CERTIFICATION TEST REPORT

Report Number. : 12049380-E2V3

Applicant	:	SONOS INC. 614 CHAPALA STREET SANTA BARBARA, CA 93101, U.S.A
Model	:	S16
FCC ID	:	SBVRM015
IC	:	5373A-RM015
EUT Description	:	4X4 802.11a/b/g/n HT20 CLIENT & MASTER DEVICE
Test Standard(s)	:	FCC 47 CFR PART 15 SUBPART C ISED RSS-247 ISSUE 2 ISED RSS-GEN ISSUE 5

Date Of Issue:
October 26, 2018

Prepared by:
UL Verification Services Inc.
47173 Benicia Street
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NVLAP Lab code: 200065-0

REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	10/5/2018	Initial Issue	-
V2	10/16/2018	Updated Section 8.4 (Directinal Anntena gain table)	K.Kedida
V3	10/26/2018	Updated Section 5.5, 10.2 & 12	K.Kedida

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1. ATTESTATION OF TEST RESULTS

COMPANY NAME: SONOS INC.
614 CHAPALA STREET
SANTA BARBARA, CA 93101, U.S.A.

EUT DESCRIPTION: 4X4 802.11a/b/g/n HT20 CLIENT & MASTER DEVICE

MODEL: S16

SERIAL NUMBER: 1807-34-7E-5C-00-10-20-4 (Radiated Sample)
1807-34-7E-5C-00-0F-D5-E (Conducted Sample)

DATE TESTED: August 14 – Spetemeber 25. 2018

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

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. All samples tested were in good operating condition throughout the entire test program. 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:

DAN CORONIA
CONSUMER TECHNOLOGY DIVISION
OPERATIONS LEADER
UL Verification Services Inc.

Reviewed By:

Kiya Kedida
CONSUMER TECHNOLOGY DIVISION
PROJECT ENGINEER
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, KDB 558074 D01 v05, KDB 662911 D01 v02r01, 662911 D02 MIMO v01, ANSI C63.10-2013, RSS-GEN Issue 5, and RSS-247 Issue 2.

3. FACILITIES AND ACCREDITATION

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

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

The above test sites and facilities are covered under FCC Test Firm Registration # 208313. Chambers 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 dBuV + 18.7 dB/m + 0.6 dB – 26.9 dB = 28.9 dBuV/m

MAINS CONDUCTED EMISSIONS

Where relevant, the following sample calculation is provided:
Final Voltage (dBuV) = Measured Voltage (dBuV) + Cable Loss (dB) + Limiter Factor (dB) + LISN Insertion Loss.
36.5 dBuV + 0 dB +10.1 dB+ 0 dB = 46.6 dBuV

4.3. MEASUREMENT UNCERTAINTY

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

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

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

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5. EQUIPMENT UNDER TEST

5.1. EUT DESCRIPTION

The EUT is a 4X4 802.11a/b/g/n HT20 CLIENT & MASTER DEVICE.

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)
4Tx			
2412 - 2462	802.11b	26.46	442.59
2412 - 2462	802.11g	25.68	369.83
2412 - 2462	802.11n HT20	25.5	354.81

5.3. DESCRIPTION OF AVAILABLE ANTENNAS

The radio utilizes PCB antenna, with maximums gain per chain as follows:

Frequency (MHz)	Peak Antenna Gain (dBi)			
	Chain 0 (Horizontal Polarization)	Chain 1 (Horizontal Polarization)	Chain 2 (Vertical Polarization)	Chain 3 (Vertical Polarization)
2400 – 2483.5	3.47	3.65	2.22	2.11

5.4. SOFTWARE AND FIRMWARE

The EUT software ware installed during testing was 44.2-53220-RF-Complianc_20180523.

The test utility software used during testing was Sonos Compliance GUI V2.2.

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5.5. WORST-CASE CONFIGURATION AND MODE

All configuration was investigated and the worst-case configuration for below 1GHz radiated emissions were performed with the EUT and exercised with all supported external accessories. The worst-case configuration for radiated emissions above 1GHz, and power line conducted emissions were performed with the EUT only.

Radiated emissions below 1GHz, above 18GHz, and power line conducted emission were performed with the EUT set to transmit at the channel with highest output power as worst-case scenario.

Band edge and radiated emissions between 1GHz and 18GHz were performed with the EUT set to transmit at the highest power on low, middle and high channels.

The fundamental of the EUT was investigated in three orthogonal orientations X,Y,Z, it was determined that X orientation was worst-case orientation; therefore, all final radiated testing was performed with the EUT in X orientation.

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

802.11b mode: 5.5 Mbps
802.11g mode: 6 Mbps
802.11n HT20mode: MCS9

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5.6. DESCRIPTION OF TEST SETUP

SUPPORT EQUIPMENT

Support Equipment List				
Description	**Manufacturer**	**Model**	**Serial Number**	**FCC ID**
Laptop	Lenovo	X1 Carbon	R9-01VD86	N/A
AC Adapter	Lenovo	ADLX65NLT2A	11S36200291ZZ200315AJU	N/A
Charging Base	Lenovo	X200	1S43R8781R934HPB	N/A

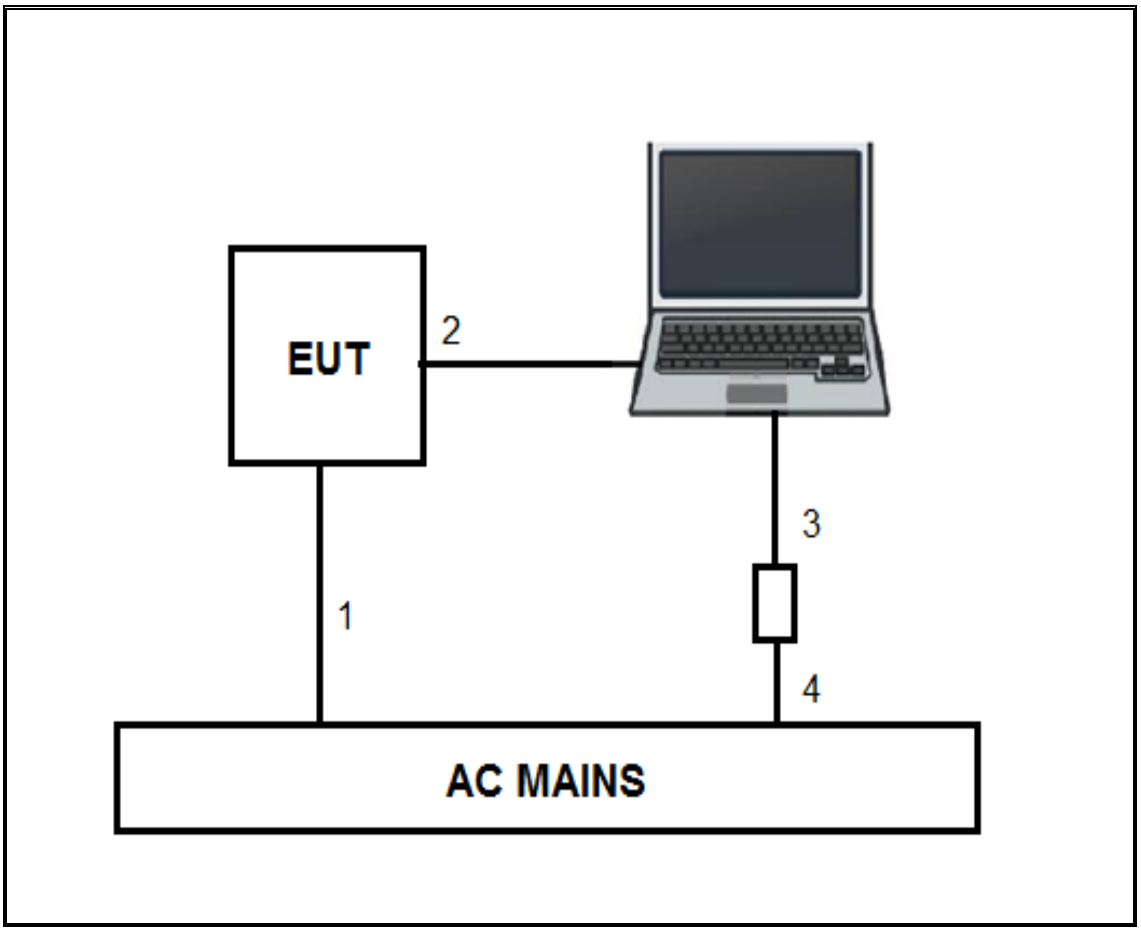
I/O CABLES

I/O Cable List						
Cable No	**Port**	**# of identical ports**	**Connector Type**	**Cable Type**	**Cable Length (m)**	**Remarks**
1	AC Power	1	AC	Unshielded	2	AC Mains to EUT
2	Ethernet	1	RJ45	Unshielded	10	EUT to Laptop
3	DC Power	1	DC	Shielded	1.2	AC/DC Adapter to Laptop
4	AC Power	1	AC	Unshielded	1	AC Mains to AC/DC Adapter

TEST SETUP

The EUT is a stand-alone unit, and the radio is exercised by Sonos Compliance GUI V2.2 test utility software via Ethernet.

