3. Carrier Frequency Separation

3.1.Test Setup

Refer to the APPENDIX I.

3.2. Limit

Limit: ≥ 20dB BW or ≥Two-Thirds of the 20dB BW

- Procedure:

The carrier frequency separation was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.
After the trace being stable, the reading value between the peaks of the adjacent channels using the marker-delta function was recorded as the measurement results.

The spectrum analyzer is set to:

Span = wide enough to capture the peaks of two adjacent channels
RBW = 1% of the span
Sweep = auto
VBW = ≥ RBW
Detector function = peak
Trace = max hold

- Measurement Data: Comply(Refer to the next page.)

- **Minimum Standard:**

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 2400-2483.5 MHz band 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 125 mW

- L54SK2

- FH mode

Hopping Mode	Test Mode	Peak of adjacent Channel (MHz)	Peak of center channel (MHz)	Test Result (MHz)
Enable	GFSK	2440.988	2441.990	1.002
	π/4-DQPSK	2440.994	2442.002	1.008
	8DPSK	2440.985	2441.987	1.002

- AFH mode

Hopping Mode	Test Mode	Peak of adjacent Channel (MHz)	Peak of center channel (MHz)	Test Result (MHz)
Enable	GFSK	2410.991	2411.999	1.008
	π/4-DQPSK	2410.991	2411.993	1.002
	8DPSK	2410.991	2411.993	1.002

- L56VW2

- FH mode

Hopping Mode	Test Mode	Peak of adjacent Channel (MHz)	Peak of center channel (MHz)	Test Result (MHz)
Enable	GFSK	2440.826	2441.828	1.002
	π/4-DQPSK	2440.994	2441.996	1.002
	8DPSK	2440.988	2441.990	1.002

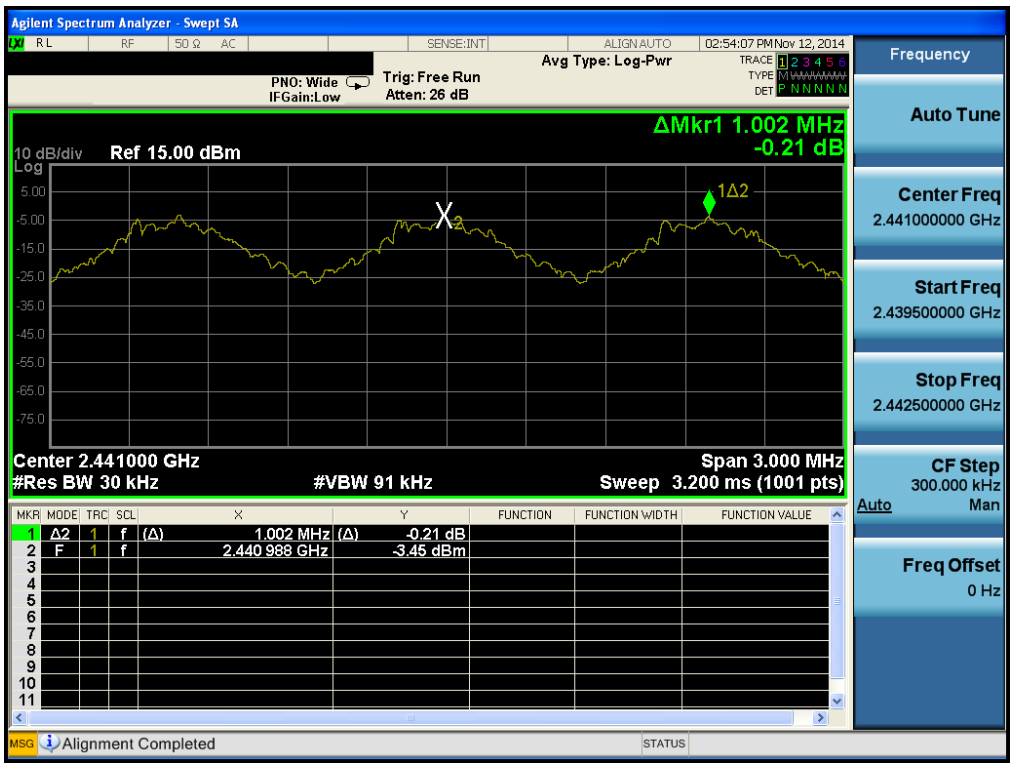
- AFH mode

Hopping Mode	Test Mode	Peak of adjacent Channel (MHz)	Peak of center channel (MHz)	Test Result (MHz)
Enable	GFSK	2410.982	2411.984	1.002
	π/4-DQPSK	2410.979	2411.981	1.002
	8DPSK	2410.979	2411.981	1.002

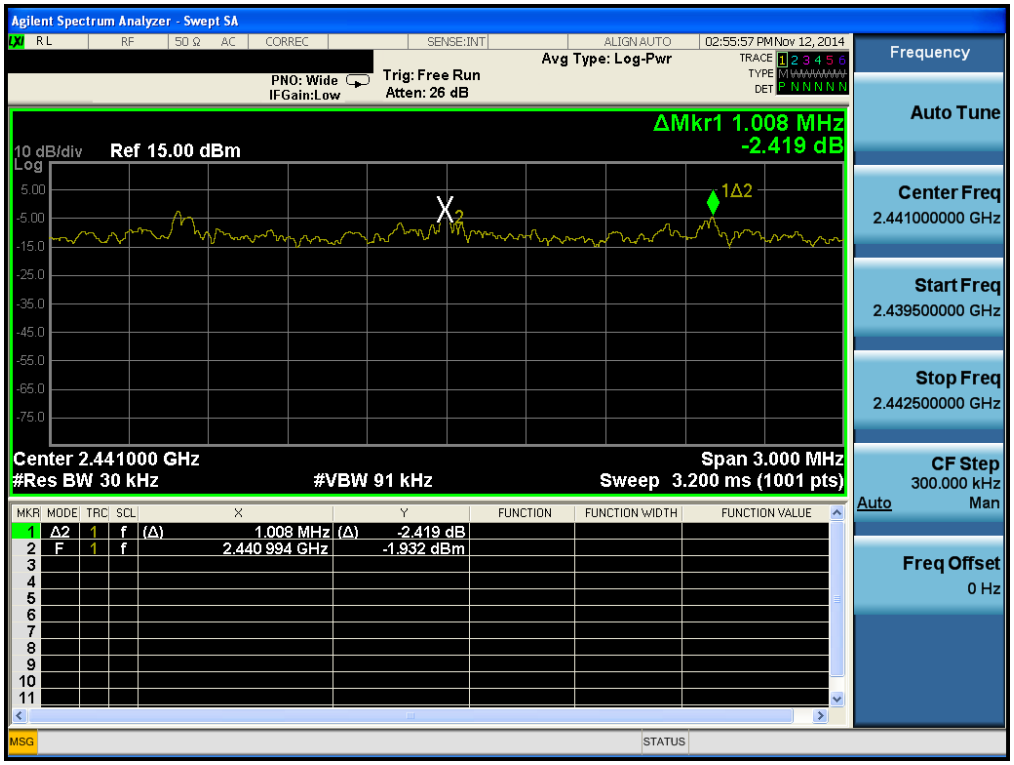
Note 1: See next pages for actual measured spectrum plots.

- L54SK2

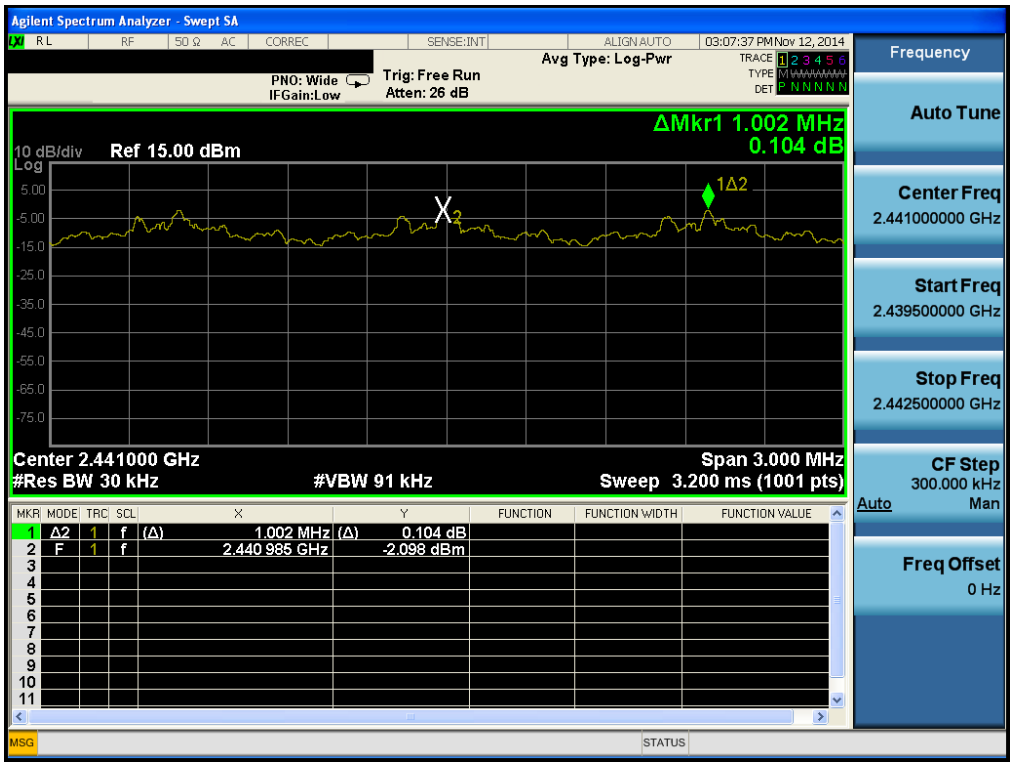
Carrier Frequency Separation (FH) ***Hopping mode: Enable&GFSK***



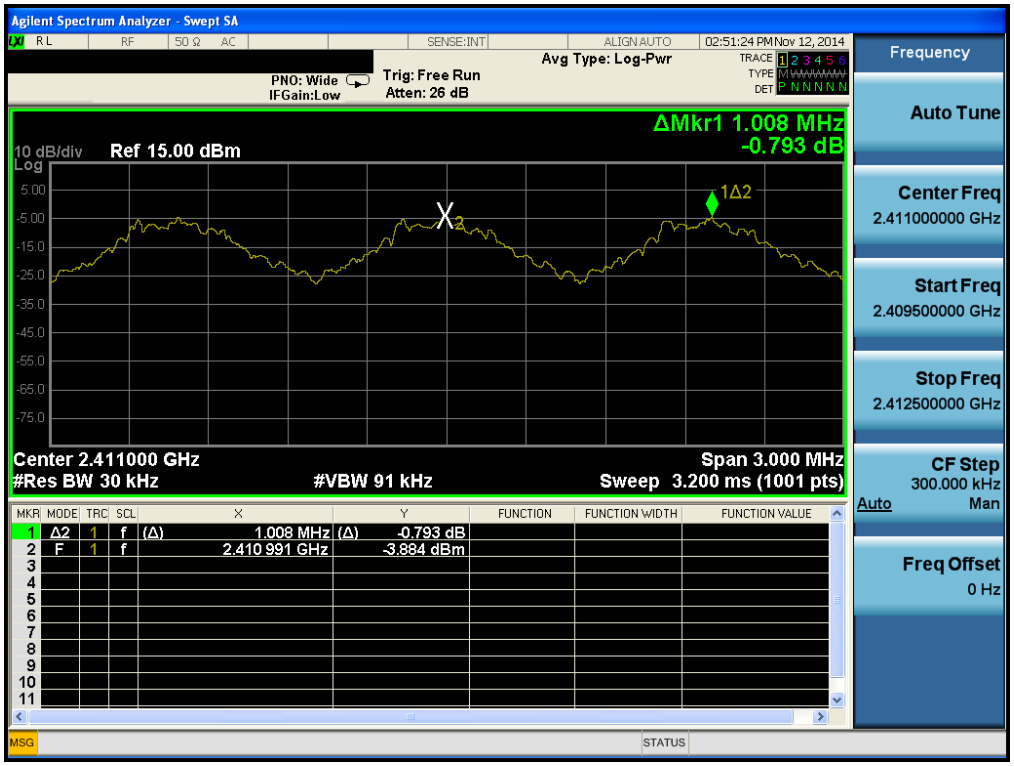
Carrier Frequency Separation (FH) ***Hopping mode: Enable&π/4-DQPSK***



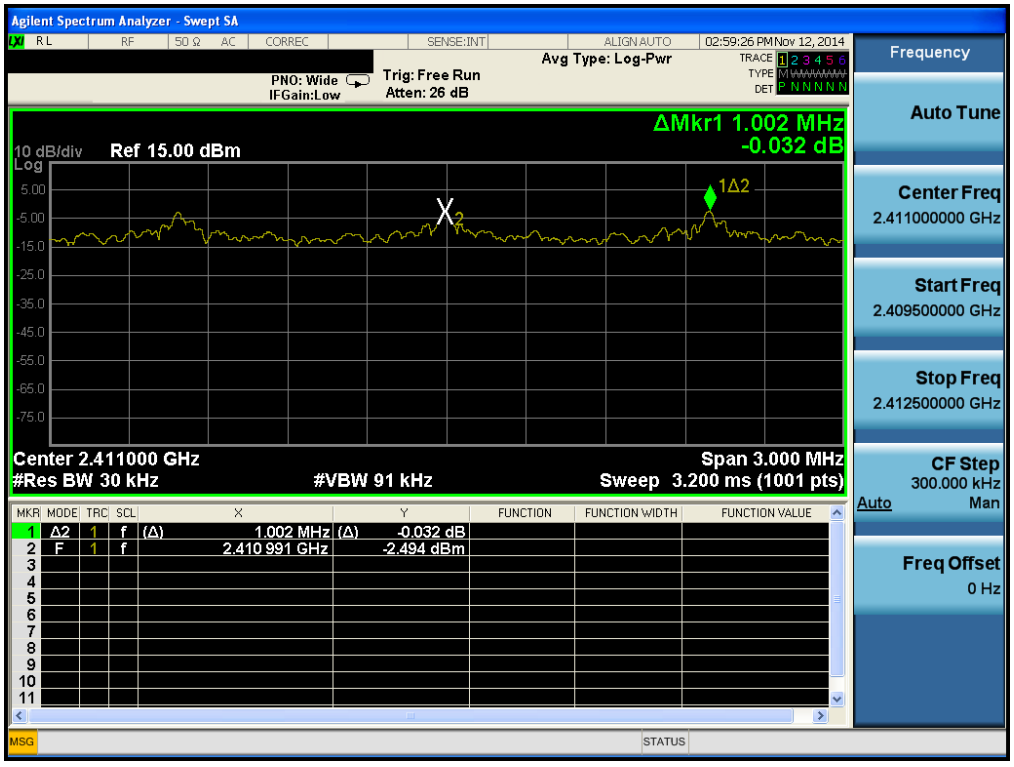
Carrier Frequency Separation (FH) ***Hopping mode: Enable&8DPSK***



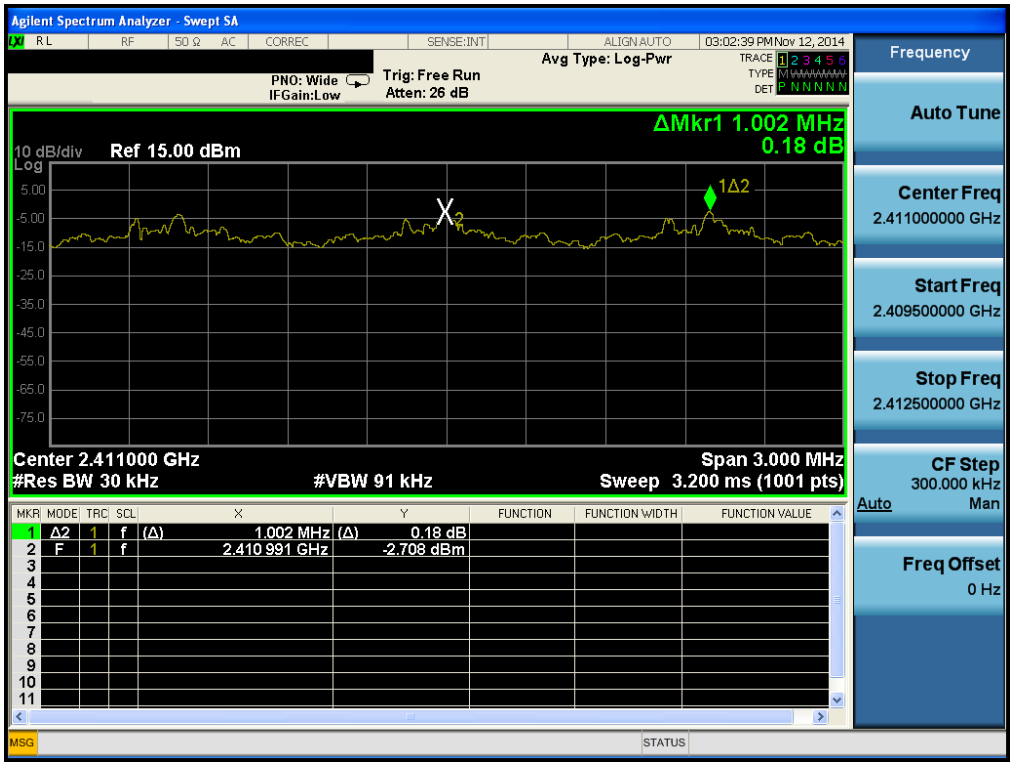
Carrier Frequency Separation (AFH) ***Hopping mode: Enable&GFSK***



