



CERTIFICATION TEST REPORT

Report Number. : 12258201-E1V2

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

Model : A2106

FCC ID : BCG-E3238A

IC : 579C-E3238A

EUT Description : SMARTPHONE

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

Date Of Issue:
August 28, 2018

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REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	8/22/2018	Initial Issue	Chin Pang
V2	8/28/2018	Address TCB questions	Jingang 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: A2016

SERIAL NUMBER: C7CWW04EKJRC

DATE TESTED: MAY 31 – JULY 27, 2018

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

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Verification Services Inc. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

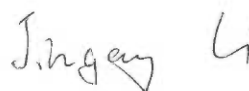
Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. 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 NVLAP, NIST, any agency of the Federal Government, or any agency of the U.S. government.

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2. 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, RSS-GEN Issue 5, and RSS-247 Issue 2.

3. FACILITIES AND ACCREDITATION

The test sites and measurement facilities used to collect data are located at 47173 and 47266 Benicia Street, and 47658 Kato Road, Fremont, California, USA. Line conducted emissions are measured only at the 47173 address. The following table identifies which facilities were utilized for radiated emission measurements documented in this report. Specific facilities are also identified in the test results sections.

47173 Benicia Street	47266 Benicia Street	47658 Kato Rd
☒ Chamber A (ISED:2324B-1)	☐ Chamber D (ISED:22541-1)	☐ Chamber K (ISED:2324A-1)
☐ Chamber B (ISED:2324B-2)	☒ Chamber E (ISED:22541-2)	☐ Chamber L (ISED:2324A-3)
☐ Chamber C (ISED:2324B-3)	☐ Chamber F (ISED:22541-3)	
	☐ Chamber G (ISED:22541-4)	
	☐ Chamber H (ISED:22541-5)	

The above test sites and facilities are covered under FCC Test Firm Registration # 208313. Chambers A through C are covered under ISED company address code 2324B with site numbers 2324B -1 through 2324B-3, respectively. Chambers D through H are covered under ISED company address code 22541 with site numbers 22541 -1 through 22541-5, respectively. Chambers K and L are covered under ISED company address code 2324A with site numbers 2324A-1 and 2324A-3, respectively.

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0

4. CALIBRATION AND UNCERTAINTY

4.1. MEASURING INSTRUMENT CALIBRATION

The measuring equipment utilized to perform the tests documented in this report has been calibrated in accordance with the manufacturer's recommendations, and is traceable to recognized national standards.

4.2. SAMPLE CALCULATION

Where relevant, the following sample calculation is provided:

$$\begin{aligned} \text{Field Strength (dBuV/m)} &= \text{Measured Voltage (dBuV)} + \text{Antenna Factor (dB/m)} + \\ &\text{Cable Loss (dB)} - \text{Preamp Gain (dB)} \\ 36.5 \text{ dBuV} + 18.7 \text{ dB/m} + 0.6 \text{ dB} - 26.9 \text{ dB} &= 28.9 \text{ dBuV/m} \end{aligned}$$

4.3. MEASUREMENT UNCERTAINTY

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

PARAMETER	UNCERTAINTY
Worst Case Conducted Disturbance, 9KHz to 0.15 MHz	3.84 dB
Worst Case Conducted Disturbance, 0.15 to 30 MHz	3.65 dB
Worst Case Radiated Disturbance, 9KHz to 30 MHz	3.15 dB
Worst Case Radiated Disturbance, 30 to 1000 MHz	5.36 dB
Worst Case Radiated Disturbance, 1000 to 18000 MHz	4.32 dB
Worst Case Radiated Disturbance, 18000 to 26000 MHz	4.45 dB
Worst Case Radiated Disturbance, 26000 to 40000 MHz	5.24 dB

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

5. EQUIPMENT UNDER TEST

5.1. EUT DESCRIPTION

The Apple iPhone, is a smartphone with multimedia functions (music, application support, and video), cellular GSM, GPRS, EGPRS, UMTS, LTE, TD-SCDMA, CDMA, IEEE 802.11a/b/g/n/ac, Bluetooth, GPS and NFC. All models support at least one UICC based SIM. The second SIM is either UICC based, electronic SIM (e-SIM), or second SIM is not present. The device has a built-in inductive charging receiver which is not user accessible. The rechargeable battery is not user accessible.

5.2. 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 2	High Power	2402 - 2480	Basic GFSK	20.39	109.40
		2402 - 2480	DQPSK	19.70	93.33
		2402 - 2480	Enhanced 8PSK	19.75	94.41
	Low Power	2402 - 2480	Basic GFSK	11.45	13.96
		2402 - 2480	DQPSK	10.15	10.35
		2402 - 2480	Enhanced 8PSK	10.21	10.50
Ant 5	High Power	2402 - 2480	Basic GFSK	20.37	108.89
		2402 - 2480	DQPSK	19.67	92.68
		2402 - 2480	Enhanced 8PSK	19.73	93.97
	Low Power	2402 - 2480	Basic GFSK	11.35	13.65
		2402 - 2480	DQPSK	10.14	10.33
		2402 - 2480	Enhanced 8PSK	10.18	10.42

5.3. DESCRIPTION OF AVAILABLE ANTENNAS

Frequency Range (GHz)	Ant. 2 (dBi)	Ant. 5 (dBi)
2.4	-2.8	-4.9

5.4. SOFTWARE AND FIRMWARE

The EUT firmware installed during testing was v1.29.99992

The test utility software used during testing was QRCT v3.0.264.0.

5.5. WORST-CASE CONFIGURATION AND MODE

The EUT was investigated in three orthogonal orientations X, Y and Z on Ant 3 (Antenna 3) and Ant 4 (Antenna 4), it was determined that Y (Landscape) orientation was the worst-case orientation for Ant 4 and Ant 3.

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

Below 1GHz tests were performed with EUT 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. There were no emissions found below 30MHz within 20dB of the limit.

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

GFSK, DQPSK, 8PSK average power are all investigated, The GFSK & 8PSK power are the worst case. For average power data please refer to section 8.7.

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

GFSK mode: DH5
8PSK mode: 3-DH5

There are two vendors of the WiFi/Bluetooth radio modules: variant 1 and variant 2. The Wi-Fi/Bluetooth 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 two variants to determine the worst case on all conducted power and radiated emissions.

Bluetooth RF output path is switched when the power exceeds 11dBm. Measurements were made therefore at the maximum power setting (with amplifier switched in) and also at the 11dBm power level (amplifier switched out) , and they are the high power and low power modes documented in this report respectively.

5.6. DESCRIPTION OF TEST SETUP

SUPPORT EQUIPMENT

Support Equipment List				
Description	Manufacturer	Model	Serial Number	FCC ID
laptop	Apple	Macbook Pro	C02P41RZG086	FCC DoC
Laptop AC/DC adapter	Liteon Technology	PA-1450-BA1	B123	NA
EUT AC Adapter	Apple	A1385	D292365CDYADHLHC3	NA

I/O CABLES (CONDUCTED TEST)

I/O Cable List						
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	N/A
3	AC	1	AC	Un-shielded	2	N/A

I/O CABLES (RADIATED ABOVE 1 GHZ)

I/O Cable List						
Cable No	Port	# of identical ports	Connector Type	Cable Type	Cable Length (m)	Remarks
NA						

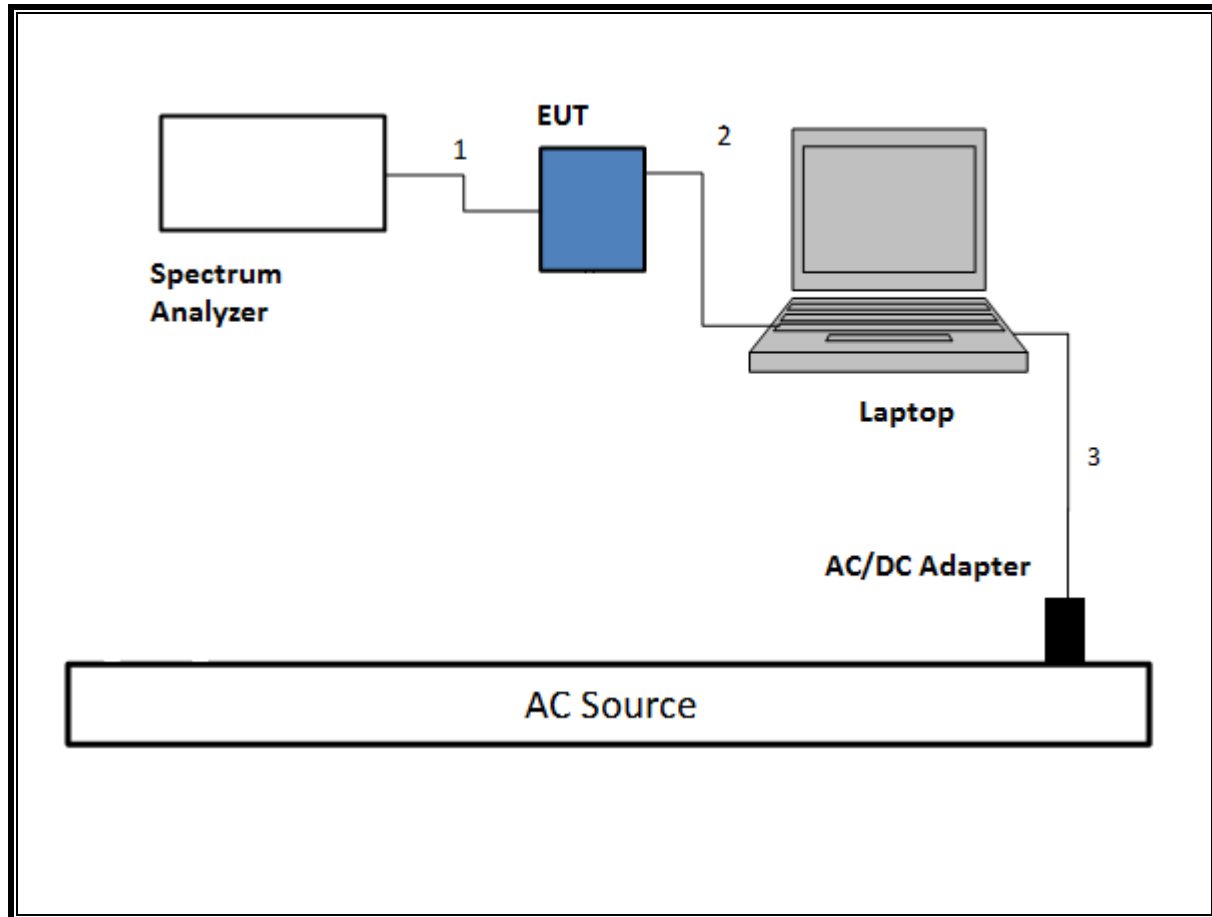
I/O CABLES (BELOW 1GHz AND AC POWER LINE TEST WITH ADAPTER AND LAPTOP)

I/O Cable List						
Cable No	Port	# of identical	Connector Type	Cable Type	Cable Length (m)	Remarks
1	AC	1	AC	Un-shielded	2	N/A
2	USB	1	USB	Un-shielded	1	N/A

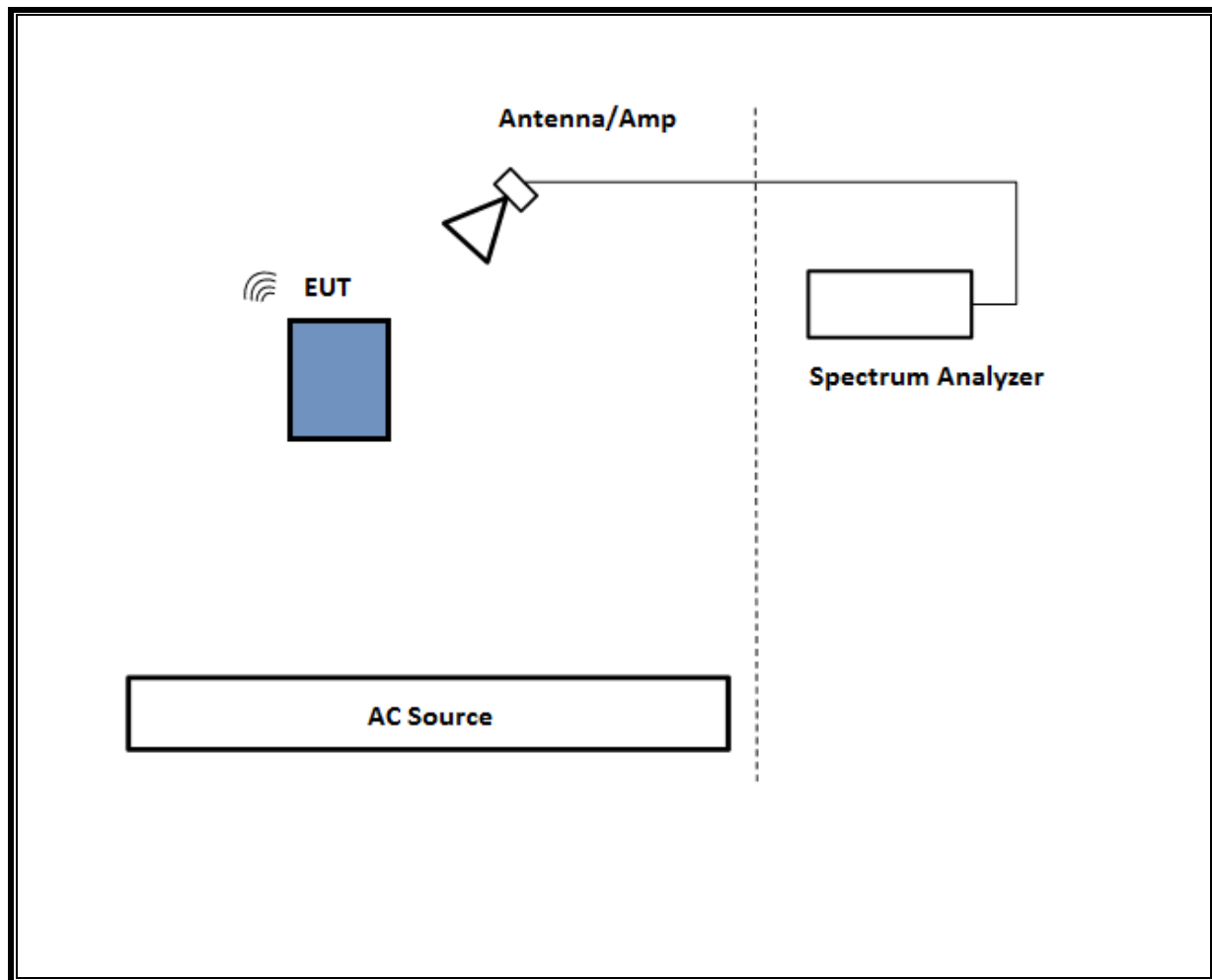
TEST SETUP

The EUT is connected to a test laptop during the tests. Test software exercised the EUT.

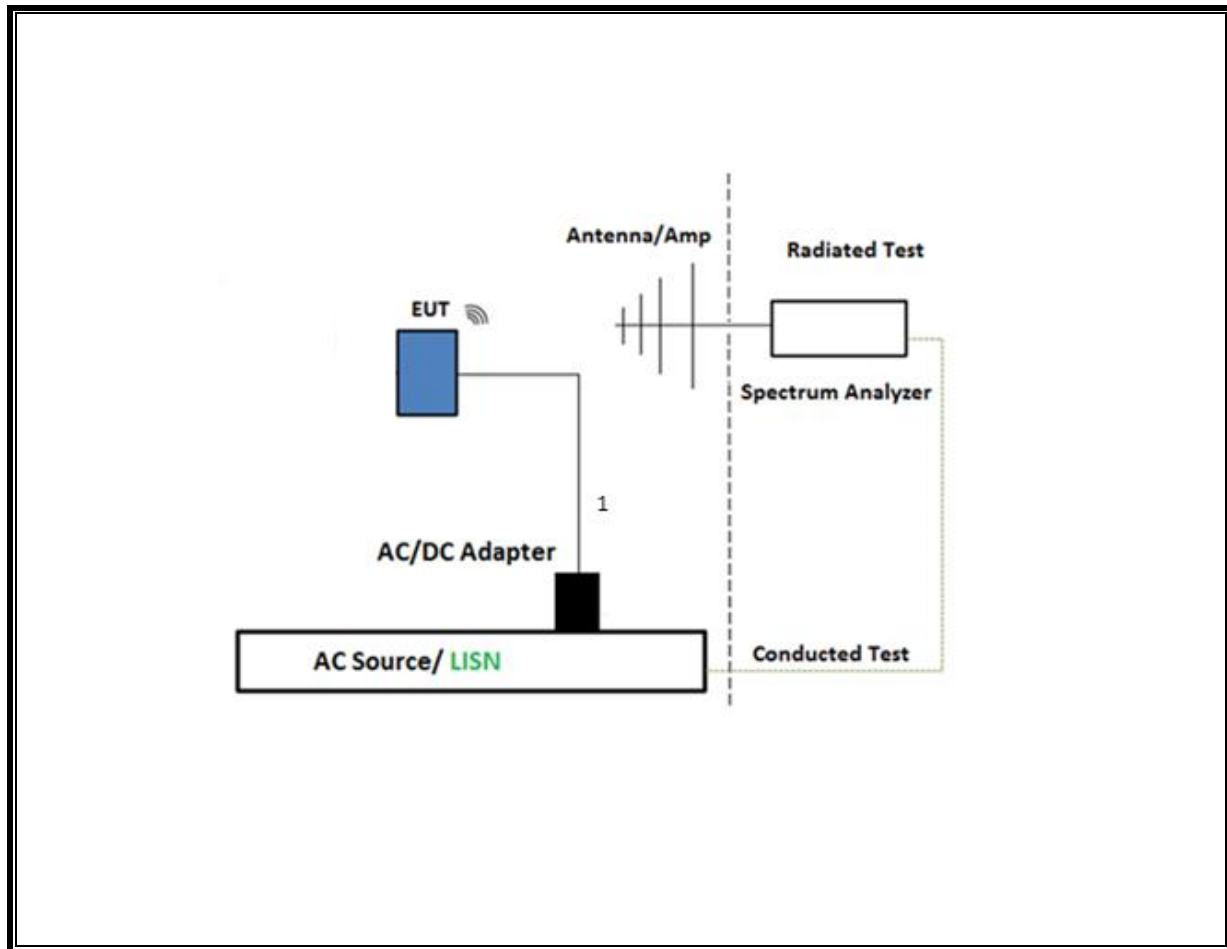
SETUP DIAGRAM FOR CONDUCTED TESTS



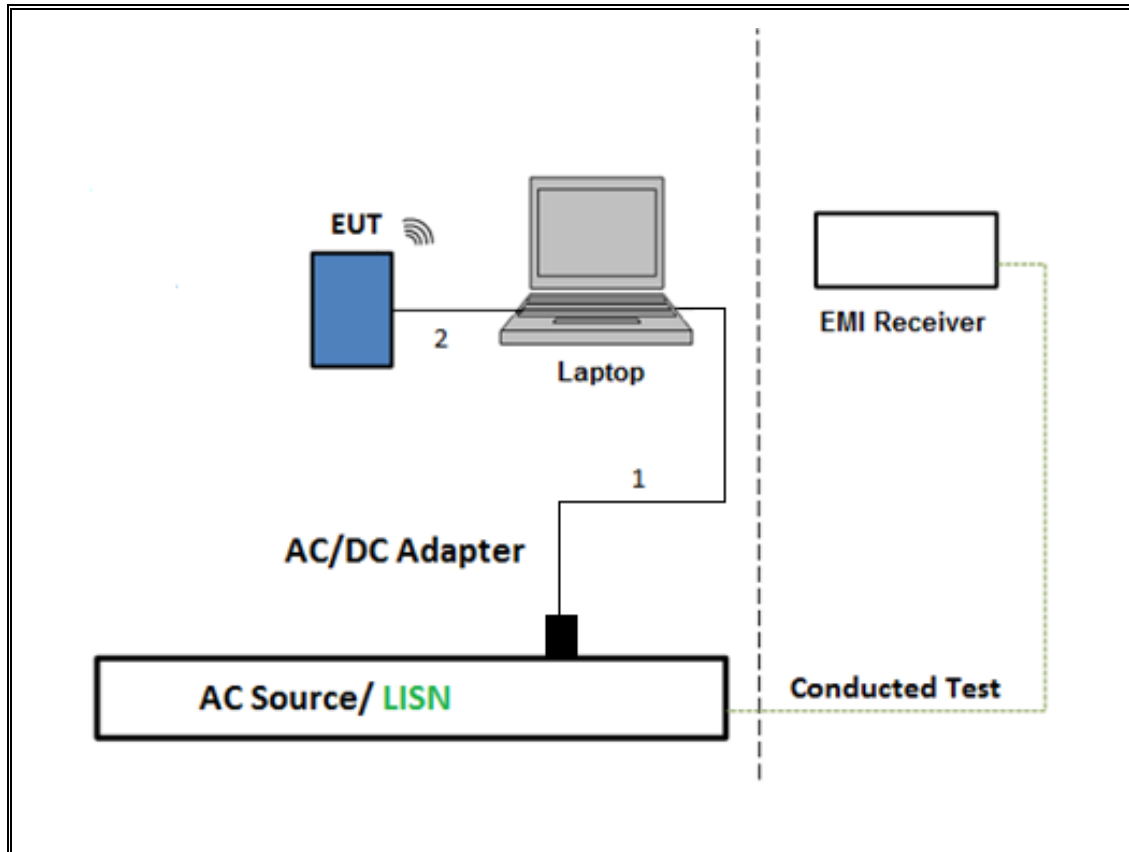
SETUP DIAGRAM FOR RADIATED TESTS Above 1 GHz