SETUP DIAGRAM



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6. MEASUREMENT METHOD

On Time and Duty Cycle: ANSI C63.10-2013 Section 11.6.

6 dB BW: ANSI C63.10 Section 11.8.1. Option 1

Output Power: ANSI C63.10 Section 11.9.2.3.2 Method AVGPM-G (Measurement using a gated RF average-reading power meter)

Power Spectral Density: ANSI C63.10 Section 11.10.3 Method AVGPSD-1.

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

Radiated emissions restricted frequency bands: ANSI C63.10 Section 11.12.1.

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

Band-edge: ANSI C63.10 Subclause -11.13.3.4 Integration method -Trace averaging across ON and OFF times DC correction

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

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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**
Amplifier, 10KHz to 1GHz, 32dB	Agilent (Keysight) Technologies	8447D	T10	2/14/2019
Antenna, Broadband Hybrid, 30MHz to 2000MHz	Sunol Sciences Corp.	JB1	T407	05/10/2019
Antenna, Horn 1-18GHz	ETS-Lindgren	3117	T862	06/21/2019
Amplifier, 1 to 8GHz, 35dB	Miteq Inc.	AMF-4D-01000800-30-29P	T1156	04/03/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T1454	01/08/2019
Spectrum Analyzer, PXA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T1113	12/21/2018
Spectrum Analyzer, PSA, 3Hz to 44GHz	Agilent (Keysight) Technologies	N9030A	T1466	04/16/2019
Power Meter, P-series single channel	Agilent (Keysight) Technologies	N1911A	T1271	07/17/2019
Power Sensor, P-series, 50MHz to 18GHz, Wideband	Agilent (Keysight) Technologies	N1921A	T1225	04/10/2019
Antenna, Active Loop 9kHz-30MHz	Com-Power Corp.	AL-130R	T1866	10/10/2018
18 - 26.5 GHz Horn Antenna	Seavey Division	MWH-1826/B	T89	01/18/2019
Pre-Amp 1-26.5 GHz	Agilent	8449B	T404	03/09/2019
EMI Reciever	Rohde & Schwarz	ESR	T1436	02/21/2019
L.I.S.N.	FCC INC.	FCC LISN 50/250	T1310	06/15/2019

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 789033 Zero-Span Spectrum Analyzer Method.

ON TIME AND DUTY CYCLE RESULTS

Mode	ON Time B (msec)	Period (msec)	Duty Cycle x (linear)	Duty Cycle (%)	Duty Cycle Correction Factor (dB)	1/B Minimum VBW (kHz)
2.4GHz Band						
802.11b	1.548	1.568	0.987	98.72%	0.00	0.010
802.11g	1.358	1.385	0.981	98.05%	0.00	0.010
802.11n HT20	0.352	0.378	0.930	92.97%	0.32	2.843

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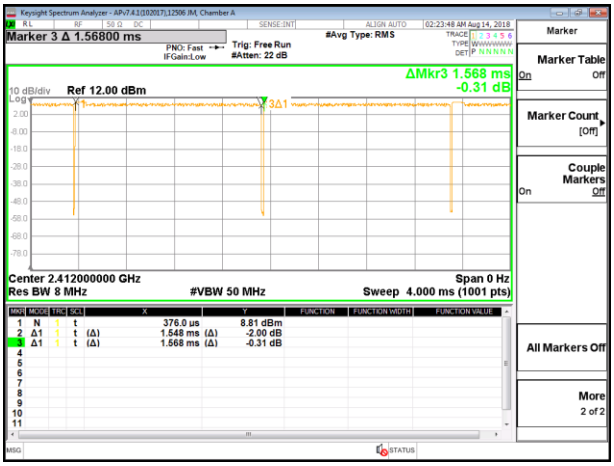
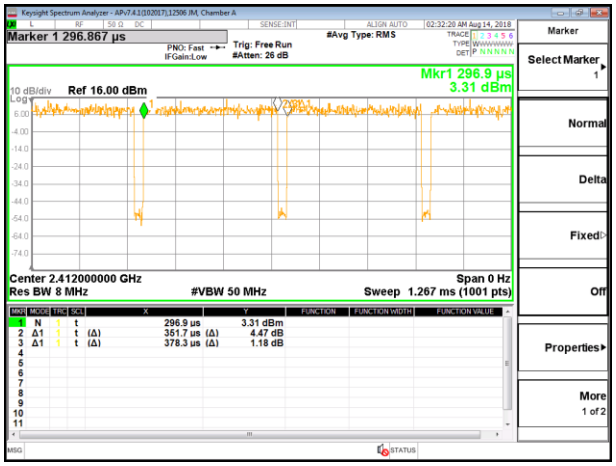
DUTY CYCLE PLOTS



DUTY CYCLE 802.11b MODE

DUTY CYCLE 802.11g MODE



DUTY CYCLE 802.11n HT20 MODE

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8.2. 99% BANDWIDTH

LIMITS

None; for reporting purposes only.

RESULTS

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8.2.1. 802.11b MODE

Channel	Frequency (MHz)	99% Bandwidth Chain 0 (MHz)	99% Bandwidth Chain 1 (MHz)	99% Bandwidth Chain 2 (MHz)	99% Bandwidth Chain 3 (MHz)
Low 1	2412	12.488	12.419	12.286	12.345
Mid 6	2437	12.294	12.386	12.263	12.506
High 11	2462	12.439	12.130	12.242	12.373

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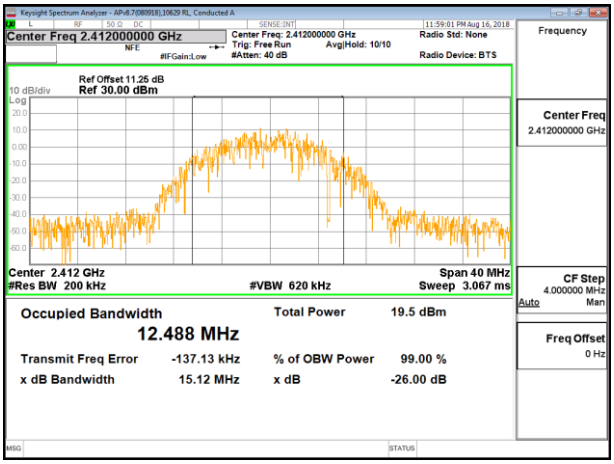
LOW CHANNEL 1



