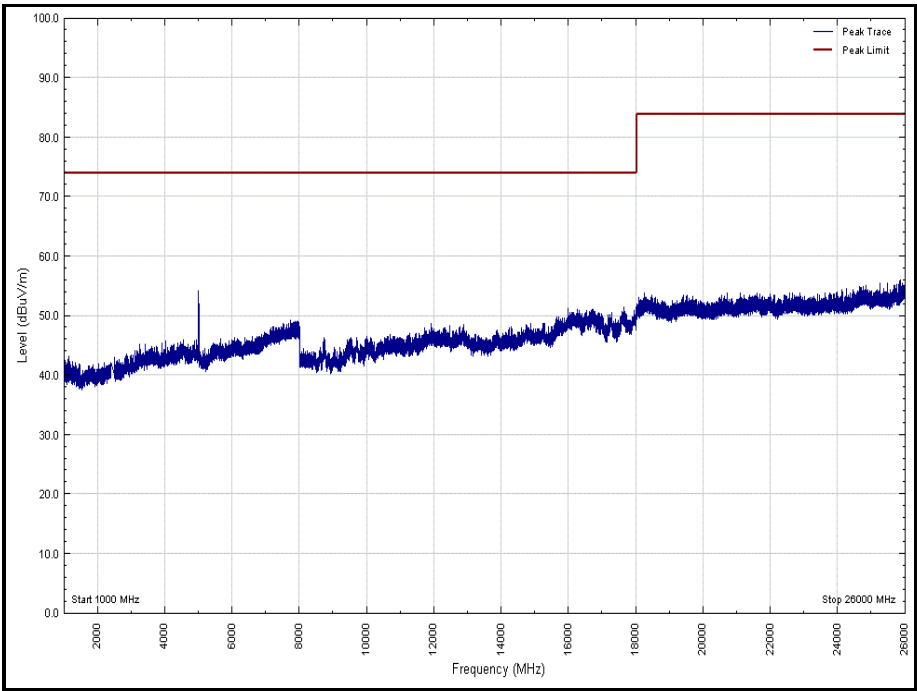
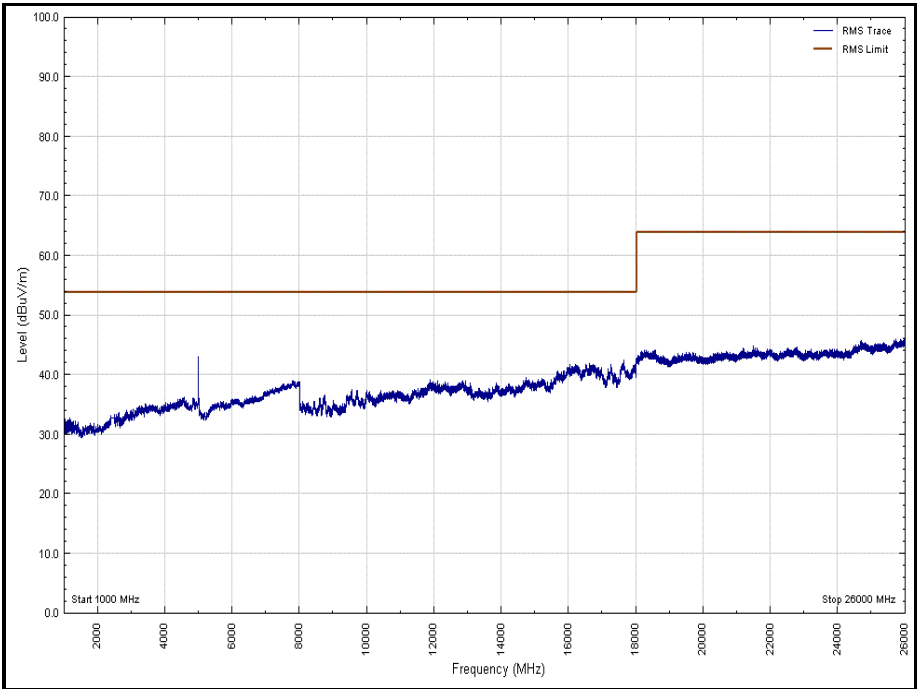


