



# **TEST REPORT**

**Test Report No. : UL-RPT-RP12173937JD09A**

**Customer** : Apple Inc.  
**Model No.** : A1989  
**FCC ID** : BCGA1989  
**Technology** : WLAN  
**Test Standard(s)** : FCC Parts 15.209(a) & 15.247

**Test Laboratory** : UL VS LTD, Basingstoke, Hampshire, RG24 8AH, United Kingdom

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2. The results in this report apply only to the sample(s) tested.
3. The sample tested is in compliance with the above standard(s).
4. The test results in this report are traceable to the national or international standards.
5. Version 1.0

**Date of Issue:** 20 June 2018

**Checked by:**

Sarah Williams  
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**Company Signatory:**

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UL VS LTD



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## **UL VS LTD**

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**Customer Information**

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<b>Contact Name:</b>	Stuart Thomas

**Report Revision History**

<b>Version Number</b>	<b>Issue Date</b>	<b>Revision Details</b>	<b>Revised By</b>
1.0	20/06/2018	Initial Version	Sarah Williams

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## **1. Attestation of Test Results**

### **1.1. Description of EUT**

The equipment under test was a Laptop Computer with WLAN and *Bluetooth*.

### **1.2. General Information**

<b>Specification Reference:</b>	47CFR15.247
<b>Specification Title:</b>	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.247
<b>Specification Reference:</b>	47CFR15.209
<b>Specification Title:</b>	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.209
<b>Site Registration:</b>	209735
<b>Location of Testing:</b>	UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
<b>Test Dates:</b>	27 January 2018 to 17 May 2018

### **1.3. Summary of Test Results**

<b>FCC Reference (47CFR)</b>	<b>Measurement</b>	<b>Result</b>
Part 15.35(c)	Transmitter Duty Cycle	Note 1
Part 15.247(a)(2)	Transmitter Minimum 6 dB Bandwidth	Complied
Part 15.247(e)	Transmitter Power Spectral Density	Complied
Part 15.247(b)(3)	Transmitter Maximum (Average) Output Power	Complied
Part 15.247(d) & 15.209(a)	Transmitter Radiated Emissions	Complied
Part 15.247(d) & 15.209(a)	Transmitter Band Edge Radiated Emissions	Complied

#### **Note(s):**

- For the data rates declared as worst case and reported in this test report, duty cycle was measured to be greater than 98%. Plots for these measurements are archived on the UL VS LTD IT server and available for inspection upon request.
- There are two vendors of the WiFi/*Bluetooth* radio modules, Vendor 1 and Vendor 2.

The WiFi/*Bluetooth* radio modules have the same mechanical outline (i.e. the same packaging dimension and pin layout), use the same on-board antenna matching circuit, have an identical antenna structure and are built and tested to conform to the same specification and to operate within the same tolerances.

Baseline testing was performed on the two vendors to determine the worst case.

### **1.4. Deviations from the Test Specification**

For the measurements contained within this test report, there were no deviations from, additions to, or exclusions from the test specification identified above.

## **2. Summary of Testing**

### **2.1. Facilities and Accreditation**

The test site and measurement facilities used to collect data are located at Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom. The following table identifies which facilities were utilised for radiated emission measurements documented in this report. Specific facilities are also identified in the test results sections.

Site 1	X
Site 2	X
Site 17	X

UL VS LTD is accredited by UKAS. The tests reported herein have been performed in accordance with its terms of accreditation.

### **2.2. Methods and Procedures**

<b>Reference:</b>	ANSI C63.10-2013
<b>Title:</b>	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
<b>Reference:</b>	KDB 558074 D01 DTS Meas Guidance v04 April 5, 2017
<b>Title:</b>	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under Section 15.247
<b>Reference:</b>	KDB 662911 D01 Multiple Transmitter Output v02r01 October 31, 2013
<b>Title:</b>	Emissions Testing of Transmitters with Multiple Outputs in the Same Band

## **2.3. Calibration and Uncertainty**

### **Measuring Instrument Calibration**

In accordance with UKAS requirements all the measurement equipment is on a calibration schedule. All equipment was within the calibration period on the date of testing.

### **Measurement Uncertainty**

No measurement or test can ever be perfect and the imperfections give rise to error of measurement in the results. Consequently the result of a measurement is only an approximation to the value measured (the specific quantity subject to measurement) and is only complete when accompanied by a statement of the uncertainty of the approximation.

The expression of uncertainty of a measurement result allows realistic comparison of results with reference values and limits given in specifications and standards.

The uncertainty of the result may need to be taken into account when interpreting the measurement results.

The reported expanded uncertainties below are based on a standard uncertainty multiplied by an appropriate coverage factor such that a confidence level of approximately 95% is maintained. For the purposes of this document "approximately" is interpreted as meaning "effectively" or "for most practical purposes".

Measurement Type	Range	Confidence Level (%)	Calculated Uncertainty
Duty Cycle	2.4 GHz to 2.4835 GHz	95%	±1.14 %
Minimum 6 dB Bandwidth	2.4 GHz to 2.4835 GHz	95%	±4.59 %
Spectral Power Density	2.4 GHz to 2.4835 GHz	95%	±1.13 dB
Conducted Maximum Output Power	2.4 GHz to 2.4835 GHz	95%	±1.13 dB
Radiated Spurious Emissions	30 MHz to 1 GHz	95%	±4.65 dB
Radiated Spurious Emissions	1 GHz to 25 GHz	95%	±2.94 dB

The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty the published guidance of the appropriate accreditation body is followed.

## 2.4. Test and Measurement Equipment

### Test Equipment Used for Transmitter Conducted Tests (non-TxBF)

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2004	Thermohygrometer	Testo	608-H1	45046425	26 Feb 2019	12
A3028	Attenuator	Broadwave Technologies	351-311-006	#2	Calibrated before use	-
A3029	Attenuator	Broadwave Technologies	351-311-006	#3	Calibrated before use	-
A3030	Attenuator	Broadwave Technologies	351-311-006	#4	Calibrated before use	-
A3004	RF Switch	Pickering Interfaces	64-102-002	XZ363230	Calibrated before use	-
M2018	Signal Analyser	Rohde & Schwarz	FSV7	102699	23 Jun 2018	12
G0607	Signal Generator	Rohde & Schwarz	SMU200A	100943	10 May 2019	36

### Test Equipment Used for Transmitter Conducted Tests (TxBF)

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2001	Thermohygrometer	Testo	608-H1	45041824	28 Feb 2019	12
M1873	Signal Analyser	Rohde & Schwarz	FSV30	103074	06 Jun 2018	12
A2505	Directional Coupler	AtlanTecRF	CDC-003060-20	1101230	Calibrated before use	-
A2534	Directional Coupler	AtlanTecRF	CDC-003060-20	14041701718	Calibrated before use	-
A2536	Directional Coupler	AtlanTecRF	CDC-003060-20	14041701720	Calibrated before use	-
A2097	Power Splitter	Mini-Circuits	ZN4PD1-63W-S+	SUU98701205	Calibrated before use	-
A2098	Power Splitter	Mini-Circuits	ZN4PD1-63W-S+	SF210501205	Calibrated before use	-
A2952	RF Switch	Pickering Interfaces	64-102-002	XZ361012	Calibrated before use	-
A248	Step Attenuator	Narda	743-60	01411	Calibrated before use	-
G0615	Signal Generator	Rohde & Schwarz	SMBV100A	260473	08 May 2020	36

**Test and Measurement Equipment (continued)****Test Equipment Used for Transmitter Radiated Emissions**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	12 Mar 2019	12
M1273	Test Receiver	Rohde & Schwarz	ESIB26	100275	08 May 2018	12
G0453	Pre-amplifier	Sonoma	310N	230801	15 Jun 2018	12
A1834	Attenuator	Hewlett Packard	8491B	10444	14 Mar 2019	12
M2009	Thermohygrometer	Testo	608-H1	45046699	20 Jun 2018	12
K0002	3m RSE Chamber	Rainford EMC	N/A	N/A	07 Feb 2019	12
M2016	Thermohygrometer	Testo	608-H1	45046428	26 Feb 2019	12
M1630	Test Receiver	Rohde & Schwarz	ESU40	100233	03 Aug 2018	12
A2948	Pre Amplifier	Com-Power Corp	PAM-118A	551087	06 Apr 2019	12
A1818	Antenna	EMCO	3115	00075692	07 Feb 2019	12
A253	Antenna	Flann Microwave	128	12240-20	07 Feb 2019	12
A254	Antenna	Flann Microwave	139	14240-20	07 Feb 2019	12
A255	Antenna	Flann Microwave	519	16240-20	07 Feb 2019	12
A256	Antenna	Flann Microwave	400	18240-20	07 Feb 2019	12
A2895	Antenna	Schwarzbeck	BBHA 9170	9170-728	20 Feb 2019	12
A2130	High Pass Filter	AtlanTecRF	AFH-08000	80rJFBD06-002	21 Feb 2019	12
A2973	High Pass Filter	AtlanTecRF	AFH-03000	16080900032	24 Jan 2019	12
M2003	Thermohygrometer	Testo	608-H1	45046641	27 Feb 2019	12
K0017	3m RSE Chamber	Rainford EMC	N/A	N/A	20 Feb 2019	12
M1630	Test Receiver	Rohde & Schwarz	ESU40	100233	03 Aug 2018	12
A2863	Pre Amplifier	Agilent	8449B	3008A02100	19 Feb 2019	12
A2889	Antenna	Schwarzbeck	BBHA 9120 B	BBHA 9120 B 653	19 Feb 2019	12
A2914	High Pass Filter	AtlanTecRF	AFH-03000	2155	22 Feb 2019	12

**Test Equipment Used for Transmitter Band Edge Radiated Emissions**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2003	Thermohygrometer	Testo	608-H1	45046641	27 Feb 2019	12
K0017	3m RSE Chamber	Rainford EMC	N/A	N/A	20 Feb 2019	12
M1995	Test Receiver	Rohde & Schwarz	ESU40	100428	18 Apr 2019	12
M1630	Test Receiver	Rohde & Schwarz	ESU40	100233	03 Aug 2018	12
A2863	Pre Amplifier	Agilent	8449B	3008A02100	19 Feb 2019	12
A2889	Antenna	Schwarzbeck	BBHA 9120 B	BBHA 9120 B 653	19 Feb 2019	12
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	21 Feb 2019	12

### **3. Equipment Under Test (EUT)**

#### **3.1. Identification of Equipment Under Test (EUT)**

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1989
<b>Test Sample Serial Number:</b>	C02VQ00SJKHY ( <i>Conducted sample #1</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2014
<b>FCC ID:</b>	BCGA1989

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1989
<b>Test Sample Serial Number:</b>	C02W6004JH90 ( <i>Conducted sample #2</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2014
<b>FCC ID:</b>	BCGA1989

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1989
<b>Test Sample Serial Number:</b>	C02VR00RJH93 ( <i>Radiated sample #1</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2014
<b>FCC ID:</b>	BCGA1989

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1989
<b>Test Sample Serial Number:</b>	C02W6011JTF2 ( <i>Radiated sample #2</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2014
<b>FCC ID:</b>	BCGA1989

#### **3.2. Modifications Incorporated in the EUT**

No modifications were applied to the EUT during testing.

### 3.3. Additional Information Related to Testing

<b>Technology Tested:</b>	WLAN (IEEE 802.11b,g,n) / Digital Transmission System	
<b>Type of Unit:</b>	Transceiver	
<b>Modulation Type:</b>	DBPSK, DQPSK, BPSK, QPSK, 16QAM & 64QAM	
<b>Data Rates:</b>	802.11b	1, 2, 5.5 & 11 Mbps (SISO, MIMO with CDD)
	802.11g	6, 9, 12, 18, 24, 36, 48 & 54 Mbps (SISO)
	802.11n HT20	MCS0 to MCS7 (1 spatial stream with either SISO or 2/3-chain MIMO CDD/TxBF operation) MCS8 to MCS15 (2 spatial streams on 2 transmit chains w/ or w/o TxBF) MCS16 to MCS23 (3 spatial streams on 3 transmit chains w/ or w/o TxBF)
<b>Power Supply Requirement(s):</b>	Nominal	3.8 VDC via 120 VAC 60 Hz AC/DC adapter
<b>Maximum Conducted Output Power:</b>	25.2 dBm	
<b>Channel Spacing:</b>	20 MHz	
<b>Transmit Frequency Range:</b>	2412 MHz to 2472 MHz	
<b>Transmit Channels Tested:</b>	<b>Channel Number</b>	<b>Channel Frequency (MHz)</b>
	1	2412
	2	2417
	3	2422
	6	2437
	7	2442
	11	2462
	12	2467
	13	2472

### 3.4. Description of Available Antennas

The radio utilizes three integrated antennas, with the following maximum gains:

<b>Frequency Band (MHz)</b>	<b>G<sub>Antenna 1</sub> / WF2 (dBi)</b>	<b>G<sub>Antenna 2</sub> / WF1 (dBi)</b>	<b>G<sub>Antenna 3</sub> / WF3 (dBi)</b>
2400 - 2480	3.3	2.3	2.0

Refer to Appendix 1 for directional antenna gain calculations for MIMO modes.

### **3.5. Description of Test Setup**

#### **Support Equipment**

The following support equipment was used to exercise the EUT during testing:

<b>Brand Name:</b>	Not marked or stated
<b>Description:</b>	Type C USB Cable. Length 2.0 metres
<b>Model Name or Number:</b>	Not marked or stated
<b>Serial Number:</b>	Not marked or stated

<b>Brand Name:</b>	Apple
<b>Description:</b>	USB-C Power Adapter
<b>Model Name or Number:</b>	A1947
<b>Serial Number:</b>	Not marked or stated

<b>Brand Name:</b>	Belkin
<b>Description:</b>	USB-C Adapter
<b>Model Name or Number:</b>	F2CU040
<b>Serial Number:</b>	Not marked or stated

<b>Brand Name:</b>	Apple
<b>Description:</b>	USB-C Power Adapter
<b>Model Name or Number:</b>	A1718
<b>Serial Number:</b>	Not marked or stated

<b>Brand Name:</b>	Apple
<b>Description:</b>	PHF (Personal Hands Free)
<b>Model Name or Number:</b>	Apple EarPods
<b>Serial Number:</b>	Not marked or stated

<b>Brand Name:</b>	Not marked or stated
<b>Description:</b>	Type A USB Cable. Length 3.0 metres
<b>Model Name or Number:</b>	Not marked or stated
<b>Serial Number:</b>	Not marked or stated

<b>Brand Name:</b>	Belkin
<b>Description:</b>	4 Port USB Hub
<b>Model Name or Number:</b>	F5U404-BLK
<b>Serial Number:</b>	Not marked or stated

**Support Equipment (continued)**

<b>Brand Name:</b>	Apple
<b>Description:</b>	Support Laptop (Conducted beamforming tests)
<b>Model Name or Number:</b>	MacBook
<b>Serial Number:</b>	C02S400GH7C5

<b>Brand Name:</b>	Apple
<b>Description:</b>	Support Laptop (Radiated beamforming tests)
<b>Model Name or Number:</b>	MacBook
<b>Serial Number:</b>	C02S3008H7CF

