

ELECTROMAGNETIC EMISSIONS COMPLIANCE REPORT



EUT Description Sparrow Wi-Fi Module
Applicant: BOTS UNLIMITED LLC
5817 La Colonia, San Antonio, Texas 78218, USA
Manufacturer: BOTS UNLIMITED LLC
5817 La Colonia, San Antonio, Texas 78218, USA
Brand Name: Bots Unlimited
Model No./ISED HVIN: SP-01-100
ISED PMN: SP-01-100
Report Number: TERF2506001926ER
FCC ID 2BPPF-SP01
IC: 34356-SP01
Date of EUT Received: June 6, 2025
Date of Test: June 9, 2025 ~ August 13, 2025
Issue Date: August 26, 2025

Approved By _____

Jim Chang

We hereby certify that:

The above equipment was tested by SGS Taiwan Ltd. Central RF Lab. The test data, data evaluation, test procedures, and equipment configurations shown in this report were made in accordance with the procedures given in ANSI C63.10:2020 and the energy emitted by the sample EUT comply with FCC rule part §15.247, ISSED RSS-247.

The results of this report relate only to the sample identified in this report.

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Revision History

Report Number	Revision	Description	Issue Date	Revised By	Remark
TERF2506001926ER	00	Original	Aug. 26, 2025	Candice Li	

Note:

- 1、The remark "" indicates modification of the report upon requests from certification body.

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1 GENERAL INFORMATION

1.1 Product Description

EUT Description	Sparrow Wi-Fi Module
Brand Name	Bots Unlimited
Model No./ISED HVIN	SP-01-100
Hardware Version	1
Firmware Version	W16.88.10.p173-16.26.10.p173-C4X16698_V4
EUT Series No.	254WSP-01-EVKAAAA101000001
Power Supply	3.3 Vdc, 1.8Vdc
Test Software (Name/Version)	Dut labtool

1.2 RF Specification

Radio Technology:	BT BR+EDR
Channel number:	79 channels
Modulation type:	GFSK + $\pi/4$ DQPSK + 8DPSK
Transmit Power:	7.25m
Frequency Range:	2.402GHz – 2.480GHz
Dwell Time:	$\leq 0.4s$

1.3 Antenna Designation

Antenna Type	Supplier	Antenna Part No.	Freq. (MHz)	Peak Antenna Gain (dBi)
Flexible Printed Circuit	ABRACON	AFG4507W2	2400 - 2500	6.62

Note:

1. Pre-scanned was done on the above antennas, measurements were demonstrated by using the antenna with the highest gain as the worst case scenarios.
2. The antenna information is provided by the applicant. The laboratory does not verify the accuracy of this information, and all test results related to antenna characteristics are based solely on the data supplied. Responsibility for the authenticity and accuracy of these specifications rests entirely with the party who provided the information.
3. The antenna complies with part 15.203 requirement and no consideration of replacement. Please see EUT photo for details.

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1.4 Operating Frequencies

2400~2483.5 MHz							
CH	Freq. (MHz)	CH	Freq. (MHz)	CH	Freq. (MHz)	CH	Freq. (MHz)
0	2402	20	2422	40	2442	60	2462
1	2403	21	2423	41	2443	61	2463
2	2404	22	2424	42	2444	62	2464
3	2405	23	2425	43	2445	63	2465
4	2406	24	2426	44	2446	64	2466
5	2407	25	2427	45	2447	65	2467
6	2408	26	2428	46	2448	66	2468
7	2409	27	2429	47	2449	67	2469
8	2410	28	2430	48	2450	68	2470
9	2411	29	2431	49	2451	69	2471
10	2412	30	2432	50	2452	70	2472
11	2413	31	2433	51	2453	71	2473
12	2414	32	2434	52	2454	72	2474
13	2415	33	2435	53	2455	73	2475
14	2416	34	2436	54	2456	74	2476
15	2417	35	2437	55	2457	75	2477
16	2418	36	2438	56	2458	76	2478
17	2419	37	2439	57	2459	77	2479
18	2420	38	2440	58	2460	78	2480
19	2421	39	2441	59	2461		

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1.5 EUT Availability and The Worst Test Modes

- 1 The EUT has been tested under operating condition.
- 2 Test program used to control the EUT for staying in continuous transmitting and receiving mode is programmed.
- 3 The field strength of radiated emission was measured as the EUT positioned in different orthogonal planes (E1/E2/H) based on actual usage of the EUT to pre-scan the emissions for determining the worst case scenario.
- 4 Investigation has been done on all the possible configurations for searching the worst case.

ANTNNA PORT CONDUCTED TEST				
MODE	AVAILABLE CHANNEL	TESTED CHANNEL	MODULATION	PACKET TYPE
Peak Output Power, 20dB Band Width, Spurious Emission				
Bluetooth	0 to 78	0,39,78	GFSK	DH5
	0 to 78	0,39,78	$\pi/4$ -DQPSK	2DH5
	0 to 78	0,39,78	8-DPSK	3DH5
Band Edge				
Bluetooth	0 to 78	0,78	GFSK/8-DPSK	DH5/3DH5
Frequency Separation				
Bluetooth	0 to 78	0,1,2, 38,39,40, 76,77,78	GFSK	DH5
			$\pi/4$ -DQPSK	2DH5
			8-DPSK	3DH5
Number of Hopping Frequency, Hopping Band edge				
Bluetooth	0 to 78	0 to 78	GFSK/8-DPSK	DH5/3DH5
Time of Occupancy(Dwell time)				
Bluetooth	0 to 78	39	GFSK	DH1/DH3/DH5
			$\pi/4$ -DQPSK	2DH1/2DH3/2DH5
			8-DPSK	3DH1/3DH3/3DH5

MODE	AVAILABLE CHANNEL	TESTED CHANNEL	MODULATION	PACKET TYPE
TRANSMIT RADIATED EMISSION TEST (BELOW 1 GHz)				
Bluetooth	0 to 78	39	GFSK	DH5
TRANSMIT RADIATED EMISSION TEST (ABOVE 1 GHz)				
Bluetooth	0 to 78	0,39,78	GFSK,8-DPSK	DH5,3DH5
Note: The field strength of radiation emission was measured as EUT stand-up position (H mode) and lie down position (E1, E2 mode) for channel Low, Mid and High, the worst case position was reported.				

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2 SUMMARY OF TEST RESULTS

FCC Rules	ISED Rules	Description Of Test	Result
§15.207(a)	RSS-Gen §8.8	AC Power Line Conducted Emission	Compliant
§15.247(b)(1)	RSS-247 §6.2.3.2	Peak Output Power	Compliant
§15.247(a)(1)	RSS-247 §6.2.1.a RSS-Gen §6.7	Emission Bandwidth	Compliant
§15.205 §15.209 §15.247(d)	RSS-247 §6.6 RSS-Gen §8.9 RSS-Gen §8.10	Out of Band Emission	Compliant
§15.205 §15.209 §15.247(d)	RSS-247 §6.6 RSS-Gen §8.9 RSS-Gen §8.10	Unwanted Emission	Compliant
§15.247(a)(1)	RSS-247 §6.2.1.b & 6.2.3.1.a	Frequency Separation	Compliant
§15.247(a)(1)(iii)	RSS-247 §6.2.3.1.b	Number of hopping frequency Time of Occupancy	Compliant
§15.203	N/A	Antenna Requirement	Compliant

2.1 Test Methodology of Applied Standards

1. FCC Part 15, Subpart C §15.247
2. FCC KDB 558074 D01 15.247 Meas Guidance v05r02
3. ISED RSS-247 issue 4 July 2025
4. ISED RSS-Gen, Issue 5 April 2018, Amendment 2 (February 2021)
5. ANSI C63.10:2020
6. ANSI C63.10-2020+Cor. 1-2023+C63.10a-2024 + Errata to C63.10a-2024

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2.2 Measurement Uncertainty

Test Items	Uncertainty
AC Power Line Conducted Emission	+/- 1.54 dB
Output Power measurement	+/- 0.97 dB
Emission Bandwidth	+/- 1.38 Hz
Conducted emission measurement	+/- 0.77 dB
Frequency Separation	+/- 1.48 Hz
Number of hopping frequency	+/- 1.48 Hz
Time of Occupancy	+/- 1.48 Hz
Temperature	+/- 0.60 °C
Humidity	+/- 3.00 %
DC / AC Power Source	+/- 1.00 %

Radiated Spurious Emission Measurement Uncertainty		
Polarization: Vertical	+/- 1.89 dB	9kHz - 30MHz
	+/- 4.10 dB	30MHz - 1000MHz
	+/- 3.37 dB	1GHz - 18GHz
	+/- 3.83 dB	18GHz - 40GHz
Polarization: Horizontal	+/- 1.89 dB	9kHz - 30MHz
	+/- 4.10 dB	30MHz - 1000MHz
	+/- 3.37 dB	1GHz - 18GHz
	+/- 3.83 dB	18GHz - 40GHz
Radiated Spurious Emission	+/- 2.00 dB	33GHz - 50GHz
	+/- 1.59 dB	50GHz - 60GHz
	+/- 1.71 dB	60GHz - 90GHz
	+/- 1.64 dB	90GHz - 140GHz
	+/- 3.84 dB	140GHz - 220GHz

Note:

1. This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2.
2. The conformity assessment statement in this report is based solely on the test results, measurement uncertainty is excluded.

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2.3 Test Facility

Laboratory	Test Site Address	Test Site Name	FCC Designation number / Registration Number	IC CAB identifier
SGS Taiwan Ltd. Central RF Lab. (TAF code 3702)	No.134, Wu Kung Road, New Taipei Industrial Park, Wuku District, New Taipei City, Taiwan.	SAC 1	TW0027 / 891563	TW3702
		SAC 2		
		SAC 3		
		Conduction 1		
		Conducted 1		
		Conducted 2		
		Conducted 3		
		Conducted 4		
		Conducted 5		
		Conducted 6		
	No.2, Keji 1st Rd., Guishan District, Taoyuan City, Taiwan 333	Conduction C	TW0028 / 200037	
		SAC C		
		SAC D		
		SAC G		
		Conducted A		
		Conducted B		
		Conducted C		
		Conducted D		
		Conducted E		
		Conducted F		
		Conducted G		

Note: Test site name is remarked on the equipment list in each section of this report as an indication where measurements occurred in specific test site and address.

