TEST REPORT

Report Number: 14040866-E1V2

Applicant : APPLE, INC.
1 APPLE PARK WAY
CUPERTINO, CA 95014, USA

Model : A2651 (Parent Model, Full Test)
A2893, A2894, A2895, A2896 (Variant Models)

FCC ID : BCG-E8141A (Parent Model)
BCG-E8154A, BCG-E8155A, BCG-E8156A
(Variant Models)

IC : 579C-E8141A (Parent Model)
579C-E8154A, 579C-E8155A, 579C-E8156A
(Variant Models)

EUT Description : SMARTPHONE

Test Standard(s) : FCC 47 CFR PART 15 SUBPART C
ISED RSS-247 ISSUE 2
ISED RSS-GEN ISSUE 5 + A1 + A2

Date Of Issue:
July 29, 2022

Prepared by:
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ilac-MRA

ACCREDITED
CERT #0751.05

REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	7/15/2022	Initial Issue	Chin Pang
V2	7/29/2022	Addressed TCB Feedback on Section 7	Tony X. Li

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1. ATTESTATION OF TEST RESULTS

COMPANY NAME: APPLE INC.
1 APPLE PARK WAY
CUPERTINO, CA 95014, U.S.A

EUT DESCRIPTION: Smartphone

MODEL: A2651 (Parent Model)
A2893, A2894, A2895, A2896 (Variant Models)

BRAND: APPLE

FCC ID: BCG-E8141A (Parent Model)
BCG-E8154A, BCG-E8155A, BCG-E8156A (Variant Models)

IC: 579C-E8141A (Parent Model)
579C-E8154A, 579C-E8155A, 579C-E8156A (Variant Models)

SERIAL NUMBER: JHXP7PXL52 (Radiated), RXPYHWRP4V (Conducted)

SAMPLE RECEIPT DATE: MARCH 28, 2022

DATE TESTED: APRIL 06 – JULY 29, 2022

APPLICABLE STANDARDS	
STANDARD	**TEST RESULTS**
CFR 47 Part 15 Subpart C	Complies
ISED RSS-247 Issue 2	Complies
ISED RSS-GEN Issue 5 + A1 + A2	Complies

UL LLC tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

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2. TEST SUMMARY

This report contains data provided by the customer which can impact the validity of results. UL LLC is only responsible for the validity of results after the integration of the data provided by the customer.

FCC Clause	ISED Clause	Requirement	Result	Comment
See Comment		Duty Cycle	Reporting purposes only	Per ANSI C63.10, Section 11.6.
See Comment	RSS-GEN 6.7	20dB BW/99% OBW	Reporting purposes only	ANSI C63.10 Sections 6.9.2 and 6.9.3
15.247 (a)(1)	RSS-247 (5.1) (b)	Hopping Frequency Separation	Complies	None.
15.247 (a)(1)(iii)	RSS-247 (5.1) (d)	Number of Hopping Channels	Complies	None.
15.247 (a)(1)(iii)	RSS-247 (5.1) (d)	Average Time of Occupancy	Complies	None.
15.247 (b)(1)	RSS-247 (5.4) (b)	Output Power	Complies	None.
See Comment		Average Power	Reporting purposes only	Per ANSI C63.10, Section 11.9.2.3.2.
15.247 (d)	RSS-247 (5.5)	Conducted Spurious Emissions	Complies	None.
15.209, 15.205	RSS-GEN 8.9, 8.10	Radiated Emissions	Complies	None.
15.207	RSS-Gen 8.8	AC Mains Conducted Emissions	Complies	None.

3. TEST METHODOLOGY

The tests documented in this report were performed in accordance with FCC CFR 47 Part 2, FCC CFR 47 Part 15, ANSI C63.10-2013, KDB 558074 D01 15.247 Meas Guidance v05r02, KDB 414788 D01 Radiated Test Site v01r01, KDB 662911, RSS-GEN Issue 5 + A1 + A2, and RSS-247 Issue 2.

4. FACILITIES AND ACCREDITATION

UL LLC is accredited by A2LA, certification #0751.05, for all testing performed within the scope of this report. Testing was performed at the locations noted below.

Location	Address	ISED CABID	ISED Company Number	FCC Registration
☐	Building 1: 47173 Benicia Street, Fremont, CA 94538, USA	US0104	2324A	550739
☒	Building 2: 47266 Benicia Street, Fremont, CA 94538, USA	US0104	22541	550739
☒	Building 4: 47658 Kato Rd, Fremont, CA 94538, USA	US0104	2324B	550739

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5. DECISION RULES AND MEASUREMENT UNCERTAINTY

5.1. METROLOGICAL TRACEABILITY

All test and measuring equipment utilized to perform the tests documented in this report are calibrated on a regular basis, with a maximum time between calibrations of one year or the manufacturers' recommendation, whichever is less, and where applicable is traceable to recognized national standards.

5.2. DECISION RULES

The Decision Rule is based on Simple Acceptance in accordance with ISO Guide 98-4:2012 Clause 8.2. (Measurement uncertainty is not taken into account when stating conformity with a specified requirement.)

5.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

Uncertainty figures are valid to a confidence level of 95%.

PARAMETER	U_{Lab}
Worst Case Conducted Disturbance, 9KHz to 0.15 MHz	3.78 dB
Worst Case Conducted Disturbance, 0.15 to 30 MHz	3.40 dB
Worst Case Radiated Disturbance, 9KHz to 30 MHz	2.87 dB
Worst Case Radiated Disturbance, 30 to 1000 MHz	6.01 dB
Worst Case Radiated Disturbance, 1000 to 18000 MHz	4.73 dB
Worst Case Radiated Disturbance, 18000 to 26000 MHz	4.51 dB
Worst Case Radiated Disturbance, 26000 to 40000 MHz	5.29 dB

Uncertainty figures are valid to a confidence level of 95%.

5.4. SAMPLE CALCULATION

RADIATED EMISSIONS

Where relevant, the following sample calculation is provided:
Field Strength (dBuV/m) = Measured Voltage (dBuV) + Antenna Factor (dB/m) + Cable Loss (dB) – Preamp Gain (dB)
36.5 dBuV + 18.7 dB/m + 0.6 dB – 26.9 dB = 28.9 dBuV/m

MAINS CONDUCTED EMISSIONS

Where relevant, the following sample calculation is provided:
Final Voltage (dBuV) = Measured Voltage (dBuV) + Cable Loss (dB) + Limiter Factor (dB) + LISN Insertion Loss.
36.5 dBuV + 0 dB +10.1 dB+ 0 dB = 46.6 dBuV

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6. EQUIPMENT UNDER TEST

6.1. EUT DESCRIPTION

The Apple iPhone is a smartphone with multimedia functions (music, application support, and video), cellular GSM, GPRS, EGPRS, UMTS, LTE, 5G, IEEE 802.11a/b/g/n/ac/ax, Bluetooth, Ultra-Wideband, GPS, NFC and MSS. All models except reference model support at least one UICC based SIM. The second SIM is either an UICC based p-SIM (physical SIM) or e-SIM (electronic SIM). The device supports a built-in inductive charging transmitter and receiver. The rechargeable battery is not user accessible.

Testing was performed on the parent model and is used to support the application for the parent and variants identified in this report based on the test plan submitted and approved via KDB inquiry by the FCC and by ISED-Canada.

The Model and FCC/IC ID covered by this report includes:

Parent Model: A2651, FCC ID: BCG-E8141A, IC: 579C-E8141A

Variant Models: A2893, FCC ID: BCG-E8154A, IC: 579C-E8154A
A2894; FCC ID: BCG-E8155A, IC: 579C-E8155A
A2895 & A2896; FCC ID: BCG-E8156A, IC: 579C-E8156A

6.2. MAXIMUM OUTPUT POWER

The transmitter has a maximum peak conducted output power as follows:

Antenna	Config	Frequency Range (MHz)	Mode	Output Power (dBm)	Output Power (mW)
ANT 4	High Power	2402 - 2480	Basic GFSK	20.07	101.62
		2402 - 2480	DQPSK	19.25	84.14
		2402 - 2480	Enhanced 8PSK	19.49	88.92
	Low Power	2402 - 2480	Basic GFSK	11.01	12.62
		2402 - 2480	DQPSK	11.25	13.34
		2402 - 2480	Enhanced 8PSK	11.47	14.03
ANT 3	High Power	2402 - 2480	Basic GFSK	20.09	102.09
		2402 - 2480	DQPSK	19.24	83.95
		2402 - 2480	Enhanced 8PSK	19.51	89.33
	Low Power	2402 - 2480	Basic GFSK	11.02	12.65
		2402 - 2480	DQPSK	11.23	13.27
		2402 - 2480	Enhanced 8PSK	11.53	14.22
Beamforming, ANT 4 + ANT 3	High Power	2402 - 2480	Basic GFSK TxBF	20.10	102.33
		2402 - 2480	DQPSK TxBF	19.25	84.14
		2402 - 2480	Enhanced 8PSK TxBF	19.48	88.72
	Low Power	2402 - 2480	Basic GFSK TxBF	14.02	25.23
		2402 - 2480	DQPSK TxBF	14.30	26.92
		2402 - 2480	Enhanced 8PSK TxBF	14.49	28.12

Note: GFSK, DQPSK, 8PSK Average Power are all investigated. GFSK & 8PSK Powers are the worst case. Testing is based on these modes to show compliance. For Average Power data, please refer to Section 9.7.

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6.3. DESCRIPTION OF AVAILABLE ANTENNAS

The antenna(s) gain, as provided by the manufacturer' are as follow:

Frequency Range (GHz)	ANT 4 (dBi)	ANT 3 (dBi)
2.4	-1.0	-1.1

6.4. SOFTWARE AND FIRMWARE

The EUT firmware version installed for testing is 20.1.467.5699.

6.5. WORST-CASE CONFIGURATION AND MODE

The EUT was investigated in three orthogonal orientations X, Y and Z on ANT 4, ANT 3 and 2TX beamforming. It was determined that Y (Landscape) was the worst-case orientation for ANT 4 and X (Flatbed) was the worst-case orientation for ANT 3 and 2TX Beamforming.

Radiated band edge, harmonic, and spurious emissions from 1GHz to 18GHz were performed. The EUT was set to transmit at highest power on Low/Middle/High channels.

Radiated emissions below 30MHz, below 1GHz, 18-26GHz and power line conducted emissions were performed with the EUT transmitting at the channel with the highest output power as worst-case scenario. There were no emissions found below 30MHz within 20dB of the limit

For below 1GHz tests, the EUT was connected to AC power adapter as the worst case; and for above 1GHz, the worst-case configuration reported was tested with EUT only. For AC line conducted emission, test was investigated with AC power adapter and with laptop.

For simultaneous transmission of multiple channels in the 2.4GHz BT and 5GHz bands, no noticeable emission was found.

For radiated harmonic spurious emissions test, beamforming GFSK and 8PSK modes were set to maximum power per chain based on SISO power to cover both non-BF and BF modes to complies with radiated spurious emissions limits in the restricted bands between 1GHz and 18GHz low/mid/high channel.

GFSK, DQPSK, 8PSK average power are all investigated. The GFSK & 8PSK power are the worst case. For average power data please refer to section 9.7.

Worst-case data rates as provided by the client were:

GFSK Mode: DH5
8PSK Mode: 3-DH5
Beamforming Mode: GFSK(DH5), 8PSK (3-DH5)

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There are three vendors of the Wi-Fi/Bluetooth radio modules: variant 1, 2 and 3. The WiFi/BT radio modules have the same mechanical outline (e.g., the same package dimension and pin-out layout), use the same on-board antenna matching circuit, have an identical antenna structure, and are built and tested to conform to the same specifications and to operate within the same tolerances.

Baseline testing was performed on the three variants to determine the worst case on all conducted power and radiated emissions.

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6.6. DESCRIPTION OF TEST SETUP

SUPPORT TEST EQUIPMENT						
Description		**Manufacturer**	**Model**	**Serial Number**		**FCC ID/ DoC**
Laptop		Apple	MacBook Pro	C02VD7SAHV22		BCGA1708
Laptop AC/DC adapter		Liteon Technology	A1424	NSW25679		DoC
EUT AC/DC adapter		Apple	A1720	C3D8417A7R93KVPA8		DoC
I/O CABLES (RF CONDUCTED TEST)						
Cable No.	**Port**	**# of Identical Ports**	**Connector Type**	**Cable Type**	**Cable Length (m)**	**Remarks**
1	Antenna	1	SMA	Un-shielded	0.2	To spectrum Analyzer
2	USB	1	USB	Shielded	1.0	N/A
3	AC	1	AC	Un-shielded	2	N/A
I/O CABLES (RF RADIATED AND AC LINE AC TEST)						
Cable No.	**Port**	**# of Identical Ports**	**Connector Type**	**Cable Type**	**Cable Length (m)**	**Remarks**
1	AC	1	AC	Un-shielded	2	N/A
2	USB	1	USB	shielded	1	N/A

TEST SETUP

The EUT setup is shown as below. Test software exercised the radio card.

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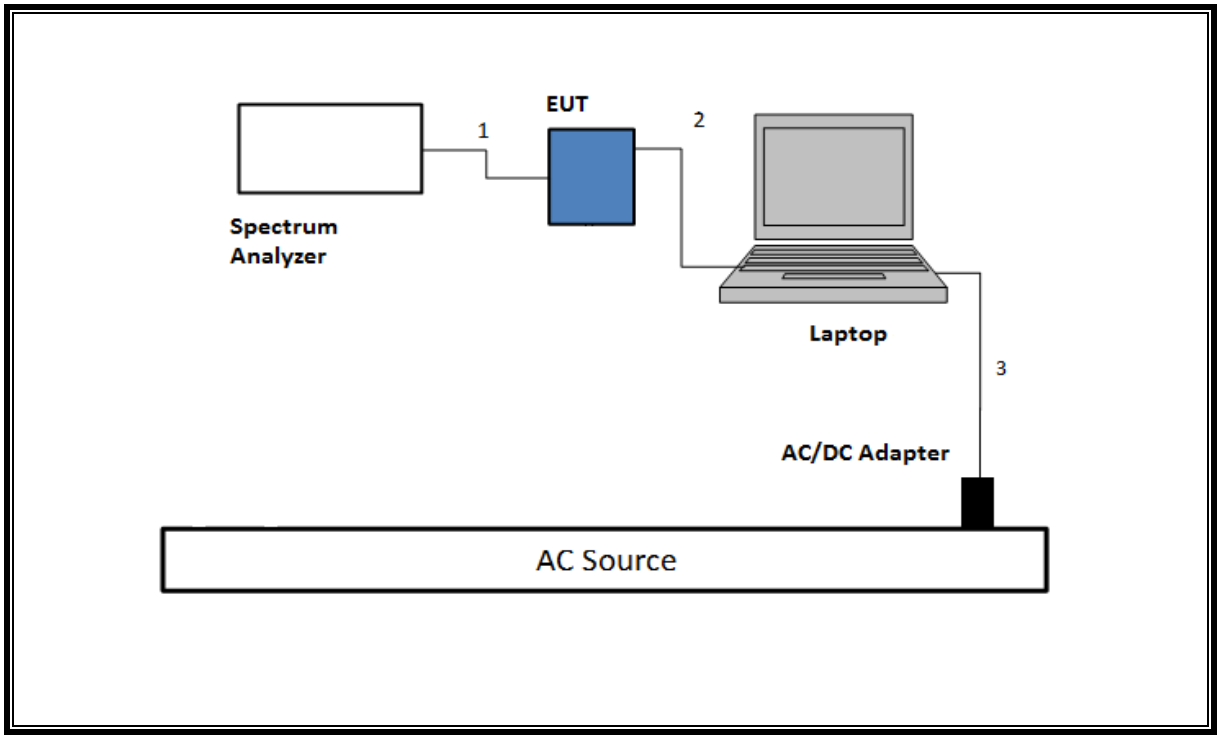
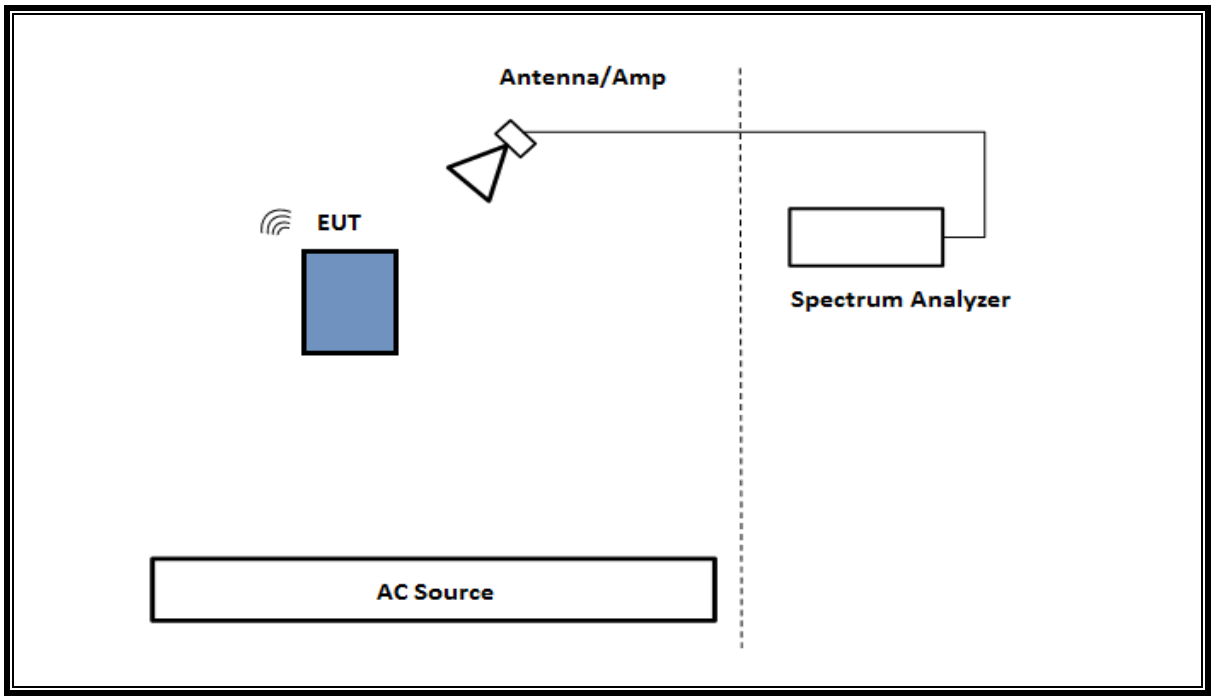
SETUP DIAGRAM FOR CONDUCTED TESTS



