



CERTIFICATION TEST REPORT

Report Number: 12696945-E11V4

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

Model : A2221

FCC ID : BCG-E3304A

IC : 579C-E3304A

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:

July 31, 2019

Prepared by:

UL Verification Services Inc.
47173 Benicia Street
Fremont, CA 94538 U.S.A.
TEL: (510) 319-4000
FAX: (510) 661-0888



NVLAP Lab code: 200065-0

REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	7/19/2019	Initial Issue	Chris Xiong
V2	7/23/2019	Address TCB Questions	Chris Xiong
V3	7/29/2019	Address TCB Questions on section 5.2	Chris Xiong
V4	7/31/2019	Address TCB Questions on section 8.4 & 8.11	Chin Pang

TABLE OF CONTENTS

REPORT REVISION HISTORY	2
TABLE OF CONTENTS	3
1. ATTESTATION OF TEST RESULTS	6
2. TEST METHODOLOGY	7
3. FACILITIES AND ACCREDITATION	7
4. CALIBRATION AND UNCERTAINTY	8
4.1. MEASURING INSTRUMENT CALIBRATION	8
4.2. SAMPLE CALCULATION	8
4.3. MEASUREMENT UNCERTAINTY	8
5. EQUIPMENT UNDER TEST	9
5.1. EUT DESCRIPTION	9
5.2. MAXIMUM OUTPUT POWER.....	9
5.3. DESCRIPTION OF AVAILABLE ANTENNAS	9
5.4. SOFTWARE AND FIRMWARE.....	9
5.5. WORST-CASE CONFIGURATION AND MODE.....	10
5.6. DESCRIPTION OF TEST SETUP.....	11
6. MEASUREMENT METHOD.....	16
7. TEST AND MEASUREMENT EQUIPMENT	17
8. ANTENNA PORT TEST RESULTS	18
8.1. ON TIME AND DUTY CYCLE	18
8.2. 99% BANDWIDTH.....	20
8.2.1. HIGH POWER HDR (HDR4).....	21
8.2.2. HIGH POWER HDR (HDR8).....	23
8.2.3. LOW POWER HDR (HDR4)	25
8.2.4. LOW POWER HDR (HDR8)	27
8.3. 6 dB BANDWIDTH.....	29
8.3.1. HIGH POWER HDR (HDR4).....	30
8.3.2. HIGH POWER HDR (HDR8).....	32
8.3.3. LOW POWER HDR (HDR4)	34
8.3.4. LOW POWER HDR (HDR8)	36
8.4. OUTPUT POWER.....	38
8.4.1. HIGH POWER HDR (HDR4).....	39
8.4.2. HIGH POWER HDR (HDR8).....	40
8.4.3. LOW POWER HDR (HDR4)	41
8.4.4. LOW POWER HDR (HDR8)	42

8.5.	AVERAGE POWER	43
8.5.1.	HIGH POWER HDR (HDR4).....	44
8.5.2.	HIGH POWER HDR (HDR8).....	45
8.5.3.	LOW POWER HDR (HDR4)	46
8.5.4.	LOW POWER HDR (HDR8)	47
8.6.	POWER SPECTRAL DENSITY	48
8.6.1.	HIGH POWER HDR (HDR4).....	49
8.6.2.	HIGH POWER HDR (HDR8).....	51
8.6.3.	LOW POWER HDR (HDR4)	53
8.6.4.	LOW POWER HDR (HDR8)	55
8.7.	CONDUCTED SPURIOUS EMISSIONS.....	57
8.7.1.	HIGH POWER HDR (HDR4).....	58
8.7.2.	HIGH POWER HDR (HDR8).....	60
8.7.3.	LOW POWER HDR (HDR4)	62
8.7.4.	LOW POWER HDR (HDR8)	64
8.8.	BEAMFORMING, 99% BANDWIDTH	66
8.8.1.	HIGH POWER HDR (HDR4).....	66
8.8.2.	HIGH POWER HDR (HDR8).....	68
8.8.3.	LOW POWER HDR (HDR4)	70
8.8.4.	LOW POWER HDR (HDR8)	72
8.9.	BEAMFORMING, 6dB BANDWIDTH	74
8.9.1.	HIGH POWER HDR (HDR4).....	74
8.9.2.	HIGH POWER HDR (HDR8).....	76
8.9.3.	LOW POWER HDR (HDR4)	78
8.9.4.	LOW POWER HDR (HDR8)	80
8.10.	BEAMFORMING, POWER SPECTRAL DENSITY	82
8.10.1.	HIGH POWER HDR (HDR4)	82
8.10.2.	HIGH POWER HDR (HDR8)	84
8.10.3.	LOW POWER HDR (HDR4).....	86
8.10.4.	LOW POWER HDR (HDR8).....	88
8.11.	BEAMFORMING OUTPUT POWER	90
8.11.1.	HIGH POWER HDR (HDR4)	90
8.11.2.	HIGH POWER HDR (HDR8)	90
8.11.3.	LOW POWER HDR (HDR4).....	91
8.11.4.	LOW POWER HDR (HDR8).....	91
8.12.	BEAMFORMING AVERAGE POWER	92
8.12.1.	HIGH POWER HDR (HDR4)	92
8.12.2.	HIGH POWER HDR (HDR8)	92
8.12.3.	LOW POWER HDR (HDR4).....	93
8.12.4.	LOW POWER HDR (HDR8).....	93
8.13.	BEAMFORMING, CONDUCTED SPURIOUS	94
8.13.1.	HIGH POWER HDR (HDR4)	94
8.13.2.	HIGH POWER HDR (HDR8)	96
8.13.3.	LOW POWER HDR (HDR4).....	98
8.13.4.	LOW POWER HDR (HDR8).....	100
9.	RADIATED TEST RESULTS.....	102
9.1.	LIMITS AND PROCEDURE	102

9.2.	TRANSMITTER ABOVE 1 GHz	104
9.2.1.	HIGH POWER HDR (HDR4).....	104
9.2.2.	HIGH POWER HDR (HDR8).....	124
9.2.3.	LOW POWER HDR (HDR4)	144
9.2.4.	LOW POWER HDR (HDR8)	164
9.2.5.	BEAMFORMING HIGH POWER HDR (HDR4)	184
9.2.6.	BEAMFORMING HIGH POWER HDR (HDR8).....	194
9.2.7.	BEAMFORMING LOW POWER HDR (HDR4).....	204
9.2.8.	BEAMFORMING LOW POWER HDR (HDR8).....	214
9.3.	WORST CASE BELOW 30MHZ	224
9.4.	WORST CASE BELOW 1 GHZ.....	225
9.5.	WORST CASE 18-26 GHZ	227
10.	AC POWER LINE CONDUCTED EMISSIONS	229
10.1.	AC Power Line Host	230
10.2.	AC Power Line Norm.....	232
11.	SETUP PHOTOS	234

1. ATTESTATION OF TEST RESULTS

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

EUT DESCRIPTION: SMARTPHONE

MODEL: A2221

SERIAL NUMBER: C7CYQ00BMTCF; C7CYG01XMCHV

DATE TESTED: FEBRUARY 20, 2019 – JULY 09, 2019

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. 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.

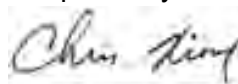
This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This 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.

Approved & Released For
UL Verification Services Inc. By:



Chin Pang
Senior Engineer
Consumer Technology Division
UL Verification Services Inc.

Prepared By:



Chis Xiong
Test Engineer
Consumer Technology Division
UL Verification Services Inc.

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, KDB 558074 D01 15.247 Meas Guidance v05r02, 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 I (ISED:2324A-5)
☒ Chamber B (ISED:2324B-2)	☐ Chamber E (ISED:22541-2)	☐ Chamber J (ISED:2324A-6)
☐ Chamber C (ISED:2324B-3)	☒ Chamber F (ISED:22541-3)	☐ Chamber K (ISED:2324A-1)
	☐ Chamber G (ISED:22541-4)	☐ Chamber L (ISED:2324A-3)
	☐ Chamber H (ISED:22541-5)	

The above test sites and facilities are covered under FCC Test Firm Registration # 208313. Chambers above are covered under Industry Canada company address and respective code

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

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)
 $36.5 \text{ dBuV} + 18.7 \text{ dB/m} + 0.6 \text{ dB} - 26.9 \text{ dB} = 28.9 \text{ dBuV/m}$

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.
 $36.5 \text{ dBuV} + 0 \text{ dB} + 10.1 \text{ dB} + 0 \text{ dB} = 46.6 \text{ dBuV}$

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	2.52 dB
Worst Case Radiated Disturbance, 30 to 1000 MHz	4.88 dB
Worst Case Radiated Disturbance, 1000 to 18000 MHz	4.24 dB
Worst Case Radiated Disturbance, 18000 to 26000 MHz	4.37 dB
Worst Case Radiated Disturbance, 26000 to 40000 MHz	5.17 dB

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

5. EQUIPMENT UNDER TEST

5.1. EUT DESCRIPTION

EUT 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/ax, Bluetooth, Ultra-Wide band, GPS and NFC. All models support at least one UICC based SIM. The second SIM, if present, is either UICC based pSIM (physical SIM) or e-SIM (electronic SIM). The device has a built-in inductive charging receiver. The rechargeable battery is also not user accessible.

5.2. MAXIMUM OUTPUT POWER

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

Antenna	Configuration	Frequency Range (MHz)	Mode	Output Power (dBm)	Output Power (mW)
Antenna 2	High Power	2404 - 2478	HDR4	14.25	26.61
	Low Power			8.83	7.64
	High Power		HDR8	14.77	29.99
	Low Power			9.29	8.49
Antenna 5	High Power	2404 - 2478	HDR4	14.26	26.67
	Low Power			8.78	7.55
	High Power		HDR8	14.79	30.13
	Low Power			9.28	8.47
Antenna 2 + Antenna 5	High Power	2404 - 2478	HDR4	17.21	52.60
	Low Power			11.73	14.89
	High Power		HDR8	17.78	59.98
	Low Power			12.26	16.83

5.3. DESCRIPTION OF AVAILABLE ANTENNAS

Frequency Range (GHz)	Ant. 2 (dBi)	Ant. 5 (dBi)
2.4	-4.5	-2.6

5.4. SOFTWARE AND FIRMWARE

The EUT firmware installed during testing FW Version: 17.1.140.1283

5.5. WORST-CASE CONFIGURATION AND MODE

The EUT was investigated in three orthogonal orientations X, Y and Z on Ant 2 (Core 0) and Ant 5 (Core 1). It was determined that X (Flatbed) was the worst-case orientation for both ANT 2 and 2TX beamforming and Y (Landscape) for Ant 5.

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.

For 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 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.

5.6. DESCRIPTION OF TEST SETUP

Support Equipment List				
Description	Manufacturer	Model	Serial Number	FCC ID
laptop	Apple	A1398	C02PM012G3QD	QDS-BRCM1069
Laptop AC/DC adapter	Liteon Technology	PA-1450-BA1	B123	NA
EUT AC Adapter	Apple	A1385	D29325SM03XDHLHC9	NA

I/O CABLES

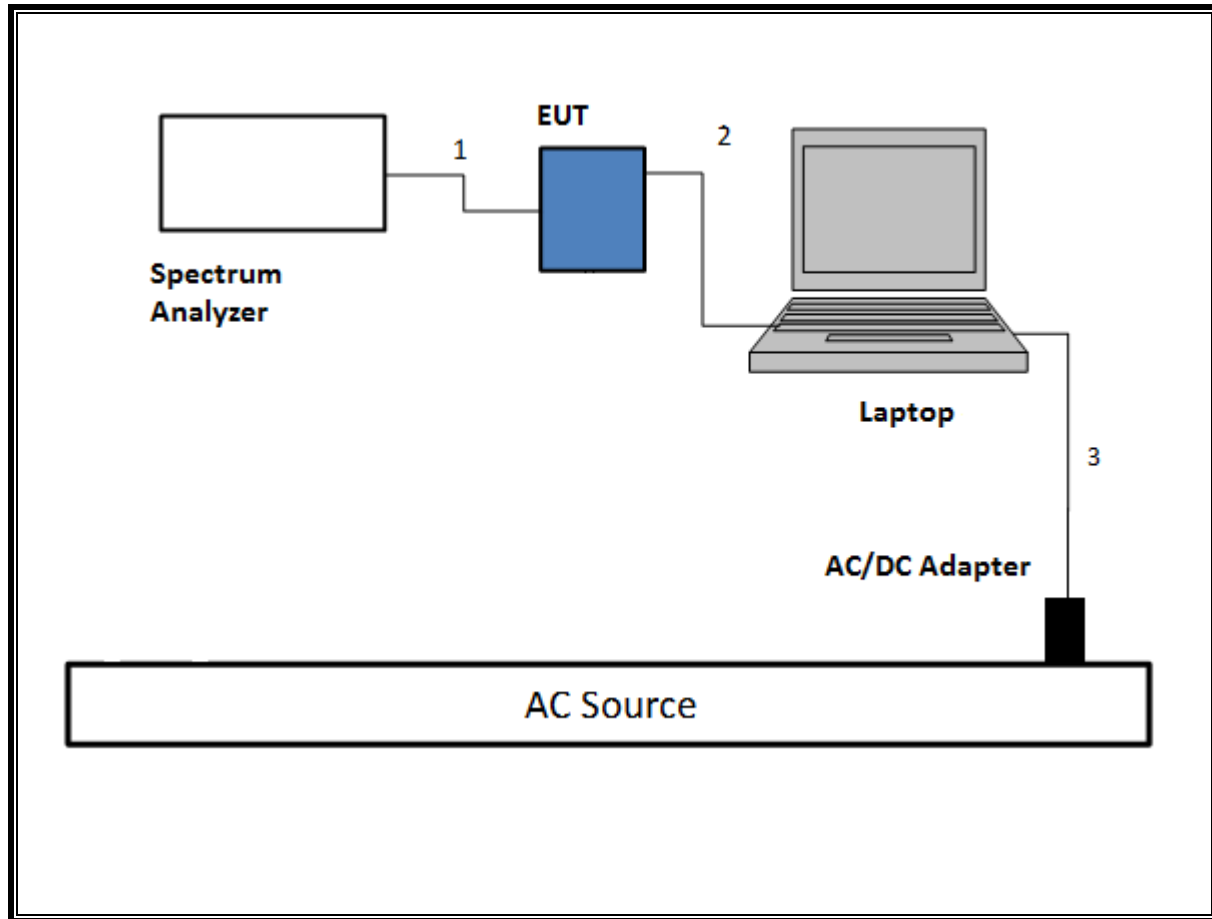
I/O Cable List						
Cable No	Port	# of identical ports	Connector Type	Cable Type	Cable Length (m)	Remarks
1	Antenna	1	SMA	Un-Shielded	0.2	To spectrum Analyzer
2	USB	1	USB	Shielded	1	N/A
3	AC	1	AC	Un-shielded	2	N/A

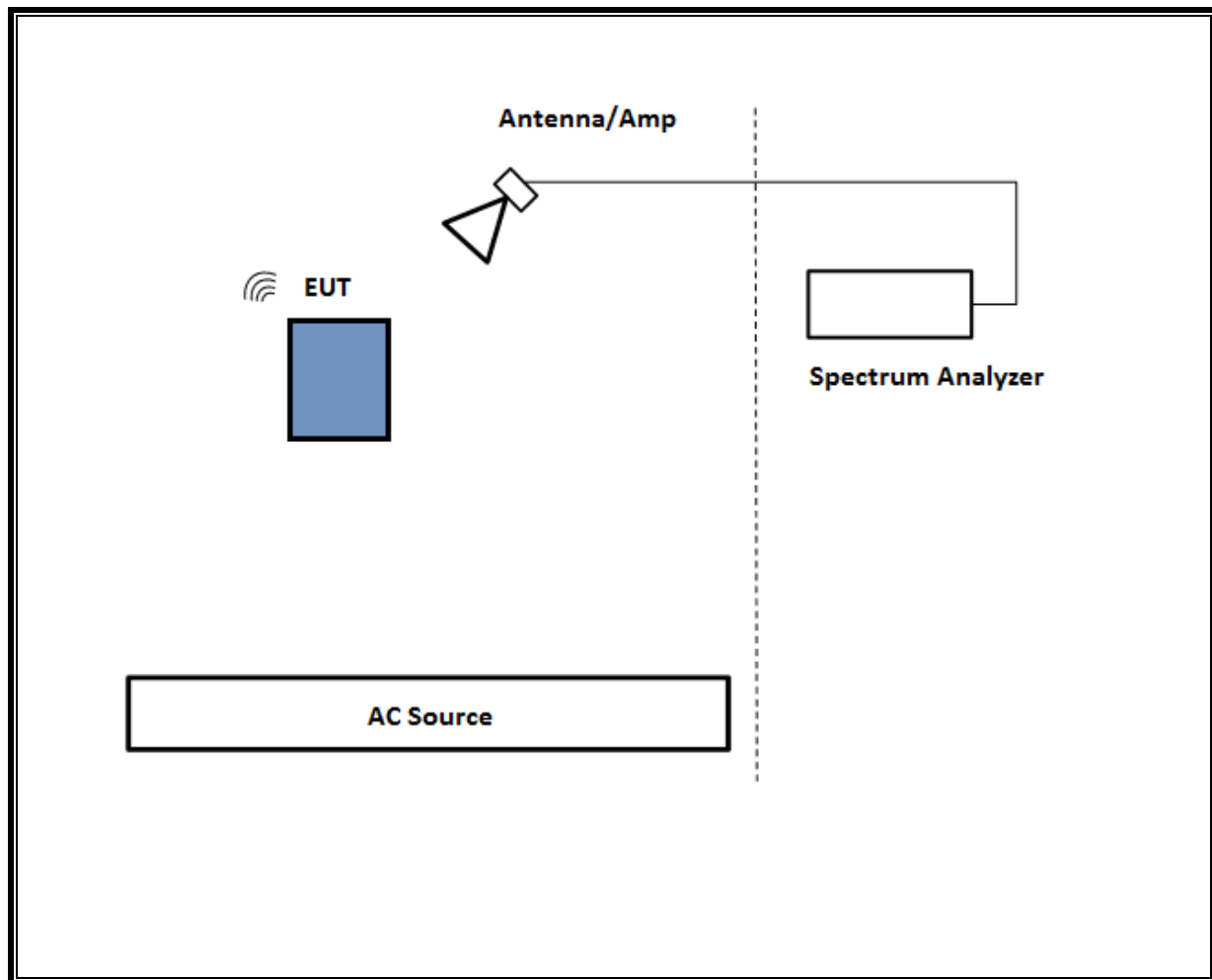
I/O CABLES (BELOW 1GHz AND AC POWER LINE TEST WITH ADAPTER AND LAPTOP)

