

FCC and ISCED Test Report

Apple Inc
Model: A2338

In accordance with FCC 47 CFR Part 15C, ISCED
RSS-247 and ISCED RSS-GEN (2.4 GHz Bluetooth)

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

FCC ID: BCGA2338

IC: 579C-A2338



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Document 75948987-09 Issue 01

SIGNATURE

NAME	JOB TITLE	RESPONSIBLE FOR	ISSUE DATE
Steve Marshall	Senior Engineer	Authorised Signatory	06 October 2020

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, ISCED RSS-247 and ISCED 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	06 October 2020	
Testing	Connor Lee	06 October 2020	
Testing	Liang Tian	06 October 2020	

FCC Accreditation

90987 Octagon House, Fareham Test Laboratory

ISCED Accreditation

12669A 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: 2019, ISCED RSS-247: Issue 2 (02-2017) and ISCED RSS-GEN: Issue 5 (04-2018) + A1 (03-2019) for the tests detailed in section 1.3.



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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	06-October-2020

Table 1

1.2 Introduction

Applicant	Apple Inc
Manufacturer	Apple Inc
Model Number(s)	A2338
Serial Number(s)	C02CX02PQC36 and C02CX02JQC36
Hardware Version(s)	REV 1.0
Software Version(s)	20W112771j
Number of Samples Tested	2
Test Specification/Issue/Date	FCC 47 CFR Part 15C: 2019 ISED RSS-247: Issue 2 (02-2017) ISED RSS-GEN: Issue 5 (04-2018) + A1 (03-2019)
Order Number	0540201117
Date	05-May-2020
Date of Receipt of EUT	17-July-2020 and 17-August-2020
Start of Test	04-August-2020
Finish of Test	11-September-2020
Name of Engineer(s)	Mehadi Choudhury, Connor Lee and Liang Tian
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, ISSED RSS-247 and ISSED RSS-GEN is shown below.

Section	Specification Clause			Test Description	Result	Comments/Base Standard
	Part 15C	RSS-247	RSS-GEN			
Configuration and Mode: 2.4 GHz Bluetooth (FHSS)						
-	15.203	-	-	Antenna Requirement	N/T	The devices complies with the provisions of this section, as it uses a permanently attached antenna
2.1	15.247 (a)(1)	5.1	-	Frequency Hopping Systems - Average Time of Occupancy	Pass	
2.2	15.247 (a)(1)	5.1	-	Frequency Hopping Systems - Channel Separation	Pass	
2.3	15.247 (a)(1)	5.1	-	Frequency Hopping Systems - Number of Hopping Channels	Pass	
2.4	15.247 (a)(1)	5.1	6.7	Frequency Hopping Systems - 20 dB Bandwidth	Pass	
2.5	15.247 (b)	5.4	6.12	Maximum Conducted Output Power	Pass	
2.6	15.247 (d)	5.5	-	Authorised Band Edges	Pass	
2.7	15.205	-	8.10	Restricted Band Edges	Pass	
2.8	15.247 (d) and 15.205	5.5	6.13	Spurious Radiated Emissions	Pass	

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/ax capabilities in the 2.4 GHz and 5 GHz bands.

1.4.2 Test Set-up

For conducted tests, a conducted test point was provided by the manufacturer via a UFL connector and cable. The loss of these test cables were known and compensated for in any conducted measurements.

For tests in SISO operation, conducted tests were performed on the Core with the highest antenna gain as Core 0 and Core 1 are identical but with unequal antenna gains. The EUT supports TxBF on Core 0 + Core 1.

Bluetooth BDR/EDR was assessed as a FHSS system. The EUT supports Bluetooth on the following mode of operations across it's antenna ports:

- BT Core 0 – SISO (iPA and ePA), TxBF (iPA and ePA)
- BT Core 1 – SISO (iPA and ePA), TxBF (iPA and ePA)
- BT Core 0 + BT Core 1 - TxBF (iPA and ePA)

For all tests, the EUT was put into a continuous transmit test mode with the manufacturer's test commands via a script running in the EUTs terminal application. The EUT then transmitted the required type of modulation/packet type on either a static channel selected within the test script or frequency hopping over the maximum number of supported channels.

All testing was performed with the EUT powered via a 120 V AC, 60 Hz source.

1.4.3 Antenna Gain Table (2.4GHz Bluetooth)

Antenna Port	Frequency Range (MHz)	Peak Gain (dBi)	Conducted Cable Loss (dB)
BT Core 0	2400 to 2480	0.57	1.0
BT Core 1	2400 to 2480	1.18	1.0

Table 3



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: A2338, Serial Number: C02CX02JQC36			
0	As supplied by the customer	Not Applicable	Not Applicable
Model: A2338, Serial Number: C02CX02PQC36			
0	As supplied by the customer	Not Applicable	Not Applicable

Table 4

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: 2.4 GHz Bluetooth (FHSS)		
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	Connor Lee and Liang Tian	UKAS
Restricted Band Edges	Connor Lee and Liang Tian	UKAS
Spurious Radiated Emissions	Connor Lee and Liang Tian	UKAS

Table 5

Office Address:

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



2 Test Details

2.1 Frequency Hopping Systems - Average Time of Occupancy

2.1.1 Specification Reference

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

2.1.2 Equipment Under Test and Modification State

A2338, S/N: C02CX02JQC36 - Modification State 0

2.1.3 Date of Test

10-September-2020 to 11-September-2020

2.1.4 Test Method

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

2.1.5 Environmental Conditions

Ambient Temperature	21.5-23.9 °C
Relative Humidity	46.0-52.9 %



2.1.6 Test Results

2.4 GHz Bluetooth (FHSS)

iPA

Antenna Port: Core 1

Modulation	2402 MHz		
	Dwell Time (ms)	Number of Transmissions	Time of Occupancy (ms)
GFSK (DH5)	2.887	99	285.8

Table 6 - Time of Occupancy Results

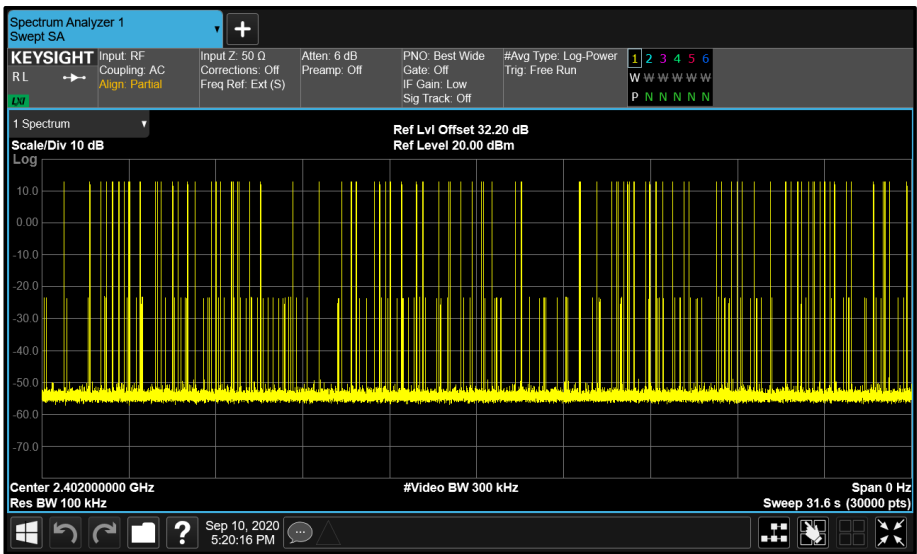


Figure 1 - GFSK (DH5) 2402 MHz - Time of Occupancy

ePA

Antenna Port: Core 1

Modulation	2402 MHz		
	Dwell Time (ms)	Number of Transmissions	Time of Occupancy (ms)
GFSK (DH5)	2.887	96	277.2

Table 7 - Time of Occupancy Results

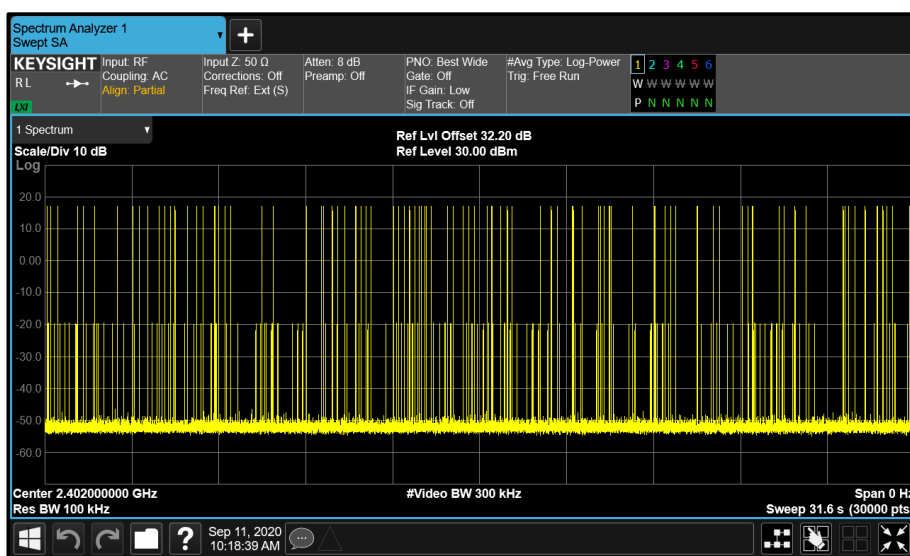


Figure 2 - GFSK (DH5) 2402 MHz - Time of Occupancy

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.

ISED 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.



2.1.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	08-Nov-2020
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2020
Hygrometer	Rotronic	I-1000	3220	12	25-Sep-2020
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	08-Nov-2020
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
MXA Signal Analyser	Keysight Technologies	N9020B	5528	24	04-Mar-2022
Signal Commissioning Unit	TUV SUD	SCU001	5546	12	15-Apr-2021

Table 8

O/P Mon – Output Monitored using calibrated equipment



2.2 Frequency Hopping Systems - Channel Separation

2.2.1 Specification Reference

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

2.2.2 Equipment Under Test and Modification State

A2338, S/N: C02CX02JQC36 - Modification State 0

2.2.3 Date of Test

10-September-2020 to 11-September-2020

2.2.4 Test Method

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

2.2.5 Environmental Conditions

Ambient Temperature 21.5-23.9 °C
Relative Humidity 46.0-52.9 %

2.2.6 Test Results

2.4 GHz Bluetooth (FHSS)

iPA

Antenna Port: Core 1

Modulation	2441 MHz (CH39)		
	F1C (MHz)	F2C (MHz)	FHS (MHz)
GFSK	2441.010	2442.010	1.000
$\pi/4$ DQPSK	2440.990	2441.990	1.000
8-DPSK	2441.000	2441.999	0.999

Table 9 - Hopping Frequency Separation Results

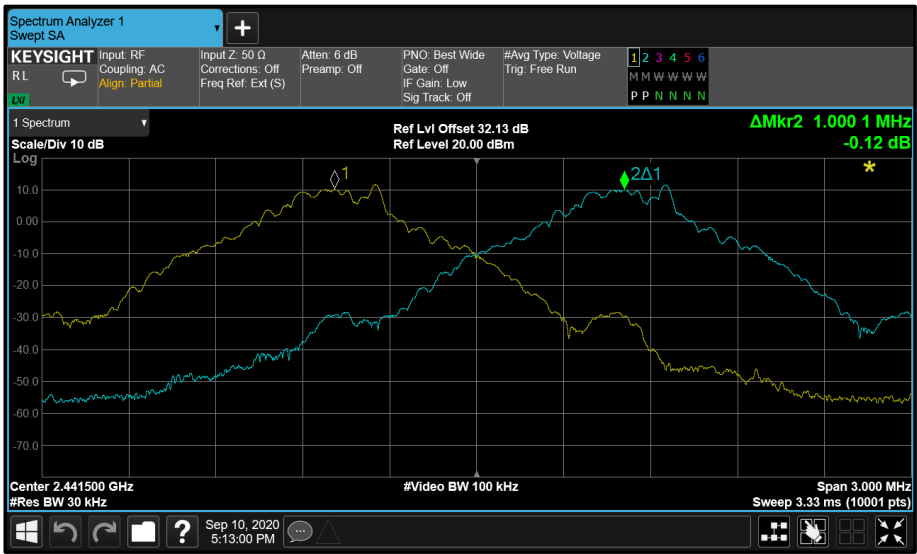


Figure 3 - GFSK - 2441 MHz (CH39)

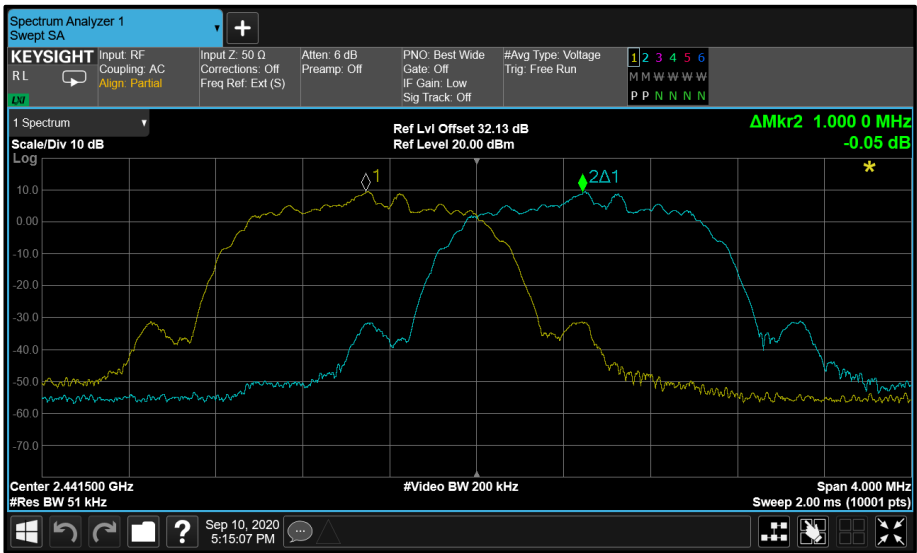


Figure 4 - $\pi/4$ DQPSK - 2441 MHz (CH39)

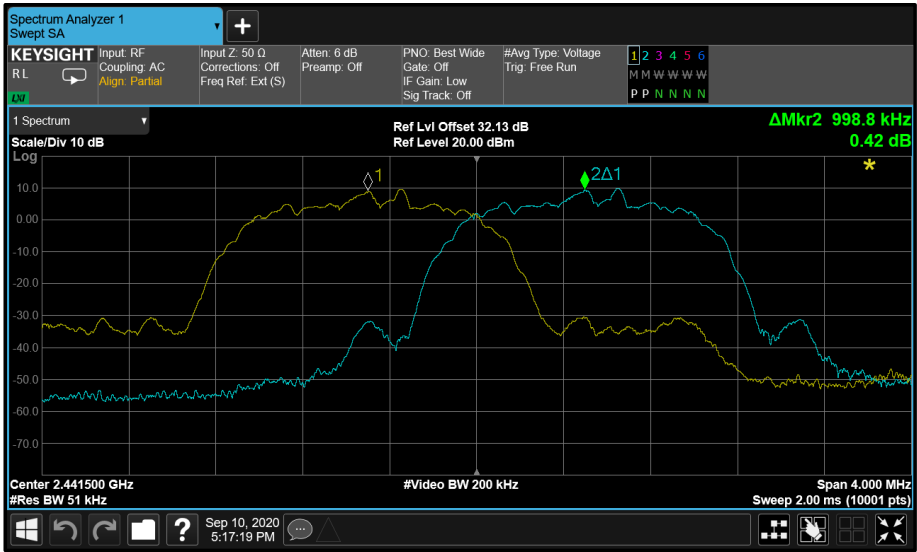


Figure 5 - 8-DPSK - 2441 MHz (CH39)

ePA

Antenna Port: Core 1

Modulation	2441 MHz (CH39)		
	F1C (MHz)	F2C (MHz)	FHS (MHz)
GFSK	2441.008	2442.008	1.000
$\pi/4$ DQPSK	2440.991	2441.991	1.000
8-DPSK	2440.999	2441.999	1.000

Table 10 - Hopping Frequency Separation Results



Figure 6 - GFSK - 2441 MHz (CH39)

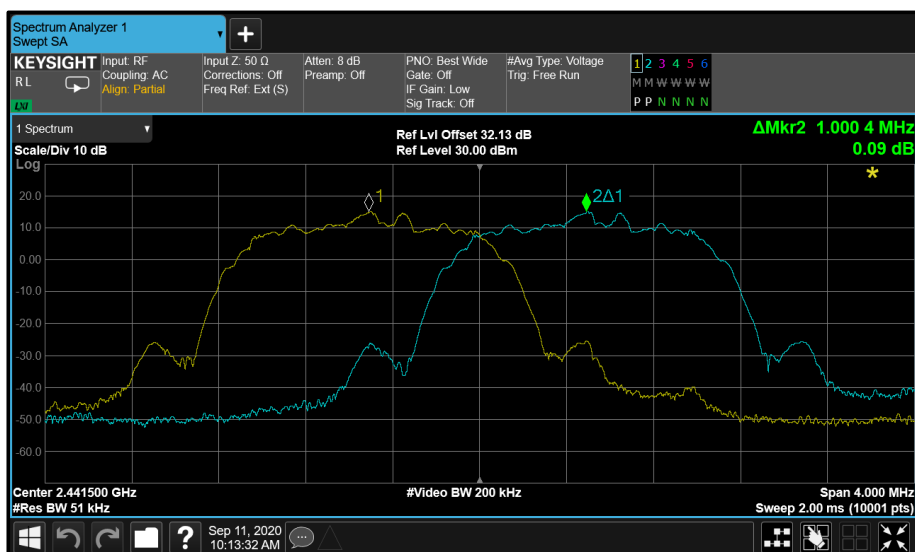


Figure 7 - $\pi/4$ DQPSK - 2441 MHz (CH39)

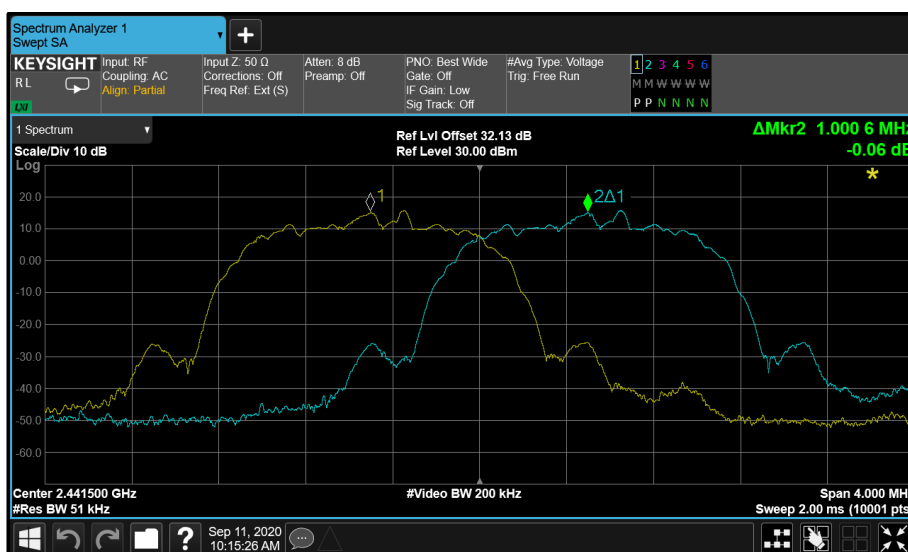


Figure 8 - 8-DPSK - 2441 MHz (CH39)

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

If the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

ISED RSS-247, Limit Clause 5.1 (c)

For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.