SETUP DIAGRAM FOR Below 1GHz and AC LINE CONDUCTED TEST



TEST SETUP- AC LINE CONDUCTED: LAPTOP CONFIGURATION



6. 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
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T931	02/24/2019
*Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T1165	06/12/2018
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T491	05/19/2019
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T740	12/30/2018
Amplifier, 1 to 8GHz	Miteq	AFS42-00101800-25-S-42	T1131	12/30/2018
*Pre-Amp 18-26GHz	Agilent Technology	8449B	T404	07/23/2018
*Antenna, Horn 1-18GHz	ETS Lindgren	3117	T120	07/02/2018
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T862	05/24/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T346	04/03/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T119	04/03/2019
*Antenna, Horn 1-18GHz	ETS Lindgren	3117	T136	07/02/2018
Antenna Horn, 18 to 26GHz	ARA	MWH-1826	T89	01/18/2019
Antenna, Broadband Hybrid, 30MHz to 2000MHz	Sunol Sciences	JB1	T130	10/16/2018
Spectrum Analyzer, PXA 3Hz to 44GHz	Keysight	N9030A	T340	12/15/2018
Spectrum Analyzer, PXA 3Hz to 44GHz	Keysight	N9030A	T906	02/16/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T342	02/22/2019
**Power Meter, P-series single channel	Keysight	N1911A	T1268	06/25/2019
Power Sensor	Keysight	N1921A	T1225	04/10/2019
Antenna, Active Loop 9KHz to 30MHz	ETS-Lindgren	6502	T757	09/14/2018
AC Line Conducted				
EMI Test Receiver 9KHz-7GHz	Rohde & Schwarz	ESC17	T1436	01/25/2019
Power Cable, Line Conducted Emissions	UL	PG1	T861	08/31/2018
**LISN for Conducted Emissions CISPR-16	Fischer	50/250-25-2-01	T1310	06/19/2019
UL AUTOMATION SOFTWARE				
Radiated Software	UL	UL EMC	Ver 9.5, April 26, 2016	
Conducted Software	UL	UL EMC	Ver 5.4, October 13, 2016	
AC Line Conducted Software	UL	UL EMC	Ver 9.5, May 26, 2015	

Note: *Testing is completed before equipment expiration date.

** Testing began after calibration was done.

7. 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 30-1000MHz: ANSI C63.10-2013 Section 6.3 and 6.5

Radiated Spurious Emissions above 1GHz: ANSI C63.10-2013 Section 6.3 and 6.6

Radiated Band-edge: ANSI C63.10-2013 Section 6.10.5

AC Power-line conducted emissions: ANSI C63.10-2013, Section 6.2.

8. ANTENNA PORT TEST RESULTS

8.1. ON TIME AND DUTY CYCLE

LIMITS

None; for reporting purposes only.

PROCEDURE

KDB 789033 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	2.50	2.50	1.00	100.0%	0.00	0.010
Bluetooth 8PSK	2.50	2.50	1.00	100.0%	0.00	0.010

Left Screenshot: Bluetooth GFSK Duty Cycle

Agilent 15:32:54 Jul 10, 2018

APv8.4(061218),30606, Cond. F

Ref 31.9 dBm *Atten 30 dB

Mkr1 2.5 ms

Center Freq 2.40200000 GHz

Start Freq 2.40200000 GHz

Stop Freq 2.40200000 GHz

CF Step 8.00000000 MHz

Freq Offset 0.00000000 Hz

Signal Track On

Copyright 2000-2011 Agilent Technologies

Right Screenshot: Bluetooth 8PSK Duty Cycle

Agilent 15:33:49 Jul 10, 2018

APv8.4(061218),30606, Cond. F

Ref 31.9 dBm *Atten 30 dB

Mkr1 2.5 ms

Center Freq 2.40200000 GHz

Start Freq 2.40200000 GHz

Stop Freq 2.40200000 GHz

CF Step 8.00000000 MHz

Freq Offset 0.00000000 Hz

Signal Track On

Copyright 2000-2011 Agilent Technologies

8.2. 20 dB AND 99% BANDWIDTH

LIMITS

None; for reporting purposes only.

TEST PROCEDURE

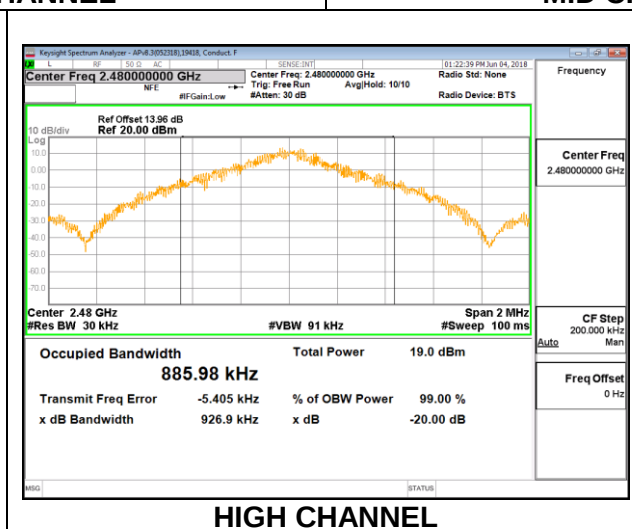
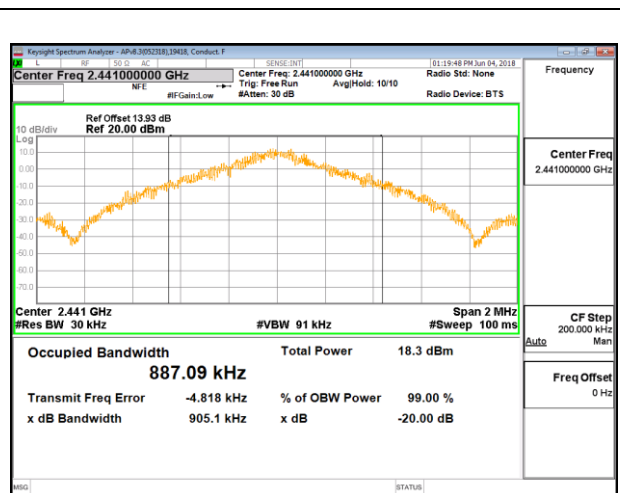
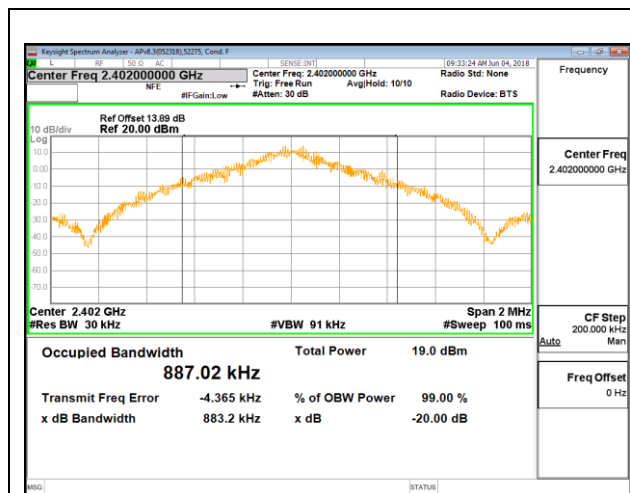
The transmitter output is connected to a spectrum analyzer. The RBW is set to $\geq 1\%$ of the 20 dB bandwidth. The VBW is set to $\geq$ RBW. The sweep time is coupled.

RESULTS

8.2.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

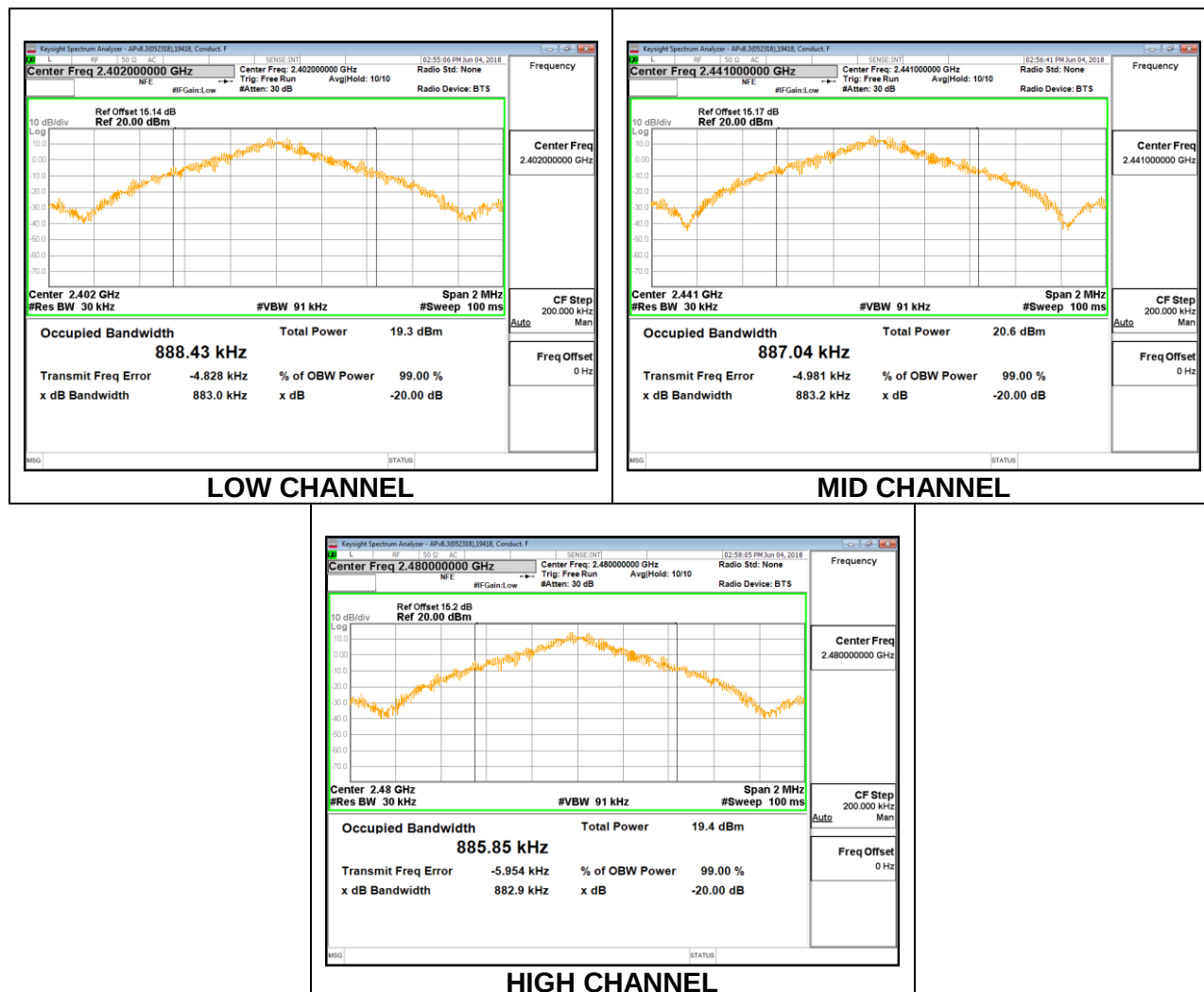
Antenna 2

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.883	0.887
Mid	2441	0.905	0.887
High	2480	0.927	0.886



Antenna 5

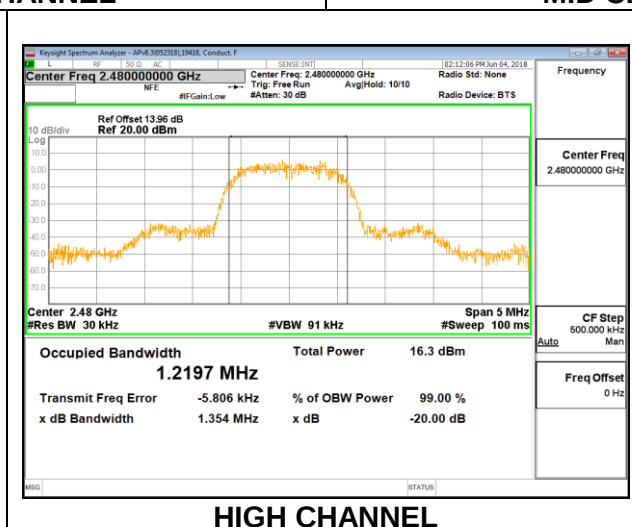
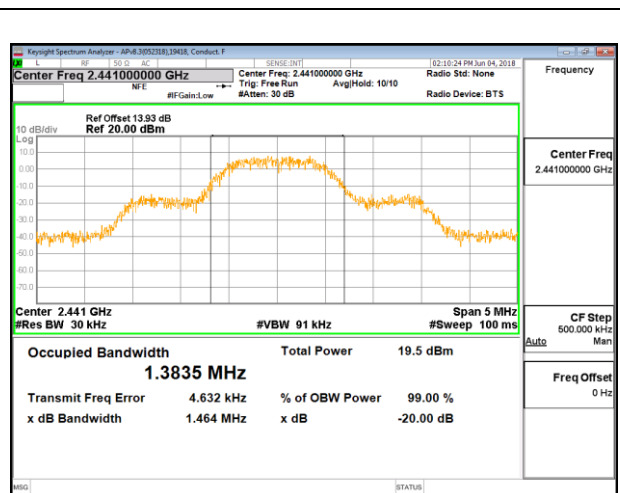
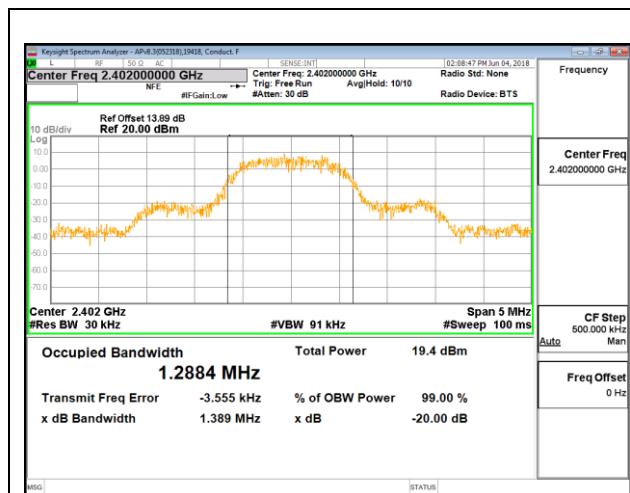
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.883	0.888
Mid	2441	0.883	0.887
High	2480	0.883	0.886



8.2.2. HIGH POWER ENCHANCED DATA RATE 8PSK MODULATION

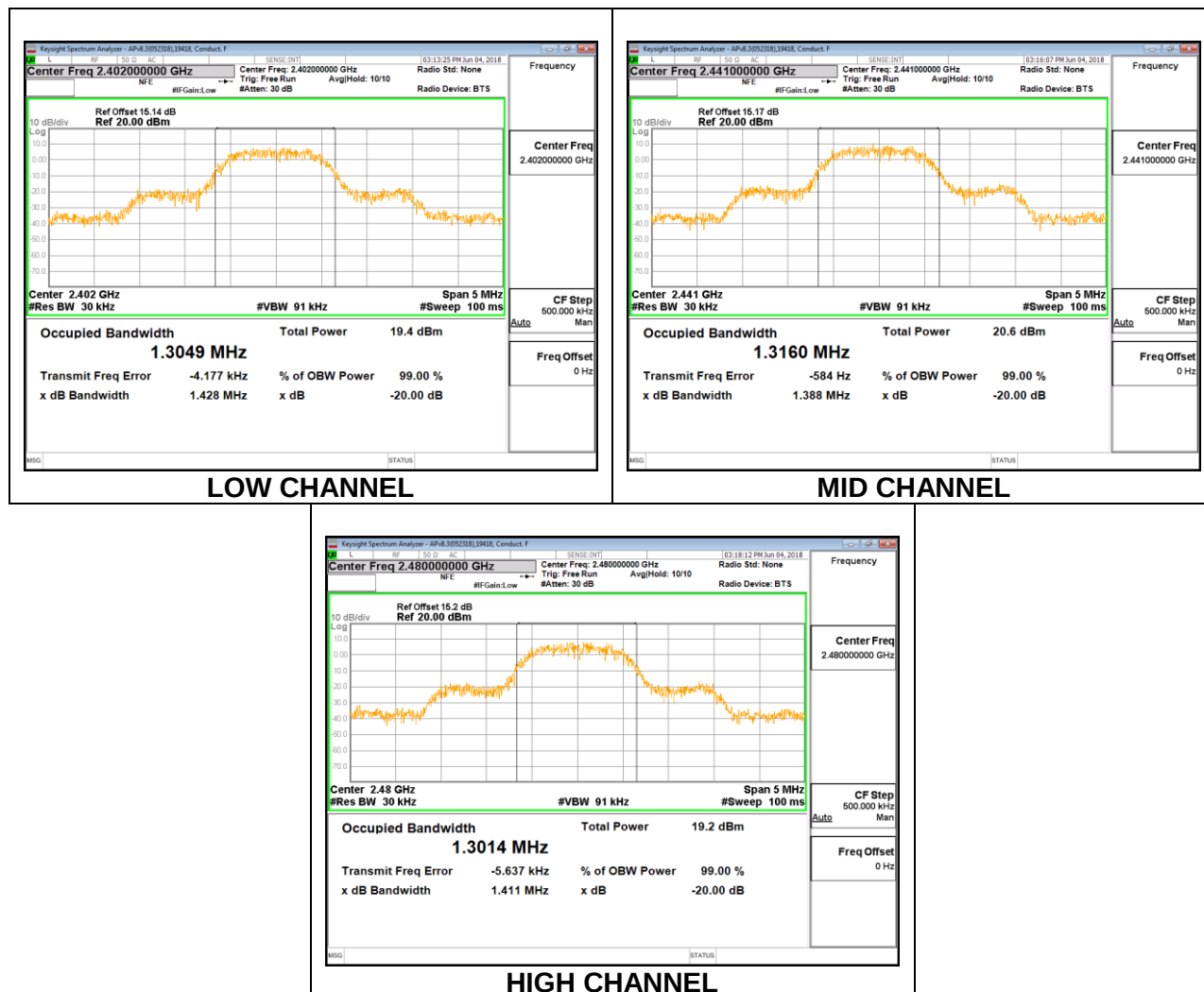
Antenna 2

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.389	1.288
Mid	2441	1.464	1.384
High	2480	1.354	1.220



Antenna 5

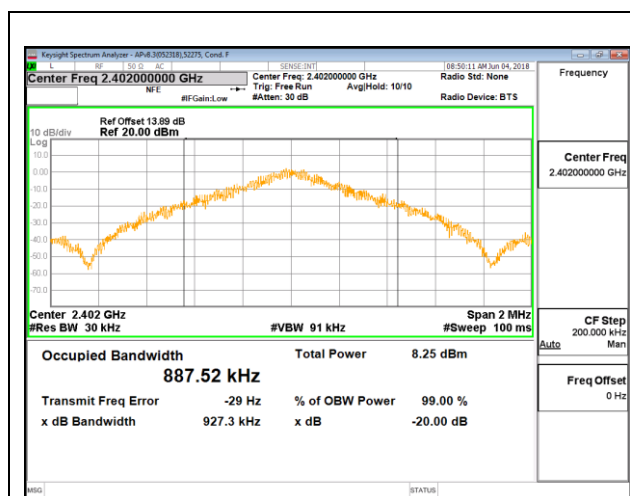
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.428	1.305
Mid	2441	1.388	1.316
High	2480	1.411	1.301



