



CERTIFICATION TEST REPORT

Report Number. : 12901678-E4V2

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

Model : A2161, A2219, A2220

FCC ID : BCG-E3306A

IC : 579C-E3306A

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 23, 2019

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NVLAP Lab code: 200065-0

REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	8/19/2019	Initial Issue	Chin Pang
V2	8/23/2019	Addressed TCB Feedback on Sections 2. 5. 7. 8	Tony 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: A2161, A2219, AND A2220

SERIAL NUMBER: Radiated & Conducted
G6TYW00YN393, G6TYW010N393, G6TYW05BN393,
G6TYW005N395

DATE TESTED: JUNE 02, 2019 – JULY 30, 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
Project Engineer/Operations Leader
Consumer Technology Division
UL Verification Services Inc.

Prepared By:



Tony Li
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, KDB 662911 D01 Multiple Transmitter Output v02r01, 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	<input type="checkbox"/> Chamber D	<input type="checkbox"/> Chamber I
<input checked="" type="checkbox"/> Chamber B	<input checked="" type="checkbox"/> Chamber E	<input type="checkbox"/> Chamber J
<input type="checkbox"/> Chamber C	<input checked="" type="checkbox"/> Chamber F	<input type="checkbox"/> Chamber K
	<input checked="" type="checkbox"/> Chamber G	<input type="checkbox"/> Chamber L
	<input checked="" type="checkbox"/> Chamber H	<input type="checkbox"/> Chamber M

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:

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

MAINS CONDUCTED EMISSIONS

Where relevant, the following sample calculation is provided:

$$\begin{aligned} \text{Final Voltage (dBuV)} &= \text{Measured Voltage (dBuV)} + \text{Cable Loss (dB)} + \text{Limiter Factor (dB)} + \\ &\text{LISN Insertion Loss.} \\ 36.5 \text{ dBuV} + 0 \text{ dB} + 10.1 \text{ dB} + 0 \text{ dB} &= 46.6 \text{ dBuV} \end{aligned}$$

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	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

The 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 conducted output power as follows:

2.4GHz BAND

Frequency Range (MHz)	Mode	Output Power (dBm)	Output Power (mW)
1Tx			
2412 - 2472	802.11b	21.25	133.35
2412 - 2472	802.11g	Covered by 802.11n HT20 1TX	
2412 - 2472	802.11n HT20	21.24	133.05
2412 - 2472	802.11ax HE20, 242-Tones	21.28	134.28
2412 - 2472	802.11ax HE20, 26-Tones	21.23	132.74

2Tx			
2412 - 2472	802.11n HT20 CDD	23.24	210.86
2412 - 2472	802.11g SDM/STBC	Covered by 802.11n HT20 2TX CDD	
2412 - 2472	802.11ax HE20, 242-Tones	23.24	210.86
2412 - 2472	802.11ax HE20, 26-Tones	22.36	172.19

5.3. DESCRIPTION OF AVAILABLE ANTENNAS

Frequency Range	Antenna 4	Antenna ANT 3
2400-2480	-0.90	-2.30

5.4. SOFTWARE AND FIRMWARE

The EUT firmware installed during testing was v1.29.99992

5.5. WORST-CASE CONFIGURATION AND MODE

EUT was investigated in three orthogonal orientations X, Y and Z on ANT 4 (Antenna 4) and ANT 3 (Antenna 3). It was determined that X (Flatbed) orientation was worst-case orientation for ANT 4 & ANT 3. For 2Tx, 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 the highest output power and PSD readings, the lowest tone had the highest PSD readings. Therefore, full testing was performed on both the highest and lowest tones.

The 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

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

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

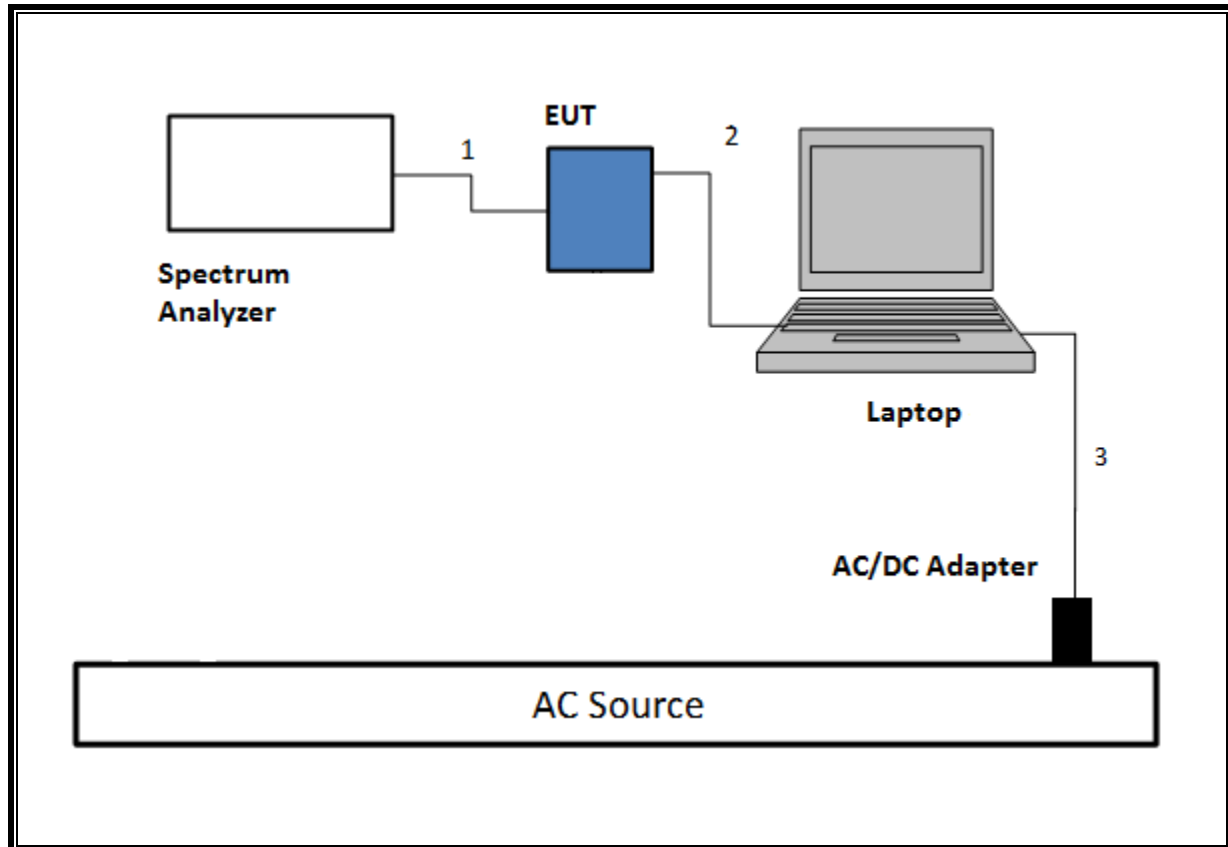
I/O CABLES (BELOW 1GHz AND AC POWER LINE TEST WITH ADAPTER AND LAPTOP)

