

10. FCC §15.247(a)(1) & RSS-247 §5.1(b), RSS-GEN §6.7– Emission Bandwidth

10.1. Applicable Standard

According to FCC §15.247(a) (1) the maximum 20 dB bandwidth of the hopping channel shall be presented.

According to RSS-247 §5.1(b)

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

According to RSS-GEN §6.7

The occupied bandwidth or the “99% emission bandwidth” is defined as the frequency range between two points, one above and the other below the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained. The occupied bandwidth shall be reported for all equipment in addition to the specified bandwidth required in the applicable RSSs.

10.2. Test Procedure

According to ANSI C63.10-2013, section 6.9.2

20 dB Emission Bandwidth

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT without connection to measurement instrument. Turn on the EUT and connect it to measurement instrument. Then set it to any one convenient frequency within its operating range. Set a reference level on the measuring instrument equal to the highest peak value.
- 3 Measure the frequency difference of two frequencies that were attenuated 20 dB from the reference level. Record the frequency difference as the emission bandwidth.
4. Repeat above procedures until all frequencies measured were complete.

According to ANSI C63.10-2013 Section 6.9.3

For the 99% emission bandwidth, the trace data points are recovered and directly summed in linear power level terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached, and that frequency recorded. The process is repeated for the highest frequency data points (starting at the highest frequency, at the right side of the span, and going down in frequency). This frequency is then recorded. The difference between the two recorded frequencies is the occupied bandwidth (or the 99% emission bandwidth).

10.3. Test Results

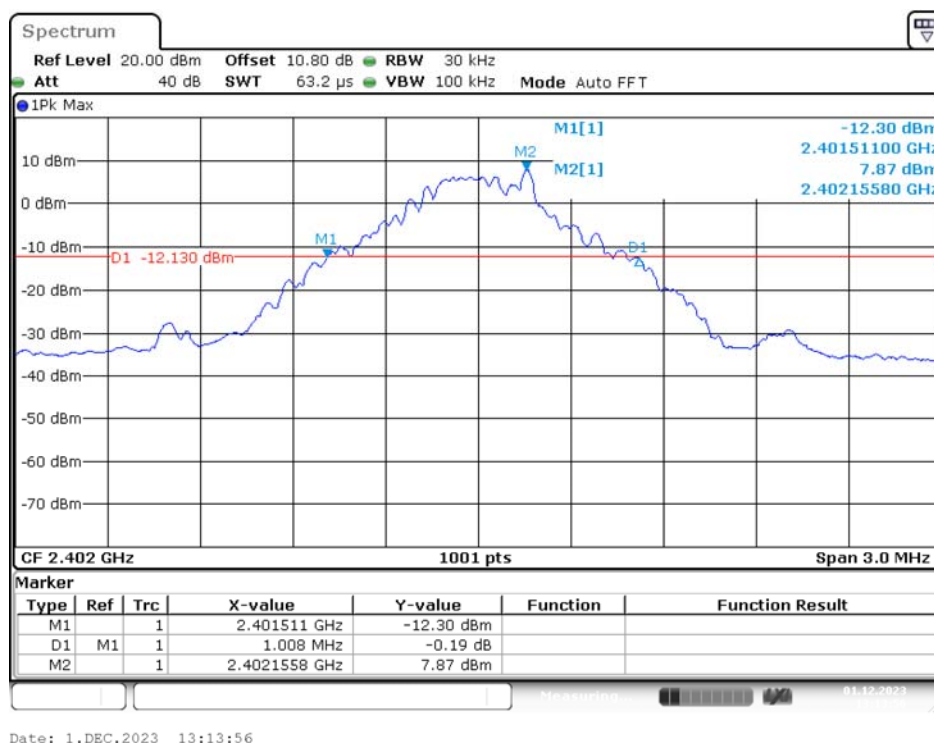
Channel	Frequency (MHz)	20 dB Bandwidth (MHz)	99% Bandwidth (MHz)
<i>BR Mode (GFSK)</i>			
Low	2402	1.01	0.91
Middle	2441	0.97	0.91
High	2480	0.98	0.91
<i>EDR Mode ($\pi/4$-DQPSK)</i>			
Low	2402	1.36	1.23
Middle	2441	1.36	1.24
High	2480	1.36	1.25
<i>EDR Mode (8DPSK)</i>			
Low	2402	1.33	1.23
Middle	2441	1.33	1.24
High	2480	1.33	1.26

Please refer to the following plots

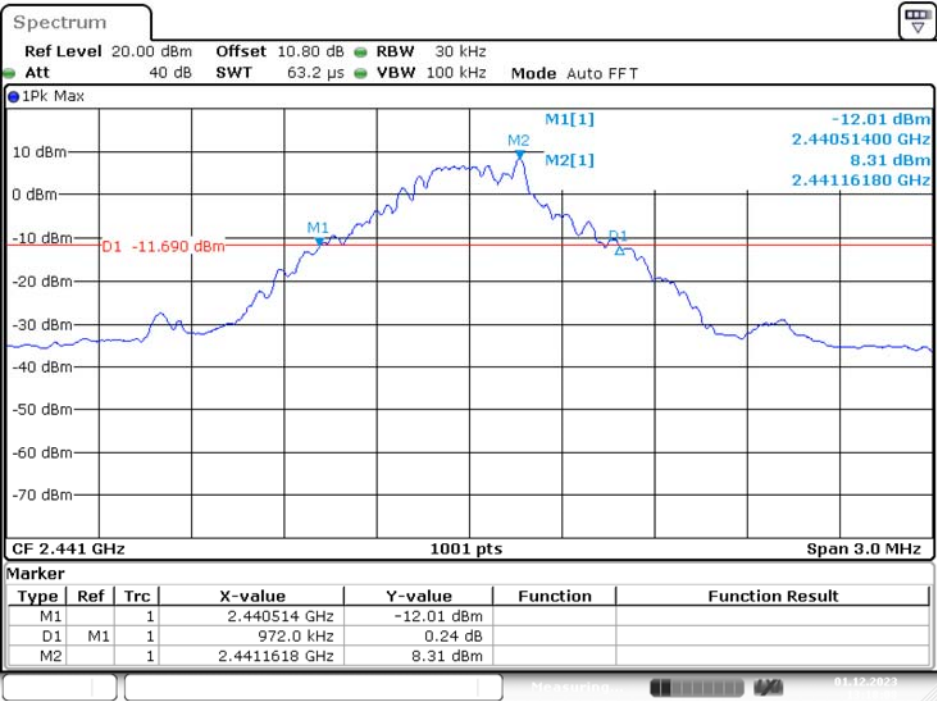
20 dB Emission Bandwidth

BR Mode (GFSK)

Low Channel

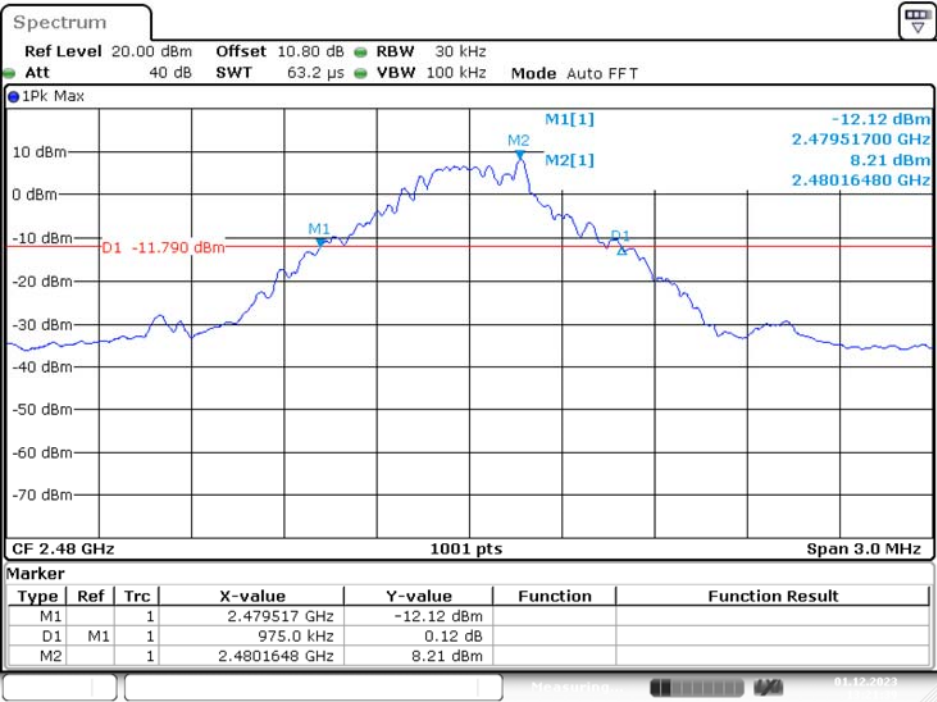


Middle Channel



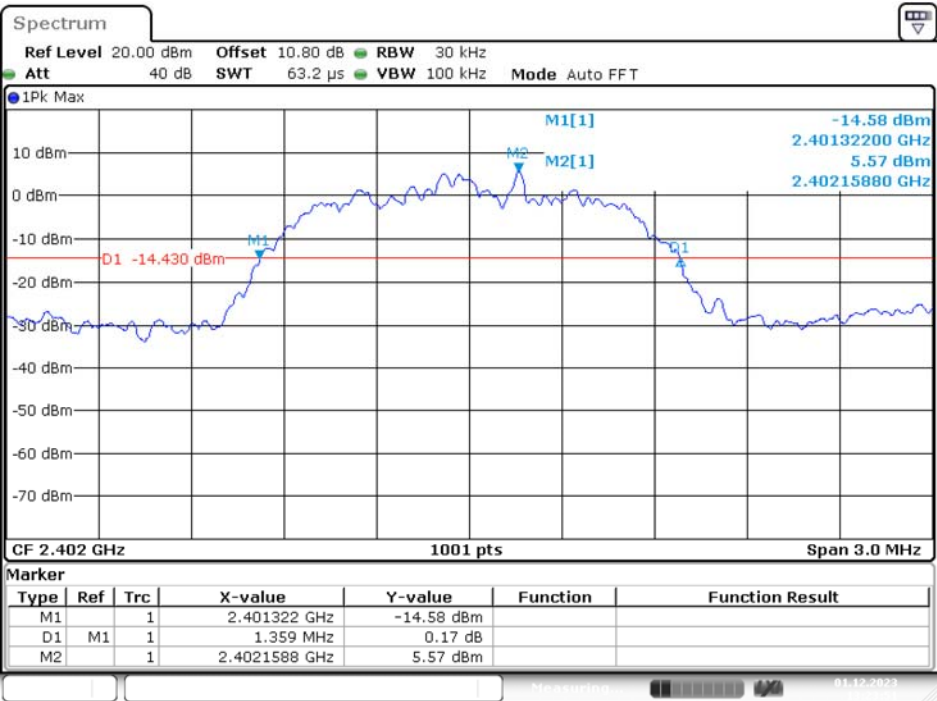
Date: 1.DEC.2023 13:18:08

High Channel



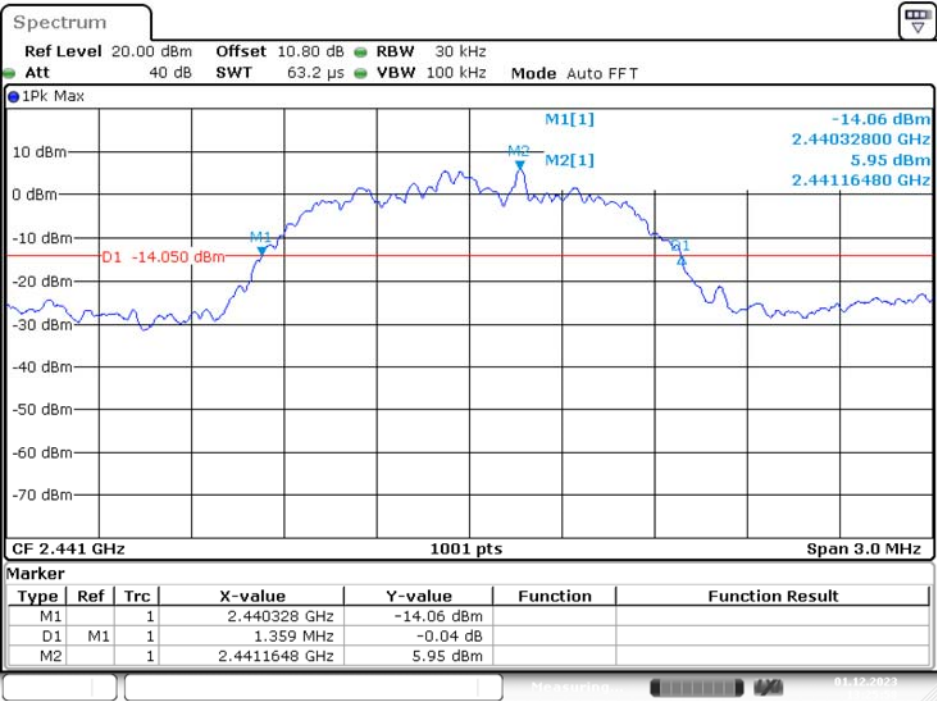
Date: 1.DEC.2023 13:21:40

EDR Mode ($\pi/4$ -DQPSK)
Low Channel



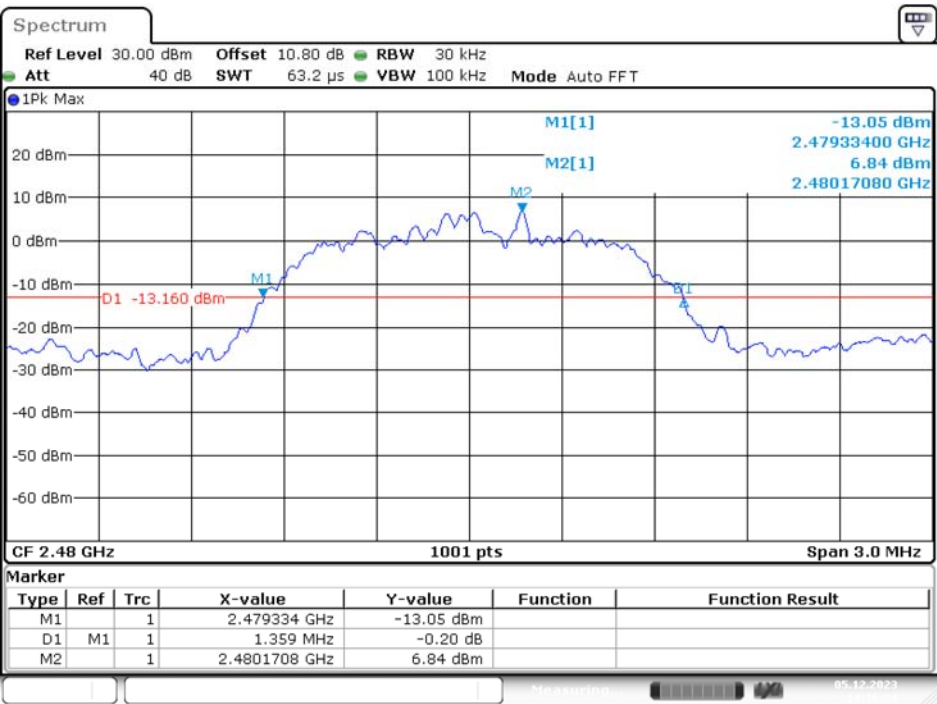
Date: 1.DEC.2023 13:23:51

Middle Channel



Date: 1.DEC.2023 13:25:58

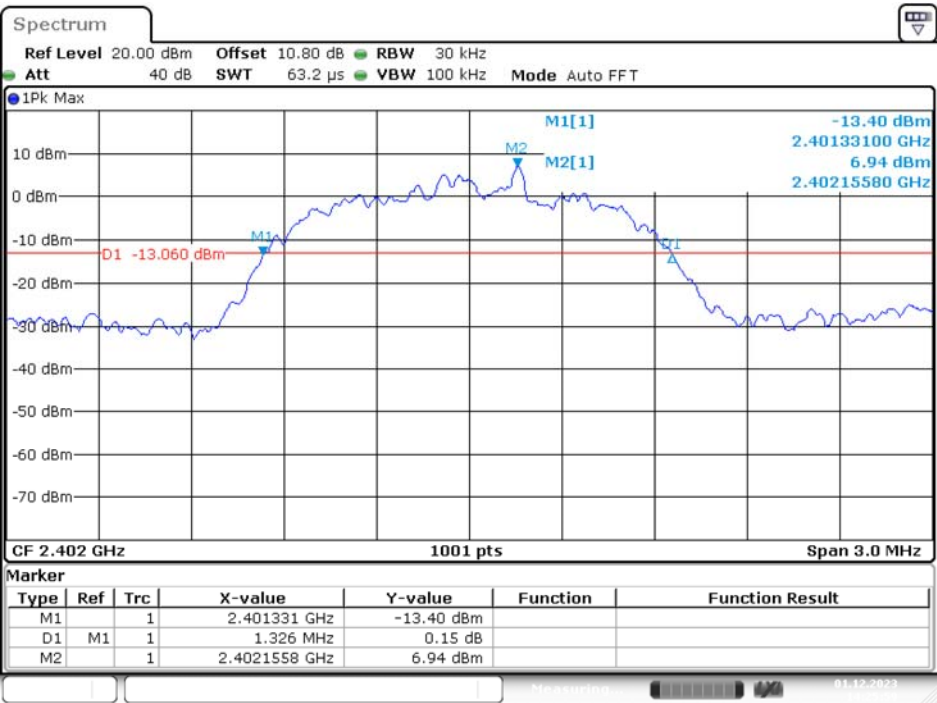
High Channel



Date: 5.DEC.2023 14:16:24

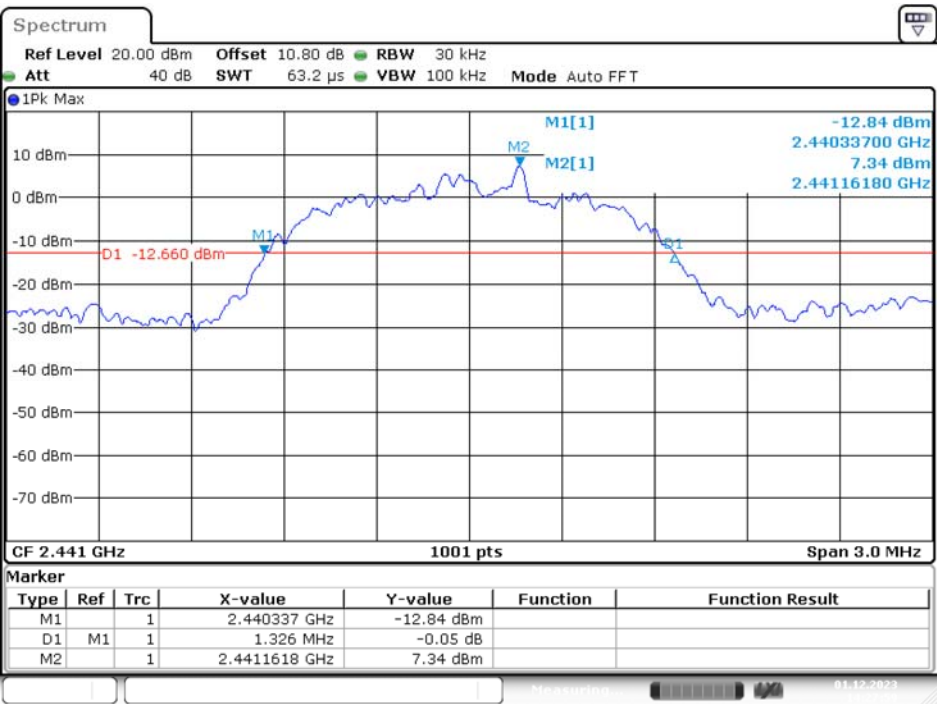
EDR Mode (8DPSK)