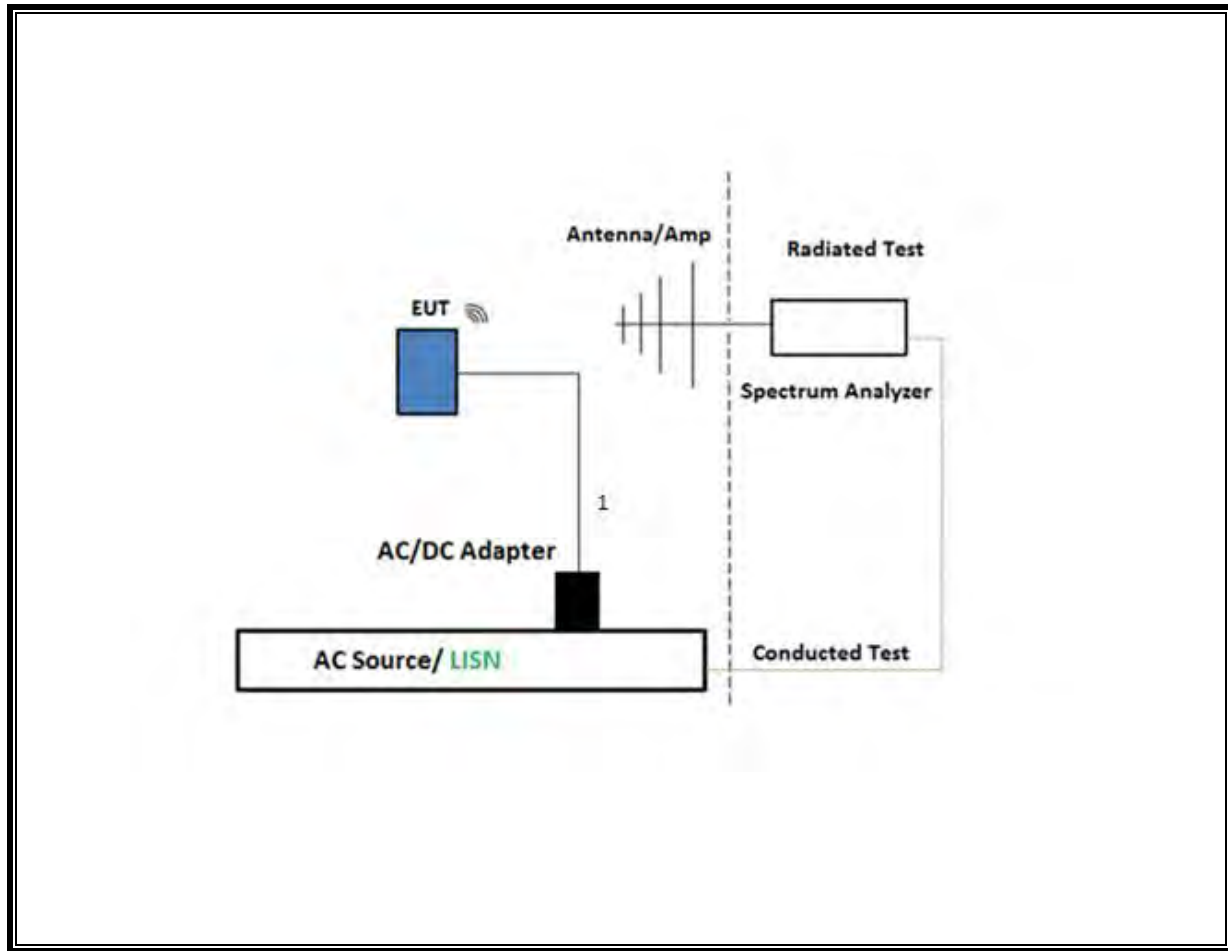
I/O Cable List						
Cable No	Port	# of identical	Connector Type	Cable Type	Cable Length (m)	Remarks
1	AC	1	AC	Un-shielded	2	N/A
2	USB	1	USB	Un-shielded	1	N/A

TEST SETUP

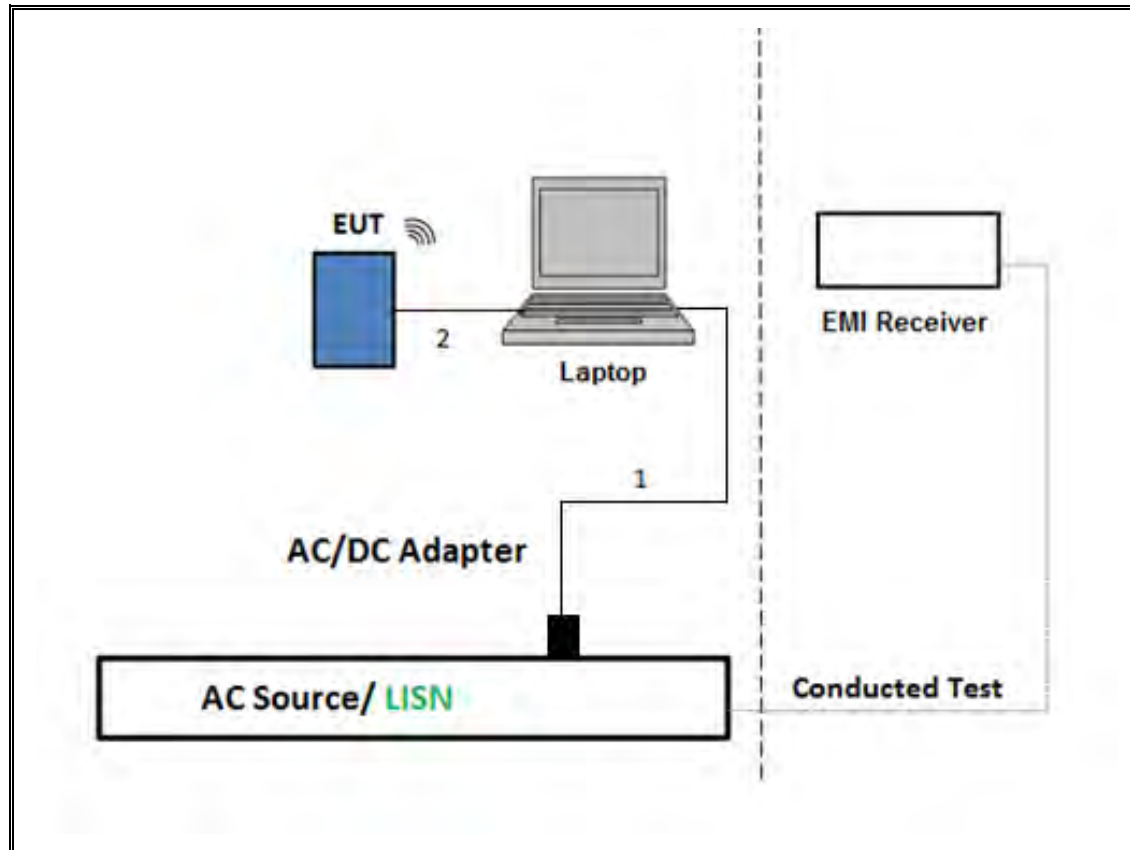
The EUT is connected to a test laptop during the tests. Test software exercised the radio card.

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. MEASUREMENT METHOD

On Time and Duty Cycle: KDB 558074 D01 v05r02, Section 6.

6 dB BW: KDB 558074 D01 v05r02, Section 2.1, ANSI C63.10 Subclause 11.8.1

Output Power (Peak): KDB 558074 D01 v05r02, Section 8.3.1, ANSI C63.10 Subclause 11.9.1

Output Power (Average): KDB 558074 D01 v05r02, Section 8.3.1, ANSI C63.10 Subclause - 11.9.2

Power Spectral Density: KDB 558074 D01 v05r02, Section 8.4,

Out-of-band emissions in non-restricted bands: KDB 558074 D01 v05r02, Section 8.1. ANSI C63.10 Subclause 11.11

Out-of-band emissions in restricted bands: KDB 558074 D01 v05r02, Section 8.1, ANSI C63.10 Subclause 11.12

Band-edge: KDB 558074 D01 v05r02, Section 8.6

AC Power Line Conducted Emissions: ANSI C63.10-2013, Section 6.2.

NOTE: All conducted testing for Beamforming applied same test procedures as BT HDR normal modes.

7. TEST AND MEASUREMENT EQUIPMENT

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

TEST EQUIPMENT LIST				
Description	Manufacturer	Model	Asset	Cal Due
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T345	04/20/2020
*Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T1165	06/12/2019
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T863	05/30/2020
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T493	08/30/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T119	03/22/2020
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T740	10/06/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T136	07/02/2020
*Amplifier, 1 to 18GHz, 35dB	Ampical	AFS42-00101800-25-S-42	T1568	06/21/2019
Antenna, Double Ridge Guide Horn Antenna 700MHz to 18GHz	A.H. SYSTEMS, INC.	SAS-571	PRE0190810	07/10/2019
Antenna, Broadband Hybrid, 30MHz to 2000MHz	Sunol Sciences	JB1	T122	03/21/2020
Amplifier, 10KHz to 1GHz, 32dB	Sonoma	310N	T835	01/02/2020
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T136	07/02/2020
Amplifier, 1 to 18GHz, 35dB	Ampical	AFS42-00101800-25-S-42	T1567	01/26/2020
*Antenna Horn, 18 to 26GHz	ARA	MWH-1826	T447	06/16/2019
Pre-Amp 18-26GHz	Agilent Technology	8449B	T404	03/23/2020
Power Meter, P-series single channel	Keysight	N1912A	T1244	01/30/2020
Power Sensor	Keysight	N1921A	T1224	02/22/2020
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T342	01/23/2020
*3GHz HPF	Micro-Tronics	HPM17543	T1013	06/21/2019
Antenna, Active Loop 9KHz to 30MHz	ETS-Lindgren	6502	T757	09/25/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T459	07/25/2019

AC Line Conducted				
EMI Test Receiver 9KHz-7GHz	Rohde & Schwarz	ESCI7	T1436	02/14/2020
Power Cable, Line Conducted Emissions	UL	PG1	T861	08/31/2019
*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	

*Testing is completed before equipment expiration date.

8. ANTENNA PORT TEST RESULTS

8.1. ON TIME AND DUTY CYCLE

LIMITS

None; for reporting purposes only.

PROCEDURE

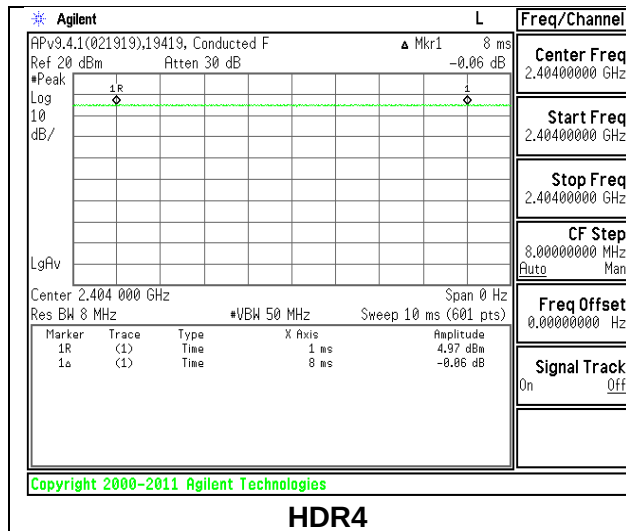
KDB 558074 Zero-Span Spectrum Analyzer Method.

ID:	30606	Date:	June 23, 2019
------------	-------	--------------	---------------

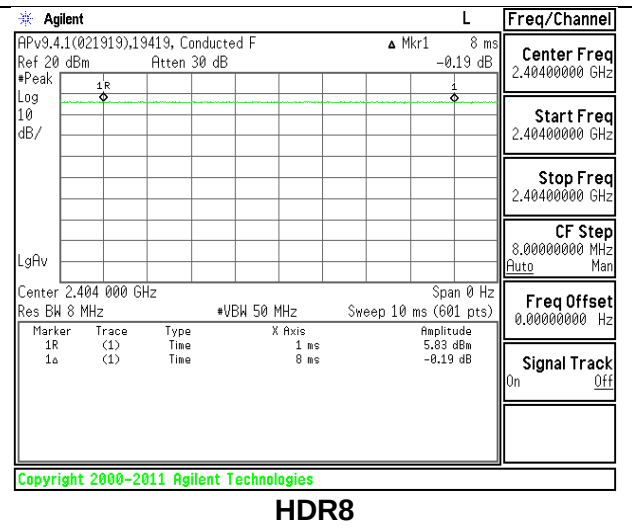
ON TIME AND DUTY CYCLE WITH HIGH POWER RESULTS

Mode	ON Time B (msec)	Period (msec)	Duty Cycle x (linear)	Duty Cycle (%)	Duty Cycle Correction Factor (dB)	1/B Minimum VBW (kHz)
2.4GHz Band						
HDR4	1.000	1.000	1.000	100.00%	0.00	0.010
HDR8	1.000	1.000	1.000	100.00%	0.00	0.010
HDR4, TXBF	1.000	1.000	1.000	100.00%	0.00	0.010
HDR8, TXBF	1.000	1.000	1.000	100.00%	0.00	0.010

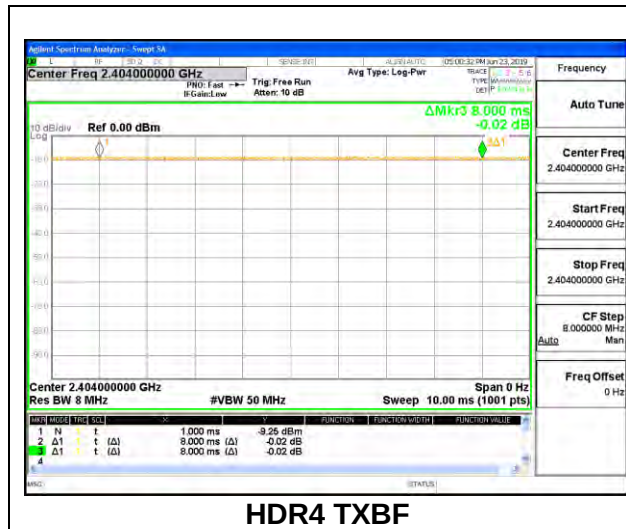
Note: Low Power duty cycle is same as high power



HDR4



HDR8



HDR4 TXBF



HHDR8 TXBF

8.2. 99% BANDWIDTH

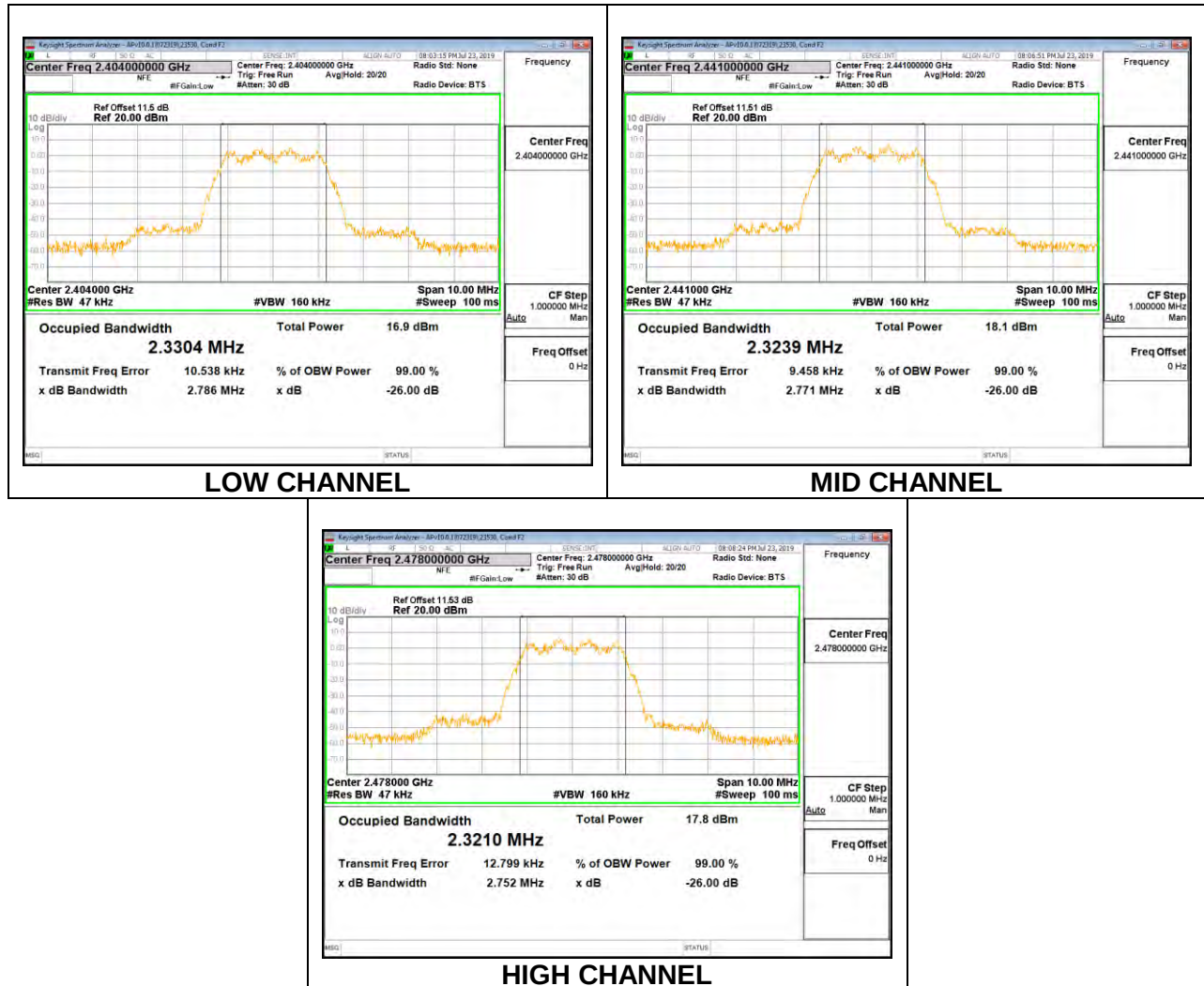
LIMITS

None; for reporting purposes only.

