



TEST REPORT

Test Report No. : UL-RPT-RP12185759JD09A V2.0

Customer : Apple Inc.
Model No. : A1990
FCC ID : BCGA1990
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 2.0 supersedes all previous versions.

Date of Issue: 30 June 2018

Checked by:

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Customer Information

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Report Revision History

Version Number	Issue Date	Revision Details	Revised By
1.0	27/06/2018	Initial Version	Ian Watch
2.0	30/06/2018	Admin updates	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

Specification Reference:	47CFR15.247
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.247
Specification Reference:	47CFR15.209
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.209
Site Registration:	209735
Location of Testing:	UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
Test Dates:	21 December 2017 to 06 June 2018

1.3. Summary of Test Results

FCC Reference (47CFR)	Measurement	Result
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. Duty cycle was measured on beamforming modes only.
- 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	
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

Reference:	ANSI C63.10-2013
Title:	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
Reference:	KDB 558074 D01 DTS Meas Guidance v04 April 5, 2017
Title:	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under Section 15.247
Reference:	KDB 662911 D01 Multiple Transmitter Output v02r01 October 31, 2013
Title:	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
M2036	Signal Analyser	Rohde & Schwarz	FSV3	101791	20 Apr 2019	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)
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
A490	Antenna	Chase	CBL6111A	1590	03 Apr 2019	12
A2889	Antenna	Schwarzbeck	BBHA 9120 B	BBHA 9120 B 653	19 Feb 2019	12
A2148	Attenuator	AtlanTecRF	AN18-06	090202-06	03 Apr 2019	12
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	21 Feb 2019	12
A2131	Low Pass Filter	AtlanTecRF	AFL-02000	JFB1004-002	22 Feb 2019	12
M2016	Thermohygrometer	Testo	608-H1	45046428	26 Feb 2019	12
K0002	3m RSE Chamber	Rainford EMC	N/A	N/A	07 Feb 2019	12
M1874	Test Receiver	Rohde & Schwarz	ESU26	100553	28 Nov 2018	12
A3025	Pre Amplifier	COM-POWER	PAM-118A	551126	12 Oct 2018	12
A2896	Pre Amplifier	Schwarzbeck	BBV 9721	9721 - 023	20 Feb 2019	12
A1818	Antenna	EMCO	3115	00075692	07 Feb 2019	12
A253	Antenna	Flann Microwave	12240-20	128	07 Feb 2019	12
A254	Antenna	Flann Microwave	14240-20	139	07 Feb 2019	12
A255	Antenna	Flann Microwave	16240-20	519	07 Feb 2019	12
A256	Antenna	Flann Microwave	18240-20	400	07 Feb 2019	12
A2895	Antenna	Schwarzbeck	BBHA 9170	9170-728	20 Feb 2019	12
A2973	High Pass Filter	AtlanTecRF	AFH-03000	16080900032	24 Jan 2019	12
A3014	High Pass Filter	AtlanTecRF	AFH-06000	17042400007	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)

Brand Name:	Apple
Model Name or Number:	A1990
Test Sample Serial Number:	C02WC003JMFN (<i>Conducted sample #1</i>)
Hardware Version:	EVT
Software Version:	17G2057
FCC ID:	BCGA1990

Brand Name:	Apple
Model Name or Number:	A1990
Test Sample Serial Number:	C02WC006JTGW (<i>Conducted sample #2</i>)
Hardware Version:	EVT
Software Version:	17G2033
FCC ID:	BCGA1990

Brand Name:	Apple
Model Name or Number:	A1990
Test Sample Serial Number:	C02WC006JTGW (<i>Radiated sample #1</i>)
Hardware Version:	EVT
Software Version:	17G2033
FCC ID:	BCGA1990

Brand Name:	Apple
Model Name or Number:	A1990
Test Sample Serial Number:	C02VT01FJLG2 (<i>Radiated sample #2</i>)
Hardware Version:	EVT
Software Version:	17G2057
FCC ID:	BCGA1990

3.2. Modifications Incorporated in the EUT

No modifications were applied to the EUT during testing.

3.3. Additional Information Related to Testing

Technology Tested:	WLAN (IEEE 802.11b,g,n) / Digital Transmission System	
Type of Unit:	Transceiver	
Modulation Type:	DBPSK, DQPSK, BPSK, QPSK, 16QAM & 64QAM	
Data Rates:	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)
Power Supply Requirement(s):	Nominal	3.8 VDC via 120 VAC 60 Hz AC/DC adapter
Maximum Conducted Output Power:	25.2 dBm	
Channel Spacing:	20 MHz	
Transmit Frequency Range:	2412 MHz to 2472 MHz	
Transmit Channels Tested:	Channel Number	Channel Frequency (MHz)
	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:

Frequency Band (MHz)	G_{Antenna 1} / Core 1 (dBi)	G_{Antenna 2} / Core 0 (dBi)	G_{Antenna 3} / Core 2 (dBi)
2400 - 2480	2.1	3.3	2.1

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:

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

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

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

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

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

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

Brand Name:	Hama
Description:	4 Port USB Hub
Model Name or Number:	F5U404-BLK
Serial Number:	Not marked or stated

Support Equipment (continued)

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

Operating Modes

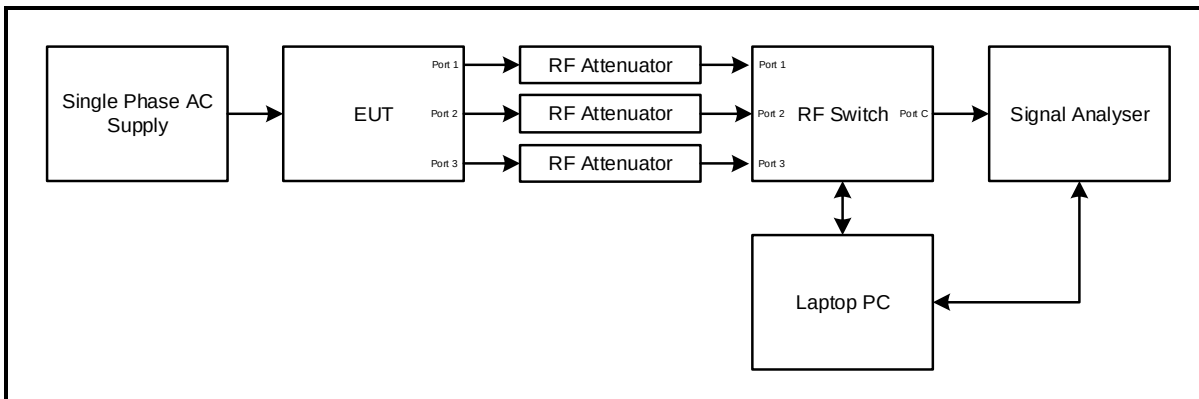
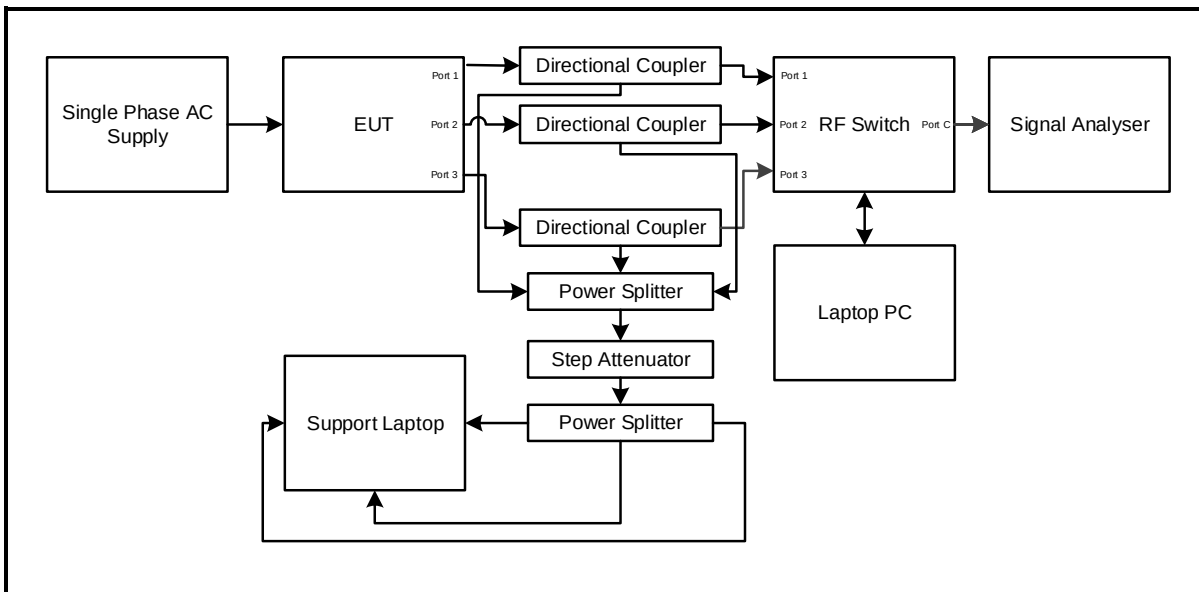
The EUT was tested in the following operating mode(s):

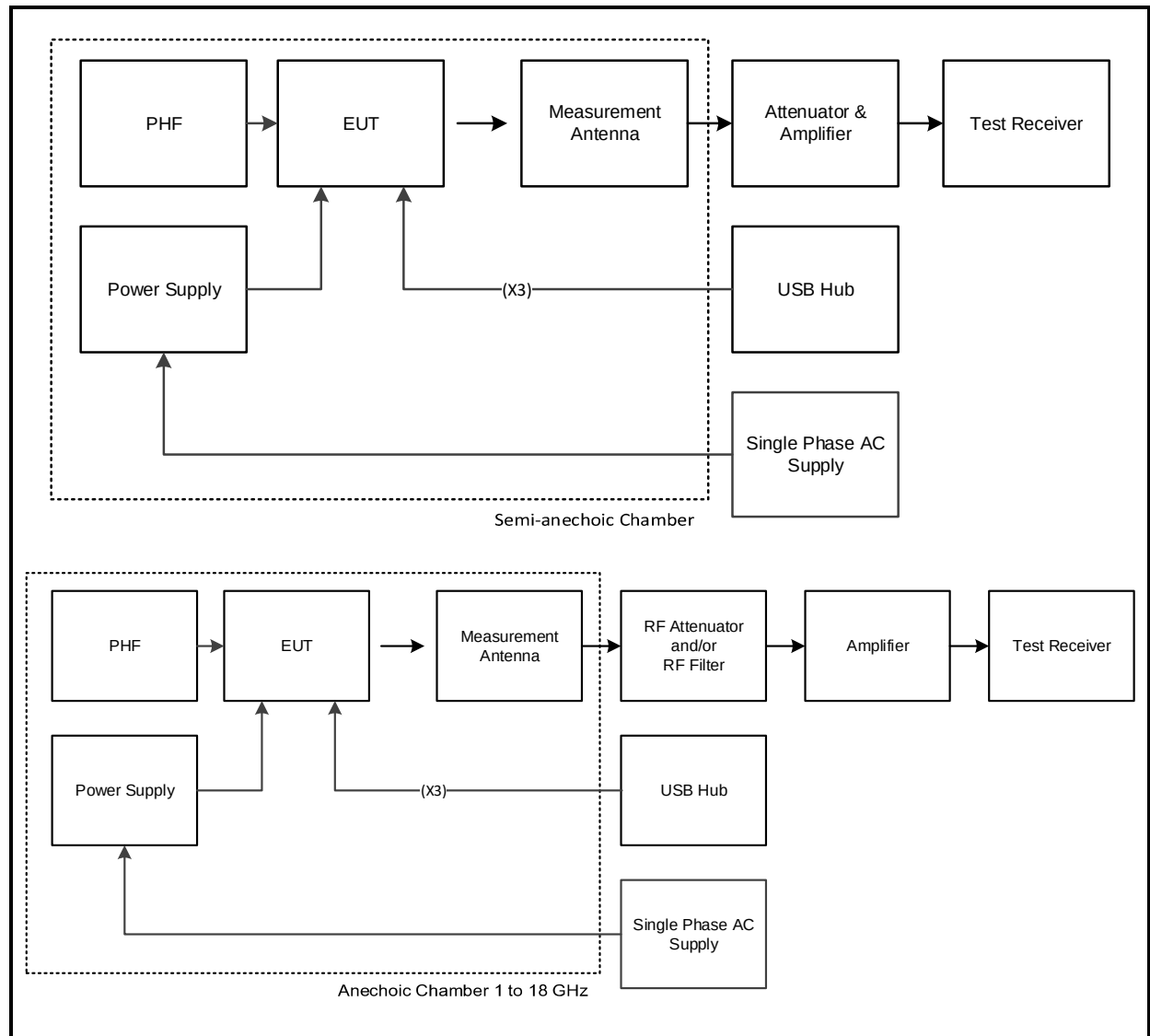
- Non-TxBF modes: Continuously transmitting with a modulated carrier at maximum power on the relevant channels as required using the supported data rates/modulation types.
- TxBF modes: Transmitting a modulated carrier with maximum possible duty cycle at maximum power on the relevant channels as required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