2.2.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	08-Nov-2020
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2020
Hygrometer	Rotronic	I-1000	3220	12	25-Sep-2020
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	08-Nov-2020
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
MXA Signal Analyser	Keysight Technologies	N9020B	5528	24	04-Mar-2022
Signal Commissioning Unit	TUV SUD	SCU001	5546	12	15-Apr-2021

Table 11

O/P Mon – Output Monitored using calibrated equipment

2.3 Frequency Hopping Systems - Number of Hopping Channels

2.3.1 Specification Reference

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

2.3.2 Equipment Under Test and Modification State

A2338, S/N: C02CX02JQC36 - Modification State 0

2.3.3 Date of Test

10-September-2020 to 11-September-2020

2.3.4 Test Method

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

2.3.5 Environmental Conditions

Ambient Temperature 21.5-23.9 °C
Relative Humidity 46.0-52.9 %

2.3.6 Test Results

2.4 GHz Bluetooth (FHSS)

iPA

Antenna Port: Core 1

Number of Hopping Channels: 79

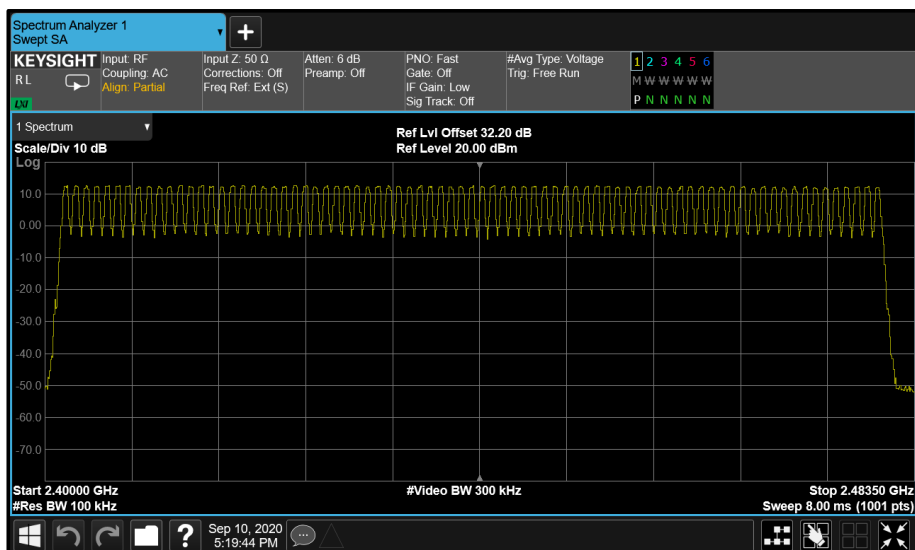


Figure 9 - GFSK (DH5) - Number of Hopping Channels

ePA

Antenna Port: Core 1

Number of Hopping Channels: 79

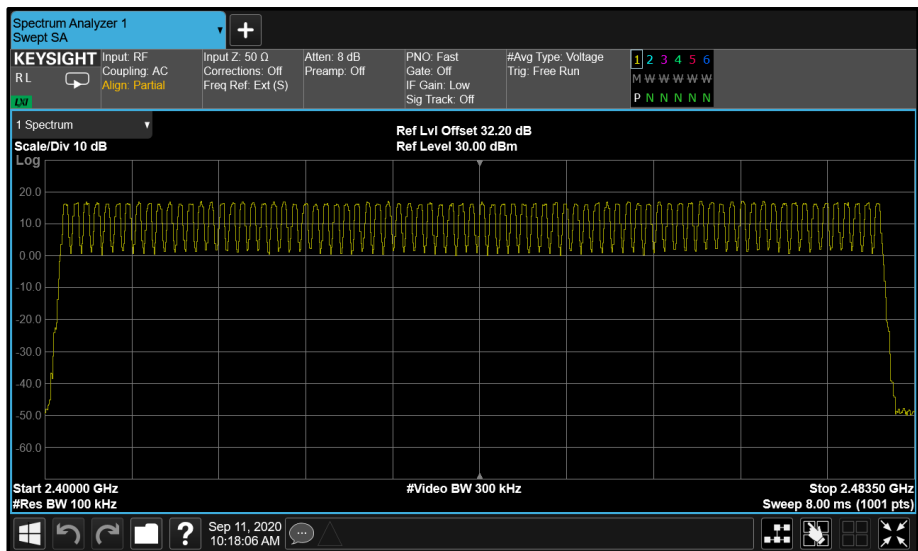


Figure 10 - GFSK (DH5) - Number of Hopping Channels

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

≥ 15 channels

ISED RSS-247, Limit Clause 5.1 (d)

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



2.3.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	08-Nov-2020
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2020
Hygrometer	Rotronic	I-1000	3220	12	25-Sep-2020
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	08-Nov-2020
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
MXA Signal Analyser	Keysight Technologies	N9020B	5528	24	04-Mar-2022
Signal Commissioning Unit	TUV SUD	SCU001	5546	12	15-Apr-2021

Table 12

O/P Mon – Output Monitored using calibrated equipment



2.4 Frequency Hopping Systems - 20 dB Bandwidth

2.4.1 Specification Reference

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

2.4.2 Equipment Under Test and Modification State

A2338, S/N: C02CX02JQC36 - Modification State 0

2.4.3 Date of Test

10-September-2020 to 11-September-2020

2.4.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 6.9.1.

2.4.5 Environmental Conditions

Ambient Temperature 21.5-23.9 °C
Relative Humidity 46.0-52.9 %

2.4.6 Test Results

2.4 GHz Bluetooth (FHSS)

iPA

Antenna Port Configuration: SISO

Modulation: GFSK (DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)
	Port(s)
	Core 1
2402	888.0
2441	888.0
2480	885.0

Table 13 - 20 dB Bandwidth Results

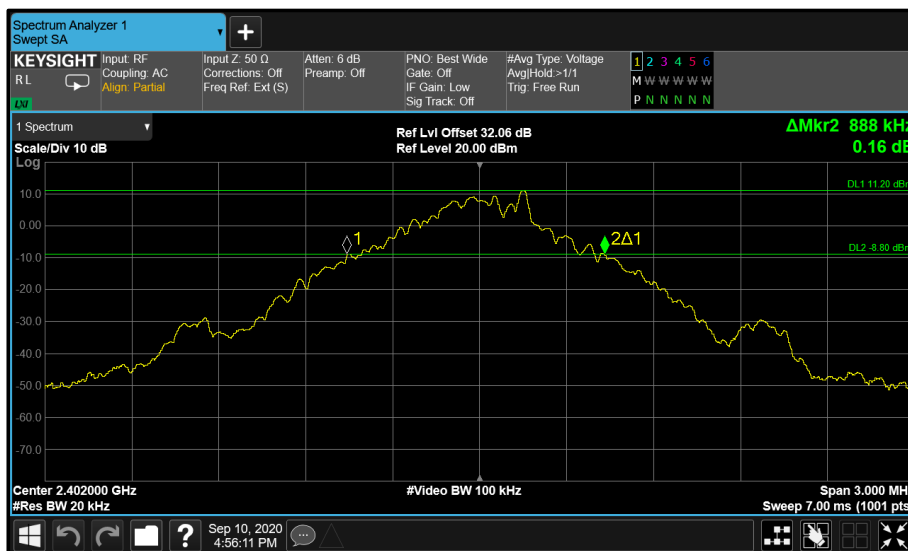


Figure 11 - Core 1 GFSK 2402 MHz (CH0)

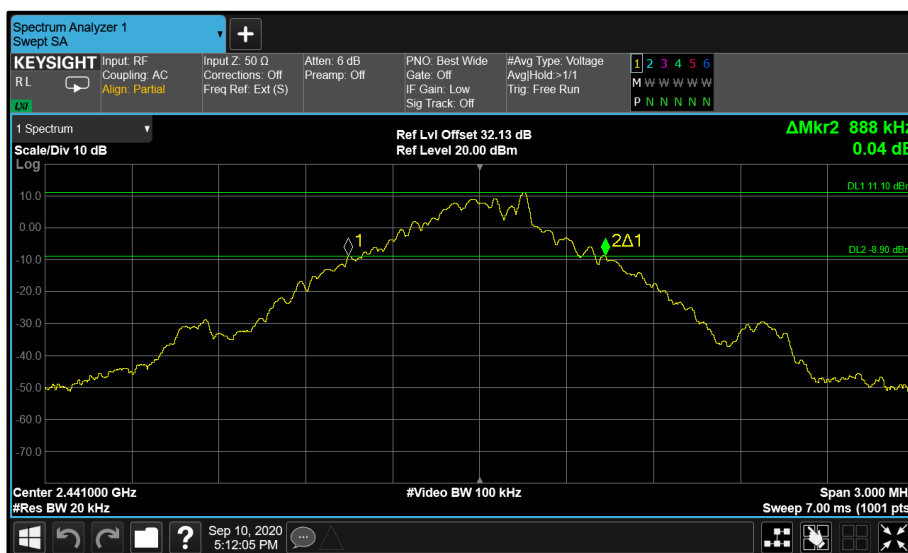


Figure 12 - Core 1 GFSK 2441 MHz (CH39)

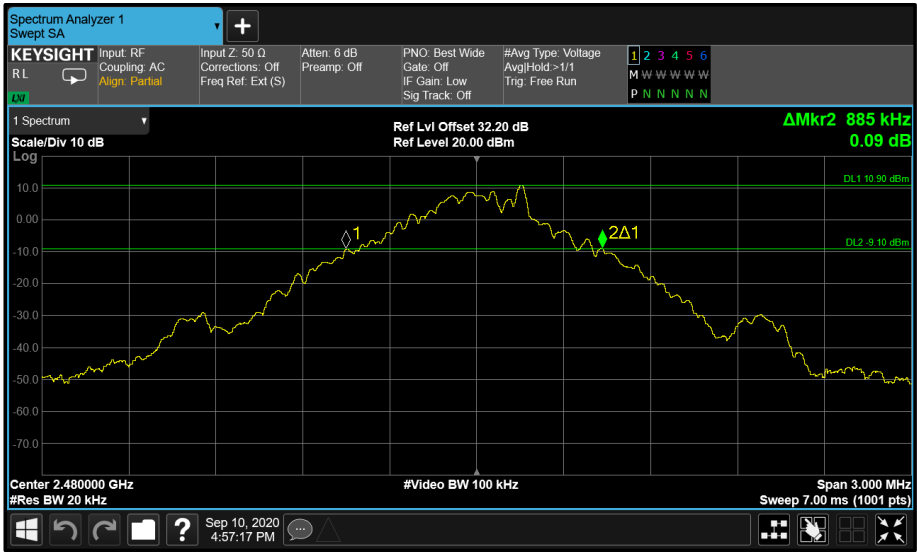


Figure 13 - Core 1 GFSK 2480 MHz (CH78)

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)
	Port(s)
	Core 1
2402	1335.0
2441	1330.0
2480	1330.0

Table 14 - 20 dB Bandwidth Results

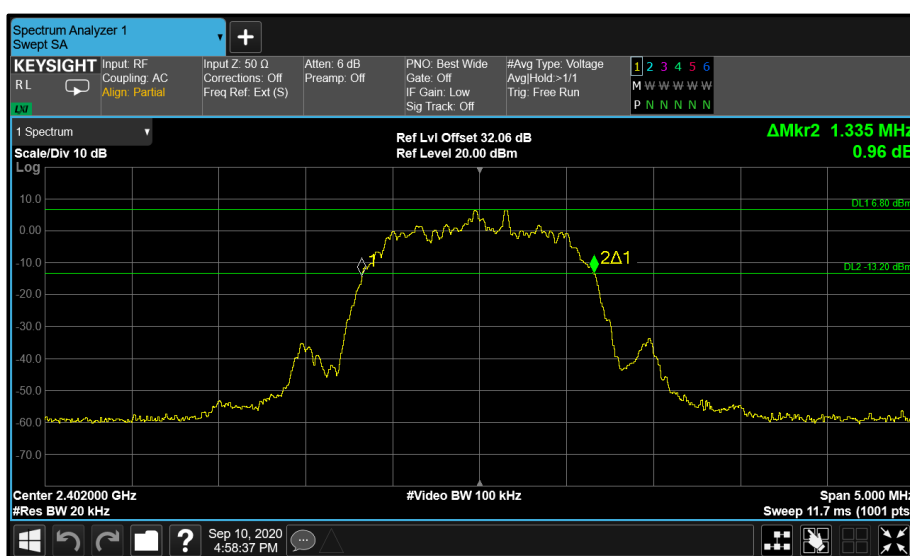


Figure 14 - Core 1 $\pi/4$ DQPSK 2402 MHz (CH0)

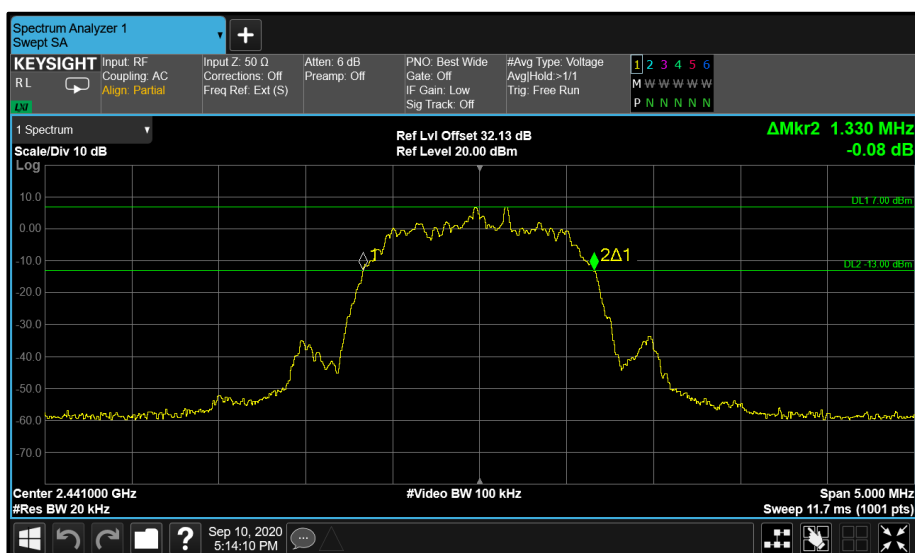


Figure 15 - Core 1 $\pi/4$ DQPSK 2441 MHz (CH39)

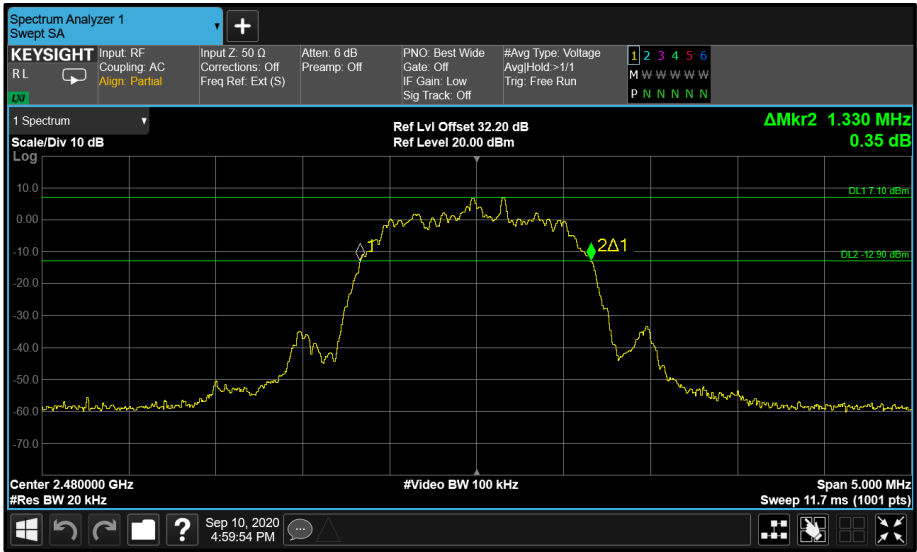


Figure 16 - Core 1 $\pi/4$ DQPSK 2480 MHz (CH78)

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)
	Port(s)
	Core 1
2402	1270.0
2441	1270.0
2480	1275.0

Table 15 - 20 dB Bandwidth Results

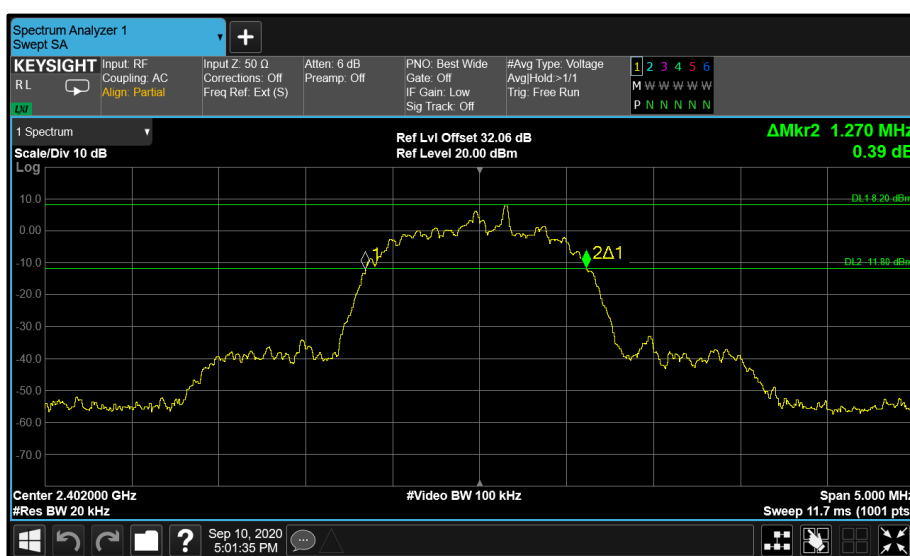


Figure 17 - Core 1 8-DPSK 2402 MHz (CH0)

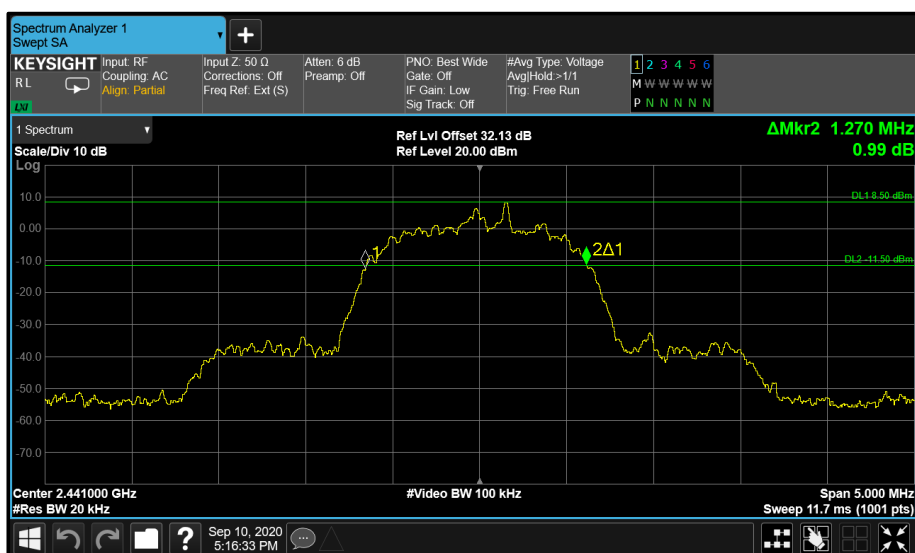


Figure 18 - Core 1 8-DPSK 2441 MHz (CH39)

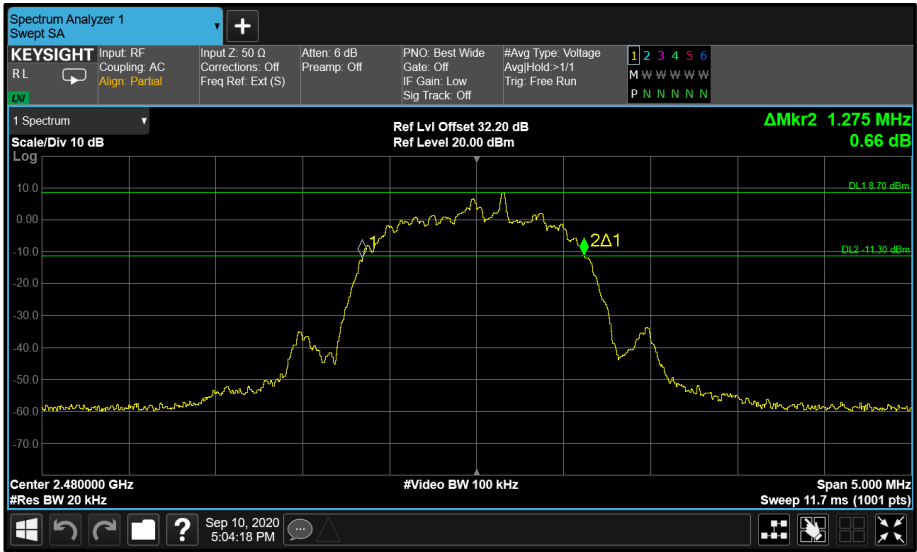


Figure 19 - Core 1 8-DPSK 2480 MHz (CH78)

Antenna Port Configuration: Beamforming

Modulation: GFSK (DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)	
	Port(s)	
	Core 1	Core 0
2402	888.0	840.0
2441	885.0	840.0
2480	888.0	882.0

Table 16 - 20 dB Bandwidth Results

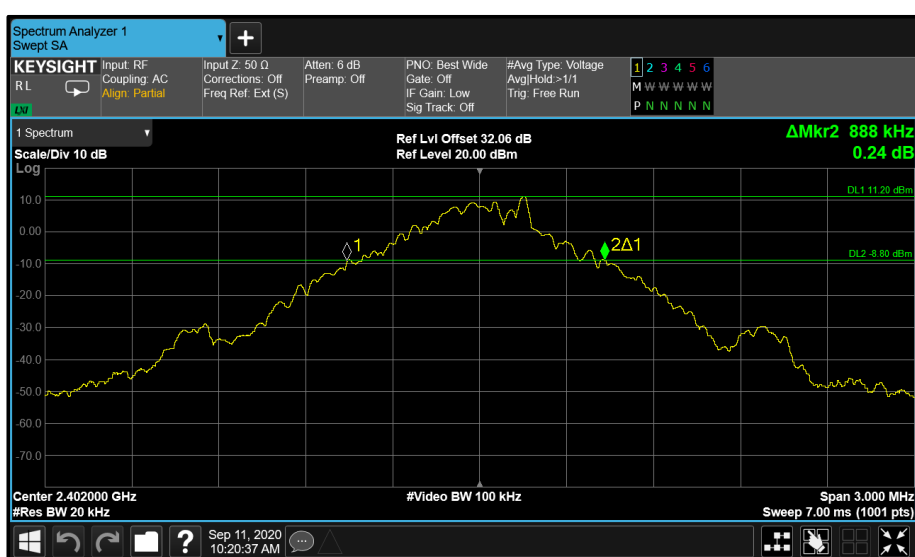


Figure 20 - Core 1 GFSK 2402 MHz (CH0)