RESULTS

Antenna 5

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2404	2.3304
Middle	2441	2.3239
High	2478	2.3210



8.2.2. HIGH POWER HDR (HDR8)

Antenna 2

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2404	4.6736
Middle	2441	4.6922
High	2478	4.7092





8.2.3. LOW POWER HDR (HDR4)

Antenna 2

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2404	2.3220
Middle	2441	2.3269
High	2478	2.3234

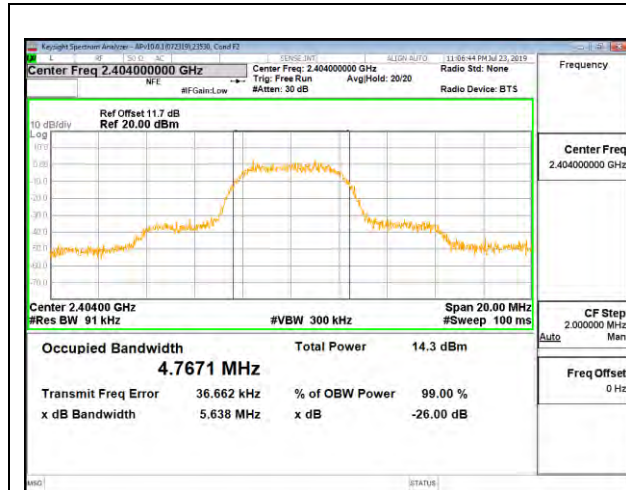




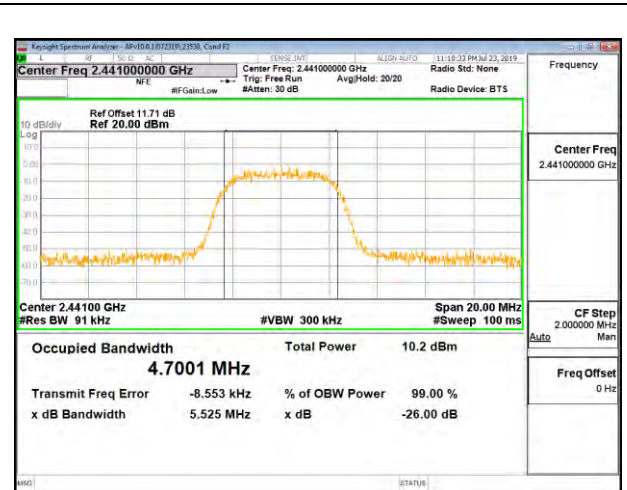
8.2.4. LOW POWER HDR (HDR8)

Antenna 2

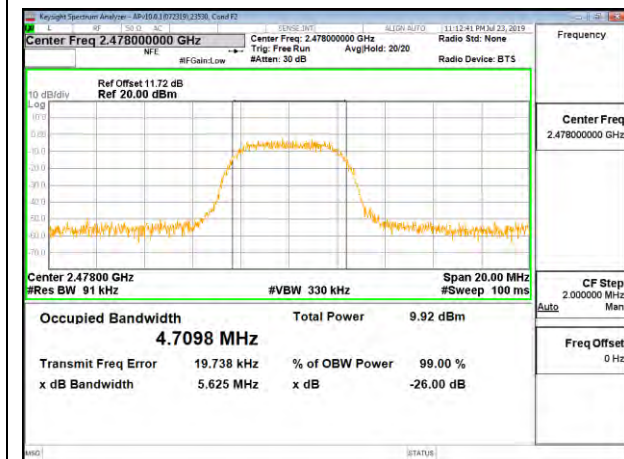
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2404	4.7671
Middle	2441	4.7001
High	2478	4.7098



LOW CHANNEL



MID CHANNEL



HIGH CHANNEL

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2404	4.7795
Middle	2441	4.7442
High	2478	4.7607



8.3. 6 dB BANDWIDTH

LIMITS

FCC §15.407 (e)

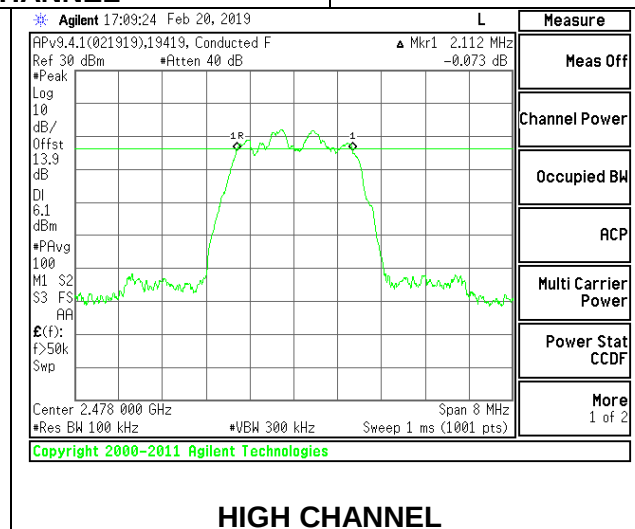
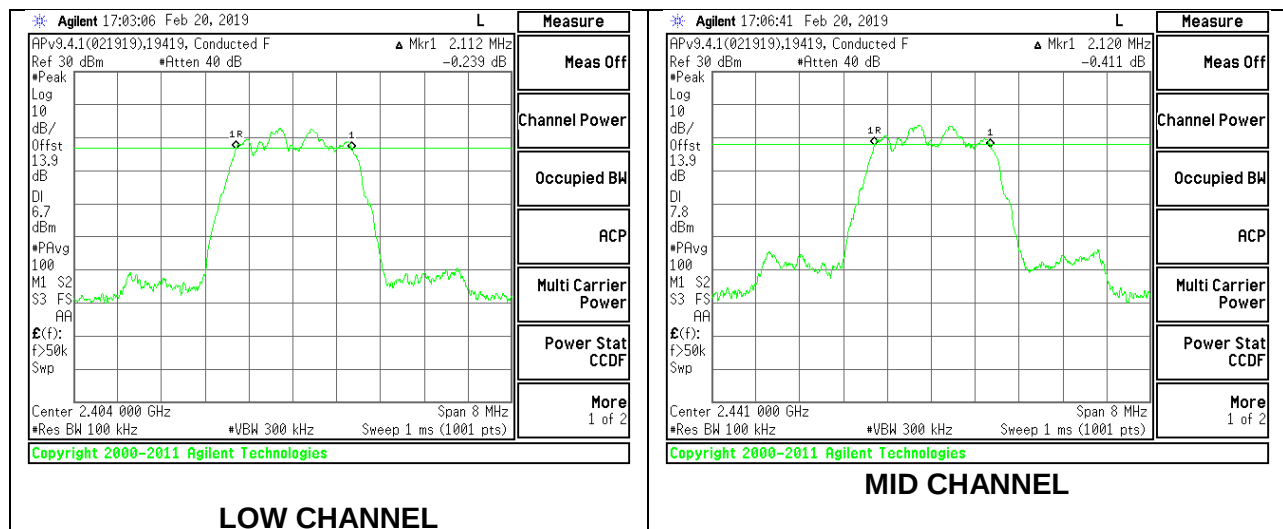
RSS-247 5.2 (a)

The minimum 6 dB bandwidth shall be at least 500 kHz.

RESULTS

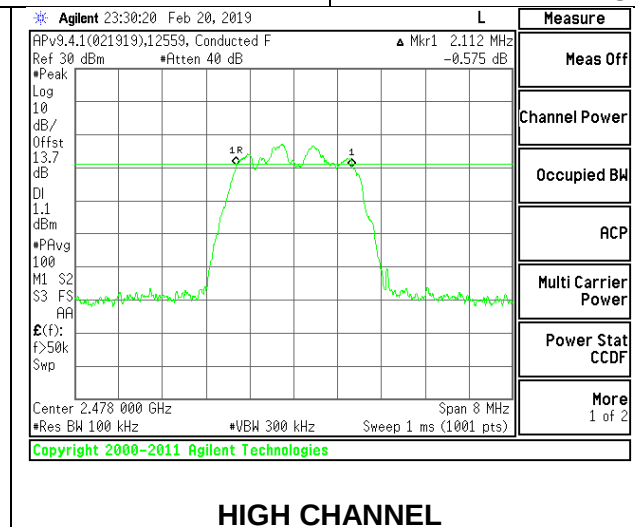
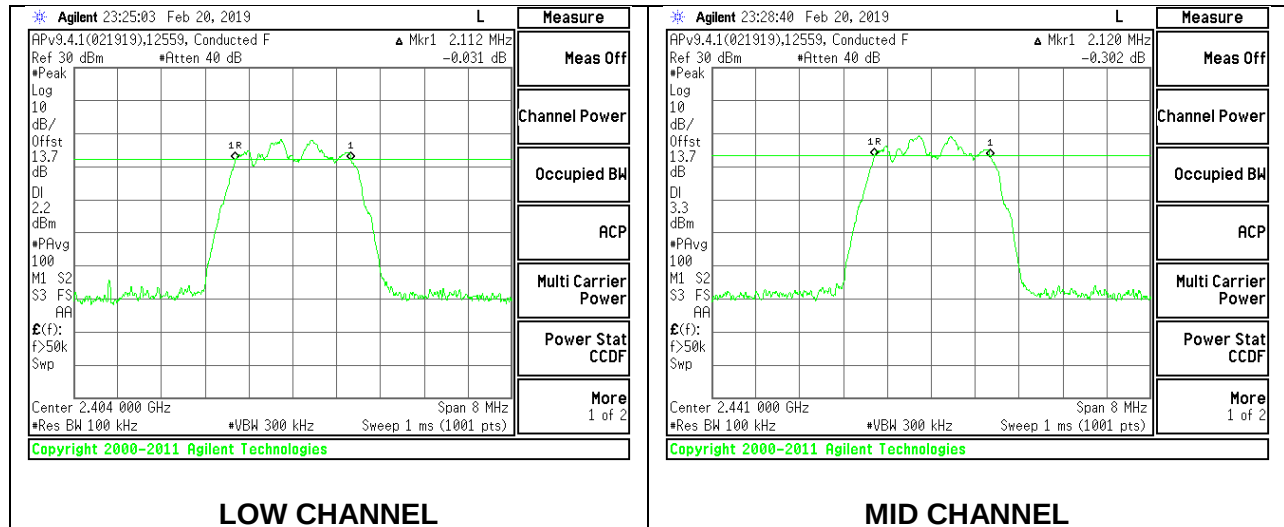
8.3.1. HIGH POWER HDR (HDR4)**Antenna 2**

Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	2.1120	0.5
Middle	2441	2.1200	0.5
High	2478	2.1120	0.5



Antenna 5

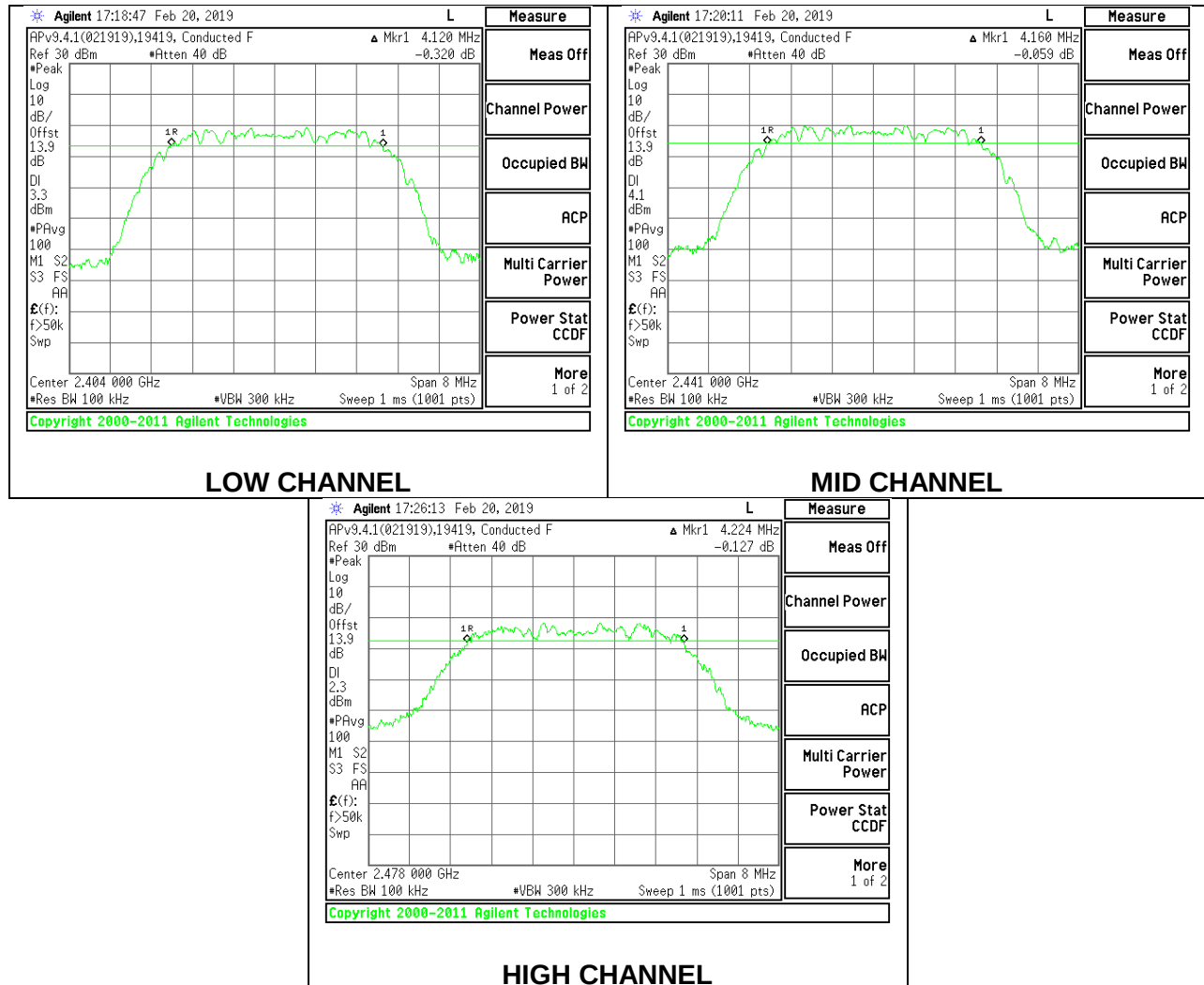
Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	2.1120	0.5
Middle	2441	2.1200	0.5
High	2478	2.1120	0.5



8.3.2. HIGH POWER HDR (HDR8)

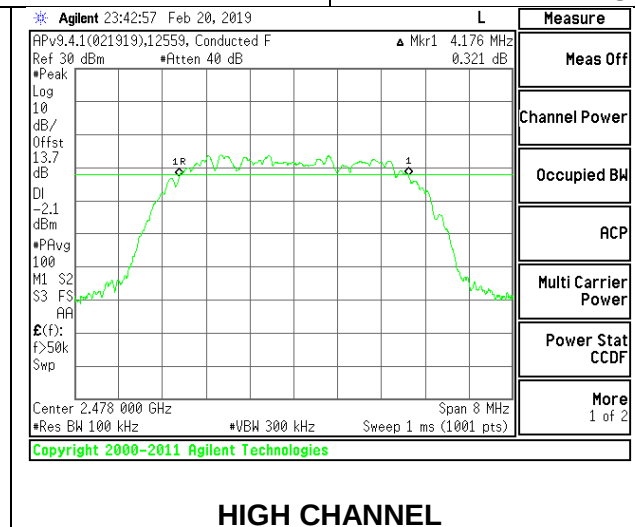
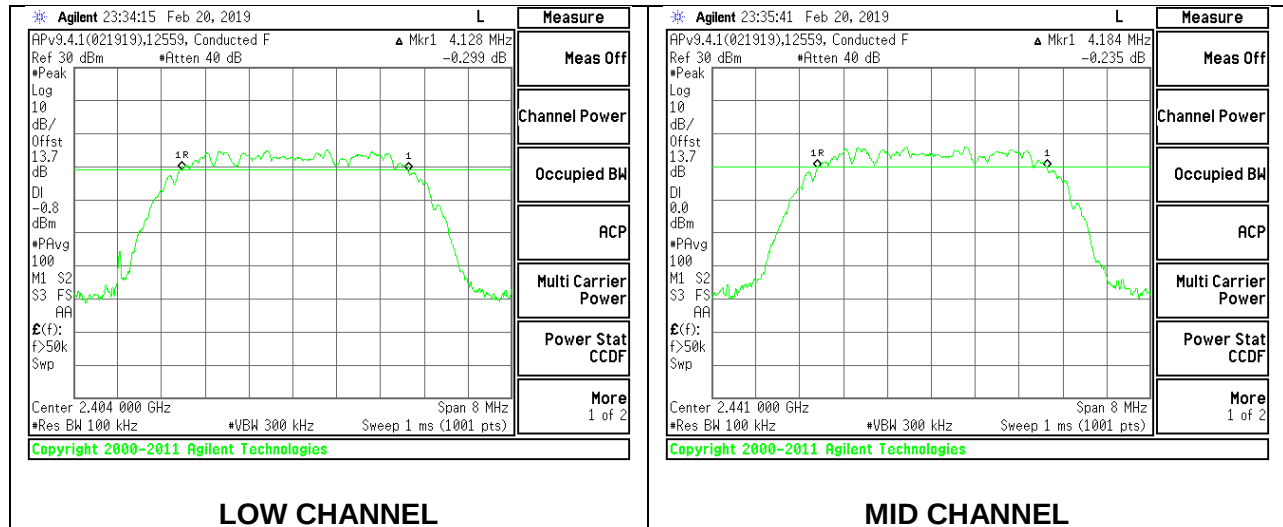
Antenna 2

Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	4.120	0.5
Middle	2441	4.160	0.5
High	2478	4.224	0.5



Antenna 5

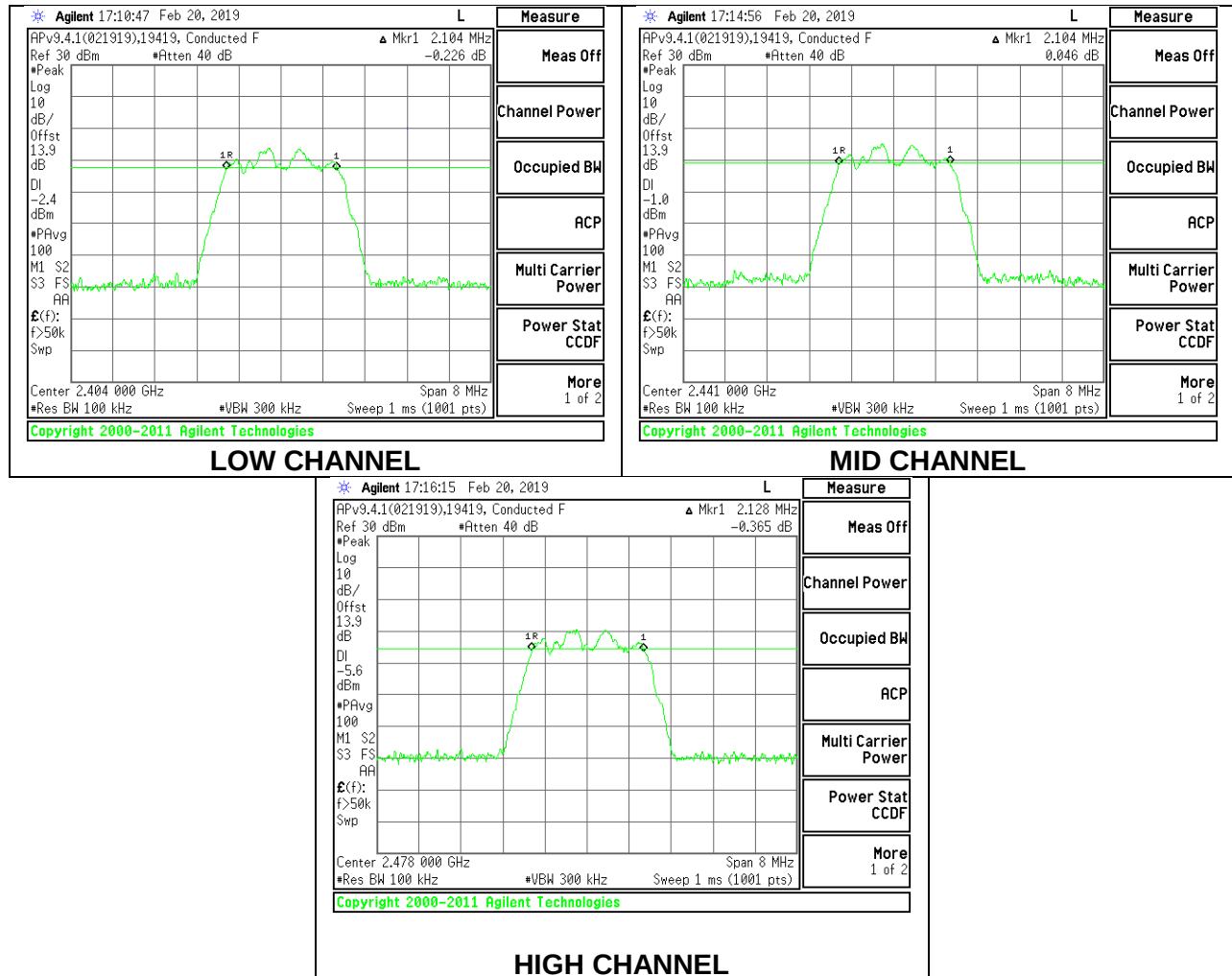
Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	4.128	0.5
Middle	2441	4.184	0.5
High	2478	4.176	0.5