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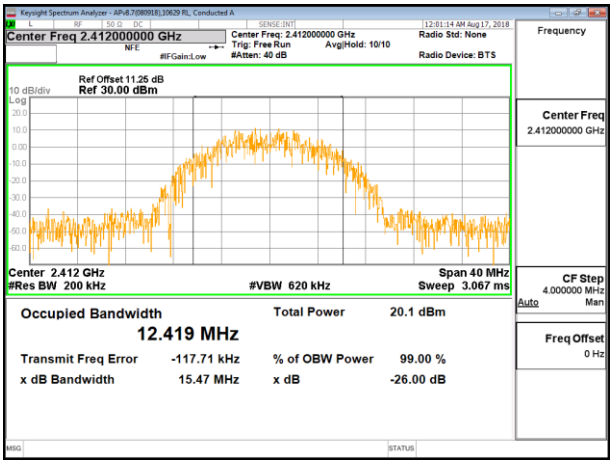
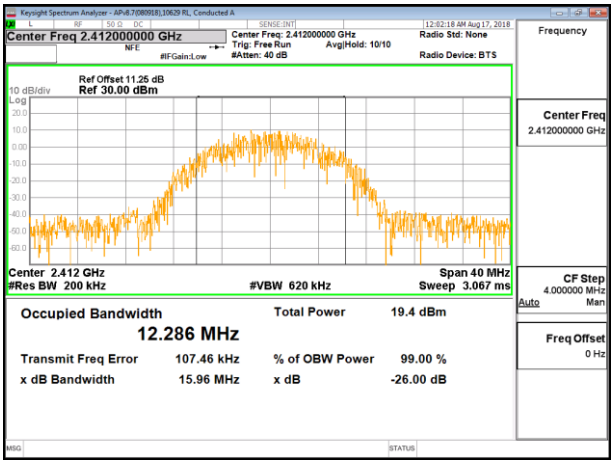
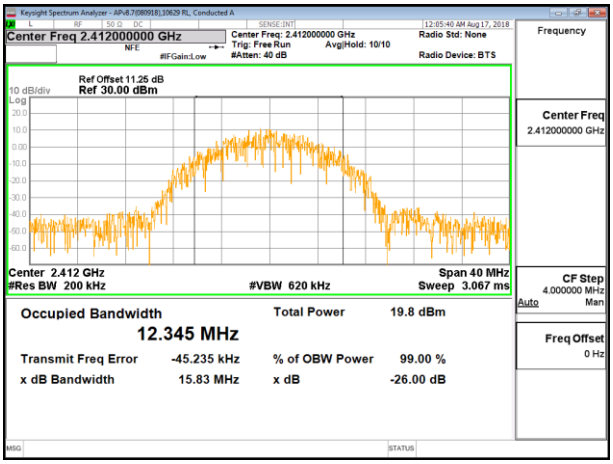


LOW CHANNEL 1 CHAIN 1

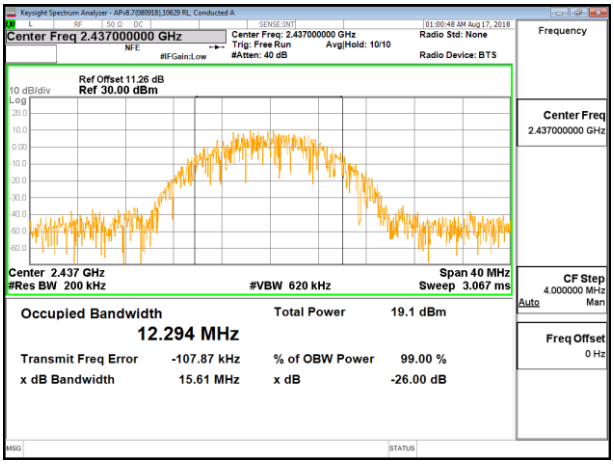


LOW CHANNEL 1 CHAIN 2



LOW CHANNEL 1 CHAIN 3

MID CHANNEL 6



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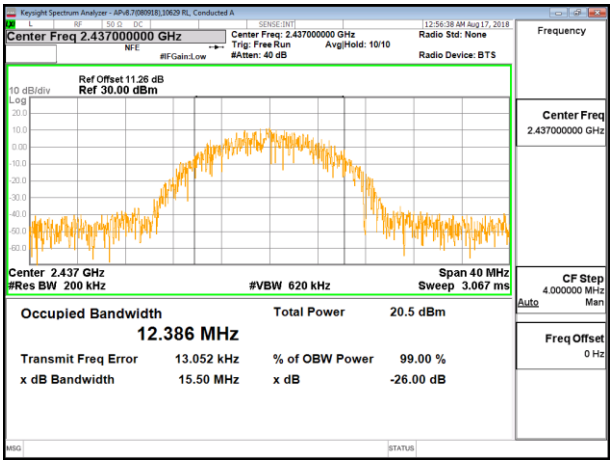

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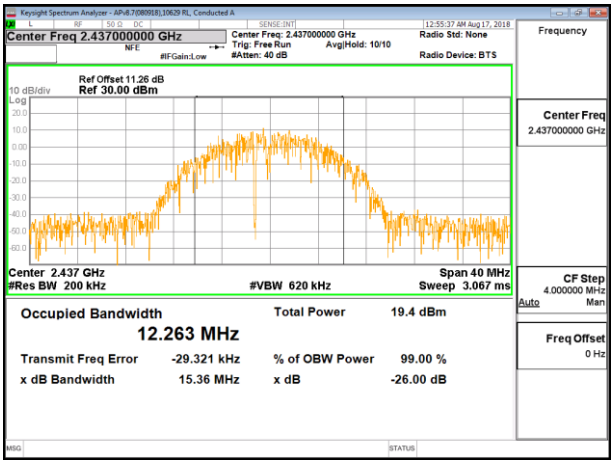

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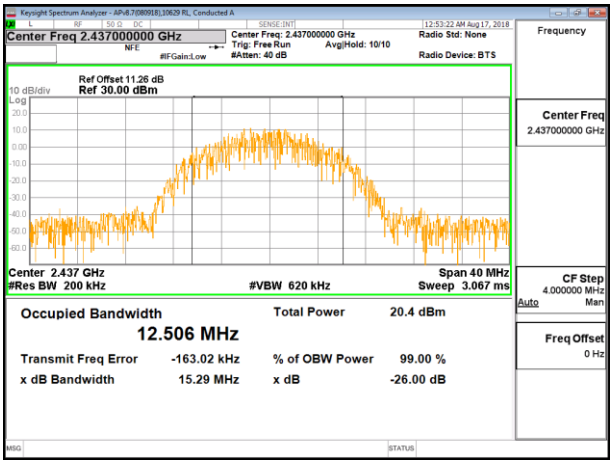
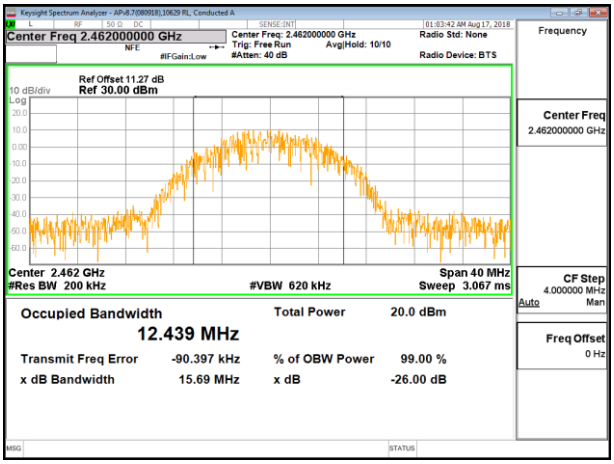


MID CHANNEL 6 CHAIN 3

HIGH CHANNEL 11



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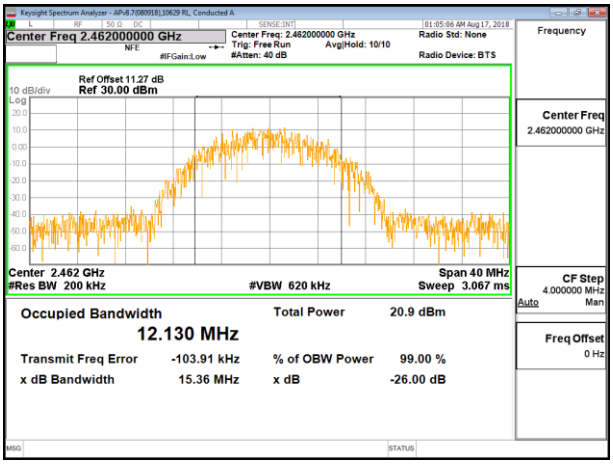
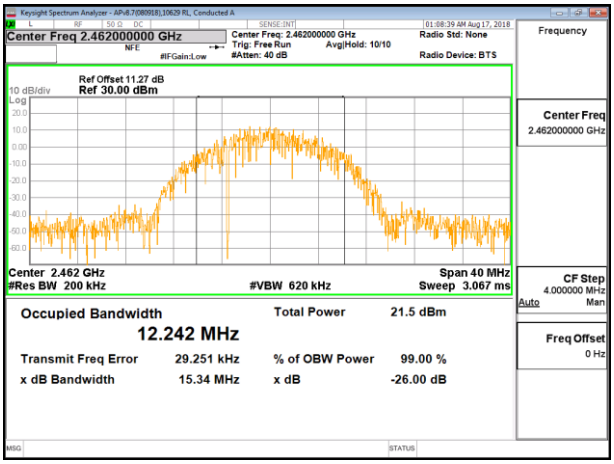
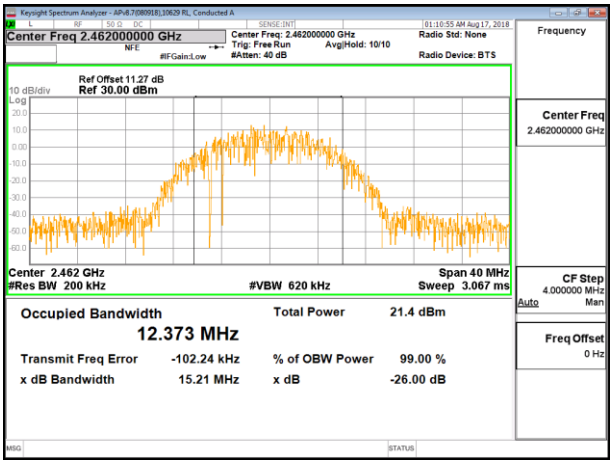