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

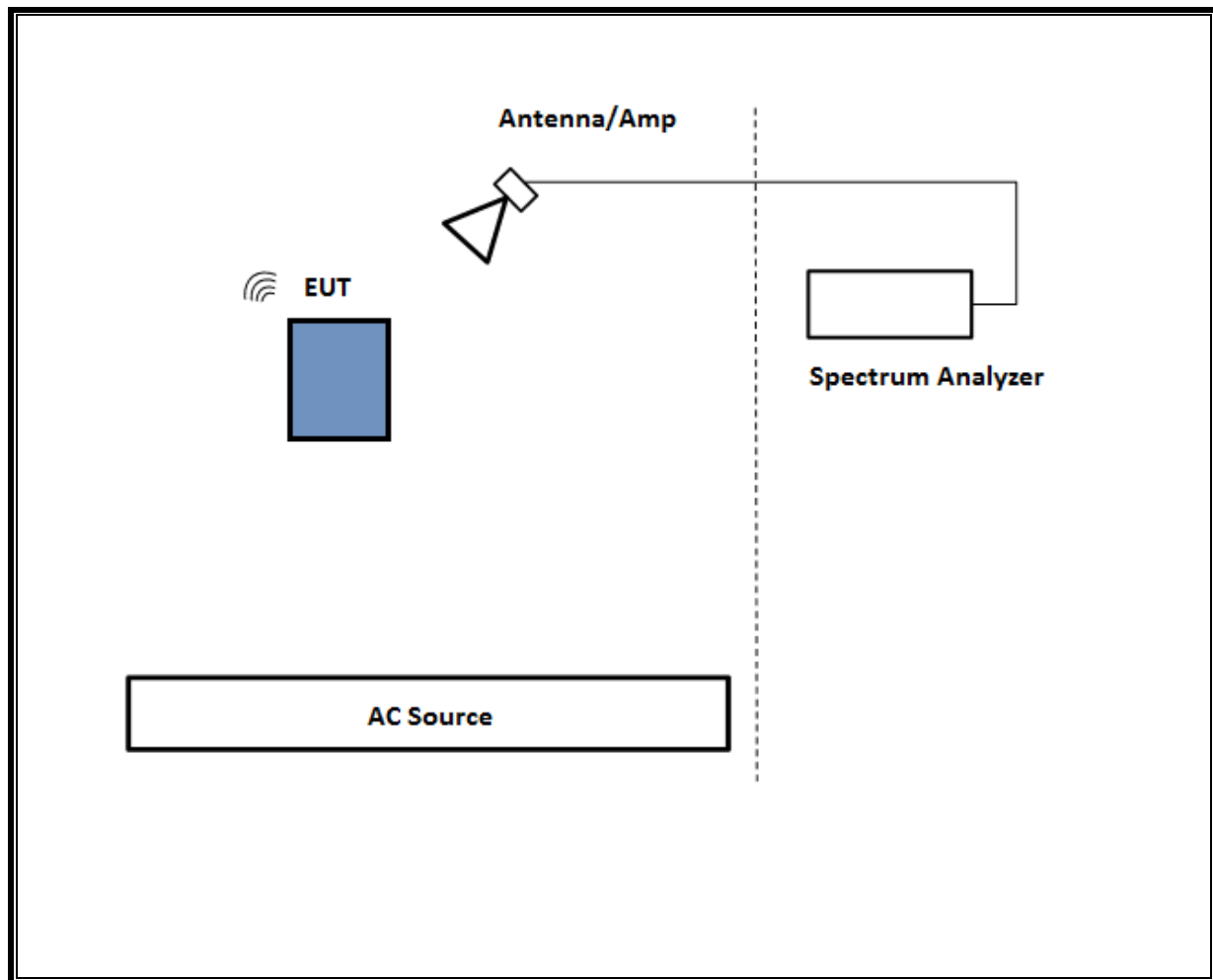
TEST SETUP

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

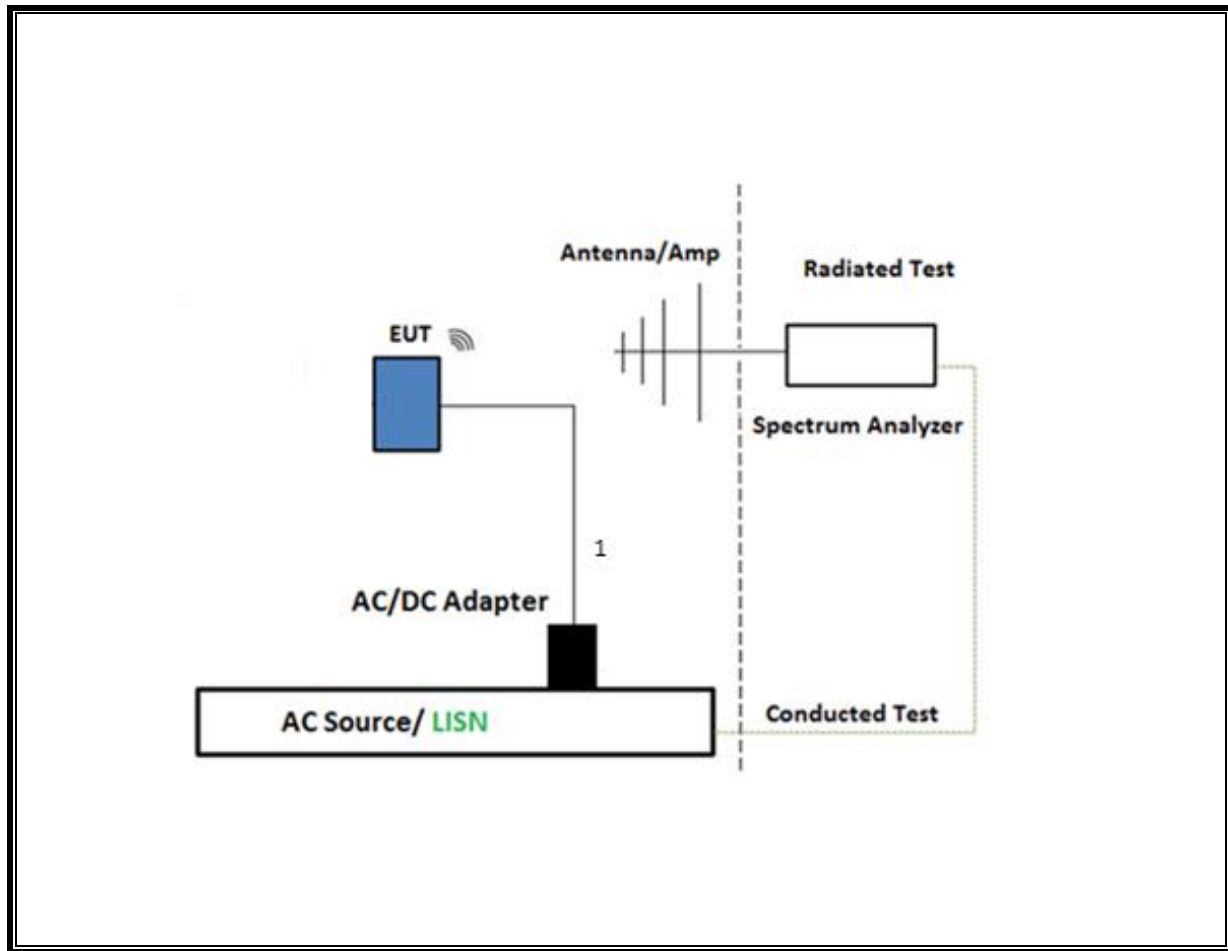
SETUP DIAGRAM FOR CONDUCTED TESTS



SETUP DIAGRAM FOR RADIATED TESTS Above 1GHz



SETUP DIAGRAM FOR Below 1GHz and AC LINE CONDUCTED TEST



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 -11.9.2.3.1 Method AVGPM (Measurement using an RF average-reading power meter)

PSD: ANSI C63.10 Subclause -11.10.3 Method AVGPS-1

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
*Antenna Horn, 18 to 26GHz	ARA	MWH-1826	T447	06/16/2019
*Power Meter, P-series single channel	Keysight	N1911A	T1268	06/25/2019
Amplifier, 1 to 18GHz, 35dB	AMPLICAL	AMP1G18-35	138301	09/15/2019
Amplifier, 10kHz to 1GHz, 32dB	SONOMA INSTRUMENT	310N	T834	06/01/2020
Amplifier, 1-18GHz	MITEQ	AFS42-00101800-25-s-42	T931	05/11/2020
Amplifier, 1-18GHz	MITEQ	AFS42-00101800-25-S-42	T1567	01/26/2020
Antenna, Active Loop 9KHz to 30MHz	ETS-Lindgren	6502	T757	09/25/2019
*Antenna, Broadband Hybrid, 30MHz to 2000MHz w/ 4dB Pad	Sunsol Sciences Corp.	JB3	T477	07/24/2019
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T346	05/14/2020
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T119	03/22/2020
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T345	04/20/2020
Antenna, Horn 1-18GHz	ETS Lindgren	3117	T863	05/30/2020
Antenna, Horn -18GHz	ETS-Lindgren	3117	T344	05/07/2020
*Power Sensor	Keysight	N1921A	T1228	07/10/2019
Pre-Amp 18-26GHz	Agilent Technology	8449B	T404	03/23/2020
RF Amplifier, 1-18GHz	MITEQ	AFS42-00101800-25-S-42	T1165	05/24/2020
RF Filter Box	UL	N/A	173233	12/15/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T906	01/23/2020
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T1454	01/23/2020
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T1466	01/23/2020
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A-544	T1113	01/22/2020
Spectrum Analyzer, PXA, 3Hz to 50GHz w/ Ext. Mixer	Agilent (Keysight) Technologies	N9030A	T342	01/23/2020

*Testing was completed before equipment expiration date.

Test Software List			
Description	Manufacturer	Model	Version
Radiated Software	UL	UL EMC	Ver 9.5, June 24, 2015
Conducted Software	UL	UL EMC	Ver 9.5, May 26, 2015
Antenna Port Software	UL	UL RF	Ver 3.9.1, Dec 28, 2015

8. ANTENNA PORT TEST RESULTS

8.1. ON TIME AND DUTY CYCLE

LIMITS

None; for reporting purposes only.