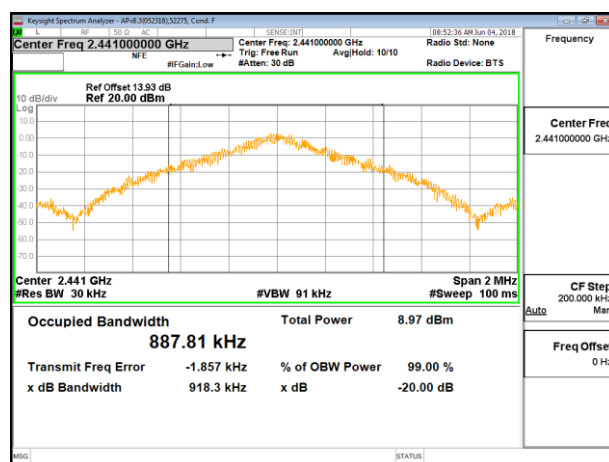
8.2.3. LOW POWER BASIC DATA RATE GFSK MODULATION

Antenna 2

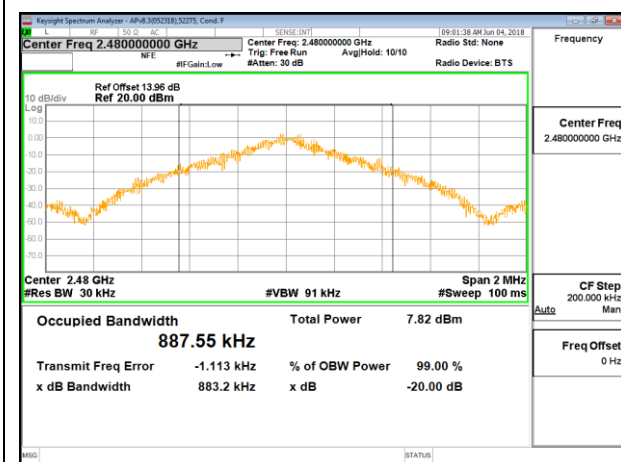
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.927	0.888
Mid	2441	0.918	0.888
High	2480	0.883	0.888



LOW CHANNEL



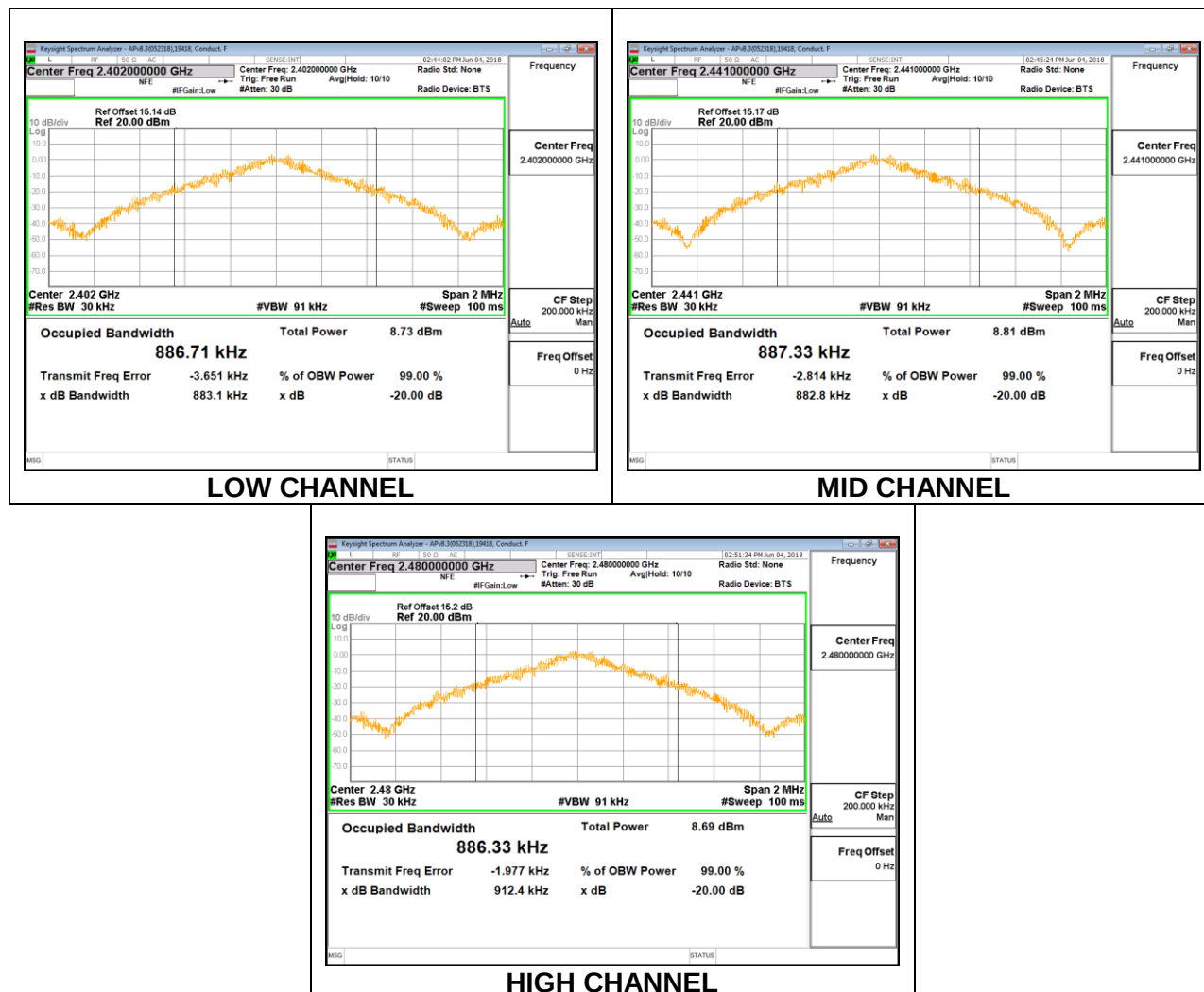
MID CHANNEL



HIGH CHANNEL

Antenna 5

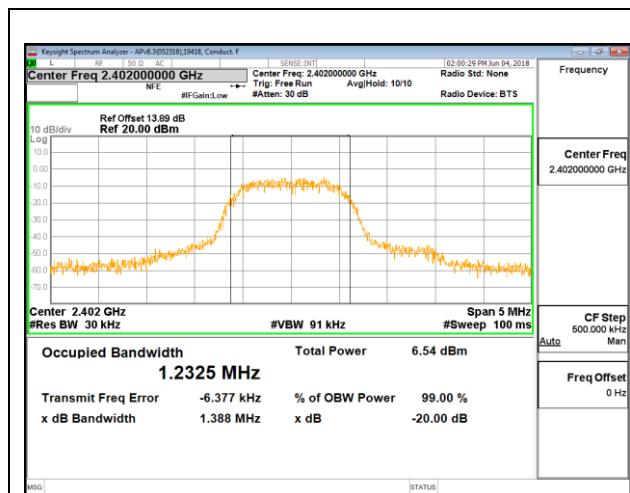
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.883	0.887
Mid	2441	0.883	0.887
High	2480	0.912	0.886



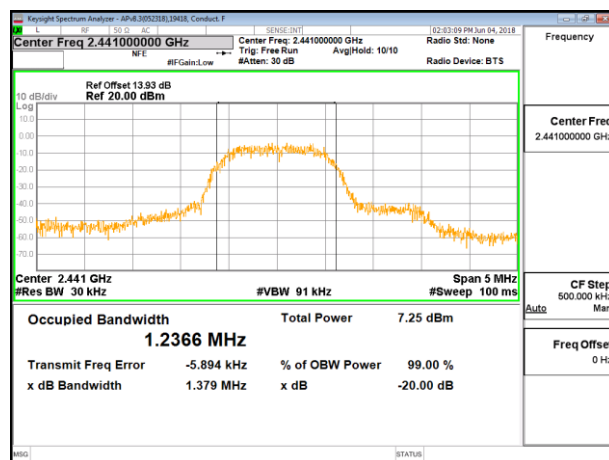
8.2.4. LOW POWER ENCHANCED DATA RATE 8PSK MODULATION

Antenna 2

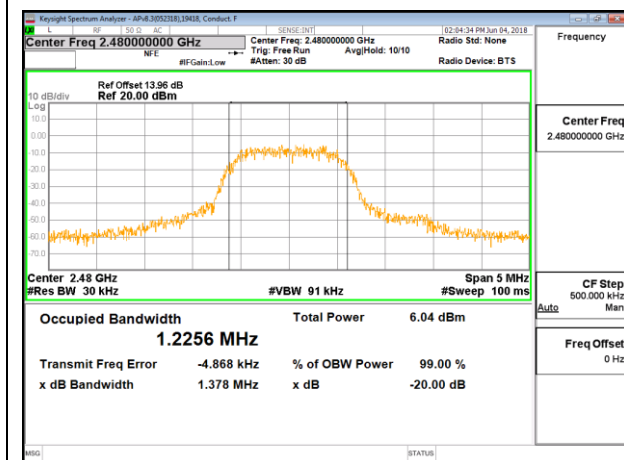
Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.388	1.233
Mid	2441	1.379	1.237
High	2480	1.387	1.226



LOW CHANNEL



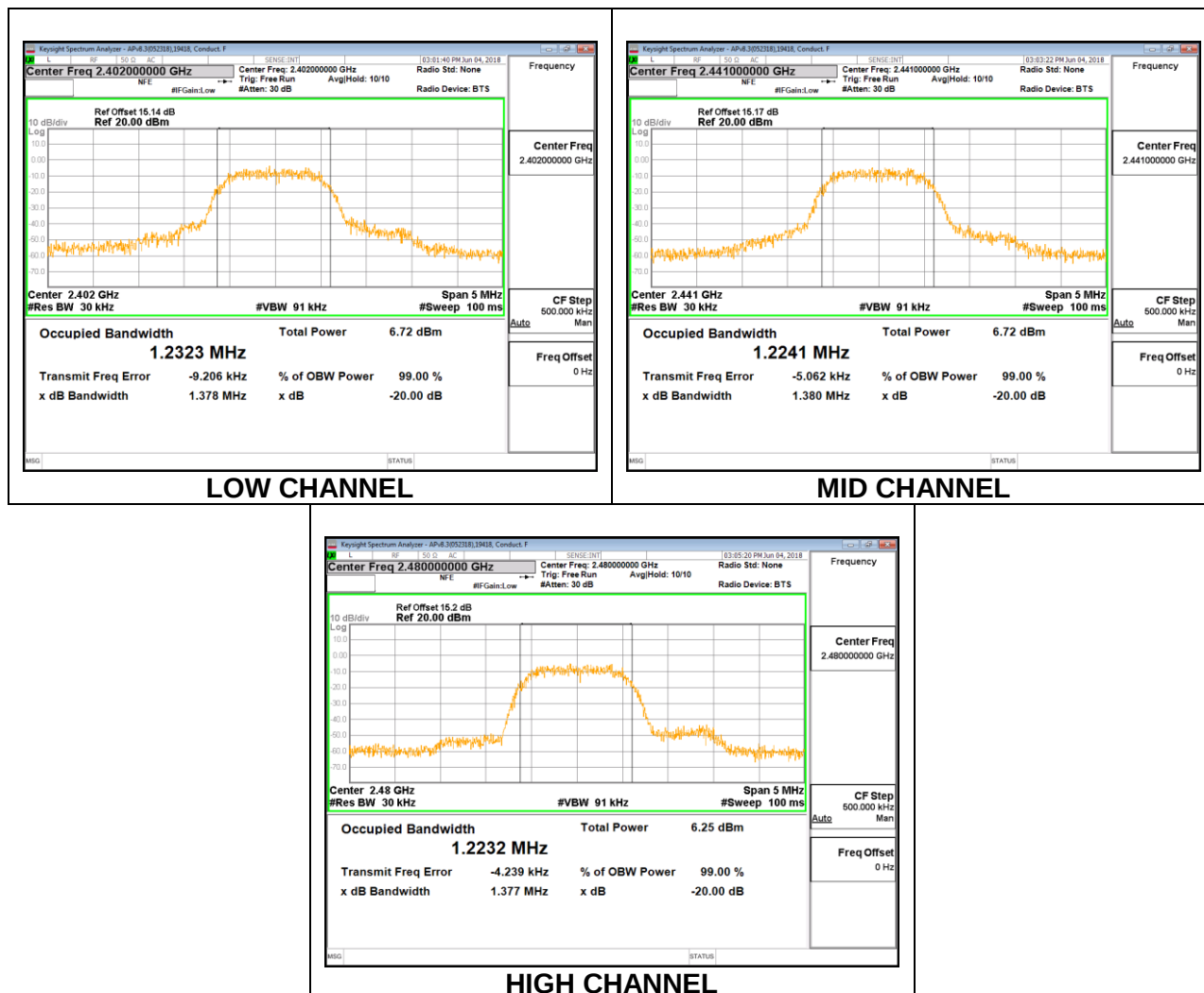
MID CHANNEL



HIGH CHANNEL

Antenna 5

Channel	Frequency (MHz)	20dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	1.378	1.232
Mid	2441	1.380	1.224
High	2480	1.377	1.223



8.3. 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 hopping channel, whichever is greater.

Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

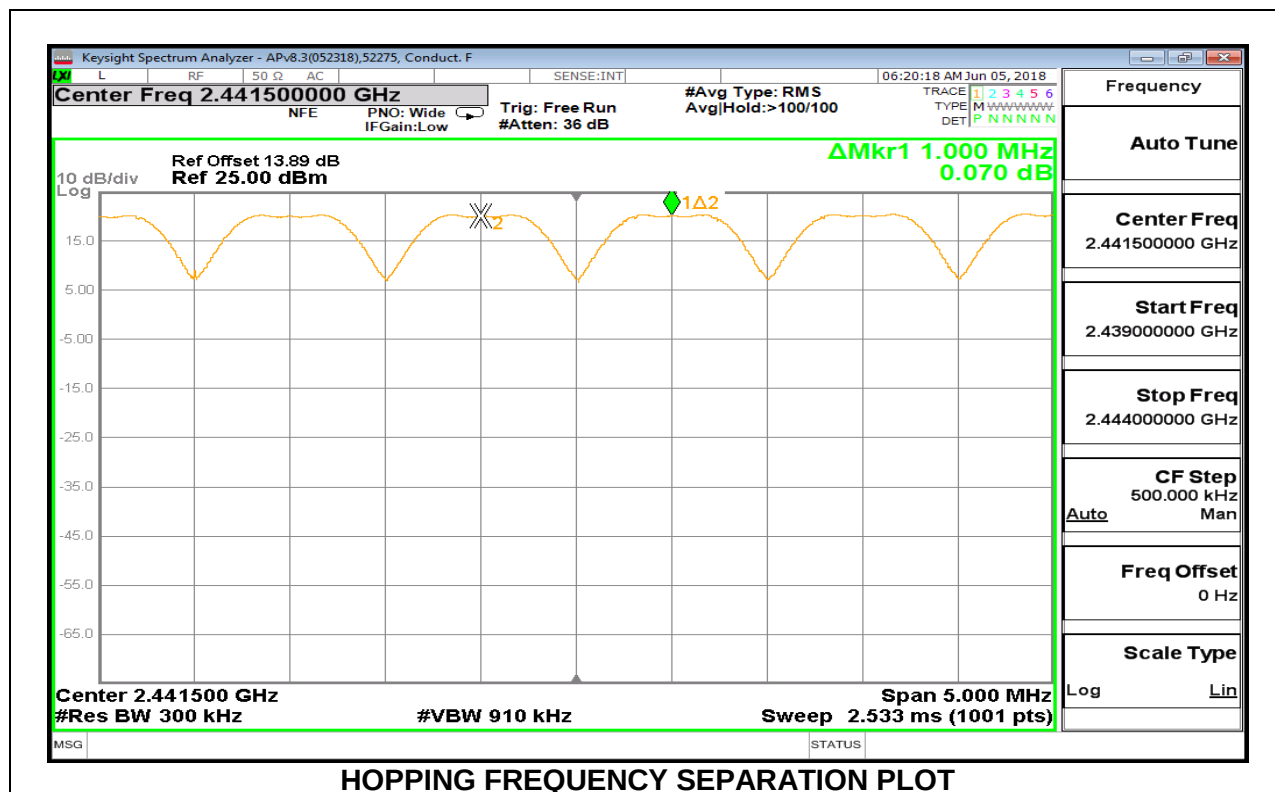
TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to 300 kHz and the VBW is set to 910 kHz. The sweep time is coupled.