HIGH CHANNEL 11 CHAIN 1



HIGH CHANNEL 11 CHAIN 2



HIGH CHANNEL 11 CHAIN 3

8.2.2. 802.11g MODE

Channel	Frequency (MHz)	99% Bandwidth Chain 0 (MHz)	99% Bandwidth Chain 1 (MHz)	99% Bandwidth Chain 2 (MHz)	99% Bandwidth Chain 3 (MHz)
Low 1	2412	16.270	16.375	16.315	16.343
Low 2	2417	16.390	16.348	16.409	16.349
Mid 6	2437	16.259	16.416	16.304	16.315
High 10	2457	16.398	16.336	16.477	16.419
High 11	2462	16.403	16.350	16.376	16.379

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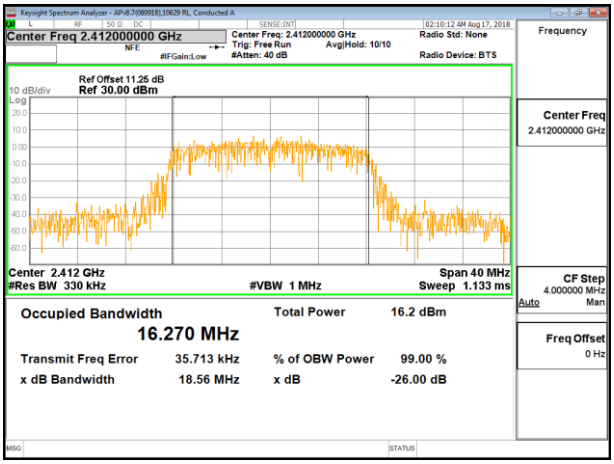
LOW CHANNEL 1



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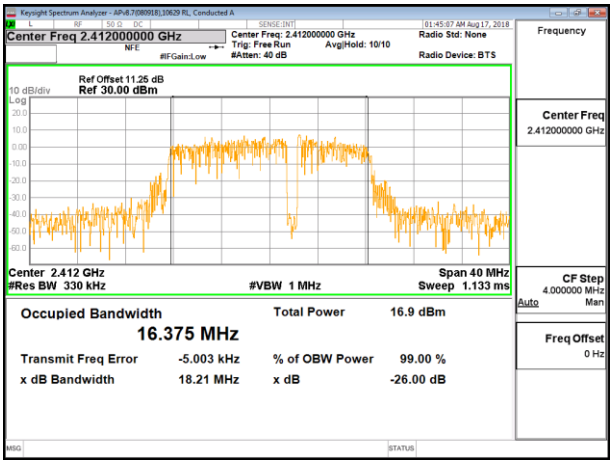

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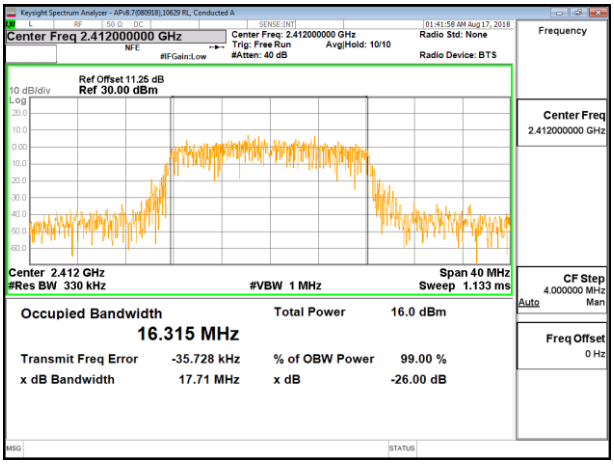

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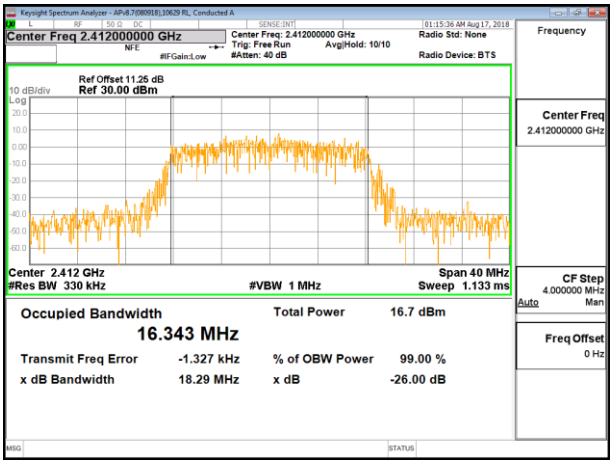
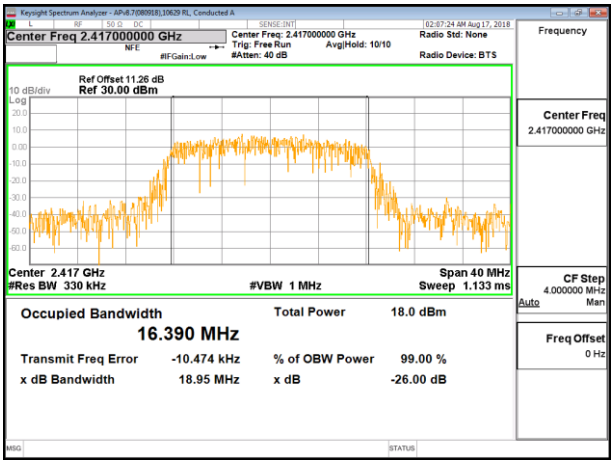


LOW CHANNEL 1 CHAIN 3

LOW CHANNEL 2



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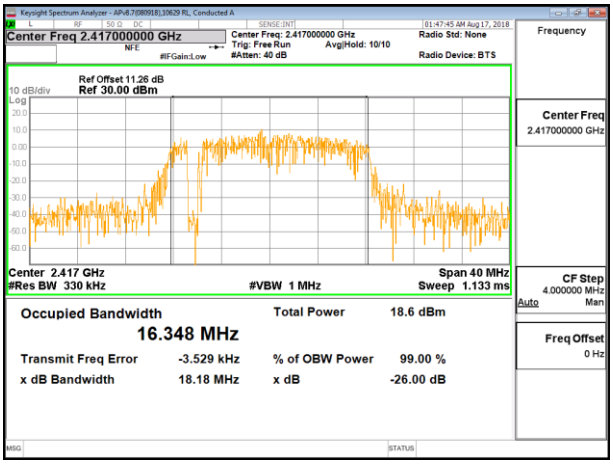