Low Channel



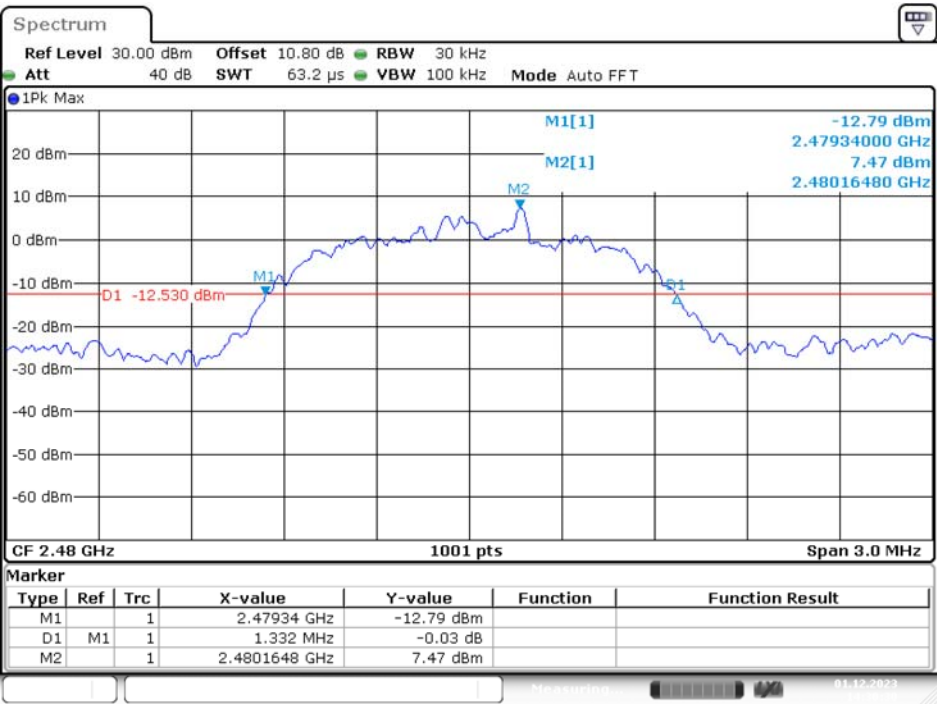
Date: 1.DEC.2023 14:25:59

Middle Channel



Date: 1.DEC.2023 14:27:59

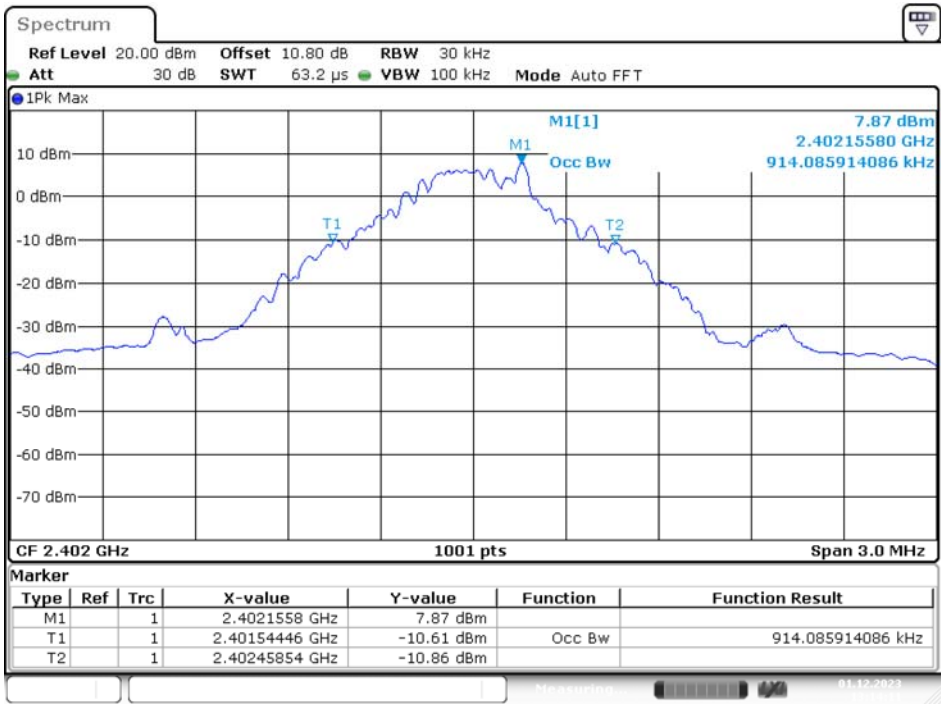
High Channel



Date: 1.DEC.2023 14:30:31

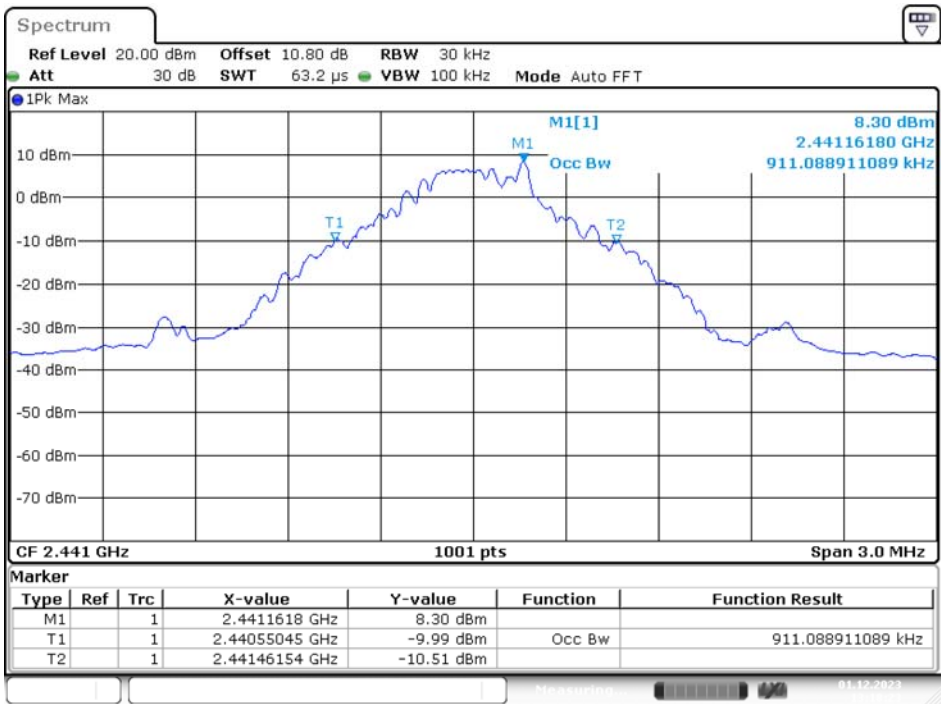
99% Bandwidth

BR Mode (GFSK)
Low Channel



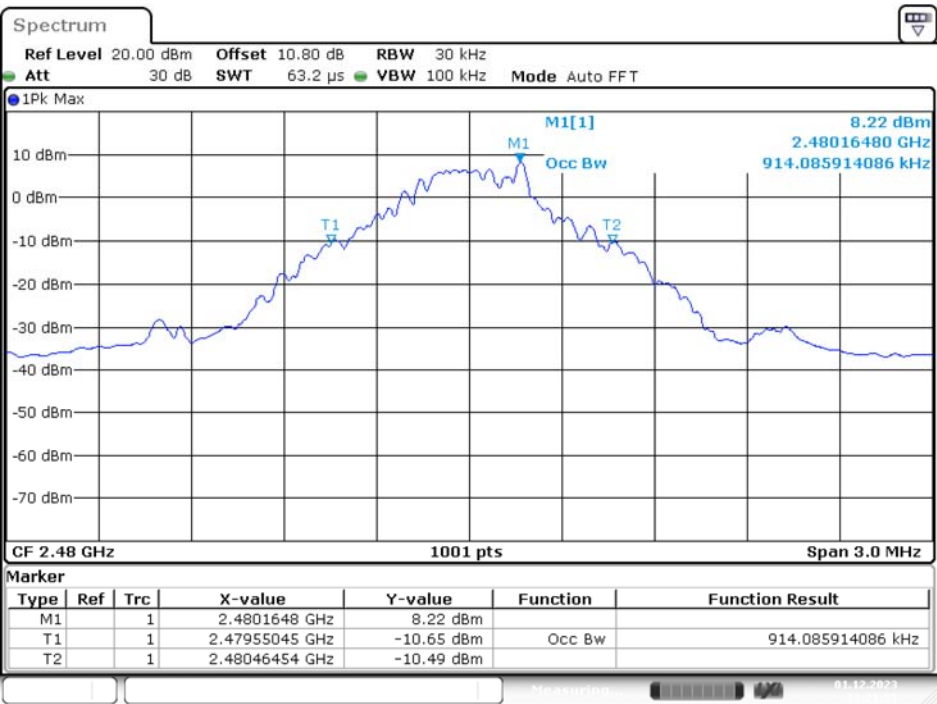
Date: 1.DEC.2023 13:14:12

Middle Channel



Date: 1.DEC.2023 13:18:23

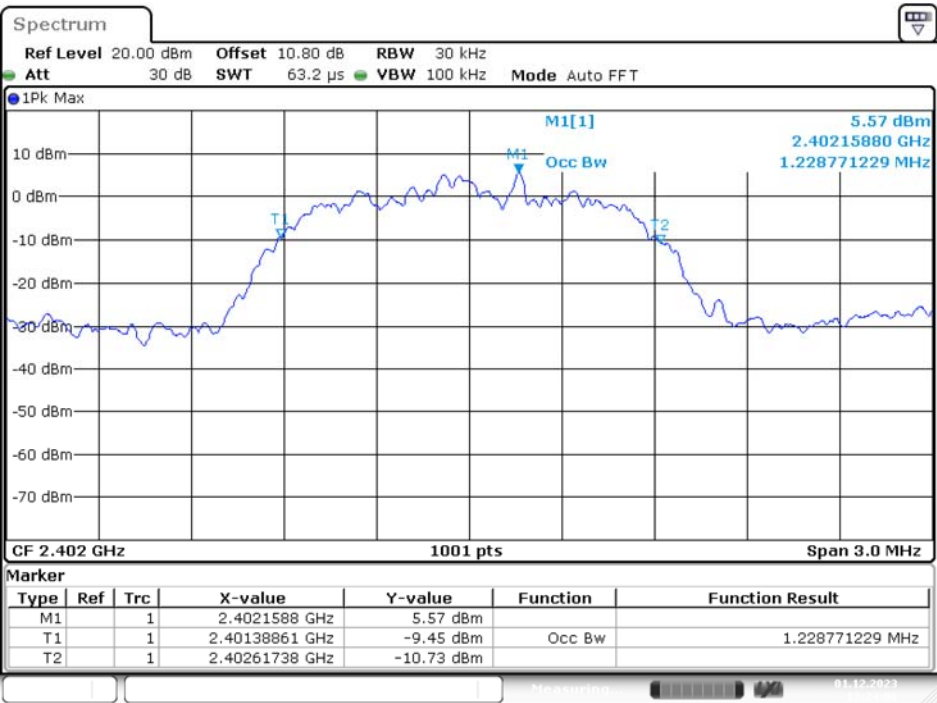
High Channel



Date: 1.DEC.2023 13:21:55

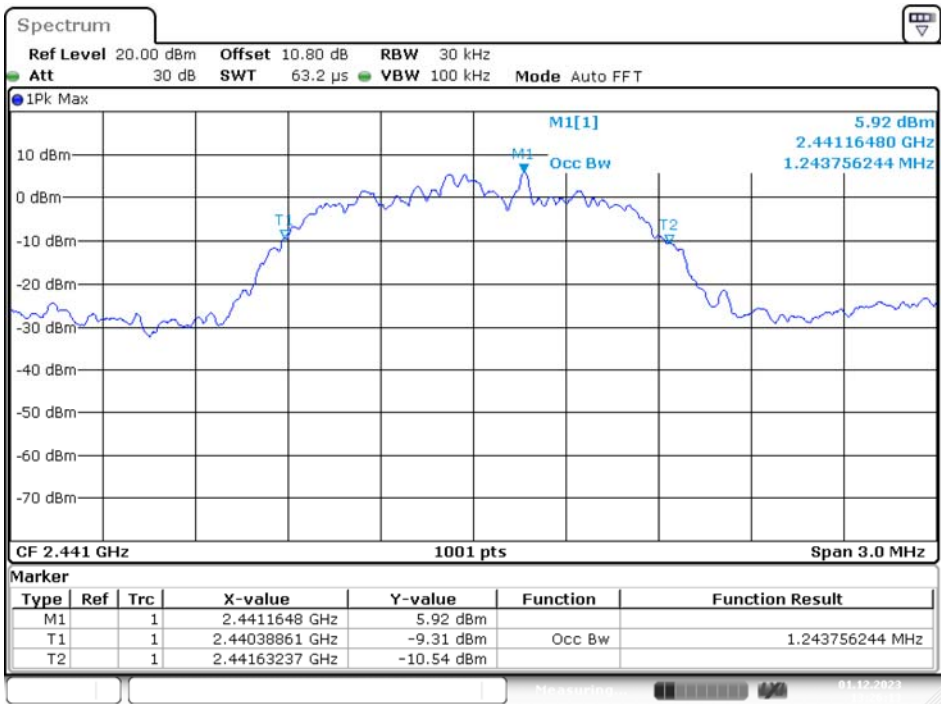
EDR Mode ($\pi/4$ -DQPSK)