8.3.3. LOW POWER HDR (HDR4)

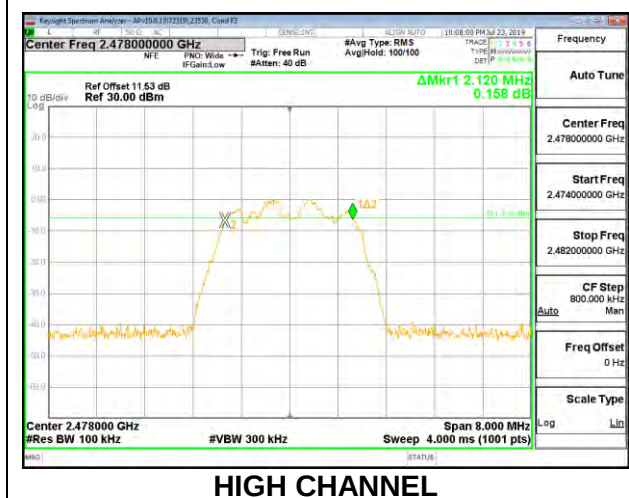
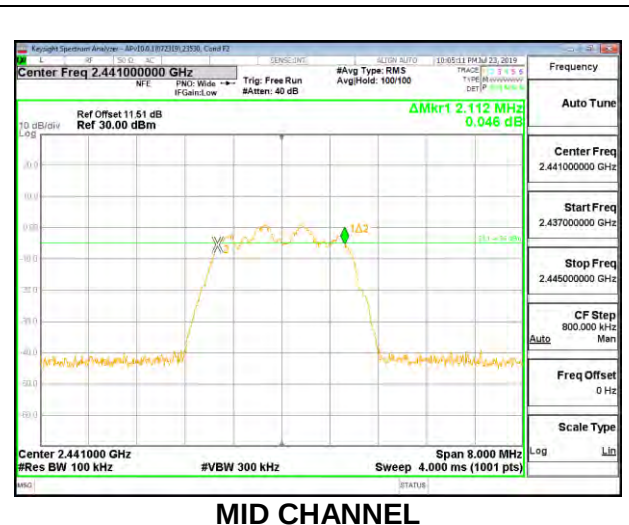
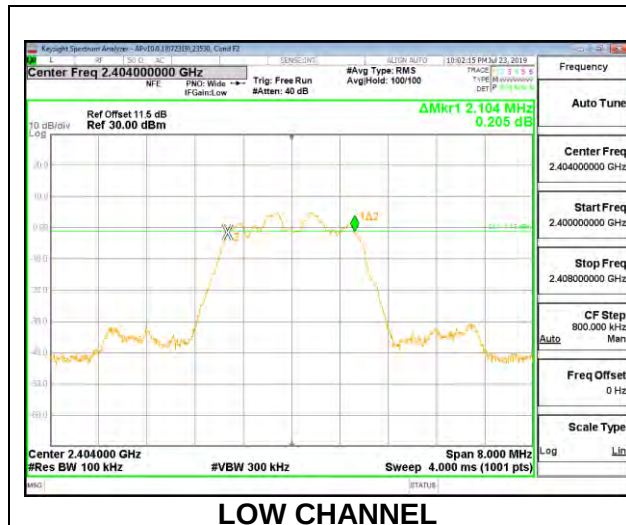
Antenna 2

Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	2.104	0.5
Middle	2441	2.104	0.5
High	2478	2.128	0.5



Antenna 5

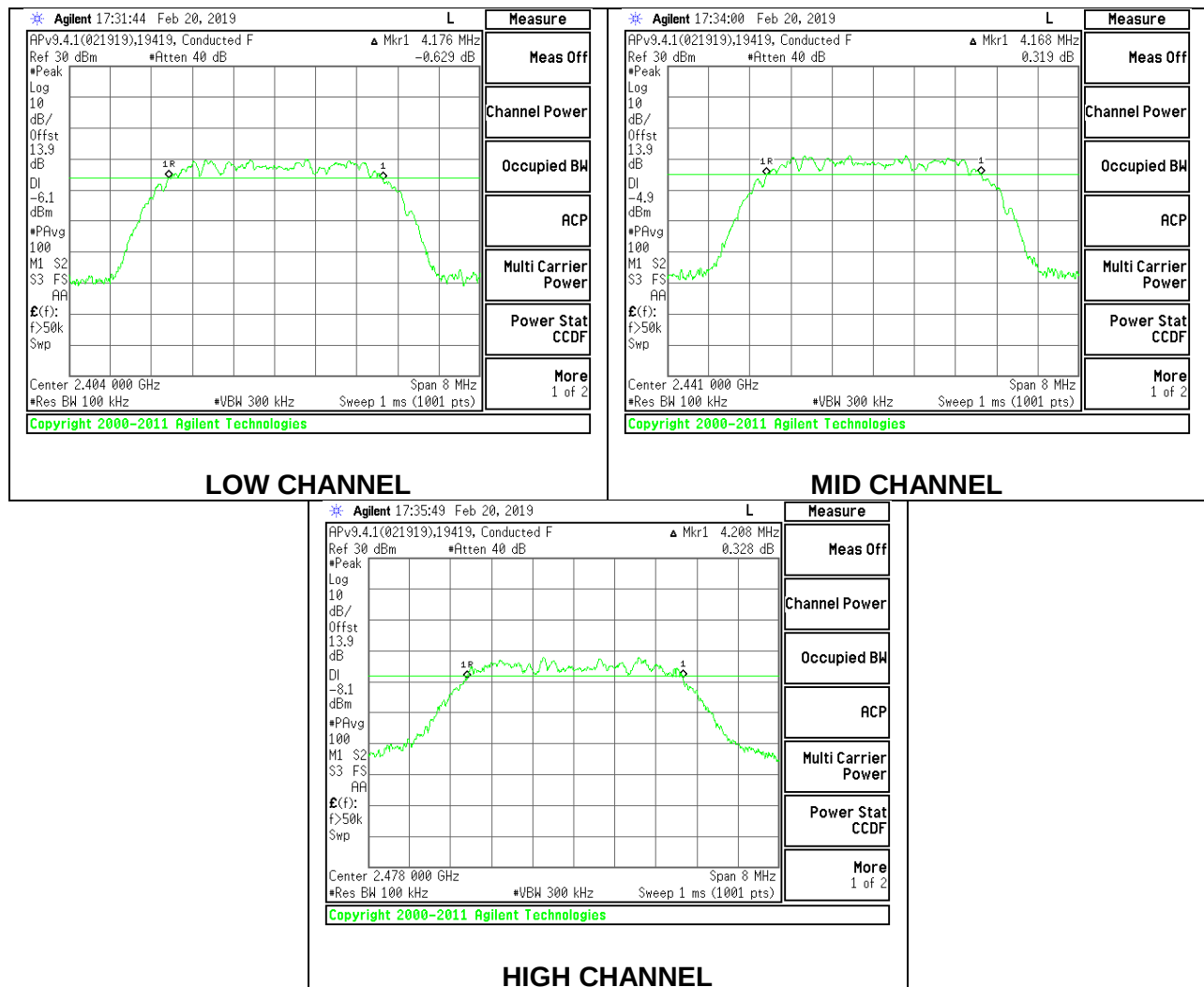
Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	2.104	0.5
Middle	2441	2.112	0.5
High	2478	2.120	0.5



8.3.4. LOW POWER HDR (HDR8)

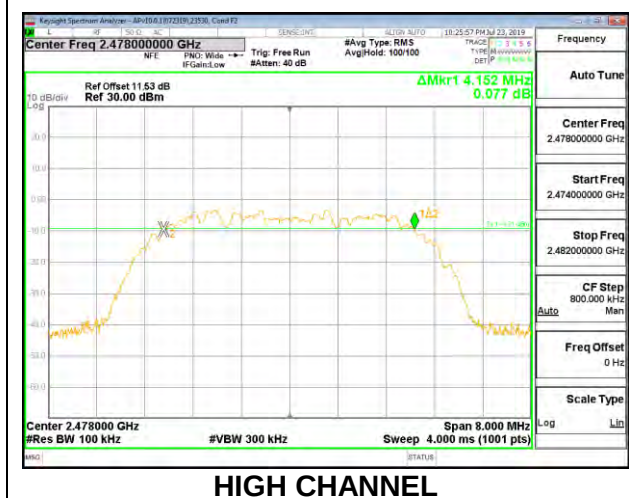
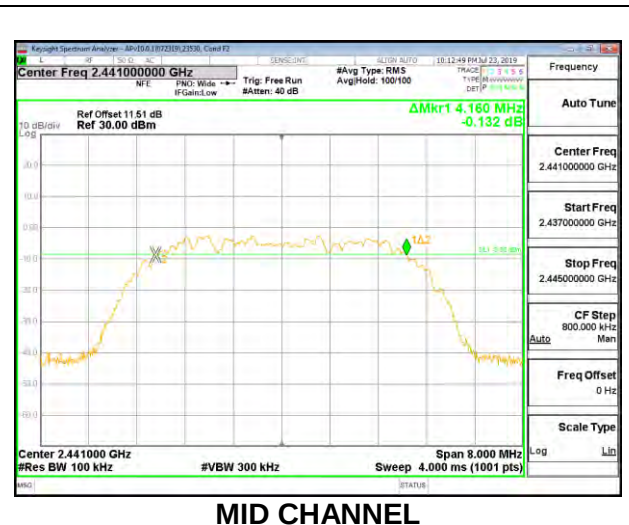
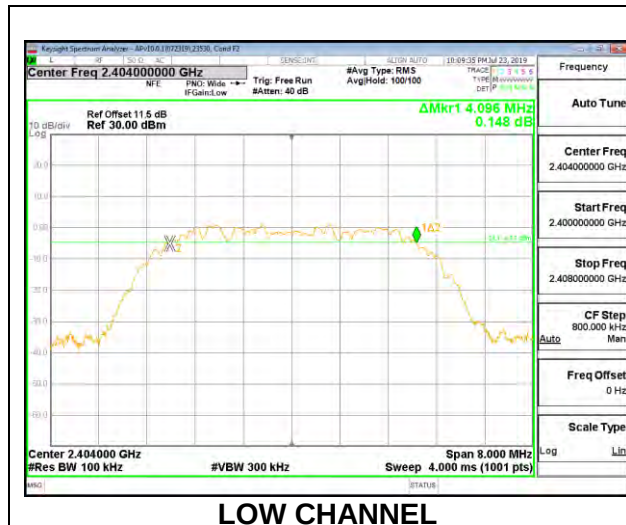
Antenna 2

Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	4.176	0.5
Middle	2441	4.168	0.5
High	2478	4.208	0.5



Antenna 5

Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	2404	4.096	0.5
Middle	2441	4.160	0.5
High	2478	4.152	0.5



8.4. OUTPUT POWER

LIMITS

FCC §15.247 (b) (3)

RSS-247 5.4 (d)

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

TEST PROCEDURE

The transmitter output is connected to a power meter.

The cable assembly insertion loss of 10.5 dB (including 10 dB pad and 0.5 dB cable) was entered as an offset in the power meter to allow for a gated peak reading of power.

RESULTS

8.4.1. HIGH POWER HDR (HDR4)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	14.17	30	-15.83
Middle	2441	14.25	30	-15.75
High	2478	14.16	30	-15.84

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	14.16	30	-15.84
Middle	2441	14.26	30	-15.74
High	2478	14.15	30	-15.85

8.4.2. HIGH POWER HDR (HDR8)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	14.75	30	-15.25
Middle	2441	14.77	30	-15.23
High	2478	14.67	30	-15.33

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	14.75	30	-15.25
Middle	2441	14.79	30	-15.21
High	2478	14.70	30	-15.30

8.4.3. LOW POWER HDR (HDR4)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	8.68	30	-21.32
Middle	2441	8.83	30	-21.17
High	2478	8.78	30	-21.22

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	8.44	30	-21.56
Middle	2441	8.78	30	-21.22
High	2478	8.46	30	-21.54

8.4.4. LOW POWER HDR (HDR8)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	9.26	30	-20.74
Middle	2441	9.27	30	-20.73
High	2478	9.29	30	-20.71

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	Peak Power Reading (dBm)	Limit (dBm)	Margin (dB)
Low	2404	9.17	30	-20.83
Middle	2441	9.28	30	-20.72
High	2478	9.20	30	-20.80

8.5. AVERAGE POWER

LIMITS

None; for reporting purposes only.

TEST PROCEDURE

The transmitter output is connected to a power meter.

The cable assembly insertion loss of 10.5 dB (including 10 dB pad and 0.5 dB cable) was entered as an offset in the power meter to allow for a gated average reading of power.

RESULTS

8.5.1. HIGH POWER HDR (HDR4)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	11.65
Middle	2441	11.73
High	2478	11.63

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	11.66
Middle	2441	11.75
High	2478	11.62

8.5.2. HIGH POWER HDR (HDR8)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	11.70
Middle	2441	11.73
High	2478	11.63

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	11.73
Middle	2441	11.75
High	2478	11.68

8.5.3. LOW POWER HDR (HDR4)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	6.22
Middle	2441	6.25
High	2478	6.23

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	6.11
Middle	2441	6.23
High	2478	6.12

8.5.4. LOW POWER HDR (HDR8)

Antenna 2

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	6.21
Middle	2441	6.22
High	2478	6.25

Antenna 5

Tested By:	39316
Date:	6/26/2019

Channel	Frequency (MHz)	AV power (dBm)
Low	2404	6.15
Middle	2441	6.25
High	2478	6.16

8.6. POWER SPECTRAL DENSITY

LIMITS

FCC §15.247 (e)

RSS-247 (5.2) (b)

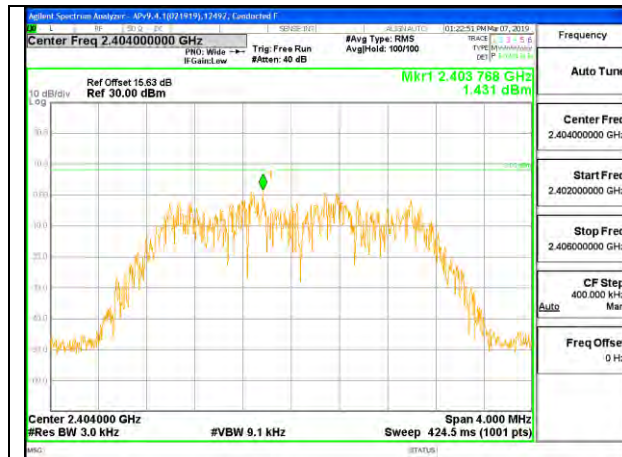
The power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

RESULTS

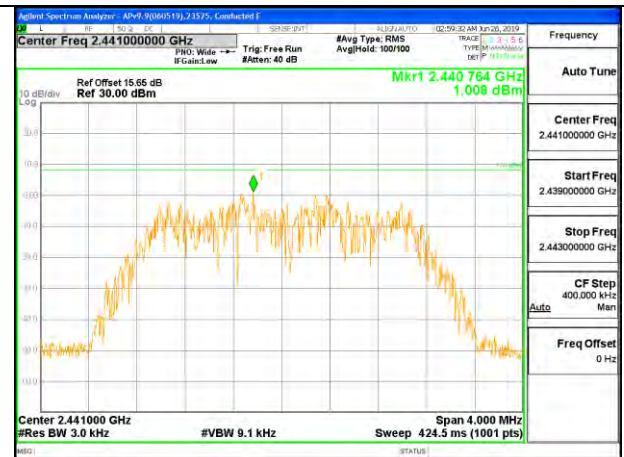
8.6.1. HIGH POWER HDR (HDR4)

Antenna 2

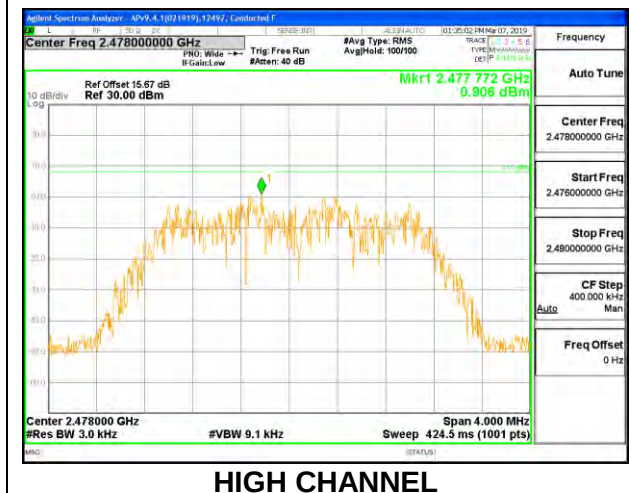
Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	1.431	8	-6.57
Middle	2441	1.008	8	-6.99
High	2478	0.906	8	-7.09



LOW CHANNEL



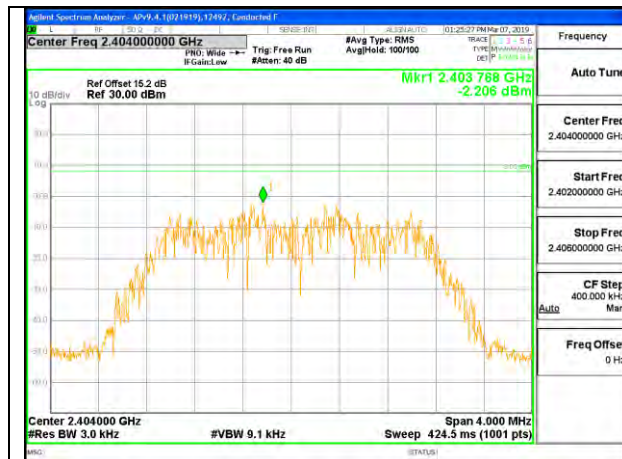
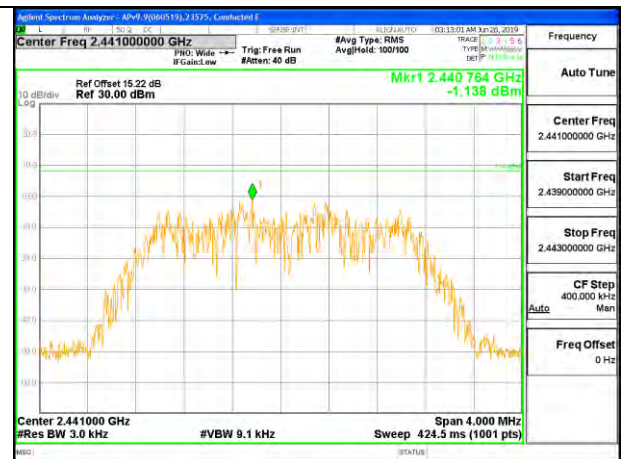
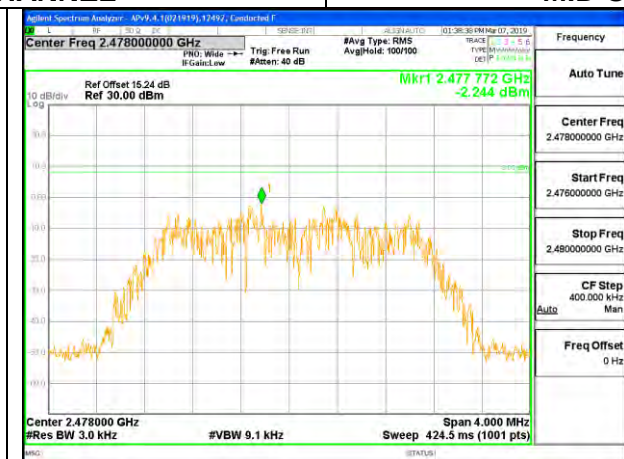
MID CHANNEL