SETUP DIAGRAM FOR RADIATED TESTS Above 1 GHz



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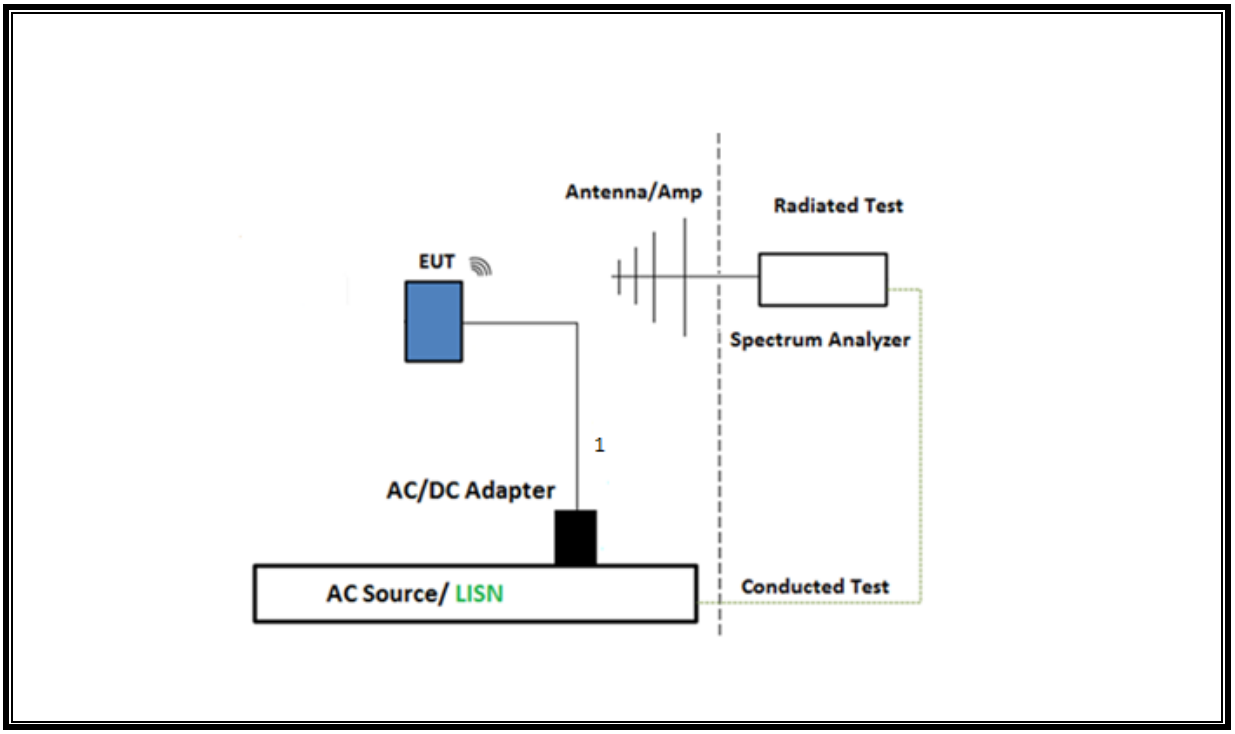
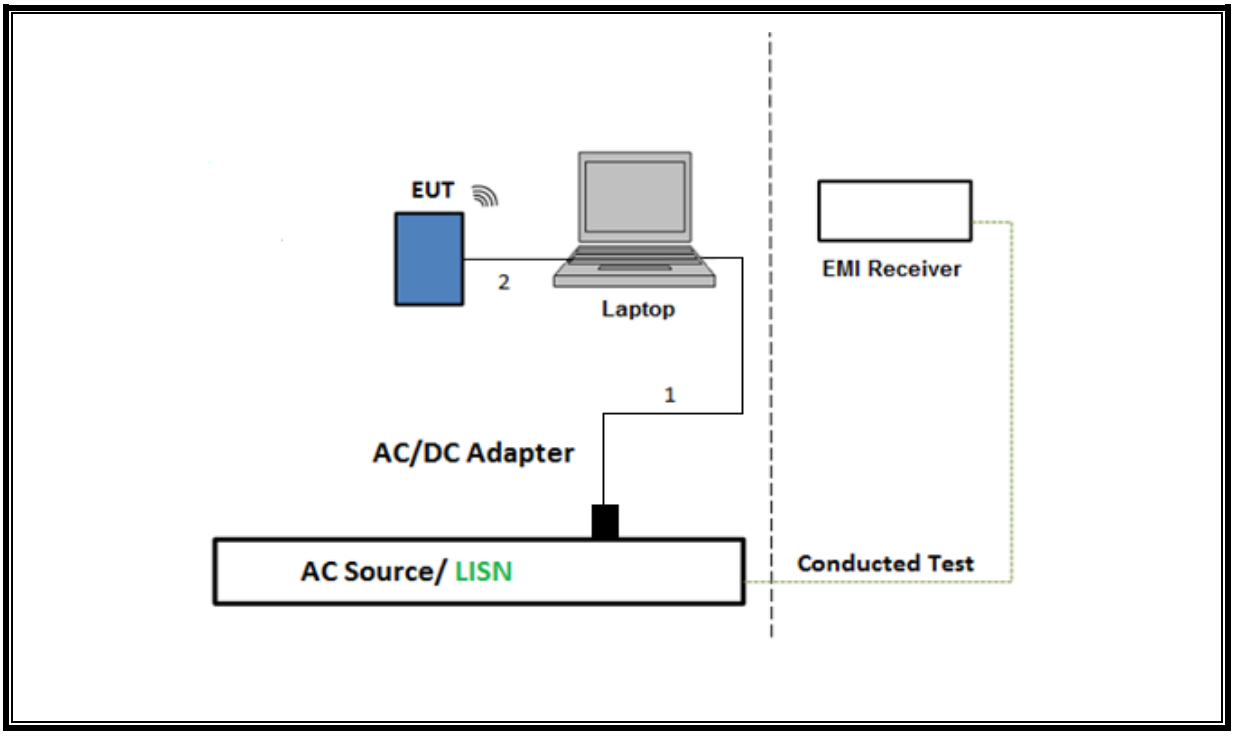
SETUP DIAGRAM FOR BELOW 1GHz and AC LINE CONDUCTED TEST



TEST SETUP- AC LINE CONDUCTED: LAPTOP CONFIGURATION



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7. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

Description	Manufacturer	Model	ID Num	Cal Due	Last Cal
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	200786	2/24/2023	2/24/2022
RF Filter Box, 1-18GHz	UL-FR1 (CTECH)	N/A	PRE0183530	11/17/2022	11/17/2021
EMI TEST RECEIVER	Rohde & Schwarz	ESW44	191428	2/20/2023	2/20/2022
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	200897	2/24/2023	2/24/2022
*RF Filter Box	UL-FR1 (CTECH)	N/A	PRE0182865	4/13/2023	4/13/2022
Spectrum Analyzer, PXA, 3Hz to 44GHz	Keysight Technologies Inc	N9030A	125188	1/30/2023	1/30/2022
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	81887	3/16/2023	3/16/2022
Rf Filter Box	UL-FR1 (CTECH)	N/A	PRE0183207	10/23/2022	10/23/2021
EMI TEST RECEIVER	Rohde & Schwarz	ESW44	191429	2/20/2023	2/20/2022
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	200895	10/13/2022	10/13/2021
RF Filter Box, 6 port, 1-18GHz	UL-FR1 (CTECH)	SAC 6 port rf box	203957	2/12/2023	2/12/2022
EMI TEST RECEIVER	Rohde & Schwarz	ESW44	201498	2/20/2023	2/20/2022
Antenna, Broadband Hybrid, 30MHz to 2000MHz	Sunol Sciences Corp.	JB1	82258	10/01/2022	10/01/2021
Amplifier, 9KHz to 1GHz, 32dB	SONOMA INSTRUMENT	310	175953	2/08/2023	2/08/2022
EMI TEST RECEIVER	Rohde & Schwarz	ESW44	169927	2/16/2023	2/16/2022
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent	N9030A	87738	02/02/2023	02/02/2022
Antenna. Horn 18 to 26.5GHz	A.R.A.	MWH-1826/B	172363	12/07/2022	12/07/2021
Amplifier 18-26.5GHz,+5Vdc,-54dBmP1dB	AMPLICAL	AMP18G26.5-60	172583	1/27/2023	1/27/2022
Power sensor	Keysight	N1921A	90389	02/03/2023	02/03/2022
Power Meter, P-series single channel	Keysight	N1911A	PRE0177682	01/24/2023	01/24/2022
Antenna, Passive Loop 30Hz to 1MHz	Electro-Metrics	EM-6871	170013	07/29/2022	07/29/2021
Antenna, Passive Loop 100KHz to 30MHz	ETS-Lindgren	EM-6872	170015	07/29/2022	07/29/2021
AC Line Conducted					
Description	**Manufacturer**	**Model**	**ID Num**	**Cal Due**	**Last Cal**
EMI Test Receiver 9kHz-7GHz	Rohde & Schwarz	ESR	T1436	02/21/2023	02/21/2022
Power Cable, Line Conducted Emissions	UL	PR1	T861	10/27/2022	10/27/2021
LISN for Conducted Emissions CISPR-16	FISCHER CUSTOM COMMUNICATIONS	FCC-LISN-50/250-25-2-01-480V	175765	01/26/2023	01/26/2022
UL AUTOMATION SOFTWARE					
Radiated Software	UL	UL EMC	Ver 9.5, Mar 6, 2020		
Conducted Software	UL	UL EMC	2020.2.26		
AC Line Conducted Software	UL	UL EMC	Ver 9.5, February 21, 2020		

*Equipment was set to test after calibration was done

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8. MEASUREMENT METHODS

Test Item	Test Method
On Time and Duty Cycle	• ANSI C63.10-2013 Section 11.6
Occupied BW (20dB)	• ANSI C63.10-2013 Section 6.9.2
Occupied BW (99%)	• ANSI C63.10-2013 Section 6.9.3
Carrier Frequency Separation	• ANSI C63.10-2013 Section 7.8.2
Number of Hopping Frequencies	• ANSI C63.10-2013 Section 7.8.3
Time of Occupancy (Dwell Time)	• ANSI C63.10-2013 Section 7.8.4
Peak Output Power	• ANSI C63.10-2013 Section 7.8.5
Conducted Spurious Emissions	• ANSI C63.10-2013 Section 7.8.8
Conducted Band-Edge	• ANSI C63.10-2013 Section 6.10.4
Radiated Spurious Emissions Below 30MHz	• ANSI C63.10-2013 Section 6.4 & 13
Radiated Spurious Emissions 30-1000MHz	• ANSI C63.10-2013 Section 6.3, 6.5 & 13
Radiated Spurious Emissions Above 1GHz	• ANSI C63.10-2013 Section 6.3, 6.6 & 13
Radiated Band-Edge	• ANSI C63.10-2013 Section 6.10.5 & 13
AC Power-Line Conducted Emissions	• ANSI C63.10-2013, Section 6.2

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9. ANTENNA PORT TEST RESULTS

9.1. ON TIME AND DUTY CYCLE

LIMITS

None; for reporting purposes only.

PROCEDURE

ANSI C63.10, Section 11.6: Zero-Span Spectrum Analyzer Method.

ON TIME AND DUTY CYCLE RESULTS

Mode	ON Time B (msec)	Period (msec)	Duty Cycle x (linear)	Duty Cycle (%)	Duty Cycle Correction Factor (dB)	1/T Minimum VBW (kHz)
Bluetooth GFSK	1.00	1.00	1.000	100.0%	0.00	0.010
Bluetooth 8PSK	1.00	1.00	1.000	100.0%	0.00	0.010
Bluetooth GFSK TxBF	1.00	1.00	1.000	100.0%	0.00	0.010
Bluetooth 8PSK TxBF	1.00	1.00	1.000	100.0%	0.00	0.010

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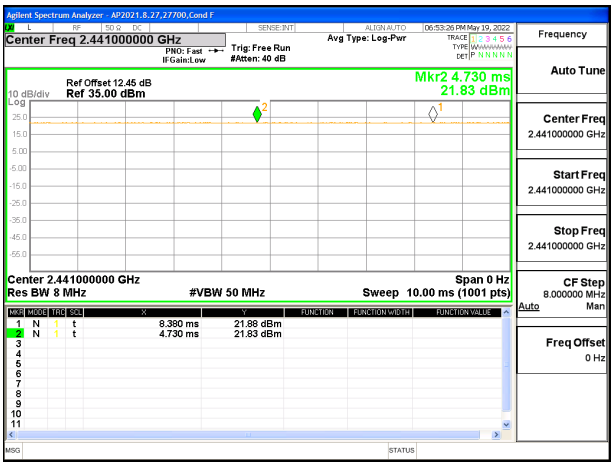
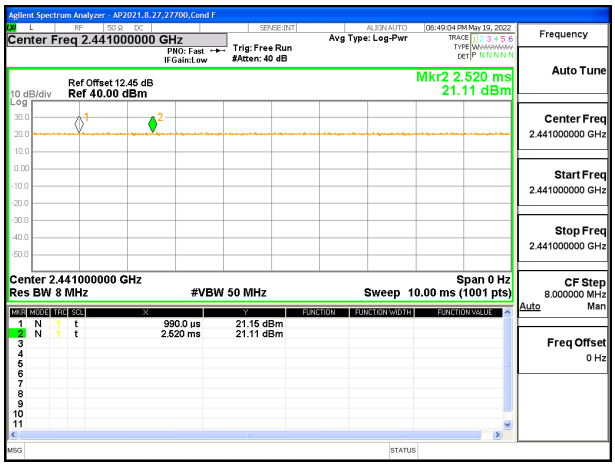
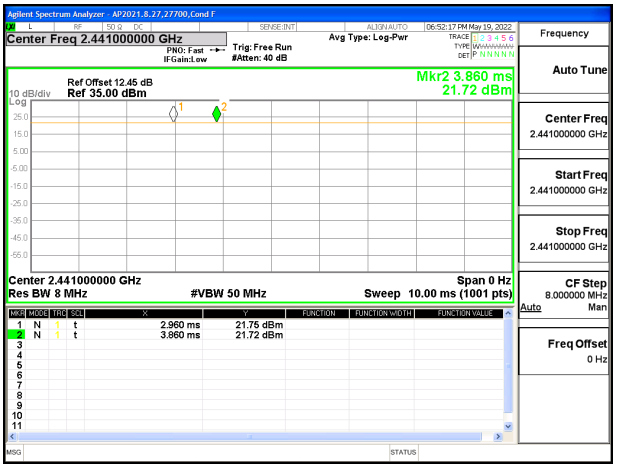
DUTY CYCLE PLOTS



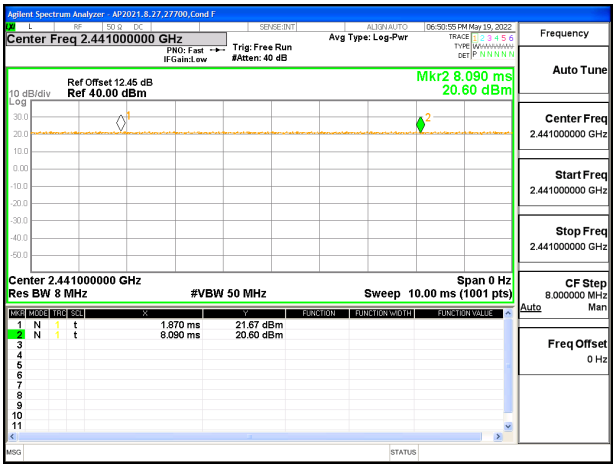
BLUETOOTH GFSK



BLUETOOTH 8PSK



BLUETOOTH TxBF GFSK



BLUETOOTH TxBF 8PSK

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9.2. 20 dB AND 99% BANDWIDTH

LIMITS

None; for reporting purposes only.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to ≥ 1% of the 20 dB bandwidth. The VBW is set to ≥ 3xRBW. The sweep time is coupled.