## **Operating Modes**

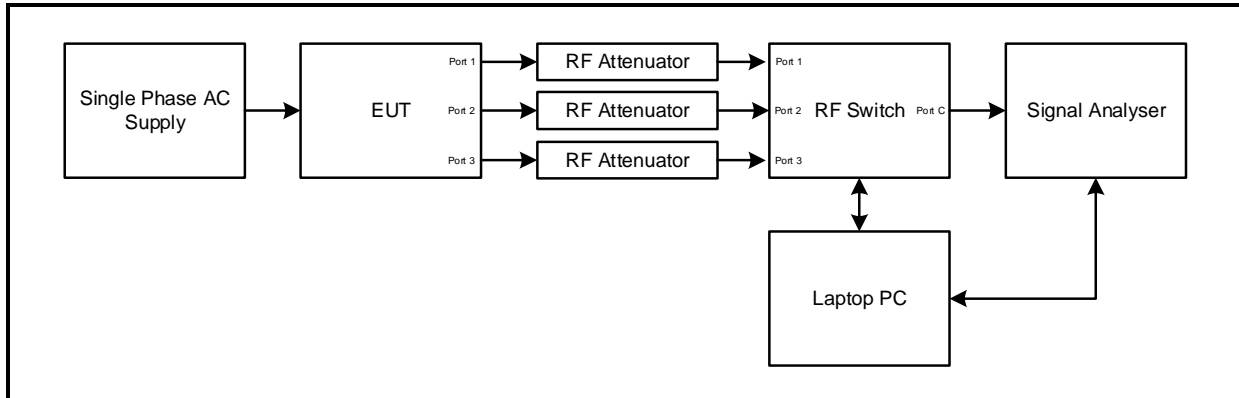
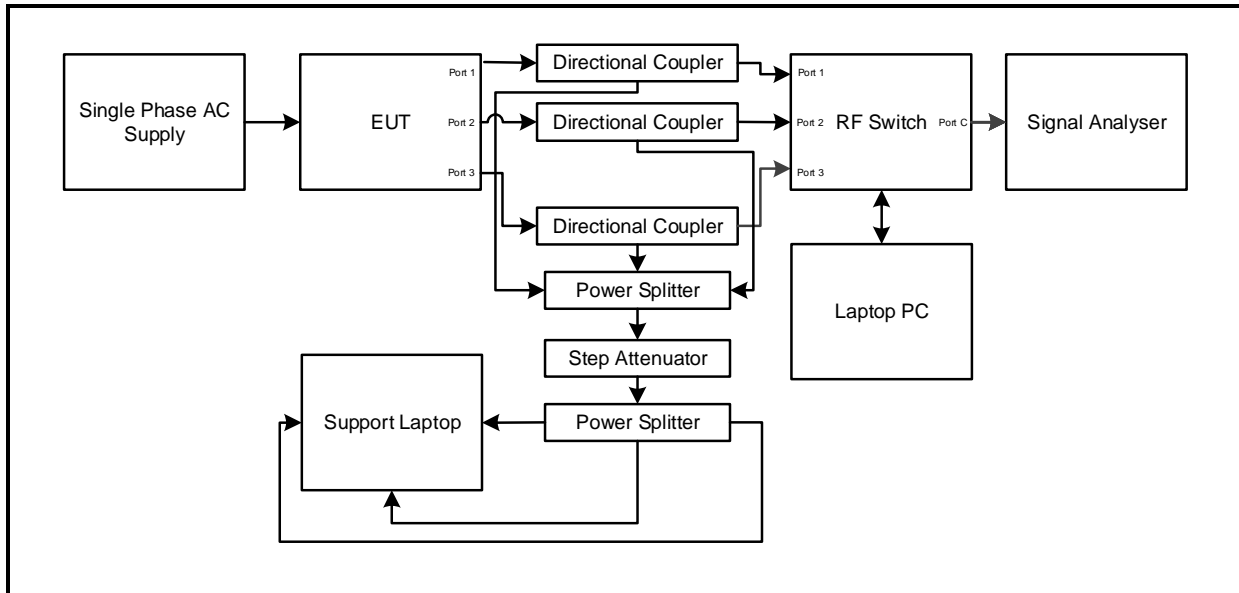
The EUT was tested in the following operating mode(s):

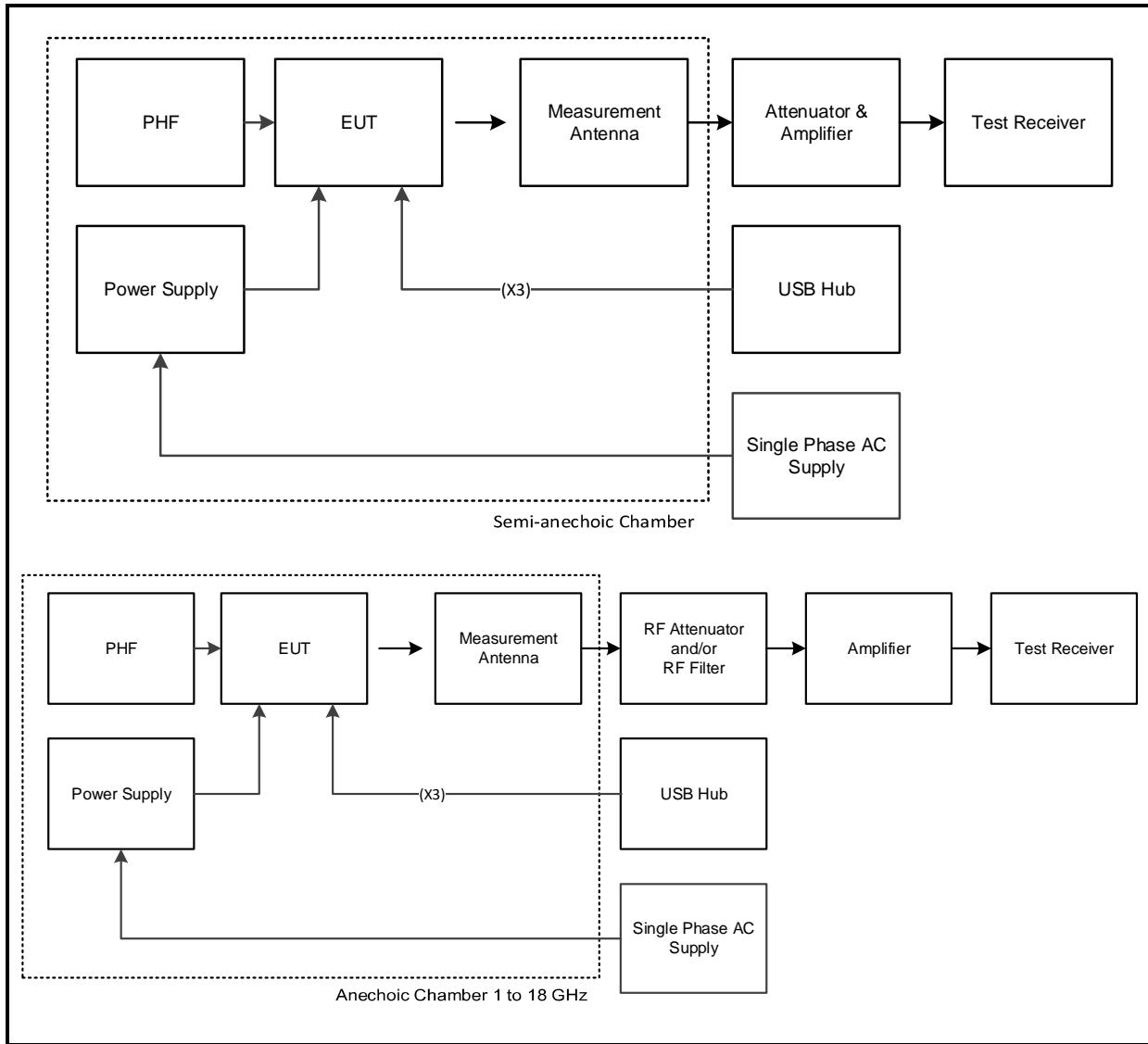
- Non-TxBF modes: Continuously transmitting with a modulated carrier at maximum power on the relevant channels as required using the supported data rates/modulation types.
- TxBF modes: Transmitting a modulated carrier with maximum possible duty cycle at maximum power on the relevant channels as required using the supported data rates/modulation types.

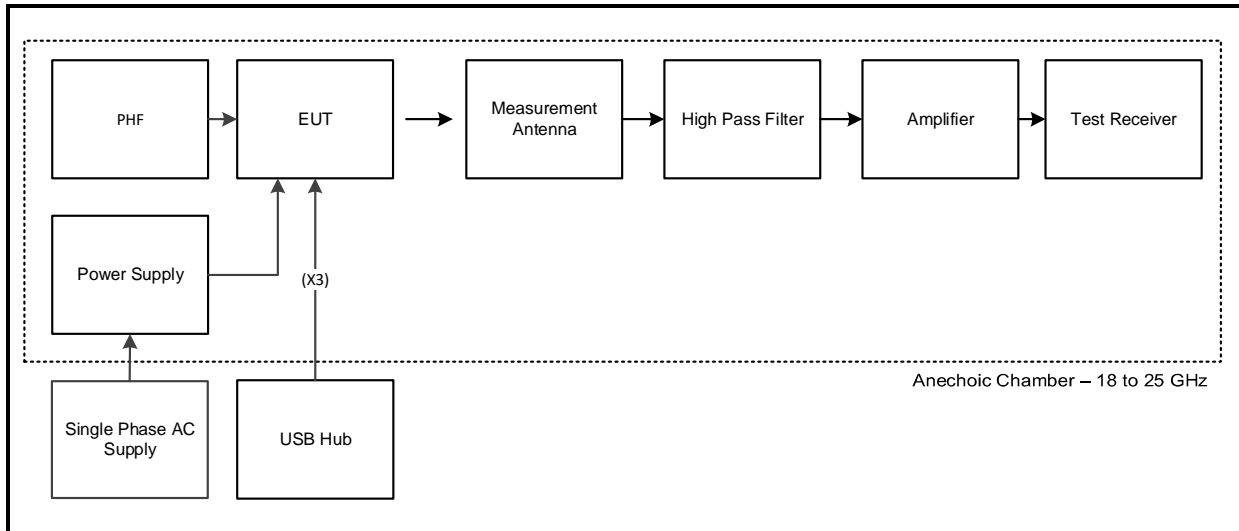
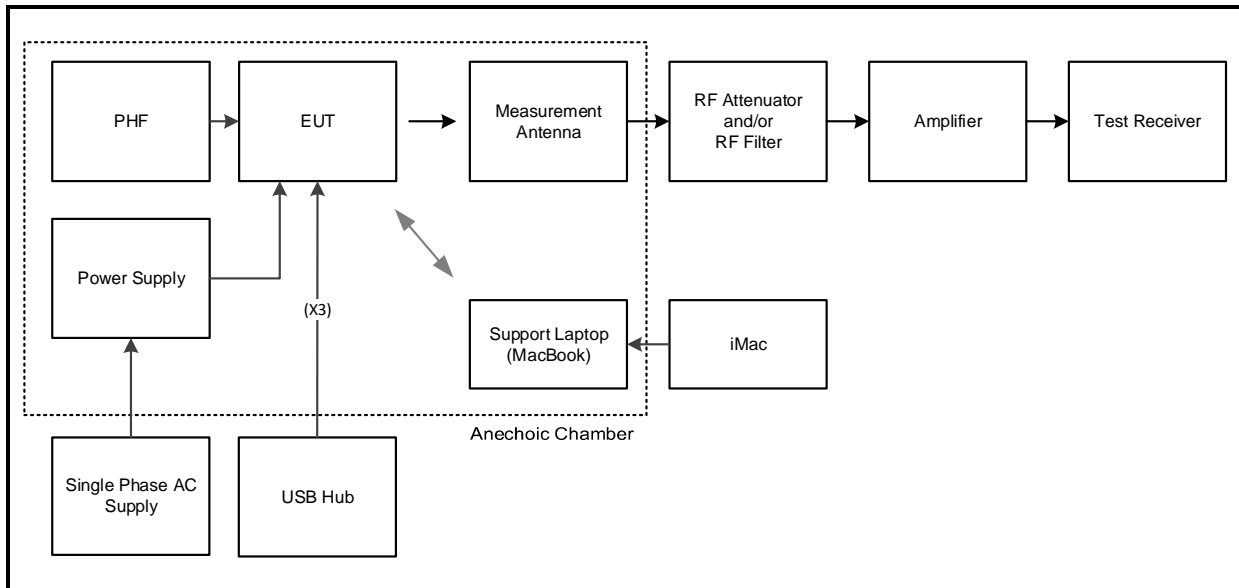
## **Configuration and Peripherals**

The EUT was tested in the following configuration(s):

- Controlled in test mode using a software application on the EUT supplied by the customer. The application was used to enable a continuous transmission and to select the test channels as required. The customer supplied scripts 'EUT\_EVT\_wlan\_setup\_v1.sh' to control the EUT.
- For TxBF modes, the EUT was communicating via a conducted RF link with an equivalent device. The EUT ran iPerf bandwidth testing application in client mode to produce maximum throughput. The customer supplied a document containing the setup instructions 'EUT\_TXBF\_operating\_procedures\_v1.5.pdf'
- For TxBF modes, the EUT was communicating via a radiated RF link with an equivalent device. The EUT ran iPerf bandwidth testing application in client mode to produce maximum throughput. The customer supplied a document containing the setup instructions 'EUT\_TXBF\_operating\_procedures\_v1.4.pdf'.
- The customer declared the following data rates to be used for all measurements as:
  - 802.11b / SISO – DBPSK / 1 Mbps
  - 802.11g / SISO – BPSK / 6 Mbps
  - 802.11n HT20 / SISO – BPSK / MCS0
  - 802.11b / MIMO / 2Tx CDD – DBPSK / 1 Mbps
  - 802.11b / MIMO / 3Tx CDD – DBPSK / 1 Mbps
  - 802.11n HT20 / MIMO / 2Tx CDD – BPSK/ MCS0
  - 802.11n HT20 / MIMO / 3Tx CDD – BPSK / MCS0
  - 802.11n HT20 / MIMO / 2Tx TxBF – BPSK/ MCS0
  - 802.11n HT20 / MIMO / 3Tx TxBF – BPSK/ MCS0
- The EUT has three separate antennas which correspond to three separate antenna ports. Port WF1, Port WF2 and Port WF3 correspond to antenna 2, antenna 1 and antenna 3 respectively.
- For the Transmitter Minimum 6 dB Bandwidth test, only SISO modes were tested since the bandwidth does not change depending on chains used.
- The customer supplied U.FL RF cables with the EUT in order to perform conducted measurements. The measured additional path loss was included in any path loss calculations.
- Transmitter spurious emissions were performed with the EUT transmitting with a data rate of 802.11b / 1 Mbps / MIMO 3Tx CDD.
- Transmitter radiated spurious emissions tests were performed with the AC Charger and PHF connected to the EUT. The USB ports were terminated to a USB hub which was placed outside the chamber.
- Additional testing on channels near the upper band edge was requested.
- The EUT was powered from a 120 VAC 60 Hz single phase mains supply.