Carrier Frequency Separation (AFH) ***Hopping mode: Enable&π/4-DQPSK***

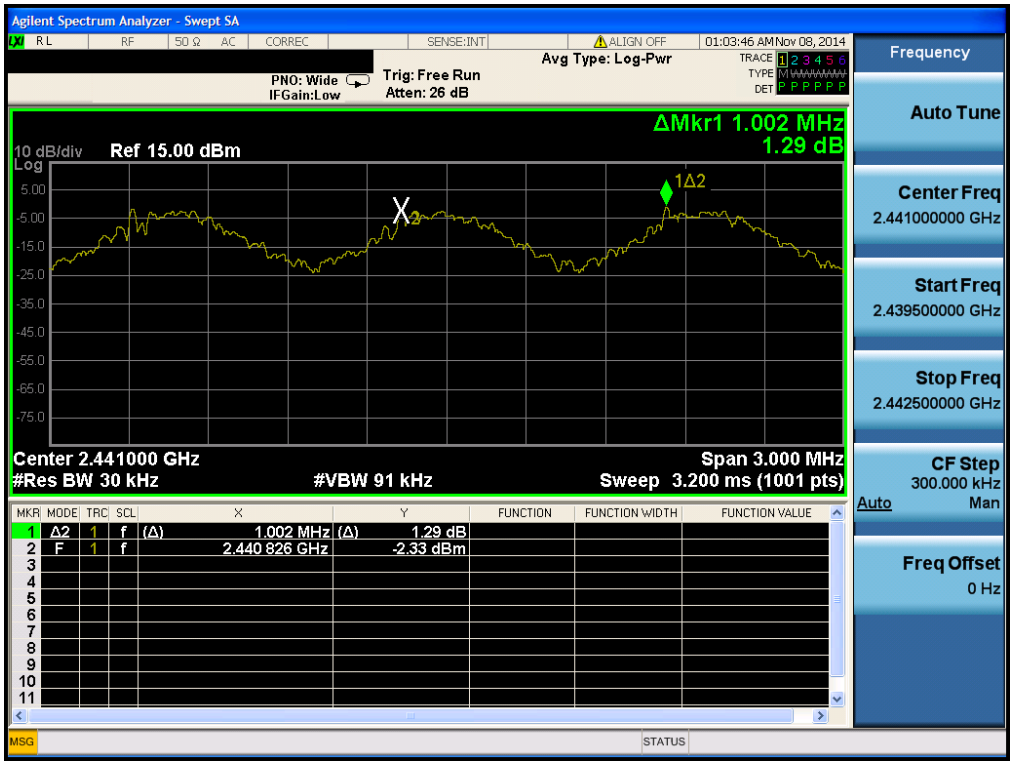


Carrier Frequency Separation (AFH) ***Hopping mode: Enable&8DPSK***

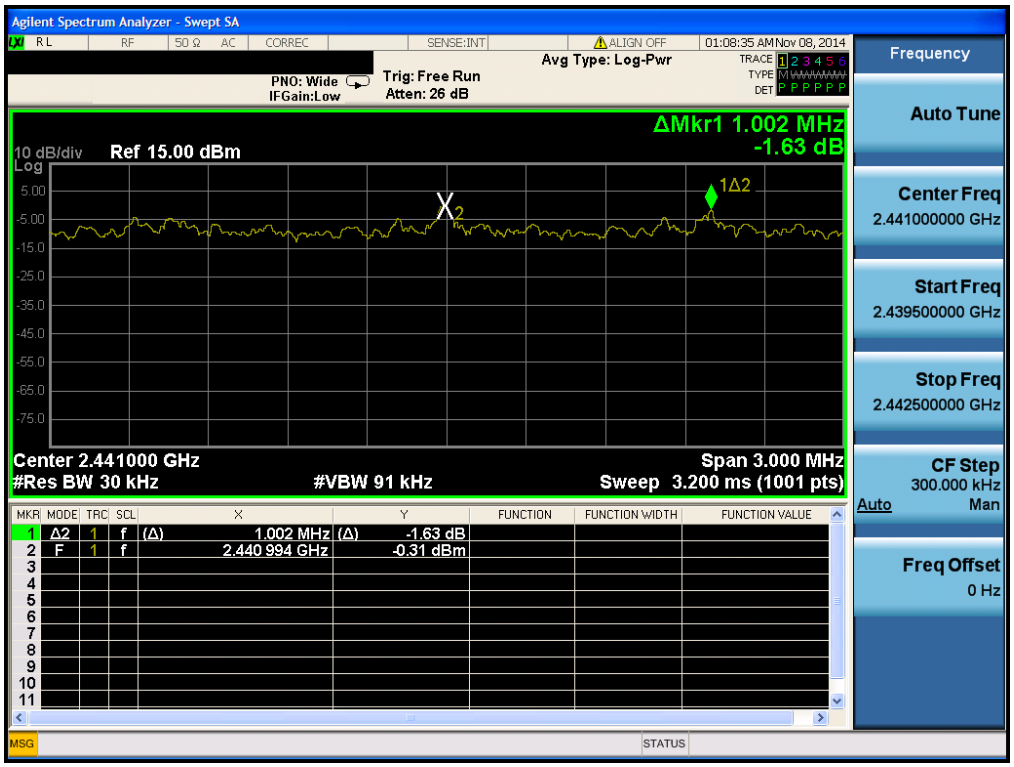


- L56VW2

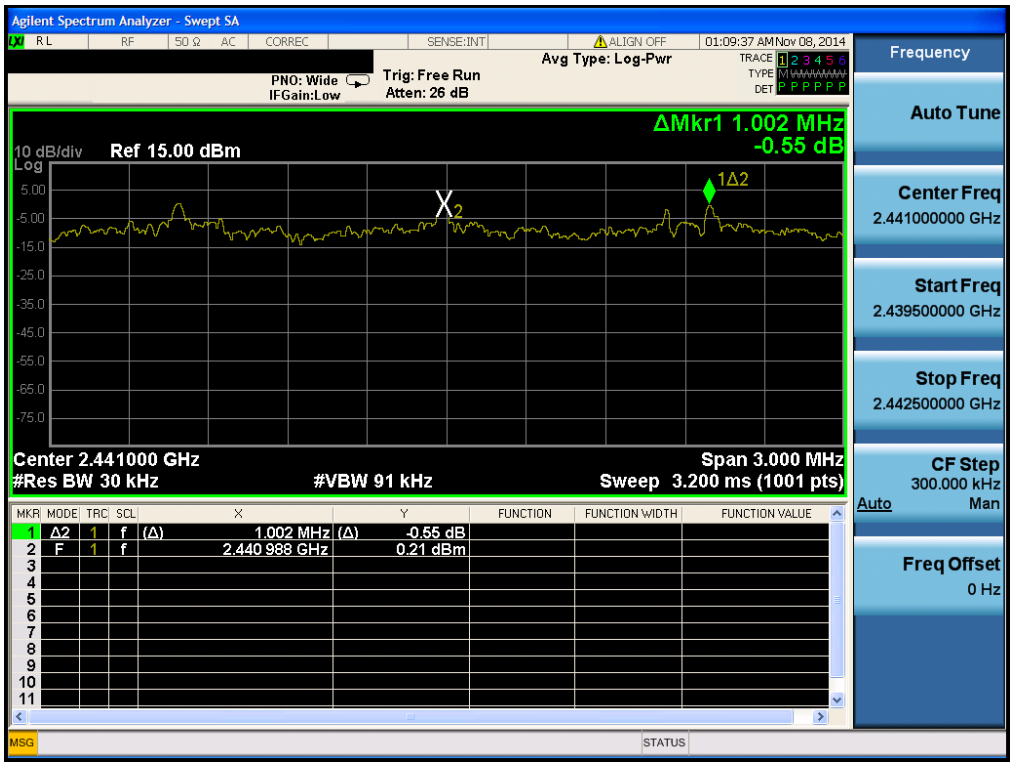
Carrier Frequency Separation (FH) ***Hopping mode: Enable&GFSK***



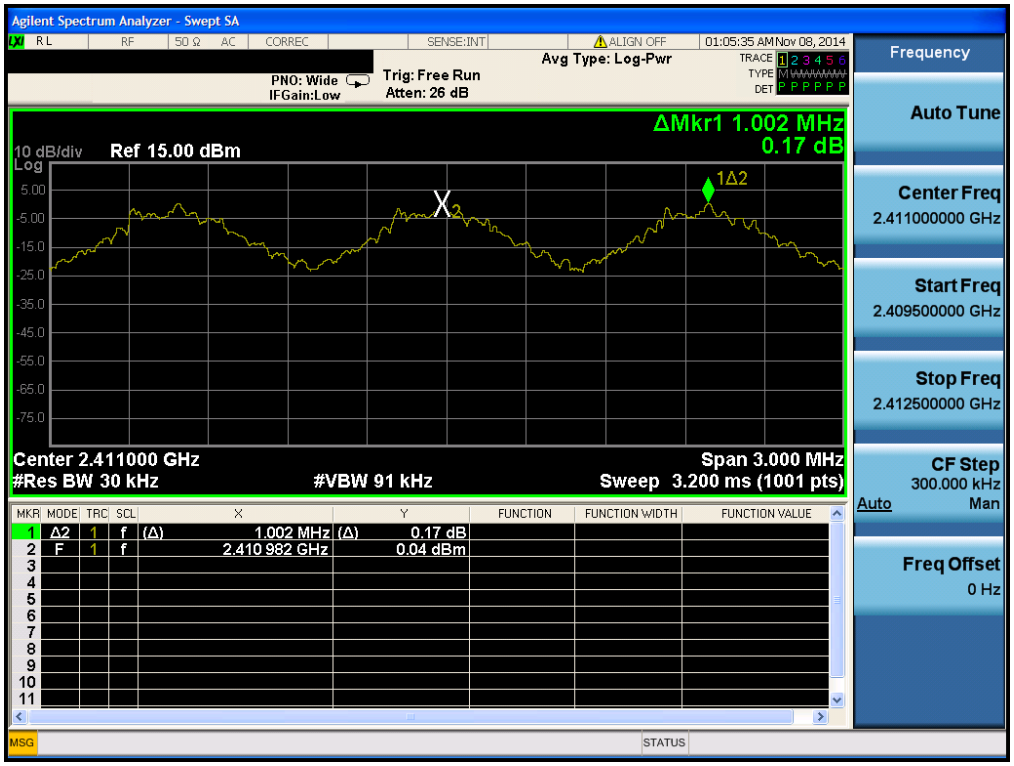
Carrier Frequency Separation (FH) ***Hopping mode: Enable&π/4-DQPSK***



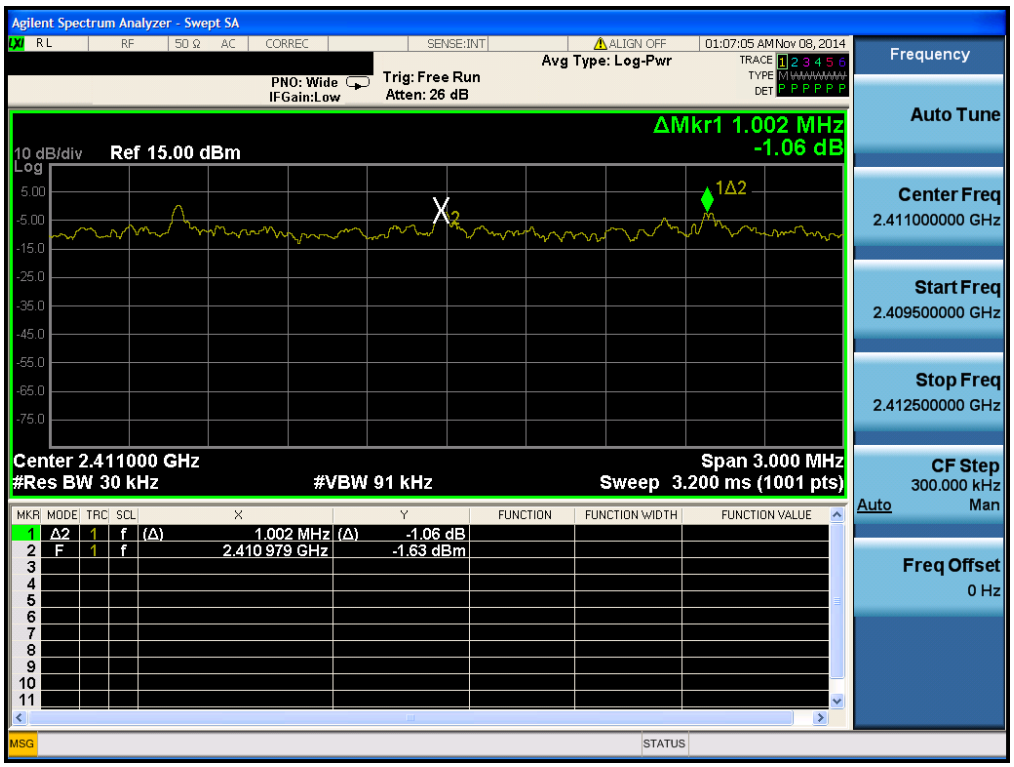
Carrier Frequency Separation (FH) ***Hopping mode: Enable&8DPSK***



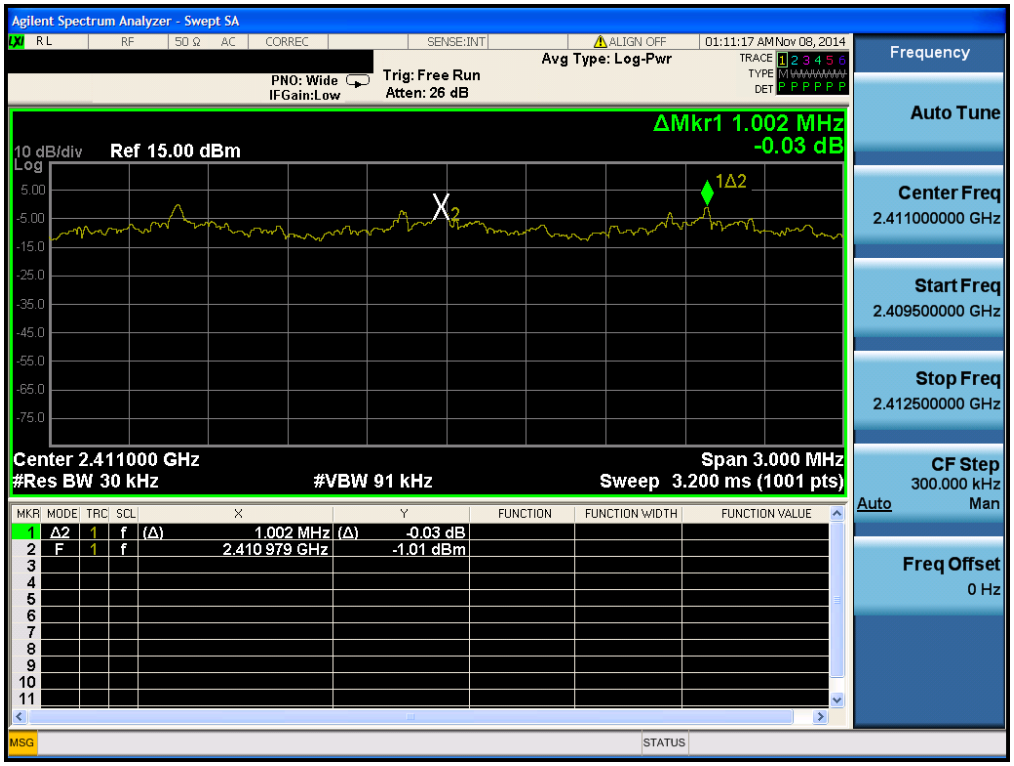
Carrier Frequency Separation (AFH) ***Hopping mode: Enable&GFSK***



Carrier Frequency Separation (AFH) ***Hopping mode: Enable&π/4-DQPSK***



Carrier Frequency Separation (AFH) ***Hopping mode: Enable&8DPSK***



4.Number of Hopping Frequencies

4.1.Test Setup

Refer to the APPENDIX I.

4.2. Limit

Limit: >= 15 hops

- Procedure:

The number of hopping frequencies was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.
To get higher resolution, two frequency ranges for FH mode within the 2400 ~ 2483.5 MHz were examined.

The spectrum analyzer is set to:

Span = 50MHz Plot 1: Start Frequency = 2391.5MHz, Stop Frequency = 2441.5 MHz
Plot 2: Start Frequency = 2441.5MHz, Stop Frequency = 2491.5 MHz

RBW = 1% of the span or more
VBW = ≥ RBW
Trace = max hold
Sweep = auto
Detector function = peak

- **Measurement Data: Comply**

- L54SK2

- FH mode

Hopping mode	Test mode	Test Result (Total Hops)
Enable	GFSK	79
	π/4-DQPSK	79
	8DPSK	79

- AFH mode

Hopping mode	Test mode	Test Result (Total Hops)
Enable	GFSK	20
	π/4-DQPSK	20
	8DPSK	20

- L56VW2

- FH mode

Hopping mode	Test mode	Test Result (Total Hops)
Enable	GFSK	79
	π/4-DQPSK	79
	8DPSK	79

- AFH mode

Hopping mode	Test mode	Test Result (Total Hops)
Enable	GFSK	20
	π/4-DQPSK	20
	8DPSK	20

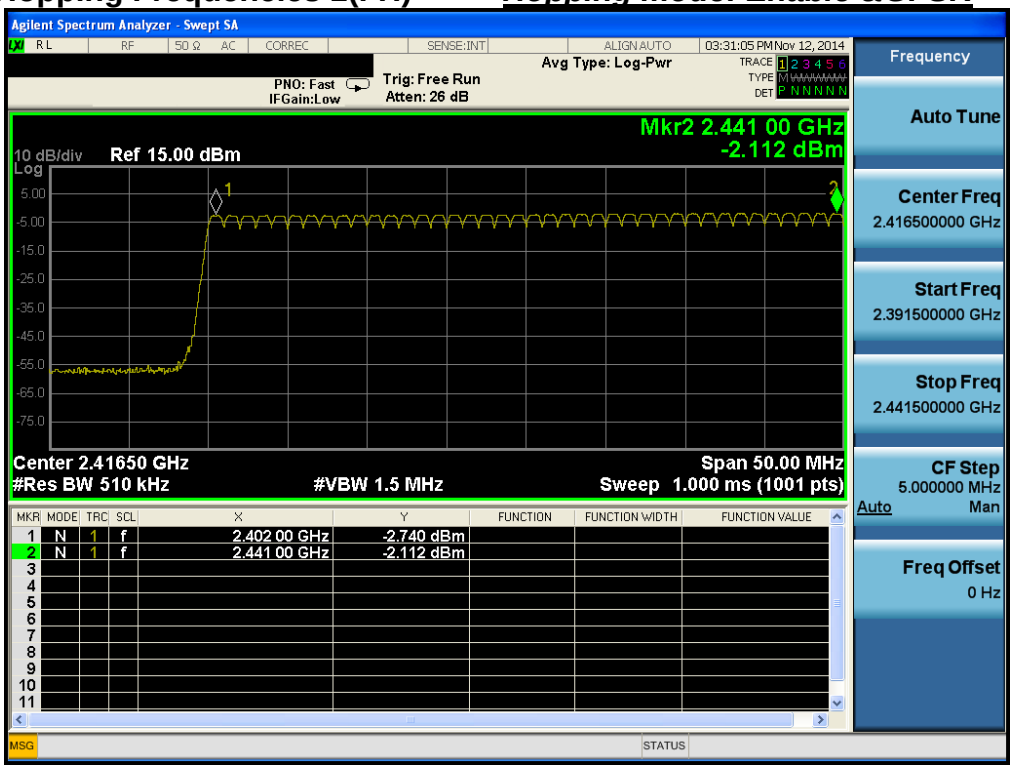
Note 1: See next pages for actual measured spectrum plots.

- Minimum Standard:

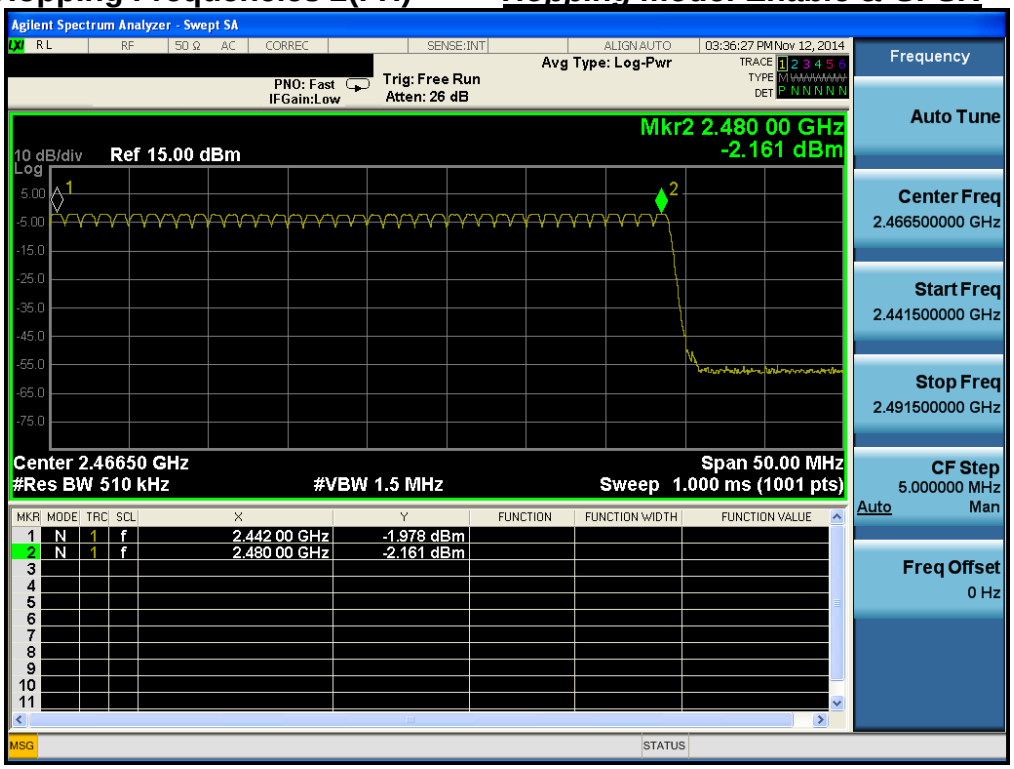
At least 15 hopes

- L54SK2

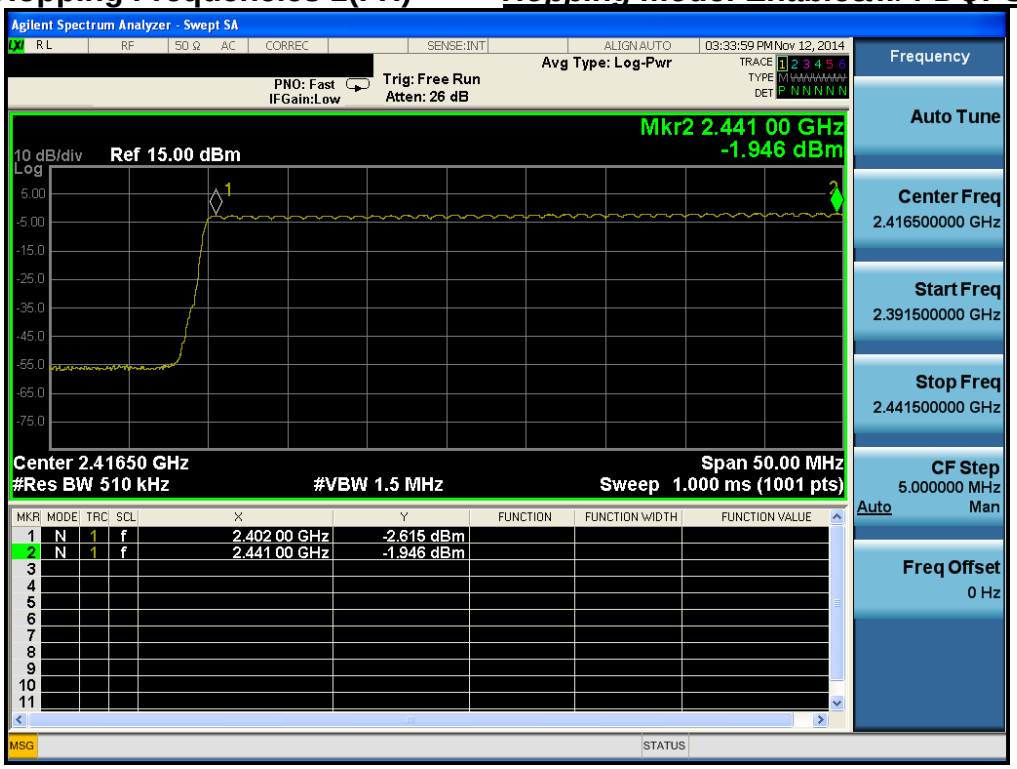
Number of Hopping Frequencies 1(FH) ***Hopping mode: Enable &GFSK***



