TEST REPORT

Report Number: 14040863-E1V4

Applicant	:	APPLE, INC. 1 APPLE PARK WAY CUPERTINO, CA 95014, U.S.A
Model	:	A2650 (Parent Model, Full Test) A2889, A2890, A2891, A2892 (Variant Models)
FCC ID	:	BCG-E8140A (Parent Model) BCG-E8150A, BCG-E8151A, BCG-E8152A (Variant Models)
IC	:	579C-E8140A (Parent Model) 579C-E8150A, 579C-E8151A, 579C-E8152A (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 08, 2022

Prepared by:
UL LLC
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ACCREDITED
CERT #0751.05

REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	6/22/2022	Initial Issue	Chin Pang
V2	6/29/2022	Address TCB's questions on section 6.1, 6.5, 7, 9.3, 9.4 & 10.1.3.1	Chin Pang
V3	7/1/2022	Address TCB's on section 6.5 , 10.1.9 & 10.1.10	Chin Pang
V4	7/8/2022	Address 2nd Level TCB questions in section 5.4 and section 9.6	Chin Pang

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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:	A2650 (Parent Model) A2889, A2890, A2891, A2892 (Variant Models)
BRAND:	APPLE
FCC ID:	BCG-E8140A (Parent Model) BCG-E8150A, BCG-E8151A, BCG-E8152A (Variant Models)
IC:	579C-E8140A (Parent Model) 579C-E8150A, 579C-E8151A, 579C-E8152A (Variant Models)
SERIAL NUMBER:	R9VD6JPQTY
SAMPLE RECEIPT DATE:	MARCH 07, 2022
DATE TESTED:	MARCH 08– JUNE 30, 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.

This document may not be altered or revised in any way unless done so by UL LLC and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL LLC will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by A2LA, NIST, any agency of the Federal Government, or any agency of the U.S. government.

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Approved & Released For
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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.

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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

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%.

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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: A2650, FCC ID: BCG-E8140A, IC: 579C-E8140A

Variant Models: A2889, FCC ID: BCG-E8150A, IC: 579C-E8150A
A2890; FCC ID: BCG-E8151A, IC: 579C-E8151A
A2891 & A2892, FCC ID: BCG-E8152A, IC: 579C-E8152A

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	19.64	92.04
		2402 - 2480	DQPSK	18.57	71.94
		2402 - 2480	Enhanced 8PSK	18.77	75.34
	Low Power	2402 - 2480	Basic GFSK	11.25	13.34
		2402 - 2480	DQPSK	11.13	12.97
		2402 - 2480	Enhanced 8PSK	11.46	14.00
ANT 3	High Power	2402 - 2480	Basic GFSK	19.73	93.97
		2402 - 2480	DQPSK	18.62	72.78
		2402 - 2480	Enhanced 8PSK	18.85	76.74
	Low Power	2402 - 2480	Basic GFSK	11.24	13.30
		2402 - 2480	DQPSK	10.90	12.30
		2402 - 2480	Enhanced 8PSK	11.13	12.97
BF, ANT 4 + ANT 3	High Power	2402 - 2480	Basic GFSK TxBF	19.68	92.90
		2402 - 2480	DQPSK TxBF	18.41	69.34
		2402 - 2480	Enhanced 8PSK TxBF	18.86	76.91
	Low Power	2402 - 2480	Basic GFSK TxBF	14.14	25.94
		2402 - 2480	DQPSK TxBF	14.07	25.53
		2402 - 2480	Enhanced 8PSK TxBF	14.13	25.88

Note: GFSK, DQPSK, 8PSK average Power are all investigated, The GFSK & 8PSK Power are the worst case. Testing is based on these modes to showing 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 and type, as provided by the manufacturer' are as follows:

Frequency Range (GHz)	ANT 4 (dBi)	ANT 3 (dBi)
2.4	-1.8	0.6

6.4. SOFTWARE AND FIRMWARE

The EUT firmware version installed during testing was 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 X (Flatbed) orientation was the worst-case orientation for ANT 3, beamforming 2TX and Z (Portrait) for ANT 4.

Radiated band edge, harmonic, and spurious emissions from 1GHz to 18GHz were performed with 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 transmits 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 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 : 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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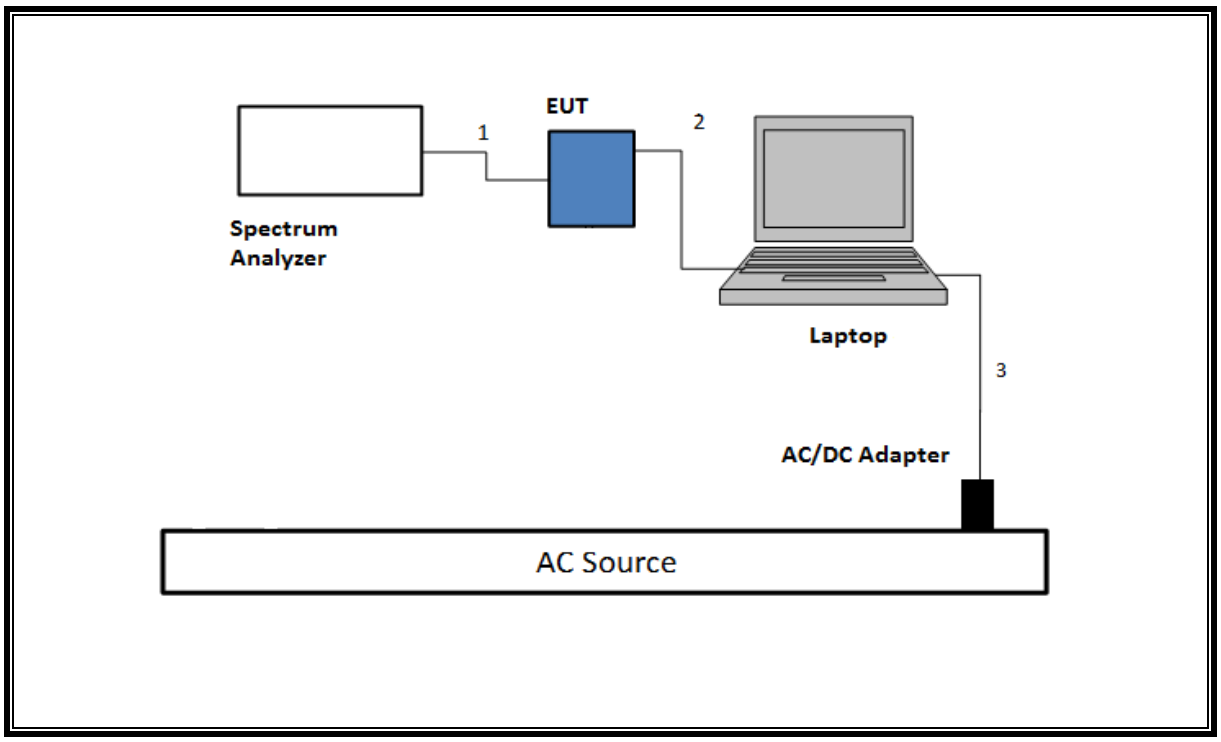
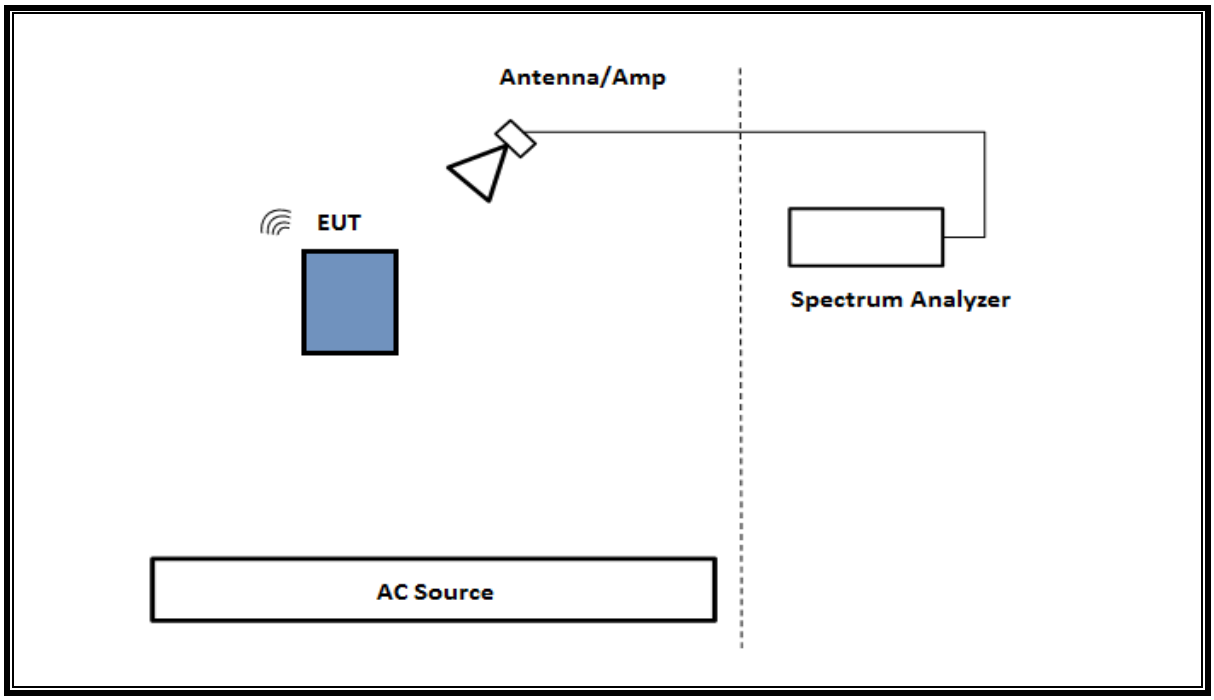
SETUP DIAGRAM FOR CONDUCTED TESTS



