

Appendix A: Test results. Bluetooth EDR (GFSK, $\pi/4$ DQPSK, 8DPSK)

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TEST CONDITIONS

POWER SUPPLY (V):

V nominal: 12 Vdc.

Type of Power Supply: External power supply (Battery).

Type of Antenna: External antenna.

Declared Gain for antenna RF port 3 (maximum): 0.7 dBi (Antenna gain plus antenna cable loss).

TEST

TEST FREQUENCIES:

Low Channel: 2402 MHz

Middle Channel: 2441 MHz

High Channel: 2480 MHz

CONDUCTED MEASUREMENTS:

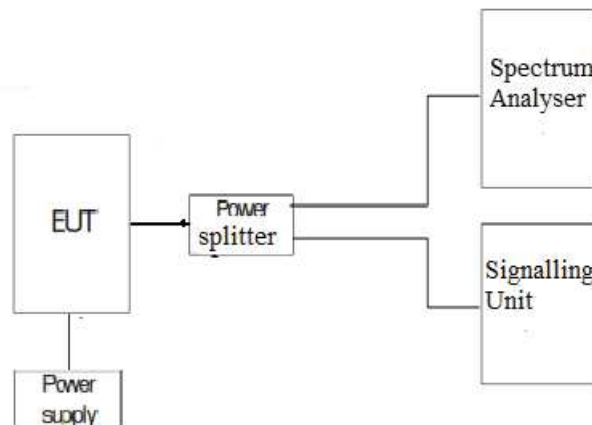
Hopping mode OFF:

The equipment under test was set up in a shielded room and it is connected to the spectrum analyser using a low loss RF cable. The reading of the spectrum analyser is corrected taking into account the cable loss.



Hopping mode ON:

The equipment under test was set up in a shielded room and it is connected to a Bluetooth signalling unit (Bluetooth test set) and to the spectrum analyzer using a 6 dB power splitter. The reading in the spectrum analyzer is corrected taking into account the power splitter loss.



The DC supply voltage is applied using an external calibrated power supply with a multimeter.

RADIATED MEASUREMENTS

All radiated tests were performed in a semi-anechoic chamber. The measurement antenna is situated at a distance of 3 m for the frequency range 30 MHz-1000 MHz (30 MHz-1000 MHz Bilog antenna) and at a distance of 1m for the frequency range 1 GHz-25 GHz (1 GHz-18 GHz Double ridge horn antenna and 18 GHz-40 GHz horn antenna).

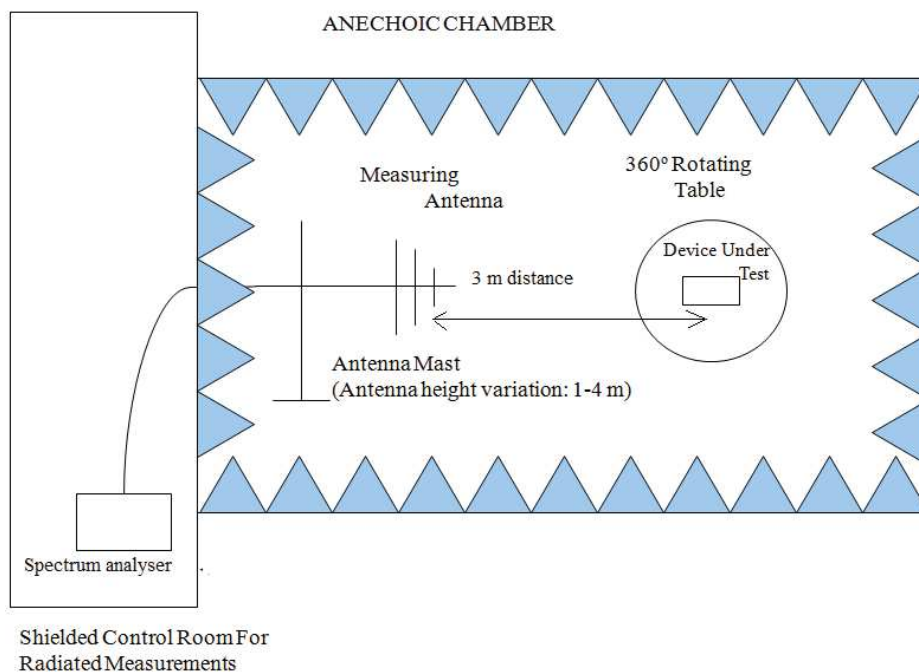
For radiated emissions in the range 1 GHz-25 GHz that is performed at a distance closer than the specified distance, an inverse proportionality factor of 20 dB per decade is used to normalize the measured data for determining compliance.

The equipment under test was set up on a non-conductive platform above the ground plane and the situation and orientation was varied to find the maximum radiated emission.

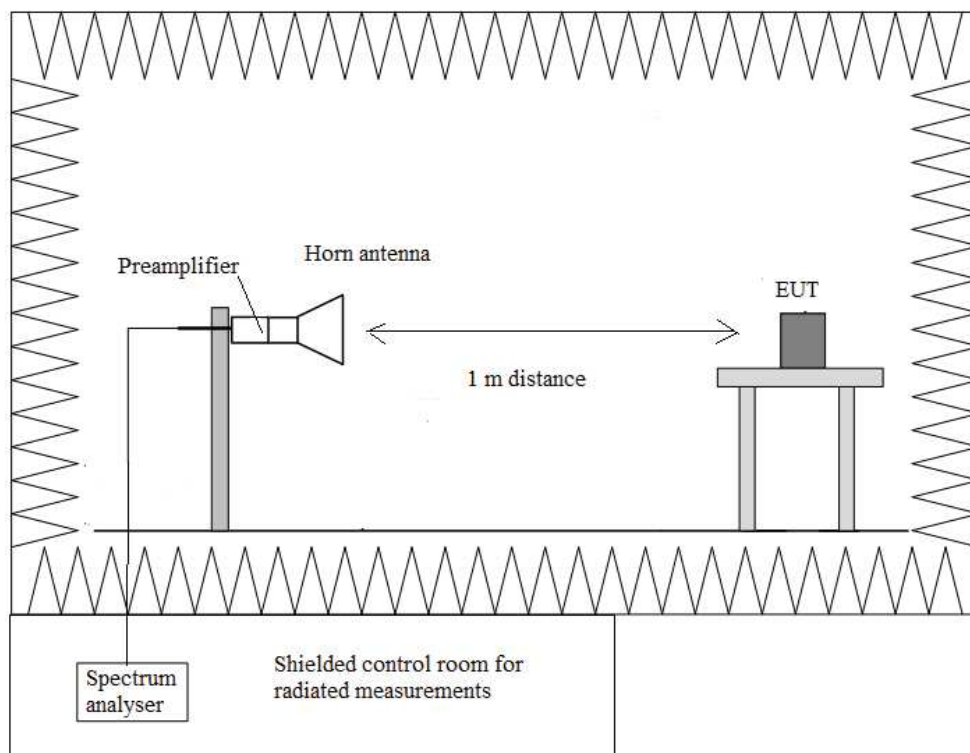
It was also rotated 360° and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission.

Measurements were made in both horizontal and vertical planes of polarization.

Radiated measurements setup from 30 MHz to 1 GHz:



Radiated measurements setup $f > 1$ GHz:



FCC section 15.247 Subclause (a) (1) / RSS-247 5.1 (b). 20 dB Bandwidth and Carrier frequency separation

SPECIFICATION:

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.

RESULTS:

- GFSK**

	Low Channel 2402 MHz	Middle Channel 2441 MHz	High Channel 2480 MHz
20 dB Spectrum Bandwidth (kHz)	942	945	940
99% Bandwidth (kHz)	888	888	885
Measurement uncertainty (kHz)	<±1.8		

- Pi/4 DQPSK**

	Low Channel 2402 MHz	Middle Channel 2441 MHz	High Channel 2480 MHz
20 dB Spectrum Bandwidth (kHz)	1356	1352	1360
99% Bandwidth (kHz)	1208	1212	1208
Measurement uncertainty (kHz)	<±1.8		

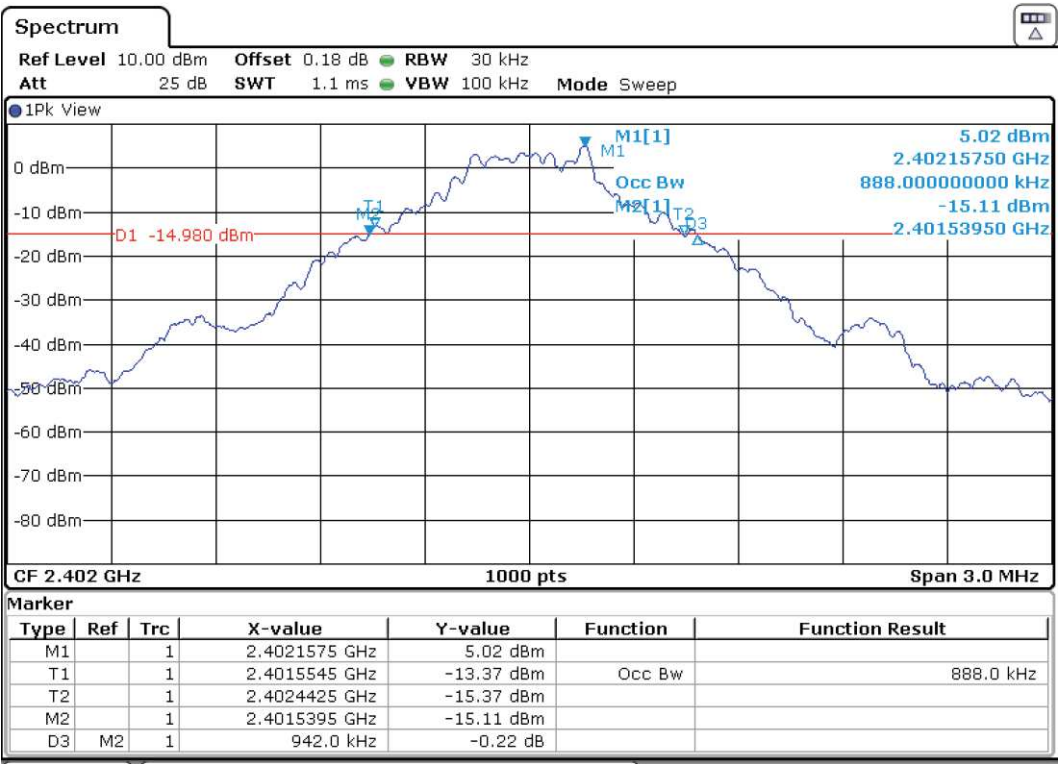
- 8DPSK**

	Low Channel 2402 MHz	Middle Channel 2441 MHz	High Channel 2480 MHz
20 dB Spectrum Bandwidth (kHz)	1328	1336	1336
99% Bandwidth (kHz)	1200	1204	1204
Measurement uncertainty (kHz)	<±1.8		

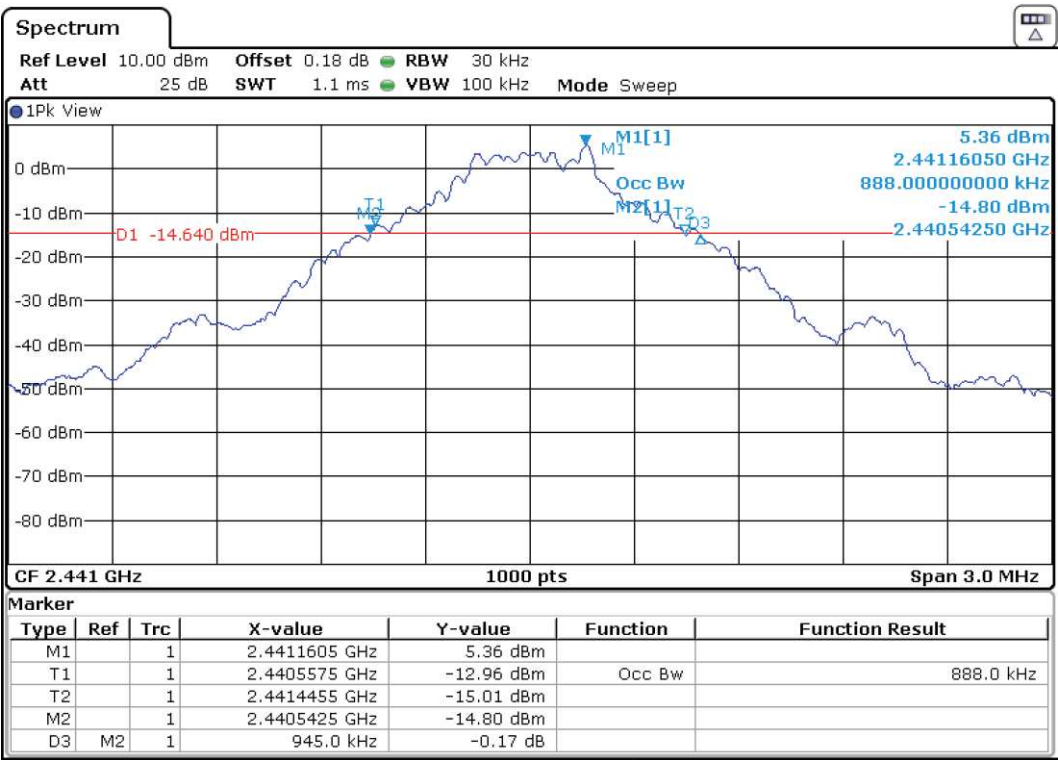
Verdict: PASS

GFSK – Bandwidths

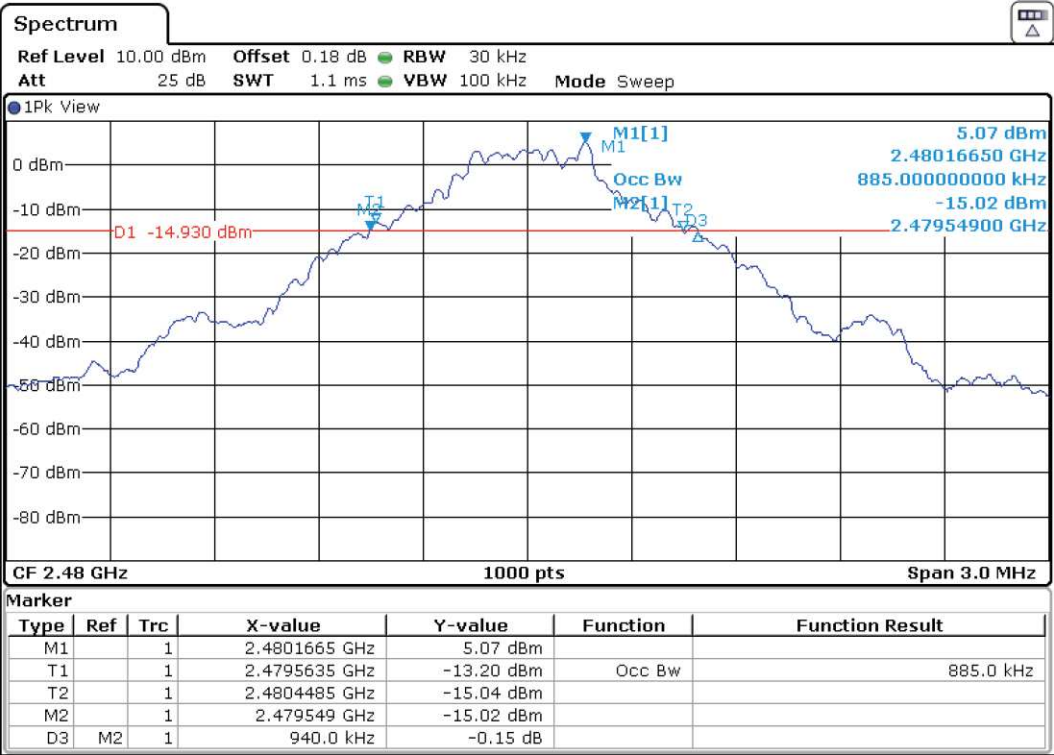
- Low Channel:



- Middle Channel:

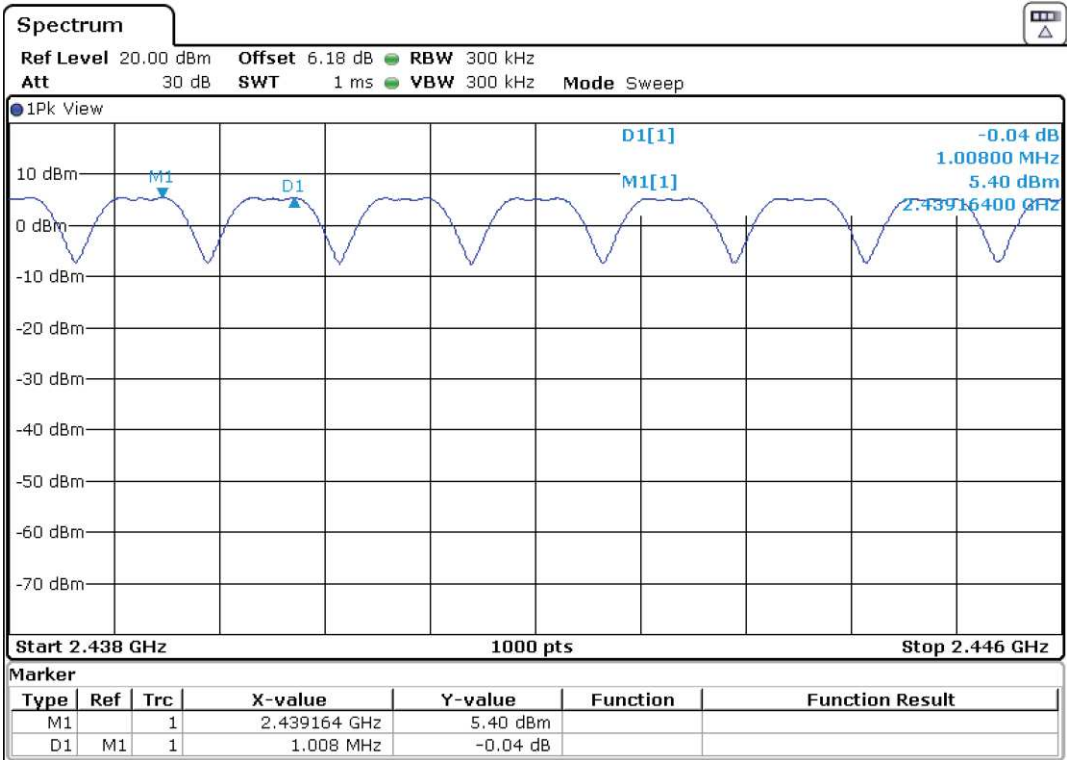


- High Channel:



Carrier frequency separation - GFSK

Carrier frequency separation: 1008 kHz

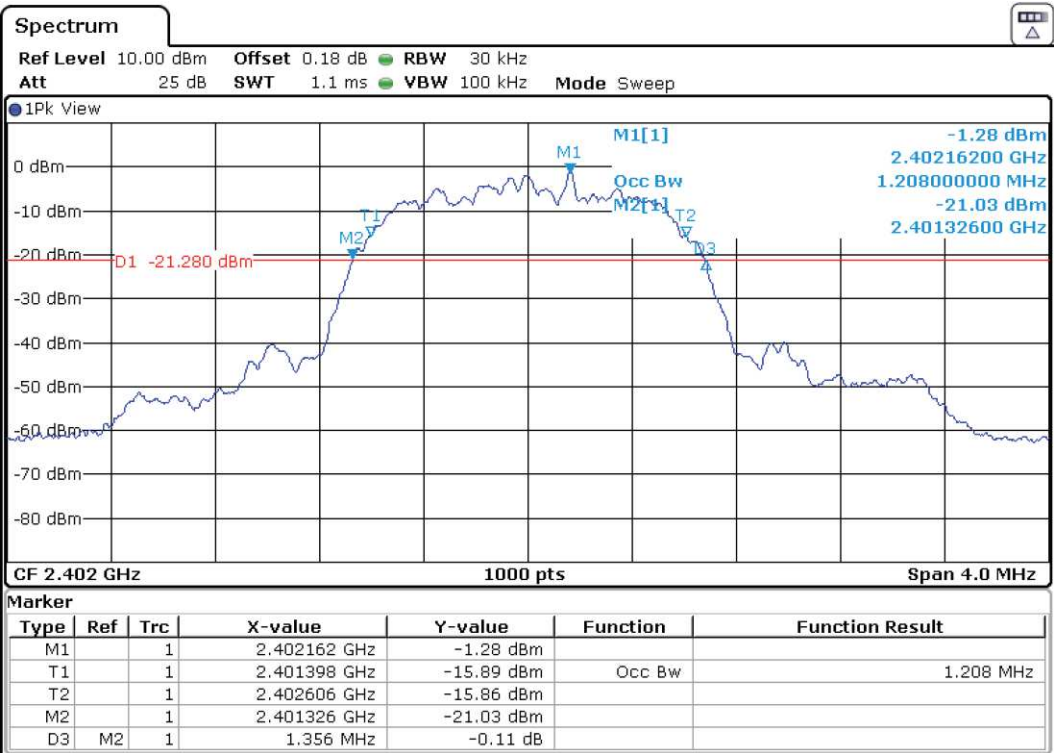


The hopping channel carrier frequencies are separated by a minimum of the two-thirds of 20 dB bandwidth of the hopping channel.

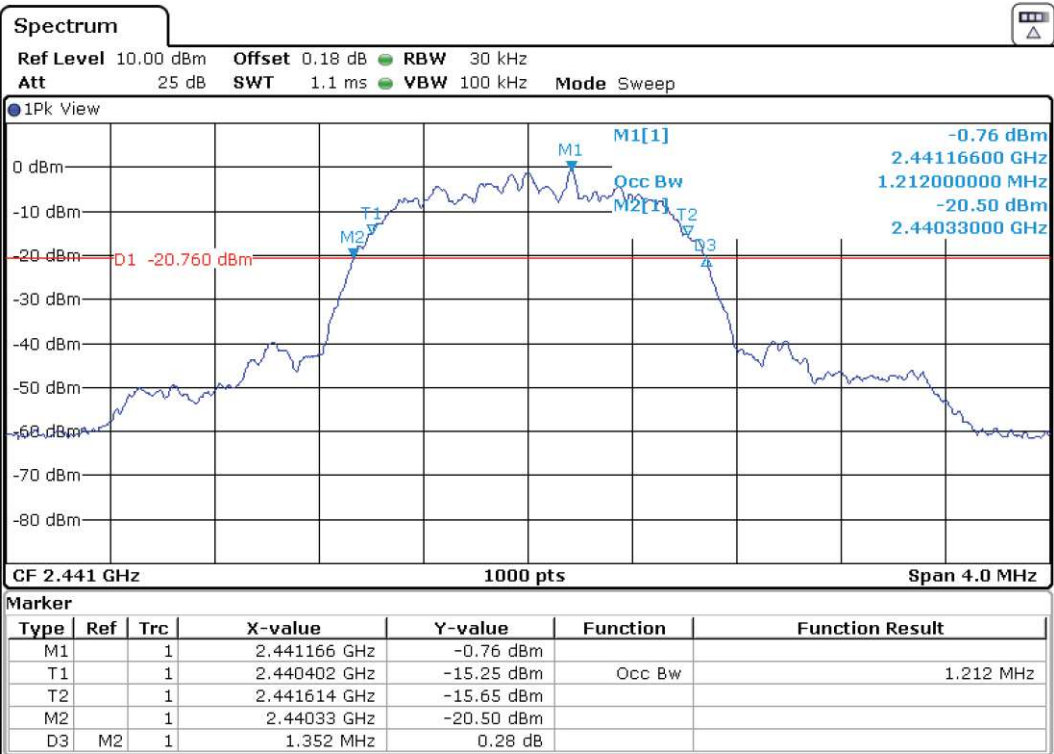
Verdict: PASS

• $\pi/4$ DQPSK – Bandwidths

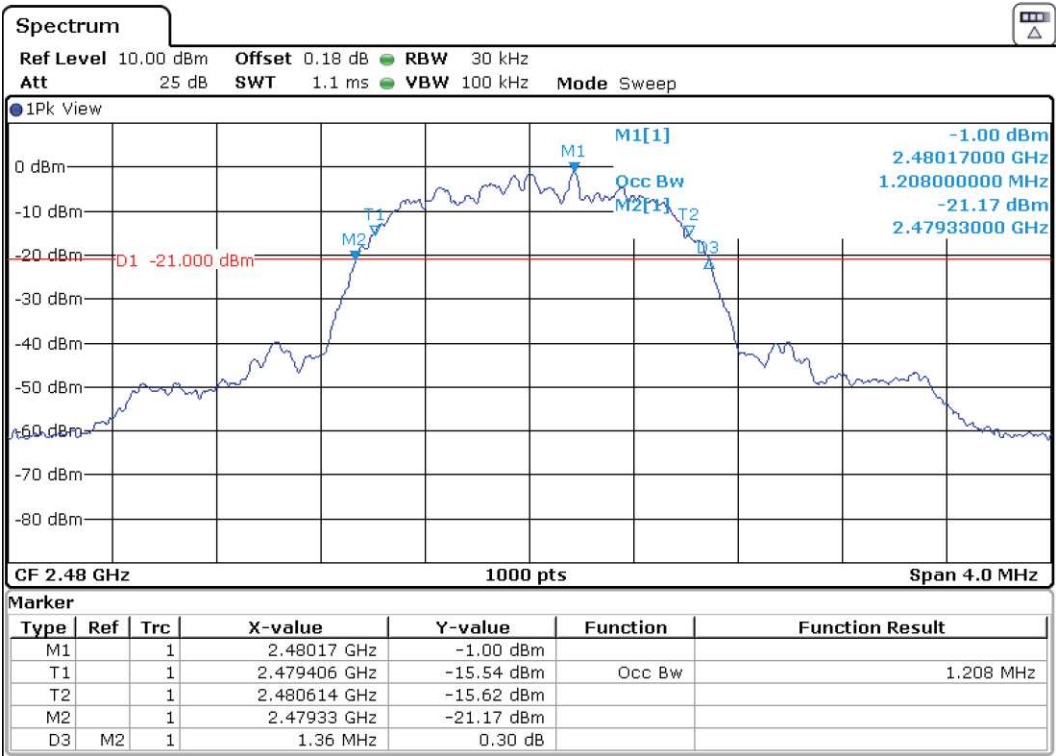
- Low Channel:



- Middle Channel:

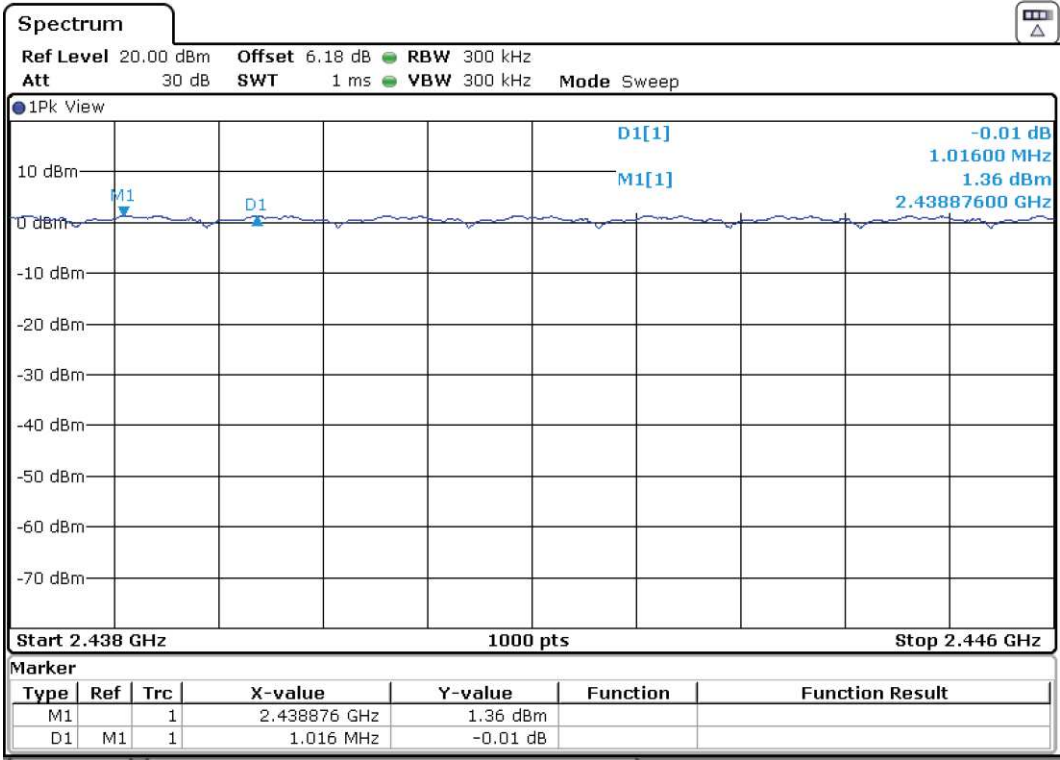


- High Channel:



Carrier frequency separation - $\pi/4$ DQPSK

Carrier frequency separation: 1016 kHz

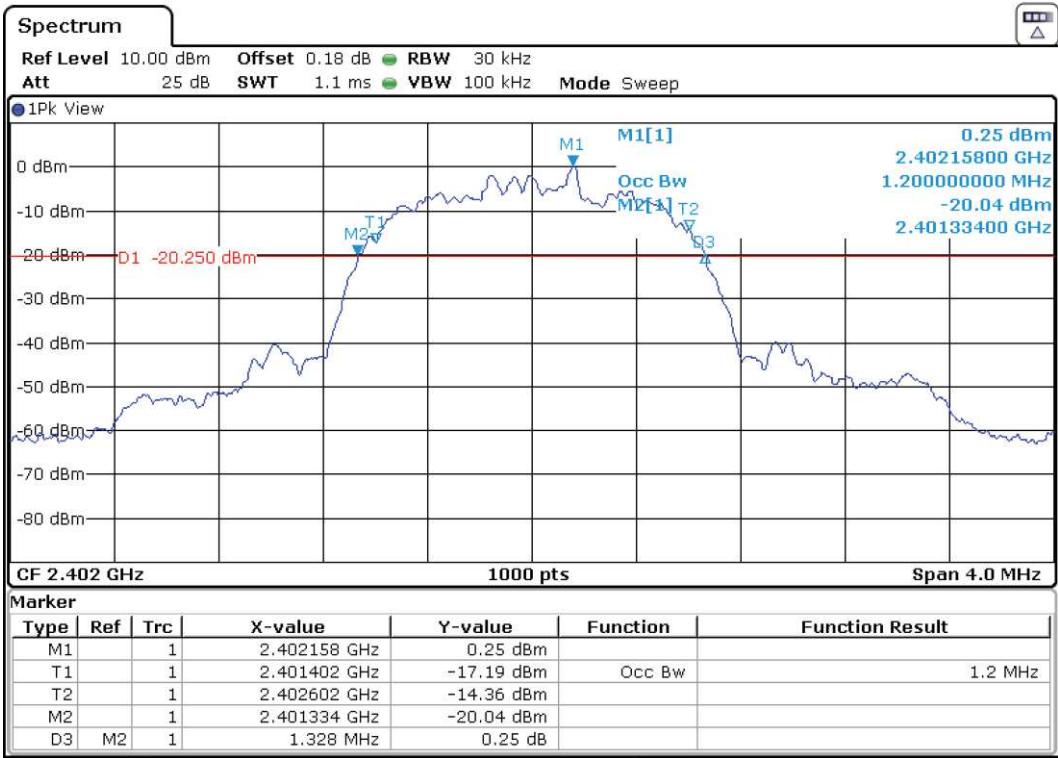


The hopping channel carrier frequencies are separated by a minimum of the two-thirds of 20 dB bandwidth of the hopping channel.

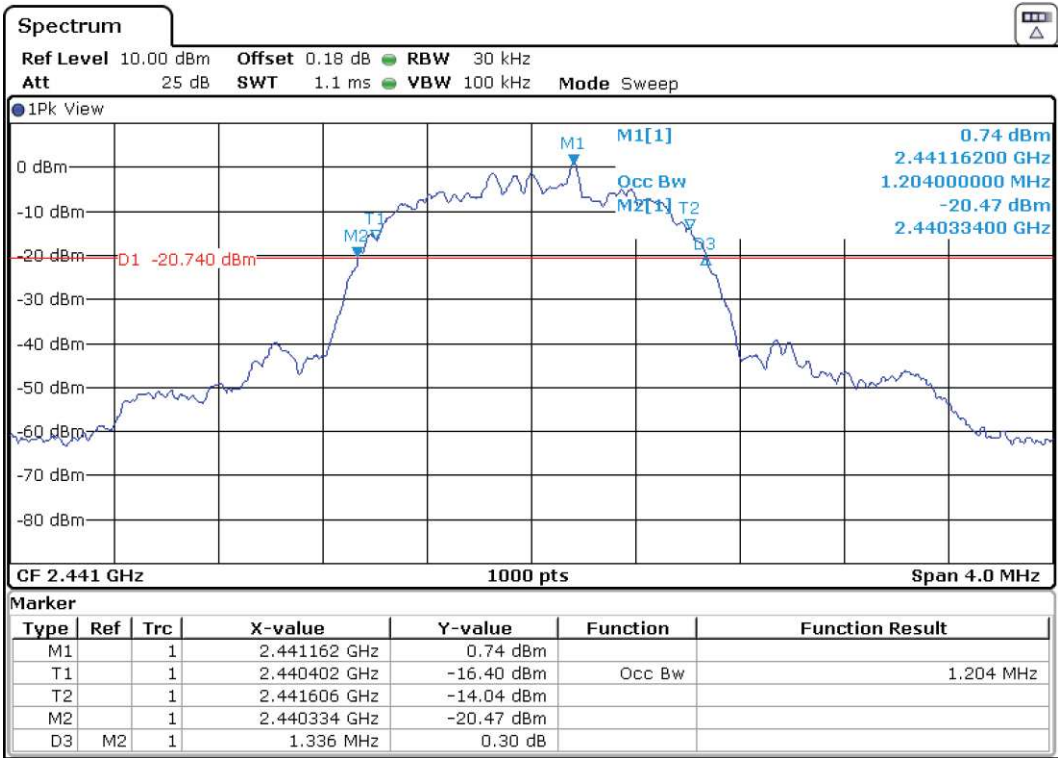
Verdict: PASS

• 8DPSK – Bandwidths

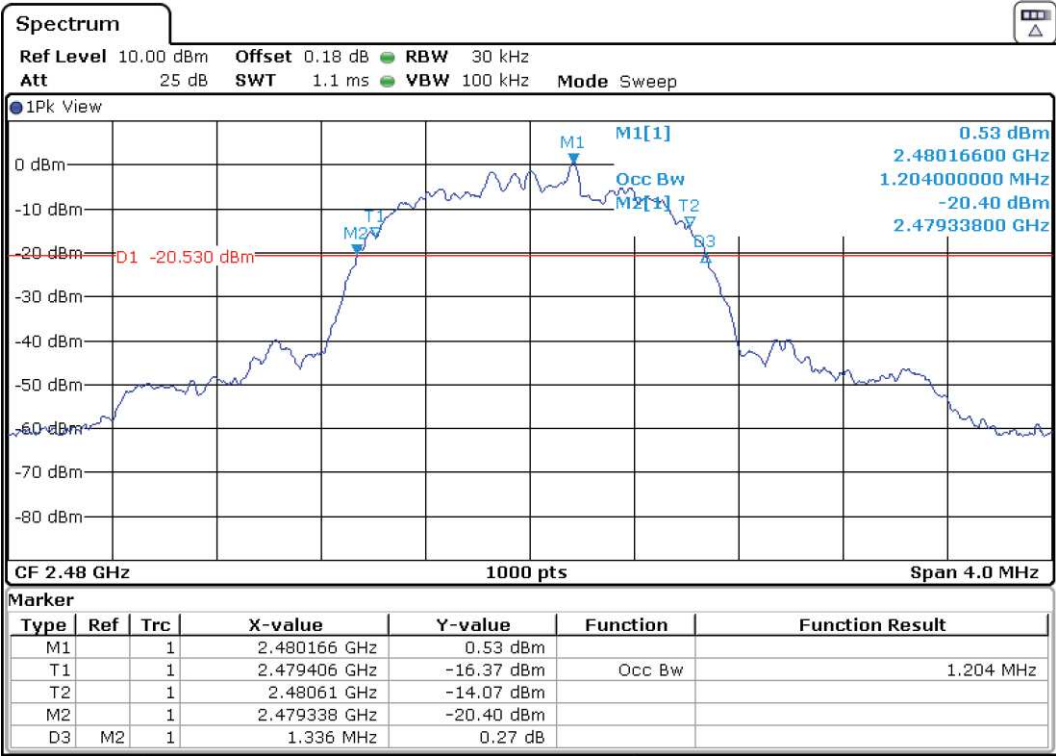
- Low Channel:



- Middle Channel:

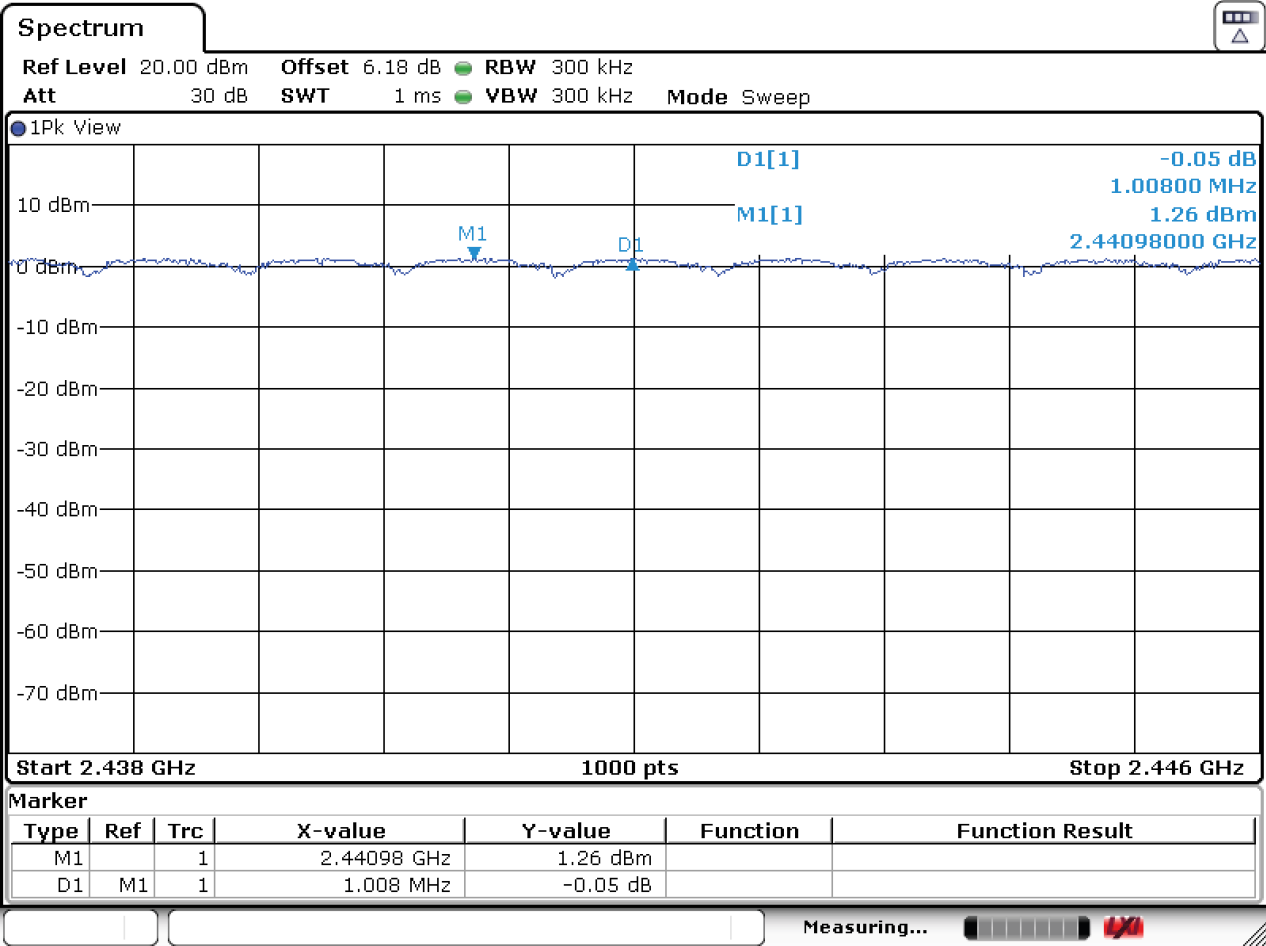


- High Channel:



Carrier frequency separation - 8DPSK

Carrier frequency separation: 1008 kHz



The hopping channel carrier frequencies are separated by a minimum of the two-thirds of 20 dB bandwidth of the hopping channel.

Verdict: PASS

FCC Section 15.247 Subclause (a)(1)(iii) / RSS-247 Clause 5.1 (d) Number of hopping channels.

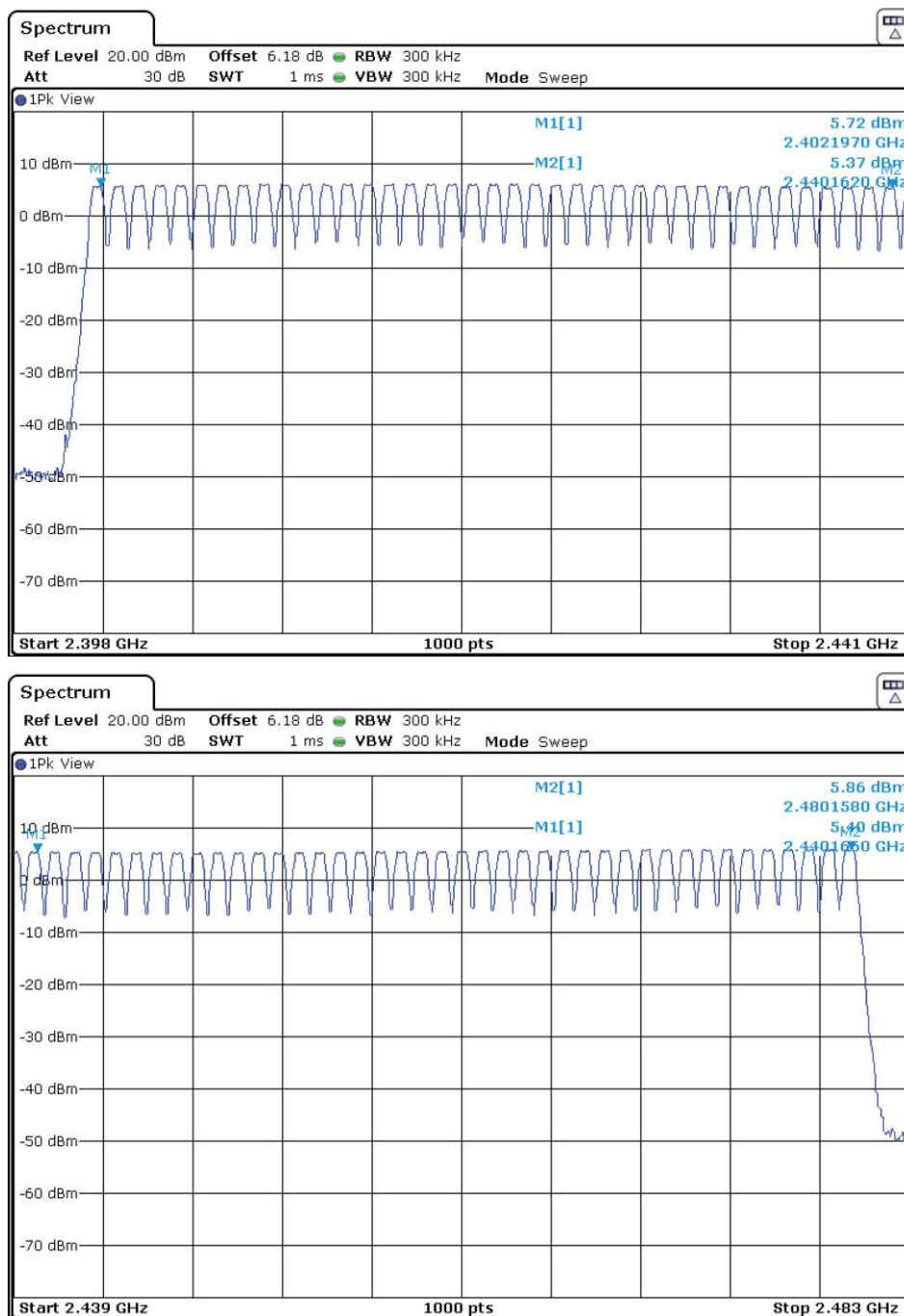
SPECIFICATION:

Frequency hopping system in the 2400-2483.5 MHz band shall use at least 15 channels.

RESULTS:

The number of hopping channels is 79 for all three modes.

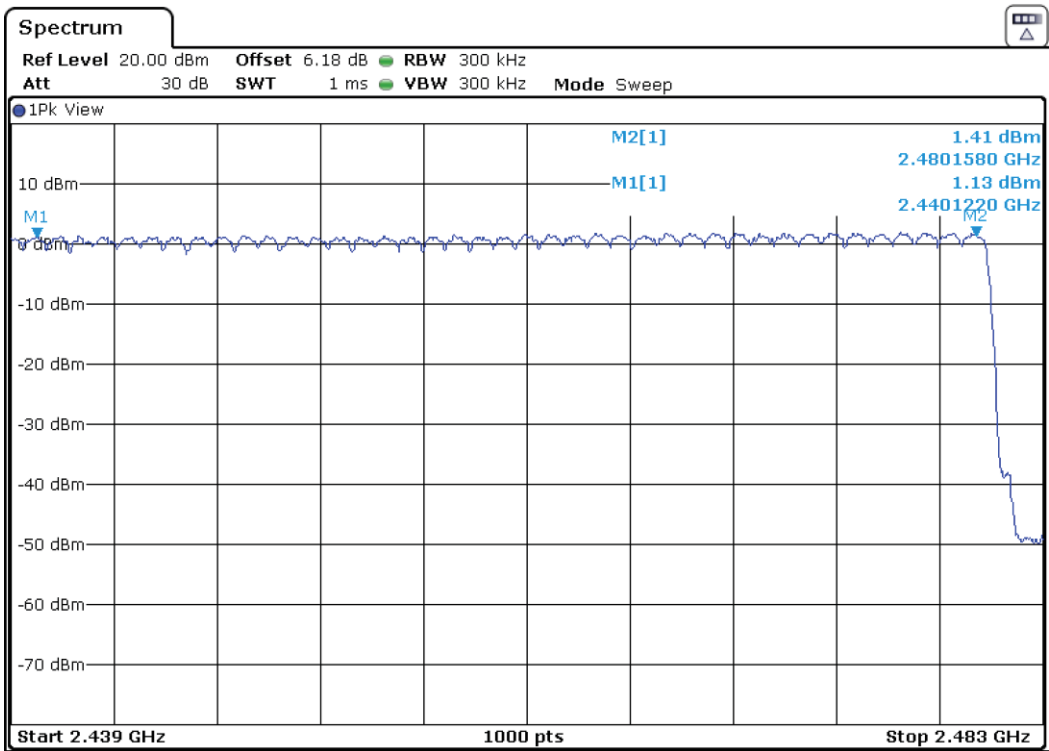
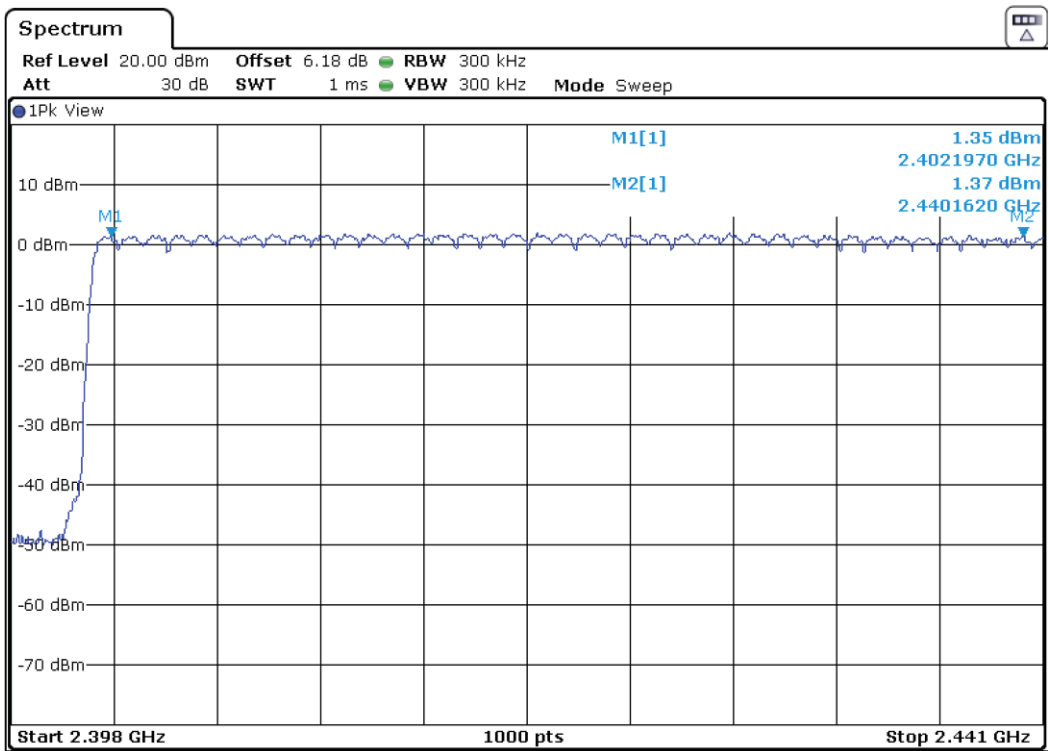
- GFSK – Number of hopping channels**