RESULTS

Only High Power modes result is reported, it covers all Low Power modes. Only Mid channel plot is reported to show setting parameter complies with testing method/procedure.

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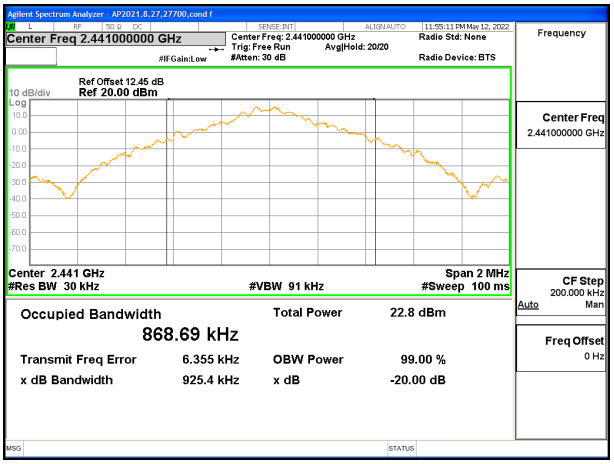
9.2.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4

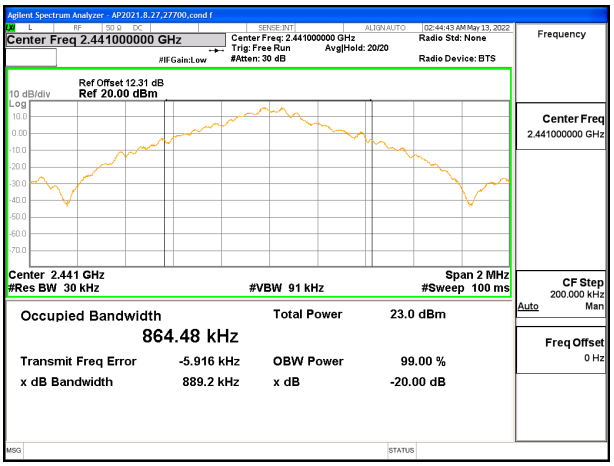
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	.8840	.86484
Mid	2441	.9254	.86869
High	2480	.8891	.86574



MID CHANNEL

ANT 3

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	.9230	.86602
Mid	2441	.8892	.86448
High	2480	.8872	.86572



MID CHANNEL

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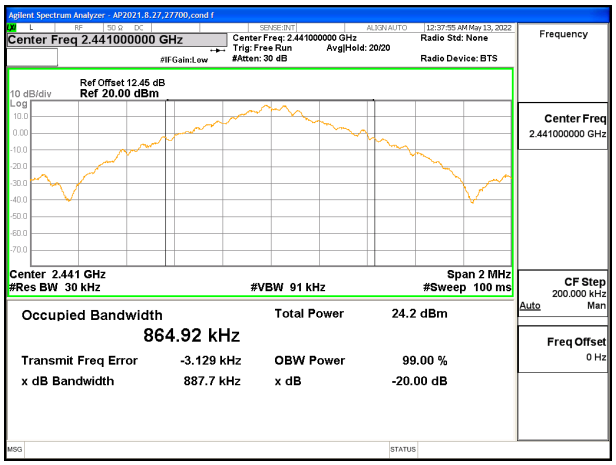
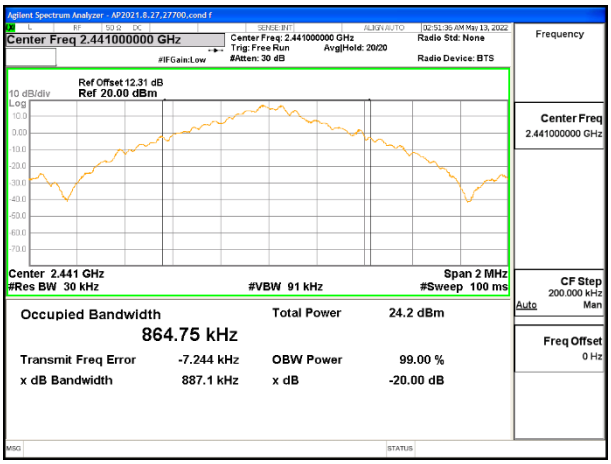
9.2.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

Note: Test procedure on beamforming mode is the same as BT basic and EDR mode

Channel	Frequency (MHz)	20dB Bandwidth ANT 4 (MHz)	20dB Bandwidth ANT 3 (MHz)	99% Bandwidth ANT 4 (MHz)	99% Bandwidth ANT 3 (MHz)
Low	2402	.9245	.8890	.87143	.86549
Mid	2441	.8877	.8871	.86492	.86475
High	2480	.8876	.8879	.86391	.86565



MID CHANNEL ANT 4



MID CHANNEL ANT 3

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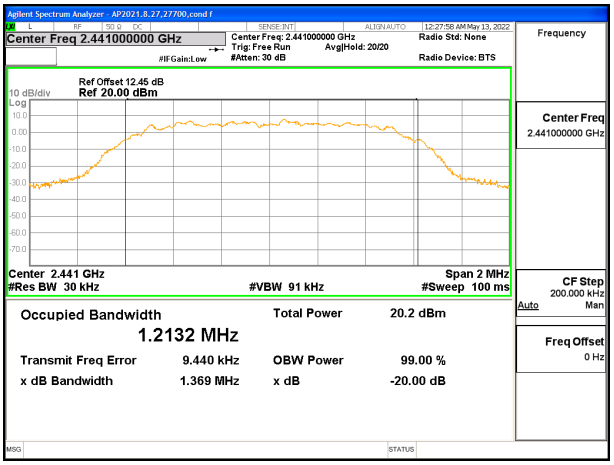
9.2.3. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

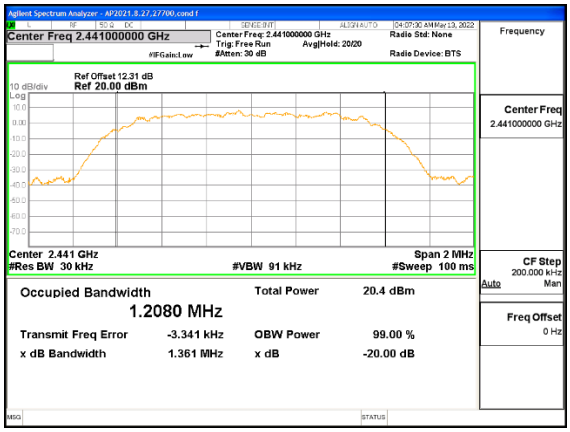
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.369	1.2149
Mid	2441	1.369	1.2132
High	2480	1.371	1.2170



MID CHANNEL

ANT 3

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.367	1.2091
Mid	2441	1.361	1.2080
High	2480	1.368	1.2136



MID CHANNEL

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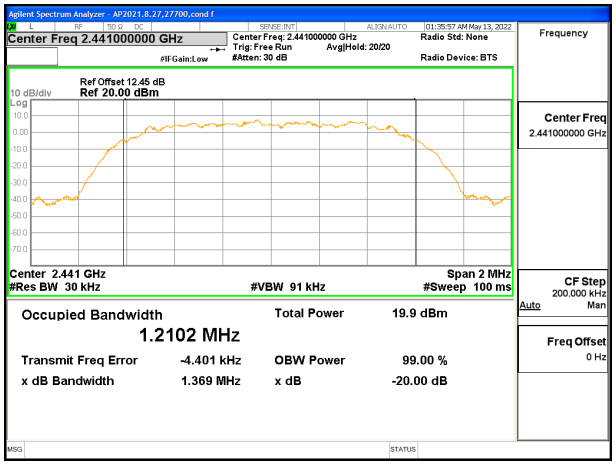
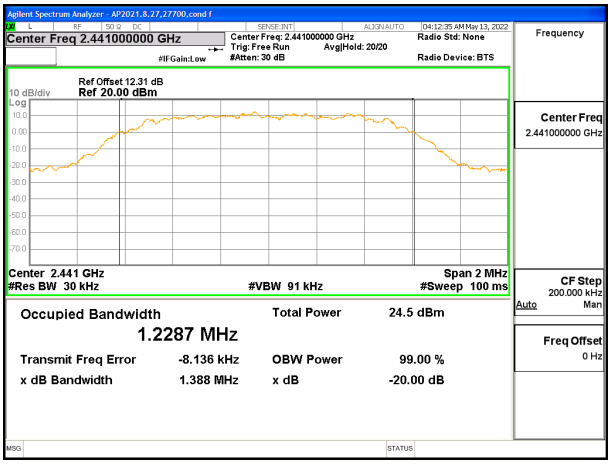
9.2.4. HIGH POWER ENHANCED DATA RATE TXBF 8PSK MODULATION

Note: Test procedure on beamforming mode is the same as BT basic and EDR mode

Channel	Frequency (MHz)	20dB Bandwidth ANT 4 (MHz)	20dB Bandwidth ANT 3 (MHz)	99% Bandwidth ANT 4 (MHz)	99% Bandwidth ANT 3 (MHz)
Low	2402	1.370	1.367	1.2103	1.2104
Mid	2441	1.369	1.388	1.2102	1.2287
High	2480	1.370	1.366	1.2142	1.2113



MID CHANNEL ANT 4



MID CHANNEL ANT 3

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9.3. HOPPING FREQUENCY SEPARATION

LIMITS

FCC §15.247 (a) (1)

RSS-247 (5.1) (b)

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hoping 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.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to 300 kHz and the VBW is set to VBW >= 3xRBW. The sweep time is coupled.

RESULTS

Only High Power GFSK mode result is reported since EDR (QPSK/8PSK) has exact same channel plan.

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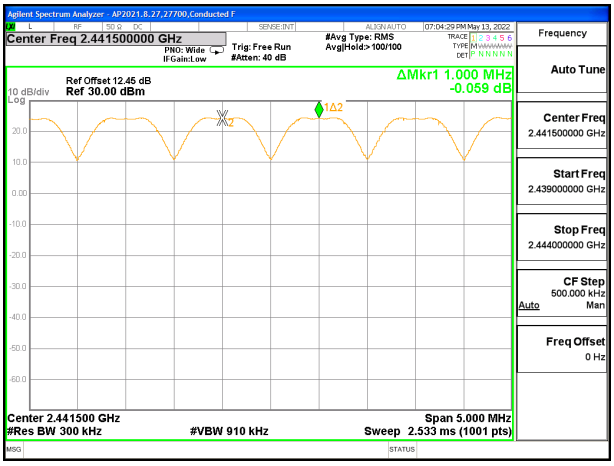
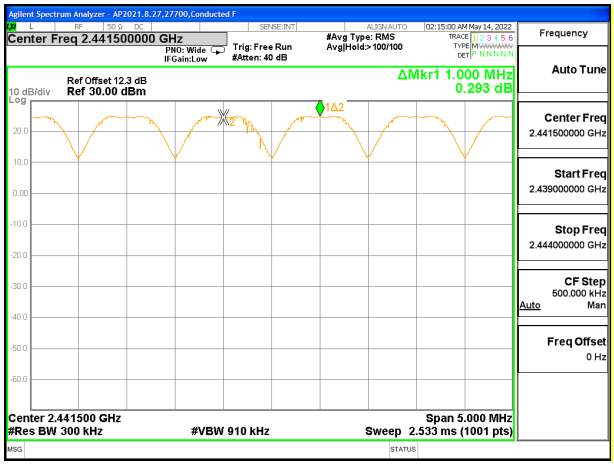
9.3.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

HOPPING FREQUENCY SEPARATION



ANT 4



ANT 3

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9.4. NUMBER OF HOPPING CHANNELS

LIMITS

FCC §15.247 (a) (1) (iii)

RSS-247 (5.1) (d)

Frequency hopping systems in the 2400 – 2483.5 MHz band shall use at least 15 non-overlapping channels.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The span is set to cover the entire authorized band, in either a single sweep or in multiple contiguous sweeps. The RBW is set to a maximum of 1 % of the span. The analyzer is set to Max Hold.

RESULTS

Normal Mode: 79 Channels Observed. Only High Power GFSK mode result is reported since EDR (QPSK/8PSK) has exact same channel plan.

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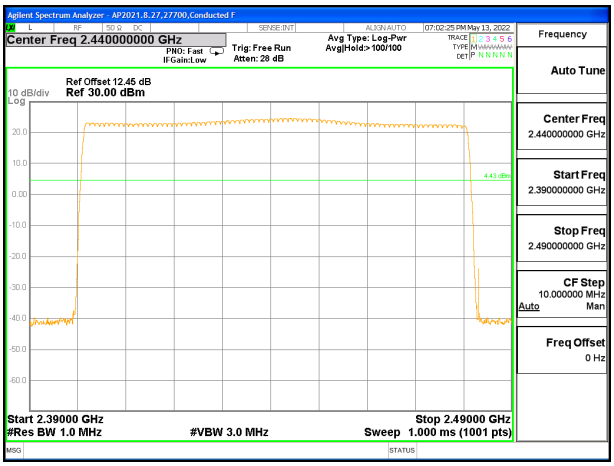
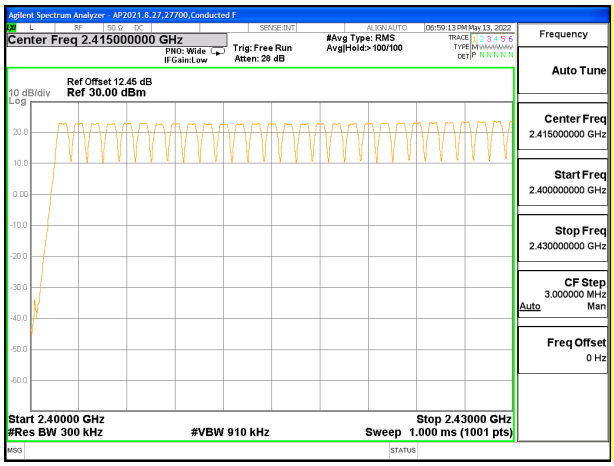
9.4.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

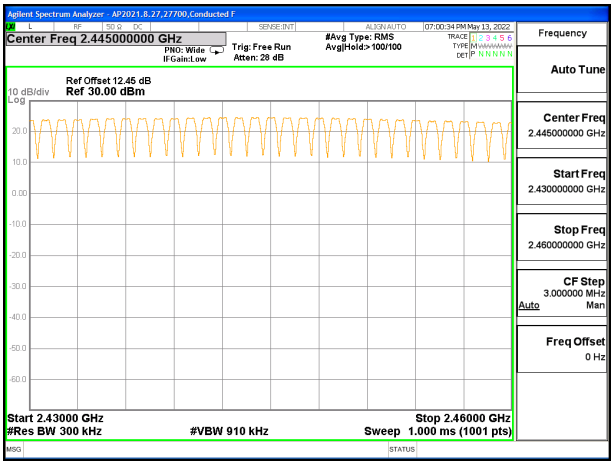
ANT 4



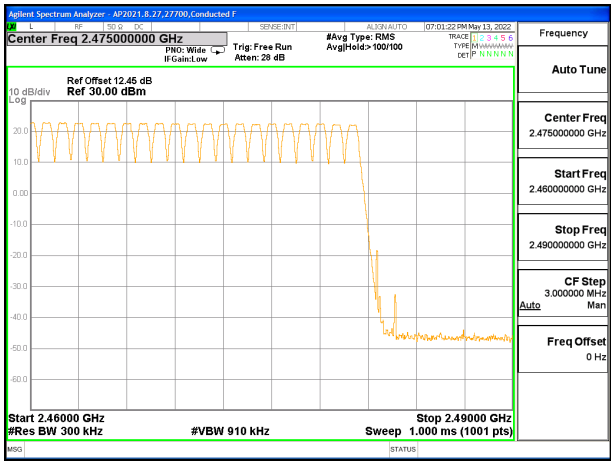
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