Low Channel



Date: 1.DEC.2023 13:24:06

Middle Channel



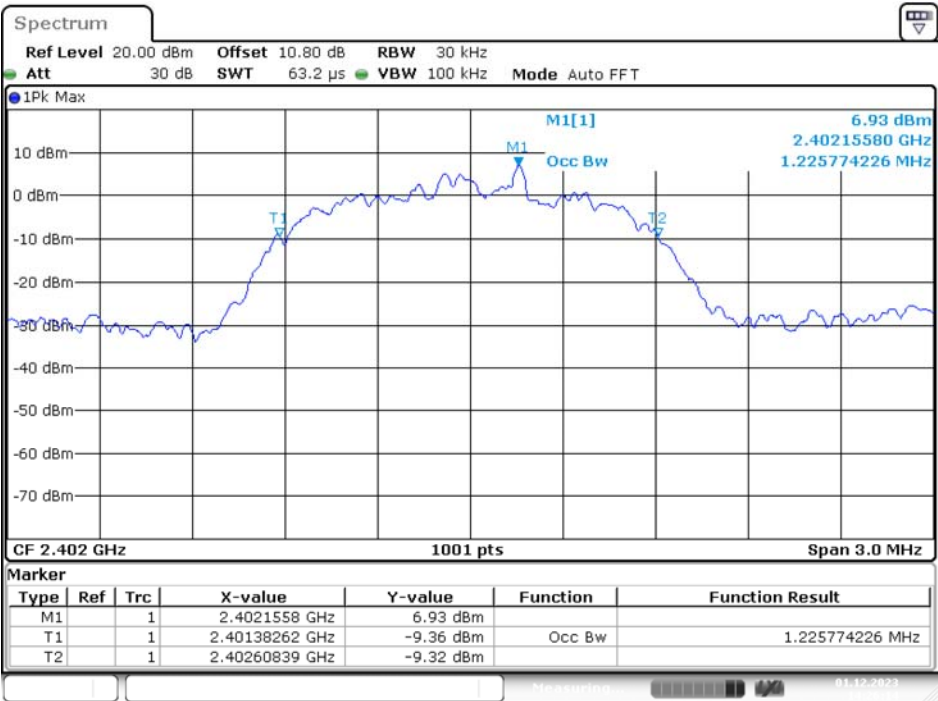
Date: 1.DEC.2023 13:26:14

High Channel



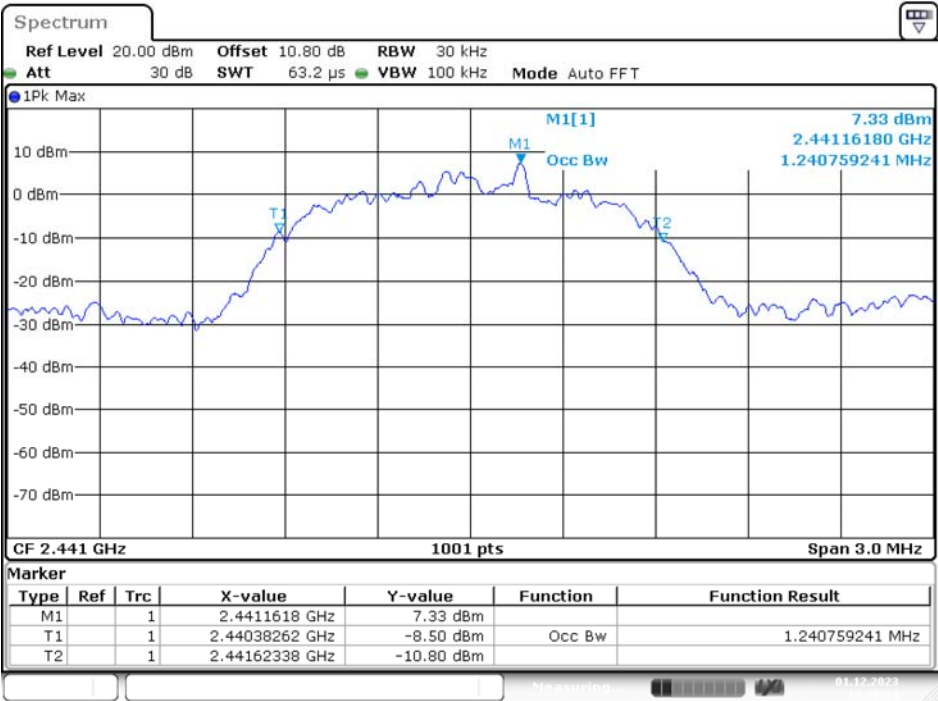
Date: 5.DEC.2023 14:18:33

EDR Mode (8DPSK)
Low Channel



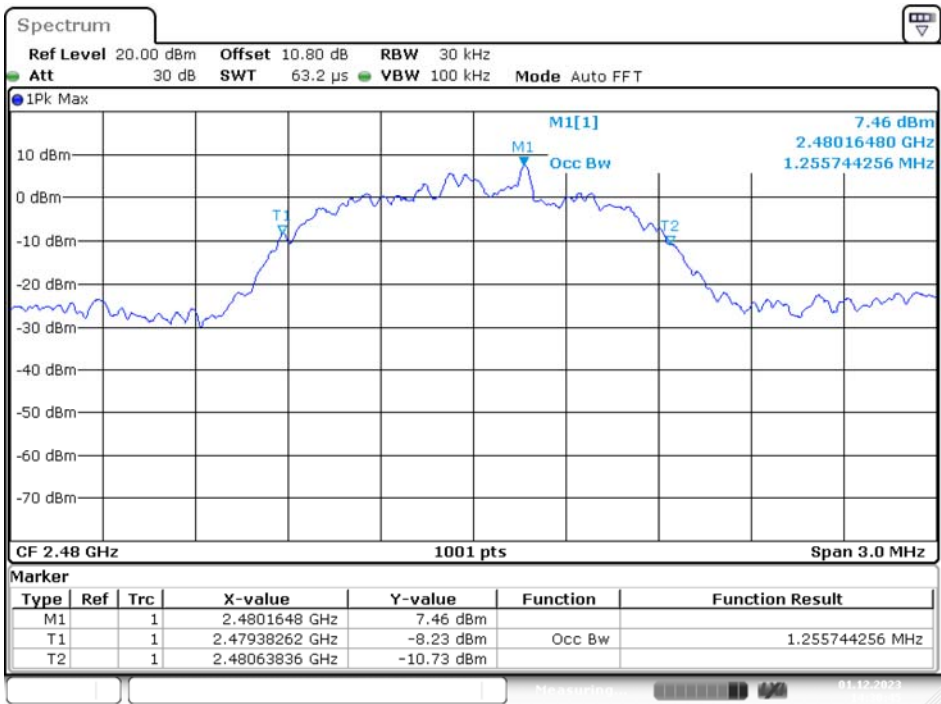
Date: 1.DEC.2023 14:26:15

Middle Channel



Date: 1.DEC.2023 14:28:14

High Channel



Date: 1.DEC.2023 14:30:46

11. FCC §15.247(a)(1) & RSS-247 §5.1(b)– Channel Separation Test

11.1. Applicable Standard

According to FCC §15.247(a) (1)

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 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. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

According to RSS-247 §5.1(b)

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

11.2. Test Procedure

According to ANSI C63.10-2013, section 7.8.2

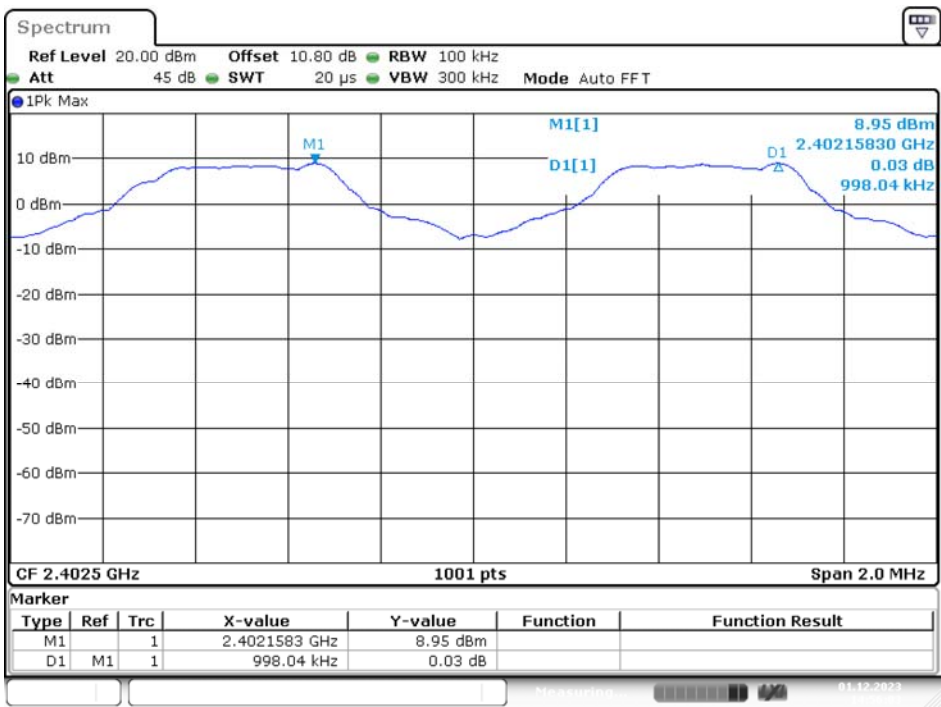
1. Set the EUT in transmitting mode, max hold the channel.
2. Set the adjacent channel of the EUT and max hold another trace.
3. Measure the channel separation.

11.3. Test Results

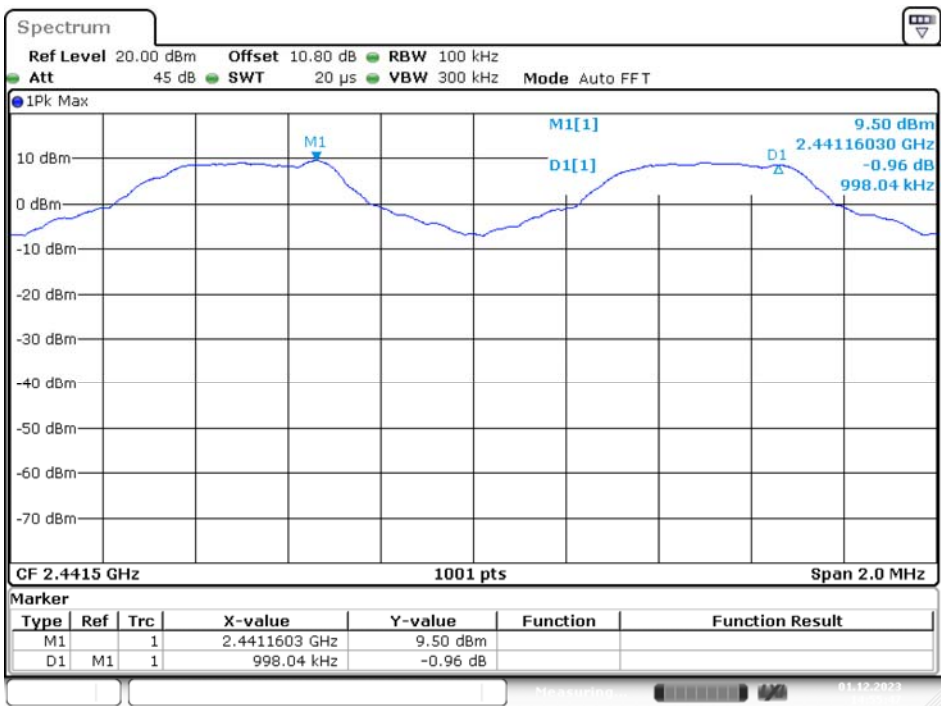
Channel	Channel Separation (MHz)	20 dBc BW (MHz)	Two-thirds of the 20 dB bandwidth (MHz)	Channel Separation Limit	Result
BR Mode (GFSK)					
Low	1.00	1.01	0.672	>two-thirds of the 20 dB bandwidth	Compliance
Middle	1.00	0.97	0.648	>two-thirds of the 20 dB bandwidth	Compliance
High	0.99	0.98	0.650	>two-thirds of the 20 dB bandwidth	Compliance
EDR Mode ($\pi/4$ -DQPSK)					
Low	1.01	1.36	0.906	>two-thirds of the 20 dB bandwidth	Compliance
Middle	0.99	1.36	0.906	>two-thirds of the 20 dB bandwidth	Compliance
High	1.01	1.36	0.906	>two-thirds of the 20 dB bandwidth	Compliance
EDR Mode (8DPSK)					
Low	1.00	1.33	0.884	>two-thirds of the 20 dB bandwidth	Compliance
Middle	1.00	1.33	0.884	>two-thirds of the 20 dB bandwidth	Compliance
High	0.99	1.33	0.888	>two-thirds of the 20 dB bandwidth	Compliance

Please refer to the following plots.

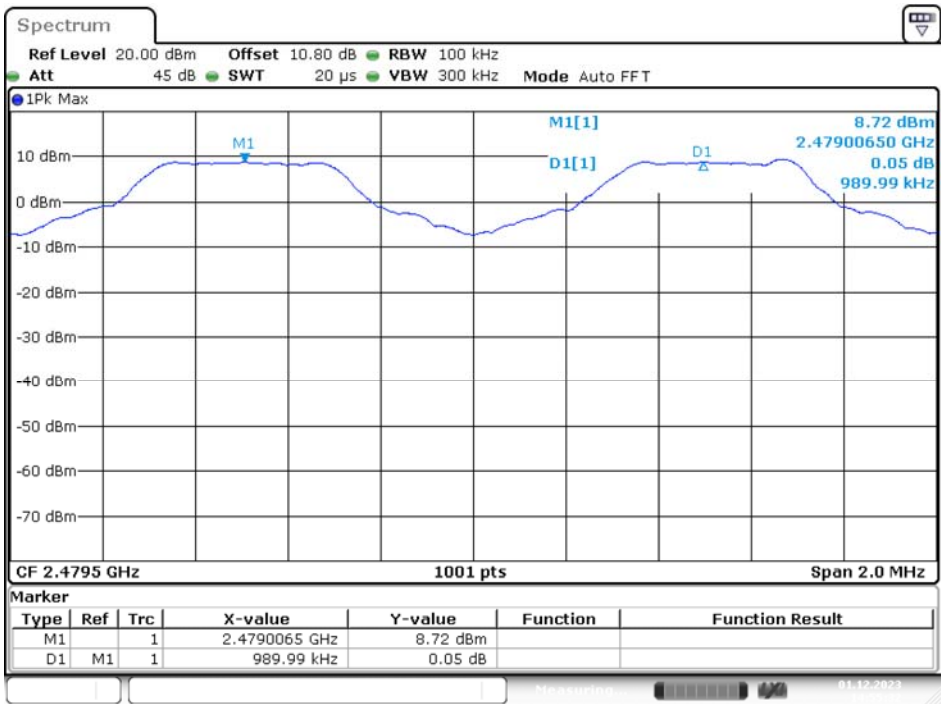
BR Mode (GFSK)
Low Channel



Middle Channel



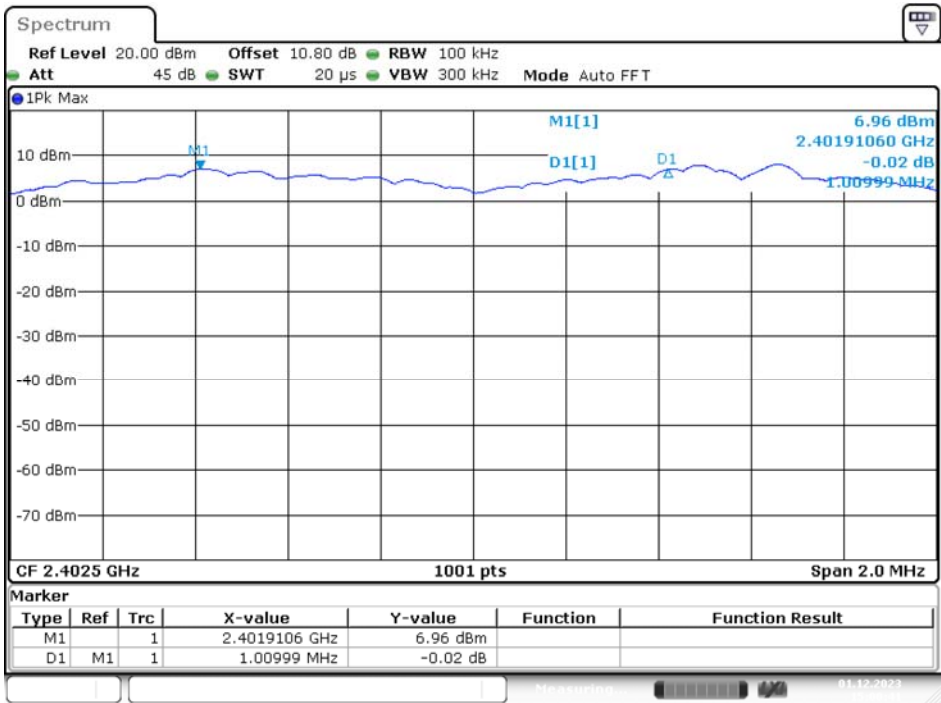
High Channel



Date: 1.DEC.2023 14:55:32

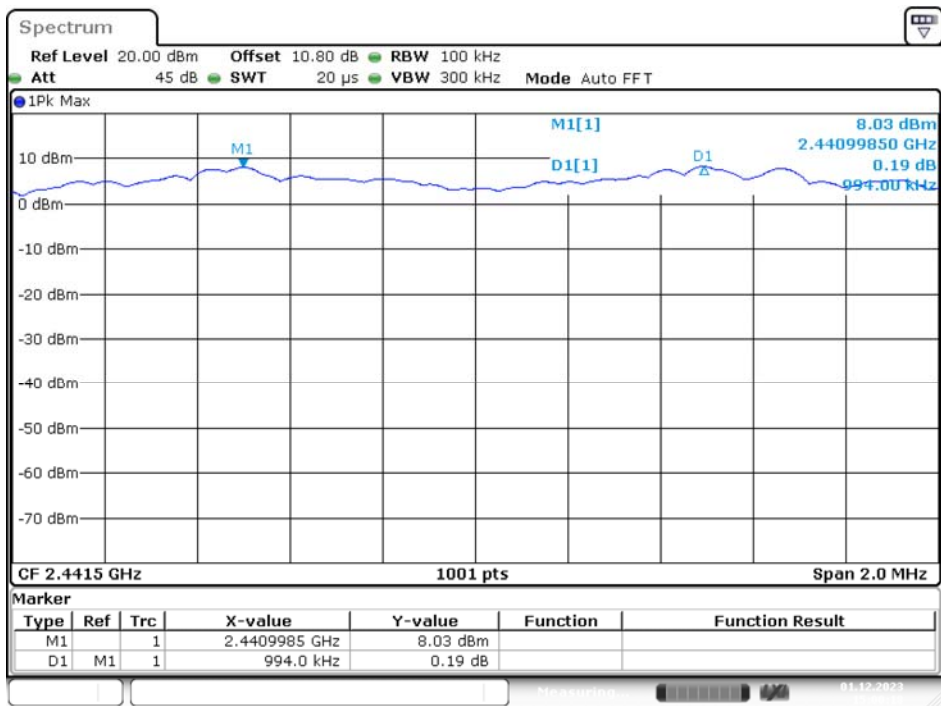
EDR Mode ($\pi/4$ -DQPSK)