Temperature:	20-23	°C	Relative Humidity:	48-79	%
Test site	Conducted 2		Test Start:	07/15/2025	
Test Engineer:	Dannis Chen		Test Done:	08/13/2025	

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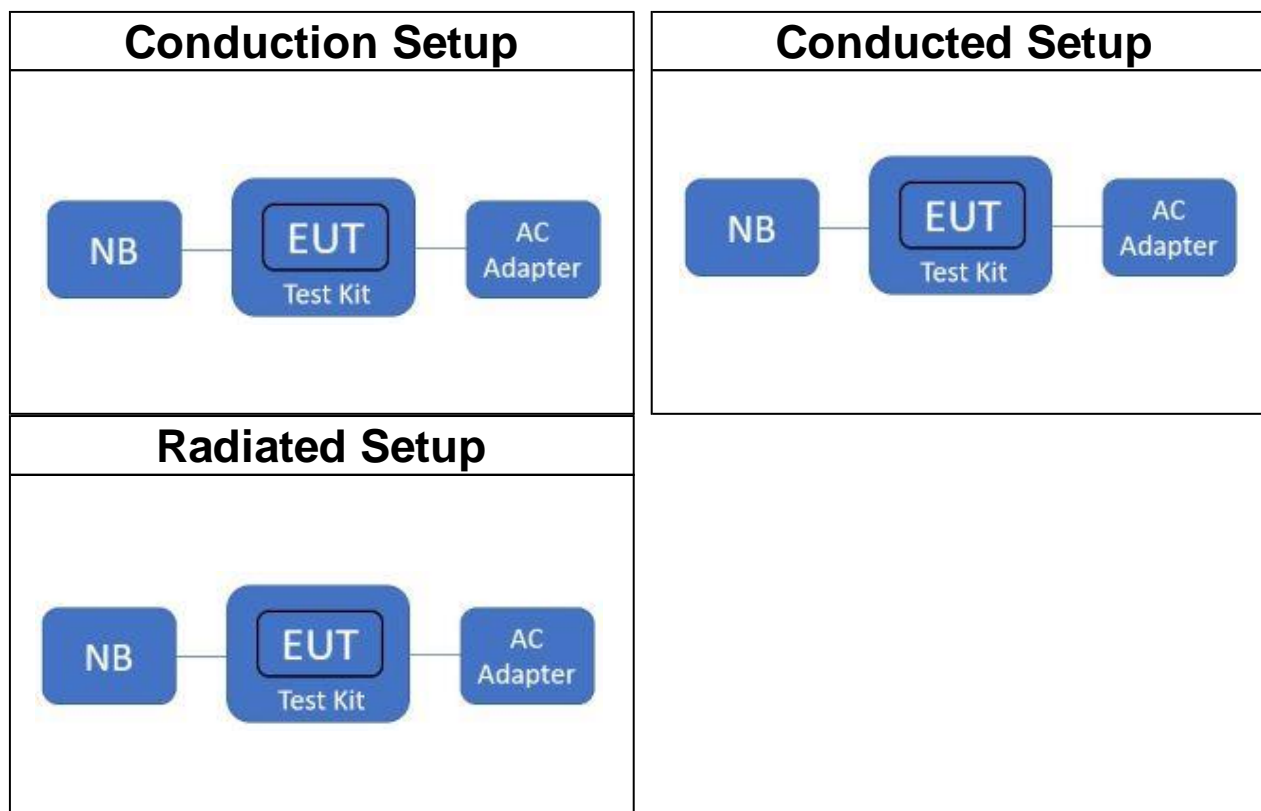
3 CONTROL UNIT(S) AND PERIPHERAL(S)

3.1 EUT Exercise

An engineering test mode (software/firmware) that applicant provided was utilized to manipulate the EUT into transmit, selection of the test channel, and modulation scheme.

The offset level is set in the spectrum analyzer to compensate the RF cable loss and attenuation factor between EUT conducted port and spectrum analyzer. With the offset compensation, the spectrum analyzer reading level is exactly EUT RF output level.

3.2 Diagrams



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3.3 List

AC Power-Line Conducted Emission Test Site: Conduction 1					
EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	LAST CAL. (mm/dd/yyyy)	CAL DUE. (mm/dd/yyyy)
AC Adapter	Tri-Mag, LLC	L6R24-120	N/A	N/A	N/A
Test Kit	Bots Unlimited	SP-01-EVK	N/A	N/A	N/A
Notebook	HP	HSN-Q35C-4	5CD238GDV5	N/A	N/A
Conducted Emission Test Site: Conducted 2					
EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	LAST CAL. (mm/dd/yyyy)	CAL DUE. (mm/dd/yyyy)
AC Adapter	Tri-Mag, LLC	L6R24-120	N/A	N/A	N/A
Test Kit	Bots Unlimited	SP-01-EVK	N/A	N/A	N/A
Notebook	HP	HSN-Q35C-4	5CD238GDV5	N/A	N/A
Radiated Emission Test Site: SAC 3					
EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	LAST CAL. (mm/dd/yyyy)	CAL DUE. (mm/dd/yyyy)
AC Adapter	Tri-Mag, LLC	L6R24-120	N/A	N/A	N/A
Test Kit	Bots Unlimited	SP-01-EVK	N/A	N/A	N/A
Notebook	HP	HSN-Q35C-4	5CD238GDV5	N/A	N/A

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4 TEST INSTRUMENT

4.1 Conducted Measurement

Conducted Emission Test Site: Conducted 2					
EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	LAST CAL. (mm/dd/yyyy)	CAL DUE. (mm/dd/yyyy)
Attenuator	Mini-Circuits	BW-S10W2+	4	12/11/2024	12/10/2025
DC Block	Titan	T0610A00127A	SNK47008	12/11/2024	12/10/2025
MXA Spectrum Analyzer	KEYSIGHT	N9021B	MY62242004	06/11/2025	06/10/2026
Power Meter	Anritsu	ML2496A	2138003	10/09/2024	10/08/2025
Power Sensor	Anritsu	MA2411B	1911393	10/09/2024	10/08/2025
Power Sensor	Anritsu	MA2411B	1911394	10/09/2024	10/08/2025
Test Software	SGS	Radio Test Software	Ver. 21	N.C.R	N.C.R

4.2 Radiated Measurement

Radiated Emission Test Site: SAC 3					
EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	LAST CAL. (mm/dd/yyyy)	CAL DUE. (mm/dd/yyyy)
4G High Pass Filter	WI	WHKX4.0	22	12/11/2024	12/10/2025
Attenuator	Mini-Circuits	BW-S10W2+	16	12/11/2024	12/10/2025
Band Reject Filter 2400-2483.5	EWT	EWT-14-0166	M2	12/11/2024	12/10/2025
Bi-log Antenna	SCHWARZBECK	VULB9168	378	08/09/2024	08/08/2025
Coaxial Cables	EMCI+Huber Suhner	EMC107-SM-SM- 1000 +SUCOFLEX 104PEA +EMC107-SM-SM- 1500 +SUCOFLEX 106	RX Cable 9K-18G (221110+MY4251/4P EA+221106+76096/6)	07/14/2025	07/13/2026
Coaxial Cables	Huber Suhner	SUCOFLEX 102	RX Cable 18G-40G MY2630/2+805062/2	07/14/2025	07/13/2026
EMI Test Receiver	R&S	ESCI 7	100759	08/28/2024	08/27/2025
EXA Spectrum Analyzer	KEYSIGHT	N9010B	MY63440386	02/05/2025	02/04/2026
Horn Antenna	SCHWARZBECK	BBHA9170	184	12/20/2024	12/19/2025
Horn Antenna	SCHWARZBECK	BBHA9120D	1441	09/23/2024	09/22/2025
Loop Antenna	COM-POWER	AL-130R	10160104	12/19/2024	12/18/2025
Pre-Amplifier	EMCI	EMC118A45SEE	980868	07/14/2025	07/13/2026
Pre-Amplifier	EMCI	EMC184045SEE	9080939	07/14/2025	07/13/2026
Pre-Amplifier	HP	8447D	2944A07676	07/14/2025	07/13/2026
Site Cal	SGS	SAC 3	N/A	07/14/2025	07/13/2026
Test Software	Audix	e3	Ver. 9.210616	N.C.R	N.C.R

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4.3 Emission from AC power line

AC Power-Line Conducted Emission Test Site: Conduction 1					
EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	LAST CAL. (mm/dd/yyyy)	CAL DUE. (mm/dd/yyyy)
Coaxial Cables	EMC Instruments Corp.	EMCCFD300-BM-BM-3000	161207	06/22/2025	06/21/2026
EMI Test Receiver	R&S	ESCI 7	100759	08/28/2024	08/27/2025
LISN	SCHWARZBECK	NSLK 8127	1040	09/07/2024	09/06/2025
Pulse Limiter	SCHWARZBECK	VTSD 9561F-N	793	06/22/2025	06/21/2026
Test Software	Audix	e3	Ver. 9.210616	N.C.R	N.C.R

NOTE: N.C.R refers to Not Calibrated Required.

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5 REGULATORY REQUIREMENTS

5.1 Emission Bandwidth

This is the factor to determine applicable frequency separation.

5.2 Frequency Separation

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.

5.3 Number Of Hopping Frequency

Frequency hopping systems operating in the 2400MHz-2483.5 MHz bands shall use at least 15 hopping frequencies.

5.4 Maximum Output Power

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 hopping channels, The Limit: 1Watt. For all other frequency hopping systems in the 2400 – 2483.5MHz band: The Limit: 0.125 Watts. The power limit for 1Mbps is 1watt, and 2Mbps, 3Mbps and AFH mode are 0.125 watts. EIRP shall not exceed 4 W.

5.5 Time Of Occupancy (Dwell Time)

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.

5.6 Out Of Band Emission

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power produced by the intentional radiator shall be at least 20 dB below the power measured in the 100 kHz bandwidth that contains the highest level of the desired signal. This requirement is based on either a conducted or radiated RF measurement, provided the transmitter complies with the applicable peak conducted power limits.

In addition, radiated emissions that fall within designated restricted frequency bands must also meet the corresponding radiated emission limits applicable to those bands.

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5.7 Unwanted Emission

5.7.1 Duty Cycle Correction Factor

The measurement of field strength shall be determined by averaging over one complete pulse train, including any blanking intervals, provided that the pulse train duration does not exceed 0.1 seconds.

Alternatively, if the transmitter operates for longer than 0.1 seconds or if the pulse train exceeds 0.1 seconds, the field strength shall be determined based on the average absolute voltage measured during a 0.1-second interval in which the field strength reaches its maximum value.

The exact method used to calculate the average field strength must be documented and included in any certification application.

5.7.2 Spurious Emission

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits.

In addition, radiated emissions which fall in the restricted bands must also comply with the applicable radiated emission limits as defined in the general emission limit tables.

Moreover, for an intentional radiator operating below 10 GHz, the frequency range of measurements shall extend up to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

Frequency (MHz)	Field strength (microvolts/meter)	Distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30	30	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

Note: The lower limit shall apply at the transition frequencies.

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5.8 AC Power Line Conducted Emission

Frequency within 150 kHz to 30MHz shall not exceed the limit table as below.

Frequency range MHz	Limits dB(uV)	
	Quasi-peak	Average
0.15 to 0.50	66 to 56	56 to 46
0.50 to 5	56	46
5 to 30	60	50

Note

- 1.The lower limit shall apply at the transition frequencies
- 2.The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz.

5.9 Antenna Requirement

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 of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of §§ 15.211, 15.213, 15.217, 15.219, 15.221, or § 15.236. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with § 15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

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6 TEST CONFIGURATION

6.1 Emission Bandwidth



Place the EUT on the table and set it in transmitting mode.

Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the spectrum analyzer.

20dB BW measurements

The testing is performed in accordance with the applicable regulatory measurement procedure.

Set the spectrum analyzer as

RBW= 1 % to 5% of OBW,

VBW = 3 X RBW,

Span= 2 to 5 times of the OBW,

Sweep=Auto, Detector = Peak, and Trace mode = Max Hold.

Mark the upper and lower frequencies of -20dB.

Repeat above procedures until all test default channel is completed.

99% BW measurements

The testing is performed in accordance with the applicable regulatory measurement procedure.

Set the spectrum analyzer as

RBW= 1 % to 5% of 99% Bandwidth,

VBW≥3 X RBW

Span= large enough to capture all products of the modulation process

Sweep=Auto, Detector = Peak, and Trace mode = Max Hold.

