



CERTIFICATION TEST REPORT

Report Number. : 12696946-E3V2

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

Model : A2111, A2222 AND A2223

FCC ID : BCG-E3309A

IC : 579C-E3309A

EUT Description : SMARTPHONE

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

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REPORT REVISION HISTORY

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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: A2111, A2222 and A2223

SERIAL NUMBER: C7CYQ004MT74, C7CYP0L2MT5Q

DATE TESTED: FEBRUARY 19, 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
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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, 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
<input checked="" type="checkbox"/> Chamber A (ISED:2324B-1)	<input checked="" type="checkbox"/> Chamber D (ISED:22541-1)	<input type="checkbox"/> Chamber I (ISED:2324A-5)
<input checked="" type="checkbox"/> Chamber B (ISED:2324B-2)	<input checked="" type="checkbox"/> Chamber E (ISED:22541-2)	<input type="checkbox"/> Chamber J (ISED:2324A-6)
<input type="checkbox"/> Chamber C (ISED:2324B-3)	<input type="checkbox"/> Chamber F (ISED:22541-3)	<input type="checkbox"/> Chamber K (ISED:2324A-1)
	<input type="checkbox"/> Chamber G (ISED:22541-4)	<input type="checkbox"/> Chamber L (ISED:2324A-3)
	<input checked="" type="checkbox"/> 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. DIFFERENCE IN MODEL NUMBER

Model A2111, A2222 and A2223 are electrically identical to Model A2111. Three model numbers are allocated for marketing and logistic purposes only. A2111 was used to perform all final tests.

5.3. MAXIMUM OUTPUT POWER

The transmitter has a maximum conducted output power as follows:

2.4GHz BAND

Frequency Range (MHz)	Mode	Output Power (dBm)	Output Power (mW)
1Tx			
2412 - 2472	802.11b	21.49	140.93
2412 - 2472	802.11g	Covered by 802.11n HT20 1TX	
2412 - 2472	802.11n HT20	21.47	140.28
2412 - 2472	802.11ax HE20, 242-Tones	21.45	139.64
2412 - 2472	802.11ax HE20, 26-Tones	21.47	140.28

2Tx			
2412 - 2472	802.11n HT20 CDD	24.46	279.25
2412 - 2472	802.11g SDM/STBC	Covered by 802.11n HT20 2TX CDD	
2412 - 2472	802.11ax HE20, 242-Tones	24.40	275.42
2412 - 2472	802.11ax HE20, 26-Tones	22.88	194.09

5.4. DESCRIPTION OF AVAILABLE ANTENNAS

Frequency Range	Antenna 2(Core 0)	Antenna Ant 5 (Core 1)
2400-2480	-4.5	-2.6

5.5. SOFTWARE AND FIRMWARE

The EUT firmware installed during testing was WiFi FW Version: 18_20_56_1.

5.6. WORST-CASE CONFIGURATION AND MODE

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

Radiated band edge, harmonic, and spurious emissions from 1GHz to 18GHz were performed with the EUT 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 radiated harmonics spurious below 1GHz, 1-18GHz L/M/H channels, 18-26GHz, and power line conducted emissions were performed with the EUT set at the 2TX CDD mode among the CDD/SDM modes and 2TX HE mode with power setting equal or higher than SISO modes as worst-case scenario. G mode covered by HT20 mode since it has the same power as HT20.

Below 1GHz tests were performed with EUT connected to AC power adapter as the worst case; and for above 1GHz tests, the worst-case configuration reported was 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.

The output power and psd for the 802.11 ax mode were investigated between all different tones, and we found that the highest tone had equal or higher output power and widest bandwidth, the lowest tone had the highest PSD reading from the target power table. Therefore, full testing was performed on both the highest and lowest tones. In addition, RU52 was investigated on channel 13 1TX and 2TX on power, PSD and band edge to show compliance.

The peak PSD were performed as worst case mode.

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

802.11b mode: 1 Mbps
802.11n HT20mode: MCS0
802.11ax HE20mode: MCS0

5.7. DESCRIPTION OF TEST SETUP

SUPPORT EQUIPMENT

Support Equipment List				
Description	Manufacturer	Model	Serial Number	FCC ID
laptop	Apple	A1502	HRP003436	QDS-BRCM1080
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

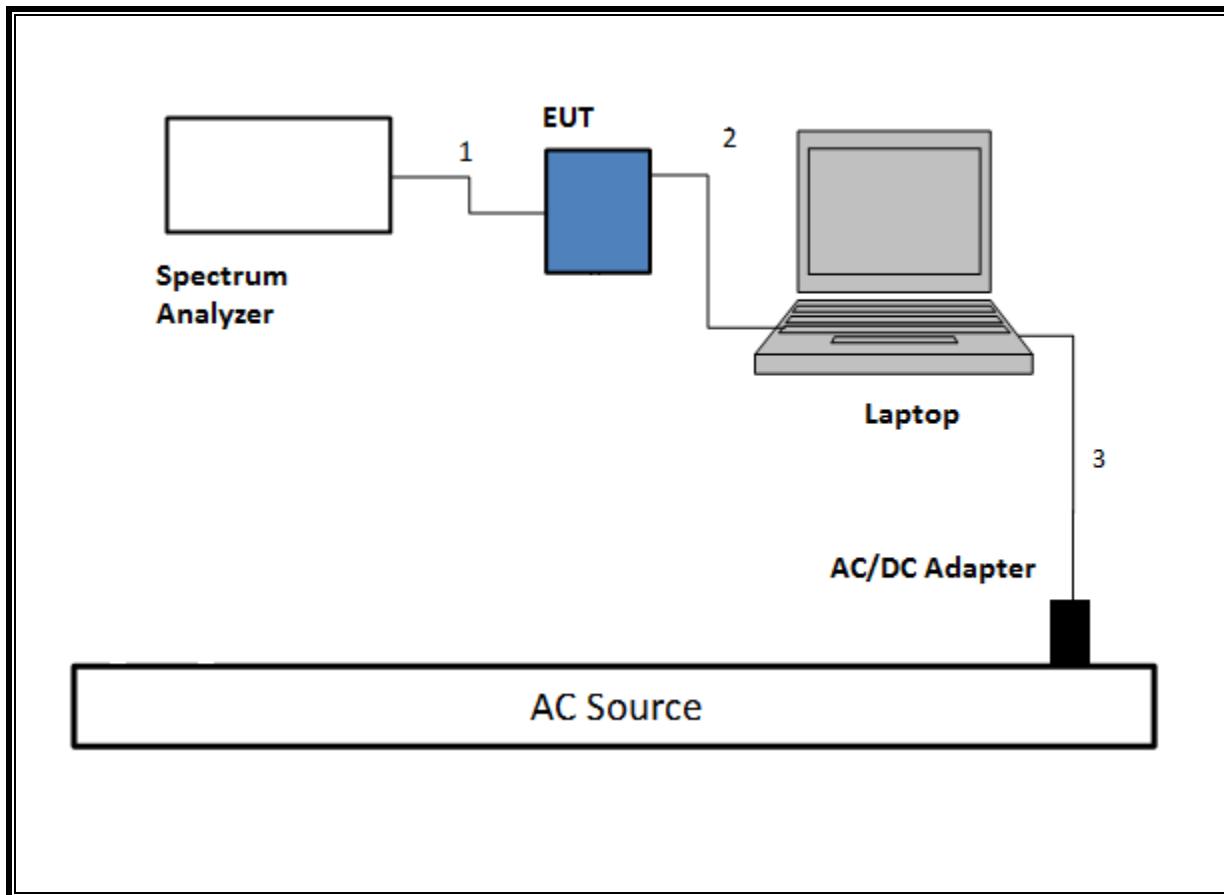
I/O CABLES (BELOW 1GHz AND AC POWER LINE TEST WITH ADAPTER AND LAPTOP)