Total number of hopping channels 79

Verdict: PASS

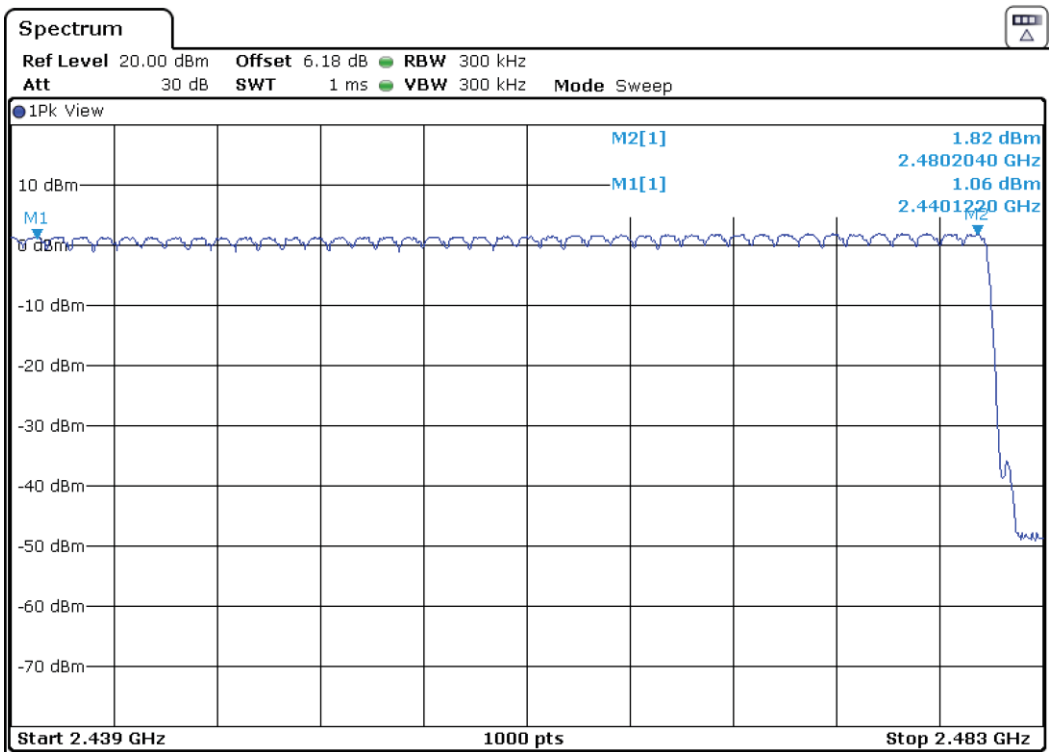
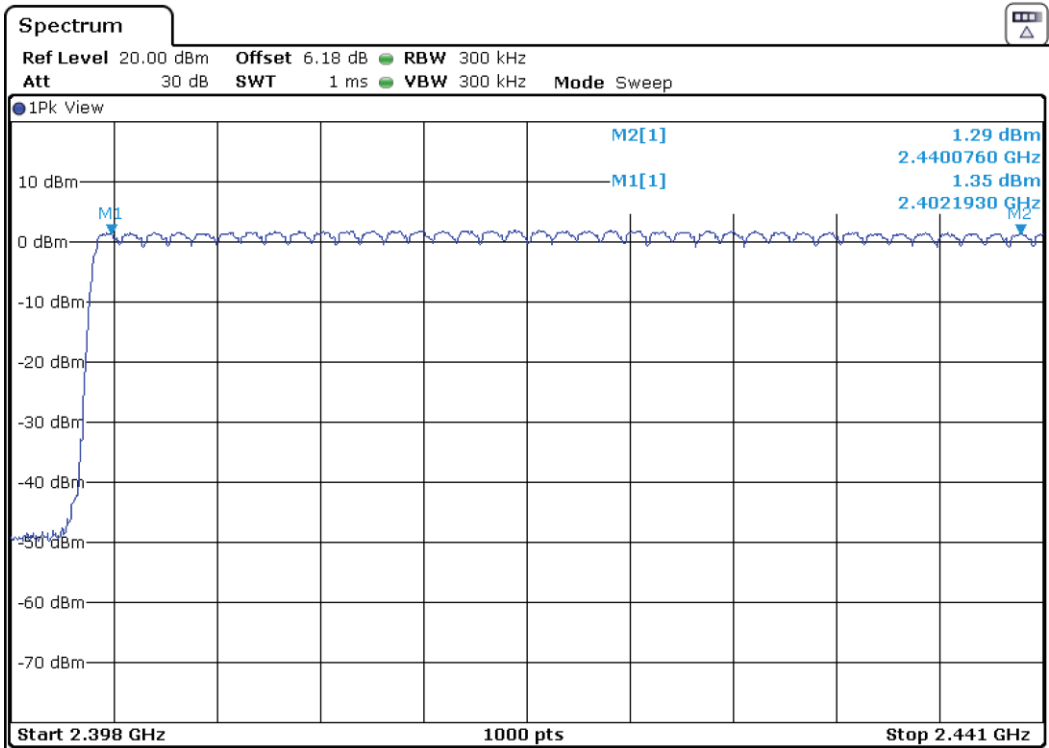
- $\pi/4$ DQPSK – Number of hopping channels



Total number of hopping channels 79

Verdict: PASS

8DPSK – Number of hopping channels



Total number of hopping channels 79

Verdict: PASS

FCC Section 15.247 Subclause (a)(1)(iii) / RSS-247 Clause 5.1 (d) Time of occupancy (Dwell Time).

SPECIFICATION:

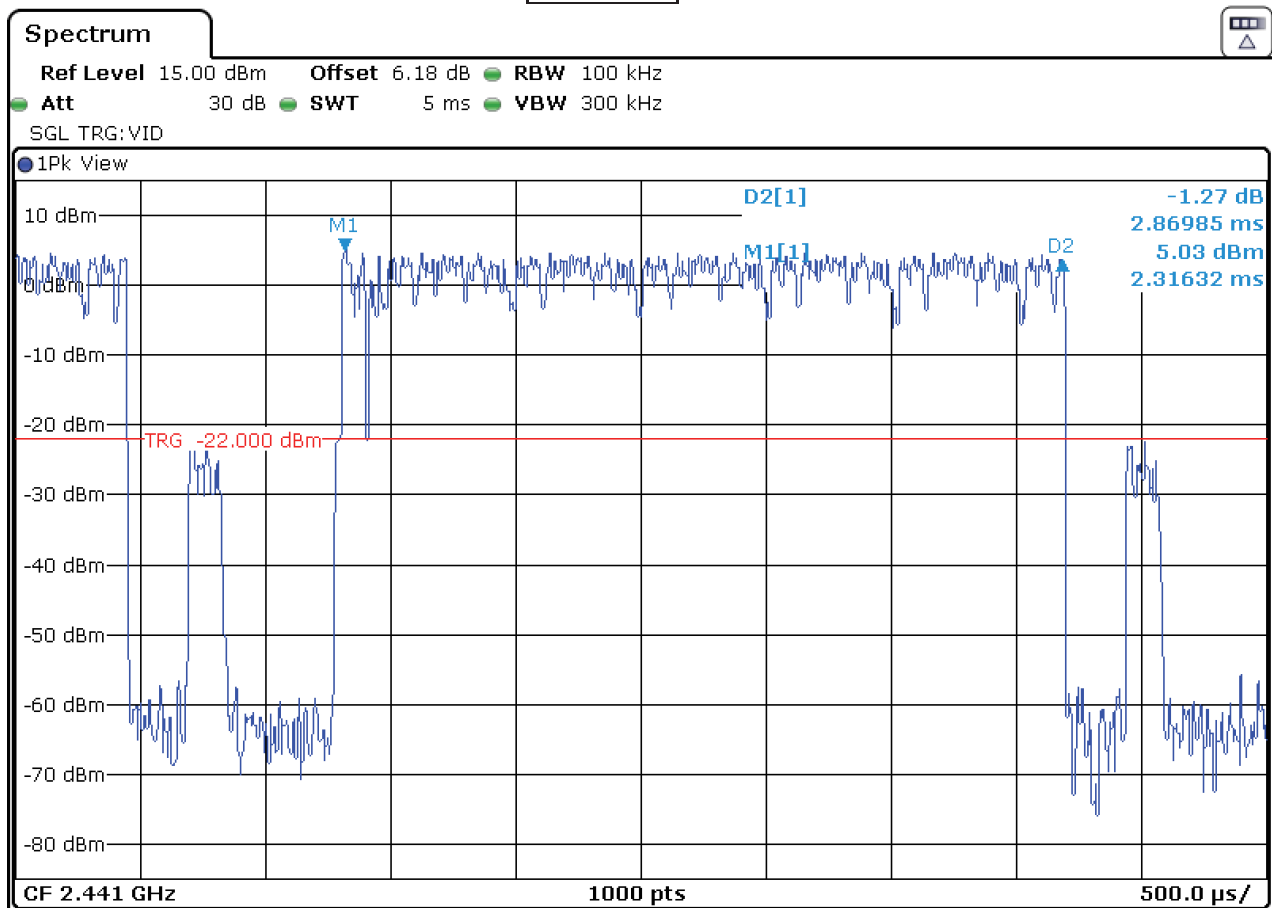
The average time of occupancy on any channel shall not be greater than 0.4 seconds (400 ms) within a period of 0.4 seconds multiplied by the number of hopping channels employed = $0.4 \times 79 = 31.6$ seconds.

RESULTS:

• GFSK (packet type DH5) – Time of Occupancy (Dwell Time)

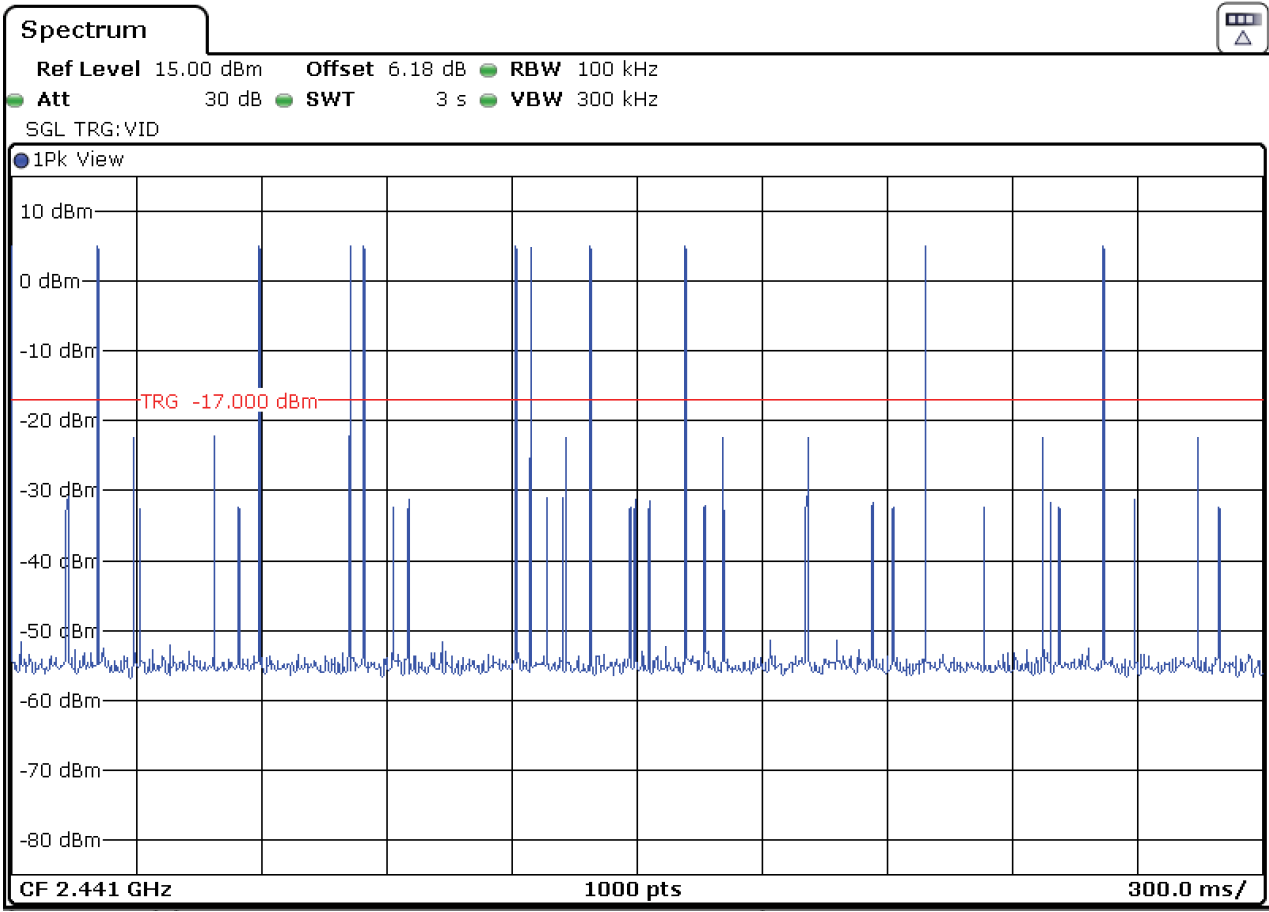
- Transmit Time per Hop:

2.86985 ms



- Time of Occupancy:

Nº of hops on spectrum analyzer	10
Nº of hops over the period	105.33
Average Time of Occupancy	302.28 ms



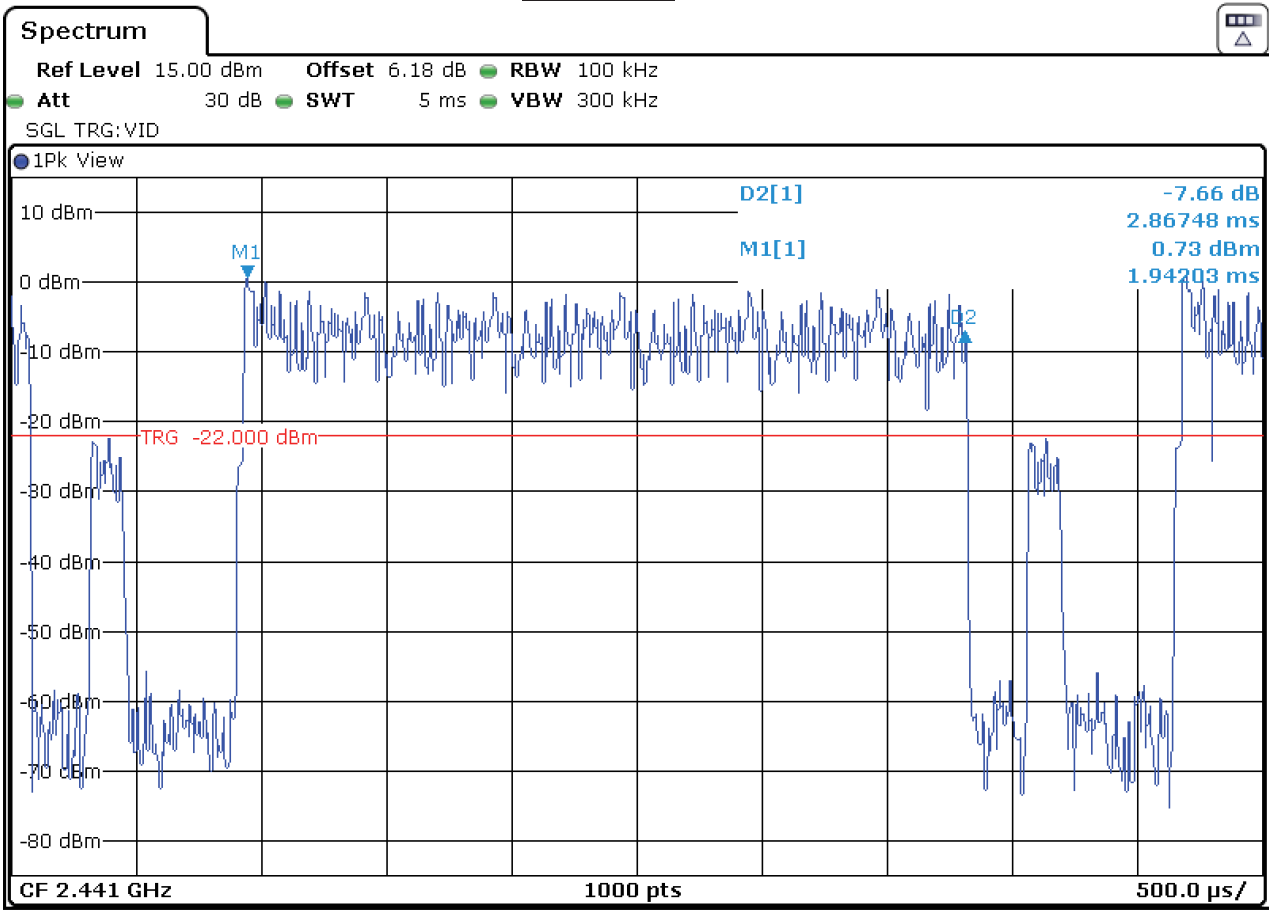
Measurement uncertainty (%)	<±0.01
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Verdict: PASS

• $\pi/4$ DQPSK (packet type 2DH5) – Time of Occupancy (Dwell Time)

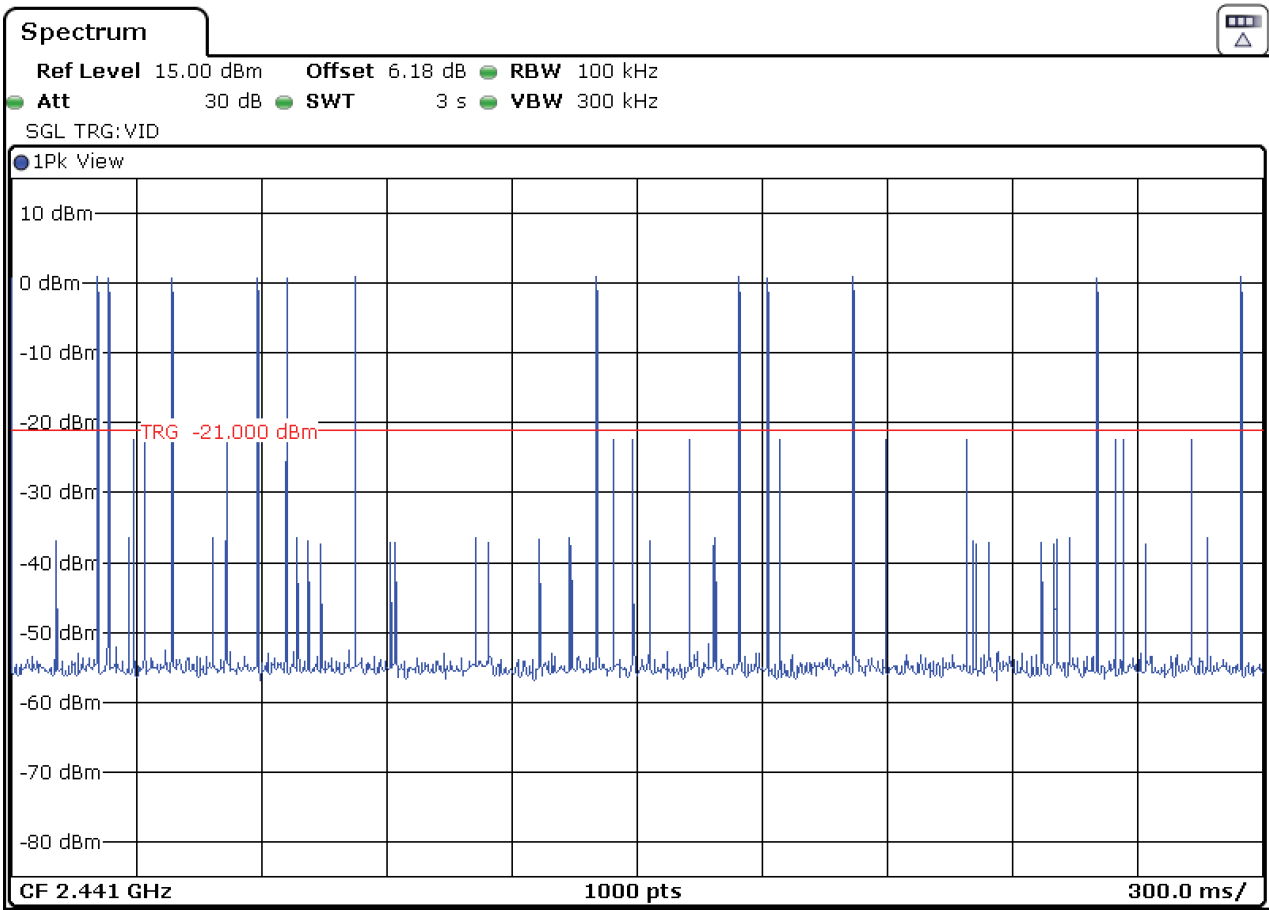
- Transmit Time per Hop:

2.86748 ms



- Time of Occupancy:

Nº of hops on spectrum analyzer	12
Nº of hops over the period	126.4
Average Time of Occupancy	362.4495 ms



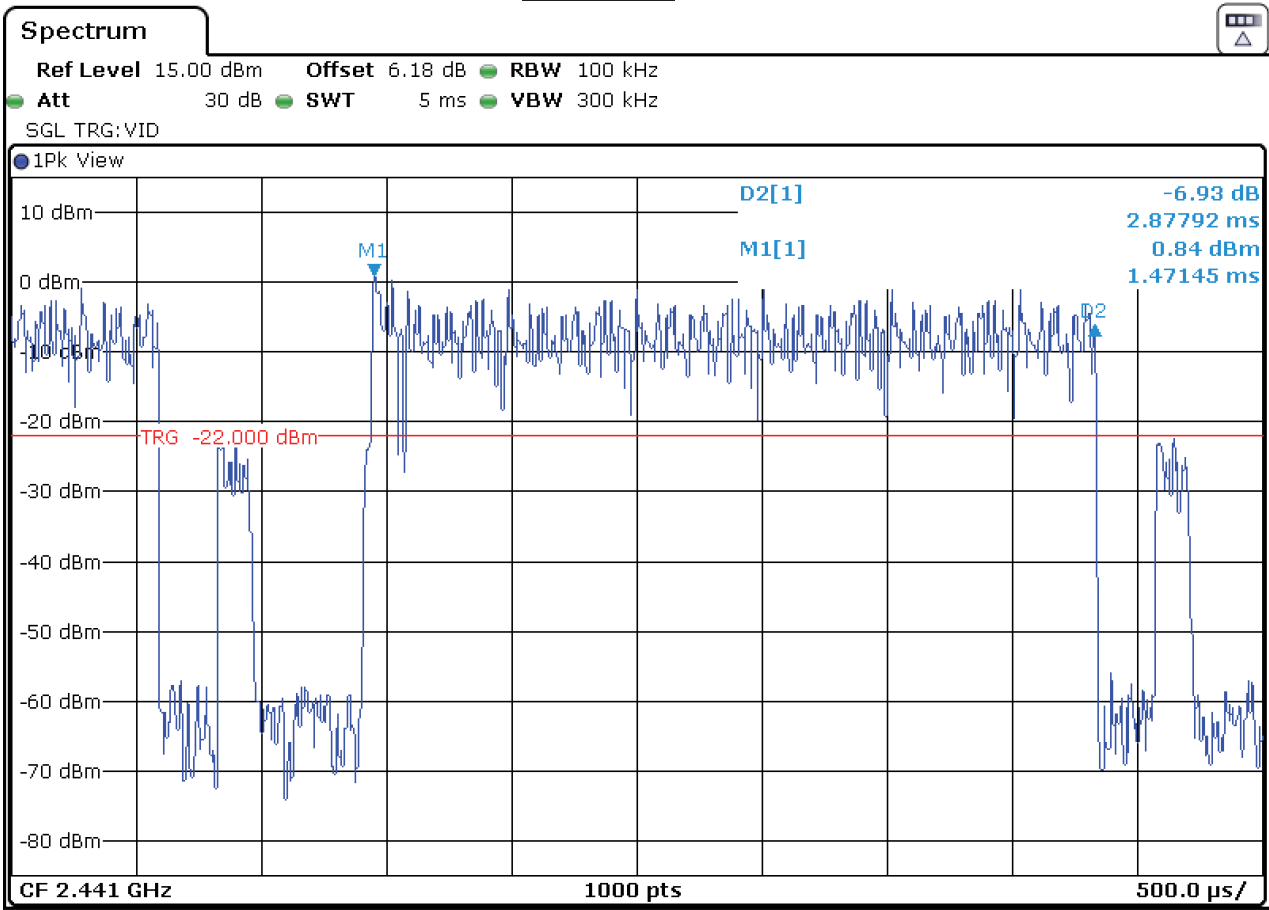
Measurement uncertainty (%)	<±0.01
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Verdict: PASS

• 8DPSK (packet type 3DH5) – Time of Occupancy (Dwell Time)

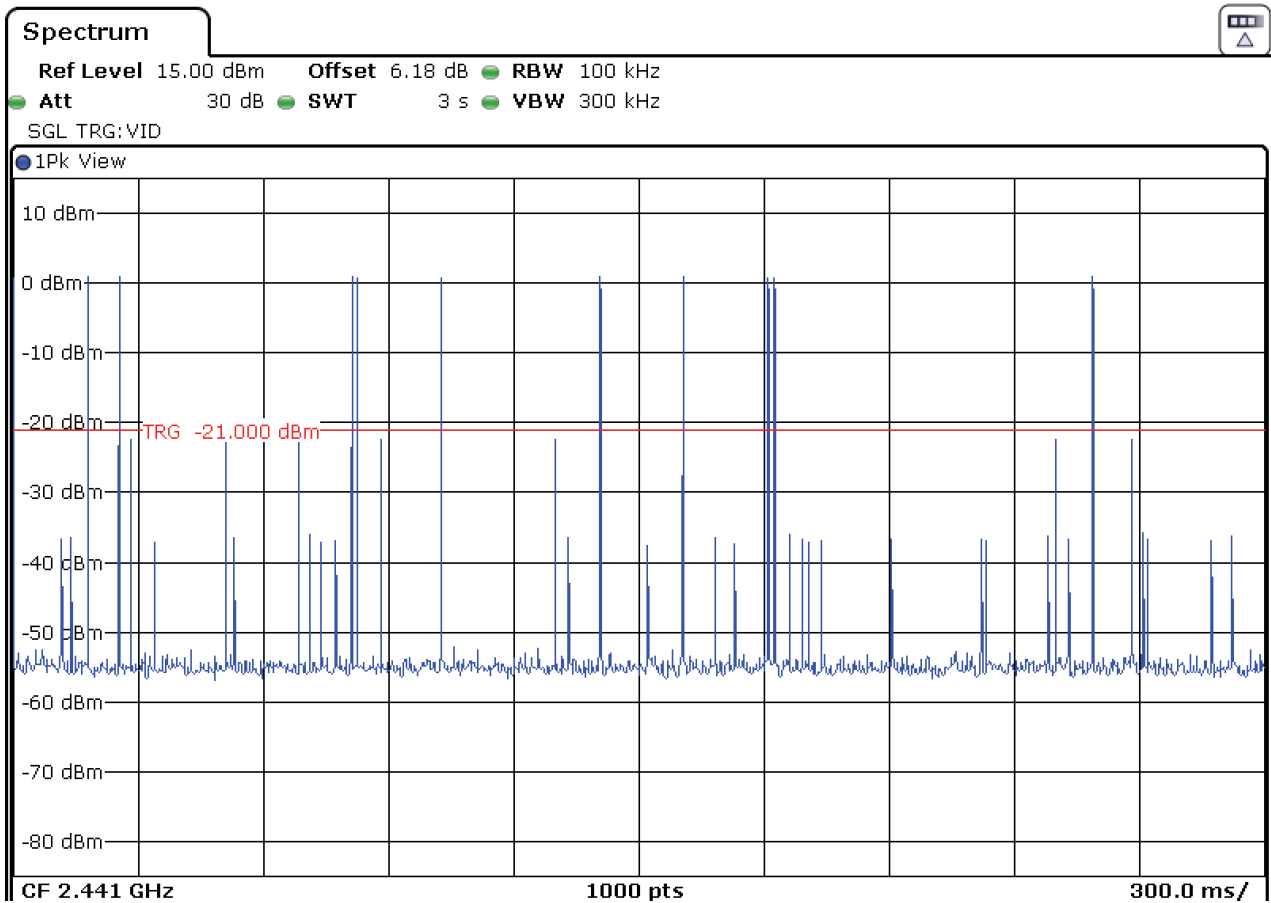
- Transmit Time per Hop:

2.87792 ms



- Time of Occupancy:

Nº of hops on spectrum analyzer	10
Nº of hops over the period	105.33
Average Time of Occupancy	303.1313 ms



Measurement uncertainty (%)	<±0.01
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Verdict: PASS

FCC Section 15.247 Subclause (b) / RSS-247 Clause 5.4 (b) Maximum peak output power and antenna gain

SPECIFICATION:

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 hopping channels: 1 watt (30 dBm). The e.i.r.p. shall not exceed 4 W (RSS-247).