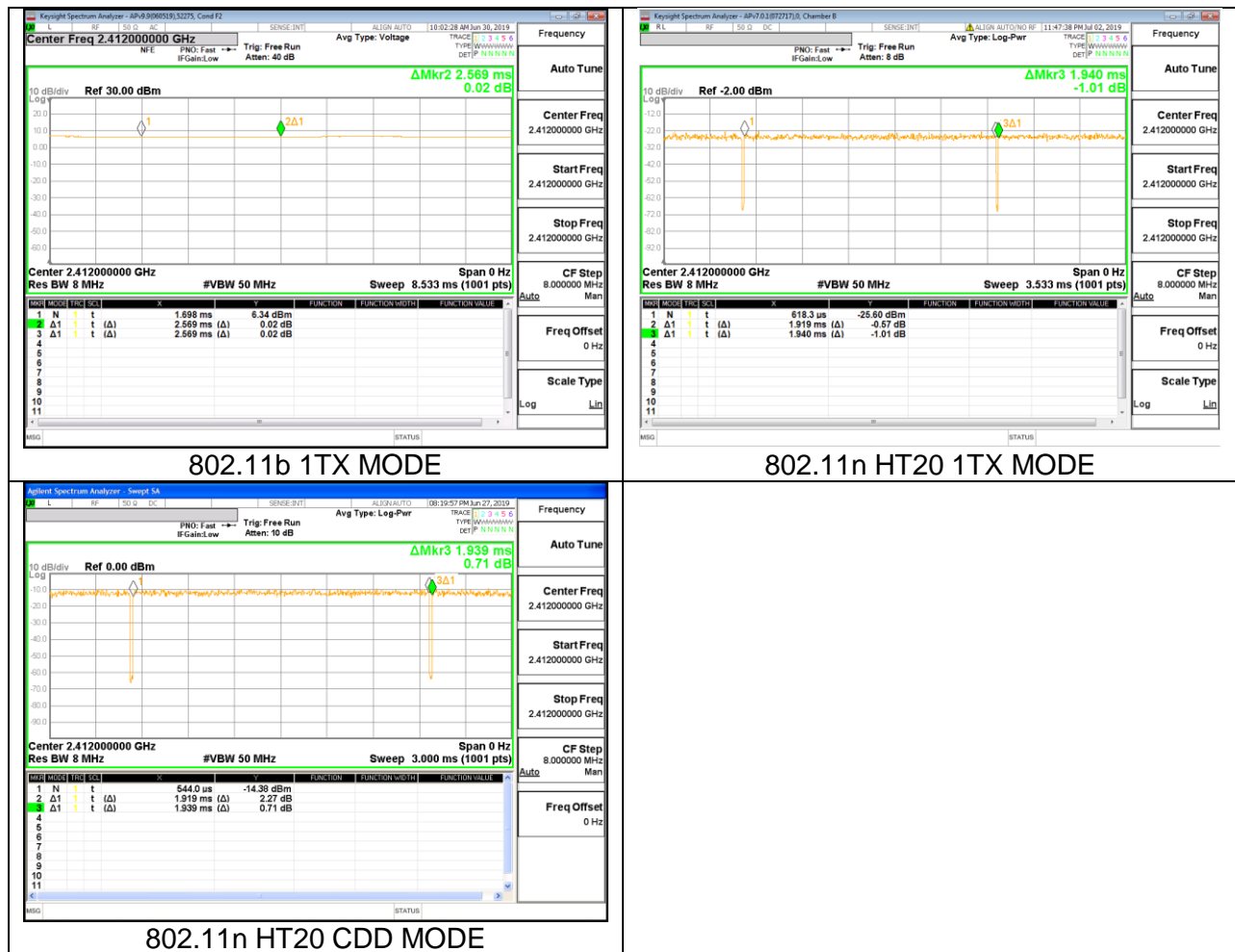
PROCEDURE

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 1TX	2.569	2.569	1.000	100.00%	0.00	0.010
802.11n HT20 1TX	1.919	1.940	0.989	98.92%	0.00	0.010
802.11n HT20 2TX CDD	1.919	1.939	0.990	98.97%	0.00	0.010
802.11ax HE20 1Tx, 242-Tones	1.577	1.595	0.989	98.87%	0.00	0.010
802.11ax HE20 1Tx, 26-Tones	4.120	4.160	0.990	99.04%	0.00	0.010
802.11ax HE20 OFDMA, 242-Tones	1.577	1.595	0.989	98.87%	0.00	0.010
802.11ax HE20 OFDMA, 26-Tones	4.120	4.160	0.990	99.04%	0.00	0.010

DUTY CYCLE PLOTS





8.2. 99% BANDWIDTH

LIMITS

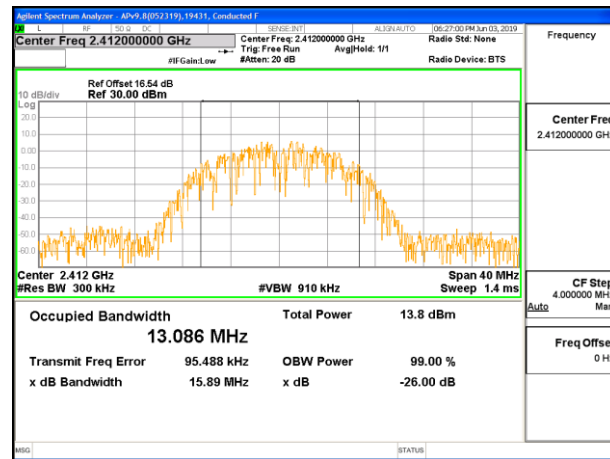
None; for reporting purposes only.

RESULTS

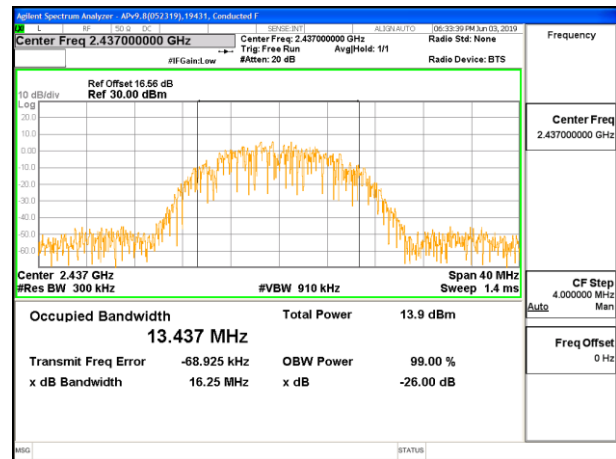
8.2.1. 802.11b MODE

1TX Antenna 4 MODE

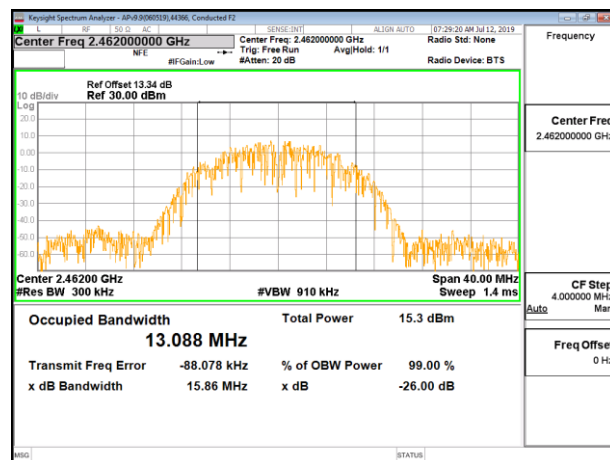
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	13.0860
Mid 6	2437	13.4370
High 11	2462	13.0880
High 12	2467	13.1000
High 13	2472	13.2680



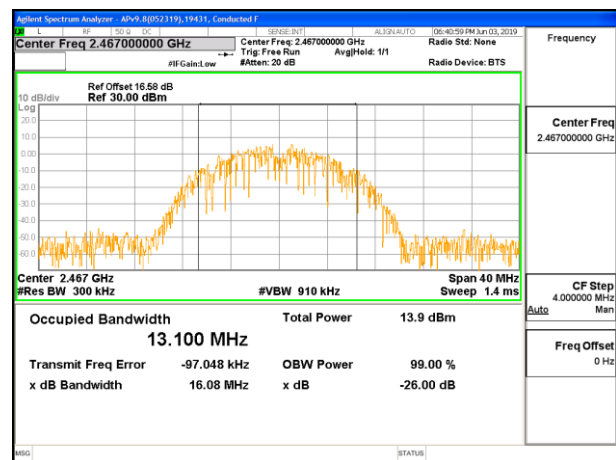
LOW CHANNEL 1



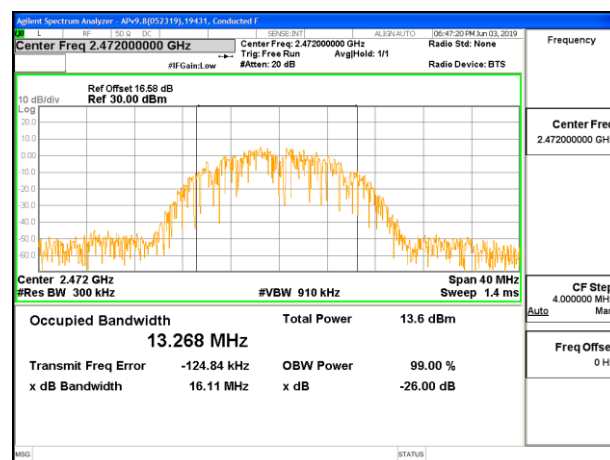
MID CHANNEL 6



HIGH CHANNEL 11



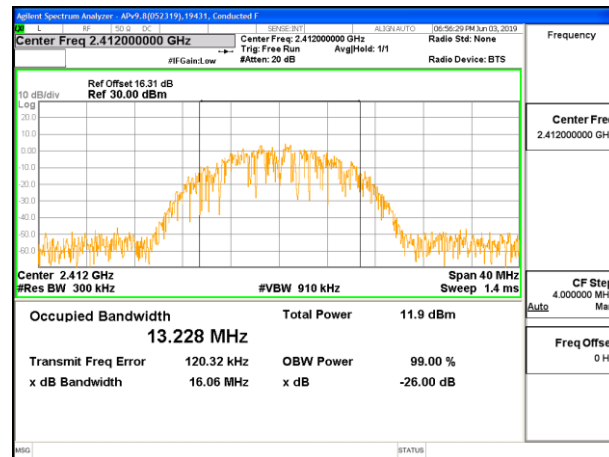
HIGH CHANNEL 12



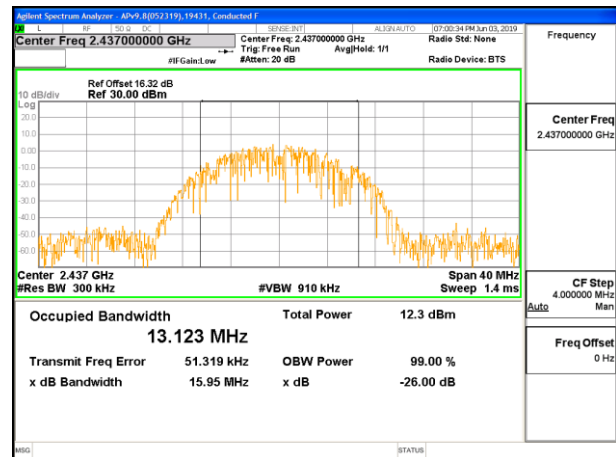
HIGH CHANNEL 13

1TX Antenna 3 MODE

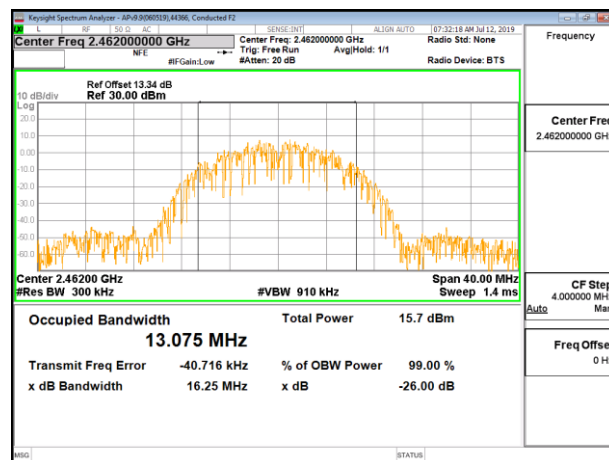
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	13.2280
Mid 6	2437	13.1230
High 11	2462	13.0750
High 12	2467	13.4170
High 13	2472	13.2800