**Test Setup Diagrams****Conducted Tests:****Test Setup for Transmitter Conducted Tests (non TxBF)****Test Setup for Transmitter Conducted Tests (TxBF)**

**Radiated Tests:****Test Setup for Transmitter Radiated Emissions (non TXBF)**

**Radiated Tests (continued):****Test Setup for Transmitter Radiated Emissions (non TXBF) (continued)****Test Setup for Transmitter Radiated Emissions (TXBF)**

## **4. Antenna Port Test Results**

### **4.1. Transmitter Minimum 6 dB Bandwidth**

#### **Test Summary:**

<b>Test Engineer:</b>	Max Passell	<b>Test Date:</b>	11 April 2018
<b>Test Sample Serial Number:</b>	C02VQ00SJKHY		

<b>FCC Reference:</b>	Part 15.247(a)(2)
<b>Test Method Used:</b>	FCC KDB 558074 Section 8.1

#### **Environmental Conditions:**

<b>Temperature (°C):</b>	24
<b>Relative Humidity (%):</b>	42

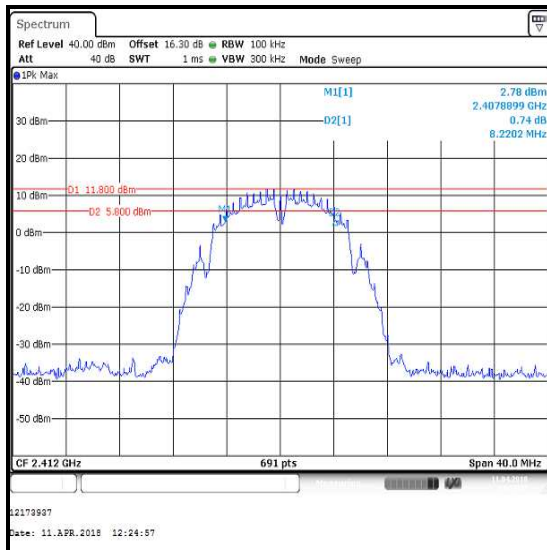
#### **Note(s):**

1. The customer declared the following data rates to be used for all measurements as:
  - 802.11b – DBPSK / 1 Mbps / Port WF2
  - 802.11g – BPSK / 6 Mbps / Port WF2
  - 802.11n HT20 – BPSK / MCS0 / Port WF2

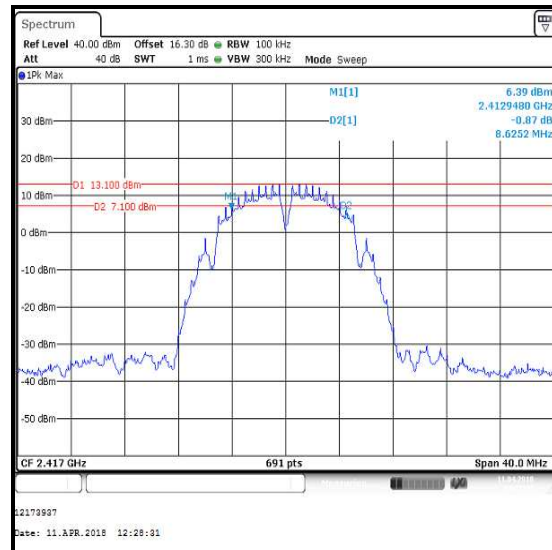
Only SISO modes are reported since the bandwidth does not change depending on the number of chains used.
2. Final measurements were performed using the above configurations on the relevant channels in accordance with KDB 558074 Section 8.1 Option 1 measurement procedure. Additional channels were tested as requested by the customer. The signal analyser resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold. The span was set to 40 MHz. The DTS bandwidth was measured at 6 dB down from the peak of the signal.
3. The signal analyser was connected to the RF port on the EUT using an RF switch, suitable attenuation and RF cables. An RF offset was entered on the signal analyser to compensate for the loss of the switch, attenuator and RF cables.

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Port WF2**

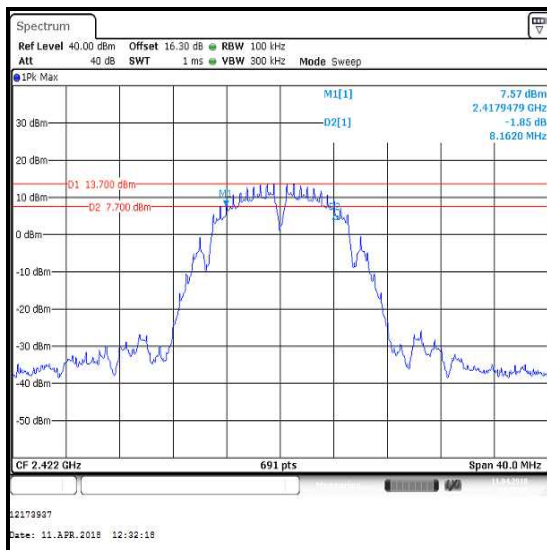
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	8220	≥500	7720	Complied
2	8625	≥500	8125	Complied
3	8162	≥500	7662	Complied
6	8220	≥500	7720	Complied
7	8625	≥500	8125	Complied
11	8162	≥500	7662	Complied
12	8162	≥500	7662	Complied
13	8220	≥500	7720	Complied

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Port WF2**

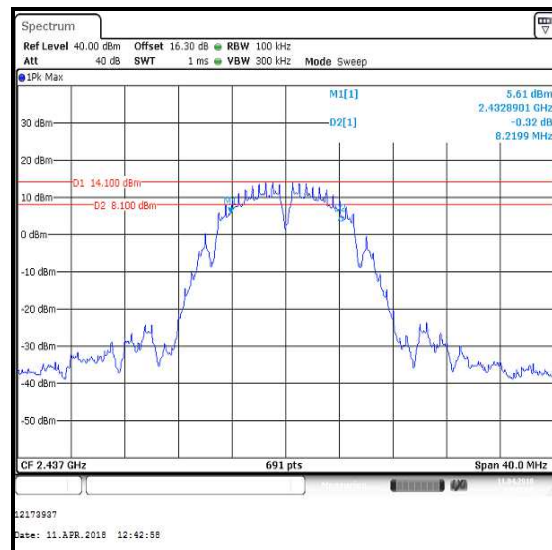
Channel 1



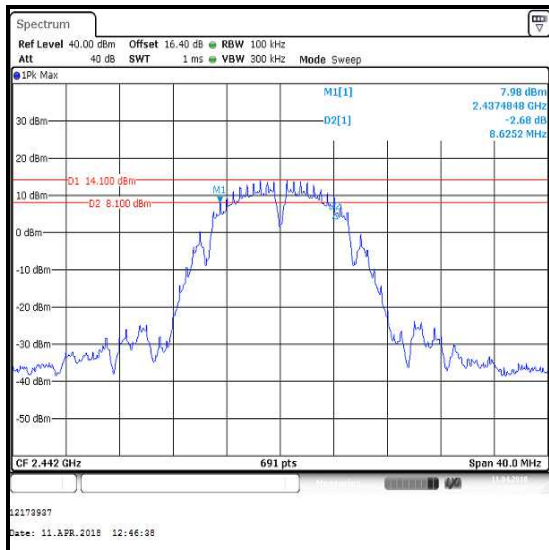
Channel 2



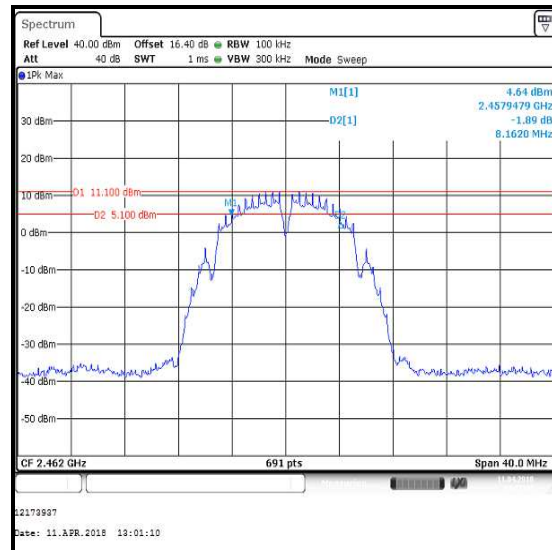
Channel 3



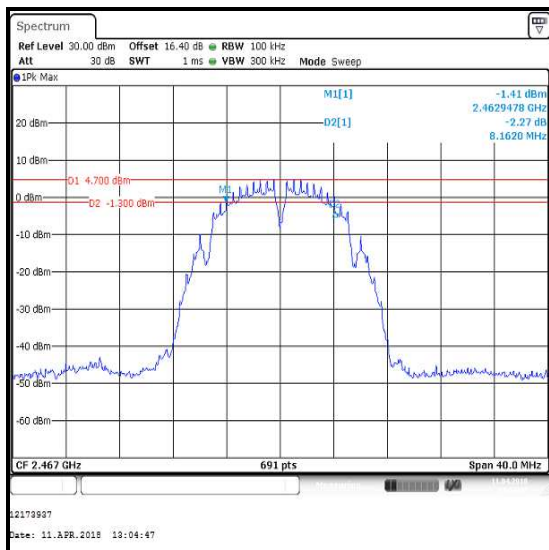
Channel 6

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Port WF2**

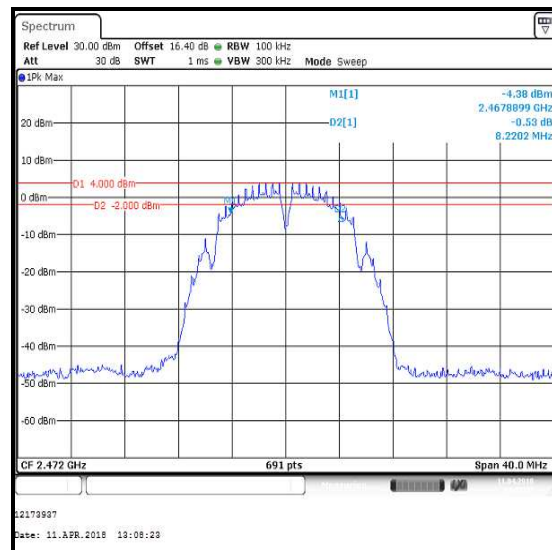
Channel 7



Channel 11



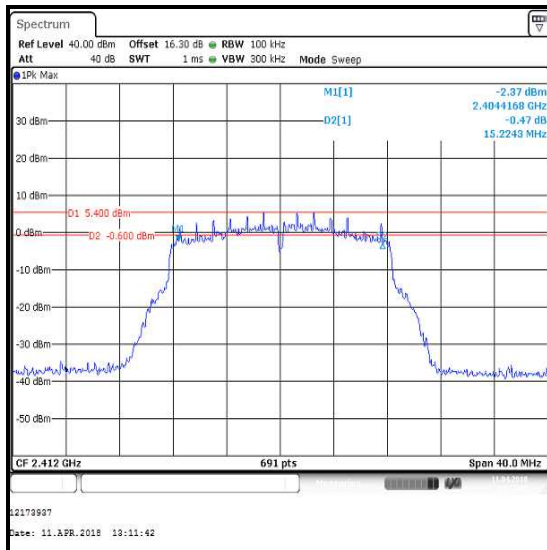
Channel 12



Channel 13

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Port WF2**

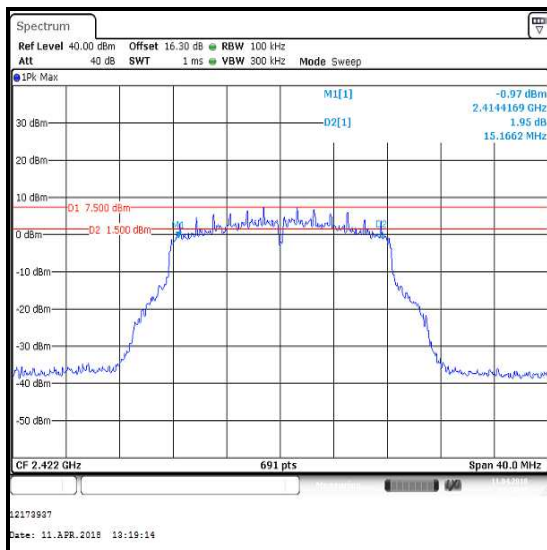
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	15224	≥500	14724	Complied
2	15224	≥500	14724	Complied
3	15166	≥500	14666	Complied
6	15167	≥500	14667	Complied
7	15224	≥500	14724	Complied
11	15224	≥500	14724	Complied
12	15224	≥500	14724	Complied
13	15167	≥500	14667	Complied

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11g / 20 MHz BPSK / 6 Mbps / Port WF2**