Low Channel



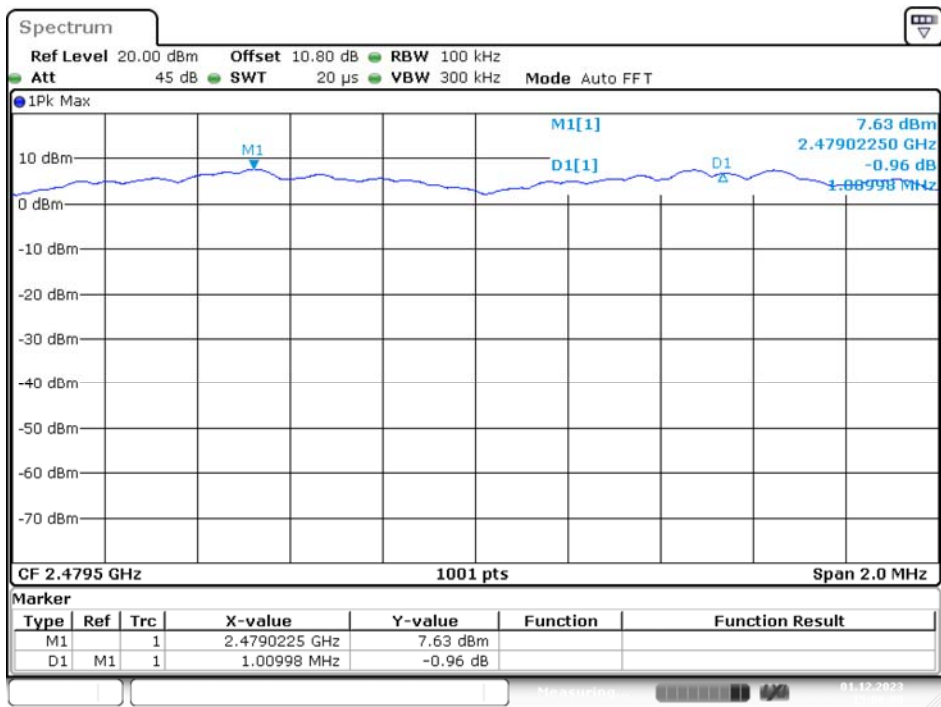
Date: 1.DEC.2023 15:00:41

Middle Channel



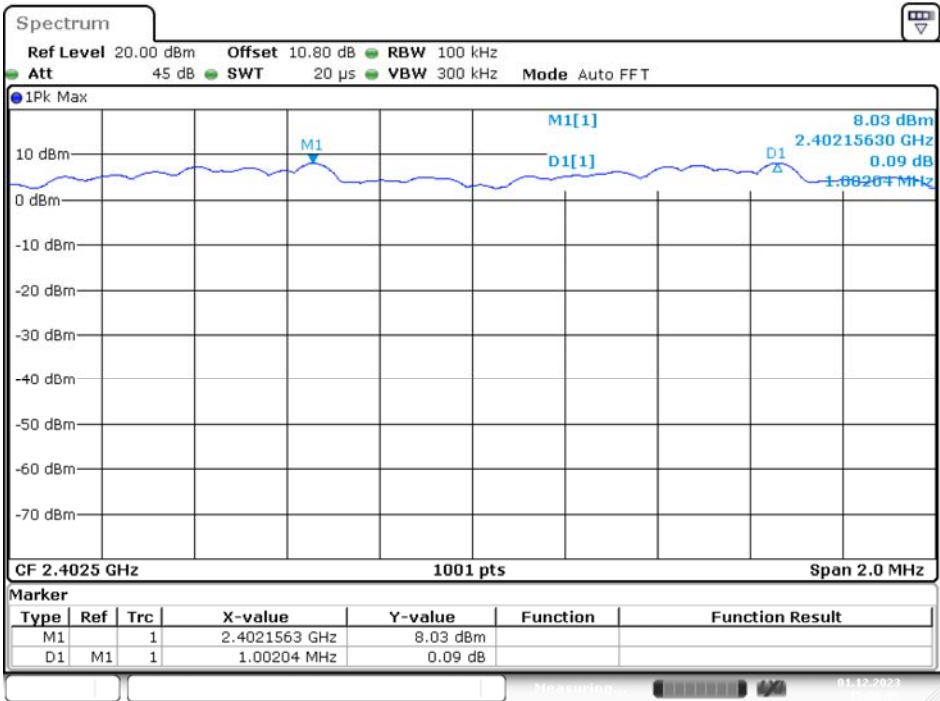
Date: 1.DEC.2023 15:00:18

High Channel



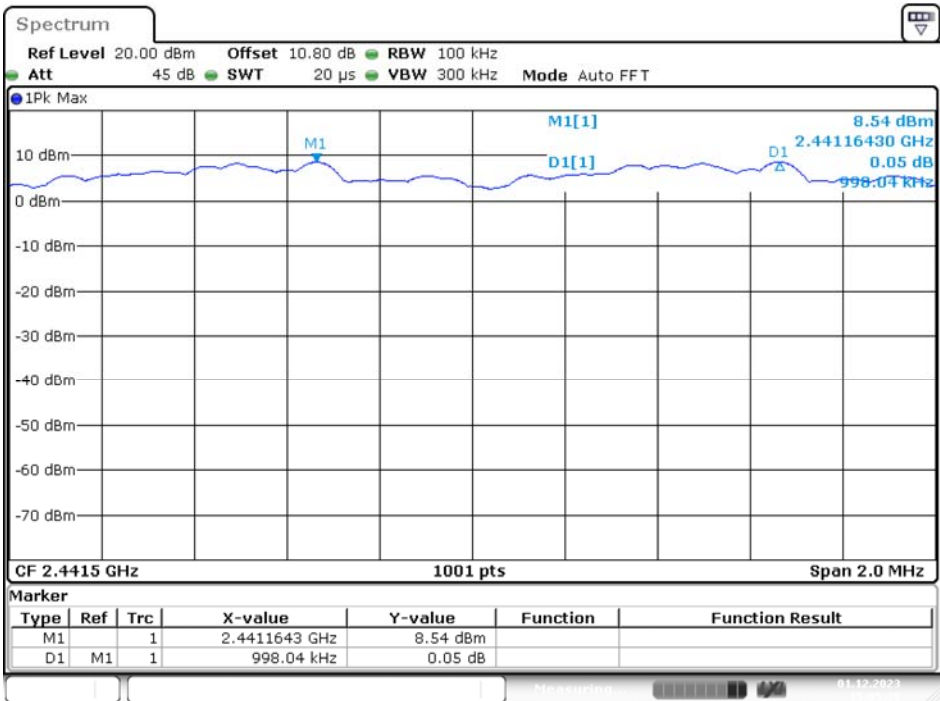
Date: 1.DEC.2023 15:00:00

EDR Mode (8DPSK)
Low Channel



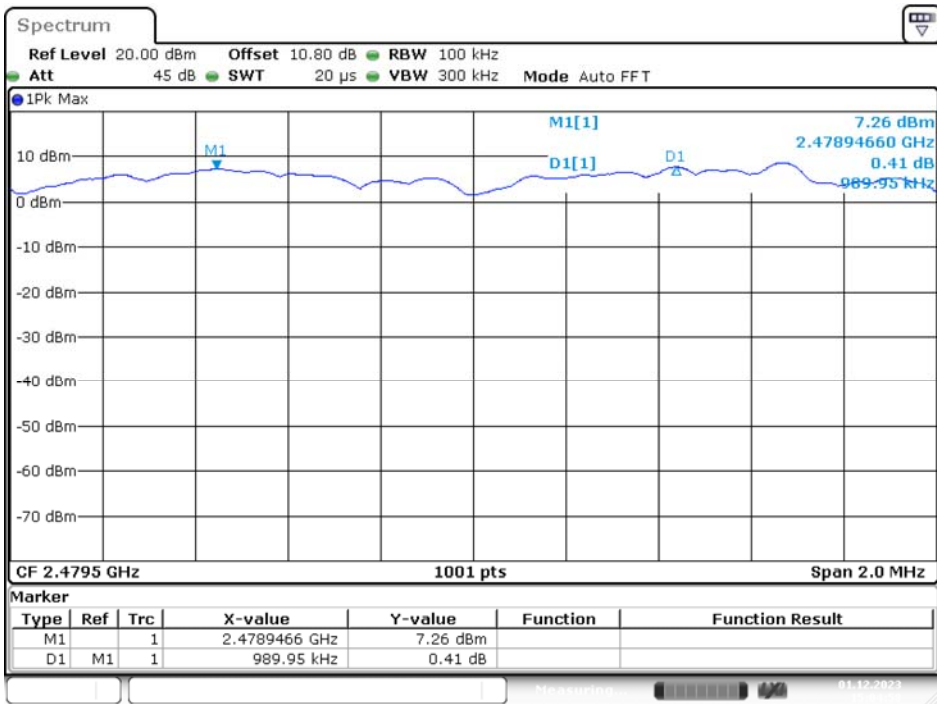
Date: 1.DEC.2023 15:06:06

Middle Channel



Date: 1.DEC.2023 15:05:38

High Channel



Date: 1.DEC.2023 15:04:58

12. FCC §15.247(a)(1)(iii) & RSS-247 §5.1 (d) – Time of Occupancy (Dwell Time)

12.1. Applicable Standard

According to FCC §15.247(a) (1) (iii).

Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 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. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

According to RSS-247 §5.1 (d).

FHSs 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 at least 15 hopping channels are used.

12.2. Test Procedure

According to ANSI C63.10-2013, section 7.8.4

The EUT must have its hopping function enabled. Use the following spectrum analyzer settings: Span = zero span, centered on a hopping channel $RBW \leq$ channel spacing and where possible RBW should be set $\gg 1/T$, where T is the expected dwell time per channel Sweep = as necessary to capture the entire dwell time per hopping channel Detector function = peak Trace = max hold

Use the marker-delta function to determine the transmit time per hop. If this value varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation in transmit time.

Repeat the measurement using a longer sweep time to determine the number of hops over the period specified in the requirements. The sweep time shall be equal to, or less than, the period specified in the requirements.

Determine the number of hops over the sweep time and calculate the total number of hops in the period specified in the requirements, using the following equation:

(Number of hops in the period specified in the requirements) = (number of hops on spectrum analyzer) x (period specified in the requirements / analyzer sweep time)

The average time of occupancy is calculated from the transmit time per hop multiplied by the number of hops in the period specified. If the number of hops in a specific time varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation.

12.3. Test Results

BR mode (GFSK)						
Mode	Pulse Time (ms)	Hopping Number	Period Time (s)	Total of Dwell (ms)	Limit (ms)	Result
DH1	0.379	310	31.6	117.49	<400	PASS
DH3	1.635	140	31.6	228.90	<400	PASS
DH5	2.885	120	31.6	346.20	<400	PASS
EDR mode ($\pi/4$-DQPSK)						
Mode	Pulse Time (ms)	Hopping Number	Period Time (s)	Total of Dwell (ms)	Limit (ms)	Result
2DH1	0.384	320	31.6	122.88	<400	PASS
2DH3	1.638	160	31.6	262.08	<400	PASS
2DH5	2.89	110	31.6	317.90	<400	PASS
EDR mode (8DPSK)						
Mode	Pulse Time (ms)	Hopping Number	Period Time (s)	Total of Dwell (ms)	Limit (ms)	Result
3DH1	0.384	310	31.6	119.04	<400	PASS
3DH3	1.635	160	31.6	261.60	<400	PASS
3DH5	2.89	90	31.6	260.10	<400	PASS

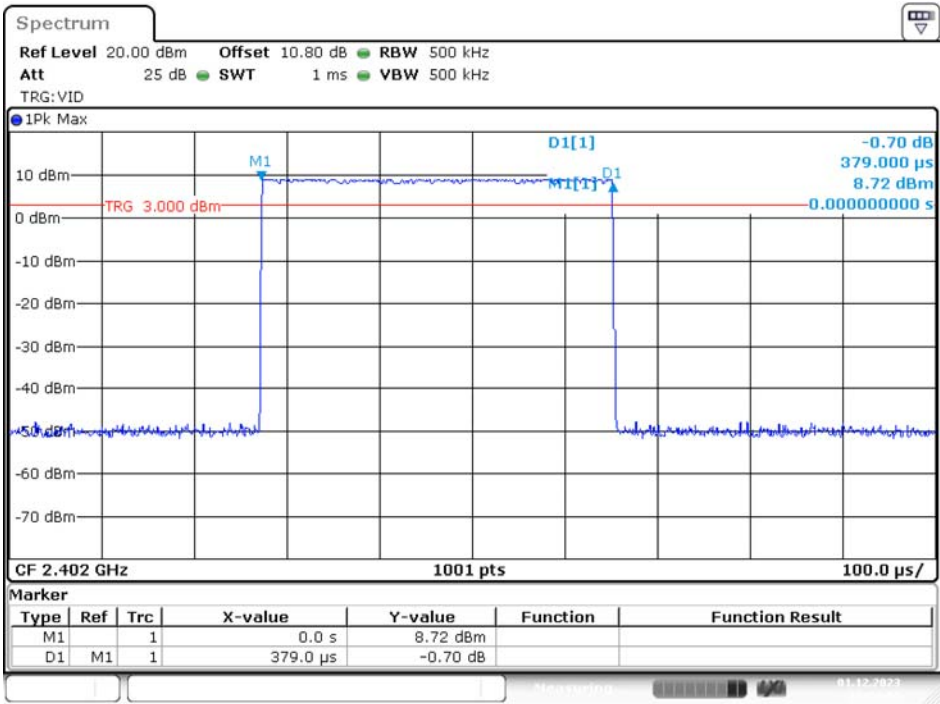
Note 1: Period time = $0.4 \times 79 = 31.6$ (s), Total of Dwell = Pulse Time * Hopping Number

Note 2: Hopping Number = Hopping Number/10 * 10

Note 3: Hopping Number/10 = Total of highest signals in 3.16s. (Second high signals were other channel)

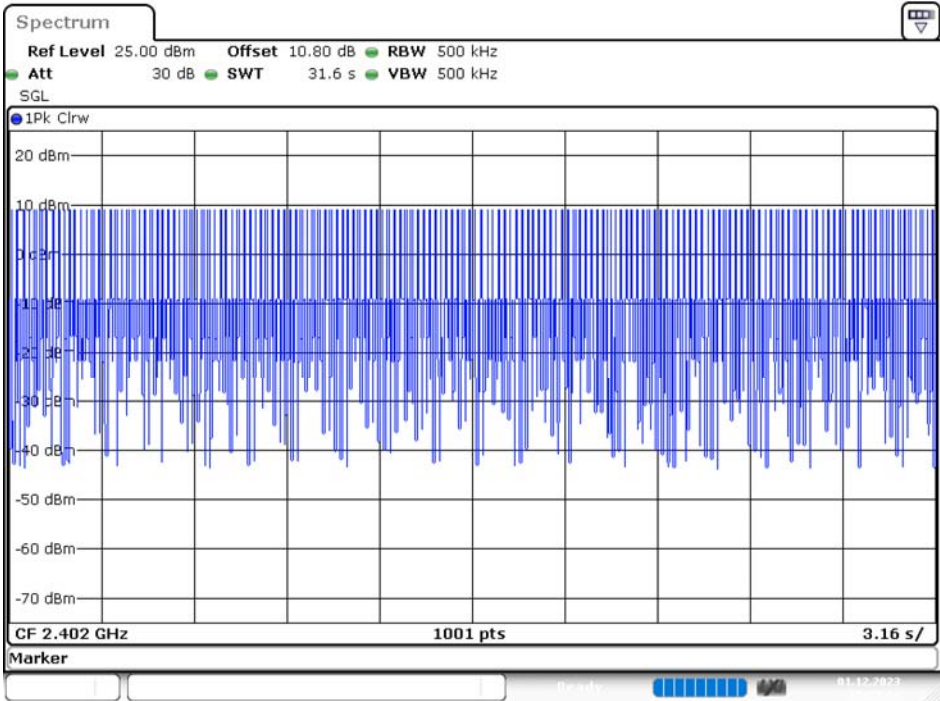
Please refer to the following plots

BR Mode (GFSK)
DH1: Pulse Width



Date: 1.DEC.2023 16:14:07

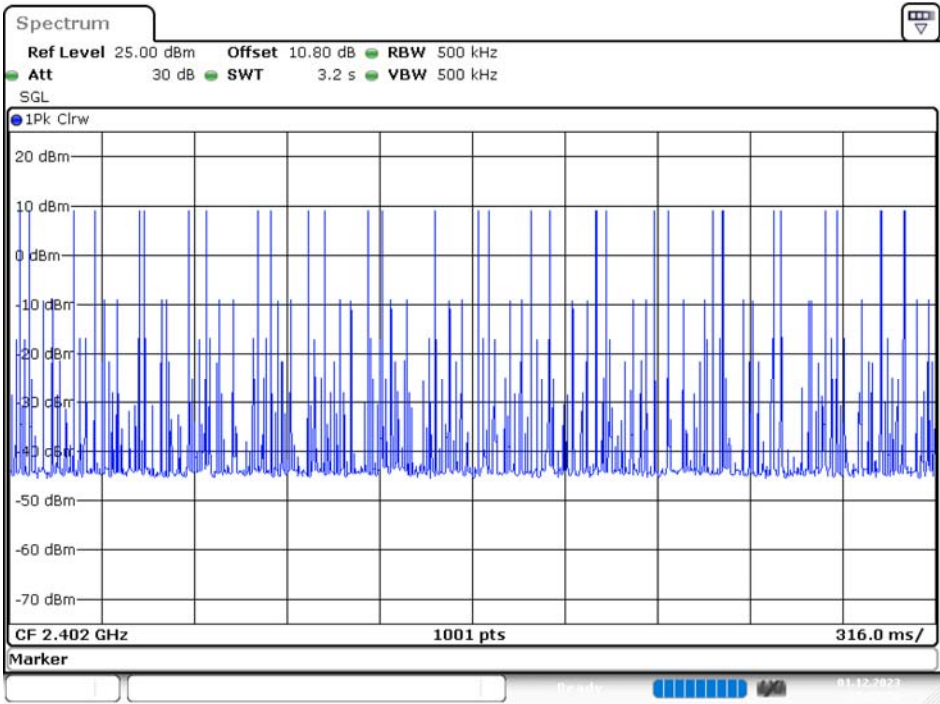
DH1: Hopping Number



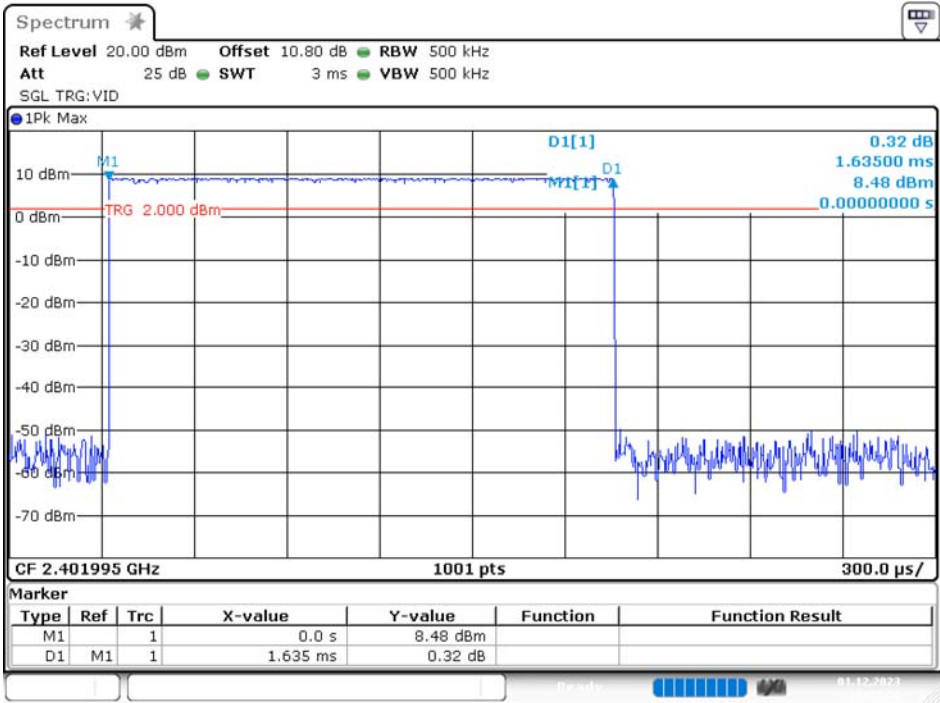
Date: 1.DEC.2023 15:22:24

DH1: Hopping Number /10

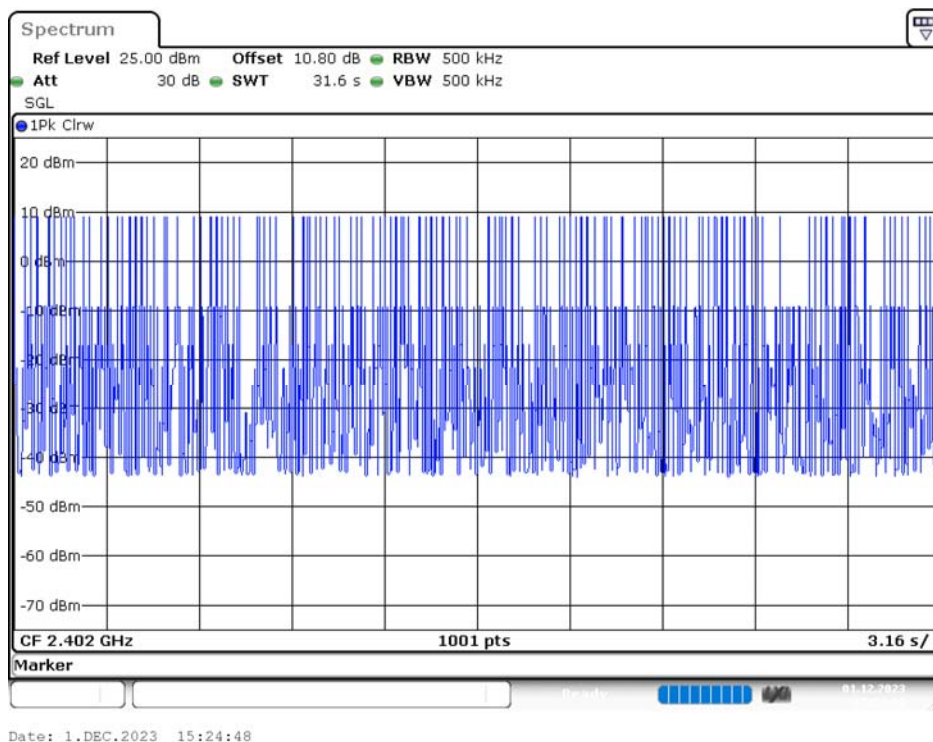
(Hopping Number = 31 in 1/10 period of highest signals, Second High signals were other channel)