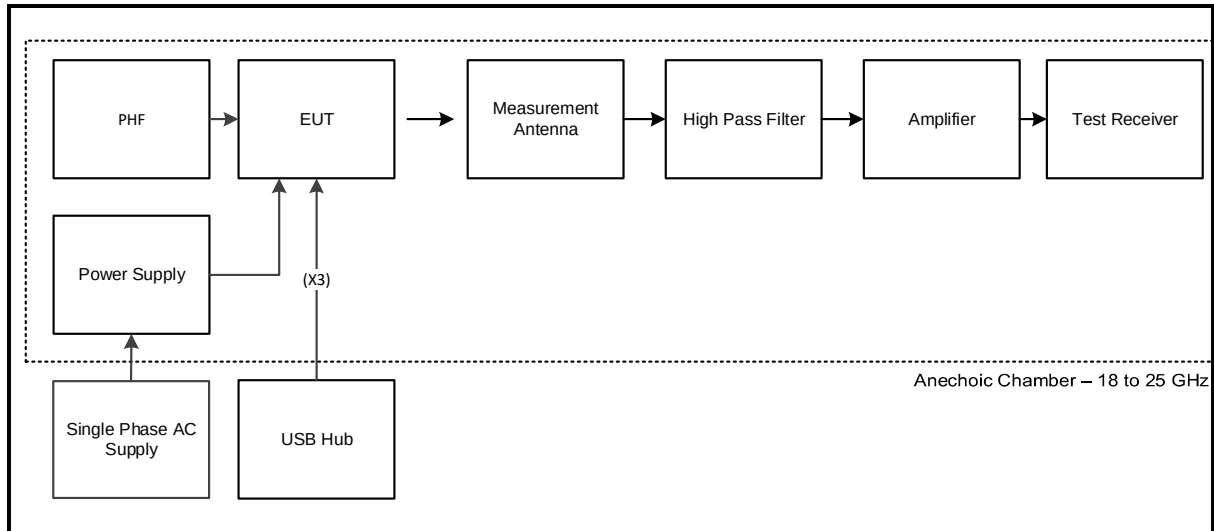
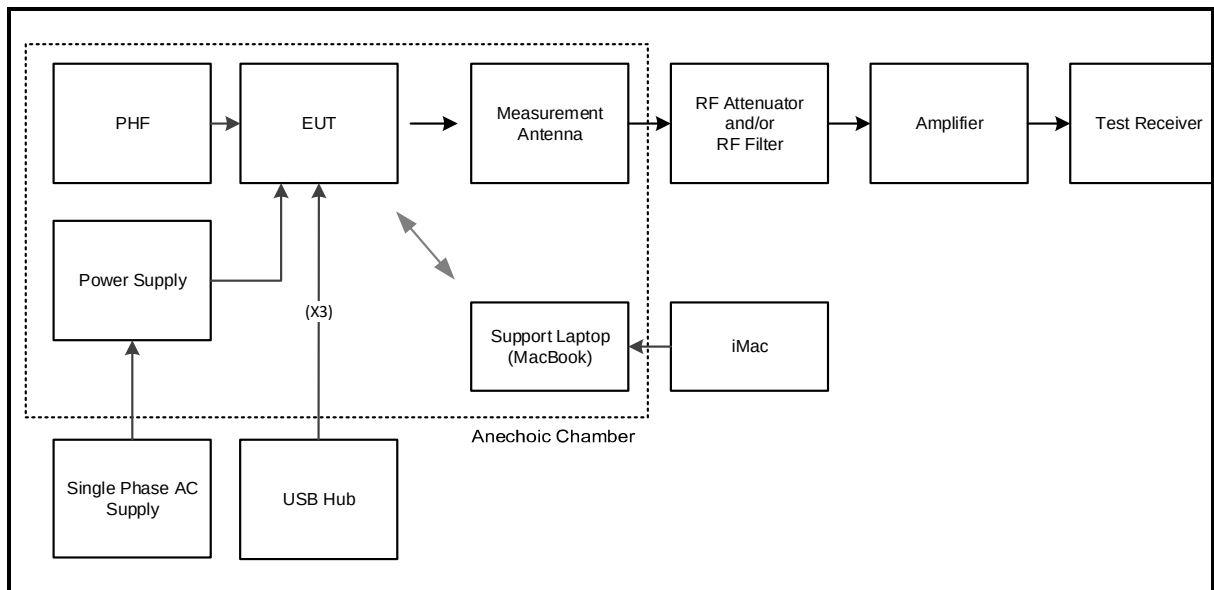
Configuration and Peripherals

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 declared the following data rates to be used for all measurements as:
 - o 802.11b / SISO – DBPSK / 1 Mbps
 - o 802.11g / SISO – BPSK / 6 Mbps
 - o 802.11n HT20 / SISO – BPSK / MCS0
 - o 802.11b / MIMO / 2Tx CDD – DBPSK / 1 Mbps
 - o 802.11b / MIMO / 3Tx CDD – DBPSK / 1 Mbps
 - o 802.11n HT20 / MIMO / 2Tx CDD – BPSK / MCS0
 - o 802.11n HT20 / MIMO / 3Tx CDD – BPSK / MCS0
 - o 802.11n HT20 / MIMO / 2Tx TxBF – BPSK / MCS0
 - o 802.11n HT20 / MIMO / 3Tx TxBF – BPSK / MCS0
- The EUT has three separate antennas which correspond to three separate antenna ports. Core 0, Core 1 and Core 2 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 Tx-BF)****Test Setup for Transmitter Conducted Tests (Tx-BF)**

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 Duty Cycle

Test Summary:

Test Engineer:	Andrew Edwards	Test Date:	20 May 2018
Test Sample Serial Number:	C02WC001JTGW		

FCC Reference:	Part 15.35(c)
Test Method Used:	FCC KDB 558074 Section 6.0

Environmental Conditions:

Temperature (°C):	25
Relative Humidity (%):	43

Note(s):

1. In order to assist with the determination of the average level of fundamental and spurious emissions field strength, measurements were made of duty cycle to determine the transmission duration and the silent period time of the transmitter. The transmitter duty cycle was measured using a signal analyser in the time domain and calculated as shown below:

$$10 \log (1 / (\text{On Time} / [\text{Period or } 100 \text{ ms whichever is the lesser}])).$$

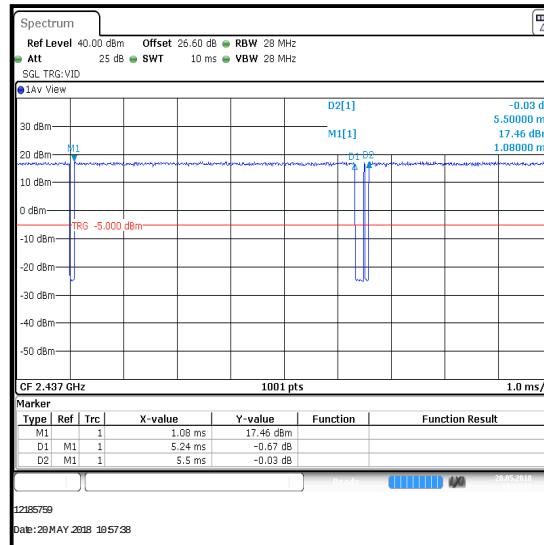
$$802.11n / HT20 / MCS0 / MIMO / 2Tx TXBF / \text{Core 0 duty cycle: } 10 \log (1 / (5.240/5.500)) = 0.2 \text{ dB}$$

$$802.11n / HT20 / MCS0 / MIMO / 3Tx TXBF / \text{Core 0 duty cycle: } 10 \log (1 / (5.360/5.660)) = 0.2 \text{ dB}$$

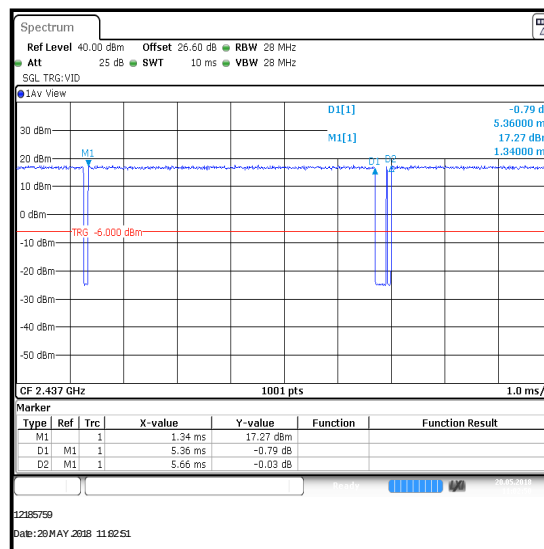
2. For all other modes, the duty cycle was measured and found to be greater than 98%. Plots for these measurements are archived on the UL VS LTD IT server and available for inspection upon request.