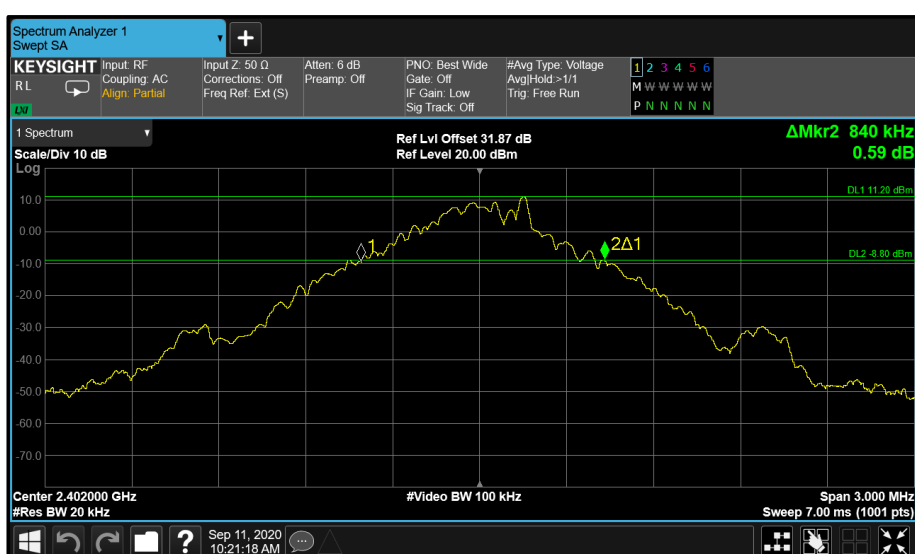


Figure 21 - Core 0 GFSK 2402 MHz (CH0)

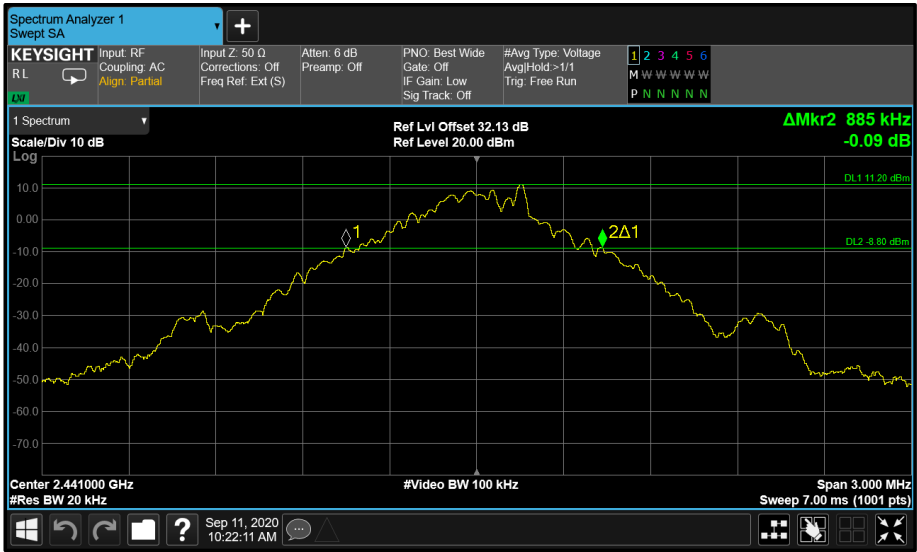


Figure 22 - Core 1 GFSK 2441 MHz (CH39)

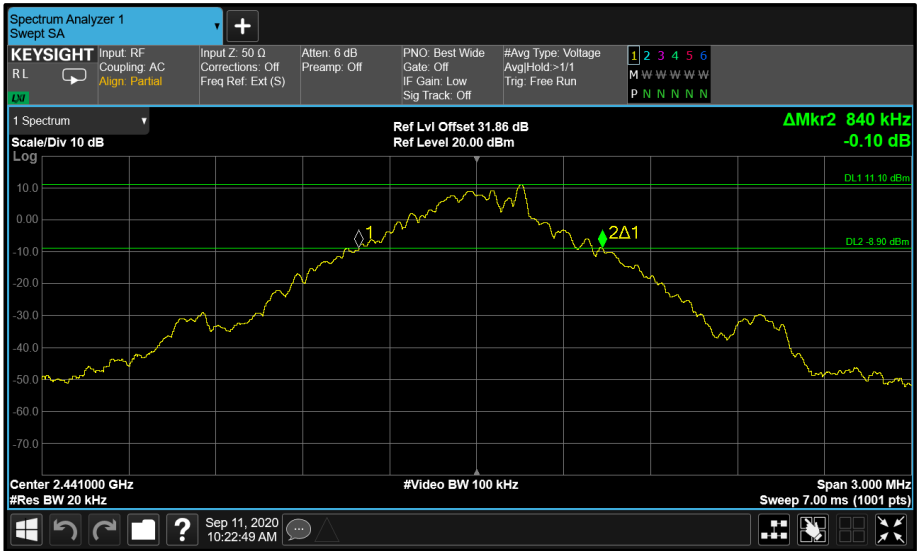


Figure 23 - Core 0 GFSK 2441 MHz (CH39)

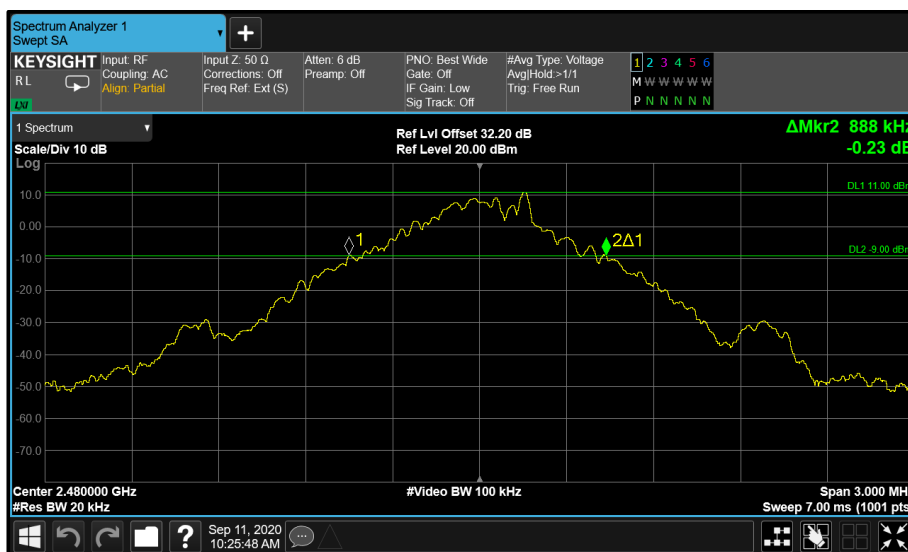


Figure 24 - Core 1 GFSK 2480 MHz (CH78)

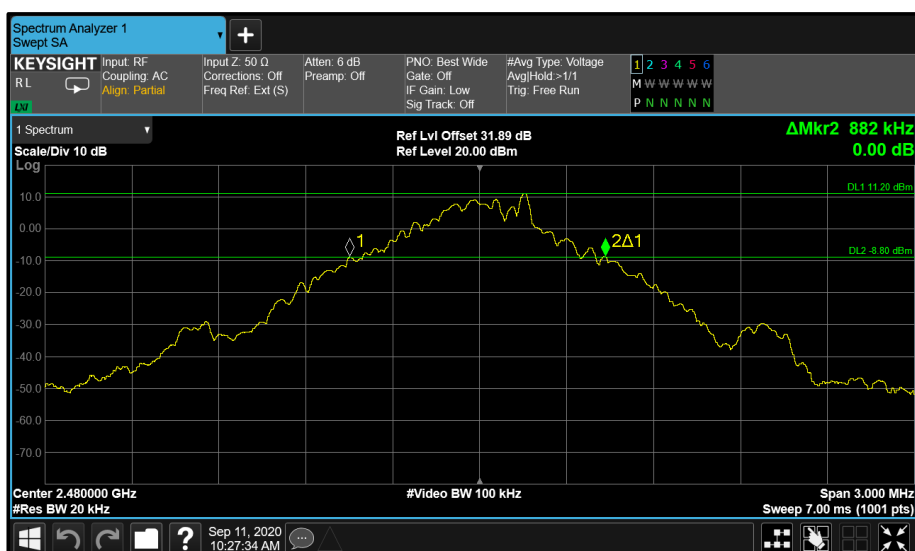


Figure 25 - Core 0 GFSK 2480 MHz (CH78)

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)	
	Port(s)	
	Core 1	Core 0
2402	1330.0	1330.0
2441	1335.0	1335.0
2480	1330.0	1330.0

Table 17 - 20 dB Bandwidth Results

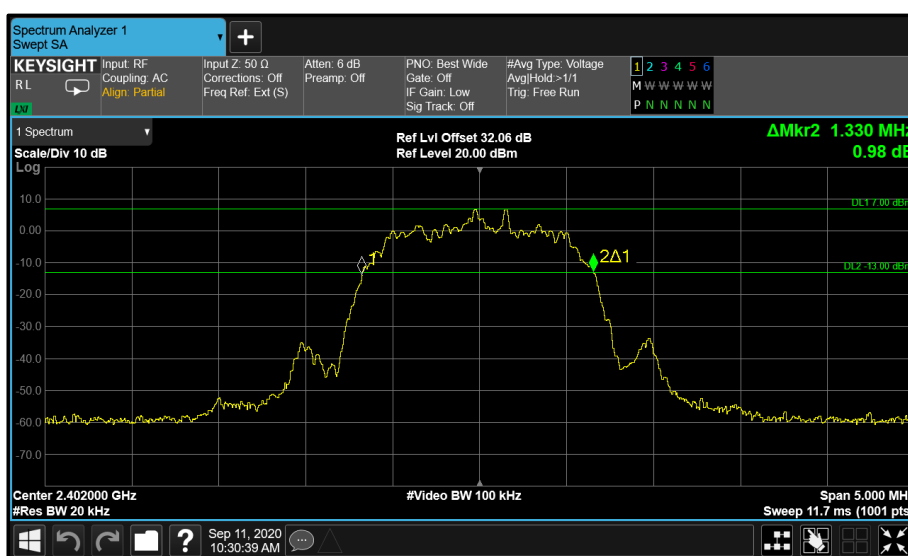


Figure 26 - Core 1 $\pi/4$ DQPSK 2402 MHz (CH0)

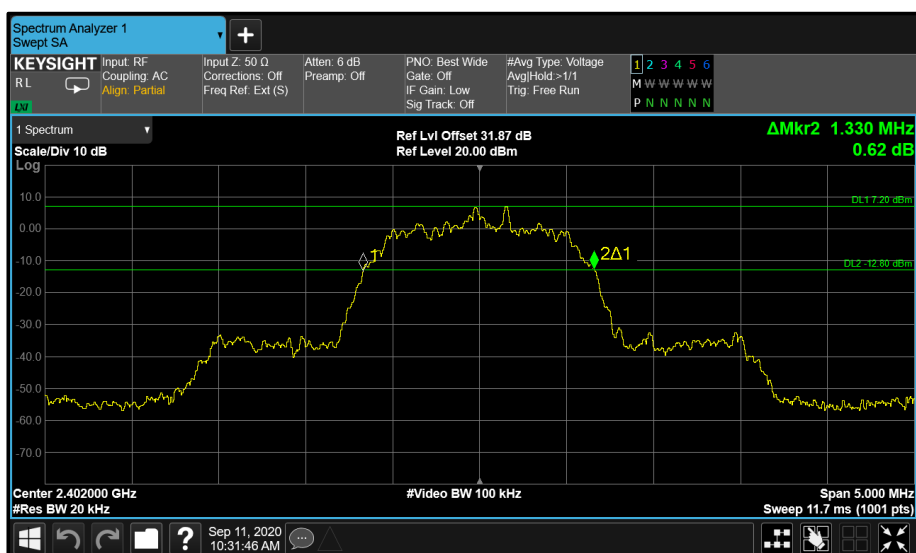


Figure 27 - Core 0 $\pi/4$ DQPSK 2402 MHz (CH0)

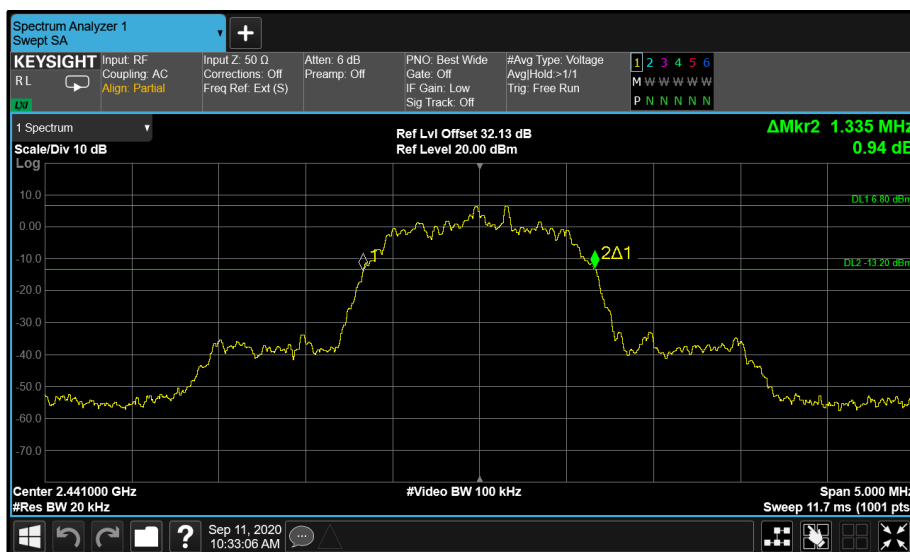


Figure 28 - Core 1 $\pi/4$ DQPSK 2441 MHz (CH39)

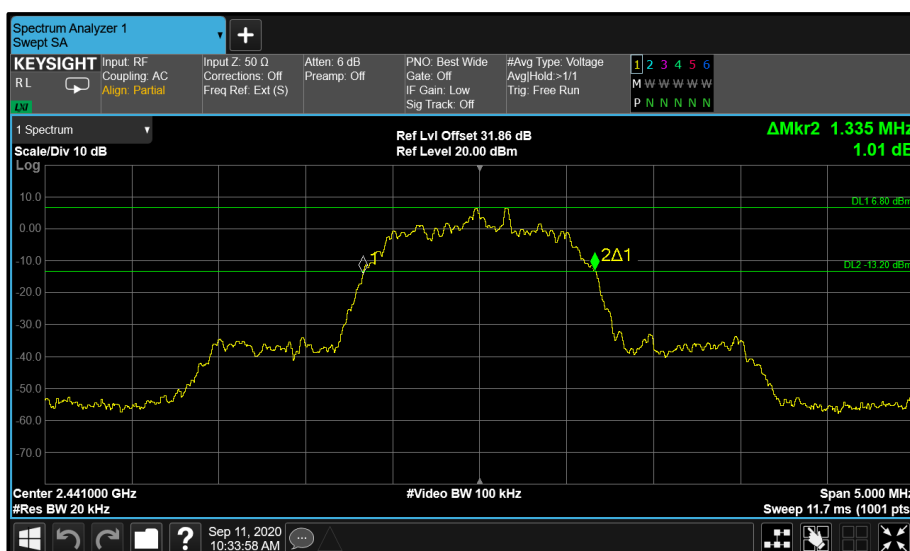


Figure 29 - Core 0 $\pi/4$ DQPSK 2441 MHz (CH39)

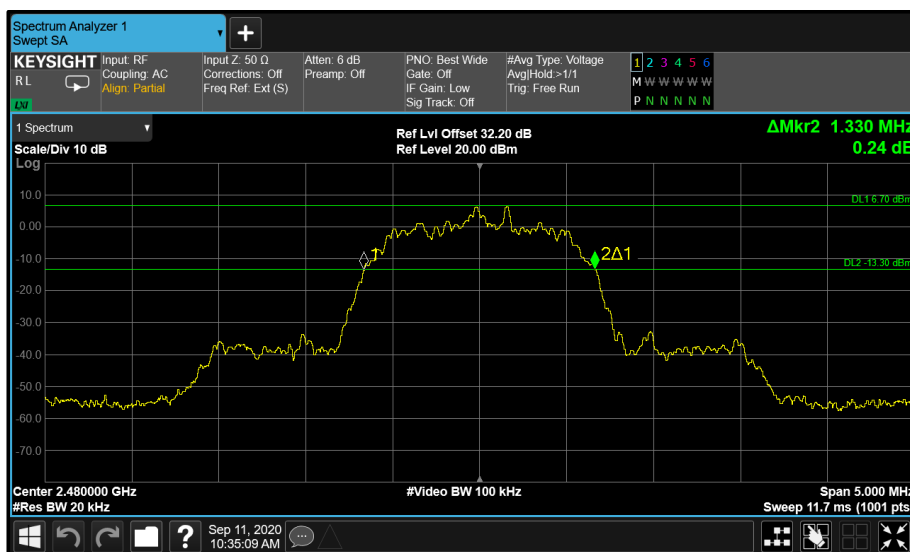


Figure 30 - Core 1 $\pi/4$ DQPSK 2480 MHz (CH78)

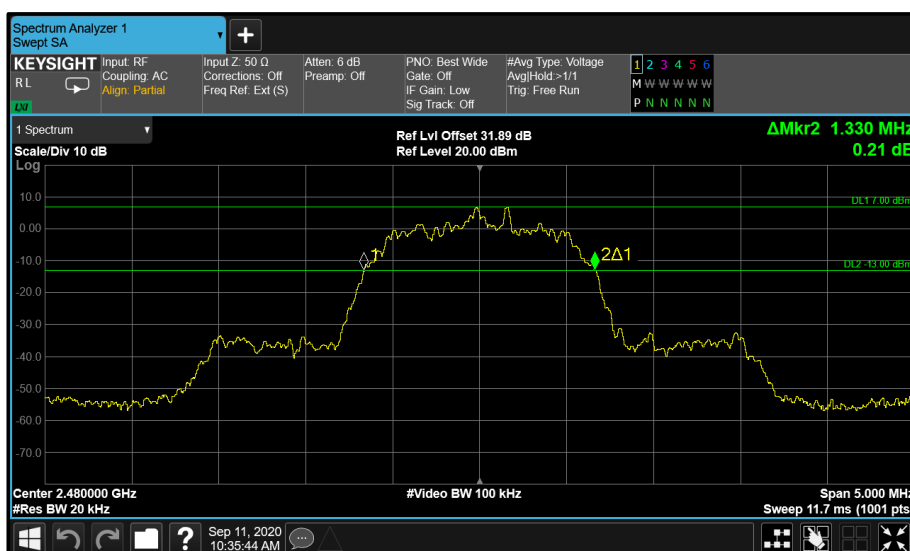


Figure 31 - Core 0 $\pi/4$ DQPSK 2480 MHz (CH78)

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)	
	Port(s)	
	Core 1	Core 0
2402	1270.0	1270.0
2441	1270.0	1270.0
2480	1270.0	1270.0

Table 18 - 20 dB Bandwidth Results

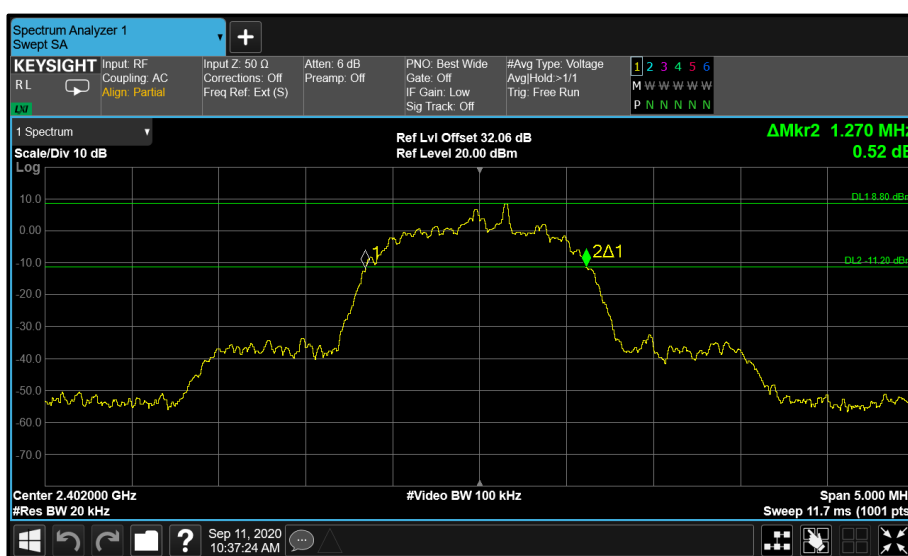


Figure 32 - Core 1 8-DPSK 2402 MHz (CH0)