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

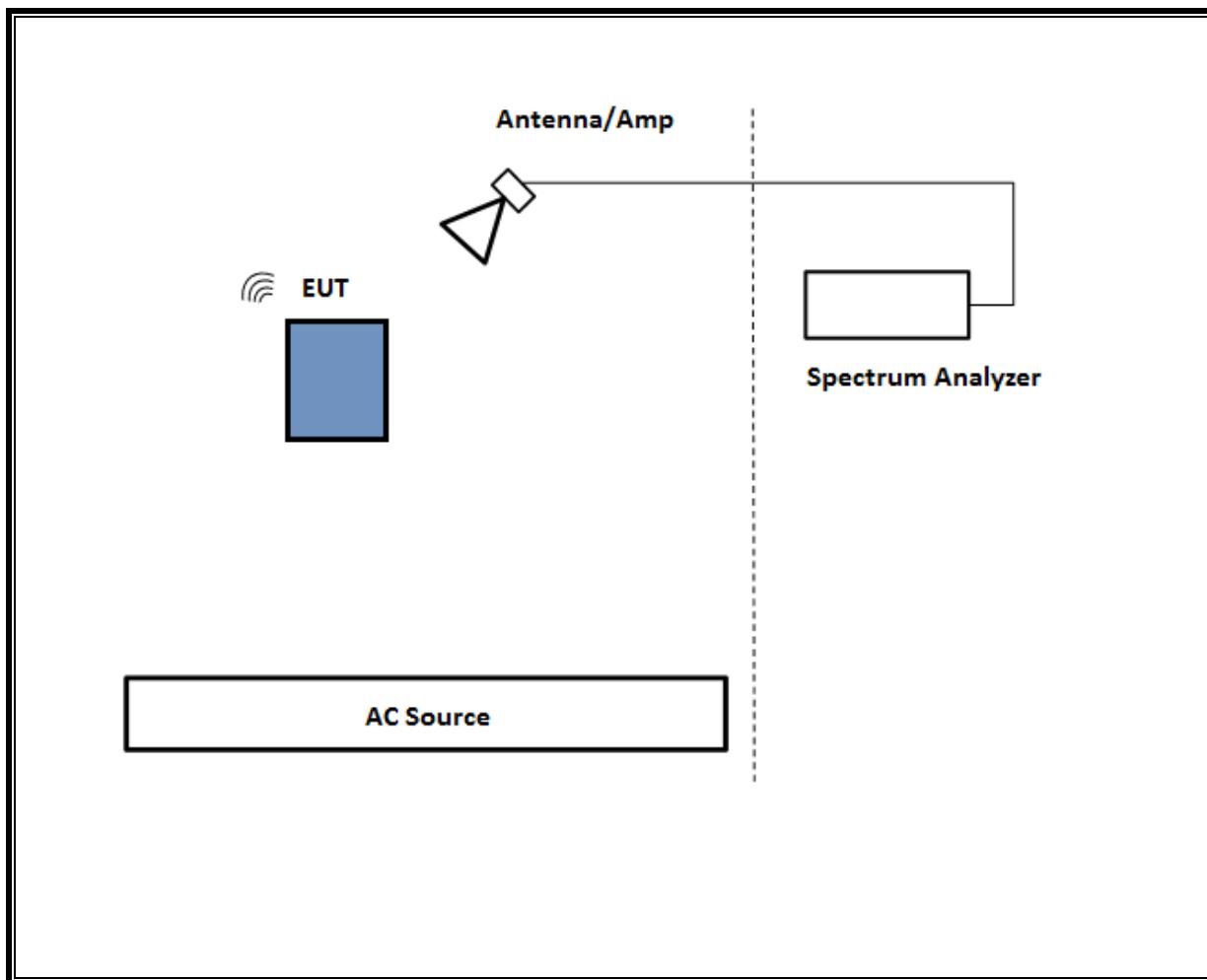
TEST SETUP

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

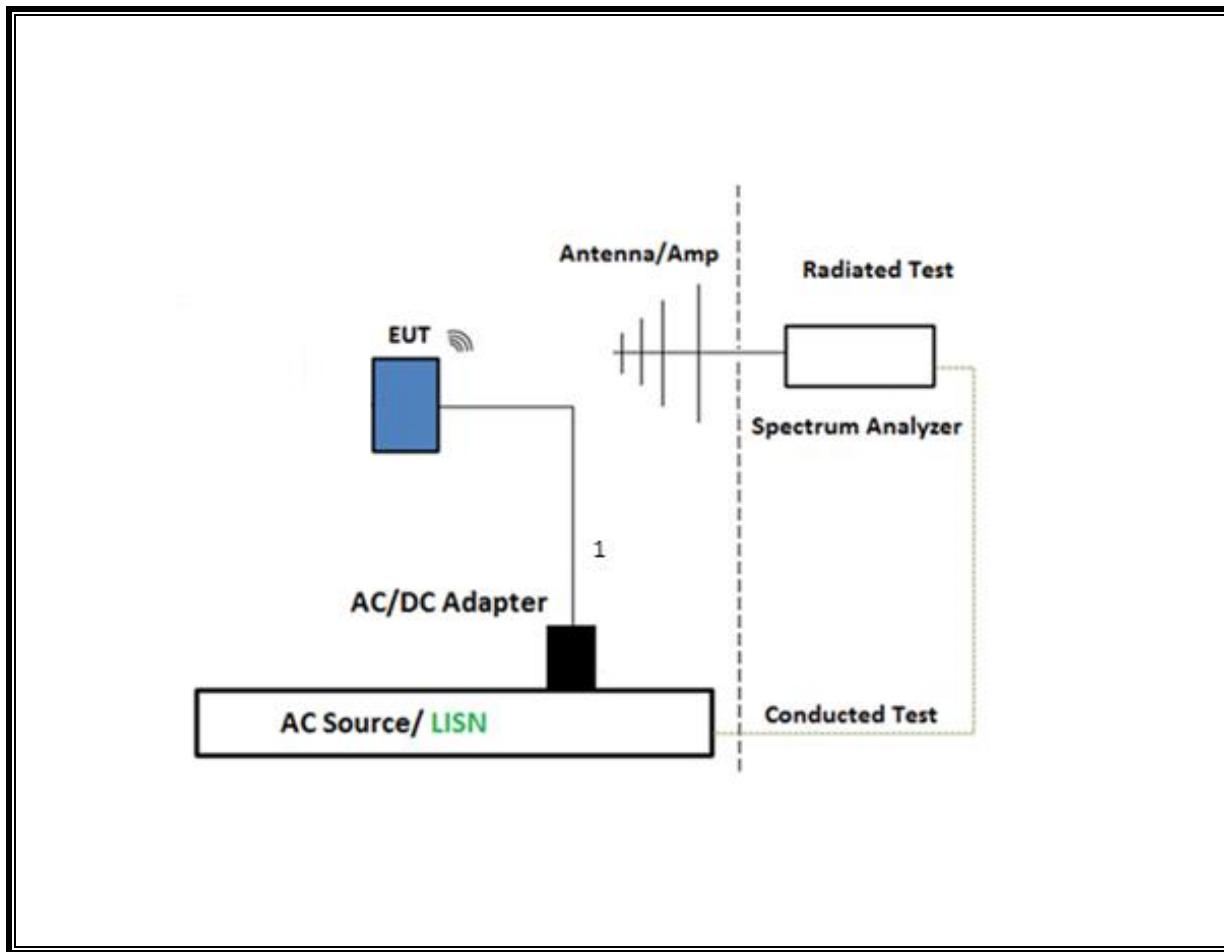
SETUP DIAGRAM FOR CONDUCTED TESTS



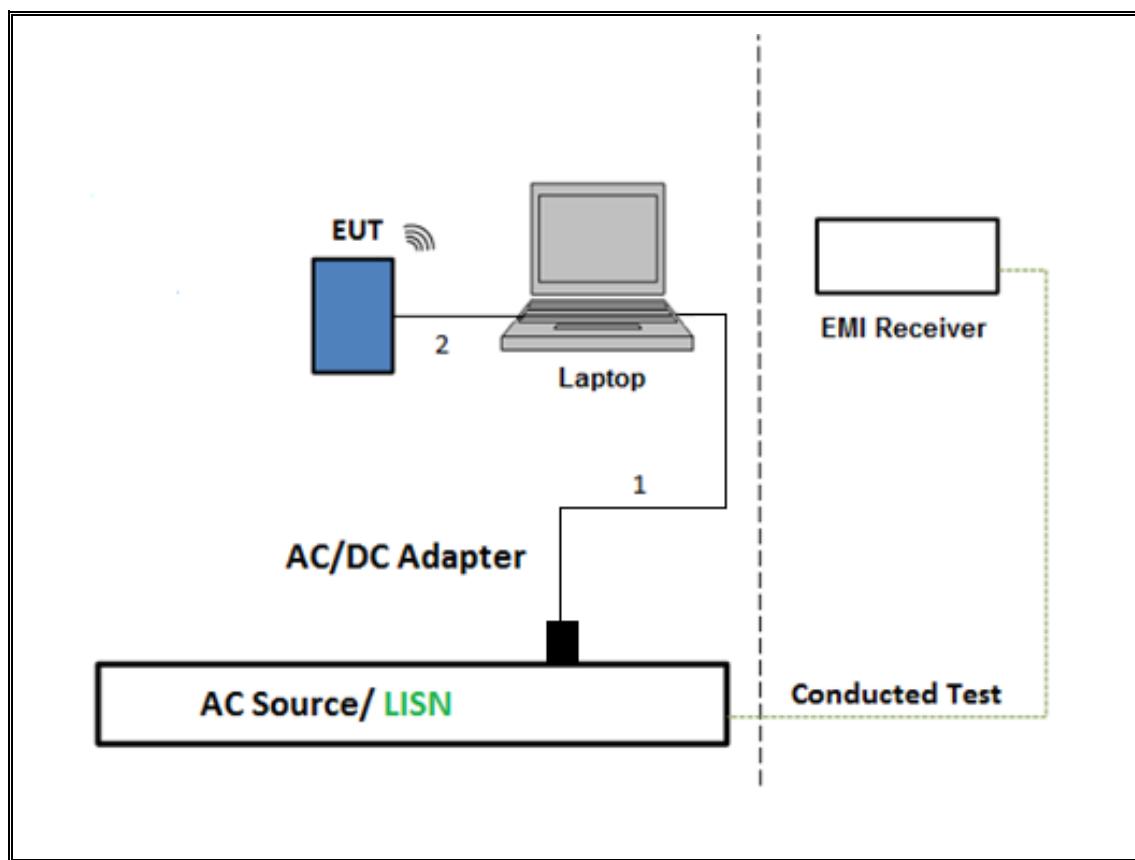
SETUP DIAGRAM FOR RADIATED TESTS Above 1GHz



SETUP DIAGRAM FOR Below 1GHz and AC LINE CONDUCTED TEST



TEST SETUP- AC LINE CONDUCTED: LAPTOP CONFIGURATION



6. MEASUREMENT METHOD

6 dB BW: ANSI C63.10 Subclause -11.8.1 RBW \geq DTS BW

99% BW: ANSI C63.10-2013, Section 6.9.3.

Output Power: ANSI C63.10 Subclause -11.9.1.3 Method PKPM1 Peak-reading power meter

Output Power: ANSI C63.10 Subclause -11.9.2.3.1 Method AVGPM (Measurement using an RF average-reading power meter)

PSD: ANSI C63.10 Subclause -11.10.2 Method PKPSD (peak PSD)

Radiated emissions non-restricted frequency bands: ANSI C63.10 Subclause -11.11

Radiated emissions restricted frequency bands: ANSI C63.10 Subclause -11.12.1

Conducted emissions in restricted frequency bands: ANSI C63.10 Subclause -11.12.2

Band-edge: ANSI C63.10 Subclause -11.13.3.2 Integration method -Peak detection

Band-edge: ANSI C63.10 Subclause -11.13.3.3 Integration method -Trace averaging with continuous transmission at full power

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

Radiated Spurious Emissions Below 30MHz: ANSI C63.10-2013 Section 6.4

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	ID Num	Cal Due	Last Cal
Antenna, Broadband Hybrid, 30MHz to 2000MHz	SunAR rf Motion	JB3	PRE0181574	08/01/2019	08/01/2018
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T136	07/02/2019	07/02/2018
RF Amplifier	MITEQ	AFS42-00101800-25-S-42	T739	01/26/2020	01/26/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T340	01/22/2020	01/22/2019
HPF 3.0GHz	Micro-Tronics	HPM17543	T1014	01/26/2020	01/26/2019
Amplifier, 9KHz-1GHz, 32dB	Sonoma	310N	T15	08/15/2019	08/15/2018
Antenna, Active Loop 9KHz to 30MHz	ETS-Lindgren	6502	T757	09/25/2019	09/25/2018
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T345	04/20/2020	4/20/2019
*Amplifier, 1 to 8GHz, 35dB	Miteq	AMF-4D-01000800-30-29P	T1573	06/12/2019	06/12/2018
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T863	05/30/2020	05/30/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T712	02/26/2020	02/26/2019
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	138301	09/15/2019	09/15/2018
Spectrum Analyzer, PXA 3Hz to 44GHz	Keysight	N9030A	T1466	01/23/2020	01/23/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T346	05/14/2020	05/14/2019
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T931	05/11/2020	05/11/2019
*Antenna Horn, 18 to 26GHz	ARA	MWH-1826/B	T449	06/29/2019	06/29/2018
Pre-Amp 18-26GHz	Agilent Technology	8449B	T404	03/23/2020	03/23/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T1454	01/23/2020	01/23/2019
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T119	03/22/2020	03/22/2019
Amplifier, 1 to 18GHz	Miteq	AFS42-00101800-25-S-42	T740	10/06/2019	10/06/2018

AC Line Conducted				
EMI Test Receiver 9Khz-7GHz	Rohde & Schwarz	ESCI7	T1436	02/14/2020
Power Cable, Line Conducted Emissions	UL	PG1	T861	10/19/2019
*LISN for Conducted Emissions CISPR-16	Fischer	50/250-25-2-01	T1310	01/24/2020
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.