DH3: Pulse Width

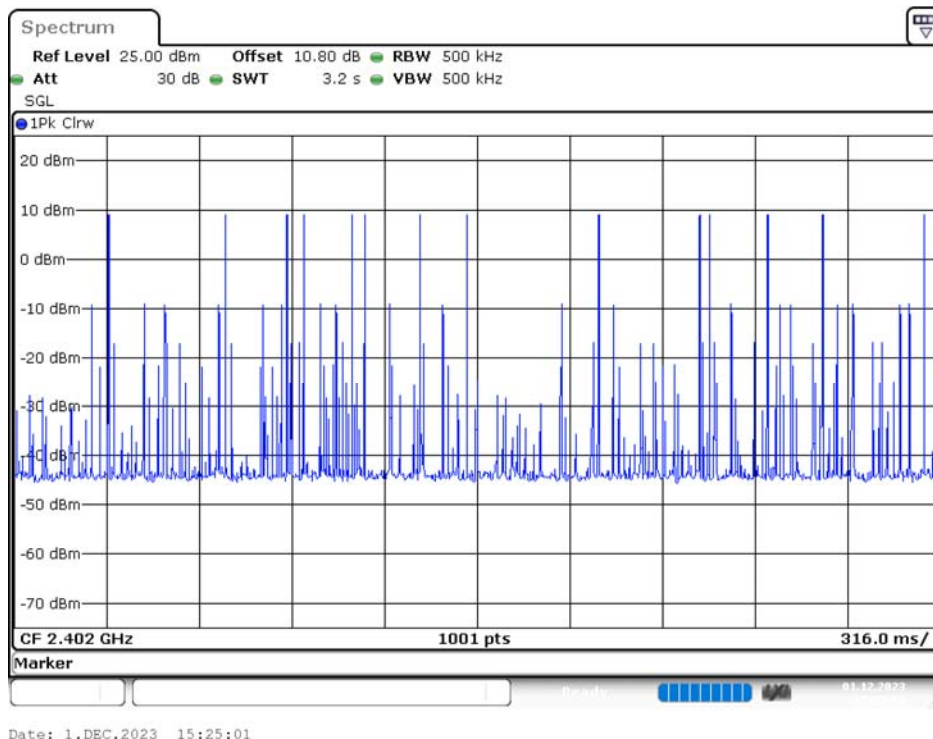


DH3: Hopping Number

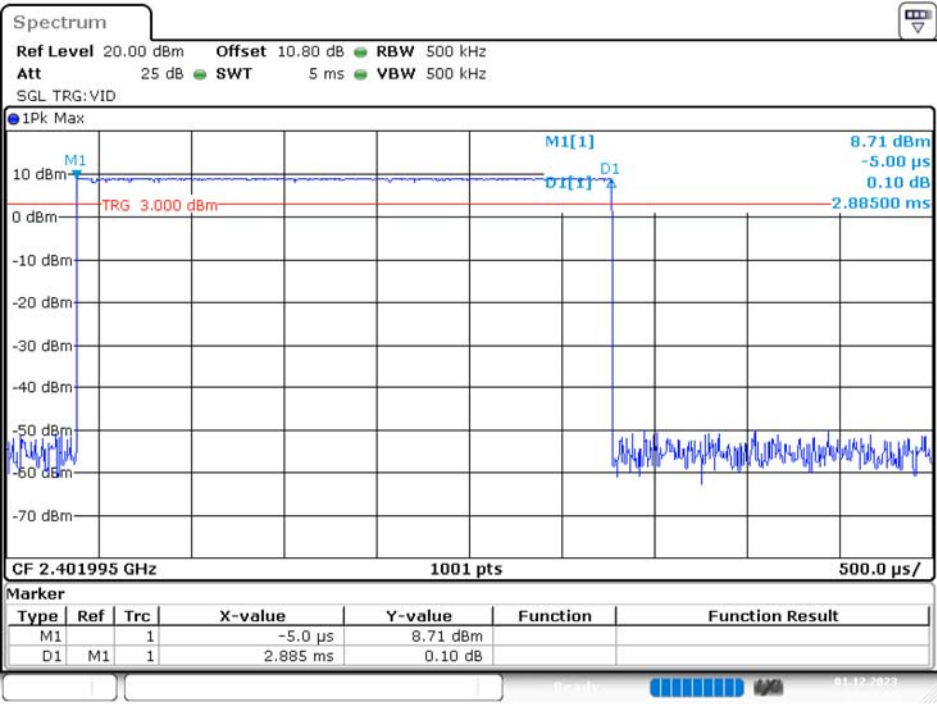


DH3: Hopping Number /10

(Hopping Number = 14 in 1/10 period of highest signals, Second High signals were other channel)

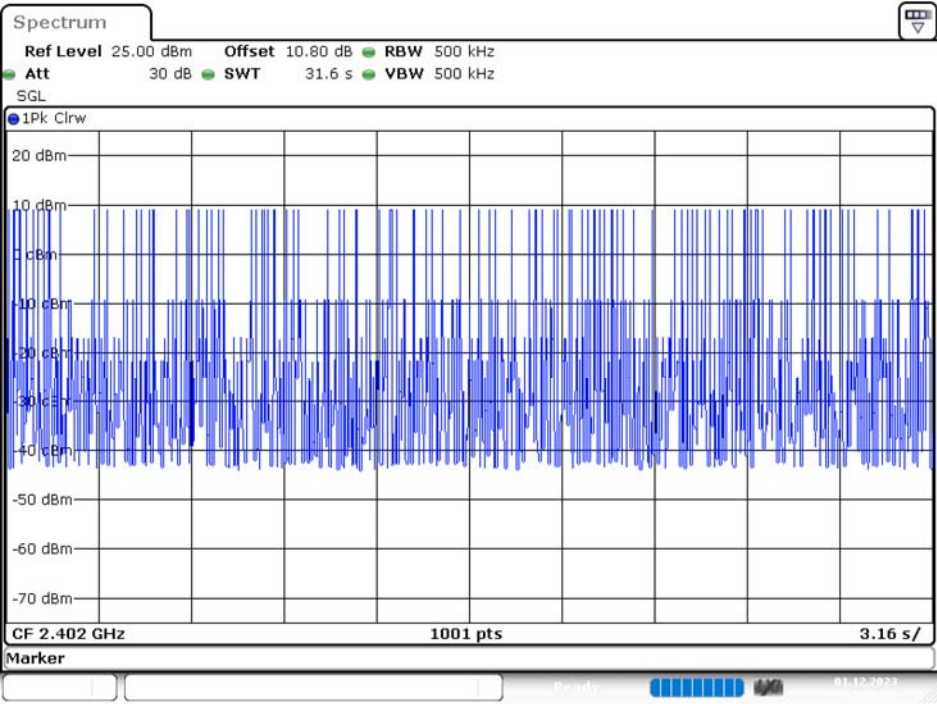


DH5: Pulse Width



Date: 1.DEC.2023 16:45:08

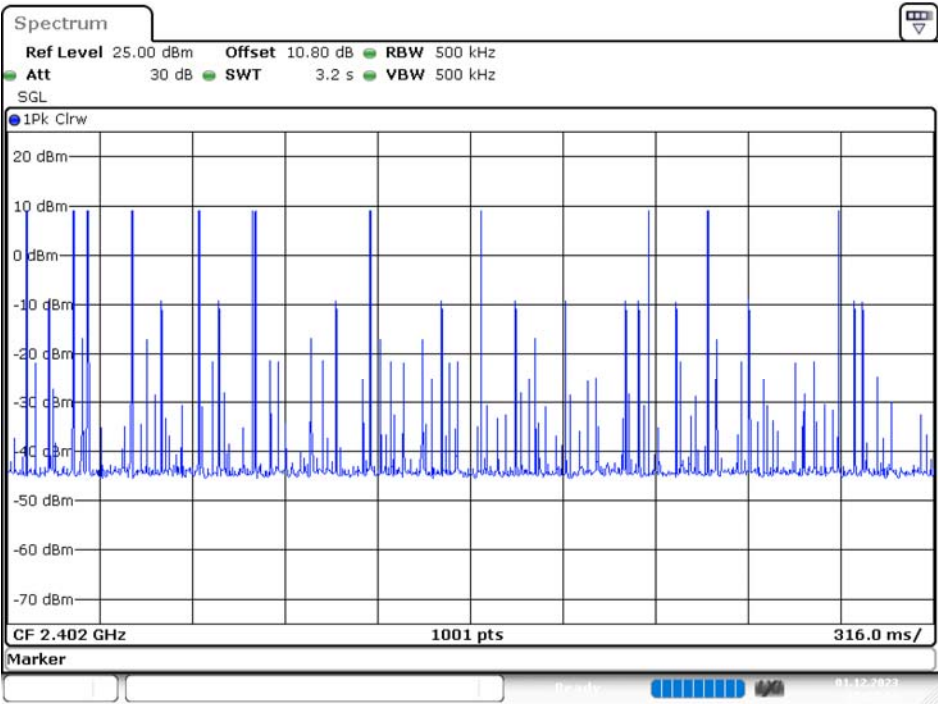
DH5: Hopping Number



Date: 1.DEC.2023 15:26:50

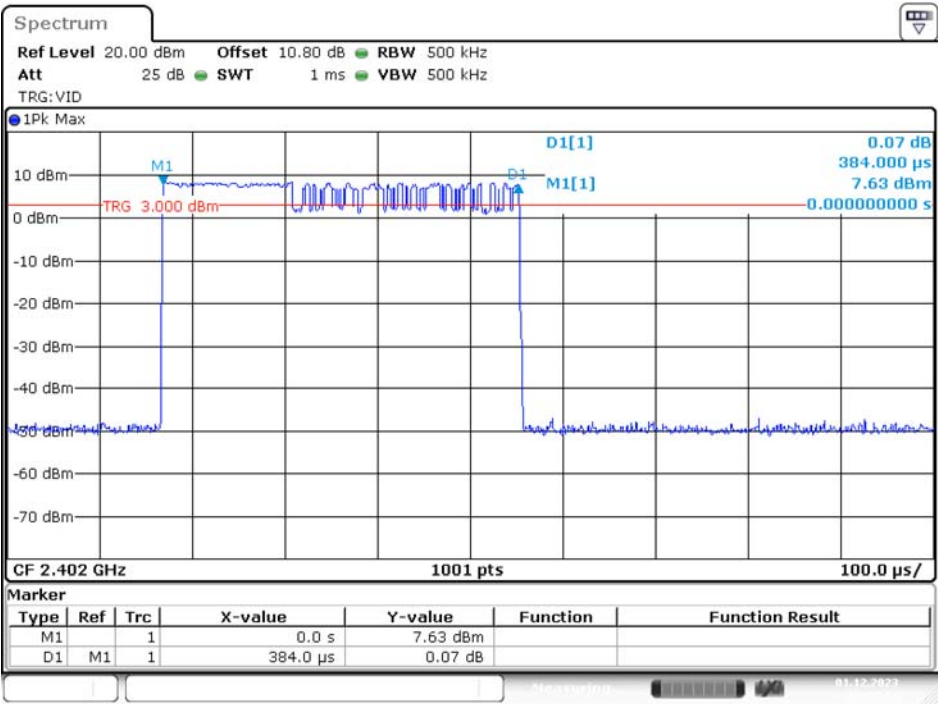
DH5: Hopping Number /10

(Hopping Number = 12 in 1/10 period of highest signals, Second High signals were other channel)

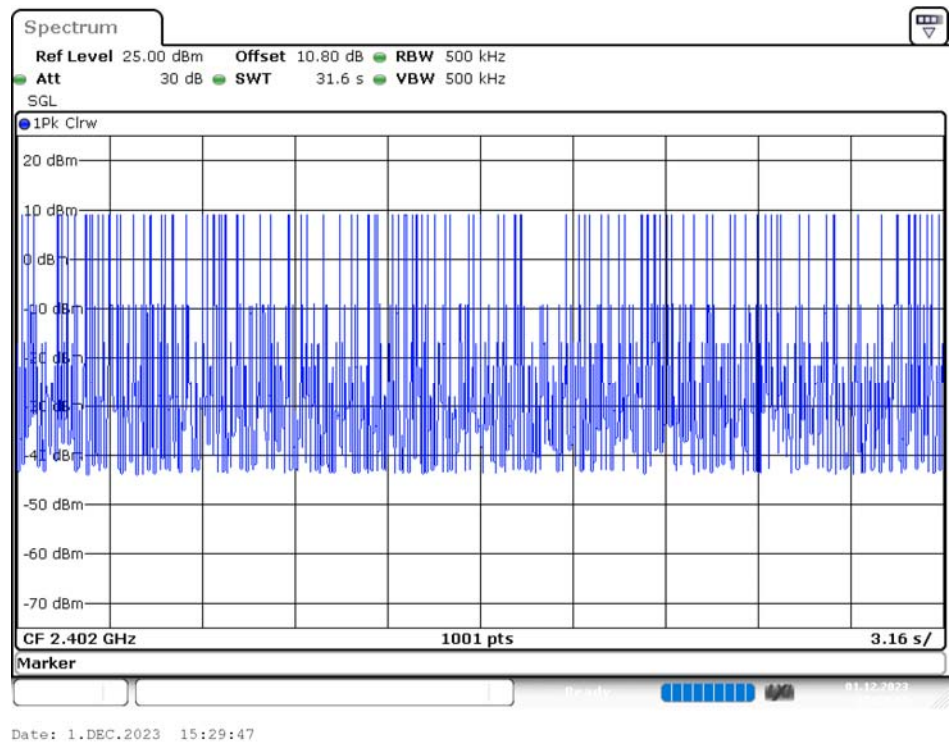


EDR Mode ($\pi/4$ -DQPSK)

2DH1: Pulse Width

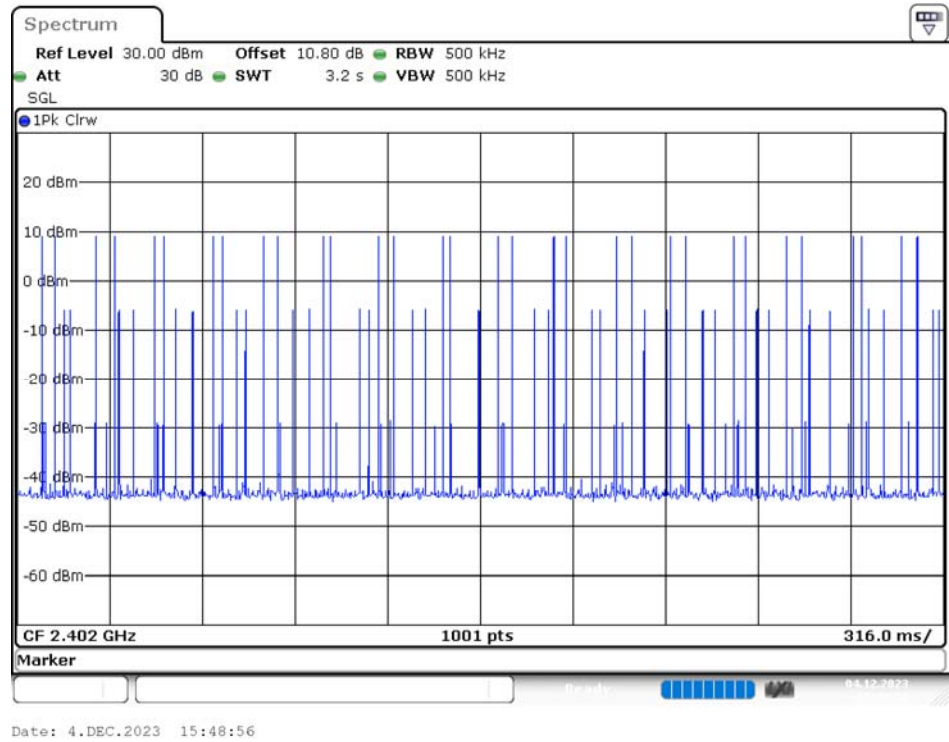


2DH1: Hopping Number



2DH1: Hopping Number /10

(Hopping Number = 32 in 1/10 period of highest signals, Second High signals were other channel)



Spectrum

Ref Level 20.00 dBm Offset 10.80 dB RBW 500 kHz
 Att 25 dB SWT 3 ms VBW 500 kHz
 SGL TRG:VID

1Pk Max

10 dBm
 0 dBm
 -10 dBm
 -20 dBm
 -30 dBm
 -40 dBm
 -50 dBm
 -60 dBm
 -70 dBm

CF 2.401995 GHz 1001 pts 300.0 μs

Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	0.0 s	8.01 dBm		
D1	M1	1	1.638 ms	-0.58 dB		

Date: 1.DEC.2023 16:25:29

Spectrum

Ref Level 25.00 dBm Offset 10.80 dB RBW 500 kHz
Att 30 dB SWT 31.6 s VBW 500 kHz
SGL