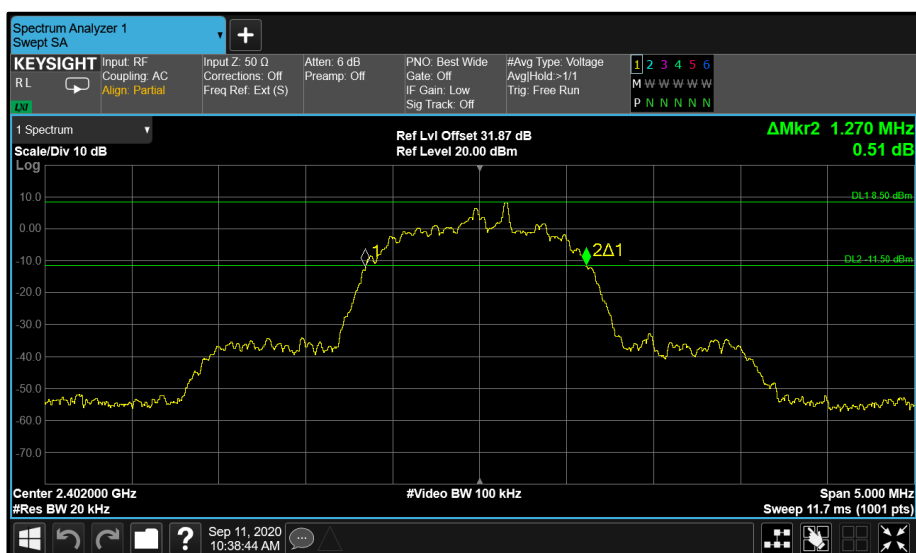


Figure 33 - Core 0 8-DPSK 2402 MHz (CH0)

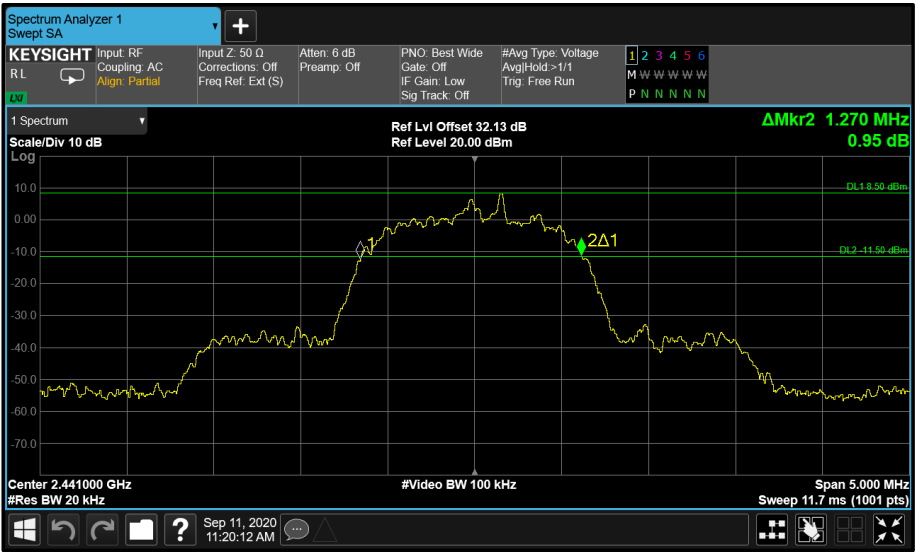


Figure 34 - Core 1 8-DPSK 2441 MHz (CH39)

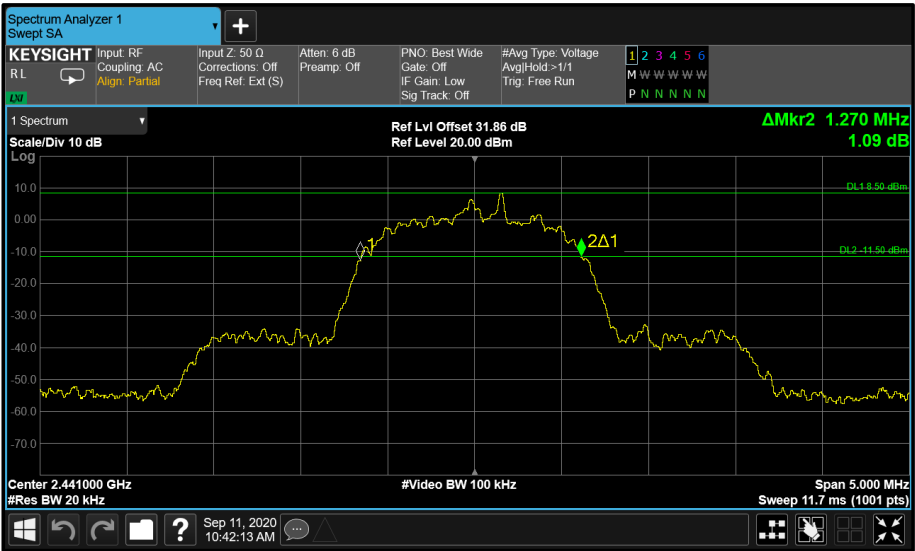


Figure 35 - Core 0 8-DPSK 2441 MHz (CH39)

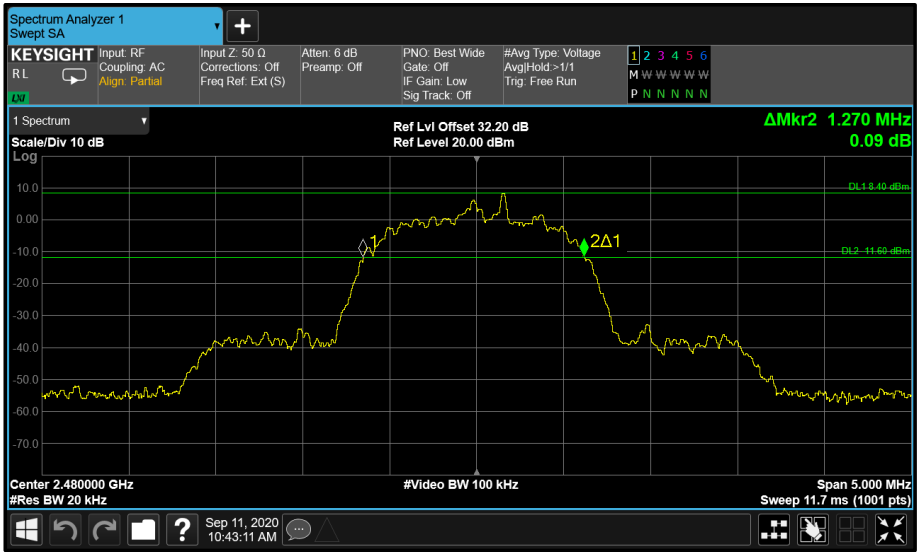


Figure 36 - Core 1 8-DPSK 2480 MHz (CH78)

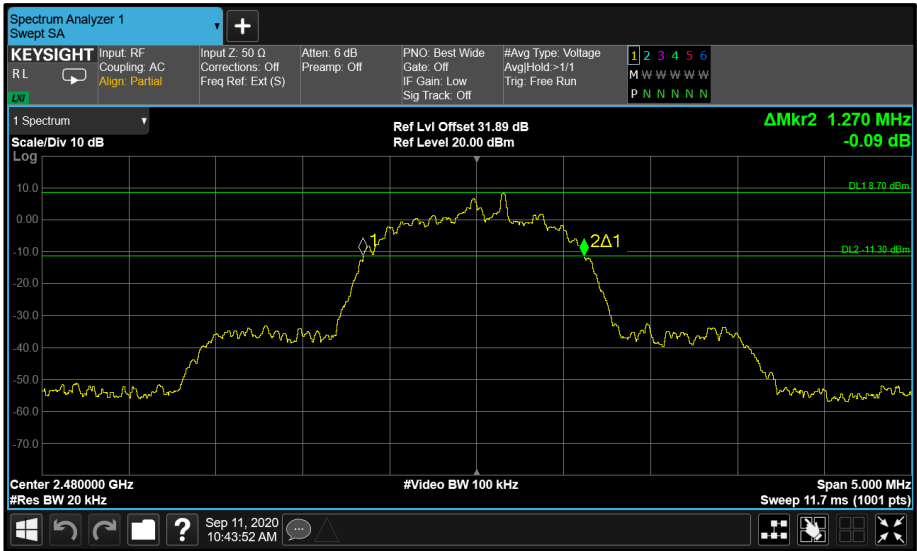


Figure 37 - Core 0 8-DPSK 2480 MHz (CH78)

ePA

Antenna Port Configuration: SISO

Modulation: GFSK (DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)
	Port(s)
	Core 1
2402	840.0
2441	840.0
2480	840.0

Table 19 - 20 dB Bandwidth Results

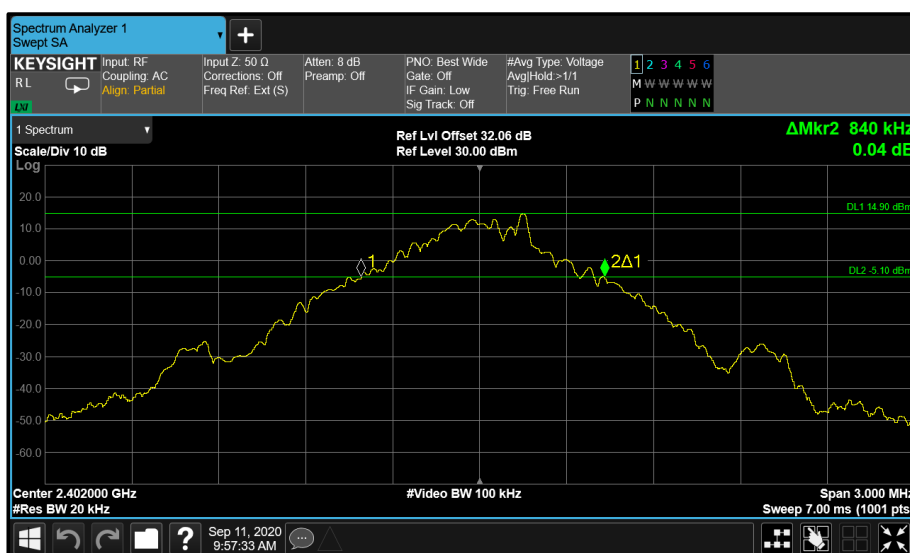


Figure 38 - Core 1 GFSK 2402 MHz (CH0)

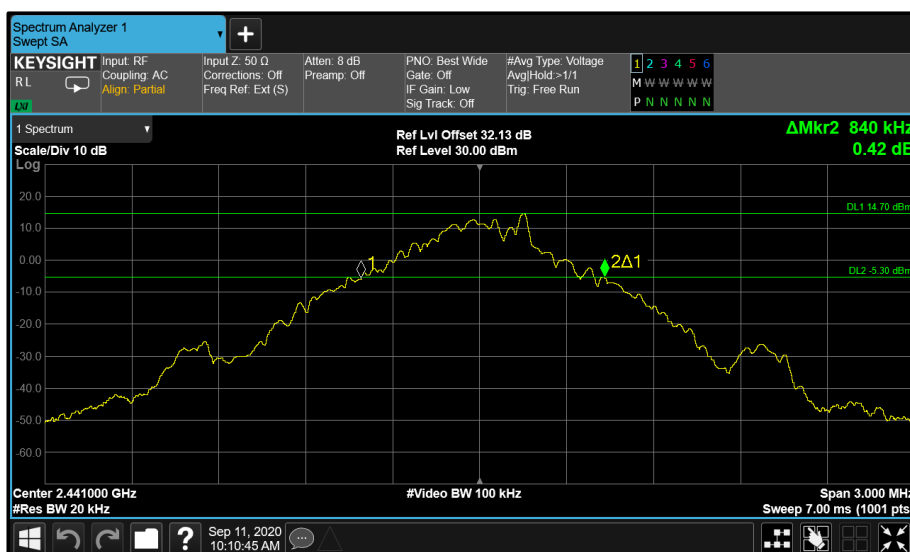


Figure 39 - Core 1 GFSK 2441 MHz (CH39)

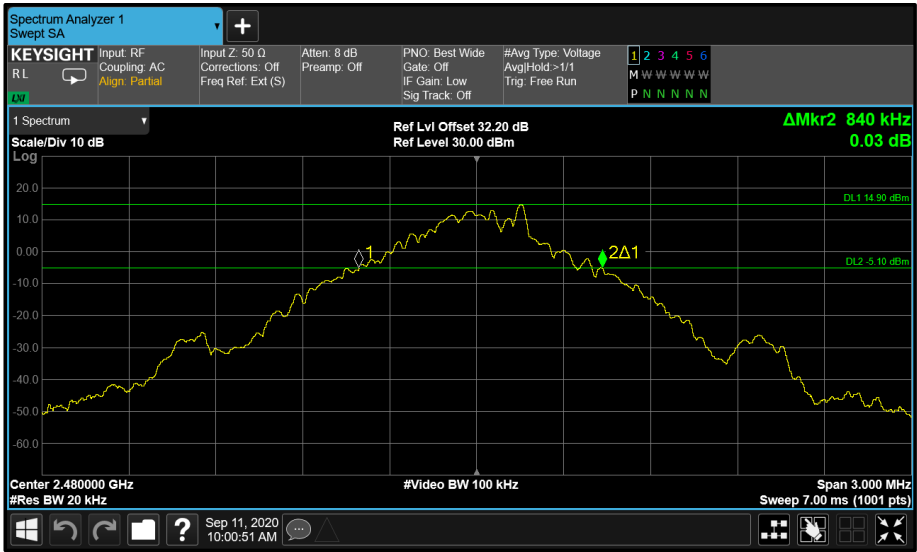


Figure 40 - Core 1 GFSK 2480 MHz (CH78)

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)
	Port(s)
	Core 1
2402	1335.0
2441	1330.0
2480	1335.0

Table 20 - 20 dB Bandwidth Results

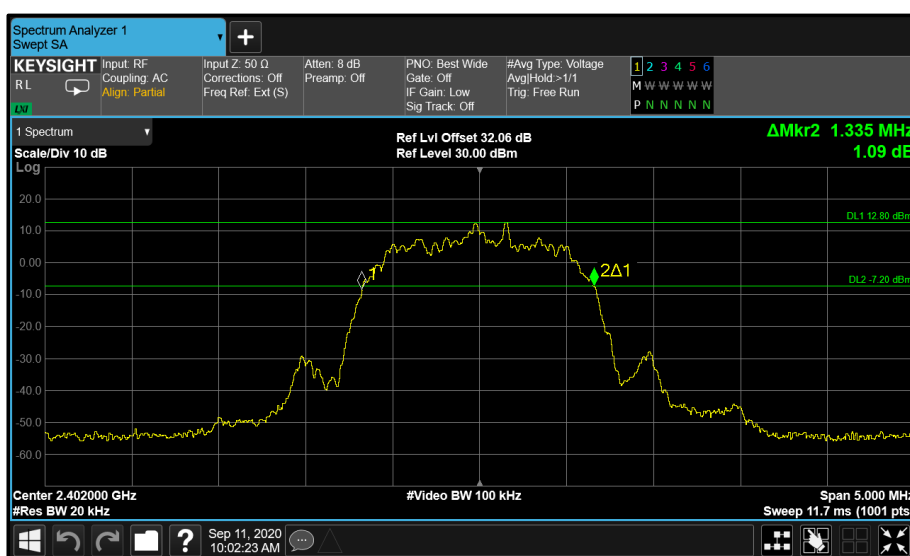


Figure 41 - Core 1 $\pi/4$ DQPSK 2402 MHz (CH0)

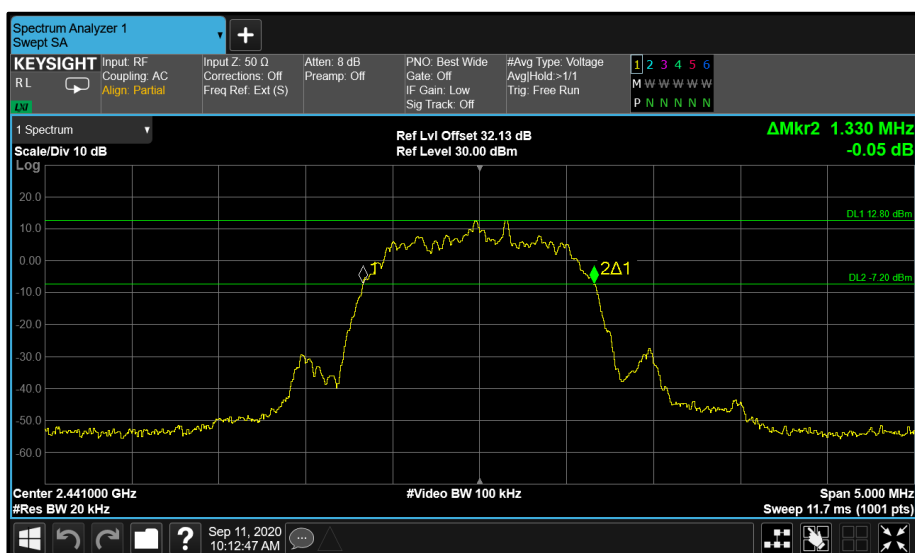


Figure 42 - Core 1 $\pi/4$ DQPSK 2441 MHz (CH39)

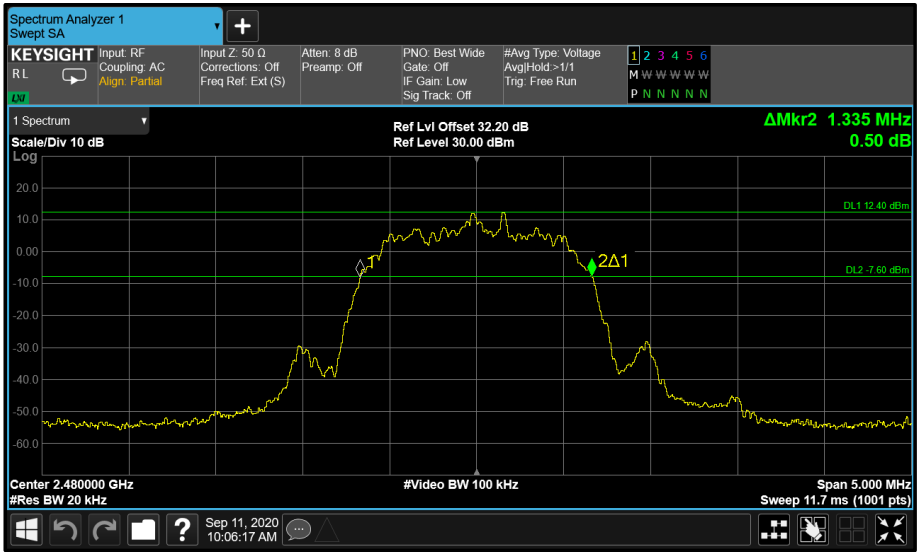


Figure 43 - Core 1 $\pi/4$ DQPSK 2480 MHz (CH78)

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)
	Port(s)
	Core 1
2402	1280.0
2441	1275.0
2480	1275.0

Table 21 - 20 dB Bandwidth Results

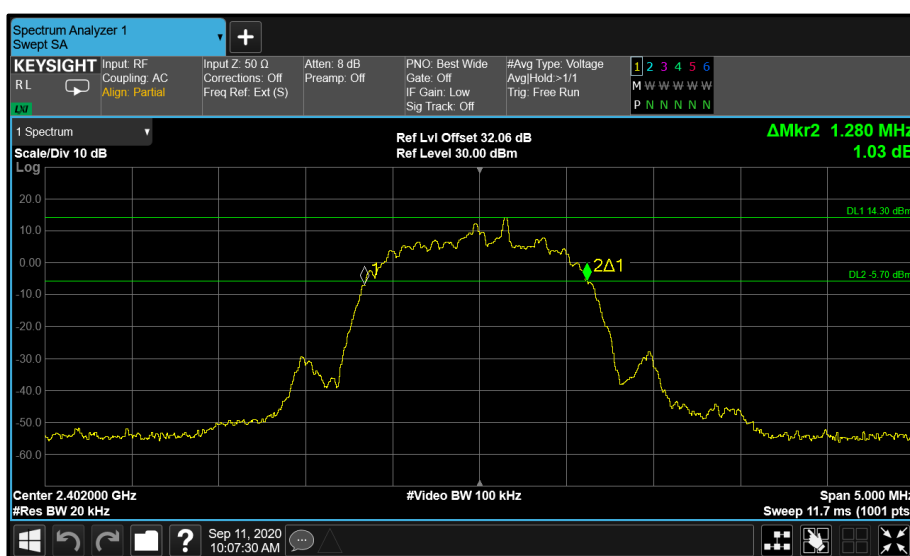


Figure 44 - Core 1 8-DPSK 2402 MHz (CH0)

