

Report on the FCC and IC Testing of:

Apple Inc, Model: A2141

In accordance with FCC 47 CFR Part 15C,
ISED C RSS-247 and ISED C RSS-GEN

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

FCC ID: BCGA2141 IC: 579C-A2141



Add value.
Inspire trust.

COMMERCIAL-IN-CONFIDENCE

Document Number: 75946284-10 | Issue: 01

SIGNATURE

A handwritten signature of Matthew Russell.

NAME	JOB TITLE	RESPONSIBLE FOR	ISSUE DATE
Matthew Russell	RF Team Leader	Authorised Signatory	24 October 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, ISED C RSS-247 and ISED C RSS-GEN. The sample tested was found to comply with the requirements defined in the applied rules.

RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Testing	Mehadi Choudhury	24 October 2019	A handwritten signature of Mehdadi Choudhury.
Testing	Cristian Onaca	24 October 2019	A handwritten signature of Cristian Onaca.
Testing	Jay Balendrarajah	24 October 2019	A handwritten signature of Jay Balendrarajah.
Testing	Ahmad Javid	24 October 2019	A handwritten signature of Ahmad Javid.
Testing	Faisal Malyar	24 October 2019	A handwritten signature of Faisal Malyar.

FCC Accreditation
90987 Octagon House, Fareham Test Laboratory

Industry Canada Accreditation
IC12669A Octagon House, Fareham Test Laboratory

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

EXECUTIVE SUMMARY

A sample of this product was tested and found to be compliant with FCC 47 CFR Part 15C: 2018, ISED C RSS-247: Issue 2 (2017-02) and ISED C RSS-GEN: Issue 5 A1 (2019-03) for the tests detailed in section 1.3.



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 Summary	2
1.1	Report Modification Record.....	2
1.2	Introduction.....	2
1.3	Brief Summary of Results	3
1.4	Product Information	4
1.5	Deviations from the Standard.....	5
1.6	EUT Modification Record	5
1.7	Test Location.....	6
2	Test Details	7
2.1	Maximum Conducted Output Power	7
2.2	Frequency Hopping Systems - Average Time of Occupancy	11
2.3	Frequency Hopping Systems - Channel Separation.....	16
2.4	Frequency Hopping Systems - Number of Hopping Channels	20
2.5	Frequency Hopping Systems - 20 dB Bandwidth	22
2.6	Authorised Band Edges	28
2.7	Restricted Band Edges.....	33
2.8	Spurious Radiated Emissions	42
3	Measurement Uncertainty	56

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	24 October 2019

Table 1

1.2 Introduction

Applicant	Apple Inc
Manufacturer	Apple Inc
Model Number(s)	A2141
Serial Number(s)	C02YT00EL51N, C02YT00GL51N and C02YT00FL51N
Hardware Version(s)	REV1.0
Software Version(s)	19A507, 19A497
Number of Samples Tested	3
Test Specification/Issue/Date	FCC 47 CFR Part 15C: 2018 ISEDC RSS-247: Issue 2 (2017-02) ISEDC RSS-GEN: Issue 5 A1 (2019-03)
Start of Test	28-June-2019
Finish of Test	16-August-2019
Name of Engineer(s)	Mehadi Choudhury, Cristian Onaca, Jay Balendrarajah, Ahmad Javid and Faisal Malyar
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, ISEDC RSS-247 and ISEDC RSS-GEN is shown below.

Section	Specification Clause			Test Description	Result	Comments/Base Standard
	Part 15C	RSS-247	RSS-GEN			
Configuration and Mode: Bluetooth - BR/EDR						
2.1	15.247 (b)	5.4	6.12	Maximum Conducted Output Power	Pass	ANSI C63.10 (2013)
2.2	15.247 (a)(1)	5.1	-	Frequency Hopping Systems - Average Time of Occupancy	Pass	ANSI C63.10 (2013)
2.3	15.247 (a)(1)	5.1	-	Frequency Hopping Systems - Channel Separation	Pass	ANSI C63.10 (2013)
2.4	15.247 (a)(1)	5.1	-	Frequency Hopping Systems - Number of Hopping Channels	Pass	ANSI C63.10 (2013)
2.5	15.247 (a)(1)	5.1	6.7	Frequency Hopping Systems - 20 dB Bandwidth	Pass	ANSI C63.10 (2013)
2.6	15.247 (d)	5.5	-	Authorised Band Edges	Pass	ANSI C63.10 (2013)
2.7	15.205	-	8.10	Restricted Band Edges	Pass	ANSI C63.10 (2013)
2.8	15.247 (d) and 15.205	5.5	6.13	Spurious Radiated Emissions	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 2.4 GHz and 5 GHz bands.

1.4.2 Conducted Test Setup Diagram(s)

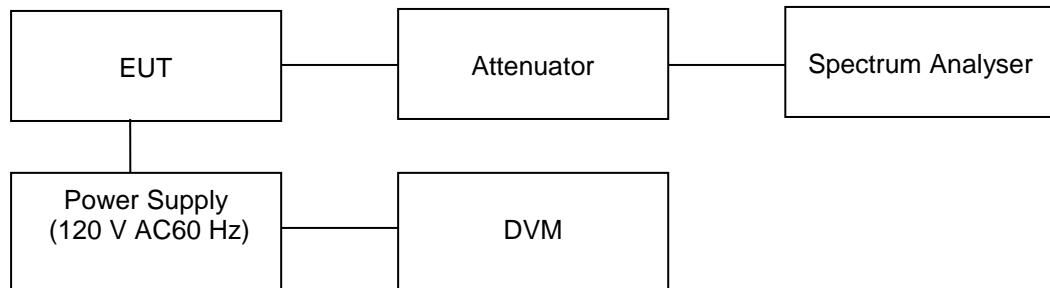
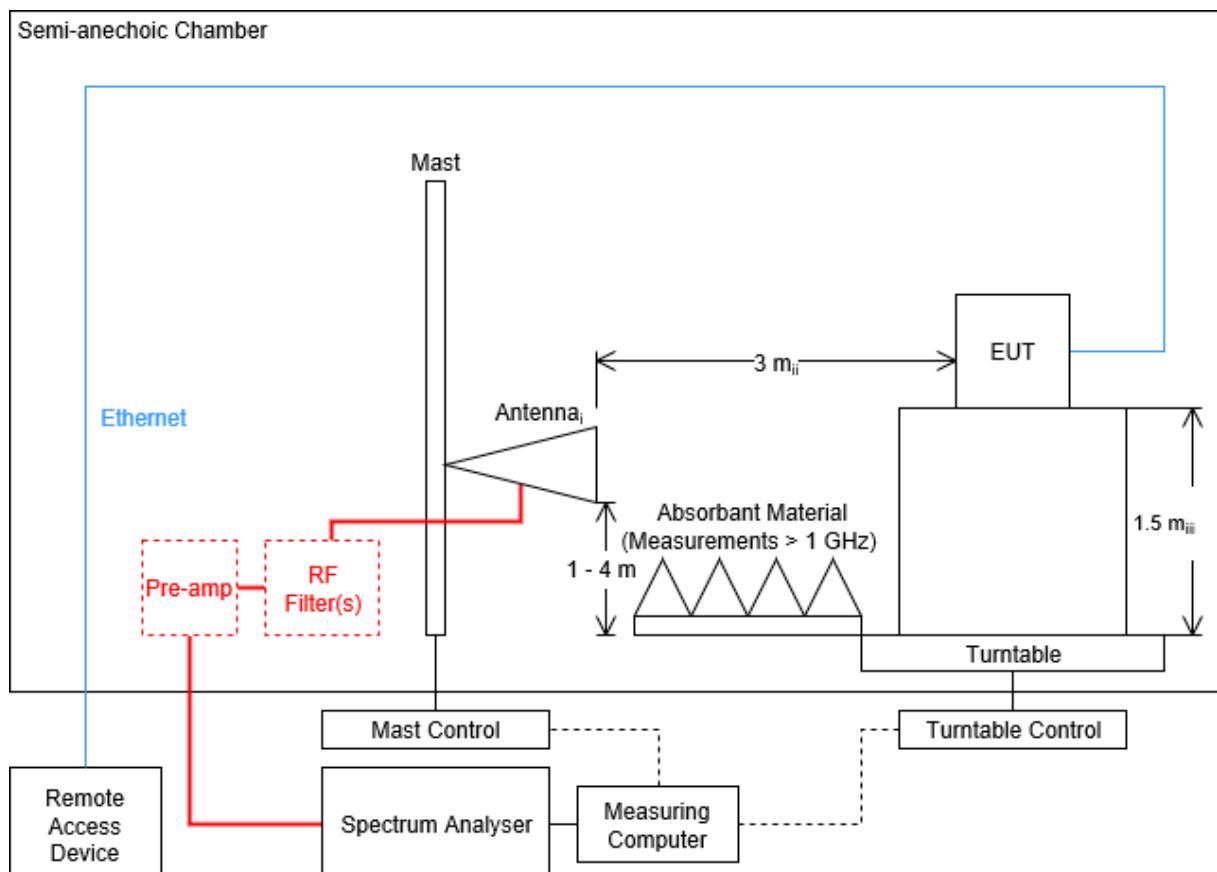


Figure 1 – Conducted Test Setup Diagram

1.4.3 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.

Figure 2 – Radiated Emissions Setup Diagram



1.4.4 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
Model: A2141: Serial Number: C02YT00EL51N			
0	As supplied by the customer	Not Applicable	Not Applicable
Model: A2141: Serial Number: C02YT00GL51N			
0	As supplied by the customer	Not Applicable	Not Applicable
Model: A2141: Serial Number: C02YT00FL51N			
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 - BR/EDR		
Maximum Conducted Output Power	Mehadi Choudhury	UKAS
Frequency Hopping Systems - Average Time of Occupancy	Mehadi Choudhury	UKAS
Frequency Hopping Systems - Channel Separation	Mehadi Choudhury	UKAS
Frequency Hopping Systems - Number of Hopping Channels	Mehadi Choudhury	UKAS
Frequency Hopping Systems - 20 dB Bandwidth	Mehadi Choudhury	UKAS
Authorised Band Edges	Cristian Onaca, Jay Balendrarajah, Ahmad Javid, Faisal Malyar	UKAS
Restricted Band Edges	Cristian Onaca, Jay Balendrarajah, Ahmad Javid, Faisal Malyar	UKAS
Spurious Radiated Emissions	Cristian Onaca, Jay Balendrarajah, Ahmad Javid, Faisal Malyar	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)
ISEDC RSS-247, Clause 5.4
ISEDC RSS-GEN, Clause 6.12

2.1.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00EL51N - Modification State 0

2.1.3 Date of Test

16-August-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 24.3 °C
Relative Humidity 53.5 %

2.1.6 Test Results

Bluetooth - BR/EDR

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	11.92	15.56
2440	11.68	14.72
2480	11.93	15.60

Table 5 - Maximum Conducted Output Power Results



Figure 3 - 2402 MHz - Maximum Output Power



Figure 4 - 2441 MHz - Maximum Output Power



Figure 5 - 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.

ISEDC 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
Multimeter	Iso-tech	IDM101	2421	12	30-Oct-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	15-Oct-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Network Analyser	Keysight Technologies	E5063A	5018	12	20-May-2020
Calibration Kit	Keysight Technologies	N4693A	5362	12	20-Feb-2020
Cable (40 GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5227	-	O/P Mon

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)
ISEDC RSS-247, Clause 5.1

2.2.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00EL51N - Modification State 0

2.2.3 Date of Test

15-August-2019

2.2.4 Test Method

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

2.2.5 Environmental Conditions

Ambient Temperature 25.5 °C
Relative Humidity 52.0 %

2.2.6 Test Results

Bluetooth - BR/EDR

Packet Type	Dwell Time (ms)	Number of Transmissions	Average Occupancy Time (ms)
DH1	0.381	314	119.634
DH3	1.640	150	246.000
DH5	2.880	96	276.480