RESULTS:

The EIRP power (dBm) is calculated by adding the maximum declared antenna gain to the measured conducted power.

Maximum Declared Antenna Gain: 0.7 dBi

The maximum directional gain of the antenna is less than 6 dBi and therefore the maximum output power is not required to be reduced from the stated values

- GFSK (1 Mbps)**

Peak Conducted Output Power	Low Channel 2402 MHz	Middle Channel 2441 MHz	High Channel 2480 MHz
Maximum Conducted Power (dBm)	6.30	6.64	6.37
Maximum EIRP Power (dBm)	7.00	7.34	7.07
Measurement uncertainty (dB)	<±0.78		

- $\pi/4$ DQPSK (2 Mbps)**

Peak Conducted Output Power	Low Channel 2402 MHz	Middle Channel 2441 MHz	High Channel 2480 MHz
Maximum Conducted Power (dBm)	3.97	4.52	4.27
Maximum EIRP Power (dBm)	4.67	5.22	4.97
Measurement uncertainty (dB)	<±0.78		

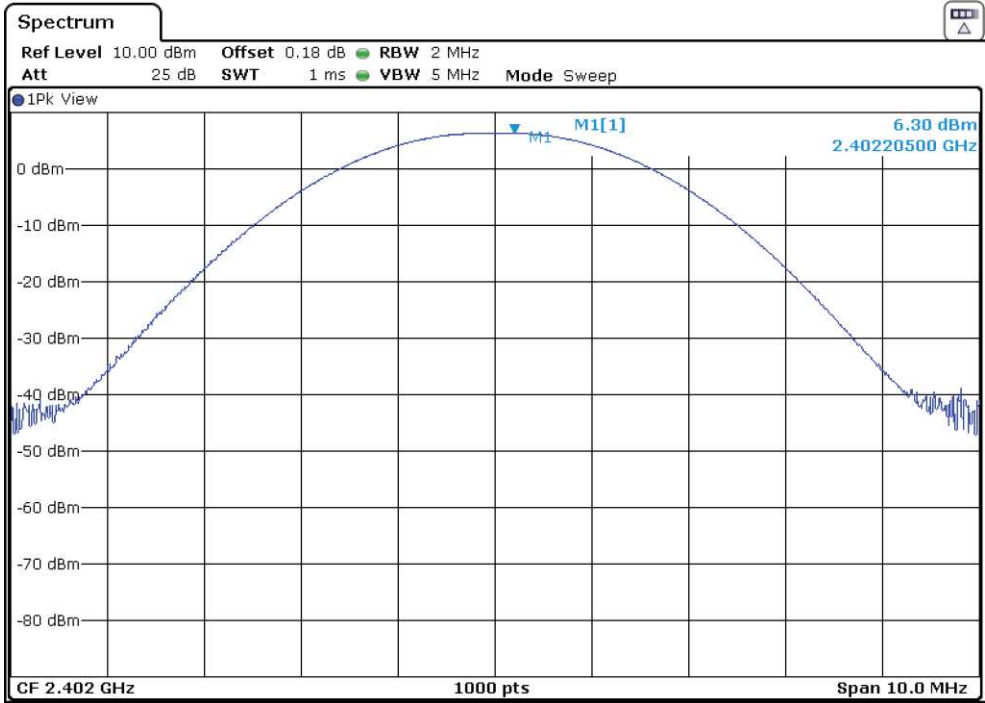
- 8DPSK (3 Mbps)**

Peak Conducted Output Power	Low Channel 2402 MHz	Middle Channel 2441 MHz	High Channel 2480 MHz
Maximum Conducted Power (dBm)	4.47	5.03	4.75
Maximum EIRP Power (dBm)	5.17	5.73	5.45
Measurement uncertainty (dB)	<±0.78		

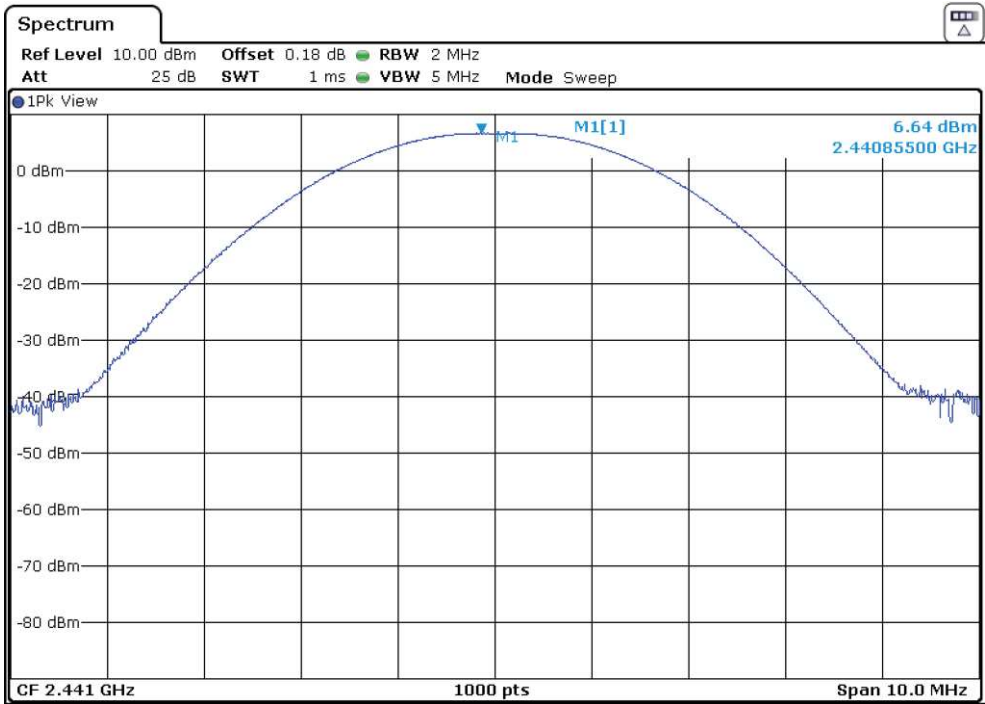
Verdict: PASS

• GFSK – Peak Output Power

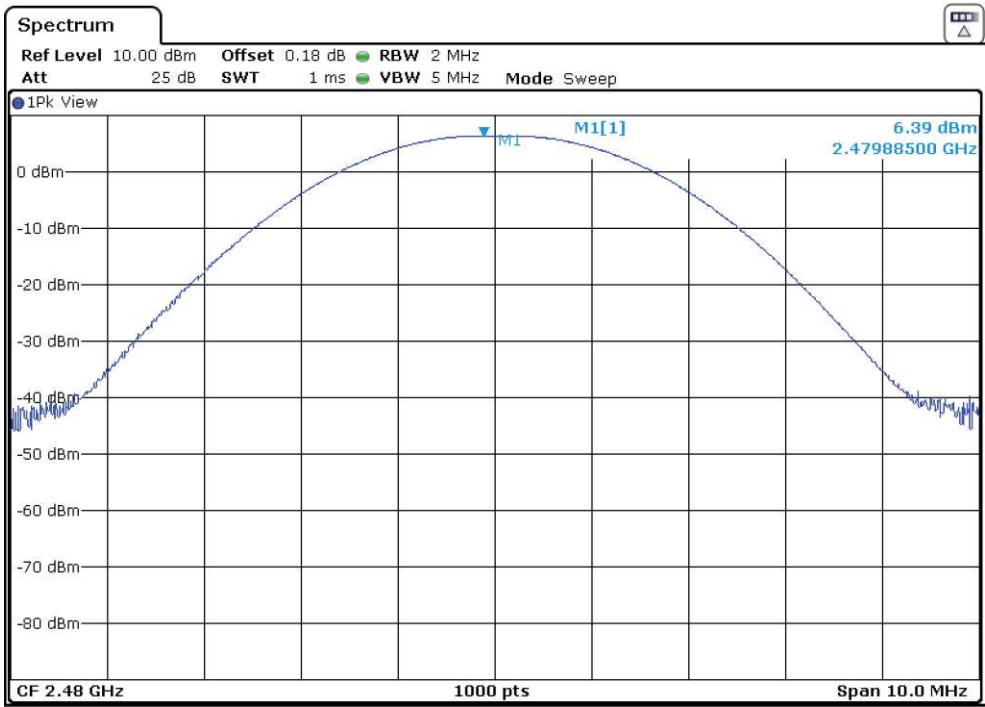
- Low Channel:



- Middle Channel:

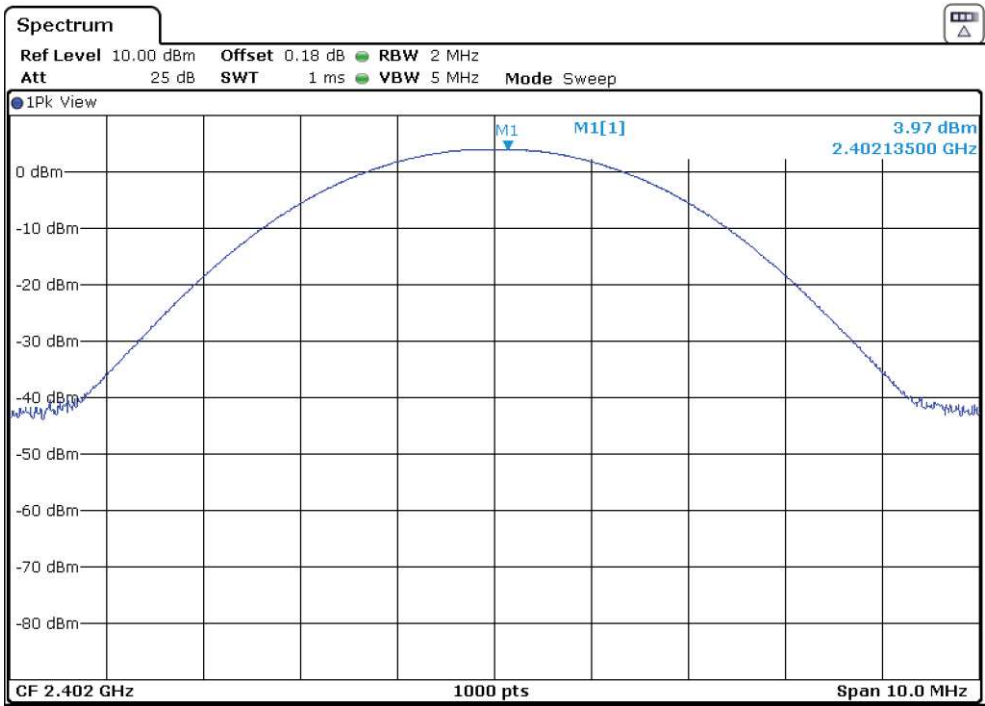


- High Channel:

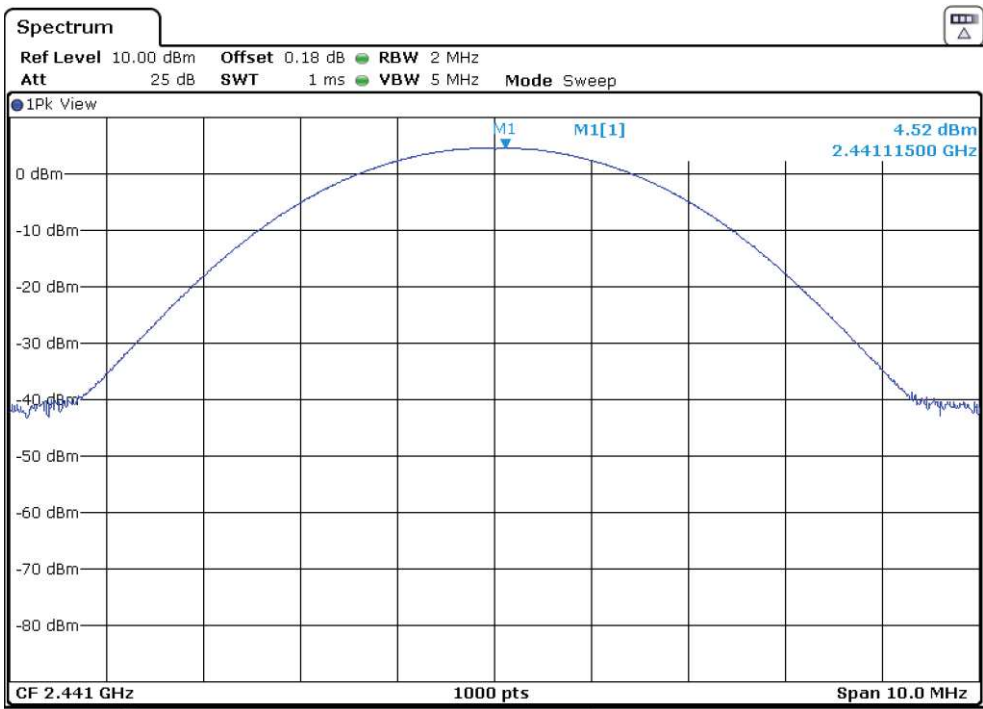


• $\pi/4$ DQPSK – Peak Output Power

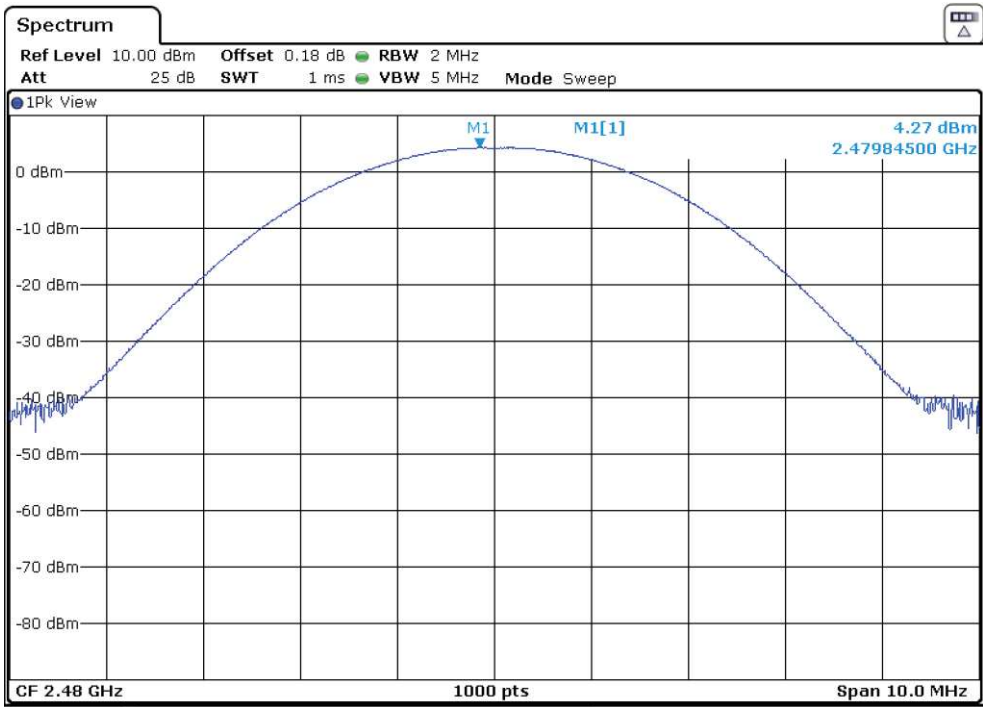
- Low Channel:



- Middle Channel:

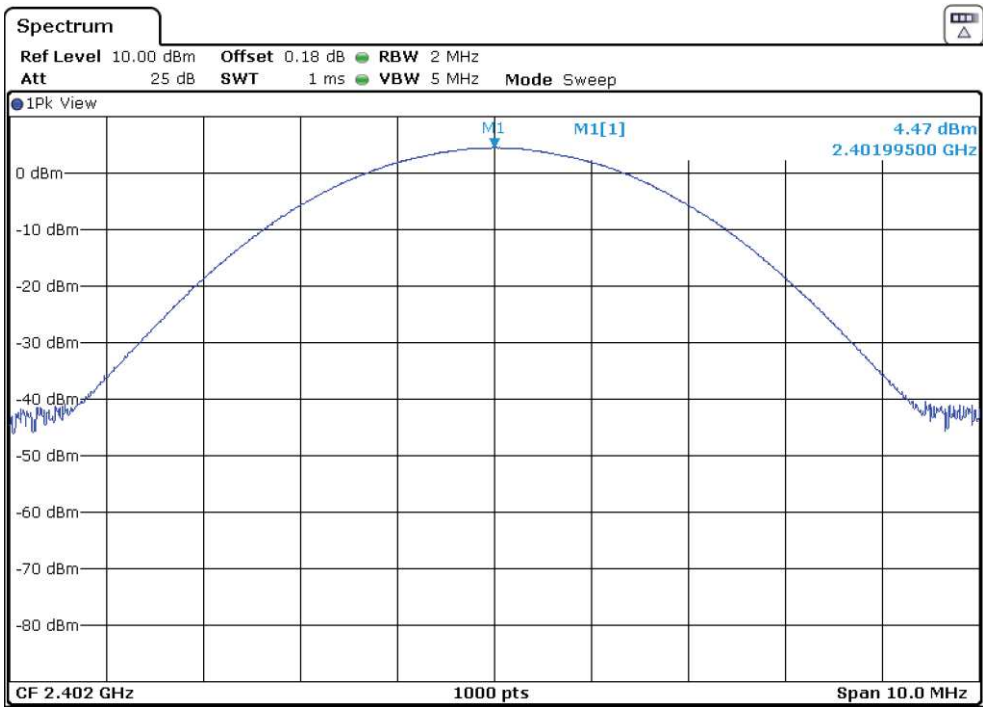


- High Channel:

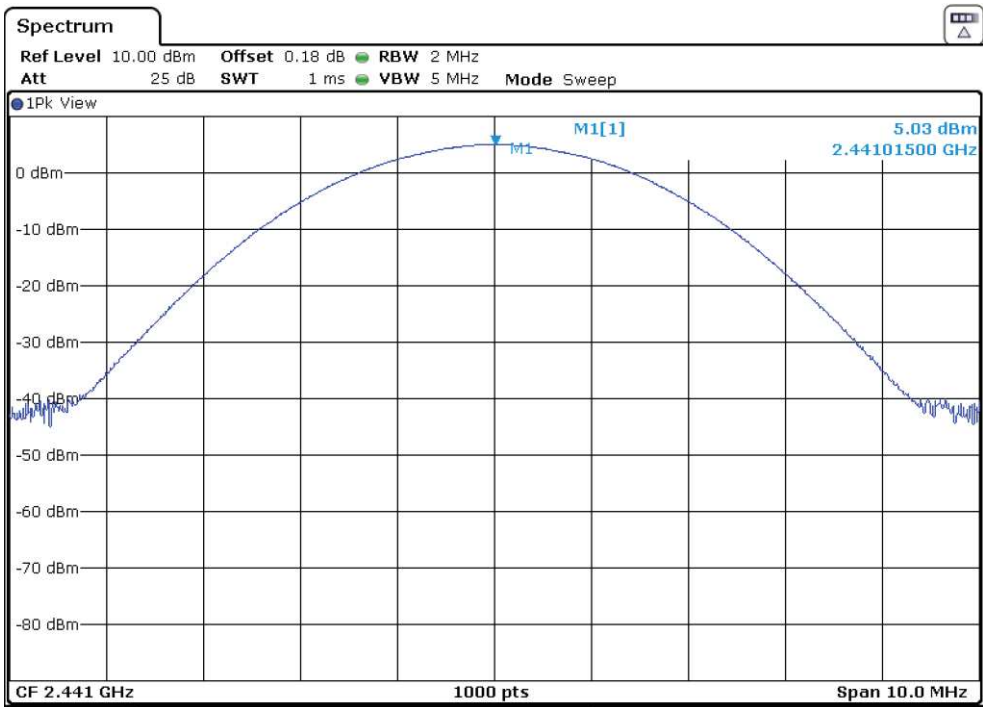


• 8DPSK – Peak Output Power

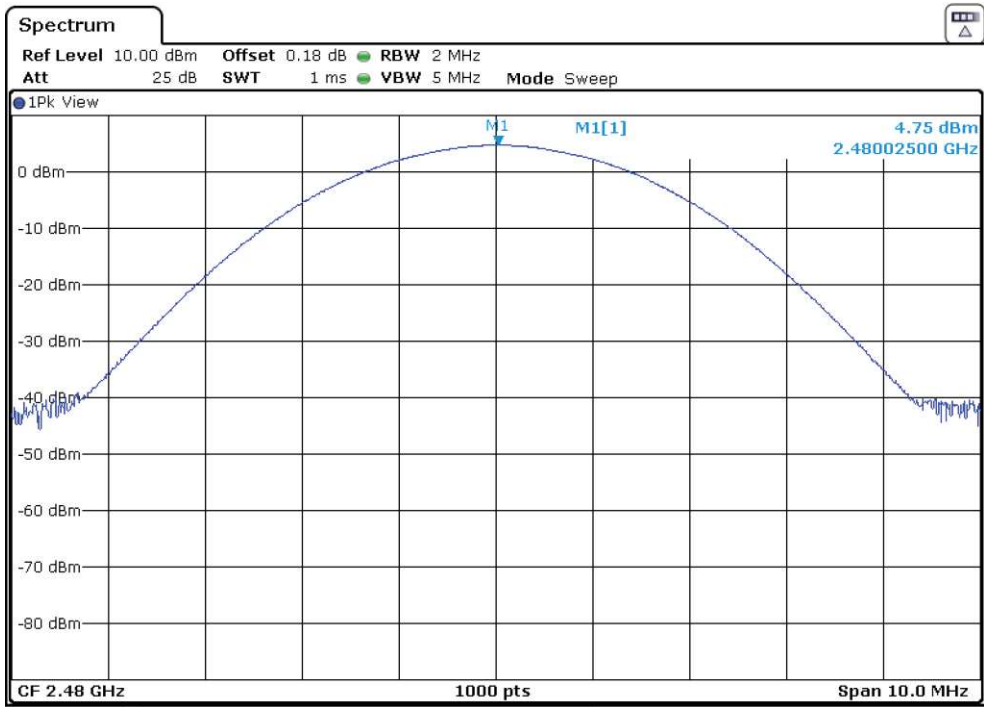
- Low Channel:



- Middle Channel:



- High Channel:



FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Band-edge emissions compliance (Transmitter) (conducted)

SPECIFICATION:

Emissions outside the frequency band in which the intentional radiator is operating shall be at least 20 dB below the highest level of the desired power.