1Pk Clrw

20 dBm
10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm

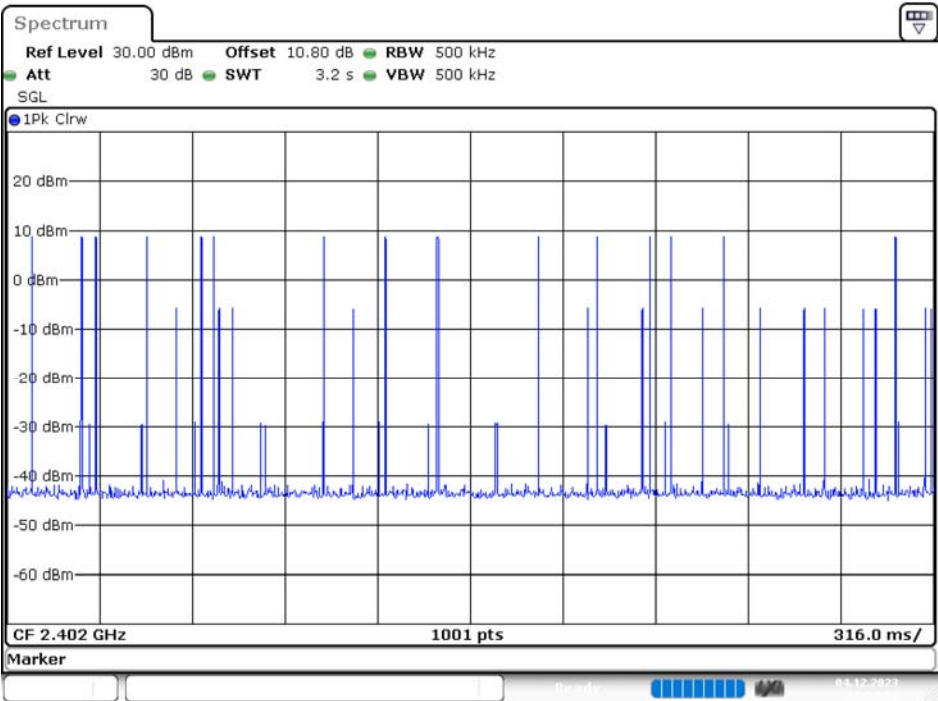
CF 2.402 GHz 1001 pts 3.16 s

Marker

Date: 1.DEC.2023 15:31:46

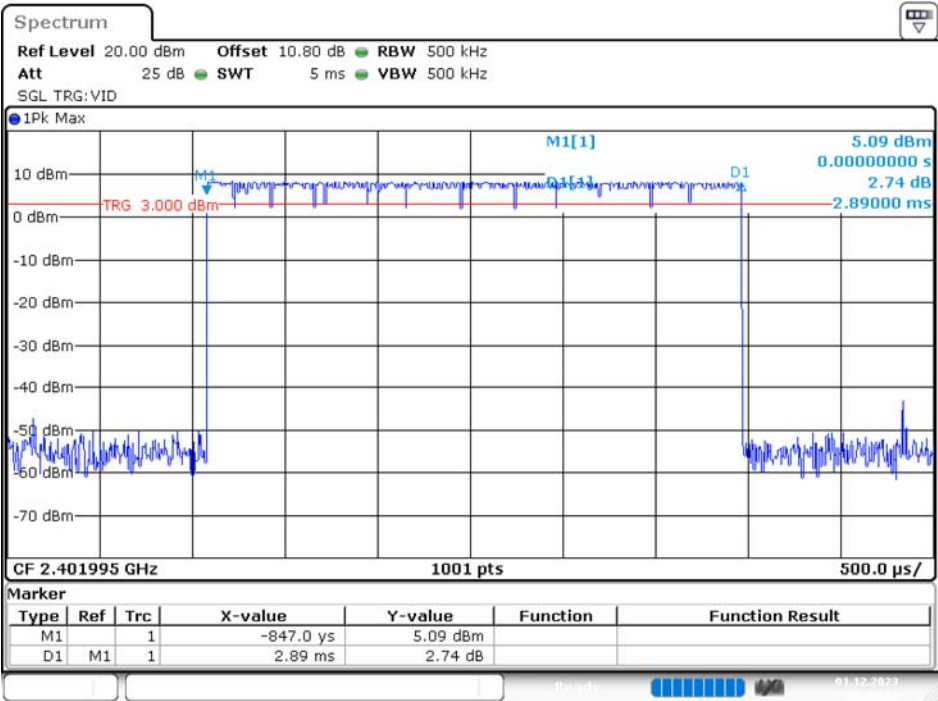
2DH3: Hopping Number /10

(Hopping Number = 16 in 1/10 period of highest signals, Second High signals were other channel)



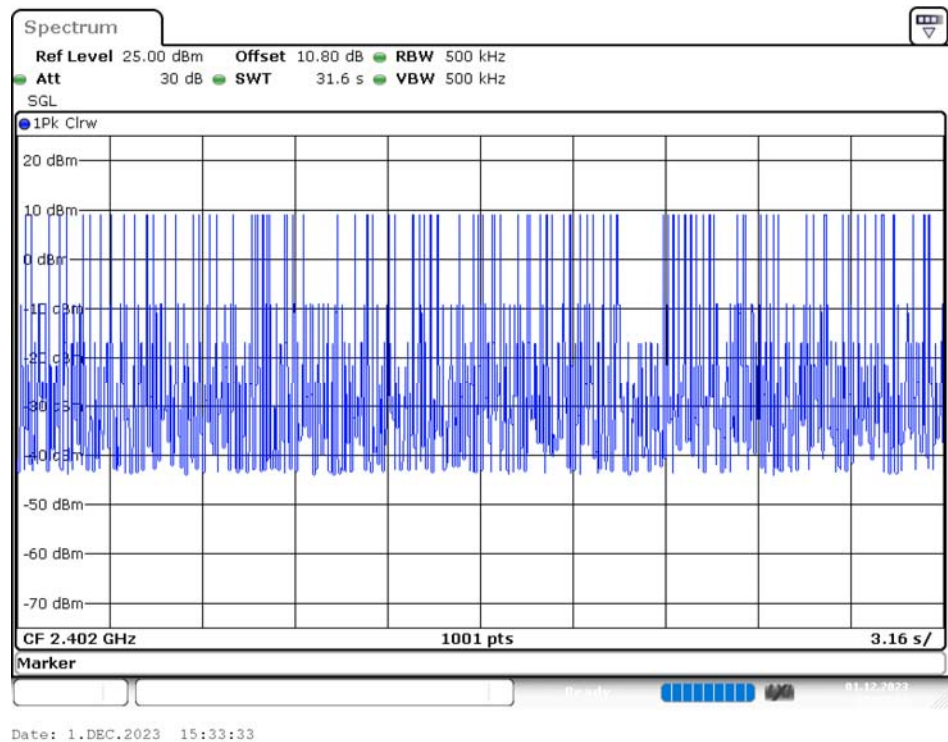
Date: 4.DEC.2023 15:50:23

2DH5: Pulse Width



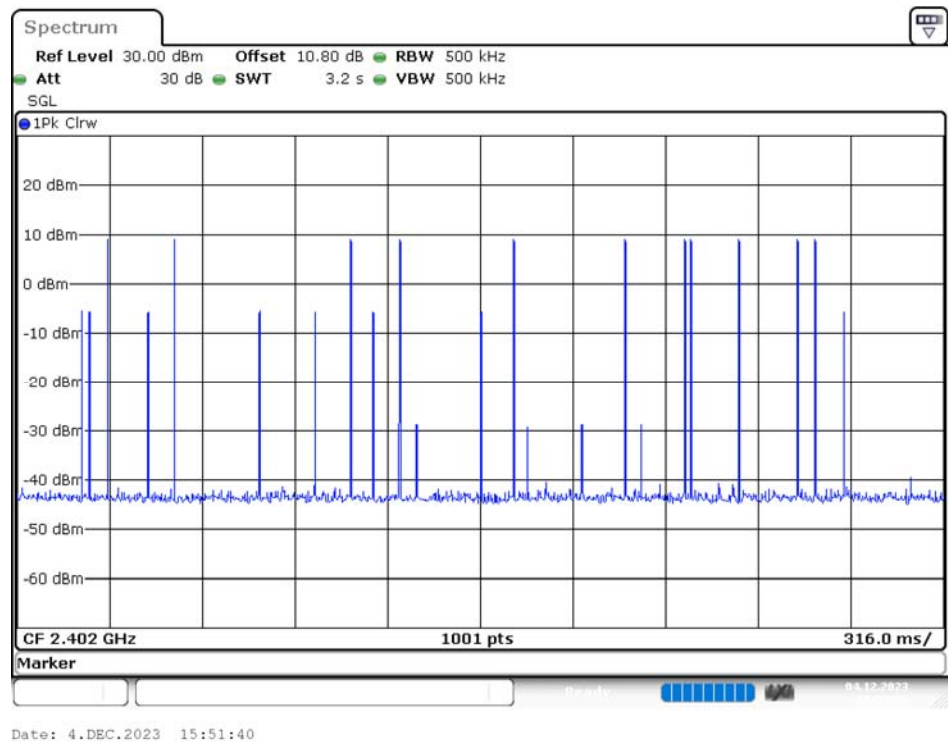
Date: 1.DEC.2023 16:49:43

2DH5: Hopping Number

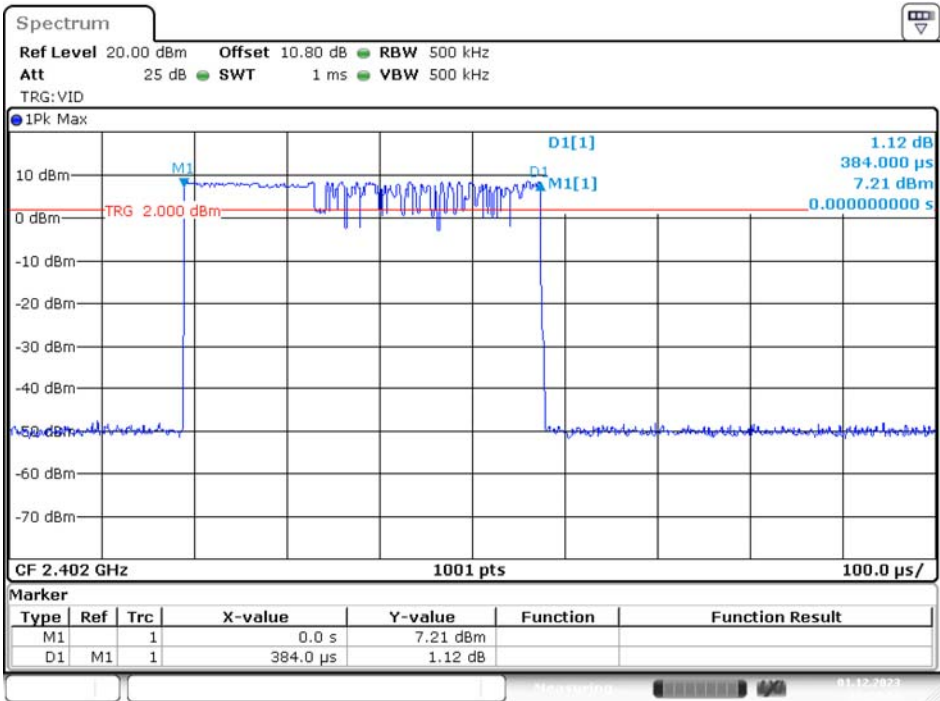


2DH5: Hopping Number /10

(Hopping Number = 11 in 1/10 period of highest signals, Second High signals were other channel)

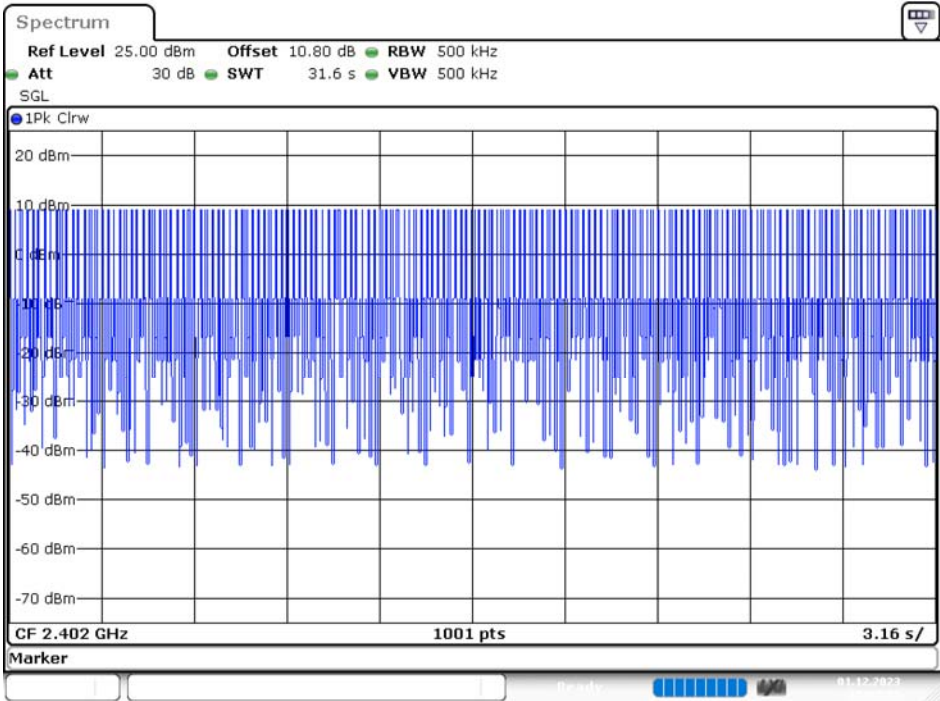


EDR Mode (8DPSK)
3DH1: Pulse Width



Date: 1.DEC.2023 16:20:04

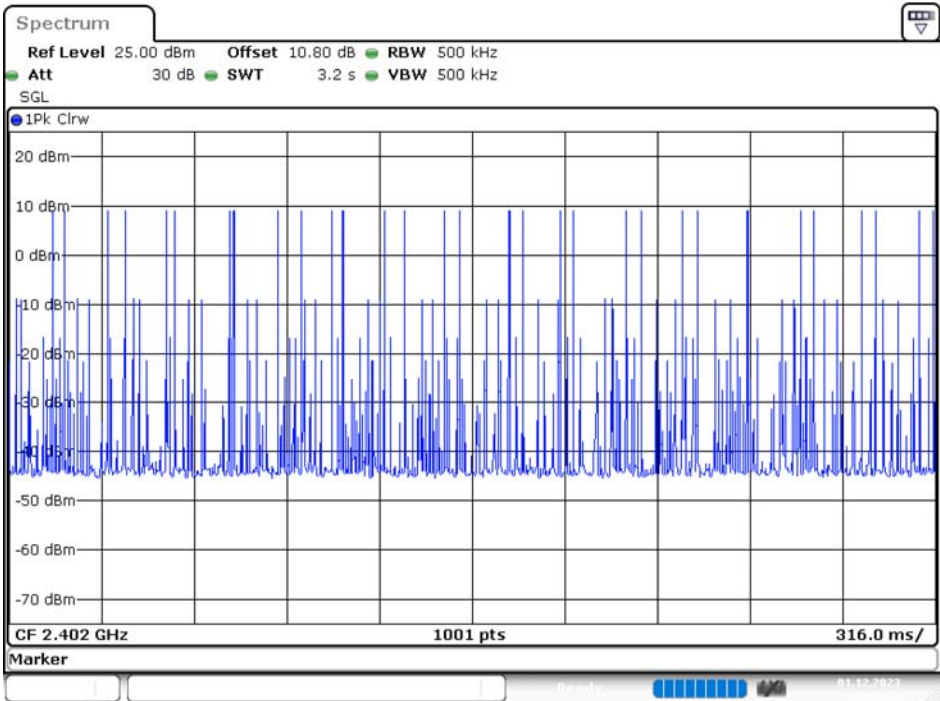
3DH1: Hopping Number



Date: 1.DEC.2023 15:37:25

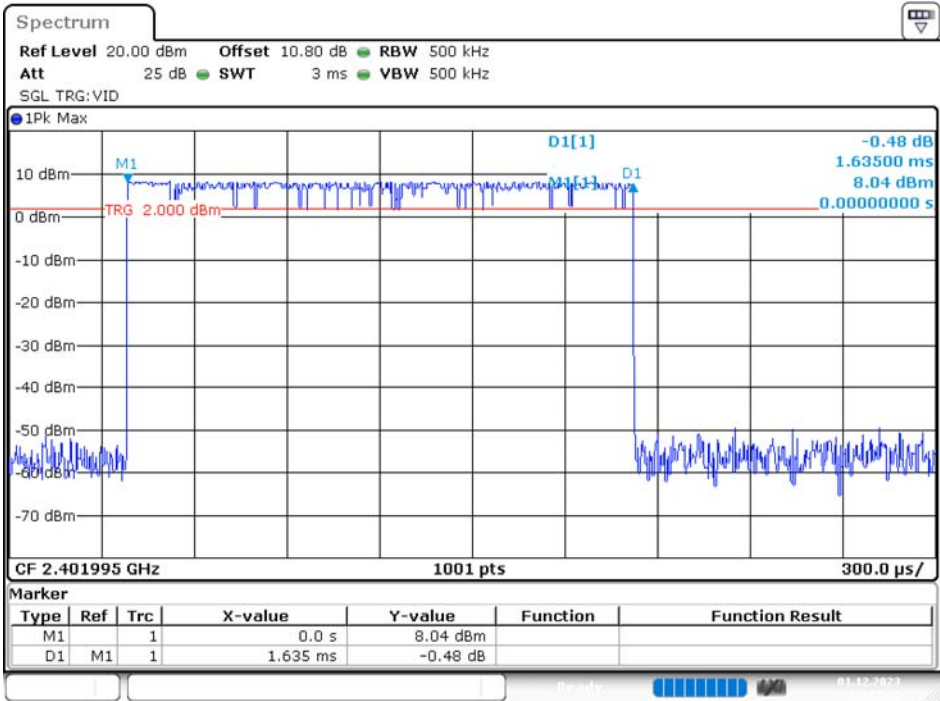
3DH1: Hopping Number /10

(Hopping Number = 31 in 1/10 period of highest signals, Second High signals were other channel)