SETUP DIAGRAM FOR RADIATED TESTS Above 1 GHz



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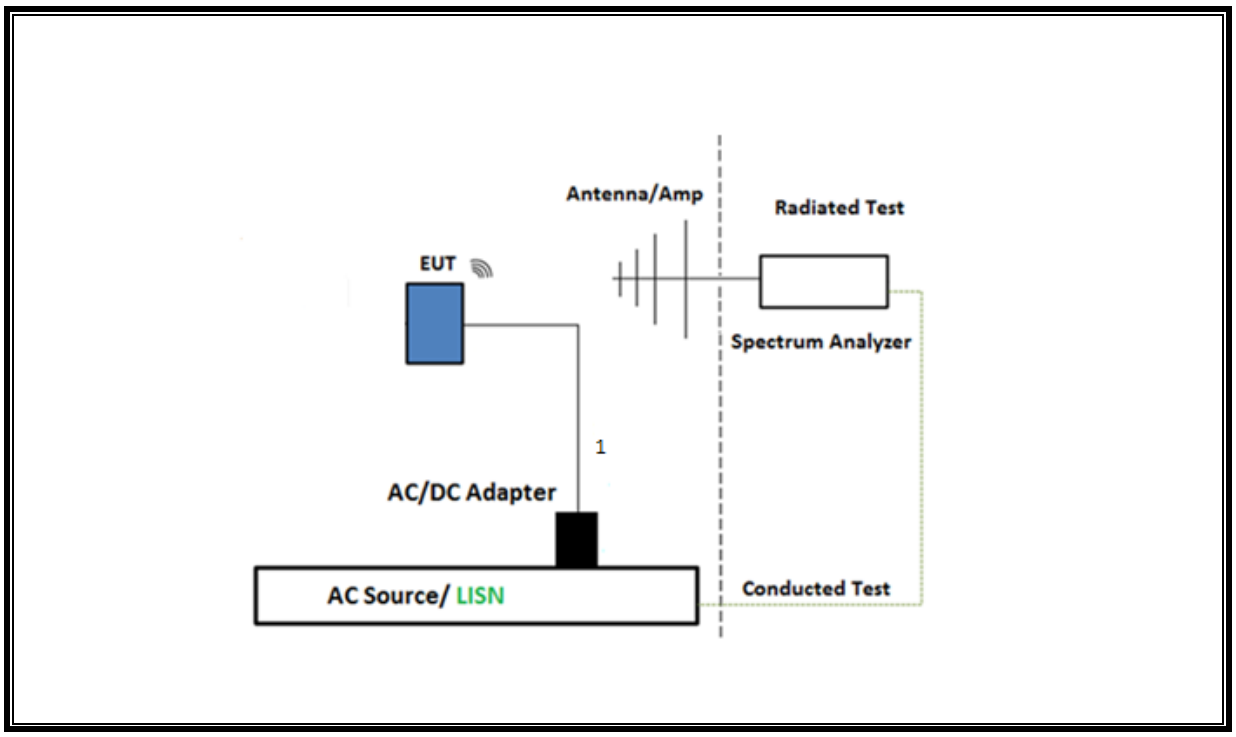
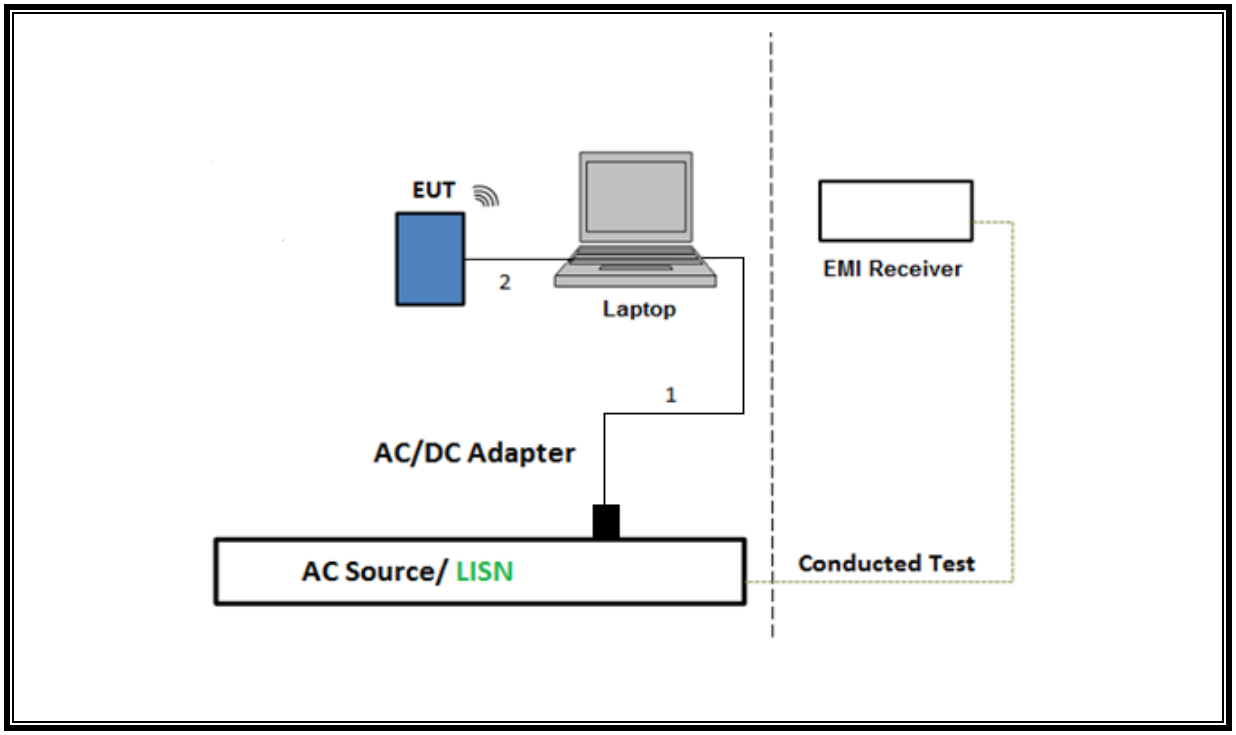
SETUP DIAGRAM FOR BELOW 1GHz and AC LINE CONDUCTED TEST



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
EMI Test Receiver	Rohde & Schwarz	ESW44	191429	02/20/2023	02/20/2022
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	81887	03/16/2023	03/16/2022
RF Filter Box 1-18GHz	UL-FR1	NA	173233	10/23/2022	10/23/2021
Amplifier, 9KHz to 1GHz, 32dB	SONOMA INSTRUMENT	310	202989	12/29/2022	12/29/2021
Antenna, Broadband Hybrid, 30MHz to 2000MHz	Sunol Sciences	JB3	174373	12/14/2022	12/14/2021
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	80396	02/01/2023	02/01/2022
*Antenna Horn 18 to 26.5GHz	ARA	MWH-1826/B	81140	04/22/2022	04/22/2021
*Pre-Amp 18-26GHz	Agilent Technology	8449B	T404	04/19/2022	04/19/2021
Power Meter, P-series single channel	Keysight	N1911A	T1244	01/24/2023	01/24/2022
Power Sensor	Keysight	N1921A	90419	02/03/2023	02/03/2022
*Antenna, Horn 1-18GHz	ETS Lindgren	3117	T120	04/07/2022	04/07/2021
Spectrum Analyzer, PXA 3Hz to 44GHz	Keysight	N9030A	125179	02/01/2023	02/01/2022
RF Filter Box 1-18GHz	UL-FR1	NA	173233	10/23/2022	10/23/2021
EMI Receiver	Rohde & Schwarz	ESW44	201499	02/20/2023	02/20/2022
Antenna, Active Loop 9KHz to 30MHz	ETS-Lindgren	6502	T757	01/28/2023	01/28/2022
Antenna	ETS-Lindgren	3117	200897	02/24/2023	02/24/2022
*RF Filter Box	UL-FR1	N/A	PRE0182865	03/30/2022	03/30/2021

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		

*Testing is completed before equipment expiration date.

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8. MEASUREMENT METHODS

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	0.40	0.40	1.000	100.0%	0.00	0.010
Bluetooth 8PSK	0.40	0.40	1.000	100.0%	0.00	0.010
Bluetooth GFSK TxBF	0.40	0.40	1.000	100.0%	0.00	0.010
Bluetooth 8PSK TxBF	0.40	0.40	1.000	100.0%	0.00	0.010

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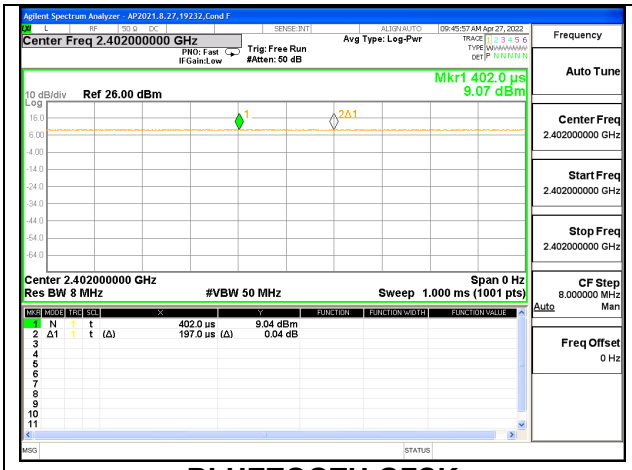
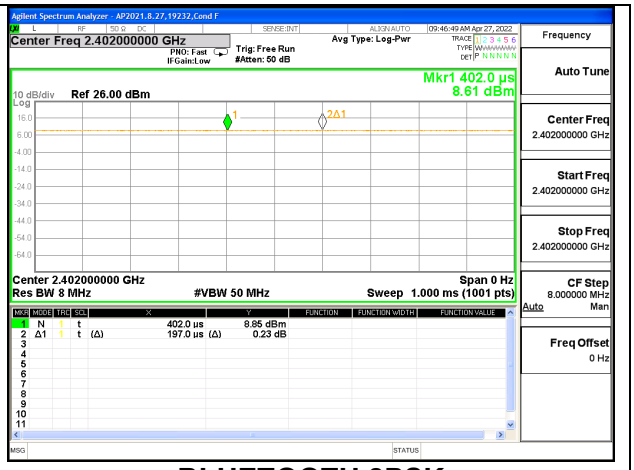
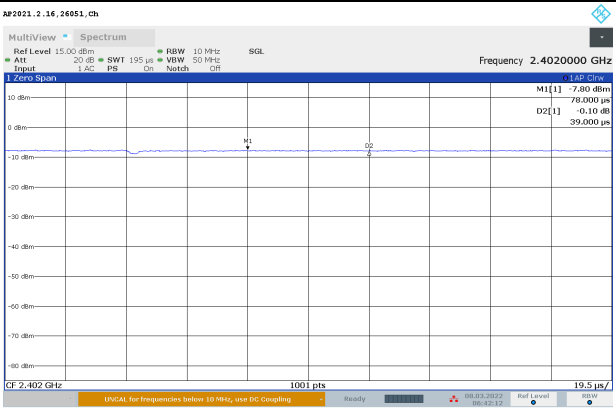
DUTY CYCLE PLOTS



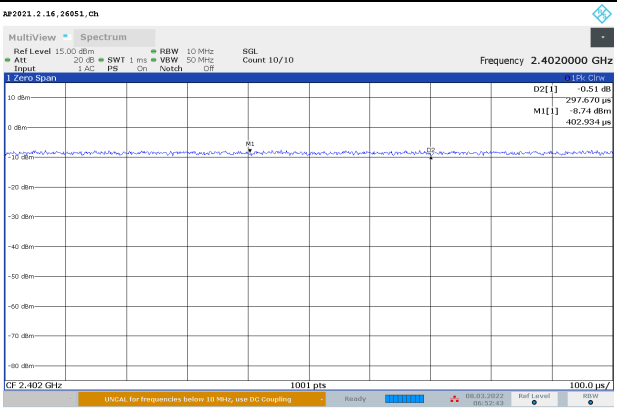
BLUETOOTH GFSK



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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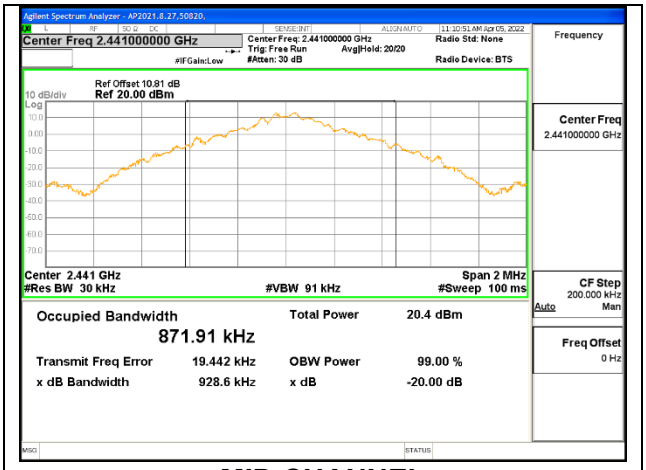
9.2.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4