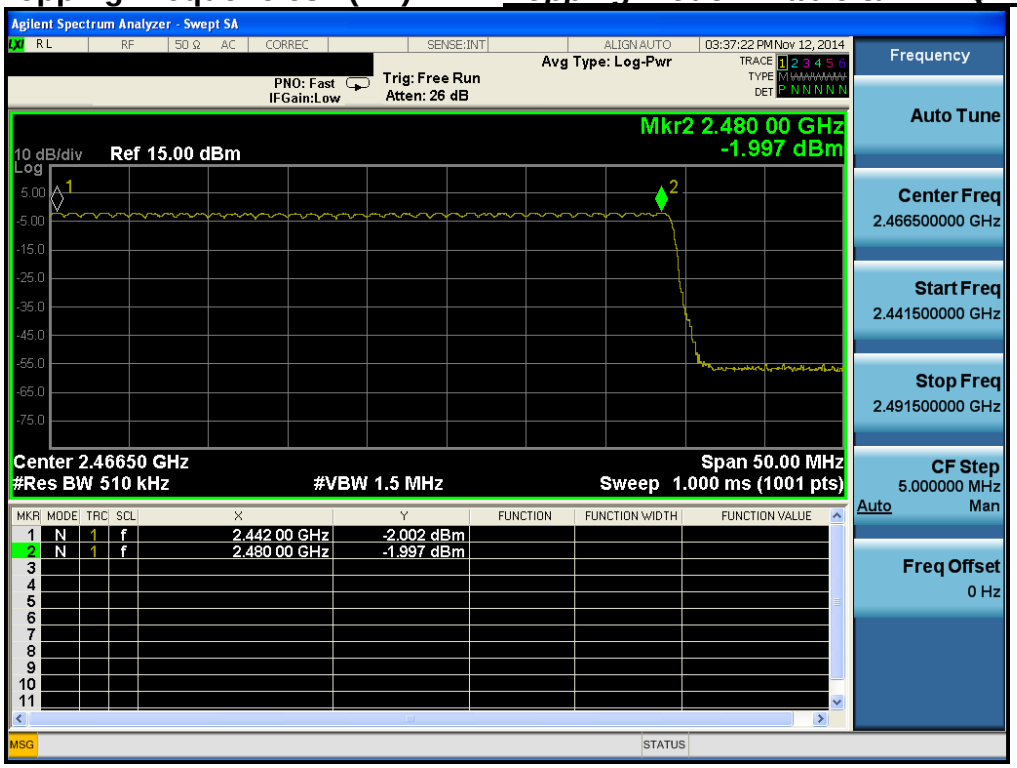
Number of Hopping Frequencies 2(FH) ***Hopping mode: Enable & GFSK***



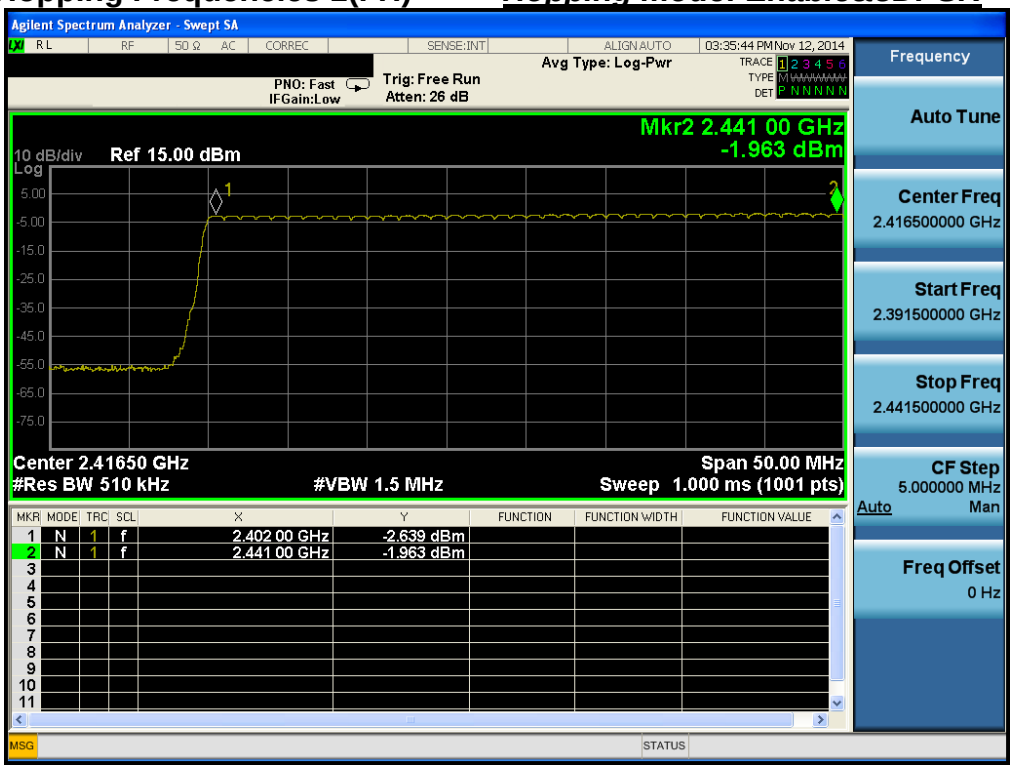
Number of Hopping Frequencies 1(FH) *Hopping mode: Enable&π/4-DQPSK*



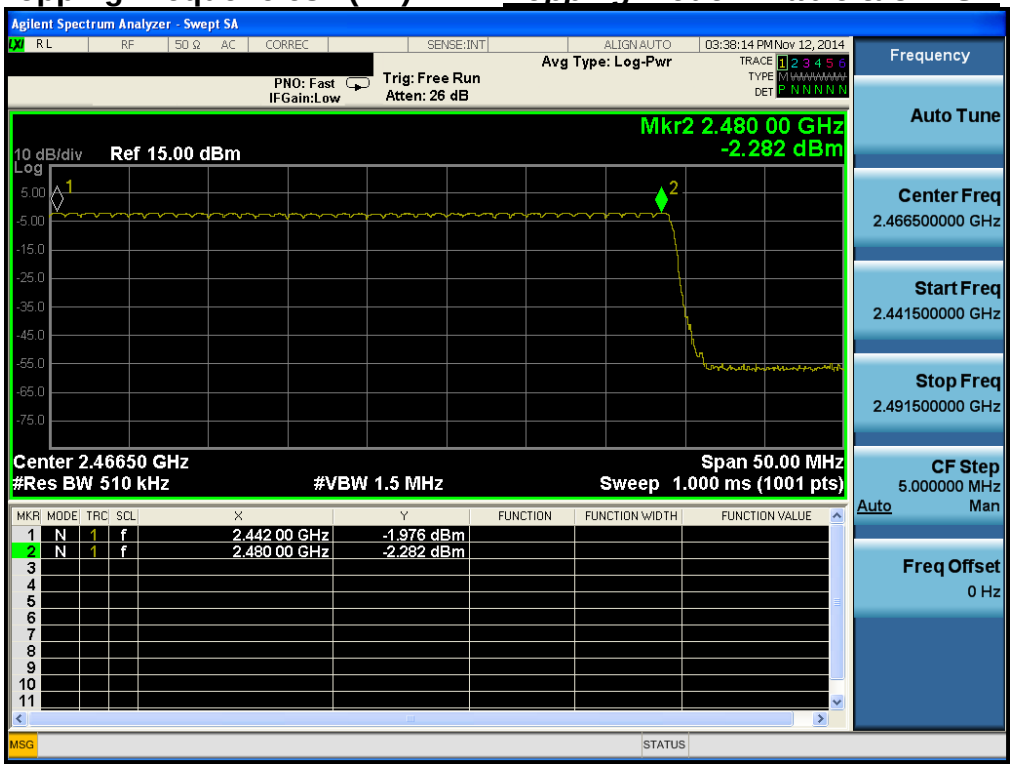
Number of Hopping Frequencies 2(FH) *Hopping mode: Enable &π/4-DQPSK*



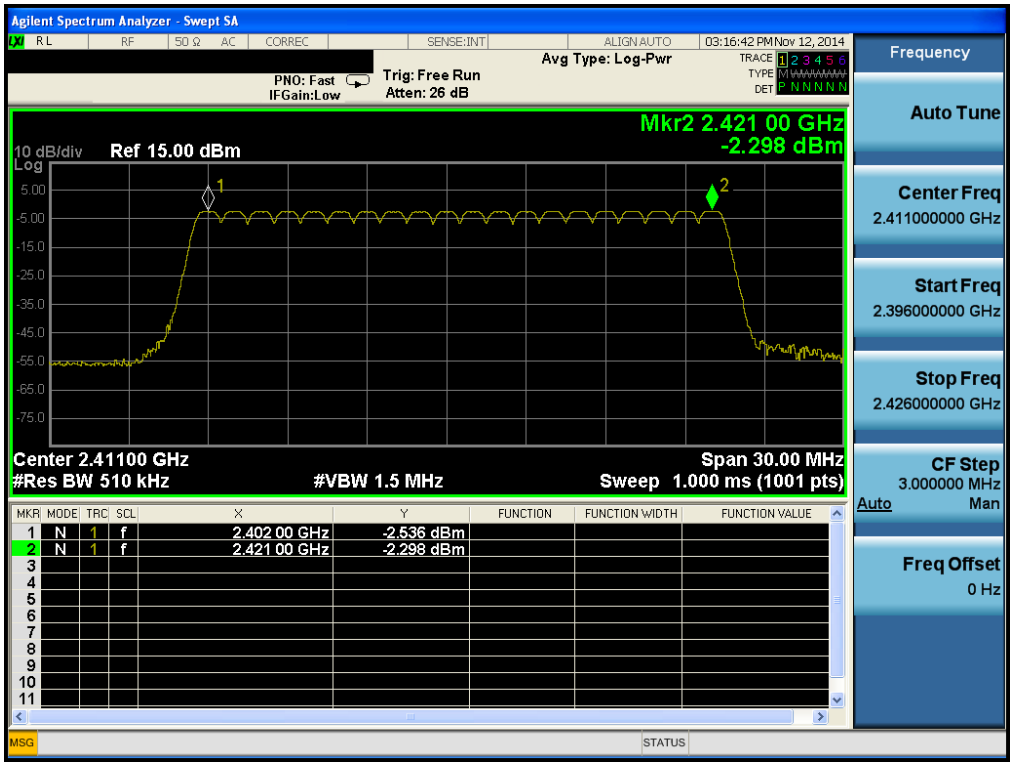
Number of Hopping Frequencies 1(FH) *Hopping mode: Enable&8DPSK*



Number of Hopping Frequencies 2(FH) *Hopping mode: Enable & 8DPSK*

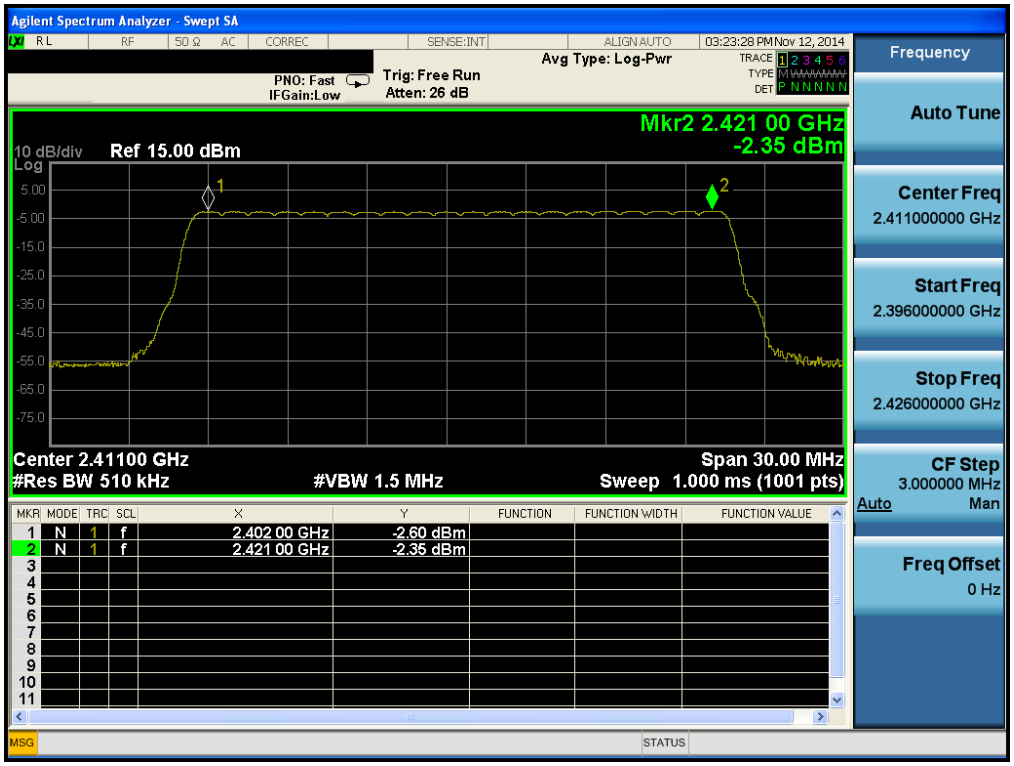


Number of Hopping Frequencies 1(AFH) ***Hopping mode: Enable &GFSK***



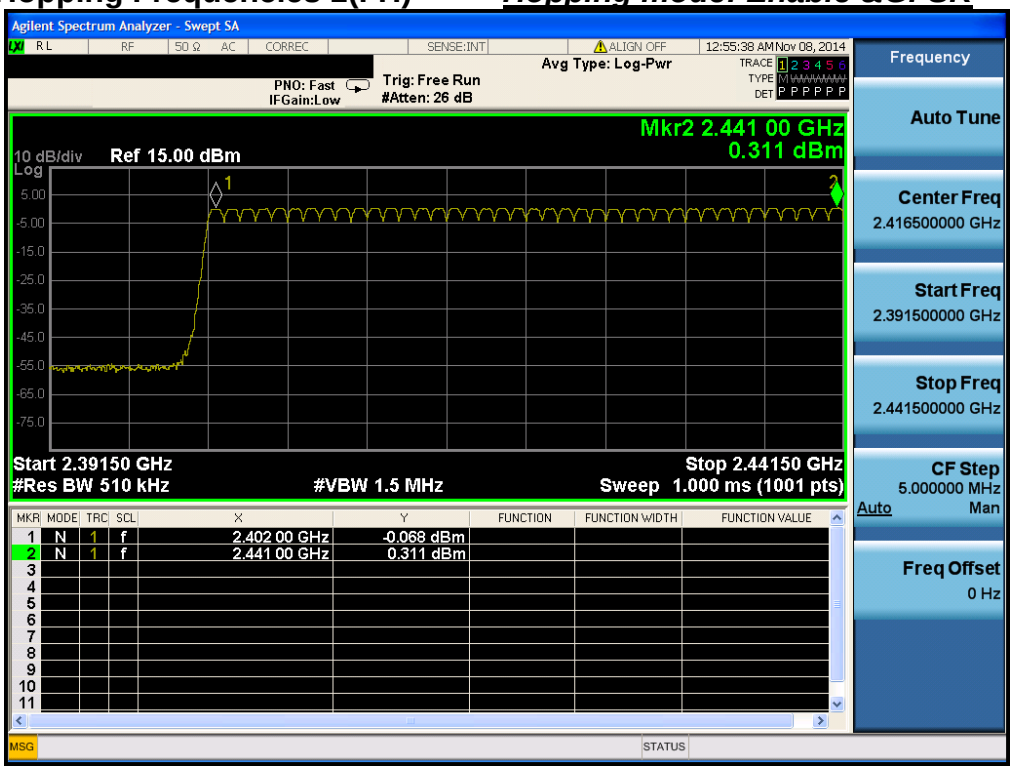
Number of Hopping Frequencies 1(AFH) ***Hopping mode: Enable &π/4-DQPSK***

Number of Hopping Frequencies 1(AFH) ***Hopping mode: Enable & 8DPSK***

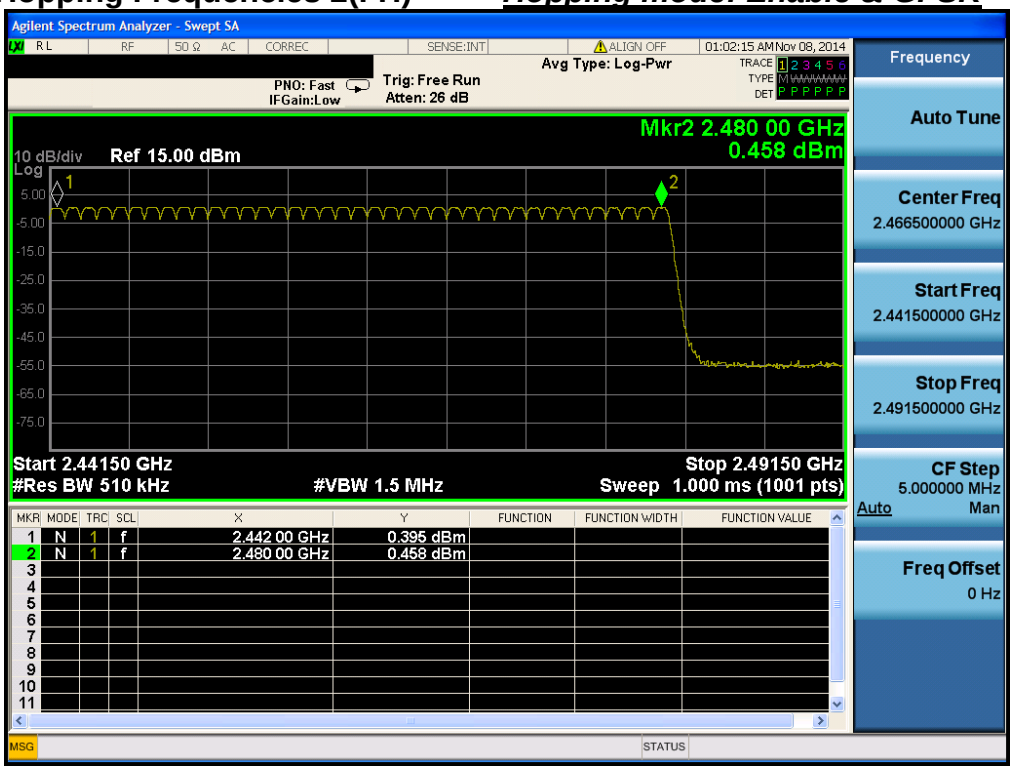


- L56VW2

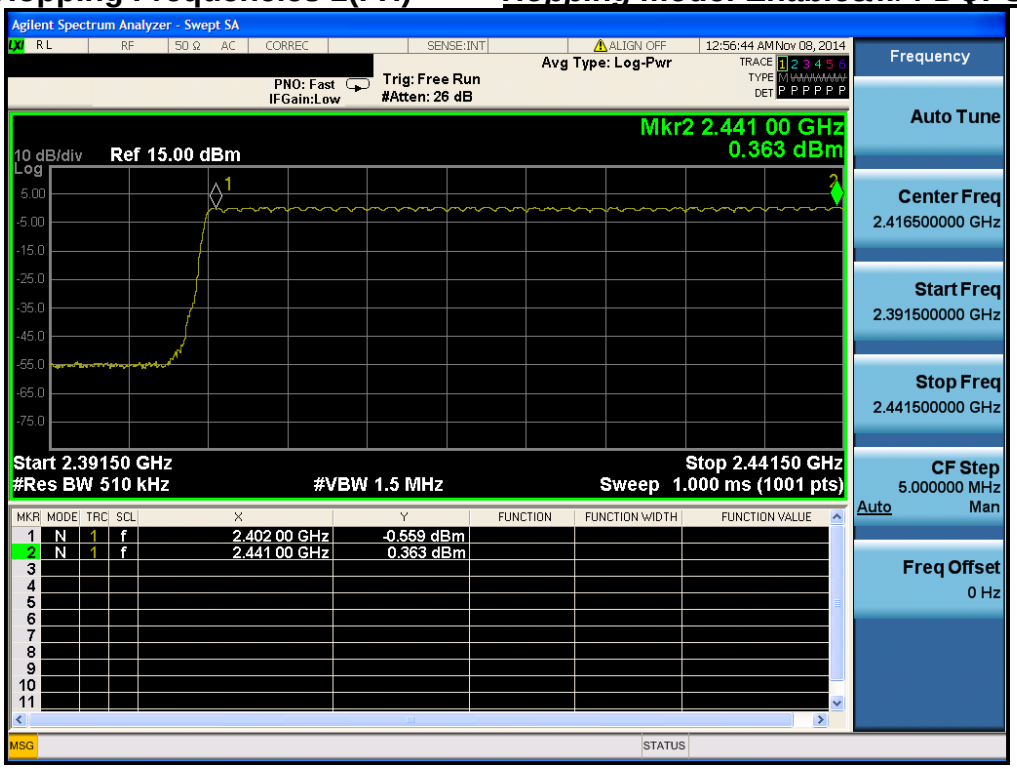
Number of Hopping Frequencies 1(FH) *Hopping mode: Enable &GFSK*