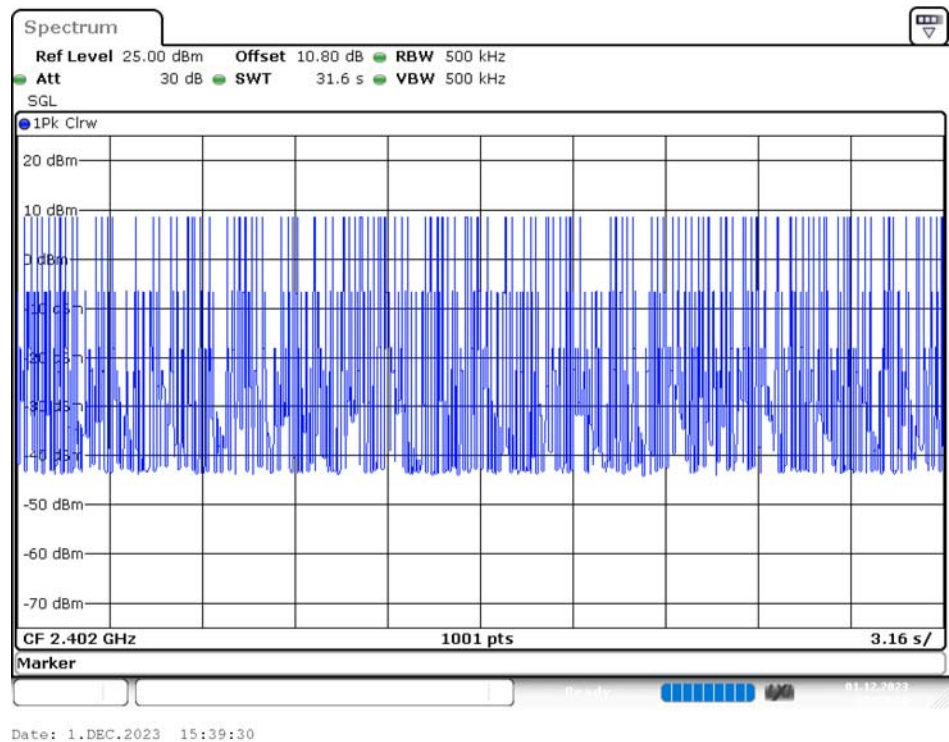
Date: 1.DEC.2023 15:37:31

3DH3: Pulse Width



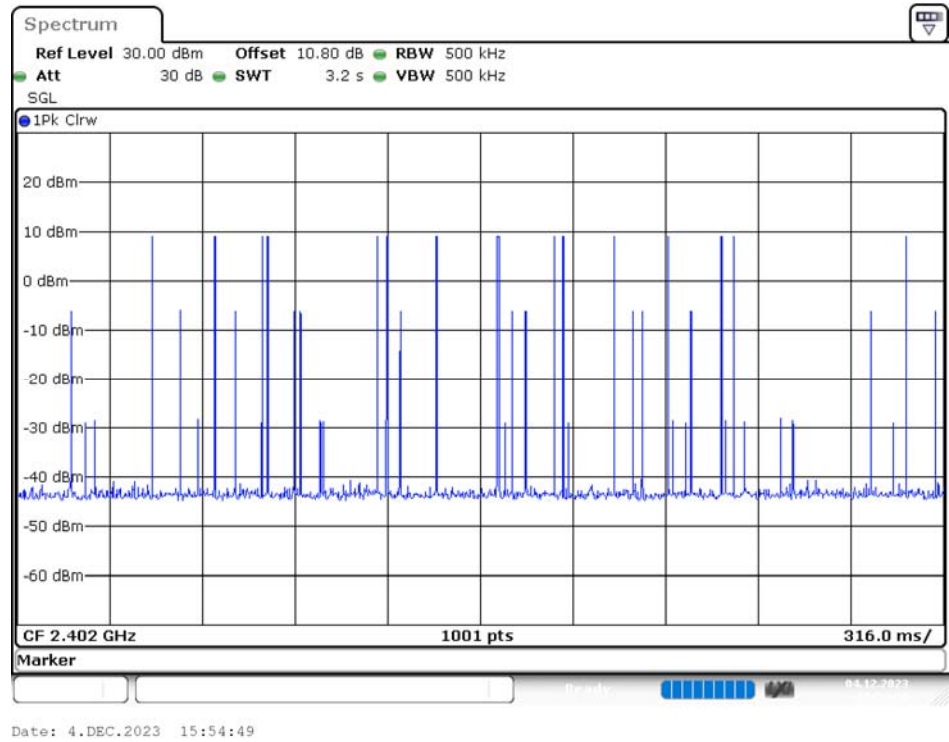
Date: 1.DEC.2023 16:42:47

3DH3: Hopping Number

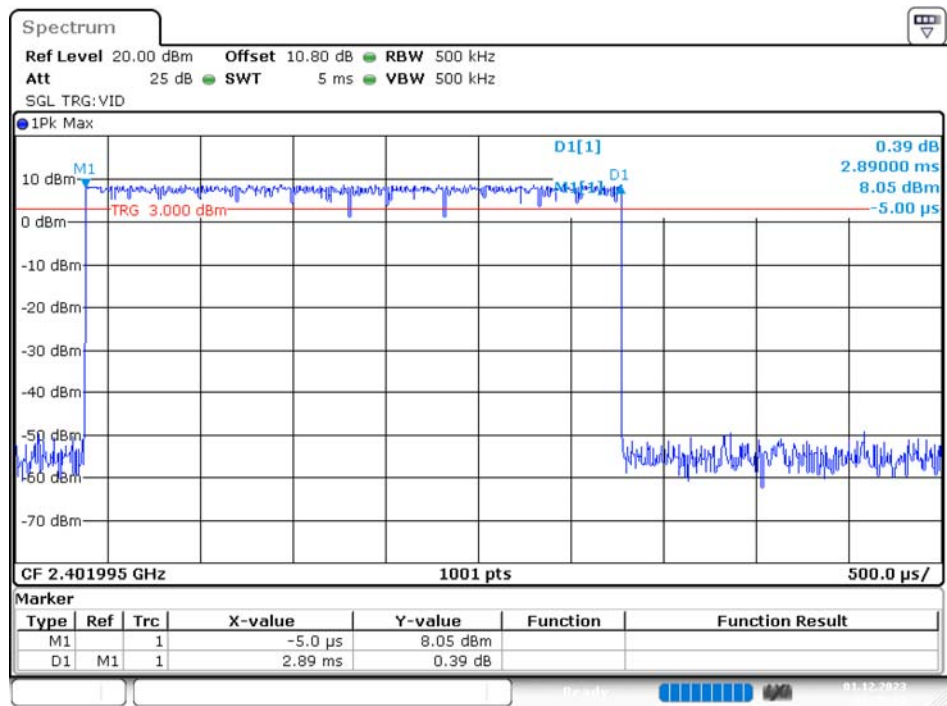


3DH3: Hopping Number /10

(Hopping Number = 16 in 1/10 period of highest signals, Second High signals were other channel)

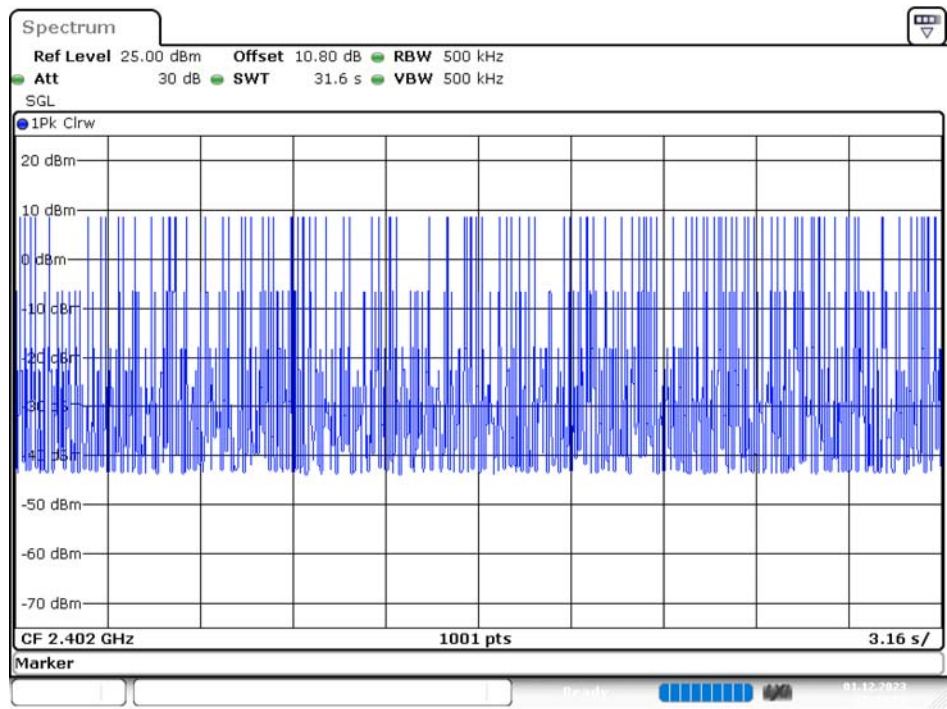


3DH5: Pulse Width



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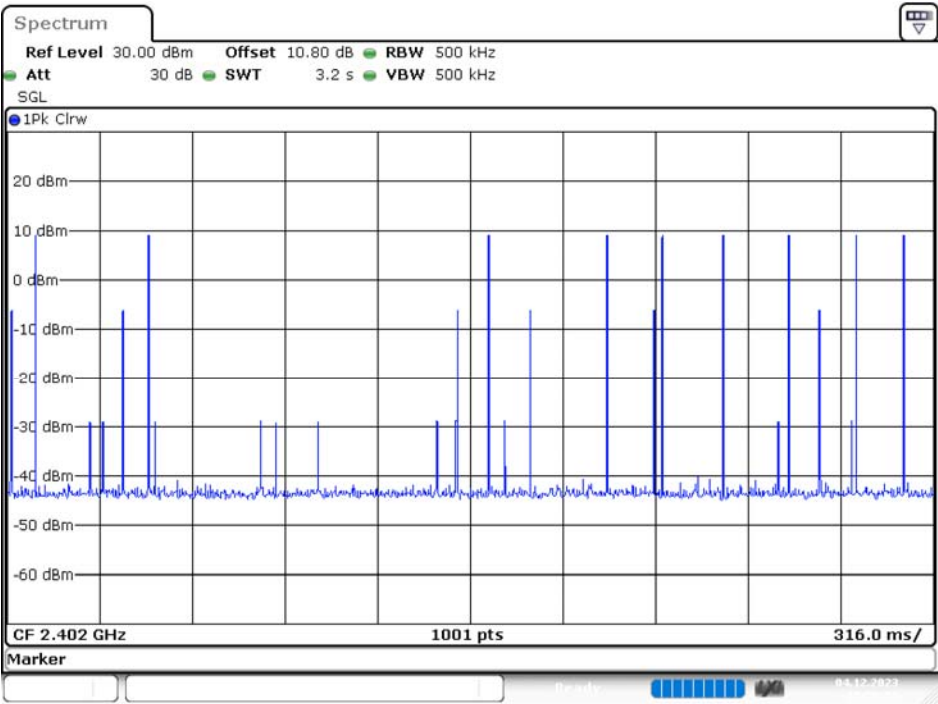
3DH5: Hopping Number



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3DH5: Hopping Number /10

(Hopping Number = 9 in 1/10 period of highest signals, Second High signals were other channel)



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13. FCC §15.247(a)(1)(iii) & RSS-247 §5.1(d) – Quantity of hopping channel Test

13.1. Applicable Standard

According to FCC §15.247(a) (1) (iii).

Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 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. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

According to RSS-247 §5.1(d).

FHSs 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 at least 15 hopping channels are used.

13.2. Test Procedure

According to ANSI C63.10-2013, section 7.8.3

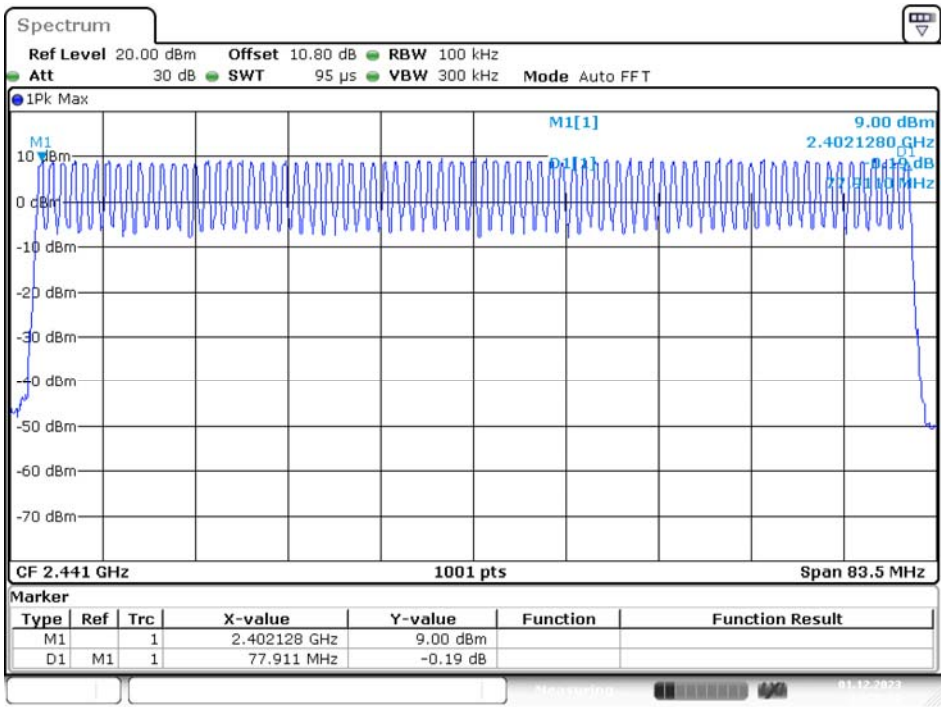
1. The EUT shall have its hopping function enabled.
2. Set the EUT in hopping mode from first channel to last.
3. By using the Max-Hold function record the Quantity of the channel.

13.3. Test Results

Mode	Frequency Range (MHz)	Number of Hopping Channel (CH)	Limit (CH)	Result
GFSK	2402-2480	79	>15	Compliance
$\pi/4$ -DQPSK	2402-2480	79	>15	Compliance
8DPSK	2402-2480	79	>15	Compliance

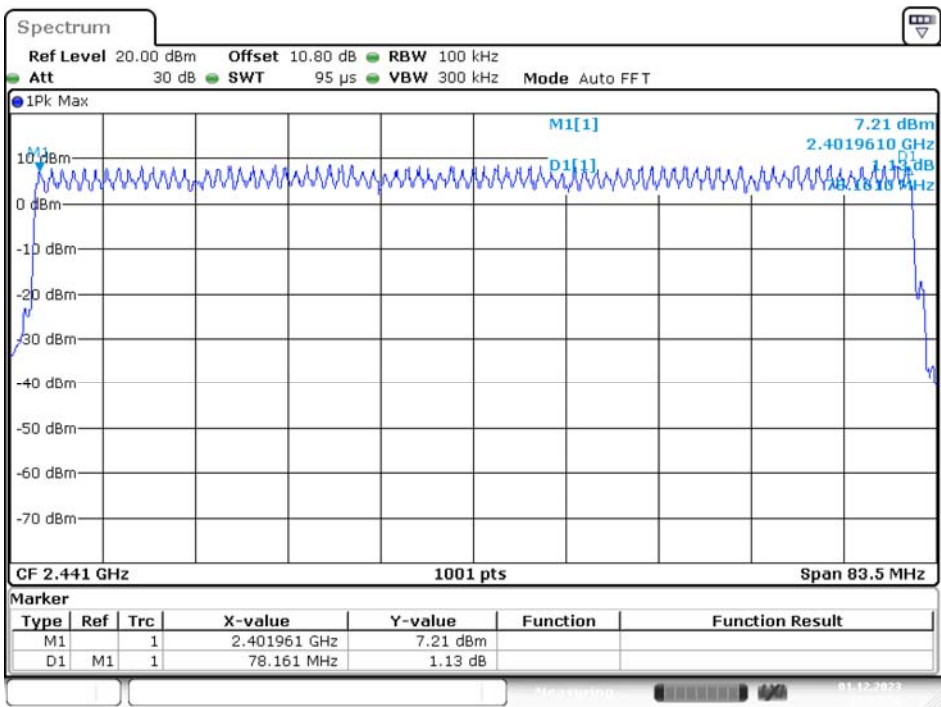
Please refer to the following plots

BR Mode (GFSK)



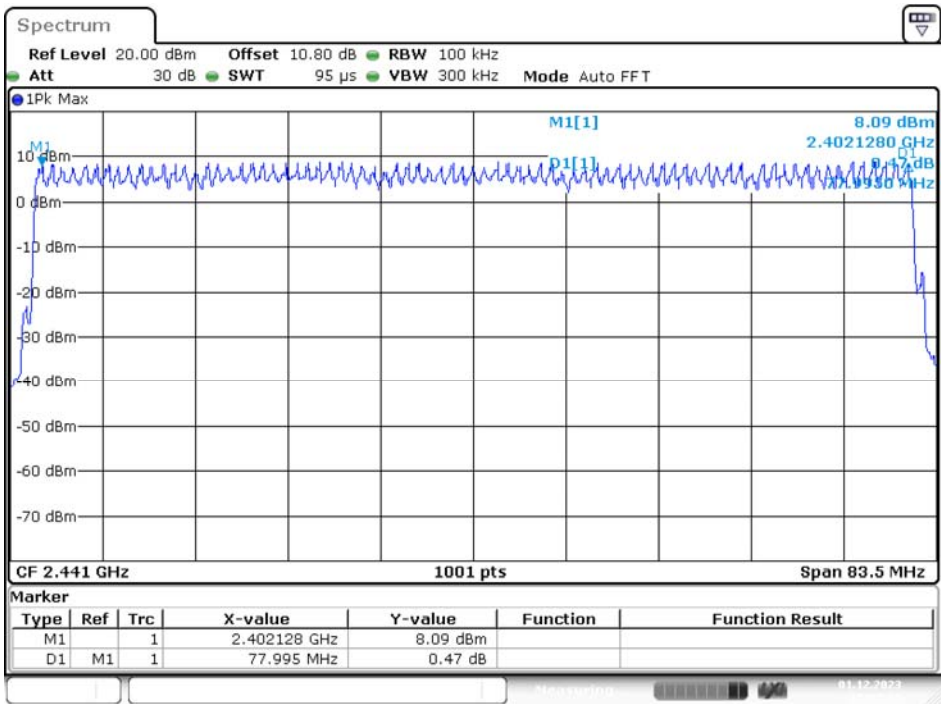
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EDR Mode ($\pi/4$ -DQPSK)



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EDR Mode (8DPSK)



Date: 1.DEC.2023 15:07:37

14. FCC §15.247(b)(1) & RSS-247 §5.4 (b)– Maximum Output Power

14.1. Applicable Standard

According to FCC §15.247(b) (1).

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

According to RSS-247 §5.4(b).

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

14.2. Test Procedure

According to ANSI C63.10-2013, section 7.8.5

1. Place the EUT on a bench and set it in transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to measuring equipment.