30MHz SPAN, SEGMENT 2 OF 3



30MHz SPAN, SEGMENT 3 OF 3

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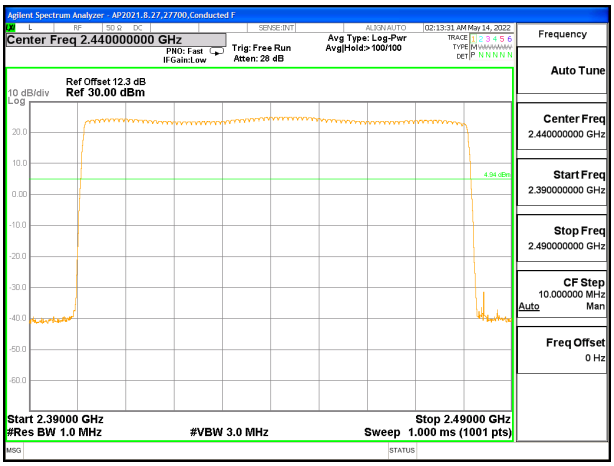
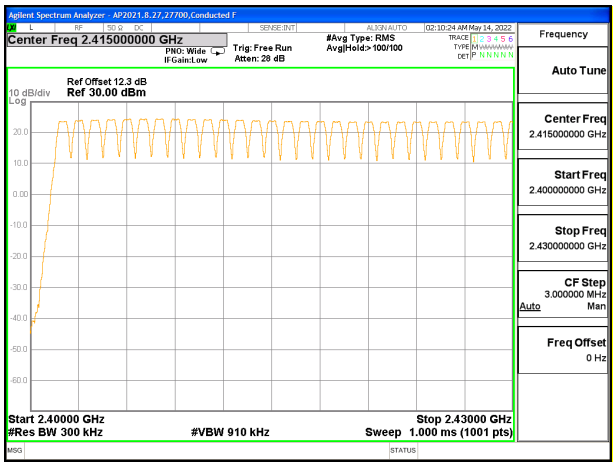
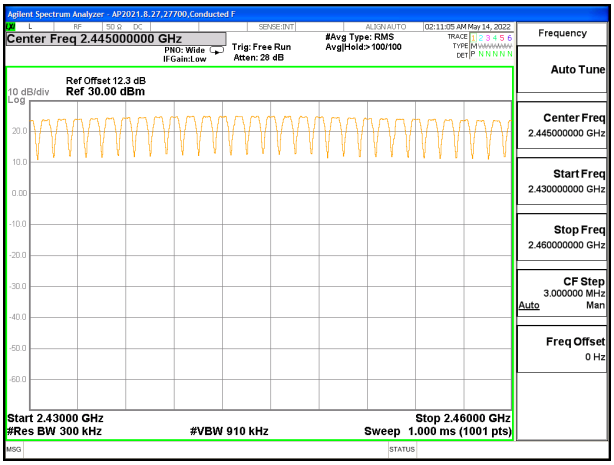
ANT 3



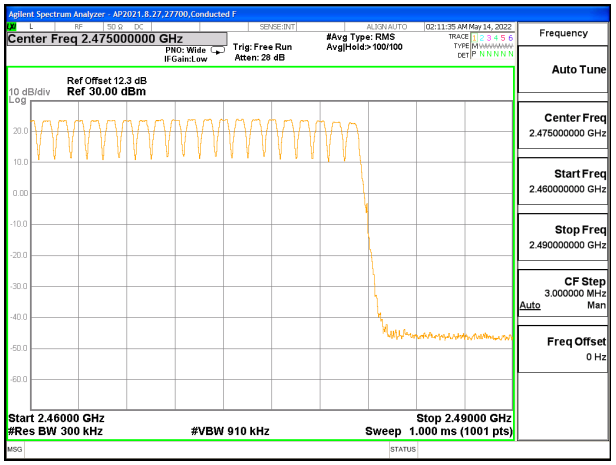
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



30MHz SPAN, SEGMENT 2 OF 3



30MHz SPAN, SEGMENT 3 OF 3

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9.5. AVERAGE TIME OF OCCUPANCY

LIMITS

FCC §15.247 (a) (1) (iii)

RSS-247 (5.1) (d)

The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The span is set to 0 Hz, centered on a single, selected hopping channel. The width of a single pulse is measured in a fast scan. The number of pulses is measured in a 3.16 second scan, to enable resolution of each occurrence.

The average time of occupancy in the specified 3.16 second period (79 channels * 0.4 s) is equal to 10 * (# of pulses in 3.16 s) * pulse width.

For AFH mode, the average time of occupancy in the specified 8 second period (20 channels * 0.4 seconds) is equal to 10 * (# of pulses in 0.8 s) * pulse width.

RESULTS

Only High Power GFSK mode result is reported since EDR (QPSK/8PSK) has exact same timing.

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9.5.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4

DH Packet	Pulse Width (msec)	Number of Pulses in 3.16 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
GFSK Normal Mode					
DH1	0.378	32	0.121	0.4	-0.279
DH3	1.632	15	0.245	0.4	-0.155
DH5	2.872	10	0.287	0.4	-0.113
DH Packet	**Pulse Width (sec)**	**Number of Pulses in 0.8 seconds**	**Average Time of Occupancy (sec)**	**Limit (sec)**	**Margin (sec)**
GFSK AFH Mode					
DH1	0.378	8	0.030	0.4	-0.370
DH3	1.632	3.75	0.061	0.4	-0.339
DH5	2.872	2.5	0.072	0.4	-0.328

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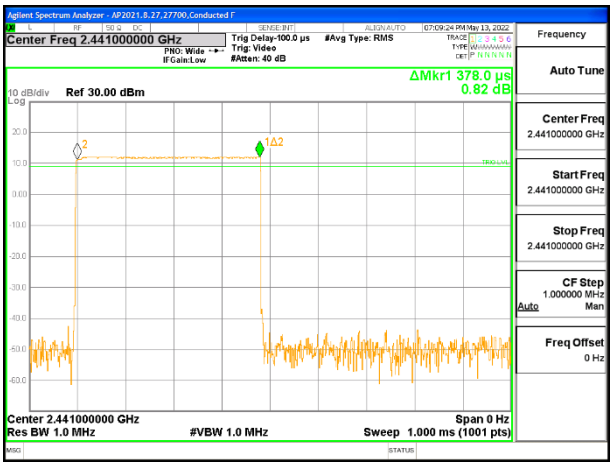
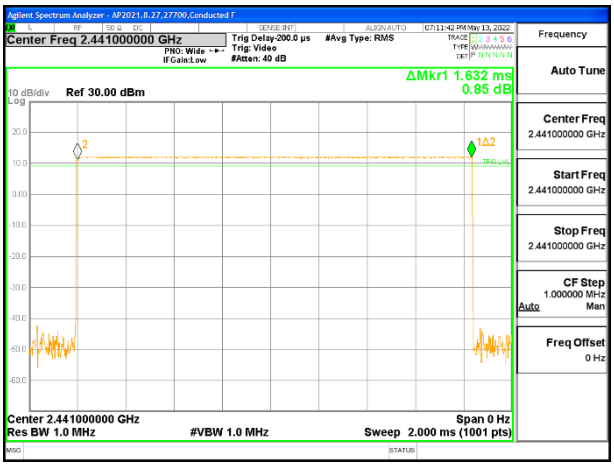
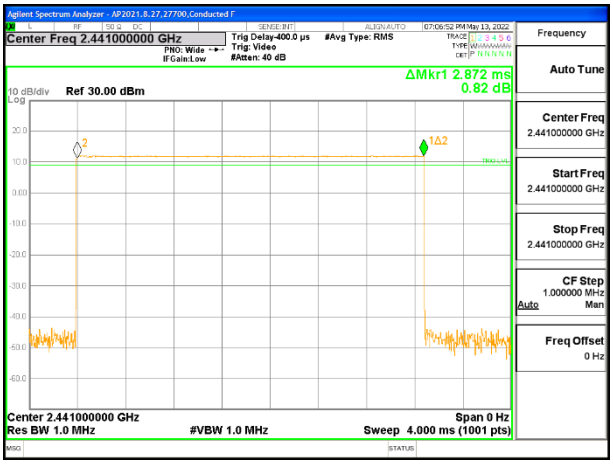


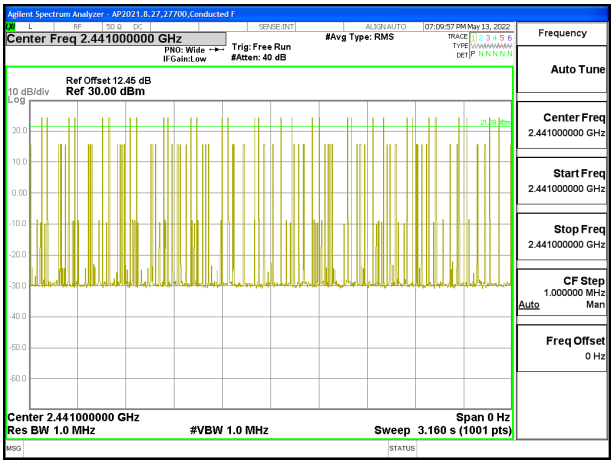
PULSE WIDTH – DH1



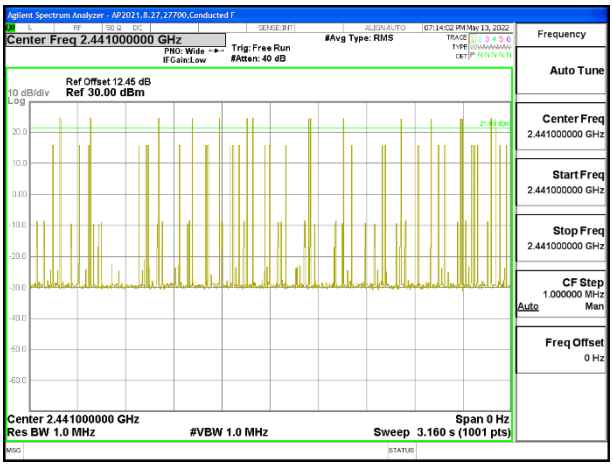
PULSE WIDTH – DH3



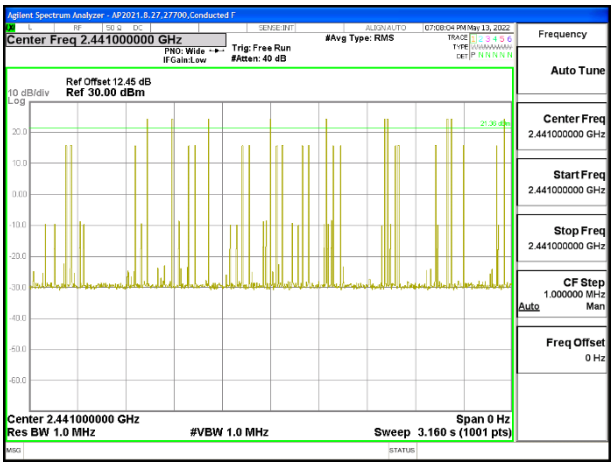
PULSE WIDTH – DH5



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH1



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH3



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH5

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ANT 3

DH Packet	Pulse Width (msec)	Number of Pulses in 3.16 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
FSK Normal Mode					
DH1	0.378	31	0.117	0.4	-0.283
DH3	1.630	15	0.245	0.4	-0.156
DH5	2.872	10	0.287	0.4	-0.113
DH Packet	**Pulse Width (sec)**	**Number of Pulses in 0.8 seconds**	**Average Time of Occupancy (sec)**	**Limit (sec)**	**Margin (sec)**
GFSK AFH Mode					
DH1	0.378	7.75	0.029	0.4	-0.371
DH3	1.63	3.75	0.061	0.4	-0.339
DH5	2.872	2.5	0.072	0.4	-0.328

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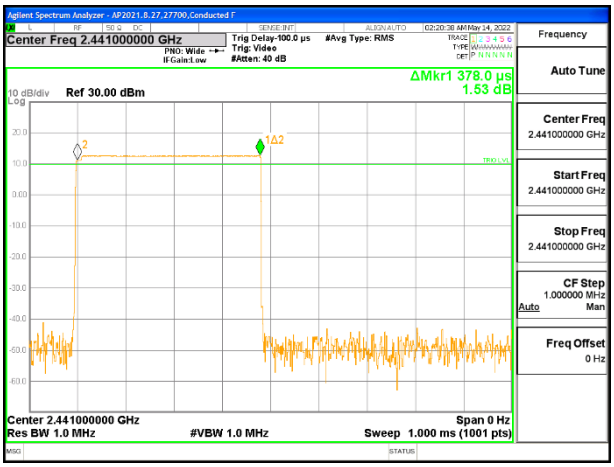
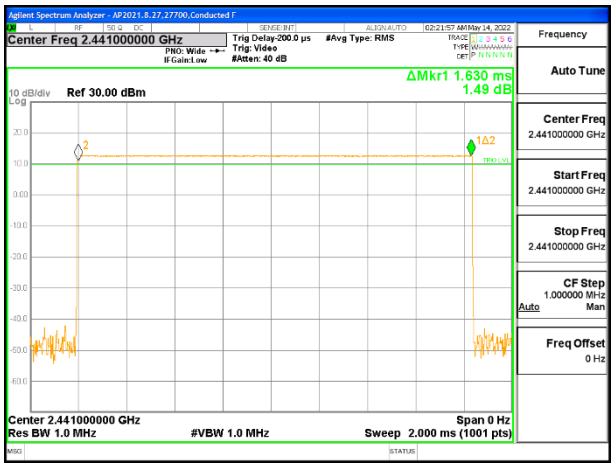
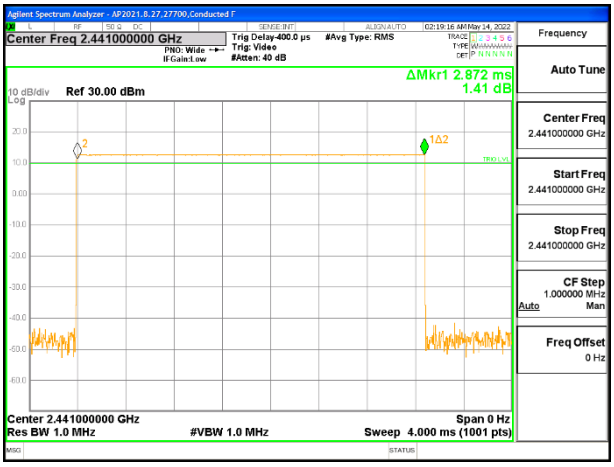


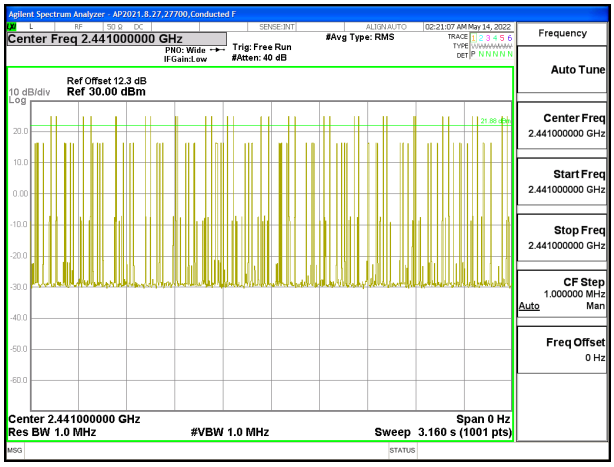
PULSE WIDTH – DH1



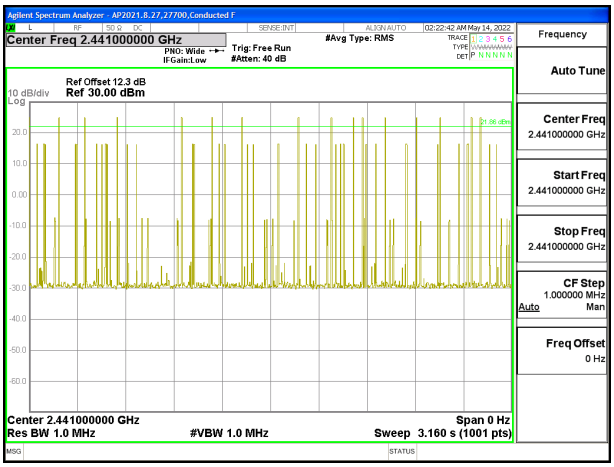
PULSE WIDTH – DH3



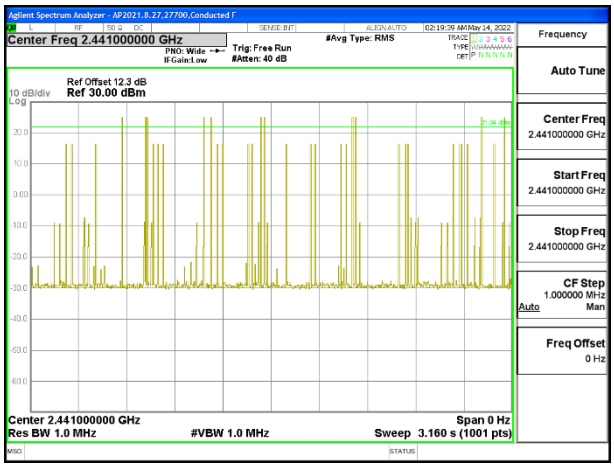
PULSE WIDTH – DH5



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH1



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH3



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH5

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9.6. OUTPUT POWER

LIMITS

§15.247 (b) (1)

RSS-247 (5.4) (b)

The maximum antenna gain is less than 6 dBi, therefore the limit is 30 dBm. 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.