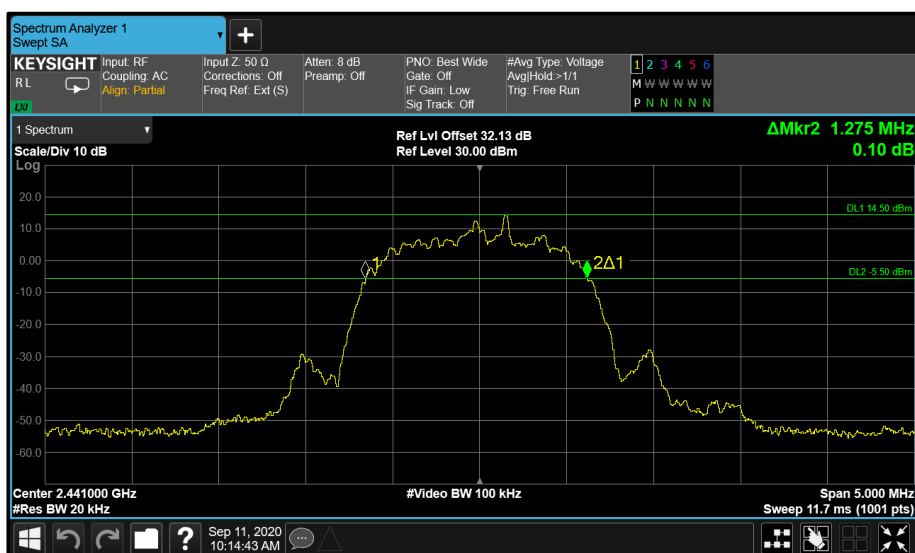


Figure 45 - Core 1 8-DPSK 2441 MHz (CH39)

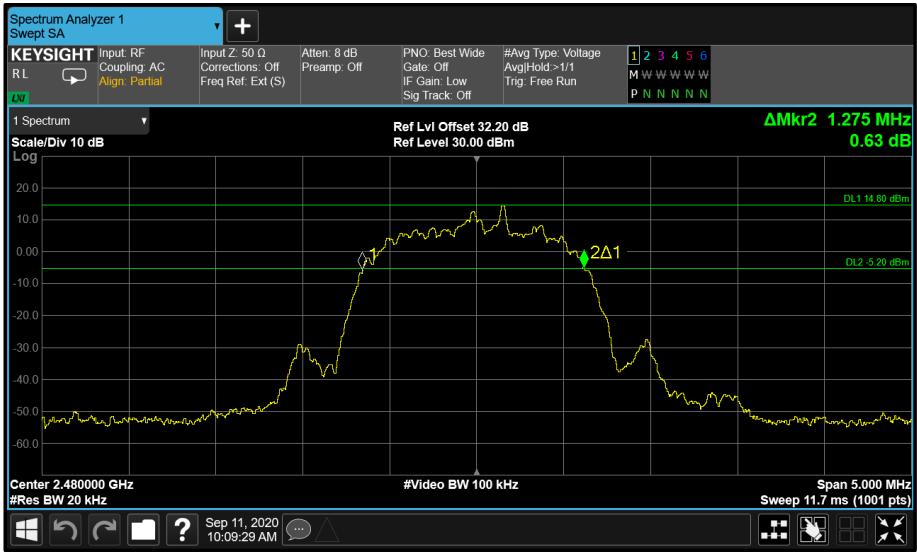


Figure 46 - Core 1 8-DPSK 2480 MHz (CH78)

Antenna Port Configuration: Beamforming

Modulation: GFSK (DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)	
	Port(s)	
	Core 1	Core 0
2402	891.0	885.0
2441	888.0	885.0
2480	888.0	888.0

Table 22 - 20 dB Bandwidth Results

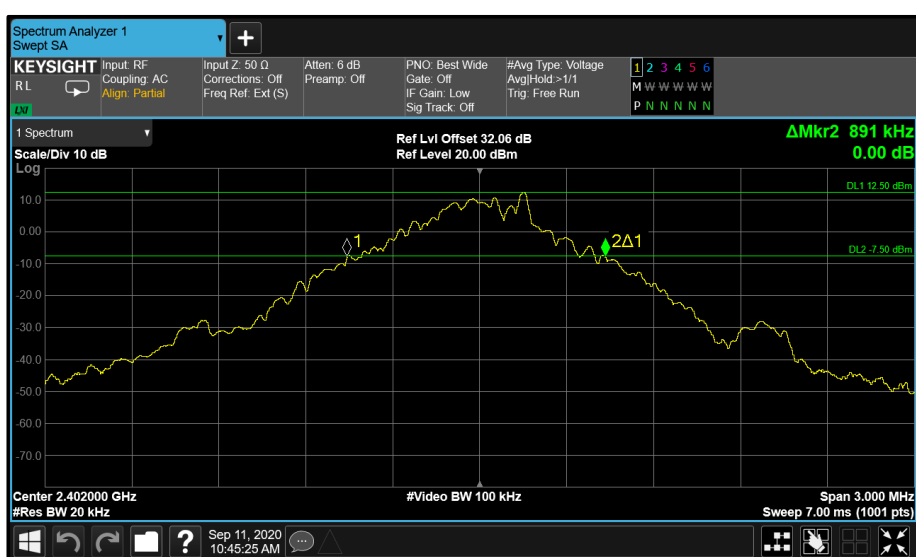


Figure 47 - Core 1 GFSK 2402 MHz (CH0)

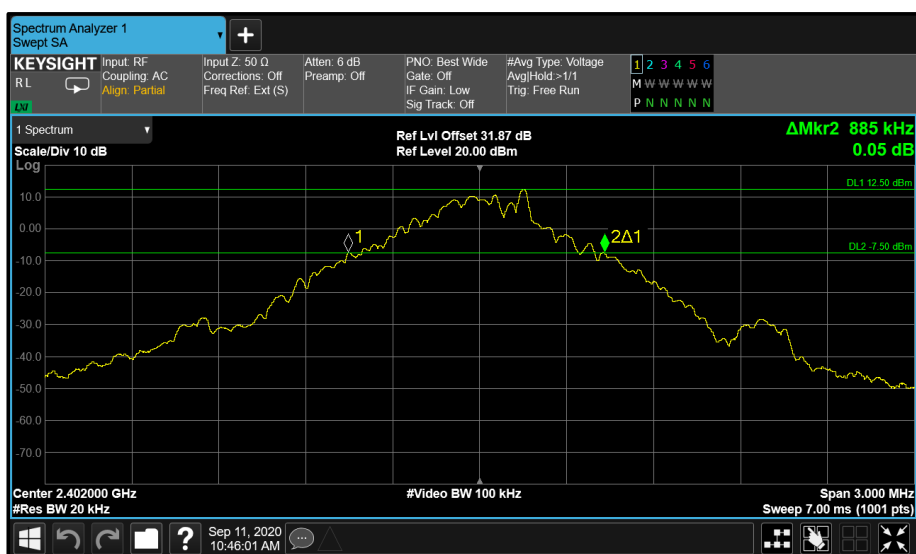


Figure 48 - Core 0 GFSK 2402 MHz (CH0)

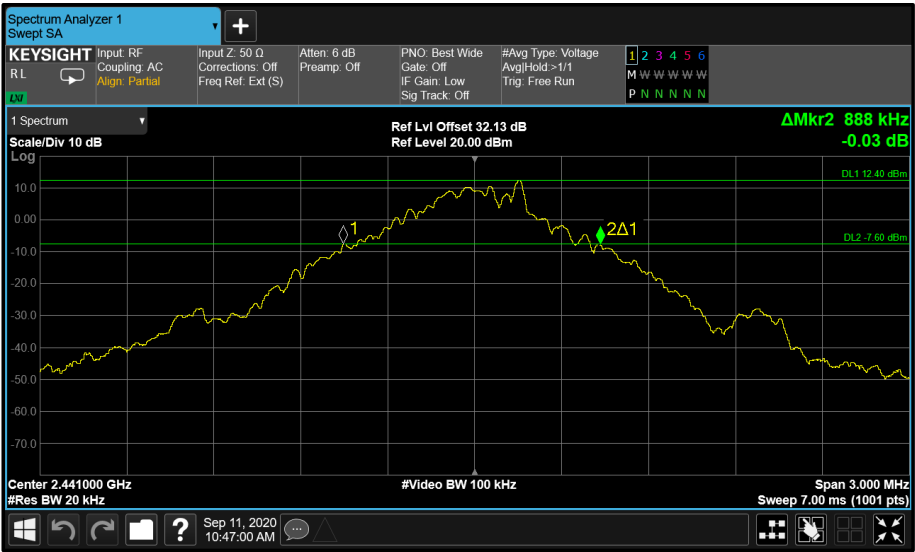


Figure 49 - Core 1 GFSK 2441 MHz (CH39)

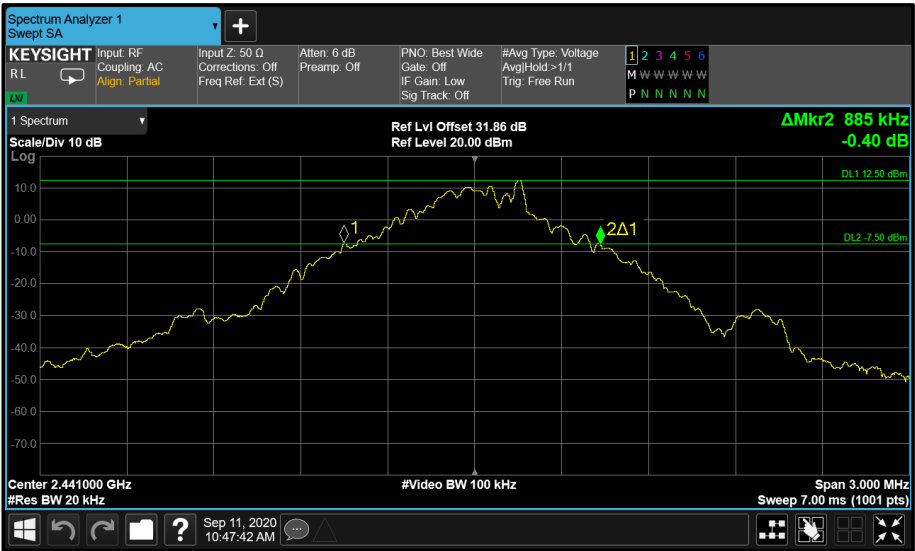


Figure 50 - Core 0 GFSK 2441 MHz (CH39)

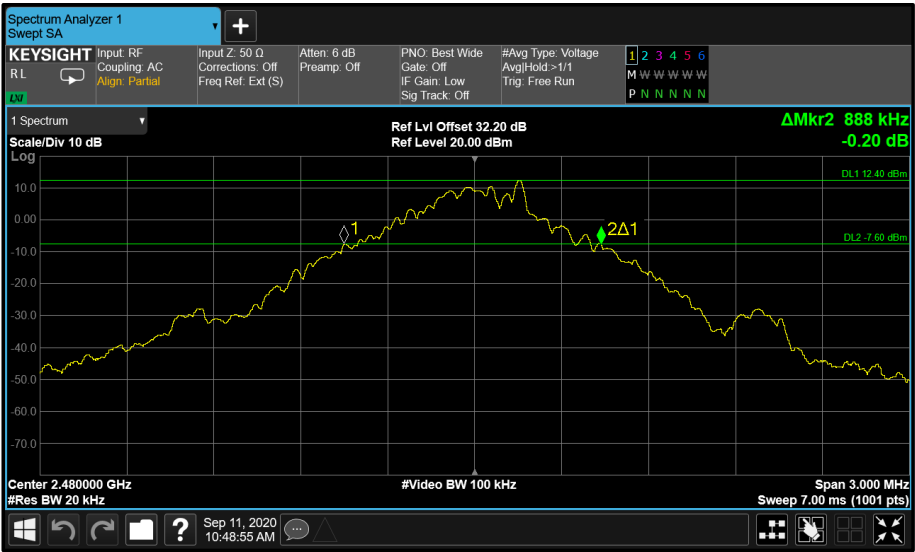


Figure 51 - Core 1 GFSK 2480 MHz (CH78)

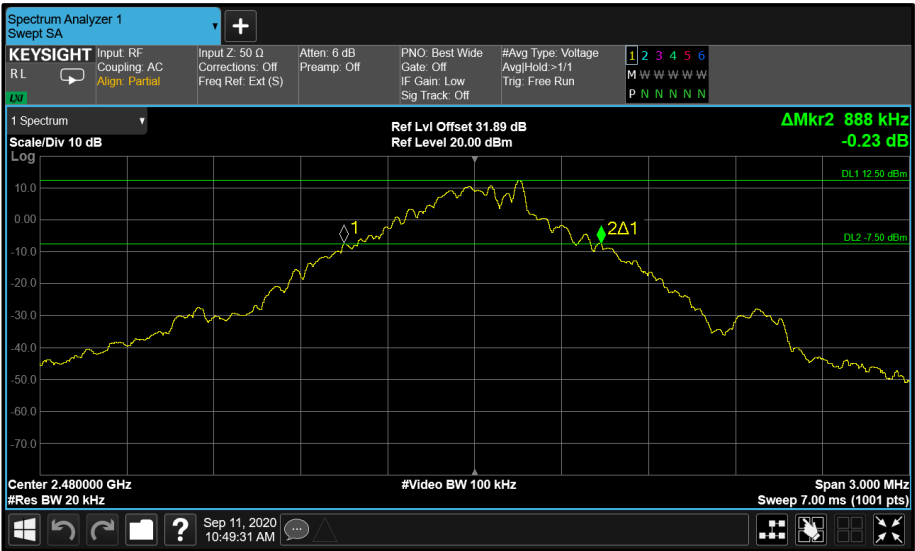


Figure 52 - Core 0 GFSK 2480 MHz (CH78)



Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)	
	Port(s)	
	Core 1	Core 0
2402	1335.0	1330.0
2441	1335.0	1335.0
2480	1330.0	1335.0

Table 23 - 20 dB Bandwidth Results

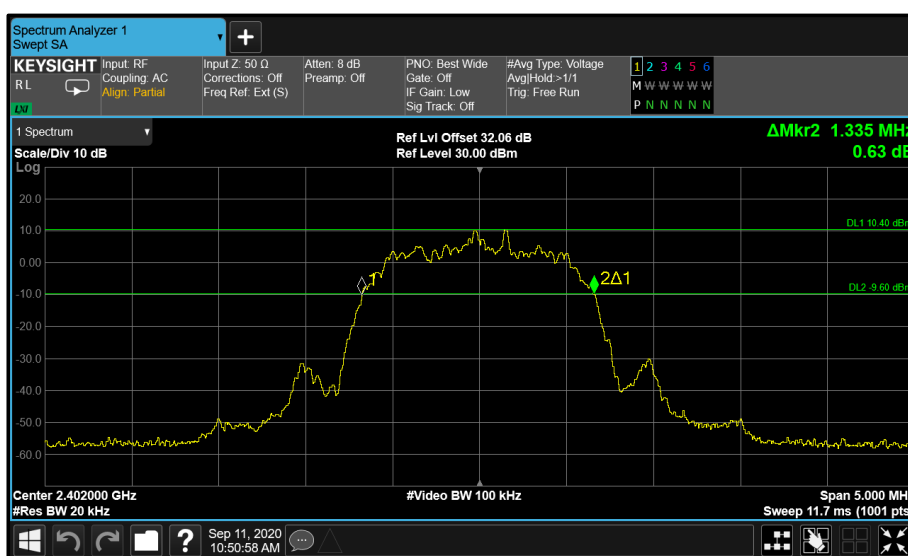


Figure 53 - Core 1 $\pi/4$ DQPSK 2402 MHz (CH0)

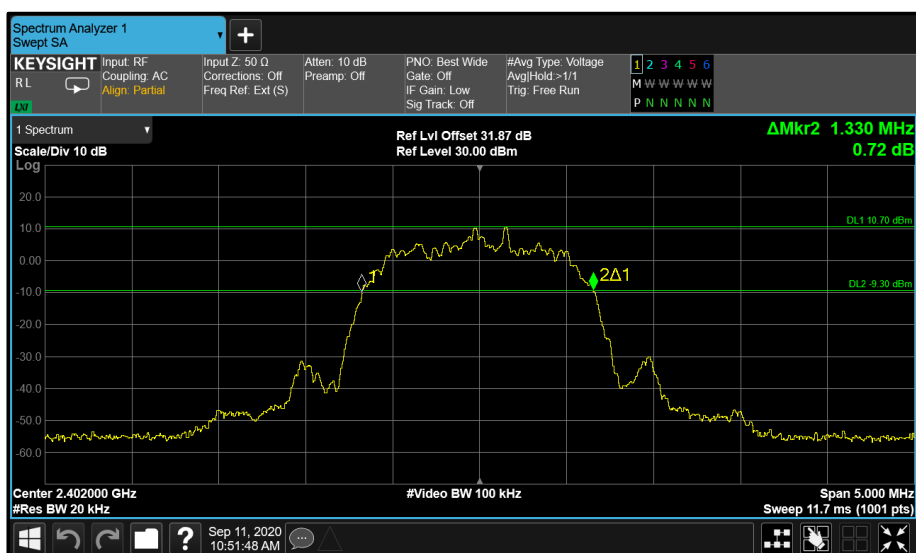


Figure 54 - Core 0 $\pi/4$ DQPSK 2402 MHz (CH0)

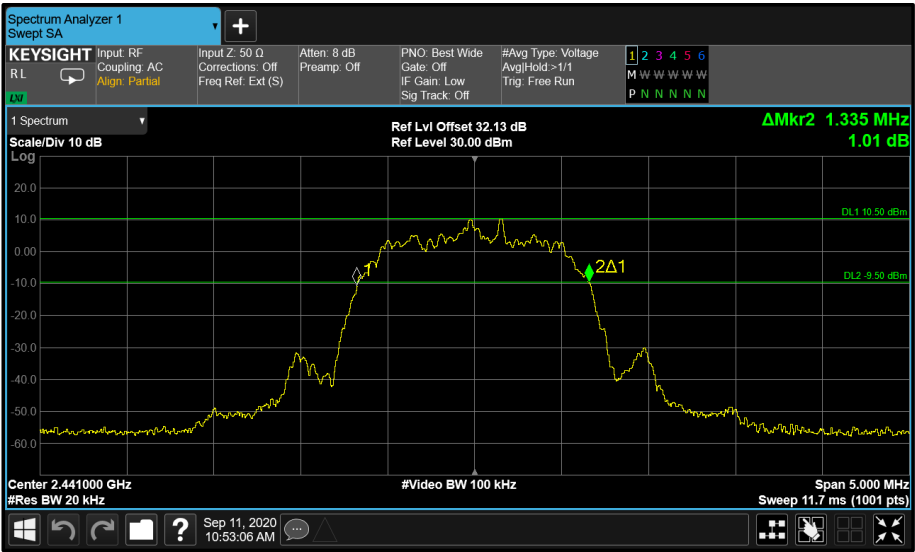


Figure 55 - Core 1 $\pi/4$ DQPSK 2441 MHz (CH39)

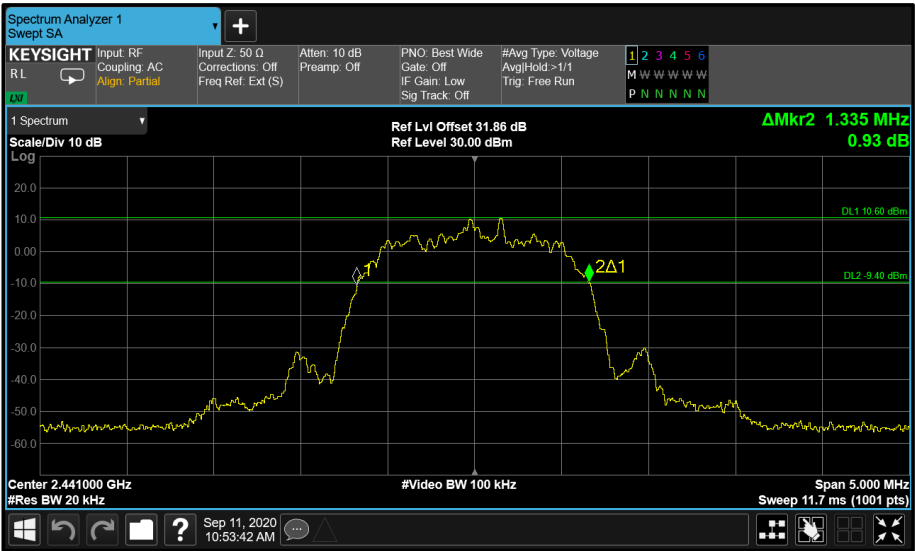


Figure 56 - Core 0 $\pi/4$ DQPSK 2441 MHz (CH39)