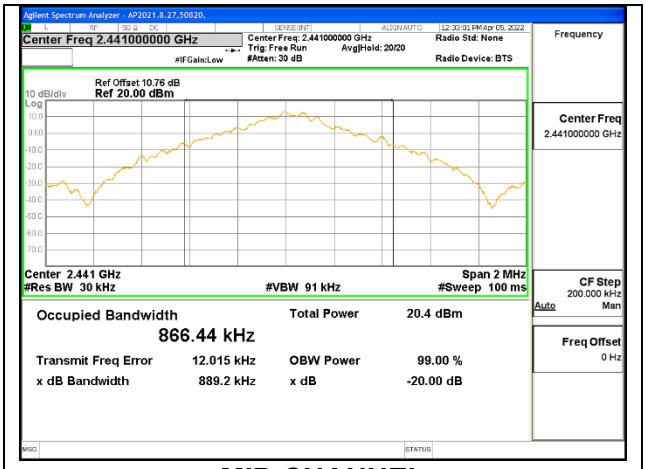
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.889	0.865
Mid	2441	0.929	0.872
High	2480	0.927	0.874



MID CHANNEL

ANT 3

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.889	0.866
Mid	2441	0.889	0.866
High	2480	0.889	0.868



MID CHANNEL

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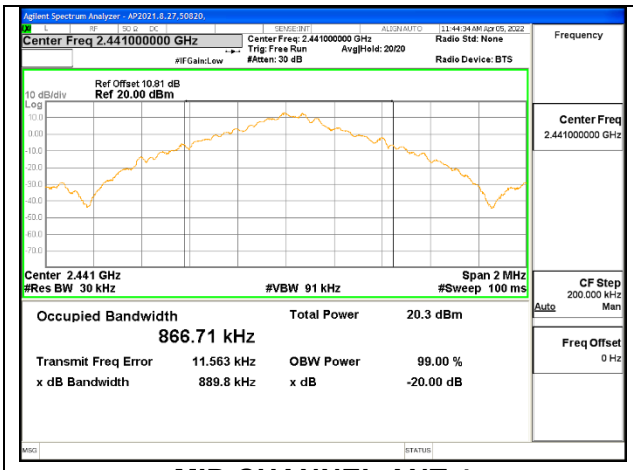
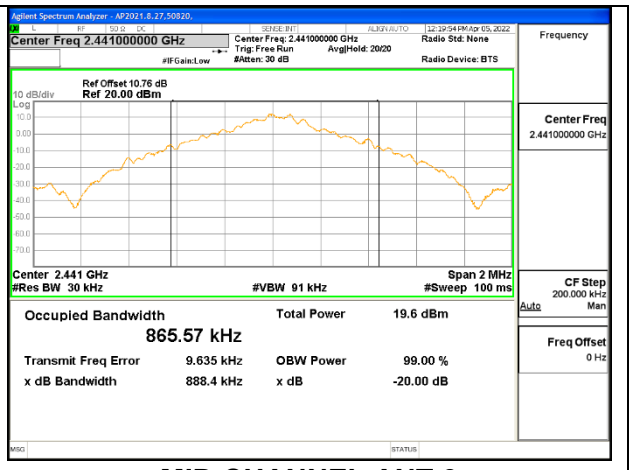
9.2.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

Note: Test procedure on beamforming mode is 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	0.932	0.919	0.871	0.866
Mid	2441	0.890	0.888	0.867	0.866
High	2480	0.888	0.888	0.866	0.868



MID CHANNEL ANT 4



MID CHANNEL ANT 3

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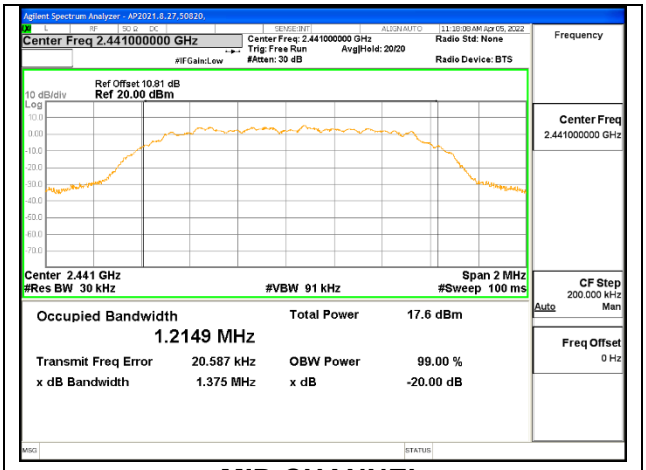
9.2.3. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

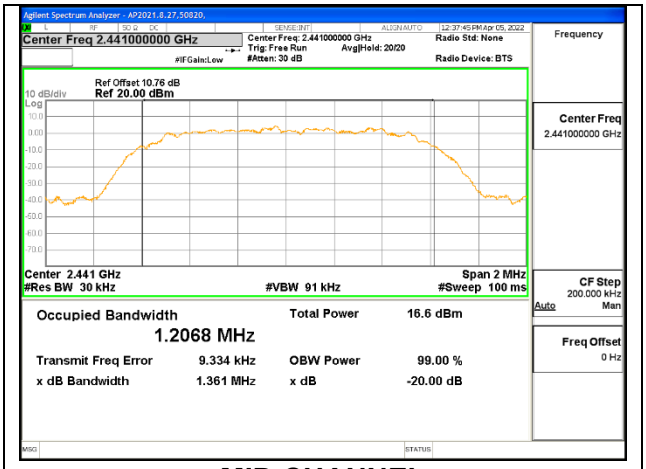
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.368	1.213
Mid	2441	1.375	1.215
High	2480	1.363	1.208



MID CHANNEL

ANT 3

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.364	1.208
Mid	2441	1.361	1.207
High	2480	1.365	1.209



MID CHANNEL

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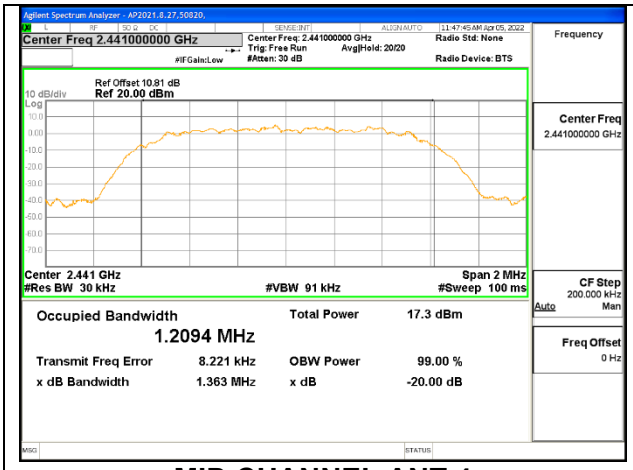
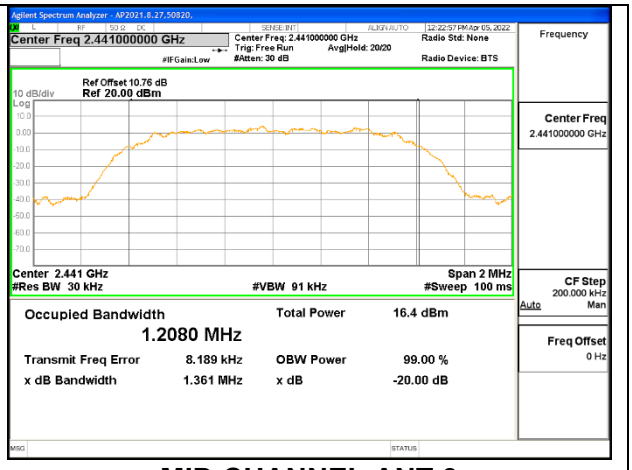
9.2.4. HIGH POWER ENHANCED DATA RATE TXBF 8PSK MODULATION

Note: Test procedure on beamforming mode is 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	1.366	1.382	1.210	1.208
Mid	2441	1.363	1.361	1.209	1.208
High	2480	1.366	1.364	1.208	1.209



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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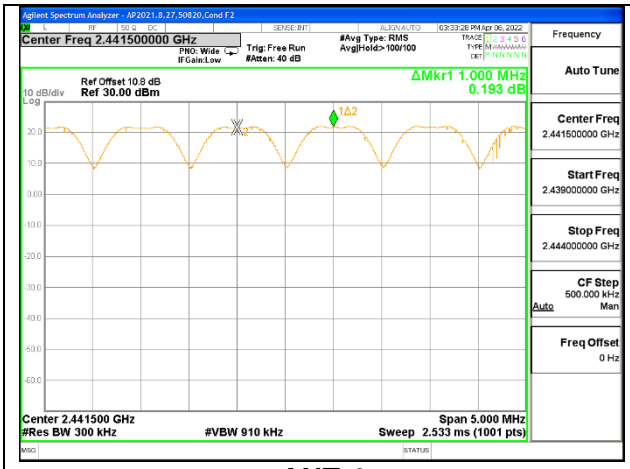
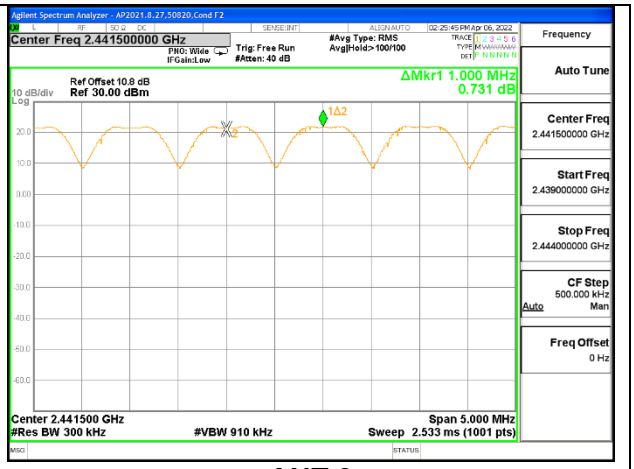
9.3.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

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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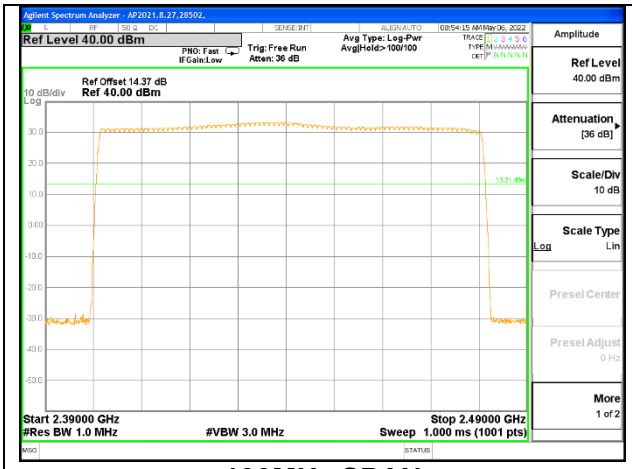
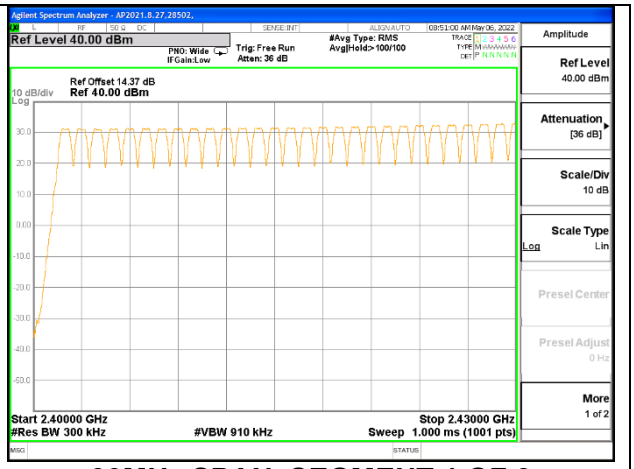
9.4.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