Channel 1



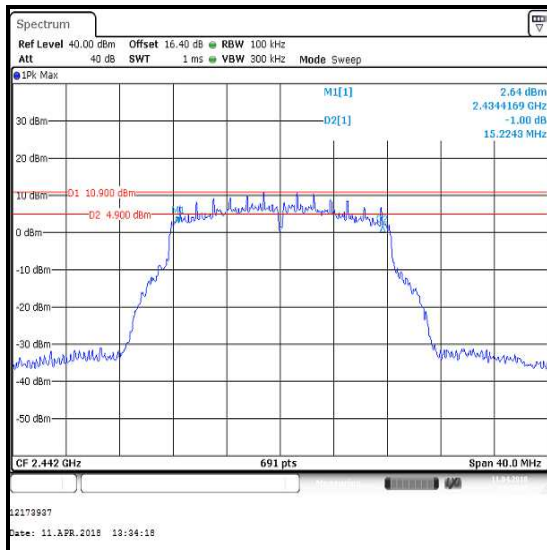
Channel 2



Channel 3



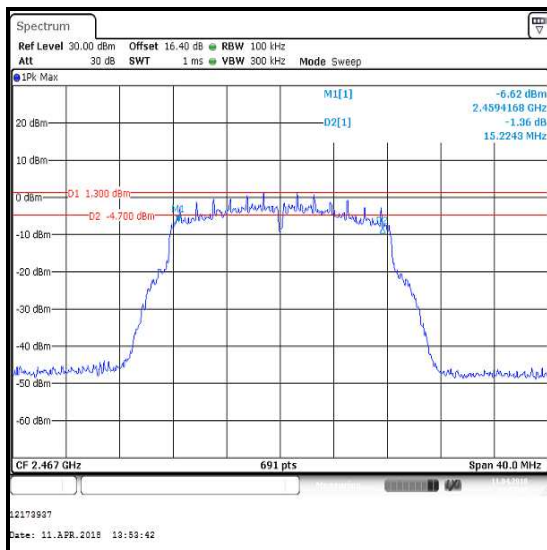
Channel 6

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Port WF2**

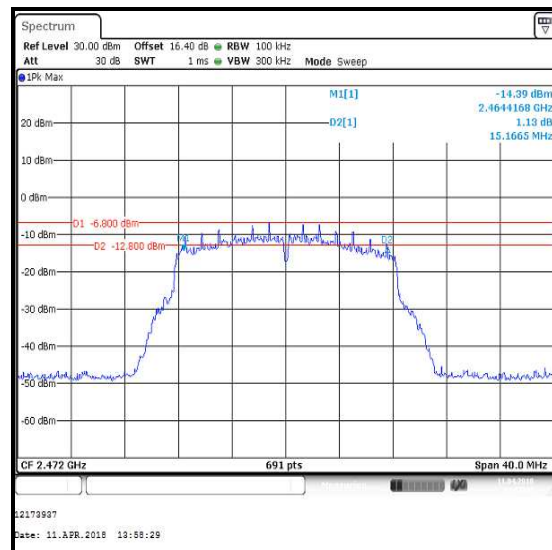
Channel 7



Channel 11



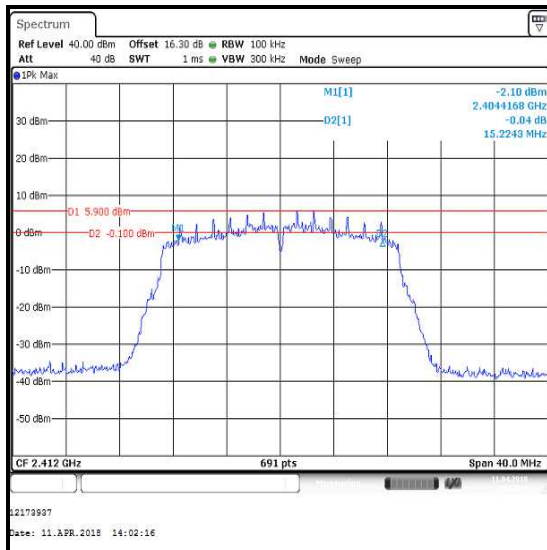
Channel 12



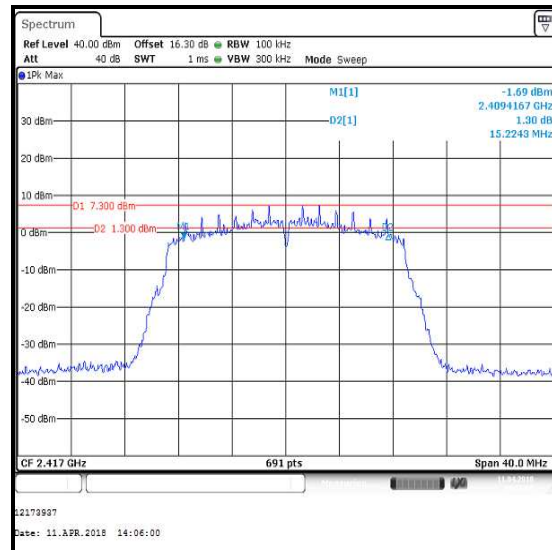
Channel 13

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Port WF2**

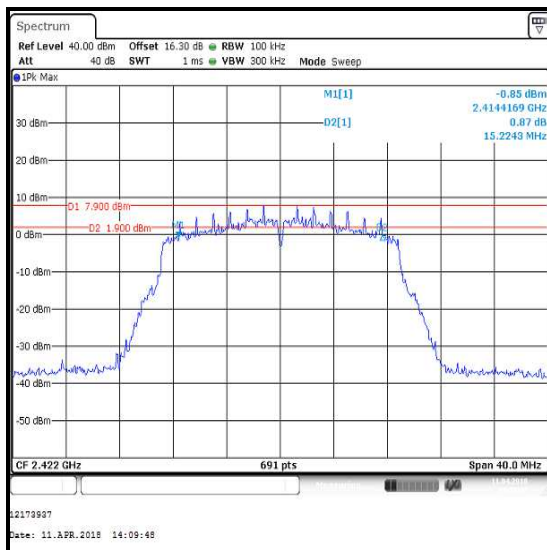
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	15224	≥500	14724	Complied
2	15224	≥500	14724	Complied
3	15224	≥500	14724	Complied
6	15167	≥500	14667	Complied
7	15224	≥500	14724	Complied
11	15224	≥500	14724	Complied
12	15224	≥500	14724	Complied
13	15167	≥500	14667	Complied

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Port WF2**

Channel 1



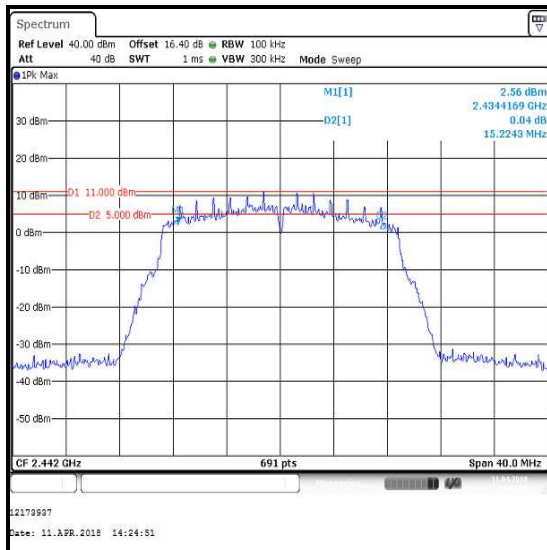
Channel 2



Channel 3



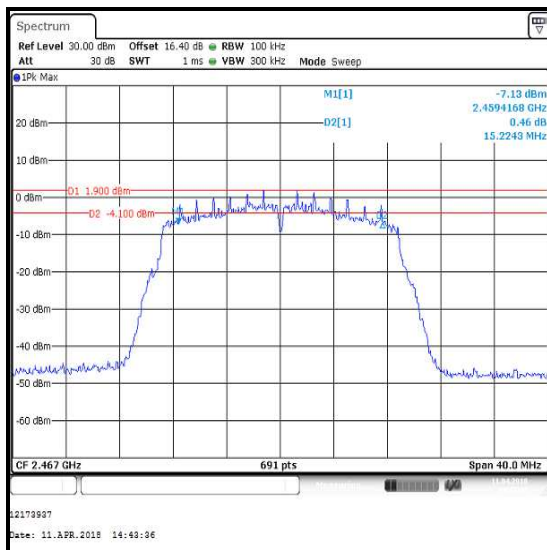
Channel 6

**Transmitter Minimum 6 dB Bandwidth (continued)****Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Port WF2**

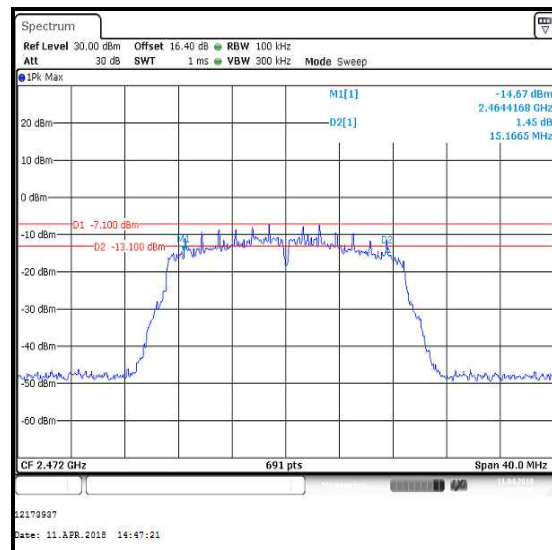
Channel 7



Channel 11



Channel 12



Channel 13

**4.2. Transmitter Power Spectral Density****Test Summary:**

<b>Test Engineers:</b>	Max Passell & Stefan Ho	<b>Test Dates:</b>	11 April 2018 to 17 May 2018
<b>Test Sample Serial Numbers:</b>	C02VQ00SJKHY & C02W6004JH90		

<b>FCC Reference:</b>	Part 15.247(e)
<b>Test Method Used:</b>	FCC KDB 558074 Section 10.3

**Environmental Conditions:**

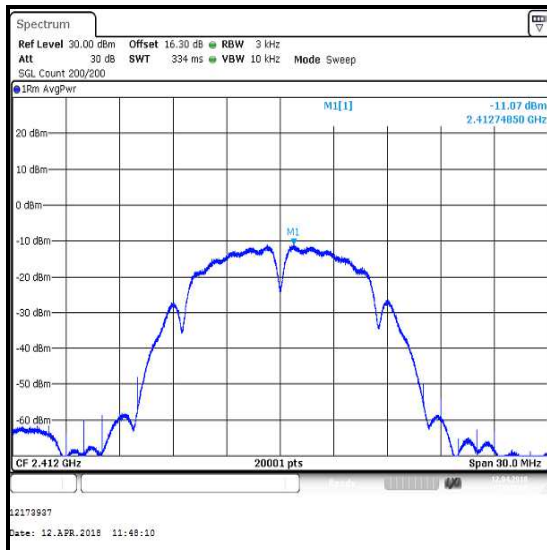
<b>Temperature (°C):</b>	22 to 24
<b>Relative Humidity (%):</b>	35 to 42

**Transmitter Power Spectral Density (continued)****Note(s):**

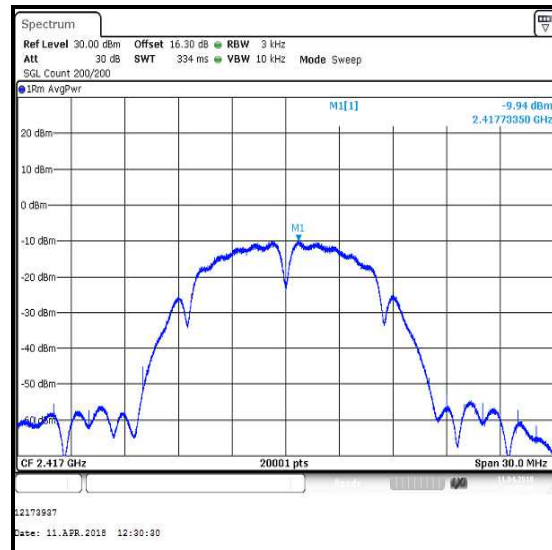
1. The customer declared the following data rates to be used for all measurements as:
  - 802.11b – DBPSK / 1 Mbps / Port WF2
  - 802.11g – BPSK / 6 Mbps / Port WF2
  - 802.11n HT20 – BPSK / MCS0 / Port WF2
  - 802.11b – DBPSK / 1 Mbps / MIMO / 2Tx CDD / Ports WF1 & WF2
  - 802.11b – DBPSK / 1 Mbps / MIMO / 3Tx CDD / Ports WF1, WF2 & WF3
  - 802.11n HT20 / MIMO / 2Tx CDD / BPSK / MCS0 / Ports WF1 & WF2
  - 802.11n HT20 / MIMO / 3Tx CDD / BPSK / MCS0 / Ports WF1, WF2 & WF3
  - 802.11n HT20 / MIMO / 2Tx TxBF / BPSK / MCS0 / Ports WF1 & WF2
  - 802.11n HT20 / MIMO / 3Tx TxBF / BPSK / MCS0 / Ports WF1, WF2 & WF3
2. Final measurements were performed using the above configurations on the relevant channels. Additional channels were tested as requested by the customer.
3. For non-TxBF modes, the EUT was transmitting at >98% duty cycle and testing was performed in accordance with KDB 558074 Section 10.3 Method AVGPS-1. The signal analyser resolution bandwidth was set to 3 kHz and video bandwidth 10 kHz. An RMS detector was used and sweep time set manually to perform trace averaging over 200 traces. The span was set greater than 1.5 times the 99% emission bandwidth. The highest peak of the measured signal was recorded.
4. For TxBF modes, the EUT was transmitting at >98% duty cycle and testing was performed in accordance with KDB 558074 Section 10.3 Method AVGPS-1. The signal analyser resolution bandwidth was set to 10 kHz and video bandwidth 30 kHz. An RMS detector was used and sweep time set manually to perform trace averaging over 200 traces. The span was set greater than 1.5 times the 99% emission bandwidth. The highest peak of the measured signal was recorded.
5. For 802.11b & 802.11n MIMO CDD, PSD was measured on all ports and then combined using the *measure and sum the spectra across the outputs* technique, stated in FCC KDB 662911 D01 Section E)2)a).
6. For 802.11n MIMO TxBF, PSD was measured on all ports and then combined using the *measure and sum spectral maxima across the outputs* technique, stated in FCC KDB 662911 D01 Section E)2)b).
7. The signal analyser was connected to the RF port on the EUT using an RF switch, suitable attenuation and RF cables. An RF offset was entered on the signal analyser to compensate for the loss of the switch, attenuator and RF cables.
8. The EUT with serial number C02VQ00SJKHY was used for non-TxBF tests, the EUT with serial number C02W6004JH90 was used for TxBF tests.

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Port WF2**

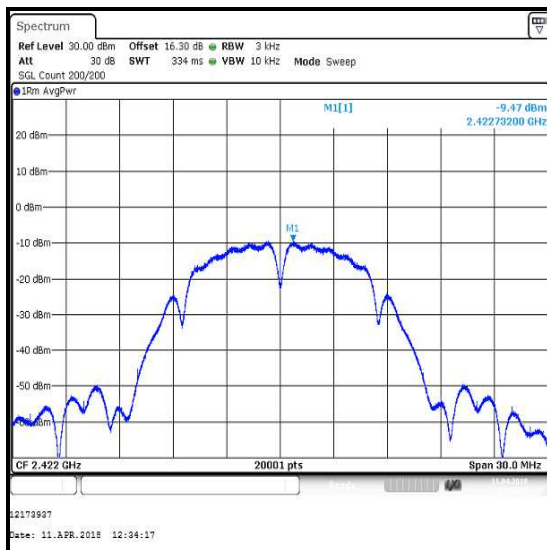
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
1	-11.1	8.0	19.1	Complied
2	-9.9	8.0	17.9	Complied
3	-9.5	8.0	17.5	Complied
6	-9.2	8.0	17.2	Complied
7	-9.1	8.0	17.1	Complied
11	-12.0	8.0	20.0	Complied
12	-18.4	8.0	26.4	Complied
13	-19.2	8.0	27.2	Complied

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Port WF2**

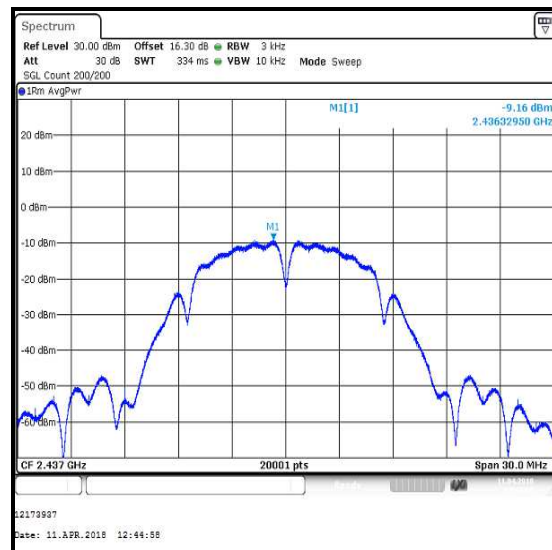
Channel 1



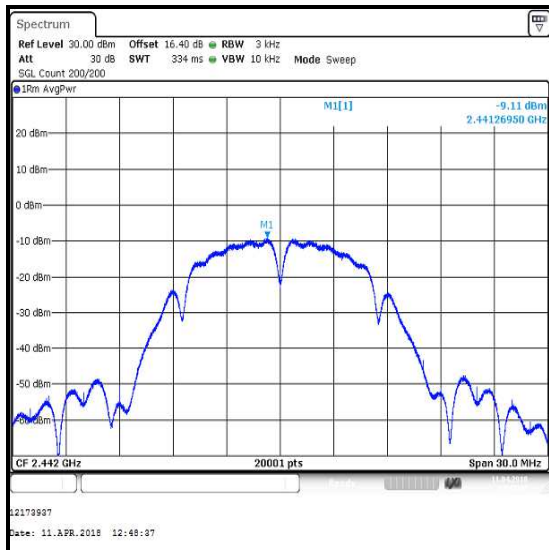
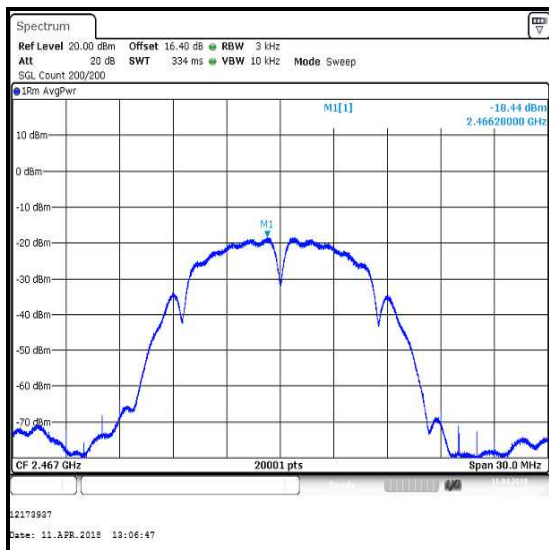
Channel 2