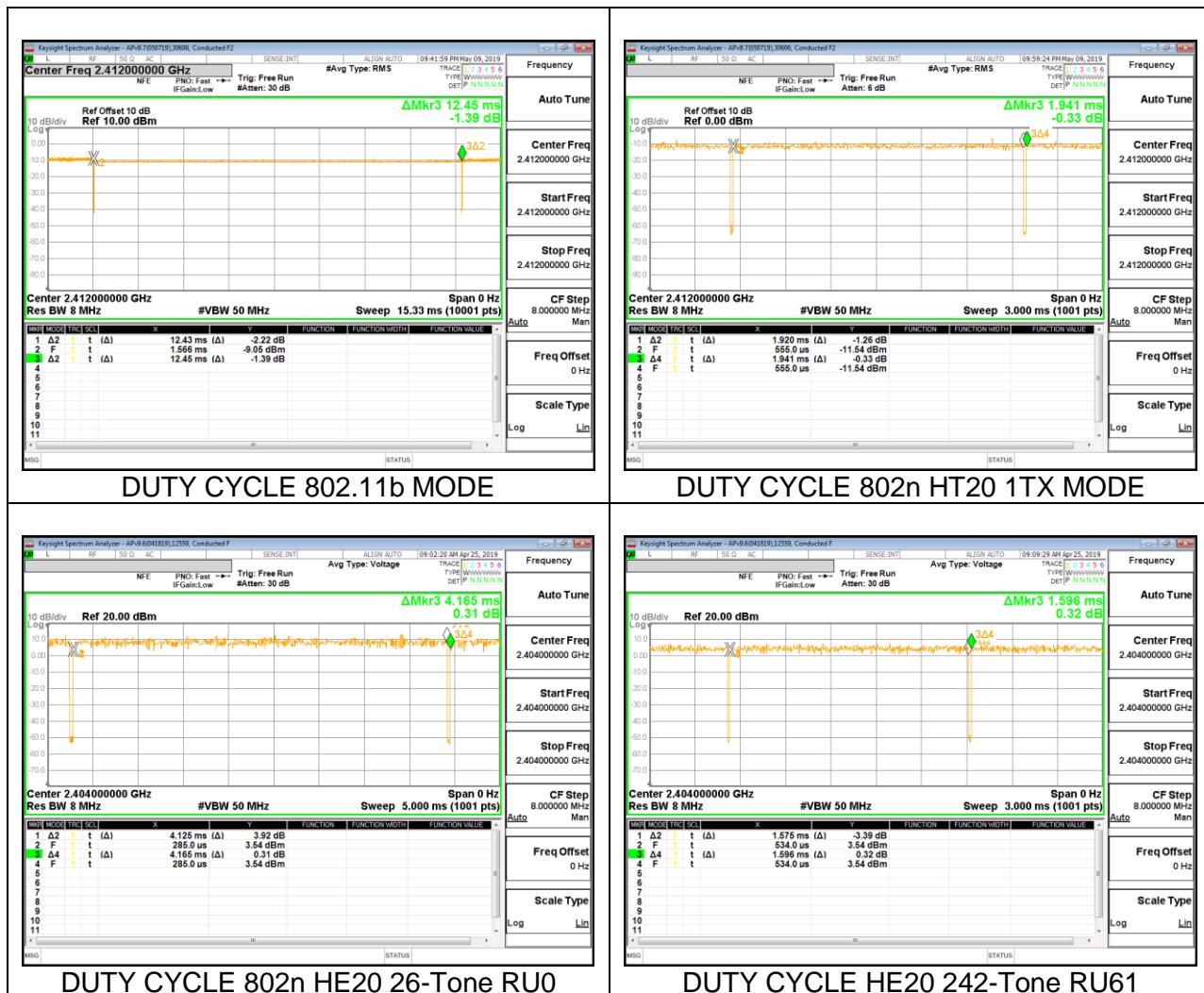
PROCEDURE

KDB 558074 Zero-Span Spectrum Analyzer Method.

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/B Minimum VBW (kHz)
2.4GHz Band						
802.11b	12.430	12.450	0.998	99.84%	0.00	0.010
802.11n HT20	1.920	1.941	0.989	98.92%	0.00	0.010
HE20 26-Tone RU0	4.125	4.165	0.990	99.04%	0.00	0.010
HE20 242-Tone RU61	1.575	1.596	0.987	98.68%	0.00	0.010

DUTY CYCLE PLOTS



8.2. 99% BANDWIDTH

LIMITS

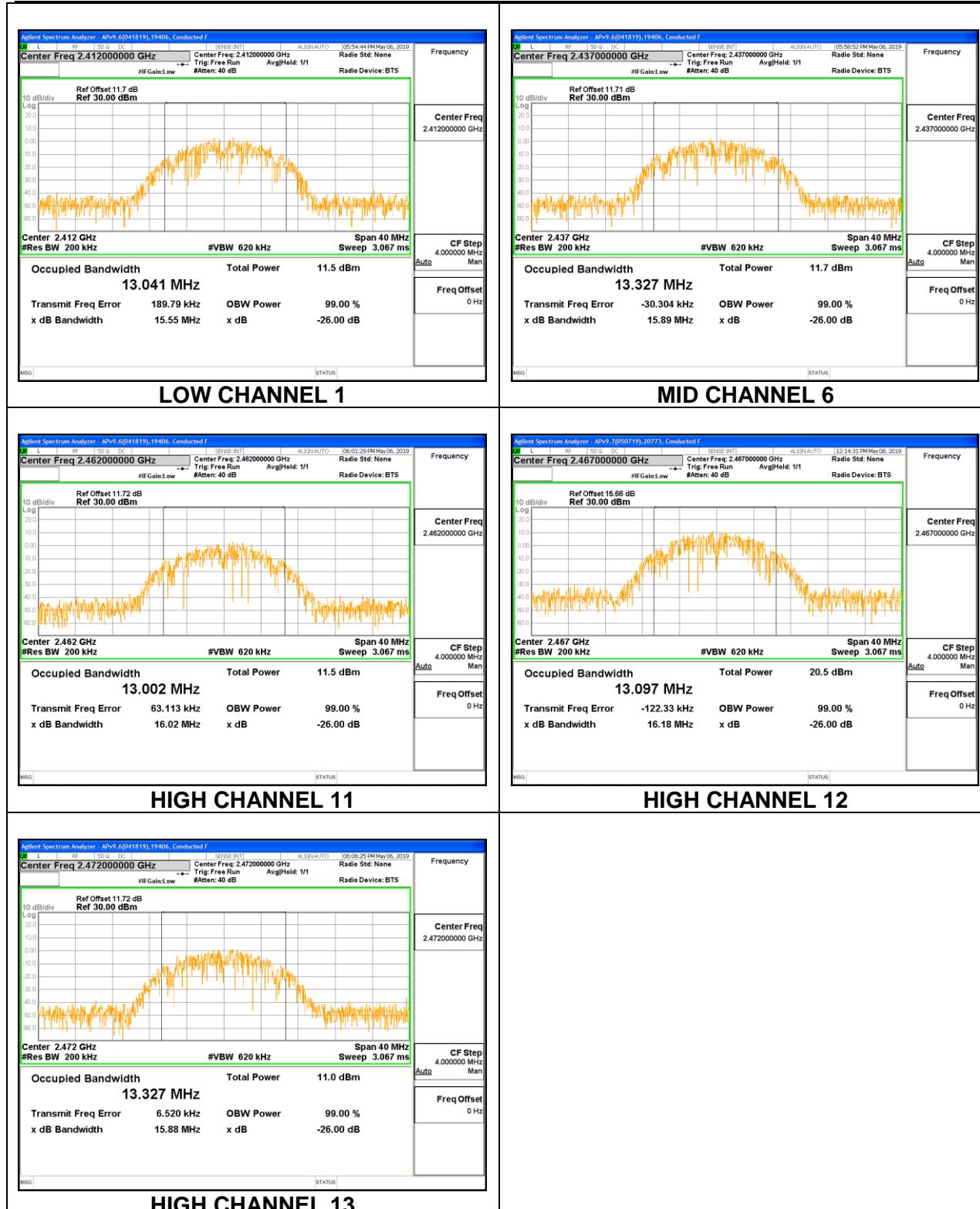
None; for reporting purposes only.

RESULTS

8.2.1. 802.11b MODE

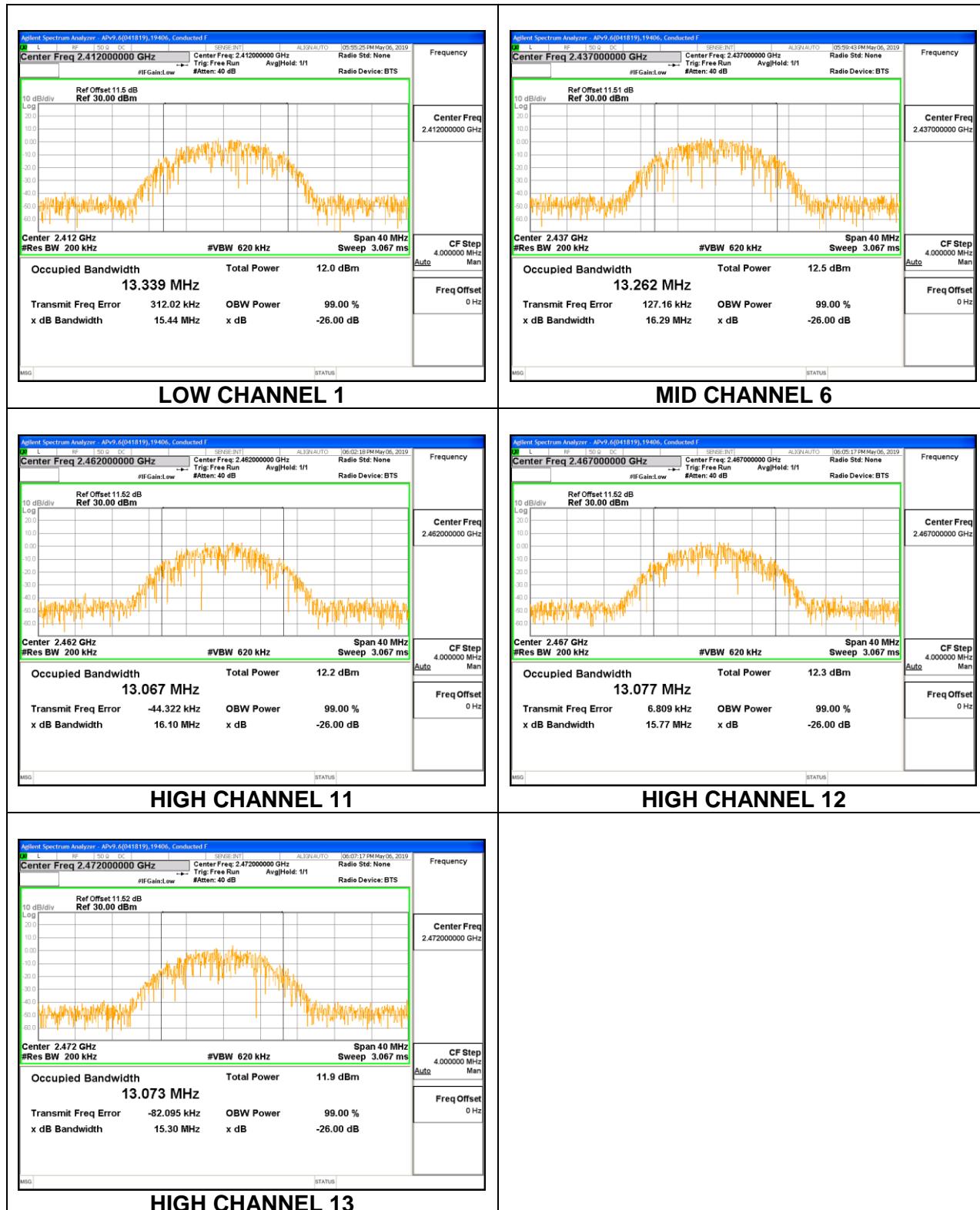
1TX Antenna 2 MODE

Channel	Frequency	99% Bandwidth
	(MHz)	(MHz)
Low 1	2412	13.041
Mid 6	2437	13.327
High 11	2462	13.002
High 12	2467	13.097
High 13	2472	13.327