For 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

TEST PROCEDURE

Measurements was perform using a power meter with wideband peak power sensor.

The power output was measured on the EUT antenna port using SMA cable with 10dB attenuator connected to a power meter via wideband peak power sensor. Peak output power was read directly from the power meter.

DIRECTIONAL ANTENNA GAIN

For 1 TX:
There is only one transmitter output therefore the directional gain is equal to the antenna gain.

For 2 TX:

Tx chains are correlated for power due to the device supporting Beamforming. The directional gains are as follows:

Band (GHz)	ANT 4 Gain (dBi)	ANT 3 Gain (dBi)	Correlated Chains Directional Gain (dBi)
2.4	-1.00	-1.10	1.96

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DIRECTIONAL GAIN CALCULATION:

ANSI C63.10-2013 section 14.4.3

Uncorrelated directional gain=10*LOG((10^(Ant1/10)+10^(Ant2/10))/2)
Correlated directional Gain=10*LOG(((10^(Ant1/20)+10^(Ant2/20))^2)/2)

Sample Calculation:

Ant1=-1.0, Ant2=-1.1

Uncorrelated Antenna gain=10log[(10^(-1.0/10)+10^(-1.1/10))/2]=-1.05dBi

Correlated Antenna gain=10log[(10^(-1.0/20)+10^(-1.1/20))^2)/2]=1.96 dBi

RESULTS

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9.6.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	20.06	21	-0.94
Middle	2441	20.07	21	-0.93
High	2480	20.03	21	-0.97

ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	20.04	21	-0.96
Middle	2441	20.09	21	-0.91
High	2480	20.03	21	-0.97

9.6.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	17.02	17.02	20.03	21	-0.97
Middle	2441	17.10	17.07	20.10	21	-0.90
High	2480	17.00	17.03	20.03	21	-0.97

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9.6.3. HIGH POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	19.20	21	-1.80
Middle	2441	19.25	21	-1.75
High	2480	19.22	21	-1.78

ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	19.18	21	-1.82
Middle	2441	19.24	21	-1.76
High	2480	19.21	21	-1.79

9.6.4. HIGH POWER ENHANCED DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	16.22	16.21	19.23	21	-1.77
Middle	2441	16.25	16.23	19.25	21	-1.75
High	2480	16.19	16.20	19.21	21	-1.79

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9.6.5. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	19.44	21	-1.56
Middle	2441	19.49	21	-1.51
High	2480	19.48	21	-1.52

ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	19.47	21	-1.53
Middle	2441	19.51	21	-1.49
High	2480	19.43	21	-1.57

9.6.6. HIGH POWER ENHANCED DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	16.41	16.42	19.43	21	-1.57
Middle	2441	16.46	16.47	19.48	21	-1.52
High	2480	16.43	16.39	19.42	21	-1.58

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9.6.7. LOW POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	10.91	21	-10.09
Middle	2441	11.01	21	-9.99
High	2480	10.93	21	-10.07

ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	10.97	21	-10.03
Middle	2441	11.02	21	-9.98
High	2480	10.92	21	-10.08

9.6.8. LOW POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	10.97	10.99	13.99	21	-7.01
Middle	2441	11.05	10.96	14.02	21	-6.98
High	2480	10.96	10.91	13.95	21	-7.05

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9.6.9. LOW POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.22	21	-9.78
Middle	2441	11.25	21	-9.75
High	2480	11.19	21	-9.81

ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.2	21	-9.8
Middle	2441	11.23	21	-9.77
High	2480	11.18	21	-9.82

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9.6.10. LOW POWER ENHANCED DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.23	11.27	14.26	21	-6.74
Middle	2441	11.27	11.30	14.30	21	-6.70
High	2480	11.25	11.22	14.25	21	-6.75

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9.6.11. LOW POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.42	21	-9.58
Middle	2441	11.47	21	-9.53
High	2480	11.45	21	-9.55

ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.46	21	-9.54
Middle	2441	11.53	21	-9.47
High	2480	11.44	21	-9.56

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9.6.12. LOW POWER ENHANCED DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.41	11.37	14.40	21	-6.60
Middle	2441	11.46	11.49	14.49	21	-6.51
High	2480	11.39	11.41	14.41	21	-6.59

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9.7. AVERAGE POWER

LIMITS

None; for reporting purposes only

TEST PROCEDURE

Measurements was performed using a power meter with wideband average power sensor.

The power output was measured on the EUT antenna port using SMA cable with 10dB attenuator connected to a power meter via wideband average power sensor. Gated average output power was read directly from power meter.

RESULTS

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9.7.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	19.70
Middle	2441	19.72
High	2480	19.69

ANT 3

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	19.71
Middle	2441	19.73
High	2480	19.68

9.7.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	16.70	16.69	19.71
Middle	2441	16.73	16.72	19.74
High	2480	16.69	16.70	19.71

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9.7.3. HIGH POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	16.19
Middle	2441	16.21
High	2480	16.20

ANT 3

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	16.18
Middle	2441	16.22
High	2480	16.20

9.7.4. HIGH POWER BASIC DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	13.18	13.19	16.20
Middle	2441	13.19	13.20	16.21
High	2480	13.16	13.17	16.18

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9.7.5. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	16.20
Middle	2441	16.23
High	2480	16.21

ANT 3

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	16.21
Middle	2441	16.22
High	2480	16.19

9.7.6. HIGH POWER BASIC DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	13.20	13.21	16.22
Middle	2441	13.23	13.22	16.24
High	2480	13.21	13.20	16.22

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9.7.7. LOW POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	10.70
Middle	2441	10.74
High	2480	10.72

ANT 3

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	10.71
Middle	2441	10.73
High	2480	10.69

9.7.8. LOW POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	10.69	10.71	13.71
Middle	2441	10.72	10.71	13.73
High	2480	10.70	10.68	13.70

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9.7.9. LOW POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.19
Middle	2441	8.20
High	2480	8.18

ANT 3

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.20
Middle	2441	8.21
High	2480	8.19

9.7.10. LOW POWER BASIC DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	8.18	8.21	11.21
Middle	2441	8.20	8.22	11.22
High	2480	8.20	8.18	11.20

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9.7.11. LOW POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.20
Middle	2441	8.23
High	2480	8.22

ANT 3

Tested By:	26118
Date	7/14/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.21
Middle	2441	8.24
High	2480	8.20

9.7.12. LOW POWER BASIC DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	26118
Date:	7/14/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	8.21	8.19	11.21
Middle	2441	8.25	8.23	11.25
High	2480	8.20	8.21	11.22

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9.8. CONDUCTED SPURIOUS EMISSIONS

LIMITS

FCC §15.247 (d)

RSS-247 5.5

Limit = -20 dBc

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The resolution bandwidth is set to 100 kHz. The video bandwidth is set to 300 kHz.

The spectrum from 30 MHz to 26 GHz is investigated with the transmitter set to the lowest, middle, and highest channels.

The band edges at 2.4 and 2.4835 GHz are investigated with the transmitter set to the normal hopping mode.

Note: Test procedure on Beamforming mode is same as BT BDR and EDR mode.

RESULTS

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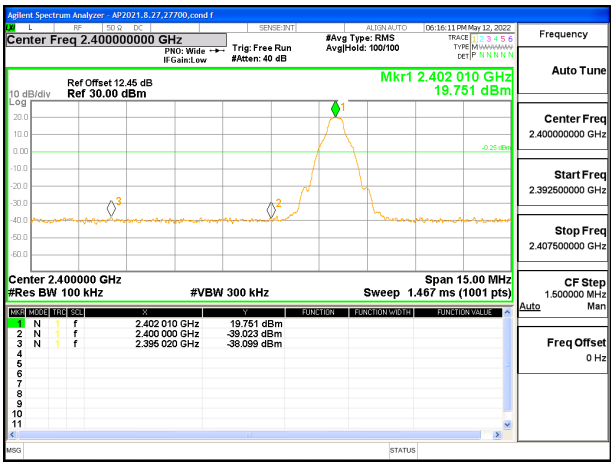
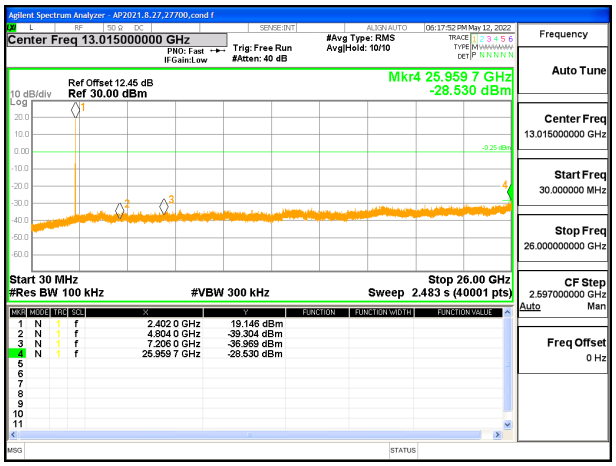
9.8.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4 SPURIOUS EMISSIONS, NON-HOPPING



LOW CHANNEL BANDEDGE



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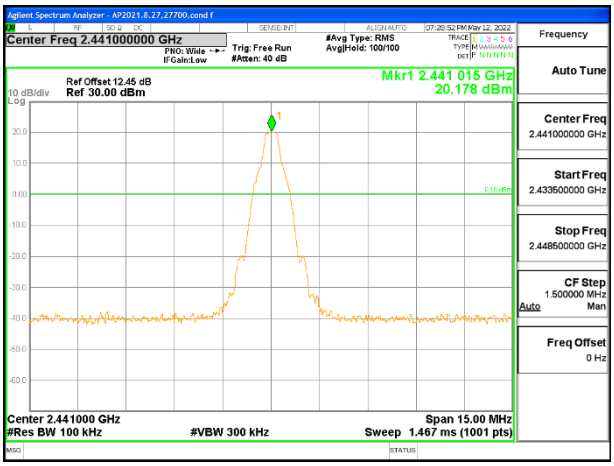

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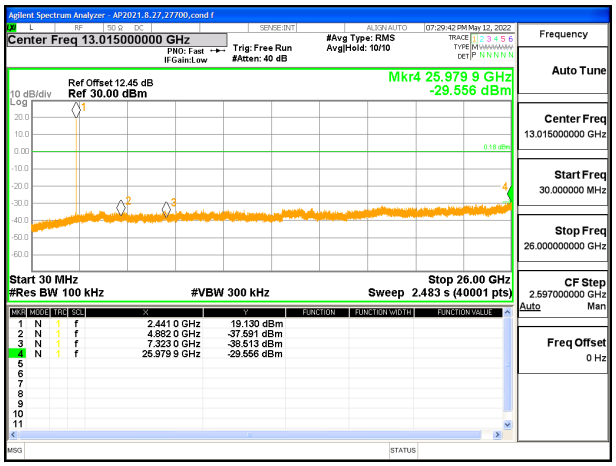

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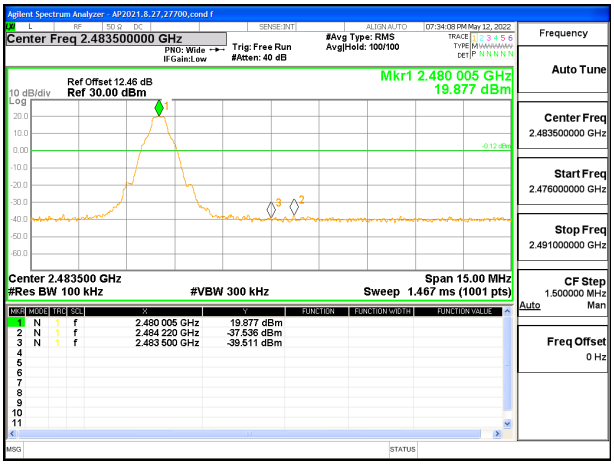

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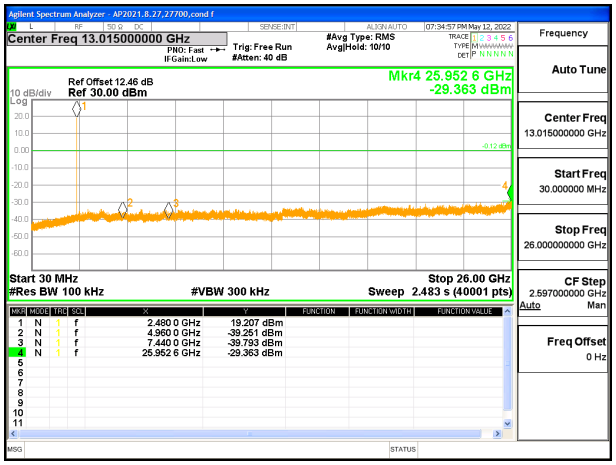

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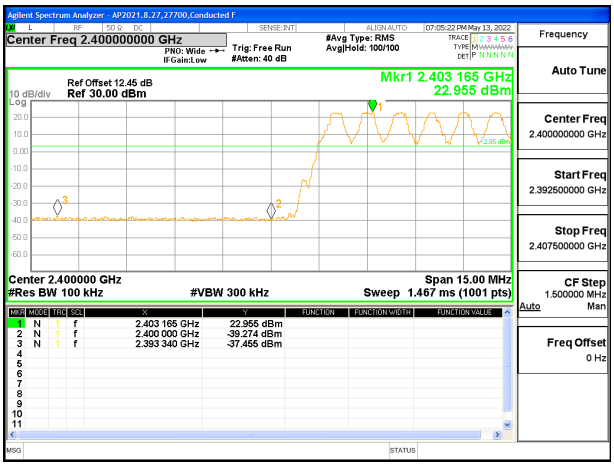
ANT 4 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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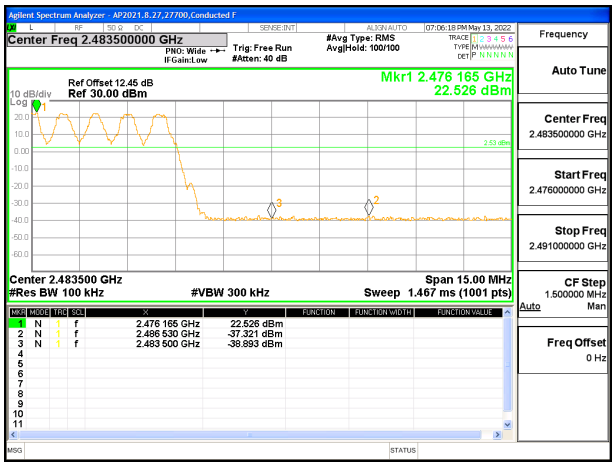

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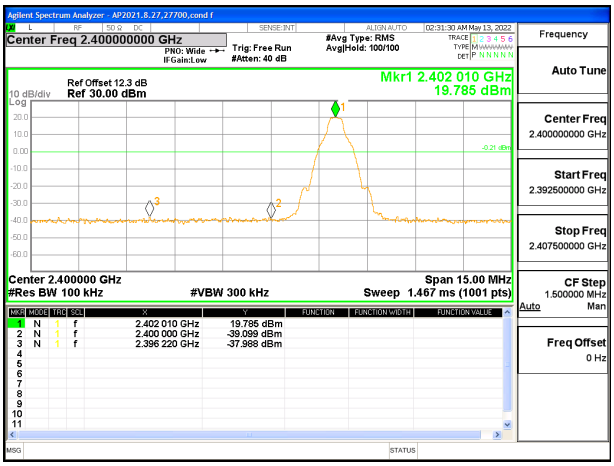
ANT 3 SPURIOUS EMISSIONS, NON-HOPPING



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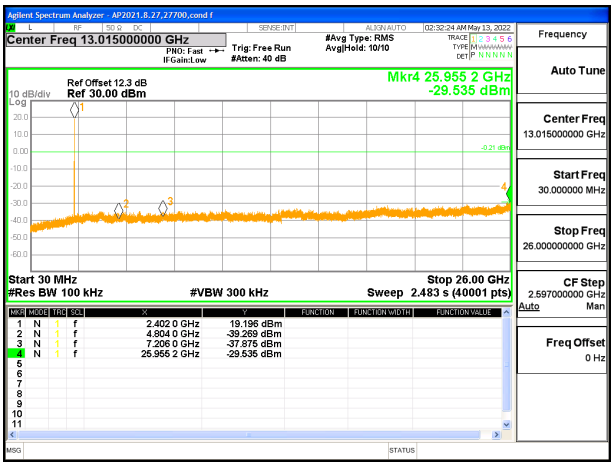
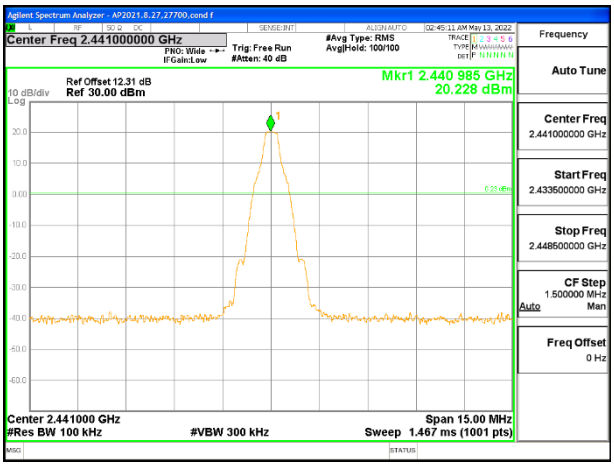