RESULTS:

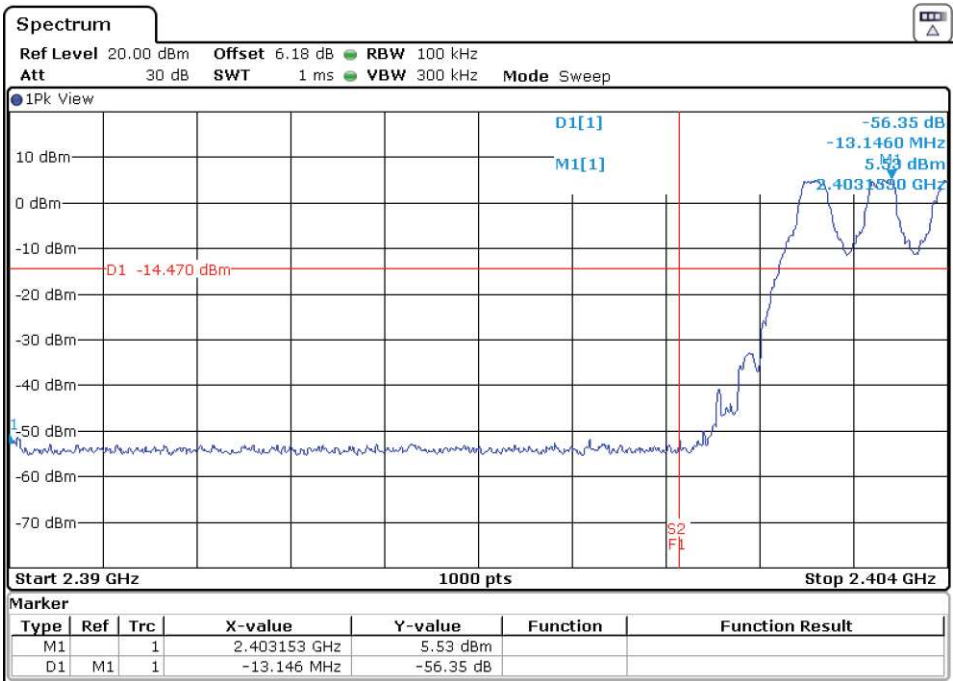
Radiated measurements were used to show compliance with the limits in the restricted bands 2.31-2.39 GHz and 2.4835-2.5 GHz.

Measurement uncertainty (dB)	<±1.56
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GFSK – Band-edge emissions compliance

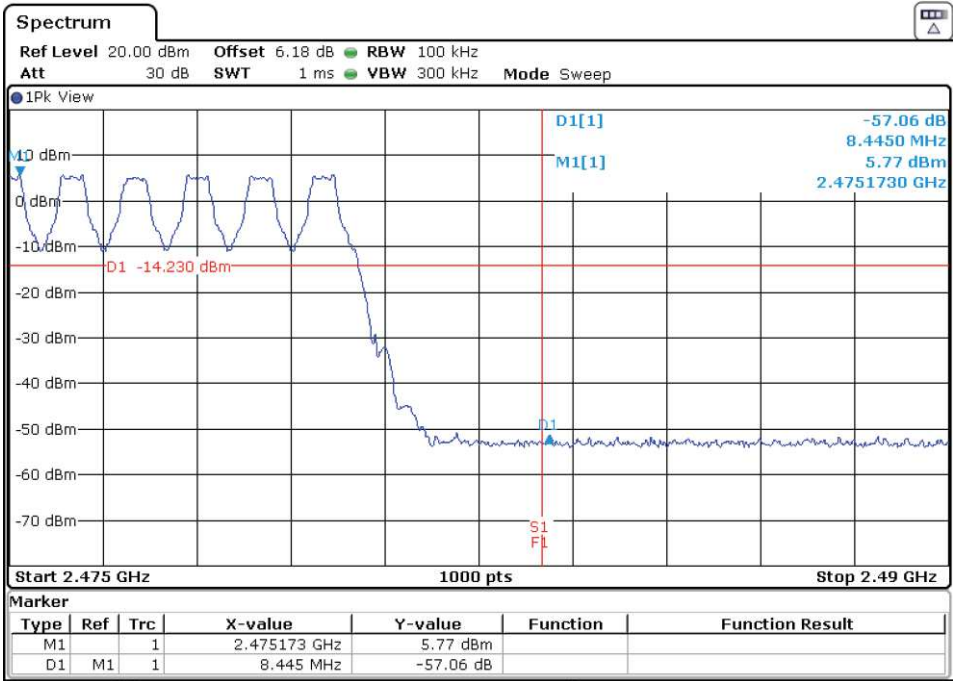
HOPPING ON:

Low Frequency Section 2402 MHz:



Verdict: PASS

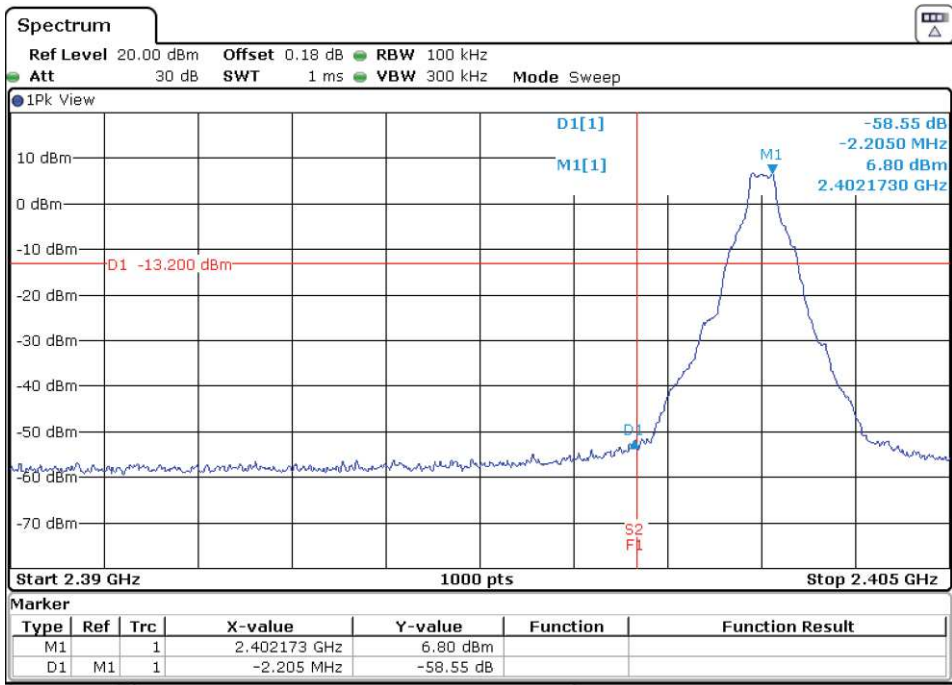
High Frequency Section 2480 MHz:



Verdict: PASS

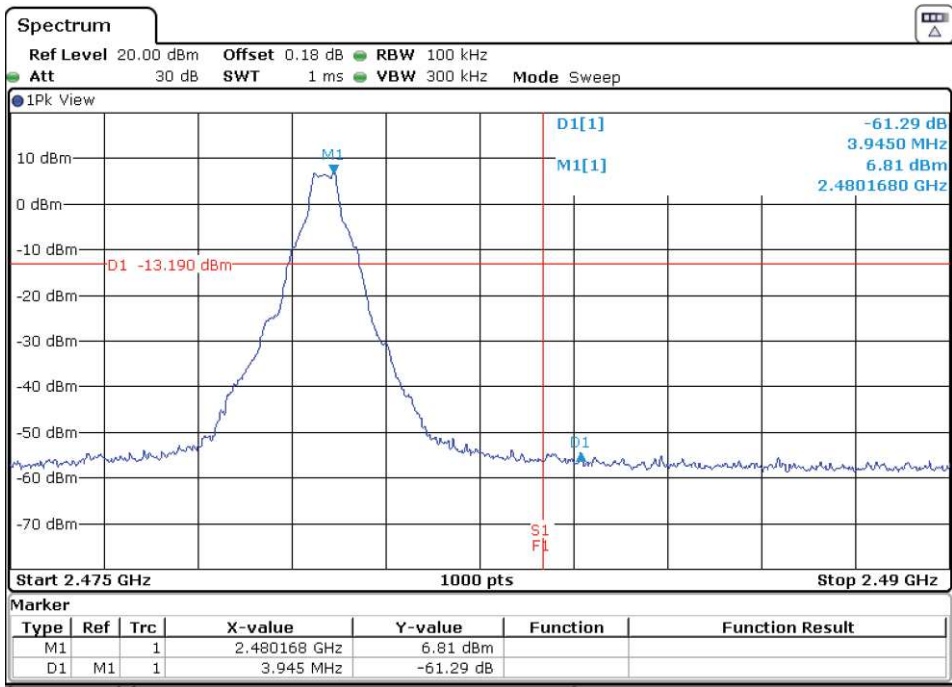
❖ HOPPING OFF:

- Low Frequency Section 2402 MHz:



Verdict: PASS

- High Frequency Section 2480 MHz:

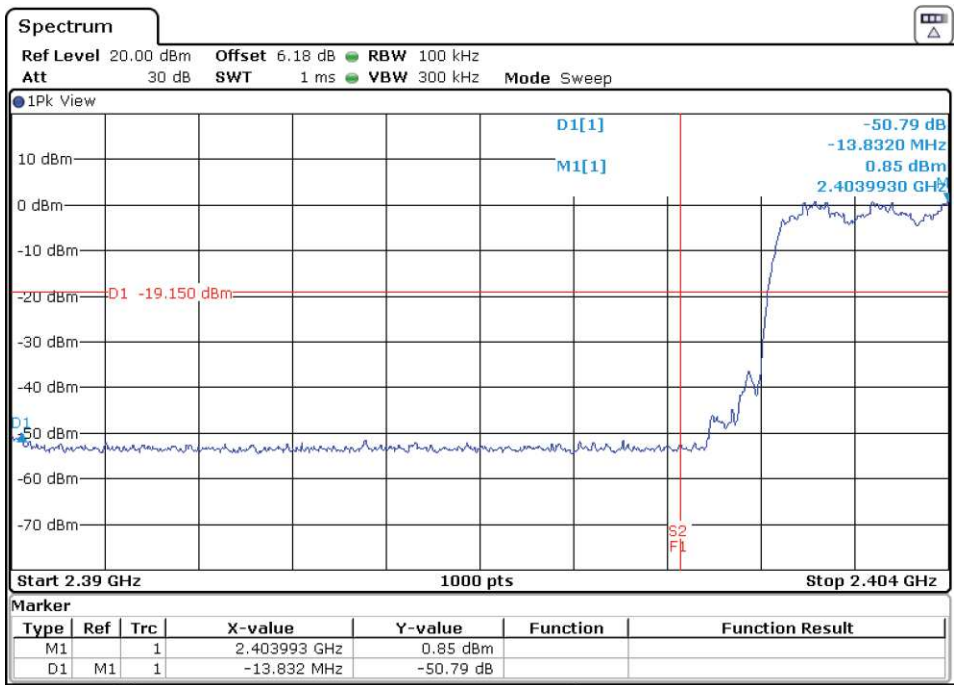


Verdict: PASS

• $\pi/4$ DQPSK – Band-edge emissions compliance

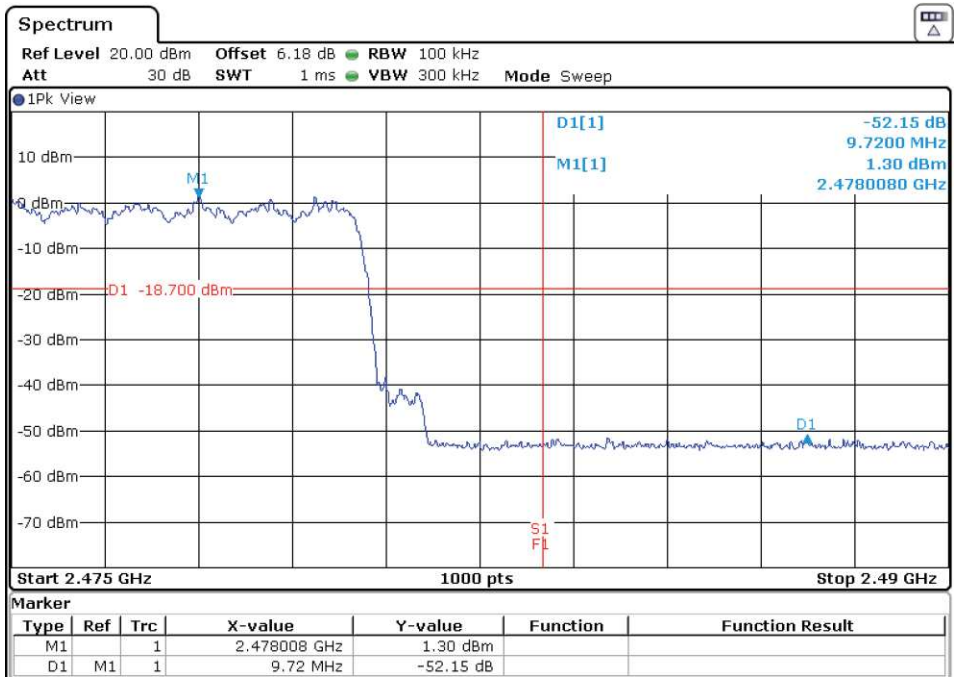
❖ HOPPING ON:

- Low Frequency Section 2402 MHz:



Verdict: PASS

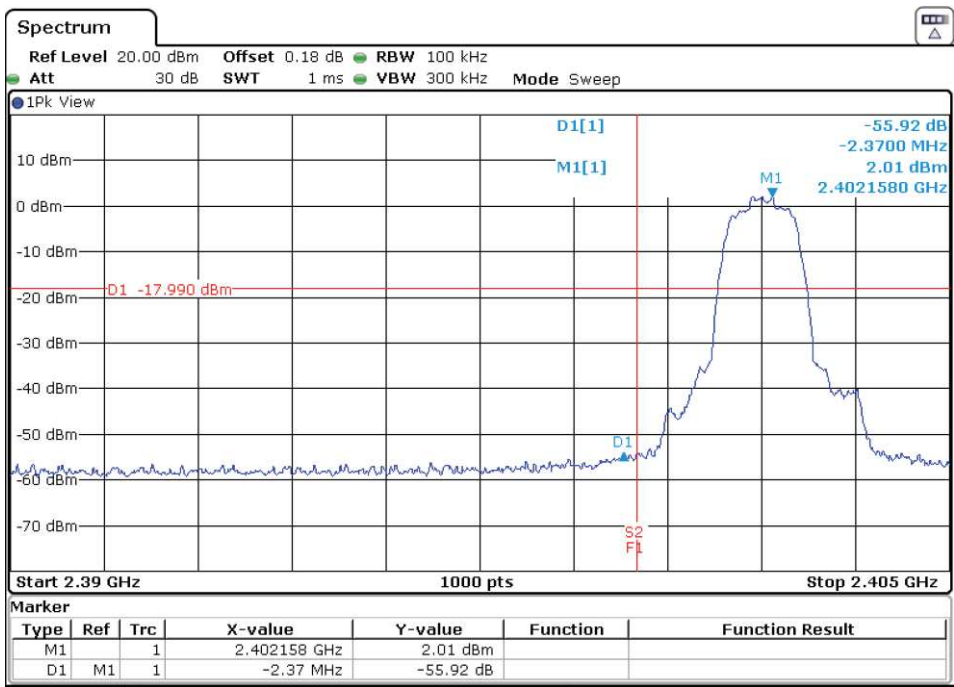
- High Frequency Section 2480 MHz:



Verdict: PASS

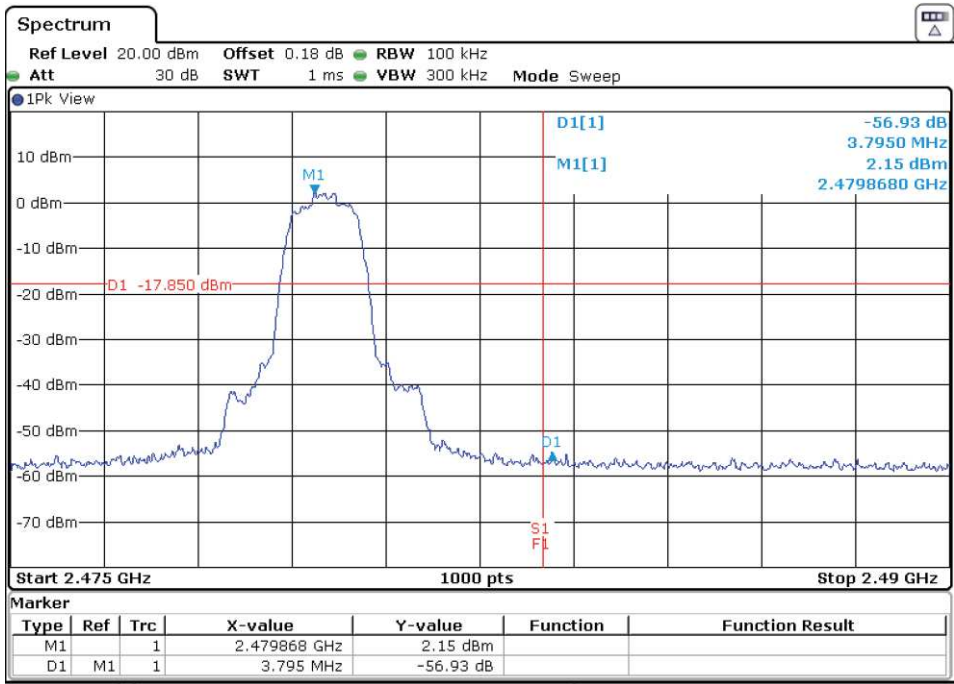
❖ HOPPING OFF:

- Low Frequency Section 2402 MHz:



Verdict: PASS

- High Frequency Section 2480 MHz:

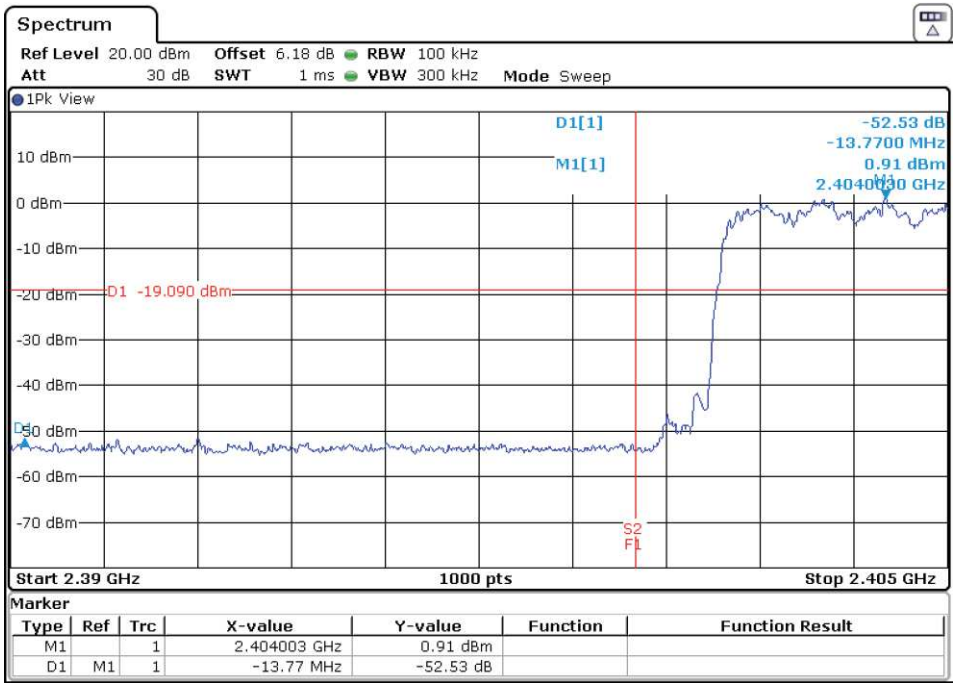


Verdict: PASS

• 8DPSK – Band-edge emissions compliance

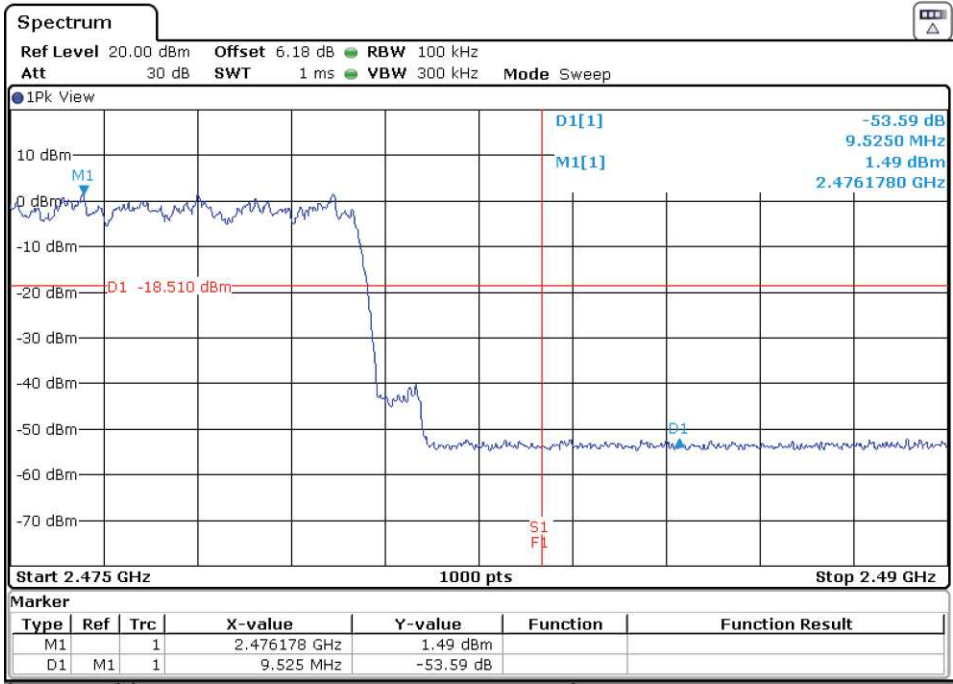
❖ HOPPING ON:

- Low Frequency Section 2402 MHz:



Verdict: PASS

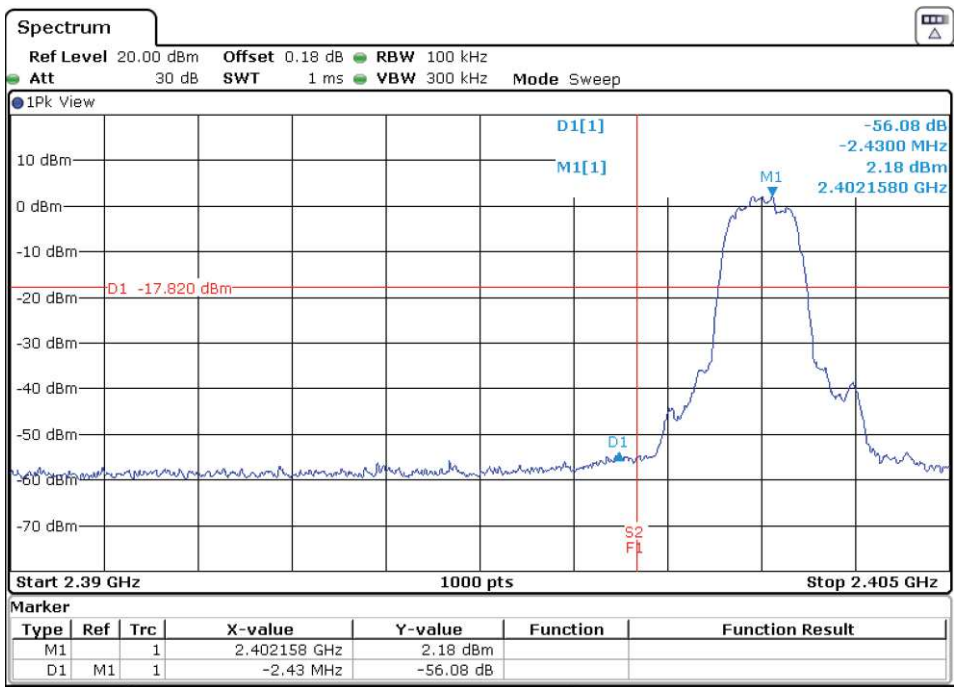
- High Frequency Section 2480 MHz:



Verdict: PASS

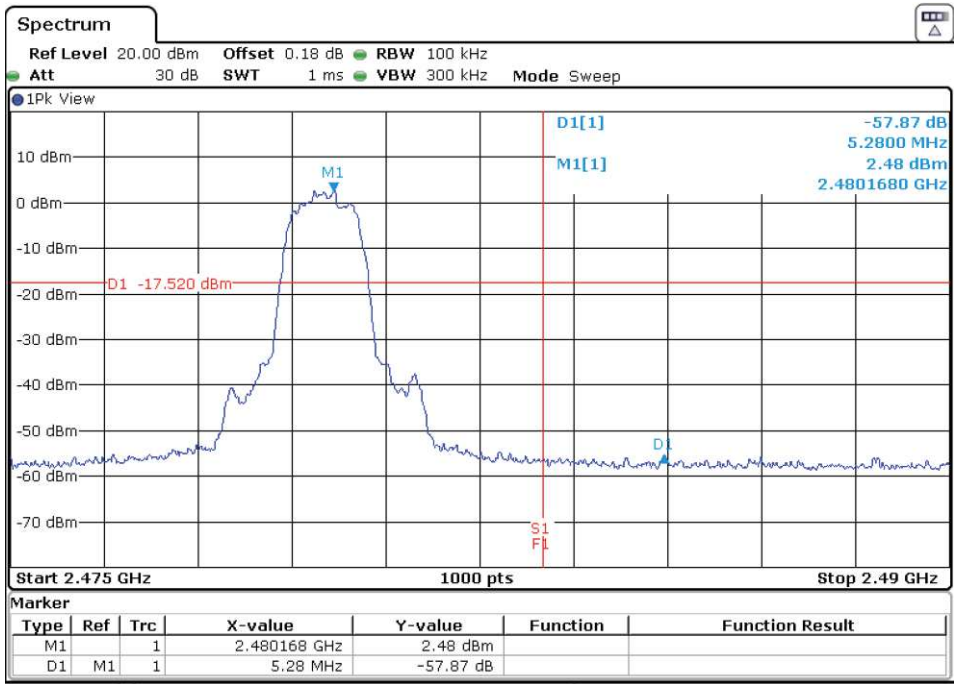
❖ HOPPING OFF:

- Low Frequency Section 2402 MHz:



Verdict: PASS

- High Frequency Section 2480 MHz:



Verdict: PASS

FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Emission limitations radiated. (Transmitter)

SPECIFICATION:

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) (see §15.205(c)/RSS-Gen):

Frequency Range (MHz)	Field strength ($\mu\text{V/m}$)	Field strength ($\text{dB}\mu\text{V/m}$)	Measurement distance (m)
0.009-0.490	2400/F(kHz)	-	300
0.490-1.705	24000/F(kHz)	-	30
1.705 - 30.0	30	-	30
30 - 88	100	40	3
88 - 216	150	43.5	3
216 - 960	200	46	3
960 - 25000	500	54	3

The emission limits shown in the above table are based on measurements employing CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

For average radiated emission measurements above 1000 MHz, there is also a limit corresponding to 20 dB above the indicated values in the table is specified when measuring with peak detector function.