1TX Antenna 5 MODE

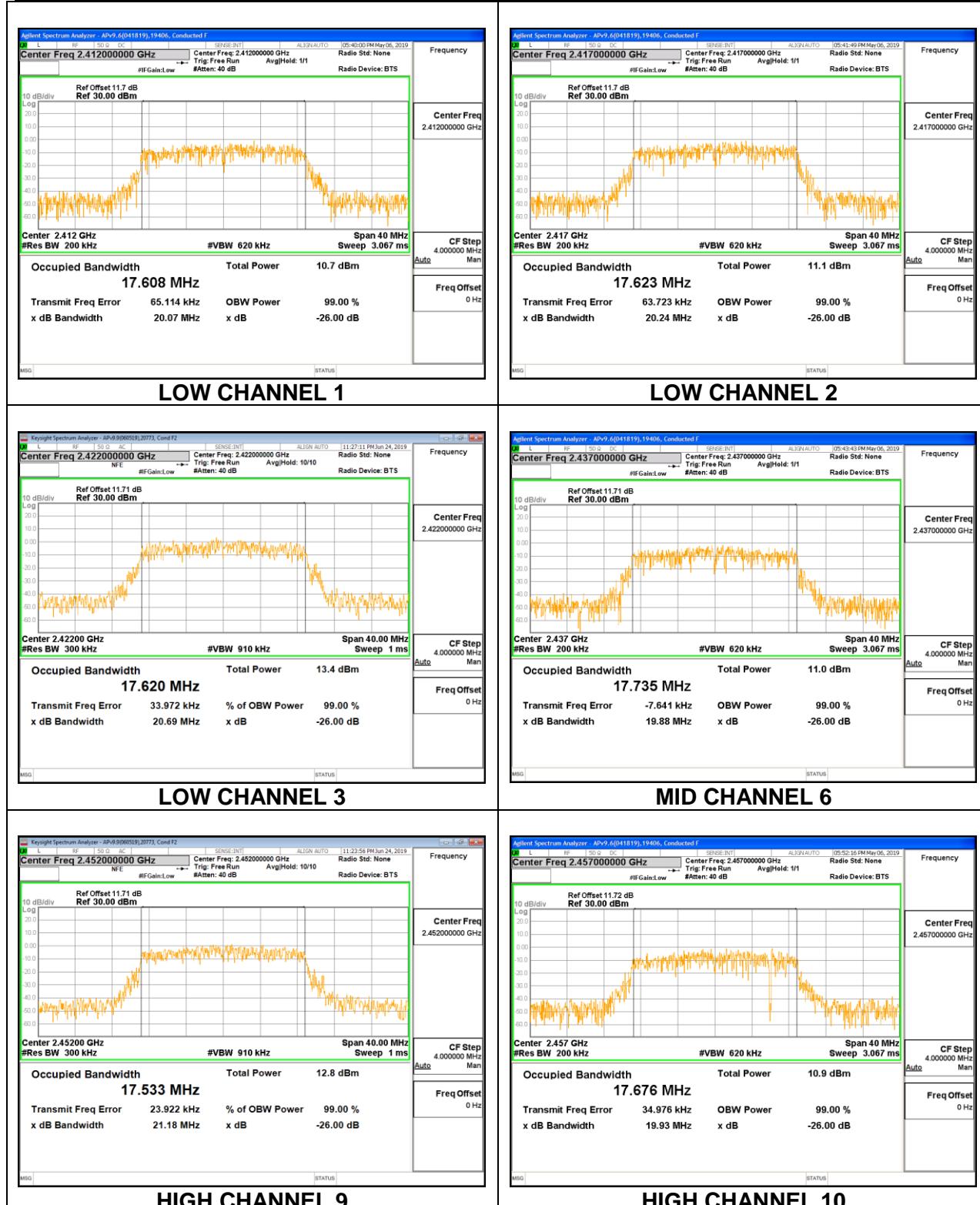
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	13.339
Mid 6	2437	13.262
High 11	2462	13.067
High 12	2467	13.077
High 13	2472	13.073