Mark the upper and lower frequencies of 99%.

Repeat above procedures until all test default channel is completed.

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6.2 Frequency Separation



Place the EUT on the table and set it to transmit mode.

The testing is performed in accordance with the applicable measurement procedure.

Set center frequency of spectrum analyzer = middle of hopping channel.

Set the RBW approximately 30% of the channel spacing, VBW \geq 1/10 of RBW.

Adjust Span to Wide enough to capture the peaks of two adjacent channels.

Sweep time = Auto Couple.

Max hold. Mark 3 Peaks of hopping channel and record the 3 peaks frequency.

6.3 Number Of Hopping Frequency



Place the EUT on the table and set it in transmitting mode.

Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the spectrum analyzer.

The testing is performed in accordance with the applicable measurement procedure.

Configure the spectrum analyzer as follows:

Start frequency= 2400 MHz

Stop frequency= 2483.5 MHz

RBW = 30% of the channel spacing

VBW \geq 1/10 of RBW

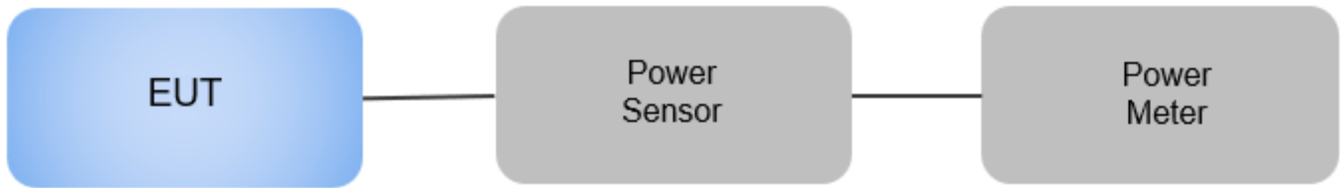
Detector = Peak

Sweep = Auto

Trace mode = Max Hold.

View and count the number of hopping channels within the band.

6.4 Maximum Output Power



Place the EUT on the table and set it to transmit mode.

The testing was performed in accordance with the applicable measurement procedure. Remove the antenna from the EUT and connect a low-loss RF cable from the antenna port to the power meter.

Record the maximum reading as observed from the power meter(Max Hold, Detector = Peak, RBW ≥ 20 dB bandwidth).

Repeat the above procedures until all default test channels have been measured.

6.5 Time Of Occupancy (Dwell Time)



Place the EUT on the table and set it in transmitting mode.

Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the spectrum analyzer.

The testing is performed in accordance with the applicable measurement procedure.

Configure the spectrum analyzer as follows:

Set the center frequency of the spectrum analyzer to the operating frequency.

RBW = 1 MHz

VBW = 3 MHz

Span = 0Hz

Detector = Peak

Adjust Sweep = 2 ~ 8ms

Repeat above procedures until all frequency of the interest measured were complete.

Formula Deduced: time occupancy of one time slot X Hopping rate / total slot in one channel / total channel that hops X period of working channels.

Where, standard hopping rate is 1600 hops/s, slot in one channel for DH1, DH3, and DH5 is 2, 4, and 6, respectively.

DH1 consists of single time slot of the uplink, and one slot of the downlink Total Slot: 2

DH3 consists of three time slot of the uplink, and one slot of the downlink. Total Slot: 4

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DH5 consists of five time slot of the uplink, and one slot of the downlink. Total Slot: 6

*Note: the result of the complete test default channel at 1Mbps is recorded on the test report, 2Mbps, and 3Mbps only records the measurement result at middle channel that reveals no much deviation.

6.6 Out Of Band Emission



6.6.1 Conducted Band Edge:

Place the EUT on the table and set it in transmitting mode.

Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the spectrum analyzer.

The testing is performed in accordance with the applicable measurement procedure.

Configure the spectrum analyzer as follows:

Set the center frequency of the spectrum analyzer to the operating frequency.

RBW = 100 kHz

VBW = 300 kHz

Sweep = Auto

Mark Peak, below 2.4GHz and above 2.4835GHz and record the max. level.

Repeat above procedures until all frequency measured were complete.

6.6.2 Conducted Spurious Emission:

The testing is performed in accordance with the applicable measurement procedure.

Connect the antenna port of the EUT to the spectrum analyzer.

Configure the spectrum analyzer as follows:

RBW = 100 kHz

VBW = 300 kHz

Detector = Peak

Sweep = Auto

Allow the trace to fully stabilize.

Use the peak marker function to determine the maximum power level in any 100 kHz band segment within the fundamental emission bandwidth (EBW).

Repeat above procedures until all default test channel measured were complete.

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6.7 Unwanted Emission

6.7.1 Duty Cycle Correction Factor



Correction Factor For Radiated Unwanted Emission

Adjust and configure any EUT switches, controls, or input data streams to ensure that the EUT is transmitting or encoded to produce the worst-case pulse ON time.

The testing was performed in accordance with the applicable measurement procedure. Remove the antenna from the EUT and connect a low-loss RF cable from the antenna port to the spectrum analyzer.

Set the center frequency of the spectrum analyzer to the operating frequency.

Configure the spectrum analyzer as follows:

RBW = 1 MHz

VBW = 3 MHz

Span = 0 Hz

Detector = Peak

Sweep Time = 100 ms (manually adjusted)

Repeat the above procedure until all frequencies of interest have been measured.

Average Value (dBμV/m) = Peak Actual Field Strength (dBμV/m) + Duty Cycle Correction Factor (dB)

Duty Cycle Correction Factor (dB) = $20 \times \log_{10} (T_{on} / 100 \text{ ms})$

6.7.2 Radiated Emission

For Measurements From 9 kHz To 30 MHz

Radiated emission below 30MHz is measured in a 9m*6m*6m semi-anechoic chamber, the measurements correspond to those obtained at an open-field test site.

There is a comparison data of both open-field test site and semi-Anechoic chamber, and the result came out very similar.

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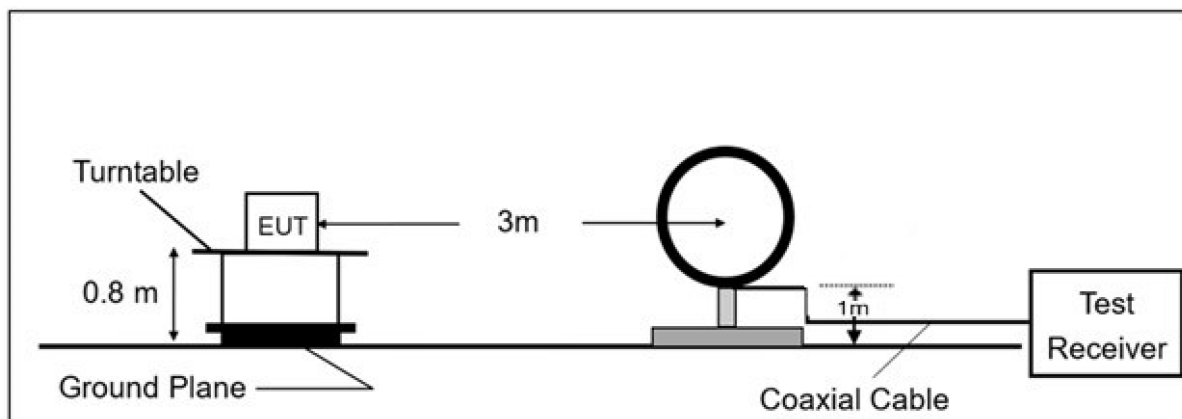
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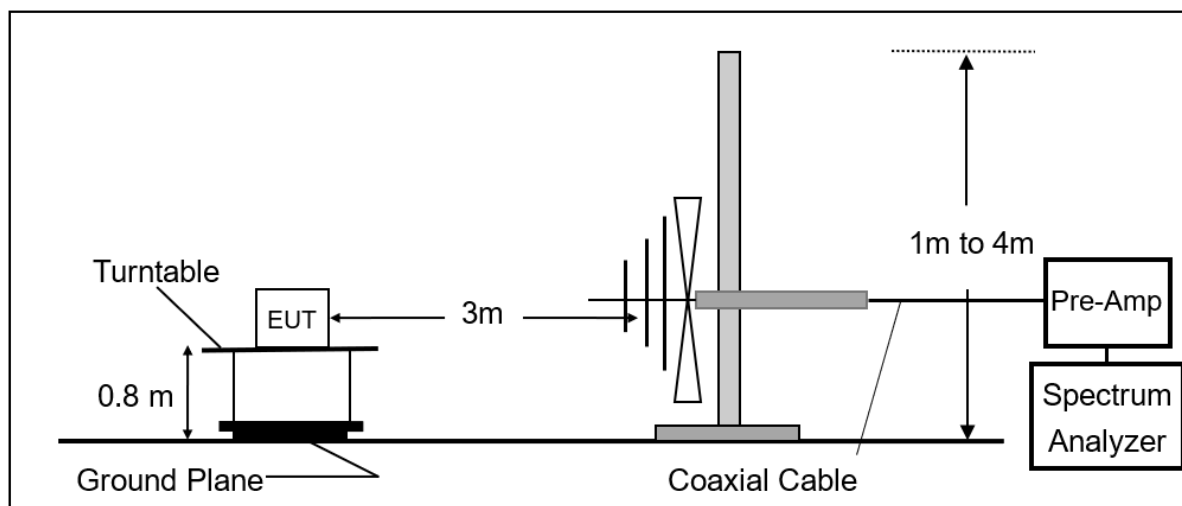
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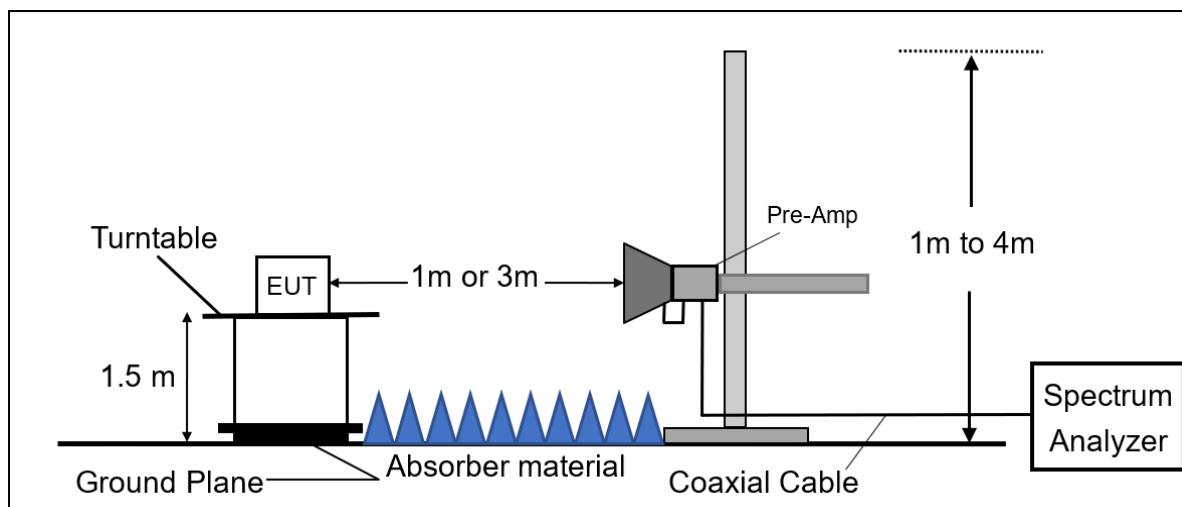
Radiated Emission Test Set-Up, Frequency Below 30MHz.