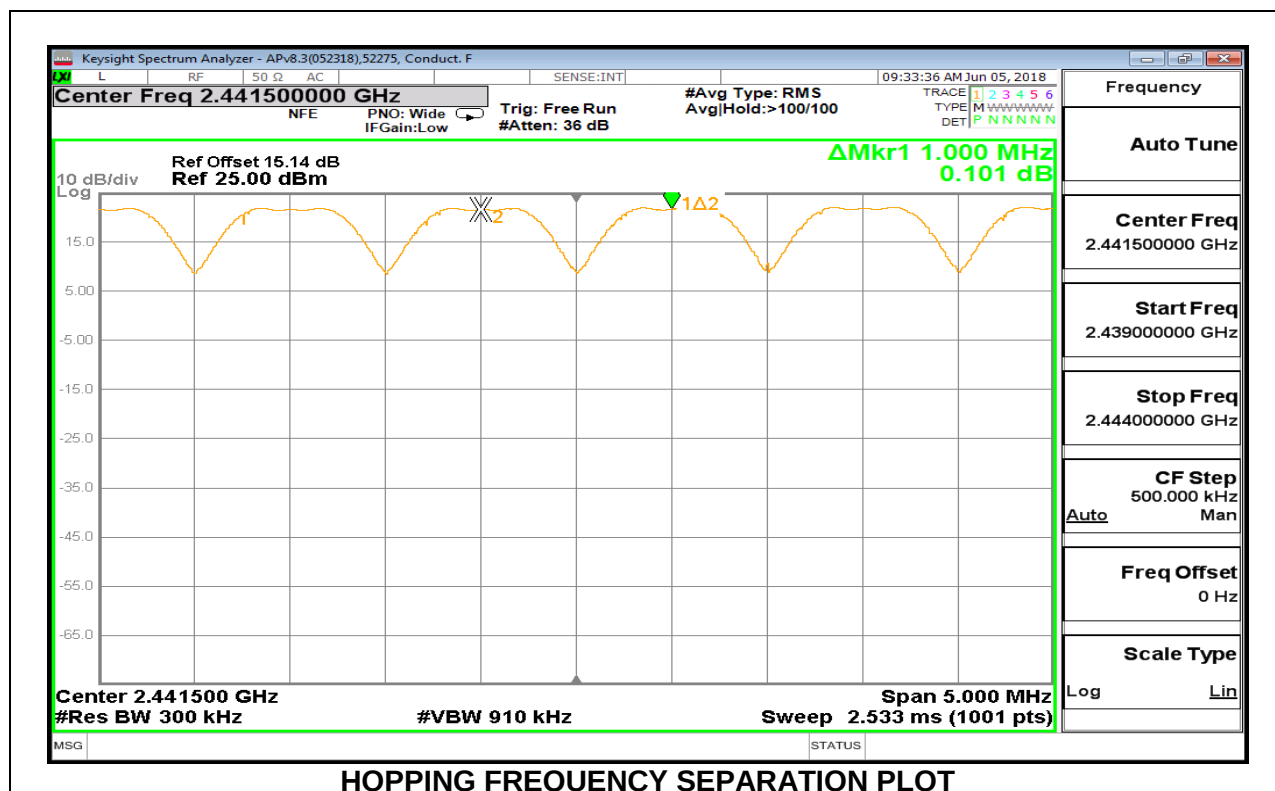
RESULTS

8.3.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

Antenna 2

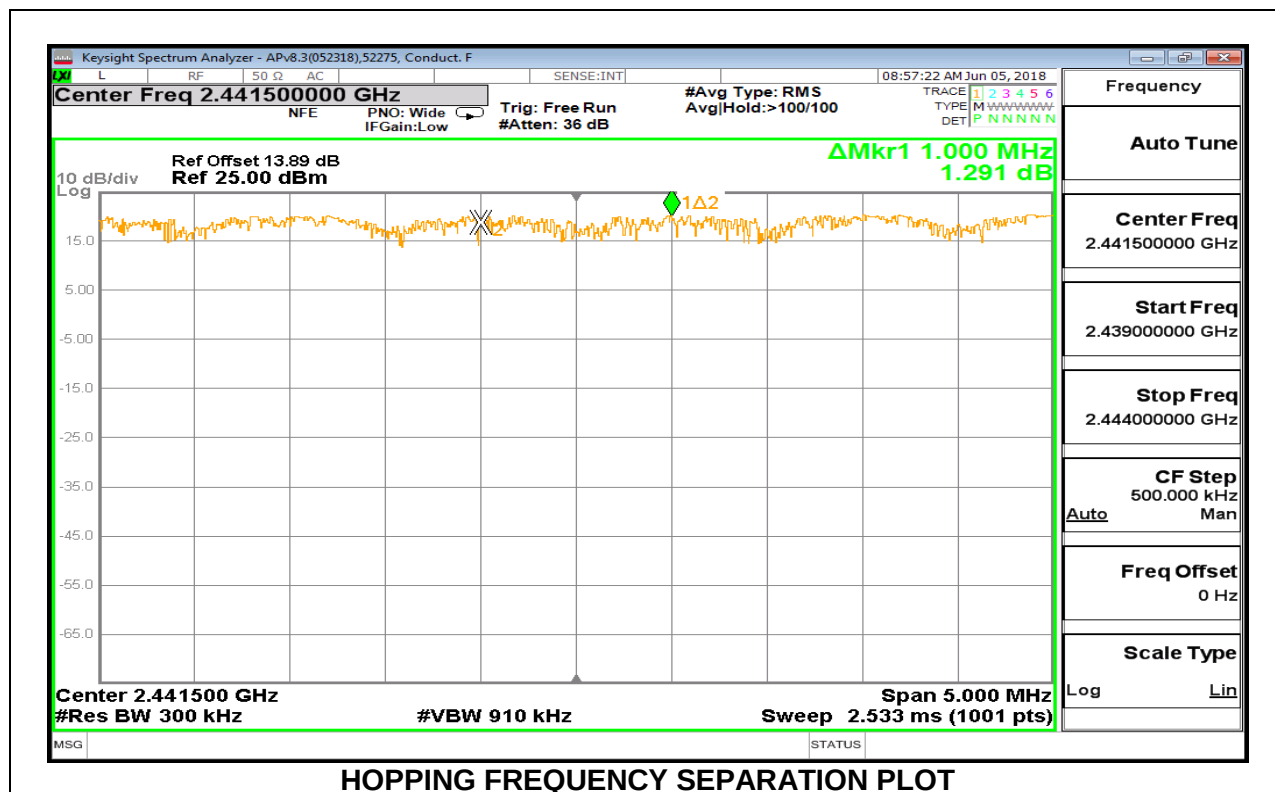


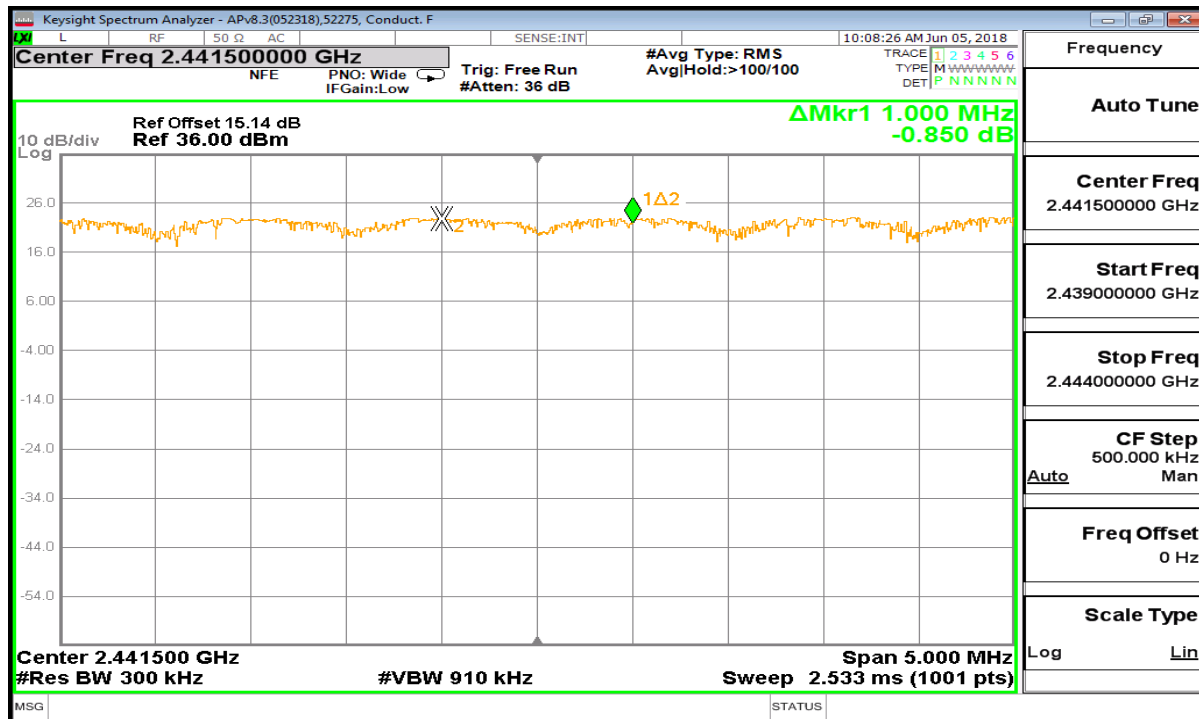
Antenna 5



8.3.2. HIGH POWER ENCHANCED DATA RATE 8PSK MODULATION

Antenna 2

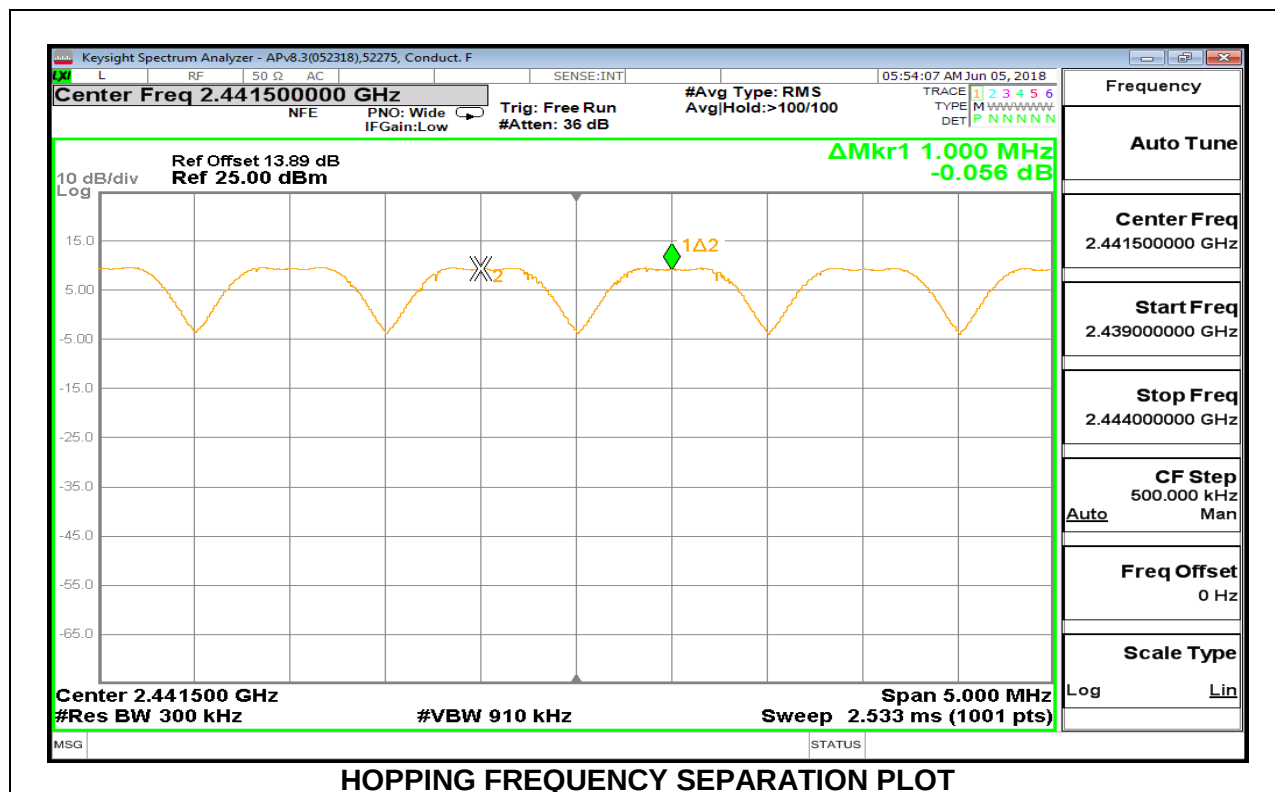




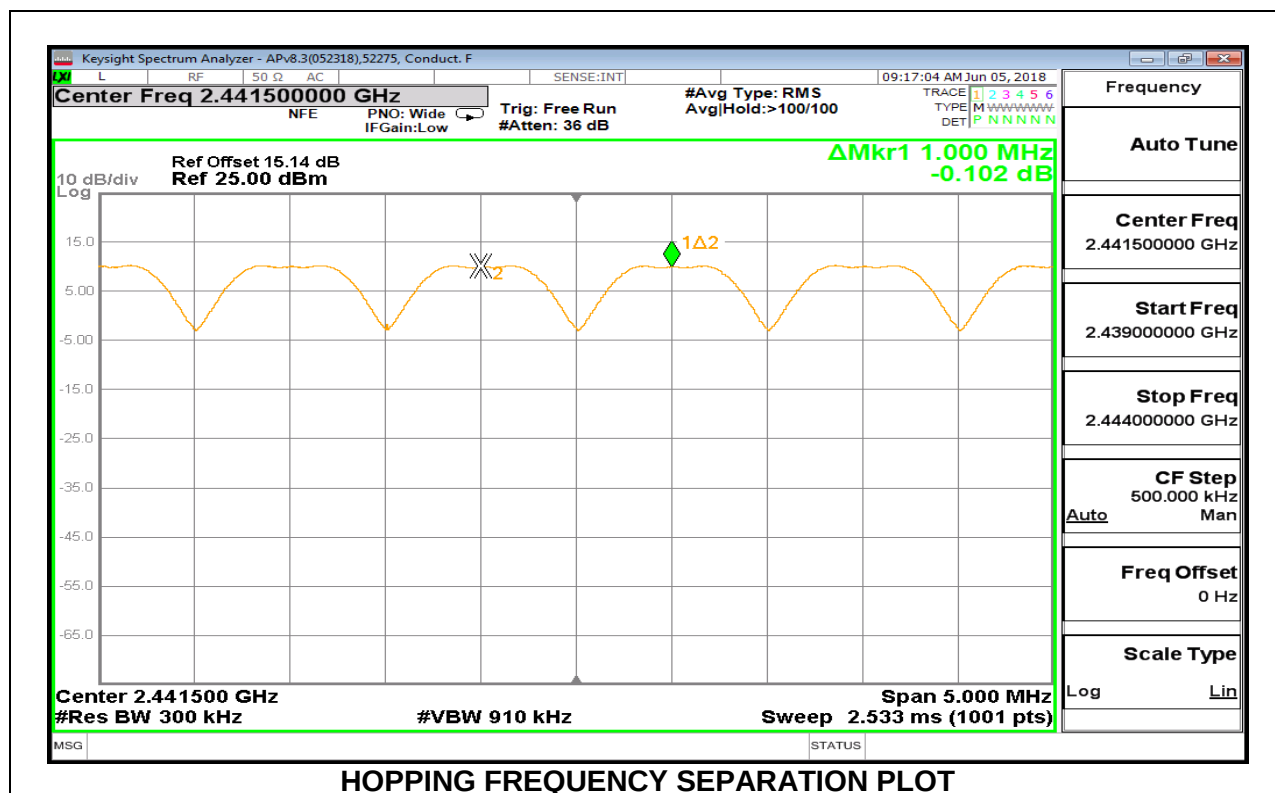
HOPPING FREQUENCY SEPARATION PLOT

8.3.3. LOW POWER BASIC DATA RATE GFSK MODULATION

Antenna 2

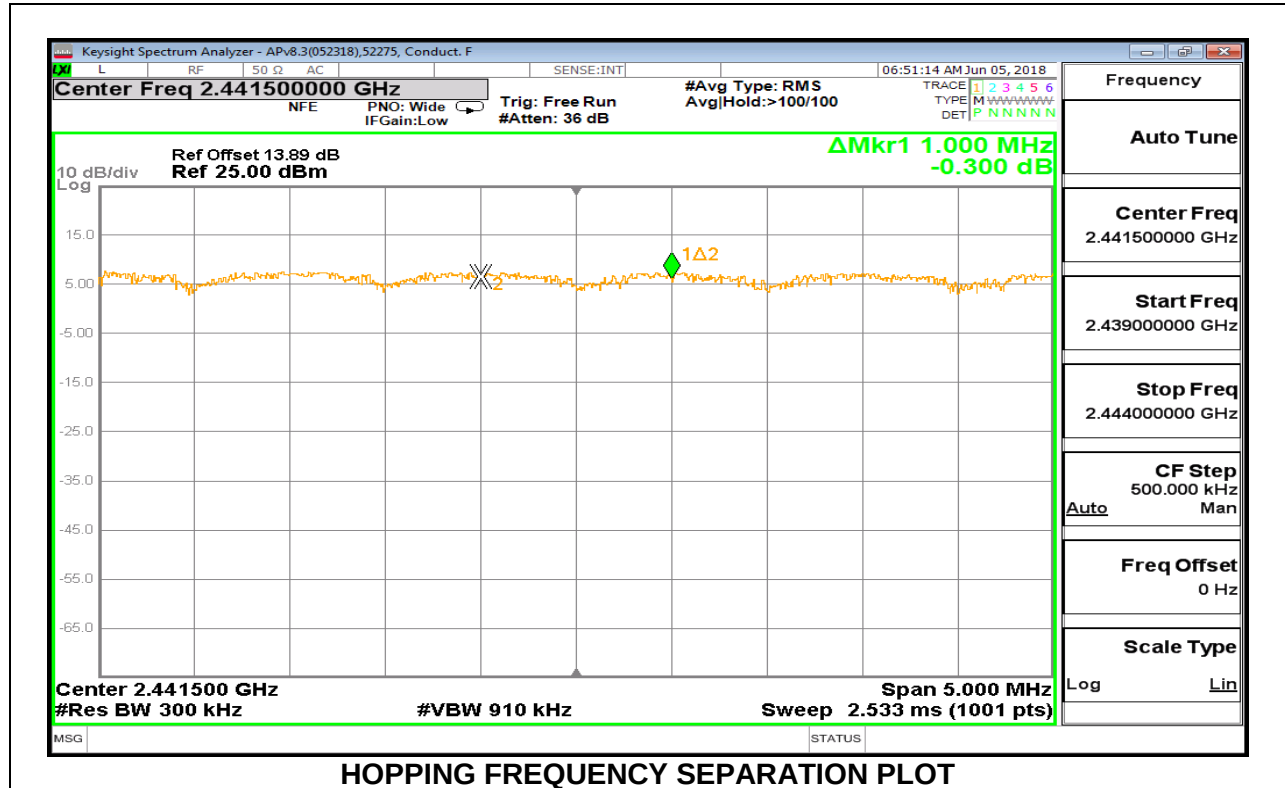


Antenna 5

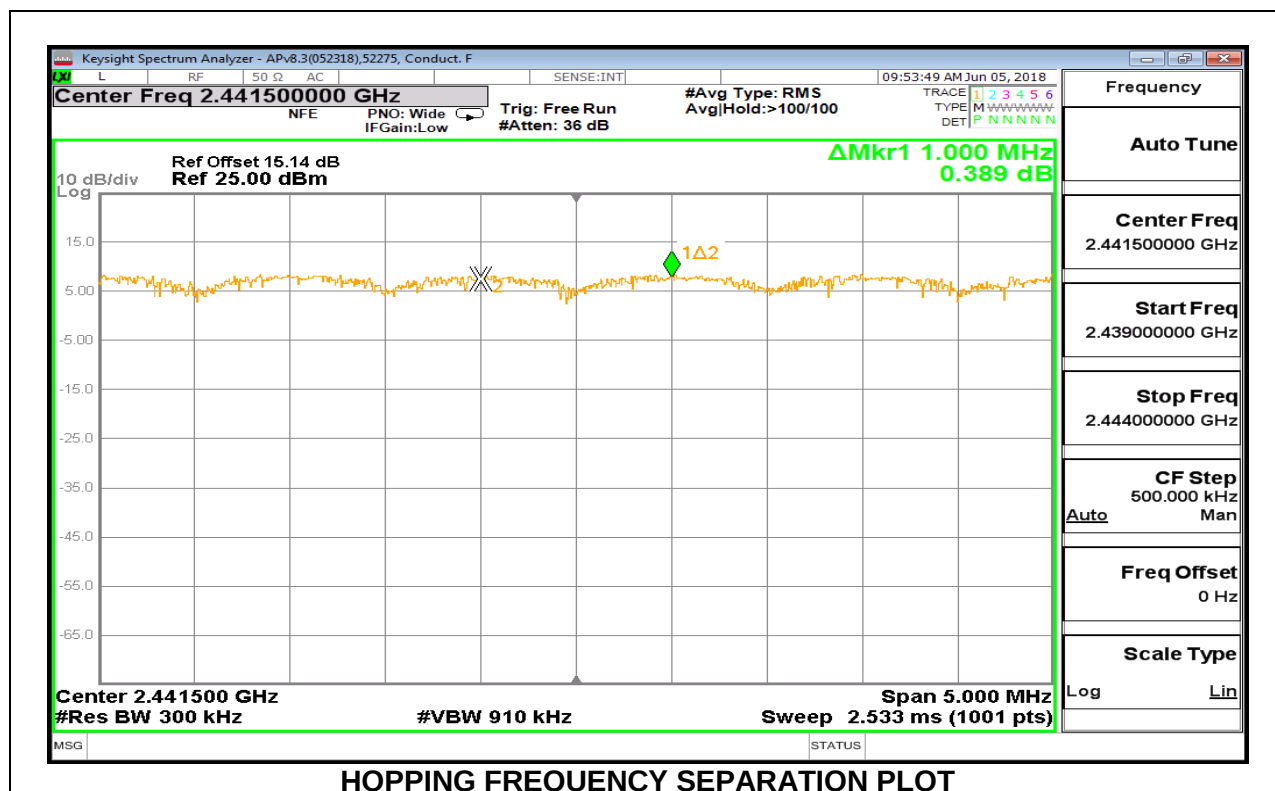


8.3.4. LOW POWER ENCHANCED DATA RATE 8PSK MODULATION

Antenna 2



Antenna 5



8.4. 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

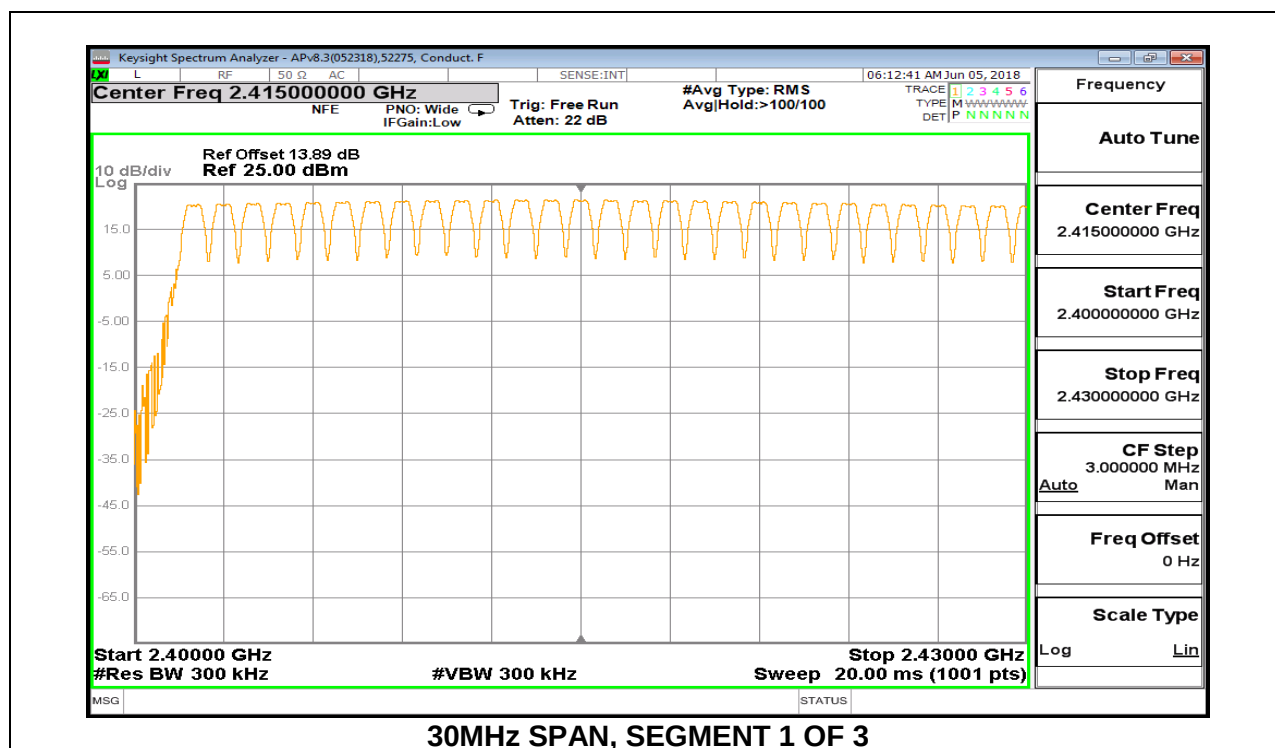