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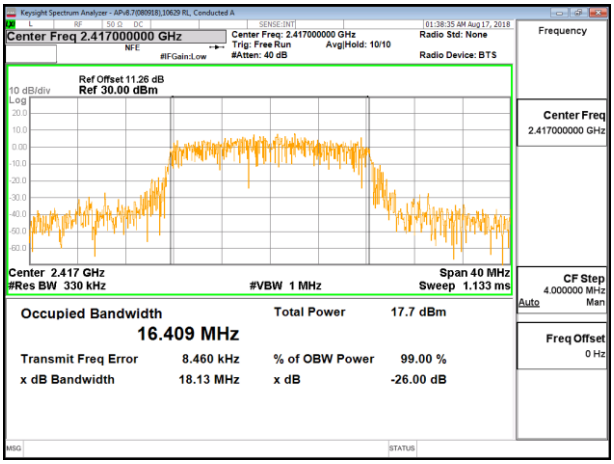
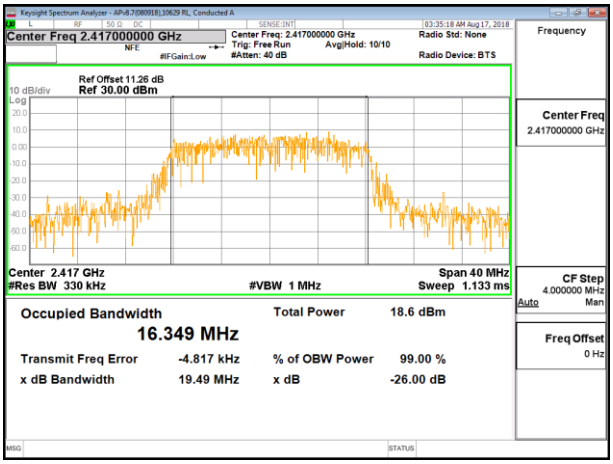
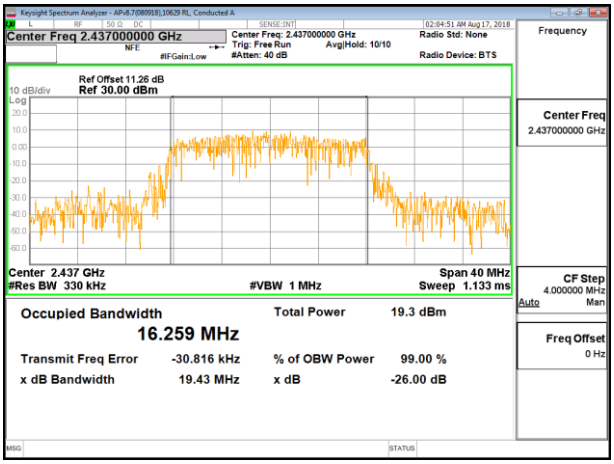