Channel 3

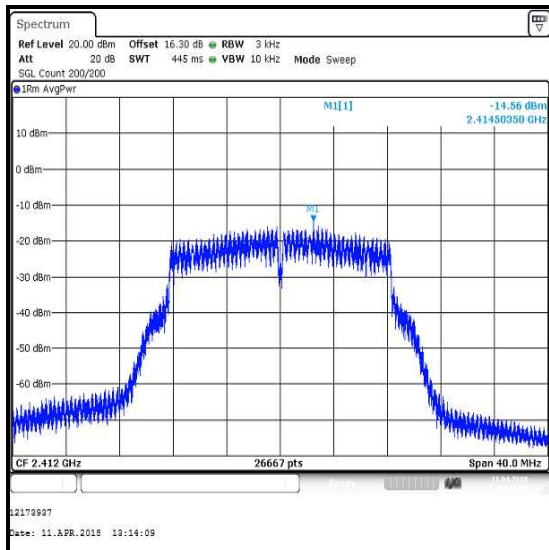


Channel 6

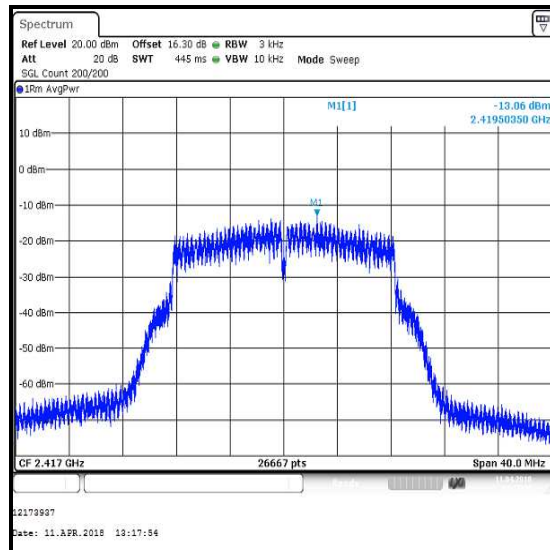
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Port WF2****Channel 7****Channel 11****Channel 12****Channel 13**

**Transmitter Power Spectral Density (continued)****Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Port WF2**

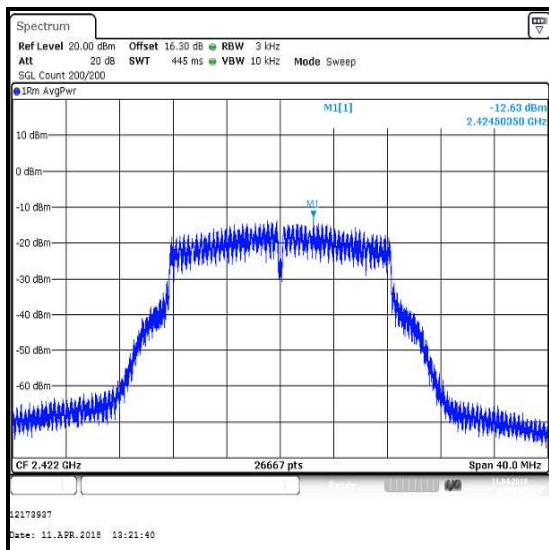
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Result
1	-14.6	8.0	22.6	Complied
2	-13.1	8.0	21.1	Complied
3	-12.6	8.0	20.6	Complied
6	-7.6	8.0	15.6	Complied
7	-9.5	8.0	17.5	Complied
11	-15.4	8.0	23.4	Complied
12	-18.7	8.0	26.7	Complied
13	-27.2	8.0	35.2	Complied

**Transmitter Power Spectral Density (continued)****Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Port WF2**

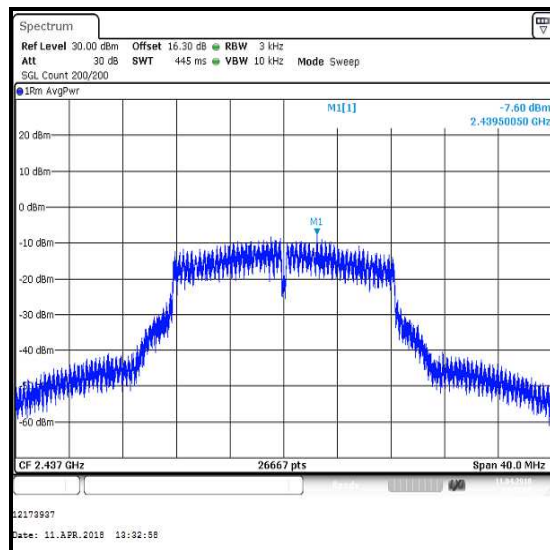
Channel 1



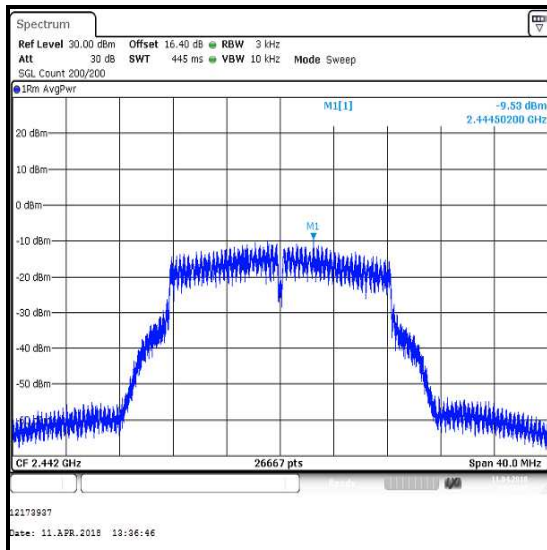
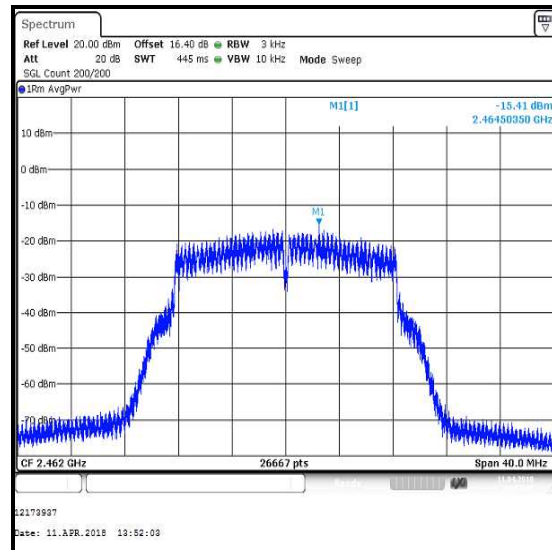
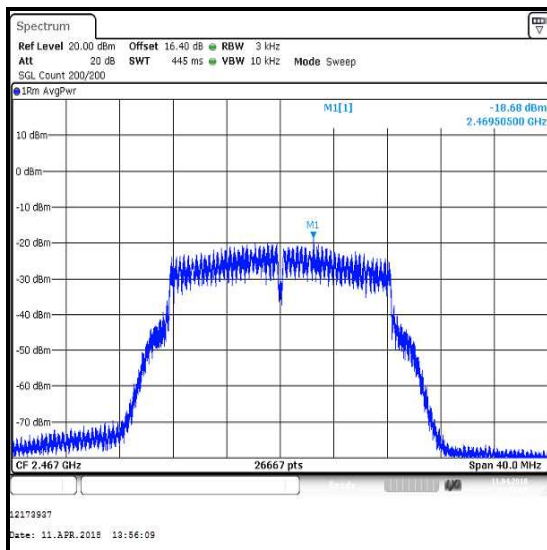
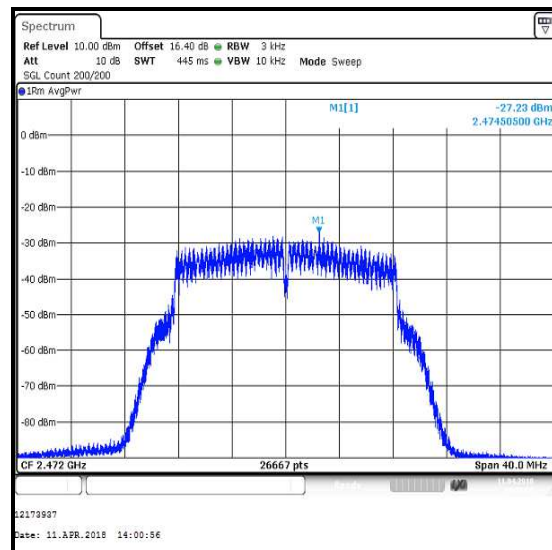
Channel 2



Channel 3

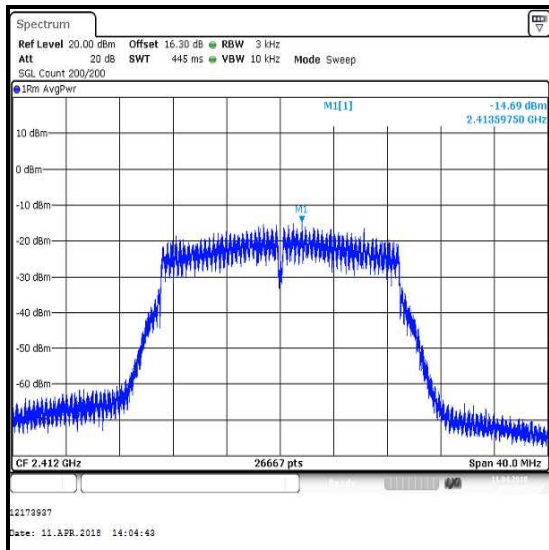
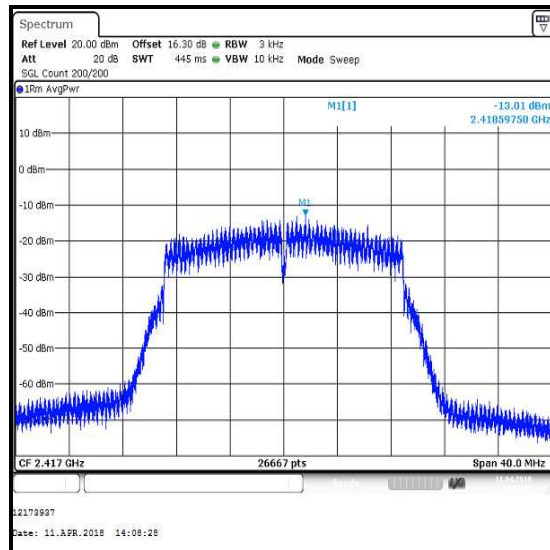
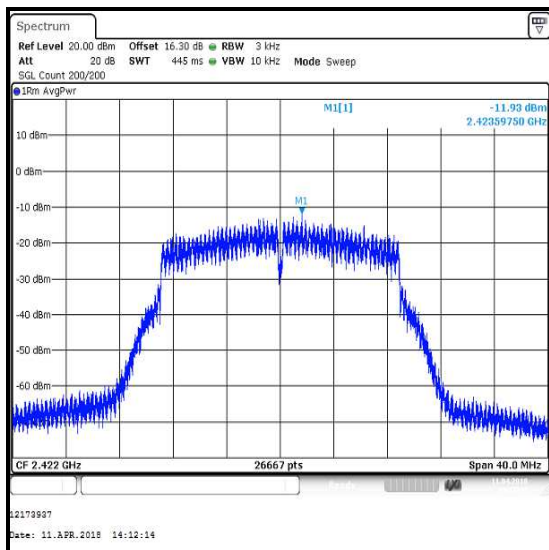
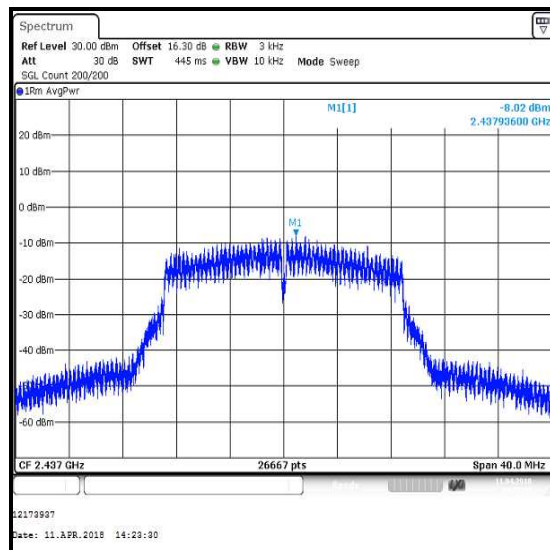


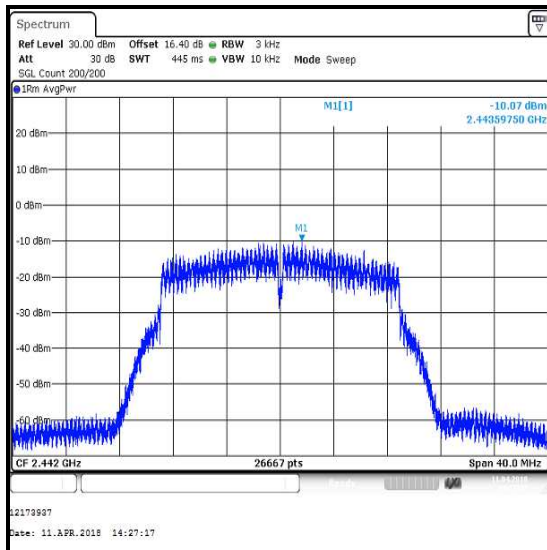
Channel 6

**Transmitter Power Spectral Density (continued)****Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Port WF2****Channel 7****Channel 11****Channel 12****Channel 13**

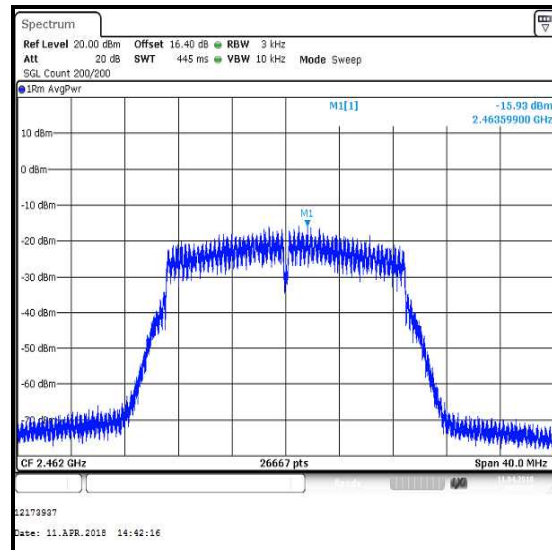
**Transmitter Power Spectral Density (continued)****Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Port WF2**

Channel	Output Power (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Result
1	-14.7	8.0	22.7	Complied
2	-13.0	8.0	21.0	Complied
3	-11.9	8.0	19.9	Complied
6	-8.0	8.0	16.0	Complied
7	-10.1	8.0	18.1	Complied
11	-15.9	8.0	23.9	Complied
12	-18.7	8.0	26.7	Complied
13	-27.8	8.0	35.8	Complied

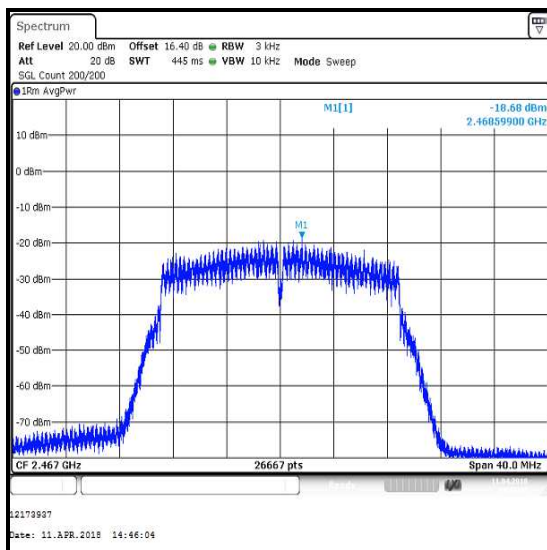
**Transmitter Power Spectral Density (continued)****Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Port WF2****Channel 1****Channel 2****Channel 3****Channel 6**