Table 7



Figure 6 – DH1, Dwell Time

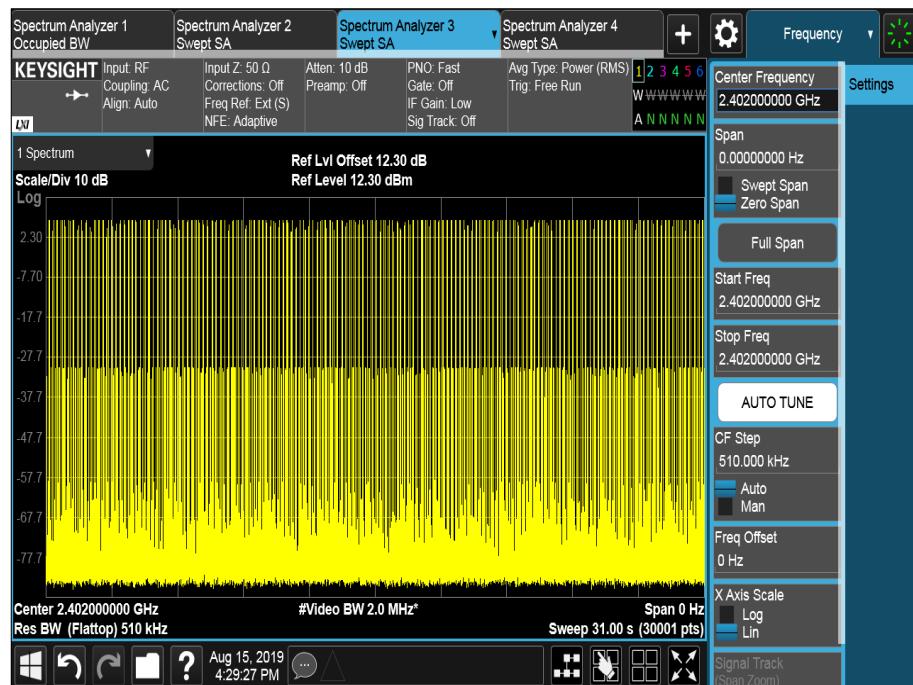


Figure 7 – DH1, Total Average Time of Occupancy

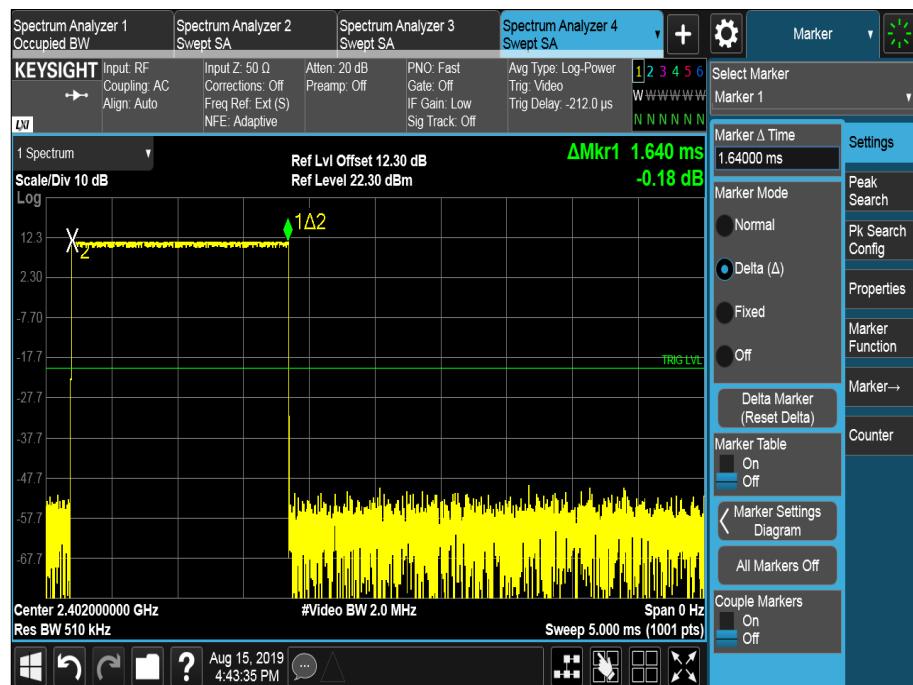


Figure 8 – DH3, Dwell Time

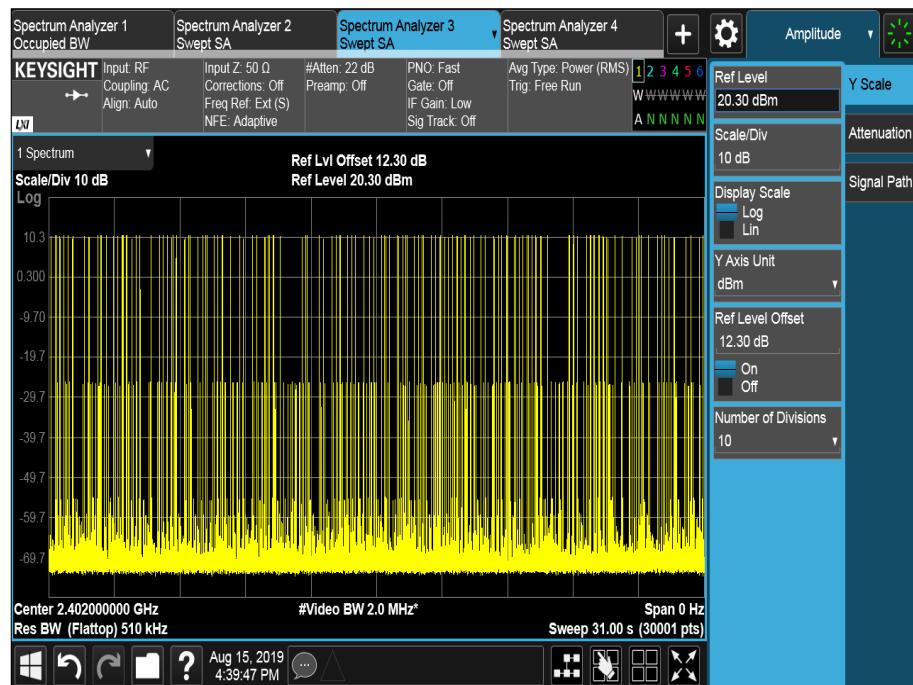


Figure 9 – DH3, Total Average Time of Occupancy

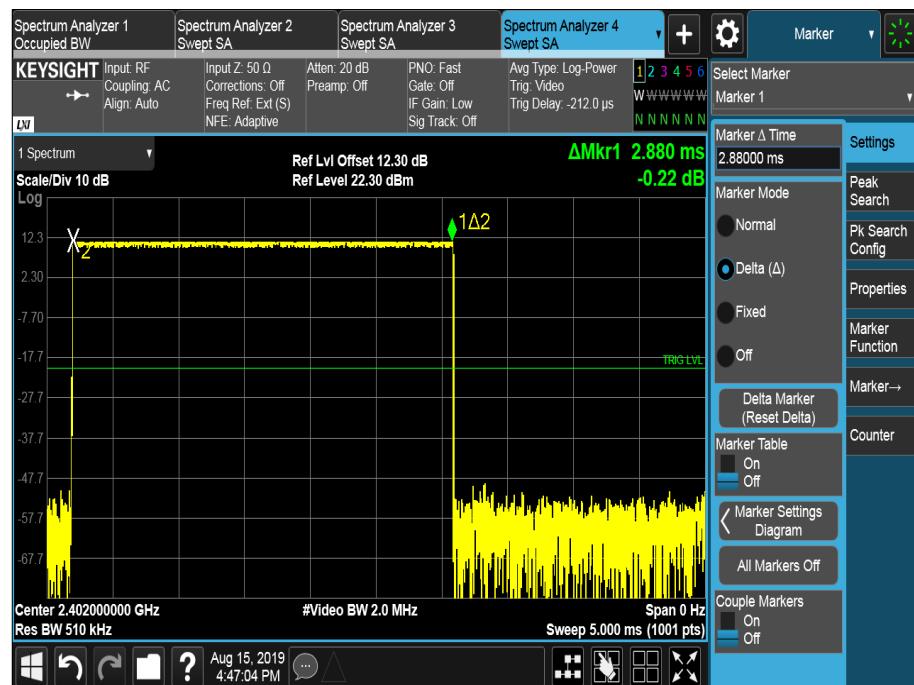


Figure 10 - DH5, Dwell Time

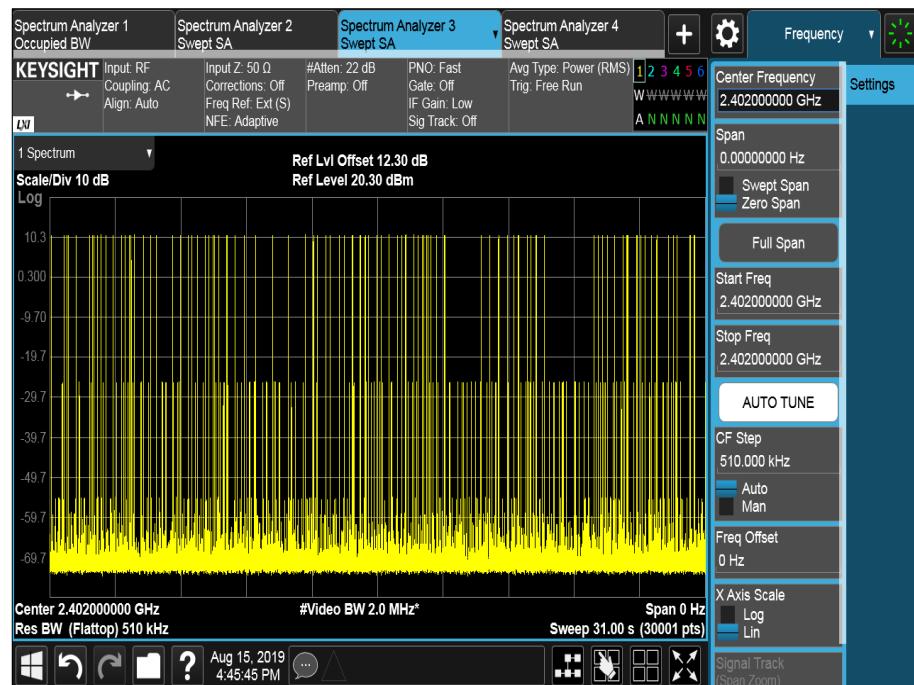


Figure 11 - DH5, Total Average Time of Occupancy



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.

ISEDC 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
Multimeter	Iso-tech	IDM101	2421	12	30-Oct-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	15-Oct-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Network Analyser	Keysight Technologies	E5063A	5018	12	20-May-2020
Calibration Kit	Keysight Technologies	N4693A	5362	12	20-Feb-2020
Cable (40 GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5227	-	O/P Mon

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, Clause 15.247 (a)(1)
ISEDC RSS-247, Clause 5.1

2.3.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00EL51N - Modification State 0

2.3.3 Date of Test

15-August-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 25.5 °C
Relative Humidity 52.0 %

2.3.6 Test Results

Bluetooth - BR/EDR

Modulation	Channel Separation (MHz)
GFSK	1.08
$\pi/4$ DQPSK	1.00
8DPSK	1.00

Table 9

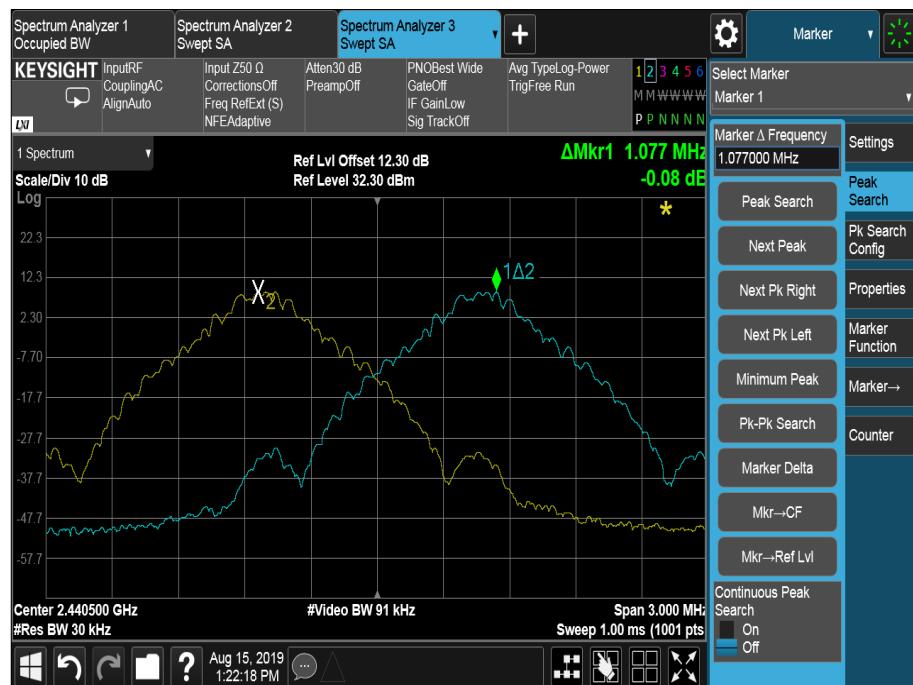


Figure 12 - GFSK



Figure 13 - $\pi/4$ DQPSK



Figure 14 - 8DPSK

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.

ISEDC 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
Multimeter	Iso-tech	IDM101	2421	12	30-Oct-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	15-Oct-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Network Analyser	Keysight Technologies	E5063A	5018	12	20-May-2020
Calibration Kit	Keysight Technologies	N4693A	5362	12	20-Feb-2020
Cable (40 GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5227	-	O/P Mon

Table 10

O/P Mon – Output Monitored using calibrated equipment



2.4 Frequency Hopping Systems - Number of Hopping Channels

2.4.1 Specification Reference

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

2.4.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00EL51N - Modification State 0

2.4.3 Date of Test

15-August-2019

2.4.4 Test Method

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

2.4.5 Environmental Conditions

Ambient Temperature 25.5 °C

Relative Humidity 52.0 %

2.4.6 Test Results

Bluetooth - BR/EDR (DH5)

Number of Hopping Channels: 79

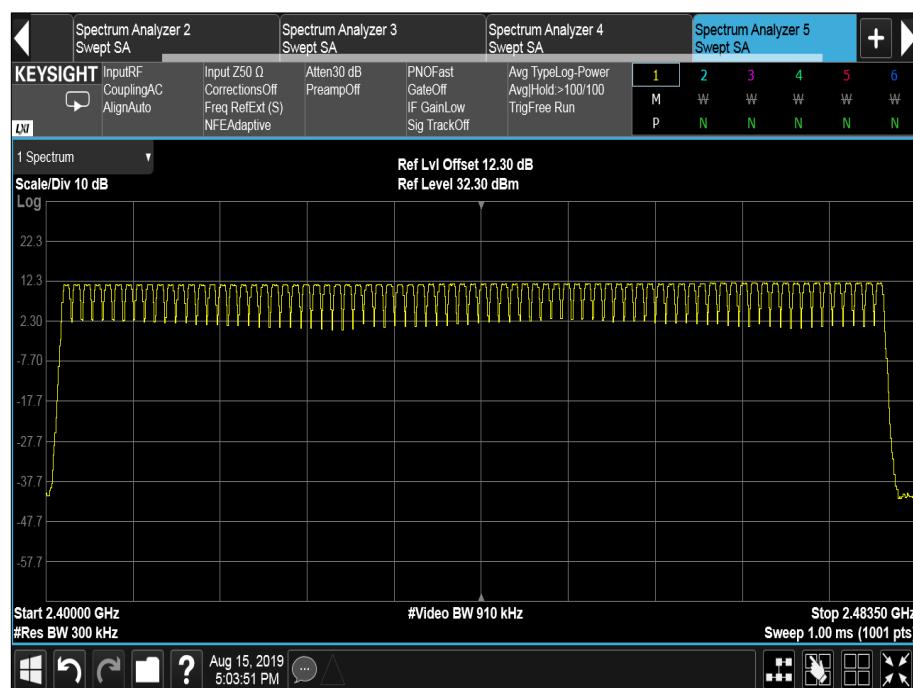


Figure 15 - Measurement Frequency Range: 2400 MHz to 2483.5 MHz



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

≥ 15 channels

ISEDC RSS-247, Limit Clause 5.1 (d)

FHSs operating in the band 2400-2483.5 MHz shall use at least 15 hopping channels.