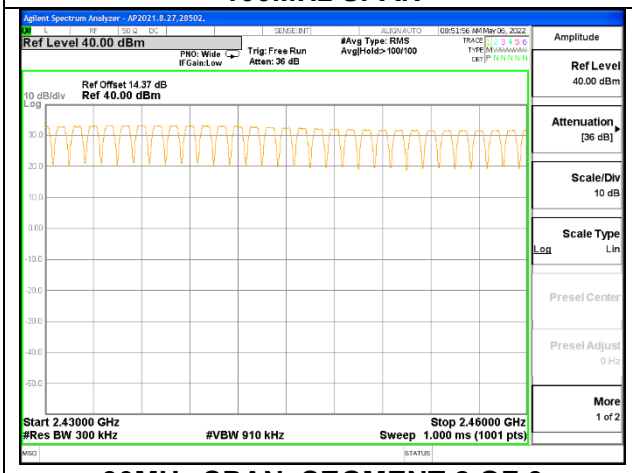
ANT 4



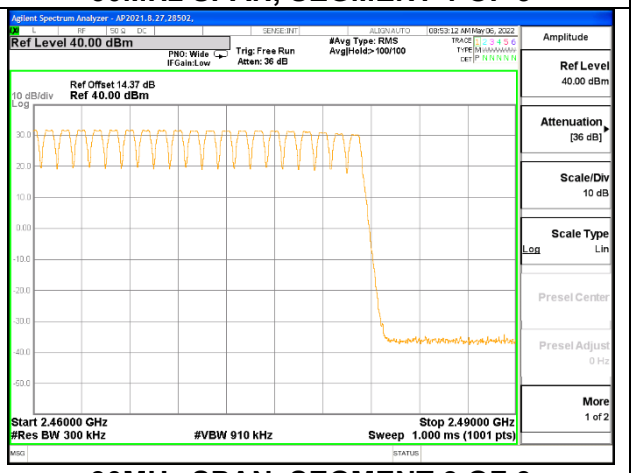
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



30MHz SPAN, SEGMENT 2 OF 3



30MHz SPAN, SEGMENT 3 OF 3

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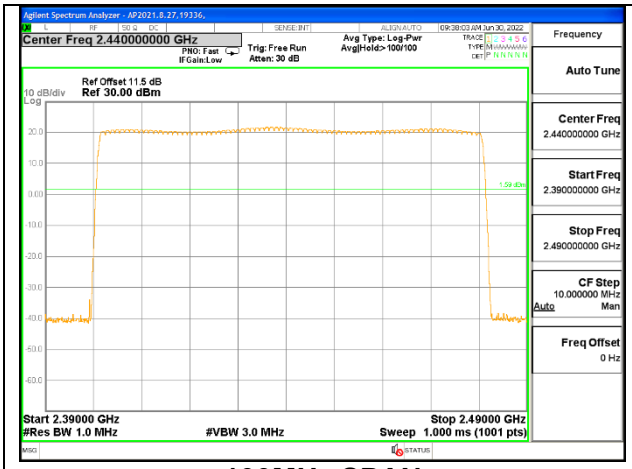
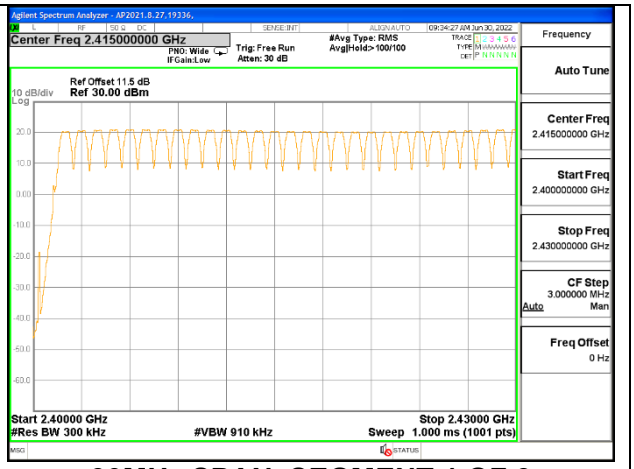
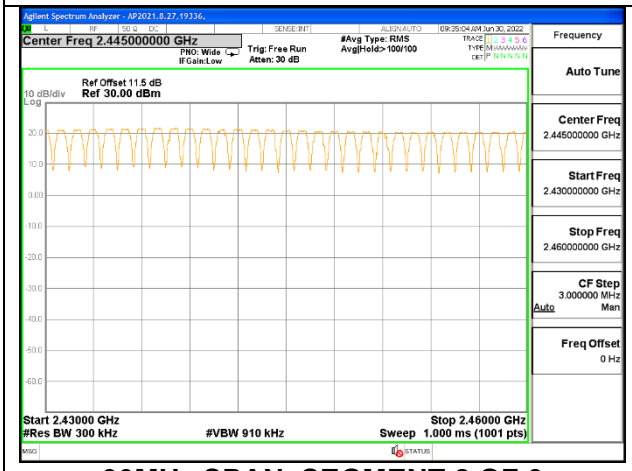
ANT 3



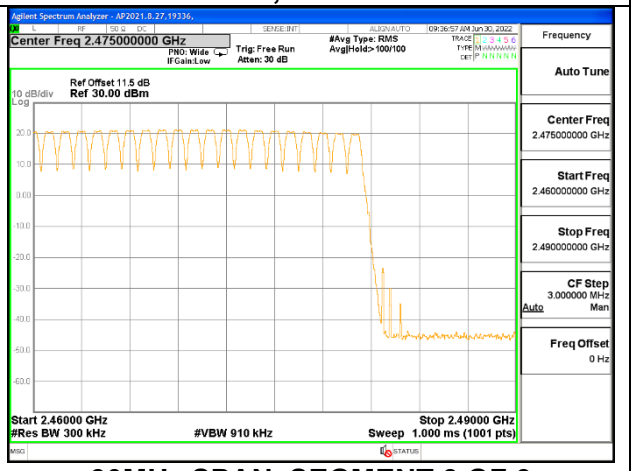
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



30MHz SPAN, SEGMENT 2 OF 3



30MHz SPAN, SEGMENT 3 OF 3

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	1.630	15	0.245	0.4	-0.156
DH5	2.872	11	0.316	0.4	-0.084
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	1.63	3.75	0.061	0.4	-0.339
DH5	2.872	2.75	0.079	0.4	-0.321

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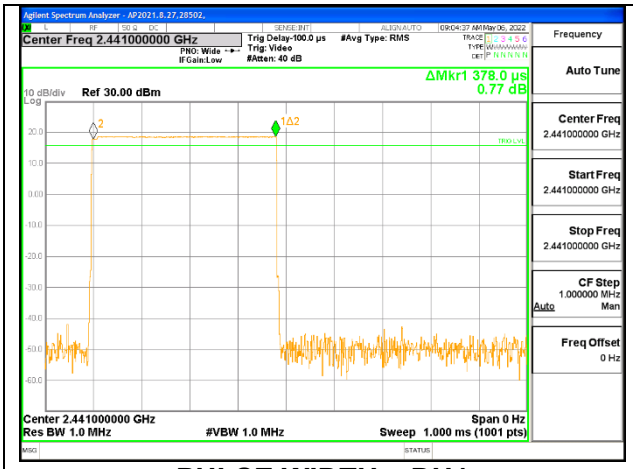
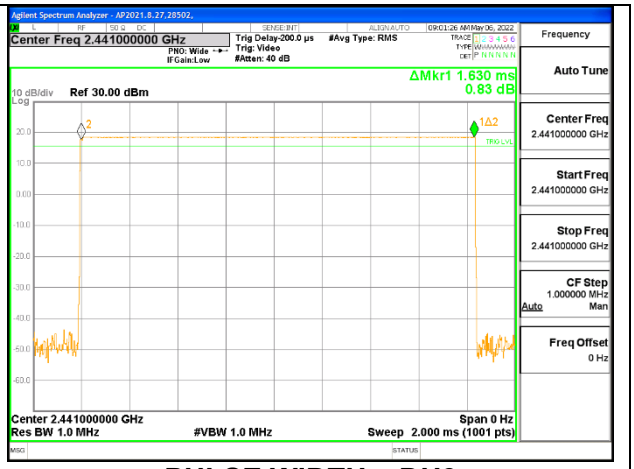
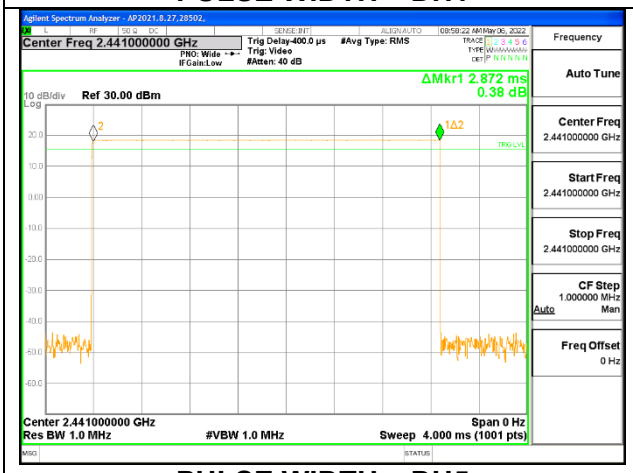


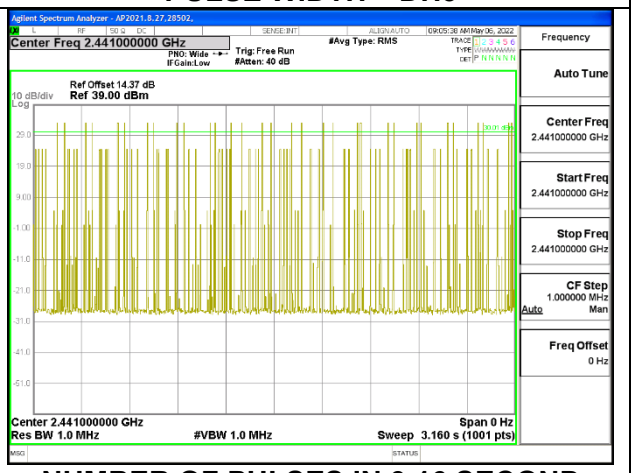
PULSE WIDTH – DH1



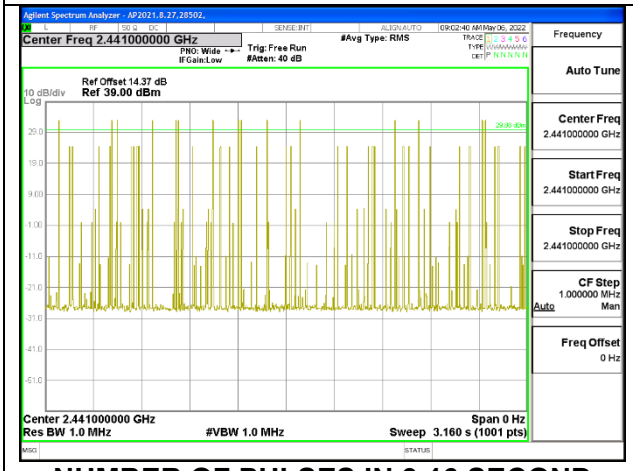
PULSE WIDTH – DH3



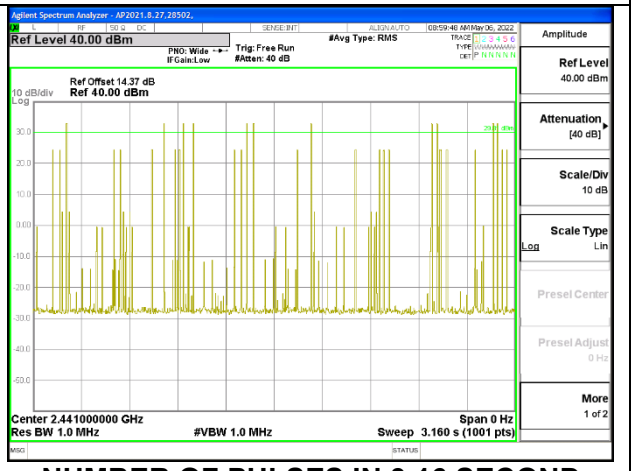
PULSE WIDTH – DH5



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

ANT 3

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	0.383	32	0.123	0.4	-0.277
DH3	1.630	13	0.212	0.4	-0.188
DH5	2.876	10	0.288	0.4	-0.112
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	0.383	8.00	0.031	0.4	-0.369
DH3	1.63	3.25	0.053	0.4	-0.347
DH5	2.876	2.50	0.072	0.4	-0.328