HIGH CHANNEL

Antenna 5

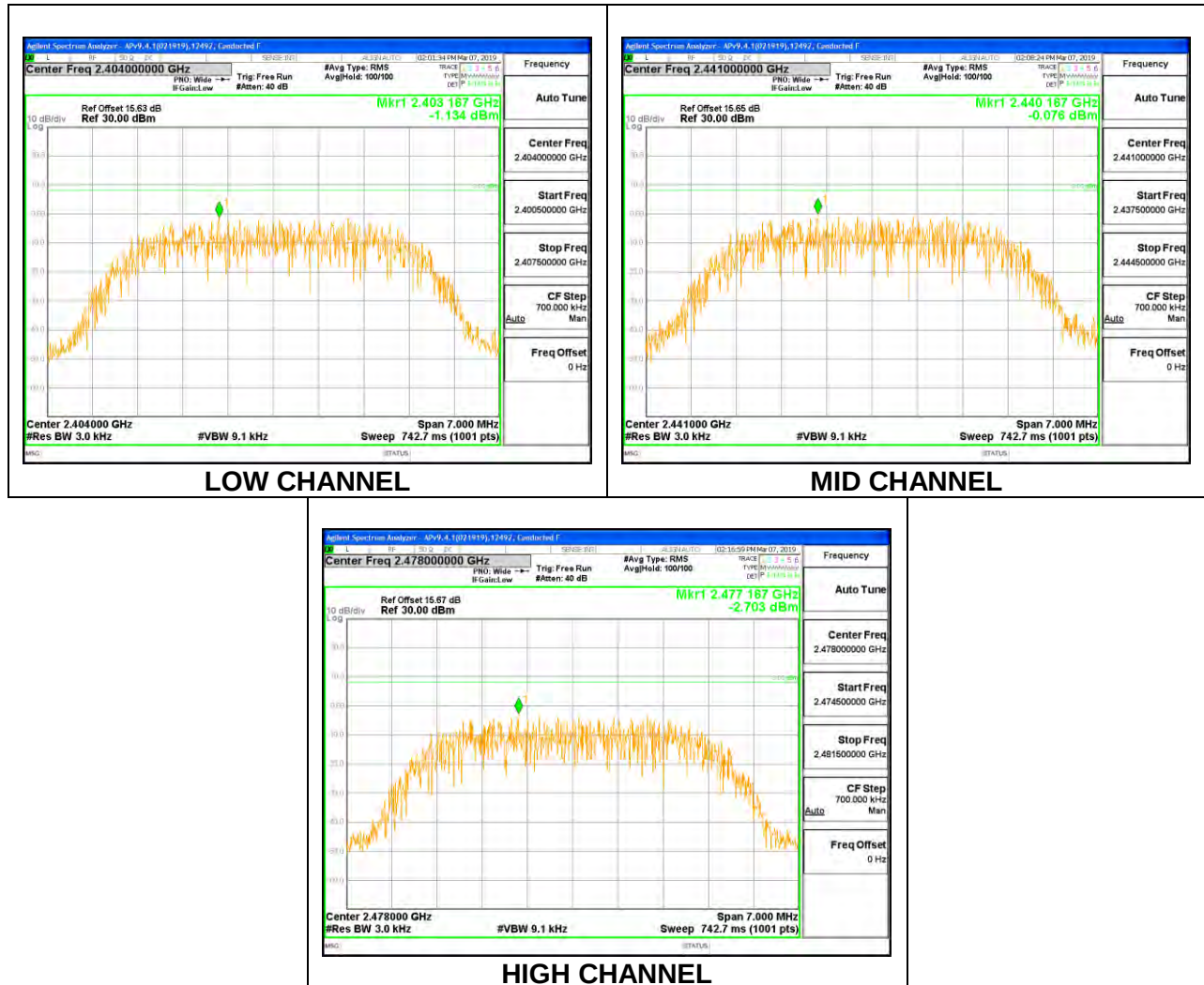
Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-2.206	8	-10.21
Middle	2441	-1.138	8	-9.14
High	2478	-2.244	8	-10.24

**LOW CHANNEL****MID CHANNEL****HIGH CHANNEL**

8.6.2. HIGH POWER HDR (HDR8)

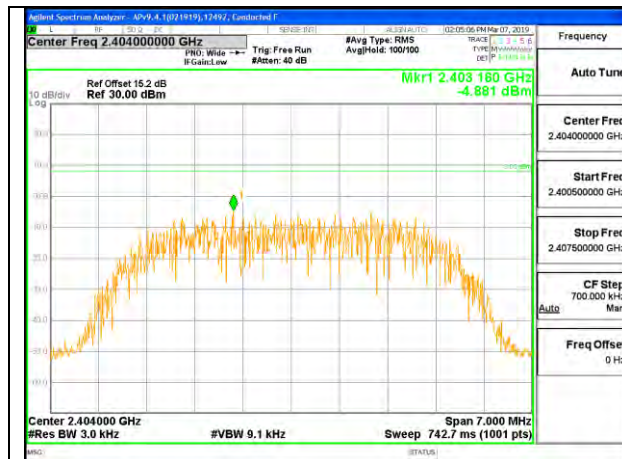
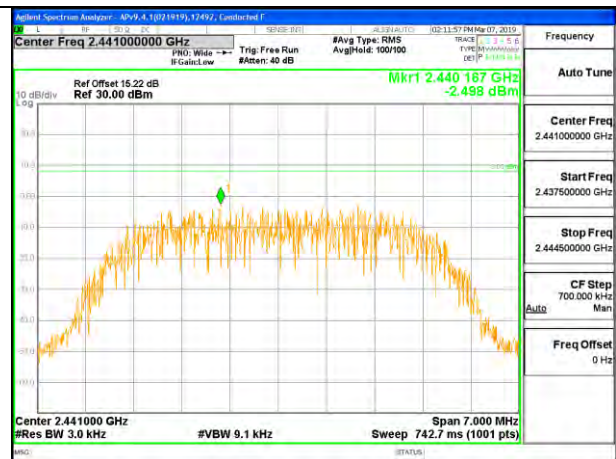
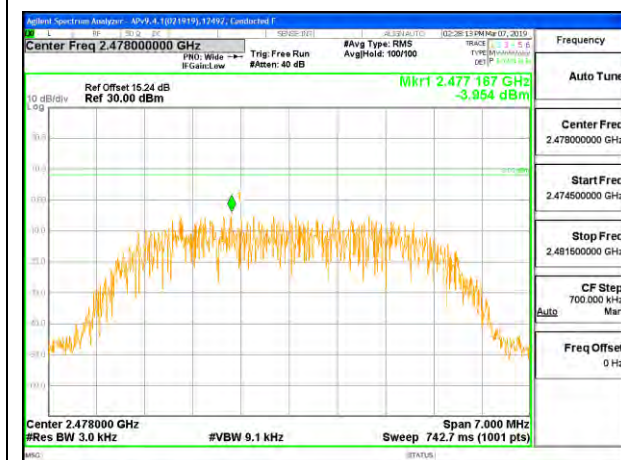
Antenna 2

Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-1.134	8	-9.13
Middle	2441	-0.076	8	-8.08
High	2478	-2.703	8	-10.70



Antenna 5

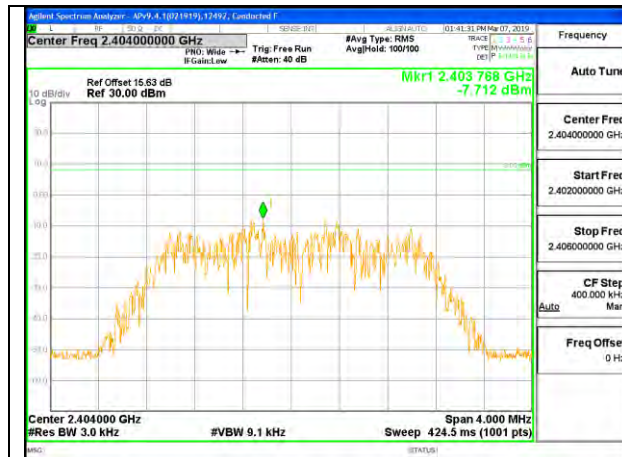
Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-4.881	8	-12.88
Middle	2441	-2.498	8	-10.50
High	2478	-3.954	8	-11.95

**LOW CHANNEL****MID CHANNEL****HIGH CHANNEL**

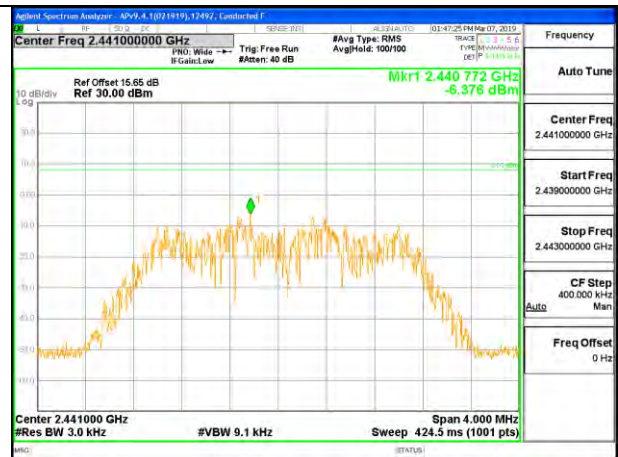
8.6.3. LOW POWER HDR (HDR4)

Antenna 2

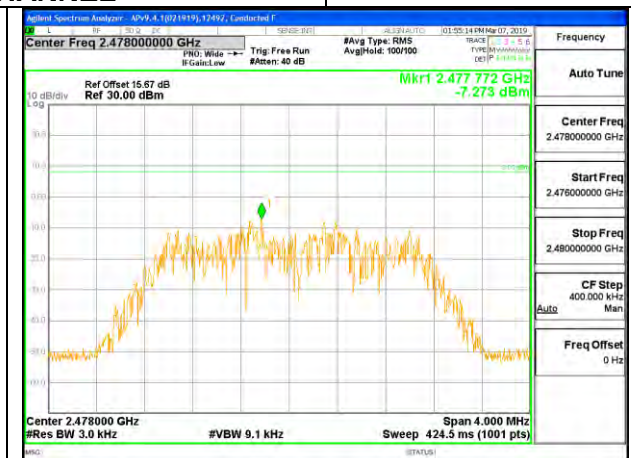
Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-7.712	8	-15.71
Middle	2441	-6.376	8	-14.38
High	2478	-7.273	8	-15.27



LOW CHANNEL



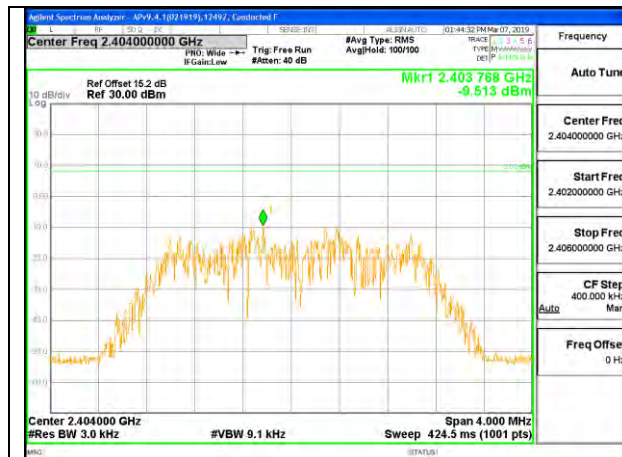
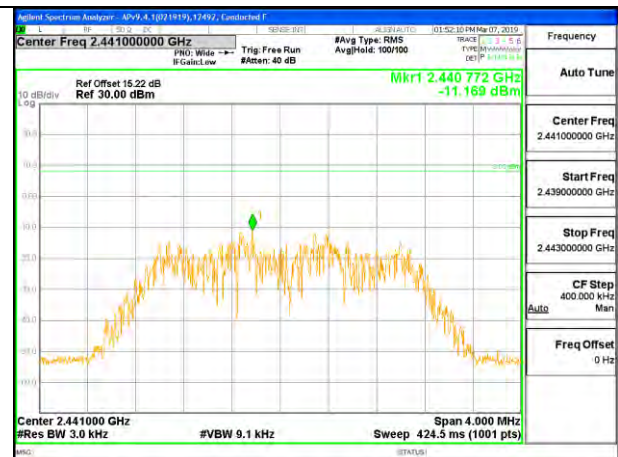
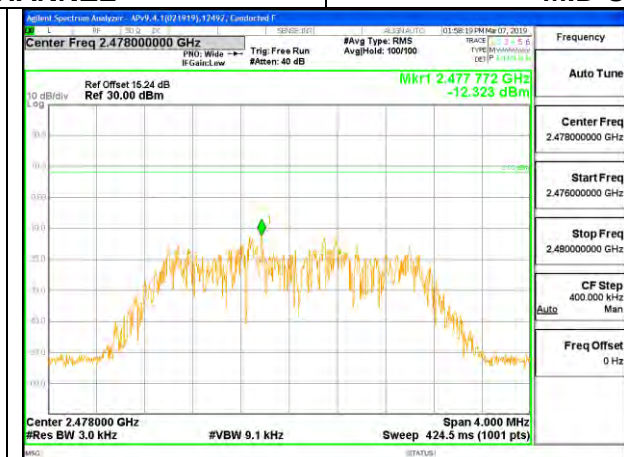
MID CHANNEL



HIGH CHANNEL

Antenna 5

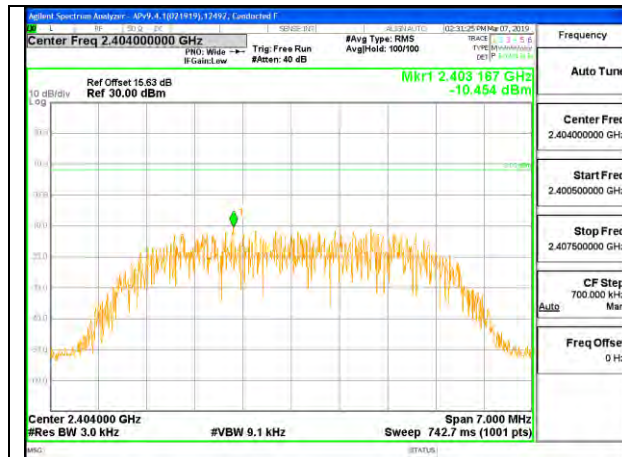
Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-9.513	8	-17.51
Middle	2441	-11.169	8	-19.17
High	2478	-12.323	8	-20.32

**LOW CHANNEL****MID CHANNEL****HIGH CHANNEL**

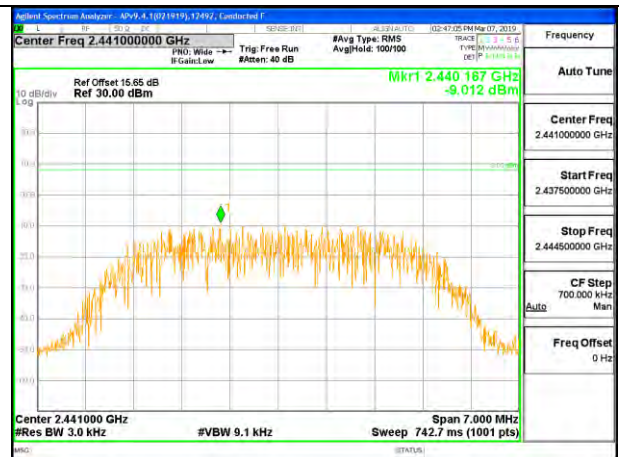
8.6.4. LOW POWER HDR (HDR8)

Antenna 2

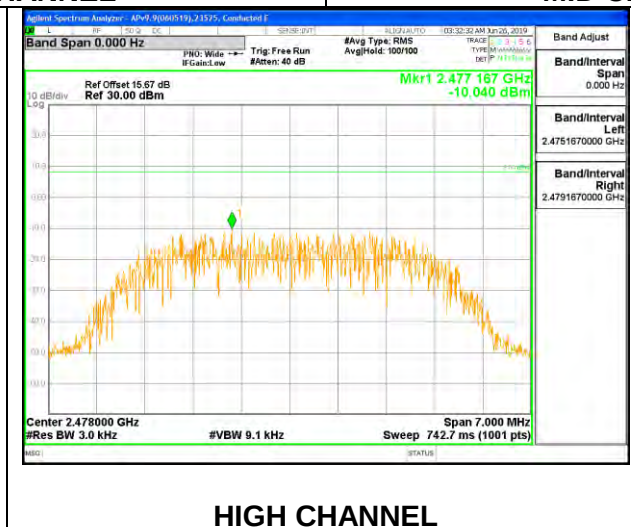
Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-10.454	8	-18.45
Middle	2441	-9.012	8	-17.01
High	2478	-10.040	8	-18.04



LOW CHANNEL



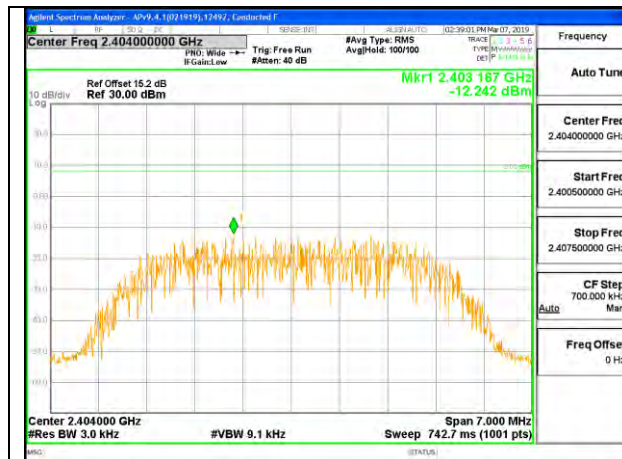
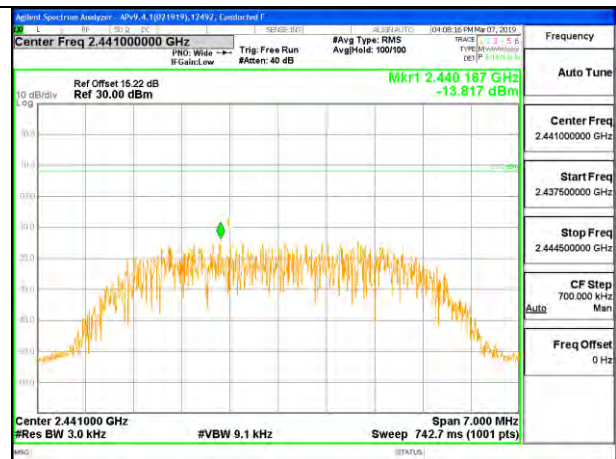
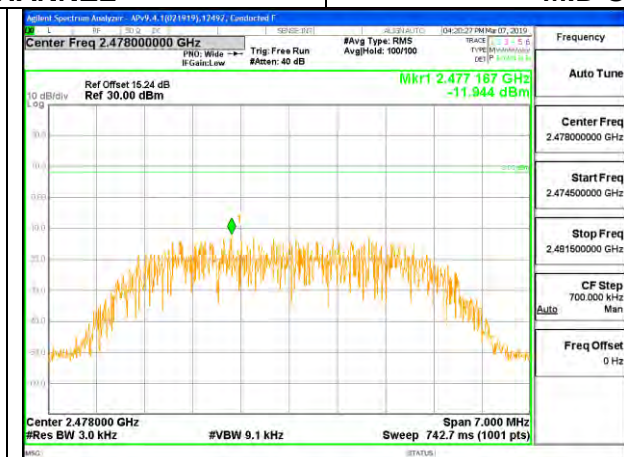
MID CHANNEL



HIGH CHANNEL

Antenna 5

Channel	Frequency (MHz)	PSD (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Low	2404	-12.242	8	-20.24
Middle	2441	-13.817	8	-21.82
High	2478	-11.944	8	-19.94

**LOW CHANNEL****MID CHANNEL****HIGH CHANNEL**

8.7. CONDUCTED SPURIOUS EMISSIONS

LIMITS

FCC §15.247 (d)