**Transmitter Power Spectral Density (continued)****Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Port WF2**

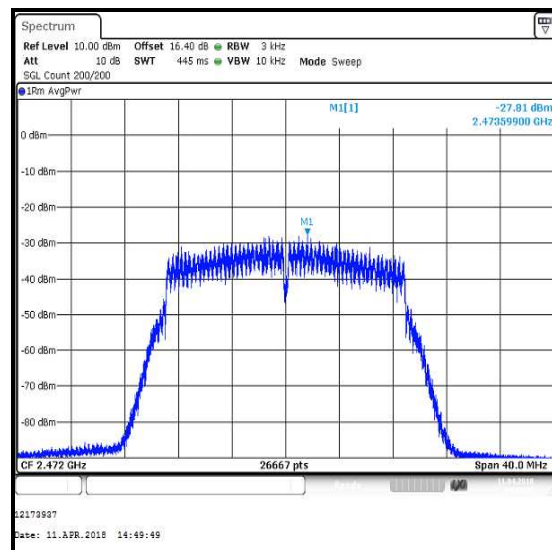
Channel 7



Channel 11



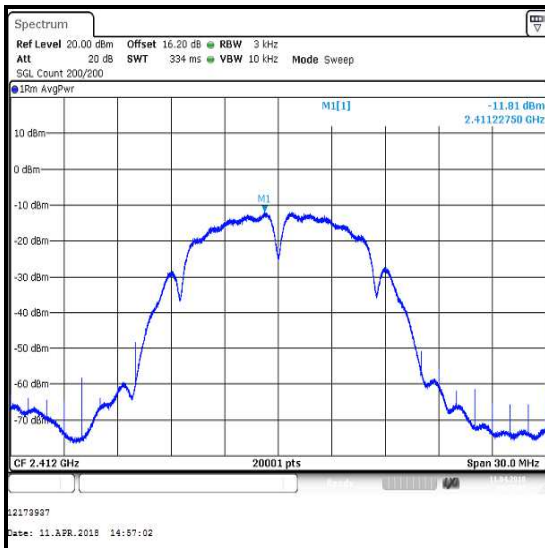
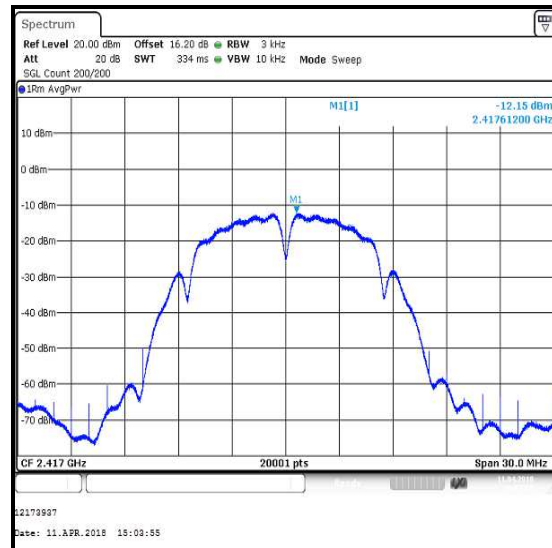
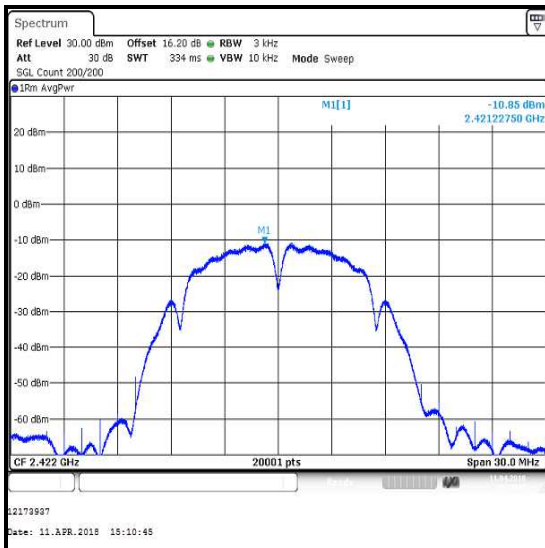
Channel 12

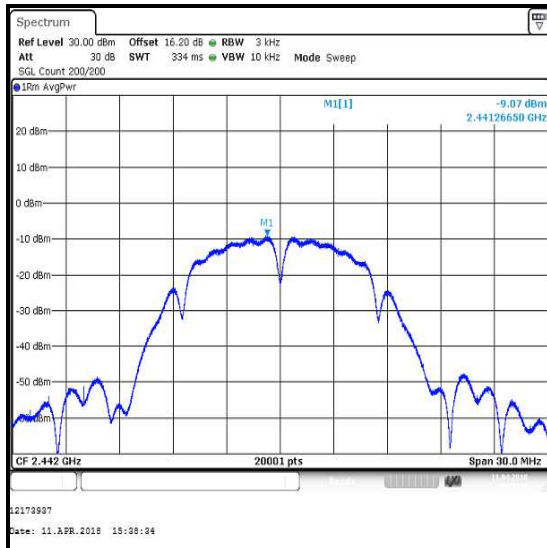
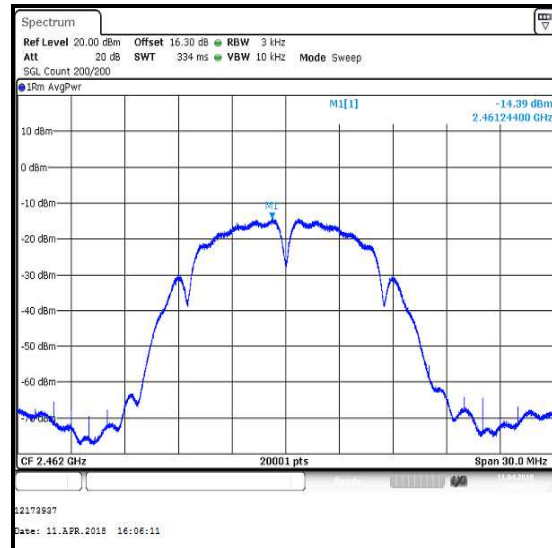
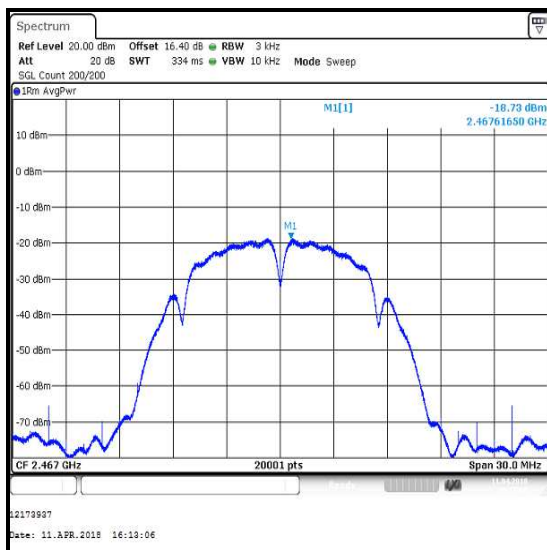
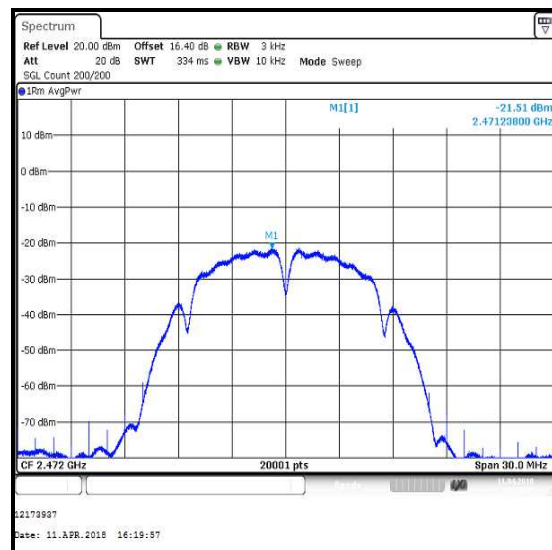


Channel 13

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps**

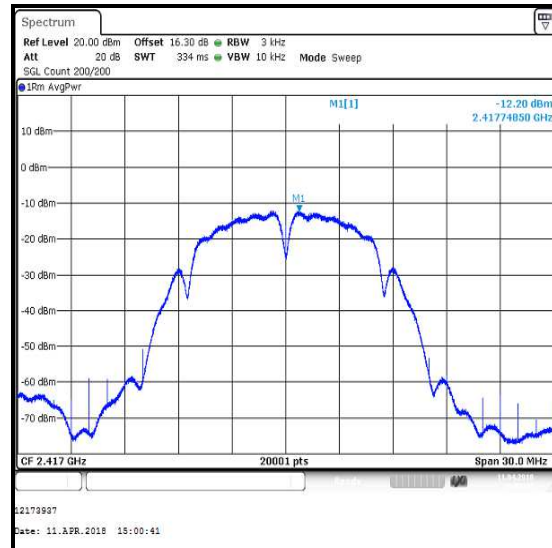
Channel	PSD at Port WF1 (dBm / 3 kHz)	PSD at Port WF2 (dBm / 3 kHz)	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-11.8	-12.0	-9.1	8.0	17.1	Complied
2	-12.2	-12.2	-9.3	8.0	17.3	Complied
3	-10.8	-10.8	-7.9	8.0	15.9	Complied
6	-9.4	-9.5	-6.5	8.0	14.5	Complied
7	-9.1	-9.1	-6.1	8.0	14.1	Complied
11	-14.4	-14.2	-11.4	8.0	19.4	Complied
-12	-18.7	-18.7	-15.8	8.0	23.8	Complied
1	-21.5	-21.2	-18.5	8.0	26.5	Complied

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Port WF1****Channel 1****Channel 2****Channel 3****Channel 6**

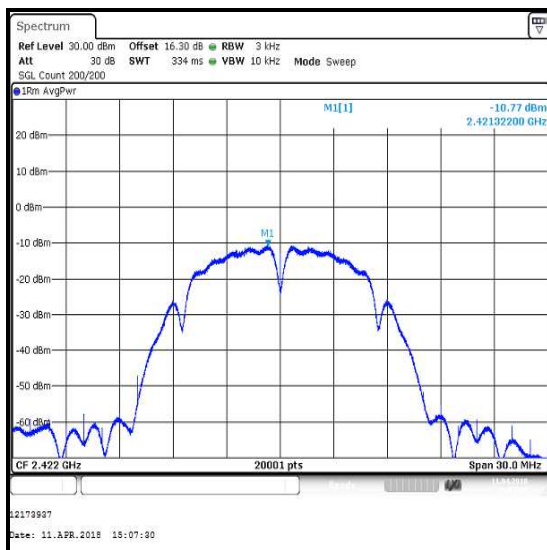
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Port WF1****Channel 7****Channel 11****Channel 12****Channel 13**

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Port WF2**

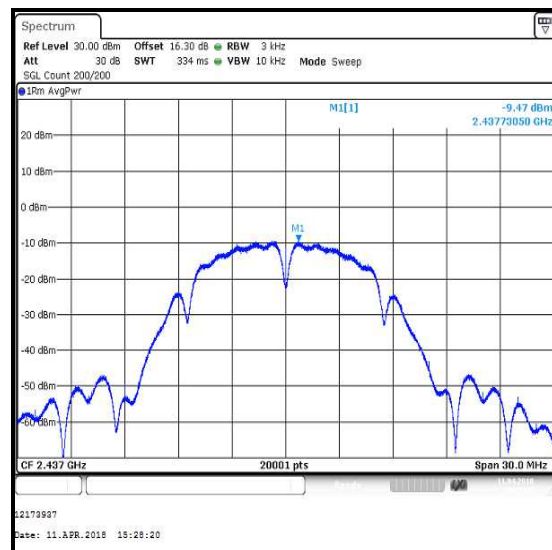
Channel 1



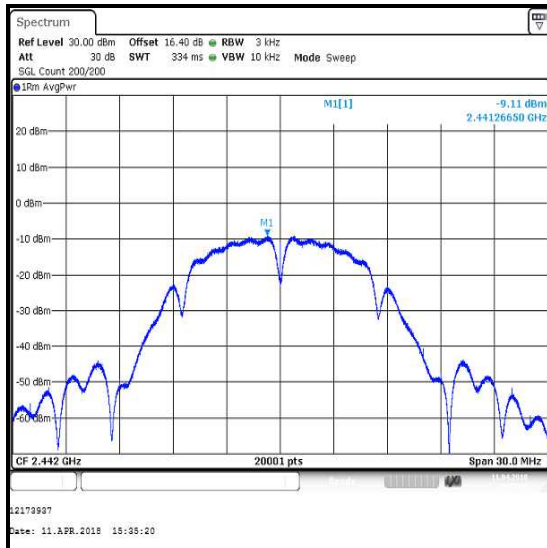
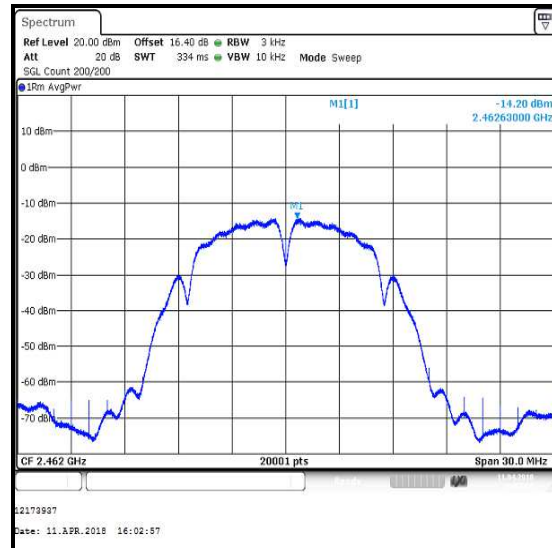
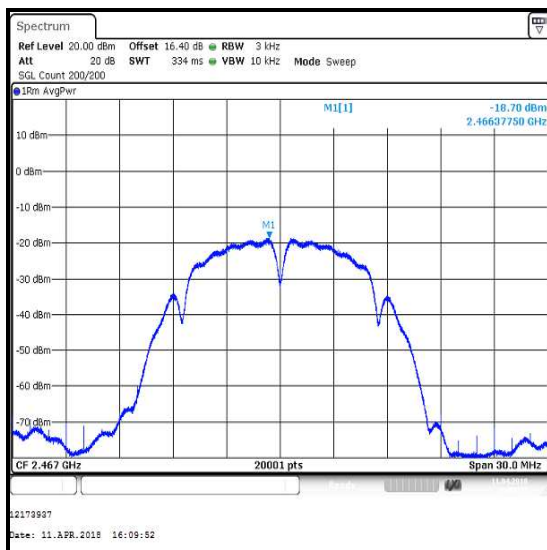
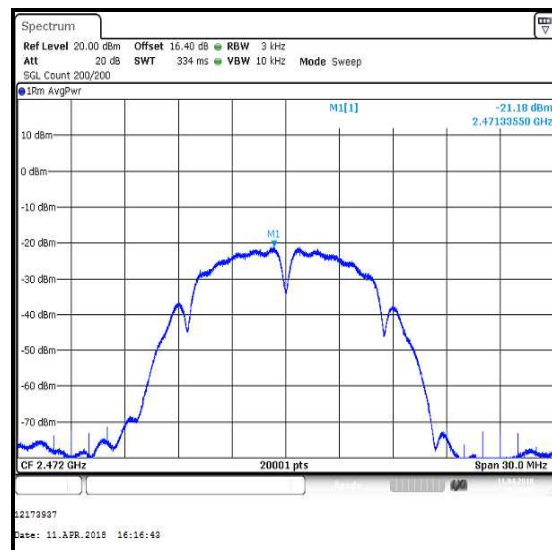
Channel 2