Radiated Emission Test Set-Up, Frequency From 30MHz to 1000MHz.



Radiated Emission Test Set-Up, Frequency Above 1 GHz.



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Radiated emissions below 30 MHz were measured in a 9 m × 6 m × 6 m semi-anechoic chamber. The measurement results are equivalent to those obtained at an open-area test site (OATS).

A comparison between data measured at the open-area test site and the semi-anechoic chamber shows very similar results.

The testing was performed in accordance with the applicable radiated emission measurement procedure.

The EUT was placed on a turntable at a height of 0.8 m for frequencies below 1 GHz and 1.5 m for frequencies above 1 GHz.

The turntable was rotated 360 degrees to determine the position of the maximum emission level.

The EUT was positioned 3 meters away from the receiving antenna, which was varied in height from 1 m to 4 m to locate the highest emissions.

The spectrum analyzer was set with RBW = 100 kHz and VBW = 300 kHz, using a Peak detector for frequencies between 30 MHz and 1 GHz.

A receiver mode with RBW = 120 kHz was used for Quasi-Peak (QP) measurements between 30 MHz and 1 GHz.

For frequencies above 1 GHz, the spectrum analyzer was set with RBW = 1 MHz, VBW = 3 MHz, and Detector = Peak for maximum emission measurements.

For average emission measurements above 1 GHz where the duty cycle (D) is $\geq 98\%$, the analyzer was set with RBW = 1 MHz, VBW = 3 MHz, and the RMS detector with correction factor $[10 \log(1/D)]$. If the emission is continuous ($D \geq 98\%$) and does not switch ON/OFF with the transmit cycle, then no duty cycle correction is required.

For average emission measurements above 1 GHz where $D < 98\%$, the analyzer was set with RBW = 1 MHz and $VBW \geq 1/T$.

The average value of pulsed emissions is determined using the duty cycle correction method, applying a correction factor of $20 \times \log_{10} (T_{on} / 100 \text{ ms})$.

When measuring radiated emissions above 1 GHz, the receiving antenna was maintained within the "cone of radiation" and pointed at the emission source in both azimuth and elevation, with polarization oriented for maximum response, ensuring it remained within the 3 dB illumination beamwidth of the measurement antenna.

The six highest emissions were fully maximized using the above procedures to ensure EUT compliance.

Each emission was further maximized by changing the receiving antenna polarization between horizontal and vertical.

Repeat the above procedures until all default test channels (low, middle, and high) are measured.

Note: Emissions from 9 kHz to 30 MHz were pre-scanned and found to be at least 20 dB below the applicable limits, and are therefore not reported.

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6.7.1 Field Strength Calculation

The field strength is calculated by adding the antenna factor and cable loss, then subtracting the amplifier gain and any applicable duty cycle correction factor from the measured reading. The basic equation and an example calculation are as follows:

$$FS = RA + AF + CL - AG$$

Where:

FS = Field Strength (dB μ V/m)

RA = Reading Amplitude (dB μ V)

AF = Antenna Factor (dB/m)

CL = Cable Loss (dB)

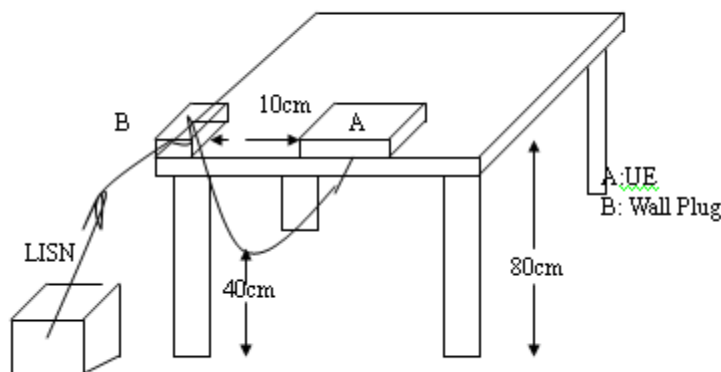
AG = Amplifier Gain (dB)

The emission limit is expressed in dB μ V/m, which corresponds to the logarithmic conversion of $20 \times \log_{10} (\mu\text{V/m})$.

Actual Field Strength (dB μ V/m) = Spectrum Analyzer Reading (dB μ V) + Total Factor (dB)

Total Factor (dB) = Antenna Factor (dB) + Cable Loss (dB) – Preamplifier Gain (dB)

6.8 AC Power Line Conducted Emission



The conducted emission tests were performed at the designated test site using a setup in accordance with the applicable version of ANSI C63.10.

1. The EUT was placed on a non-conductive table that is 0.8 meters above the ground plane. Conducted emissions were measured in the frequency range from 0.15 MHz to 30 MHz using CISPR Quasi-Peak and Average detector modes. Two LISNs were used to provide 50 μ H / 50 ohm coupling impedance to the measuring instrument. Both lines of the AC power mains connected to the EUT were evaluated to identify the maximum conducted interference.
2. The AC/DC power adapter of the EUT was connected to the LISN. The EUT was positioned flush with the rear edge of the table, maintaining at least 0.4 meters of separation from the shielding wall.

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3. The LISNs were connected to the power source and configured in accordance with the test requirements.
4. The maximum emission levels were investigated for each operating mode. The six highest emissions were further maximized to ensure compliance.
5. The above procedures were repeated for all applicable power supply configurations of the EUT.

Calculation Formula:

Level = Read Level + Factor

Factor = LISN/ISN/Current Probe Factor + Cable Loss + Attenuator

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7 TEST RESULTS

7.1 Emission Bandwidth

7.1.1 20dB Bandwidth

GFSK

CH	20 dB BW (MHz)	2/3 BW (MHz)
0	0.9554	0.64
39	0.9542	0.64
78	0.9555	0.64

$\pi/4$ -DQPSK

CH	20 dB BW (MHz)	2/3 BW (MHz)
0	1.314	0.88
39	1.312	0.87
78	1.313	0.88

8-DPSK

CH	20 dB BW (MHz)	2/3 BW (MHz)
0	1.298	0.87
39	1.298	0.87
78	1.295	0.86

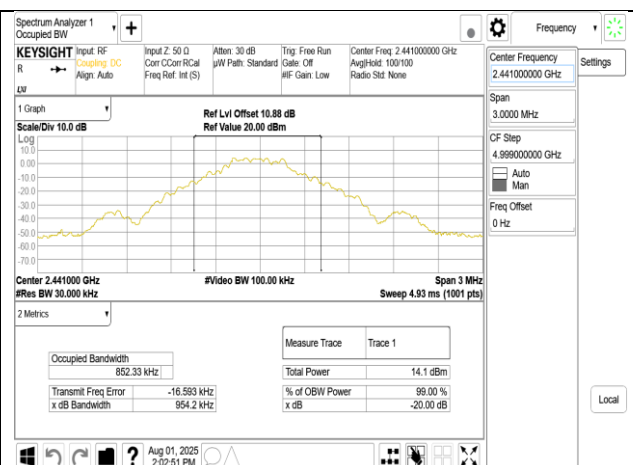
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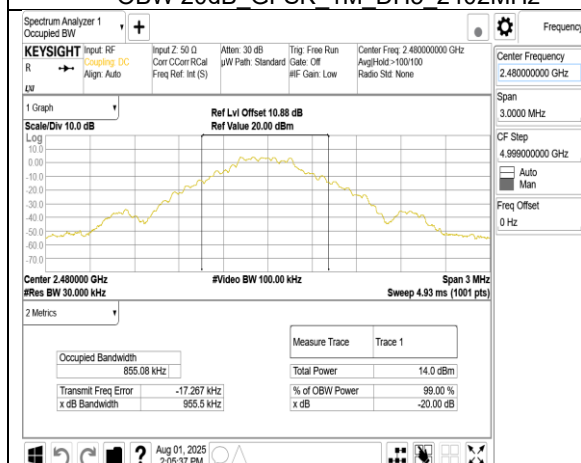
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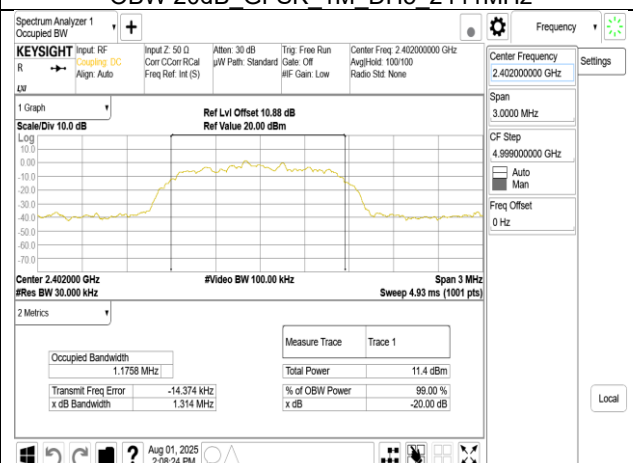
OBW 20dB GFSK 1M DH5 2402MHz