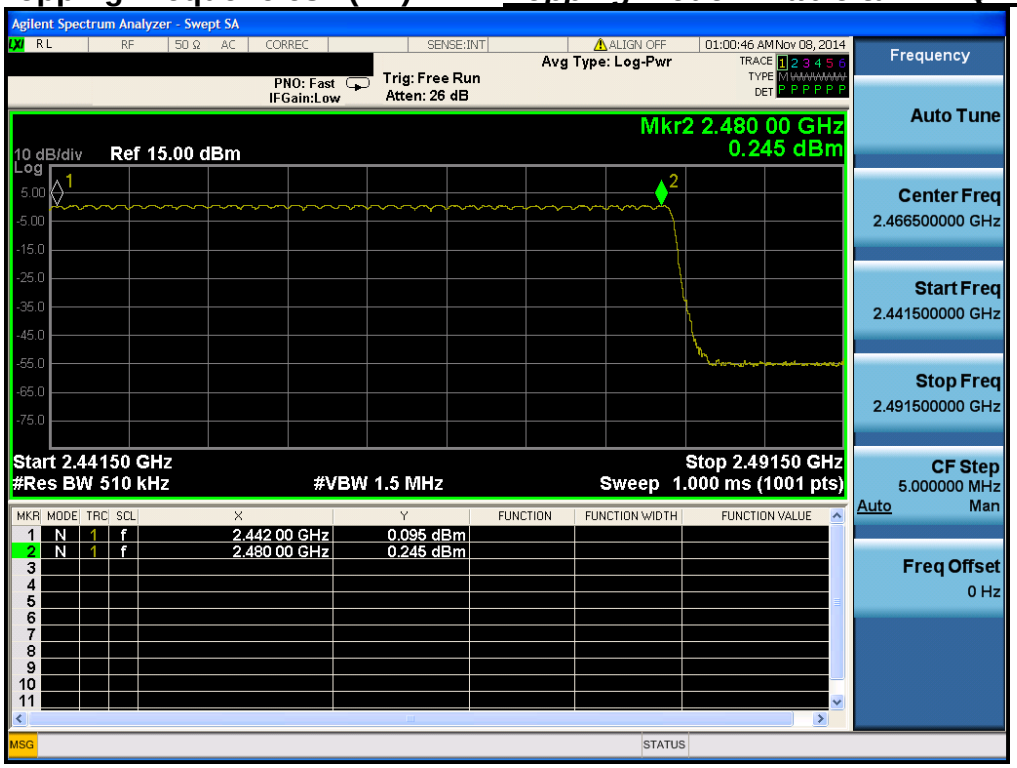
Number of Hopping Frequencies 2(FH) *Hopping mode: Enable & GFSK*



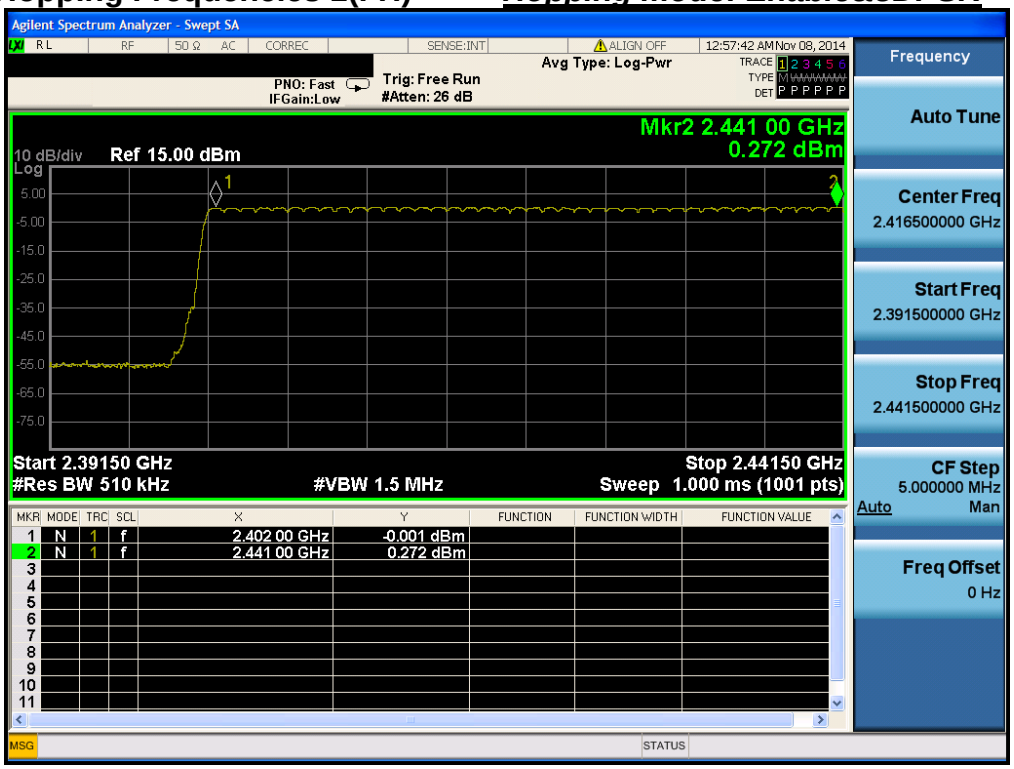
Number of Hopping Frequencies 1(FH) *Hopping mode: Enable&π/4-DQPSK*



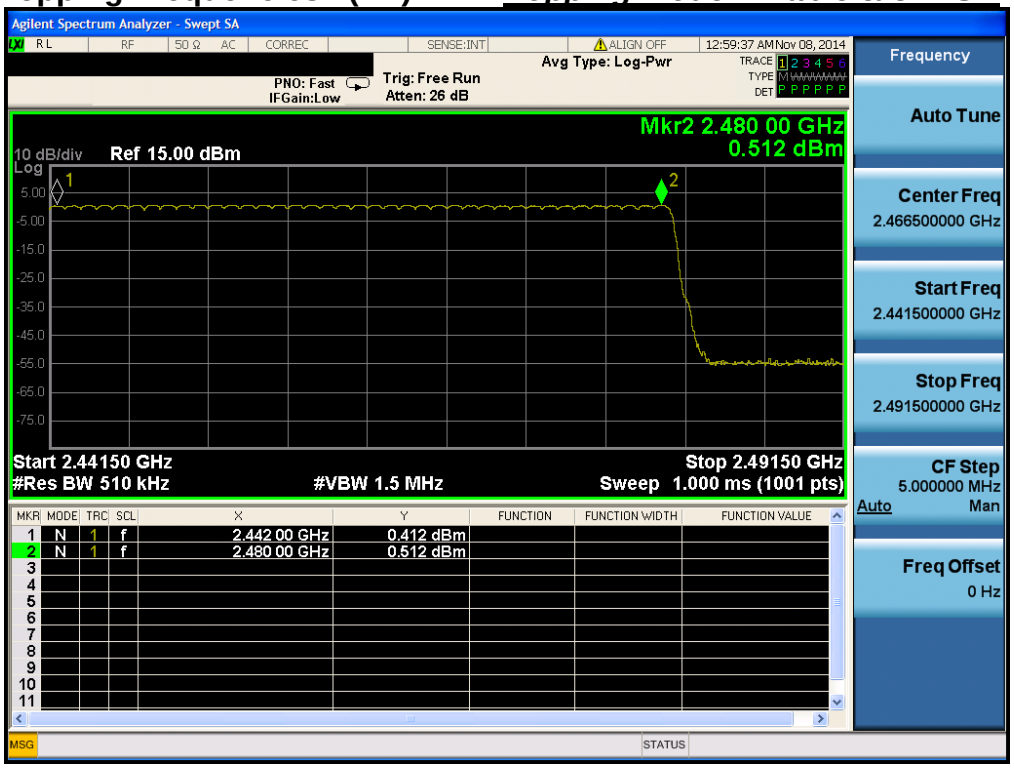
Number of Hopping Frequencies 2(FH) *Hopping mode: Enable &π/4-DQPSK*



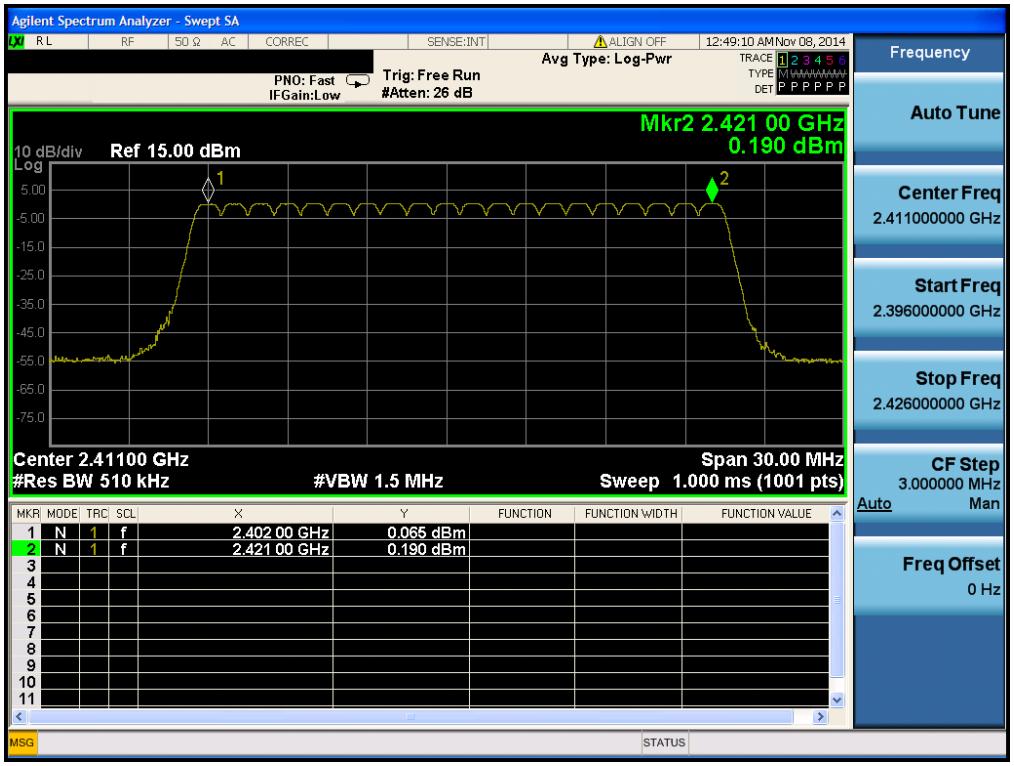
Number of Hopping Frequencies 1(FH) *Hopping mode: Enable&8DPSK*



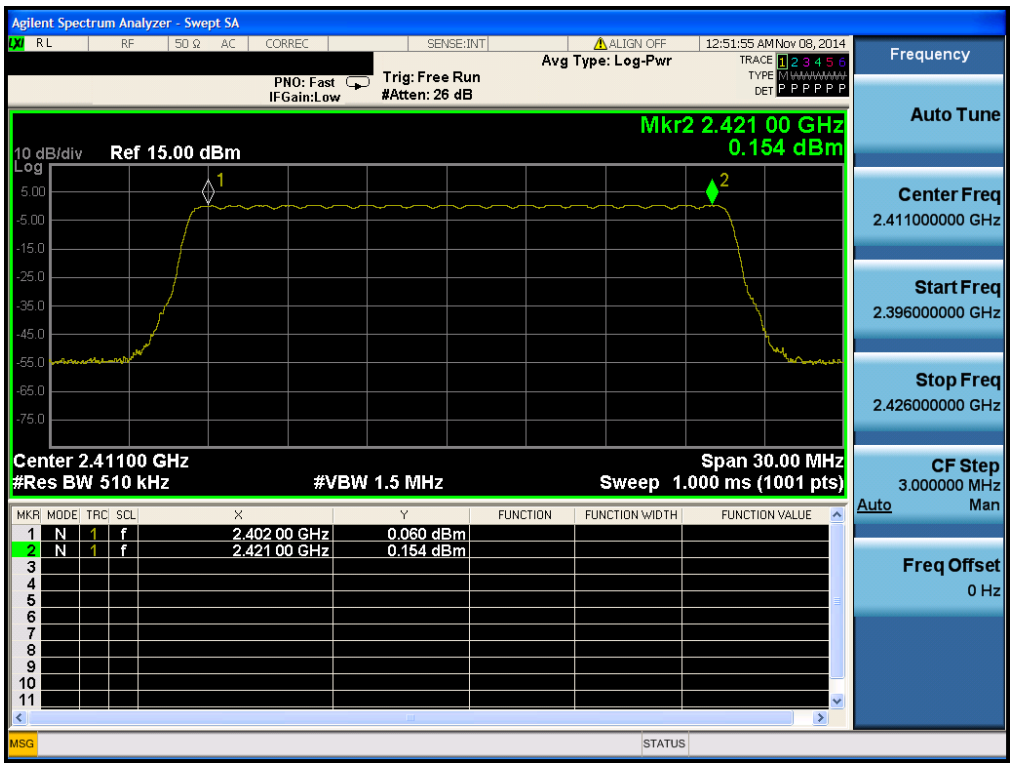
Number of Hopping Frequencies 2(FH) *Hopping mode: Enable & 8DPSK*



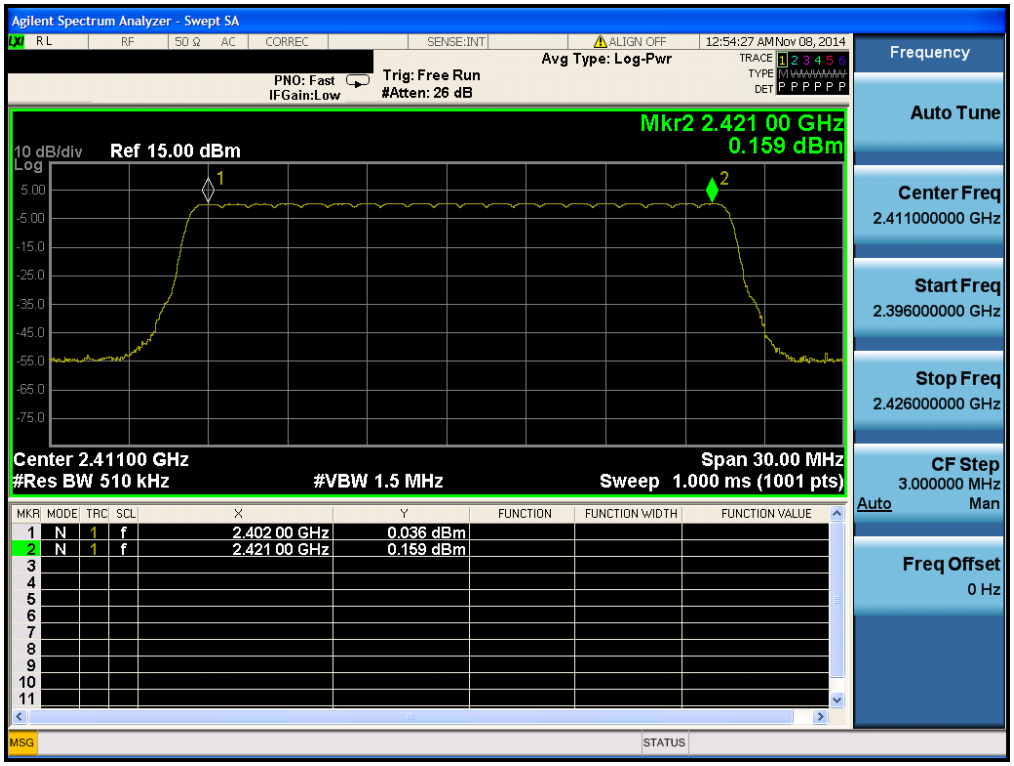
Number of Hopping Frequencies 1(AFH) ***Hopping mode: Enable &GFSK***



Number of Hopping Frequencies 1(AFH) ***Hopping mode: Enable &π/4-DQPSK***



Number of Hopping Frequencies 1(AFH) ***Hopping mode: Enable & 8DPSK***



5. 20dBc BW

5.1. Test Setup

Refer to the APPENDIX I.

5.2. Limit

Limit: Not Applicable

5.3. Test Procedure

1. The 20dBcbandwidthwere measured with a spectrum analyzer connected to RF antenna connector(conducted measurement) while EUT was operating in transmit mode. The analyzer center frequency was set to the EUT carrier frequency, using the analyzer.

2. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using RBW ≥ 1% of the 20 dB bandwidth, VBW ≥RBW, Span = 3㎒.

5.4. Test Results

Ambient temperature : 21 ~ 22°C
Relative humidity : 45 ~ 47%

- L54SK2

Modulation	Tested Channel	20dBc BW (MHz)
GFSK	**Lowest**	0.800
	Middle	0.860
	Highest	0.800
π/4DQPSK	**Lowest**	1.190
	Middle	1.190
	Highest	1.180
8DPSK	**Lowest**	1.220
	Middle	1.240
	Highest	1.240

- L56VW2

Modulation	Tested Channel	20dBc BW (MHz)
GFSK	**Lowest**	0.800
	Middle	0.800
	Highest	0.780
π/4DQPSK	**Lowest**	1.190
	Middle	1.170
	Highest	1.190
8DPSK	**Lowest**	1.220
	Middle	1.240
	Highest	1.240

Note 1: See next pages for actual measured spectrum plots.

- L54SK2

20dBc Bandwidth ***Lowest Channel & Modulation: GFSK***

20dBc Bandwidth ***Middle Channel&Modulation: GFSK***

20dBc Bandwidth *Highest Channel&Modulation: GFSK*

20dBc Bandwidth *Lowest Channel&Modulation: π/4DQPSK*

20dBc Bandwidth *Middle Channel&Modulation: π/4DQPSK*

20dBc Bandwidth *Highest Channel &Modulation: π/4DQPSK*

20dBc Bandwidth *Lowest Channel&Modulation: 8DPSK*

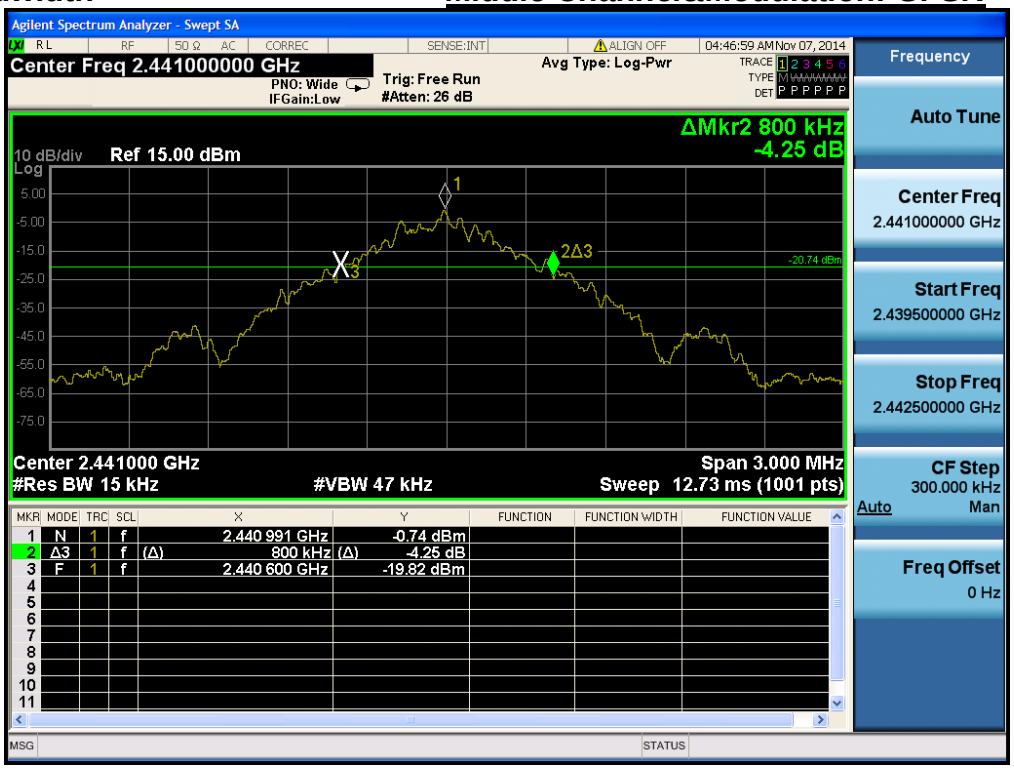
20dBc Bandwidth *Middle Channel&Modulation: 8DPSK*

20dBc Bandwidth ***Highest Channel &Modulation: 8DPSK***

- L56VW2

20dBc Bandwidth *Lowest Channel & Modulation: GFSK*

20dBc Bandwidth *Middle Channel&Modulation: GFSK*



20dBc Bandwidth ***Highest Channel&Modulation: GFSK***

20dBc Bandwidth ***Lowest Channel&Modulation: π/4DQPSK***

20dBc Bandwidth *Middle Channel&Modulation: π/4DQPSK*

20dBc Bandwidth *Highest Channel &Modulation: π/4DQPSK*

20dBc Bandwidth *Lowest Channel&Modulation: 8DPSK*

20dBc Bandwidth *Middle Channel&Modulation: 8DPSK*

20dBc Bandwidth ***Highest Channel &Modulation: 8DPSK***

6. Time of Occupancy (Dwell Time)

6.1. Test Setup

Refer to the APPENDIX I.

6.2. Limit

The maximum permissible time of occupancy is 400 ms within a period of 400 ms multiplied by the number of hopping channels employed.

6.3. Test Procedure

The dwell time was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.