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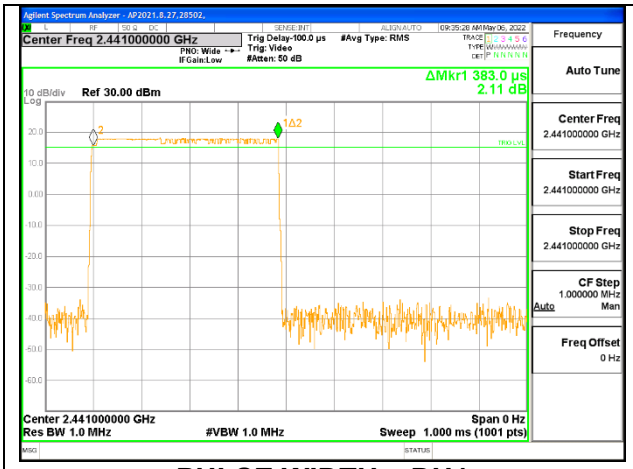
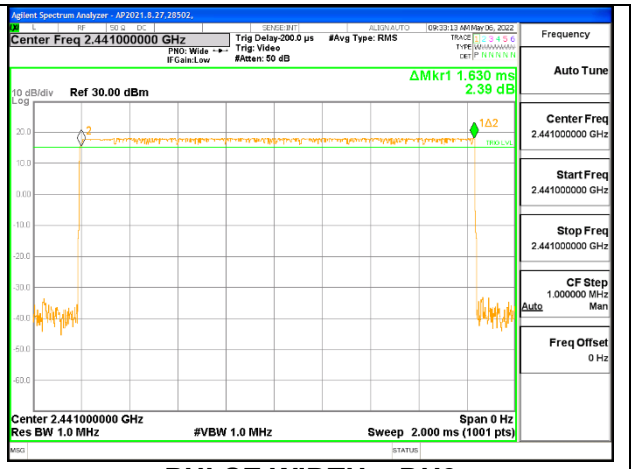
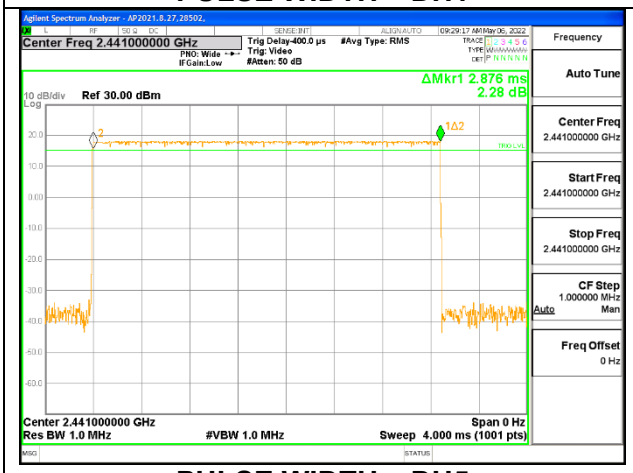


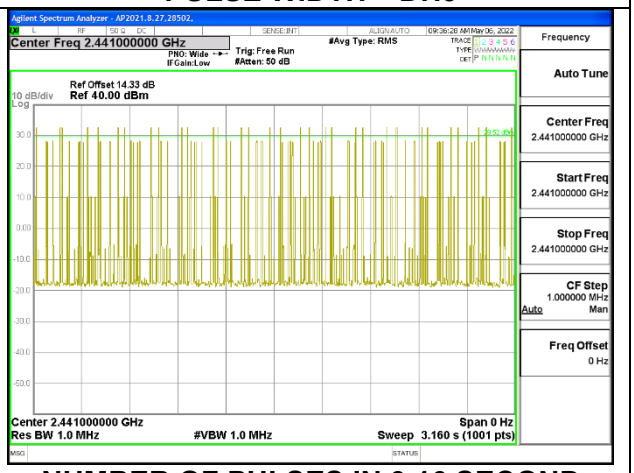
PULSE WIDTH – DH1



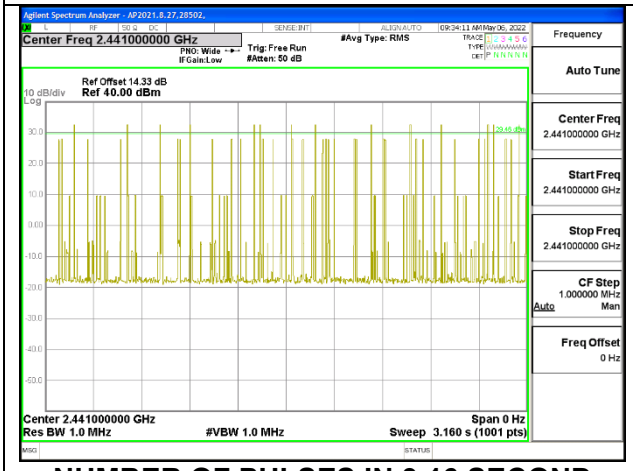
PULSE WIDTH – DH3



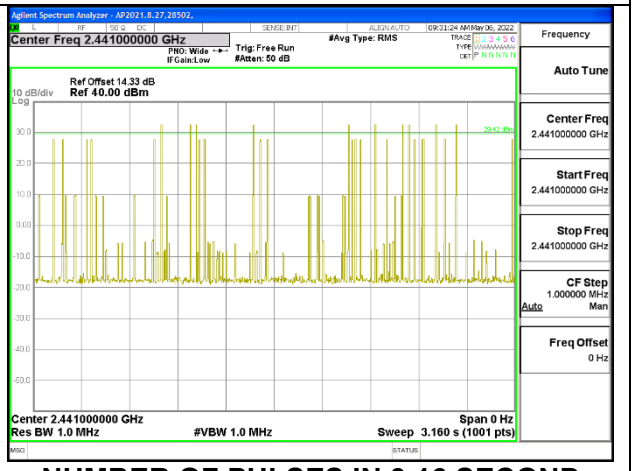
PULSE WIDTH – DH5



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)	Uncorrelated Chains Directional Gain (dBi)	Correlated Chains Directional Gain (dBi)
2.4	-1.80	0.60	-0.44	2.49

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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=-1.80, Ant2=0.6

Uncorrelated Antenna gain=10log[(10^(-1.8/10)+10^(0.6/10))/2]=-0.44dBi

Correlated Antenna gain=10log[(10^(-1.8/20)+10^(0.6/20))^2)/2]=2.49

RESULTS

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9.6.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	19.63	21	-1.37
Middle	2441	19.64	21	-1.36
High	2480	19.60	21	-1.4

ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	19.72	21	-1.28
Middle	2441	19.72	21	-1.28
High	2480	19.73	21	-1.27

9.6.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	16.60	16.67	19.65	21	-1.35
Middle	2441	16.64	16.70	19.68	21	-1.32
High	2480	16.66	16.57	19.63	21	-1.37

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9.6.3. HIGH POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.54	21	-2.46
Middle	2441	18.52	21	-2.48
High	2480	18.57	21	-2.43

ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.60	21	-2.4
Middle	2441	18.62	21	-2.38
High	2480	18.57	21	-2.43

9.6.4. HIGH POWER ENHANCED DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	14.97	15.40	18.20	21	-2.80
Middle	2441	15.40	15.25	18.34	21	-2.66
High	2480	15.38	15.42	18.41	21	-2.59

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9.6.5. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.76	21	-2.24
Middle	2441	18.77	21	-2.23
High	2480	18.77	21	-2.23

ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.83	21	-2.17
Middle	2441	18.85	21	-2.15
High	2480	18.80	21	-2.2

9.6.6. HIGH POWER ENHANCED DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	15.61	15.84	18.74	21	-2.26
Middle	2441	15.85	15.65	18.76	21	-2.24
High	2480	15.84	15.85	18.86	21	-2.14

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9.6.7. LOW POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.17	21	-9.83
Middle	2441	11.25	21	-9.75
High	2480	10.93	21	-10.07

ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.03	21	-9.97
Middle	2441	11.20	21	-9.8
High	2480	11.24	21	-9.76

9.6.8. LOW POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.03	11.15	14.10	21	-6.90
Middle	2441	11.12	11.14	14.14	21	-6.86
High	2480	11.08	11.18	14.14	21	-6.86

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9.6.9. LOW POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.08	21	-9.92
Middle	2441	11.04	21	-9.96
High	2480	11.13	21	-9.87

ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	10.90	21	-10.1
Middle	2441	10.88	21	-10.12
High	2480	10.85	21	-10.15

9.6.10. LOW POWER ENHANCED DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.04	11.00	14.03	21	-6.97
Middle	2441	11.10	11.01	14.07	21	-6.93
High	2480	11.10	10.98	14.05	21	-6.95

9.6.11. LOW POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.40	21	-9.6
Middle	2441	11.36	21	-9.64
High	2480	11.46	21	-9.54

ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	10.83	21	-10.17
Middle	2441	10.83	21	-10.17
High	2480	11.13	21	-9.87

9.6.12. LOW POWER ENHANCED DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Output Power ANT 4 (dBm)	Output Power ANT 3 (dBm)	Total Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	11.06	11.02	14.05	21	-6.95
Middle	2441	11.16	11.08	14.13	21	-6.87
High	2480	11.15	11.02	14.10	21	-6.90

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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:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	19.42
Middle	2441	19.43
High	2480	19.40

ANT 3

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	19.42
Middle	2441	19.42
High	2480	19.43

9.7.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	16.40	16.45	19.44
Middle	2441	16.45	16.48	19.48
High	2480	16.47	16.43	19.46

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9.7.3. HIGH POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	15.91
Middle	2441	15.92
High	2480	15.95

ANT 3

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	15.90
Middle	2441	15.92
High	2480	15.86

9.7.4. HIGH POWER BASIC DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	12.67	12.90	15.80
Middle	2441	12.91	12.74	15.84
High	2480	12.88	12.92	15.91