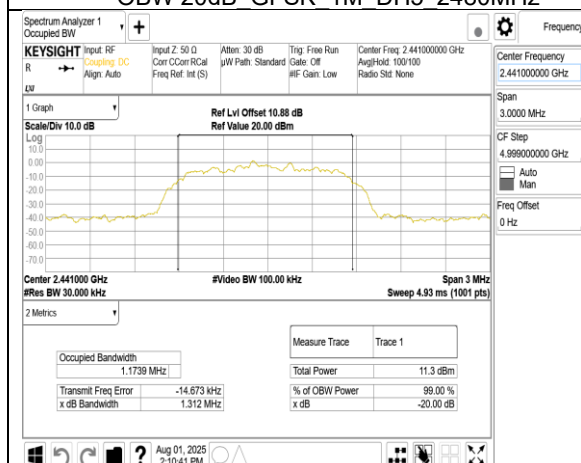
OBW 20dB GFSK 1M DH5 2441MHz



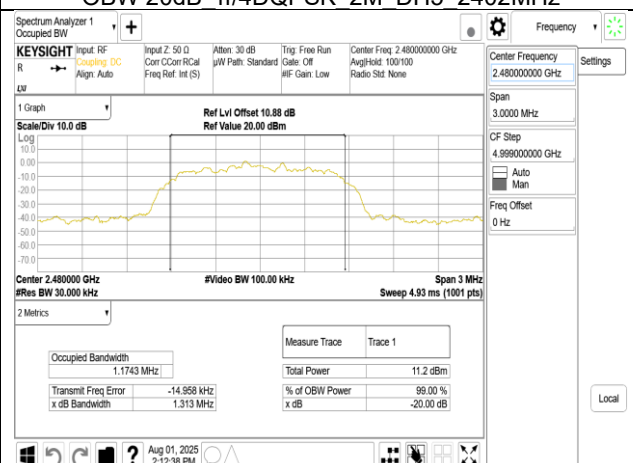
OBW 20dB GFSK 1M DH5 2480MHz



OBW 20dB π/4DQPSK 2M DH5 2402MHz



OBW 20dB π/4DQPSK 2M DH5 2441MHz

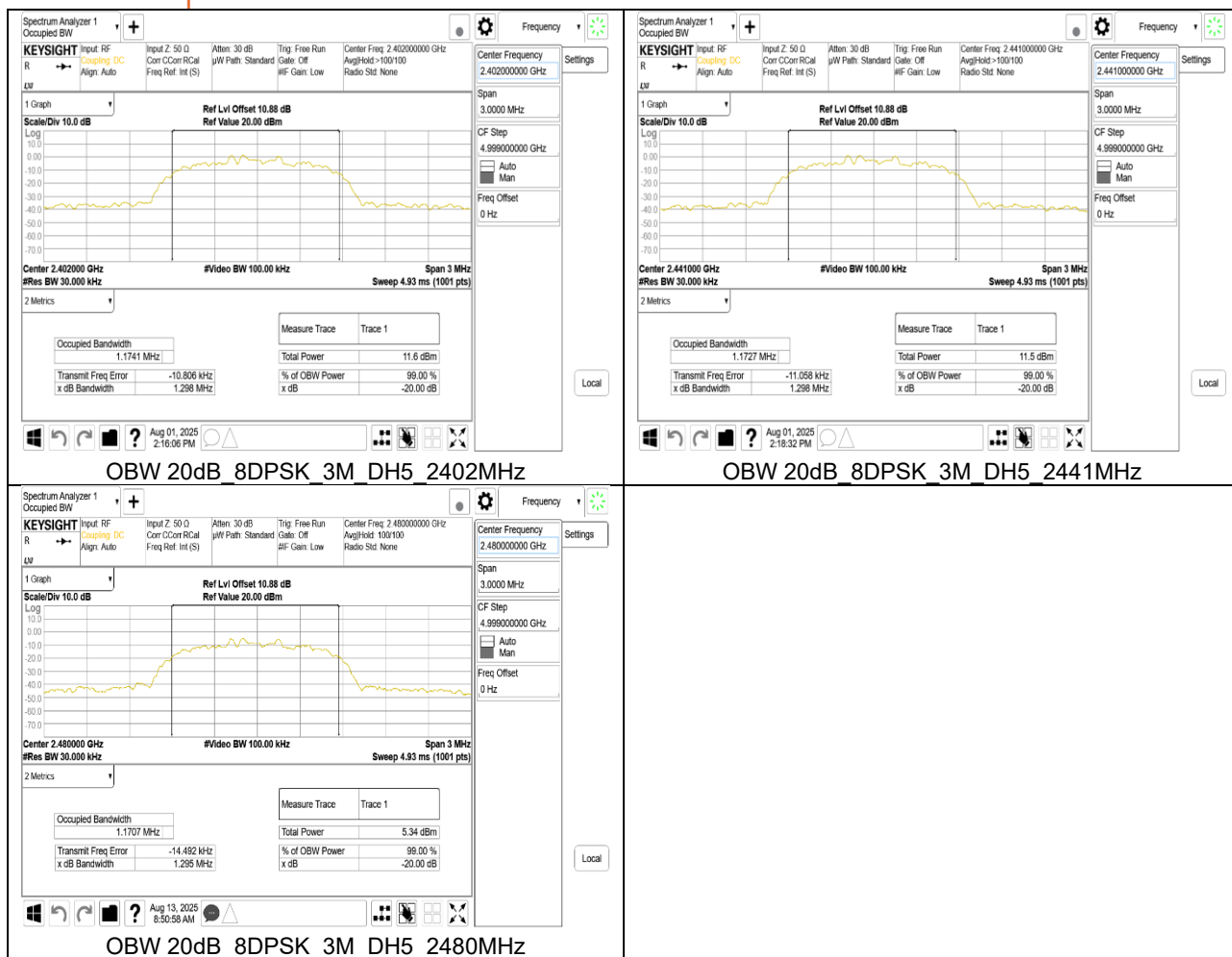


OBW 20dB π/4DQPSK 2M DH5 2480MHz

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GFSK

CH	99% BW (MHz)
0	0.85424
39	0.85111
78	0.854

$\pi/4$ -DQPSK

CH	99% BW (MHz)
0	1.1725
39	1.1710
78	1.1722

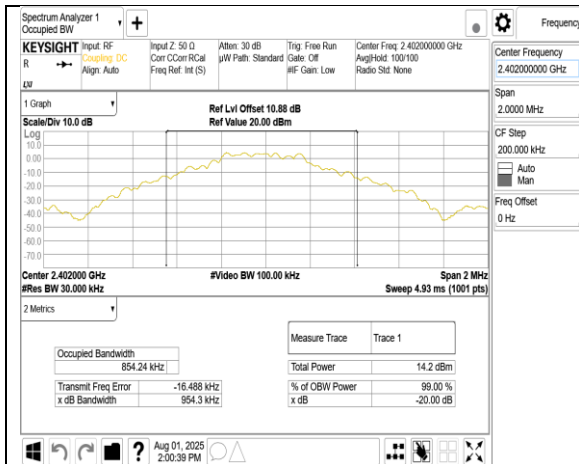
8-DPSK

CH	99% BW (MHz)
0	1.1699
39	1.1692
78	1.1673

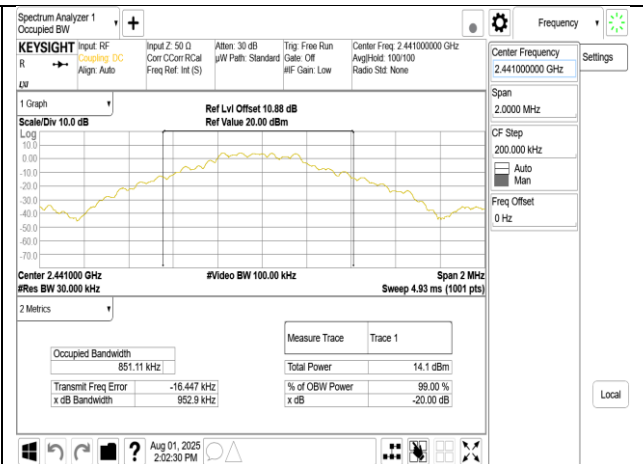
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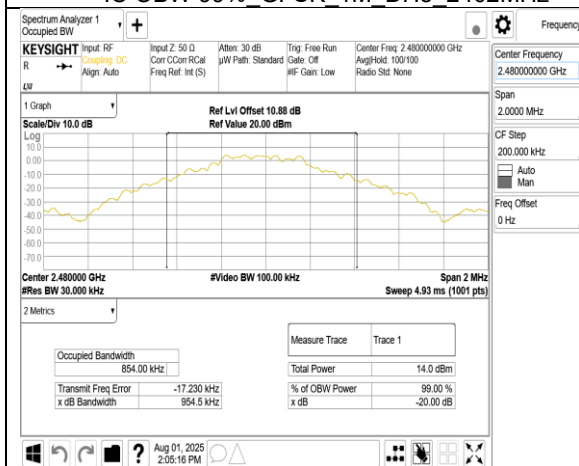
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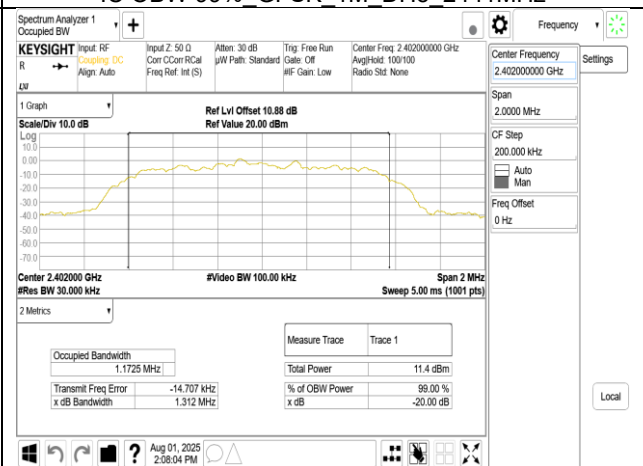
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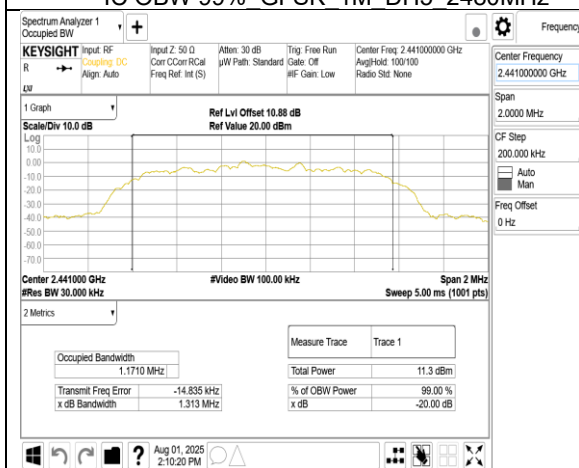
IC OBW 99% GFSK 1M DH5 2441MHz