Transmitter Duty Cycle (continued)**Results: 802.11n / HT20 / MIMO / 2Tx TXBF / BPSK / MCS0 / Core 0**

Pulse Duration (ms)	Period (ms)	Duty Cycle (dB)
5.240	5.500	0.2

**Results: 802.11n / HT20 / MIMO / 3Tx TXBF / BPSK / MCS0 / Core 0**

Pulse Duration (ms)	Period (ms)	Duty Cycle (dB)
5.360	5.660	0.2



4.2. Transmitter Minimum 6 dB Bandwidth

Test Summary:

Test Engineer:	Max Passell	Test Date:	30 May 2018
Test Sample Serial Number:	C02WC003JMFN		

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

Environmental Conditions:

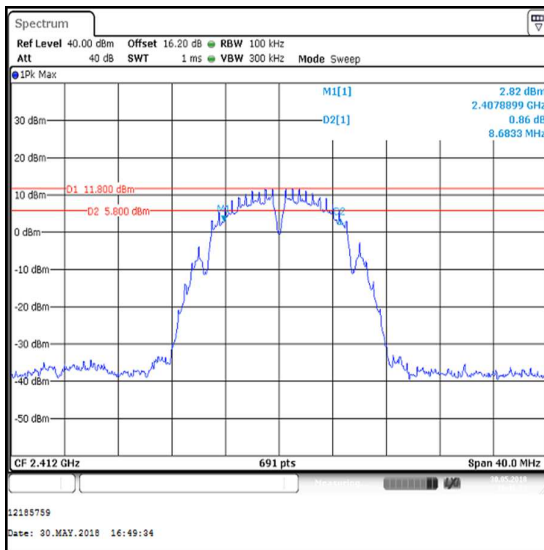
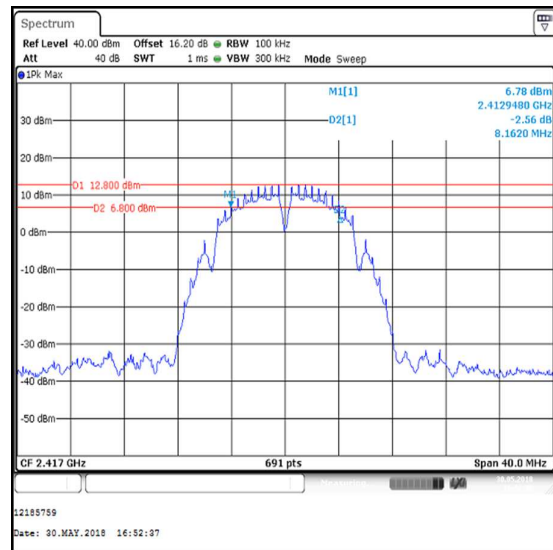
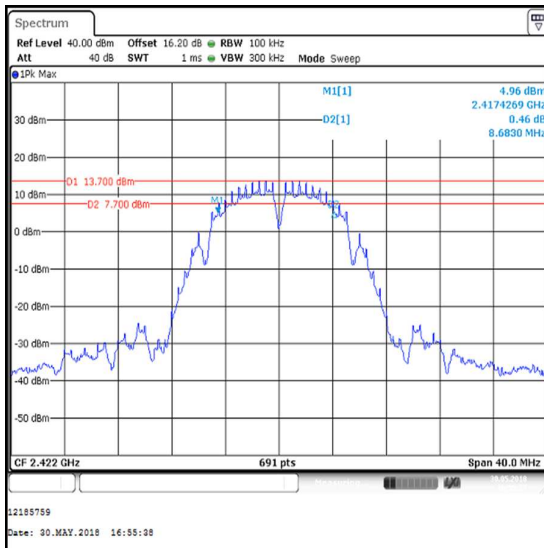
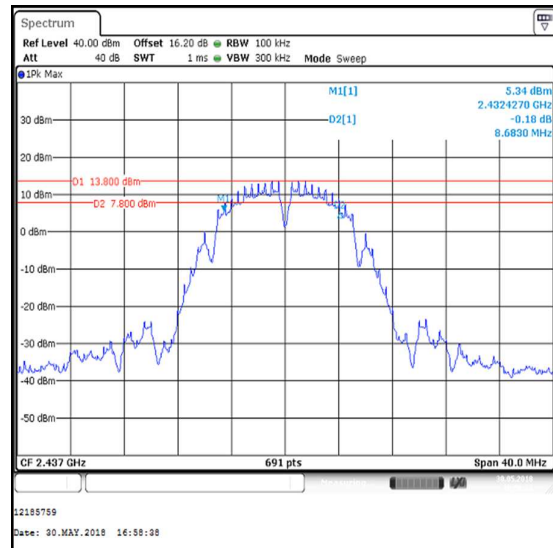
Temperature (°C):	23 to 24
Relative Humidity (%):	51 to 63

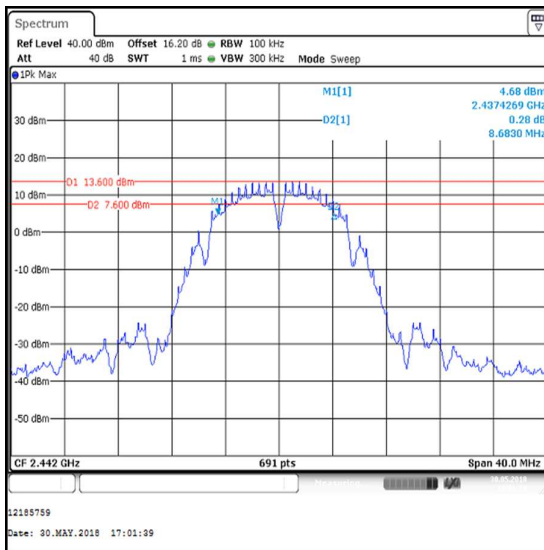
Note(s):

1. The customer declared the following data rates to be used for all measurements as:
 - o 802.11b – DBPSK / 1 Mbps / Core 0
 - o 802.11g – BPSK / 6 Mbps / Core 0
 - o 802.11n HT20 BPSK / MCS0 / Core 0Only SISO modes are reported since the bandwidth does not change depending on 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.

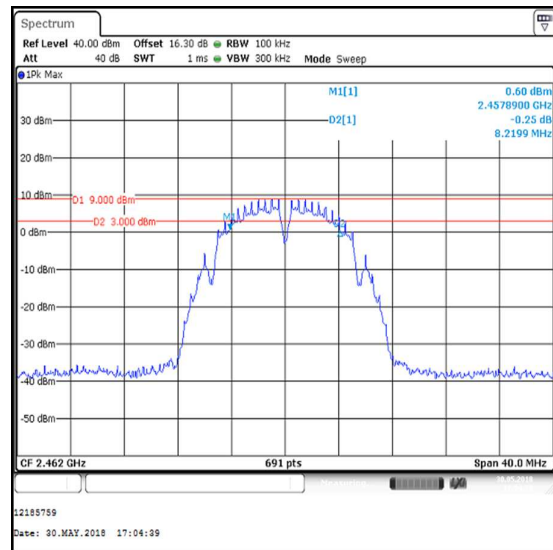
Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 0**

Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	8683	≥500	8183	Complied
2	8162	≥500	7662	Complied
3	8683	≥500	8183	Complied
6	8683	≥500	8183	Complied
7	8683	≥500	8183	Complied
11	8220	≥500	7720	Complied
12	8220	≥500	7720	Complied
13	8683	≥500	8183	Complied

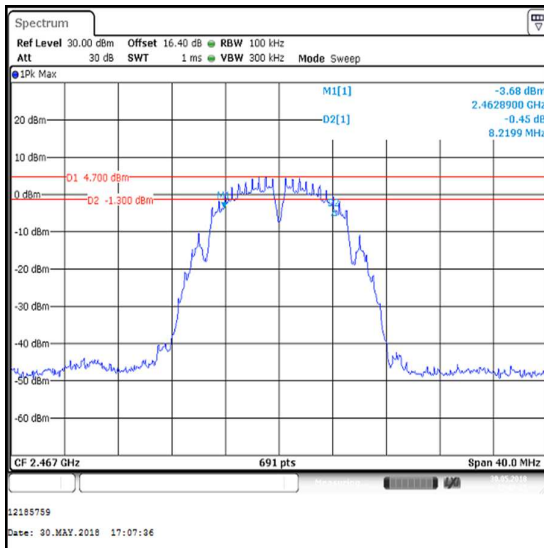
Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 0****Channel 1****Channel 2****Channel 3****Channel 6**

Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 0**

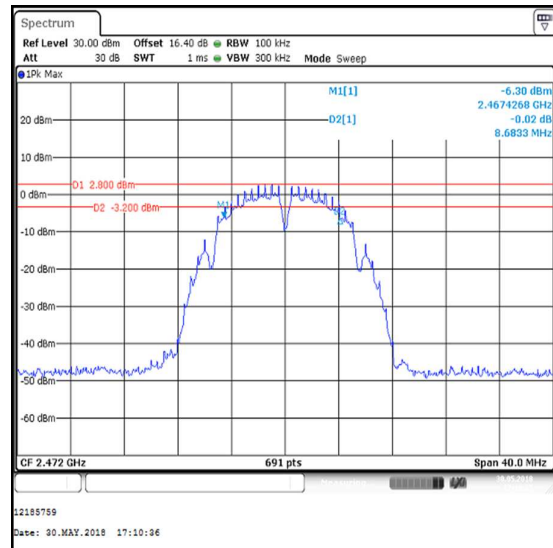
Channel 7



Channel 11



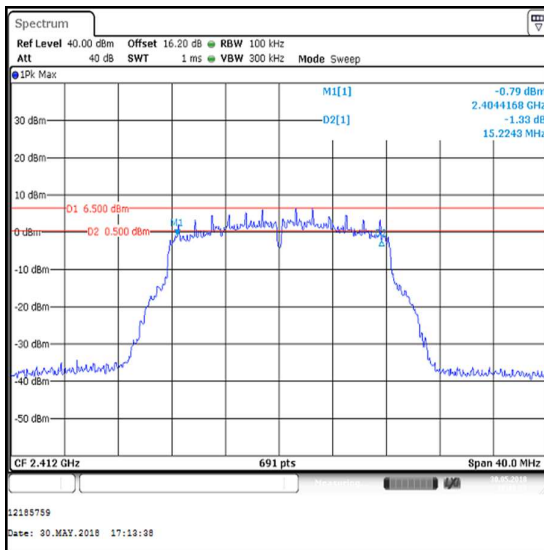
Channel 12



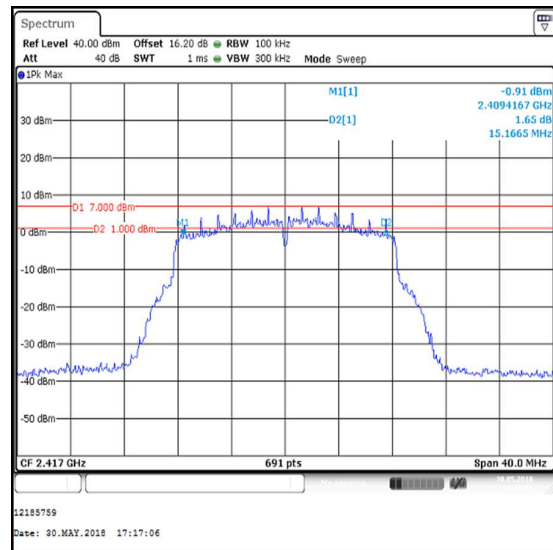
Channel 13

Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 0**

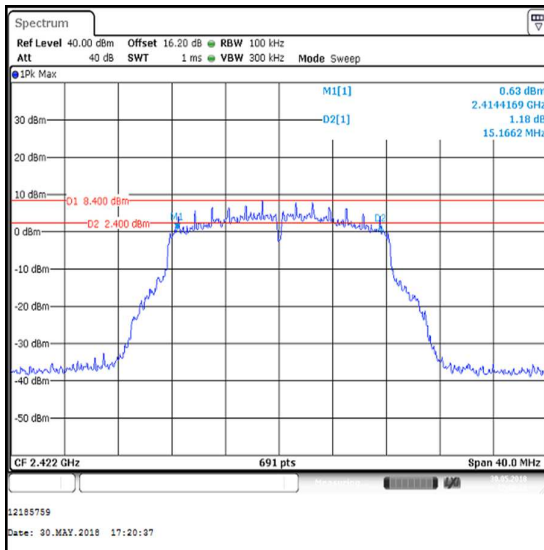
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	15224	≥500	14724	Complied
2	15167	≥500	14667	Complied
3	15166	≥500	14666	Complied
6	15224	≥500	14724	Complied
7	15224	≥500	14724	Complied
11	15166	≥500	14666	Complied
12	15167	≥500	14667	Complied
13	15167	≥500	14667	Complied

Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 0**

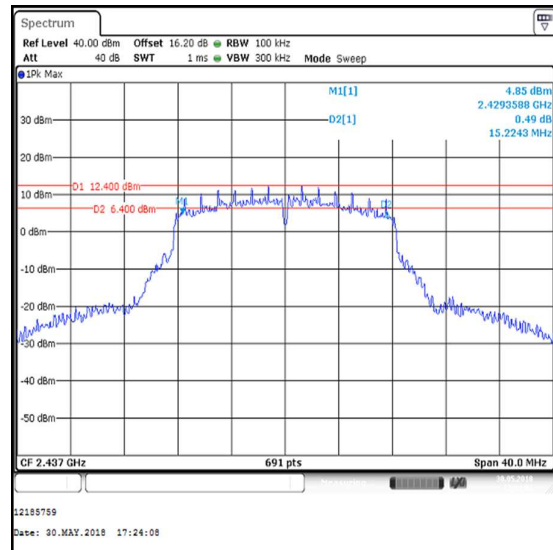
Channel 1



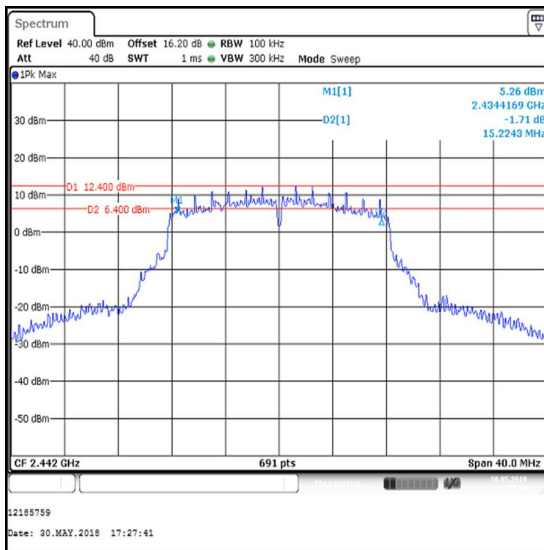
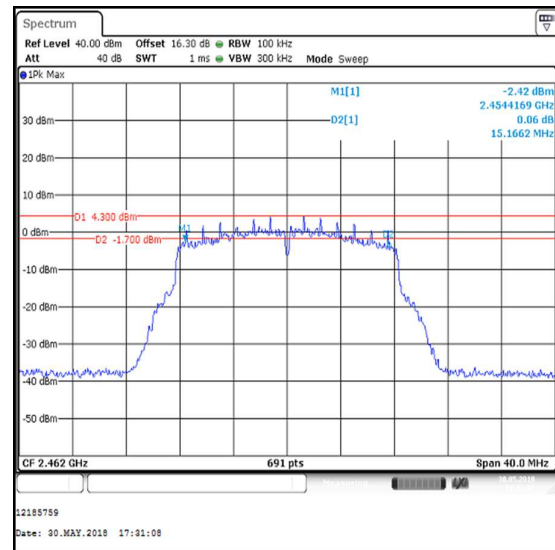
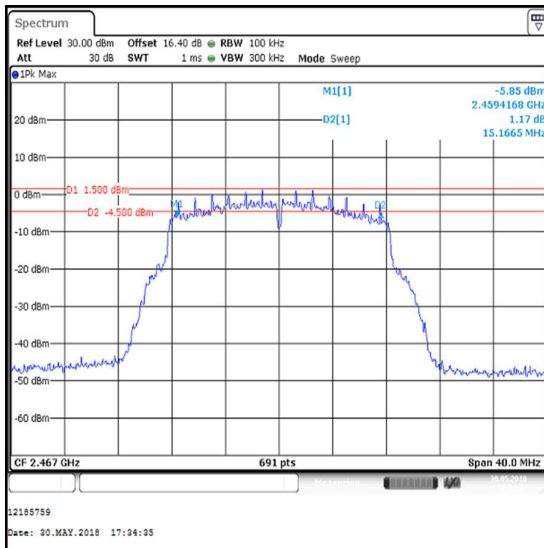
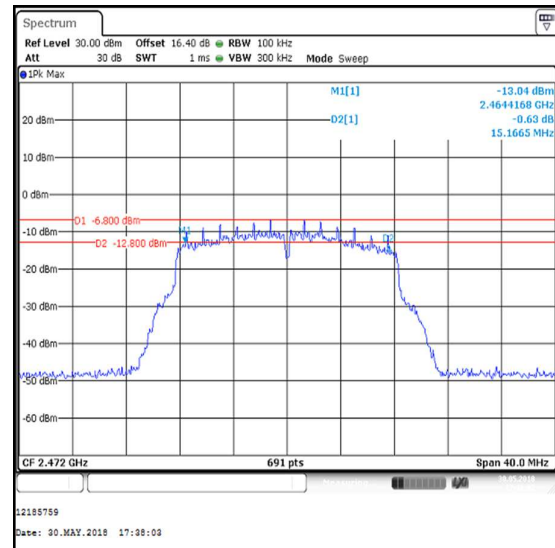
Channel 2



Channel 3

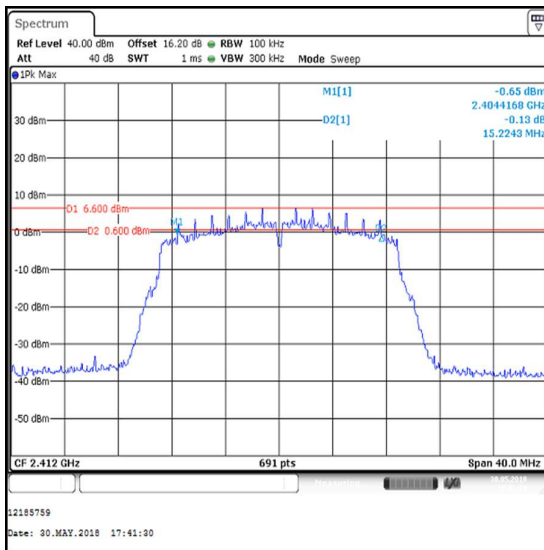
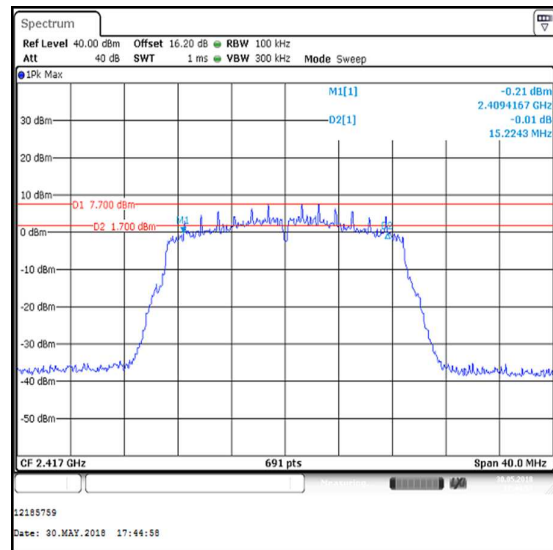
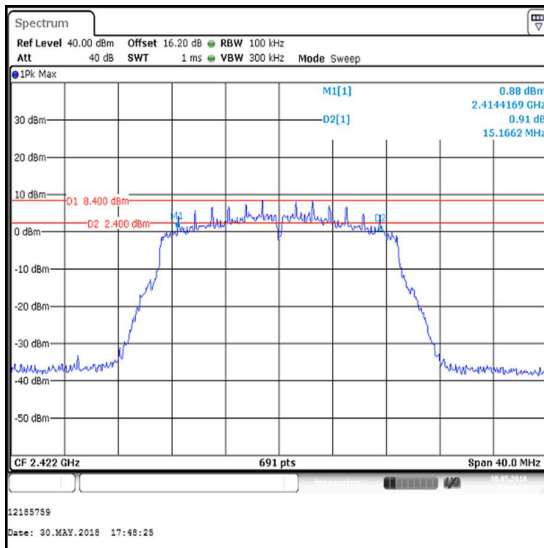
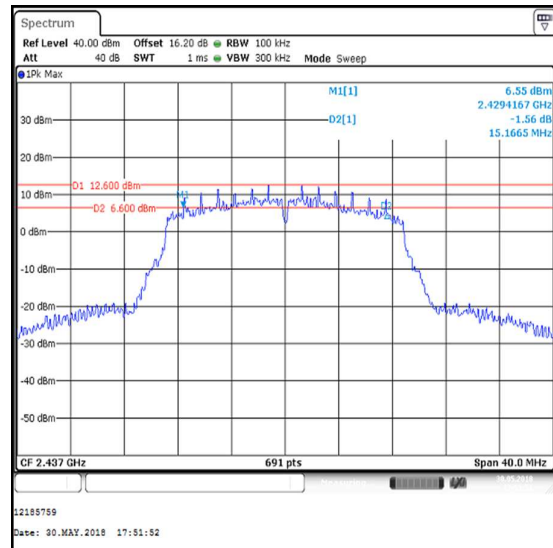


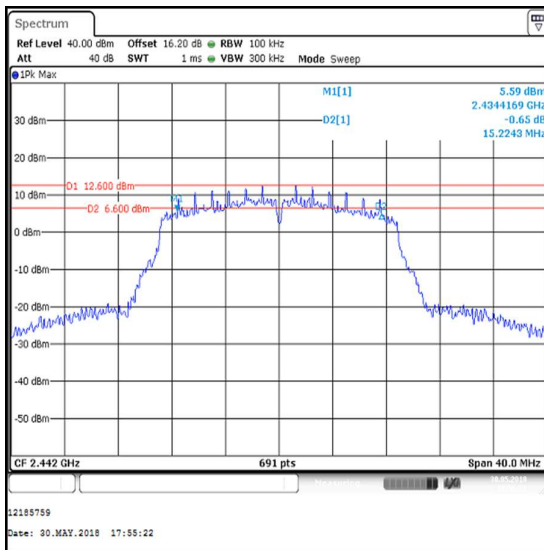
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 0****Channel 7****Channel 11****Channel 12****Channel 13**

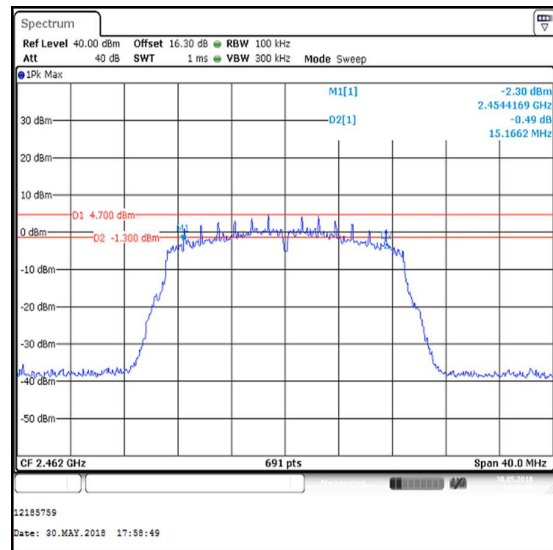
Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 0**