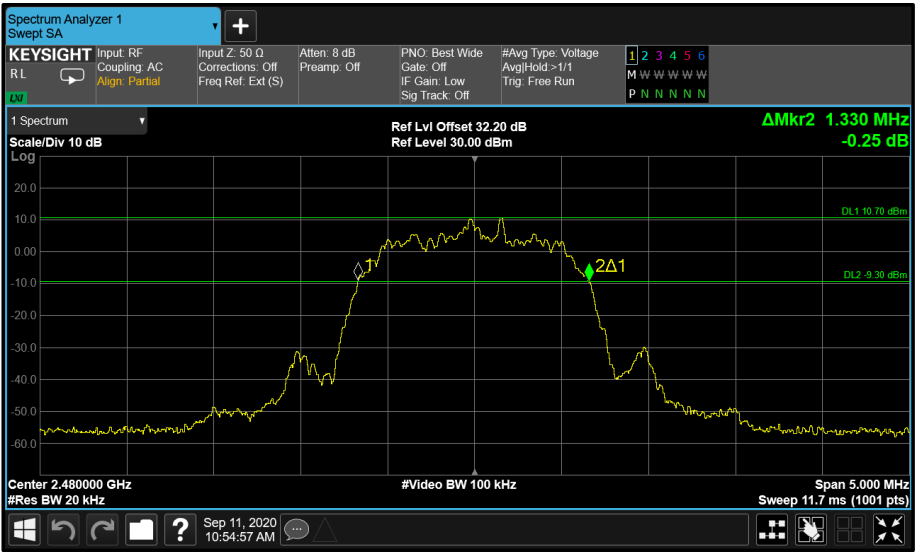


Figure 57 - Core 1 $\pi/4$ DQPSK 2480 MHz (CH78)

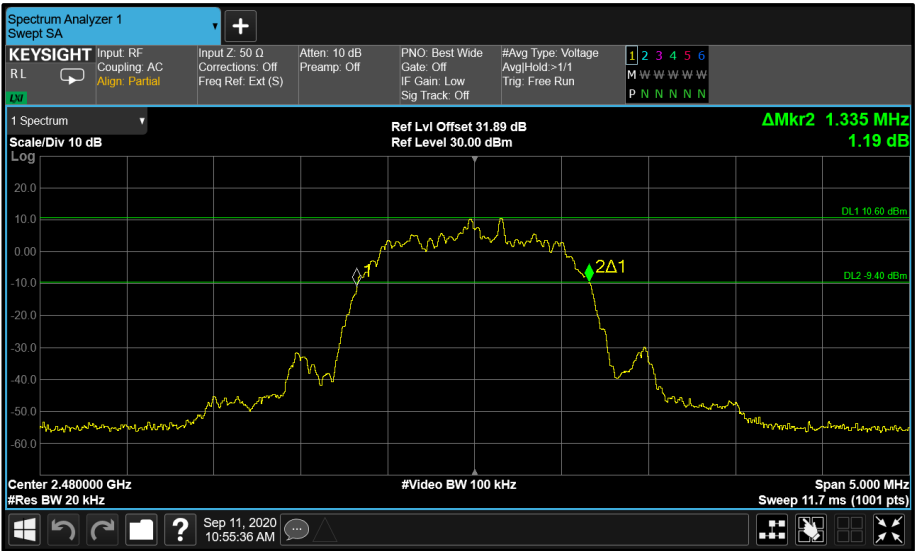


Figure 58 - Core 0 $\pi/4$ DQPSK 2480 MHz (CH78)

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	20 dB Bandwidth (kHz)	
	Port(s)	
	Core 1	Core 0
2402	1275.0	1275.0
2441	1275.0	1275.0
2480	1275.0	1270.0

Table 24 - 20 dB Bandwidth Results

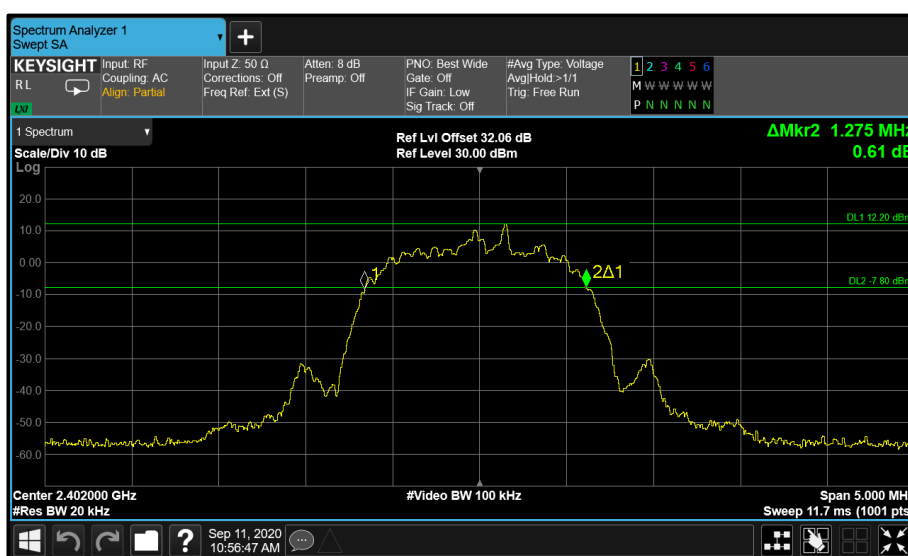


Figure 59 - Core 1 8-DPSK 2402 MHz (CH0)

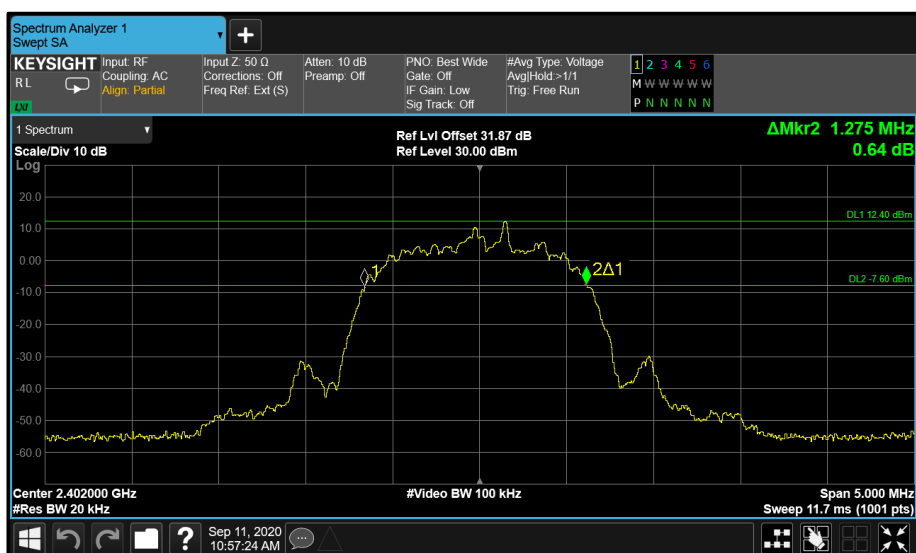


Figure 60 - Core 0 8-DPSK 2402 MHz (CH0)

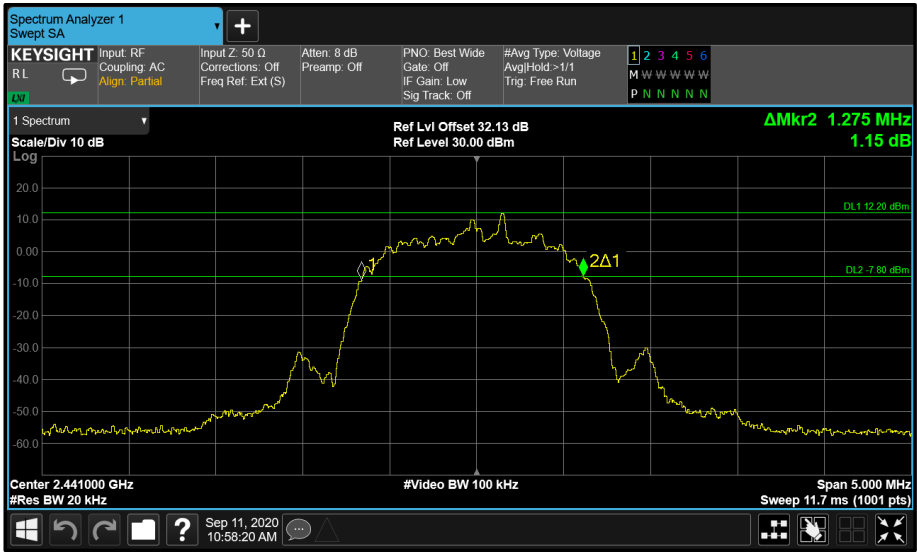


Figure 61 - Core 1 8-DPSK 2441 MHz (CH39)

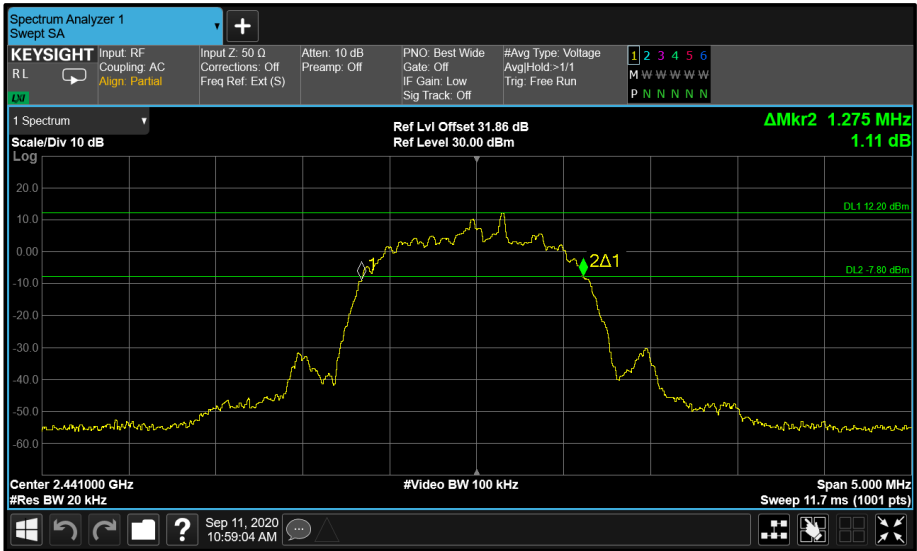


Figure 62 - Core 0 8-DPSK 2441 MHz (CH39)

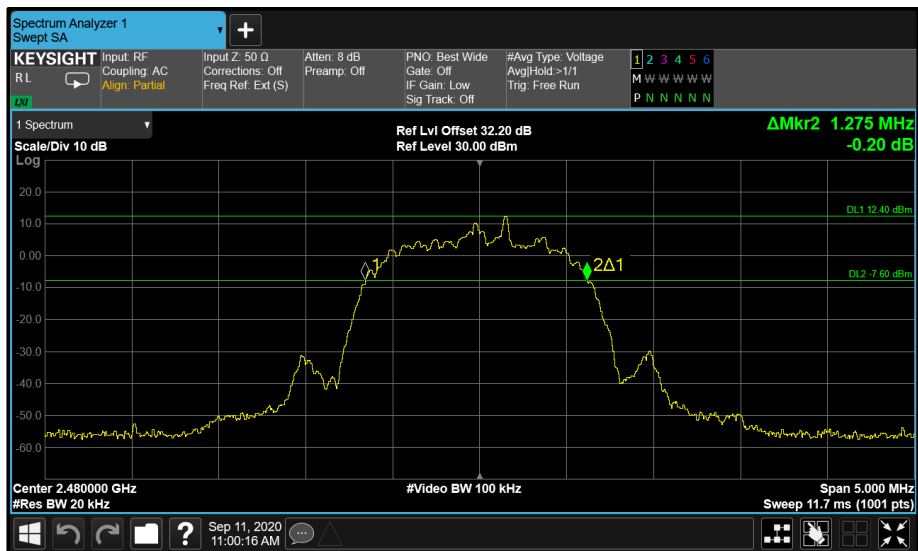


Figure 63 - Core 1 8-DPSK 2480 MHz (CH78)

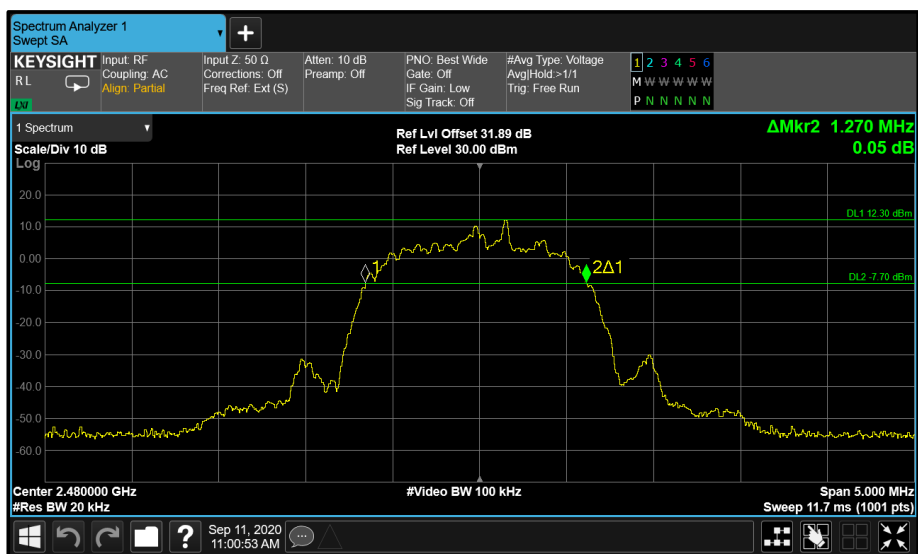


Figure 64 - Core 0 8-DPSK 2480 MHz (CH78)

FCC 47 CFR Part 15 and ISED RSS-247 Limit Clause

None specified.

FCC 47 CFR Part 15, Limit Clause 15.247 (a)(1)(i) and ISED RSS-247, Limit Clause 5.1 (3)

The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.



2.4.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	08-Nov-2020
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2020
Hygrometer	Rotronic	I-1000	3220	12	25-Sep-2020
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	08-Nov-2020
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
MXA Signal Analyser	Keysight Technologies	N9020B	5528	24	04-Mar-2022
Signal Commissioning Unit	TUV SUD	SCU001	5546	12	15-Apr-2021

Table 25

O/P Mon – Output Monitored using calibrated equipment



2.5 Maximum Conducted Output Power

2.5.1 Specification Reference

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

2.5.2 Equipment Under Test and Modification State

A2338, S/N: C02CX02JQC36 - Modification State 0

2.5.3 Date of Test

10-September-2020 to 11-September-2020

2.5.4 Test Method

Peak power measurements were performed in accordance with ANSI C63.10 11.9.1.3 PKPM1 and average measurements in accordance with clause 11.9.2.3.2 Method AVGPM-G.

Both EUT antennas are less than 6 dBi (0.57 dBi and 1.18 dBi for Cores 0 & 1 respectively). This means for non-TxBF modes, the 1 Watt FCC conducted limit does not need to be reduced, and the ISED 1 Watt (30 dBm) conducted limit is more stringent than the 4 Watt (36 dBm) EIRP limit. The conducted non-TxBF results presented below can therefore be directly compared to the 1 Watt (30 dBm) limit to show compliance.

For TxBF the combined powers were calculated using the measure and sum method. Both the power per chain and the antenna gains differed, therefore directional antenna gain was calculated using the worst-case highest antenna gain, two transmit chains and a single correlated spacial stream as per the first formula in KDB 662911 D01 v02r01 section e) (ii), with $N_{SS} = 1$ and $G_{ANT MAX}$ of 1.18 dBi. This resulted in a directional gain of 4.18 dBi. Since the directional gain is still less than 6 dBi, this results in TxBF conducted results also being directly comparable to the most stringent conducted limit of 1 Watt (30 dBm) for both FCC and ISED.

2.5.5 Environmental Conditions

Ambient Temperature	21.5-23.9 °C
Relative Humidity	46.0-52.9 %



2.5.6 Test Results

2.4 GHz Bluetooth (FHSS)

iPA

Antenna Port Configuration: SISO

Modulation: GFSK (DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)	
	Average Power	Peak Power
	Core 1	Core 1
2402	12.4	13.4
2441	12.4	13.3
2480	12.1	13.0

Table 26 - Maximum Conducted Output Power Results

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)	
	Average Power	Peak Power
	Core 1	Core 1
2402	9.9	12.8
2441	9.9	12.7
2480	10.0	12.8

Table 27 - Maximum Conducted Output Power Results

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)	
	Average Power	Peak Power
	Core 1	Core 1
2402	9.6	12.3
2441	9.8	12.5
2480	10.0	13.1

Table 28 - Maximum Conducted Output Power Results



Antenna Port Configuration: Beamforming

Modulation: GFSK (DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					
	Average Power			Peak Power		
	Core 1	Core 0	Σ	Core 1	Core 0	Σ
2402	12.5	12.4	15.5	13.4	13.4	16.4
2441	12.4	12.4	15.4	13.3	13.3	16.3
2480	12.1	12.3	15.2	13.0	13.2	16.1

Table 29 - Maximum Conducted Output Power Results

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					
	Average Power			Peak Power		
	Core 1	Core 0	Σ	Core 1	Core 0	Σ
2402	10.1	10.0	13.1	12.9	12.3	15.6
2441	9.8	9.7	12.7	12.1	12.0	15.1
2480	9.5	9.8	12.6	11.9	12.0	15.0

Table 30 - Maximum Conducted Output Power Results

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					
	Average Power			Peak Power		
	Core 1	Core 0	Σ	Core 1	Core 0	Σ
2402	10.0	9.8	12.9	12.6	12.4	15.5
2441	9.8	9.8	12.8	12.5	12.3	15.4
2480	9.8	9.9	12.9	12.5	12.4	15.5

Table 31 - Maximum Conducted Output Power Results



ePA

Antenna Port Configuration: SISO

Modulation: GFSK (DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)	
	Average Power	Peak Power
	Core 1	Core 1
2402	15.8	17.1
2441	15.9	17.2
2480	16.0	17.4

Table 32 - Maximum Conducted Output Power Results

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)	
	Average Power	Peak Power
	Core 1	Core 1
2402	15.7	18.6
2441	15.9	18.8
2480	15.5	18.3

Table 33 - Maximum Conducted Output Power Results

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)	
	Average Power	Peak Power
	Core 1	Core 1
2402	15.8	19.0
2441	15.9	19.1
2480	16.0	19.3

Table 34 - Maximum Conducted Output Power Results



Antenna Port Configuration: Beamforming

Modulation: GFSK (DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					
	Average Power			Peak Power		
	Core 1	Core 0	Σ	Core 1	Core 0	Σ
2402	13.8	13.7	16.8	14.4	14.4	17.4
2441	13.7	13.7	16.7	14.3	14.3	17.3
2480	13.6	13.7	16.7	14.1	14.2	17.2

Table 35 - Maximum Conducted Output Power Results

Modulation: $\pi/4$ DQPSK (2-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					
	Average Power			Peak Power		
	Core 1	Core 0	Σ	Core 1	Core 0	Σ
2402	13.6	13.8	16.7	16.5	16.6	19.6
2441	13.7	13.8	16.8	16.5	16.6	19.6
2480	13.7	13.7	16.7	16.5	16.5	19.5

Table 36 - Maximum Conducted Output Power Results

Modulation: 8-DPSK (3-DH5)

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					
	Average Power			Peak Power		
	Core 1	Core 0	Σ	Core 1	Core 0	Σ
2402	13.7	13.9	16.8	16.9	17.0	20.0
2441	13.7	13.7	16.7	16.9	16.8	19.9
2480	13.8	13.8	16.8	16.9	16.9	19.9

Table 37 - Maximum Conducted Output Power Results

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

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

ISED RSS-247, Limit Clause 5.4 (b)

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



2.5.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No	TE No	Calibration Period (months)	Calibration Due
Rubidium Standard	Rohde & Schwarz	XSRM	1316	6	08-Nov-2020
Multimeter	Iso-tech	IDM101	2424	12	12-Dec-2020
Hygrometer	Rotronic	I-1000	3220	12	25-Sep-2020
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	08-Nov-2020
USB Power Sensor	Boonton	RTP5006	5184	12	09-Jan-2021
USB Power Sensor	Boonton	RTP5006	5186	12	28-Nov-2020
AC Programmable Power Supply	iTech	IT7324	5225	-	O/P Mon
Signal Commissioning Unit	TUV SUD	SCU001	5546	12	15-Apr-2021

Table 38

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)
ISED RSS-247, Clause 5.5

2.6.2 Equipment Under Test and Modification State

A2338, S/N: C02CX02PQC36 - Modification State 0

2.6.3 Date of Test

04-August-2020 to 08-September-2020

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 20.9-23.5 °C
Relative Humidity 34.4-60.1 %

2.6.6 Test Results

2.4 GHz Bluetooth (FHSS)

iPA

Mode	Modulation	Core	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
Static	GFSK	0	DH5	2402	2400.0	-63.20
Static	$\pi/4$ DQPSK	0	2DH5	2402	2400.0	-57.39
Static	8-DPSK	0	3DH5	2402	2400.0	-56.95
Hopping	GFSK	0	DH5	2402	2400.0	-66.80
Hopping	$\pi/4$ DQPSK	0	2DH5	2402	2400.0	-63.44
Hopping	8-DPSK	0	3DH5	2402	2400.0	-62.00