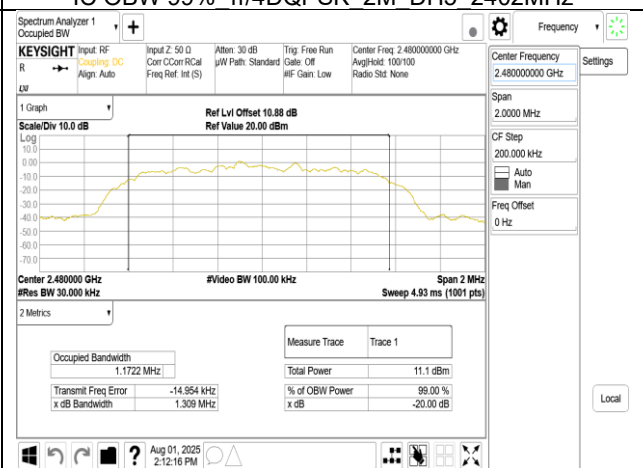
IC OBW 99% GFSK 1M DH5 2480MHz



IC OBW 99% $\pi/4$ DQPSK 2M DH5 2402MHz



IC OBW 99% $\pi/4$ DQPSK 2M DH5 2441MHz

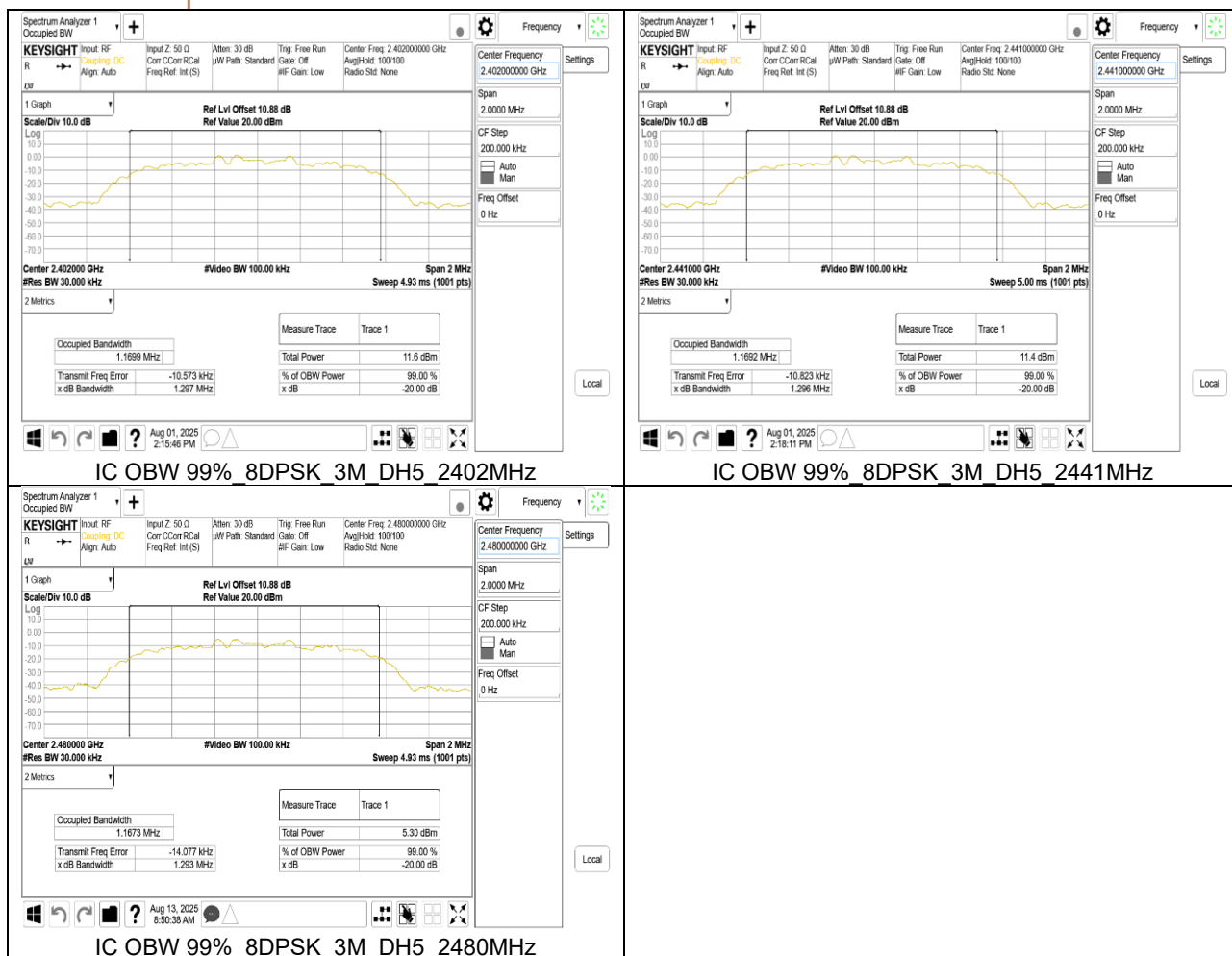


IC OBW 99% $\pi/4$ DQPSK 2M DH5 2480MHz

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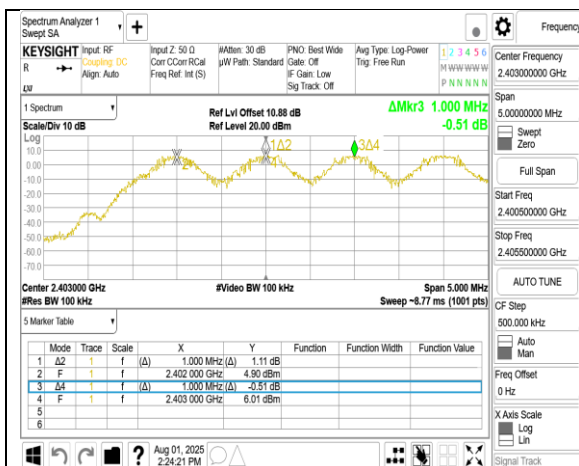
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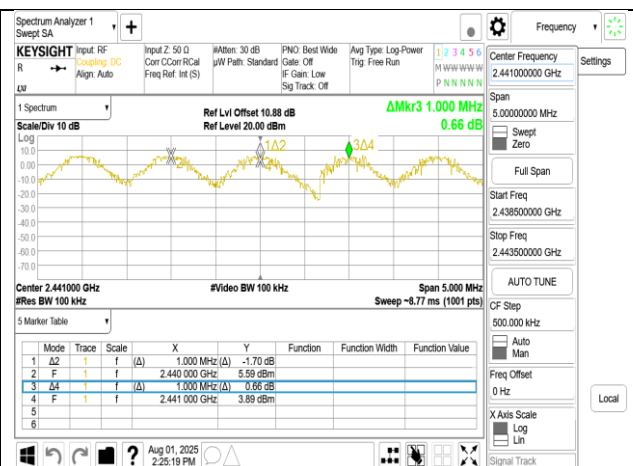
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7.2 Frequency Separation

Channel separation (MHz)	Limit	Result
1	≥ 25 kHz or 2/3 times 20dB bandwidth	PASS



GFSK 1M_DH5_CH0CH1CH2



GFSK 1M_DH5_CH38CH39CH40



GFSK 1M_DH5_CH76CH77CH78

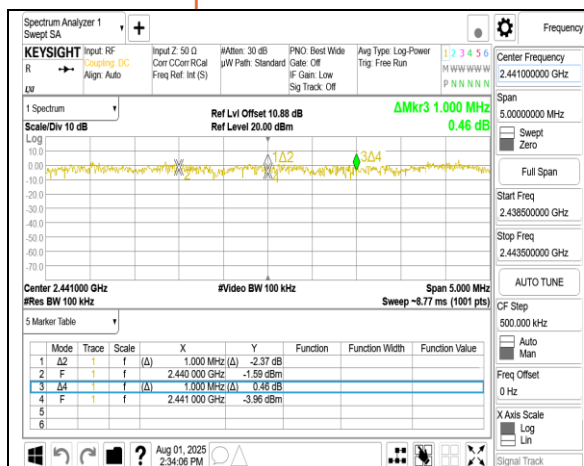


π/4DQPSK 2M_DH5_CH0CH1CH2

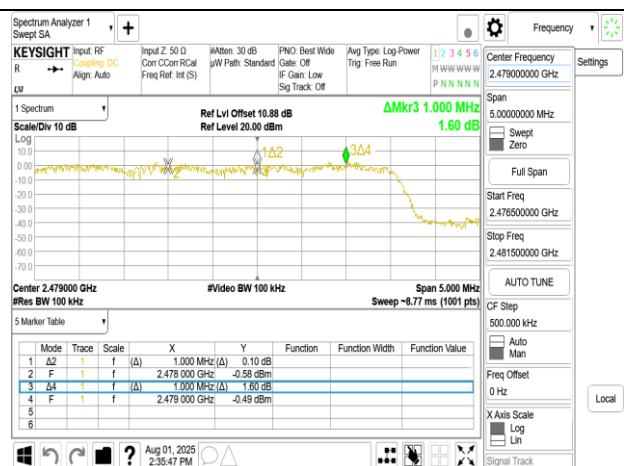
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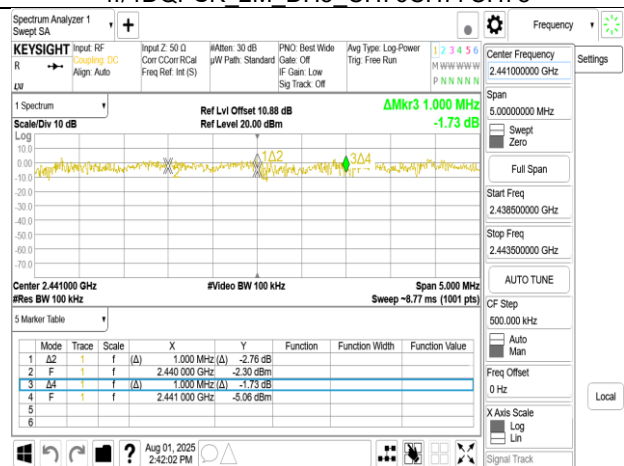
π/4DQPSK 2M DH5 CH38CH39CH40



π/4DQPSK 2M DH5 CH76CH77CH78



8DPSK 3M DH5 CH0CH1CH2



8DPSK 3M DH5 CH38CH39CH40



8DPSK 3M DH5 CH76CH77CH78

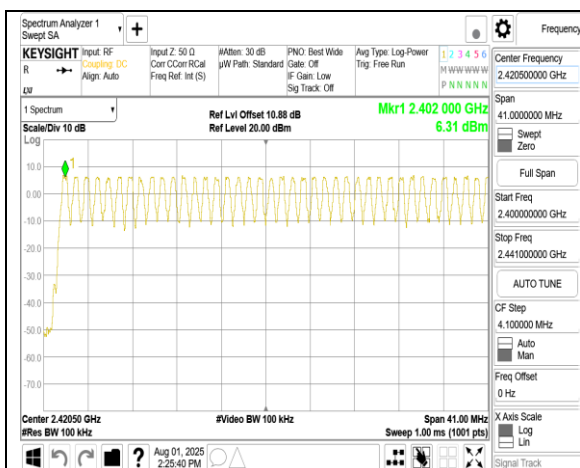
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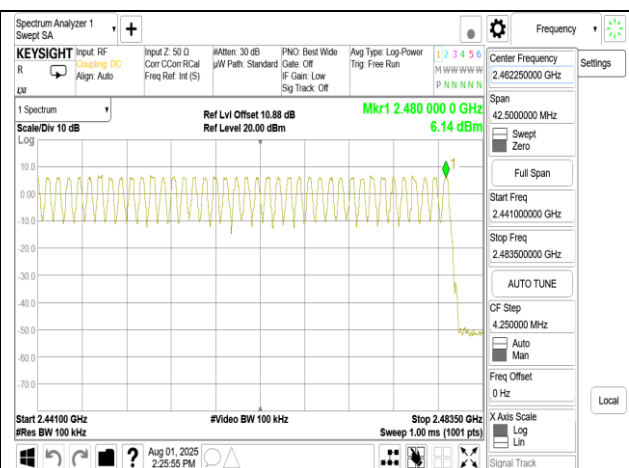
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7.3 Number Of Hopping Frequency Tabular Data of Total Channel Number

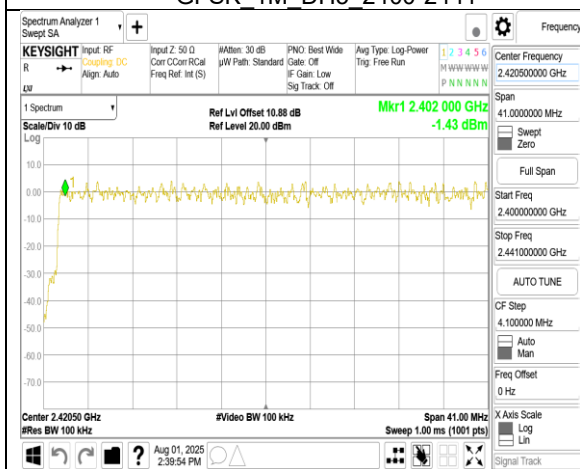
	Channel Number	Limit
2.4 GHz – 2.441 GHz	40	>15
2.441 GHz – 2.4835 GHz	39	
2.4 GHz ~2.4835 GHz	(40+39) = 79	