RSS-247. Attenuation below the general field strength limits specified in RSS-Gen is not required.

RESULTS:

The situation and orientation was varied to find the maximum radiated emission. It was also rotated 360° and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission.

Measurements were made in both horizontal and vertical planes of polarization.

All tests were performed in a semi-anechoic chamber at a distance of 3 m for the frequency range 30 MHz-1000 MHz and at distance of 1m for the frequency range 1 GHz-25 GHz.

The field strength is calculated by adding correction factor to the measured level from the spectrum analyzer. This correction factor includes antenna factor, cable loss and pre-amplifiers gain.

Frequency range 30 MHz - 1 GHz:

Note: The spurious emissions below 1 GHz do not depend on either the operating channel or the modulation mode selected in the EUT.

Spurious levels operating (radiated) closest to limit.

Spurious frequency (MHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
42.254	Quasi peak	23.6	V	< $\pm$ 3.88
786.438	Quasi peak	26.2	V	< $\pm$ 3.88
884.764	Quasi peak	30.3	V	< $\pm$ 3.88

Frequency range 1 - 26 GHz:

The results in the next tables show the maximum measured levels in the 1-26 GHz range including the restricted bands 2.31-2.39 GHz and 2.4835-2.5 GHz.

Spurious signals with peak levels above the average limit (54 dB μ V/m at 3 m) are measured with average detector for checking compliance with the average limit.

Modulation: GFSK (DH5)

1. CHANNEL: LOWEST (2402 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37417	Peak	40.01	H	< $\pm$ 3.70

2. CHANNEL: MIDDLE (2441 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37463	Peak	40.00	H	< $\pm$ 3.70

3. CHANNEL: HIGHEST (2480 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37463	Peak	39.36	H	< $\pm$ 3.70

Verdict: PASS

Modulation $\Pi/4$ -DQPSK (2DH5)

1. CHANNEL: LOWEST (2402 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37417	Peak	40.45	H	< $\pm$ 3.70

2. CHANNEL: MIDDLE (2441 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37463	Peak	39.41	H	< $\pm$ 3.70

3. CHANNEL: HIGHEST (2480 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.3737	Peak	39.42	H	< $\pm$ 3.70

Verdict: PASS

Modulation: 8-DPSK (3DH5)

1. CHANNEL: LOWEST (2402 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.3751	Peak	39.74	H	< $\pm$ 3.70

2. CHANNEL: MIDDLE (2441 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37463	Peak	39.92	H	< $\pm$ 3.70

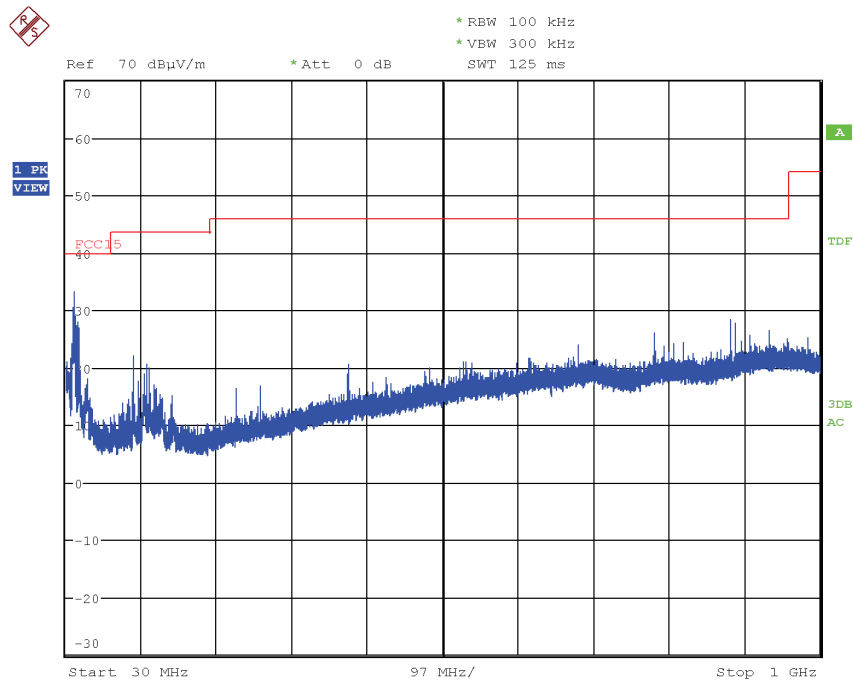
3. CHANNEL: HIGHEST (2480 MHz).

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
5.37463	Peak	39.65	H	< $\pm$ 3.70

Verdict: PASS

FREQUENCY RANGE 30 MHz - 1 GHz:

The spurious signals detected do not depend on either the operating channel or the modulation mode.

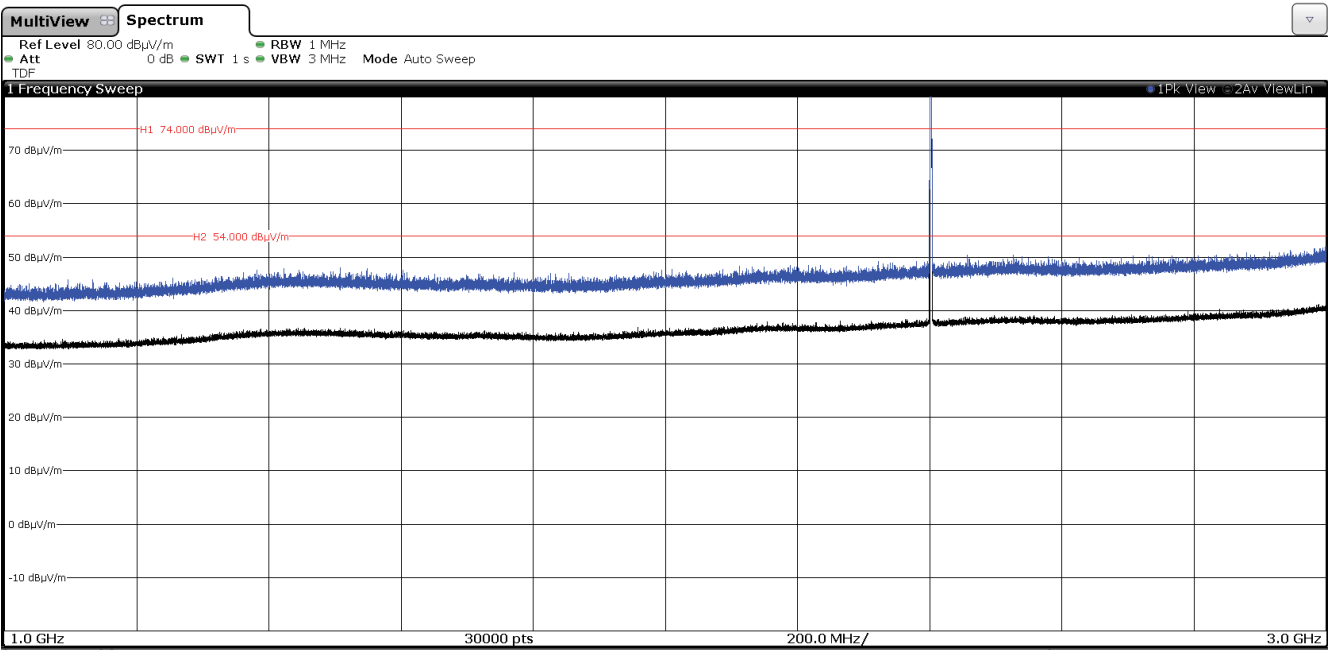


(This plot is valid for all three channels and all modulation modes).

FREQUENCY RANGE 1 - 3 GHz:

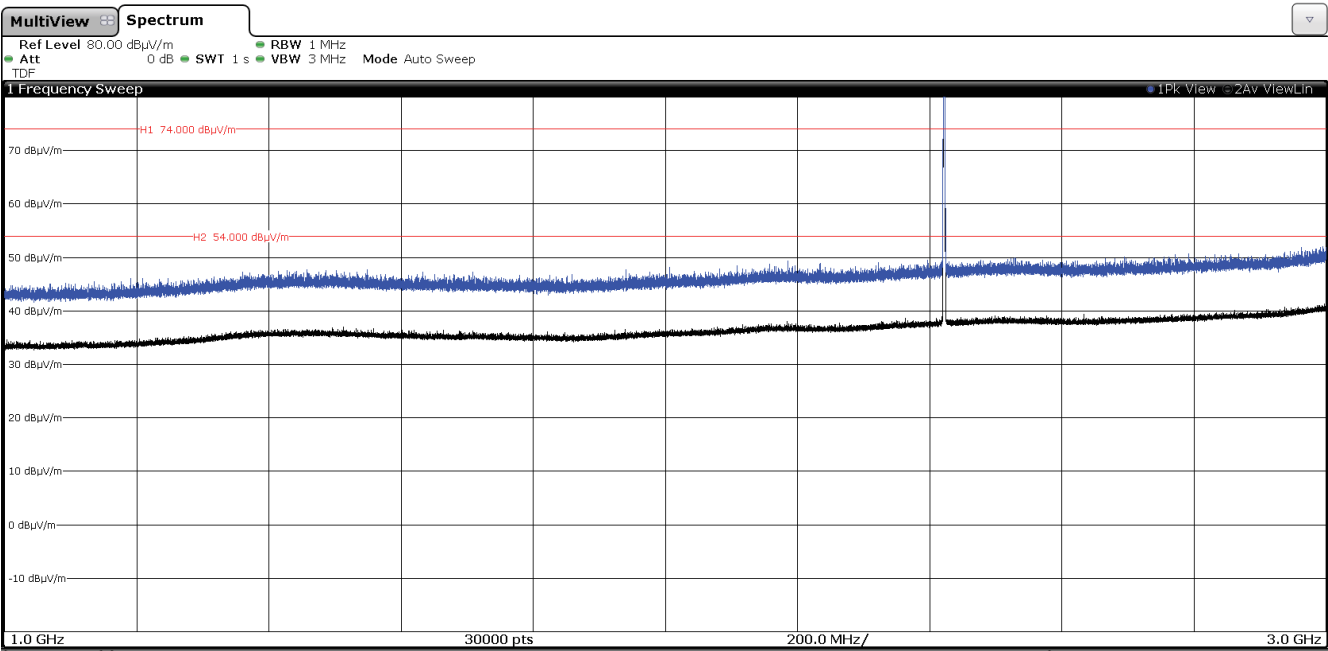
Modulation: GFSK (DH5)

CHANNEL: Lowest (2402 MHz)



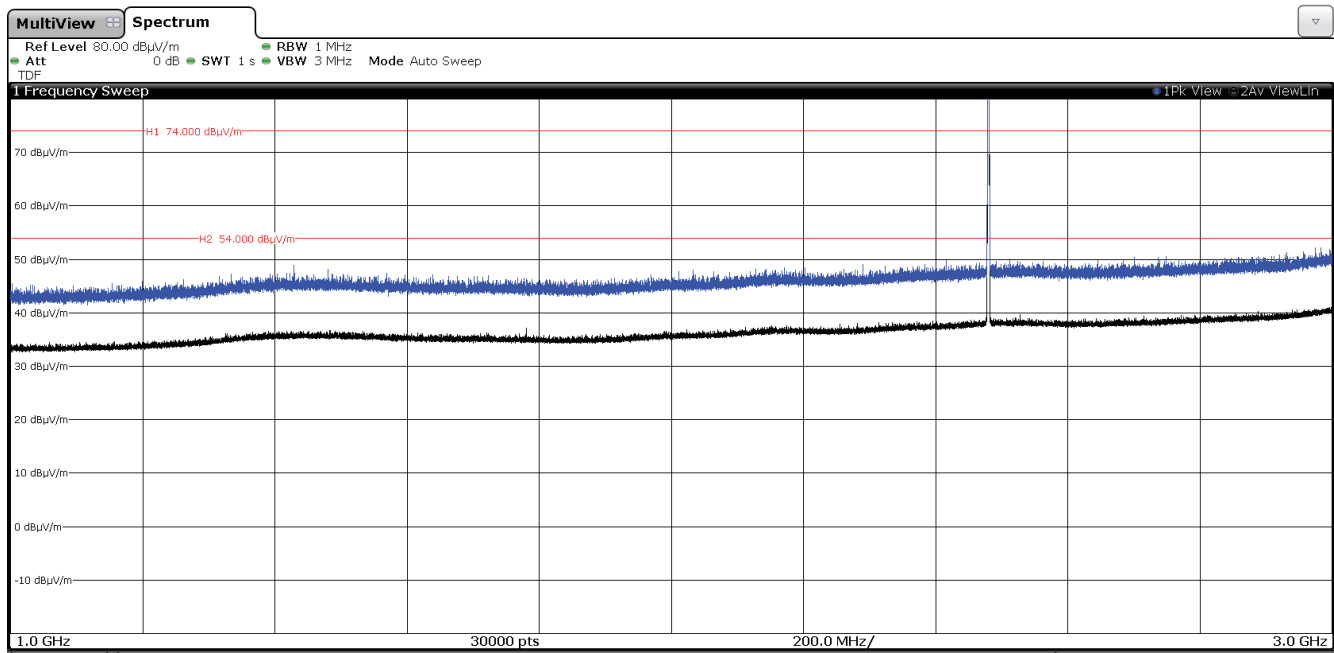
The peak above the limit is the carrier frequency.

CHANNEL: Middle (2441 MHz)



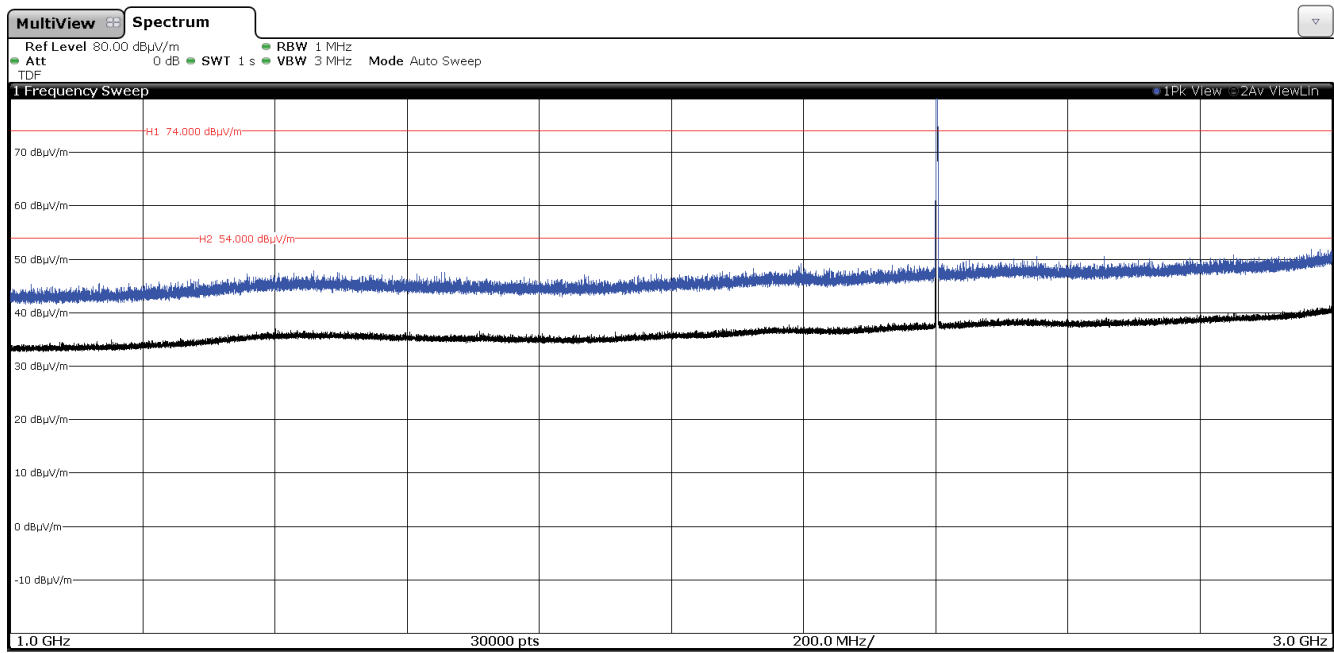
The peak above the limit is the carrier frequency.

CHANNEL: Highest (2480 MHz)



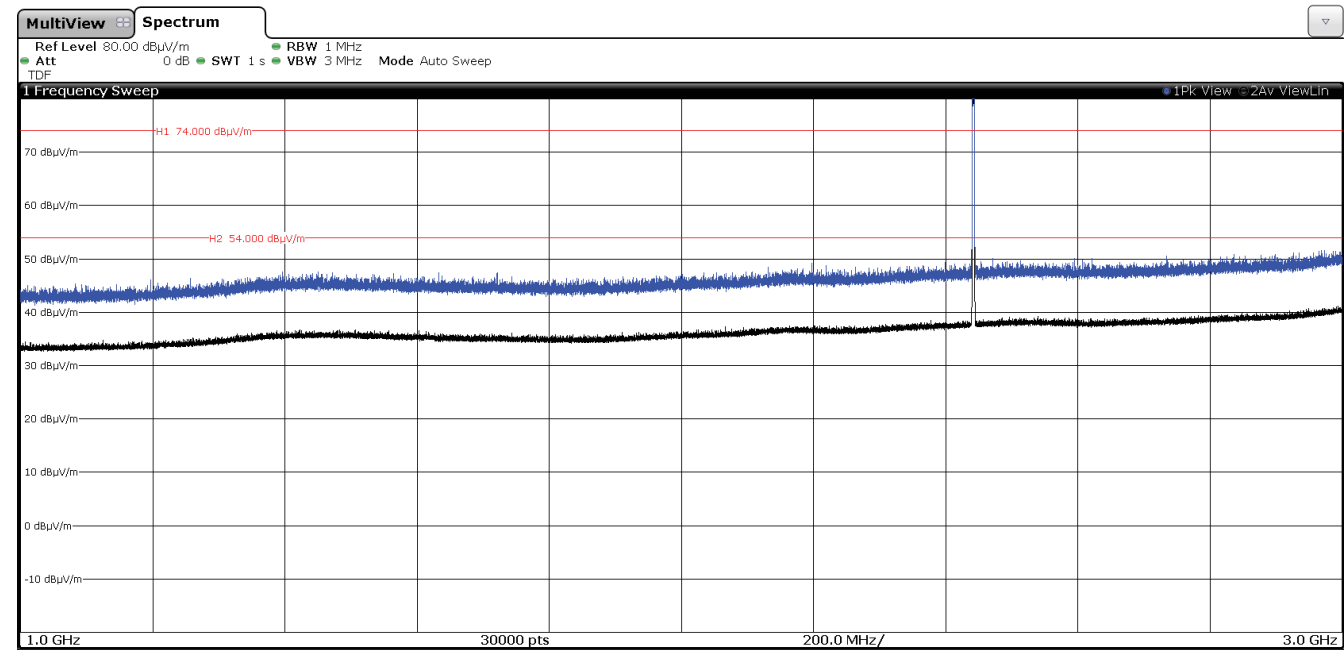
The peak above the limit is the carrier frequency.

Modulation: Π/4-DQPSK (2DH5)
CHANNEL: Lowest (2402 MHz)



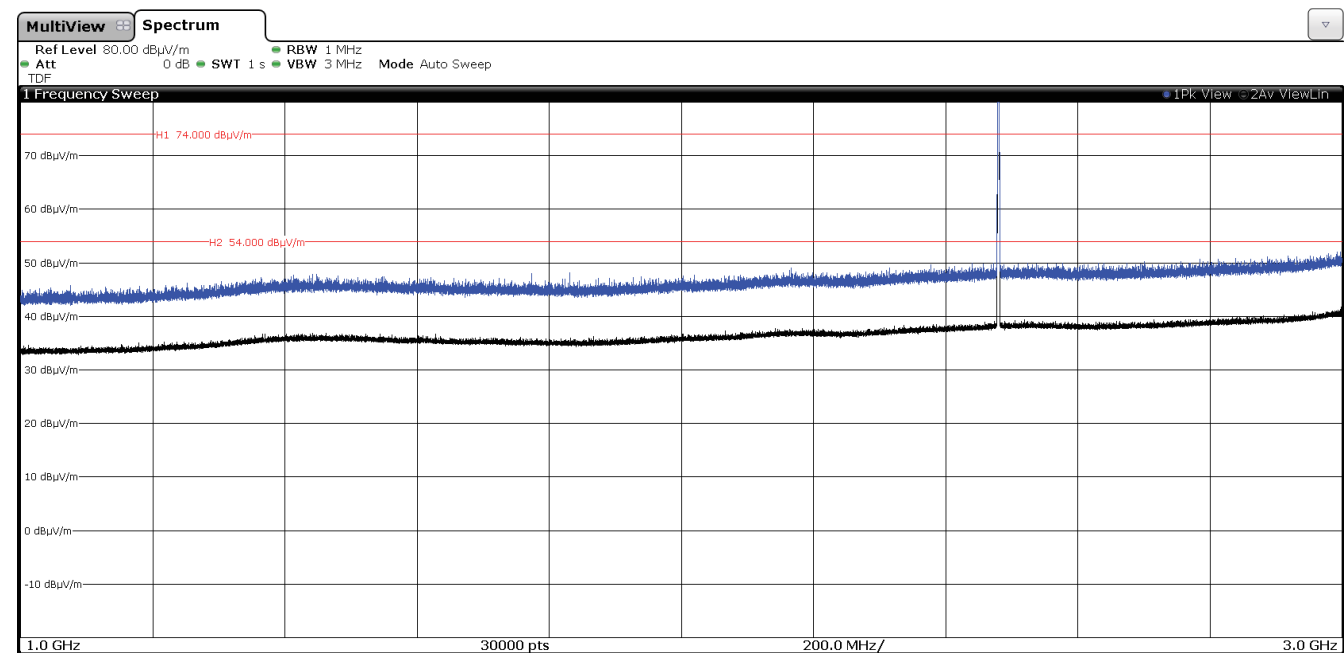
The peak above the limit is the carrier frequency.