LOW CHANNEL OUT-OF-BAND



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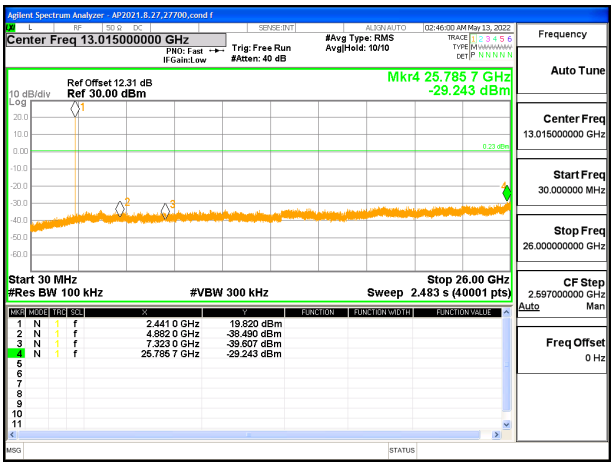

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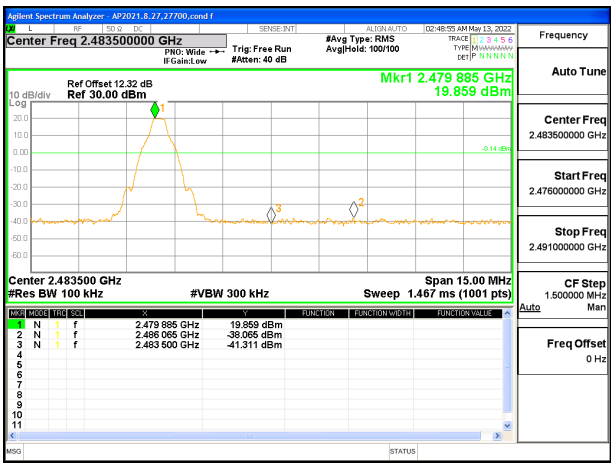

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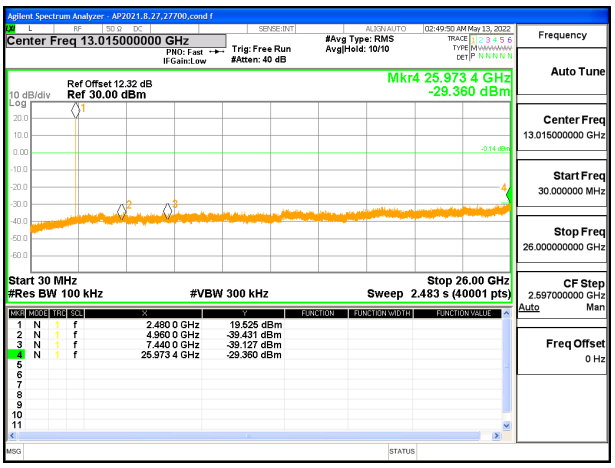

HIGH CHANNEL OUT-OF-BAND

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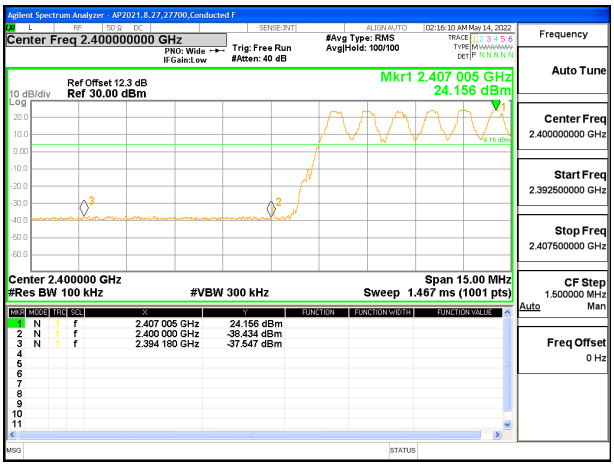
ANT 3 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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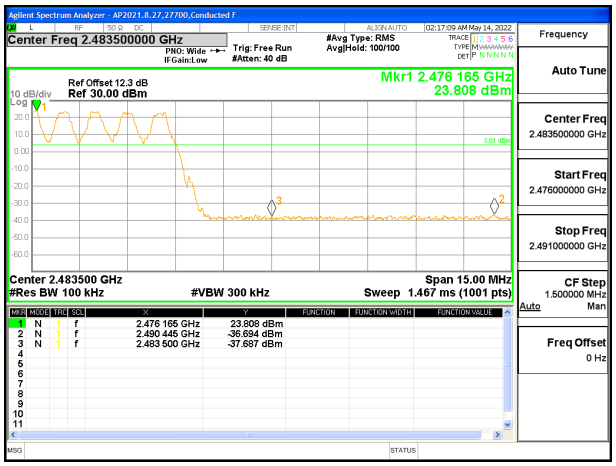

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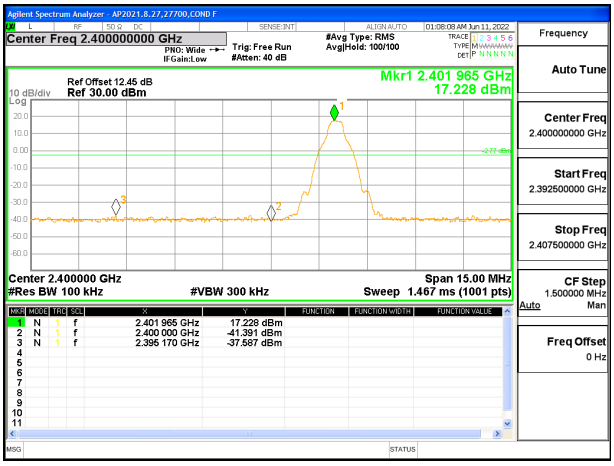
9.8.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 SPURIOUS EMISSIONS, NON-HOPPING



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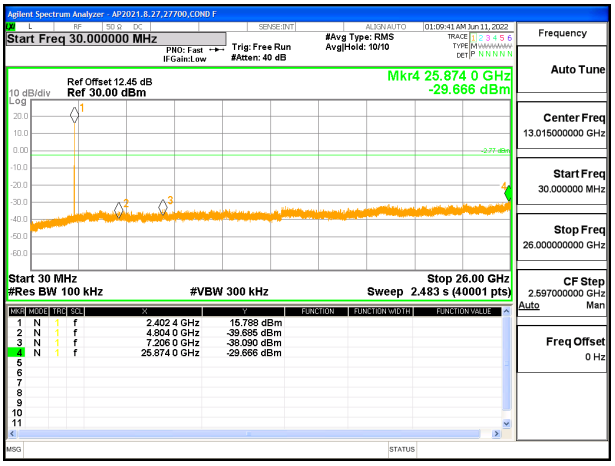

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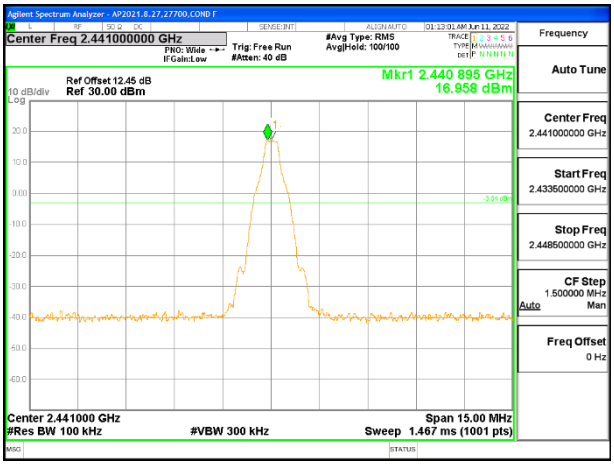

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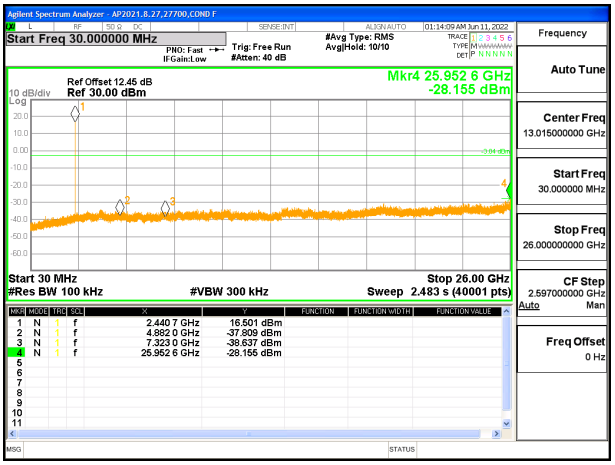

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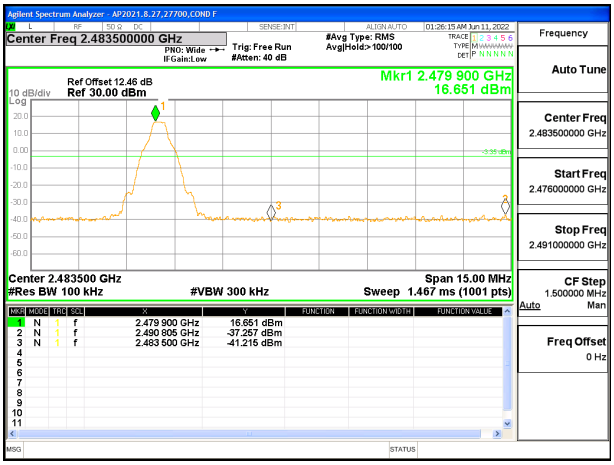

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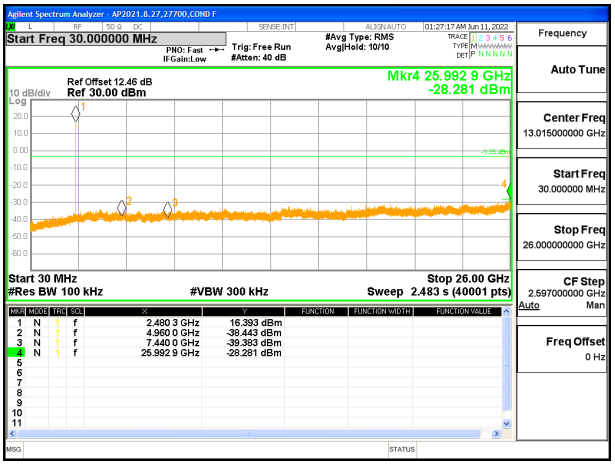

HIGH CHANNEL OUT-OF-BAND

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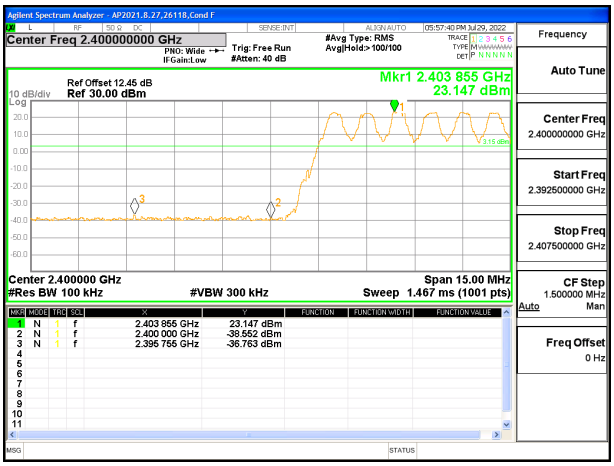
ANT 4 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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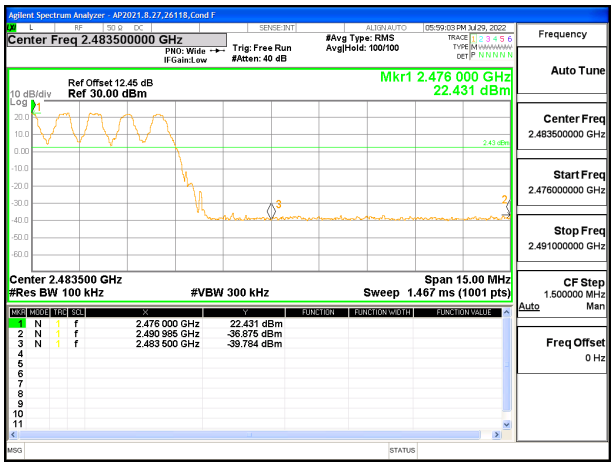

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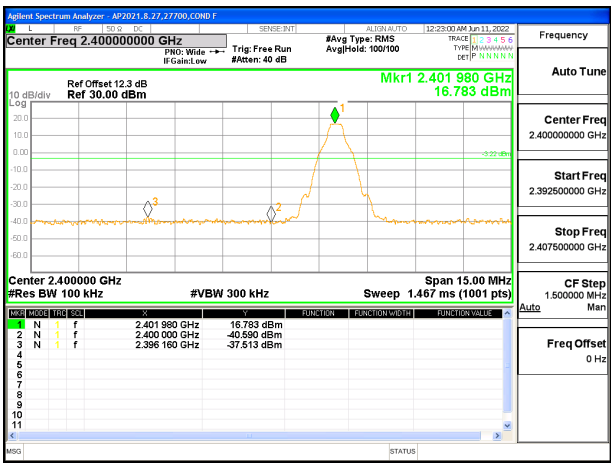
ANT 3 SPURIOUS EMISSIONS, NON-HOPPING



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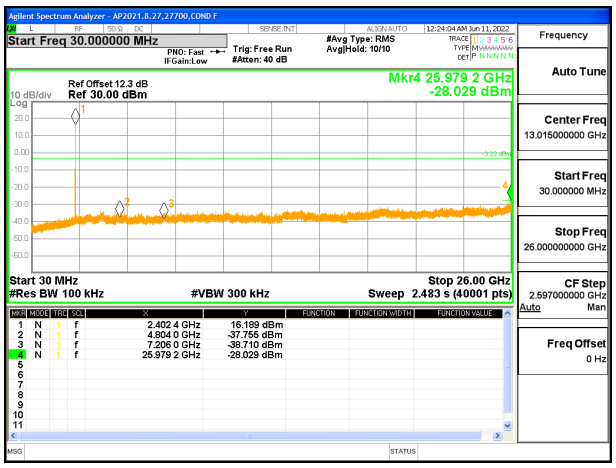

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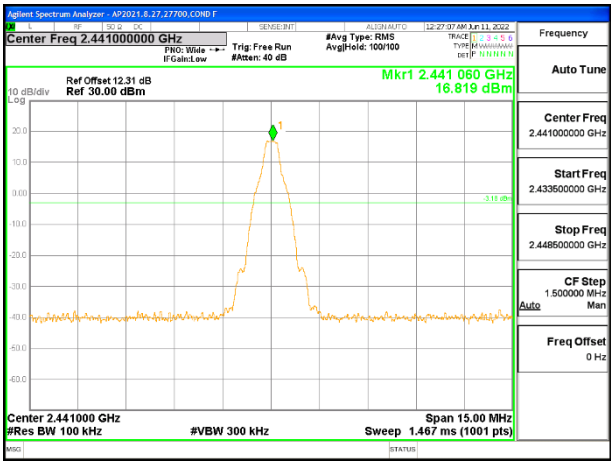
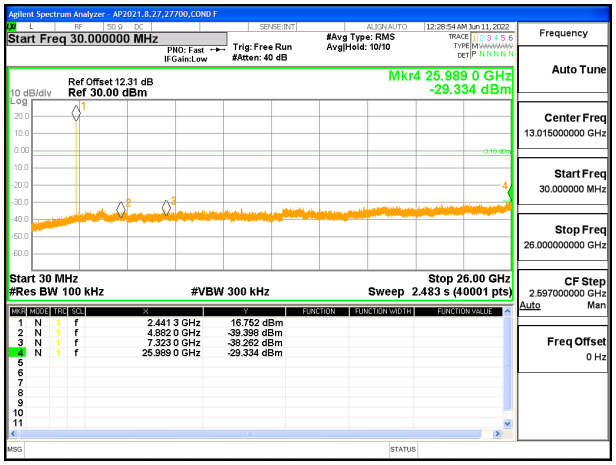