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	15166	≥500	14666	Complied
12	15167	≥500	14667	Complied
13	15167	≥500	14667	Complied

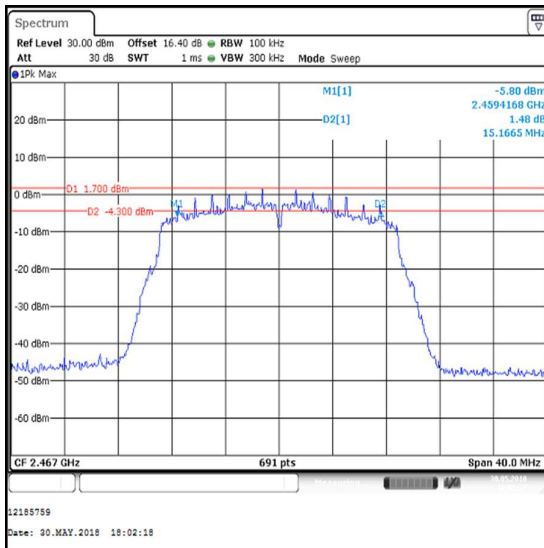
Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 0****Channel 1****Channel 2****Channel 3****Channel 6**

Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 0**

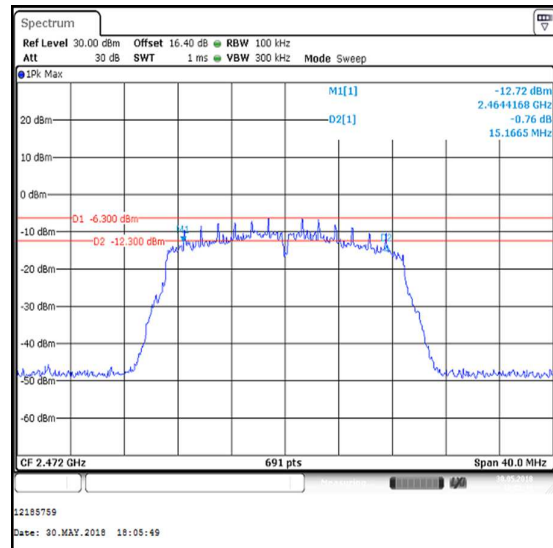
Channel 7



Channel 11



Channel 12



Channel 13

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

Test Engineers:	Stefan Ho & Max Passell	Test Dates:	30 May 2018, 31 May 2018 & 01 June 2018
Test Sample Serial Numbers:	C02WC003JMFN & C02WC001JTGW		

FCC Reference:	Part 15.247(e)
Test Method Used:	FCC KDB 558074 Sections 10.3 &10.5

Environmental Conditions:

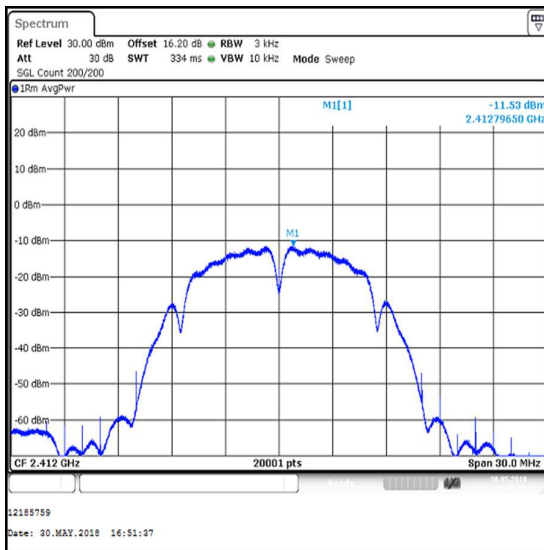
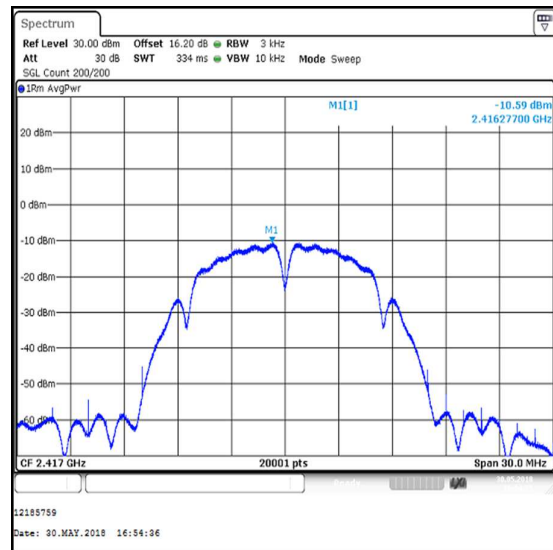
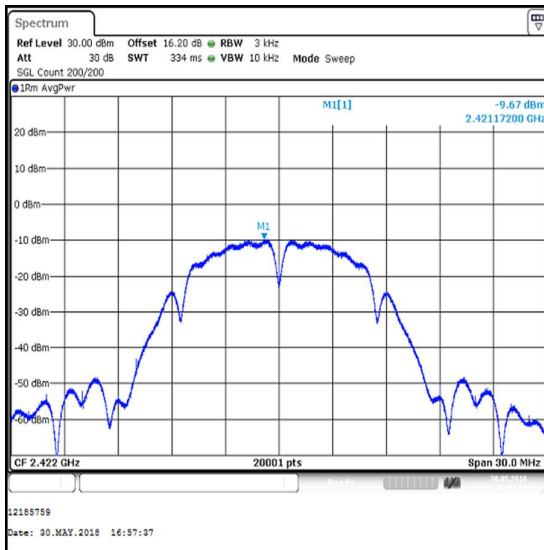
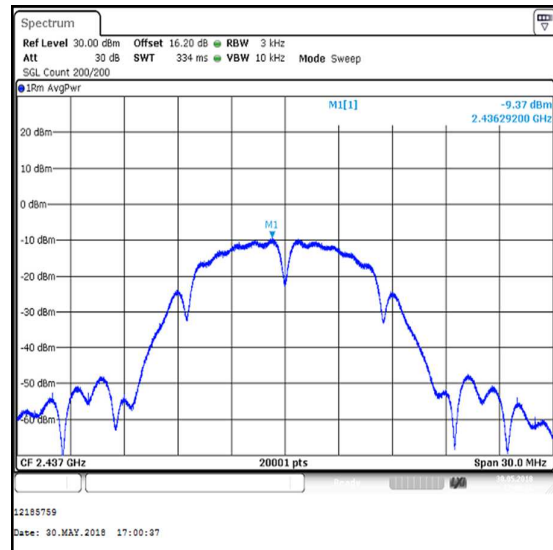
Temperature (°C):	23 to 25
Relative Humidity (%):	34 to 51

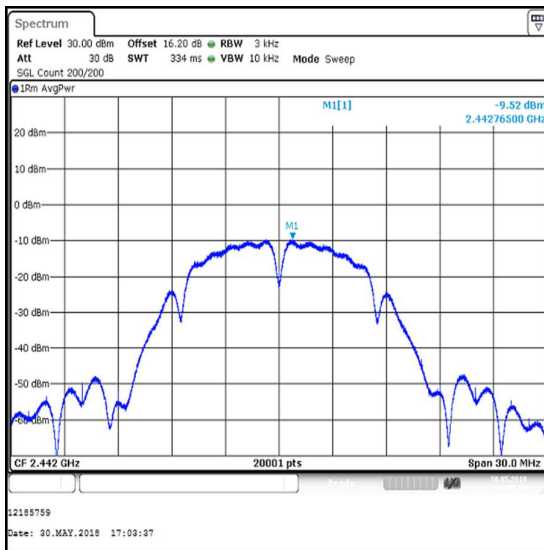
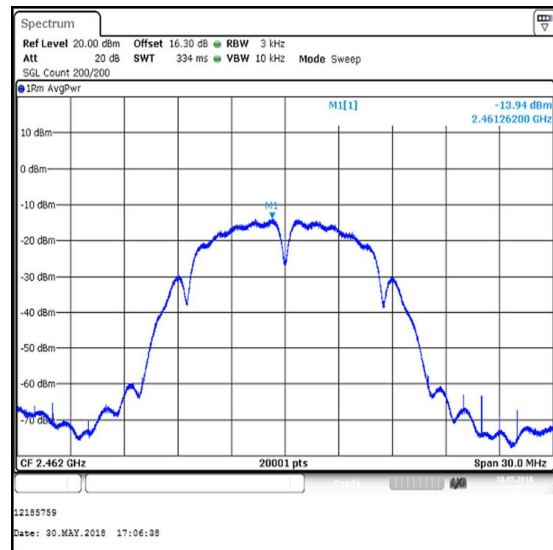
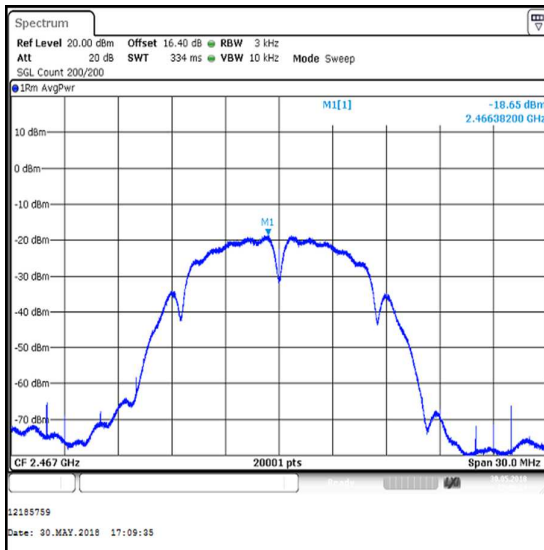
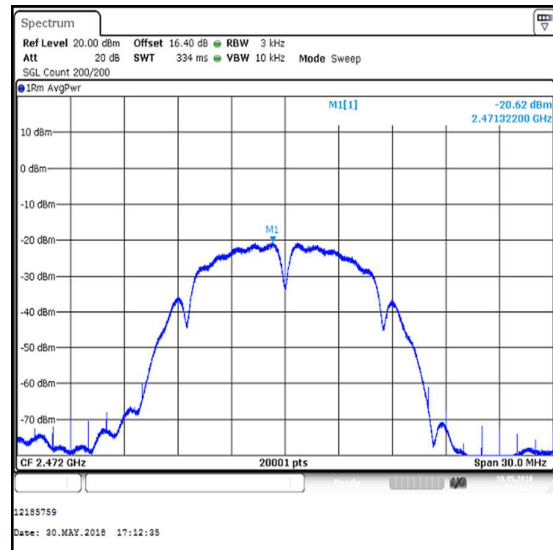
Transmitter Power Spectral Density (continued)**Note(s):**

1. The customer declared the following data rates to be used for all measurements as:
 - o 802.11b – DBPSK / 1 Mbps / Core 0
 - o 802.11g – BPSK / 6 Mbps / Core 0
 - o 802.11n HT20 / SISO / BPSK / MCS0 / Core 0
 - o 802.11b – DBPSK / 1 Mbps / MIMO / 2Tx CDD / Core 1 & Core 0
 - o 802.11b – DBPSK / 1 Mbps / MIMO / 3Tx CDD / Core 1, Core 0 & Core 2
 - o 802.11n HT20 / MIMO / 2Tx CDD / BPSK / MCS0 / Core 1 & Core 0
 - o 802.11n HT20 / MIMO / 3Tx CDD / BPSK / MCS0 / Core 1, Core 0 & Core 2
 - o 802.11n HT20 / MIMO / 2Tx TxBF / BPSK / MCS0 / Core 0 & Core 1
 - o 802.11n HT20 / MIMO / 3Tx TxBF / BPSK / MCS0 / Core 0, Core 1 & Core 2
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 10.5 Method AVGPS-2. The signal analyser resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. An RMS detector was used and sweep time set manually to perform trace averaging over 100 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 C02WC003JMFN was used for non-TxBF tests, the EUT with serial number C02WC001JTGW was used for TxBF tests.

Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 0**

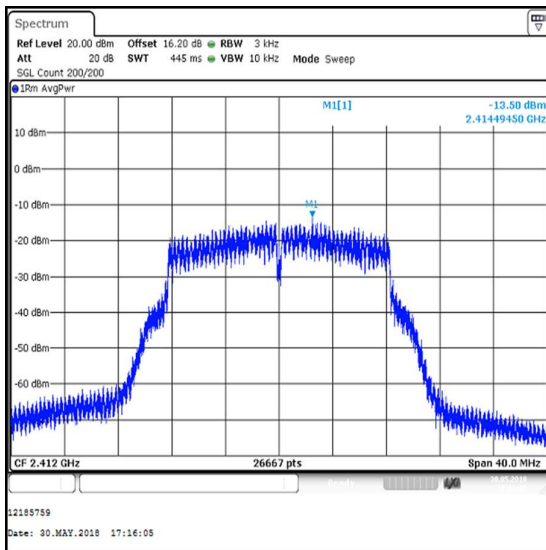
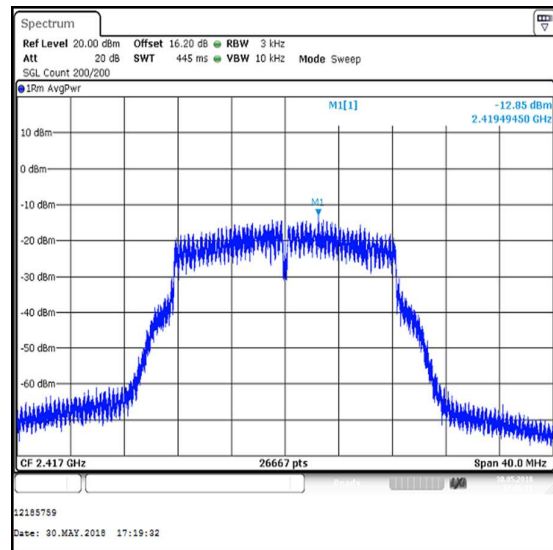
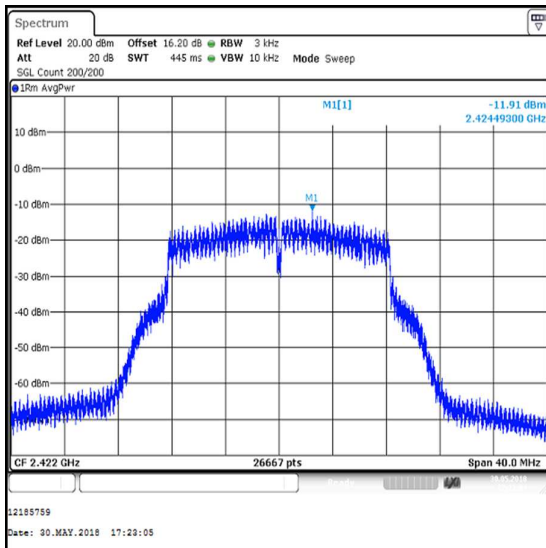
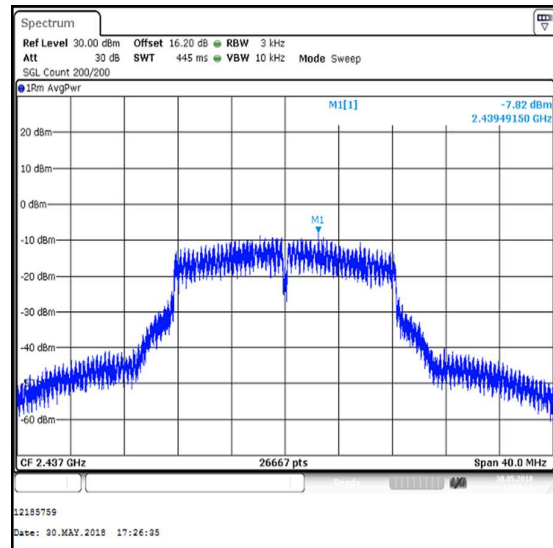
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
1	-11.5	8.0	19.5	Complied
2	-10.6	8.0	18.6	Complied
3	-9.7	8.0	17.7	Complied
6	-9.4	8.0	17.4	Complied
7	-9.5	8.0	17.5	Complied
11	-13.9	8.0	21.9	Complied
12	-18.6	8.0	26.6	Complied
13	-20.6	8.0	28.6	Complied

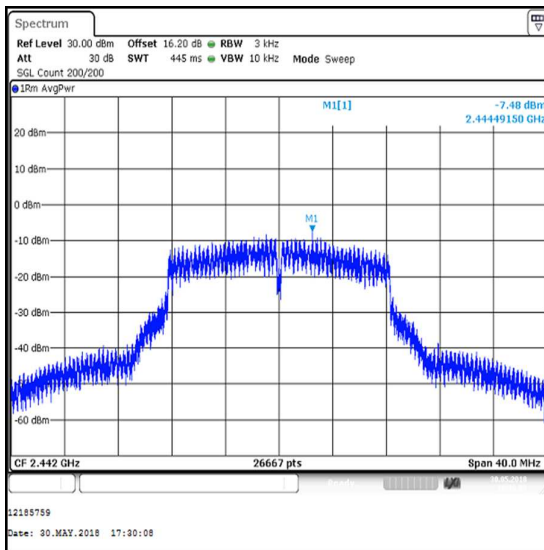
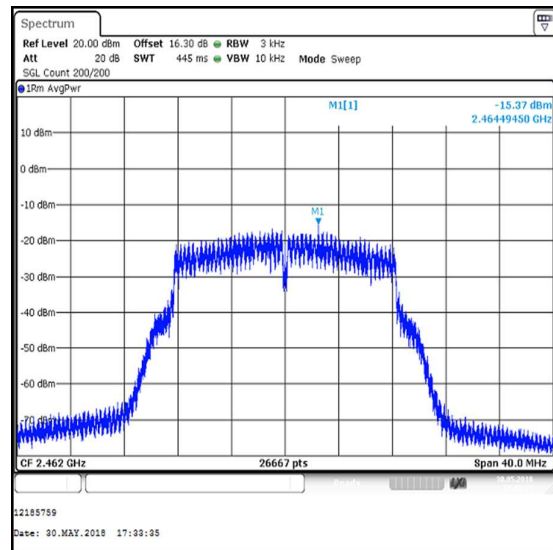
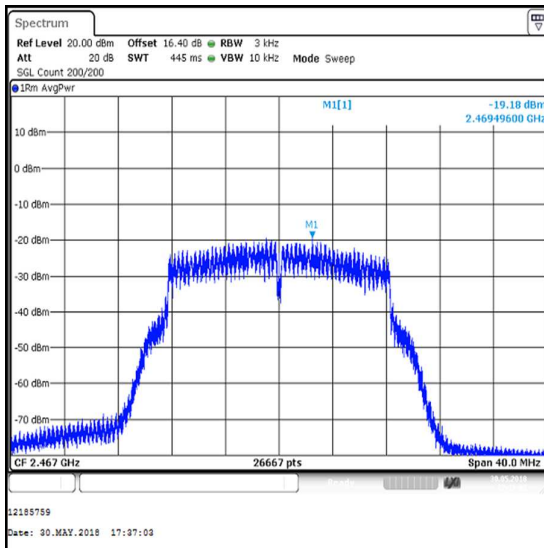
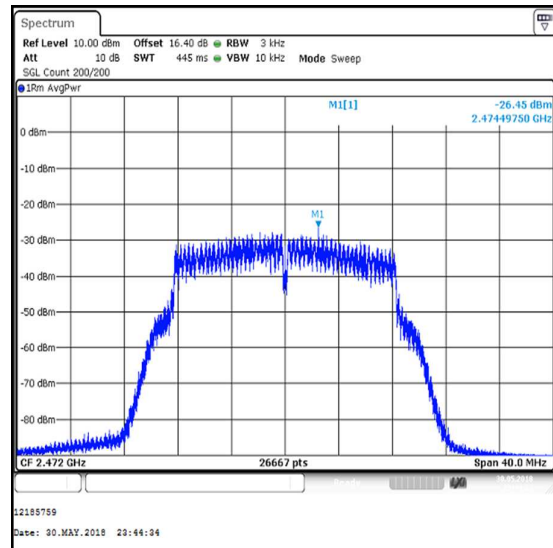
Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 0****Channel 1****Channel 2****Channel 3****Channel 6**

Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 0****Channel 7****Channel 11****Channel 12****Channel 13**

Transmitter Power Spectral Density (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 0**