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9.7.5. HIGH POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	15.96
Middle	2441	15.97
High	2480	15.97

ANT 3

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	15.93
Middle	2441	15.95
High	2480	15.91

9.7.6. HIGH POWER BASIC DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	12.71	12.95	15.84
Middle	2441	12.95	12.76	15.87
High	2480	12.94	12.96	15.96

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9.7.7. LOW POWER BASIC DATA RATE GFSK MODULATION

ANT 4

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	10.88
Middle	2441	10.95
High	2480	10.70

ANT 3

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	10.88
Middle	2441	10.95
High	2480	10.95

9.7.8. LOW POWER BASIC DATA RATE TXBF GFSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	10.78	10.94	13.87
Middle	2441	10.82	10.92	13.88
High	2480	10.80	10.93	13.88

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9.7.9. LOW POWER ENHANCED DATA RATE QPSK MODULATION

ANT 4

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.38
Middle	2441	8.34
High	2480	8.43

ANT 3

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.31
Middle	2441	8.30
High	2480	8.28

9.7.10. LOW POWER BASIC DATA RATE TXBF QPSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	8.33	8.28	11.32
Middle	2441	8.40	8.31	11.37
High	2480	8.40	8.27	11.35

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9.7.11. LOW POWER ENHANCED DATA RATE 8PSK MODULATION

ANT 4

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.41
Middle	2441	8.36
High	2480	8.46

ANT 3

Tested By:	19172
Date	5/31/2022

Channel	Frequency (MHz)	Average Power (dBm)
Low	2402	8.33
Middle	2441	8.33
High	2480	8.43

9.7.12. LOW POWER BASIC DATA RATE TXBF 8PSK MODULATION

ANT 4 + ANT 3

Tested By:	19172
Date:	5/31/2022

Channel	Frequency (MHz)	Average Power ANT 4 (dBm)	Average Power ANT 3 (dBm)	Total Power (dBm)
Low	2402	8.36	8.32	11.35
Middle	2441	8.46	8.35	11.42
High	2480	8.45	8.31	11.39

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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.

RESULTS

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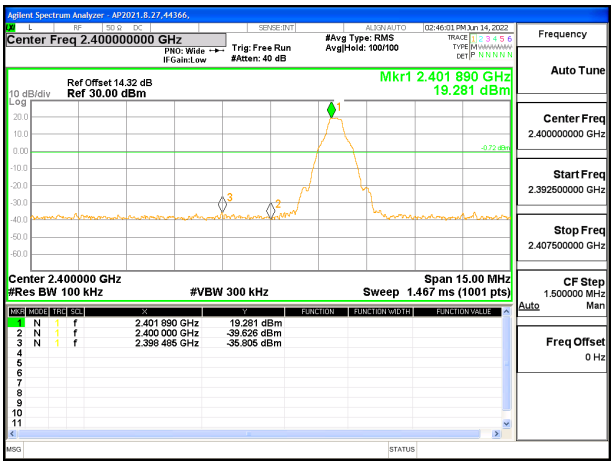
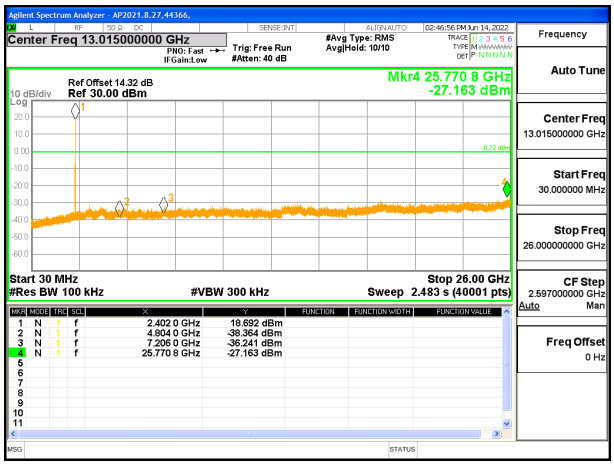
9.8.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

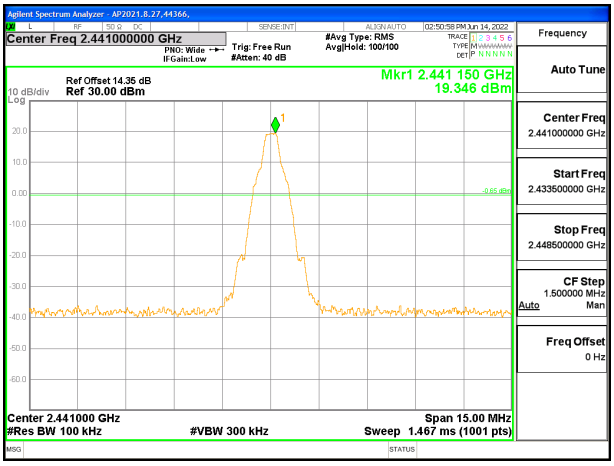
ANT 4 SPURIOUS EMISSIONS, NON-HOPPING



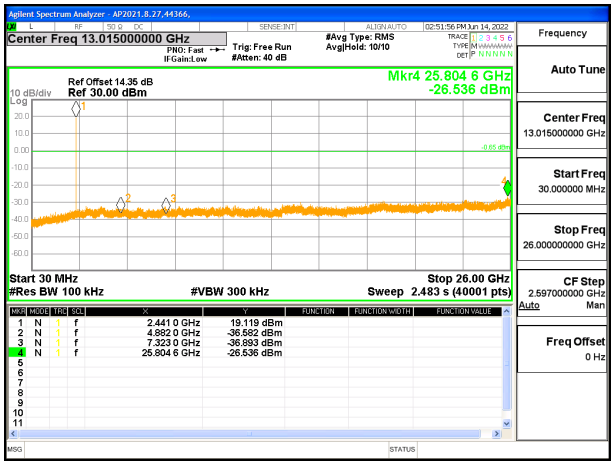
LOW CHANNEL BANDEDGE



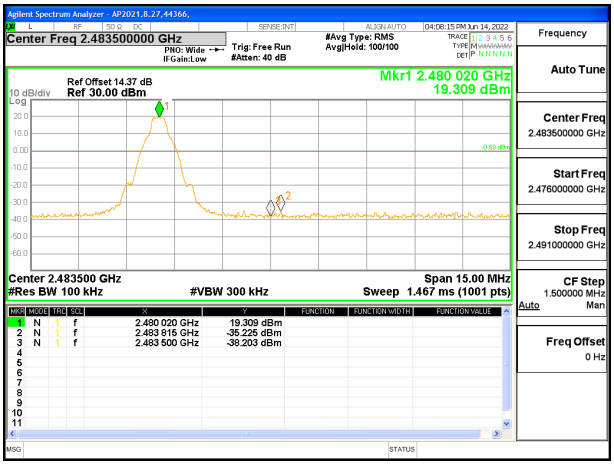
OUT-OF-BAND LOW CHANNEL



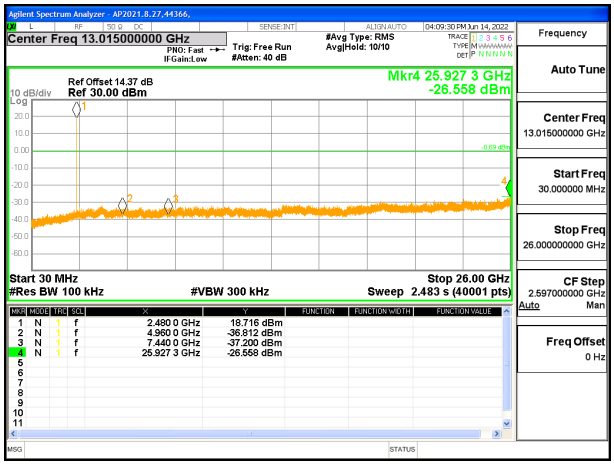
IN-BAND REFERENCE LEVEL



OUT-OF-BAND MID CHANNEL

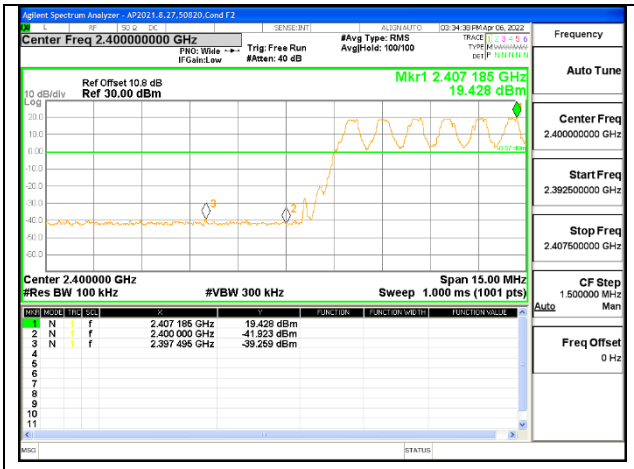


HIGH CHANNEL BANDEDGE

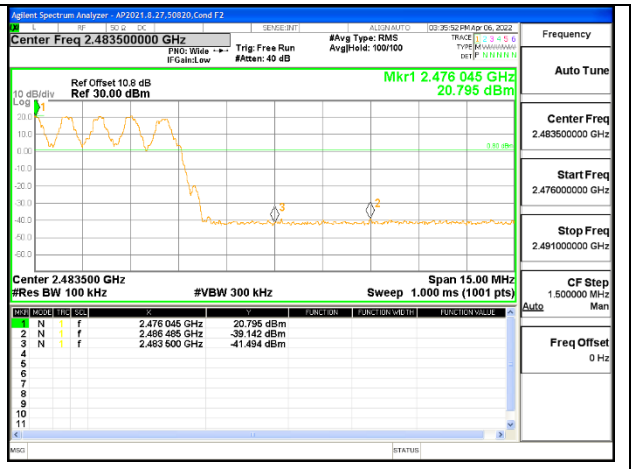


OUT-OF-BAND HIGH CHANNEL

ANT 4 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE



HIGH BANDEDGE

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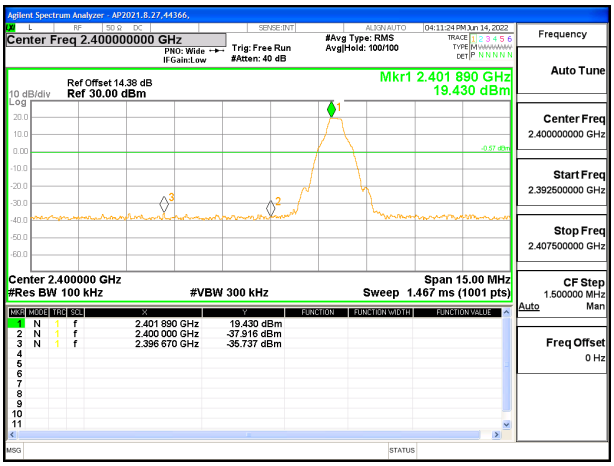
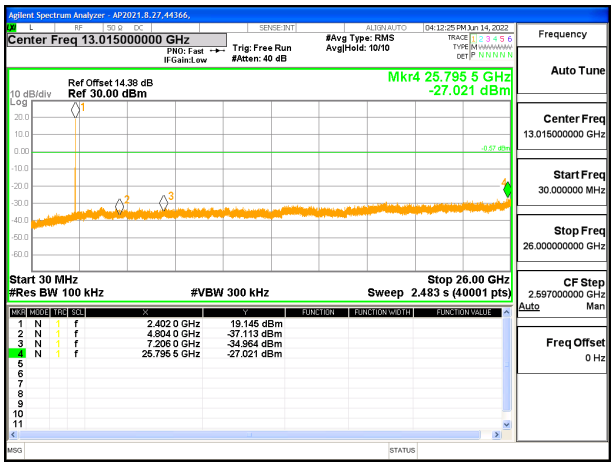
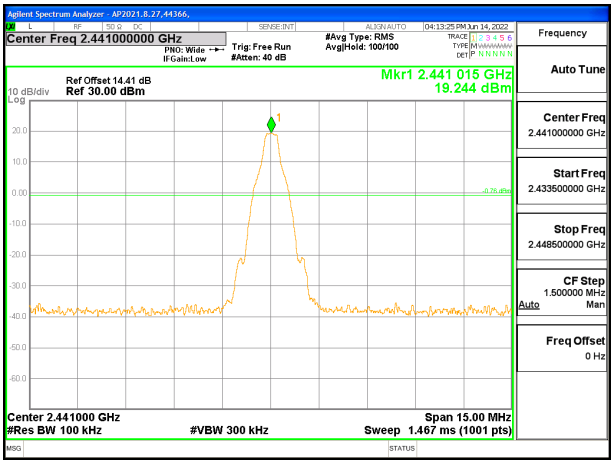
ANT 3 SPURIOUS EMISSIONS, NON-HOPPING