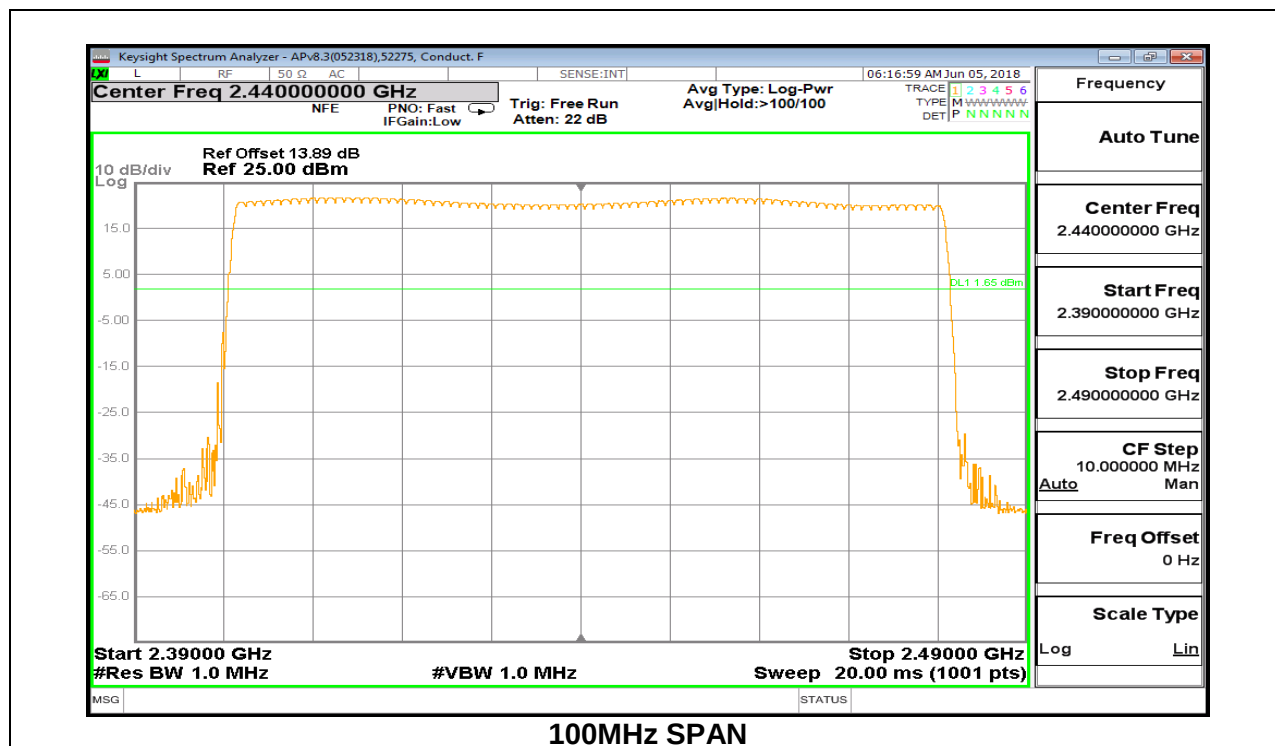
The transmitter output is connected to a spectrum analyzer. The span is set to cover the entire authorized band, in either a single sweep or in multiple contiguous sweeps. The RBW is set to a maximum of 1 % of the span. The analyzer is set to Max Hold.

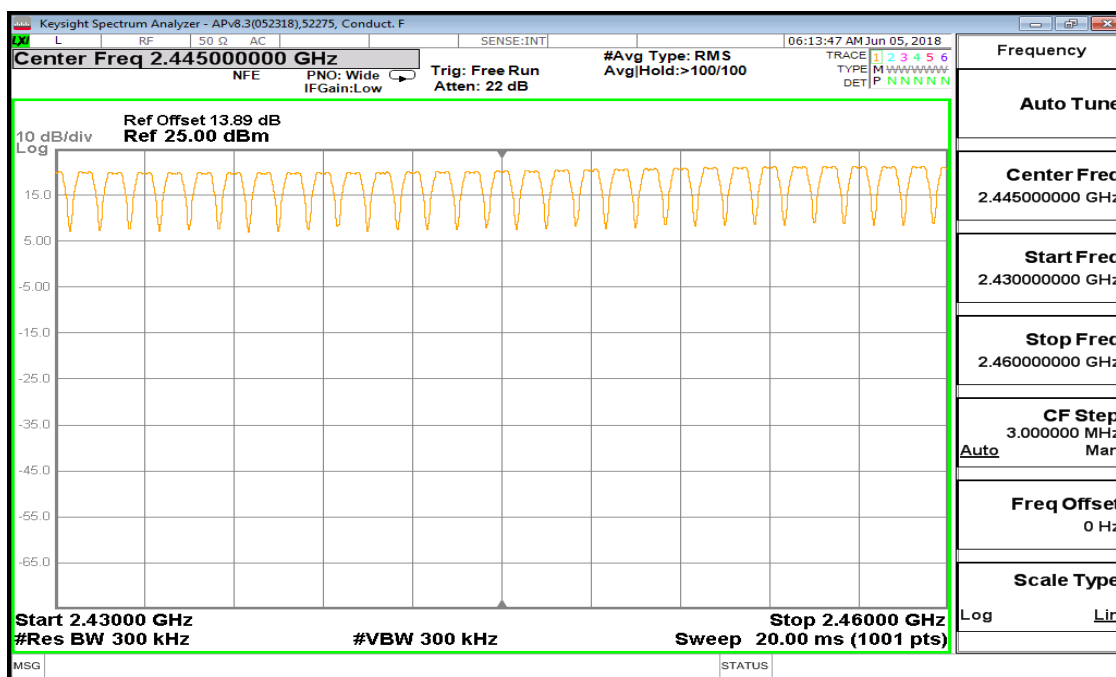
RESULTS

Normal Mode: 79 Channels Observed

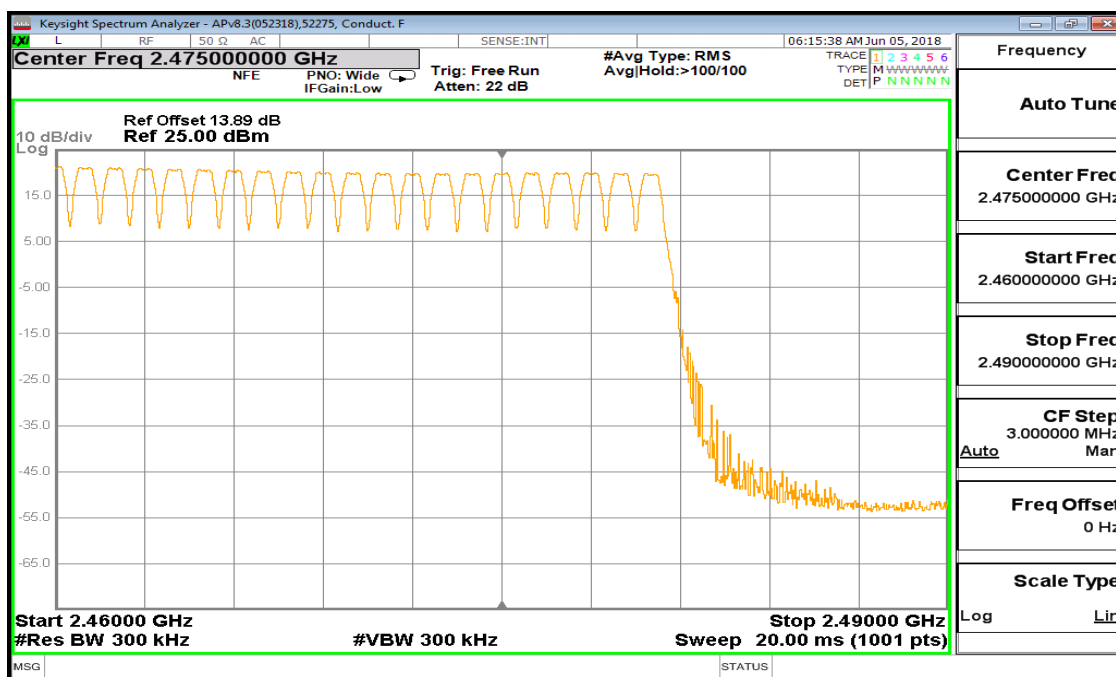
8.4.1. HIGH POWER BASIC DATA RATE GFSK MODULATION

Antenna 2



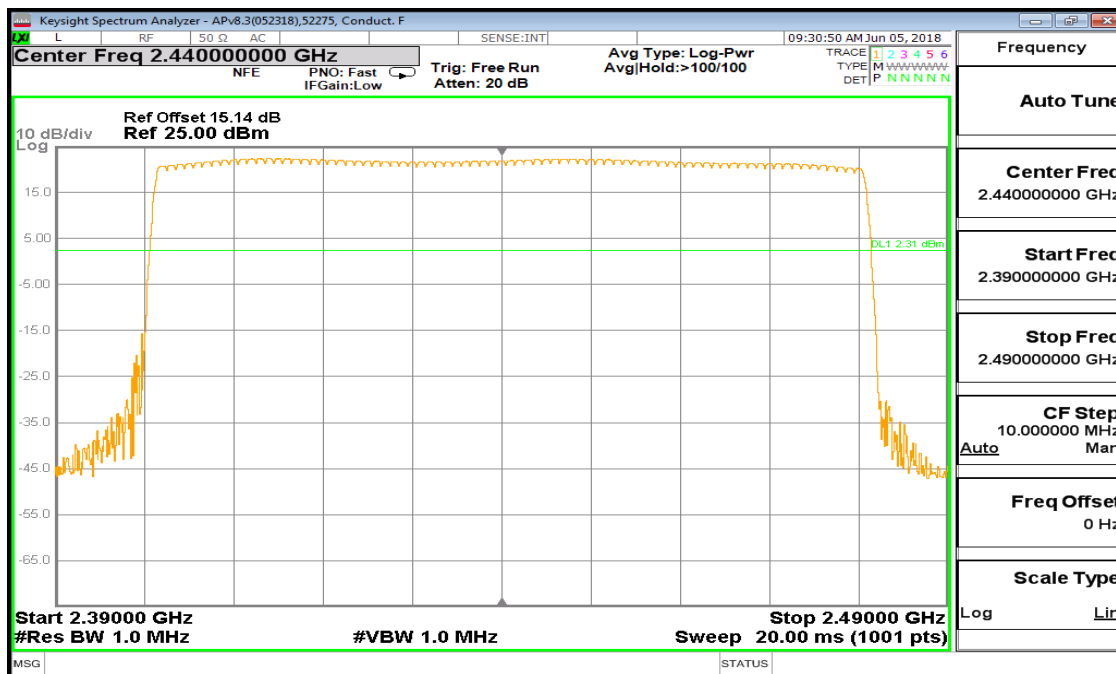


30MHz SPAN, SEGMENT 2 OF 3

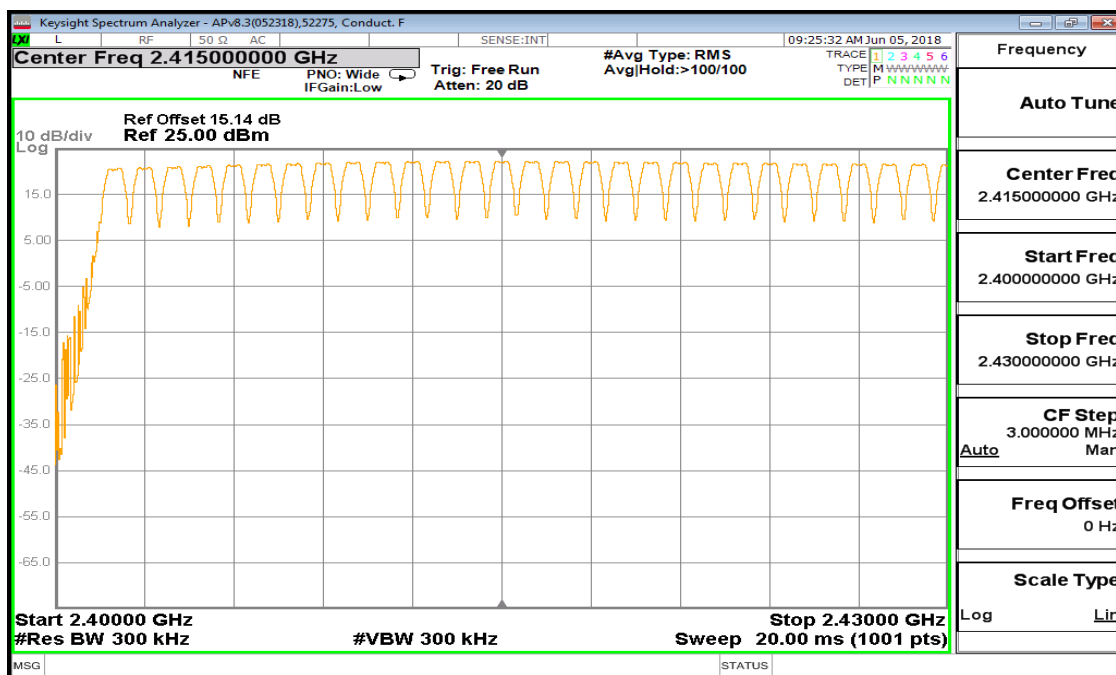


30MHz SPAN, SEGMENT 3 OF 3

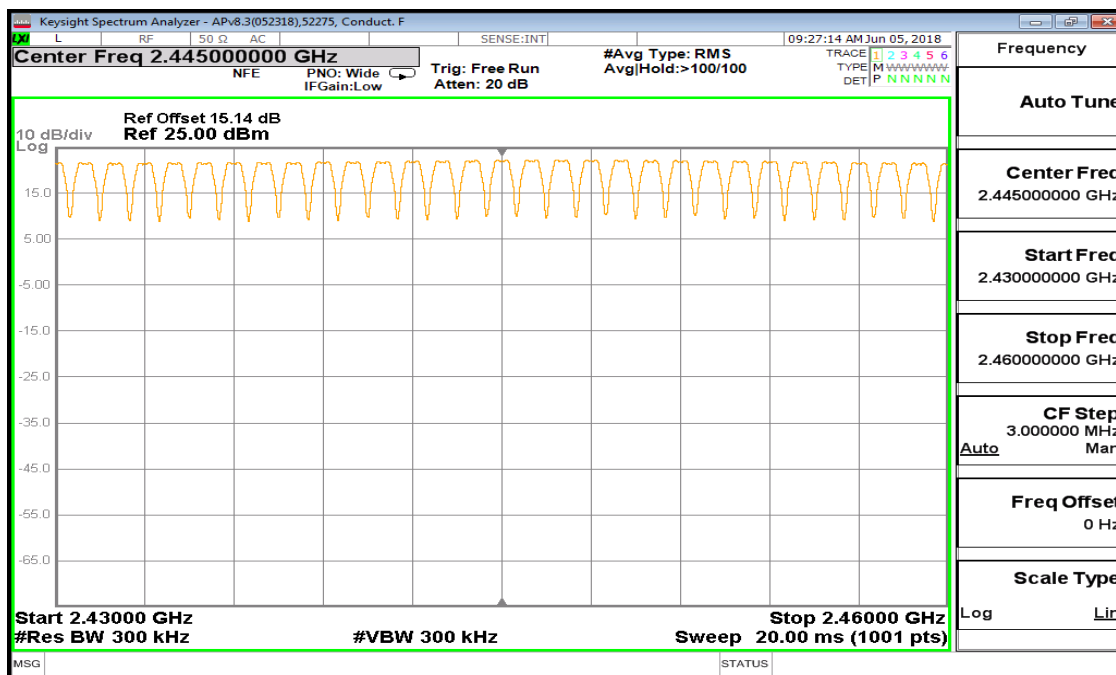
Antenna 5



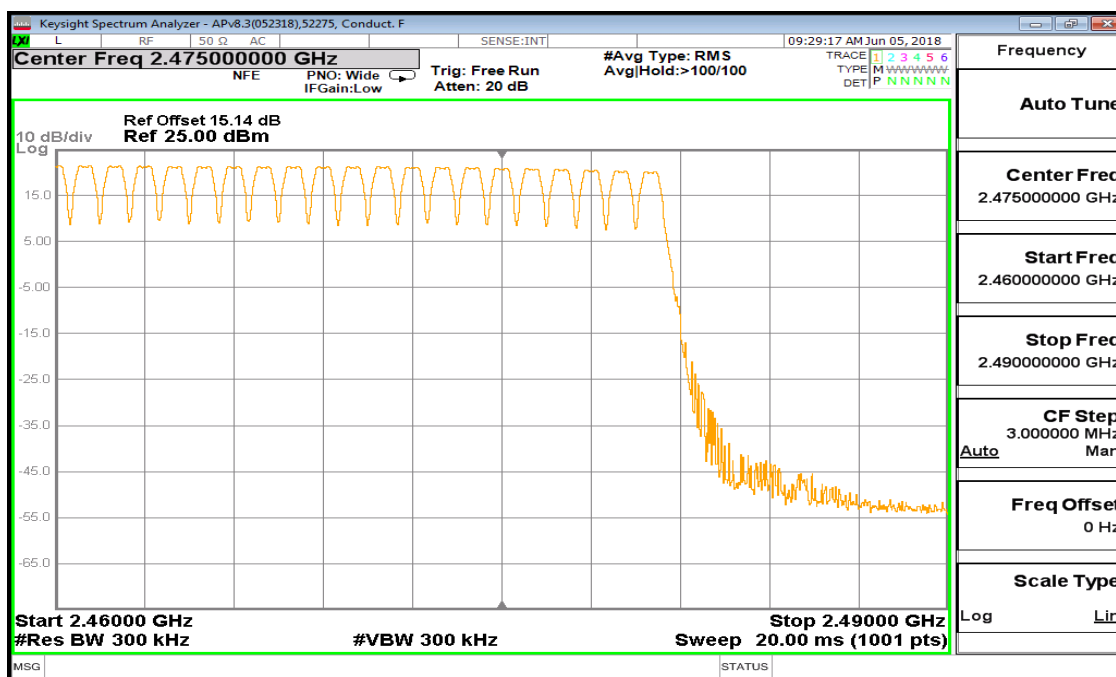
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