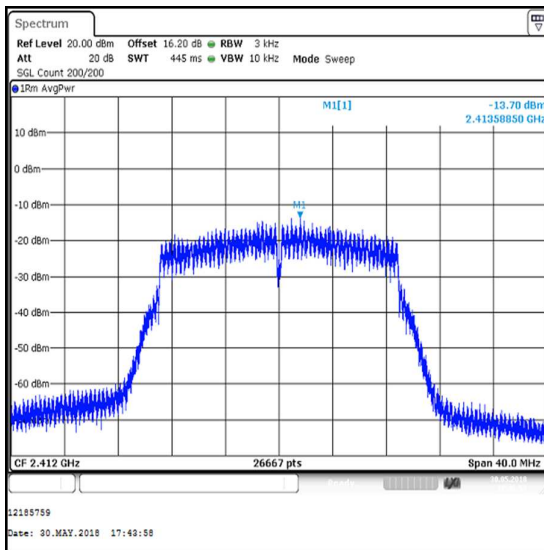
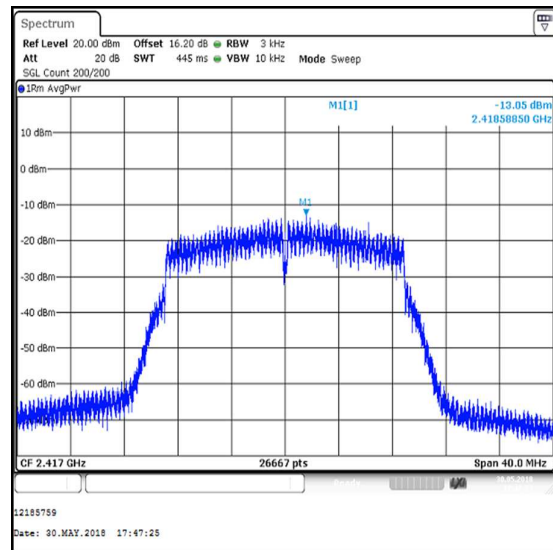
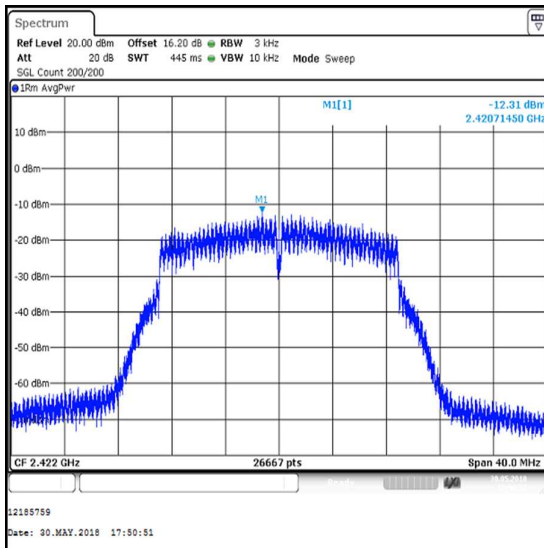
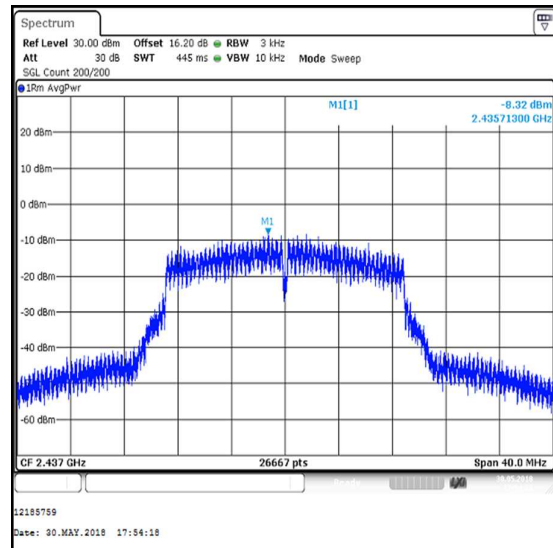
Channel	Output Power (dBm/3 kHz)	Duty Cycle Correction (dB)	Corrected Output Power (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Result
1	-13.5	0	-13.5	8.0	21.5	Complied
2	-12.8	0	-12.8	8.0	20.8	Complied
3	-11.9	0	-11.9	8.0	19.9	Complied
6	-7.8	0	-7.8	8.0	15.8	Complied
7	-7.5	0	-7.5	8.0	15.5	Complied
11	-15.4	0	-15.4	8.0	23.4	Complied
12	-19.2	0	-19.2	8.0	27.2	Complied
13	-26.4	0	-26.4	8.0	34.4	Complied

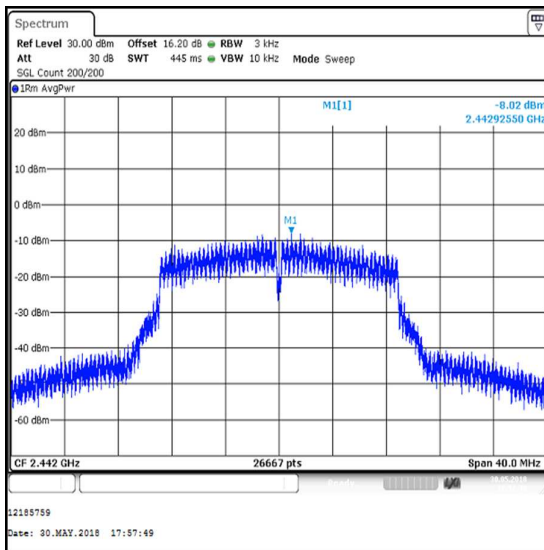
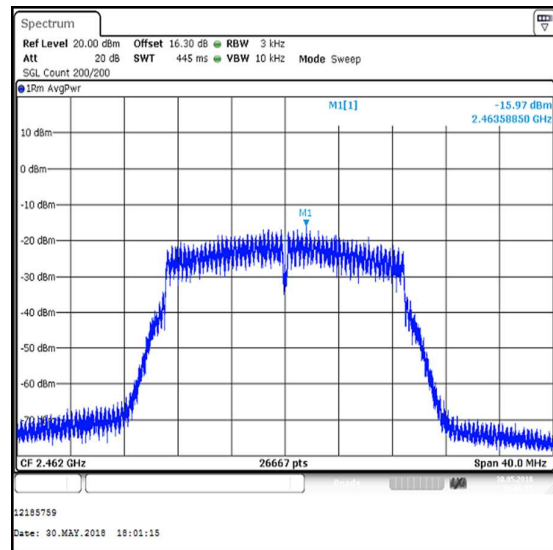
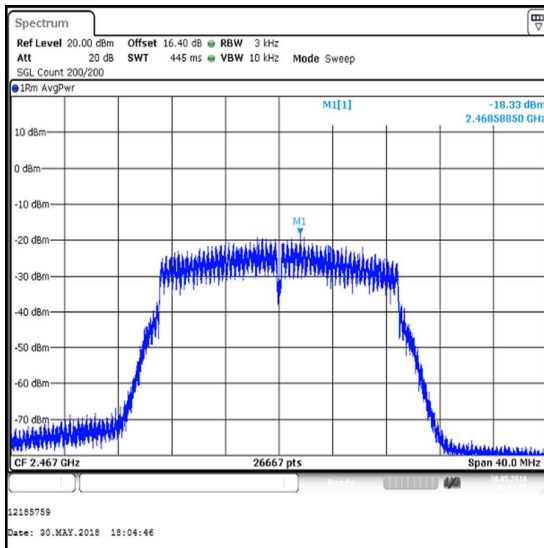
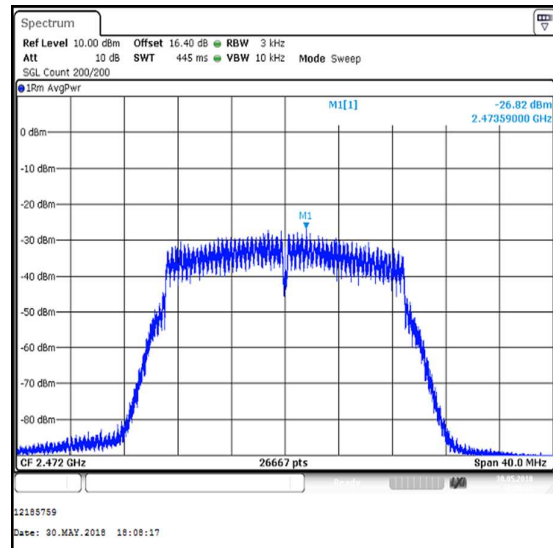
Transmitter Power Spectral Density (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 0****Channel 1****Channel 2****Channel 3****Channel 6**

Transmitter Power Spectral Density (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 0****Channel 7****Channel 11****Channel 12****Channel 13**

Transmitter Power Spectral Density (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 0**

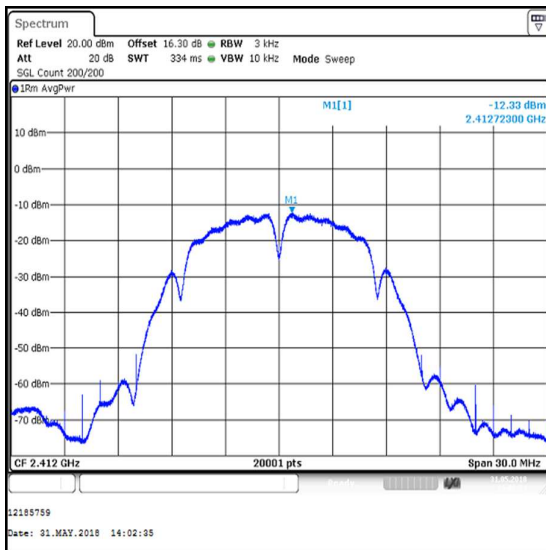
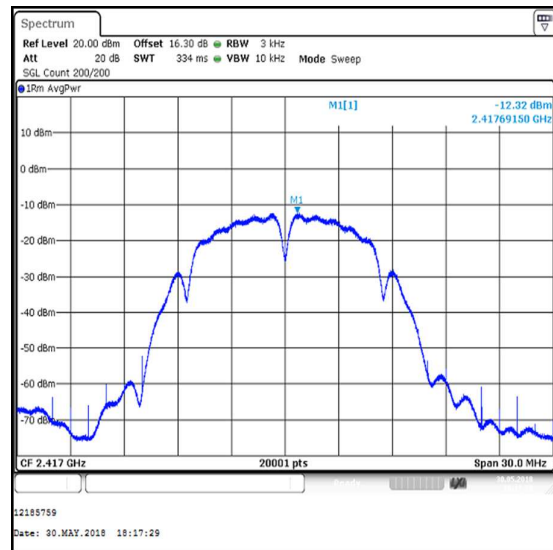
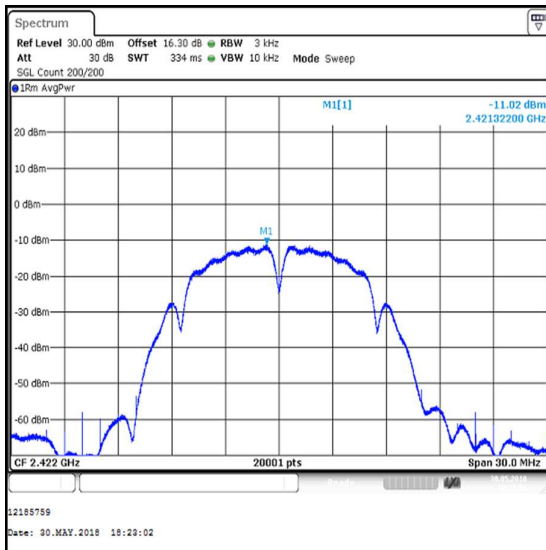
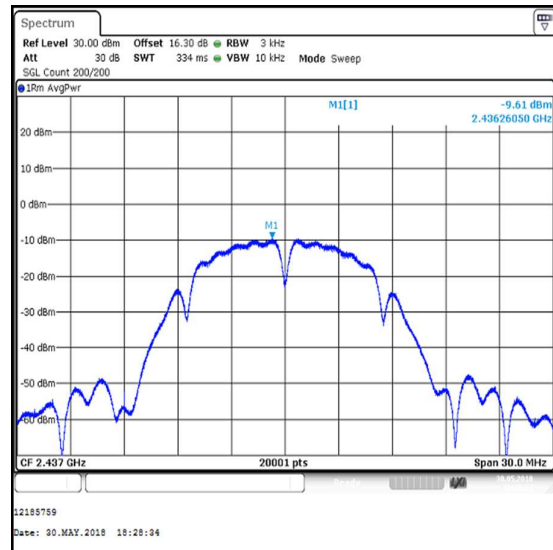
Channel	Output Power (dBm/3 kHz)	Duty Cycle Correction (dB)	Corrected Output Power (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Result
1	-13.7	0	-13.7	8.0	21.7	Complied
2	-13.0	0	-13.0	8.0	21.0	Complied
3	-12.3	0	-12.3	8.0	20.3	Complied
6	-8.3	0	-8.3	8.0	16.3	Complied
7	-8.0	0	-8.0	8.0	16.0	Complied
11	-16.0	0	-16.0	8.0	24.0	Complied
12	-18.3	0	-18.3	8.0	26.3	Complied
13	-26.8	0	-26.8	8.0	34.8	Complied