LOW CHANNEL 2 CHAIN 2

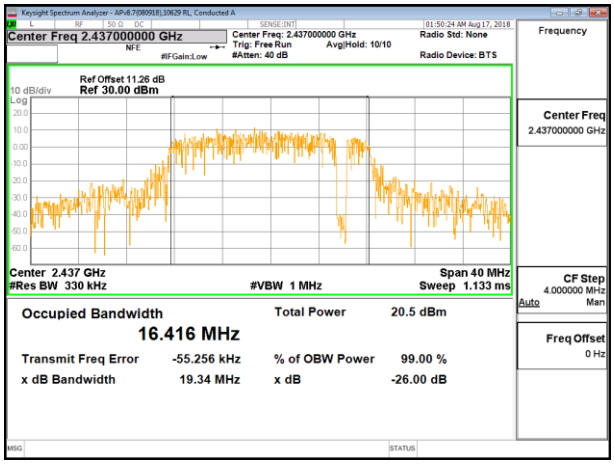


LOW CHANNEL 2 CHAIN 3

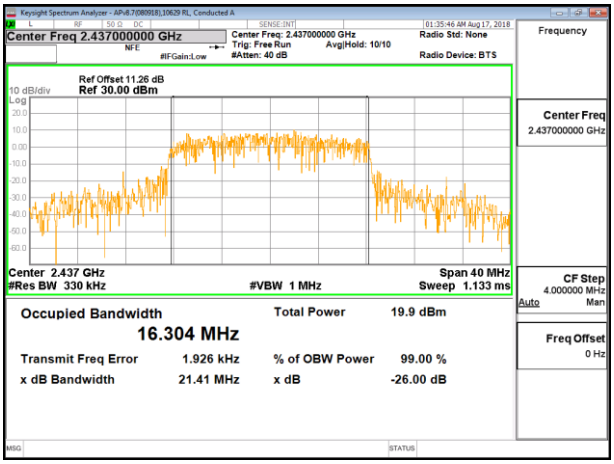
MID CHANNEL 6



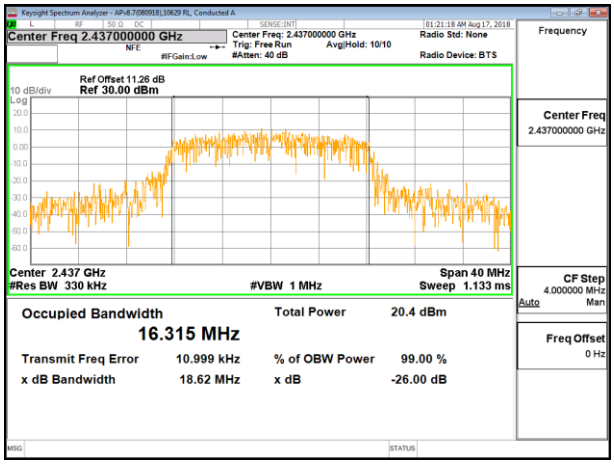
MID CHANNEL 6 CHAIN 0



MID CHANNEL 6 CHAIN 1

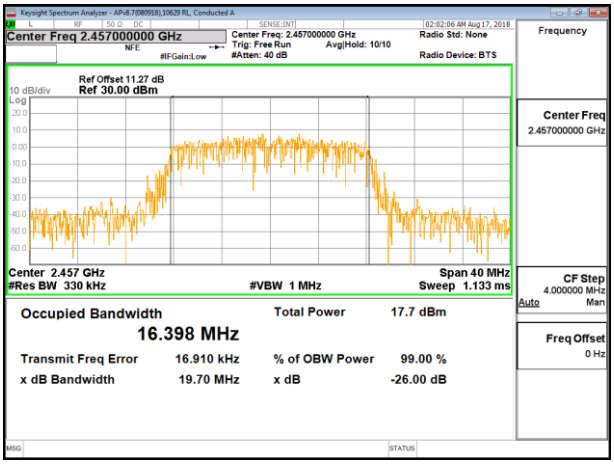


MID CHANNEL 6 CHAIN 2

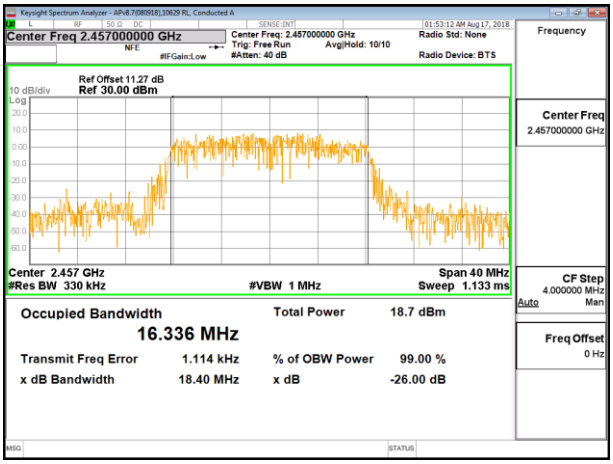


MID CHANNEL 6 CHAIN 3

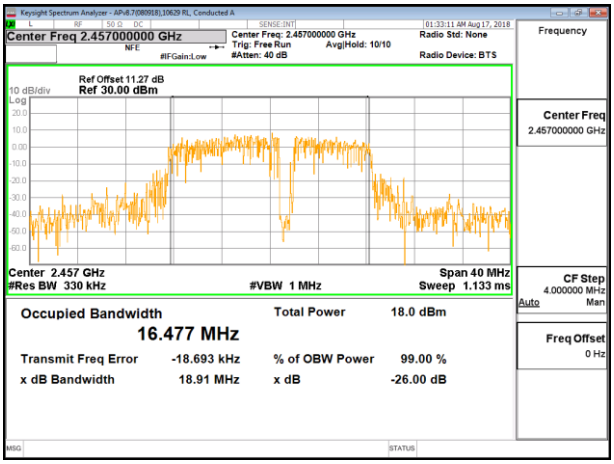
HIGH CHANNEL 10



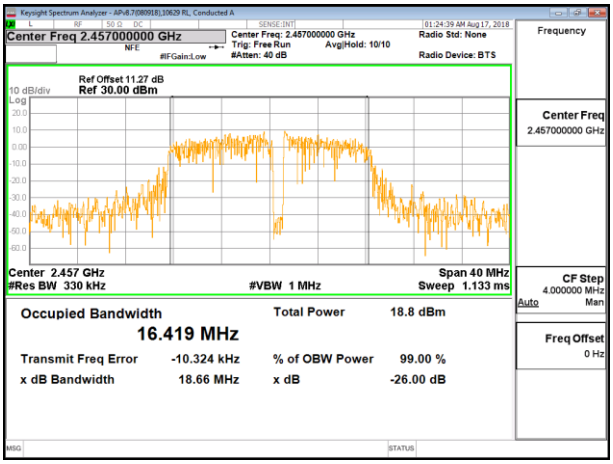
HIGH CHANNEL 10 CHAIN 0



HIGH CHANNEL 10 CHAIN 1

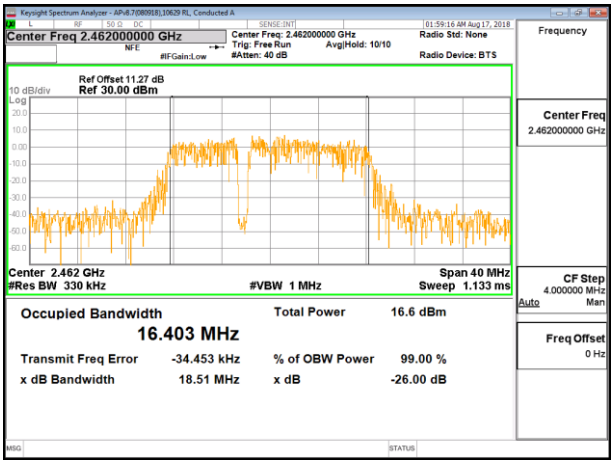


HIGH CHANNEL 10 CHAIN 2

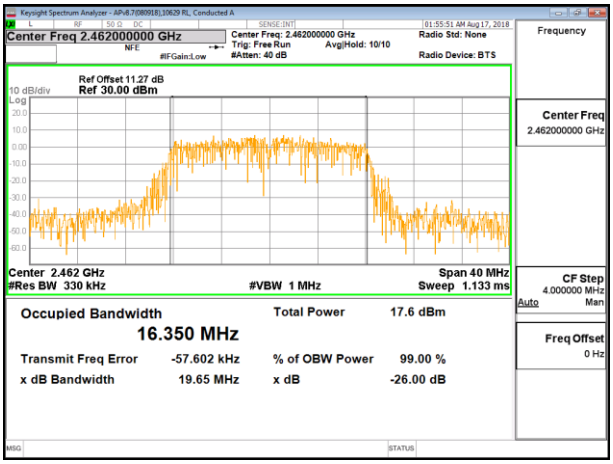


HIGH CHANNEL 10 CHAIN 3

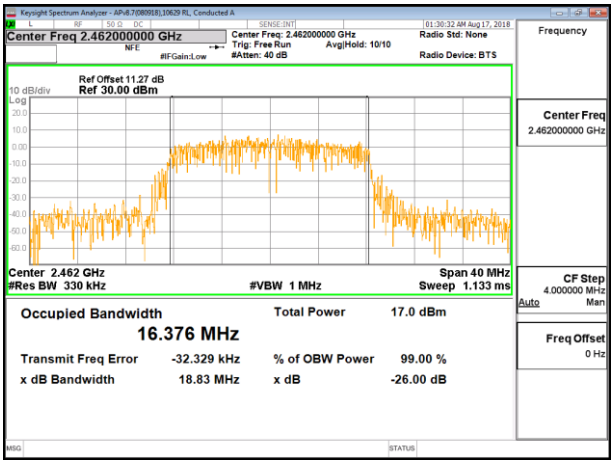
HIGH CHANNEL 11



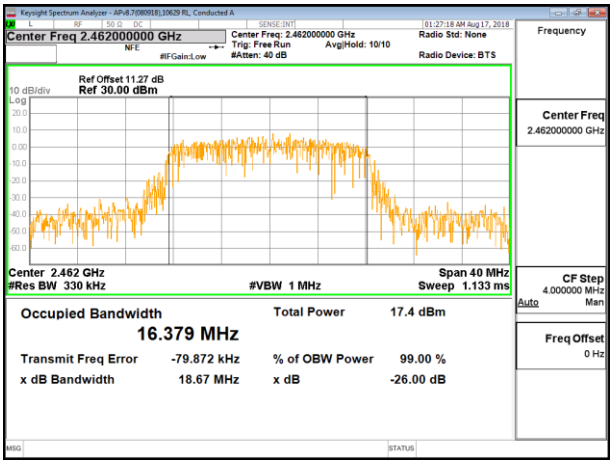
HIGH CHANNEL 11 CHAIN 0



HIGH CHANNEL 11 CHAIN 1



HIGH CHANNEL 11 CHAIN 2



HIGH CHANNEL 11 CHAIN 3

8.2.3. 802.11n HT20 MODE

Channel	Frequency (MHz)	99% Bandwidth Chain 0 (MHz)	99% Bandwidth Chain 1 (MHz)	99% Bandwidth Chain 2 (MHz)	99% Bandwidth Chain 3 (MHz)
Low 1	2412	17.656	17.633	17.373	17.358
Low 2	2417	17.642	17.541	17.479	17.388
Mid 6	2437	17.660	17.622	17.594	17.373
High 10	2457	17.532	17.546	17.875	17.565
High 11	2462	17.569	17.506	17.576	17.533

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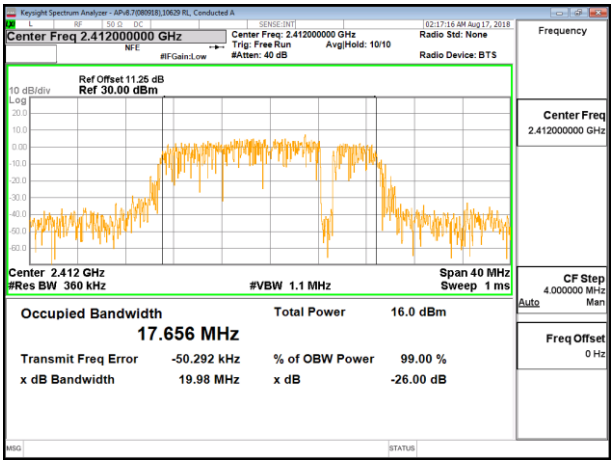
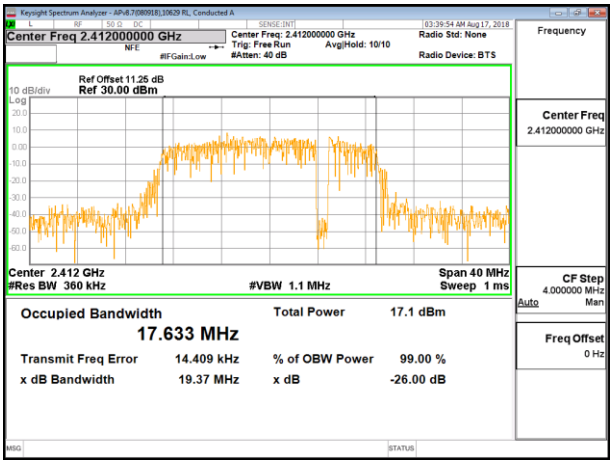
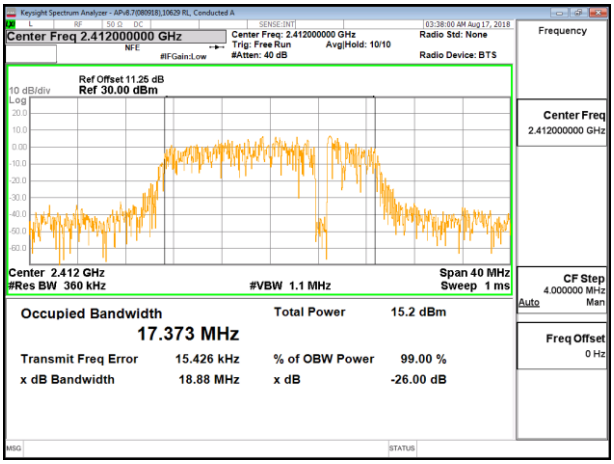
LOW CHANNEL 1