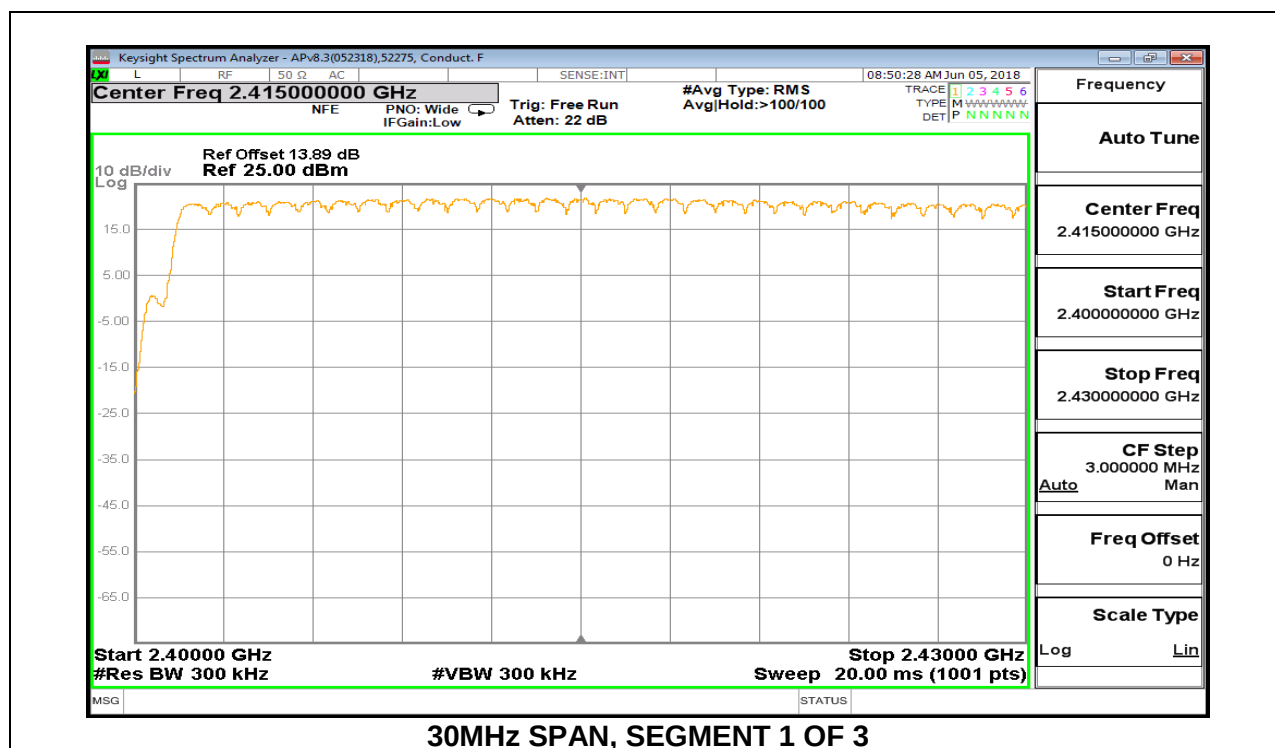
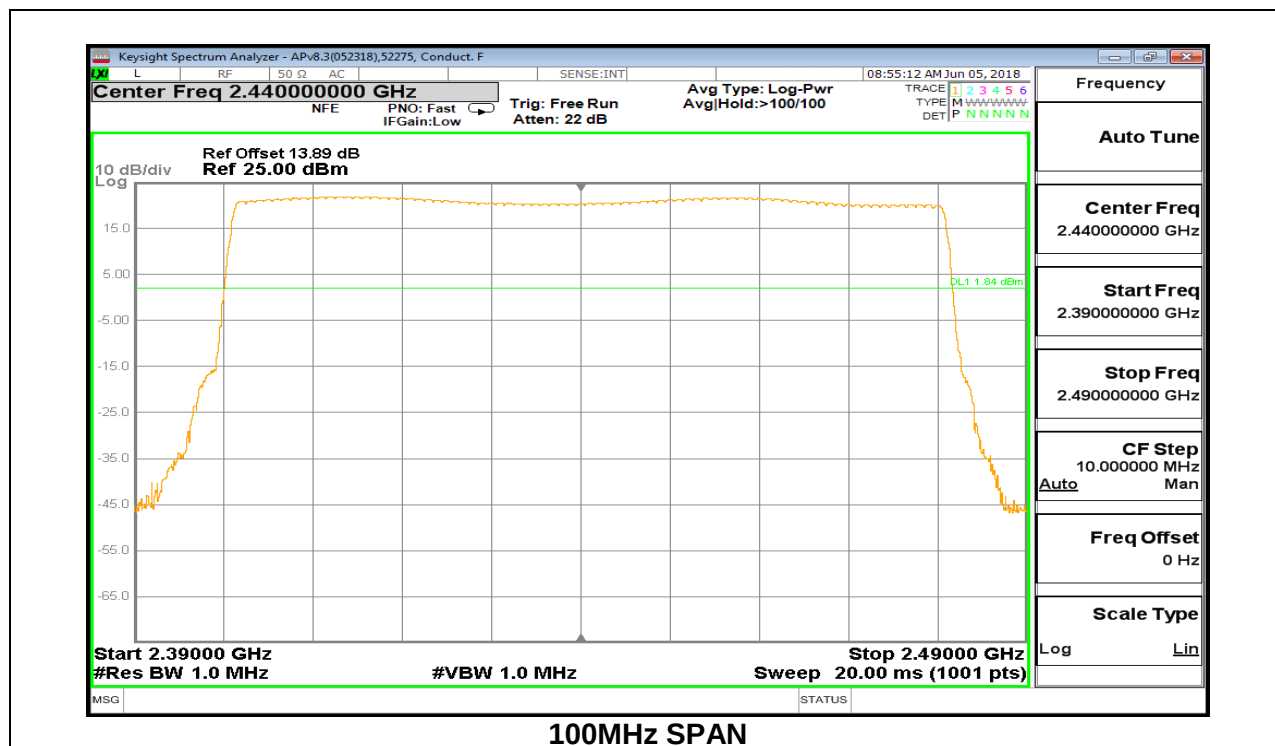
30MHz SPAN, SEGMENT 2 OF 3

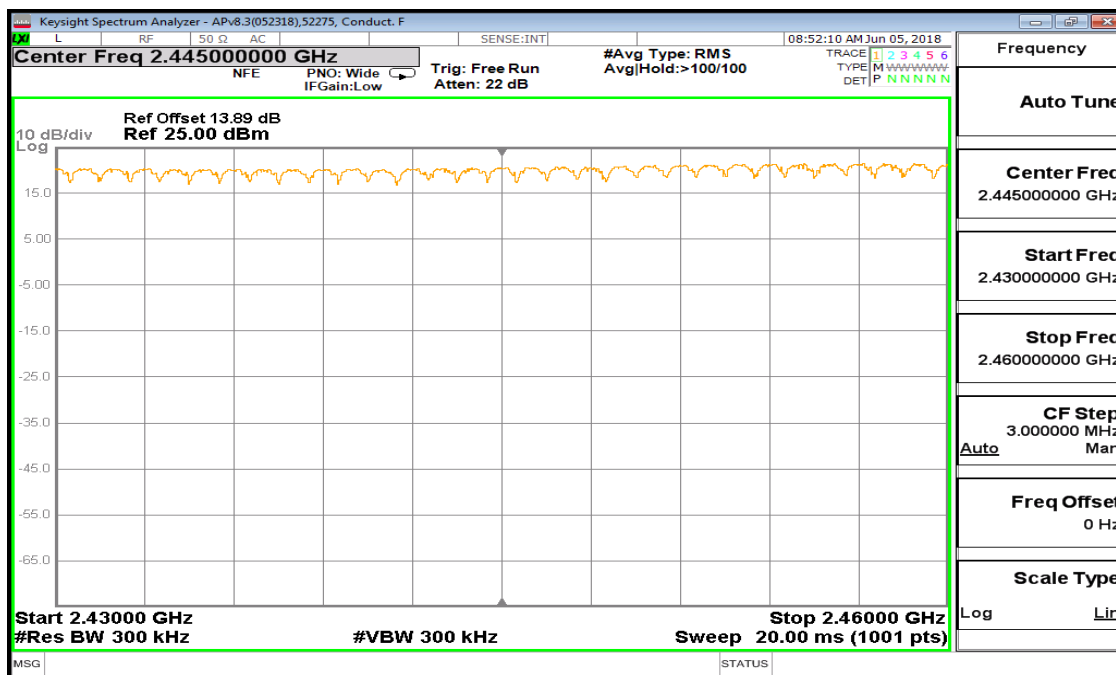


30MHz SPAN, SEGMENT 3 OF 3

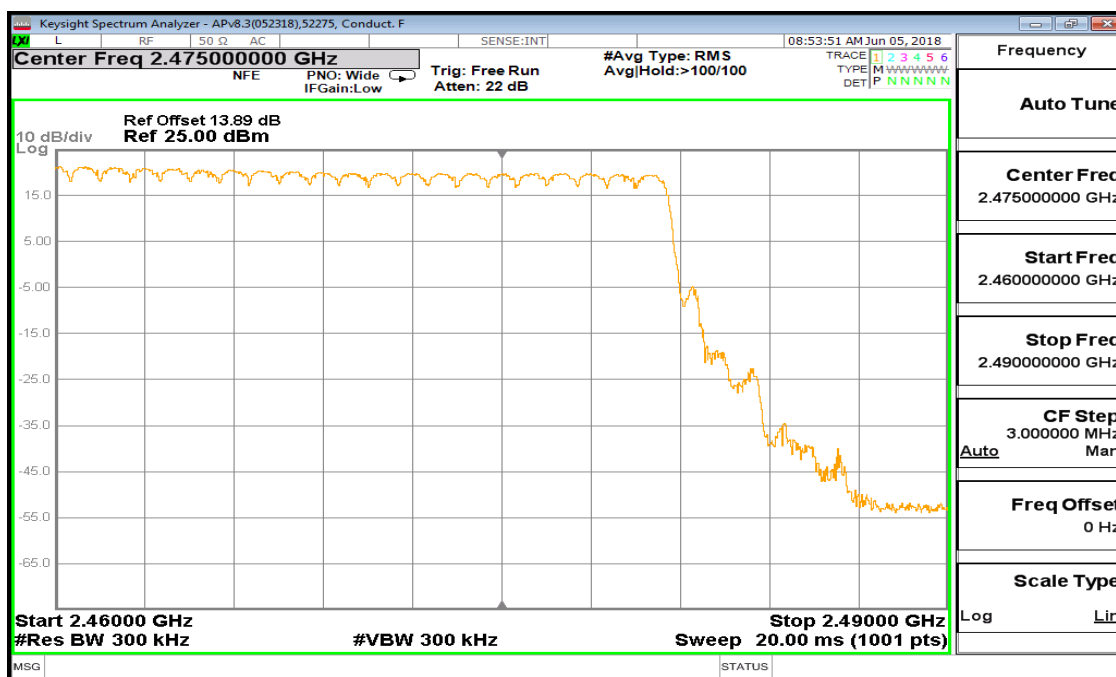
8.4.2. HIGH POWER ENCHANCED DATA RATE 8PSK MODULATION

Antenna 2



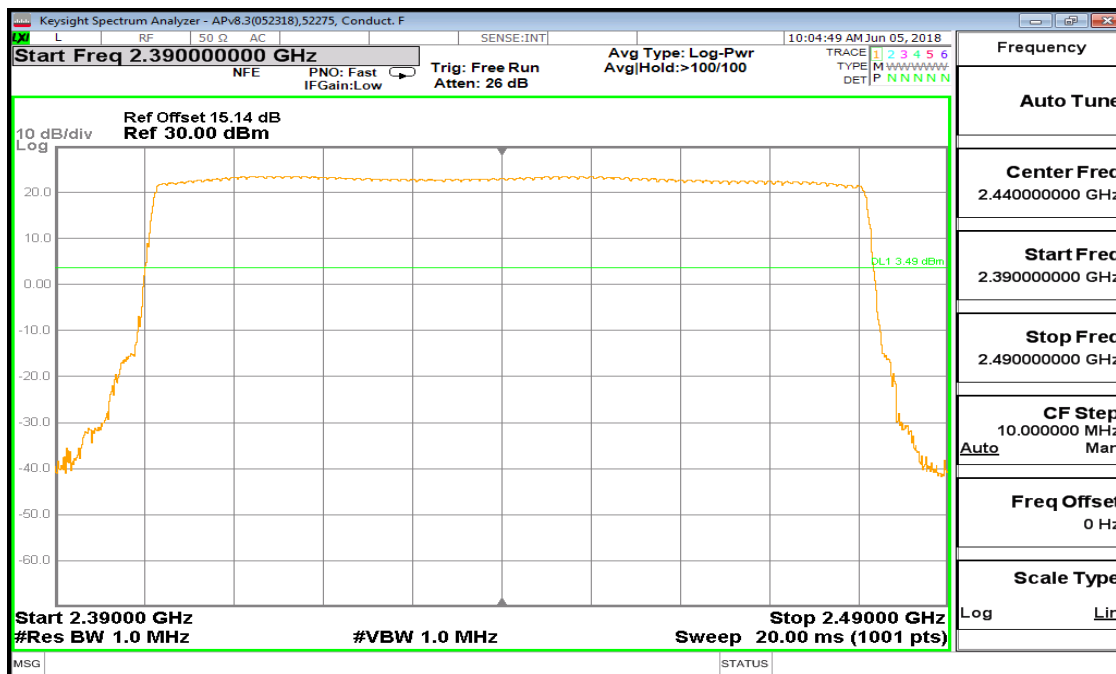


30MHz SPAN, SEGMENT 2 OF 3

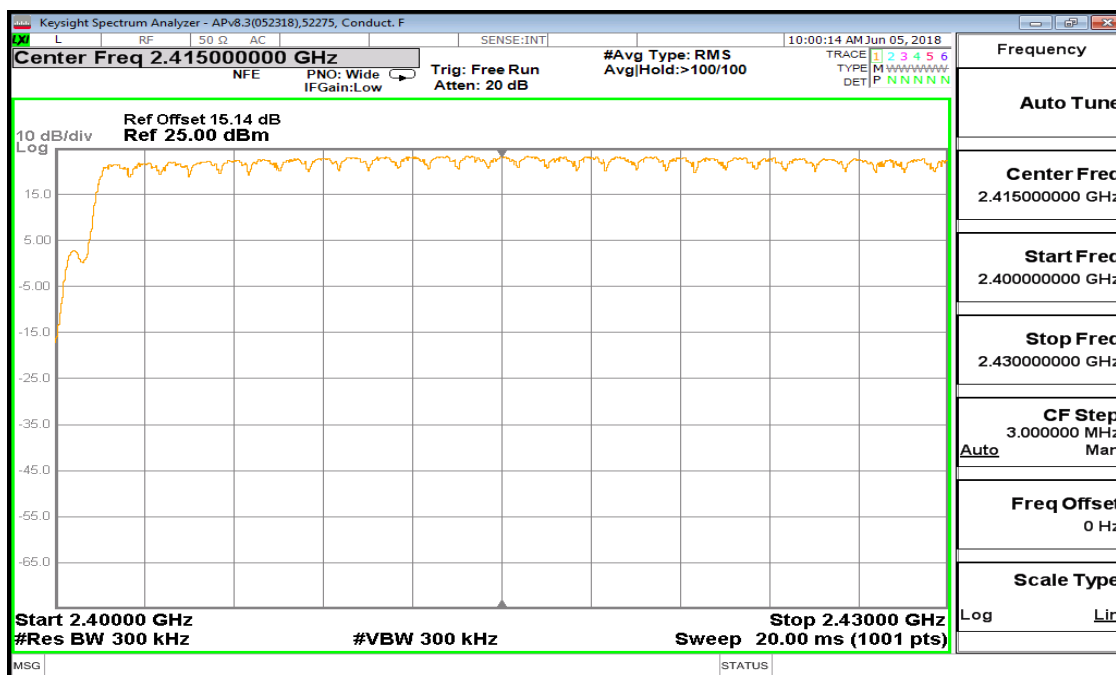


30MHz SPAN, SEGMENT 3 OF 3

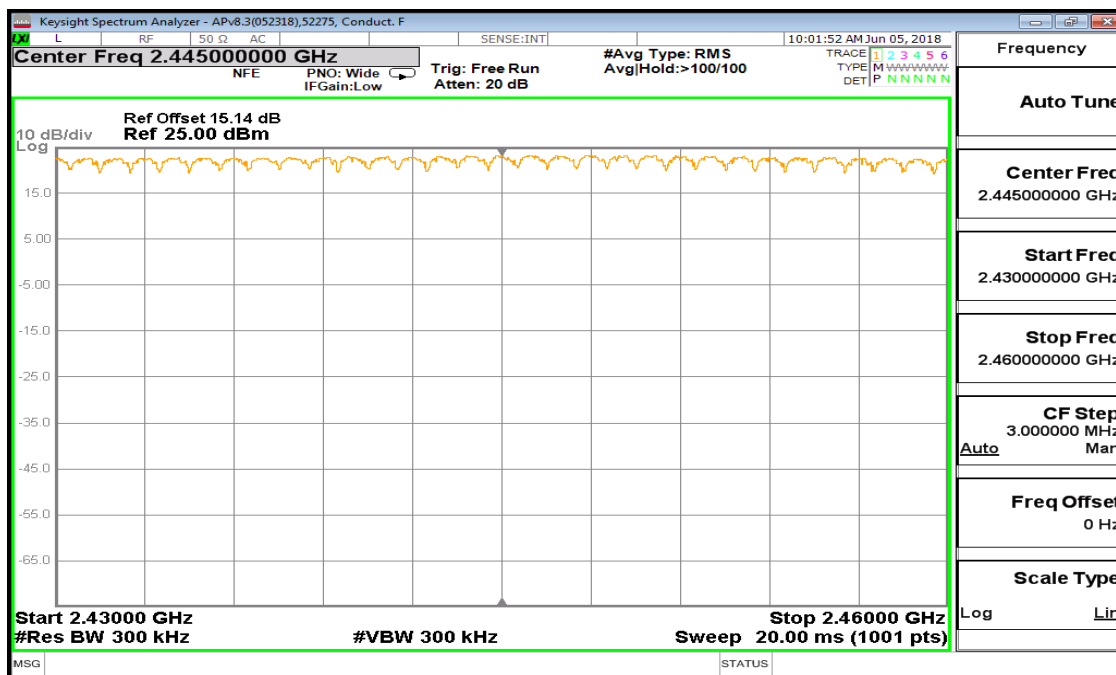
Antenna 5



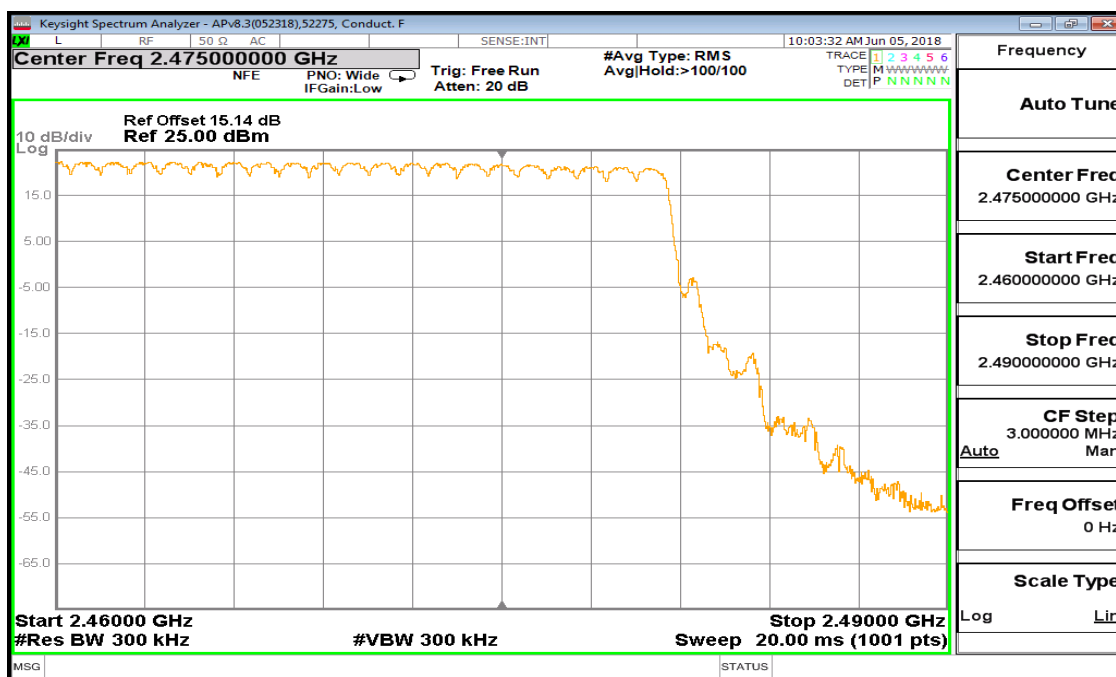
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