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
Multimeter	Iso-tech	IDM101	2421	12	30-Oct-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	15-Oct-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Network Analyser	Keysight Technologies	E5063A	5018	12	20-May-2020
Calibration Kit	Keysight Technologies	N4693A	5362	12	20-Feb-2020
Cable (40 GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5227	-	O/P Mon

Table 11

O/P Mon – Output Monitored using calibrated equipment



2.5 Frequency Hopping Systems - 20 dB Bandwidth

2.5.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (a)(1)
ISEDC RSS-247, Clause 5.1
ISECC RSS-GEN, clause 6.7

2.5.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00EL51N - Modification State 0

2.5.3 Date of Test

15-August-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 25.5 °C
Relative Humidity 52.0 %

2.5.6 Test Results

Bluetooth - BR/EDR

Frequency (MHz)	20 dB Bandwidth (kHz)		
	GFSK	$\pi/4$ DQPSK	8-DPSK
2402	957.30	1224.10	1373.00
2440	955.50	1377.00	1359.00
2480	953.10	1390.00	1375.00

Table 12

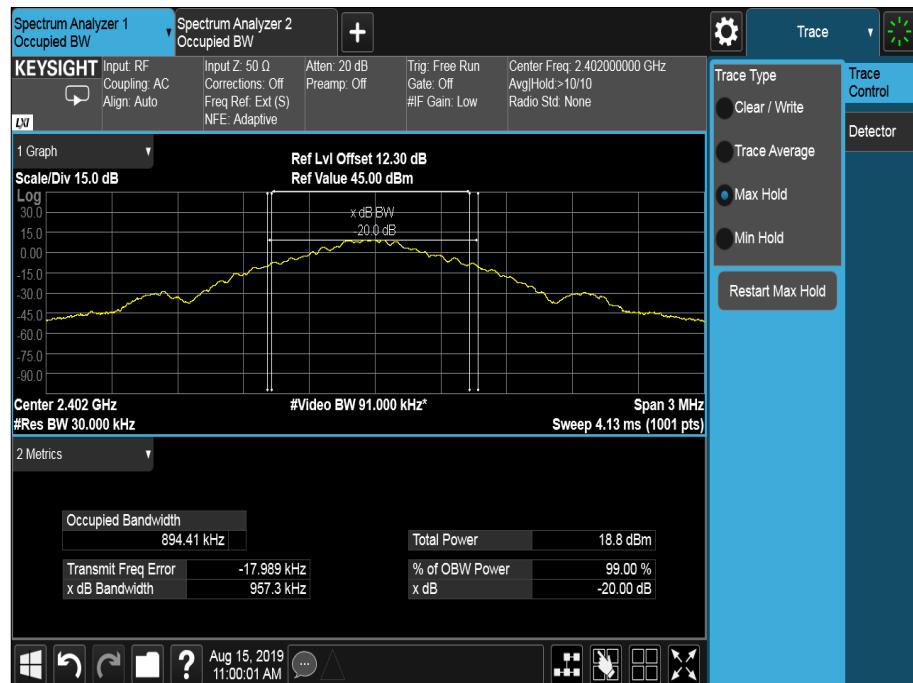


Figure 16 - 2402 MHz - GFSK

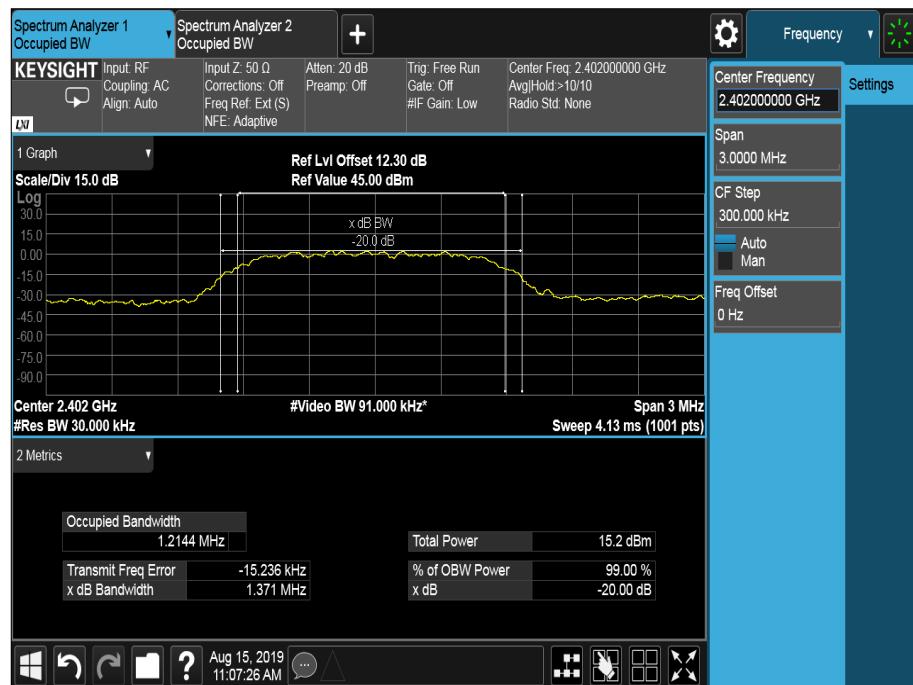


Figure 17 - 2402 MHz - $\pi/4$ DQPSK

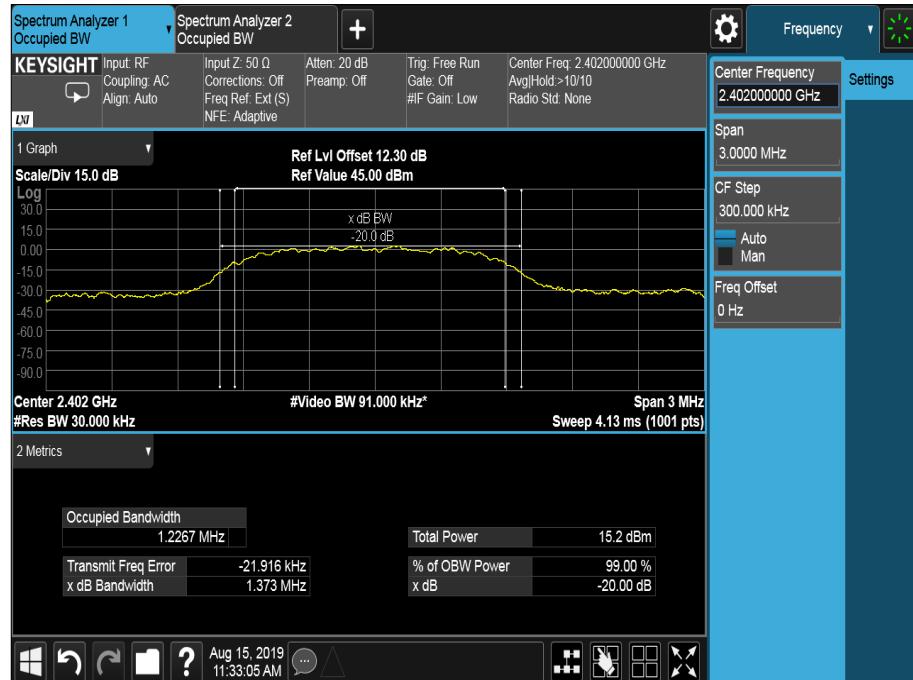


Figure 18 - 2402 MHz - 8-DPSK



Figure 19 - 2440 MHz - GFSK



Figure 20 - 2440 MHz - $\pi/4$ DQPSK

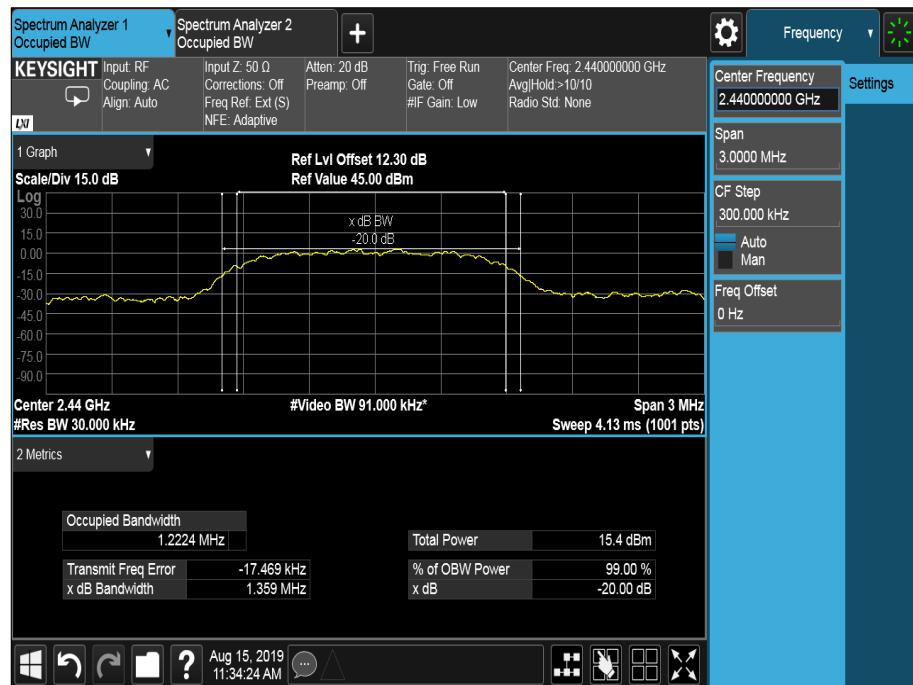


Figure 21 - 2440 MHz - 8-DPSK



Figure 22 - 2480 MHz - GFSK

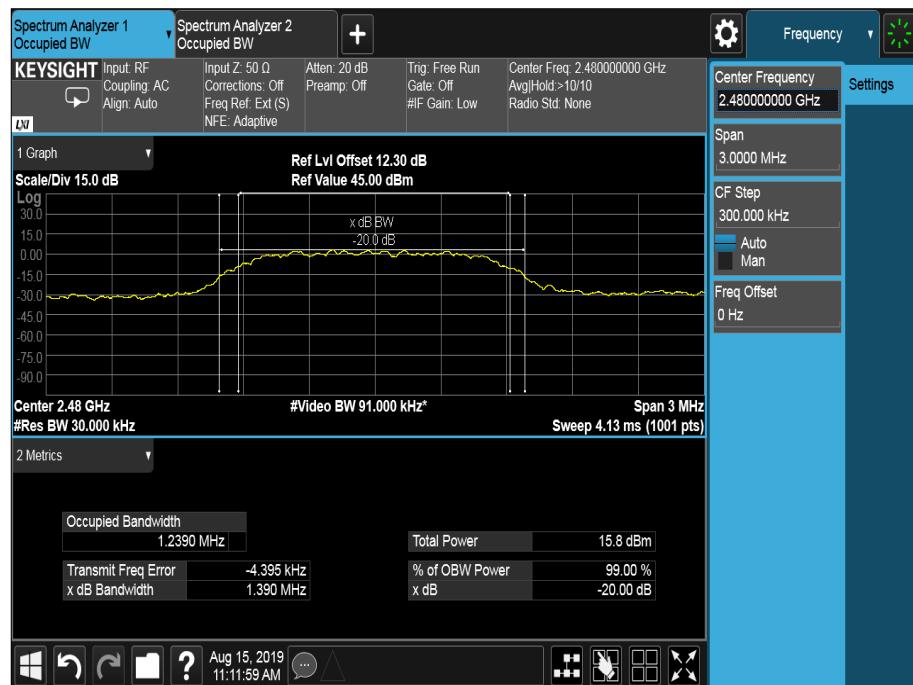


Figure 23 - 2480 MHz - $\pi/4$ DQPSK

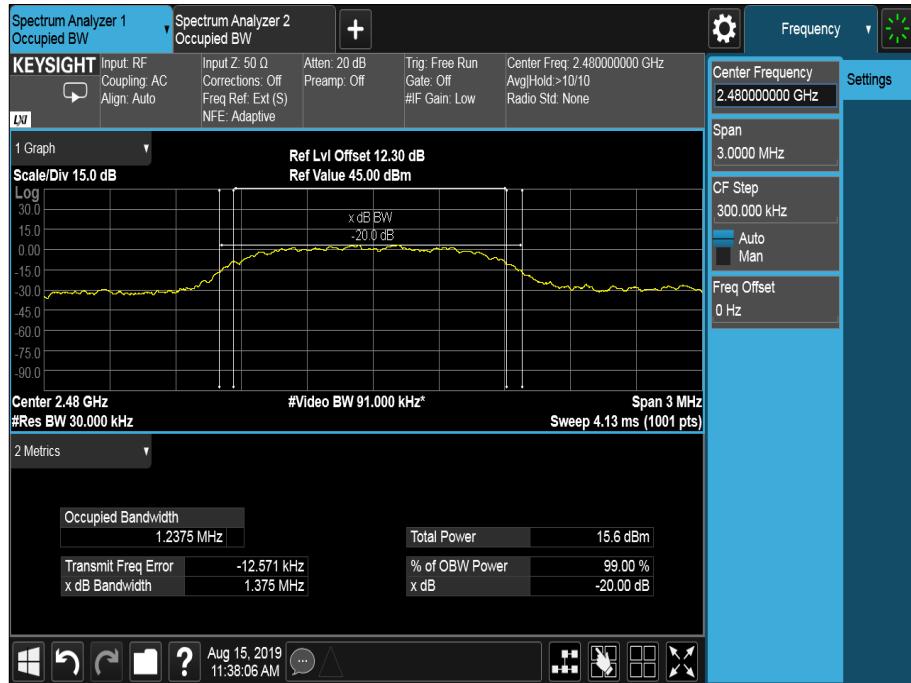


Figure 24 - 2480 MHz - 8-DPSK

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
Multimeter	Iso-tech	IDM101	2421	12	30-Oct-2019
Hygrometer	Rotronic	I-1000	2891	12	18-Sep-2019
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	15-Oct-2019
EXA	Keysight Technologies	N9010B	4968	24	21-Dec-2019
Network Analyser	Keysight Technologies	E5063A	5018	12	20-May-2020
Calibration Kit	Keysight Technologies	N4693A	5362	12	20-Feb-2020
Cable (40 GHz)	Rosenberger	LU1-001-2000	5024	-	O/P Mon
AC Programmable Power Supply	iTech	IT7324	5227	-	O/P Mon

Table 13

O/P Mon – Output Monitored using calibrated equipment



2.6 Authorised Band Edges

2.6.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (d),
ISEDC RSS-247, Clause 5.5

2.6.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00FL51N - Modification State 0

2.6.3 Date of Test

28-June-2019 to 30-July-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 21.0 - 23.0 °C
Relative Humidity 45.0 - 62.7 %

2.6.6 Test Results

Bluetooth - BR/EDR

Mode	Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
Static	GFSK	DH5	2402	2400.0	-60.73
Static	$\pi/4$ DQPSK	2DH5	2402	2400.0	-55.30
Static	8-DPSK	3DH5	2402	2400.0	-55.33
Hopping	GFSK	DH5	2402	2400.0	-65.48
Hopping	$\pi/4$ DQPSK	2DH5	2402	2400.0	-62.56
Hopping	8-DPSK	3DH5	2402	2400.0	-61.87

Table 14 - Authorised Band Edge Results

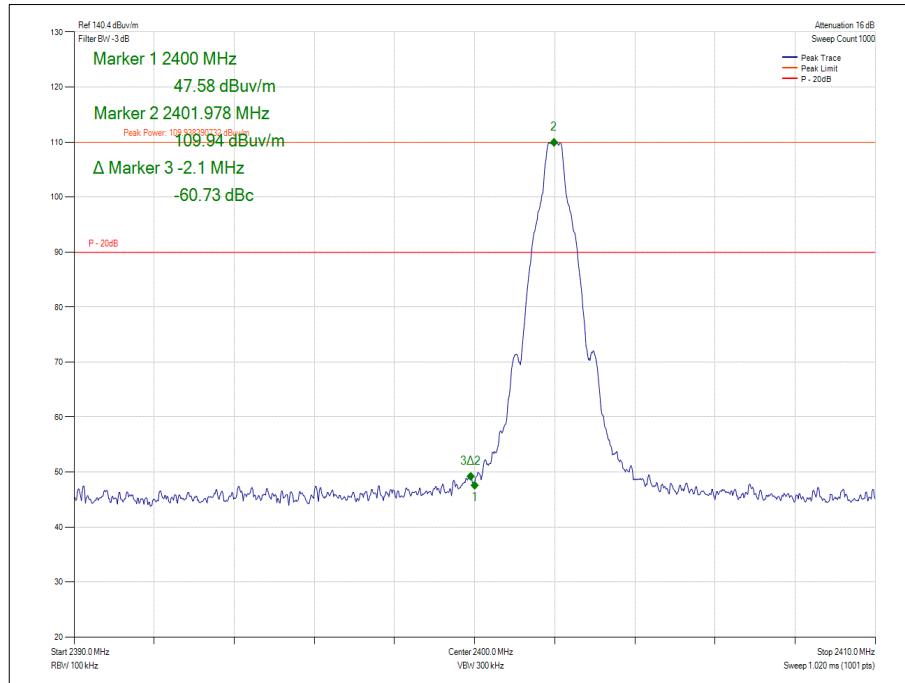


Figure 25 - Static - GFSK/DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz

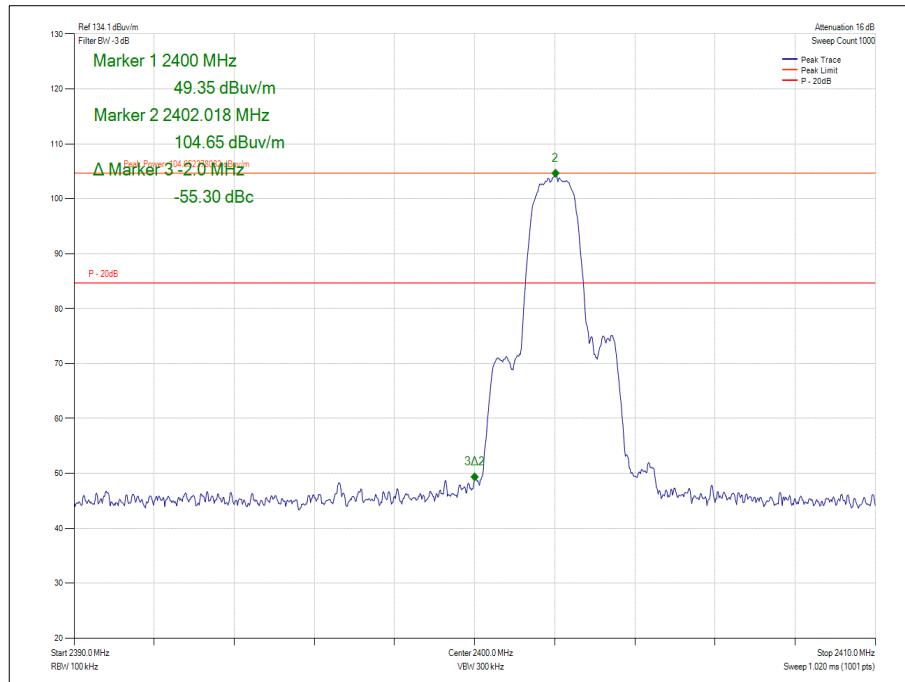


Figure 26 - Static - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz

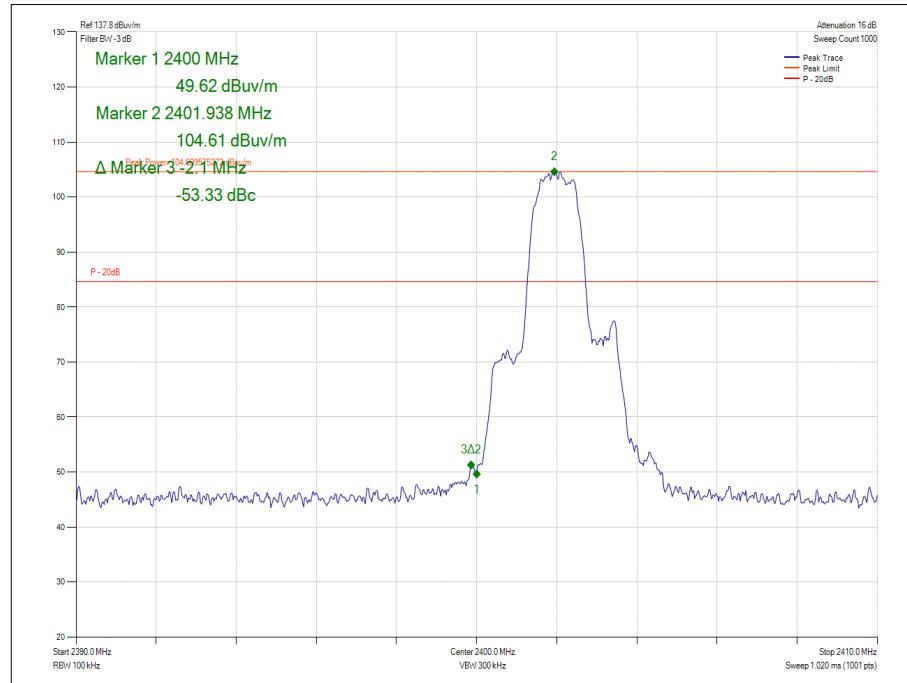


Figure 27 - Static - 8-DPSK/3DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz

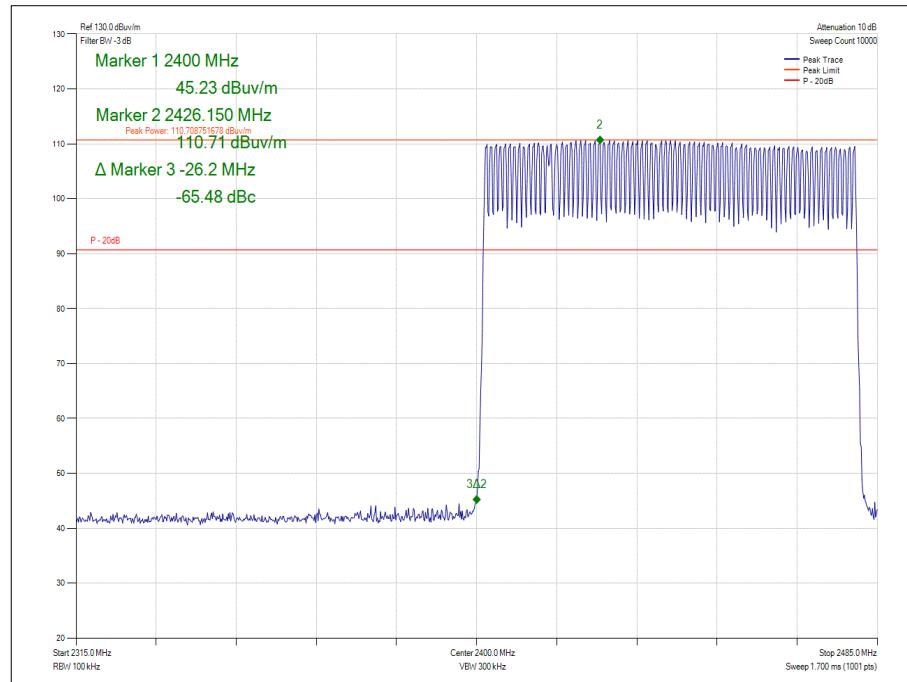


Figure 28 - Hopping - GFSK/DH5 - Band Edge Frequency 2400.0 MHz

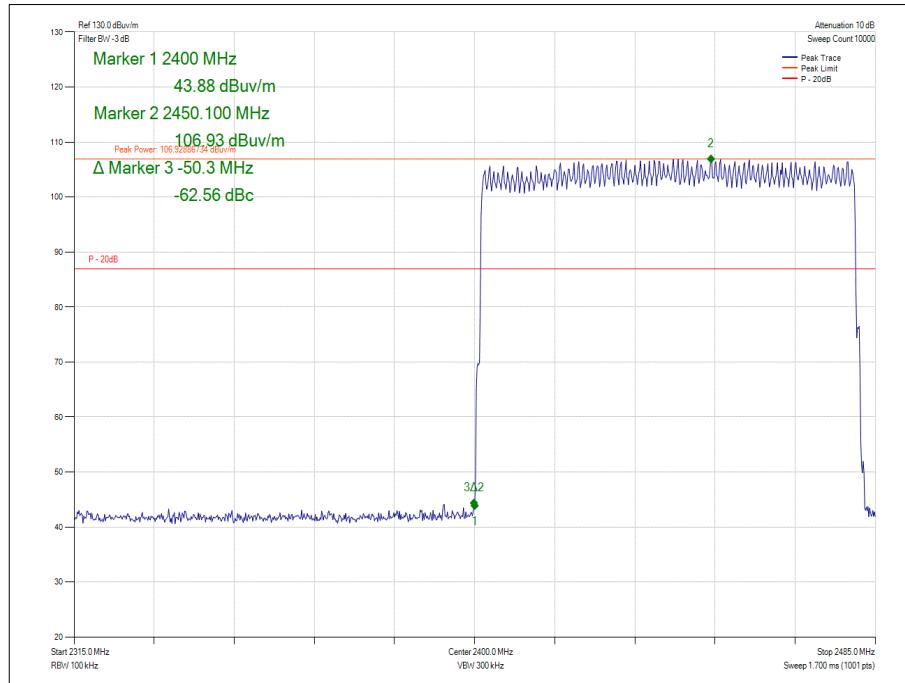


Figure 29 - Hopping - $\pi/4$ DQPSK/2DH5 - Band Edge Frequency 2400.0 MHz

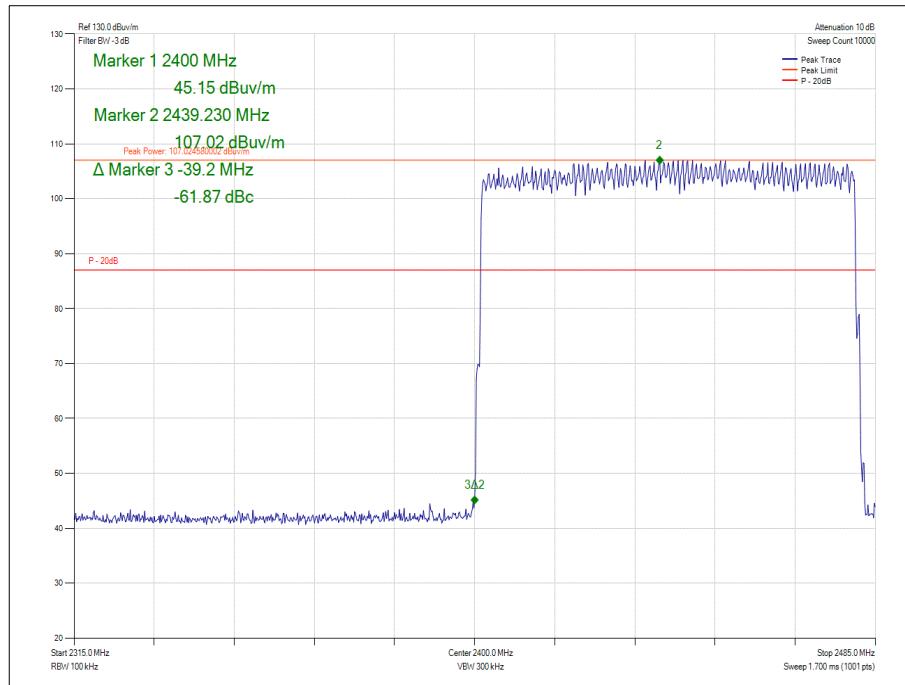


Figure 30 - Hopping - 8-DPSK/3DH5 - Band Edge Frequency 2400.0 MHz



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.

ISEDC 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
Hygrometer	Rotronic	HYGROPALM 1	2338	12	15-Nov-2019
DC - 12.4 GHz 10 dB Attenuator	Suhner	6810.17.A	3965	12	07-Aug-2020
Double Ridged Waveguide Horn Antenna	ETS-Lindgren	3117	4722	12	05-Mar-2020
8 - 18 GHz pre amp	Wright Technologies	PS06-0061	4971	12	07-Dec-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 (18 GHz)	Rosenberger	LU7-071-1000	5102	12	04-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-1000	5104	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-1000	5105	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-2000	5107	12	05-Oct-2019
EmX Software V.1.4.8.3	TÜV SUD	EmX	N/A Software	-	Software
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 15

TU – Traceability Unscheduled



2.7 Restricted Band Edges

2.7.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.205
ISEDC RSS-GEN, Clause 8.10

2.7.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00FL51N - Modification State 0

2.7.3 Date of Test

28-June-2019 to 30-July-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 4.1.4.2.5. 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 dB μ V/m to μ V/m:
10^(Field Strength in dB μ V/m/20).

2.7.5 Environmental Conditions

Ambient Temperature 22.9 - 23.3 °C

Relative Humidity 30.7 - 34.8 %

2.7.6 Test Results

Bluetooth - BR/EDR

Mode	Modulation	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Peak Level (dB μ V/m)	Average Level (dB μ V/m)
Static	GFSK	DH5	2402	2390.0	58.43	44.07
Static	$\pi/4$ DQPSK	2DH5	2402	2390.0	58.6	44.04
Static	8-DPSK	3DH5	2402	2390.0	58.77	44.02
Static	GFSK	DH5	2480	2483.5	53.69	42.12
Static	$\pi/4$ DQPSK	2DH5	2480	2483.5	52.39	41.72
Static	8-DPSK	3DH5	2480	2483.5	52.87	41.66
Hopping	GFSK	DH5	2402	2390.0	53.74	38.63
Hopping	$\pi/4$ DQPSK	2DH5	2402	2390.0	53.37	38.64
Hopping	8-DPSK	3DH5	2402	2390.0	53.11	38.62
Hopping	GFSK	DH5	2480	2483.5	52.39	39.17
Hopping	$\pi/4$ DQPSK	2DH5	2480	2483.5	52.58	39.37
Hopping	8-DPSK	3DH5	2480	2483.5	53.21	39.45