MID CHANNEL REFERENCE LEVEL



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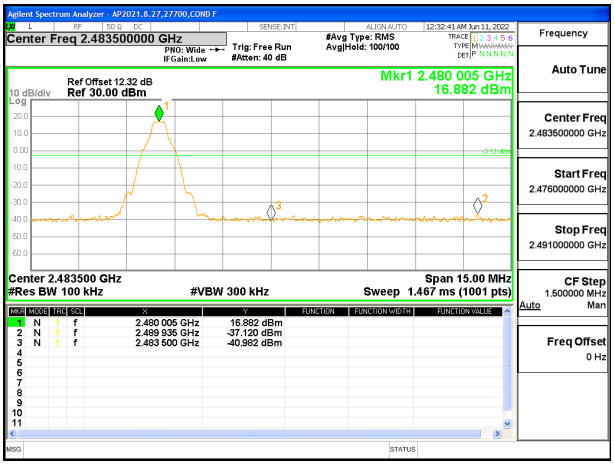

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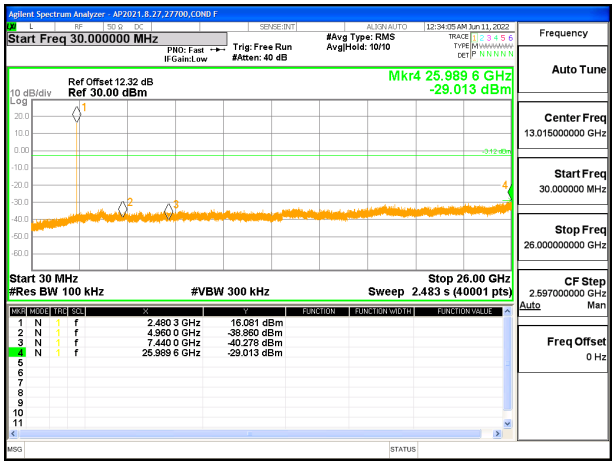

HIGH CHANNEL OUT-OF-BAND

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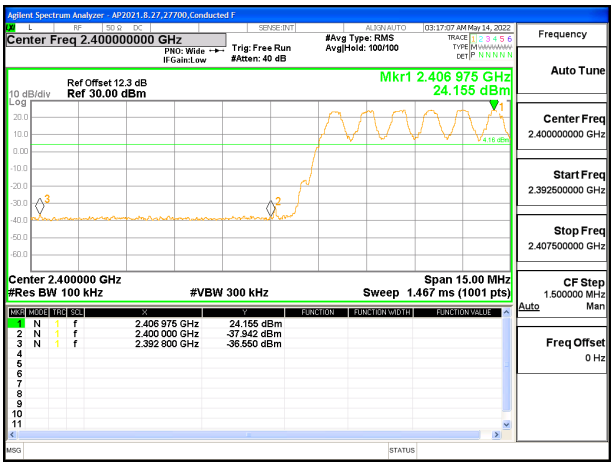
ANT 3 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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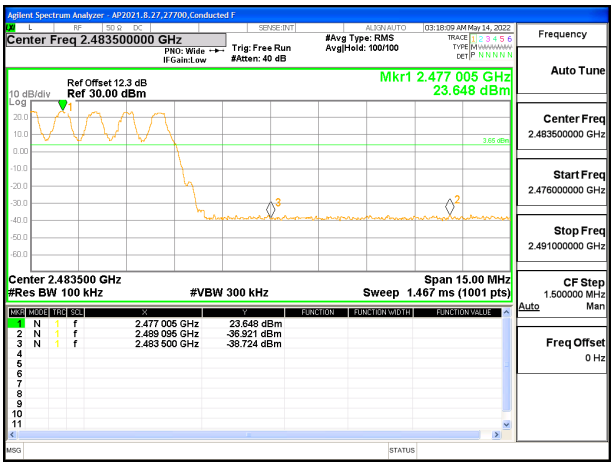

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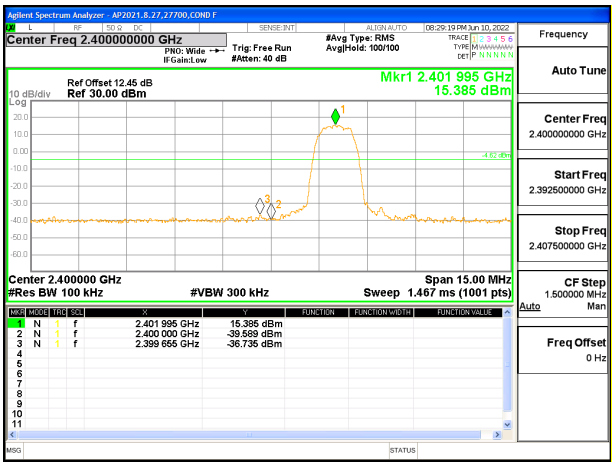
9.8.3. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4 SPURIOUS EMISSIONS, NON-HOPPING



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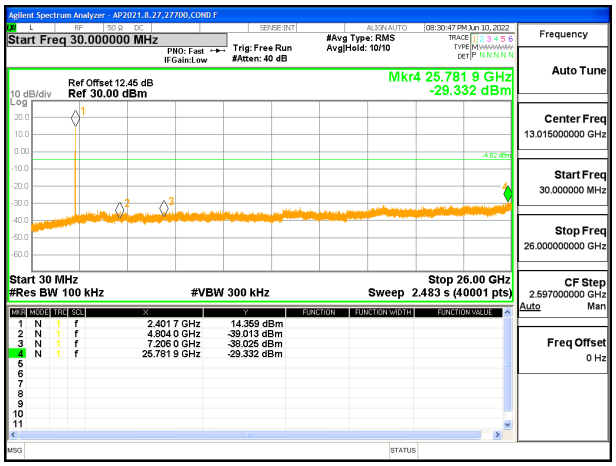

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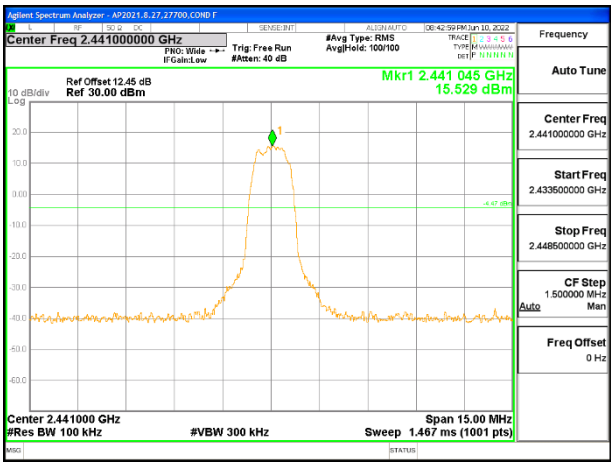
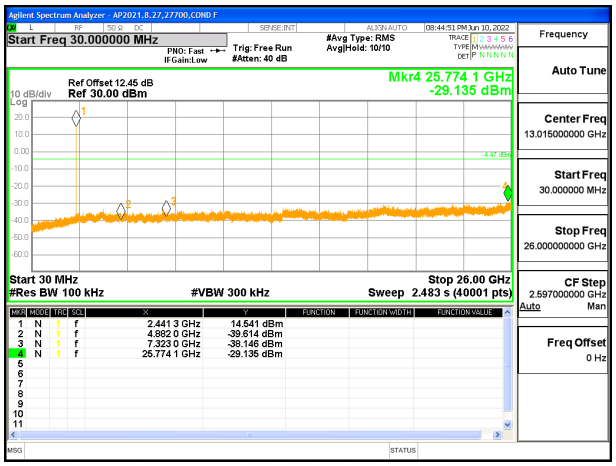


MID CHANNEL REFERENCE LEVEL



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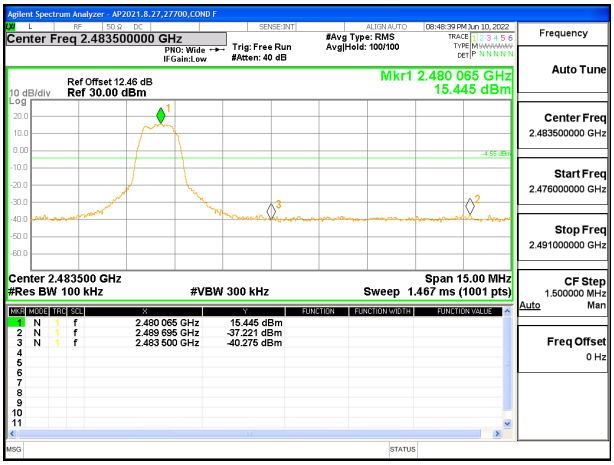

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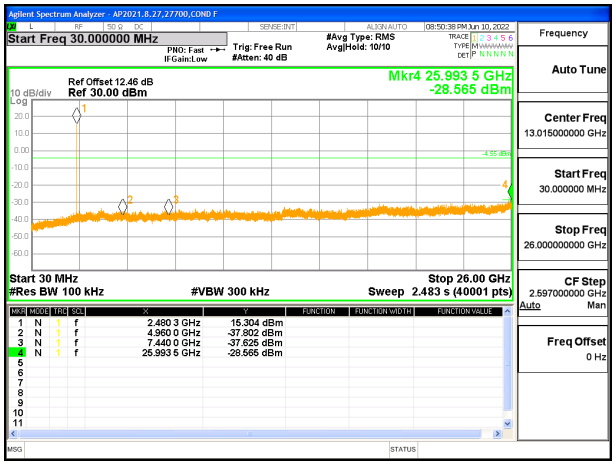

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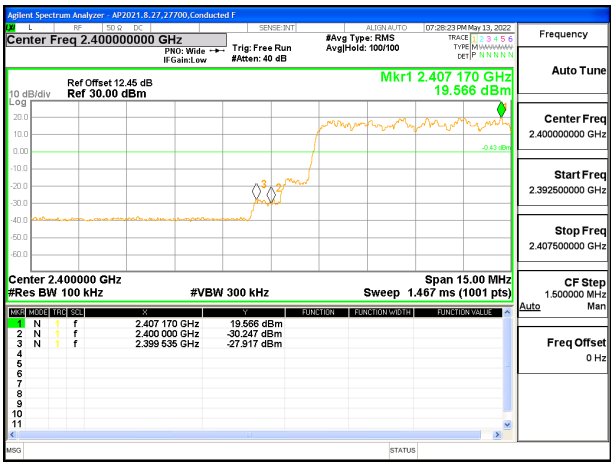
ANT 4 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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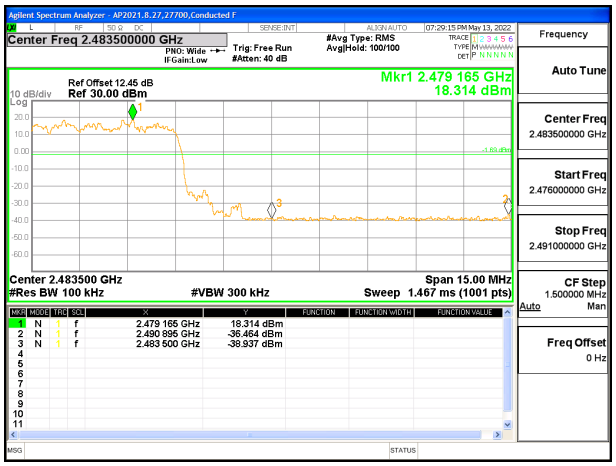

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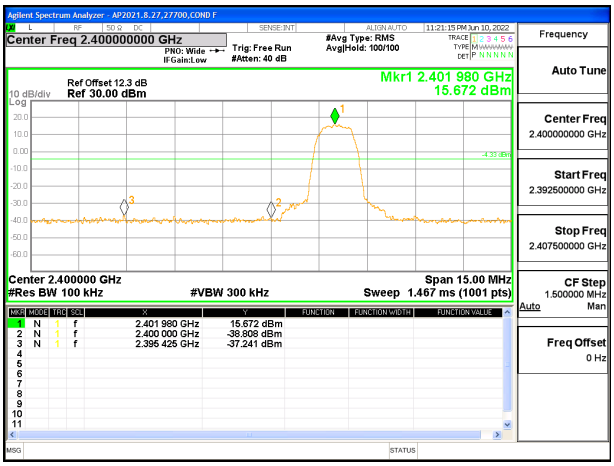
ANT 3 SPURIOUS EMISSIONS, NON-HOPPING



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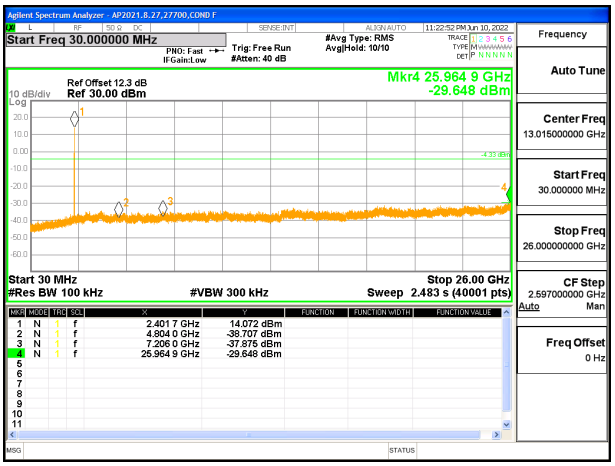

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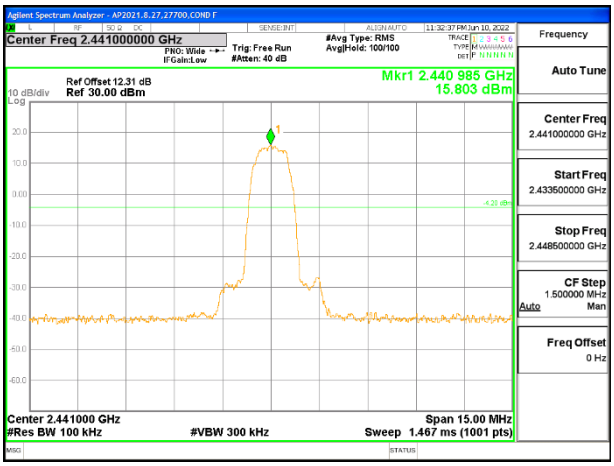
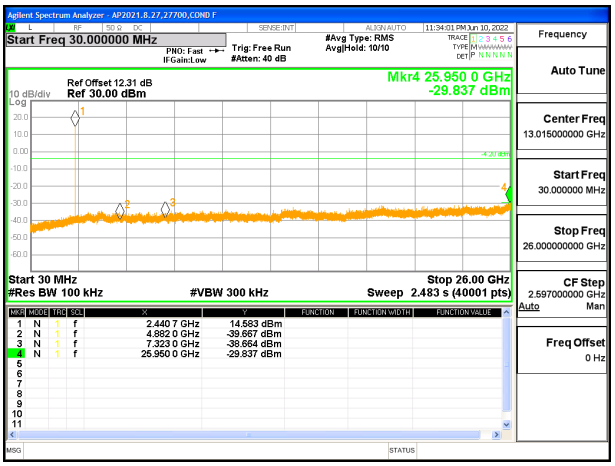


MID CHANNEL REFERENCE LEVEL



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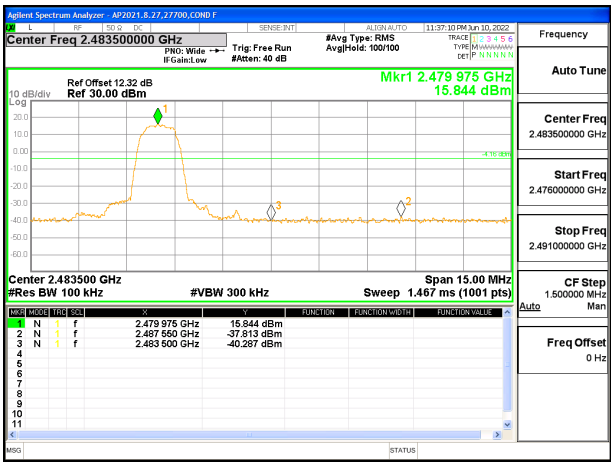

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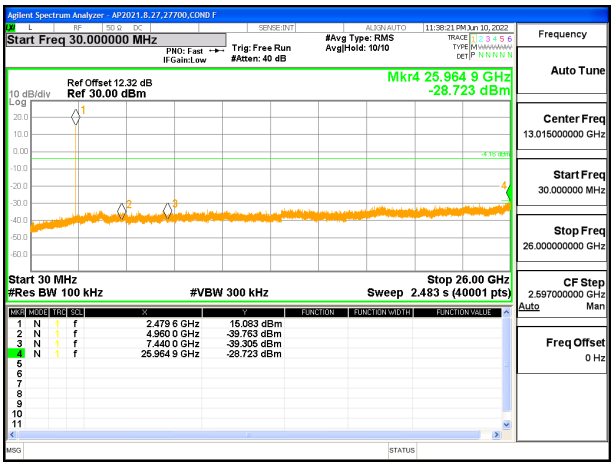