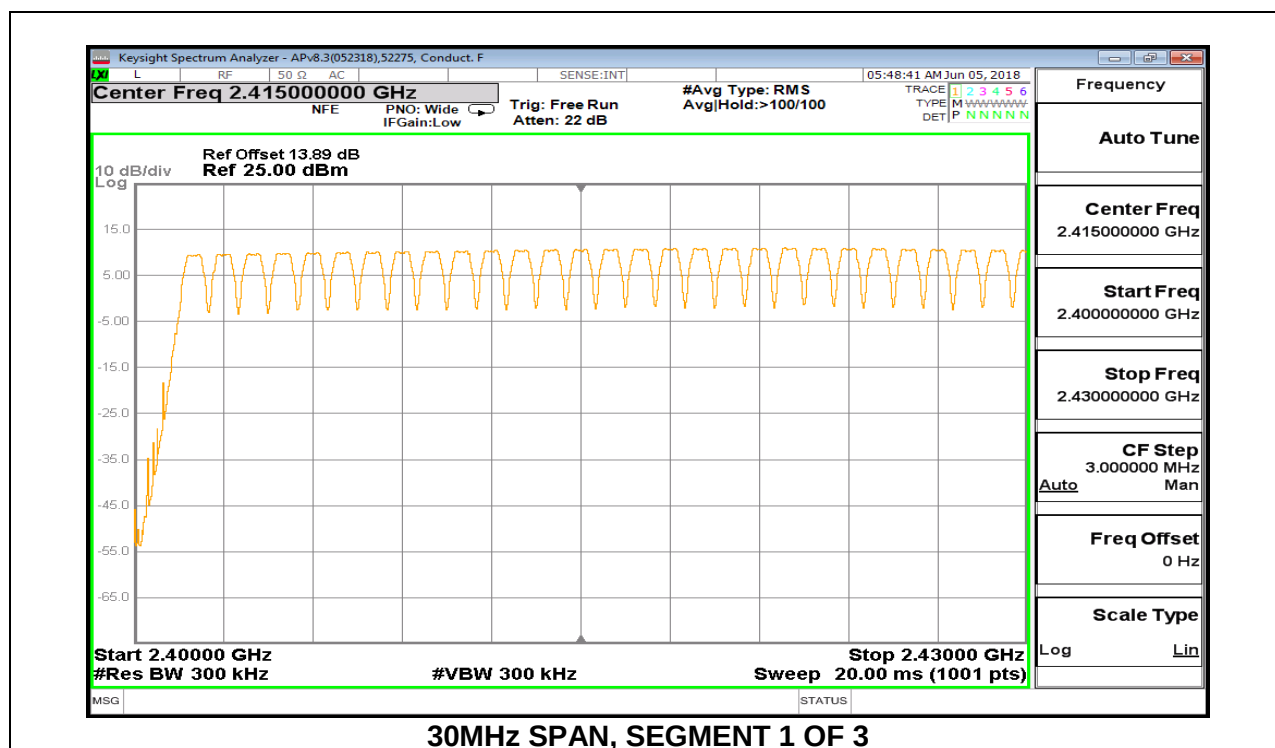
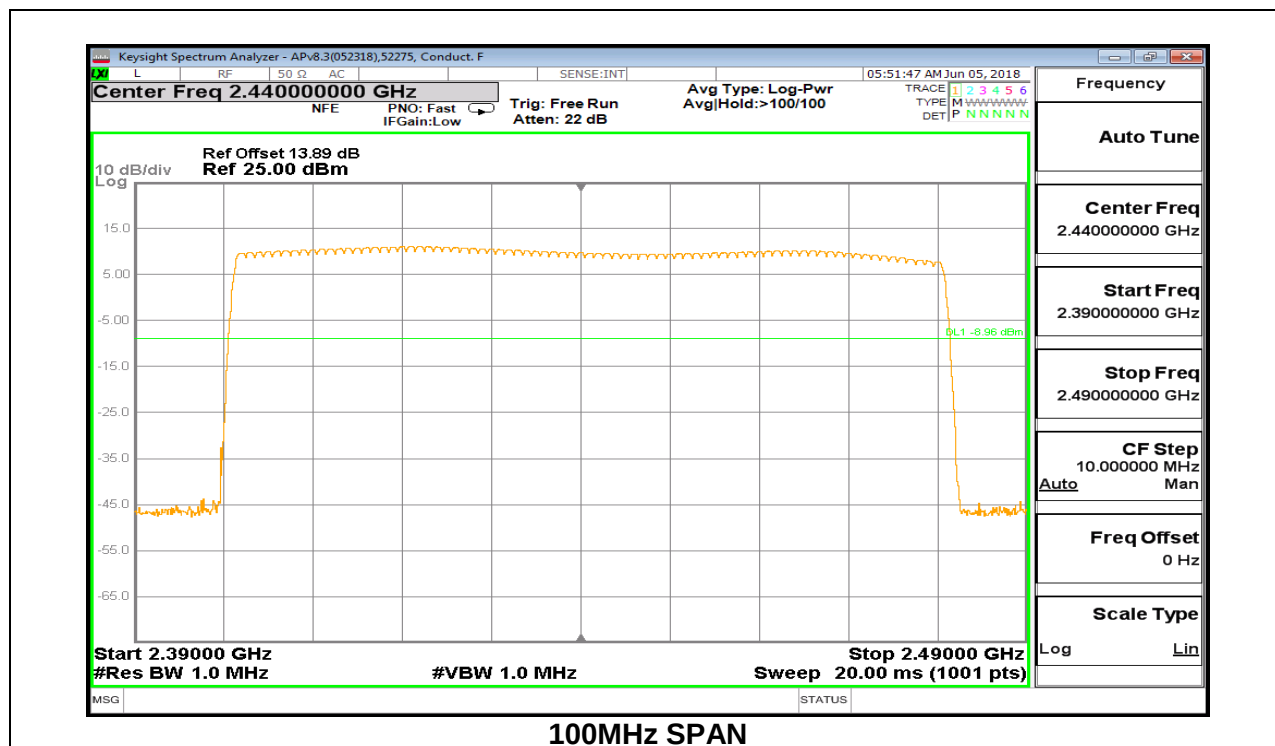
30MHz SPAN, SEGMENT 2 OF 3

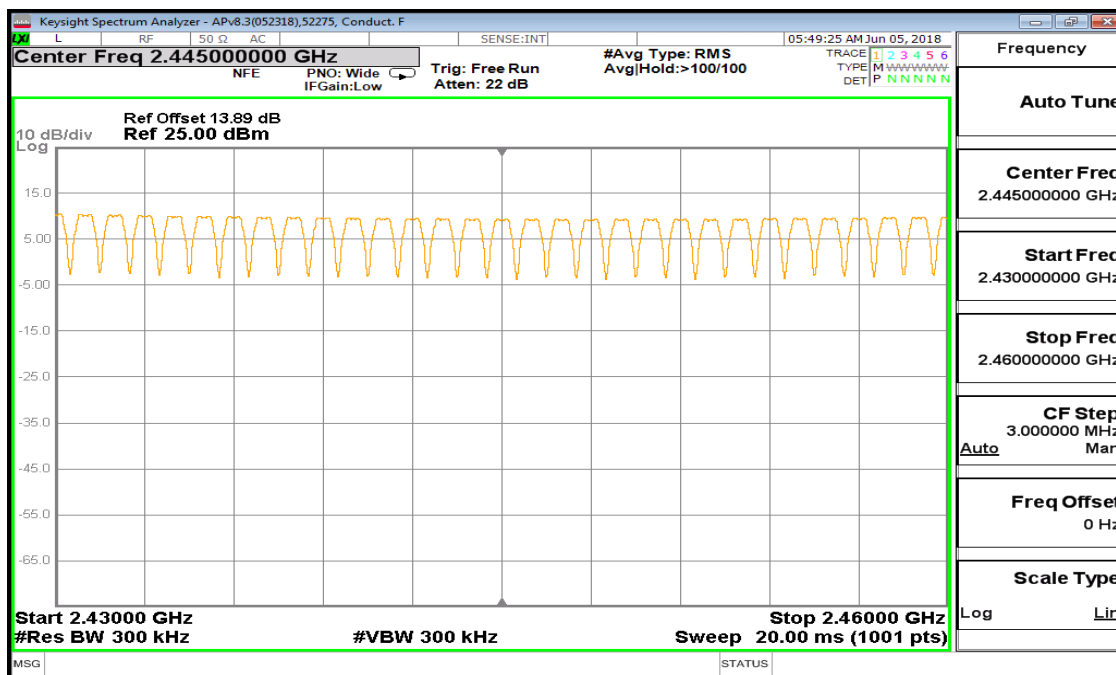


30MHz SPAN, SEGMENT 3 OF 3

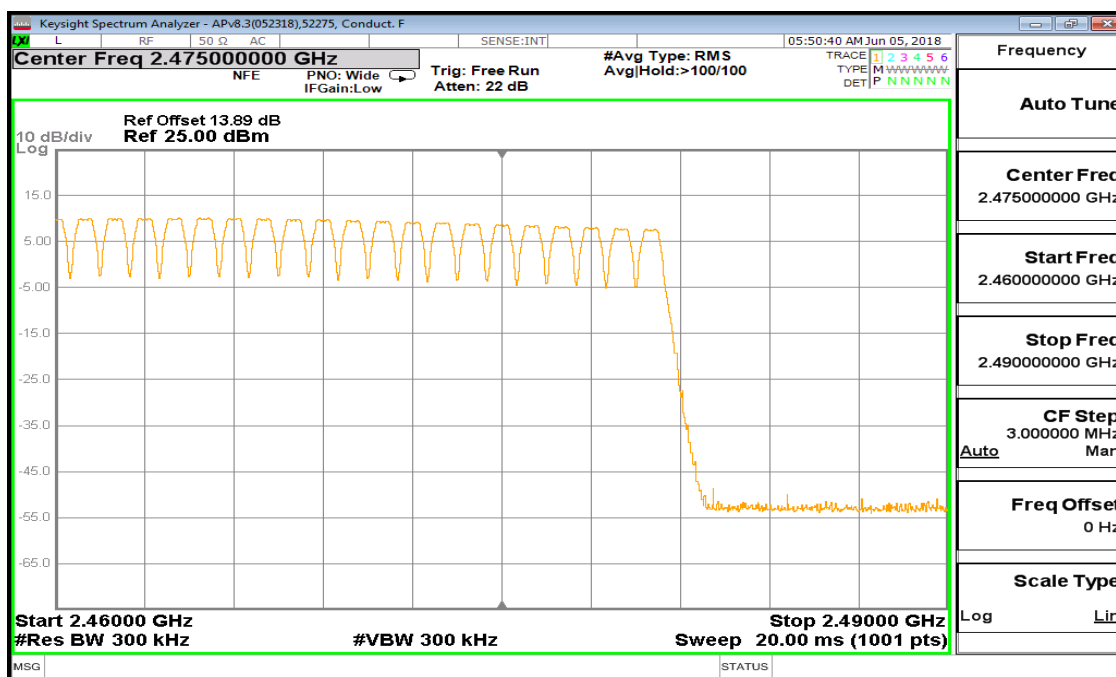
8.4.3. LOW POWER BASIC DATA RATE GFSK MODULATION

Antenna 2



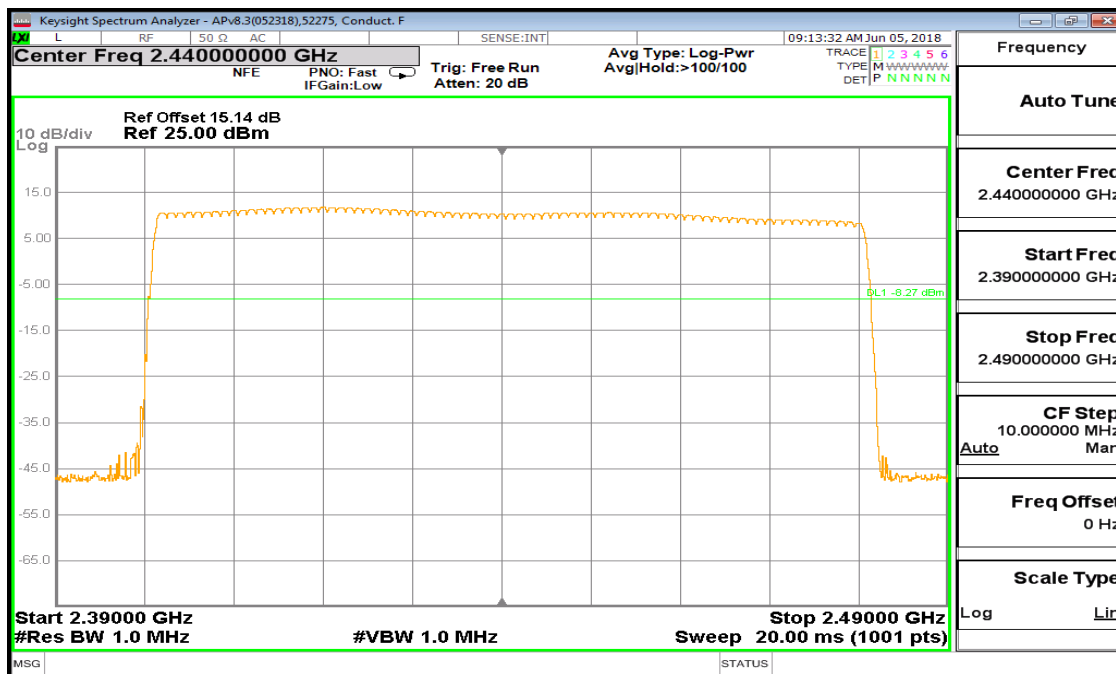


30MHz SPAN, SEGMENT 2 OF 3

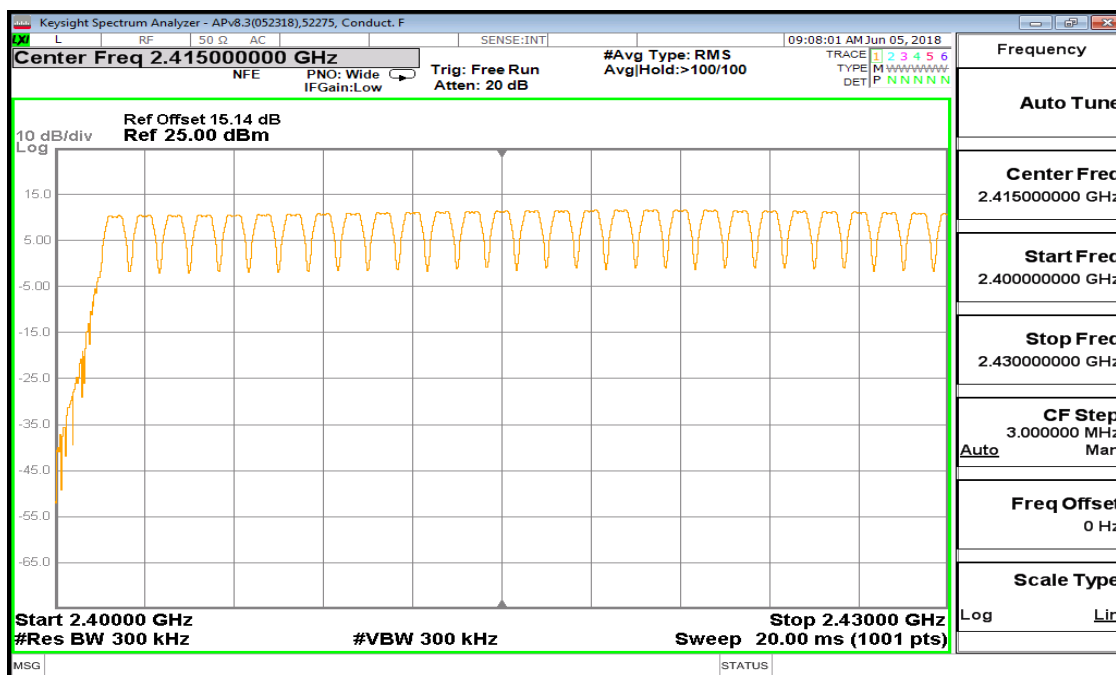


30MHz SPAN, SEGMENT 3 OF 3

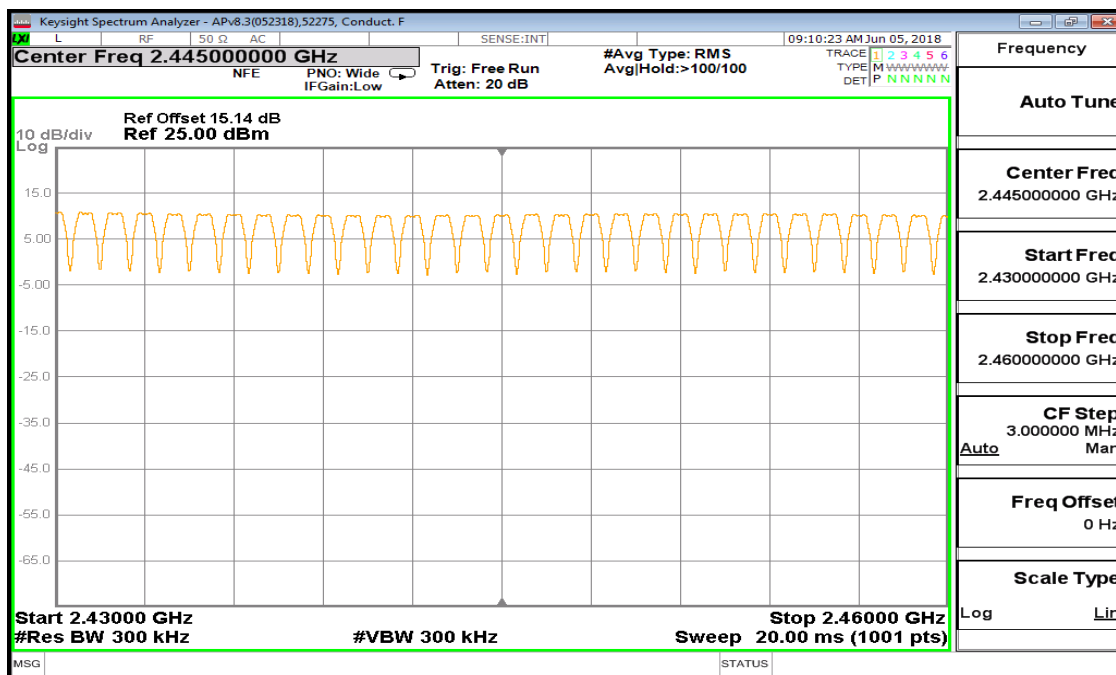
Antenna 5



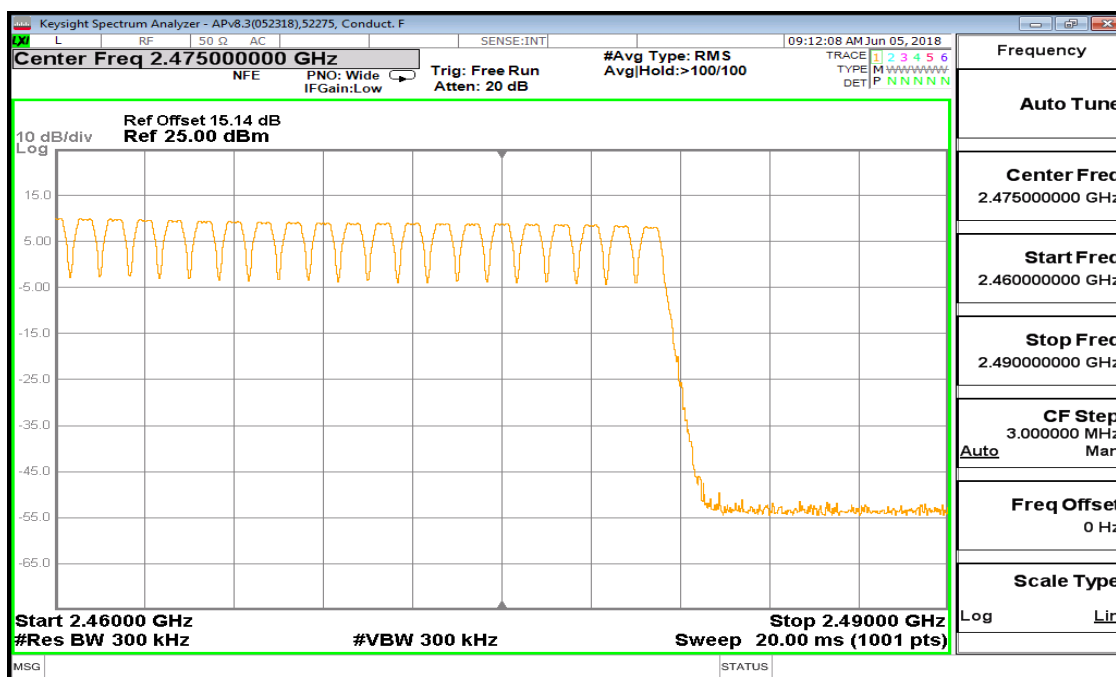
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