Channel 3



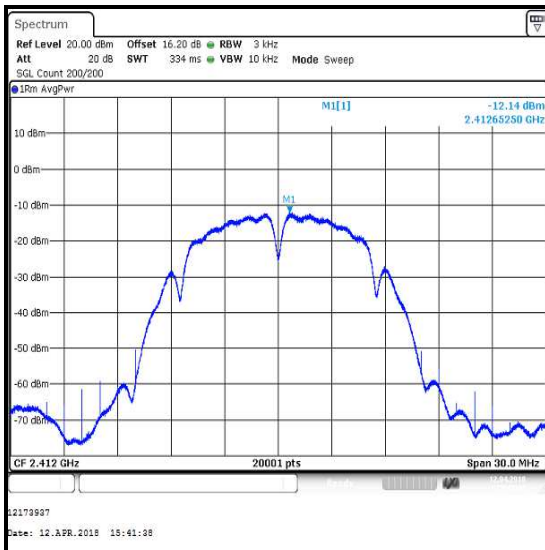
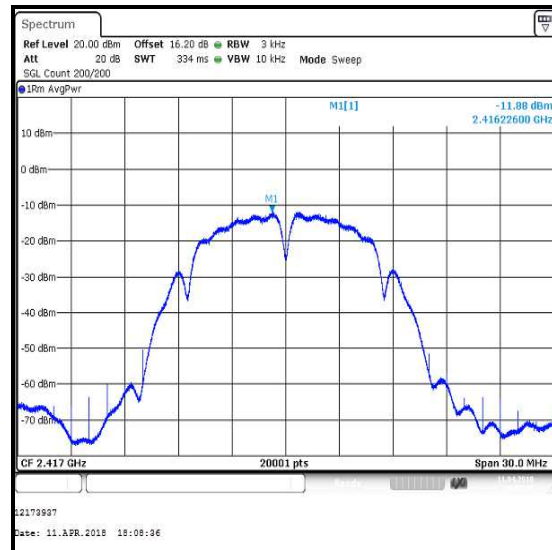
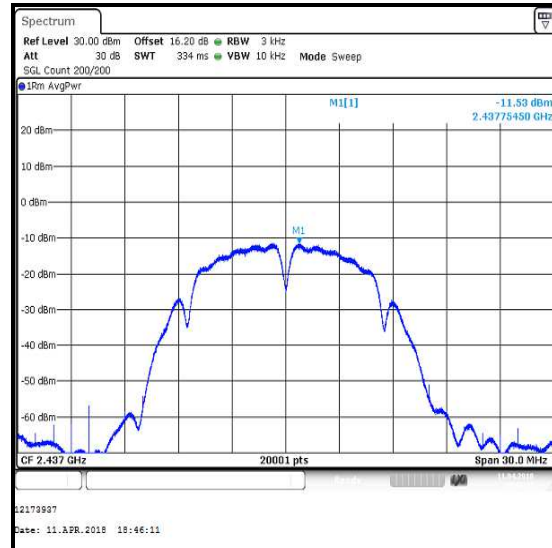
Channel 6

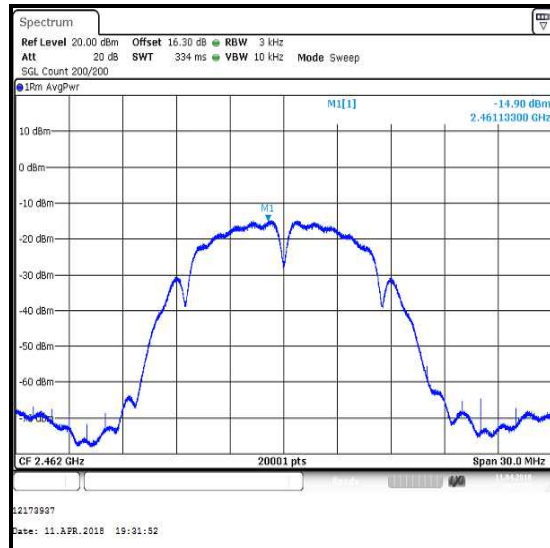
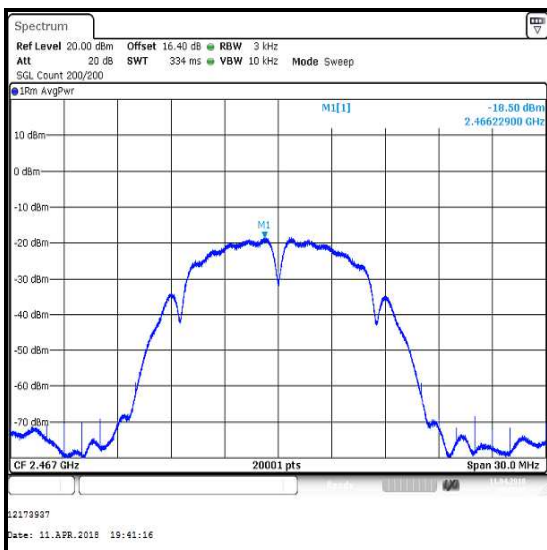
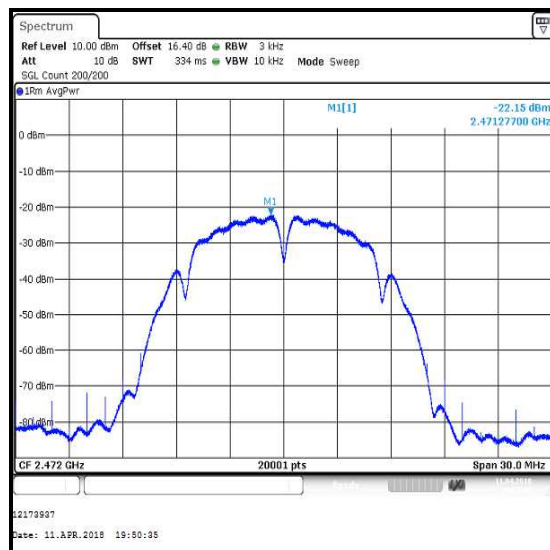
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Port WF2****Channel 7****Channel 11****Channel 12****Channel 13**

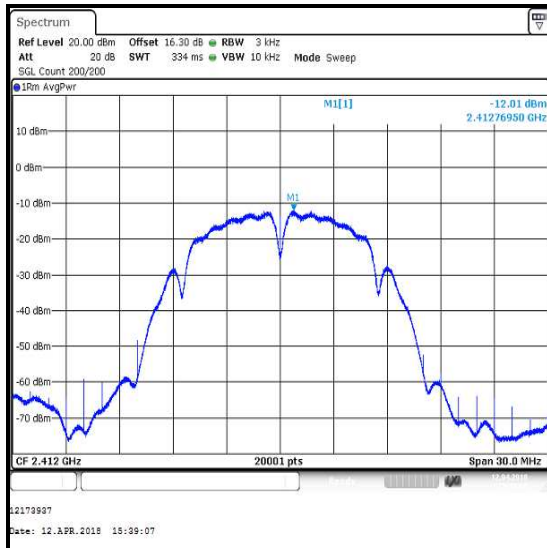
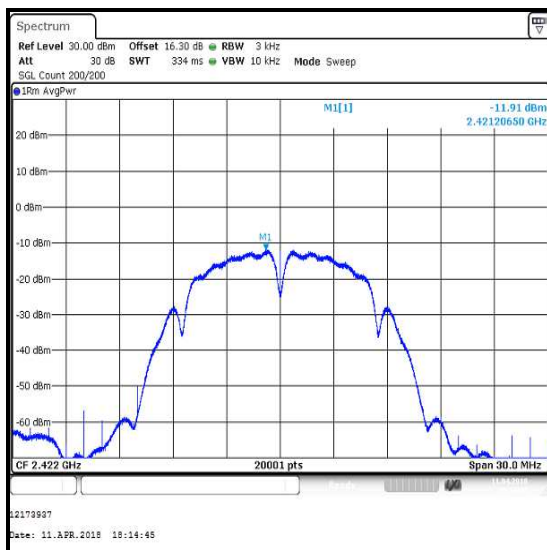
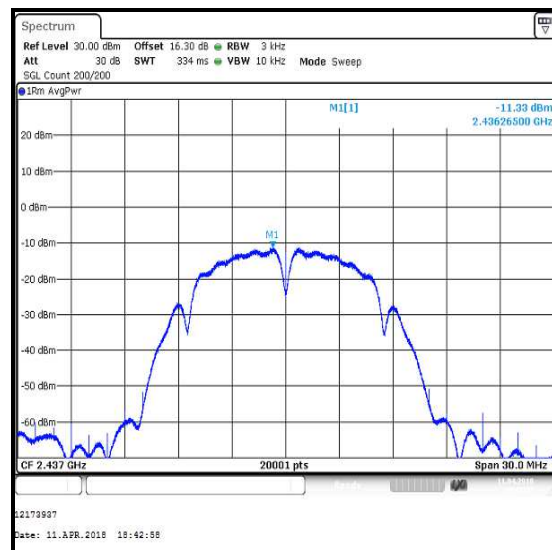
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps**

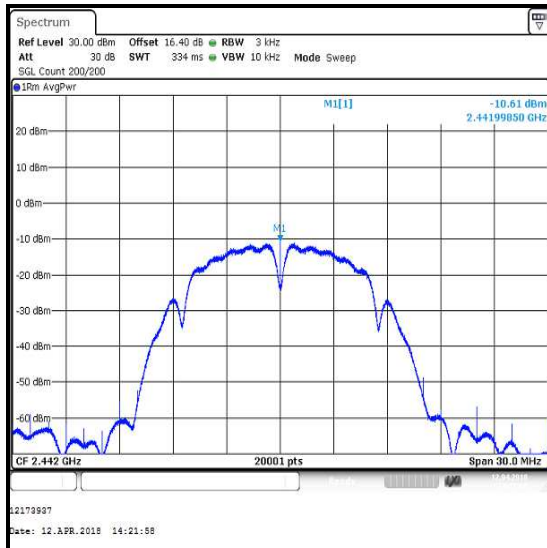
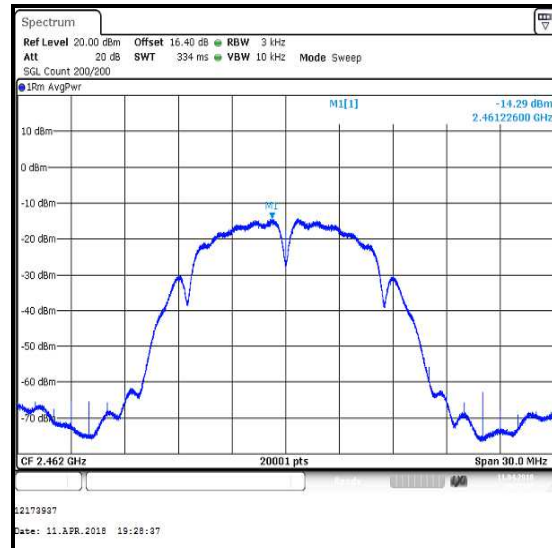
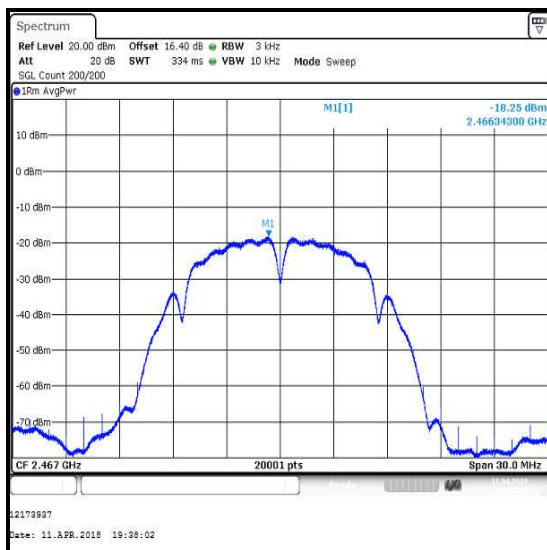
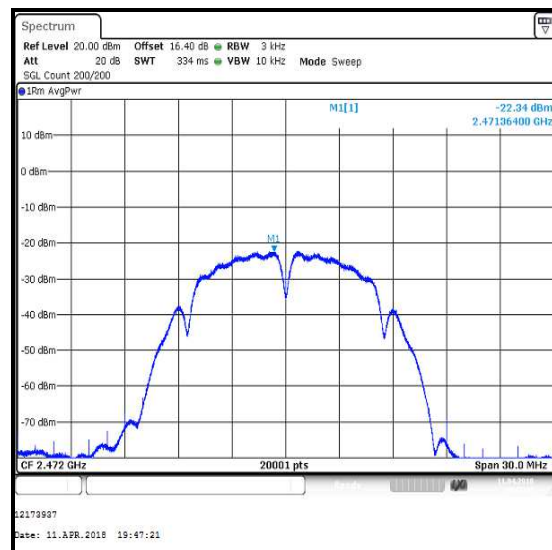
Channel	PSD on Port WF1 (dBm / 3 kHz)	PSD on Port WF2 (dBm / 3 kHz)	PSD on Port WF3 (dBm / 3 kHz)
1	-12.1	-12.0	-12.1
2	-11.9	-12.3	-12.1
3	-12.1	-11.9	-12.2
6	-11.5	-11.3	-11.7
7	-11.7	-10.6	-11.8
11	-14.9	-14.3	-14.5
12	-18.5	-18.3	-18.3
13	-22.2	-22.3	-22.2