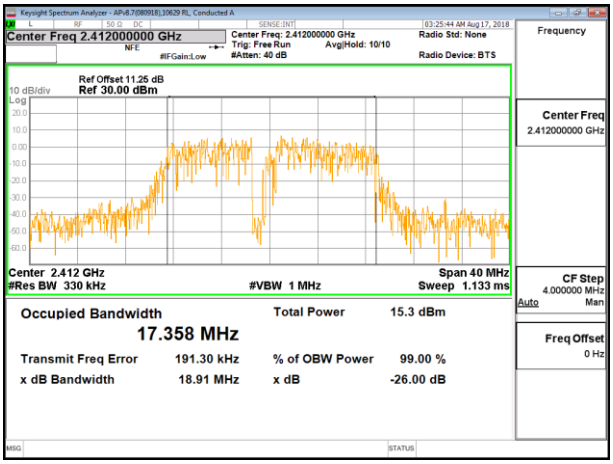
LOW CHANNEL 1 CHAIN 0



LOW CHANNEL 1 CHAIN 1

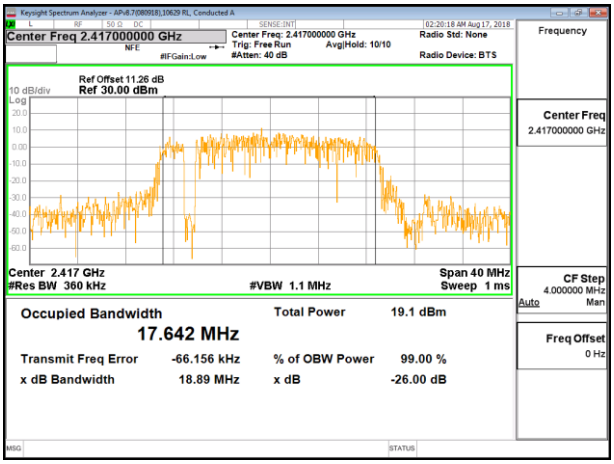


LOW CHANNEL 1 CHAIN 2

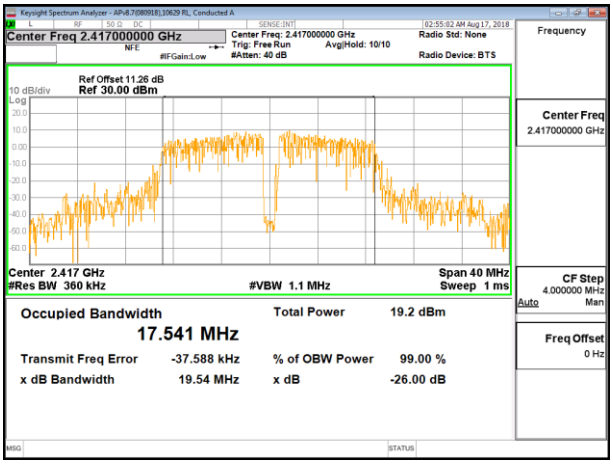


LOW CHANNEL 1 CHAIN 3

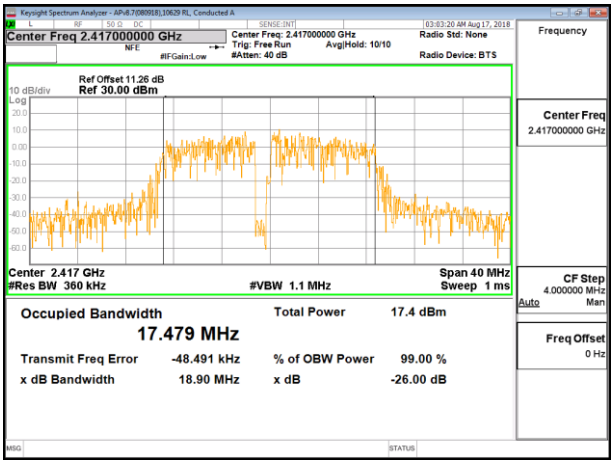
LOW CHANNEL 2



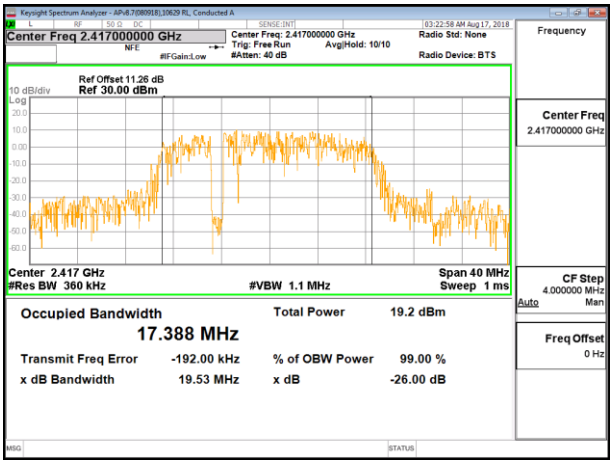
LOW CHANNEL 2 CHAIN 0



LOW CHANNEL 2 CHAIN 1

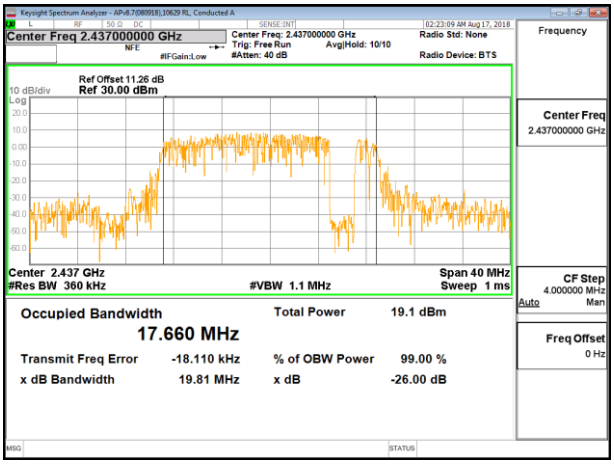


LOW CHANNEL 2 CHAIN 2

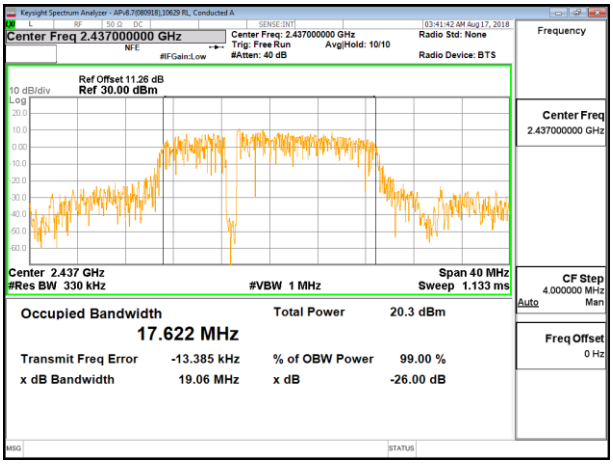


LOW CHANNEL 2 CHAIN 3

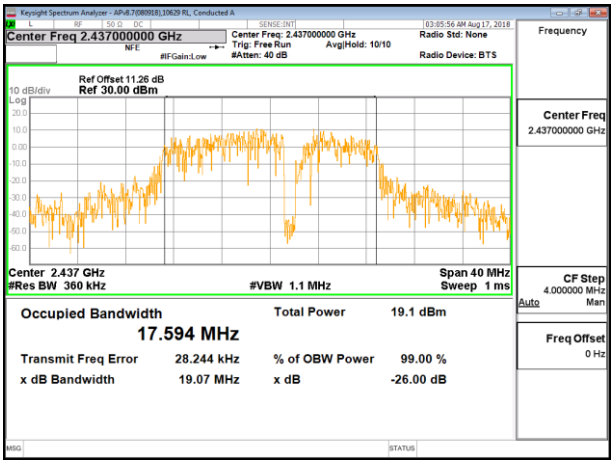
MID CHANNEL 6



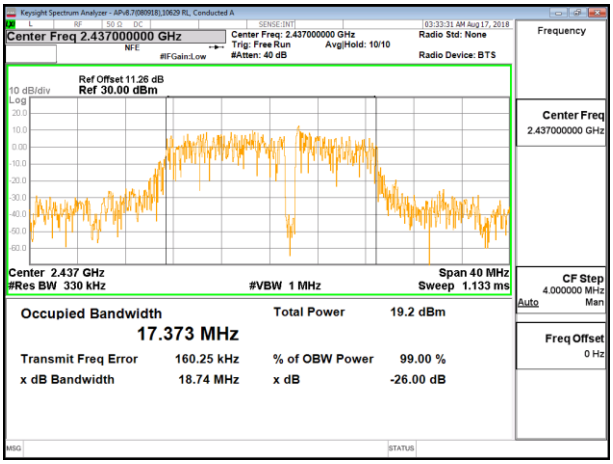
MID CHANNEL 6 CHAIN 0



MID CHANNEL 6 CHAIN 1

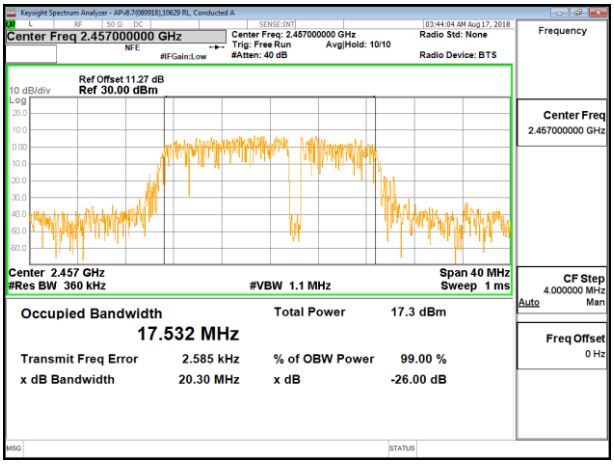


MID CHANNEL 6 CHAIN 2

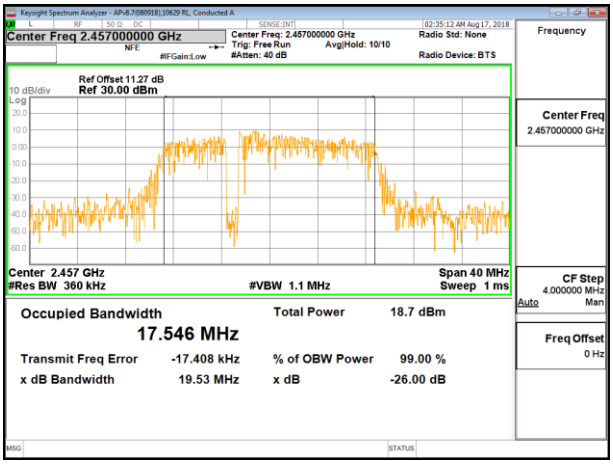


MID CHANNEL 6 CHAIN 3

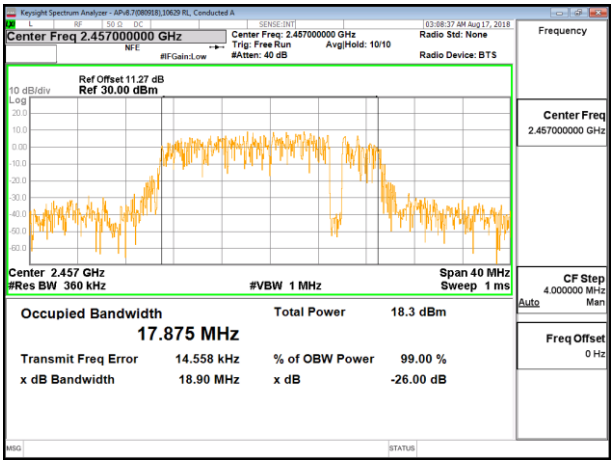
HIGH CHANNEL 10