14.3. Test Results

Channel	Frequency (MHz)	Peak Conducted Output Power (dBm)	Limit (dBm)	Antenna Gain (dBi)	EIRP Power (dBm)	EIRP Power Limit (dBm)
BR Mode (GFSK)						
Low	2402	9.86	21	4.94	14.80	36
Middle	2441	10.33	21	4.94	15.27	36
High	2480	10.22	21	4.94	15.16	36
EDR Mode ($\pi/4$ -DQPSK)						
Low	2402	10.68	21	4.94	15.62	36
Middle	2441	10.85	21	4.94	15.79	36
High	2480	10.78	21	4.94	15.72	36
EDR Mode (8DPSK)						
Low	2402	10.72	21	4.94	15.66	36
Middle	2441	10.83	21	4.94	15.77	36
High	2480	10.88	21	4.94	15.82	36

15. FCC §15.247(d) & RSS-247 §5.5– 100 kHz Bandwidth of Frequency Band Edge

15.1. Applicable Standard

According to FCC §15.247(d)

For FCC §15.247(d), in any 100 kHz bandwidth outside the frequency bands in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emissions limits specified in §15.209(a) see §15.205(c).

According to RSS-247 §5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

15.2. Test Procedure

According to ANSI C63.10-2013, section 7.8.6

Band-edge measurements shall be tested both on single channels, and with the EUT hopping.

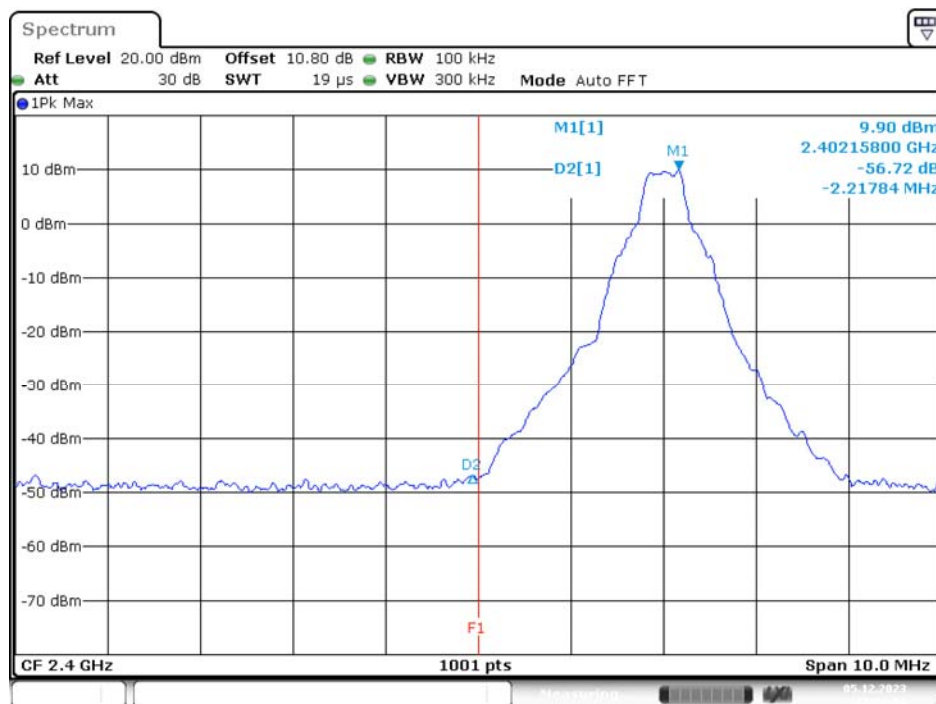
- a) Set the center frequency and span to encompass frequency range to be measured.
- b) Set the RBW = 100 kHz.
- c) Set the VBW $\geq [3 \times \text{RBW}]$.
- d) Detector = peak.
- e) Sweep time = auto couple.
- f) Trace mode = max hold.
- g) Allow trace to fully stabilize.
- h) Use the peak marker function to determine the maximum amplitude level.

15.3. Test Results

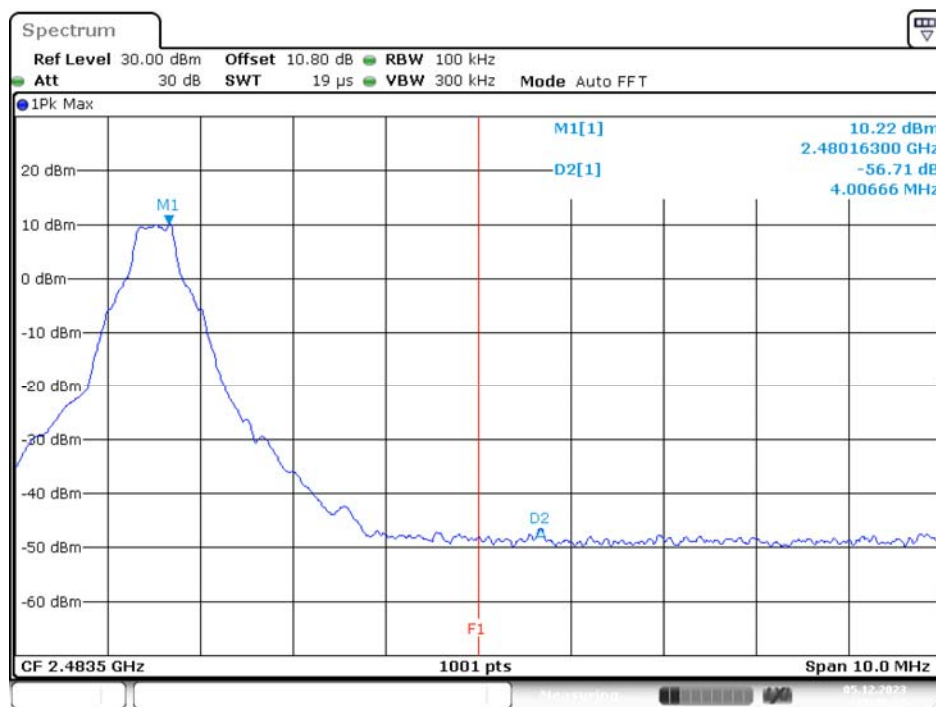
Channel	Frequency (MHz)	Delta Peak to Band Emission (dBc)	Limit (dBc)	Result
BR Mode (GFSK)				
Low	2402	56.72	≥ 20	PASS
High	2480	56.71	≥ 20	PASS
BR Hopping Mode (GFSK)				
Low	2402-2480	56.85	≥ 20	PASS
High	2402-2480	58.11	≥ 20	PASS
EDR Mode ($\pi/4$ -DQPSK)				
Low	2402	49.48	≥ 20	PASS
High	2480	54.48	≥ 20	PASS
EDR Hopping Mode ($\pi/4$ -DQPSK)				
Low	2402-2480	51.73	≥ 20	PASS
High	2402-2480	54.74	≥ 20	PASS
EDR Mode (8DPSK)				
Low	2402	50.63	≥ 20	PASS
High	2480	54.81	≥ 20	PASS
EDR Hopping Mode (8DPSK)				
Low	2402-2480	51.53	≥ 20	PASS
High	2402-2480	56.22	≥ 20	PASS

Please refer to the following plots.

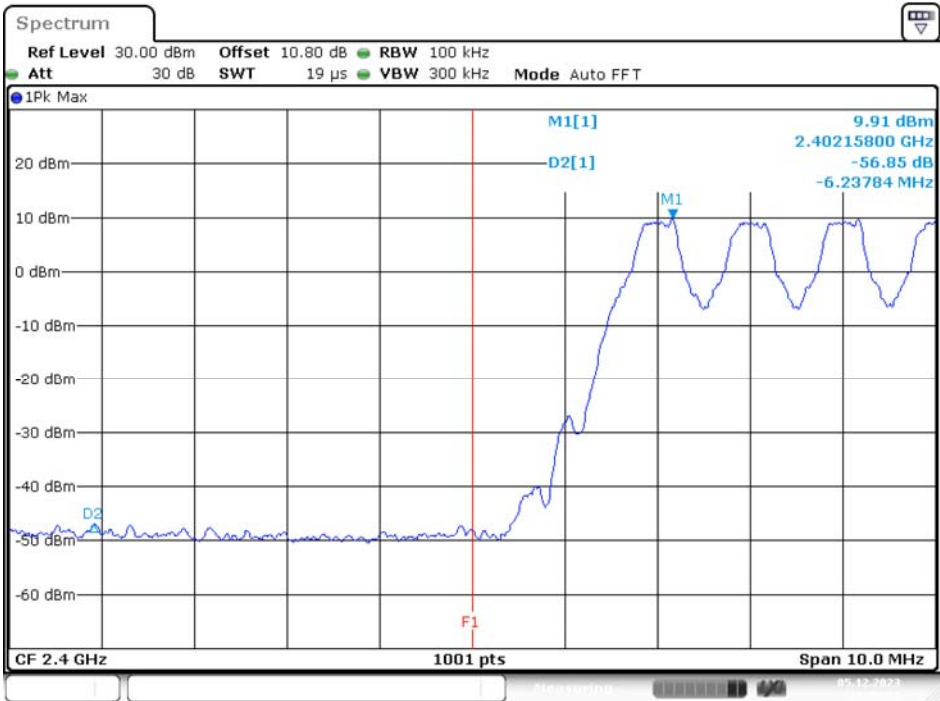
BR Mode (GFSK) Band Edge, CH Low



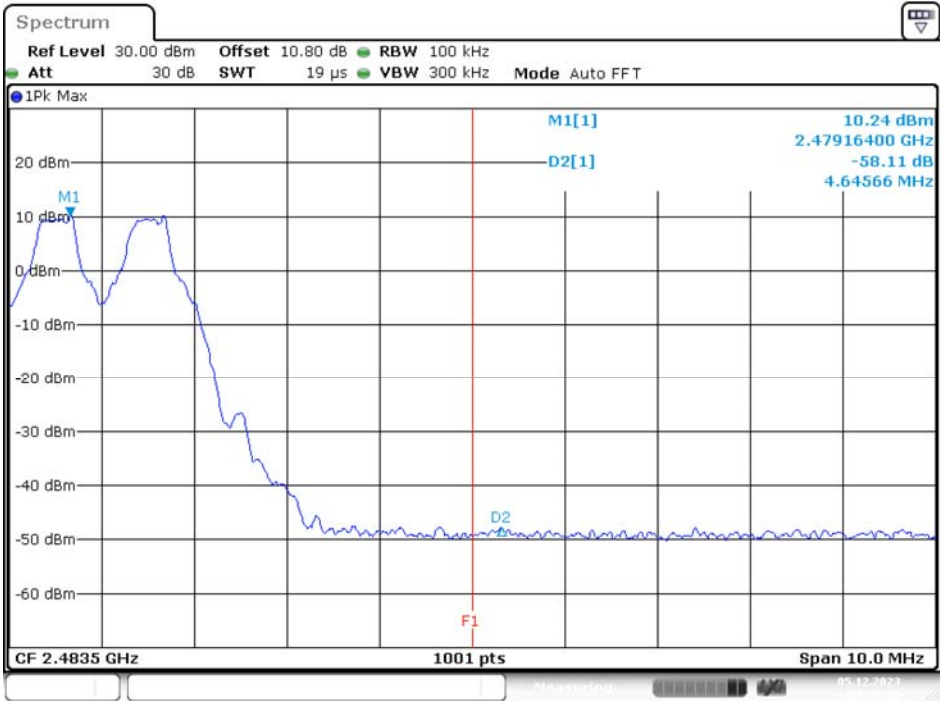
Band Edge, CH High



BR Hopping Mode (GFSK)
Band Edge, CH Low



Band Edge, CH High



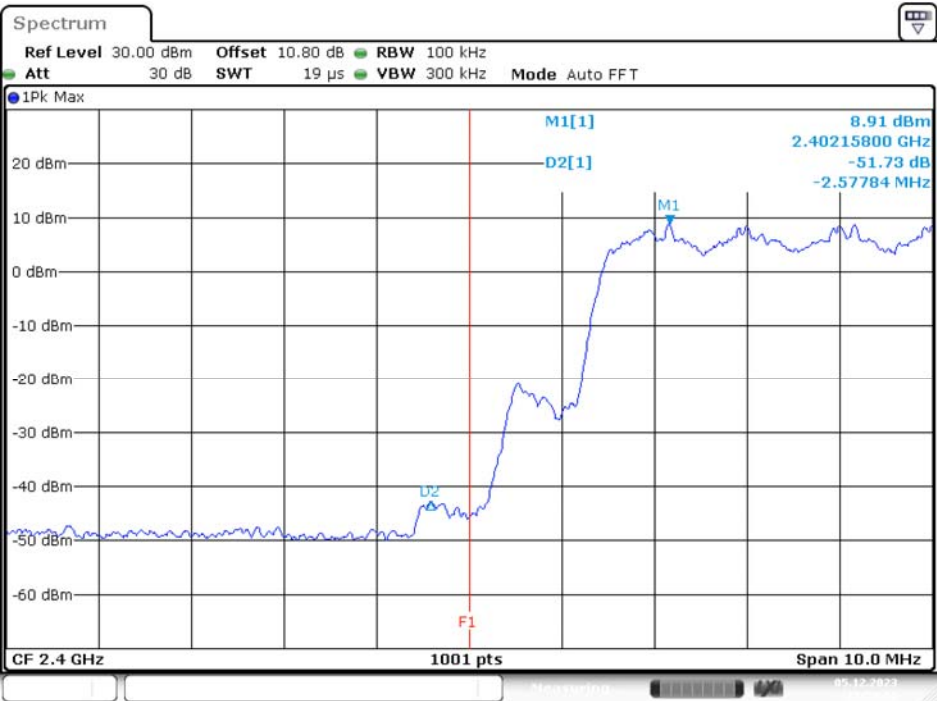
EDR Mode ($\pi/4$ -DQPSK)
Band Edge, CH Low



Band Edge, CH High

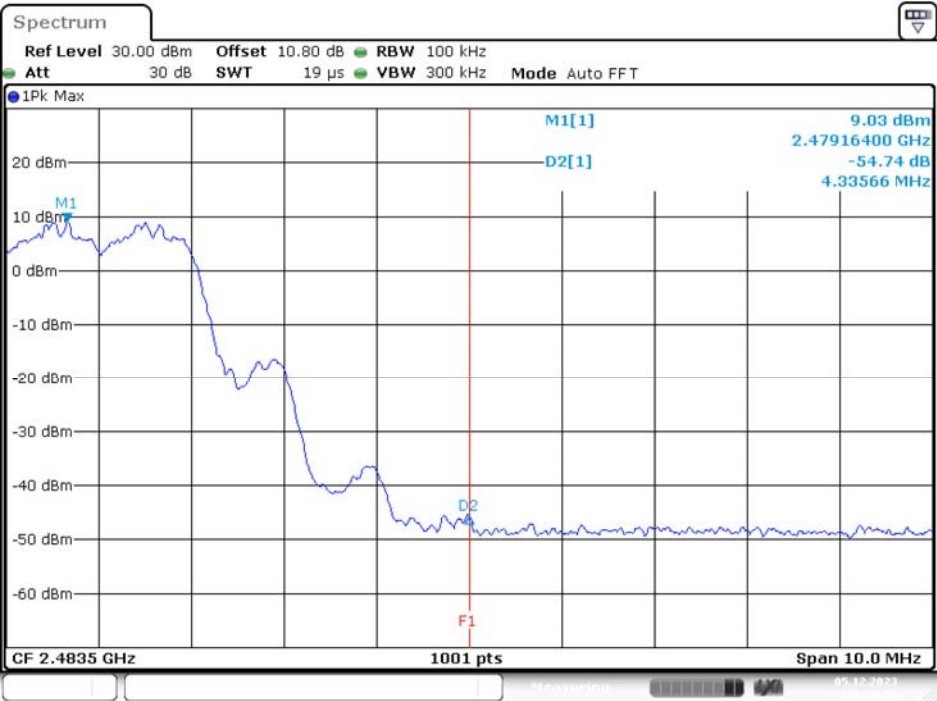


EDR Hopping Mode ($\pi/4$ -DQPSK)
Band Edge, CH Low



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Band Edge, CH High



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EDR Mode (8DPSK)
Band Edge, CH Low



Band Edge, CH High

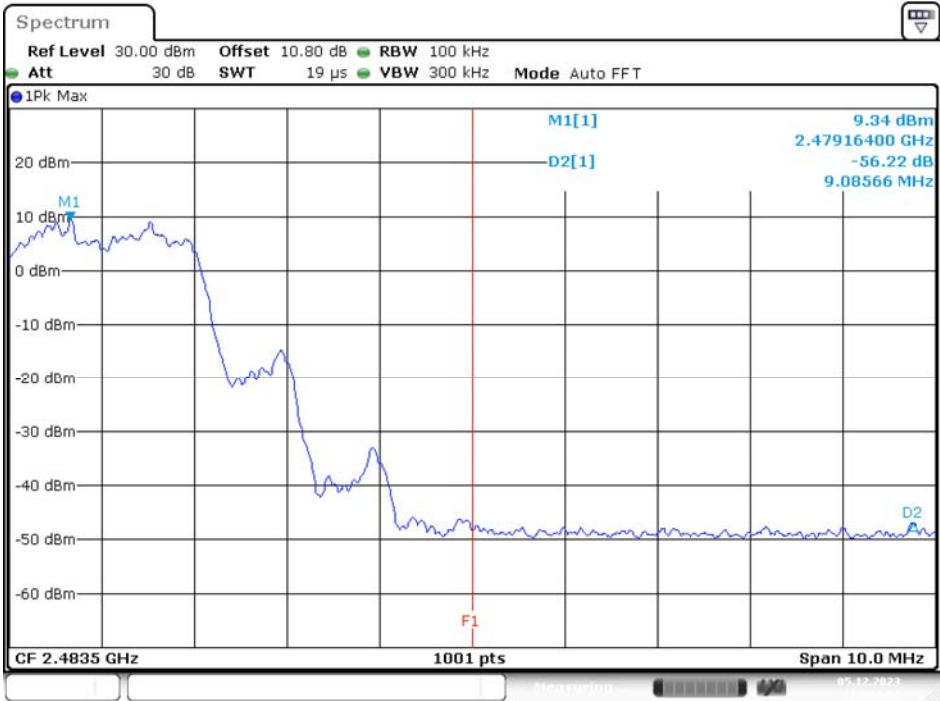


EDR Hopping Mode (8DPSK)
Band Edge, CH Low



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Band Edge, CH High



Date: 5.DEC.2023 14:04:48

***** END OF REPORT *****