RSS-247 5.5

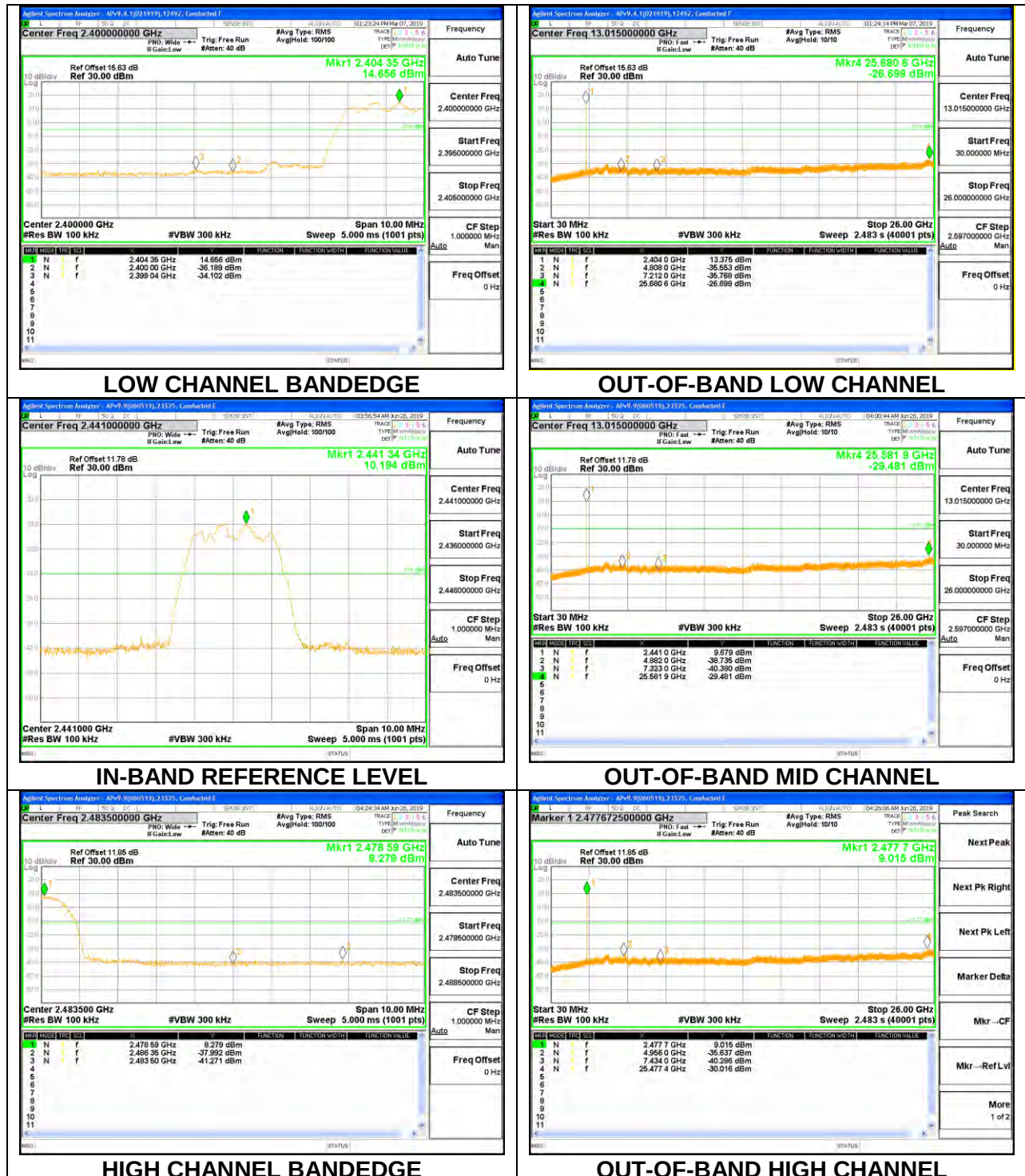
Output power was measured based on the use of a peak measurement, therefore the required attenuation is 20 dB.

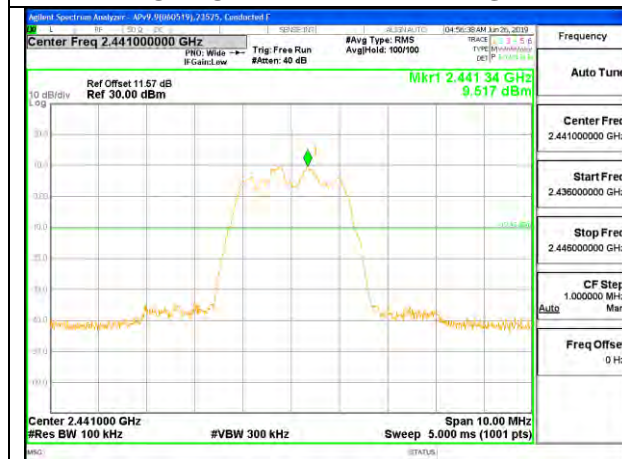
Note: Test procedures and setting on beamforming are same as HDR normal mode

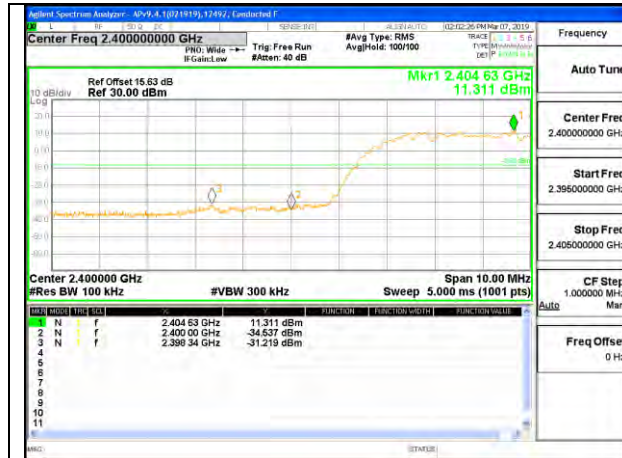
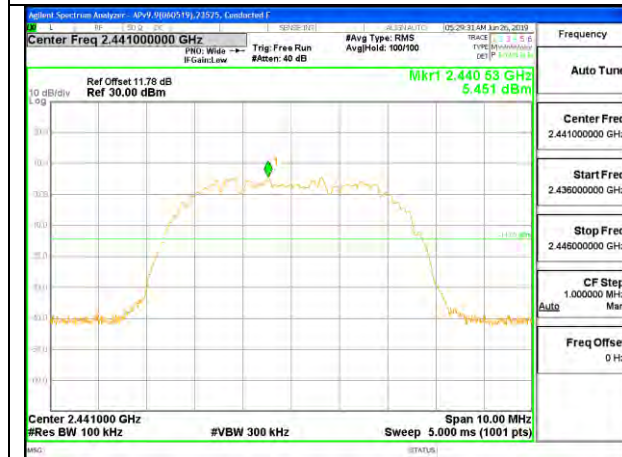
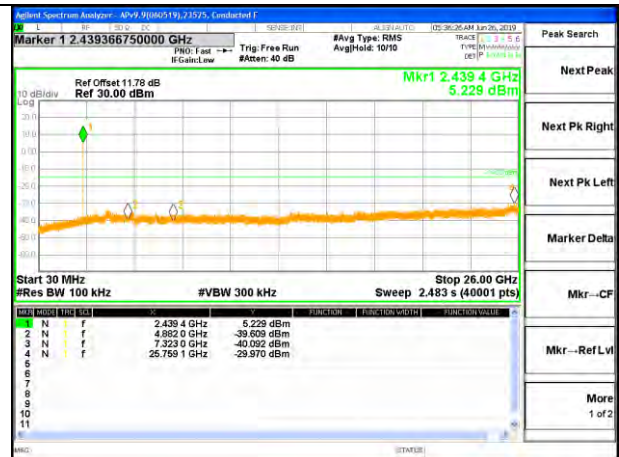
RESULTS

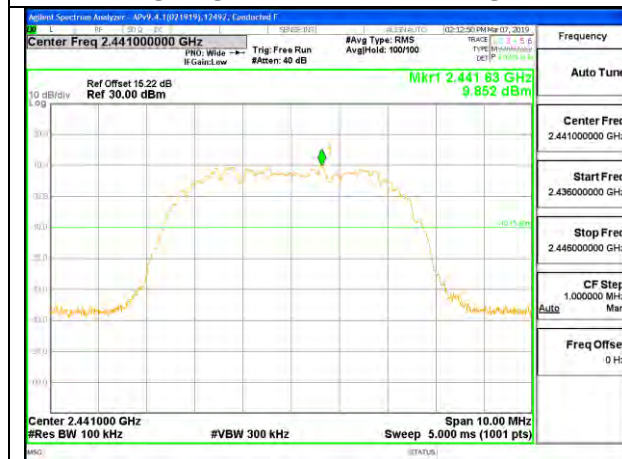
8.7.1. HIGH POWER HDR (HDR4)

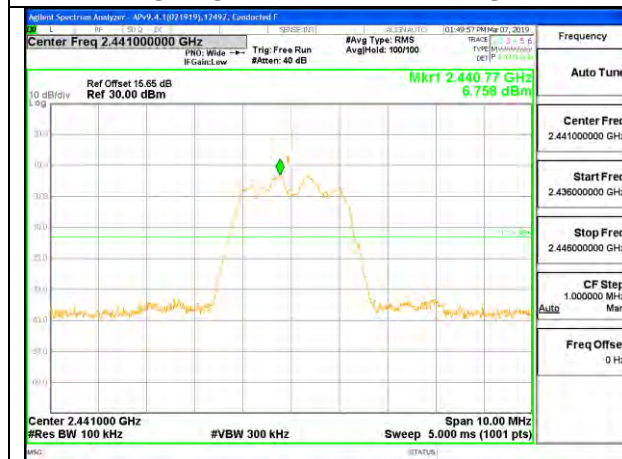
Antenna 2

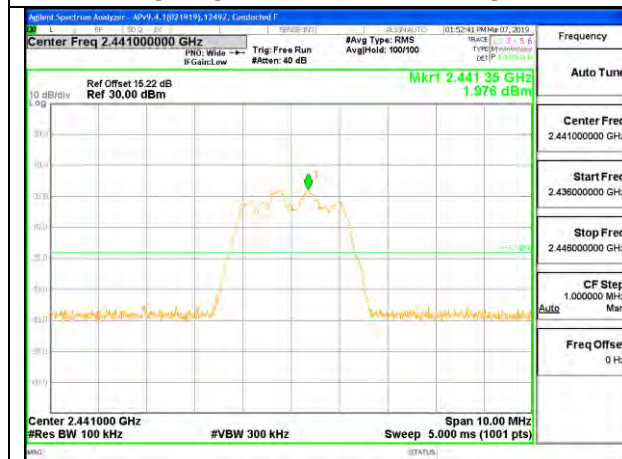


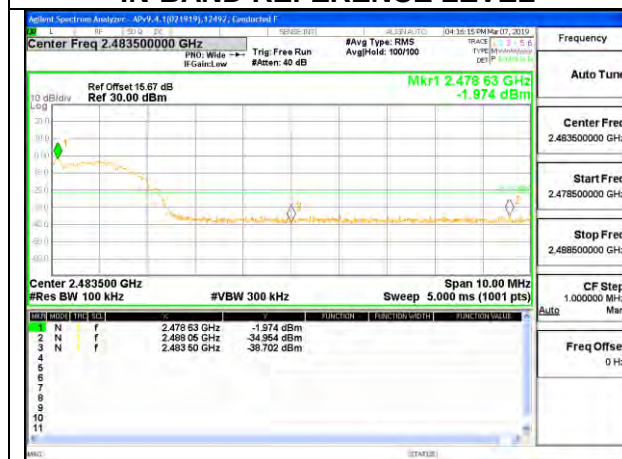
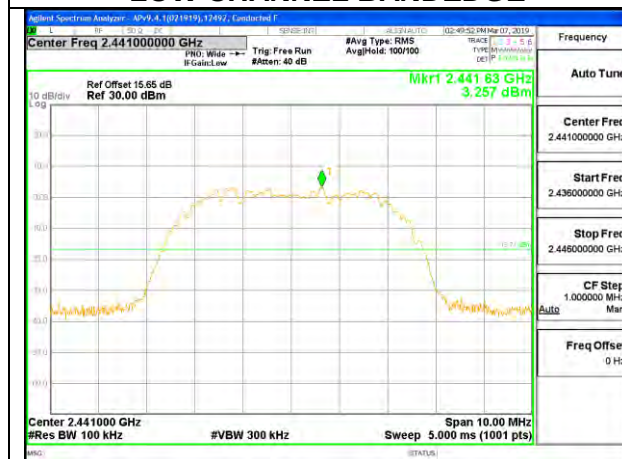
Antenna 5**LOW CHANNEL BANDEDGE****OUT-OF-BAND LOW CHANNEL****IN-BAND REFERENCE LEVEL****OUT-OF-BAND MID CHANNEL****HIGH CHANNEL BANDEDGE****OUT-OF-BAND HIGH CHANNEL**

8.7.2. HIGH POWER HDR (HDR8)**Antenna 2****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**

Antenna 5**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**

8.7.3. LOW POWER HDR (HDR4)**Antenna 2****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**

Antenna 5**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**

8.7.4. LOW POWER HDR (HDR8)**Antenna 2**

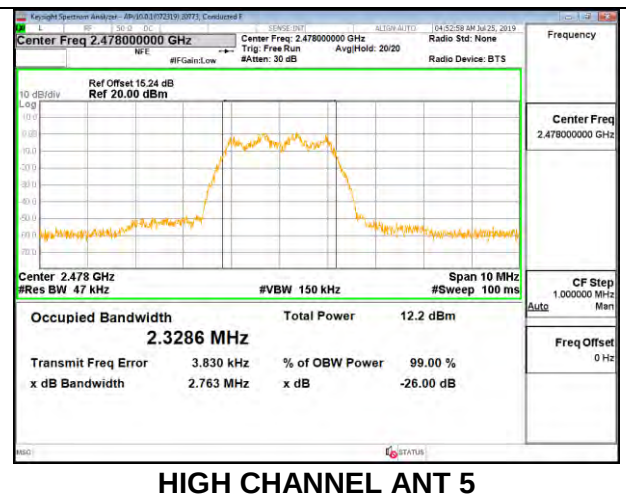
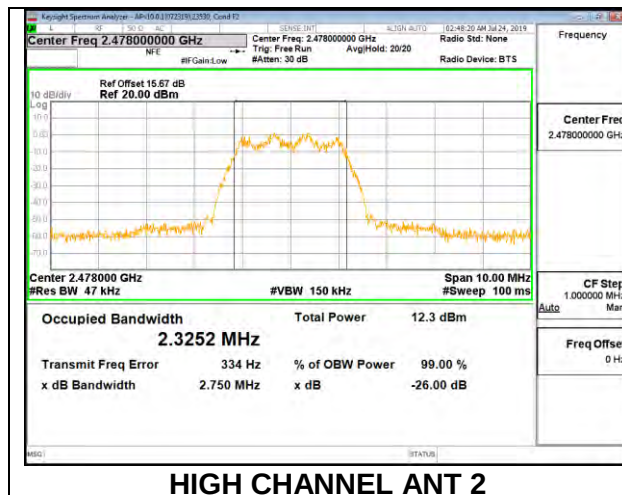
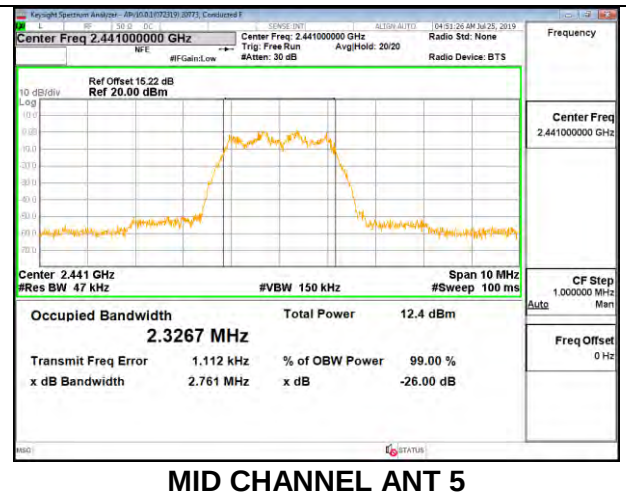
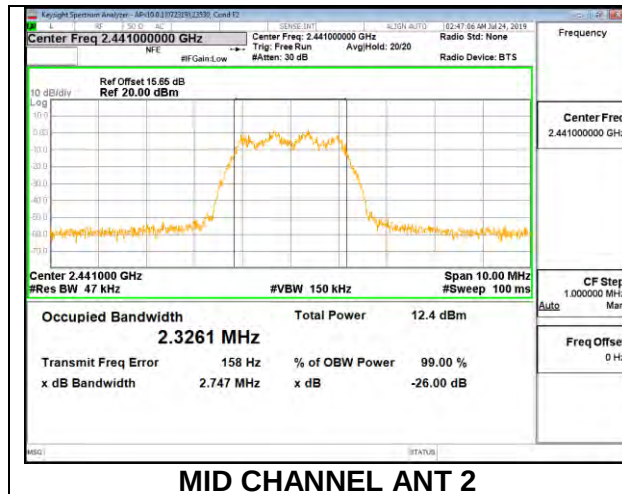
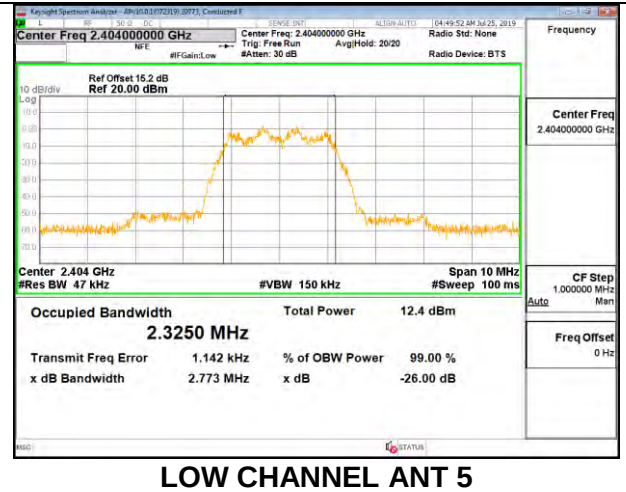
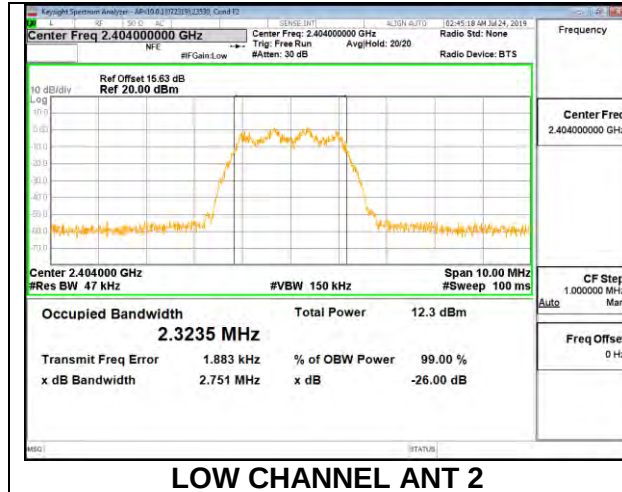
Antenna 5**LOW CHANNEL BANDEDGE****OUT-OF-BAND LOW CHANNEL****IN-BAND REFERENCE LEVEL****OUT-OF-BAND MID CHANNEL****HIGH CHANNEL BANDEDGE****OUT-OF-BAND HIGH CHANNEL**

8.8. BEAMFORMING, 99% BANDWIDTH

8.8.1. HIGH POWER HDR (HDR4)

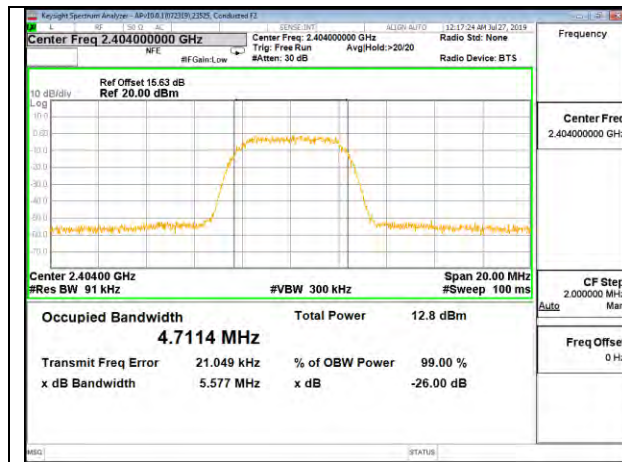
Channel	Frequency (MHz)	99% Bandwidth ANT 2 (MHz)	99% Bandwidth ANT 5 (MHz)
Low	2404	2.3235	2.3250
Mid	2441	2.3261	2.3267
High	2478	2.3252	2.3286