The spectrum analyzer is set to:

Center frequency = 2441 MHz	Span = zero
RBW = 1 MHz	VBW = ≥ RBW
Trace = max hold	Detector function = peak

6.4. Test Results

Ambient temperature : 21 ~ 22°C
Relative humidity : 45 ~ 47 %

- L54SK2

- FH mode

Hopping mode	Packet Type	Number of hopping Channels	Burst On Time (ms)	Period (ms)	Test Result (sec)
Enable	DH 5	79	2.940	3.750	0.314
	2 DH 5	79	2.940	3.750	0.314
	3 DH 5	79	2.940	3.750	0.314

- AFH mode

Hopping mode	Packet Type	Number of hopping Channels	Burst On Time (ms)	Period (ms)	Test Result (sec)
Enable	DH 5	20	2.940	3.750	0.157
	2 DH 5	20	2.940	3.750	0.157
	3 DH 5	20	2.940	3.750	0.157

- L56VW2

- FH mode

Hopping mode	Packet Type	Number of hopping Channels	Burst On Time (ms)	Period (ms)	Test Result (sec)
Enable	DH 5	79	2.940	3.750	0.314
	2 DH 5	79	2.940	3.750	0.314
	3 DH 5	79	2.940	3.750	0.314

- AFH mode

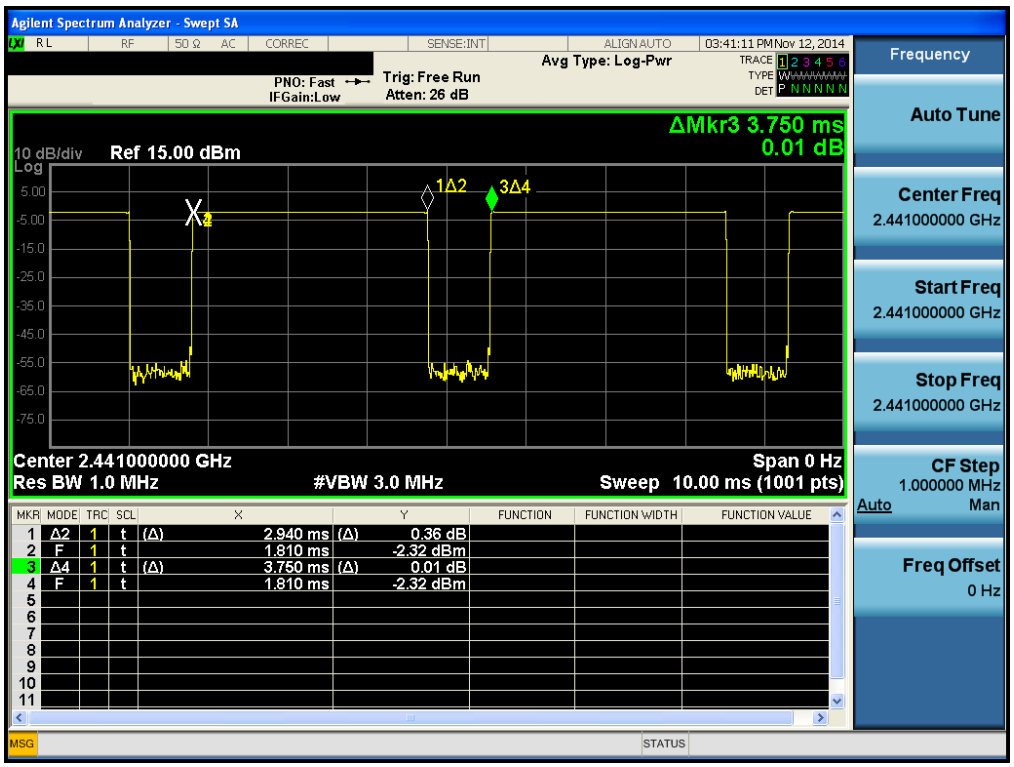
Hopping mode	Packet Type	Number of hopping Channels	Burst On Time (ms)	Period (ms)	Test Result (sec)
Enable	DH 5	20	2.940	3.750	0.157
	2 DH 5	20	2.940	3.750	0.157
	3 DH 5	20	2.940	3.750	0.157

Note 1: Dwell Time = 0.4 × Hopping channel × Burst ON time × ((Hopping rate ÷ Time slots) ÷ Hopping channel)
- Time slots for DH5 = 6 slots(TX = 5 slot / RX = 1 slot)
- Hopping Rate = 1600 for FH mode & 800 for AFH mode

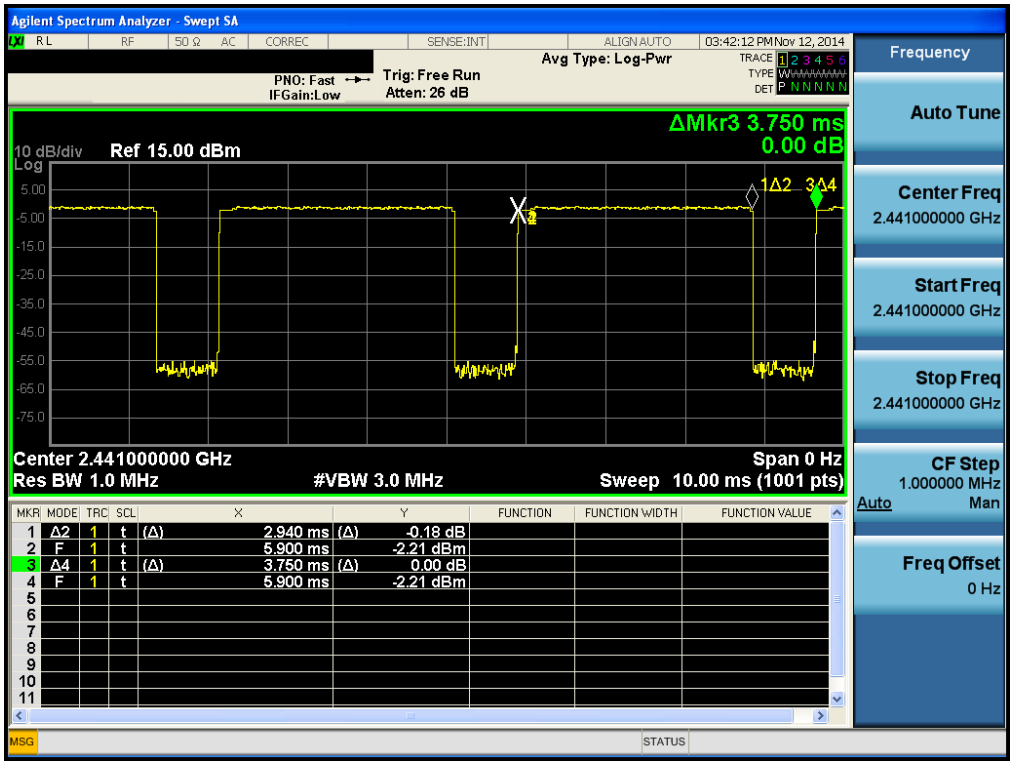
Note 2: See next pages for actual measured spectrum plots.

- L54SK2

Time of Occupancy (FH) ***Hopping mode: Enable&GFSK***

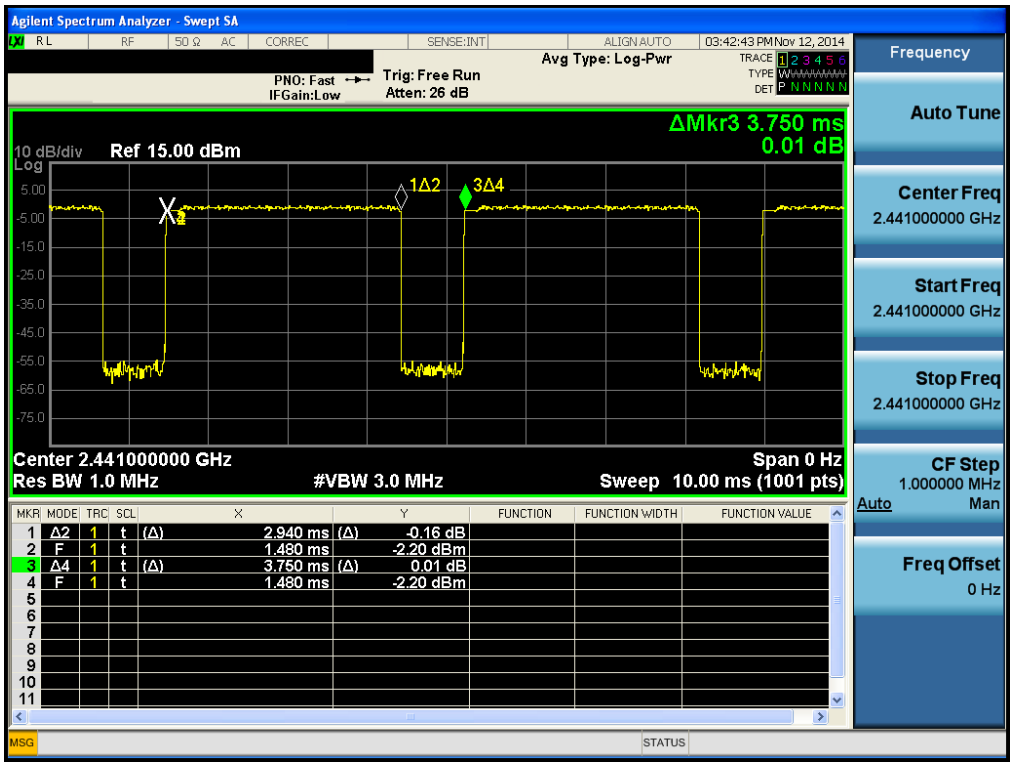


Time of Occupancy (FH) ***Hopping mode: Enable&π/4-DQPSK***

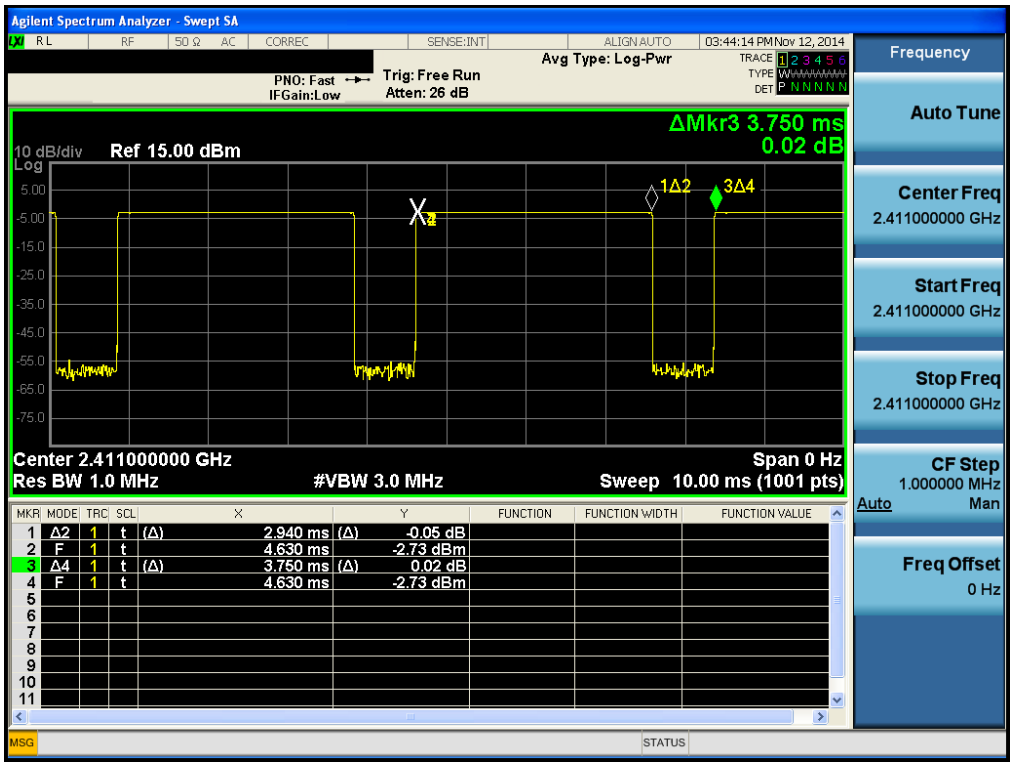


Time of Occupancy (FH)

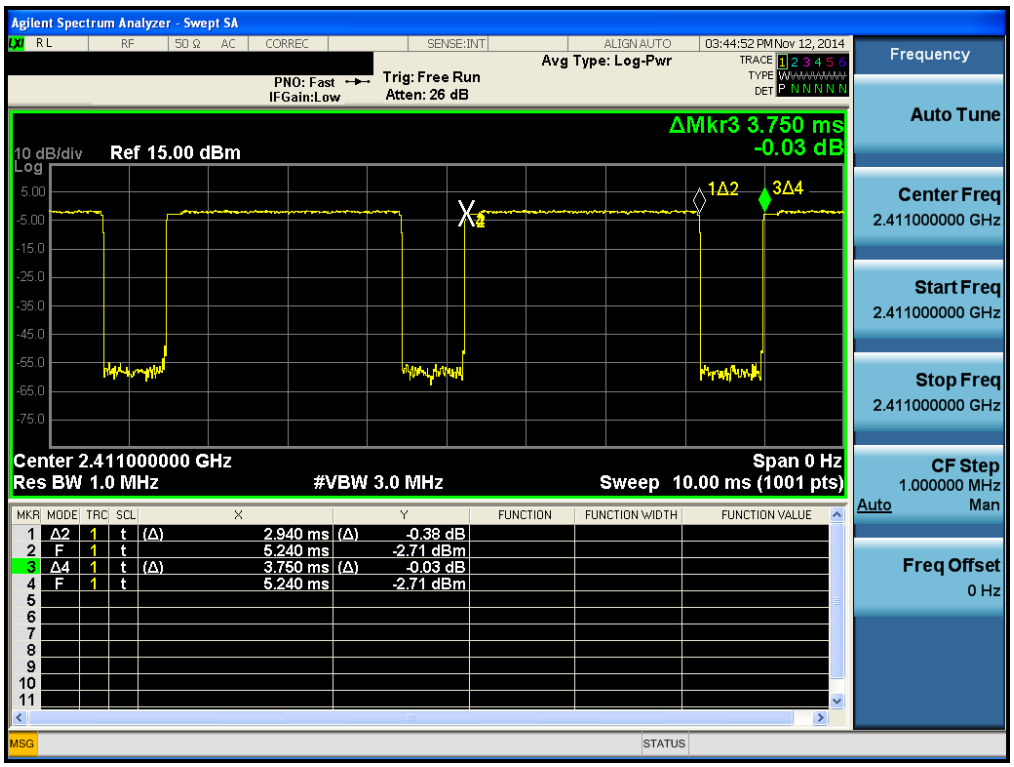
Hopping mode: Enable&8DPSK



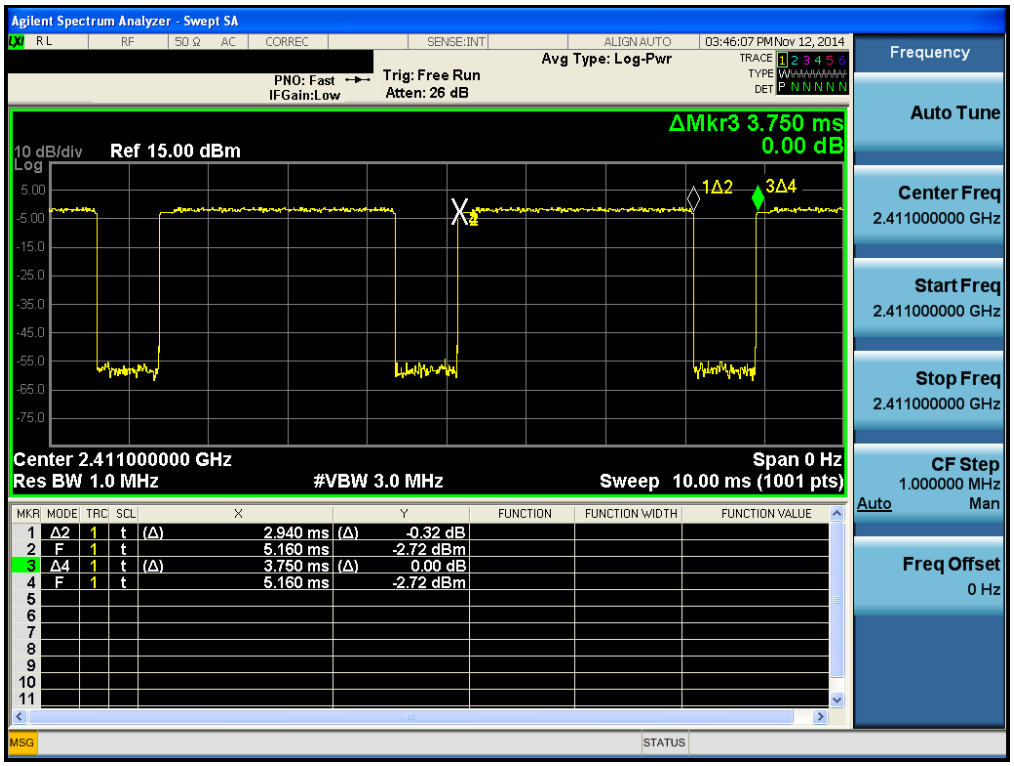
Time of Occupancy (AFH) ***Hopping mode: Enable&GFSK***



Time of Occupancy (AFH) ***Hopping mode: Enable&π/4-DQPSK***

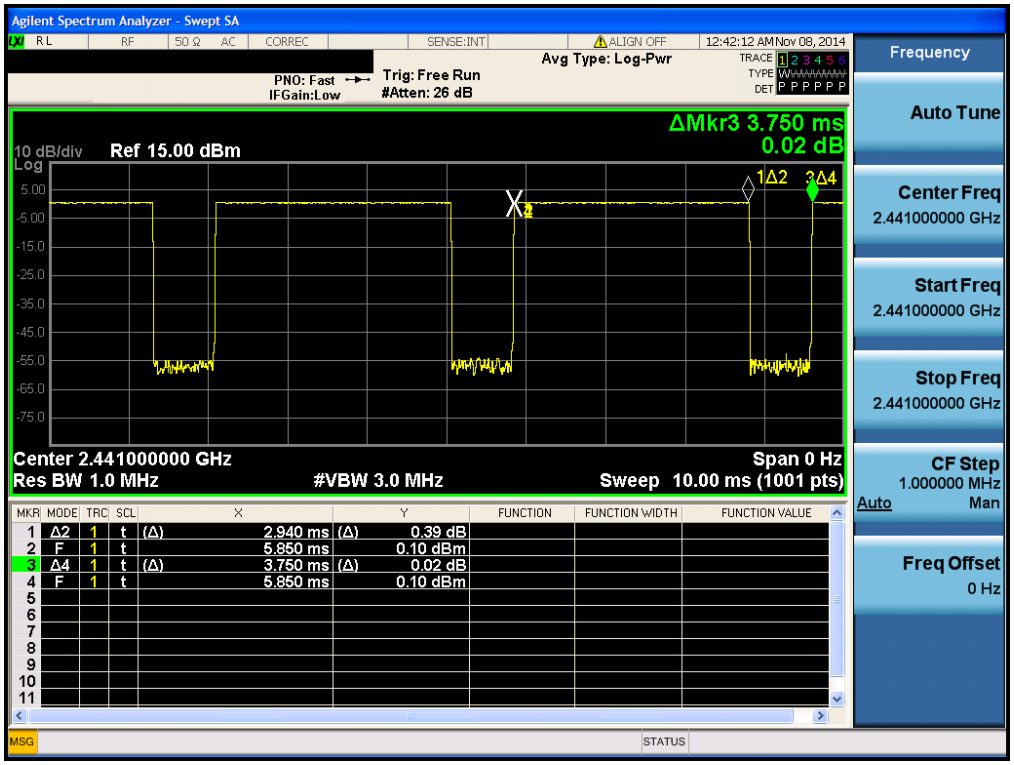


Time of Occupancy (AFH) ***Hopping mode: Enable&8DPSK***

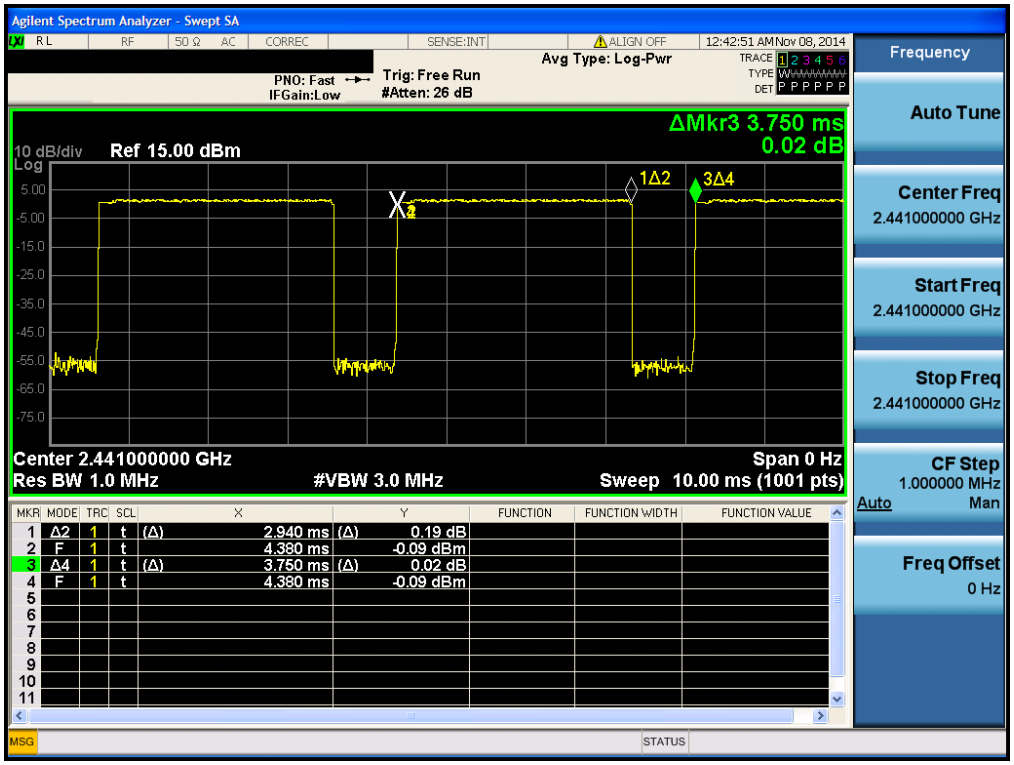


- L56VW2

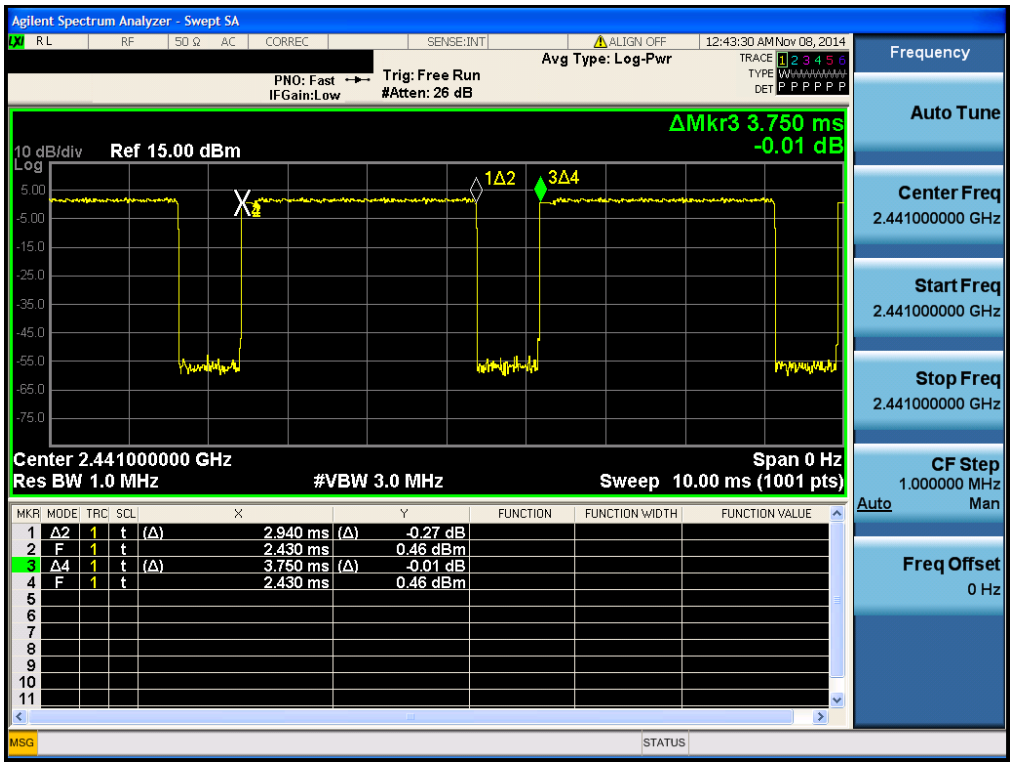
Time of Occupancy (FH) ***Hopping mode: Enable&GFSK***