CHANNEL: Middle (2441 MHz)



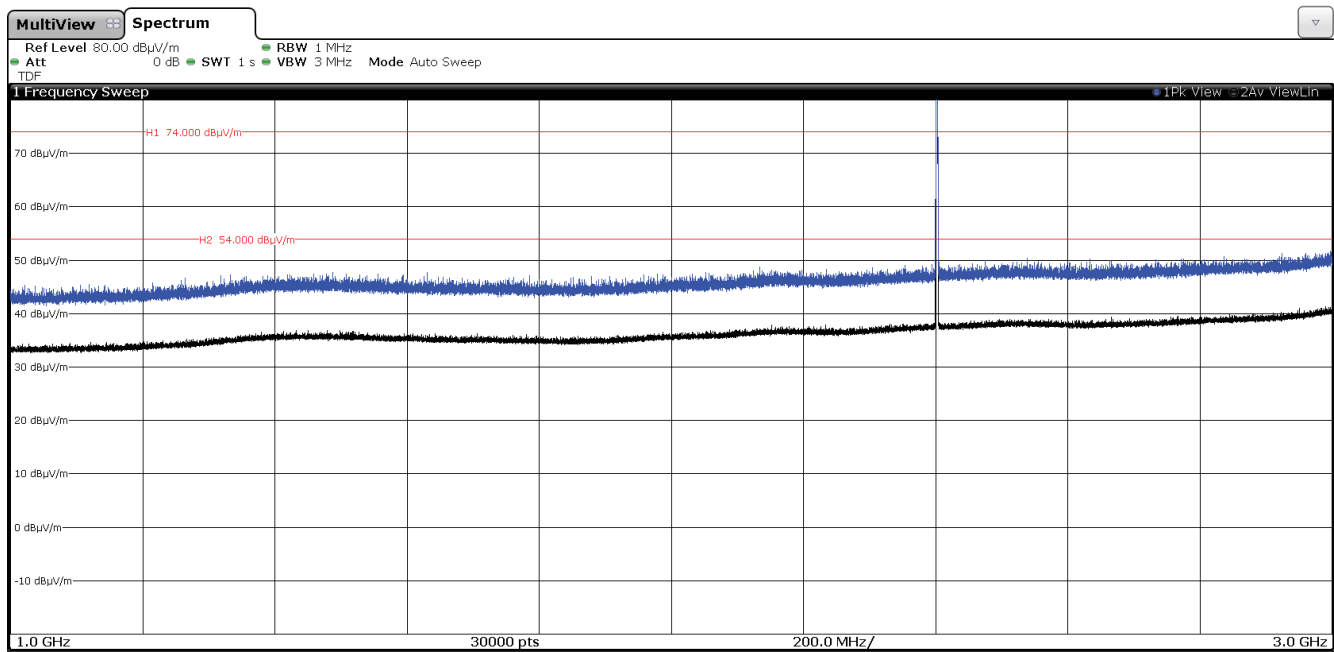
The peak above the limit is the carrier frequency.

CHANNEL: Highest (2480 MHz)



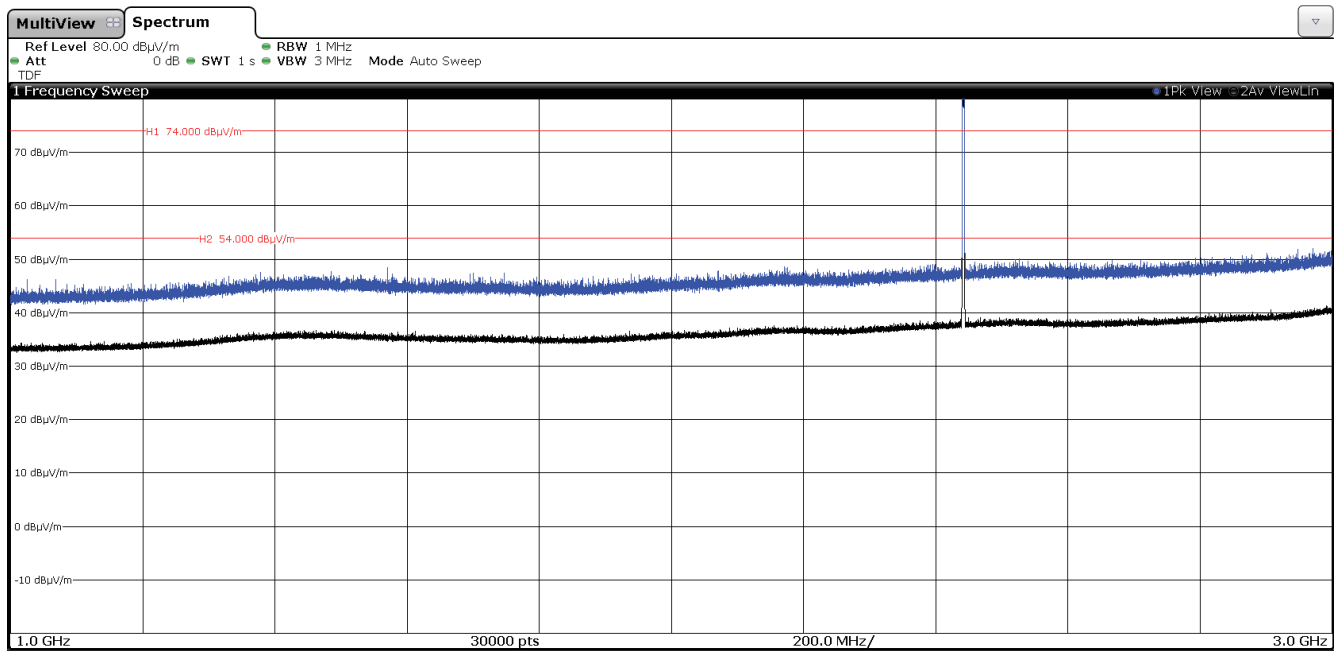
The peak above the limit is the carrier frequency.

Modulation: 8-DPSK (3DH5)
CHANNEL: Lowest (2402 MHz)



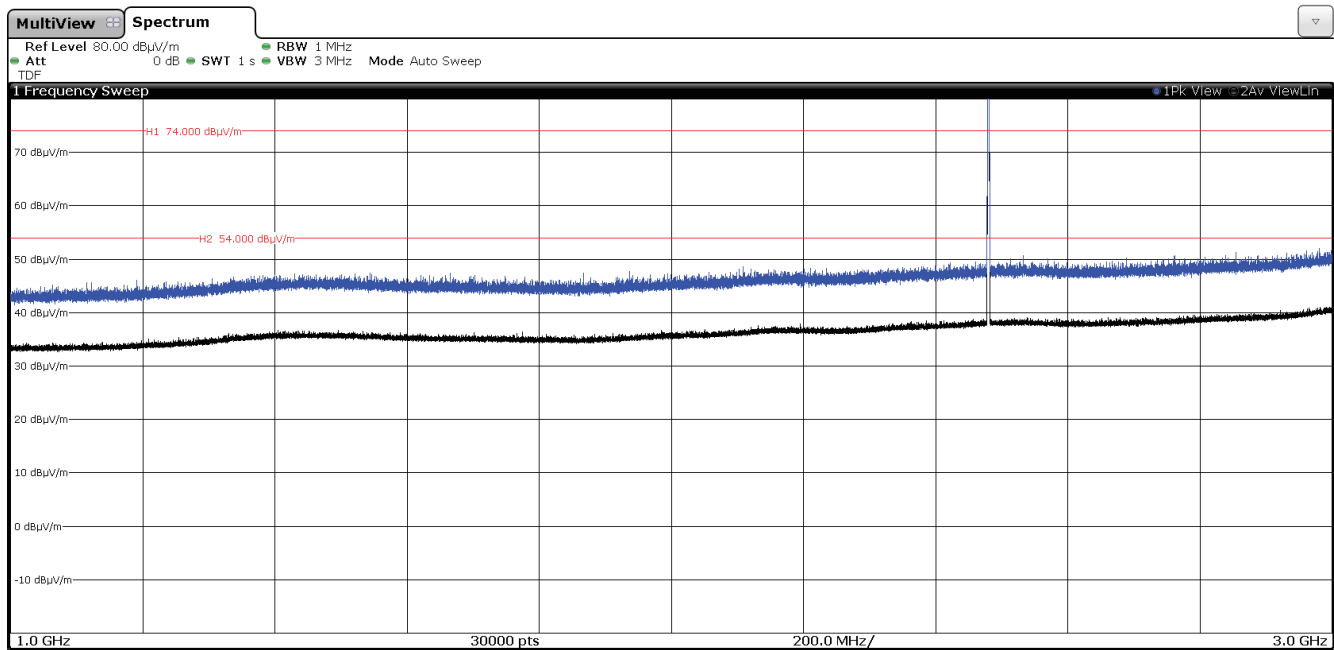
The peak above the limit is the carrier frequency.

CHANNEL: Middle (2441 MHz)



The peak above the limit is the carrier frequency.

CHANNEL: Highest (2480 MHz)

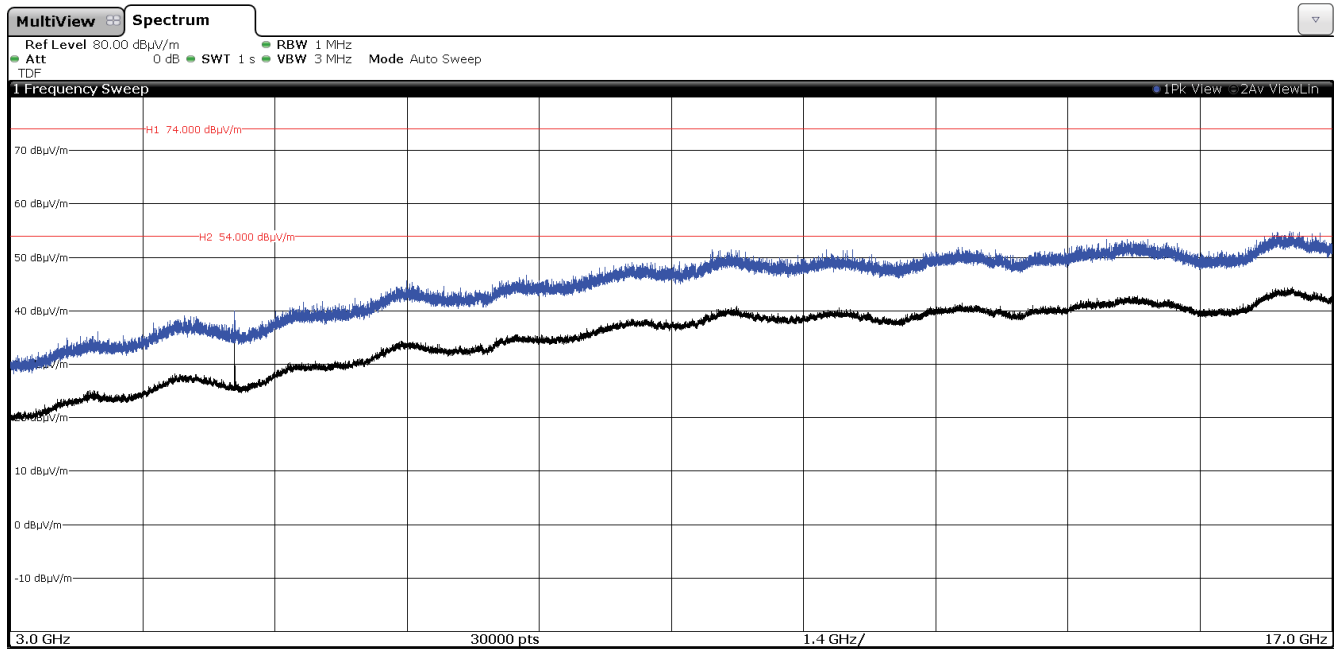


The peak above the limit is the carrier frequency.

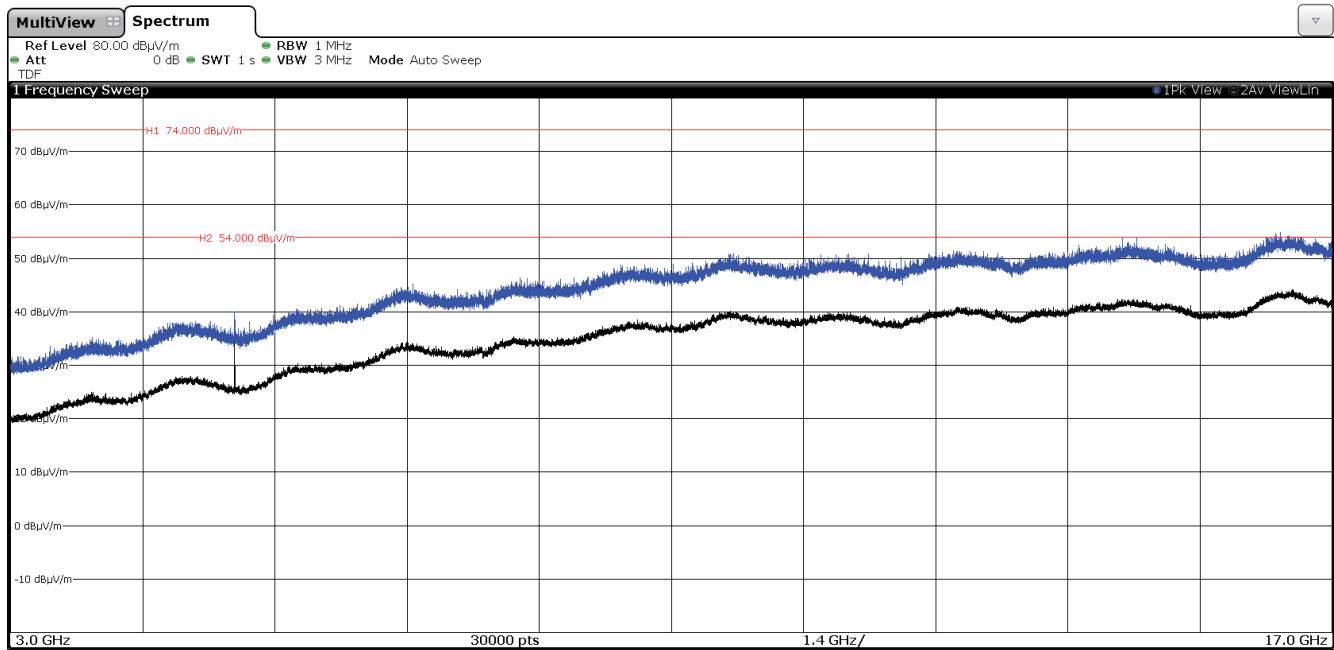
FREQUENCY RANGE 3 - 17 GHz:

Modulation: GFSK (DH5)

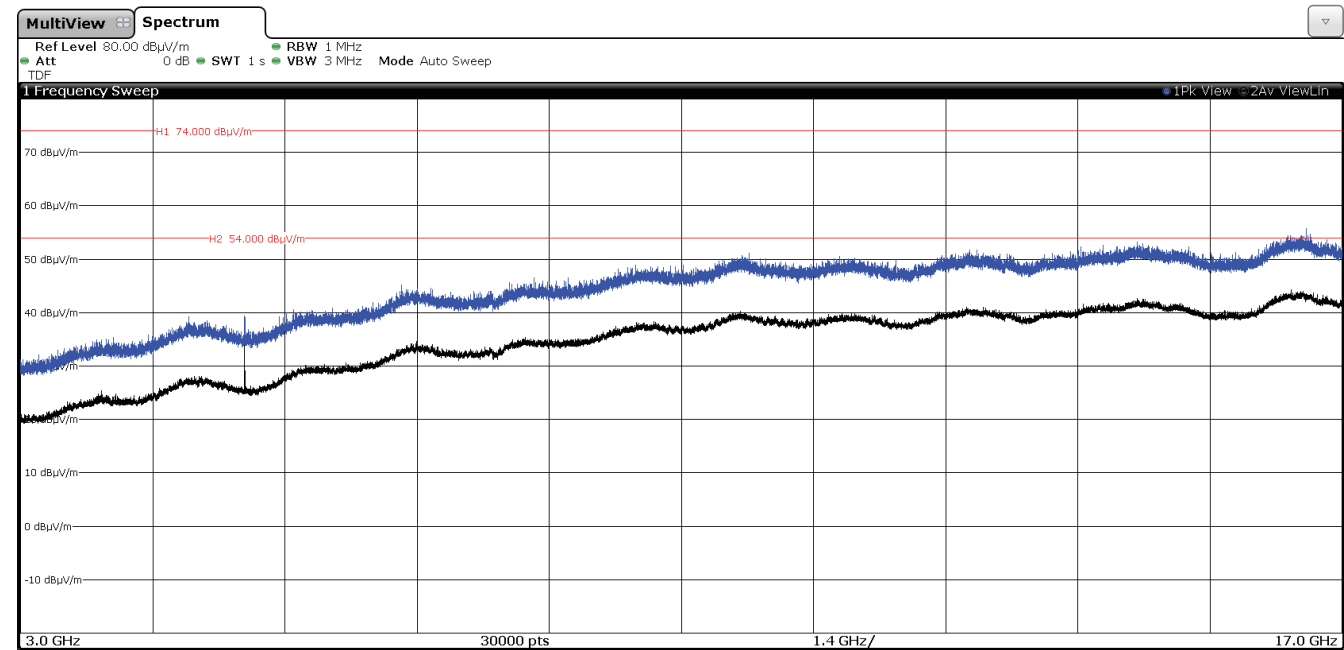
CHANNEL: Lowest (2402 MHz)



CHANNEL: Middle (2441 MHz)

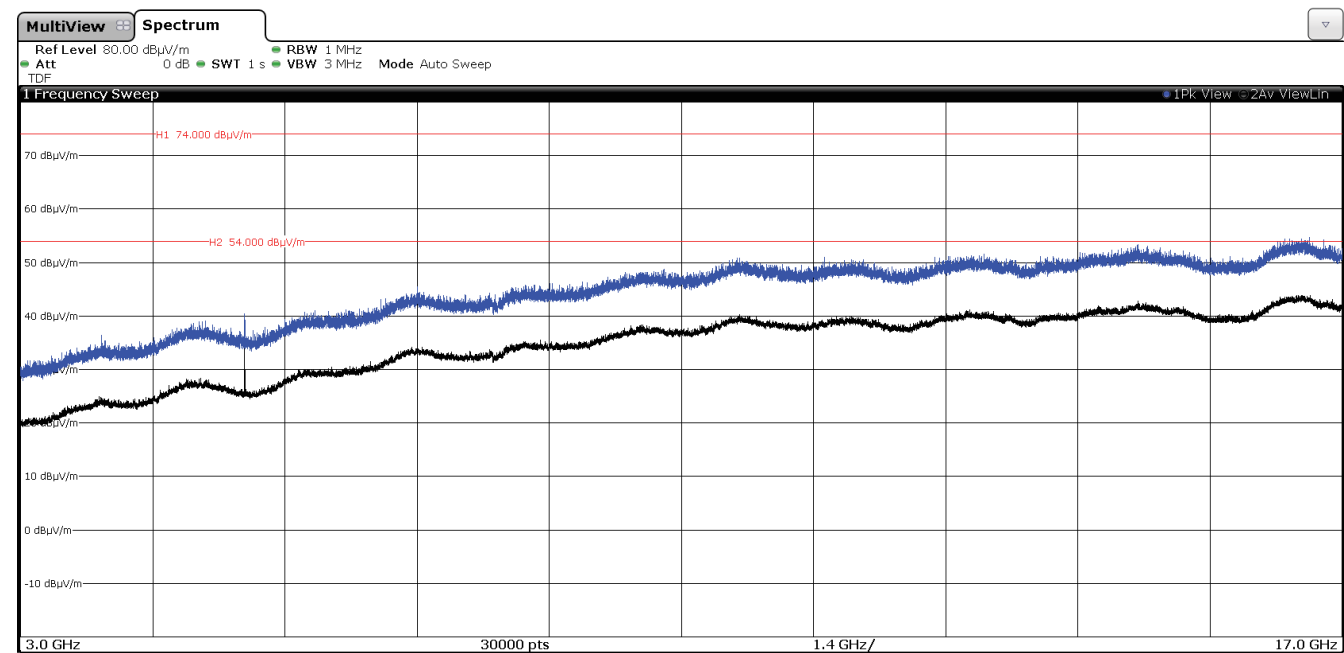


CHANNEL: Highest (2480 MHz)

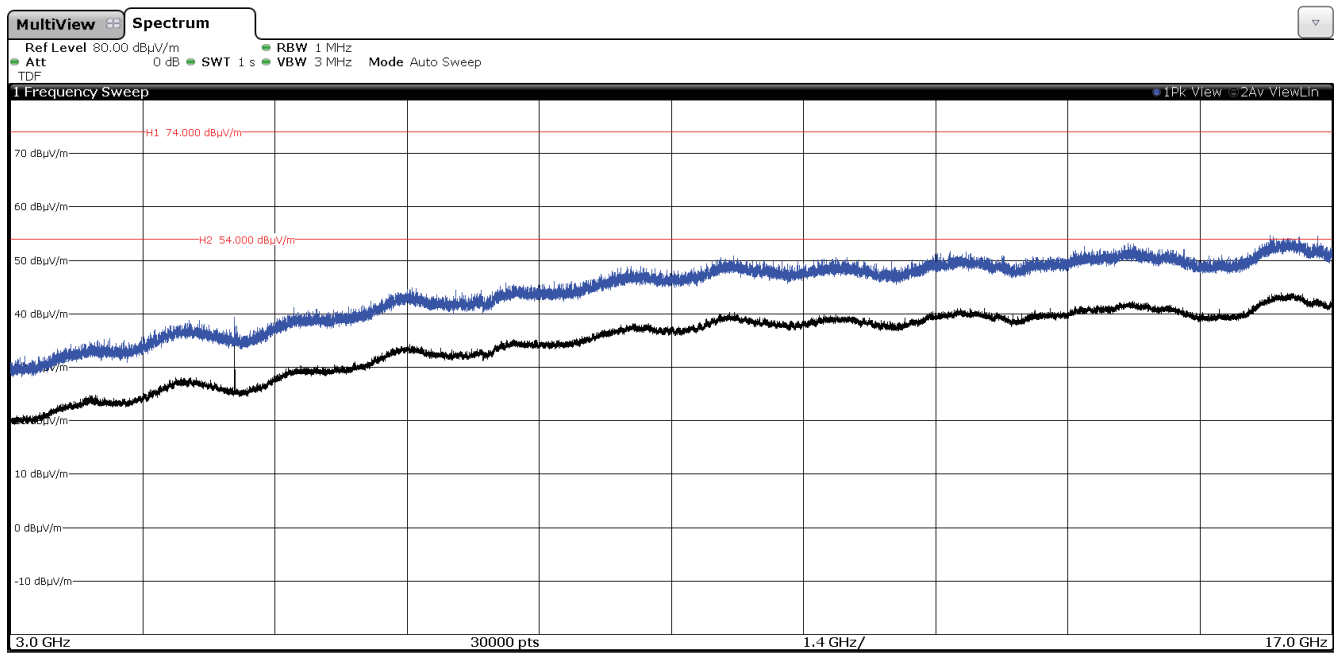


Modulation: Π/4-DQPSK (2DH5)

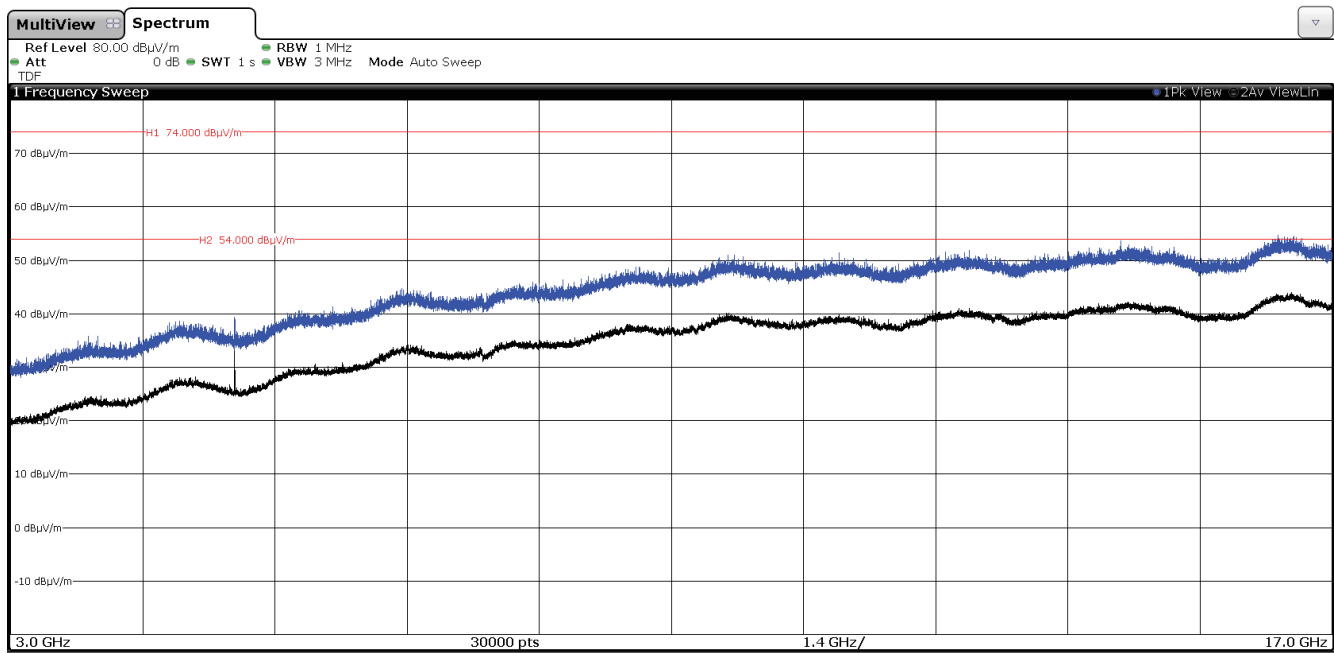
CHANNEL: Lowest (2402 MHz)