Note: Test procedures and setting on beamforming are same as HDR normal mode

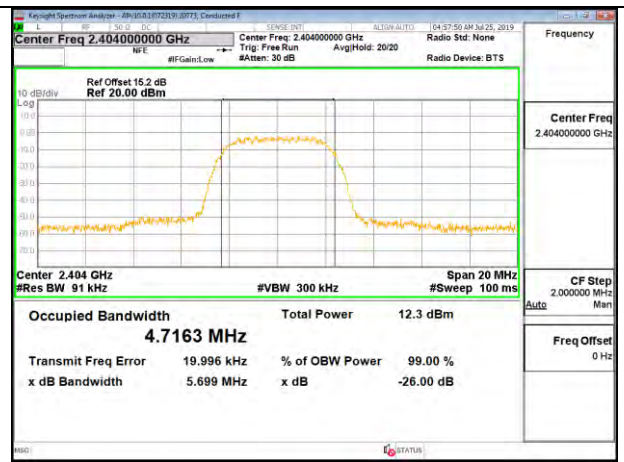


8.8.2. HIGH POWER HDR (HDR8)

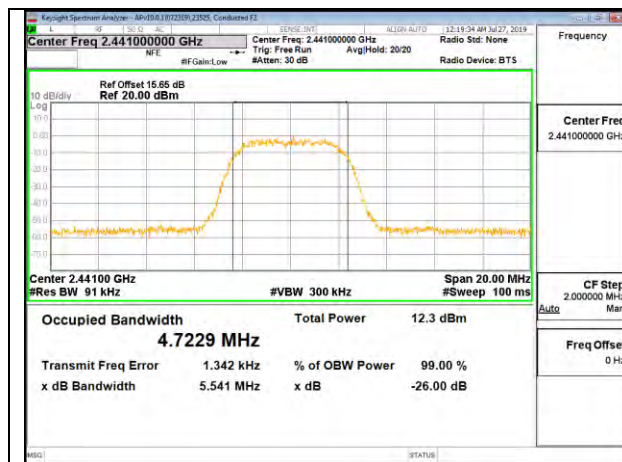
Channel	Frequency (MHz)	99% Bandwidth ANT 2 (MHz)	99% Bandwidth ANT 5 (MHz)
Low	2404	4.7114	4.7163
Mid	2441	4.7229	4.7364
High	2478	4.7241	4.7349



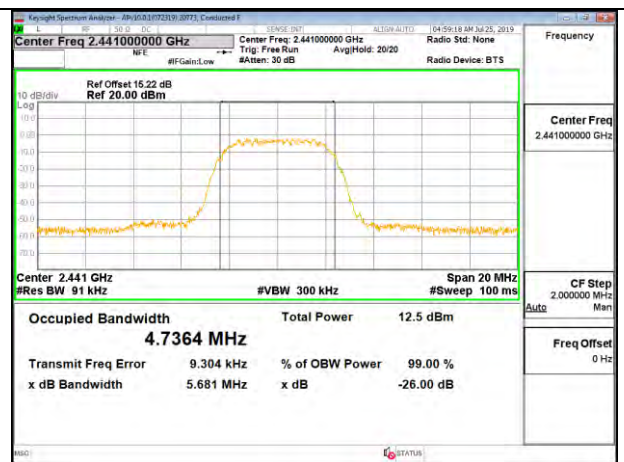
LOW CHANNEL ANT 2



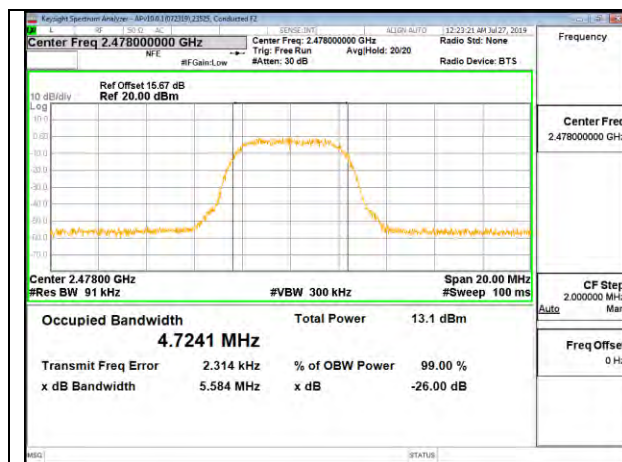
LOW CHANNEL ANT 5



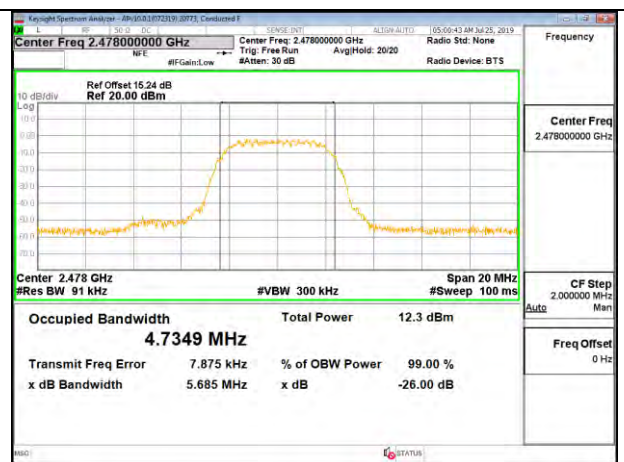
MID CHANNEL ANT 2



MID CHANNEL ANT 5



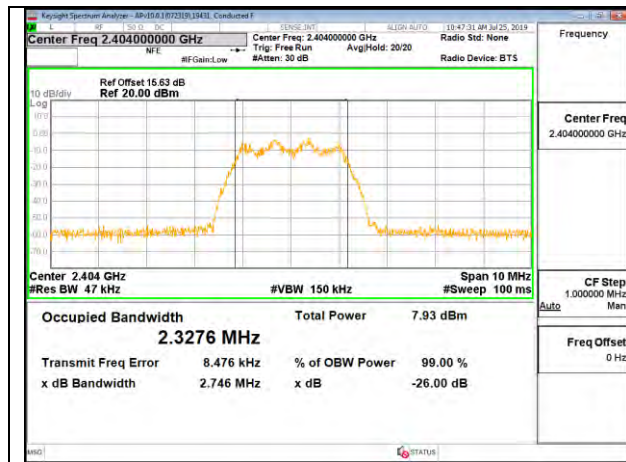
HIGH CHANNEL ANT 2



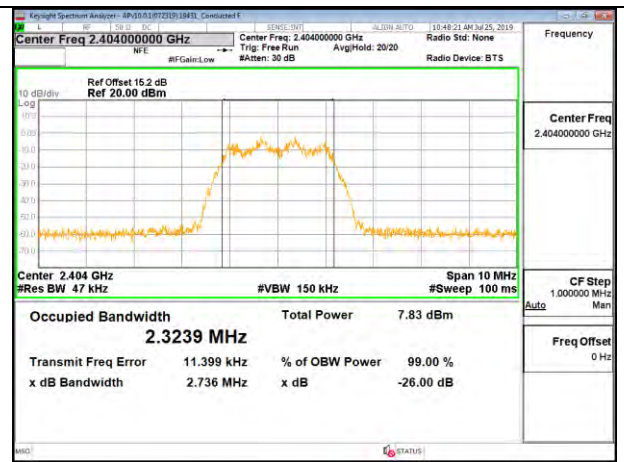
HIGH CHANNEL ANT 5

8.8.3. LOW POWER HDR (HDR4)

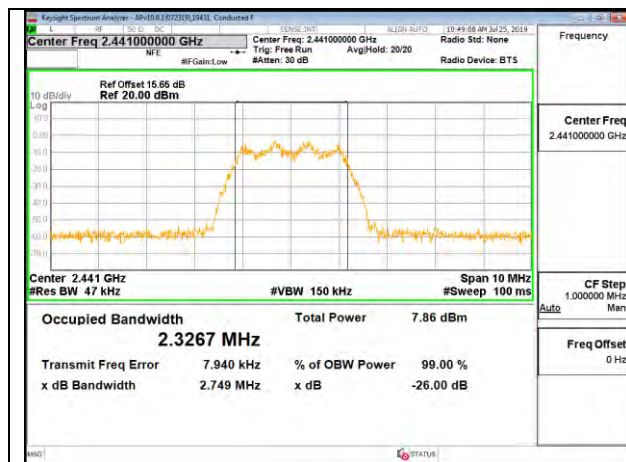
Channel	Frequency (MHz)	99% Bandwidth ANT 2 (MHz)	99% Bandwidth ANT 5 (MHz)
Low	2404	2.3276	2.3239
Mid	2441	2.3267	2.3269
High	2478	2.3301	2.3261



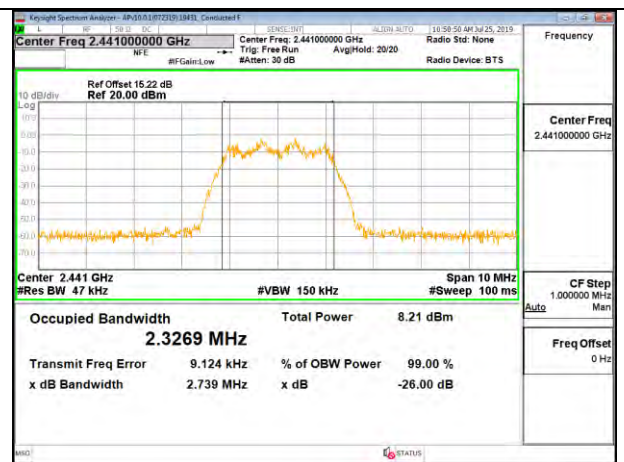
LOW CHANNEL ANT 2



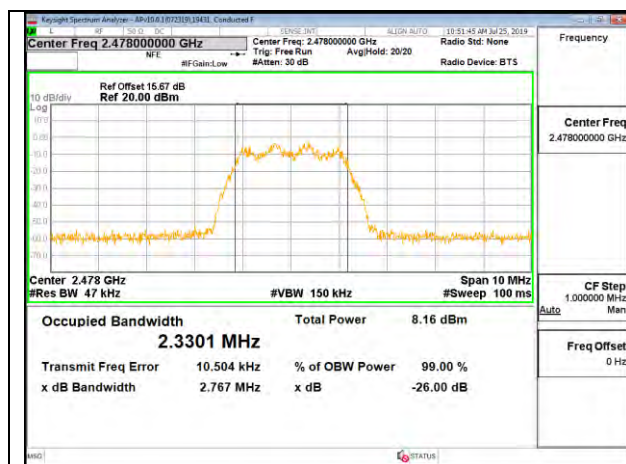
LOW CHANNEL ANT 5



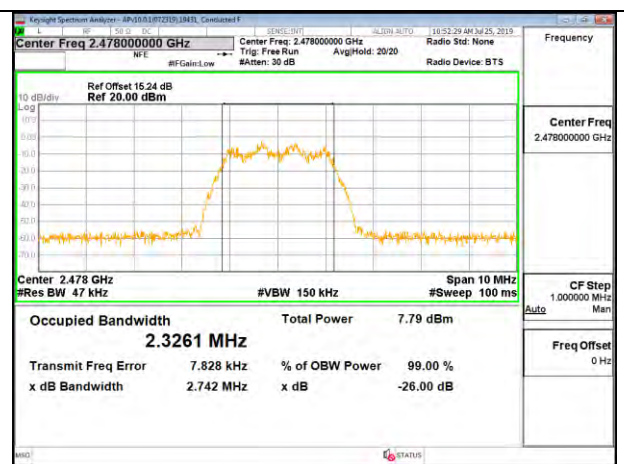
MID CHANNEL ANT 2



MID CHANNEL ANT 5



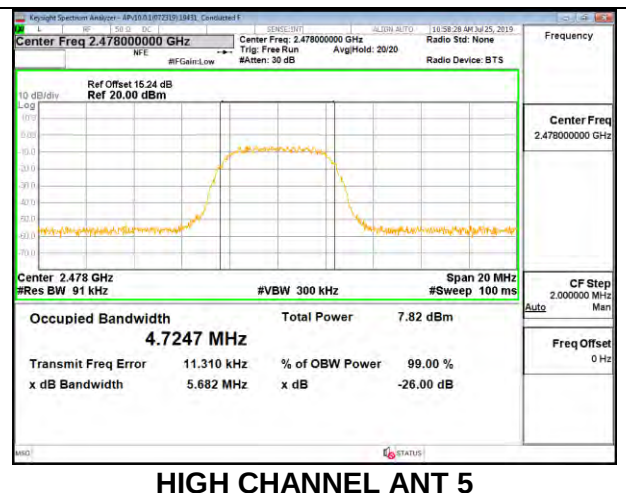
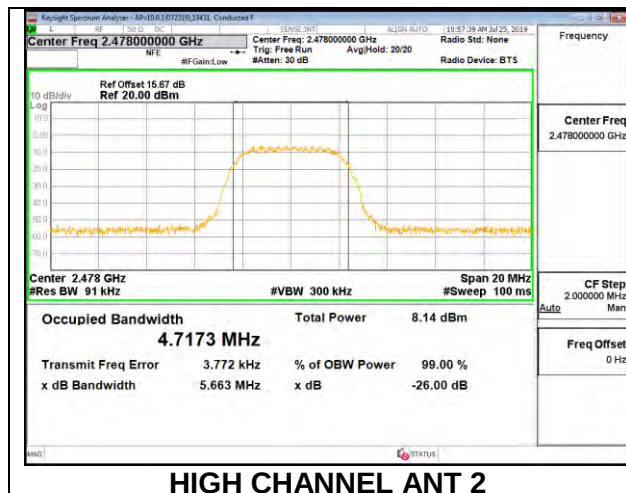
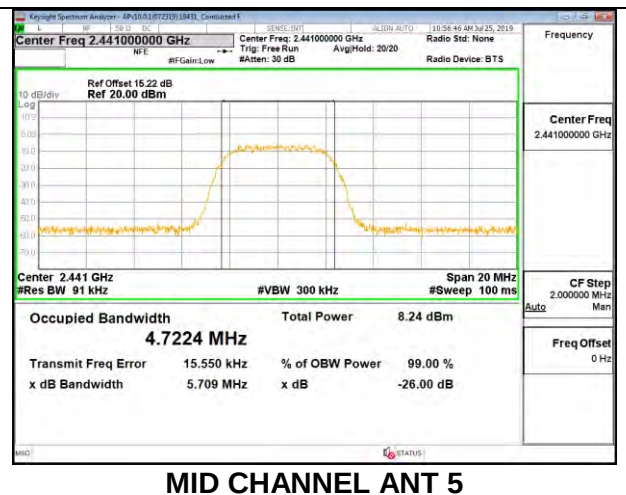
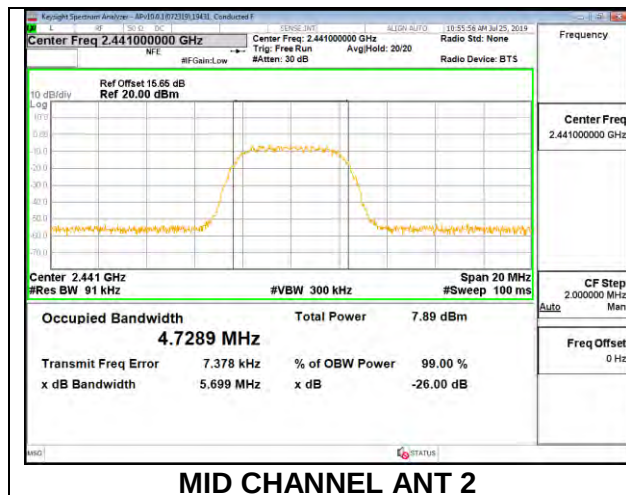
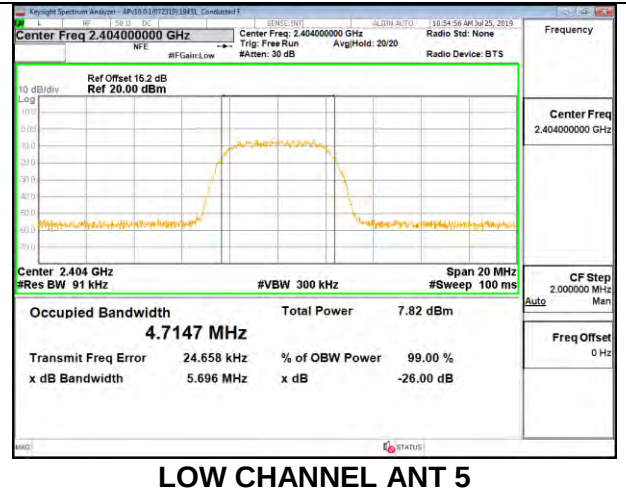
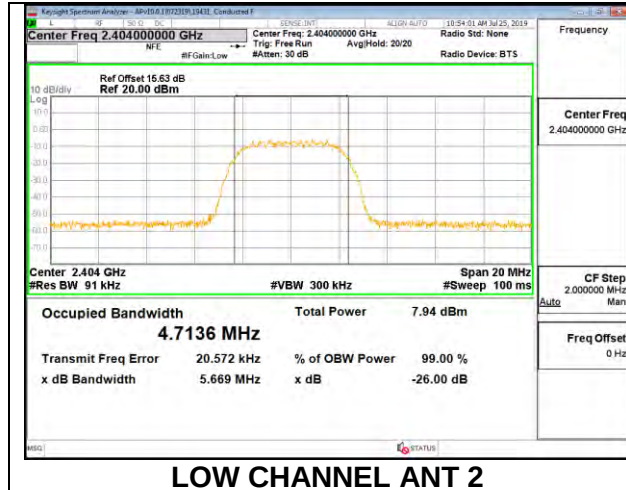
HIGH CHANNEL ANT 2



HIGH CHANNEL ANT 5

8.8.4. LOW POWER HDR (HDR8)

Channel	Frequency (MHz)	99% Bandwidth ANT 2 (MHz)	99% Bandwidth ANT 5 (MHz)
Low	2404	4.7136	4.7174
Mid	2441	4.7289	4.7224
High	2478	4.7173	4.7247