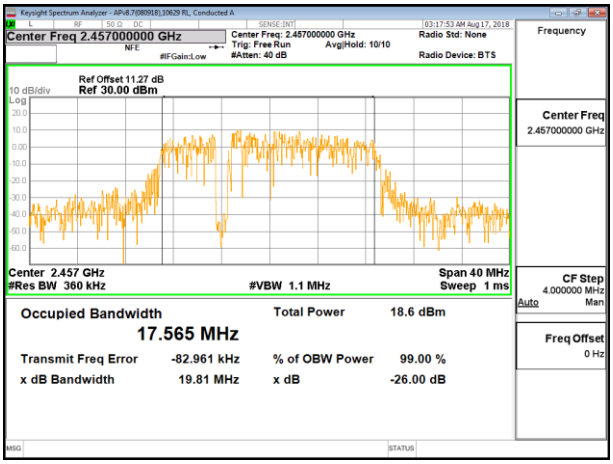
HIGH CHANNEL 10 CHAIN 0



HIGH CHANNEL 10 CHAIN 1

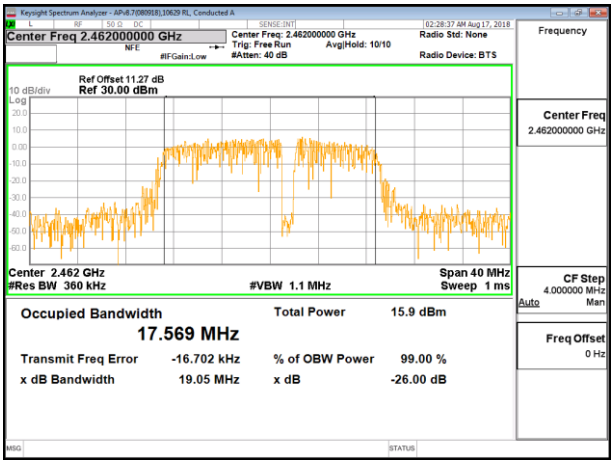


HIGH CHANNEL 10 CHAIN 2

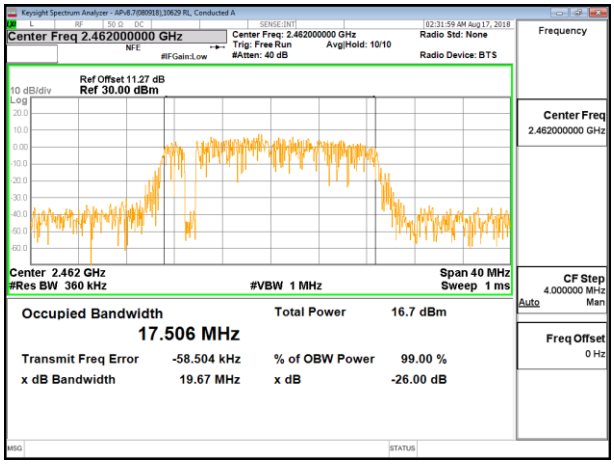


HIGH CHANNEL 10 CHAIN 3

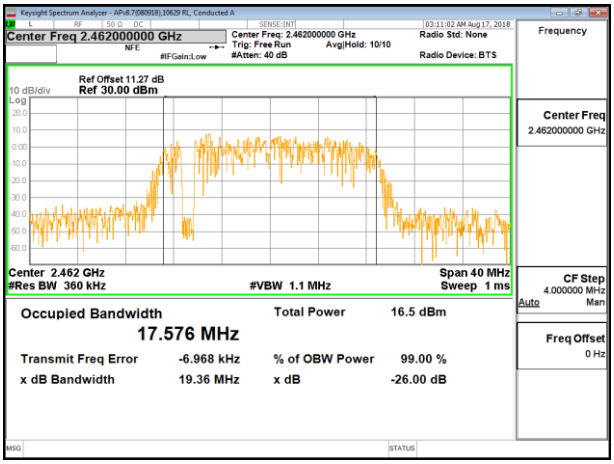
HIGH CHANNEL 11



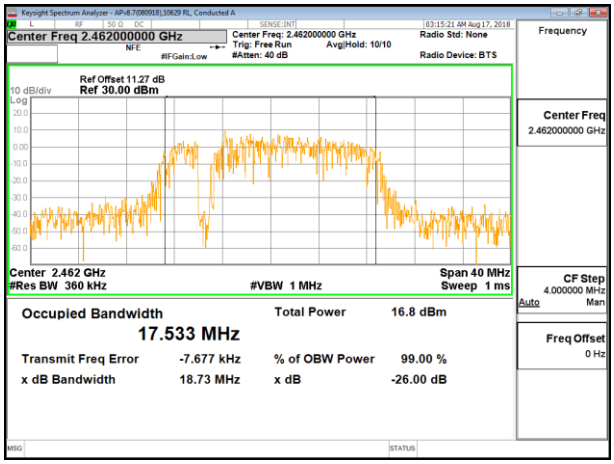
HIGH CHANNEL 11 CHAIN 0



HIGH CHANNEL 11 CHAIN 1



HIGH CHANNEL 11 CHAIN 2



HIGH CHANNEL 11 CHAIN 3

8.3. 6 dB BANDWIDTH

LIMITS

FCC §15.247 (a) (2)

RSS-247 5.2 (a)

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

RESULTS

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8.3.1. 802.11b MODE

Channel	Frequency (MHz)	6 dB BW Chain 0 (MHz)	6 dB BW Chain 1 (MHz)	6 dB BW Chain 2 (MHz)	6 dB BW Chain 3 (MHz)	Minimum Limit (MHz)
Low 1	2412	6.68	7.16	6.64	6.84	0.5
Mid 6	2437	7.04	5.88	7.52	6.64	0.5
High 11	2462	7.12	7.64	6.44	7.04	0.5