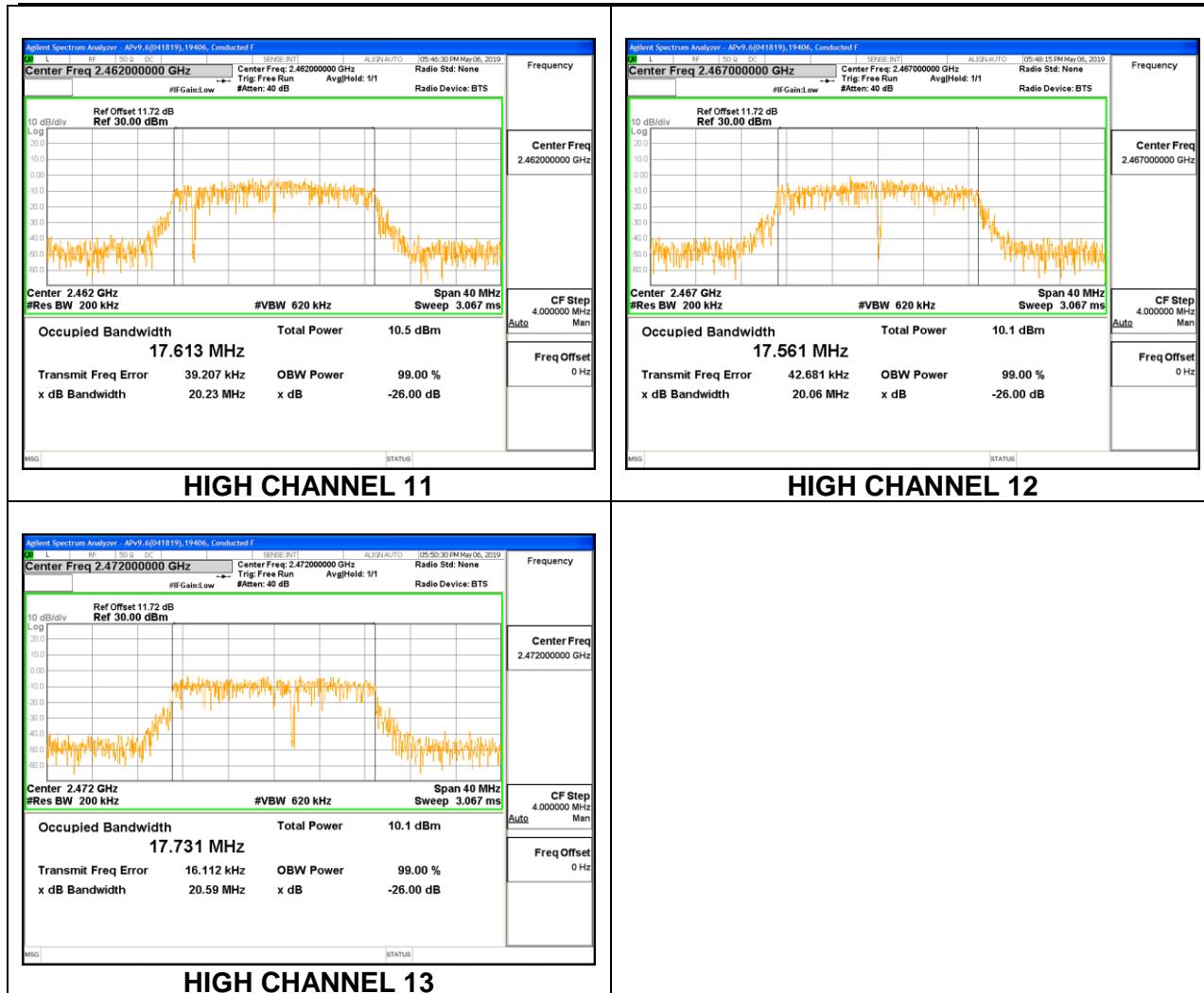


8.2.2. 802.11n HT20 MODE

1TX Antenna 2 MODE

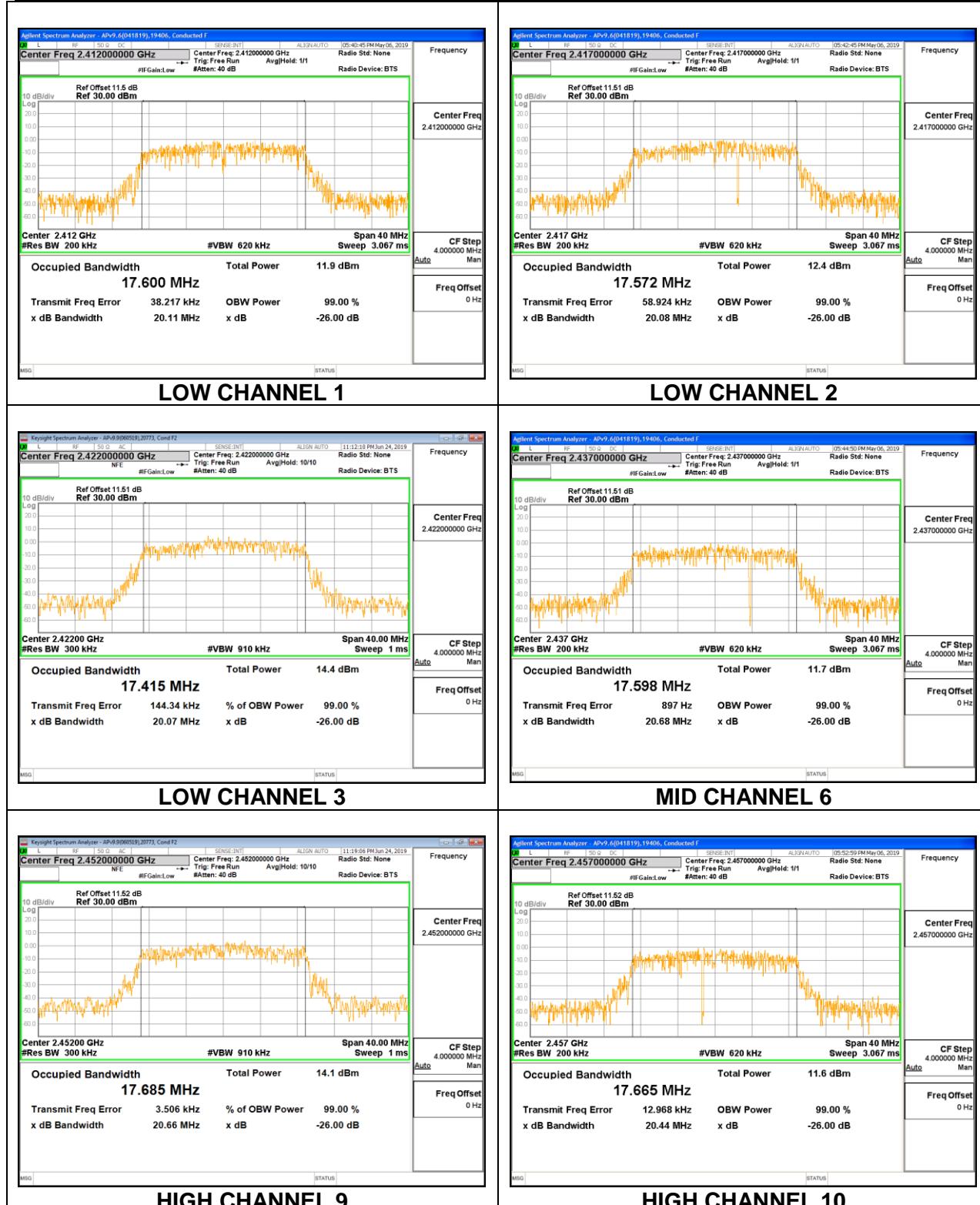
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	17.608
Low 2	2417	17.623
Low 3	2422	17.620
Mid 6	2437	17.735
High 9	2452	17.533
High 10	2457	17.676
High 11	2462	17.613
High 12	2467	17.561
High 13	2472	17.731

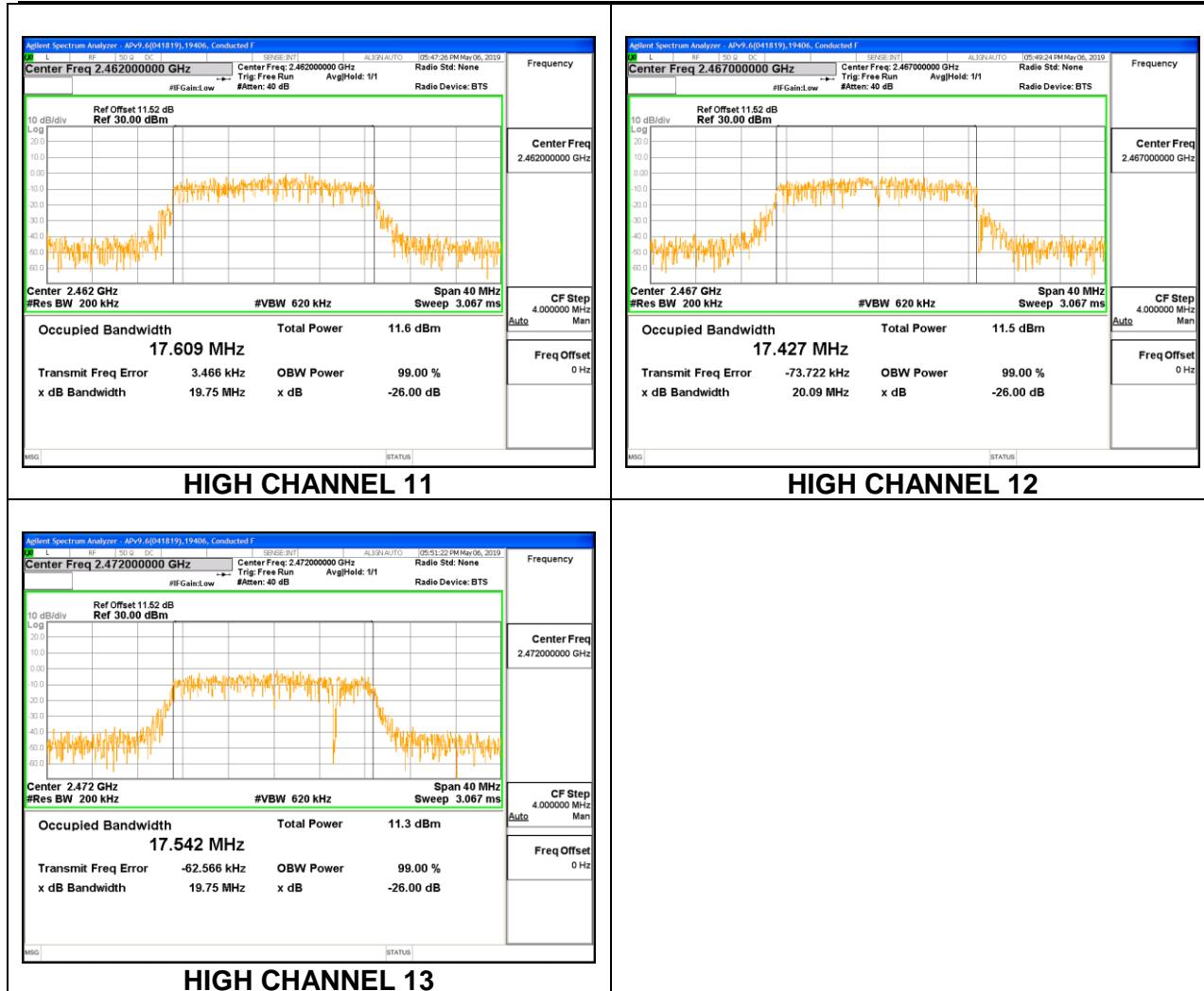




1TX Antenna 5 MODE

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	17.600
Low 2	2417	17.572
Low 3	2422	17.415
Mid 6	2437	17.598
High 9	2452	17.685
High 10	2457	17.665
High 11	2462	17.609
High 12	2467	17.427
High 13	2472	17.542

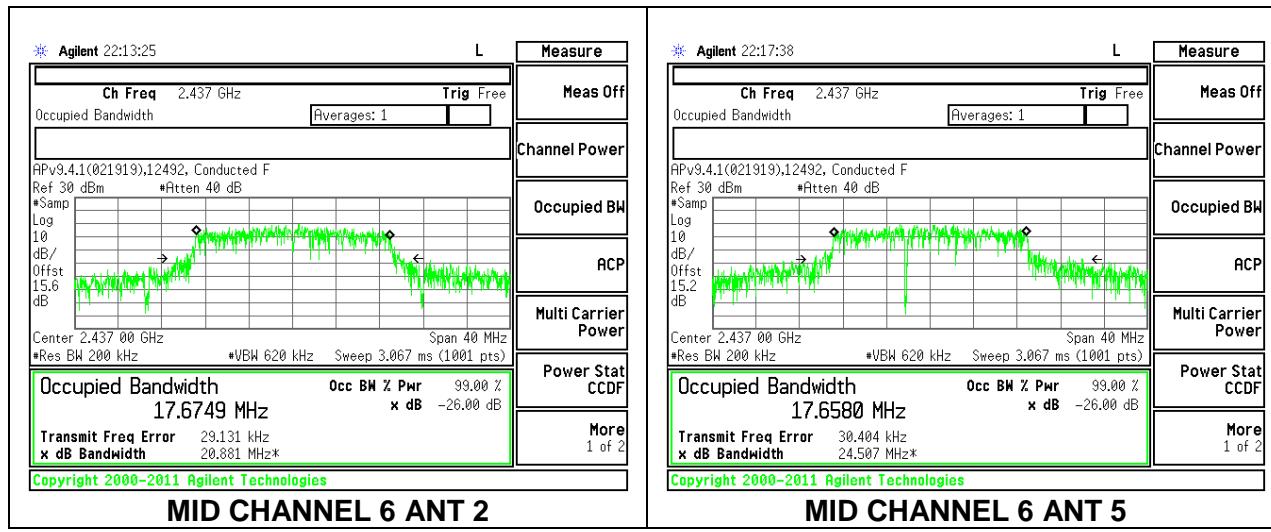
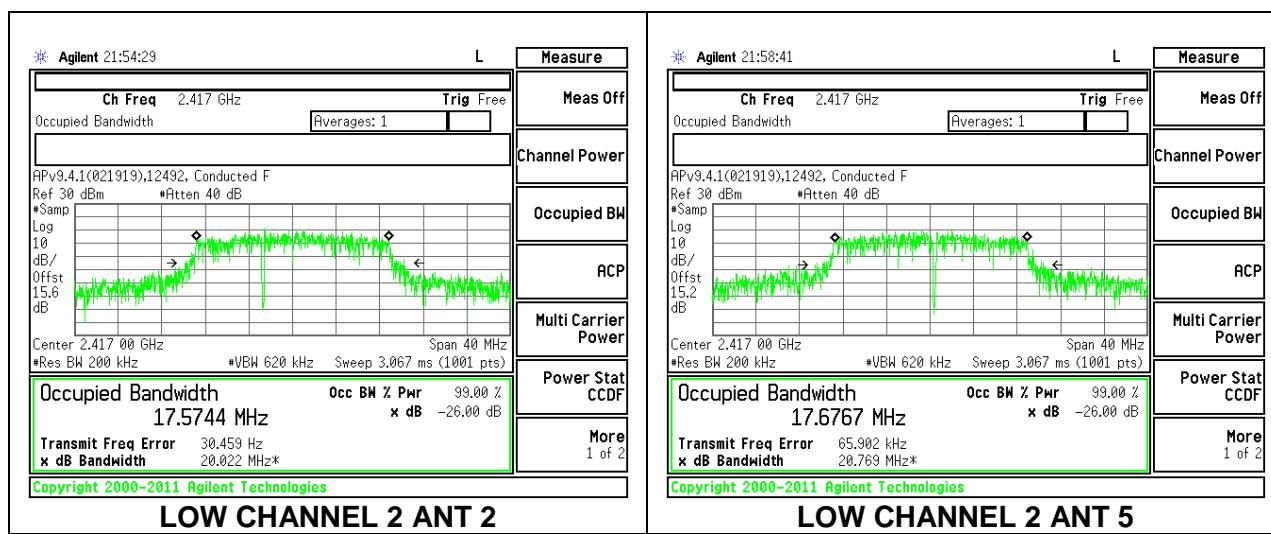
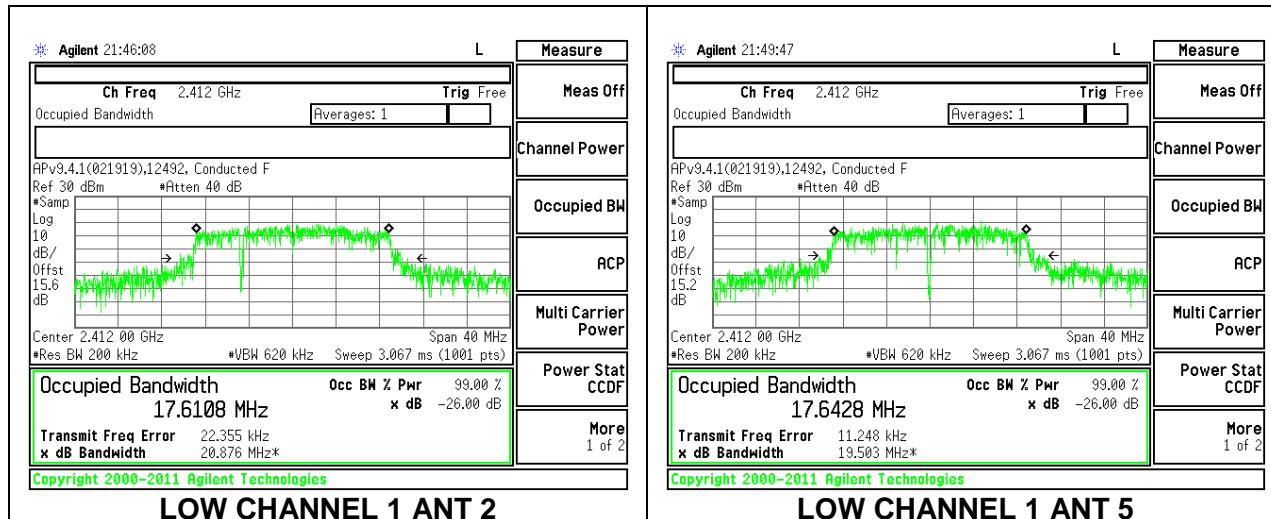