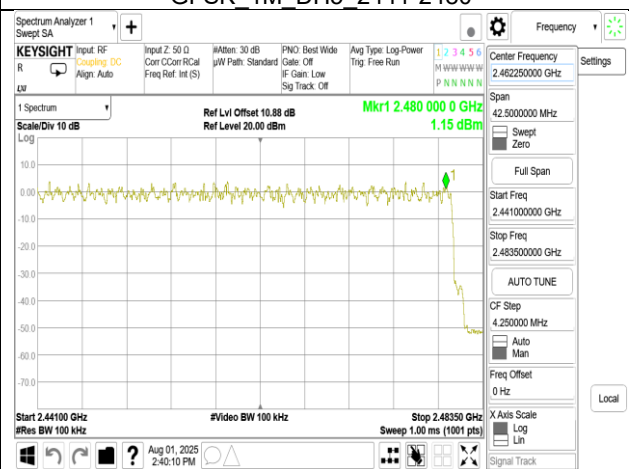
GFSK 1M DH5 2400-2441



GFSK 1M DH5 2441-2480



8DPSK 3M DH5 2400-2441



8DPSK 3M DH5 2441-2480

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7.4 Maximum Output Power

Mode	Duty Cycle (%) = Ton / (Ton+Toff)	Duty Factor (dB) =10*log (1/Duty Cycle)
DH5	77.20	1.12
2DH5	77.20	1.12
3DH5	77.20	1.12

1M BR mode (Peak):

CH	Freq. (MHz)	Power Setting	Peak Output Power (dBm)	Output Power (mW)	Limit (mW)
0	2402	13	7.25	5.309	866.96
39	2441	13	7.00	5.012	866.96
78	2480	13	6.94	4.943	866.96

1M BR mode (Average):

CH	Freq. (MHz)	Power Setting	Avg. Output Power (dBm)	Output Power (mW)	Limit (mW)
0	2402	13	7.24	5.301	866.96
39	2441	13	6.84	4.835	866.96
78	2480	13	6.81	4.802	866.96

2M EDR mode (Peak):

CH	Freq. (MHz)	Power Setting	Peak Output Power (dBm)	Output Power (mW)	Limit (mW)
0	2402	13	6.42	4.385	108.37
39	2441	13	6.26	4.227	108.37
78	2480	13	6.25	4.217	108.37

2M EDR mode (Average):

CH	Freq. (MHz)	Power Setting	Avg. Output Power (dBm)	Output Power (mW)	Limit (mW)
0	2402	13	4.12	2.585	108.37
39	2441	13	3.83	2.418	108.37
78	2480	13	3.86	2.434	108.37

3M EDR mode (Peak):

CH	Freq. (MHz)	Power Setting	Peak Output Power (dBm)	Output Power (mW)	Limit (mW)
0	2402	13	6.65	4.624	108.37
39	2441	13	6.51	4.477	108.37
78	2480	13	6.51	4.477	108.37

3M EDR mode (Average):

CH	Freq. (MHz)	Power Setting	Avg. Output Power (dBm)	Output Power (mW)	Limit (mW)
0	2402	13	4.29	2.688	108.37
39	2441	13	3.92	2.468	108.37
78	2480	13	3.81	2.406	108.37

*Note: Avg. output power has been calculated with duty factor.

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7.5 EIRP Measurement Result

1M BR mode EIRP

Channel	Frequency (MHz)	Power Setting	Avg. Output Power (dBm)	Antenna Gain (dBi)	EIRP (mW)	Limit (mW)
0	2402	13	7.24	6.62	24.343	3451.44
39	2441	13	6.84	6.62	22.202	3451.44
78	2480	13	6.81	6.62	22.049	3451.44

2M EDR mode EIRP

Channel	Frequency (MHz)	Power Setting	Avg. Output Power (dBm)	Antenna Gain (dBi)	EIRP (mW)	Limit (mW)
0	2402	13	4.12	6.62	11.868	3451.44
39	2441	13	3.83	6.62	11.102	3451.44
78	2480	13	3.86	6.62	11.178	3451.44

3M EDR mode EIRP

Channel	Frequency (MHz)	Power Setting	Avg. Output Power (dBm)	Antenna Gain (dBi)	EIRP (mW)	Limit (mW)
0	2402	13	4.29	6.62	12.342	3451.44
39	2441	13	3.92	6.62	11.334	3451.44
78	2480	13	3.81	6.62	11.051	3451.44

* **Note:** EIRP = Average Power + Gain

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7.6 Time Of Occupancy (Dwell Time)

GFSK (1Mbps)

Channel	PACKET TYPE	Measurement Result (ms)	Limit (ms)
39	DH1	124.80	400
	DH3	262.40	400
	DH5	308.80	400

$\pi/4$ DQPSK (2Mbps)

Channel	PACKET TYPE	Measurement Result (ms)	Limit (ms)
39	2DH1	124.80	400
	2DH3	262.40	400
	2DH5	308.80	400

8-DPSK (3Mbps)

Channel	PACKET TYPE	Measurement Result (ms)	Limit (ms)
39	3DH1	123.20	400
	3DH3	262.40	400
	3DH5	308.80	400

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GFSK (1Mbps):

CH Mid	DH1 time slot	=	0.390	*	(1600/2/79)	*	31.6	=	124.80 (ms)
	DH3 time slot	=	1.640	*	(1600/4/79)	*	31.6	=	262.40 (ms)
	DH5 time slot	=	2.895	*	(1600/6/79)	*	31.6	=	308.80 (ms)

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

CH Mid	2DH1 time slot	=	0.390	*	(1600/2/79)	*	31.6	=	124.80 (ms)
	2DH3 time slot	=	1.640	*	(1600/4/79)	*	31.6	=	262.40 (ms)
	2DH5 time slot	=	2.895	*	(1600/6/79)	*	31.6	=	308.80 (ms)

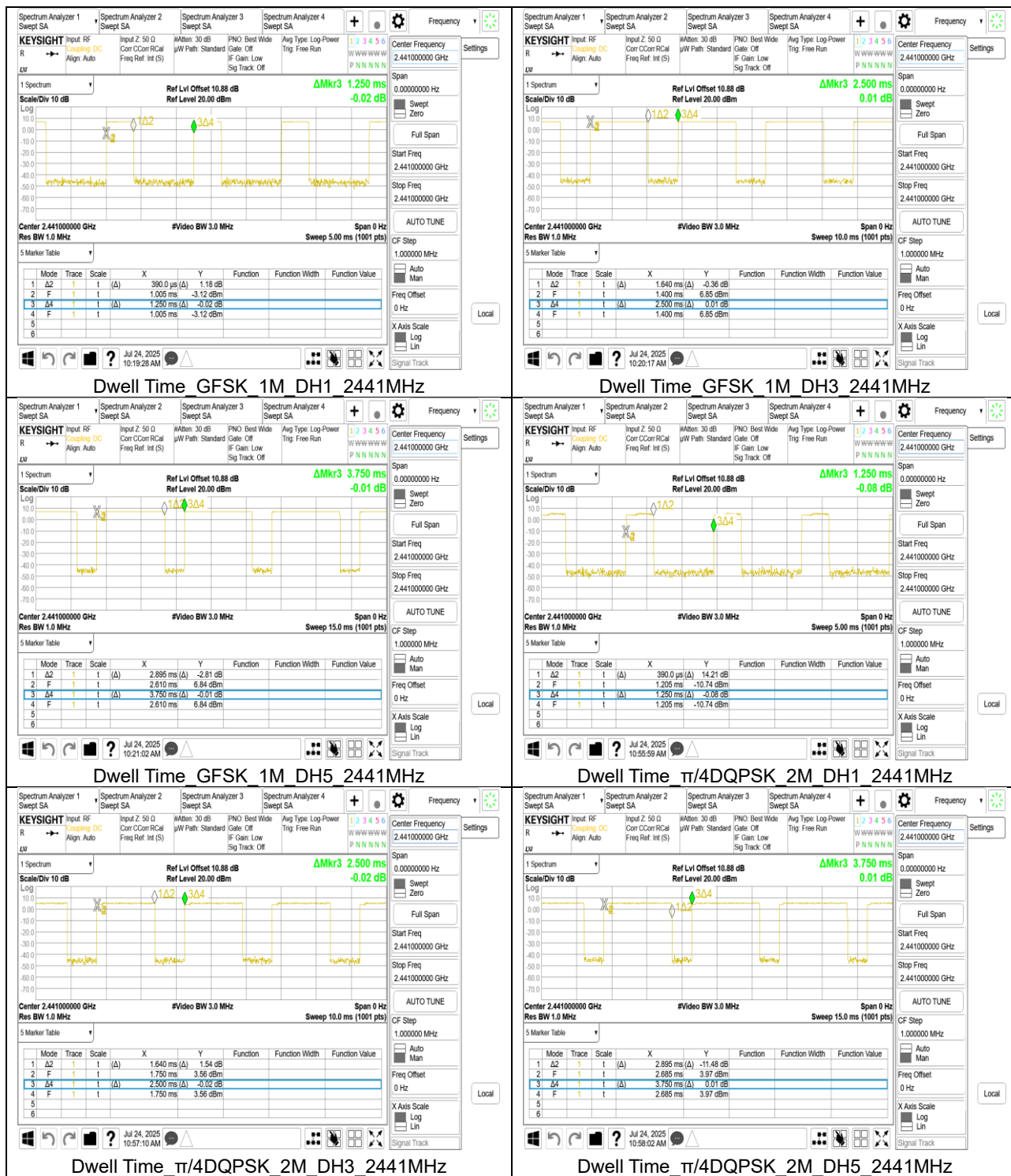
8-DPSK (3Mbps):

CH Mid	3DH1 time slot	=	0.385	*	(1600/2/79)	*	31.6	=	123.20 (ms)
	3DH3 time slot	=	1.640	*	(1600/4/79)	*	31.6	=	262.40 (ms)
	3DH5 time slot	=	2.895	*	(1600/6/79)	*	31.6	=	308.80 (ms)

A period time = 0.4 (s) * 79 = 31.6 (s)