Figure 63 - 2402 MHz - 1 GHz to 26 GHz (Average)
Polarity: Vertical



**Figure 64 - 2441 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Peak)**



**Figure 65 - 2441 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Average)**

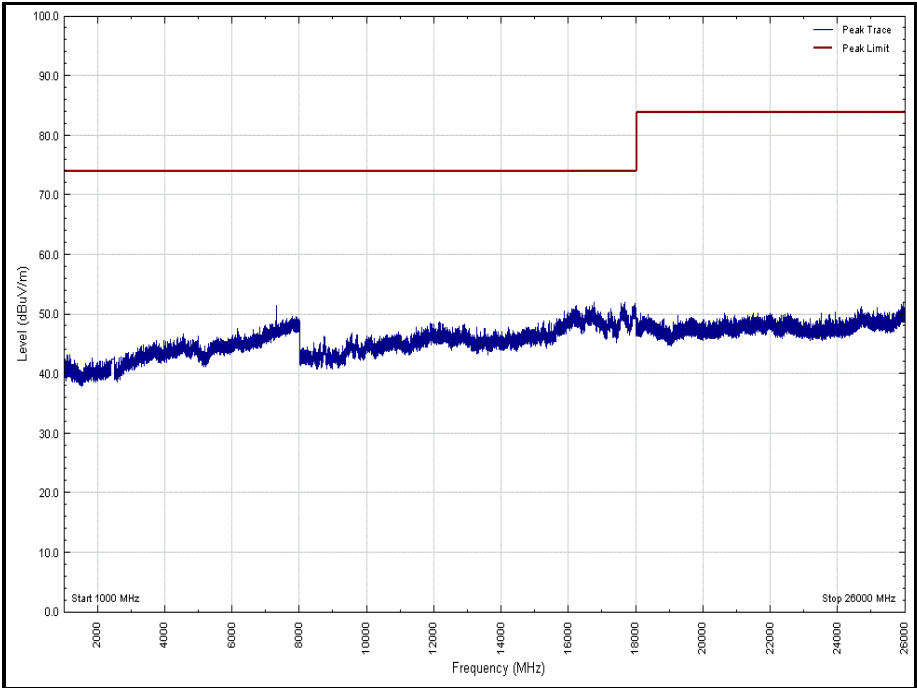


Figure 66 - 2441 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Peak)

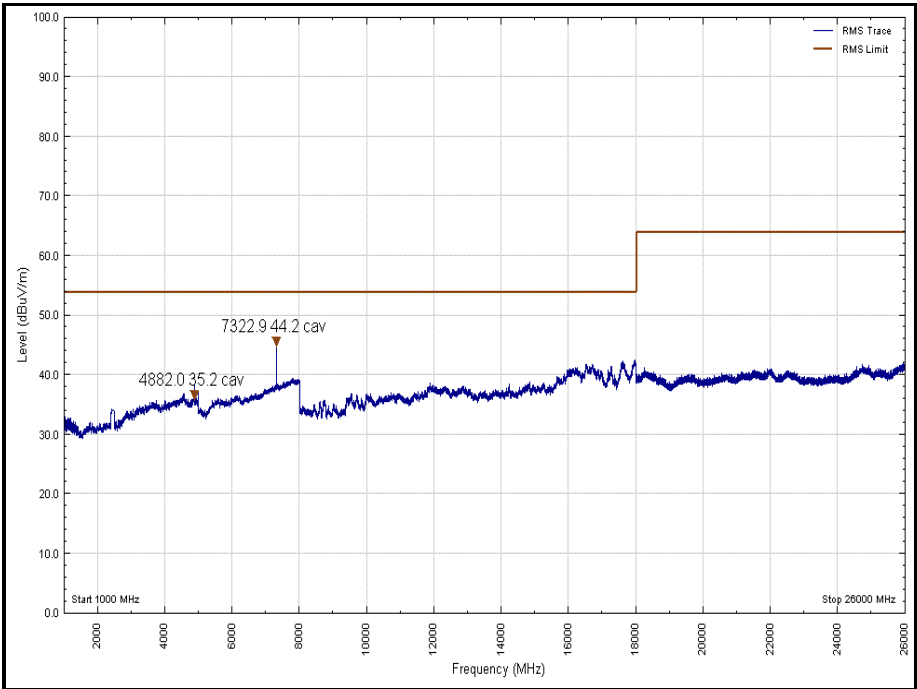


Figure 67 – 2441 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Average)