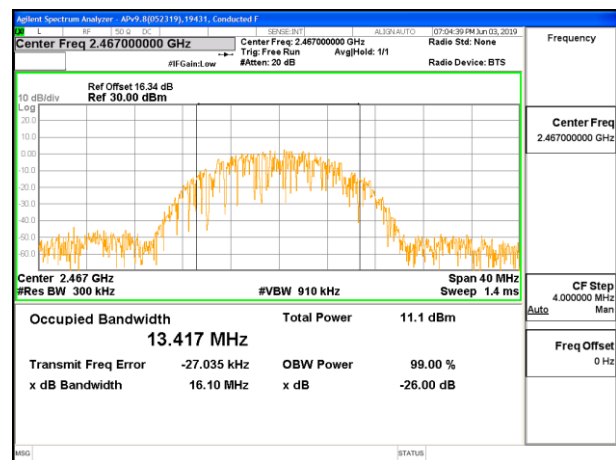
LOW CHANNEL 1



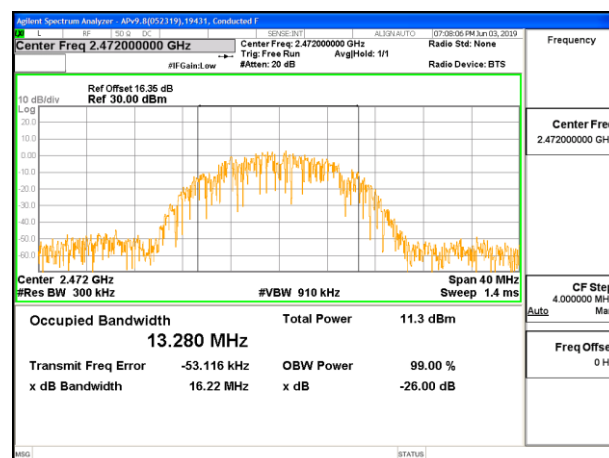
MID CHANNEL 6



HIGH CHANNEL 11



HIGH CHANNEL 12

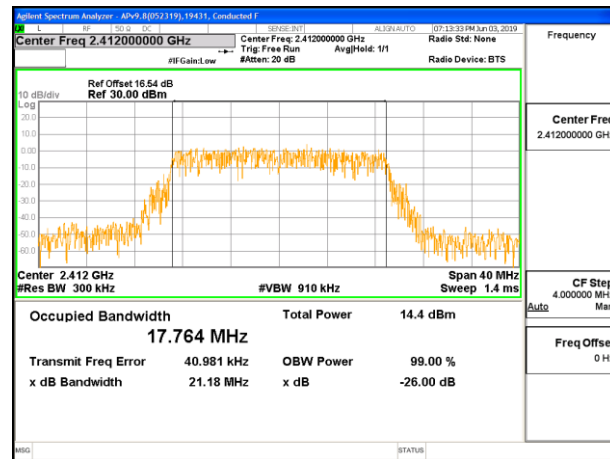


HIGH CHANNEL 13

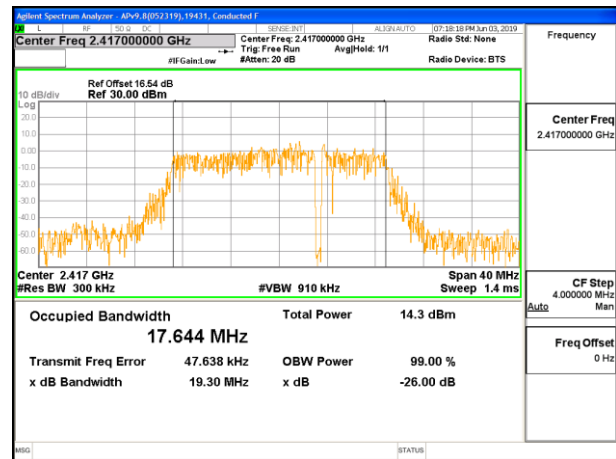
8.2.2. 802.11n HT20 MODE

1TX Antenna 4 MODE

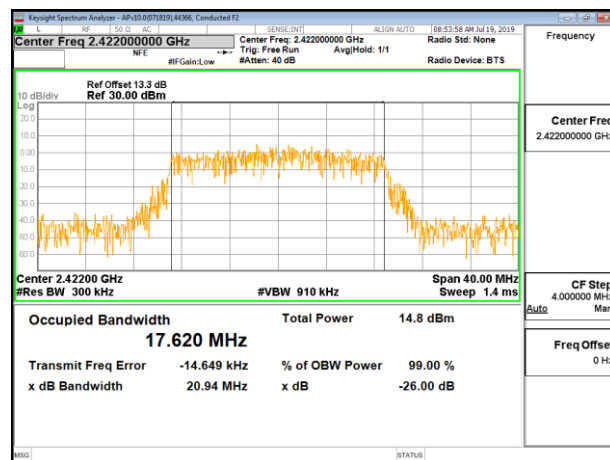
Channel	Frequency	99% Bandwidth
	(MHz)	(MHz)
Low 1	2412	17.7640
Low 2	2417	17.6440
Low 3	2422	17.6200
Mid 6	2437	17.6410
High 9	2452	17.6870
High 10	2457	17.7160
High 11	2462	17.5090
High 12	2467	17.5660
High 13	2472	17.7560