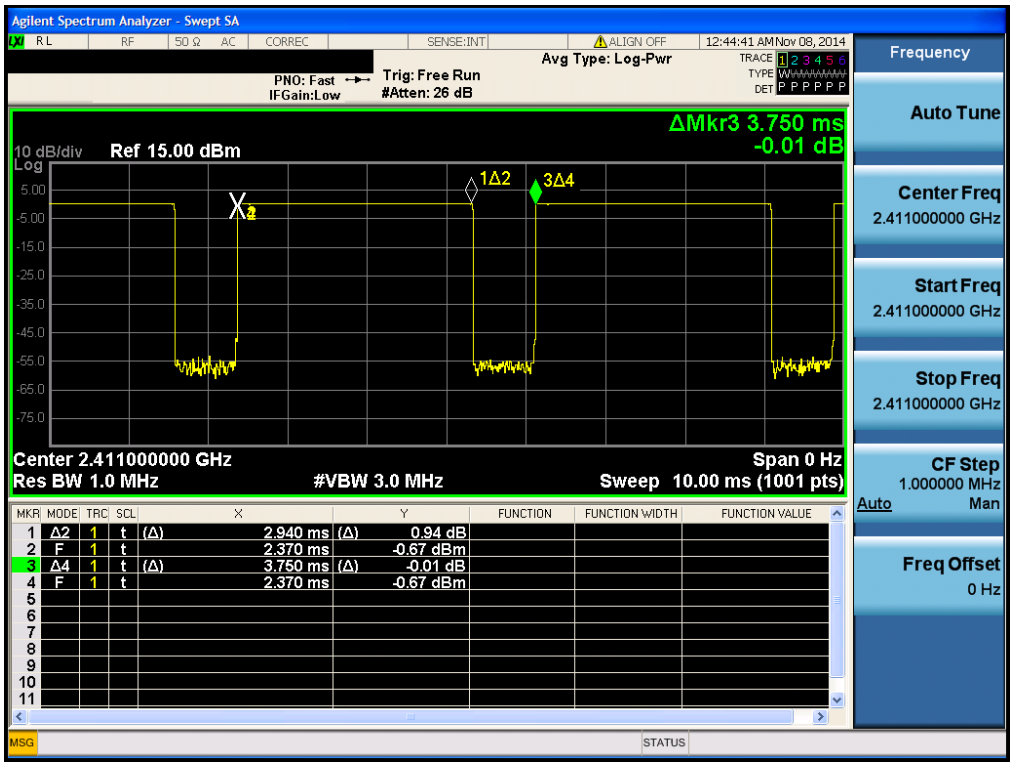
Time of Occupancy (FH) ***Hopping mode: Enable&π/4-DQPSK***



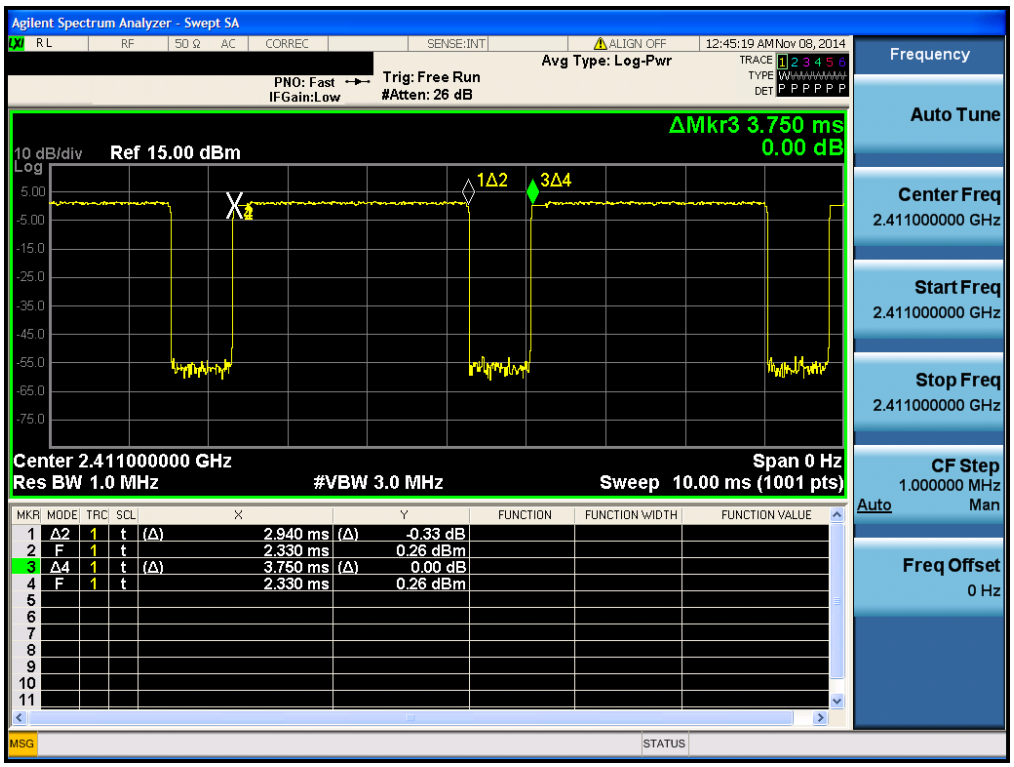
Time of Occupancy (FH) ***Hopping mode: Enable&8DPSK***



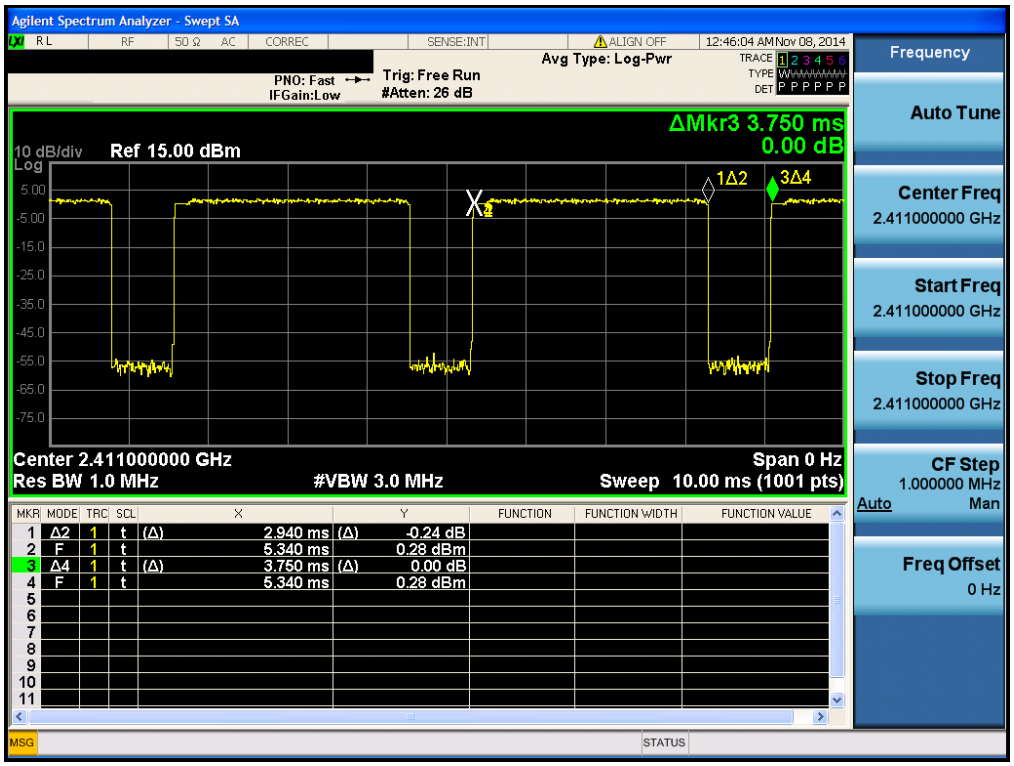
Time of Occupancy (AFH) ***Hopping mode: Enable&GFSK***



Time of Occupancy (AFH) ***Hopping mode: Enable&π/4-DQPSK***



Time of Occupancy (AFH) ***Hopping mode: Enable&8DPSK***



7. Maximum Peak Output Power Measurement

7.1. Test Setup

Refer to the APPENDIX I.

7.2. Limit

The maximum peak output power of the intentional radiator shall not exceed the following :

1. §15.247(a)(1), Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 ㎑ or the 20 ㏈ bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 ㎽.

2. §15.247(b)(1), For frequency hopping systems operating in the 2 400 – 2 483.5 ㎒ employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5 725 – 5 805 ㎒ band: 1 Watt.

7.3. Test Procedure

1. The RF power output was measured with a Spectrum analyzer connected to the RF Antenna connector (conducted measurement) while EUT was operating in transmit mode at the appropriate center frequency, A spectrum analyzer was used to record the shape of the transmit signal.

2. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using ;
   Span = approximately 5 times of the 20 ㏈bandwidth, centered on a hopping channel
   RBW ≥ 20㏈BW
   VBW ≥ RBW
   Sweep = auto
   Detector function = peak
   Trace = max hold

7.4. Test Results

Ambient temperature : 21 ~ 22°C
Relative humidity : 45 ~ 47 %

- L54SK2

Modulation	Tested Channel	Peak Output Power	
		dBm	mW
GFSK	**Lowest**	-2.100	0.617
	Middle	**-1.510**	**0.706**
	Highest	-1.630	0.687
π/4DQPSK	**Lowest**	-0.440	0.904
	Middle	**0.090**	**1.021**
	Highest	-0.080	0.982
8DPSK	**Lowest**	-0.090	0.979
	Middle	**0.350**	**1.084**
	Highest	0.250	1.059

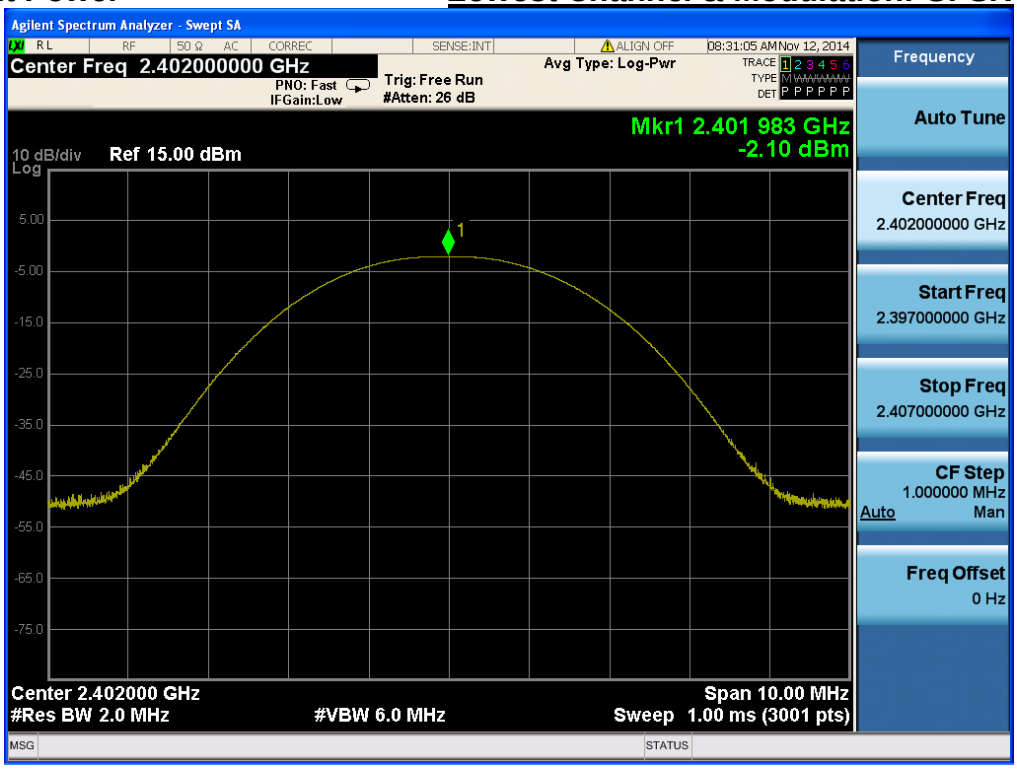
- L56VW2

Modulation	Tested Channel	Peak Output Power	
		dBm	mW
GFSK	**Lowest**	0.250	1.059
	Middle	0.650	1.161
	Highest	**0.730**	**1.183**
π/4DQPSK	**Lowest**	1.920	1.556
	Middle	2.220	1.667
	Highest	**2.480**	**1.770**
8DPSK	**Lowest**	2.350	1.718
	Middle	2.650	1.841
	Highest	**2.950**	**1.972**

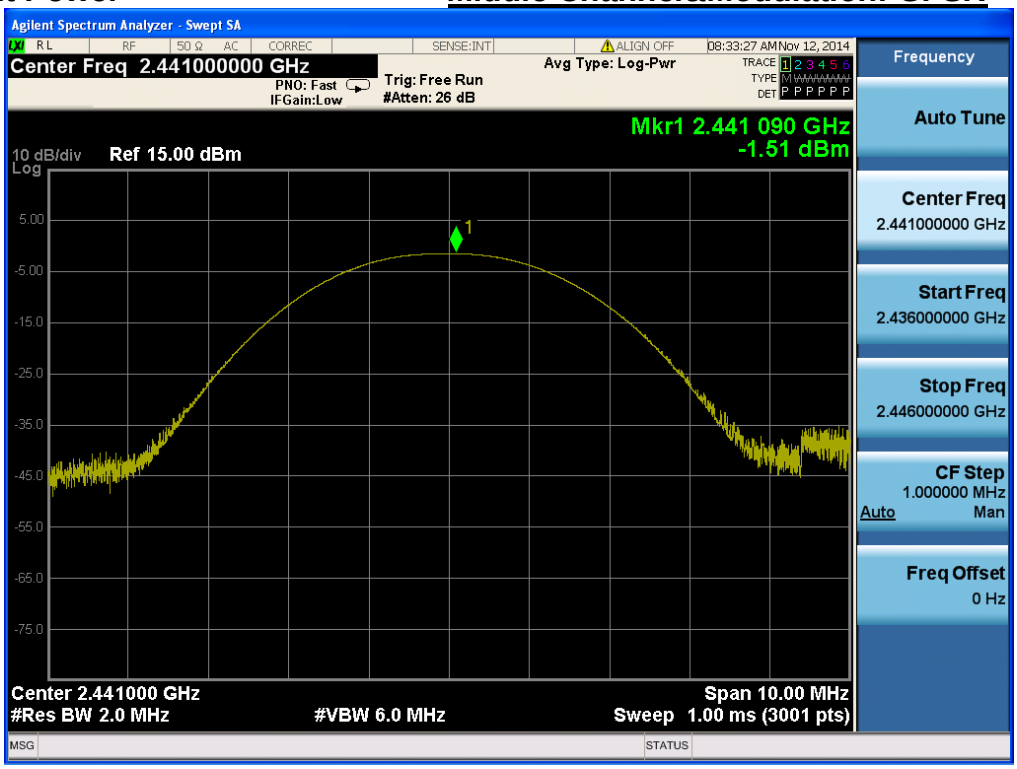
Note 1: See next pages for actual measured spectrum plots.

- L54SK2

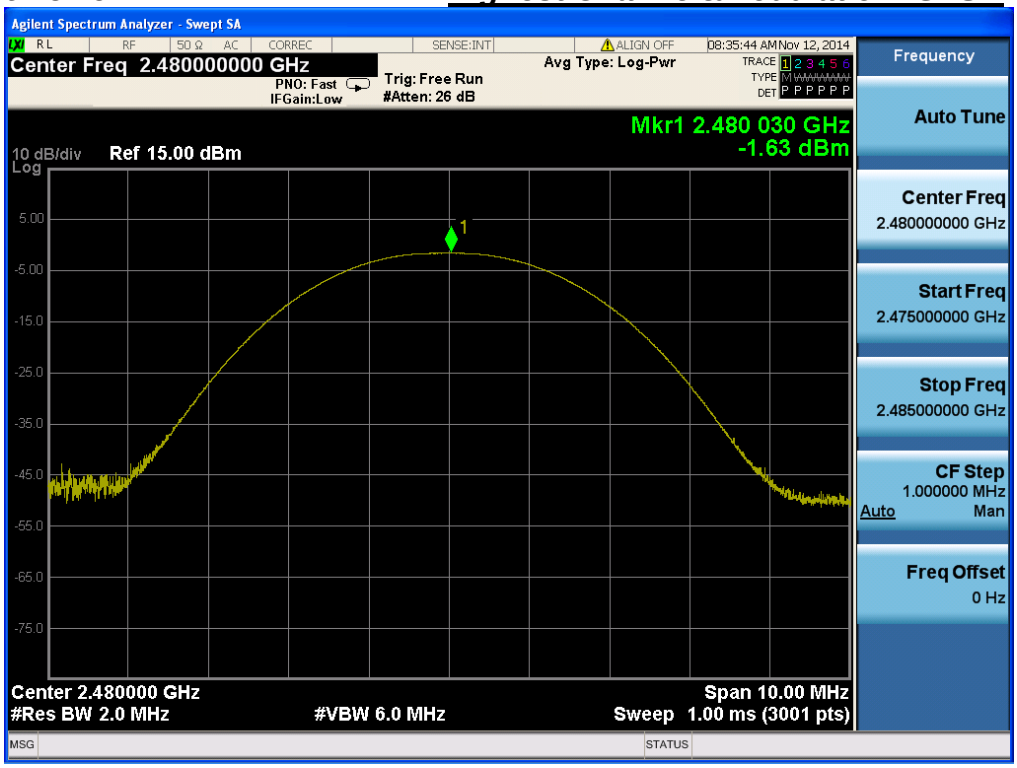
Peak Output Power ***Lowest Channel & Modulation: GFSK***