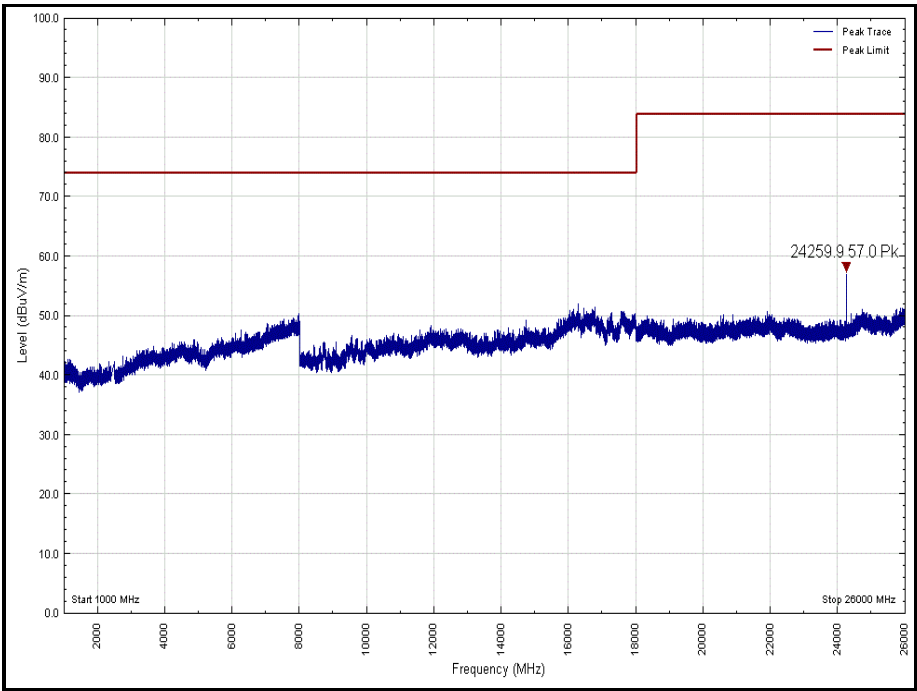


Figure 68 - 2472 MHz 1 GHz to 26 GHz
Polarity: Horizontal (Peak)

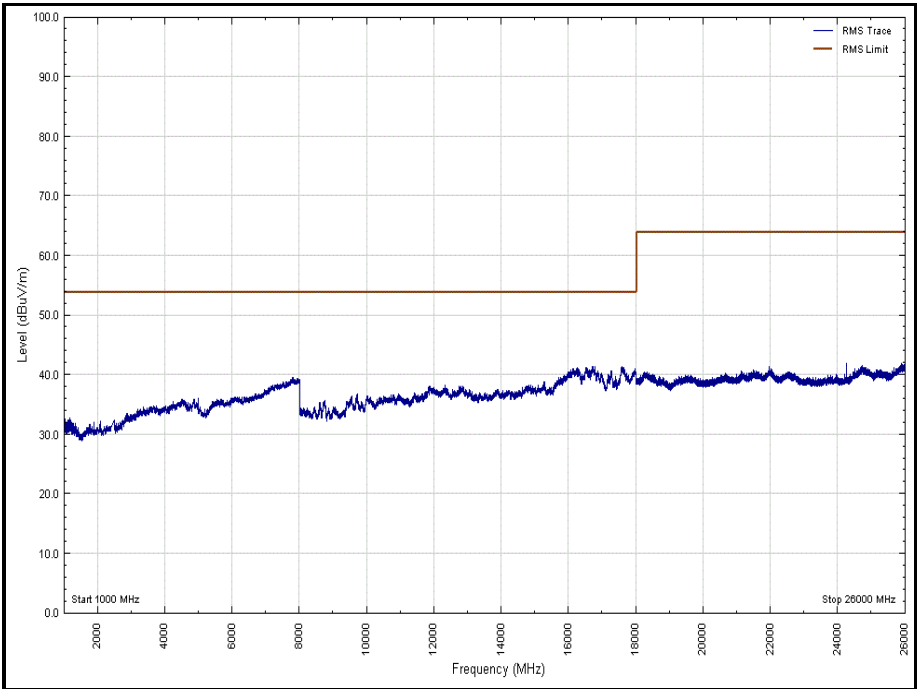


Figure 69 - 2472 MHz - 1 GHz to 26 GHz
Polarity: Horizontal (Average)