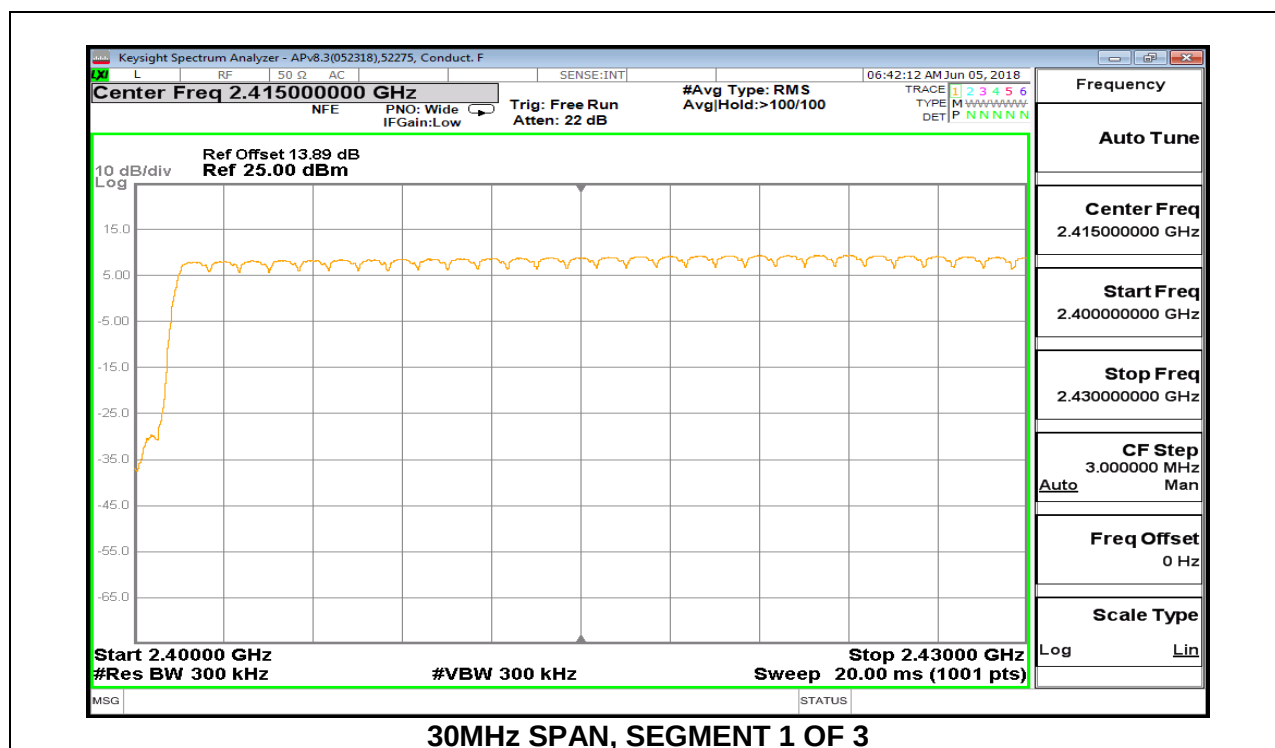
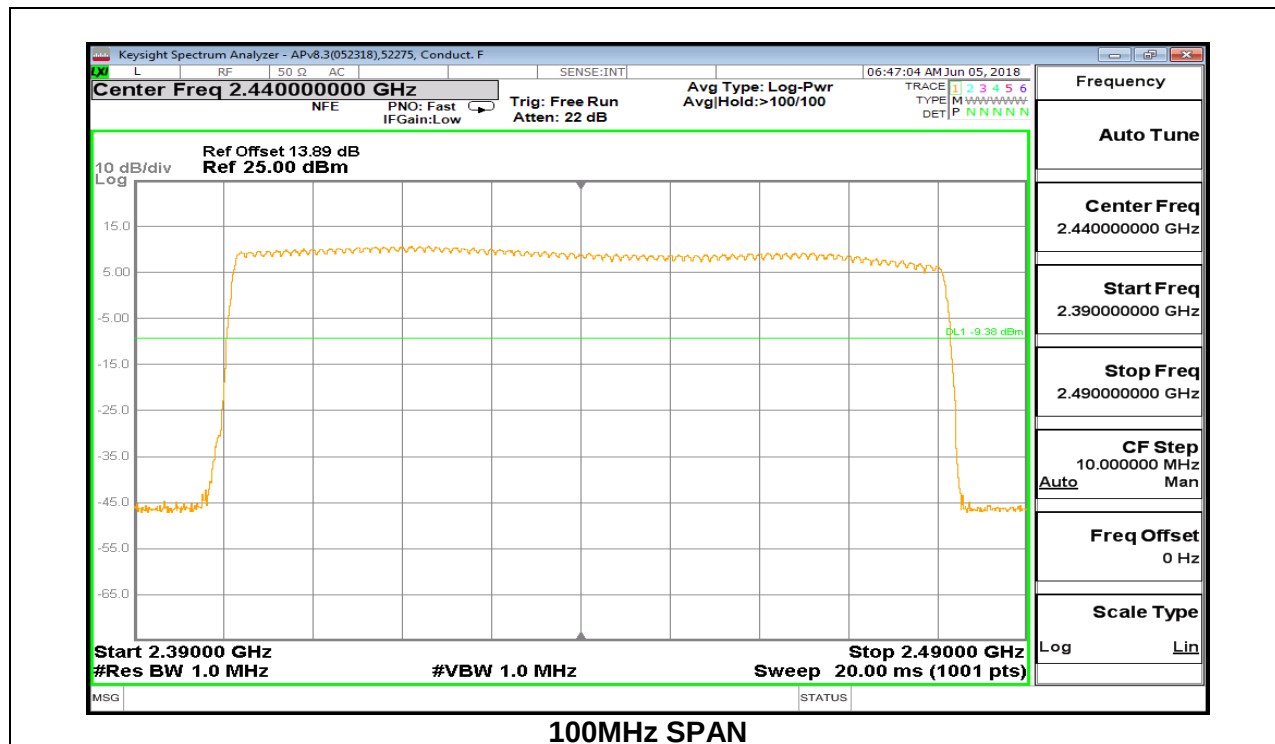
30MHz SPAN, SEGMENT 2 OF 3

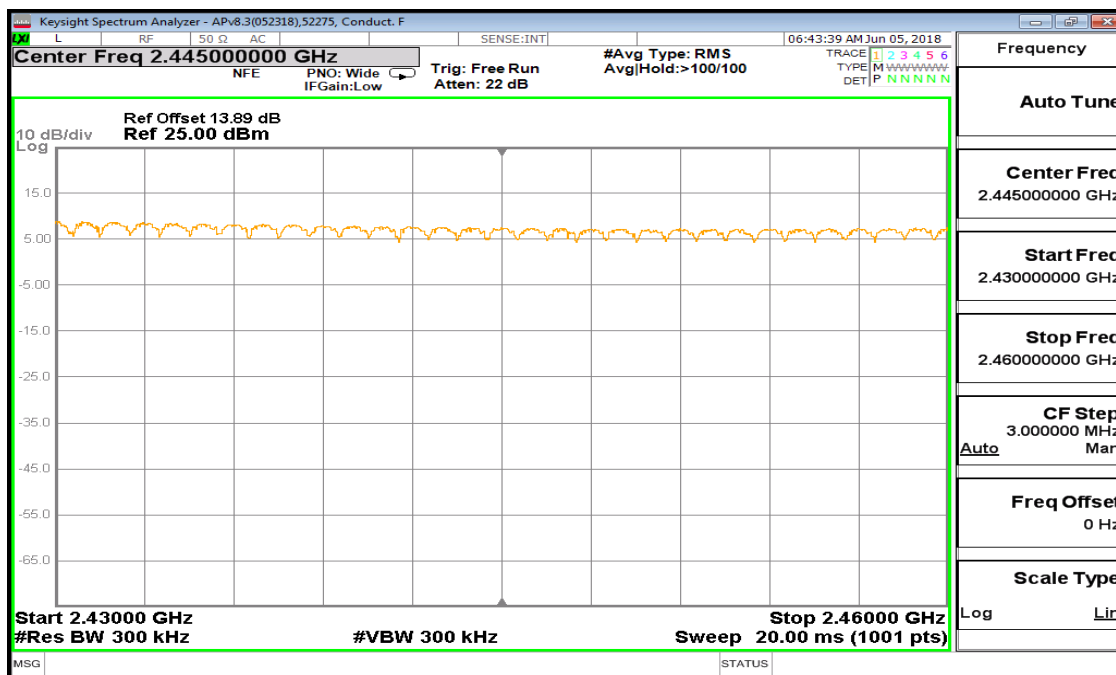


30MHz SPAN, SEGMENT 3 OF 3

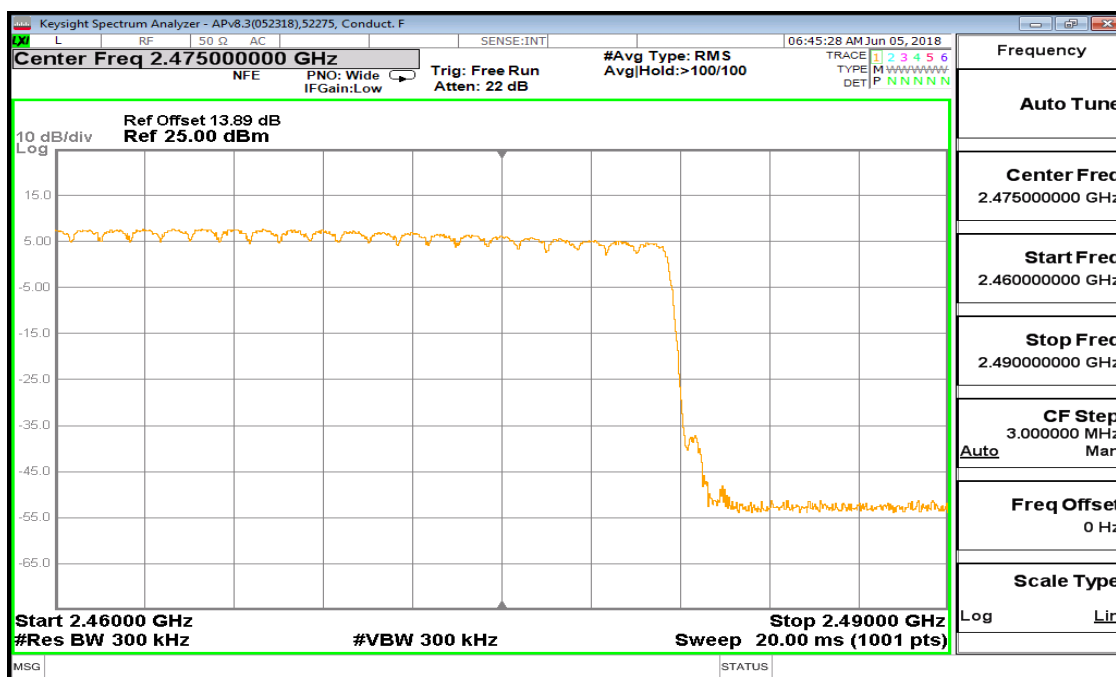
8.4.4. LOW POWER ENCHANCED DATA RATE 8PSK MODULATION

Antenna 2



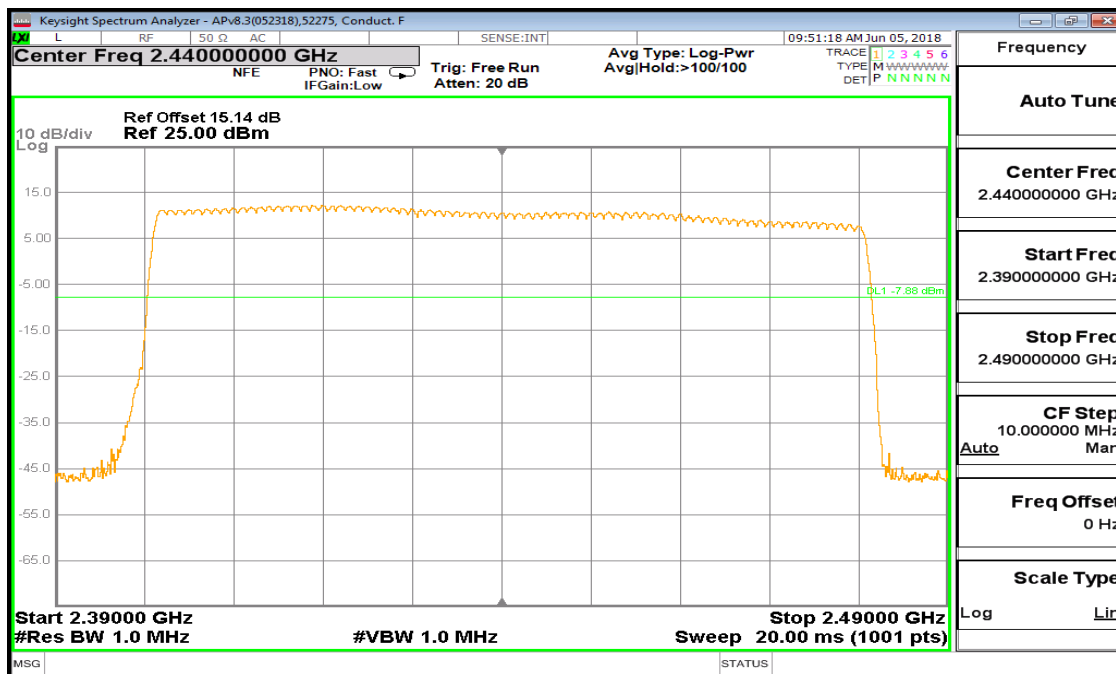


30MHz SPAN, SEGMENT 2 OF 3

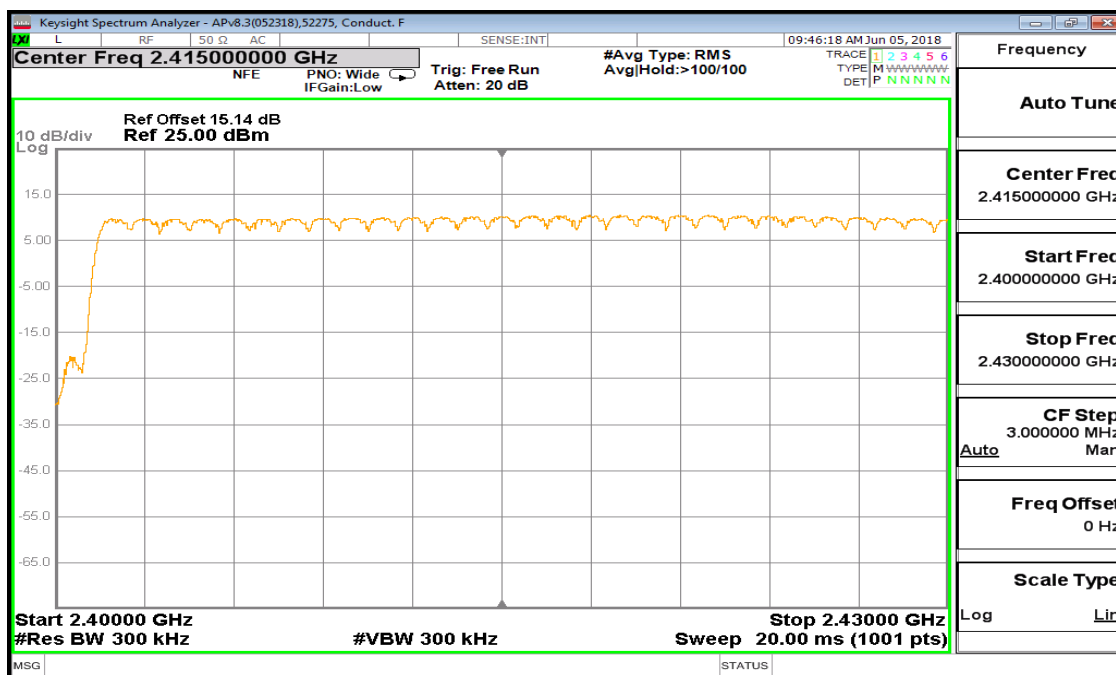


30MHz SPAN, SEGMENT 3 OF 3

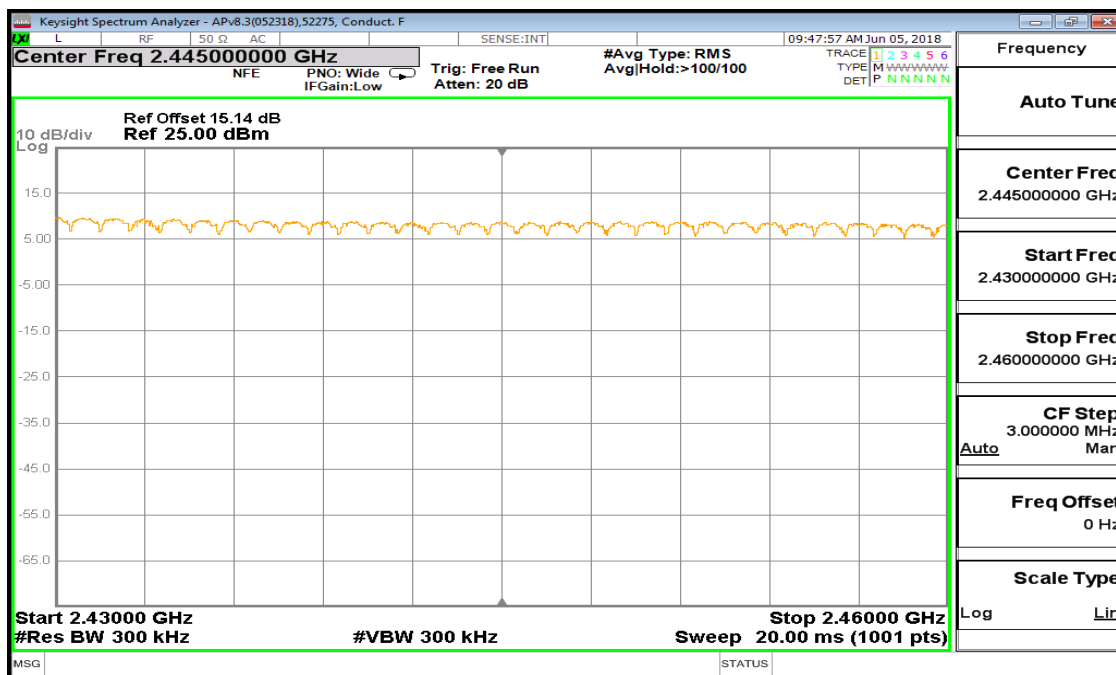
Antenna 5



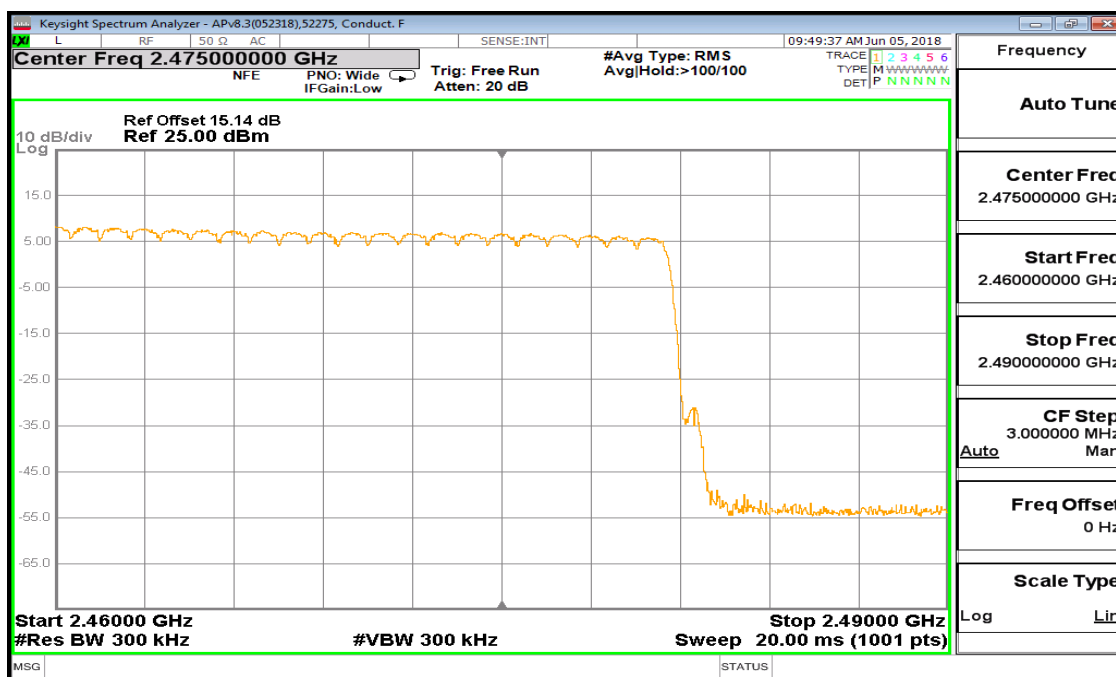
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3



30MHz SPAN, SEGMENT 2 OF 3



30MHz SPAN, SEGMENT 3 OF 3