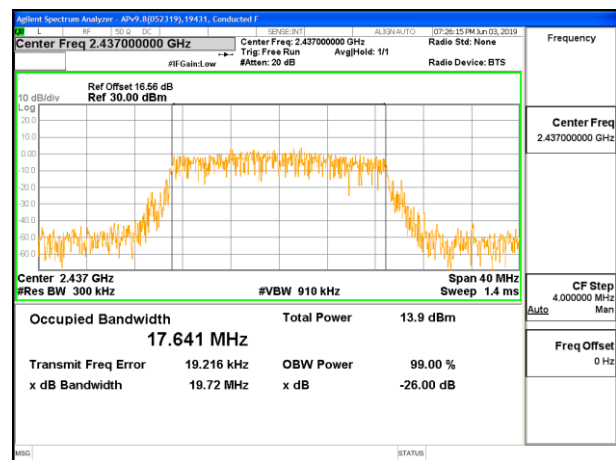
LOW CHANNEL 1



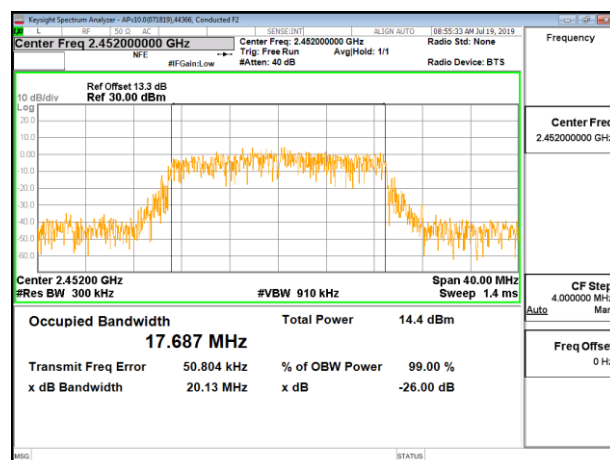
LOW CHANNEL 2



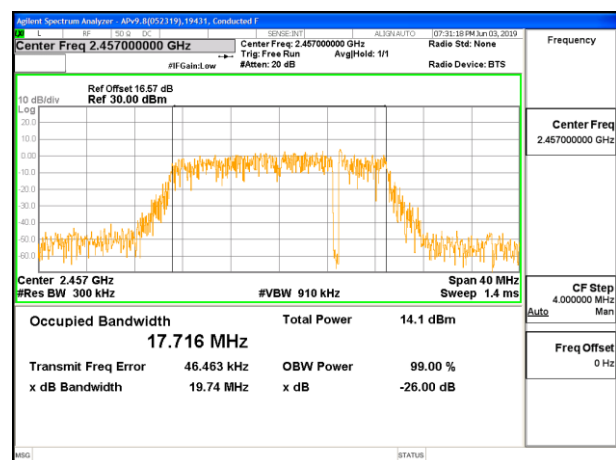
LOW CHANNEL 3



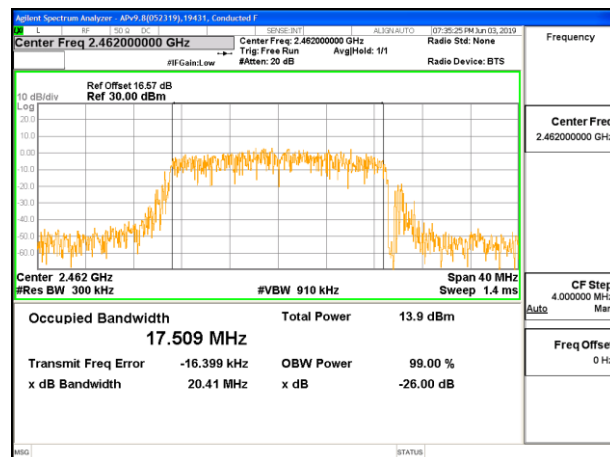
MID CHANNEL 6



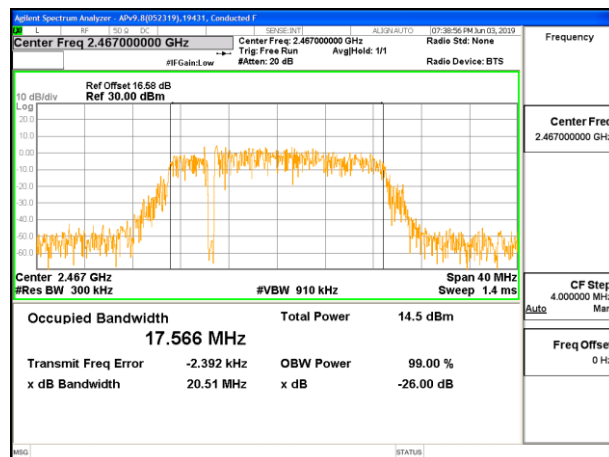
HIGH CHANNEL 9



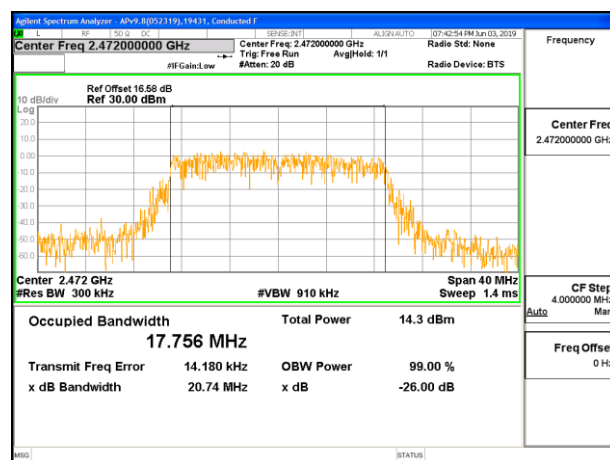
HIGH CHANNEL 10



HIGH CHANNEL 11



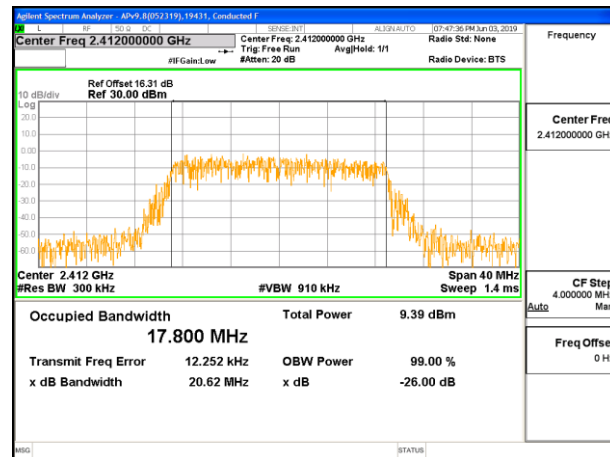
HIGH CHANNEL 12



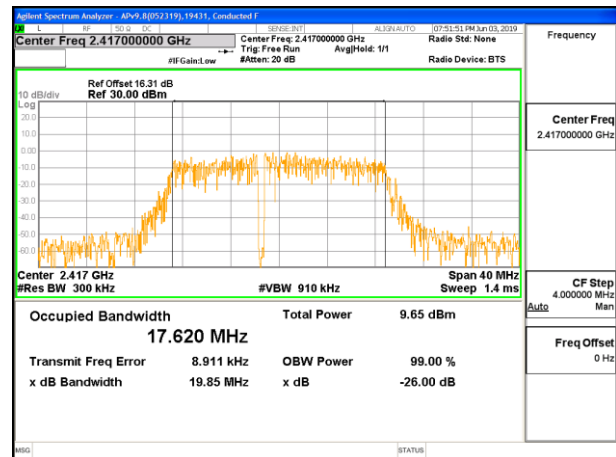
HIGH CHANNEL 13

1TX Antenna 3 MODE

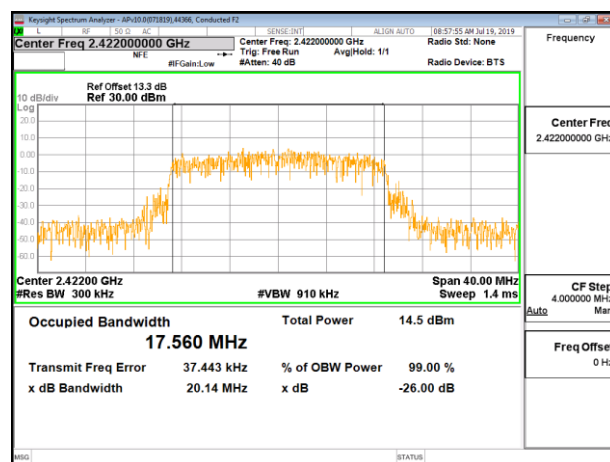
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	17.8000
Low 2	2417	17.6200
Low 3	2422	17.5600
Mid 6	2437	17.6920
High 9	2452	17.6920
High 10	2457	17.6110
High 11	2462	17.6450
High 12	2467	17.6230
High 13	2472	17.7810