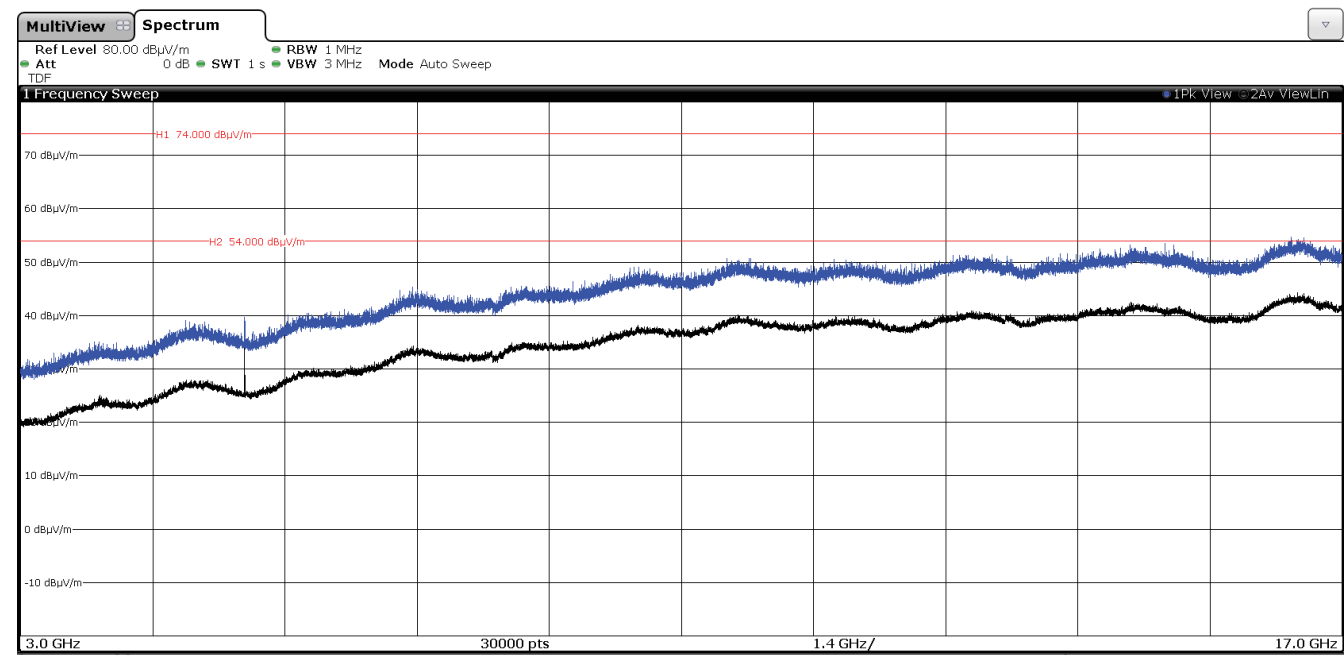
CHANNEL: Middle (2441 MHz)



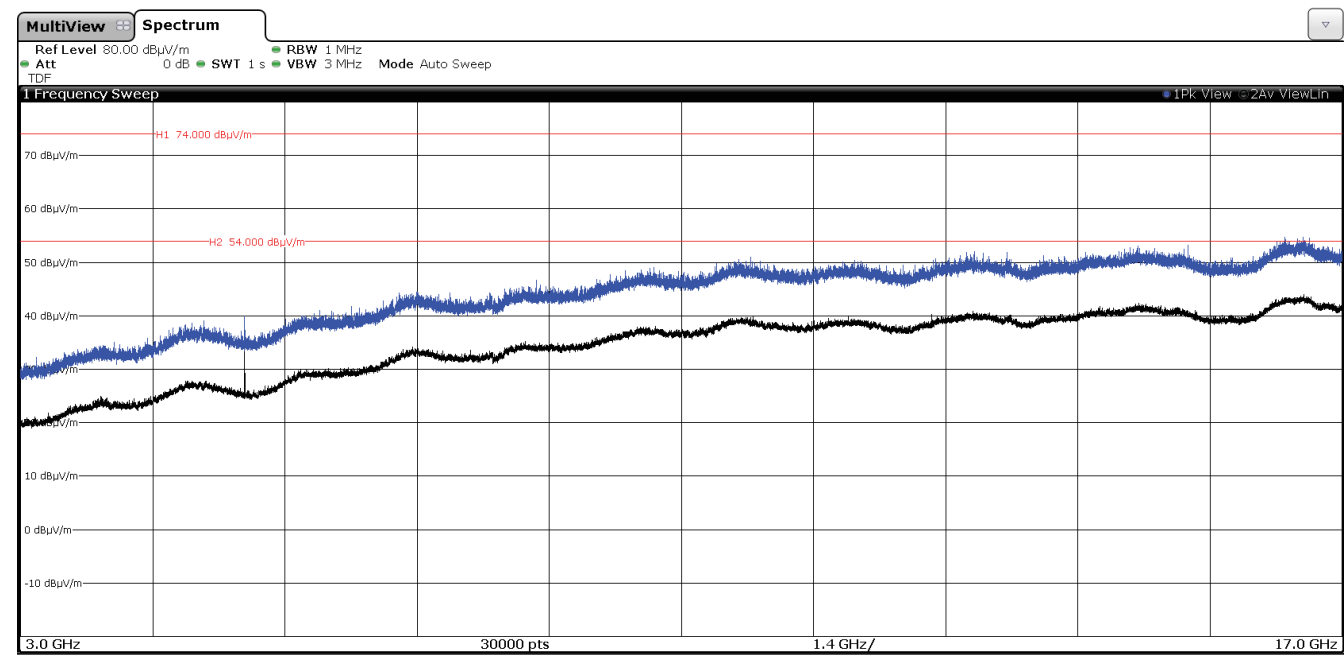
CHANNEL: Highest (2480 MHz)



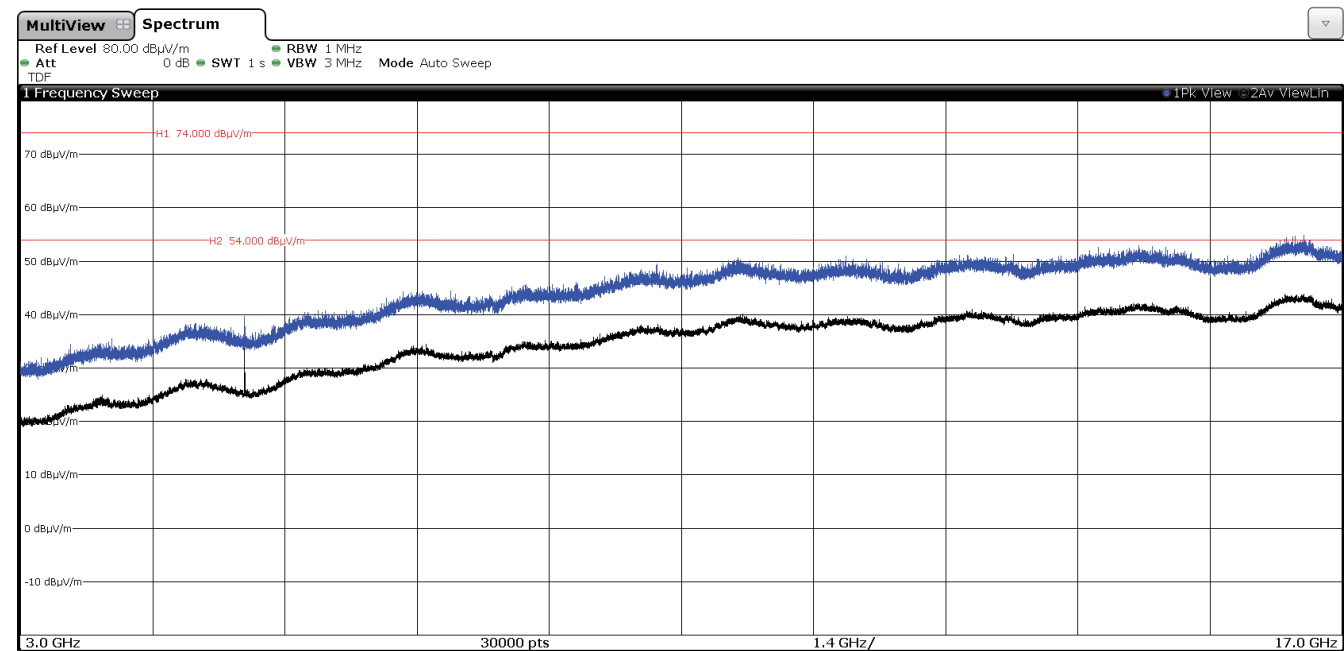
Modulation: 8-DPSK (3DH5)
CHANNEL: Lowest (2402 MHz)



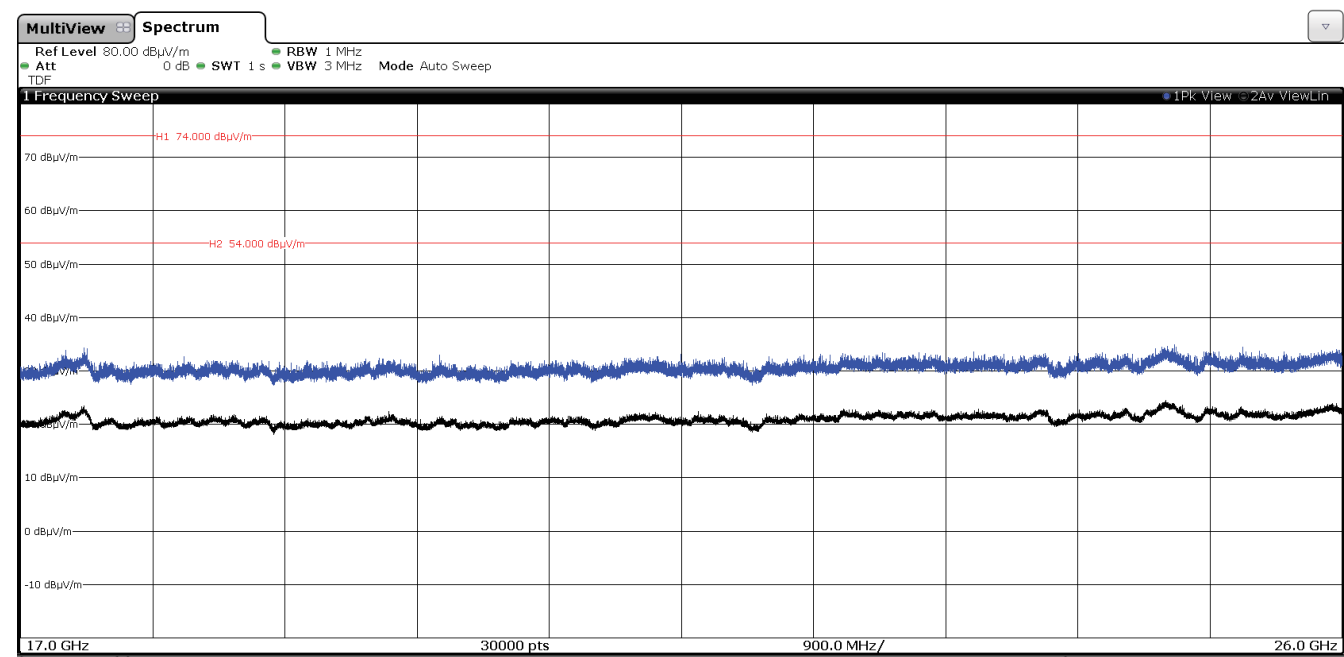
CHANNEL: Middle (2441 MHz):



CHANNEL: Highest (2480 MHz):



FREQUENCY RANGE 17 - 26 GHz:

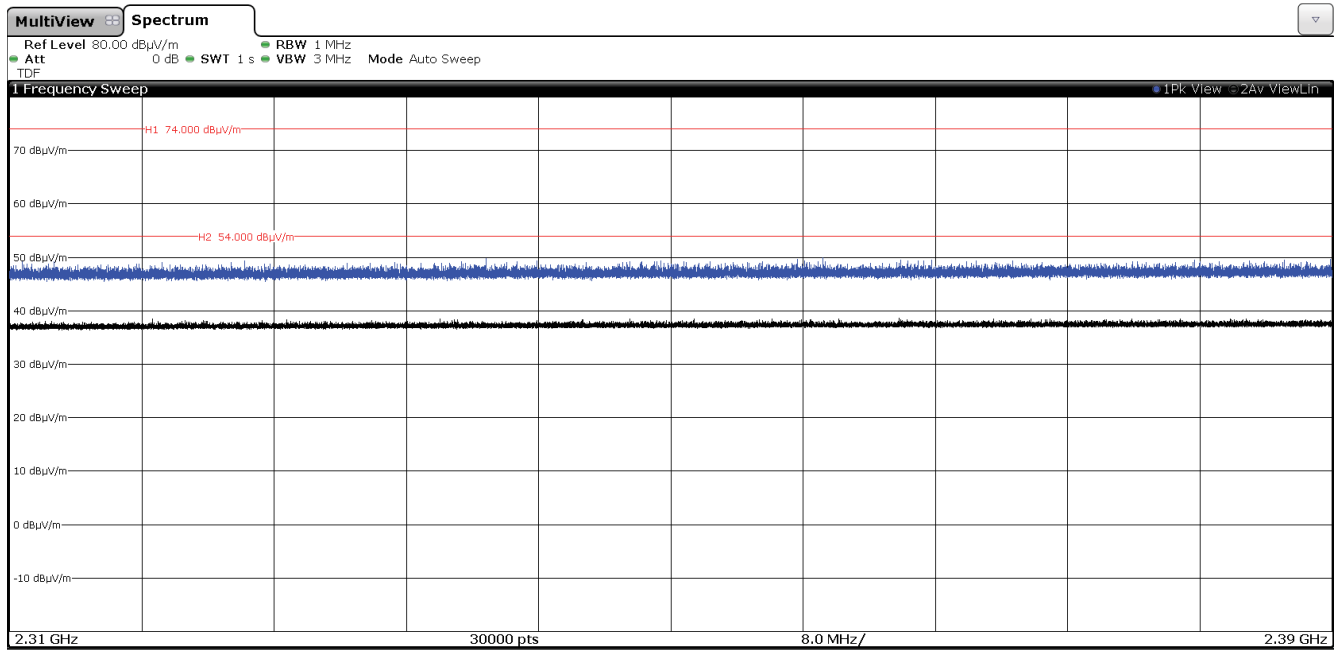


(This plot is valid for all three channels and all modulation modes).

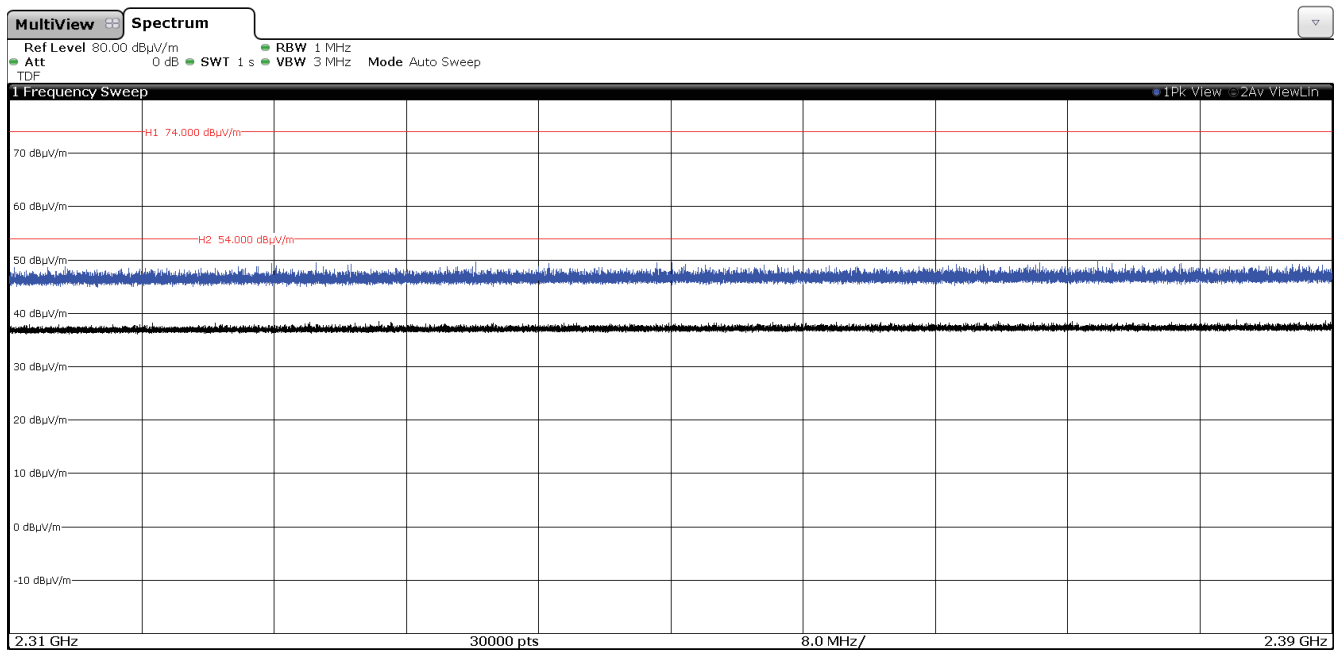
FREQUENCY RANGE 2.31-2.39 GHz (Restricted Band 1):

CHANNEL: Lowest (2402 MHz)

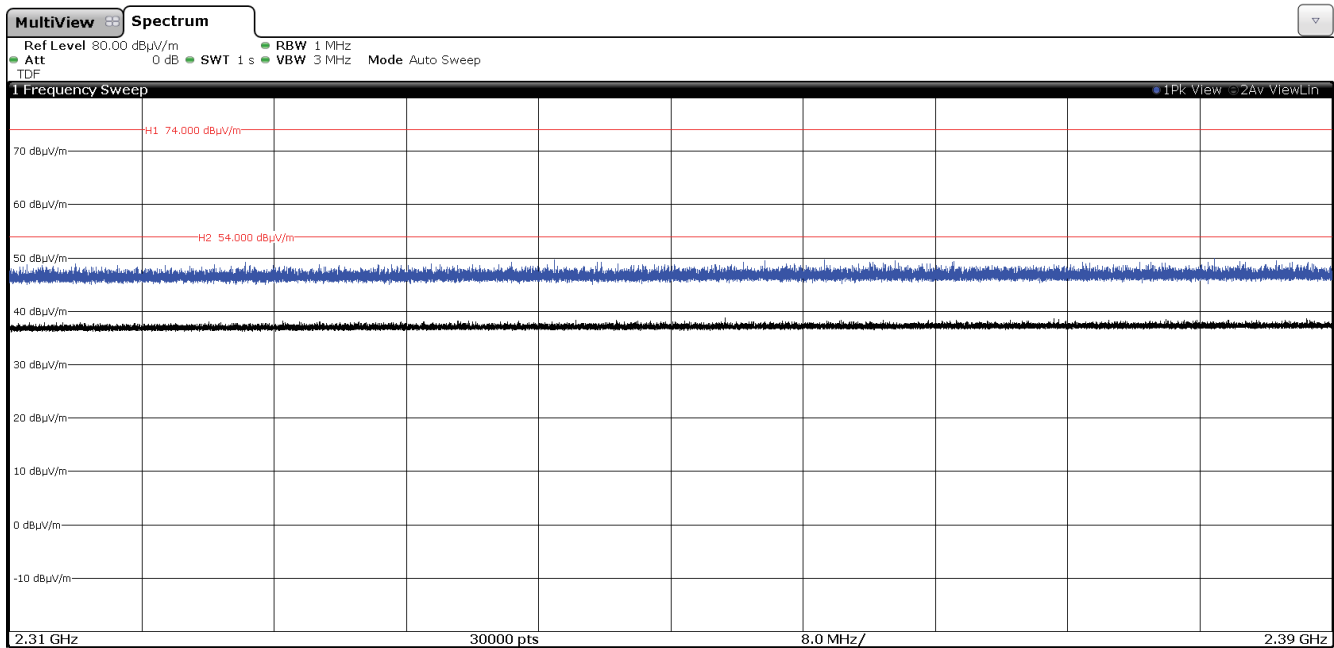
Modulation: GFSK (DH5)



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



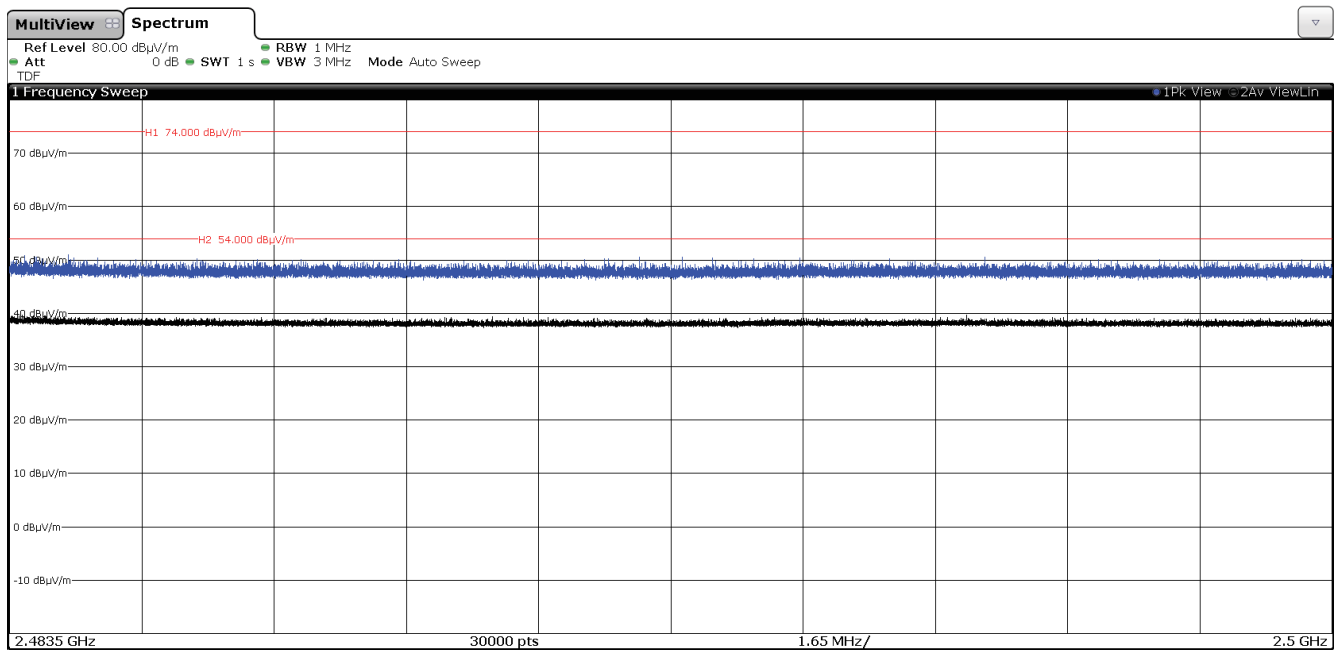
Modulation: 8-DPSK (3DH5)



FREQUENCY RANGE 2.4835-2.5 GHz (Restricted Band 2):

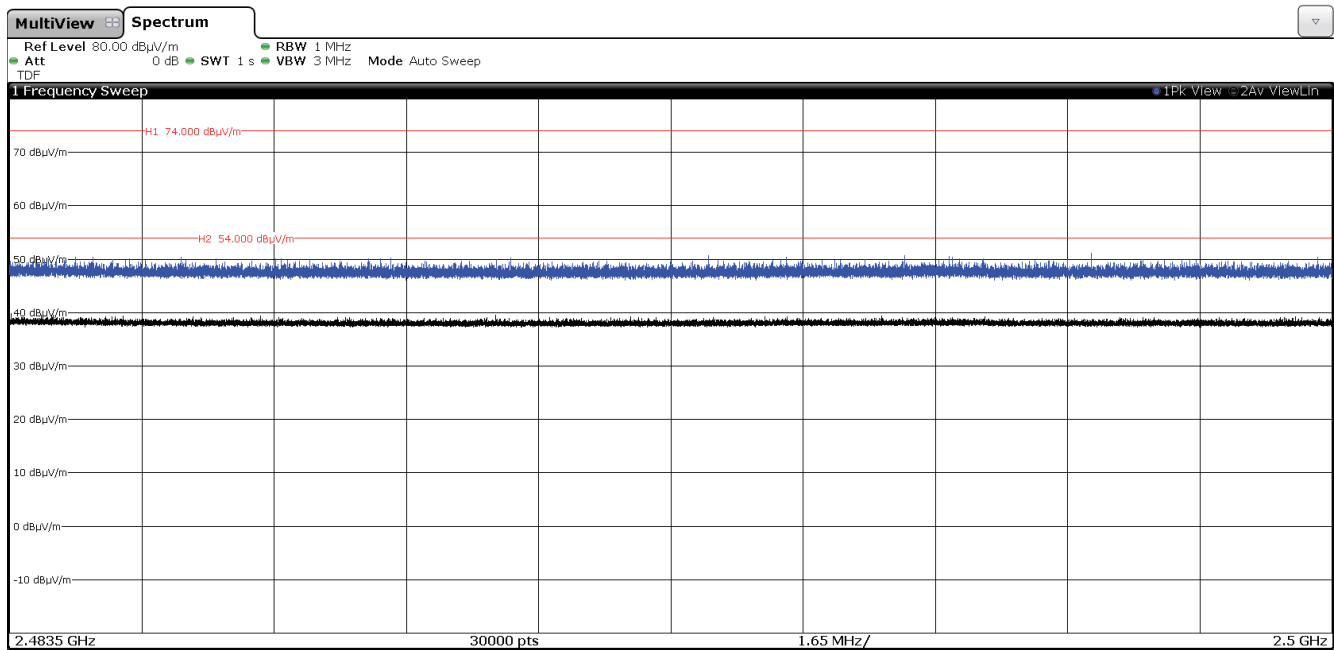
CHANNEL: Highest (2480 MHz)

Modulation: GFSK (DH5)



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

High Channel:



Modulation: 8-DPSK (3DH5)