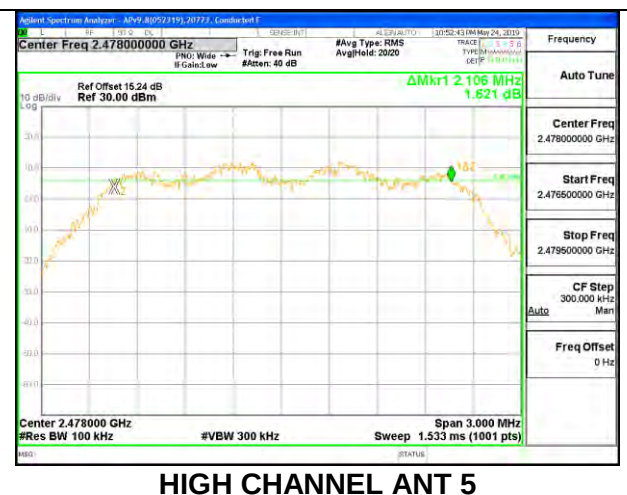
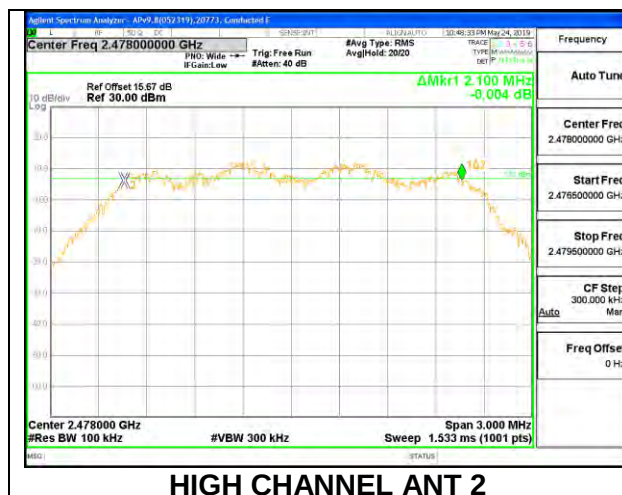
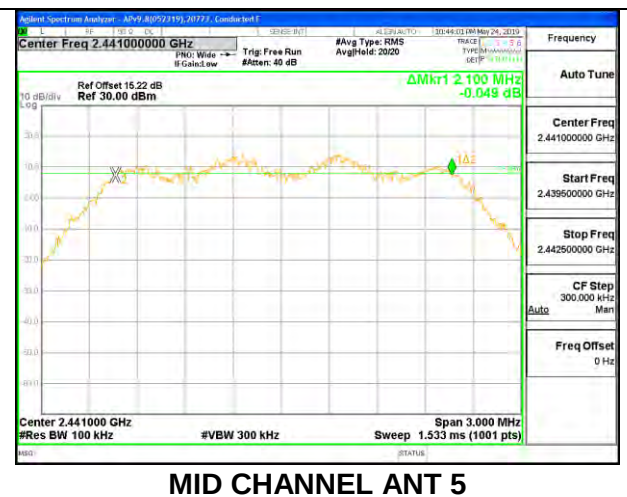
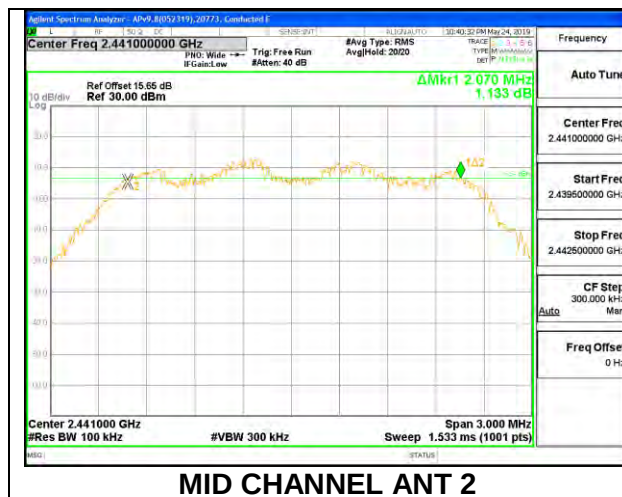
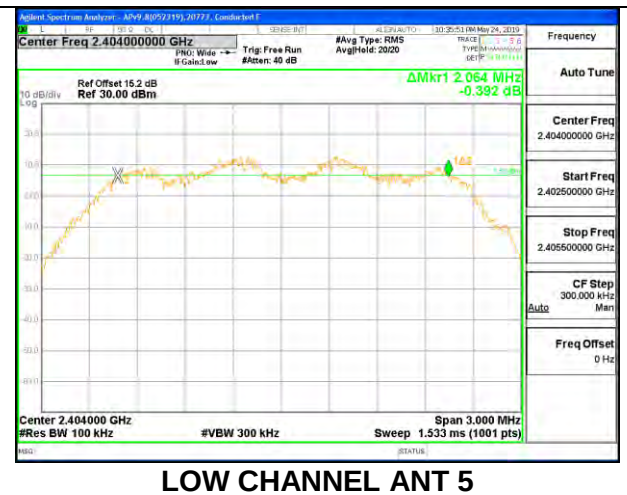
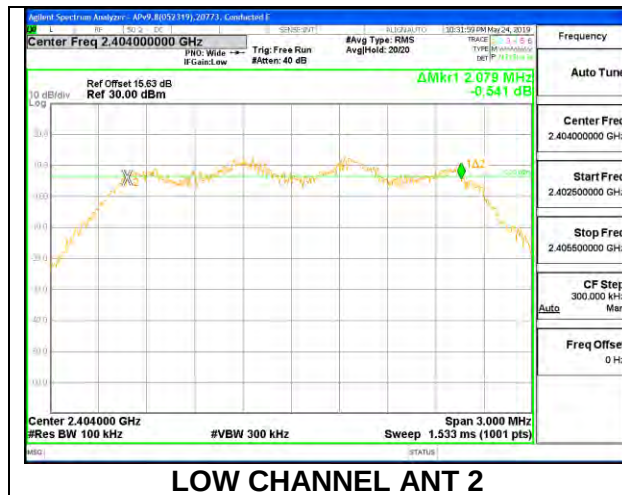


8.9. BEAMFORMING, 6dB BANDWIDTH

8.9.1. HIGH POWER HDR (HDR4)

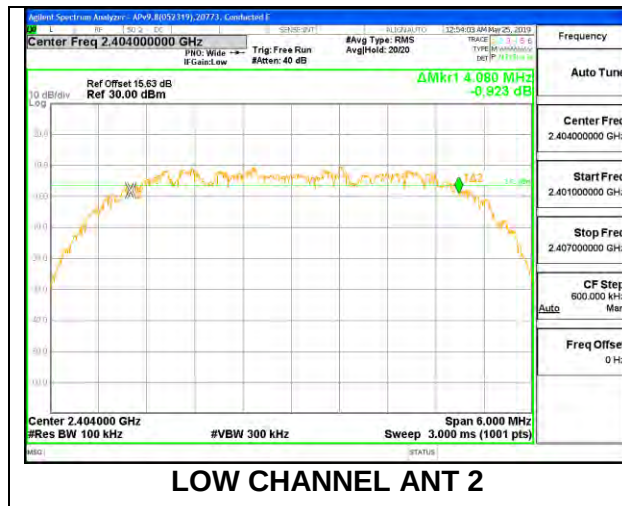
Channel	Frequency (MHz)	6dB Bandwidth ANT 2 (MHz)	6dB Bandwidth ANT 5 (MHz)
Low	2404	2.079	2.064
Mid	2441	2.070	2.100
High	2478	2.100	2.106

Note: Test procedures and setting on beamforming are same as HDR normal mode

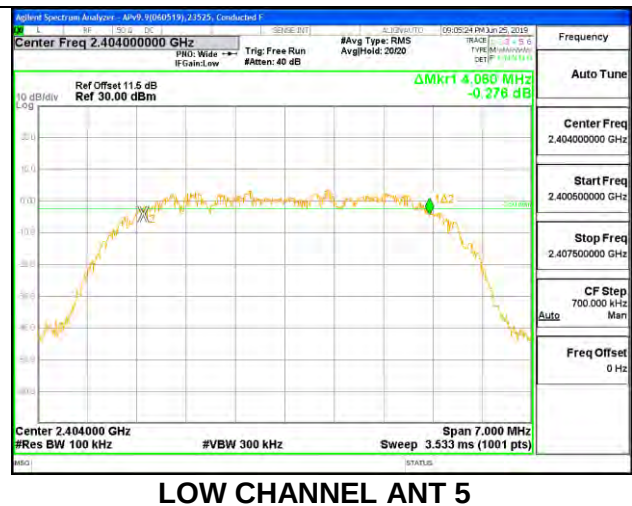


8.9.2. HIGH POWER HDR (HDR8)

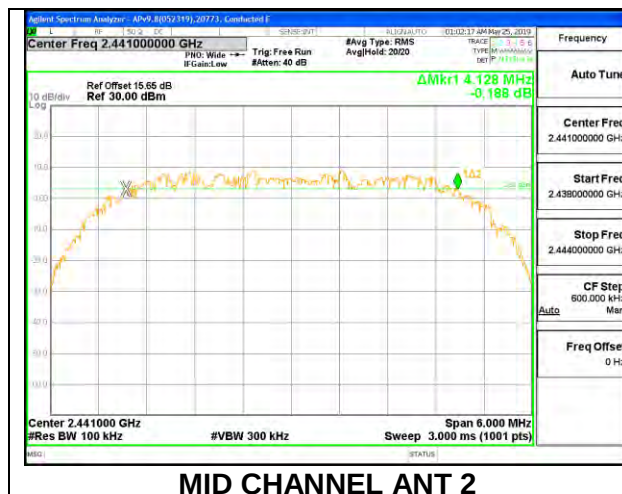
Channel	Frequency (MHz)	6dB Bandwidth ANT 2 (MHz)	6dB Bandwidth ANT 5 (MHz)
Low	2404	4.080	4.060
Mid	2441	4.128	4.092
High	2478	4.046	4.164



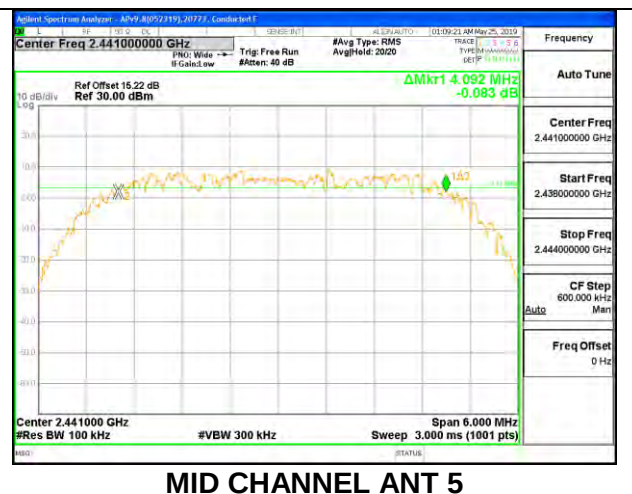
LOW CHANNEL ANT 2



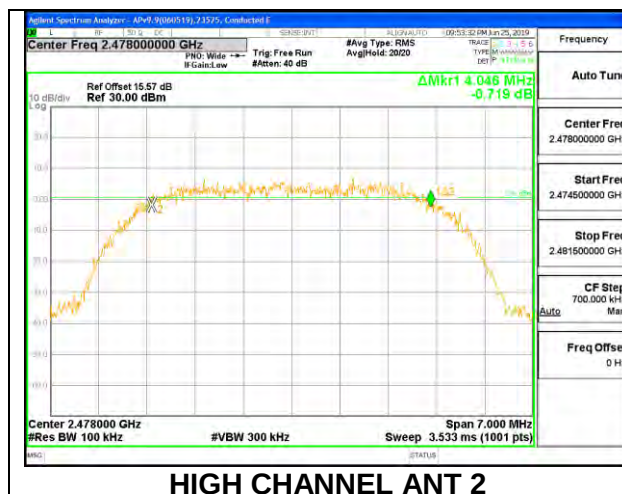
LOW CHANNEL ANT 5



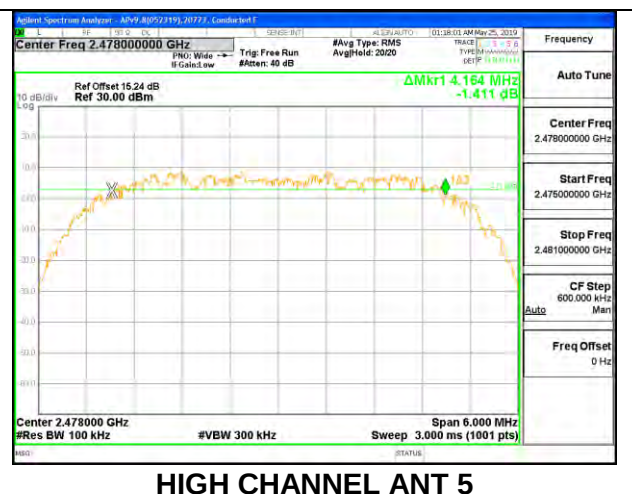
MID CHANNEL ANT 2



MID CHANNEL ANT 5



HIGH CHANNEL ANT 2



HIGH CHANNEL ANT 5

8.9.3. LOW POWER HDR (HDR4)

Channel	Frequency (MHz)	6dB Bandwidth ANT 2 (MHz)	6dB Bandwidth ANT 5 (MHz)
Low	2404	2.094	2.067
Mid	2441	2.073	2.076
High	2478	2.070	2.085



LOW CHANNEL ANT 2



LOW CHANNEL ANT 5



MID CHANNEL ANT 2



MID CHANNEL ANT 5



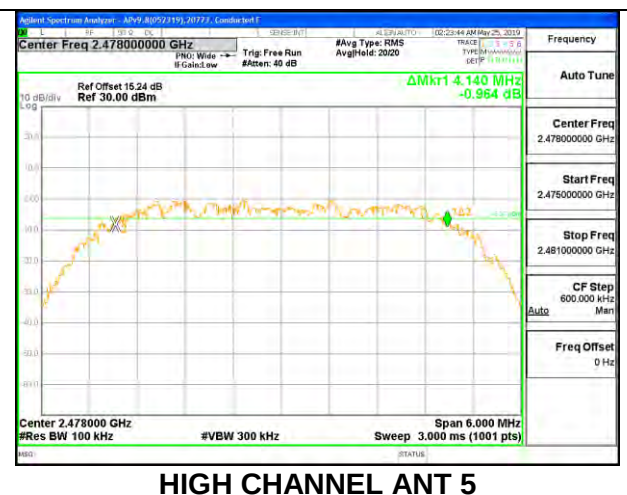
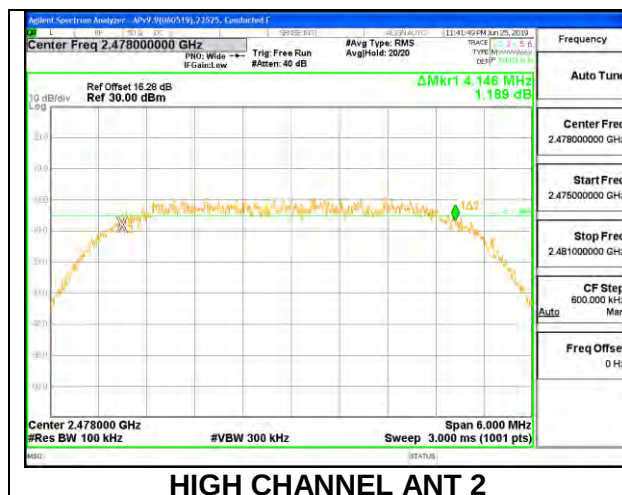
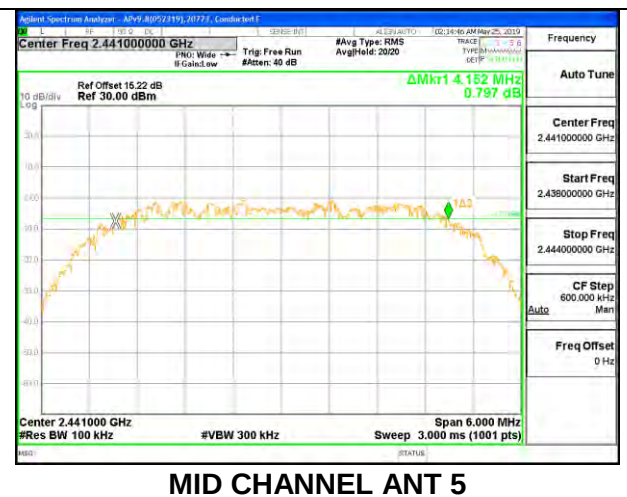
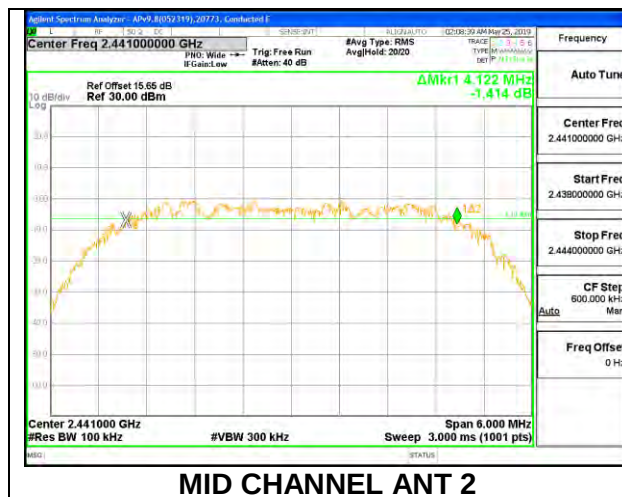
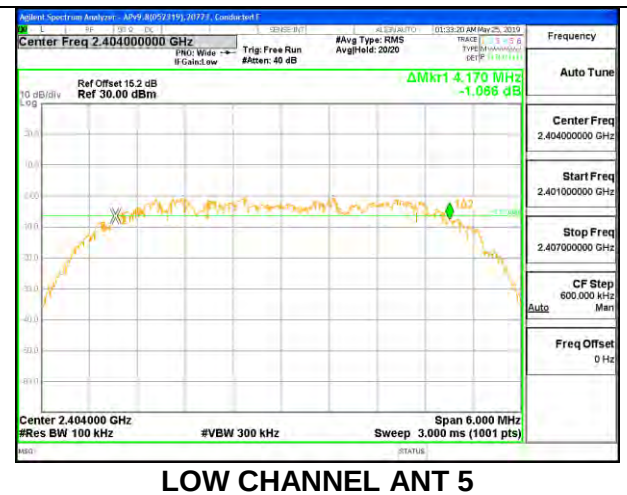
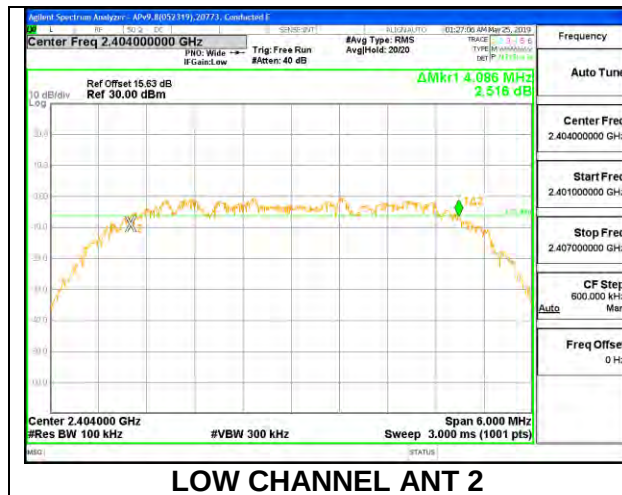
HIGH CHANNEL ANT 2



HIGH CHANNEL ANT 5

8.9.4. LOW POWER HDR (HDR8)

Channel	Frequency (MHz)	6dB Bandwidth ANT 2 (MHz)	6dB Bandwidth ANT 5 (MHz)
Low	2404	4.086	4.170
Mid	2441	4.122	4.152
High	2478	4.146	4.140



8.10. BEAMFORMING, POWER SPECTRAL DENSITY

8.10.1. HIGH POWER HDR (HDR4)

Duty Cycle CF (dB)	Included in Calculations of Corr'd PSD
--------------------	--

PSD Results

Channel	Frequency (MHz)	ANT 2 Meas (dBm/ 3kHz)	ANT 5 Meas (dBm/ 3kHz)	Total Corr'd PSD (dBm/ 3kHz)	Limit (dBm/ 3kHz)	Margin (dB)
Low	2404	-0.882	-0.577	2.283	8.0	-5.717
Mid	2441	-0.501	0.918	3.276	8.0	-4.724
High	2478	-0.453	-0.812	2.382	8.0	-5.618

Note: Test procedures and setting on beamforming are same as HDR normal mode