Table 16 - Restricted Band Edge Results

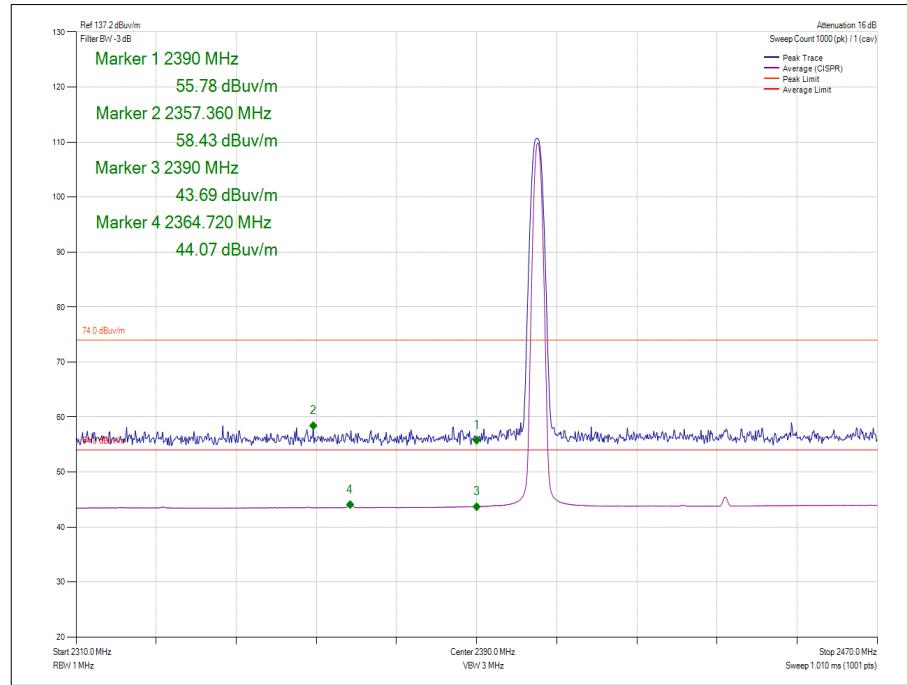


Figure 31 - Static - GFSK/DH5 - 2402 MHz - Band Edge Frequency 2390.0 MHz

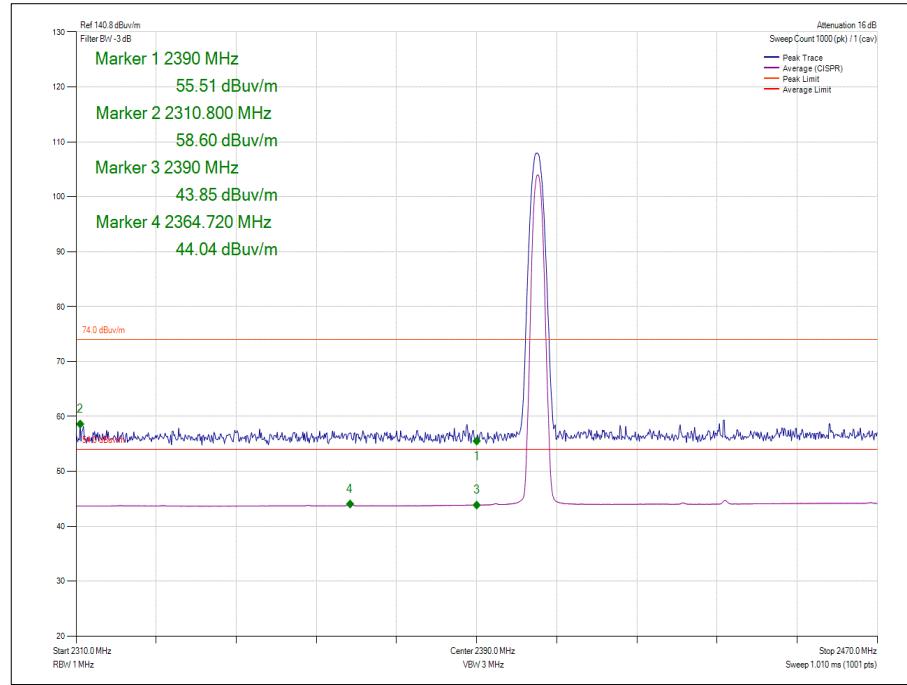


Figure 32 - Static - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Band Edge Frequency 2390.0 MHz

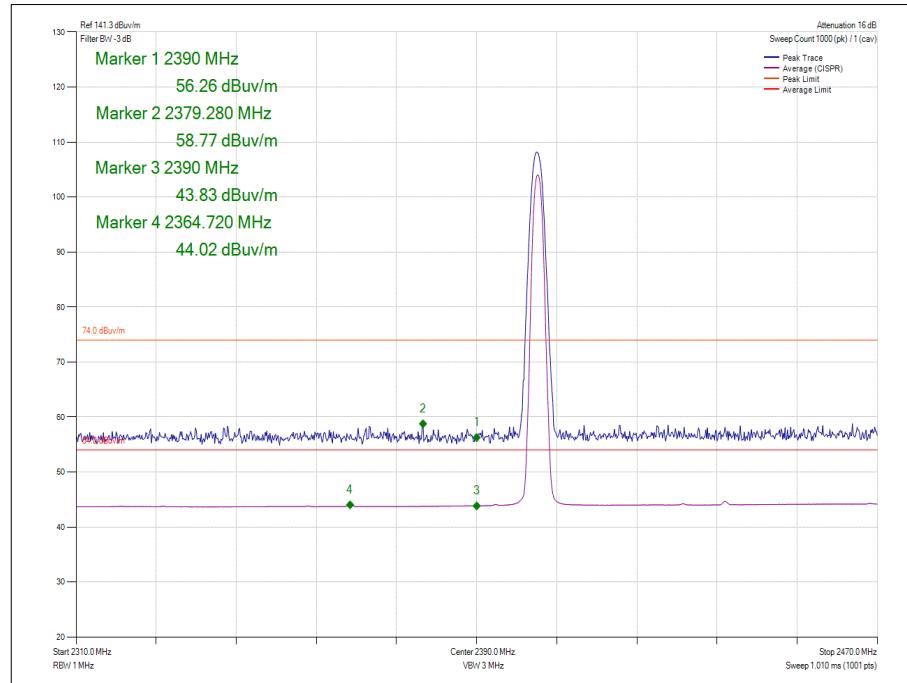


Figure 33 - Static - 8-DPSK/3DH5 - 2402 MHz Band Edge Frequency 2390.0 MHz

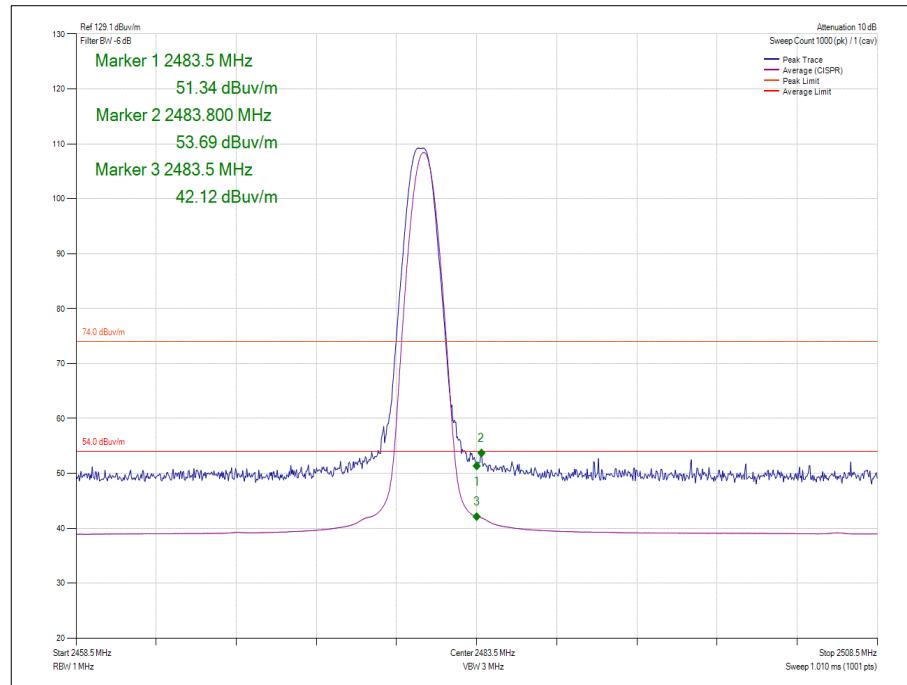


Figure 34 - Static - GFSK/DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz

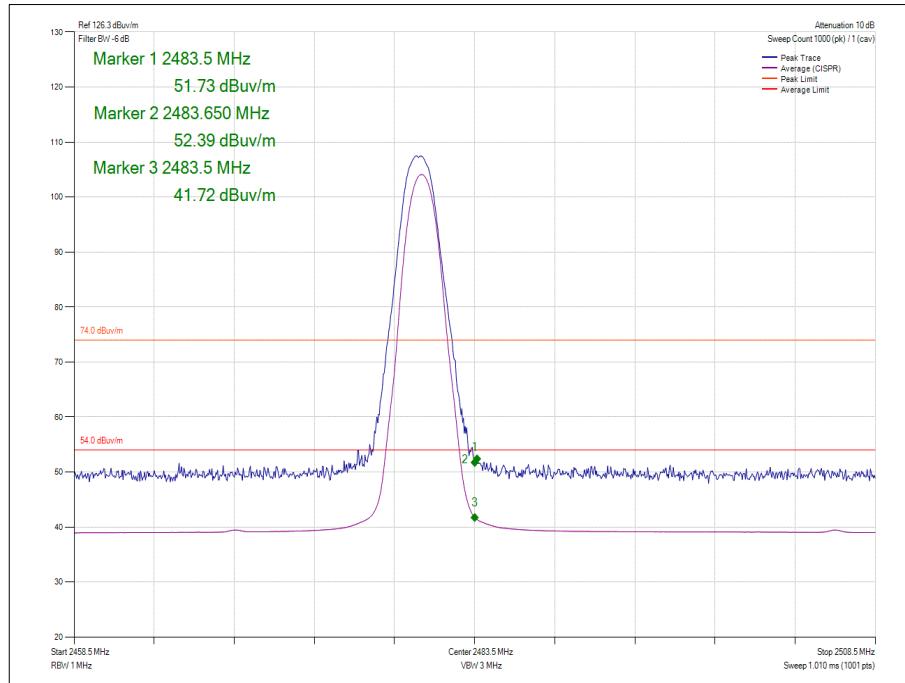


Figure 35 - Static - $\pi/4$ DQPSK/2DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz

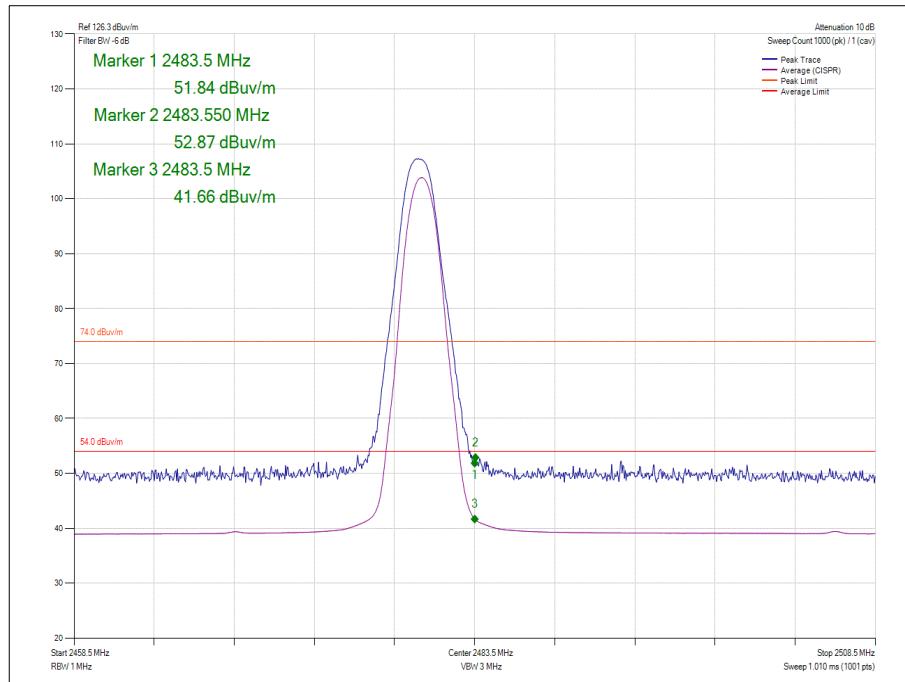


Figure 36 - Static - 8-DPSK/3DH5 - 2480 MHz - Band Edge Frequency 2483.5 MHz

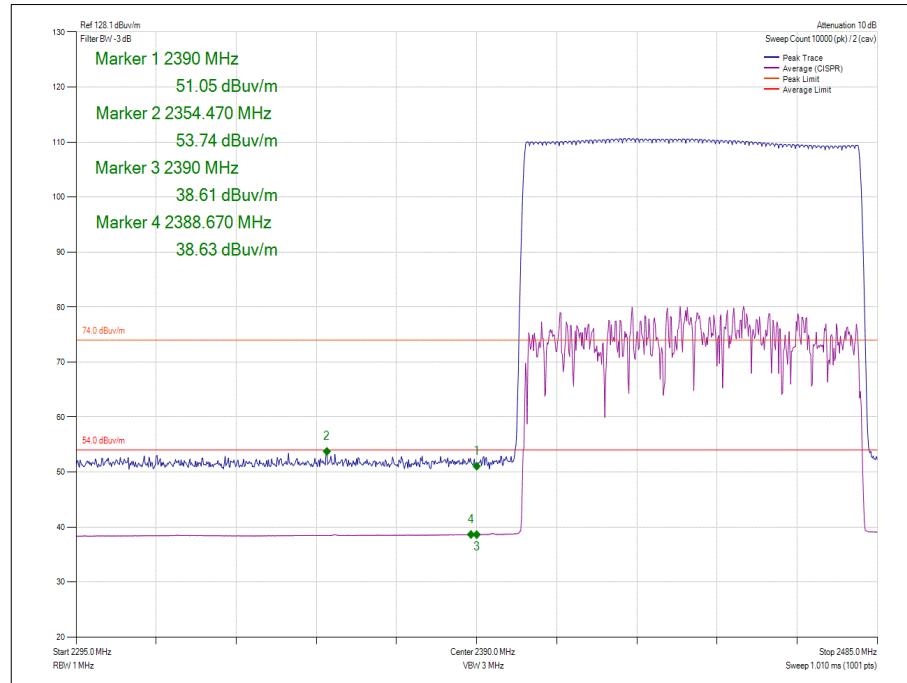


Figure 37 - Hopping - GFSK/DH5 - Band Edge Frequency 2390.0 MHz

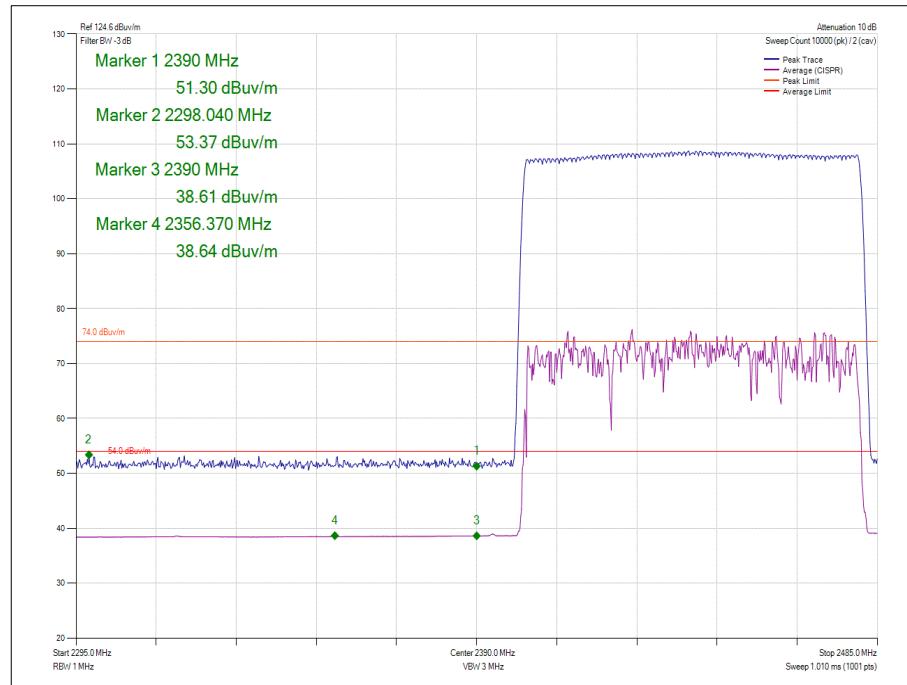


Figure 38 - Hopping - $\pi/4$ DQPSK/2DH5 - Band Edge Frequency 2390.0 MHz

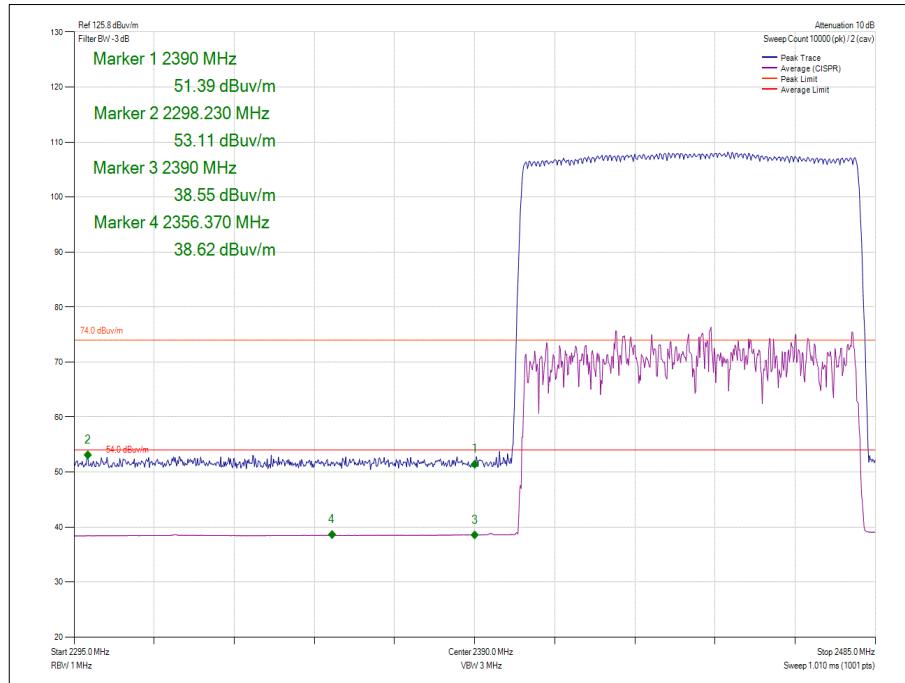


Figure 39 - Hopping - 8-DPSK/3DH5 - Band Edge Frequency 2390.0 MHz

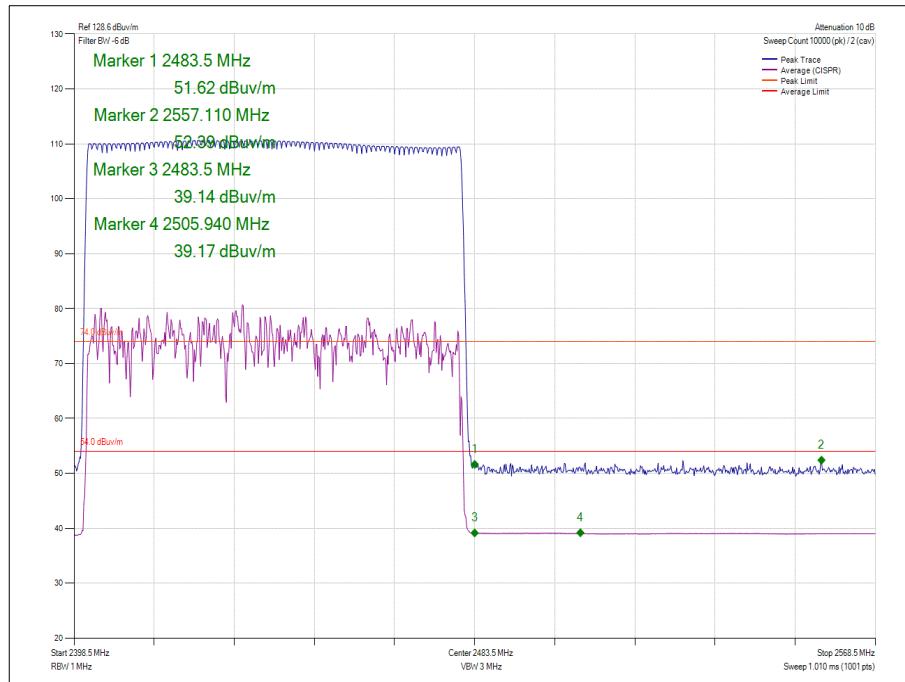


Figure 40 - Hopping - GFSK/DH5 - Band Edge Frequency 2483.5 MHz

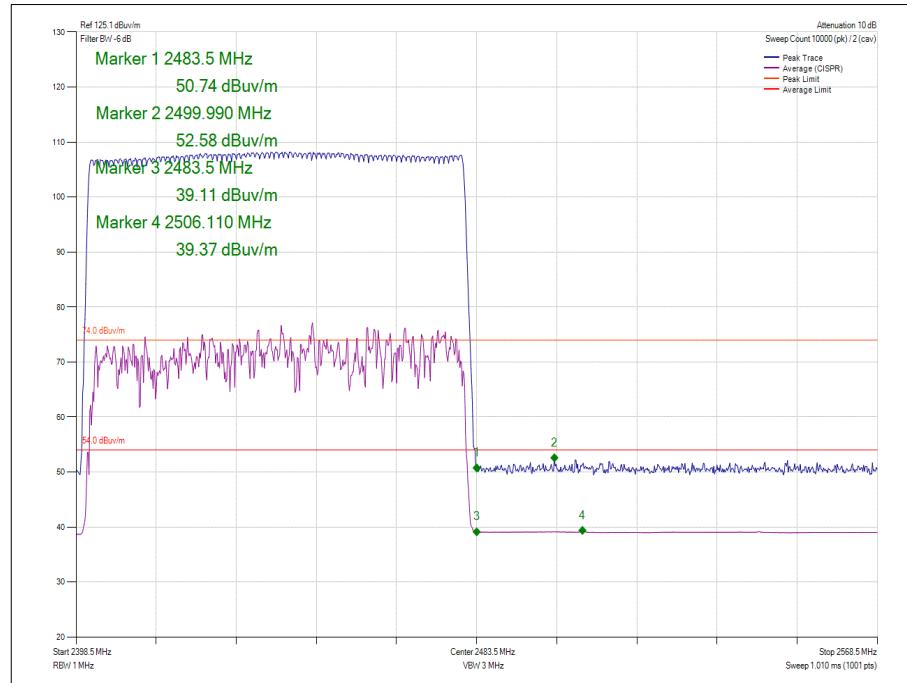


Figure 41 - Hopping - $\pi/4$ DQPSK/2DH5 - Band Edge Frequency 2483.5 MHz

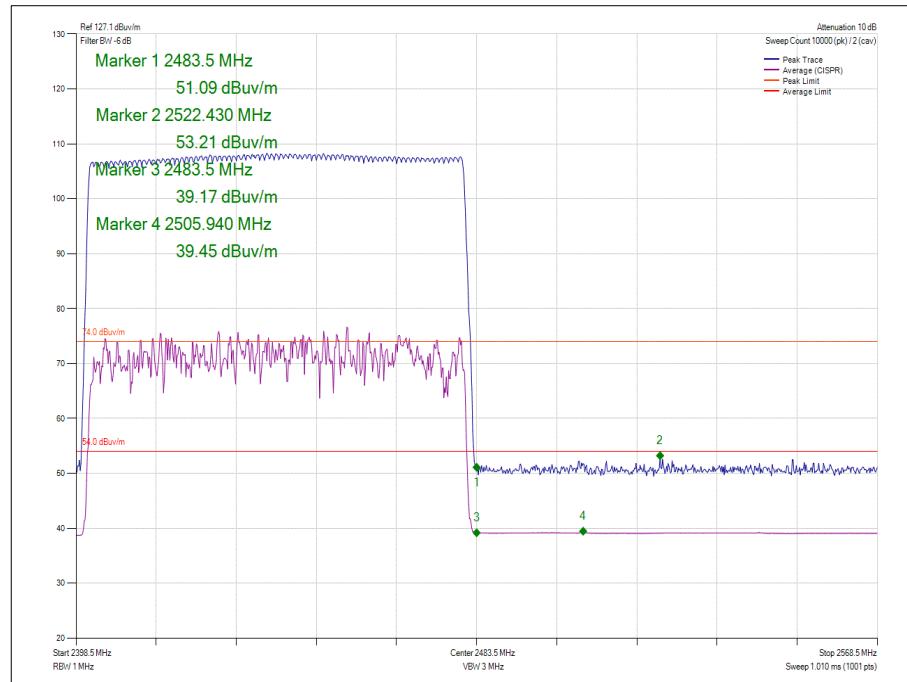


Figure 42 - Hopping - 8-DPSK/3DH5 - Band Edge Frequency 2483.5 MHz



FCC 47 CFR Part 15, Limit Clause 15.209

Frequency (MHz)	Field Strength (μ V/m at 3 m)
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

Table 17
ISEDC RSS-GEN, Limit Clause 8.9

Frequency (MHz)	Field Strength (μ V/m at 3 metres)
30-88	100
88-216	150
216-960	200
Above 960*	500

Table 18

*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 EMC Chamber 11

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Hygrometer	Rotronic	HYGROPALM 1	2338	12	15-Nov-2019
DC - 12.4 GHz 10 dB Attenuator	Suhner	6810.17.A	3965	12	07-Aug-2020
Double Ridged Waveguide Horn Antenna	ETS-Lindgren	3117	4722	12	05-Mar-2020
8 - 18 GHz pre amp	Wright Technologies	PS06-0061	4971	12	07-Dec-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 (18 GHz)	Rosenberger	LU7-071-1000	5102	12	04-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-1000	5104	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-1000	5105	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-2000	5107	12	05-Oct-2019
EmX Software V.1.4.8.3	TÜV SUD	EmX	N/A Software	-	Software
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 19

TU – Traceability Unscheduled



2.8 Spurious Radiated Emissions

2.8.1 Specification Reference

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

2.8.2 Equipment Under Test and Modification State

A2141, S/N: C02YT00GL51N - Modification State 0

2.8.3 Date of Test

03-August-2019 to 12-August-2019

2.8.4 Test Method

This test was performed in accordance with ANSI C63.10-2013 clause 6.3, 6.5 and 6.6.

The EUT was placed on the non-conducting platform in a manner typical of a normal installation..

Ports on the EUT were terminated with loads as described in ANSI C63.4 clause 6.2.4. For EUT's with multiple connectors of the same type, additional interconnecting cables were connected and pre-scans performed to determine whether the level of the emissions were increased by >2 dB.

For frequencies > 1 GHz, plots for average measurements were taken in accordance with ANSI C63.10 clause 4.1.4.2.5 to characterize the EUT. Where emissions were detected, final average measurements were taken in accordance with ANSI C63.10 clause 4.1.4.2.2.

The plots shown are the characterization of the EUT. The limits on the plots represent the most stringent case for restricted bands, (74/54 dB μ V/m) 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 dB μ V/m to μ V/m:
 $10^{(Field\ Strength\ in\ dB\mu\ V/m/20)}$.

2.8.5 Environmental Conditions

Ambient Temperature 24.3 °C

Relative Humidity 53.3 %



2.8.6 Test Results

Bluetooth - BR/EDR

Frequency (MHz)	QP Level (dB μ V/m)	QP Limit (dB μ V/m)	QP Margin (dB)	Angle (Deg)	Height(cm)	Polarity
34.930	31.73	40	8.27	24	111	Vertical

Table 20 – 2440 MHz, 30 MHz to 1 GHz Radiated Emissions Results

No other emissions were detected within 10 dB of the limit.

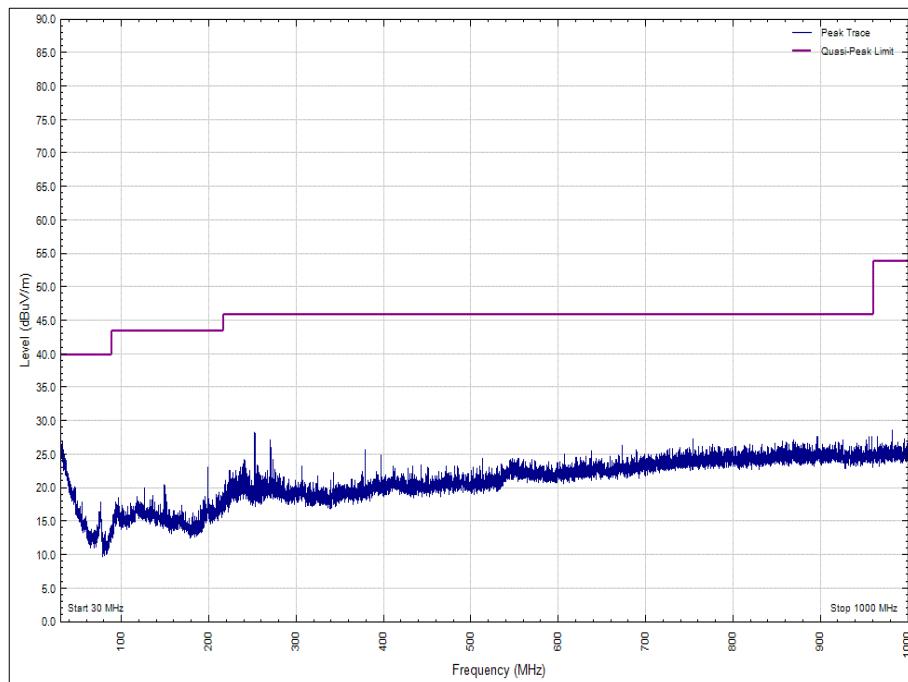


Figure 43 - 2440 MHz, 30 MHz to 1 GHz, Polarity: Horizontal

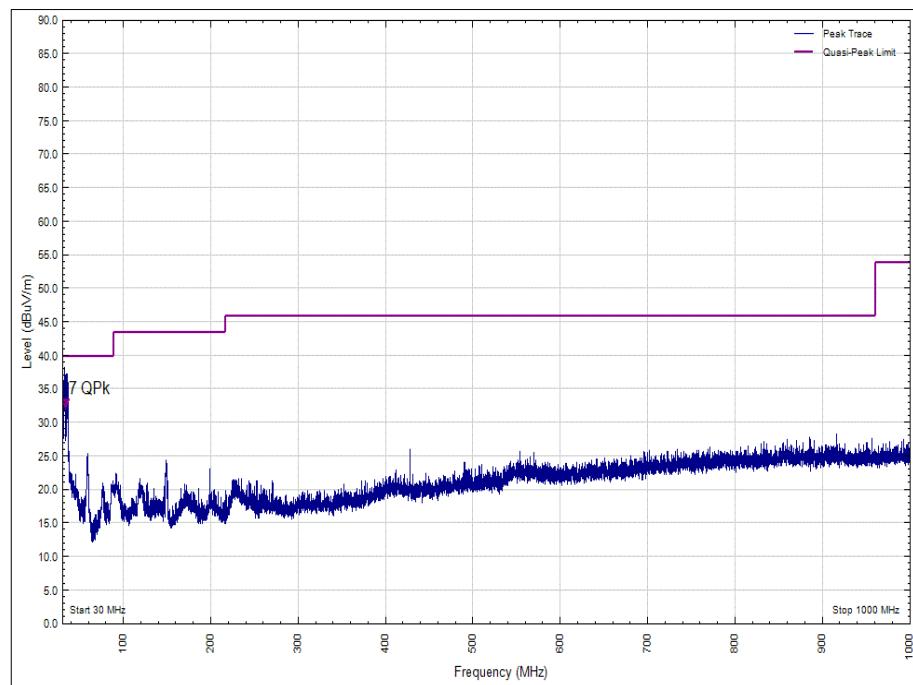


Figure 44 - 2440 MHz, 30 MHz to 1 GHz, Polarity: Vertical

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

Table 21 - 2402 MHz - 1 GHz to 26 GHz – Radiated Emissions Results

*No emissions were detected within 10 dB of the limit.