Table 39 - Authorised Band Edge Results

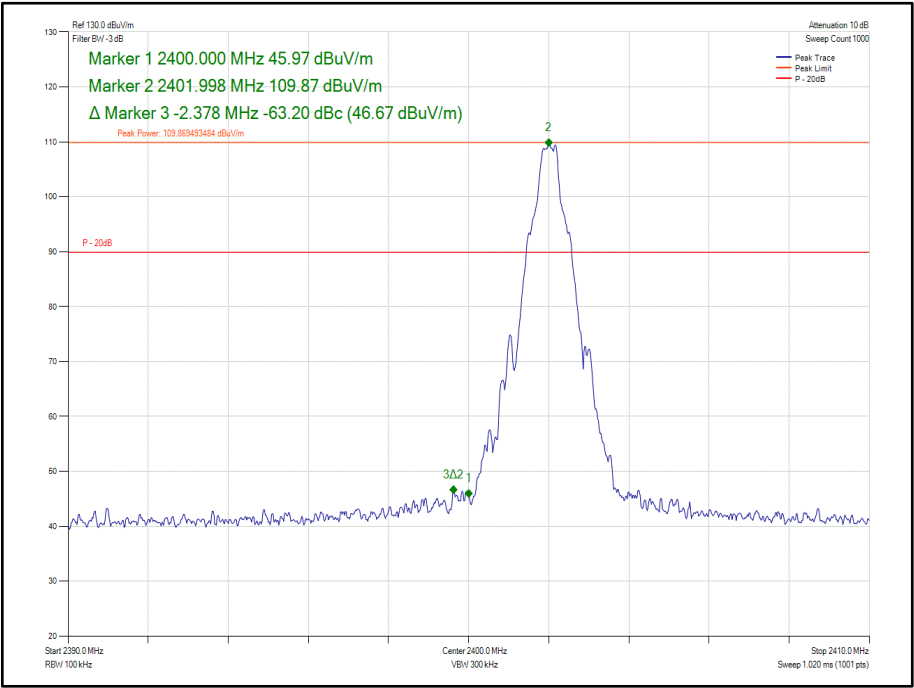


Figure 65 - Static - Core 0 - GFSK/DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz

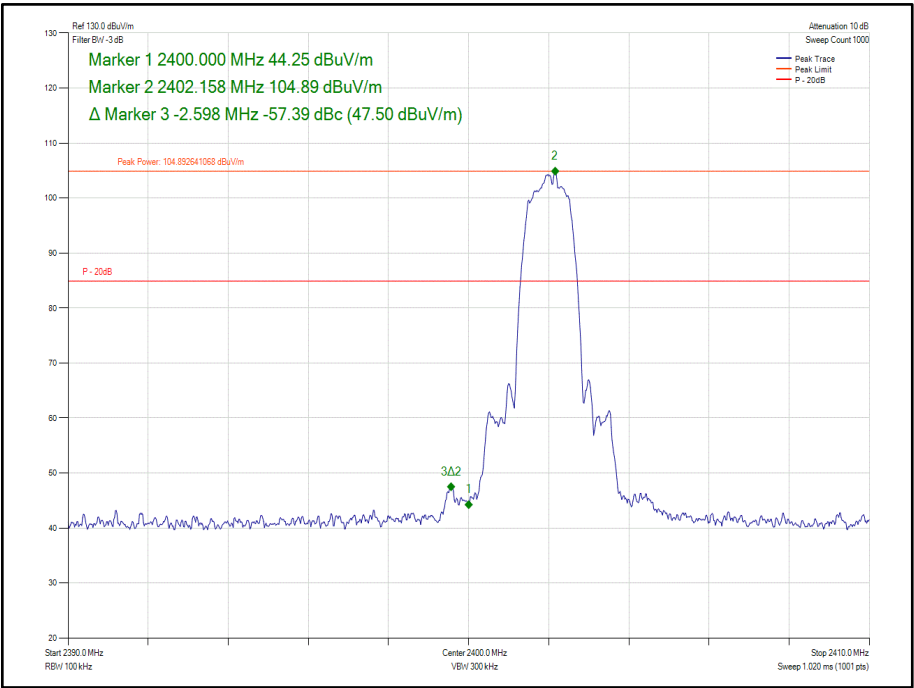
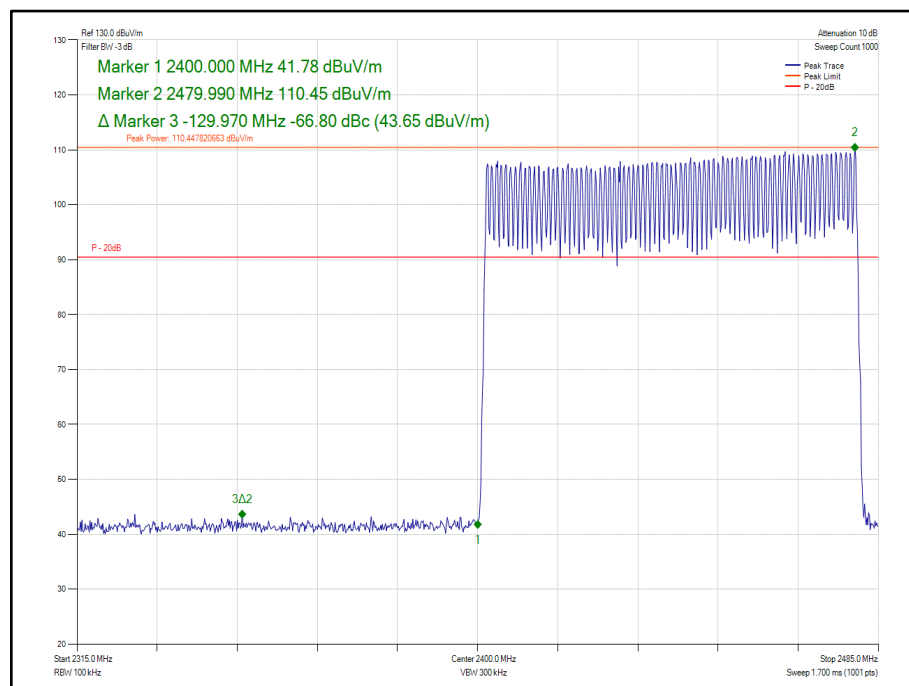
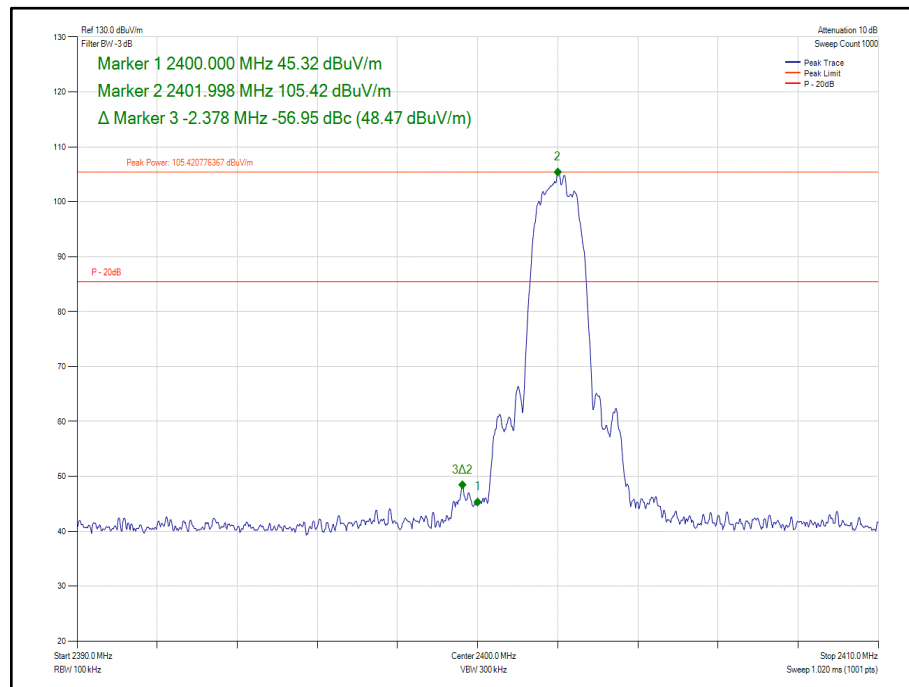


Figure 66 - Static - Core 0 - $\pi/4$ DQPSK/2DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz



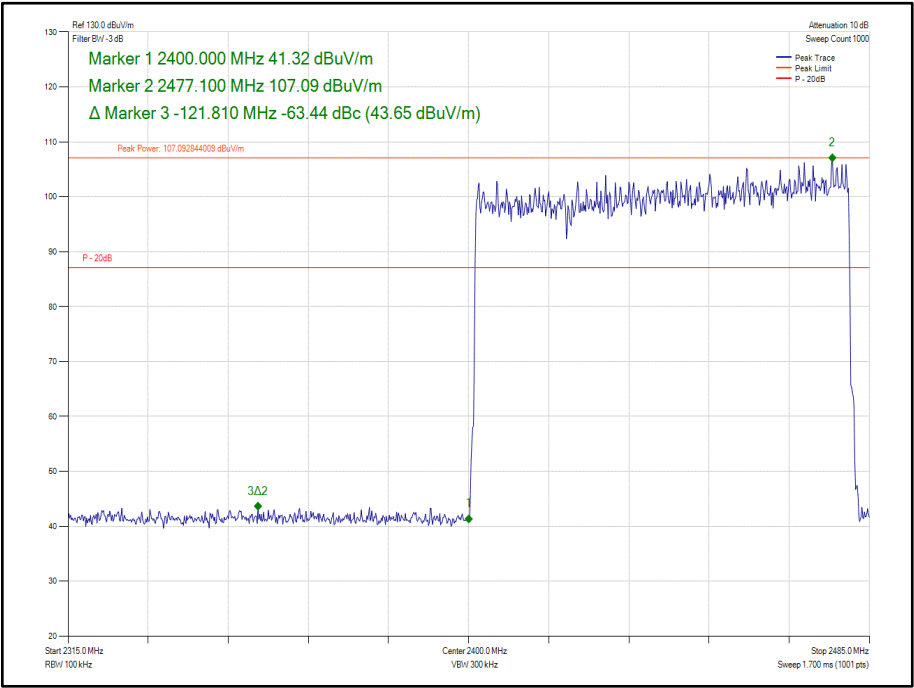


Figure 69 - Hopping - Core 0 - $\pi/4$ DQPSK/2DH5 - Band Edge Frequency 2400.0 MHz

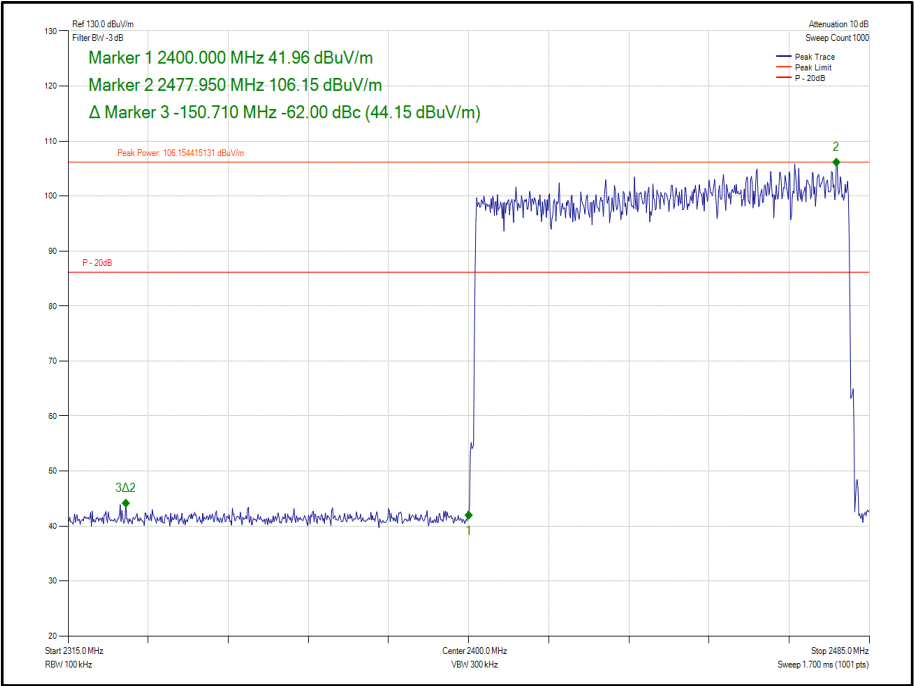


Figure 70 - Hopping - Core 0 - 8-DPSK/3DH5 - Band Edge Frequency 2400.0 MHz

Mode	Modulation	Core	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
Static	GFSK	1	DH5	2402	2400.0	-60.01
Static	$\pi/4$ DQPSK	1	2DH5	2402	2400.0	-53.14
Static	8-DPSK	1	3DH5	2402	2400.0	-53.33
Hopping	GFSK	1	DH5	2402	2400.0	-65.11
Hopping	$\pi/4$ DQPSK	1	2DH5	2402	2400.0	-55.72
Hopping	8-DPSK	1	3DH5	2402	2400.0	-56.48

Table 40 - Authorised Band Edge Results

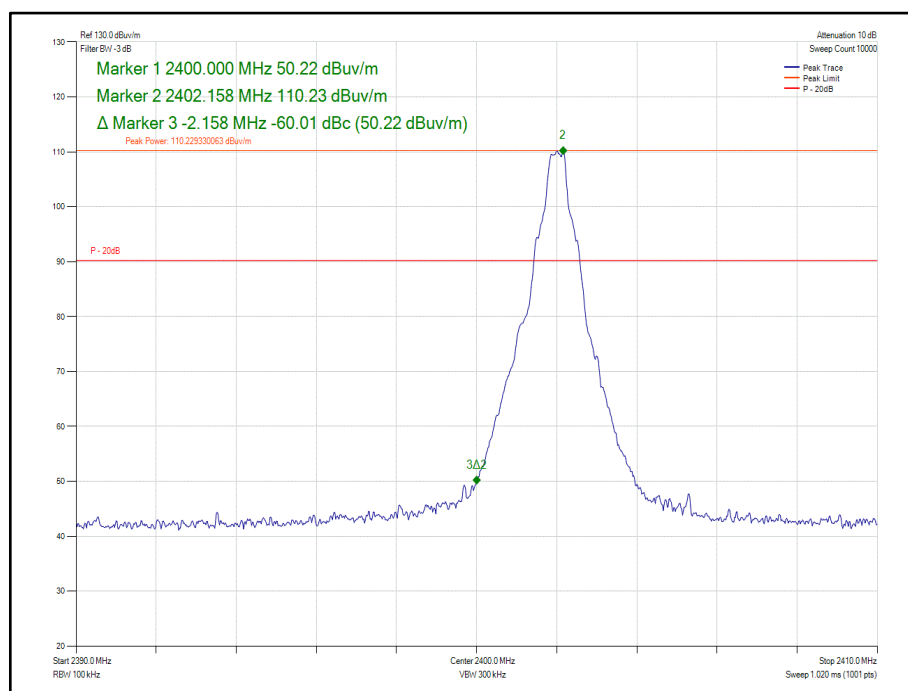


Figure 71 - Static - Core 1 - GFSK/DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz

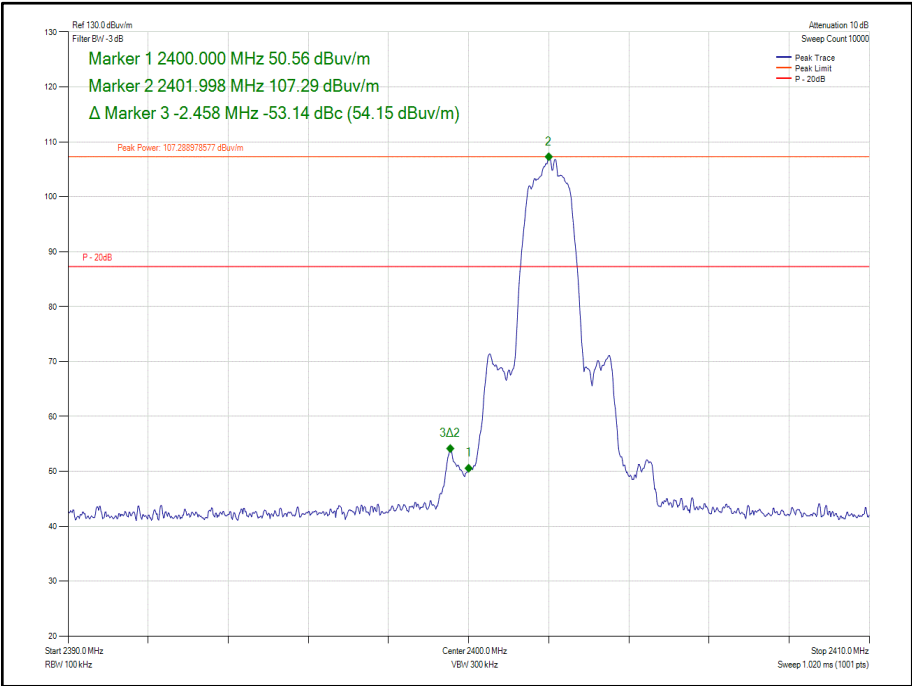


Figure 72 - Static - Core 1 - $\pi/4$ DQPSK/2DH5 - 2402 MHz -
Band Edge Frequency 2400.0 MHz

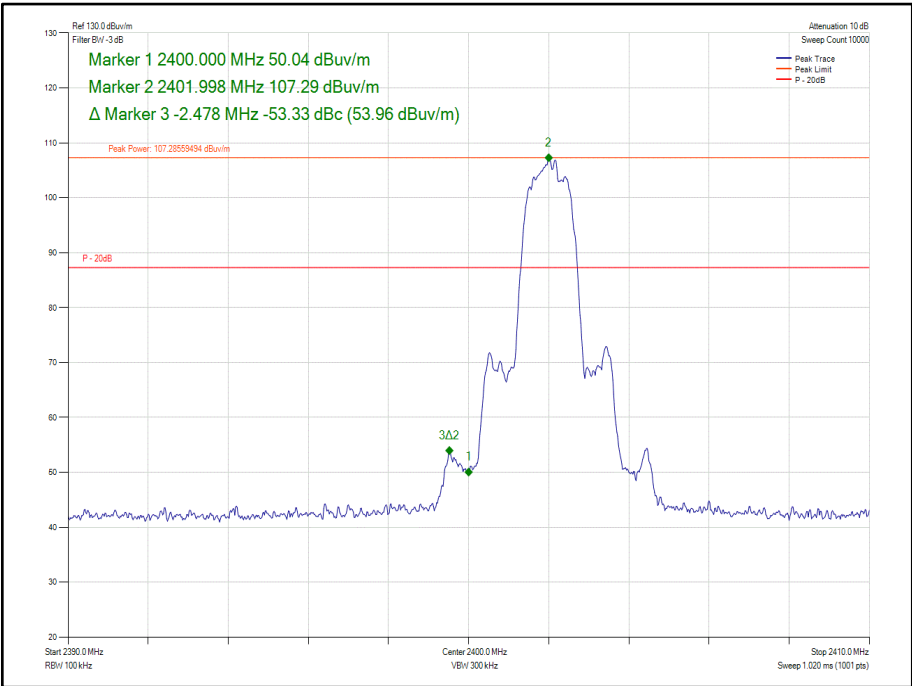


Figure 73 - Static - Core 1 - 8-DPSK/3DH5 - 2402 MHz -
Band Edge Frequency 2400.0 MHz