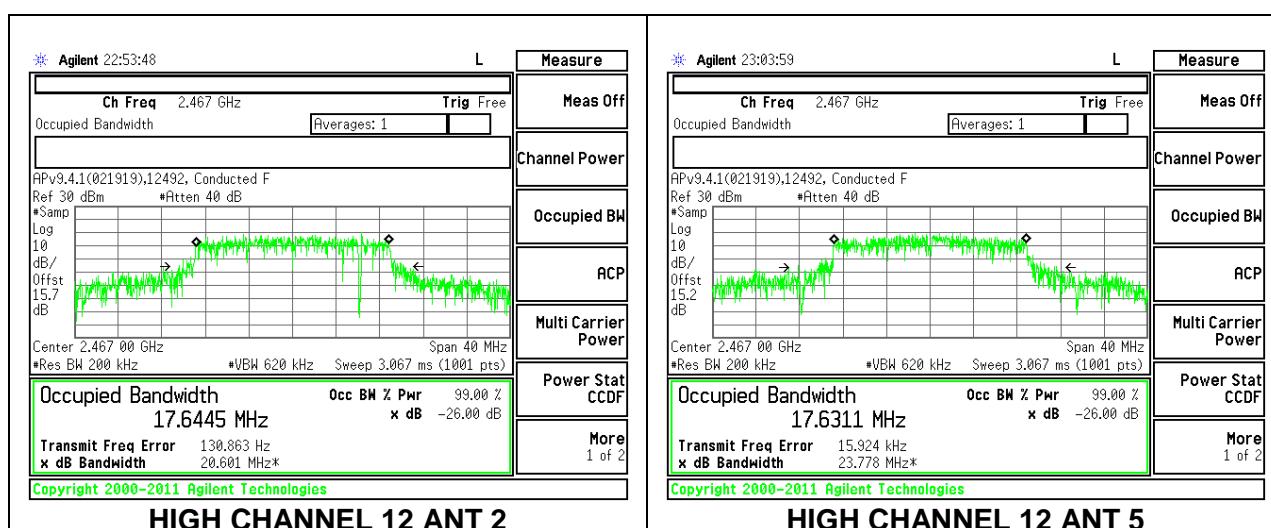
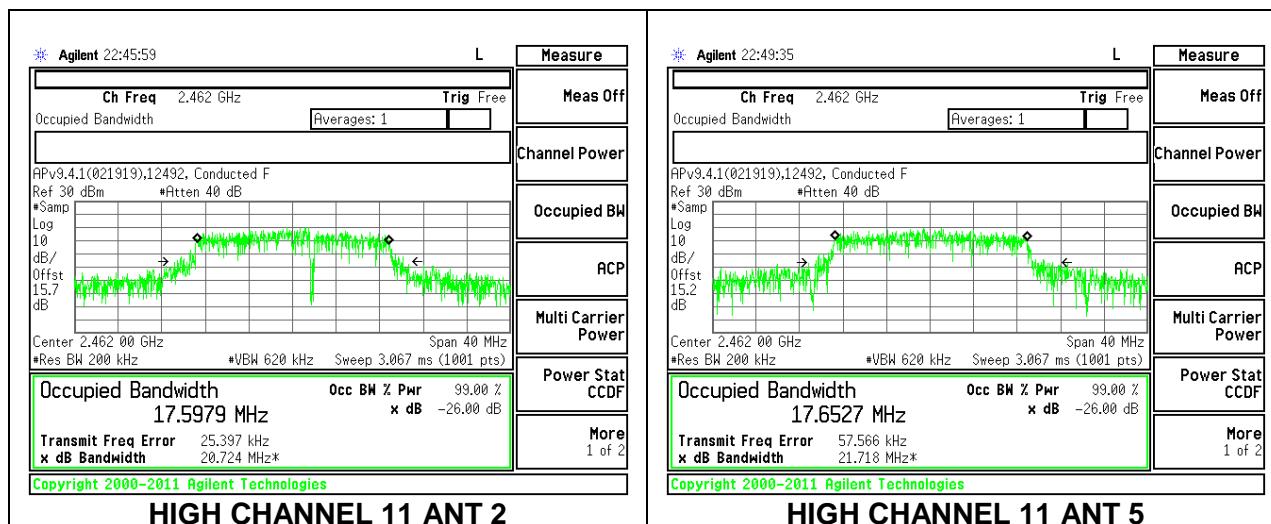
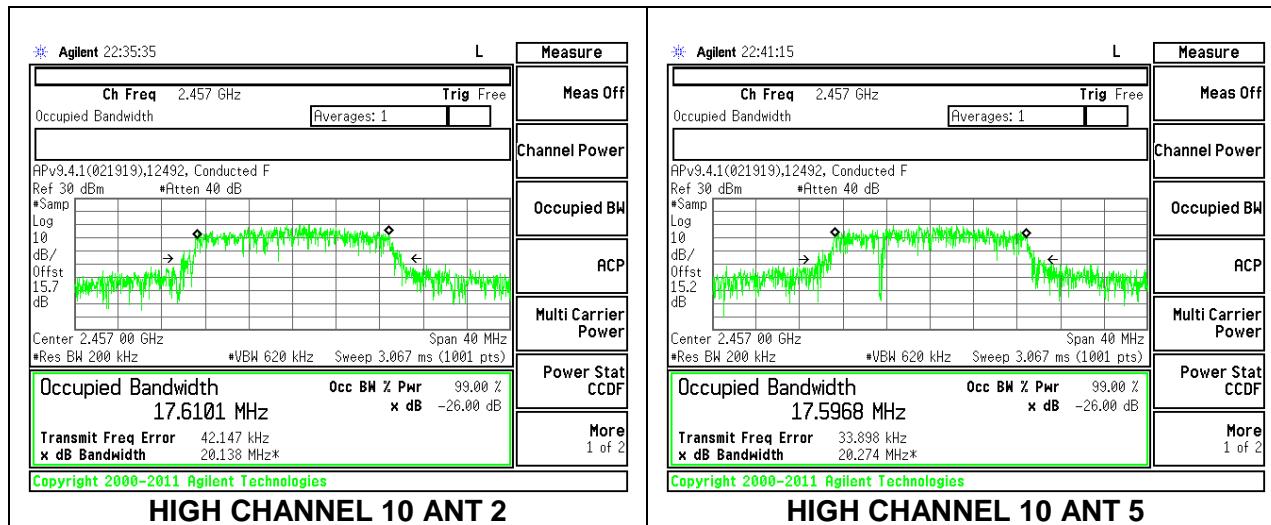


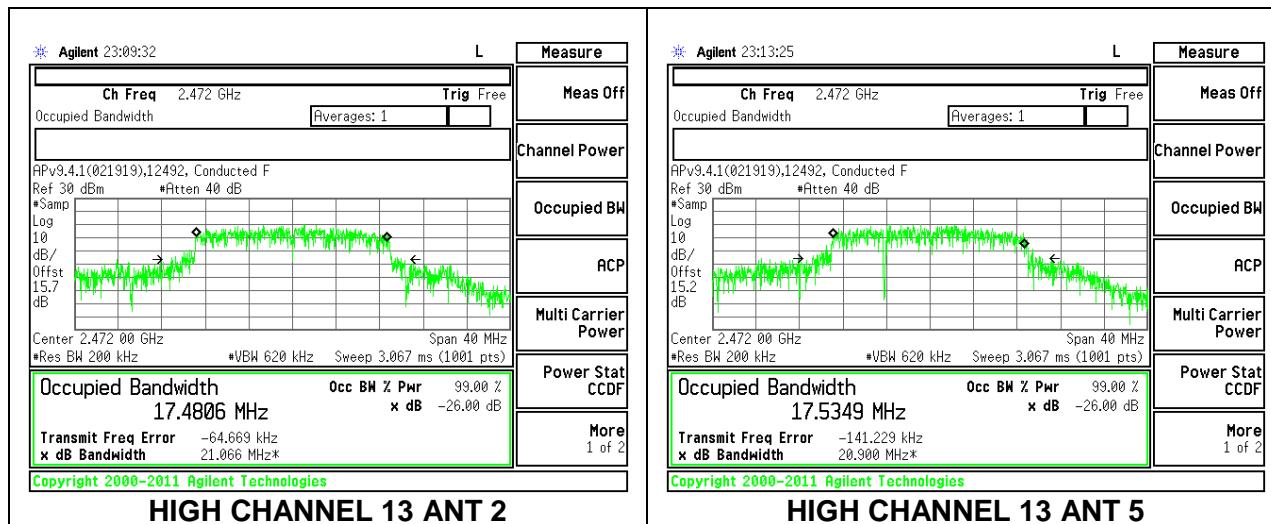
8.2.3. 802.11n HT20 CDD MODE 2TX

Antenna 2 + Antenna 5 2TX MODE

Channel	Frequency (MHz)	99% Bandwidth ANT 2 (MHz)	99% Bandwidth ANT 5 (MHz)
Low 1	2412	17.611	17.643
Low 2	2417	17.574	17.677
Mid 6	2437	17.675	17.658
High 10	2457	17.610	17.597
High 11	2462	17.598	17.653
High 12	2467	17.645	17.631
High 13	2472	17.481	17.535