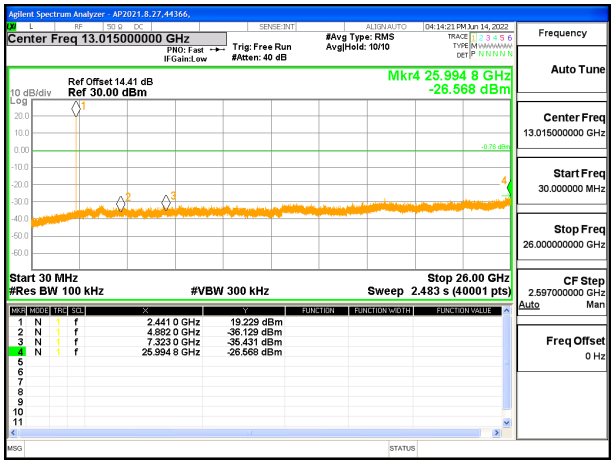
LOW CHANNEL BANDEDGE



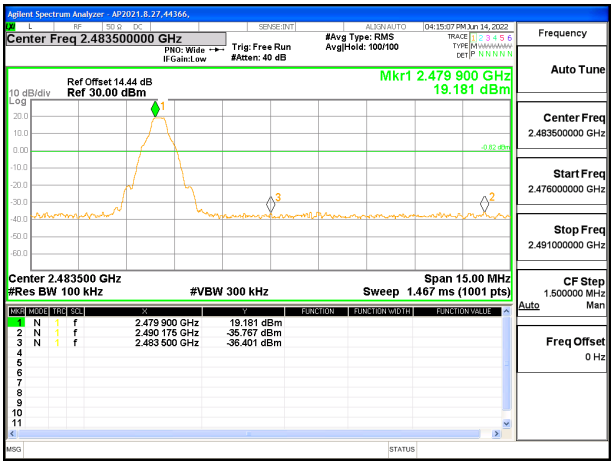
OUT-OF-BAND LOW CHANNEL



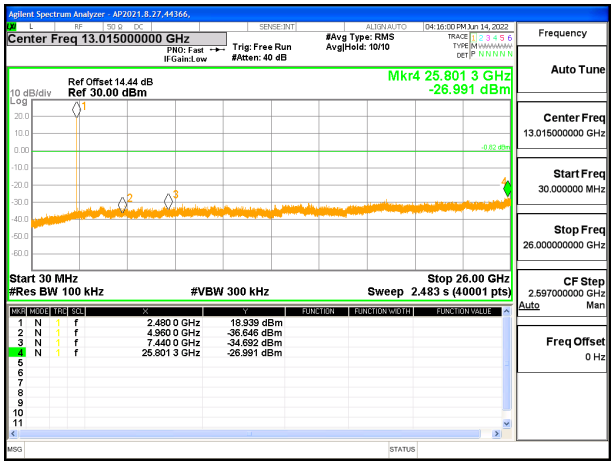
IN-BAND REFERENCE LEVEL



OUT-OF-BAND MID CHANNEL

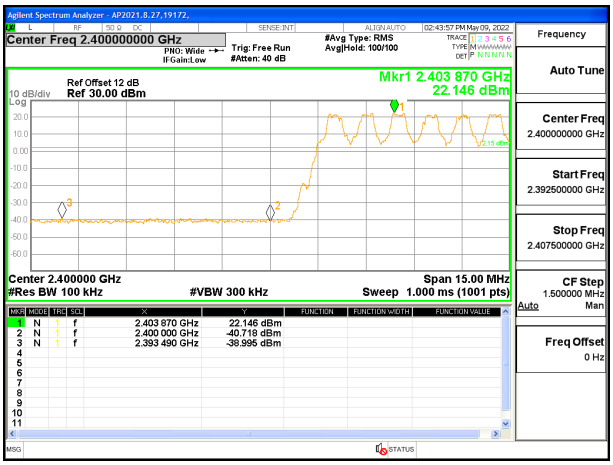


HIGH CHANNEL BANDEDGE

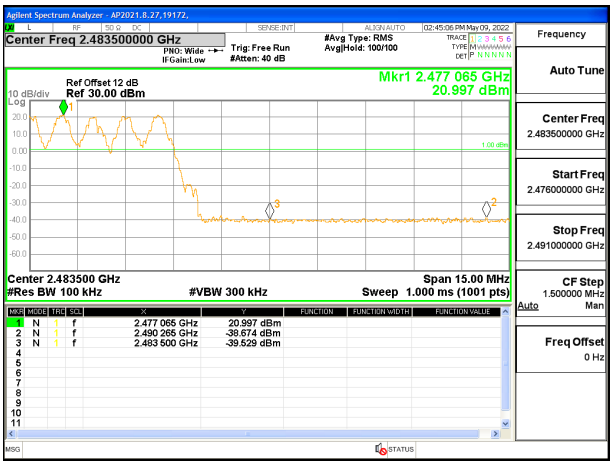


OUT-OF-BAND HIGH CHANNEL

ANT 3 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE



HIGH BANDEDGE

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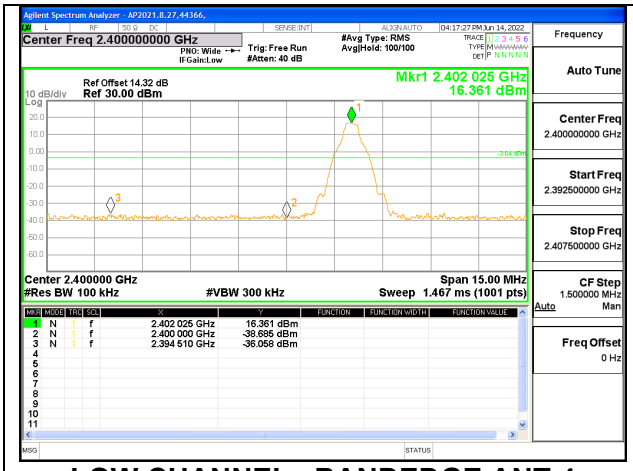
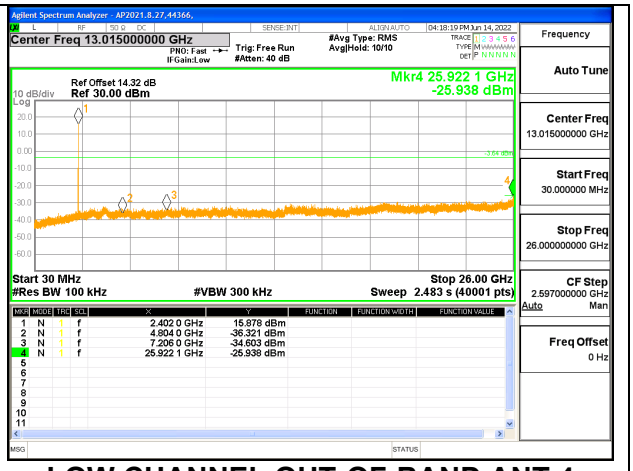
9.8.2. HIGH POWER BASIC DATA RATE TXBF GFSK MODULATION