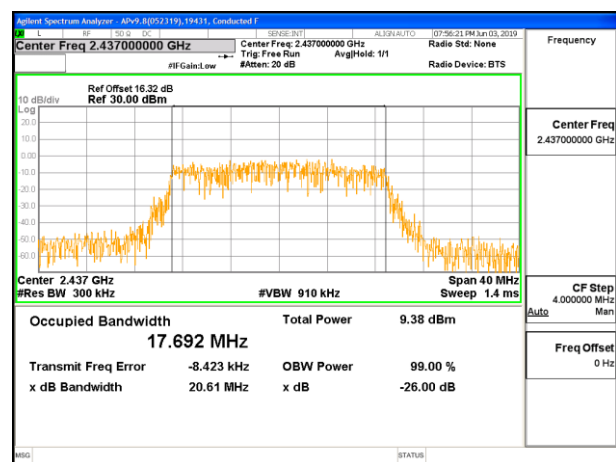
LOW CHANNEL 1



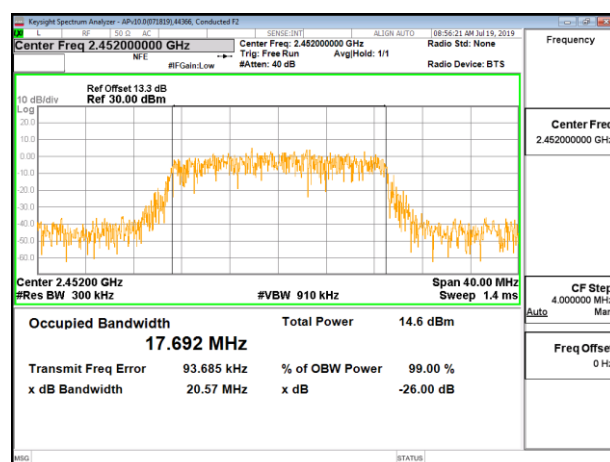
LOW CHANNEL 2



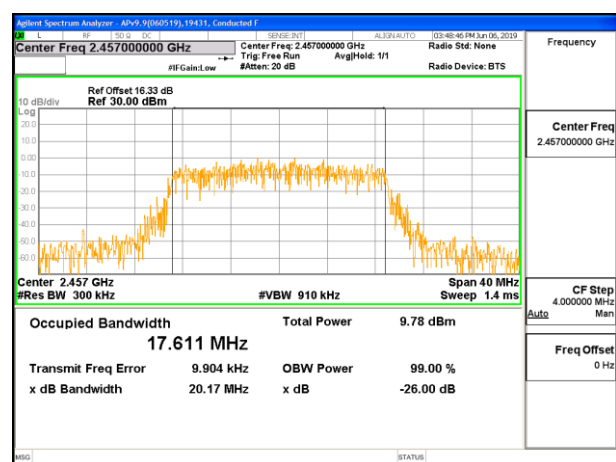
LOW CHANNEL 3



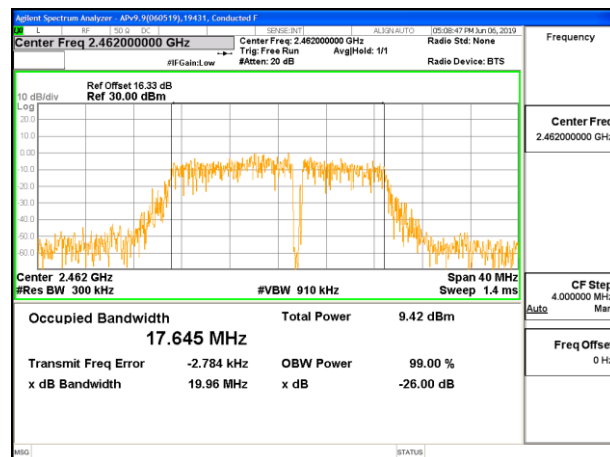
MID CHANNEL 6



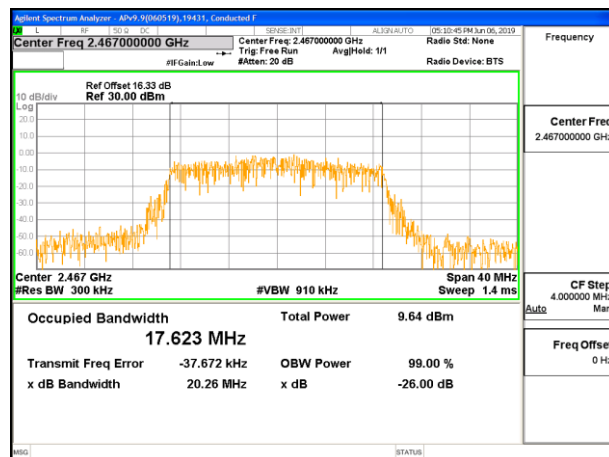
HIGH CHANNEL 9



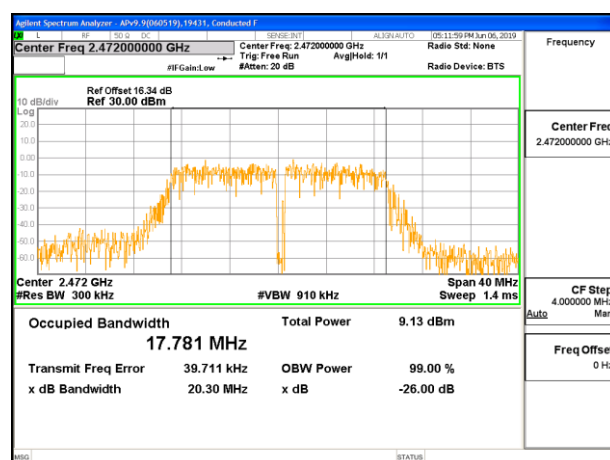
HIGH CHANNEL 10



HIGH CHANNEL 11



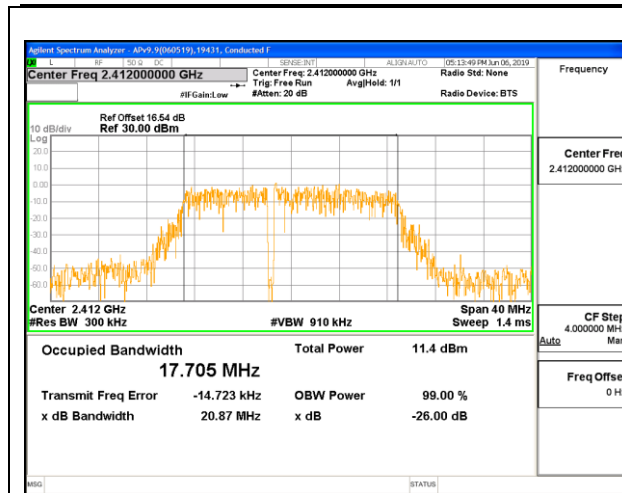
HIGH CHANNEL 12



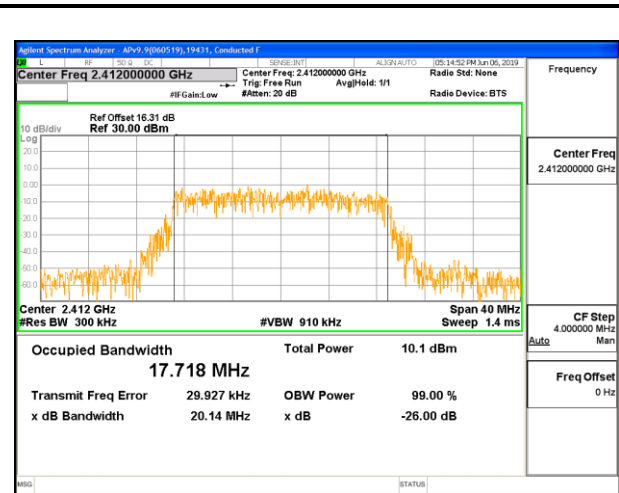
HIGH CHANNEL 13

2TX Antenna 4 + Antenna 3 CDD MODE

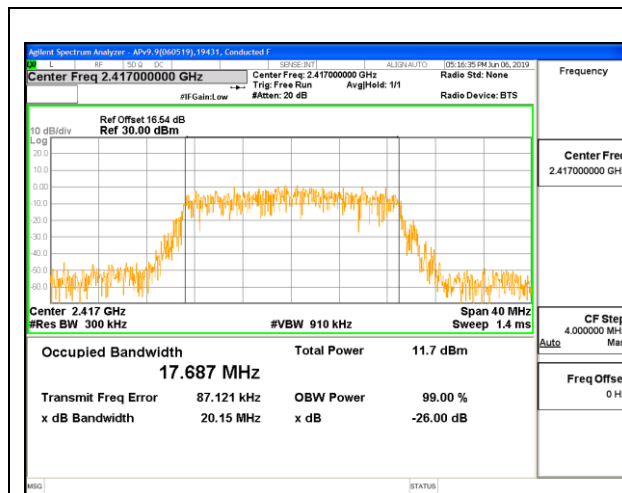
Channel	Frequency (MHz)	99% Bandwidth Ant 4 (MHz)	99% Bandwidth Ant 3 (MHz)
Low 1	2412	17.7050	17.7180