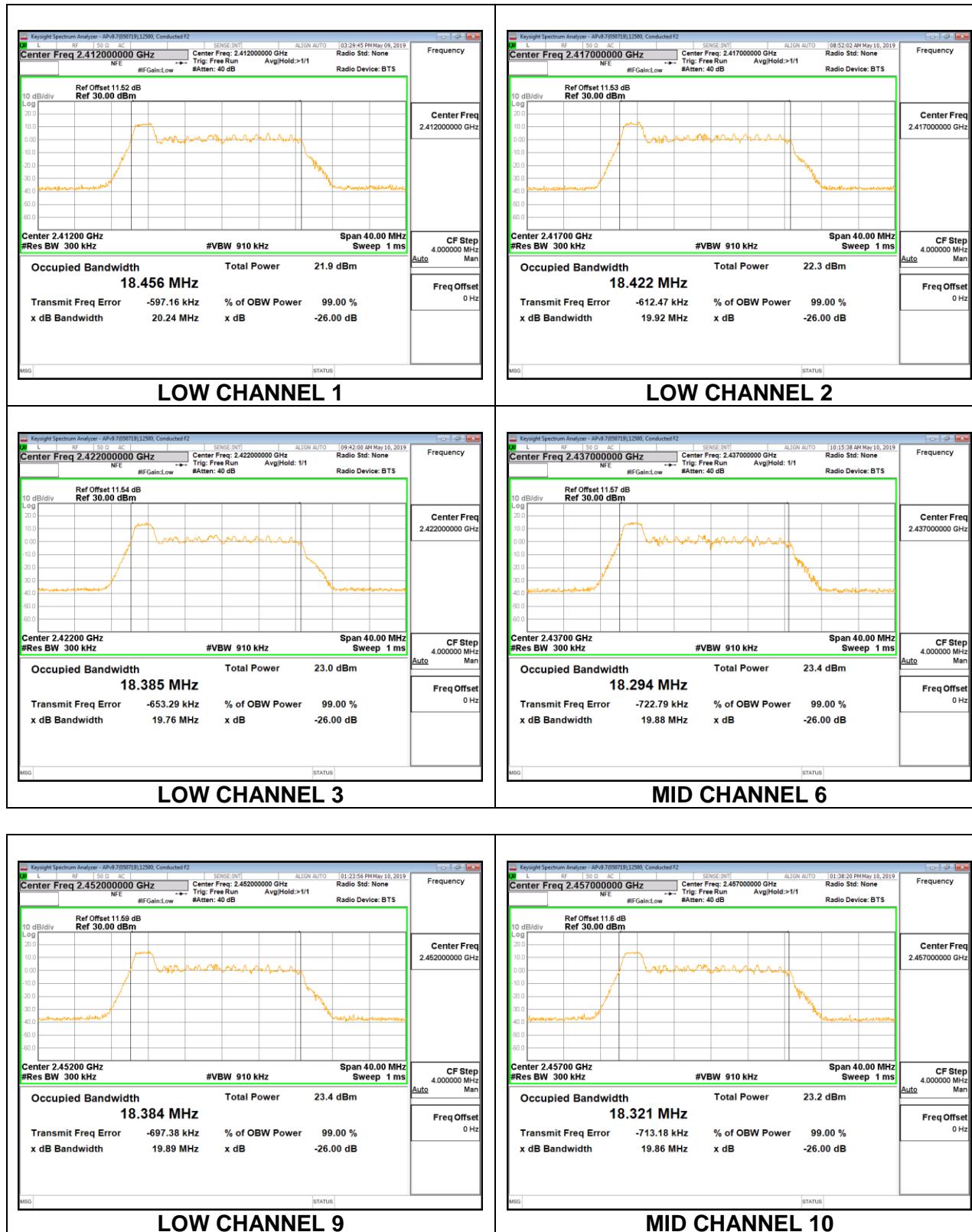




8.2.4. 802.11ax HE20 MODE

Antenna 2, LEGACY SISO MODE: 26-Tones, RU index 0

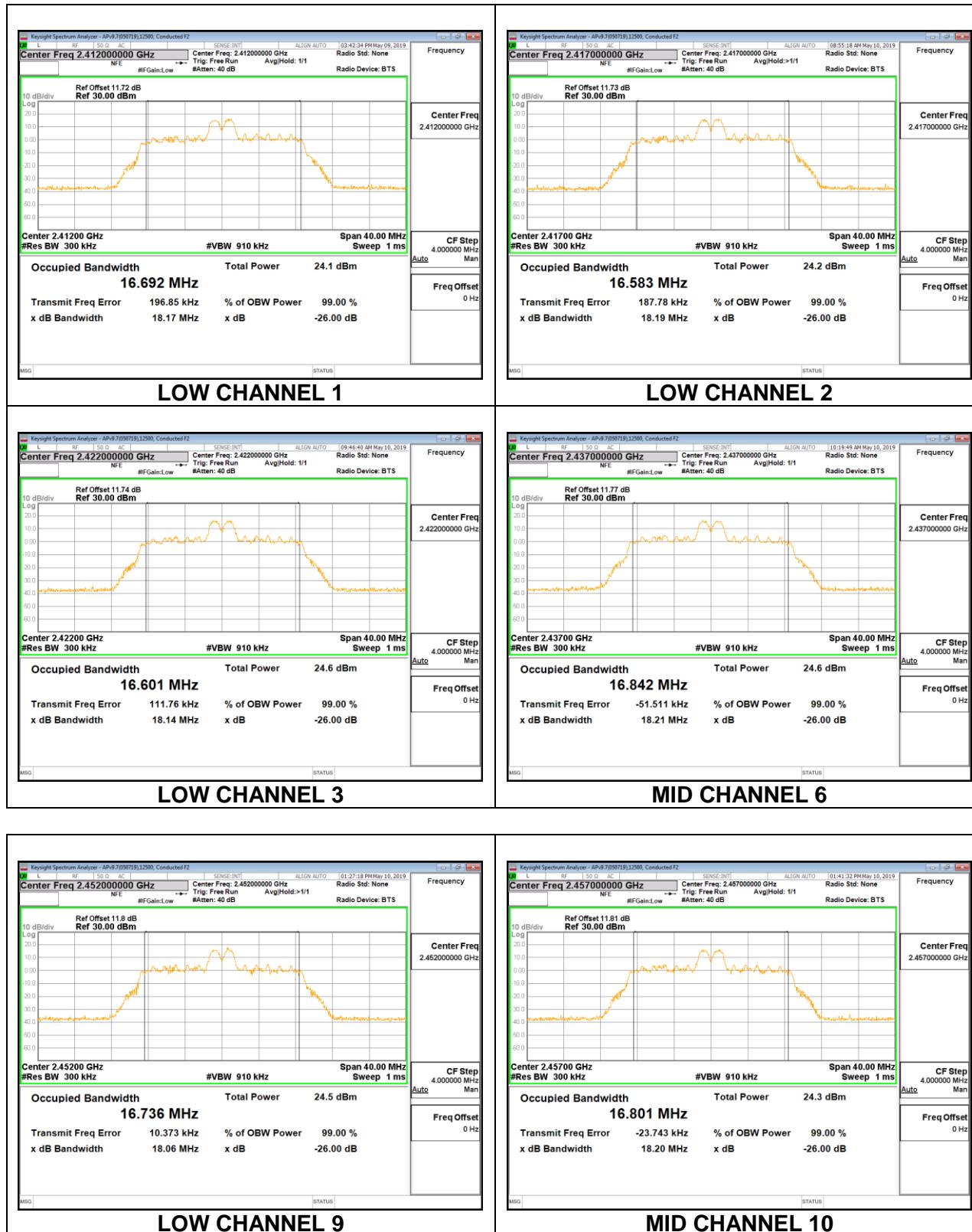
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	18.456
Low 2	2417	18.422
Low 3	2422	18.385
Mid 6	2437	18.294
High 9	2452	18.384
High 10	2457	18.321
High 11	2462	18.226
High 12	2467	18.232
High 13	2472	18.011





Antenna 2, LEGACY SISO MODE: 26-Tones, RU index 4

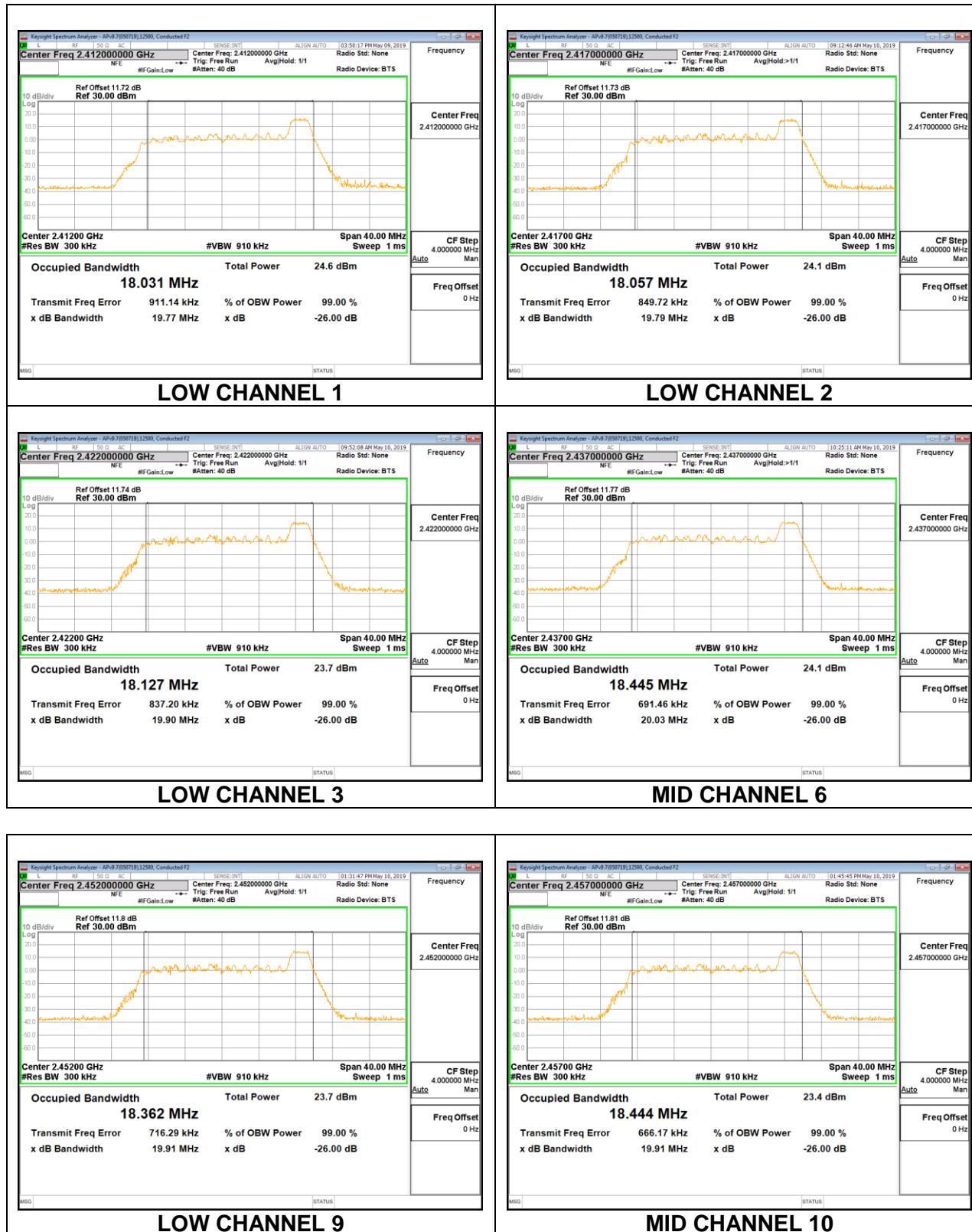
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	16.692
Low 2	2417	16.583
Low 3	2422	16.601
Mid 6	2437	16.842
High 9	2452	16.736
High 10	2457	16.801
High 11	2462	16.706
High 12	2467	16.694
High 13	2472	16.603