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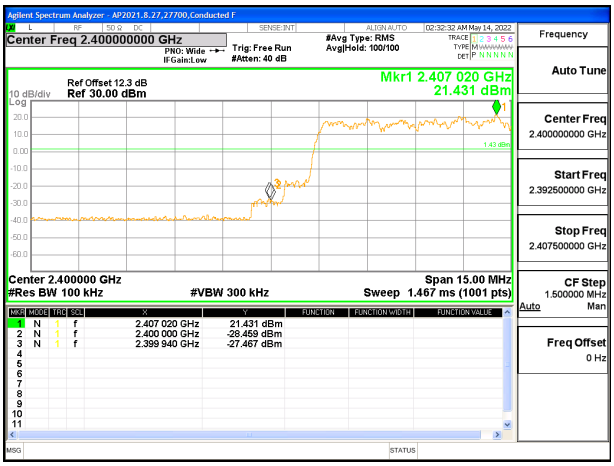
ANT 3 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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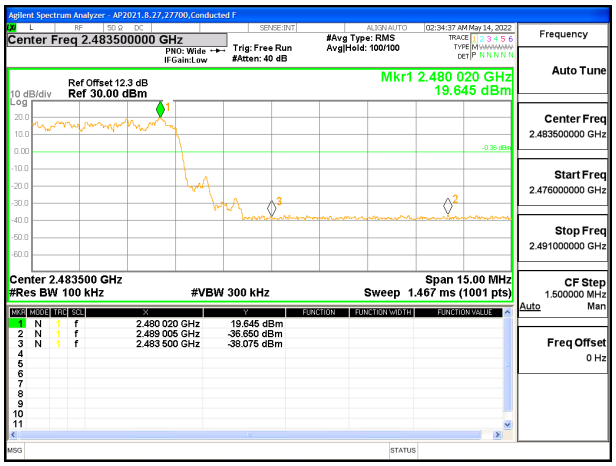

HIGH BANDEDGE

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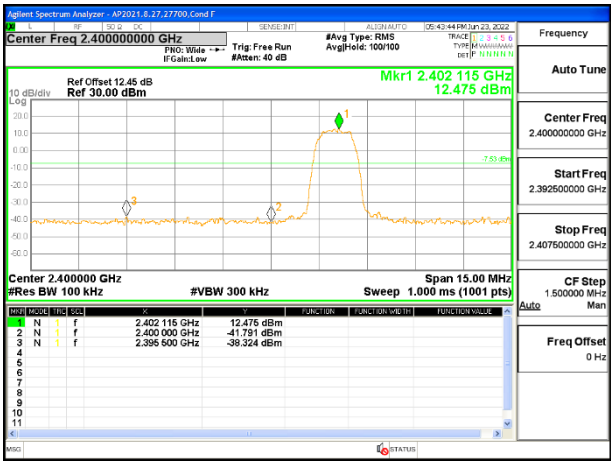
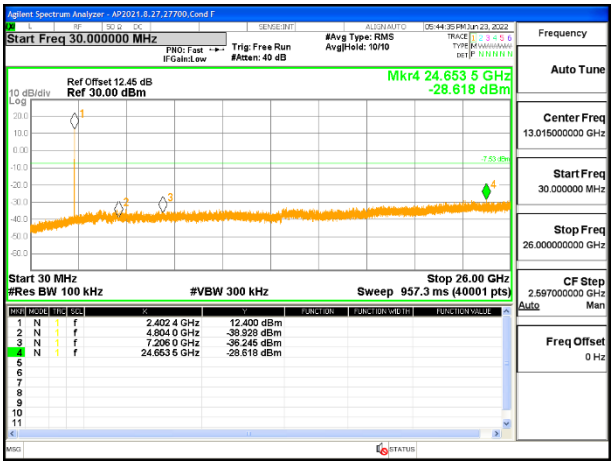
9.8.4. HIGH POWER BASIC DATA RATE TXBF 8PSK MODULATION

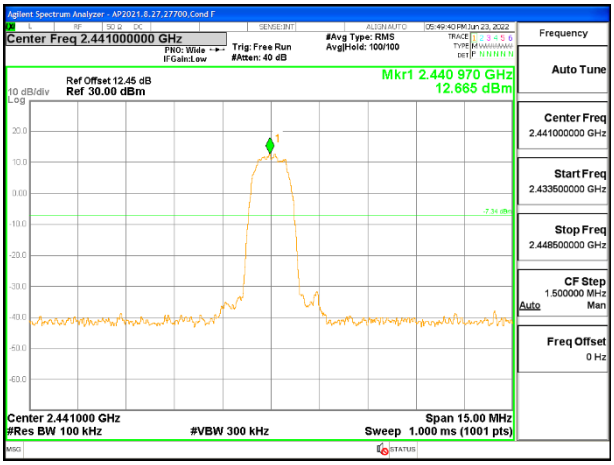
ANT 4 SPURIOUS EMISSIONS, NON-HOPPING



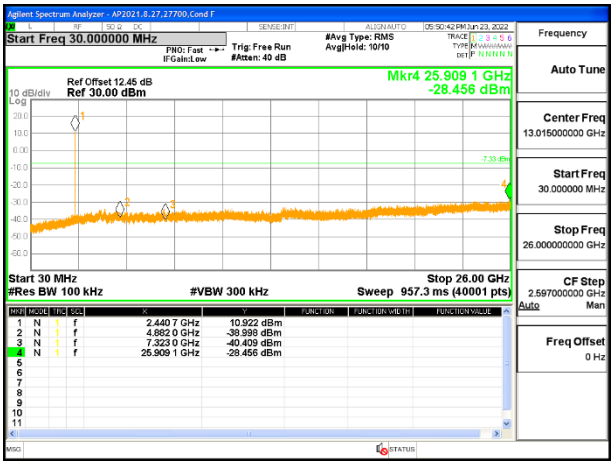
LOW CHANNEL BANDEDGE



LOW CHANNEL OUT-OF-BAND



MID CHANNEL REFERENCE LEVEL



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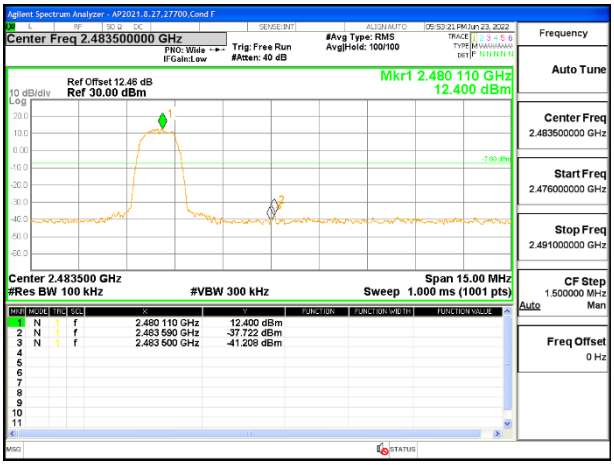

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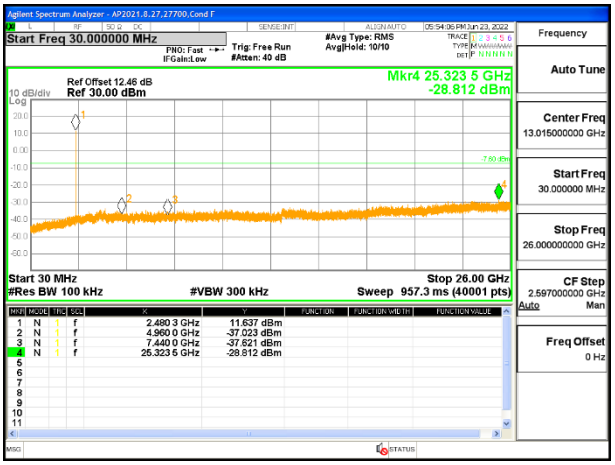

HIGH CHANNEL OUT-OF-BAND

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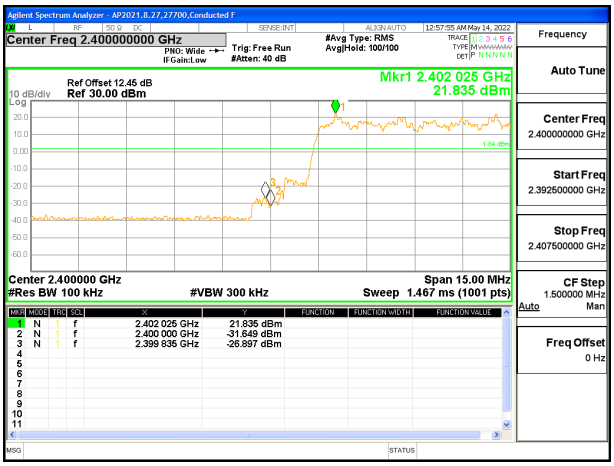
ANT 4 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



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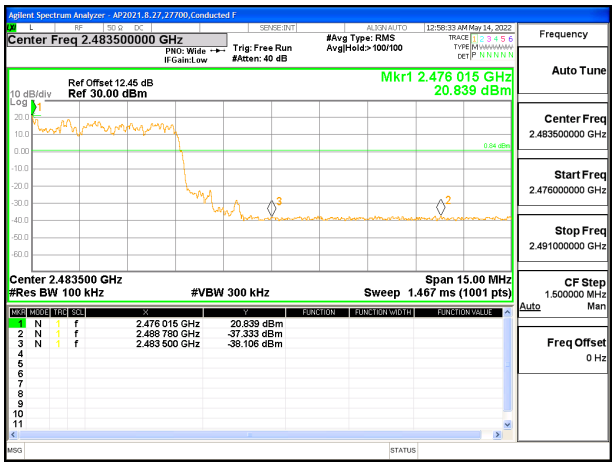

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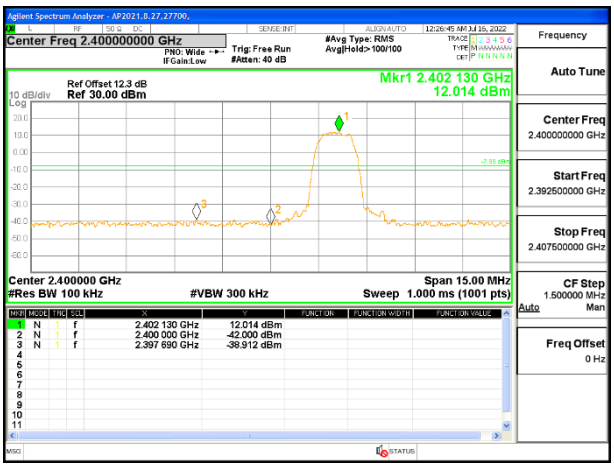
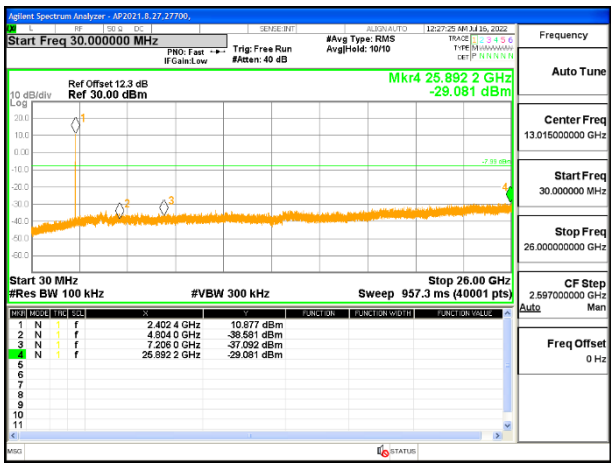
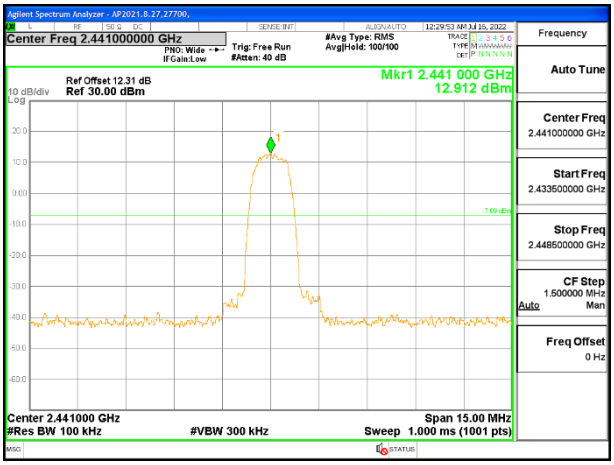
ANT 3 SPURIOUS EMISSIONS, NON-HOPPING



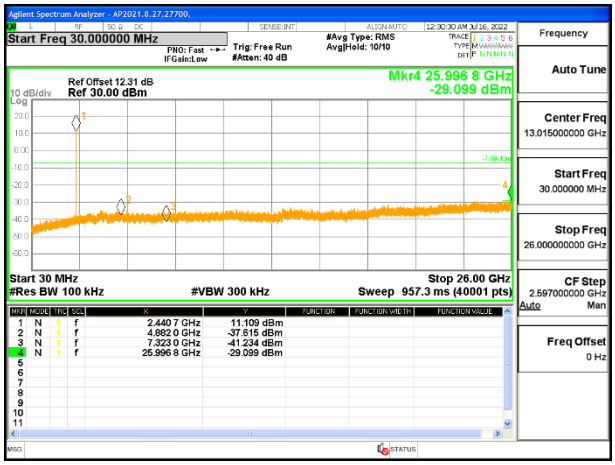
LOW CHANNEL BANDEDGE



LOW CHANNEL OUT-OF-BAND



MID CHANNEL REFERENCE LEVEL



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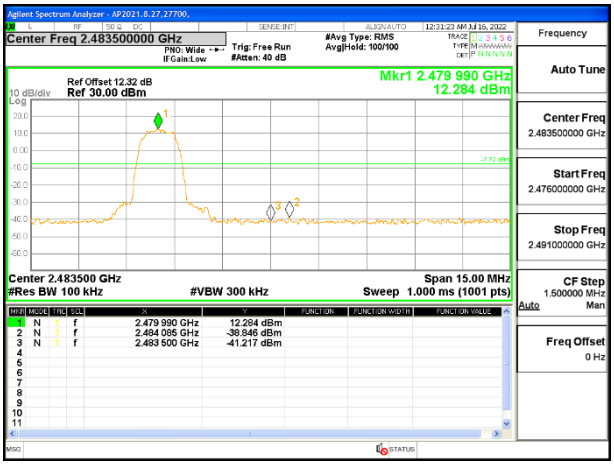
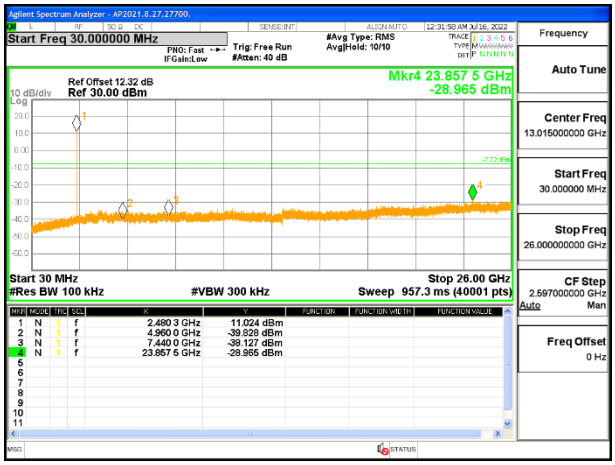


HIGH CHANNEL BANDEDGE



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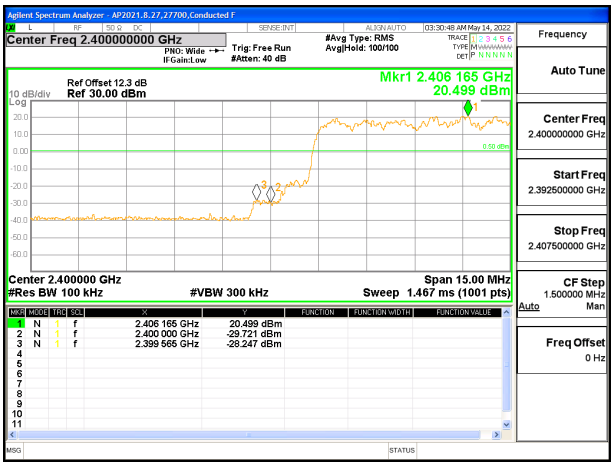
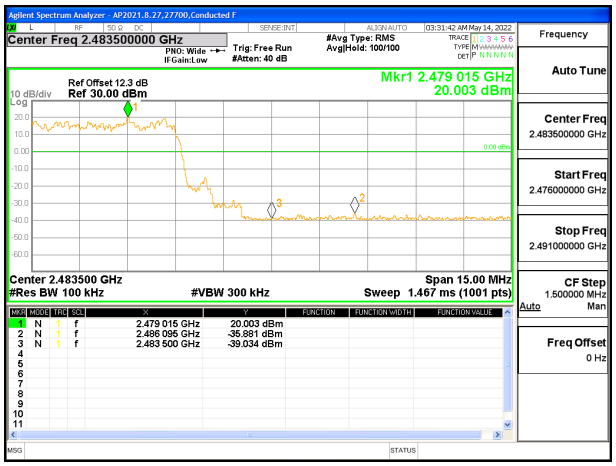
ANT 3 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE



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