Low 2	2417	17.6870	17.6260
Low 3	2422	17.5510	17.6560
Mid 6	2437	17.6120	17.6700
High 9	2452	17.5940	17.6600
High 10	2457	17.6140	17.6470
High 11	2462	17.5910	17.6010
High 12	2467	17.5930	17.6280
High 13	2472	17.7220	17.6690



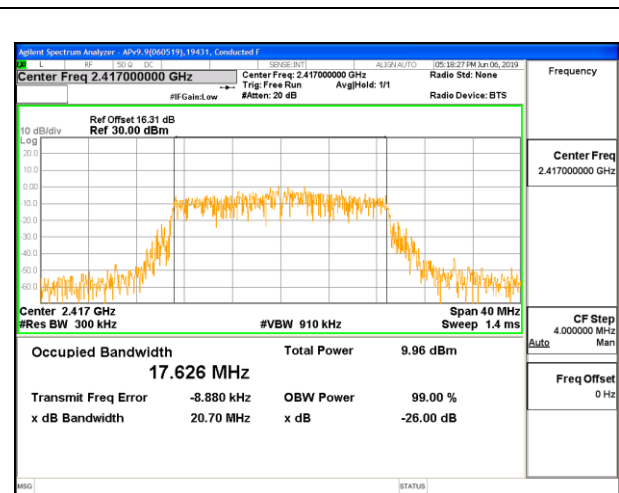
LOW CHANNEL 1 ANT 4



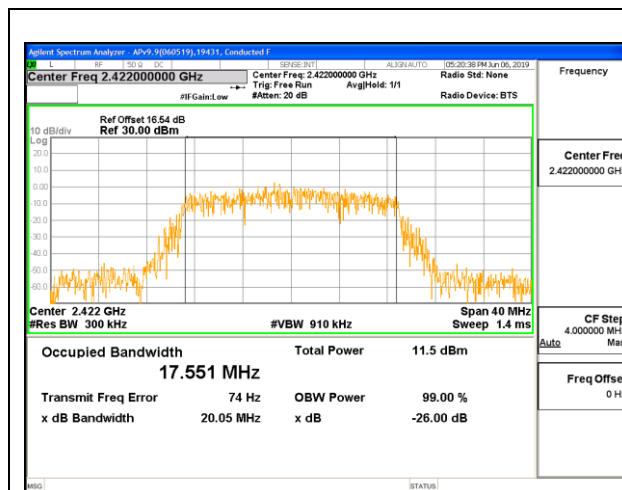
LOW CHANNEL 1 ANT 3



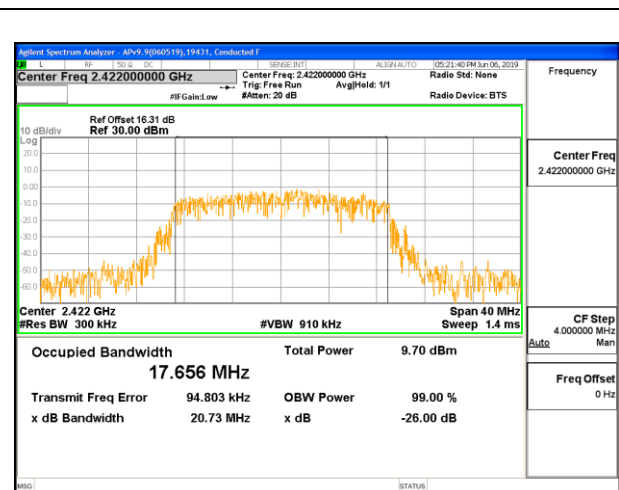
LOW CHANNEL 2 ANT 4



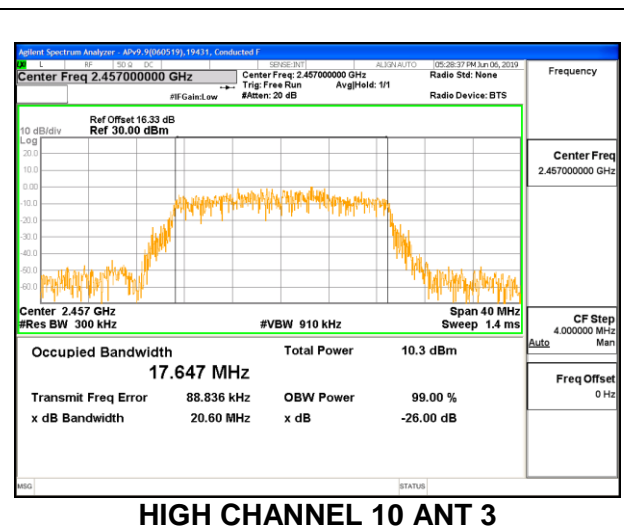
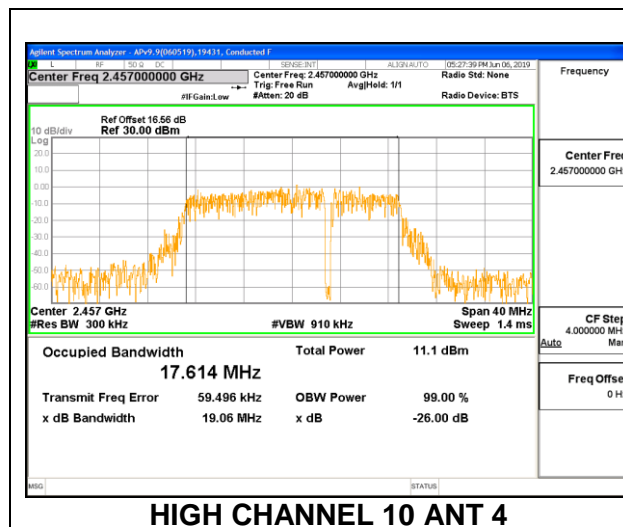
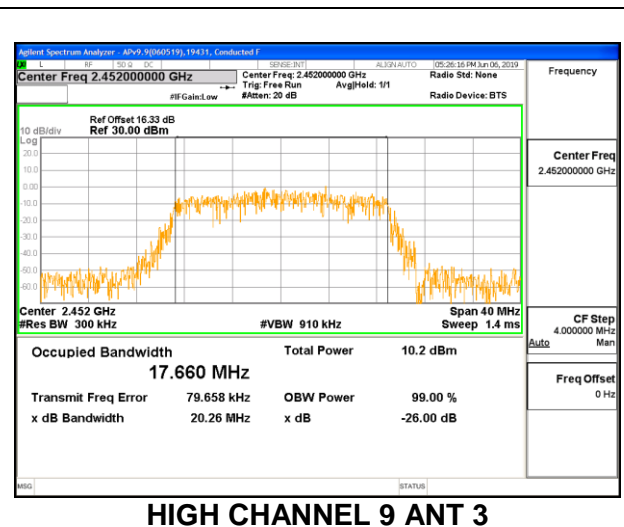
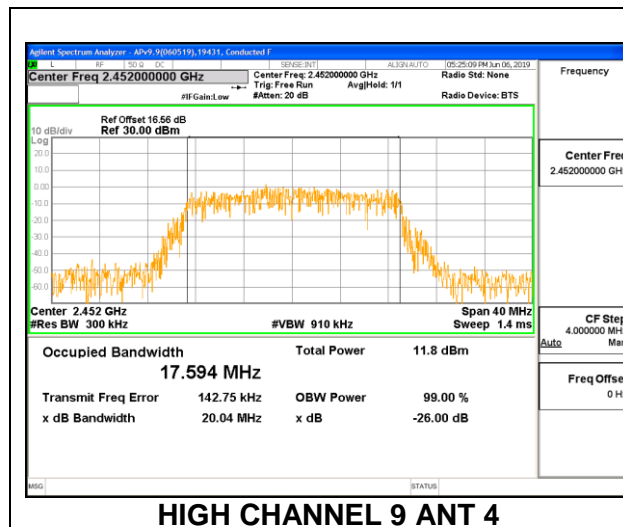
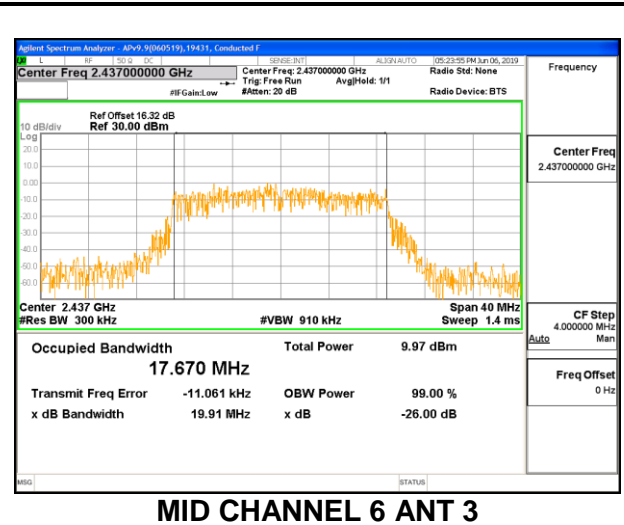
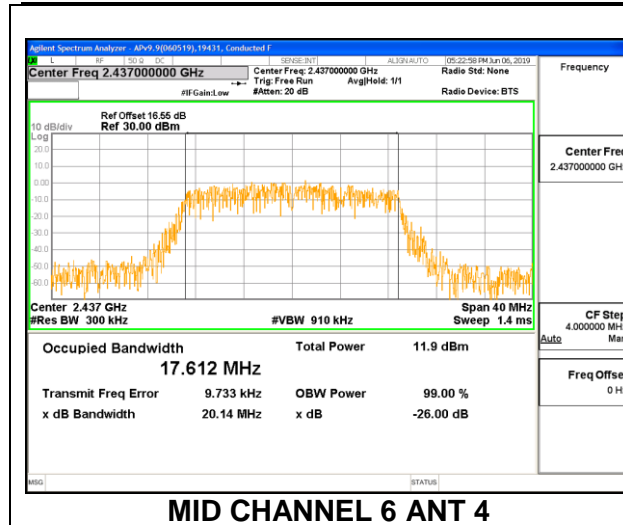
LOW CHANNEL 2 ANT 3