Antenna 2, LEGACY SISO MODE: 26-Tones, RU index 8

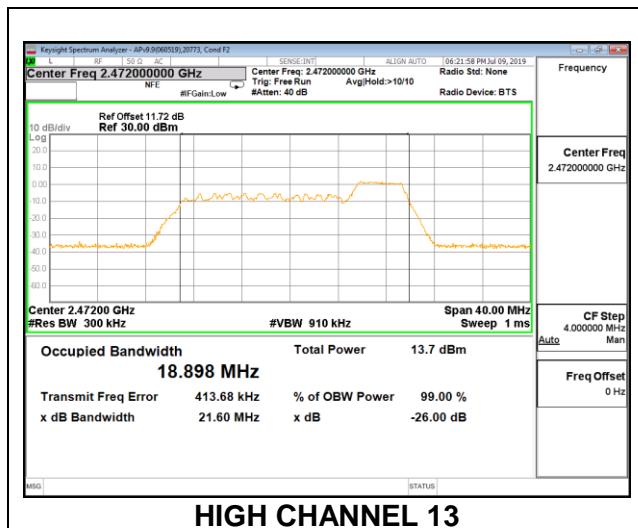
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	18.031
Low 2	2417	18.057
Low 3	2422	18.127
Mid 6	2437	18.445
High 9	2452	18.362
High 10	2457	18.444
High 11	2462	18.440
High 12	2467	18.452
High 13	2472	18.490





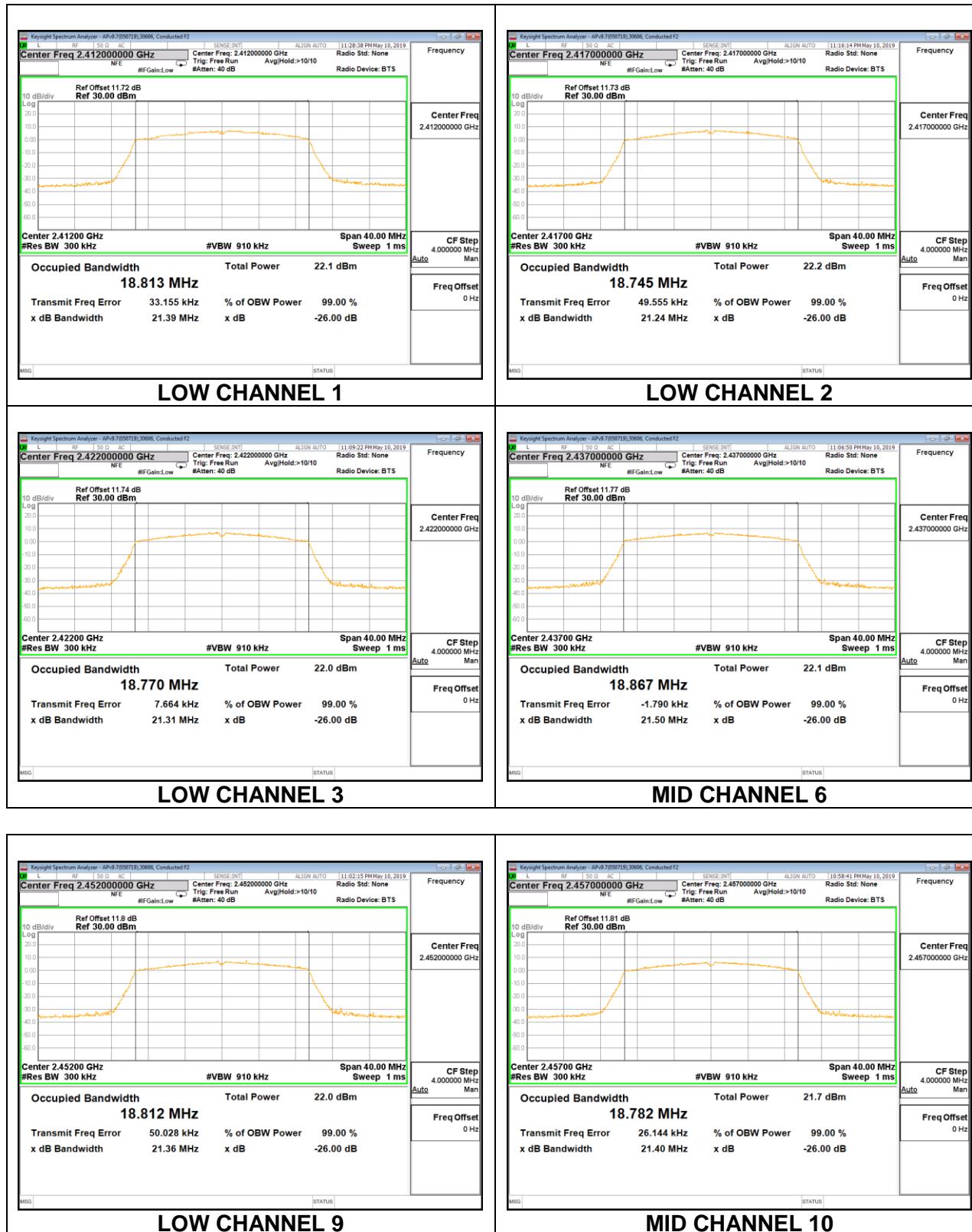
Antenna 2, LEGACY SISO MODE: 52-Tones, RU index 40

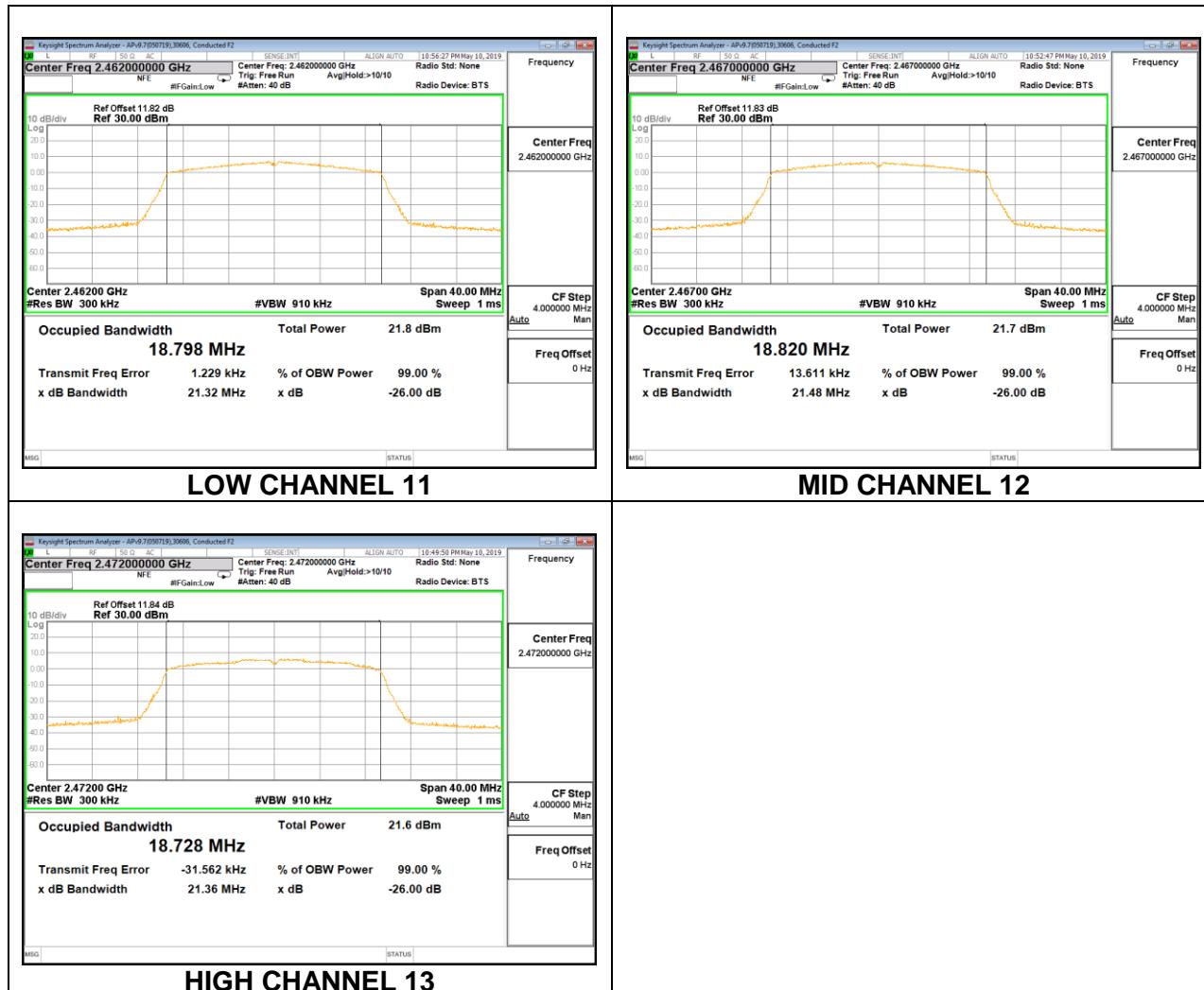
Channel	Frequency (MHz)	99% Bandwidth (MHz)
High 13	2472	18.898



Antenna 2, LEGACY SISO MODE: 242-Tones, RU index 61

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	18.813
Low 2	2417	18.745
Low 3	2422	18.770
Mid 6	2437	18.867
High 9	2452	18.812
High 10	2457	18.872
High 11	2462	18.798
High 12	2467	18.820
High 13	2472	18.728





Antenna 5, LEGACY SISO MODE: 26-Tones, RU index 0

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	18.456
Low 2	2417	18.422
Low 3	2422	18.385
Mid 6	2437	18.294
High 9	2452	18.384
High 10	2457	18.321
High 11	2462	18.226
High 12	2467	18.232
High 13	2472	18.011