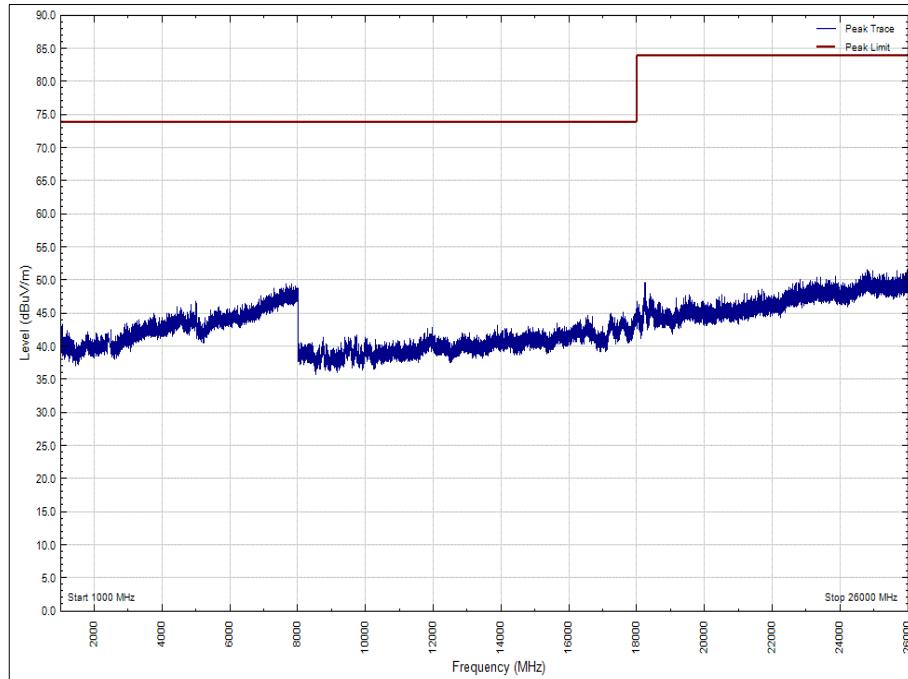


Figure 45 - 2402 MHz - 1 GHz to 26 GHz, Polarity: Horizontal (Peak)

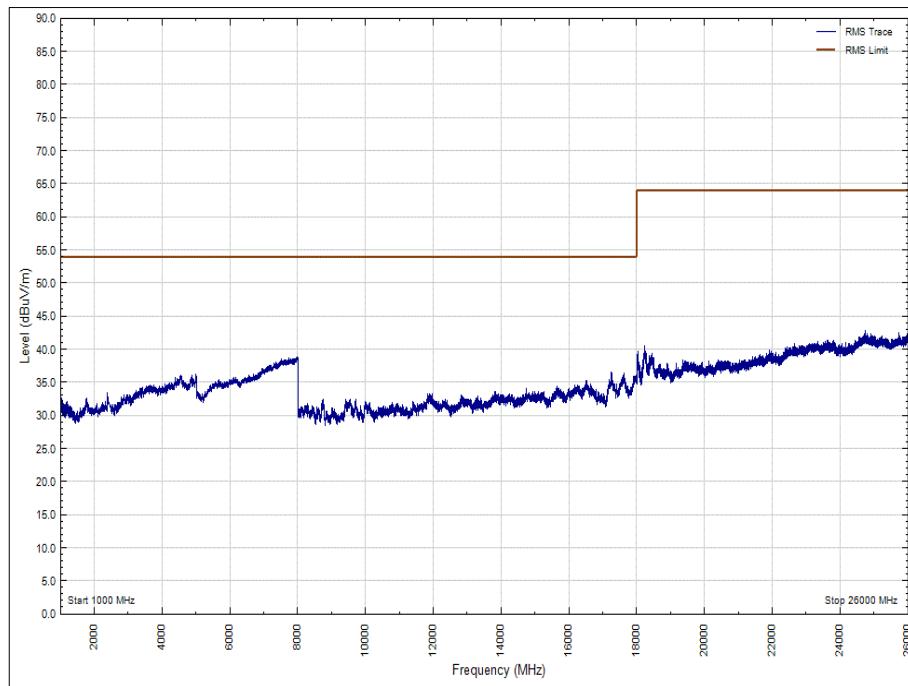


Figure 46 - 2402 MHz - 1 GHz to 26 GHz, Polarity: Horizontal (Average)

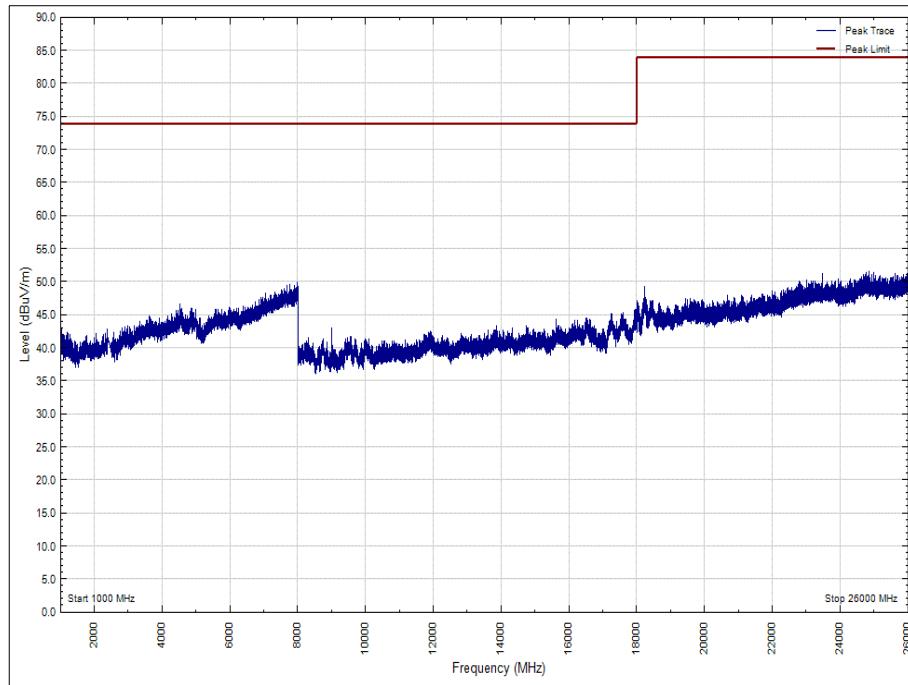


Figure 47 - 2402 MHz - 1 GHz to 26 GHz, Polarity: Vertical (Peak)

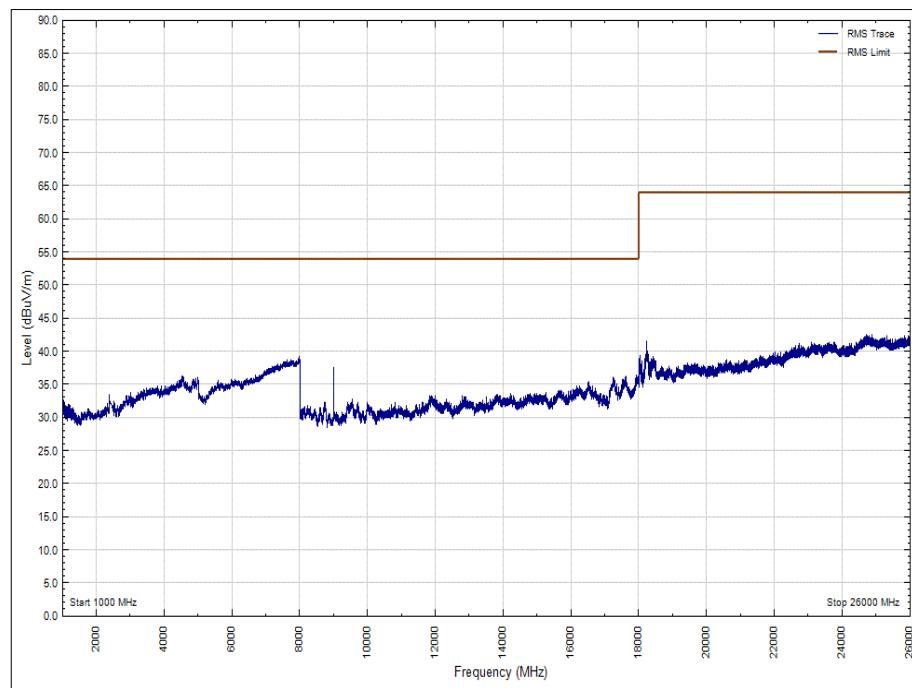


Figure 48 - 2402 MHz - 1 GHz to 26 GHz, Polarity: Vertical (Average)

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

Table 22 - 2440 MHz - 1 GHz to 26 GHz – Radiated Emissions Results

*No emissions were detected within 10 dB of the limit.

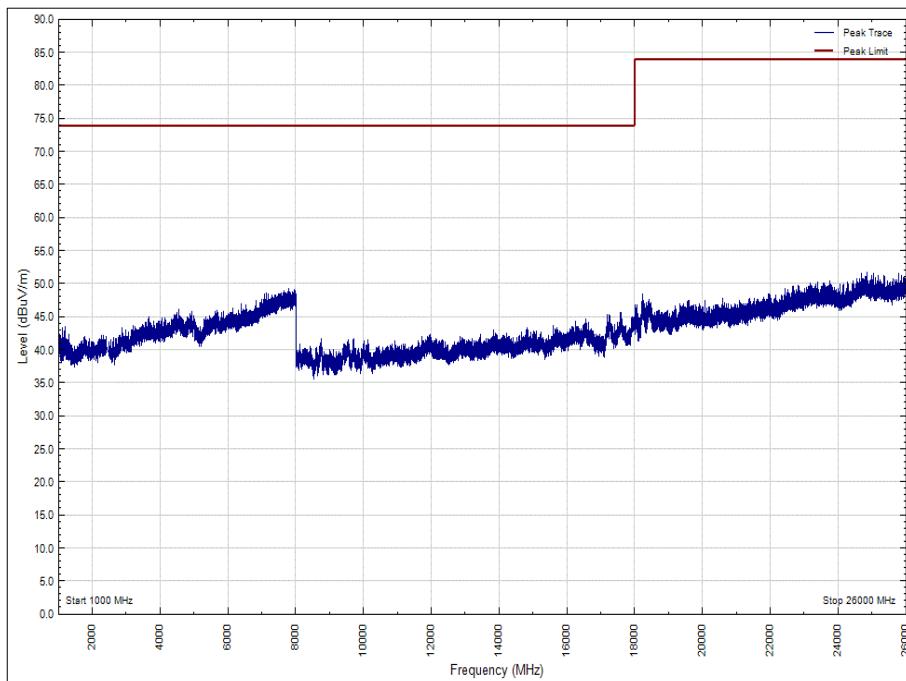


Figure 49 - 2440 MHz - 1 GHz to 26 GHz, Polarity: Horizontal (Peak)

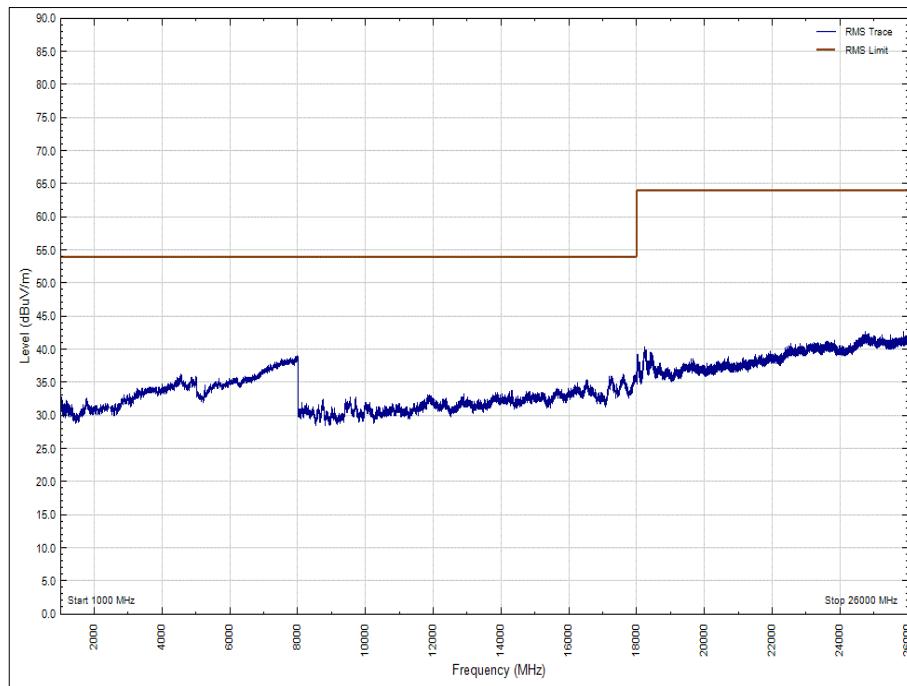


Figure 50 - 2440 MHz - 1 GHz to 26 GHz, Polarity: Horizontal (Average)