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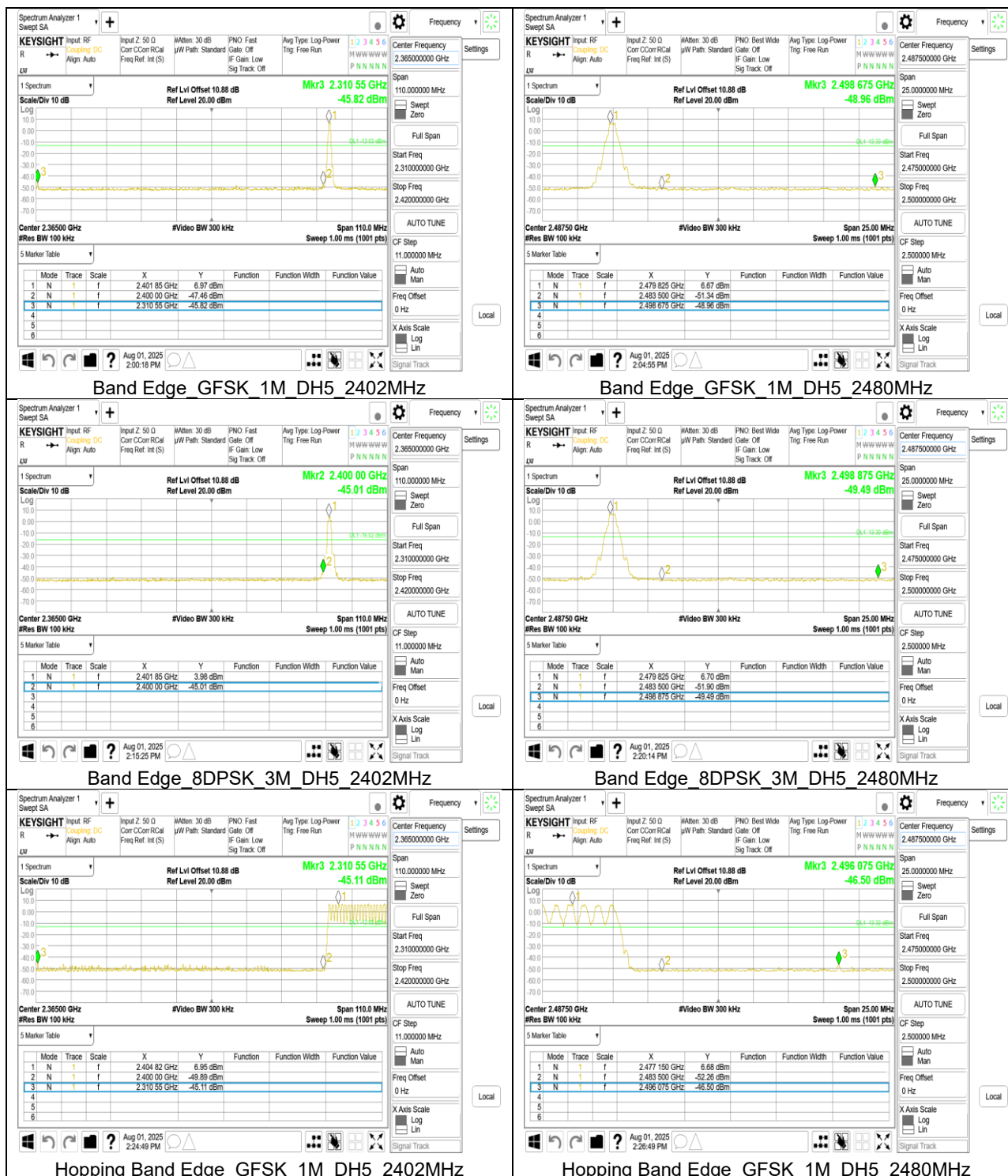
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7.7 Out Of Band Emission



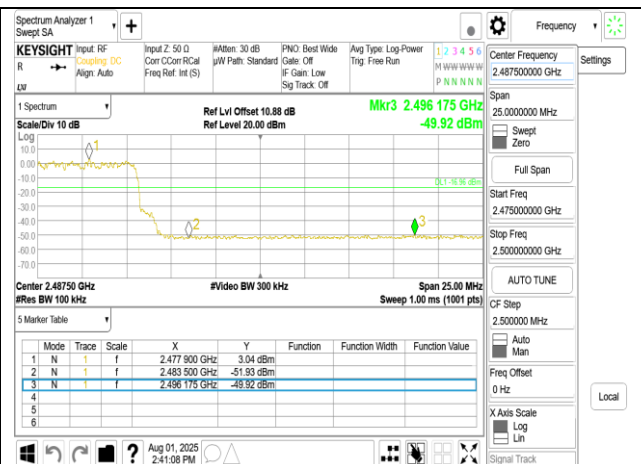
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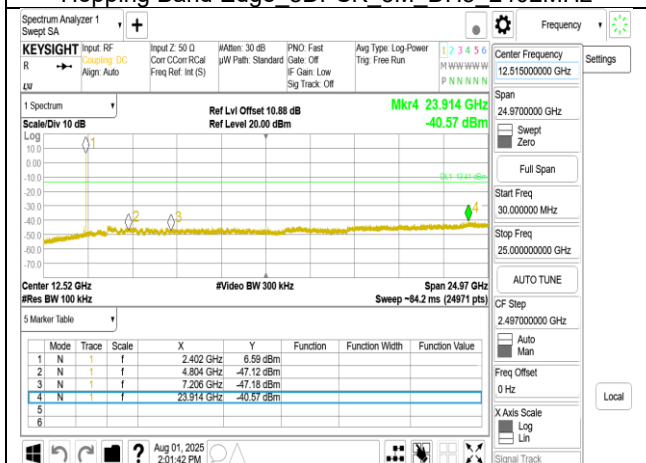
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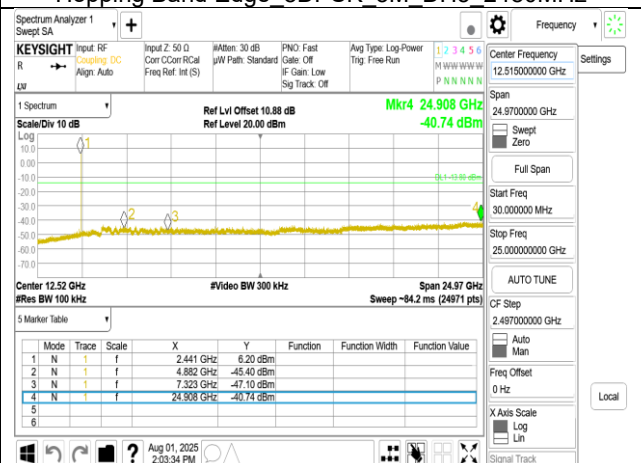
Hopping Band Edge 8DPSK 3M DH5 2402MHz



Hopping Band Edge 8DPSK 3M DH5 2480MHz



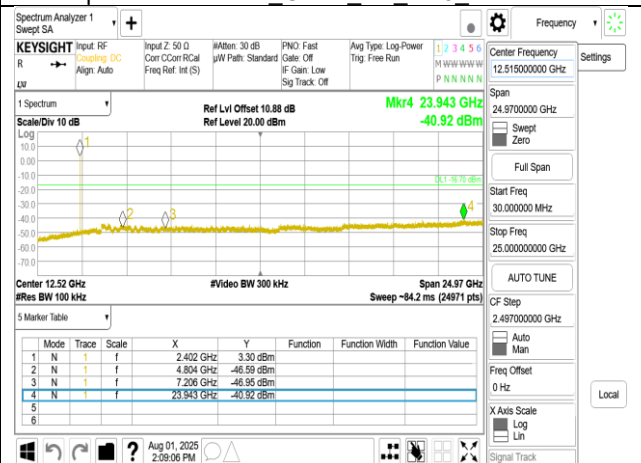
Spurious Emission GFSK 1M DH5 2402MHz



Spurious Emission GFSK 1M DH5 2441MHz



Spurious Emission GFSK 1M DH5 2480MHz

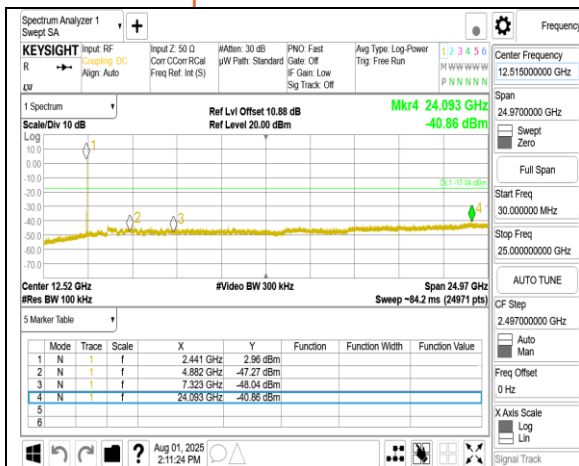


Spurious Emission π/4DQPSK 2M DH5 2402MHz

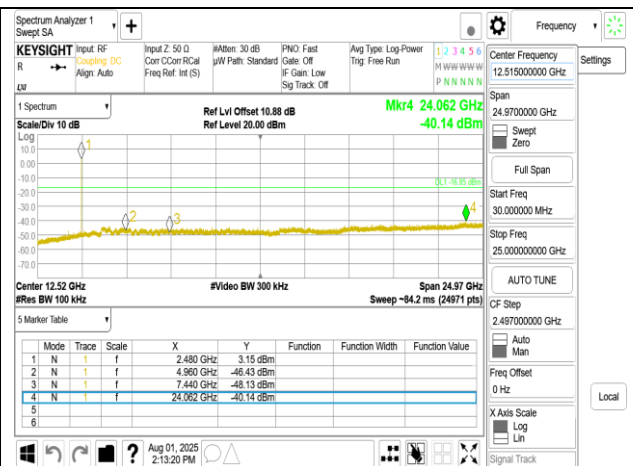
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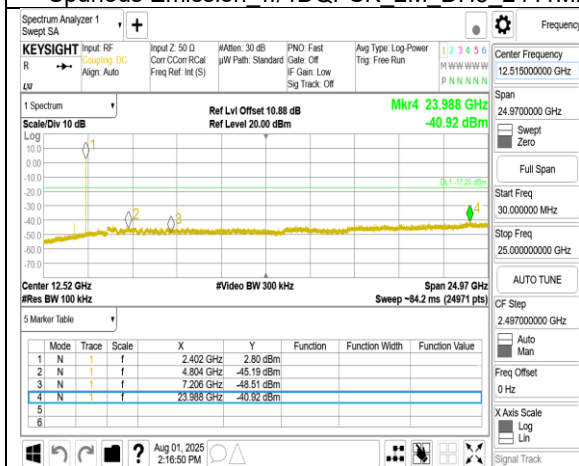
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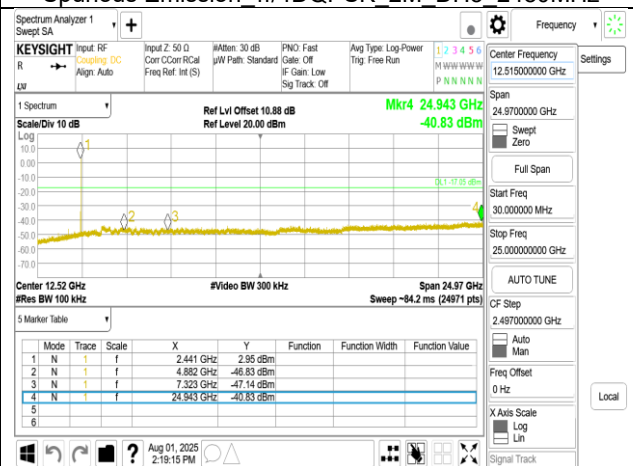
Spurious Emission $\pi/4$ DQPSK 2M DH5 2441MHz



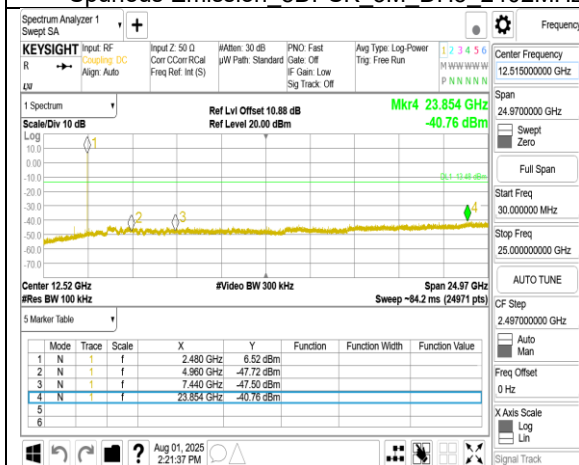
Spurious Emission $\pi/4$ DQPSK 2M DH5 2480MHz



Spurious Emission 8DPSK 3M DH5 2402MHz



Spurious Emission 8DPSK 3M DH5 2441MHz



Spurious Emission 8DPSK 3M DH5 2480MHz

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