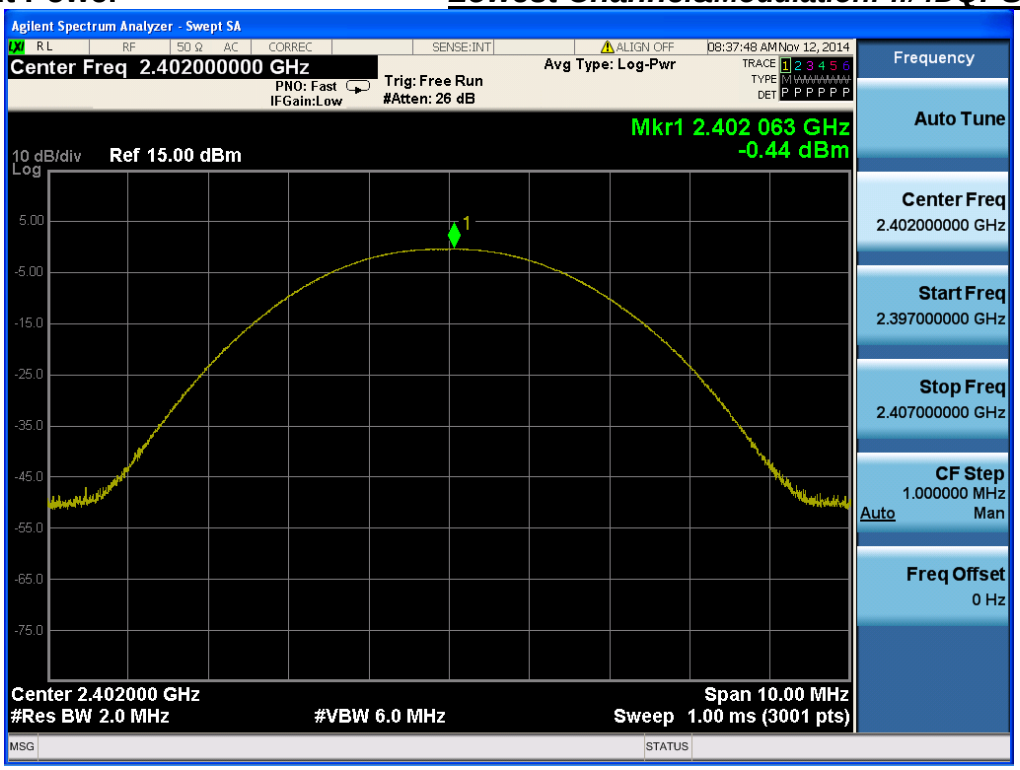
Peak Output Power ***Middle Channel&Modulation: GFSK***



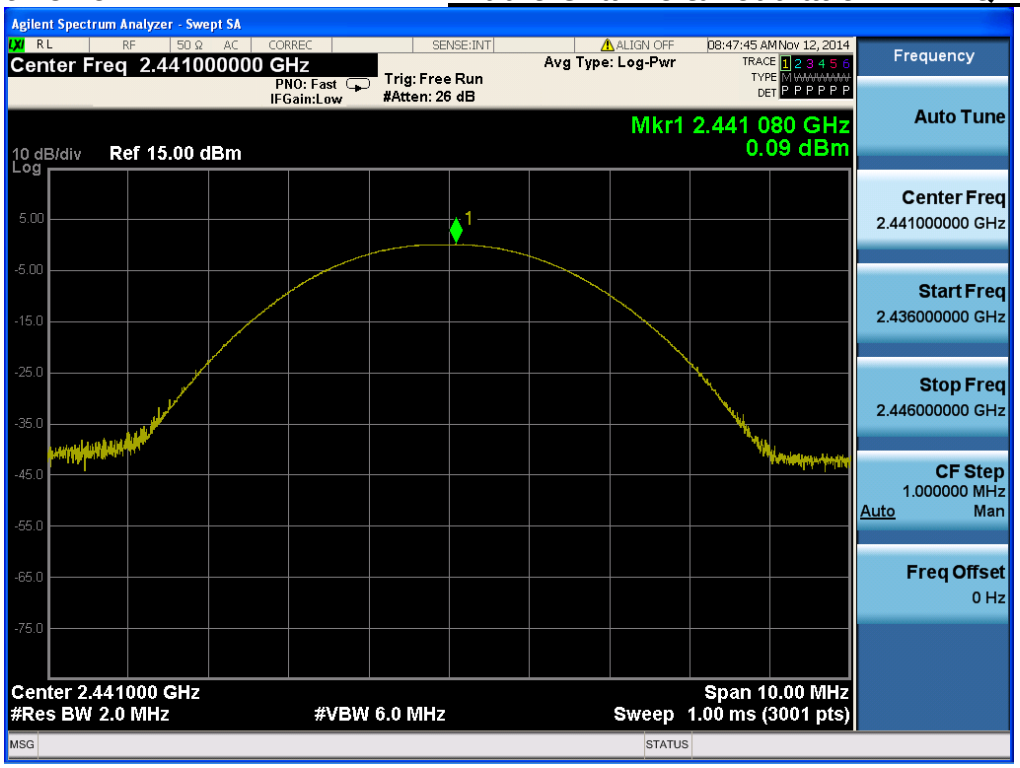
Peak Output Power ***Highest Channel&Modulation: GFSK***



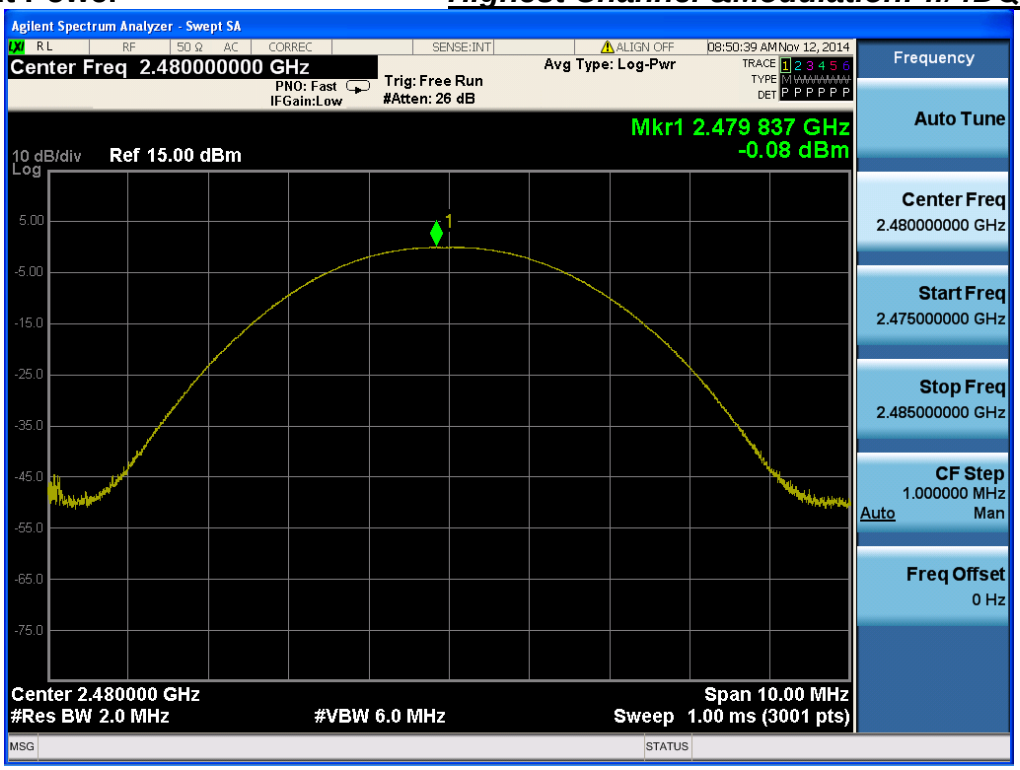
Peak Output Power ***Lowest Channel&Modulation: π/4DQPSK***



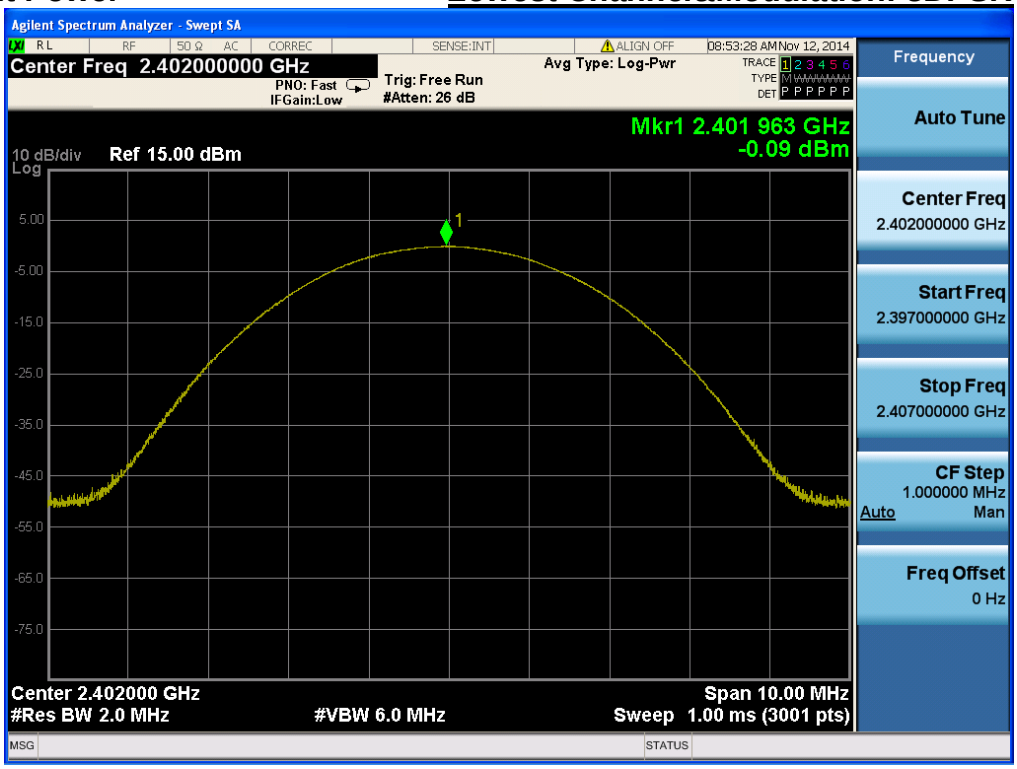
Peak Output Power ***Middle Channel&Modulation: π/4DQPSK***



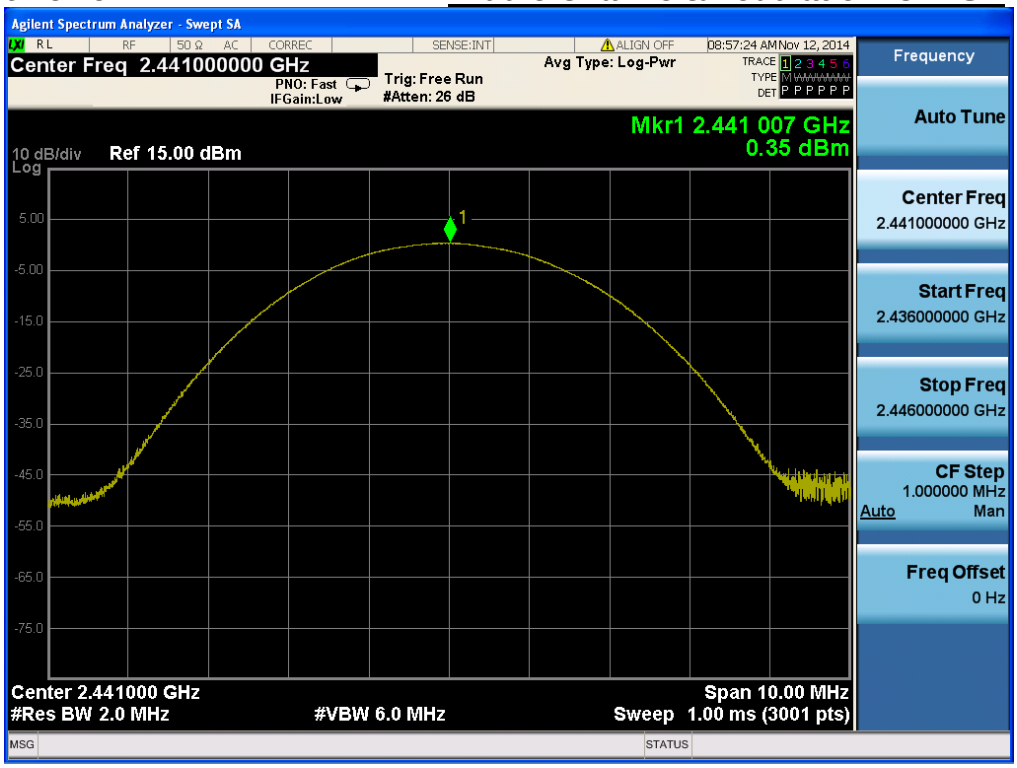
Peak Output Power ***Highest Channel &Modulation: π/4DQPSK***



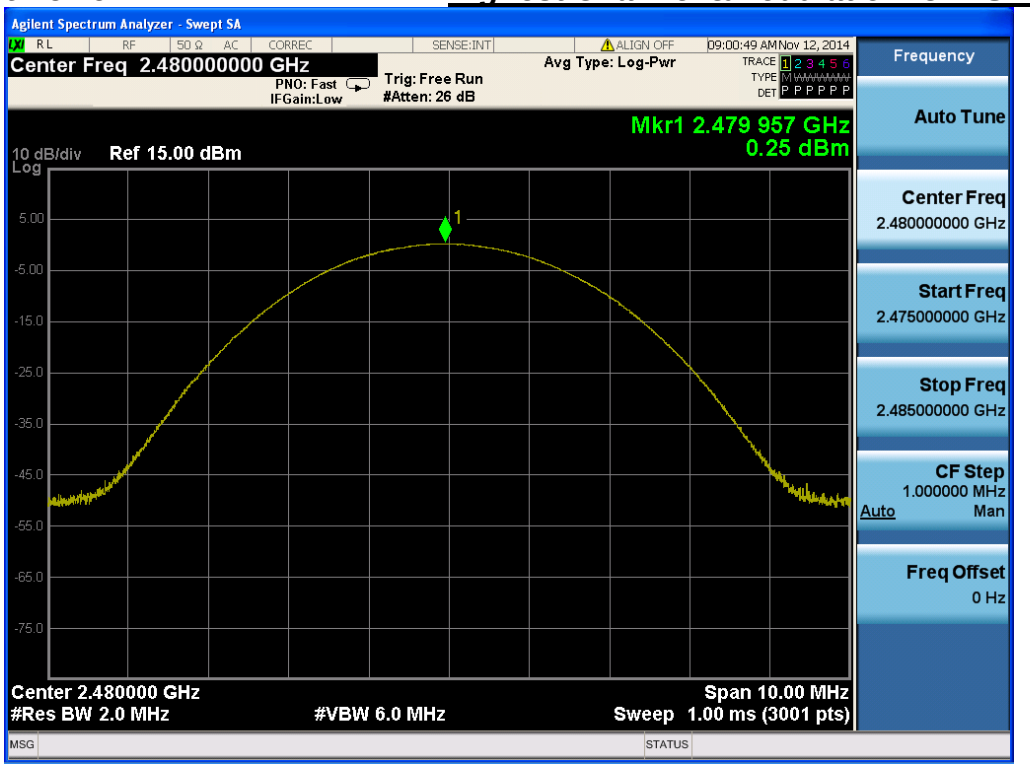
Peak Output Power ***Lowest Channel&Modulation: 8DPSK***



Peak Output Power ***Middle Channel&Modulation: 8DPSK***

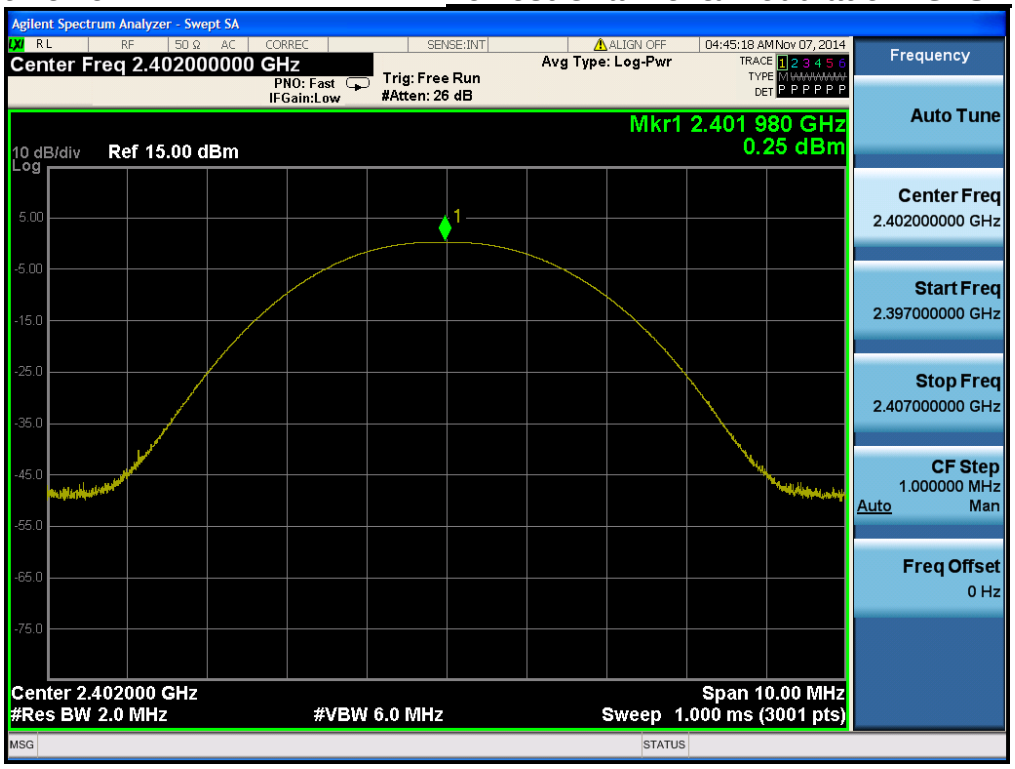


Peak Output Power ***Highest Channel &Modulation: 8DPSK***

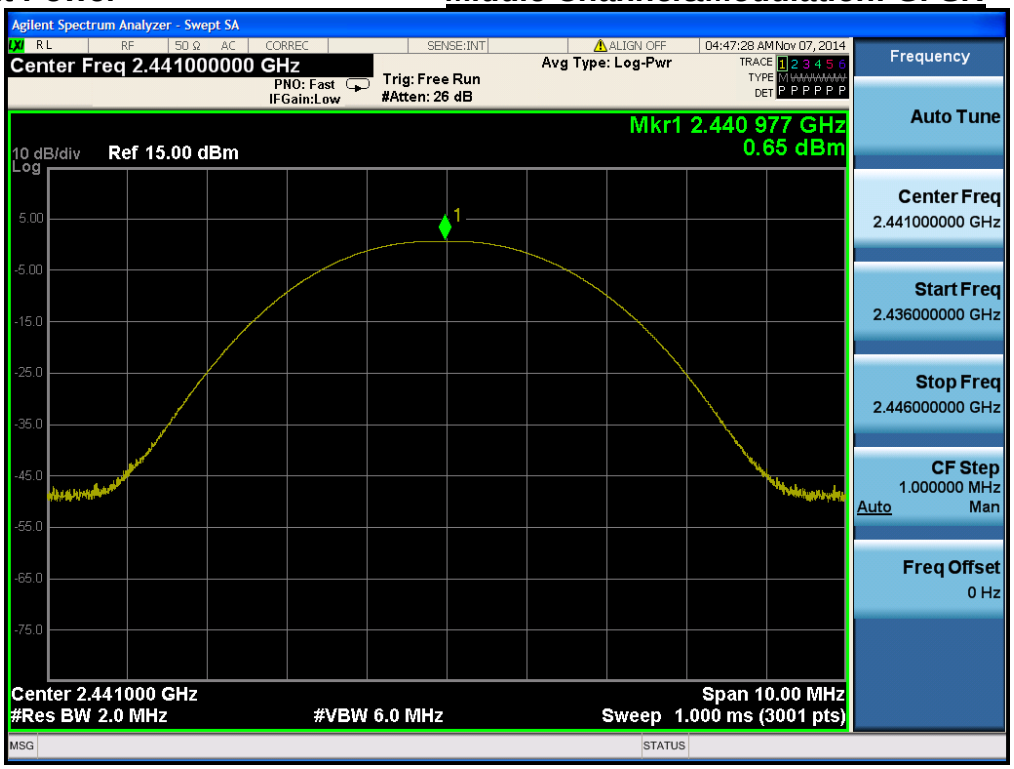


- L56VW2

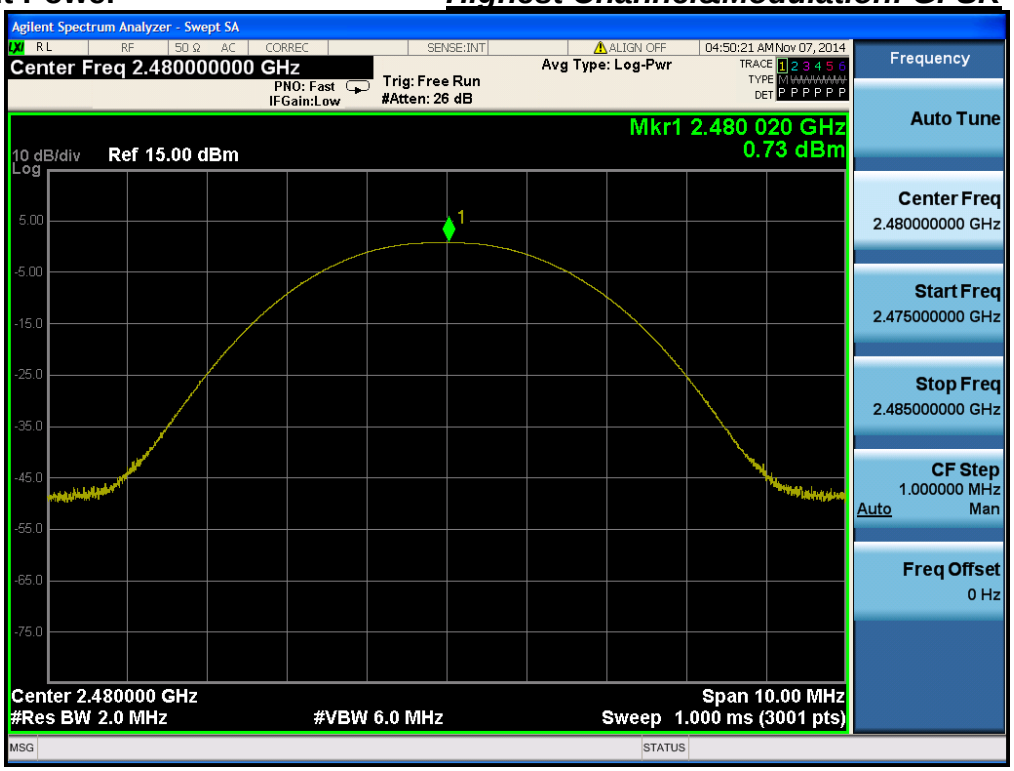
Peak Output Power ***Lowest Channel & Modulation: GFSK***