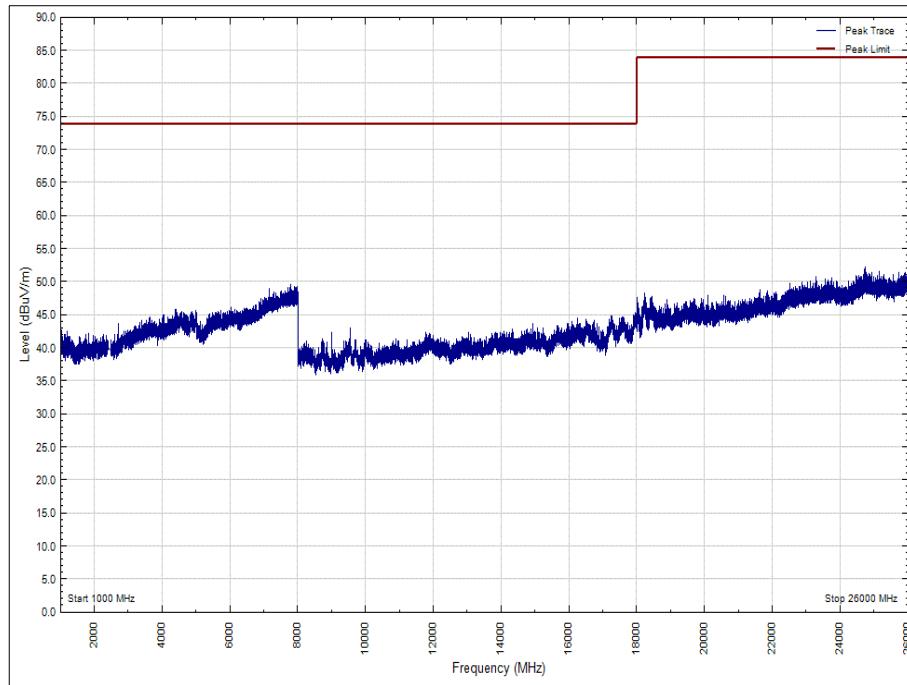


Figure 51 - 2440 MHz - 1 GHz to 26 GHz, Polarity: Vertical (Peak)

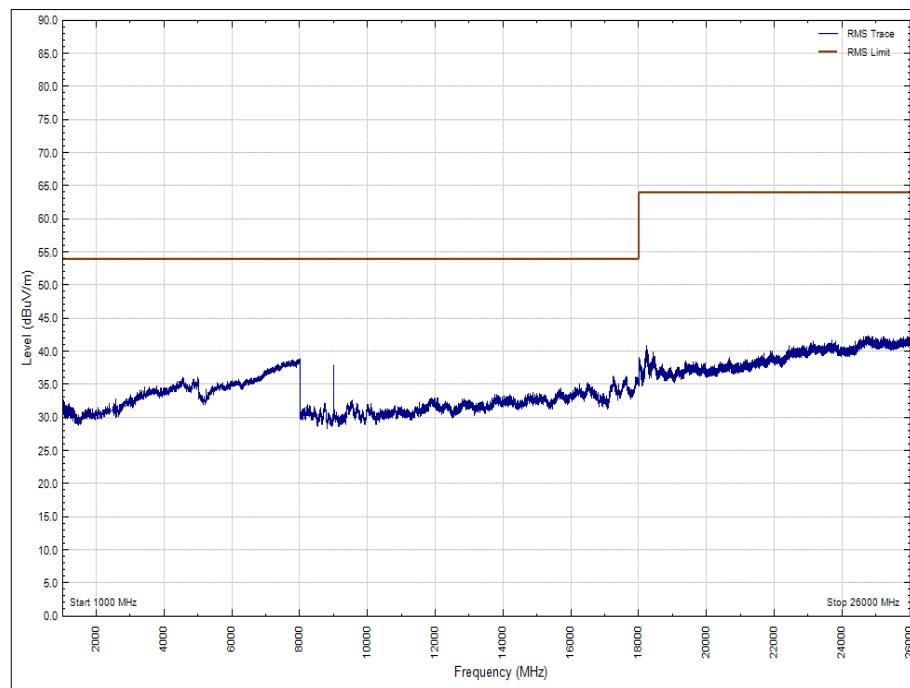


Figure 52 - 2440 MHz - 1 GHz to 26 GHz, Polarity: Vertical (Average)

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

Table 23 - 2480 MHz - 1 GHz to 26 GHz – Radiated Emissions Results

*No emissions were detected within 10 dB of the limit.

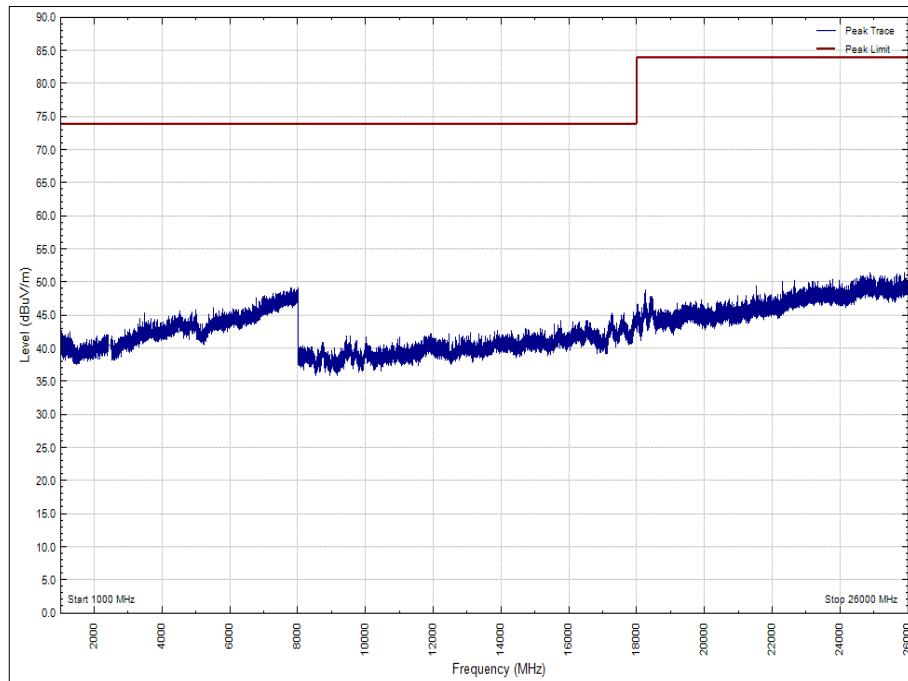


Figure 53 - 2480 MHz - 1 GHz to 26 GHz, Polarity: Horizontal (Peak)

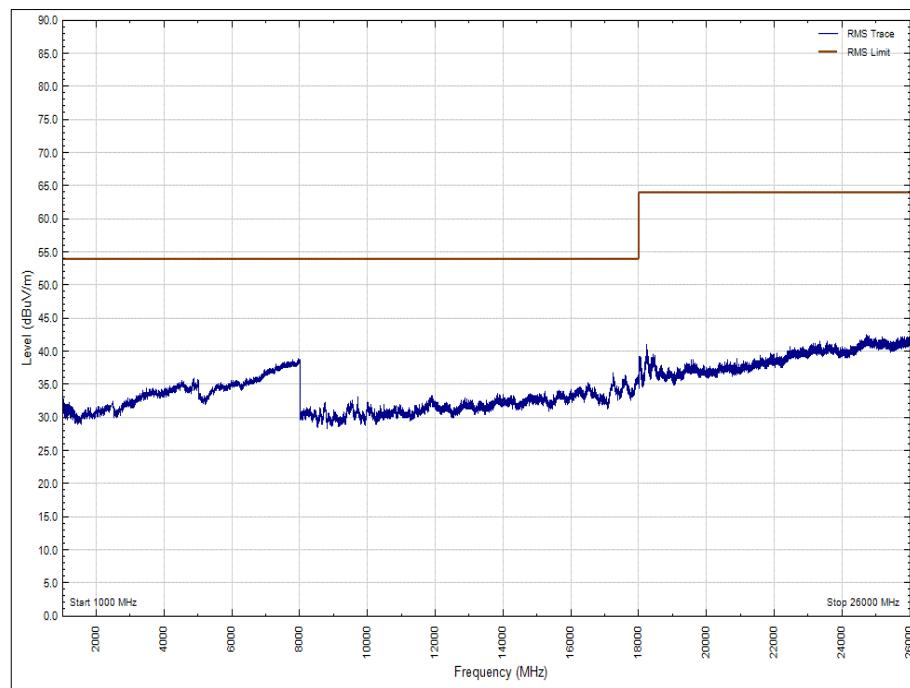


Figure 54 - 2480 MHz - 1 GHz to 26 GHz, Polarity: Horizontal (Average)

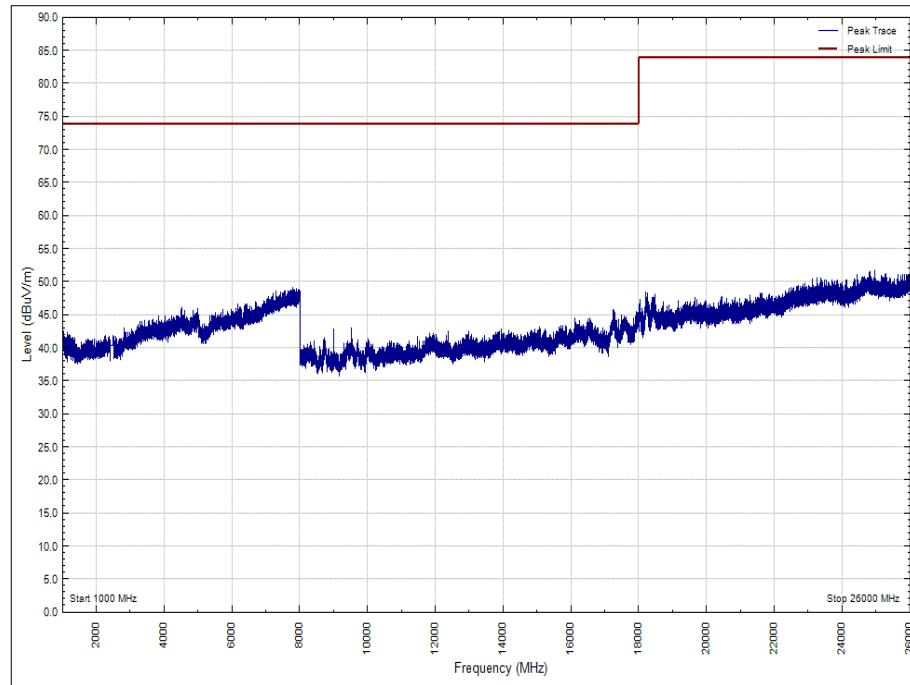


Figure 55 - 2480 MHz - 1 GHz to 26 GHz, Polarity: Vertical (Peak)

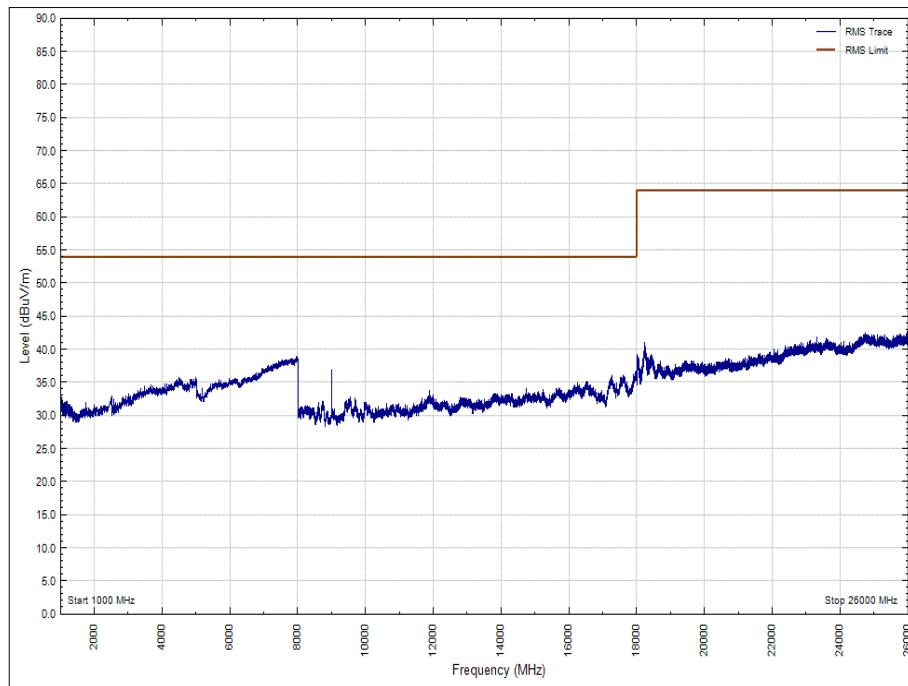


Figure 56 - 2480 MHz - 1 GHz to 26 GHz, Polarity: Vertical (Average)

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)

ISEDC 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 RF Chamber 11.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Pre-Amplifier	Phase One	PS04-0086	1533	12	08-Feb-2020
Turntable Controller	Inn-Co GmbH	CO 1000	1606	-	TU
Hygrometer	Rotronic	HYGROPALM 1	2338	12	15-Nov-2019
1GHz to 8GHz Low Noise Amplifier	Wright Technologies	APS04-0085	4365	12	25-Oct-2019
Cable (Rx, Km-Km 2m)	Scott Cables	KPS-1501-2000-KPS	4526	6	11-Dec-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
Mast Controller	Maturo GmbH	NCD	4810	-	TU
Tilt Antenna Mast	Maturo GmbH	TAM 4.0-P	4811	-	TU
Double Ridge Broadband Horn Antenna	Schwarzbeck	BBHA 9120 B	4848	12	11-Mar-2020
8 - 18 GHz pre amp	Wright Technologies	PS06-0061	4971	12	07-Dec-2019
Band Reject Filter - 2.425 GHz	Wainwright	WRCGV14-2390-2400-2450-2460-50SS	5066	12	02-Oct-2019
Band Reject Filter - 2.425 GHz	Wainwright	WRCGV14-2390-2400-2450-2460-50SS	5067	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
Band Reject Filter - 2.4585 GHz	Wainwright	WRCGV14-2423.5-2433.5-2483.5-2493.5-50SS	5069	12	02-Oct-2019
EMI Test Receiver	Rohde & Schwarz	ESW44	5084	12	12-Sep-2019
8m N-Type RF Cable	Teledyne	PR90-088-8MTR	5093	12	04-Oct-2019
8m N-Type RF Cable	Teledyne	PR90-088-8MTR	5095	12	04-Oct-2019

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Cable (18 GHz)	Rosenberger	LU7-071-1000	5102	12	04-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-1000	5104	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-1000	5105	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-2000	5107	12	05-Oct-2019
Cable (18 GHz)	Rosenberger	LU7-071-2000	5109	12	05-Oct-2019
EmX Software	TUV SUD	EmX V.1.4.8.3	5125	-	Software
1.5m 40GHz RF Cable	Scott Cables	KPS-1501-2000-KPS	5127	6	11-Dec-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
Horn Antenna (1-10GHz)	Schwarzbeck	BBHA 9120 B	5215	12	11-Mar-2020
DRG Horn Antenna (7.5-18GHz)	Schwarzbeck	HWRD750	5216	12	11-Mar-2020

Table 24

TU – Traceability Unscheduled

3 Measurement Uncertainty

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

Test Name	Measurement Uncertainty
AC Power Line Conducted Emissions	150 kHz to 30 MHz, LISN, ± 3.7 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
Spurious Radiated Emissions	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB

Table 25