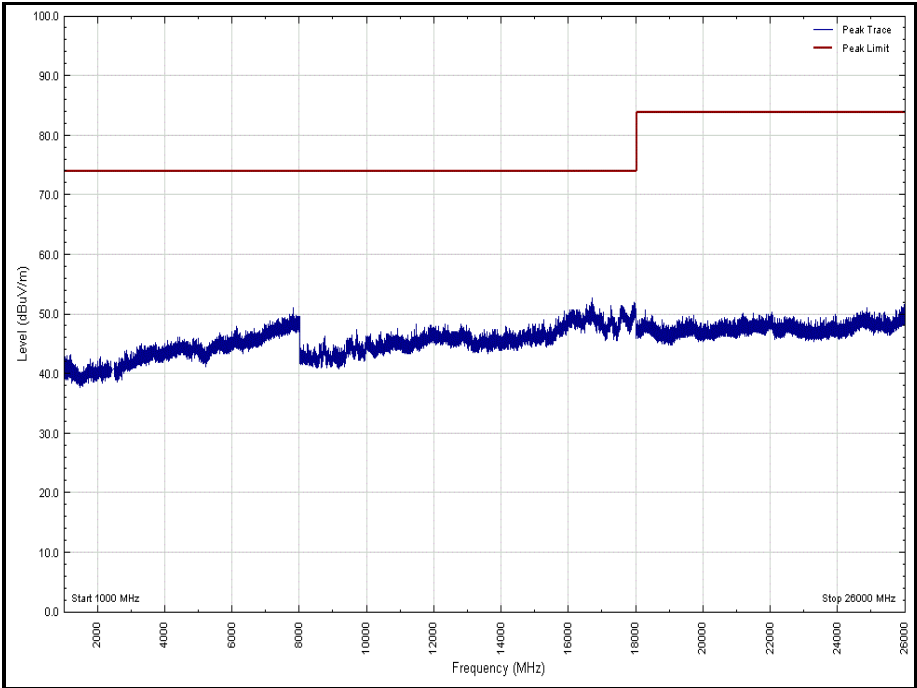


Figure 70 - 2472 MHz 1 GHz to 26 GHz
Polarity: Vertical (Peak)

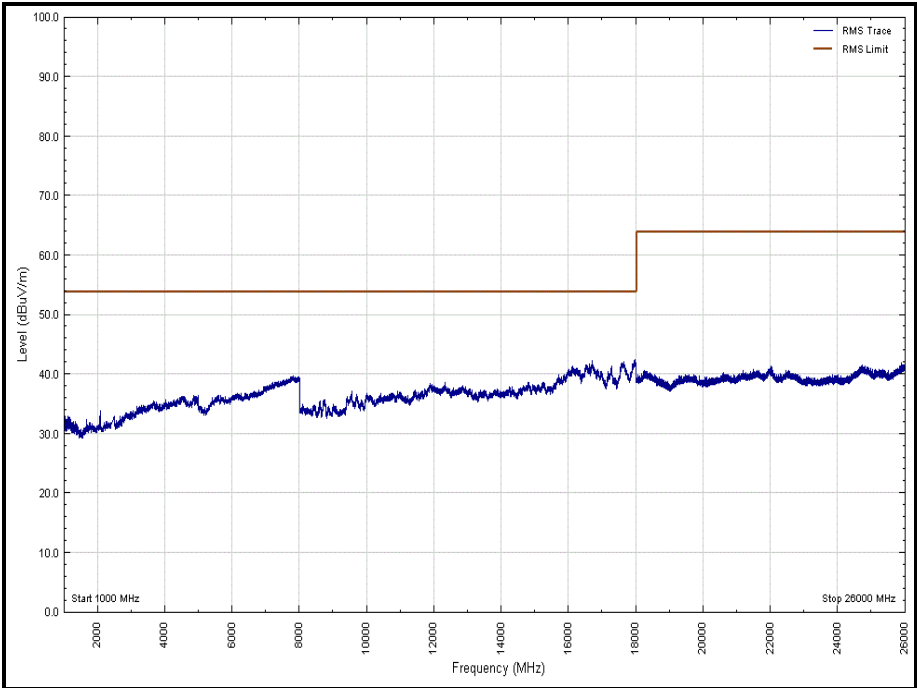


Figure 71 - 2472 MHz - 1 GHz to 26 GHz
Polarity: Vertical (Average)



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.



2.8.7 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
Hygrometer	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 30



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
Frequency Hopping Systems - 20 dB Bandwidth	± 30.43 kHz
Frequency Hopping Systems - Number of Hopping Channels	-
Frequency Hopping Systems - Channel Separation	± 30.43 kHz
Frequency Hopping Systems - Average Time of Occupancy	-
Maximum Conducted Output Power	± 3.2 dB

Table 31