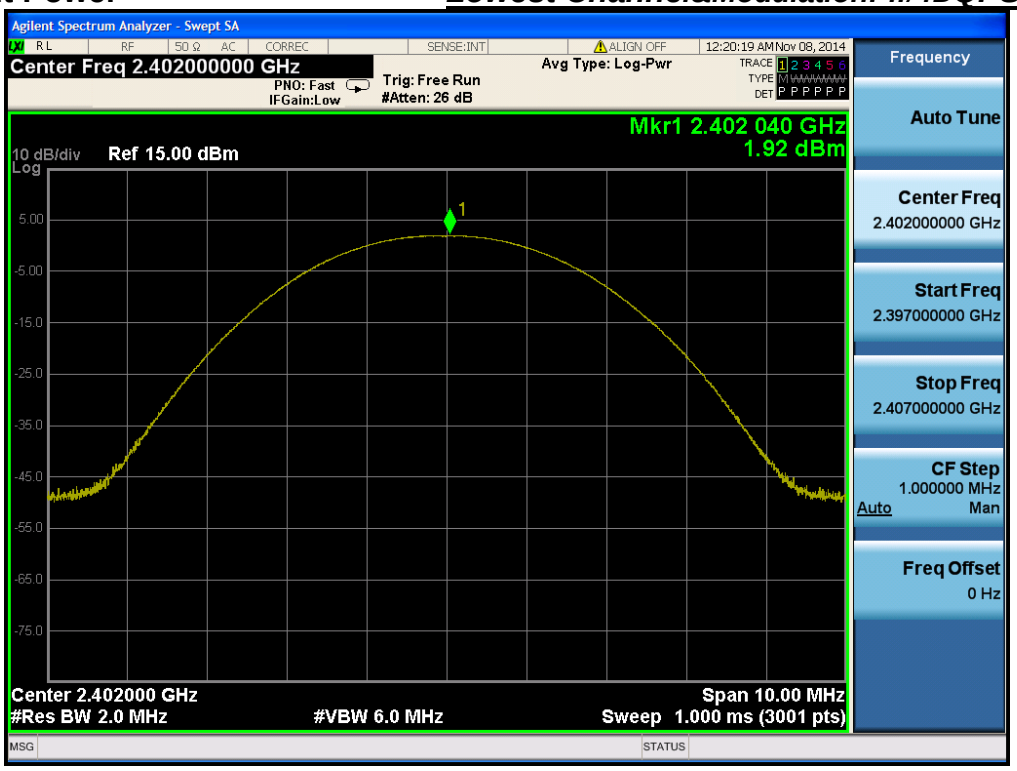
Peak Output Power ***Middle Channel&Modulation: GFSK***



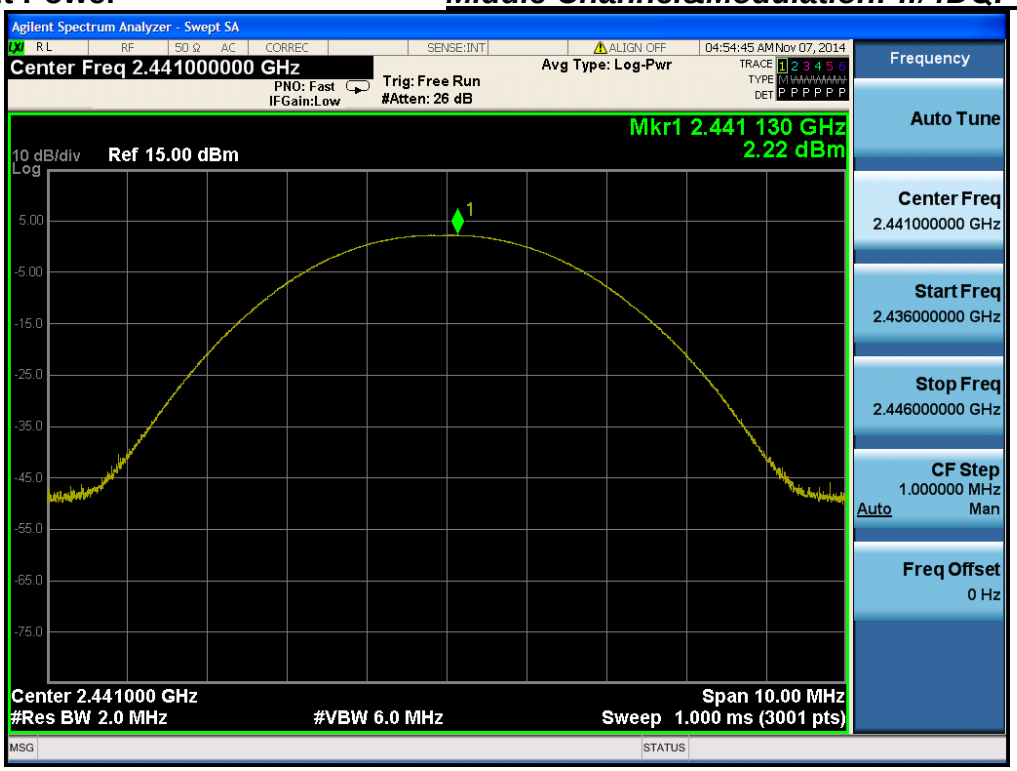
Peak Output Power ***Highest Channel&Modulation: GFSK***



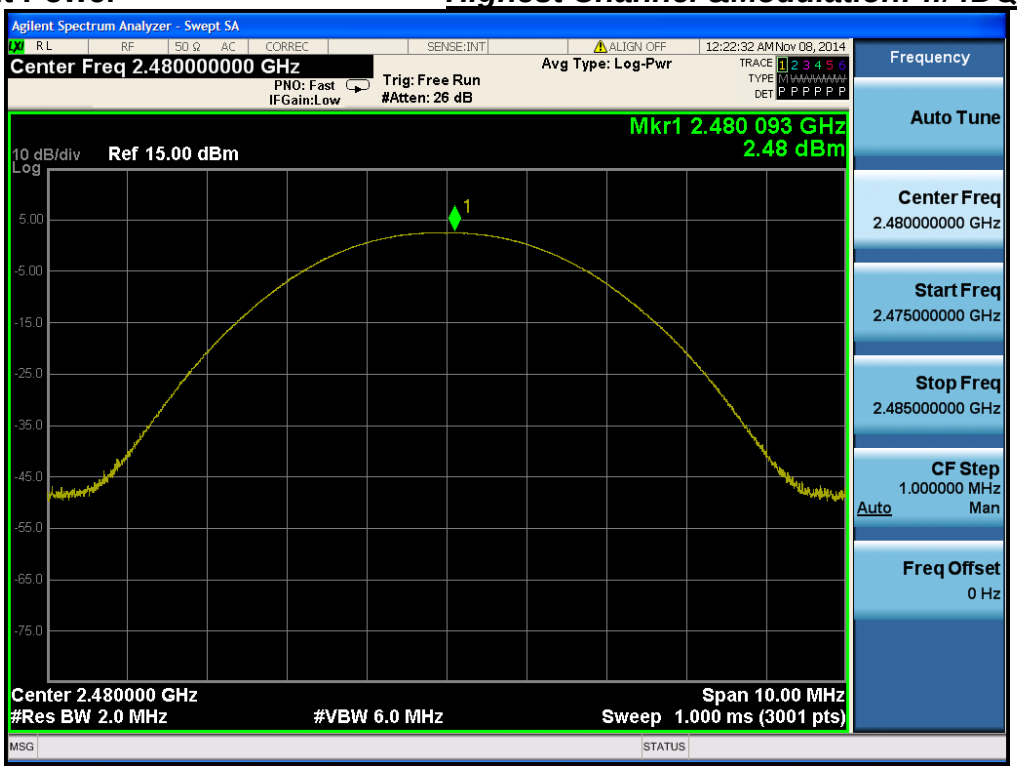
Peak Output Power ***Lowest Channel&Modulation: π/4DQPSK***



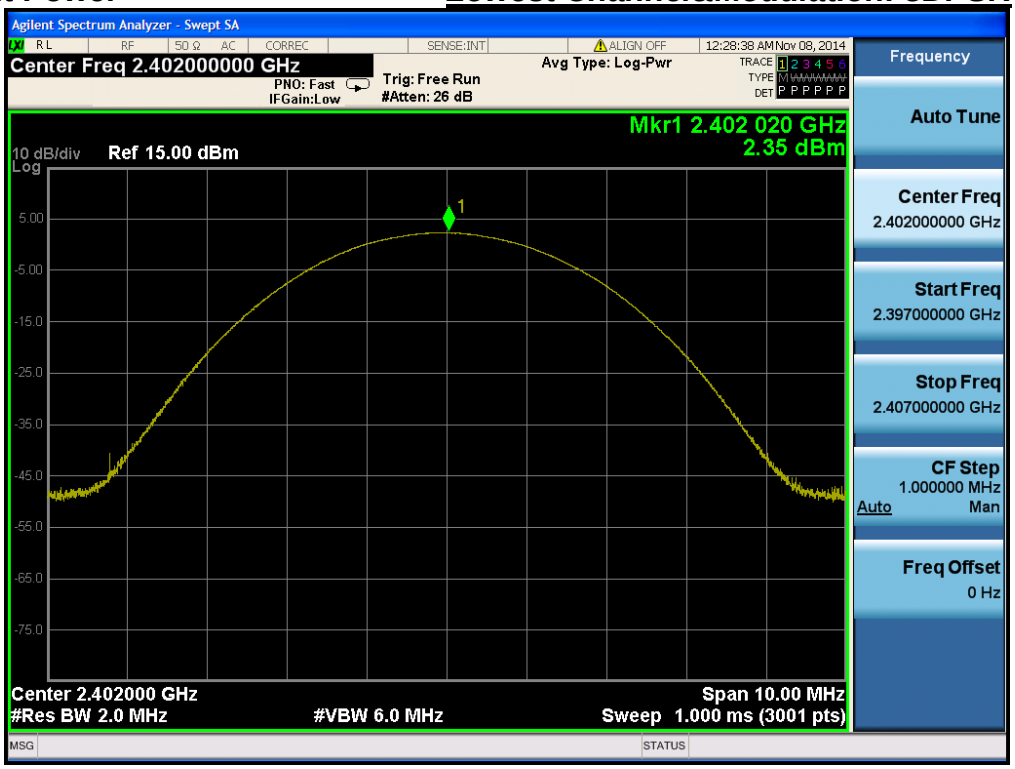
Peak Output Power ***Middle Channel&Modulation: π/4DQPSK***



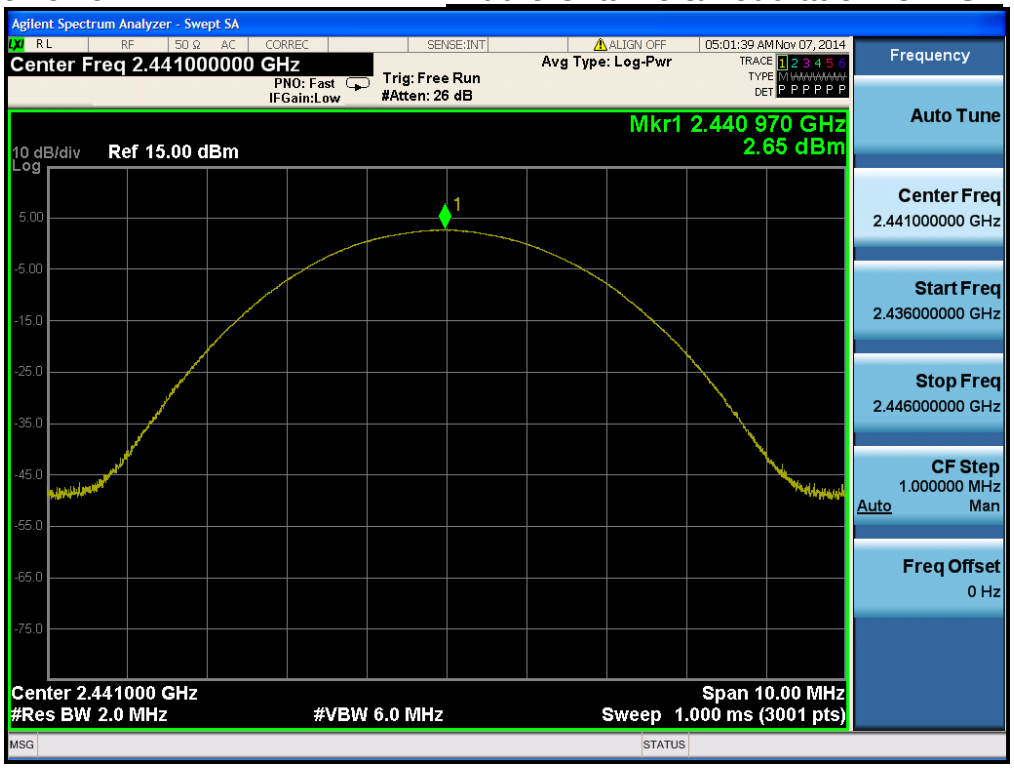
Peak Output Power ***Highest Channel &Modulation: π/4DQPSK***



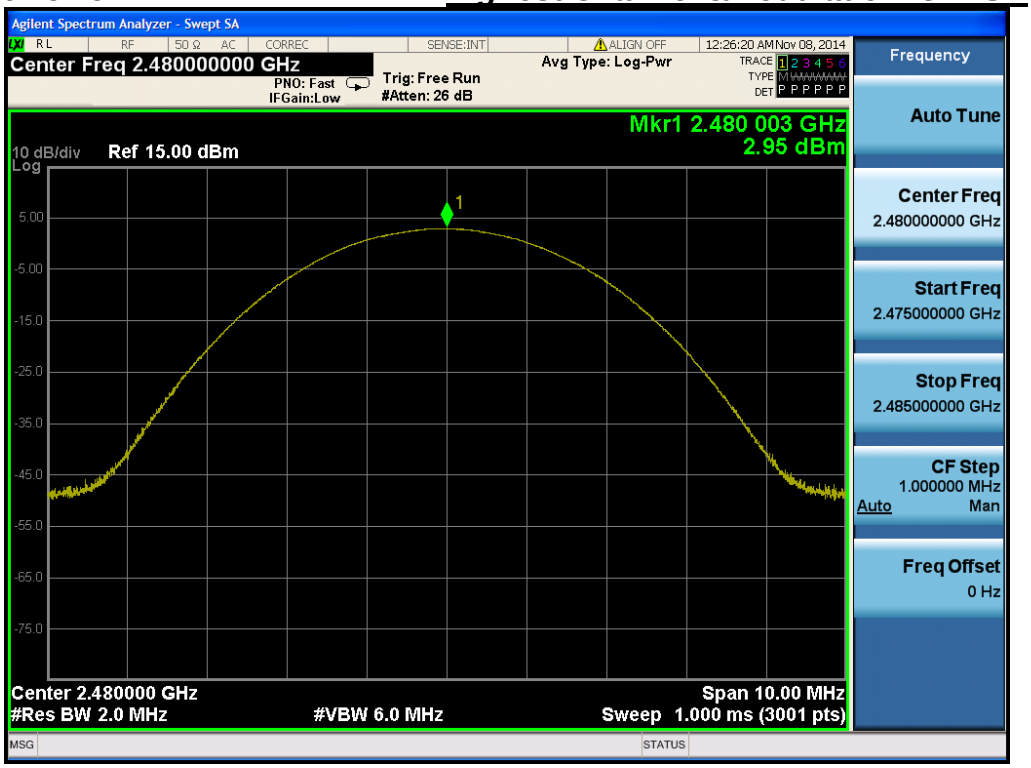
Peak Output Power ***Lowest Channel&Modulation: 8DPSK***



Peak Output Power ***Middle Channel&Modulation: 8DPSK***



Peak Output Power ***Highest Channel &Modulation: 8DPSK***



8. Transmitter AC Power Line Conducted Emission

8.1. Test Setup

Refer to test setup photo.

8.2. Limit

According to §15.207(a) for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 ㎑ to 30 ㎒, shall not exceed the limits in the following table, as measured using a 50 uH/50 ohm line impedance stabilization network(LISN).
Compliance with the provision of this paragraph shall on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower applies at the boundary between the frequency ranges.

Frequency Range (MHz)	Conducted Limit (dBuV)	
	Quasi-Peak	Average
0.15 ~ 0.5	66 to 56 *	56 to 46 *
0.5 ~ 5	56	46
5 ~ 30	60	50

* Decreases with the logarithm of the frequency

8.3. Test Procedures

Conducted emissions from the EUT were measured according to the ANSI C63.10-2009

1. The test procedure is performed in a 6.5 m × 3.5 m × 3.5 m (L × W × H) shielded room. The EUT along with its peripherals were placed on a 1.0 m (W) × 1.5 m (L) and 0.8 m in height wooden table and the EUT was adjusted to maintain a 0.4 meter space from a vertical reference plane.
2. The EUT was connected to power mains through a line impedance stabilization network (LISN) which provides 50 ohm coupling impedance for measuring instrument and the chassis ground was bounded to the horizontal ground plane of shielded room.
3. All peripherals were connected to the second LISN and the chassis ground also bounded to the horizontal ground plane of shielded room.
4. The excess power cable between the EUT and the LISN was bundled. The power cables of peripherals were unbundled. All connecting cables of EUT and peripherals were moved to find the maximum emission.

8.4. Test Results: NA

9. Antenna Requirement

▣ **Procedure:**

Describe how the EUT complies with the requirement that either its antenna is permanently attached, or that it employs a unique antenna connector, for every antenna proposed for use with the EUT.

▣ **Conclusion: Comply**

The internal antenna is attached on the main PCB using soldering. (Refer to Internal Photo file.)

▣ **Minimum Standard:**

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device.The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions.

10. Occupied Bandwidth(99%)

- Procedure:(RSS-Gen Issue 3)
- The 99% power bandwidth was measured with a calibrated spectrum analyzer.
- Spectrum analyzer plots are included on the following pages.

- Measurement Data: NA

- **Minimum Standard:**

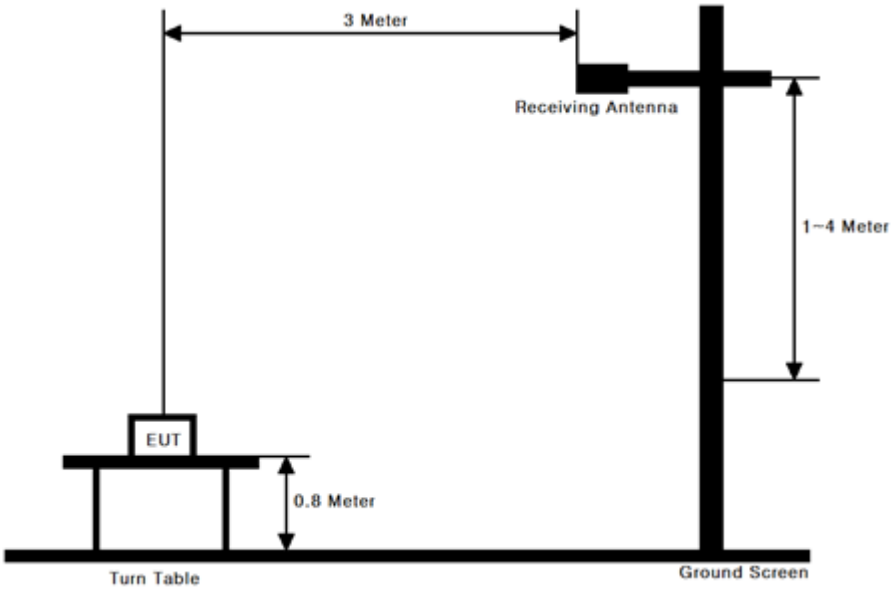
NA

APPENDIX I

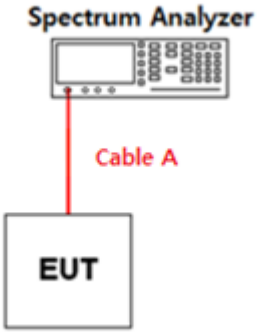
Test set up Diagrams&Path lossInformation

▪Radiated Measurement

The diagram below shows the test setup that is utilized to make the measurements for emission from 9kHz to 25GHz Emissions.



▪Conducted Measurement



Path loss information

Frequency (GHz)	Path Loss (dB)	Frequency (GHz)	Path Loss (dB)
0.03	0.03	15	1.22
1	0.21	20	1.54
2.402 & 2.441 & 2.480	0.54	25	2.05
5	0.60	-	-
10	0.92	-	-

Note. 1: The path loss from EUT to Spectrum analyzer were measured and used for test.
Path loss (= S/A's Correction factor) = Cable A