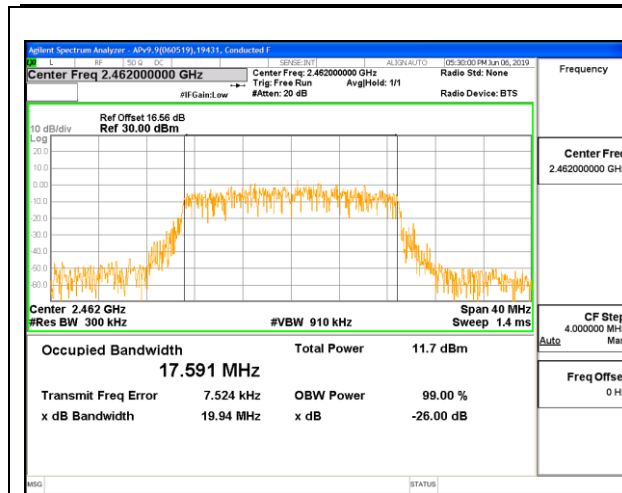


LOW CHANNEL 3 ANT 4

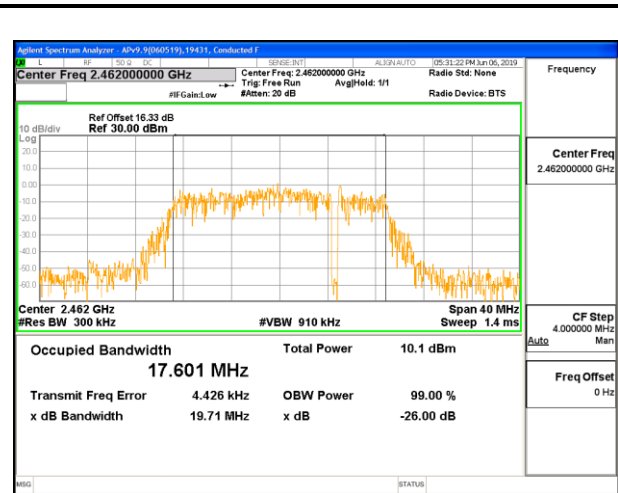


LOW CHANNEL 3 ANT 3

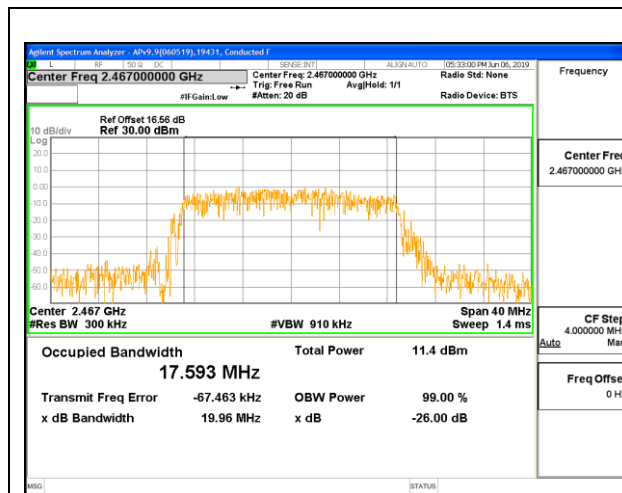




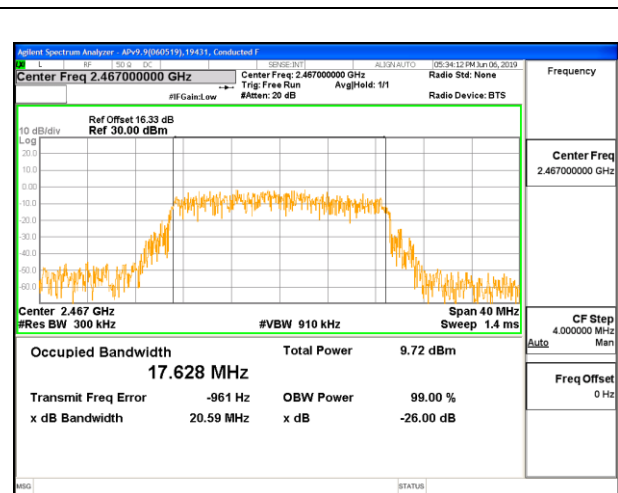
HIGH CHANNEL 11 ANT 4



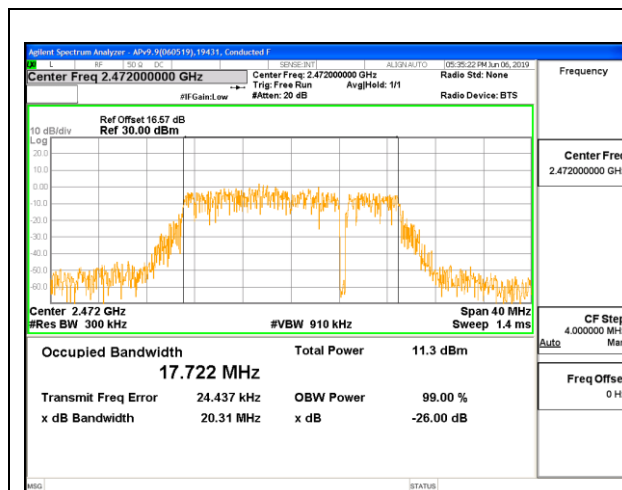
HIGH CHANNEL 11 ANT 3



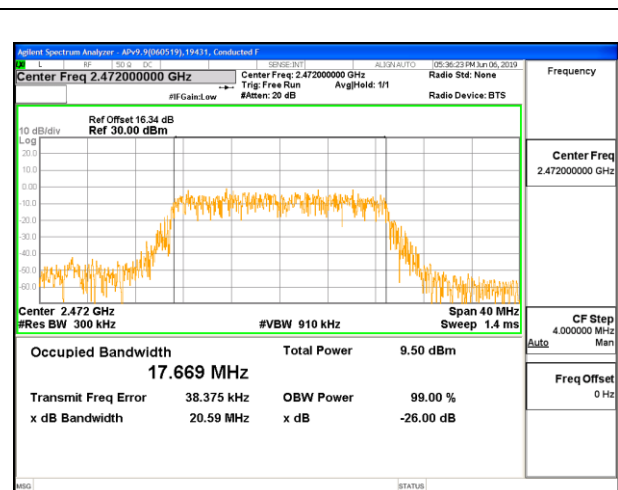
HIGH CHANNEL 12 ANT 4



HIGH CHANNEL 12 ANT 3



HIGH CHANNEL 13 ANT 4

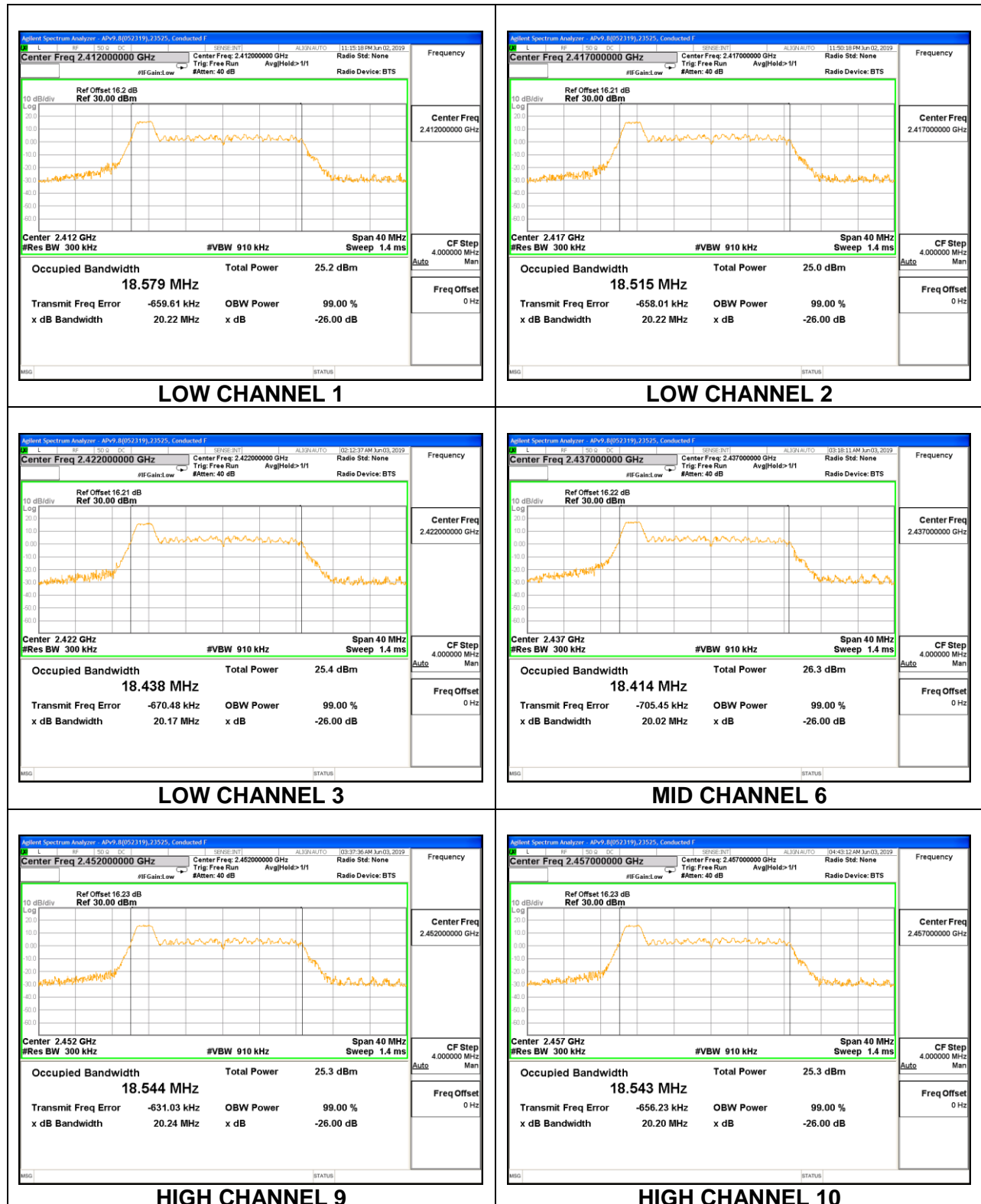


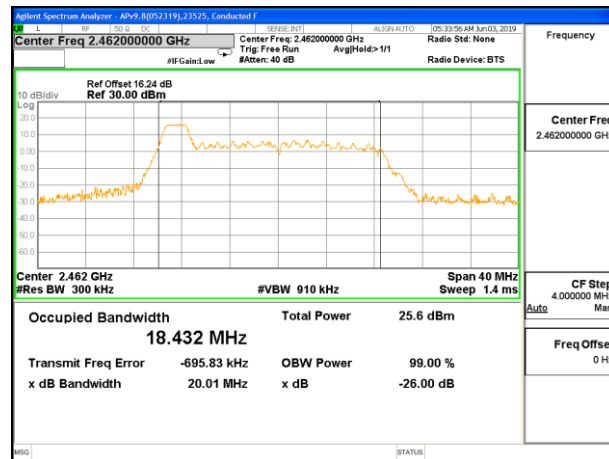
HIGH CHANNEL 13 ANT 3

8.2.1. 802.11ax HE20 MODE

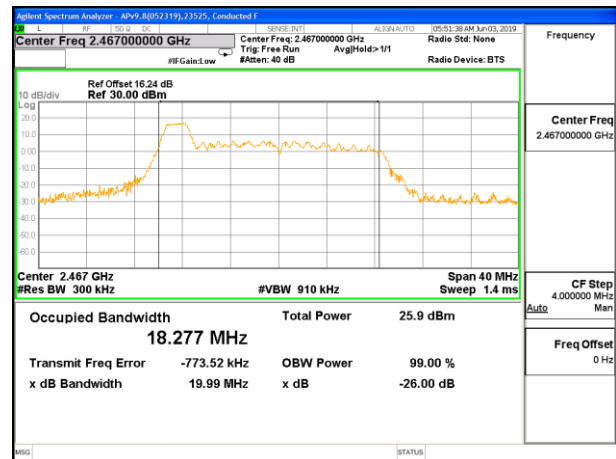
Antenna 4, LEGACY SISO MODE: 26-Tones, RU index 0

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	18.5790
Low 2	2417	18.5150
Low 3	2422	18.4380
Mid 6	2437	18.4140
High 9	2452	18.5440
High 10	2457	18.5430
High 11	2462	18.4320
High 12	2467	18.2770
High 13	2472	18.2750

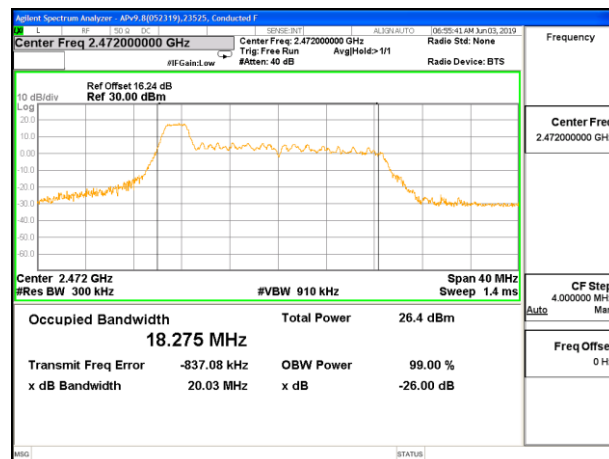




HIGH CHANNEL 11



HIGH CHANNEL 12

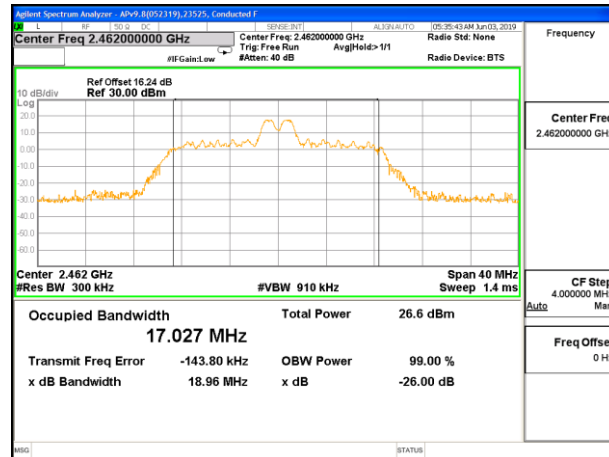


HIGH CHANNEL 13

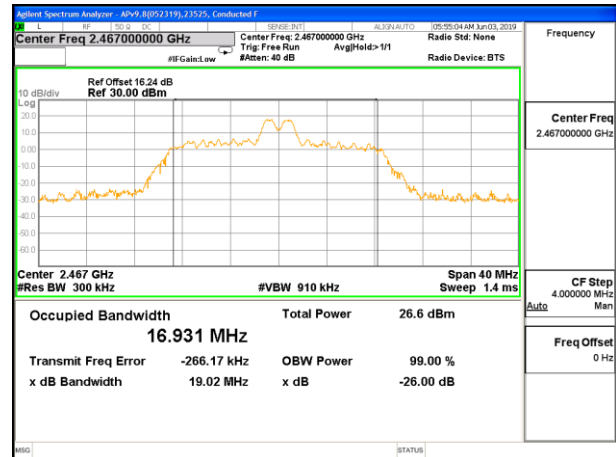
Antenna 4, LEGACY SISO MODE: 26-Tones, RU index 4

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	17.2820
Low 2	2417	17.2020
Low 3	2422	17.0230
Mid 6	2437	17.3010
High 9	2452	17.2510
High 10	2457	17.1650
High 11	2462	17.0270
High 12	2467	16.9310
High 13	2472	17.0850

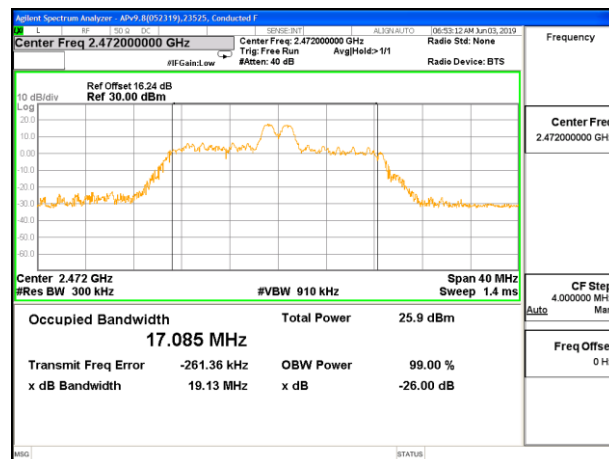




HIGH CHANNEL 11



HIGH CHANNEL 12



HIGH CHANNEL 13

Antenna 4, LEGACY SISO MODE: 26-Tones, RU index 8

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low 1	2412	18.7120
Low 2	2417	18.6300
Low 3	2422	18.7250
Mid 6	2437	18.7430
High 9	2452	18.6440
High 10	2457	18.6570
High 11	2462	18.6630
High 12	2467	18.7930
High 13	2472	18.9100