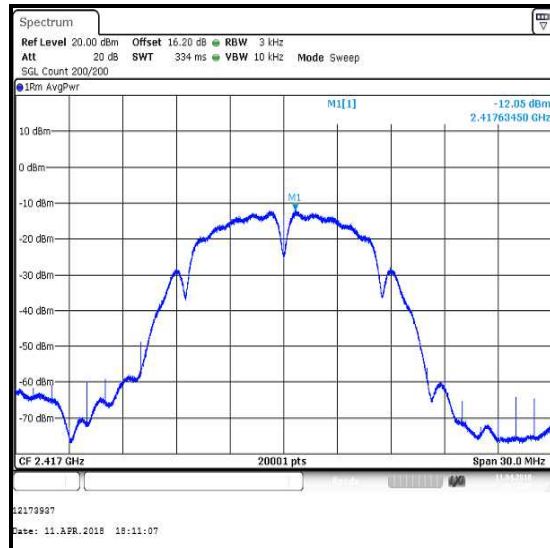
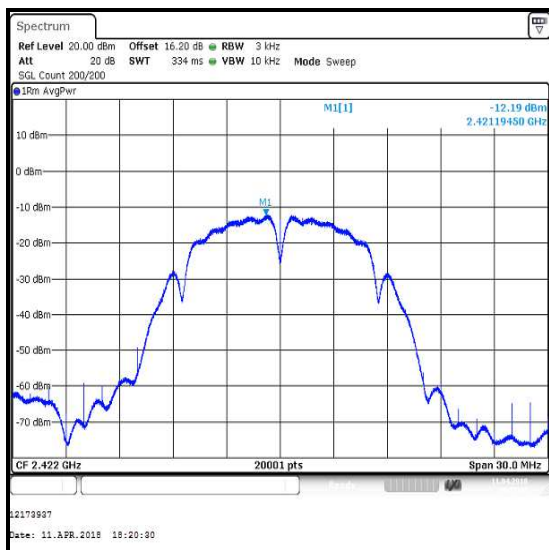
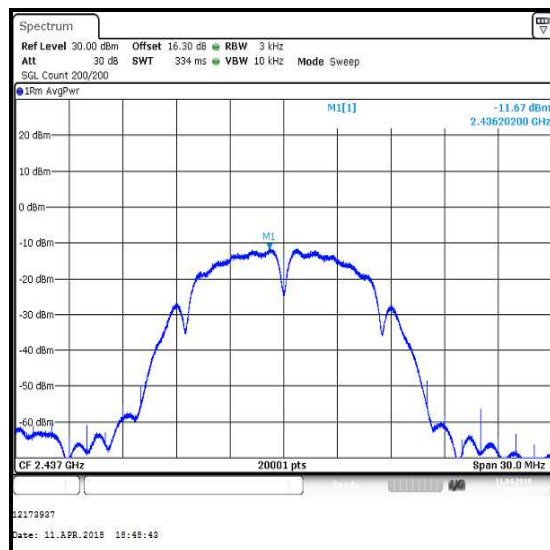
Channel	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-7.6	8.0	15.6	Complied
2	-7.5	8.0	15.5	Complied
3	-7.5	8.0	15.5	Complied
6	-6.9	8.0	14.9	Complied
7	-7.0	8.0	15.0	Complied
11	-10.0	8.0	18.0	Complied
12	-13.7	8.0	21.7	Complied
13	-17.6	8.0	25.6	Complied

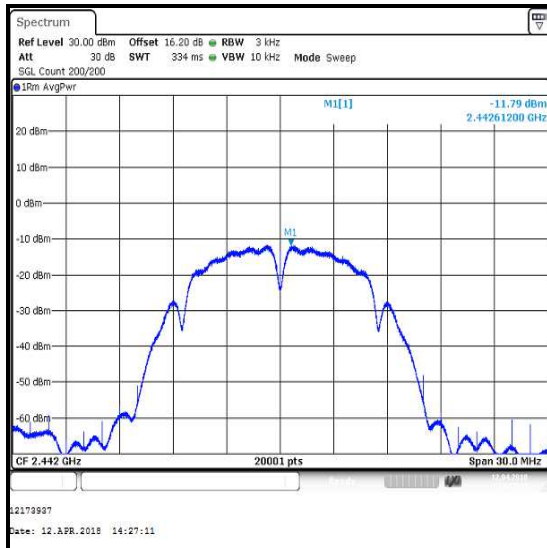
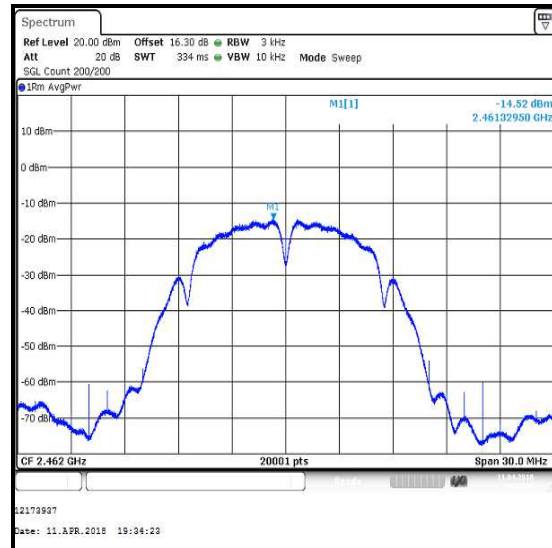
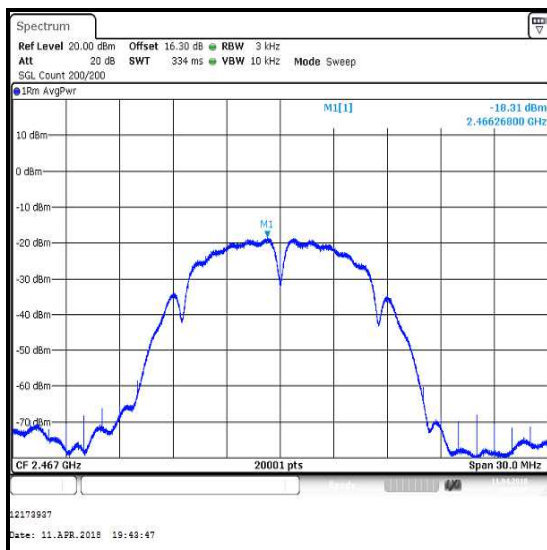
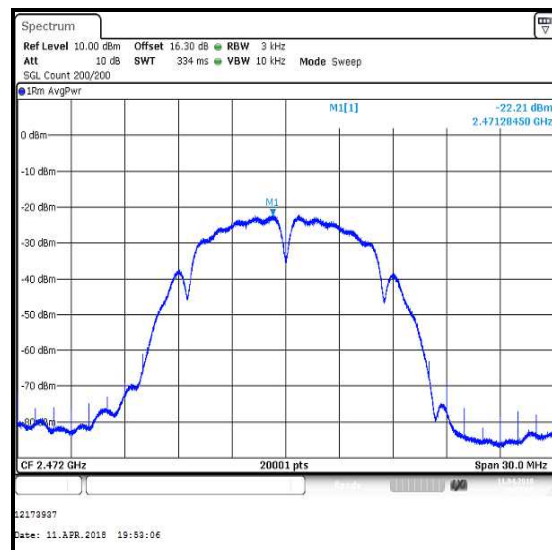
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Port WF1****Channel 1****Channel 2****Channel 3****Channel 6**

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Port WF1****Channel 7****Channel 11****Channel 12****Channel 13**

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Port WF2****Channel 1****Channel 2****Channel 3****Channel 6**

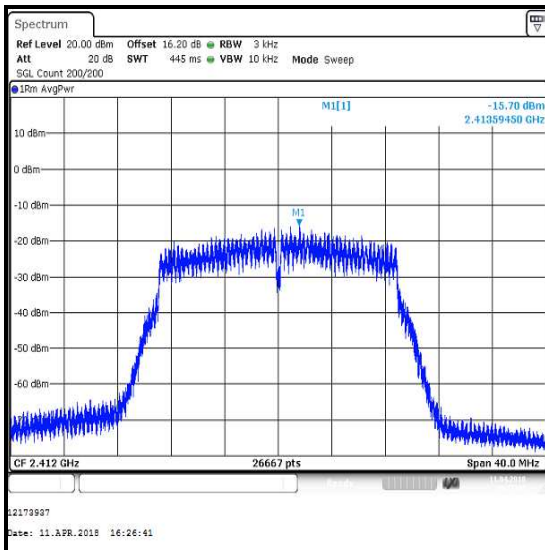
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Port WF2****Channel 7****Channel 11****Channel 12****Channel 13**

**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Port WF3****Channel 1****Channel 2****Channel 3****Channel 6**

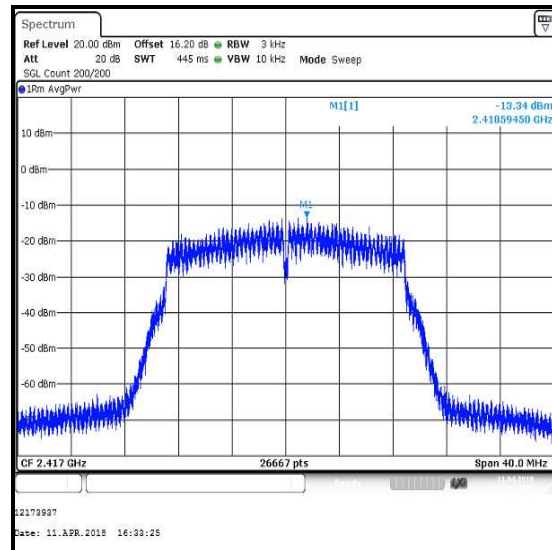
**Transmitter Power Spectral Density (continued)****Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Port WF3****Channel 7****Channel 11****Channel 12****Channel 13**

**Transmitter Power Spectral Density (continued)****Results: 802.11n / HT20 / MIMO / 2Tx CDD / BPSK / MCS0**

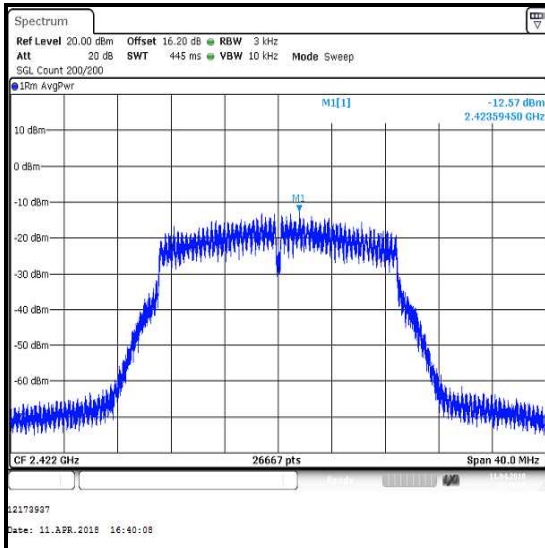
Channel	PSD at Port WF1 (dBm / 3 kHz)	PSD at Port WF2 (dBm / 3 kHz)	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-15.7	-15.7	-12.7	8.0	20.7	Complied
2	-13.3	-13.0	-10.2	8.0	18.2	Complied
3	-12.6	-12.9	-9.9	8.0	17.9	Complied
6	-8.2	-8.1	-5.2	8.0	13.2	Complied
7	-10.4	-9.9	-7.2	8.0	15.2	Complied
11	-18.4	-17.5	-14.9	8.0	22.9	Complied
12	-19.4	-19.9	-16.7	8.0	24.7	Complied
13	-31.2	-30.7	-27.9	8.0	35.9	Complied

**Transmitter Power Spectral Density (continued)****Results: 802.11n / HT20 / MIMO / 2Tx CDD / BPSK / MCS0 / Port WF1**

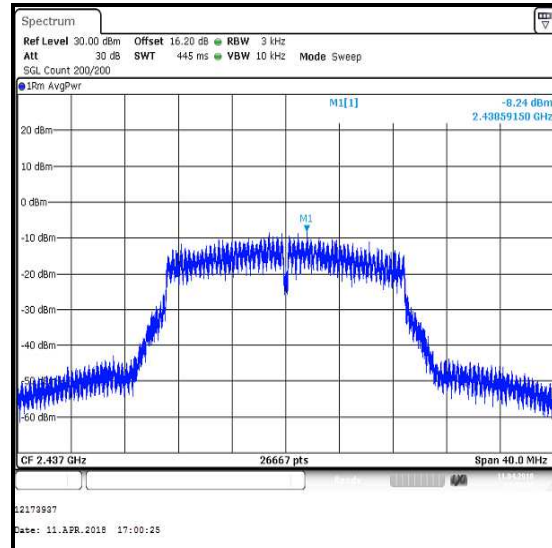
Channel 1



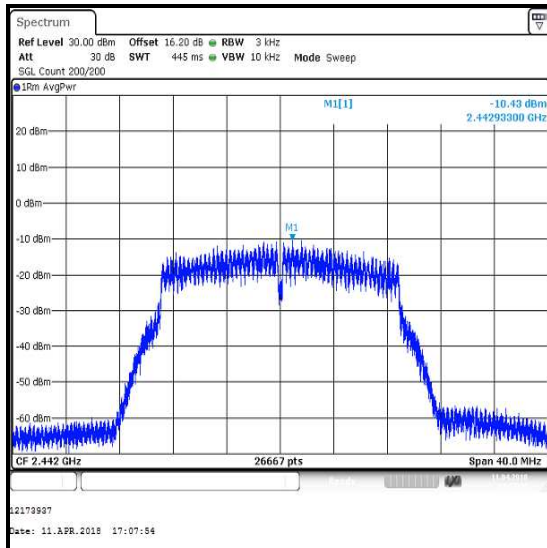
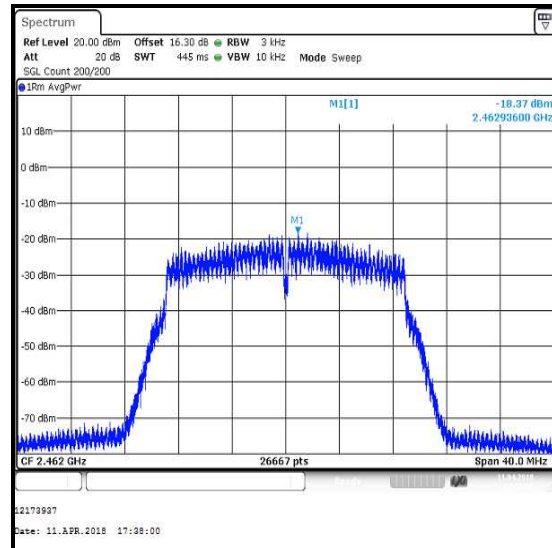
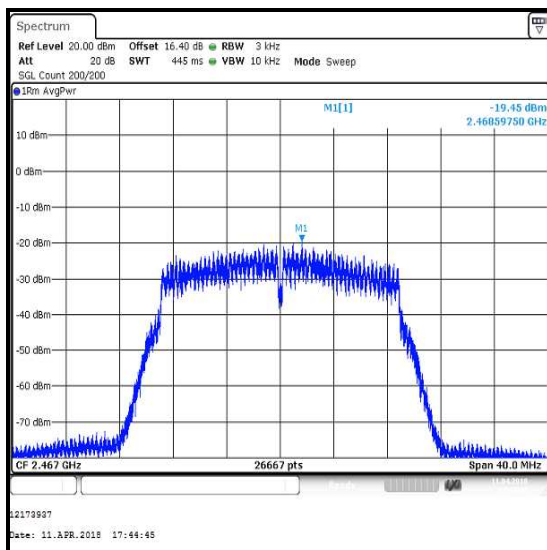
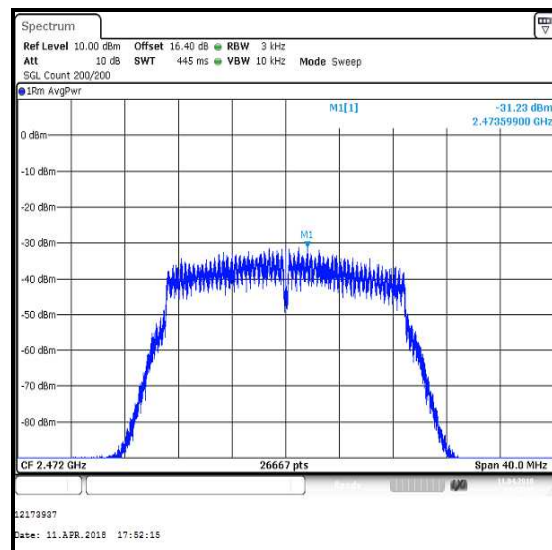
Channel 2



Channel 3



Channel 6

**Transmitter Power Spectral Density (continued)****Results: 802.11n / HT20 / MIMO / 2Tx CDD / BPSK / MCS0 / Port WF1****Channel 7****Channel 11****Channel 12****Channel 13**