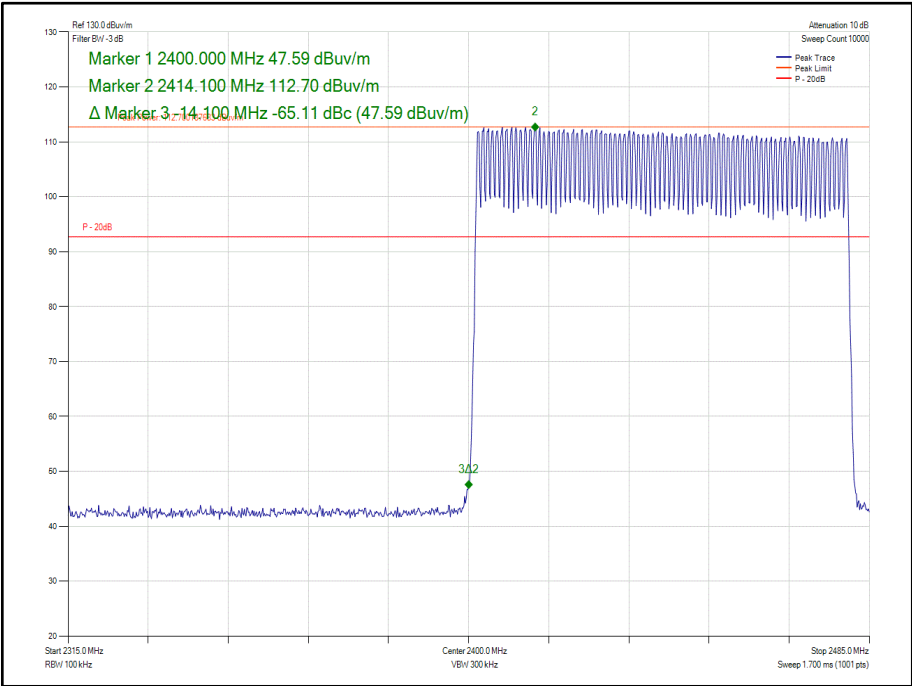


Figure 74 - Hopping - Core 1 - GFSK/DH5 - Band Edge Frequency 2400.0 MHz

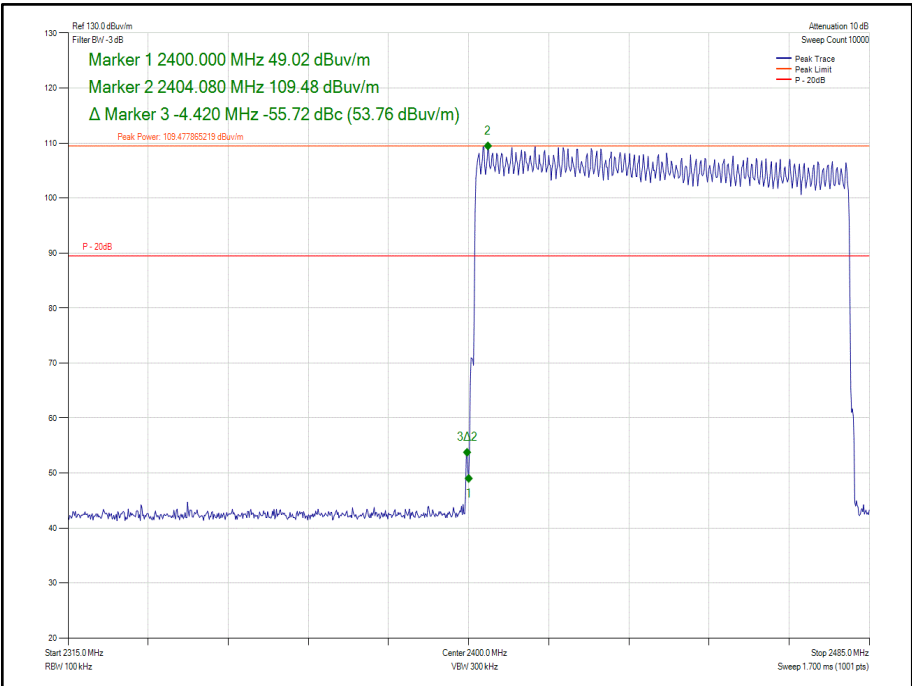


Figure 75 - Hopping - Core 1 - $\pi/4$ DQPSK/2DH5 - Band Edge Frequency 2400.0 MHz

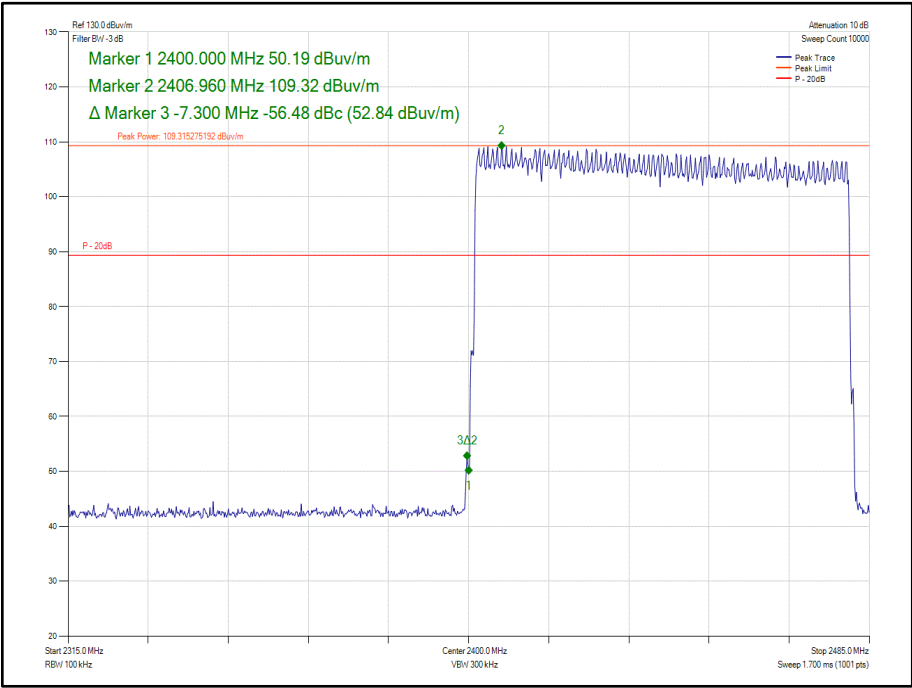
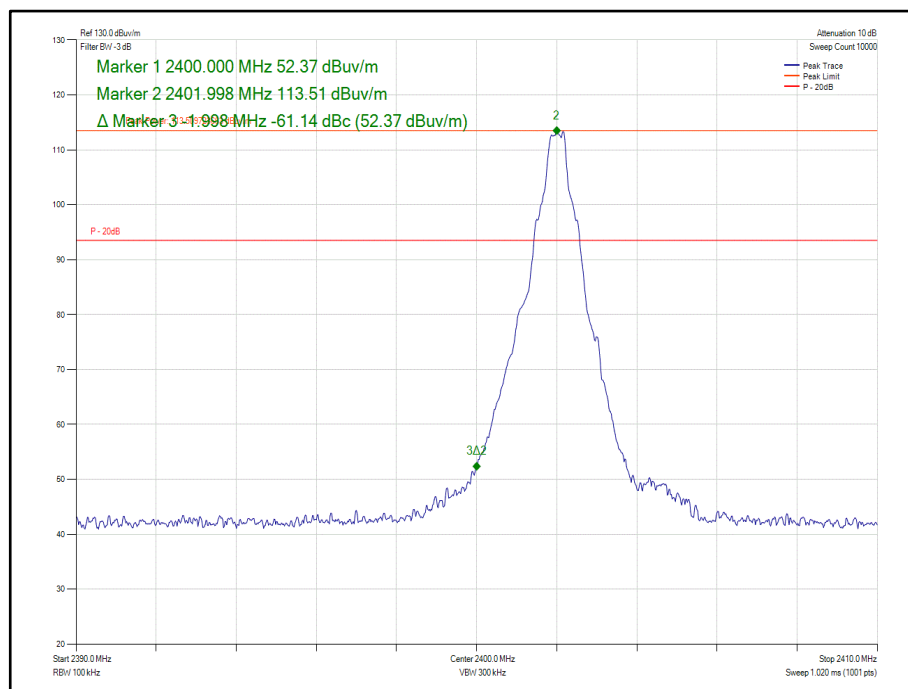


Figure 76 - Hopping - Core 1 - 8-DPSK/3DH5 - Band Edge Frequency 2400.0 MHz

Mode	Modulation	Core	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
Static	GFSK	0-1	DH5	2402	2400.0	-61.14
Static	$\pi/4$ DQPSK	0-1	2DH5	2402	2400.0	-55.20
Static	8-DPSK	0-1	3DH5	2402	2400.0	-55.16
Hopping	GFSK	0-1	DH5	2402	2400.0	-68.74
Hopping	$\pi/4$ DQPSK	0-1	2DH5	2402	2400.0	-58.95
Hopping	8-DPSK	0-1	3DH5	2402	2400.0	-56.93

Table 41 - MIMO 2TX Authorised Band Edge Results



**Figure 77 - Static - Core 0-1- GFSK/DH5 - 2402 MHz -
Band Edge Frequency 2400.0 MHz**

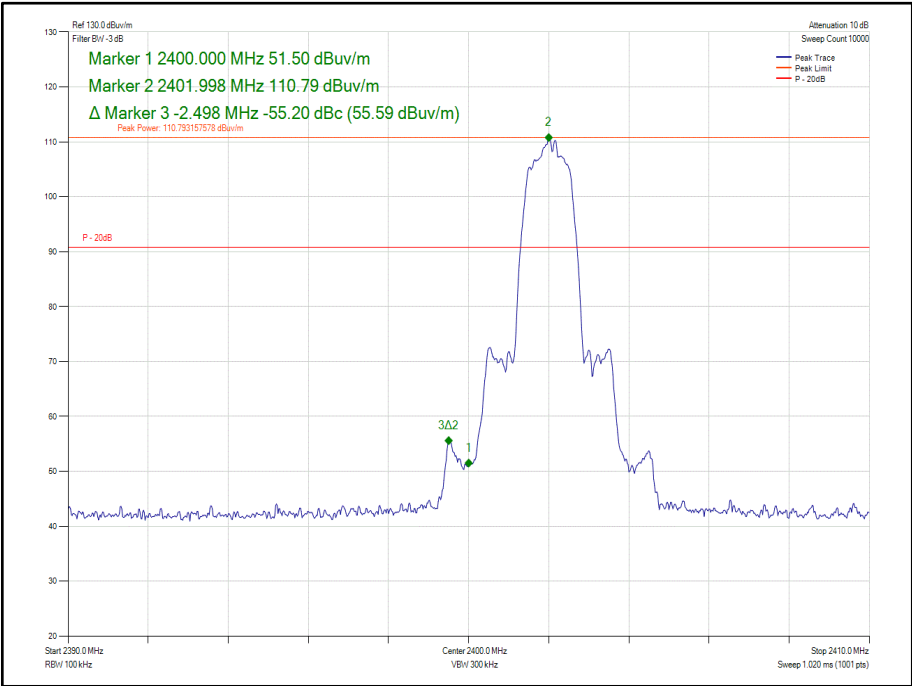


Figure 78 - Static - Core 0-1- $\pi/4$ DQPSK/2DH5 - 2402 MHz -
Band Edge Frequency 2400.0 MHz

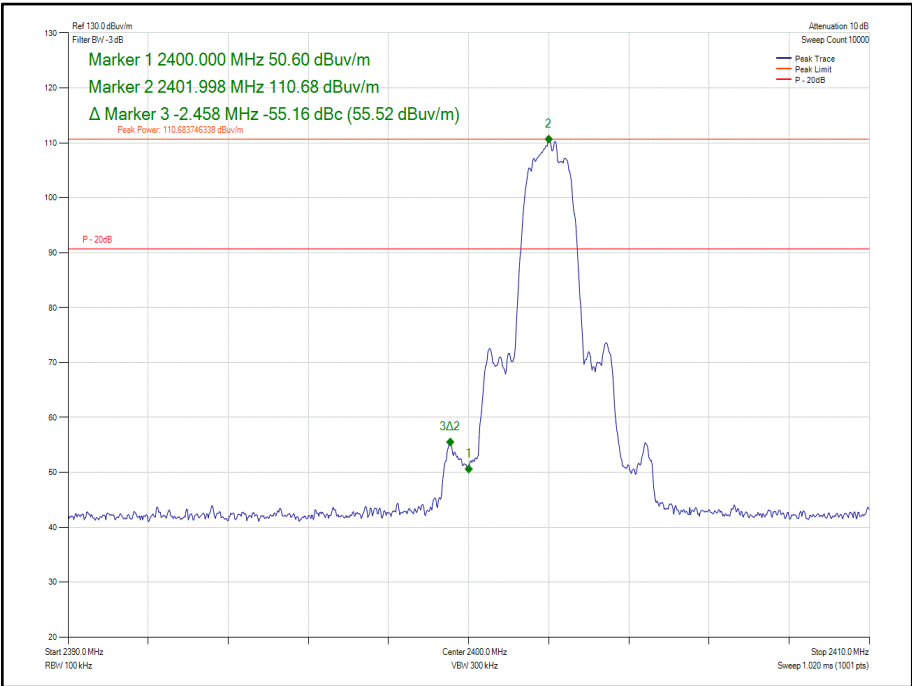


Figure 79 - Static - Core 0-1- 8-DPSK/3DH5 - 2402 MHz -
Band Edge Frequency 2400.0 MHz

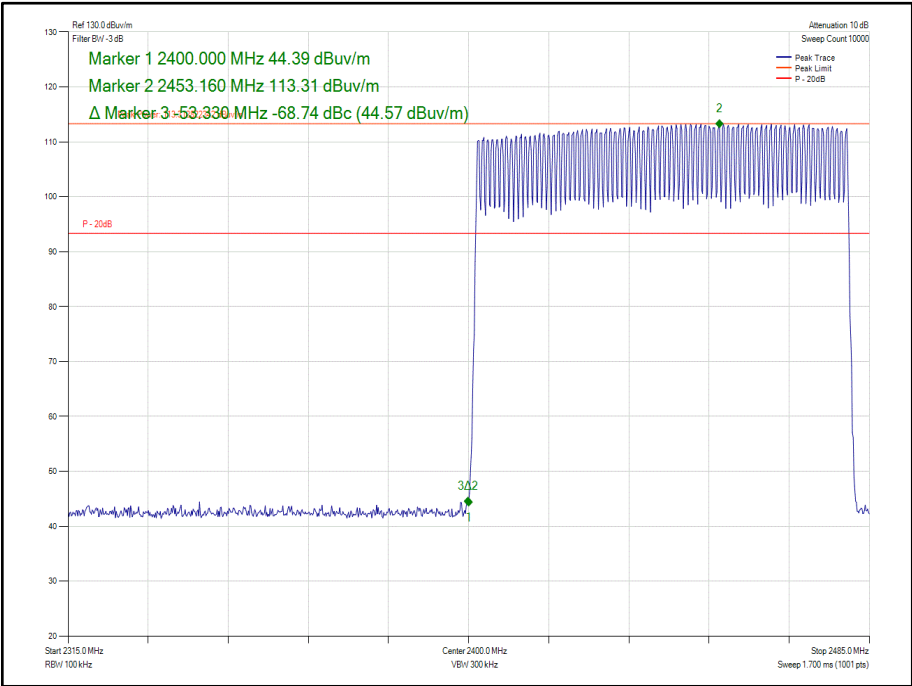


Figure 80 - Hopping - Core 0-1- GFSK/DH5 - Band Edge Frequency 2400.0 MHz

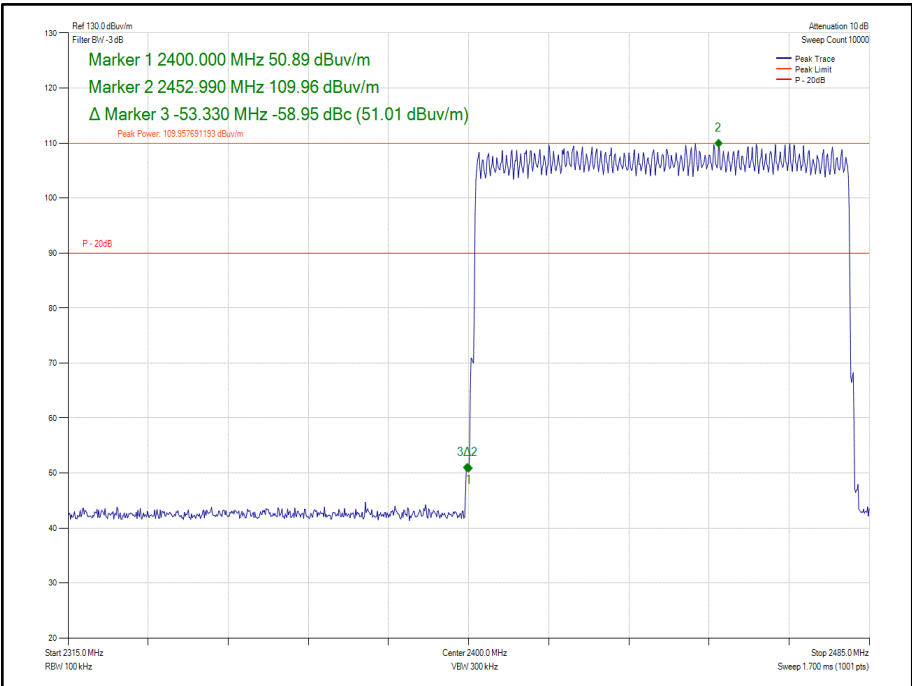


Figure 81 - Hopping - Core 0-1- $\pi/4$ DQPSK/2DH5 - Band Edge Frequency 2400.0 MHz

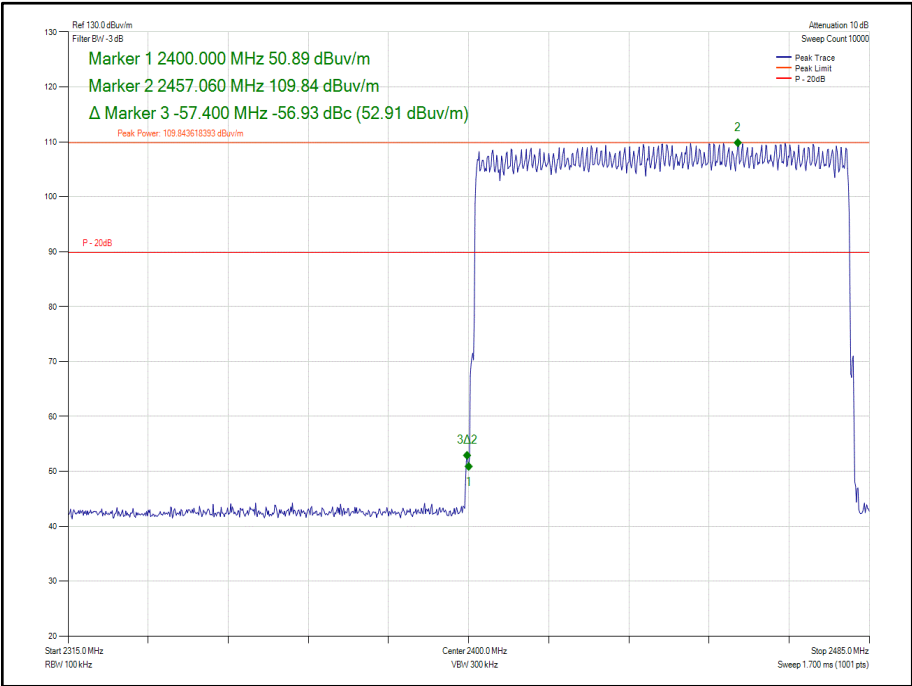


Figure 82 - Hopping - Core 0-1- 8-DPSK/3DH5 - Band Edge Frequency 2400.0 MHz

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Mode	Modulation	Core	Packet Type	Tx Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
Static	GFSK	0	DH5	2402	2400.0	-67.48
Static	$\pi/4$ DQPSK	0	2DH5	2402	2400.0	-61.32
Static	8-DPSK	0	3DH5	2402	2400.0	-60.93
Hopping	GFSK	0	DH5	2402	2400.0	-68.23
Hopping	$\pi/4$ DQPSK	0	2DH5	2402	2400.0	-65.24
Hopping	8-DPSK	0	3DH5	2402	2400.0	-65.57

Table 42 - Authorised Band Edge Results

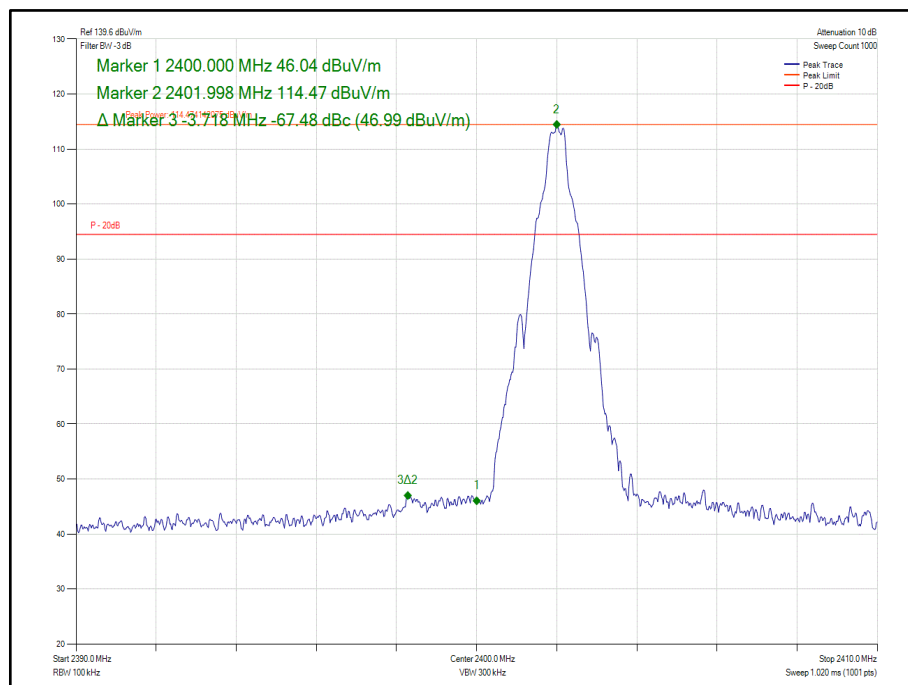


Figure 83 - Static - Core 0 - GFSK/DH5 - 2402 MHz - Band Edge Frequency 2400.0 MHz