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

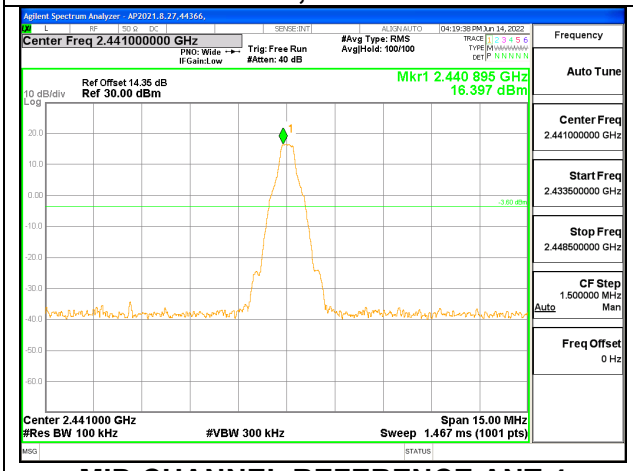
ANT 4 SPURIOUS EMISSIONS, NON-HOPPING



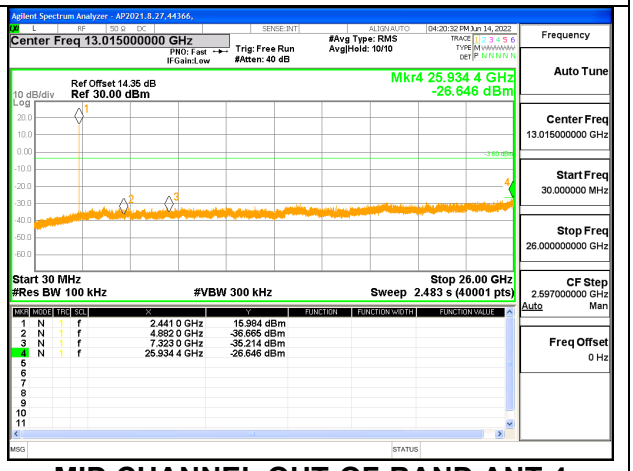
LOW CHANNEL , BANDEDGE ANT 4



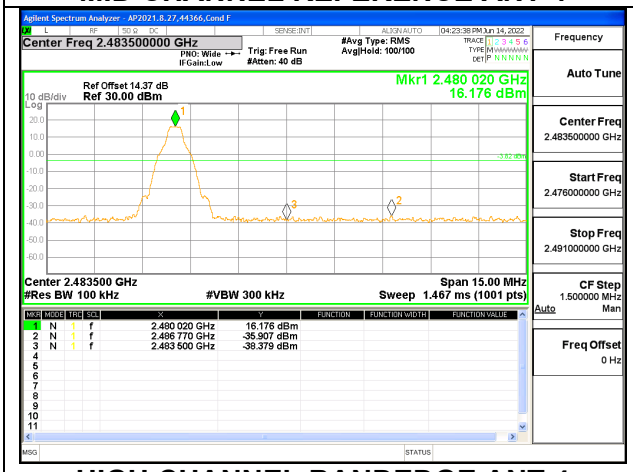
LOW CHANNEL OUT-OF-BAND ANT 4



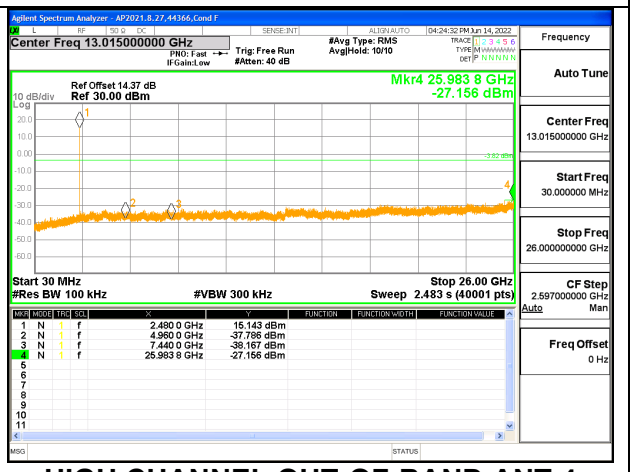
MID CHANNEL REFERENCE ANT 4



MID CHANNEL OUT-OF-BAND ANT 4

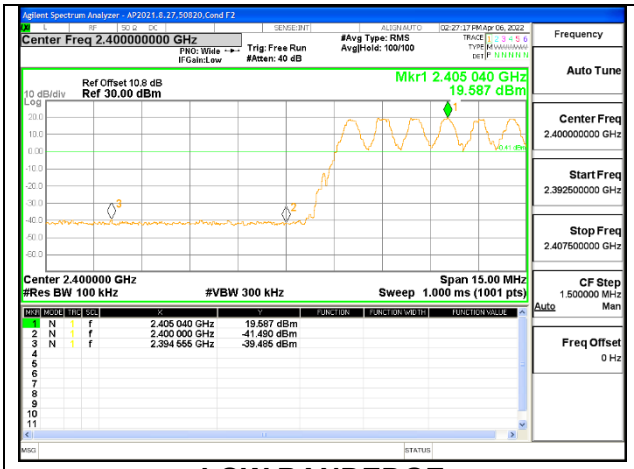


HIGH CHANNEL BANDEDGE ANT 4

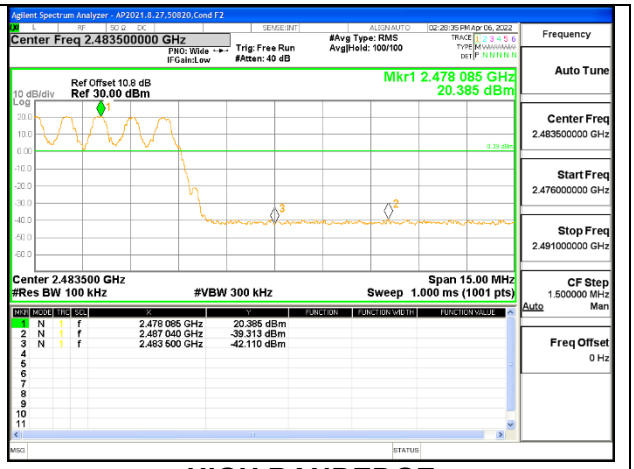


HIGH CHANNEL OUT-OF-BAND ANT 4

ANT 4 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE



HIGH BANDEDGE

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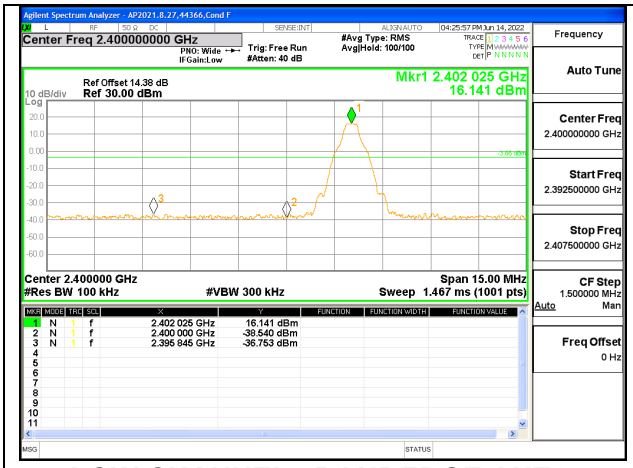
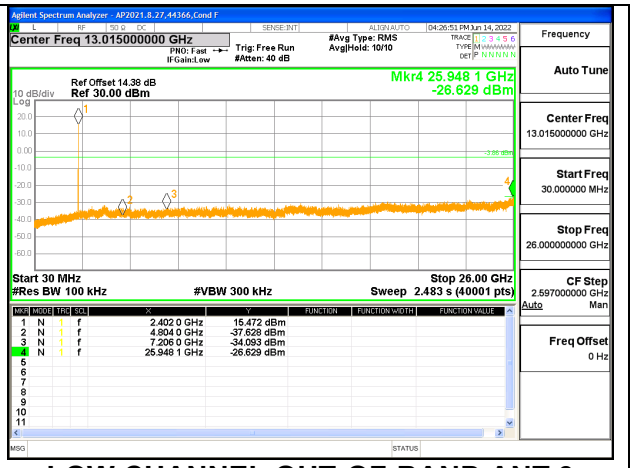
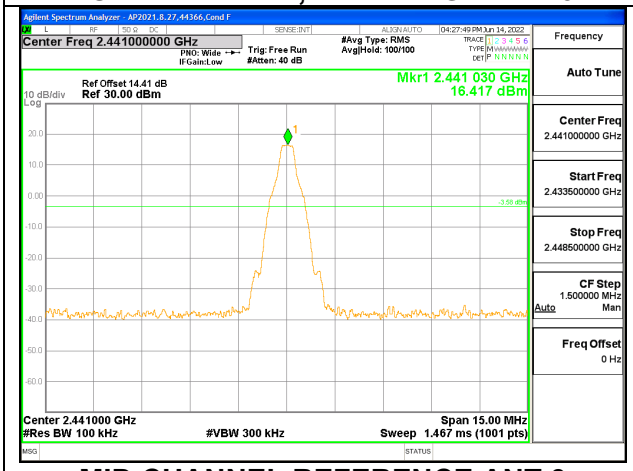
ANT 3 SPURIOUS EMISSIONS, NON-HOPPING



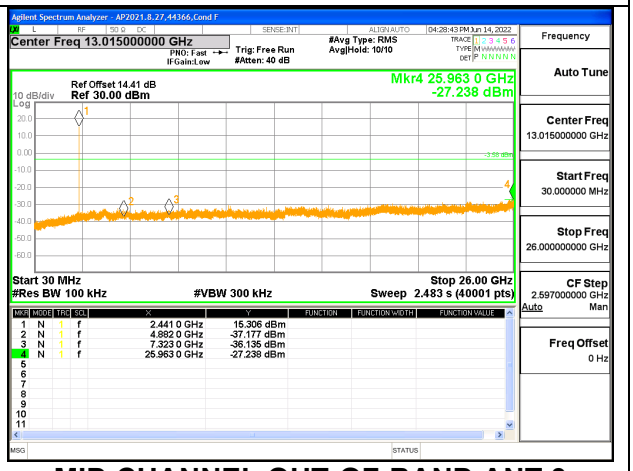
LOW CHANNEL , BANDEDGE ANT 3



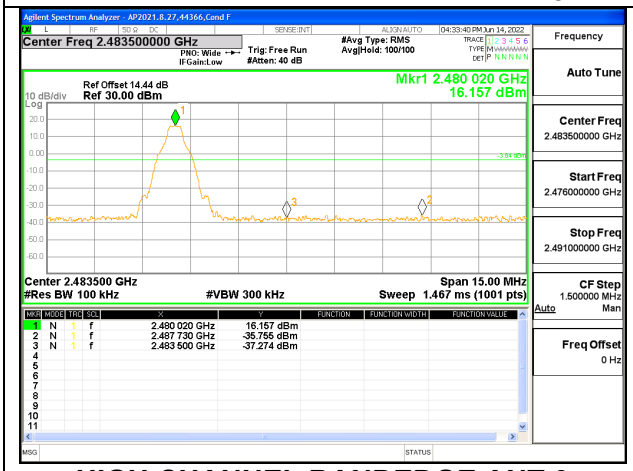
LOW CHANNEL OUT-OF-BAND ANT 3



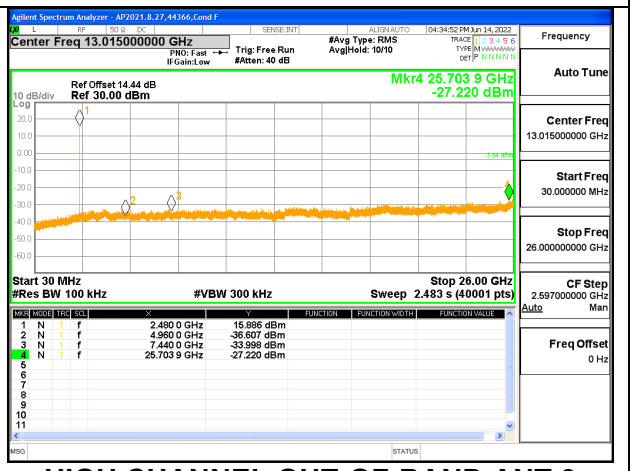
MID CHANNEL REFERENCE ANT 3



MID CHANNEL OUT-OF-BAND ANT 3



HIGH CHANNEL BANDEDGE ANT 3



HIGH CHANNEL OUT-OF-BAND ANT 3

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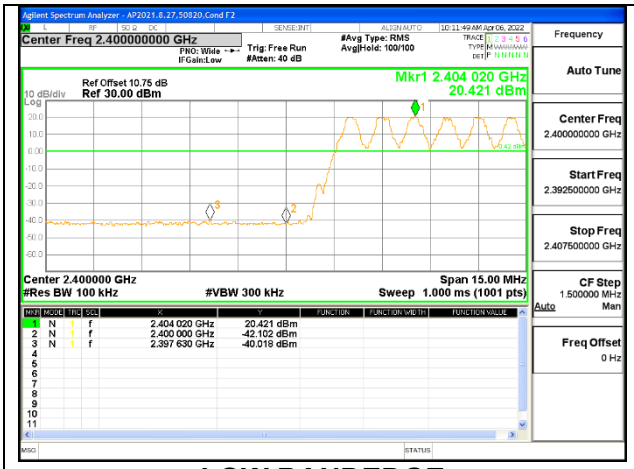
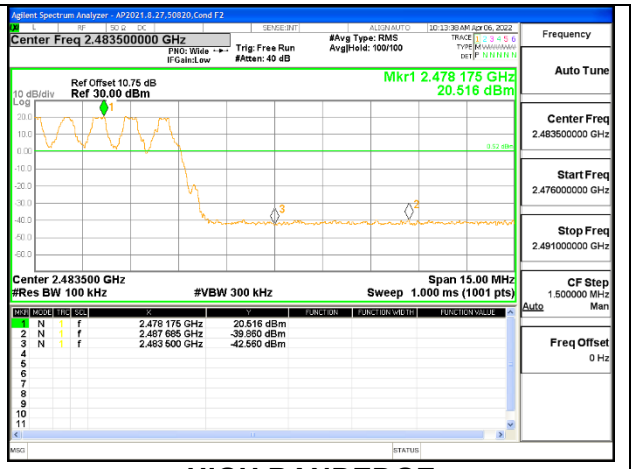
ANT 3 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE



HIGH BANDEDGE

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