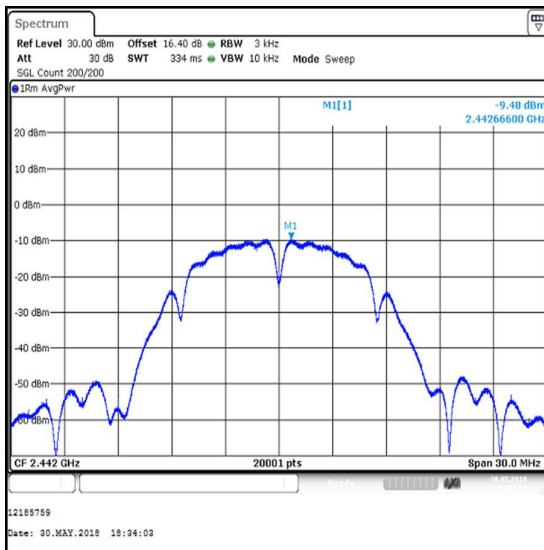
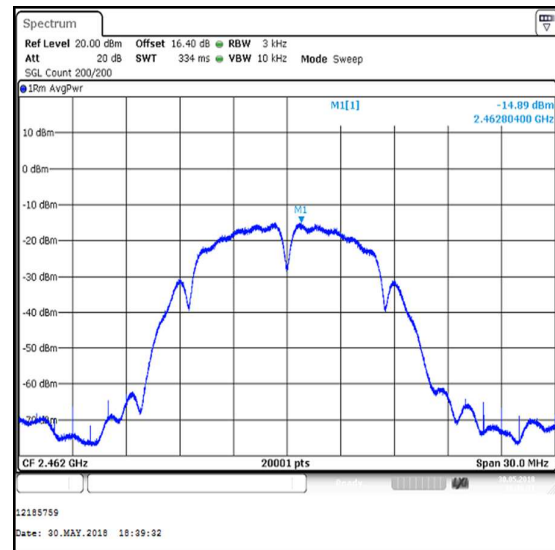
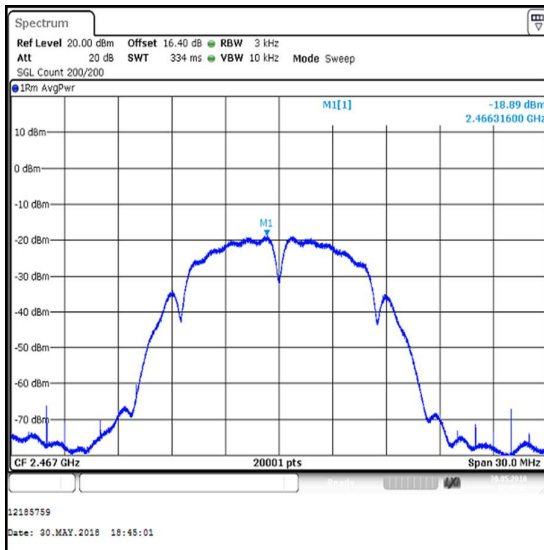
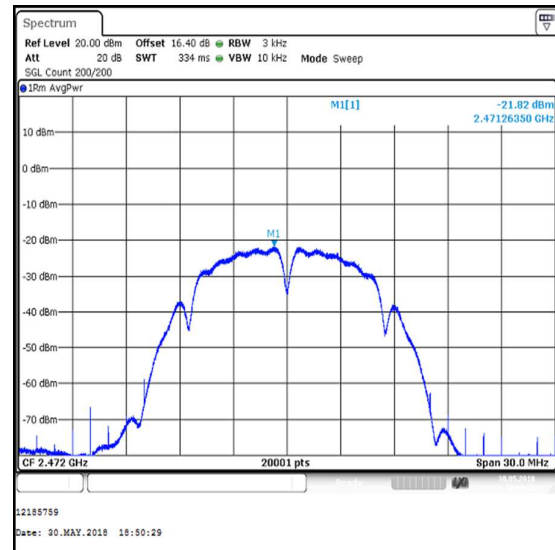
Transmitter Power Spectral Density (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 0****Channel 1****Channel 2****Channel 3****Channel 6**

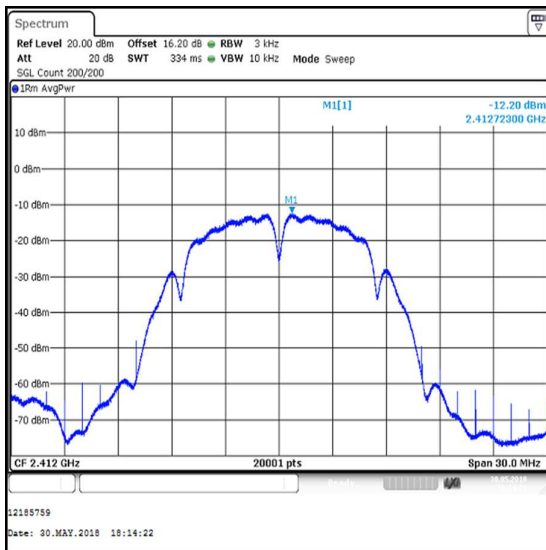
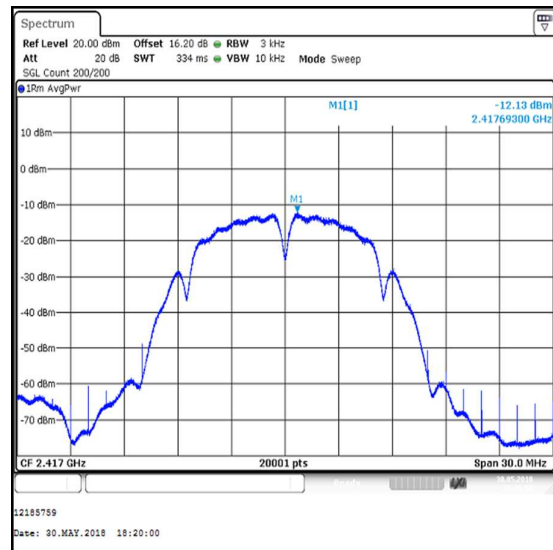
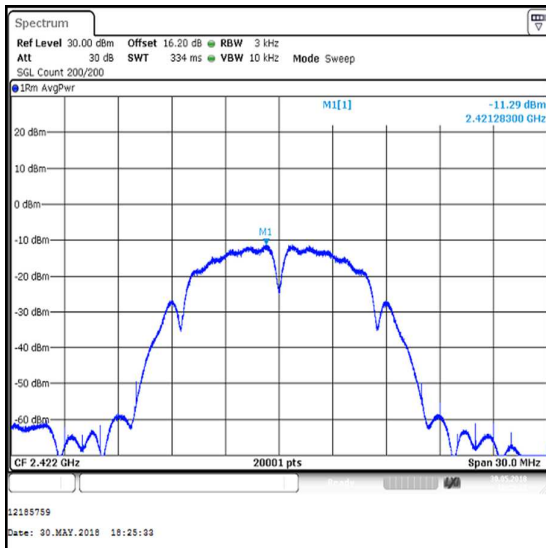
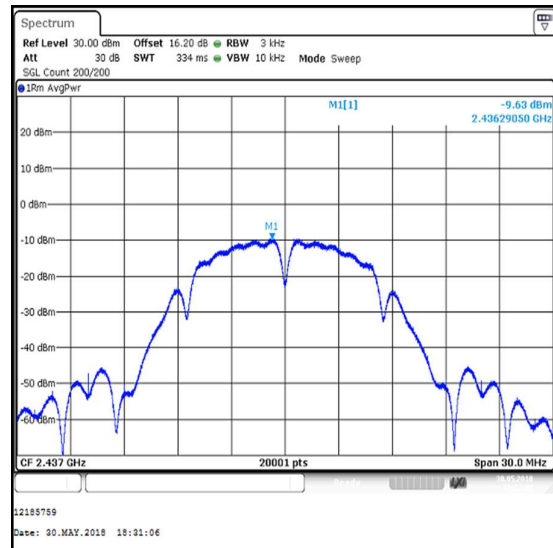
Transmitter Power Spectral Density (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 0****Channel 7****Channel 11****Channel 12****Channel 13**

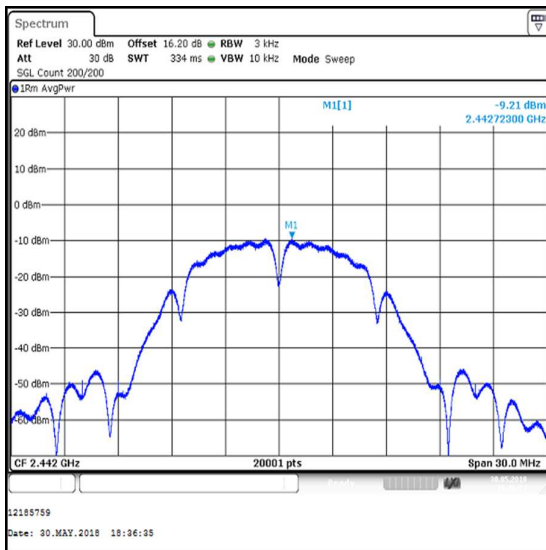
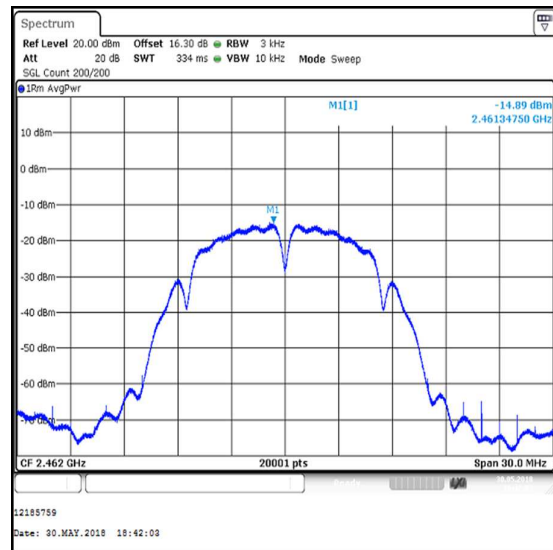
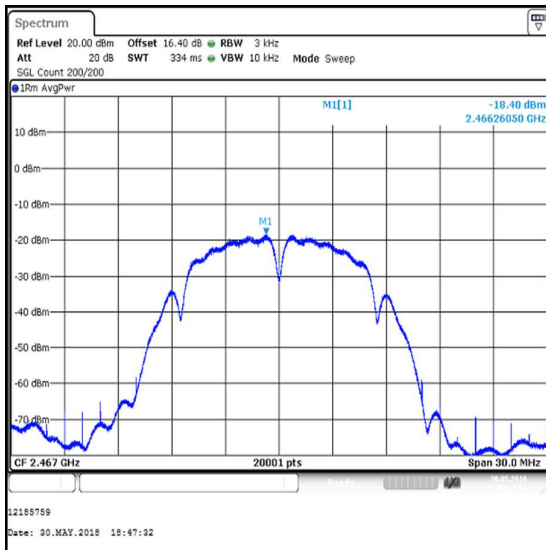
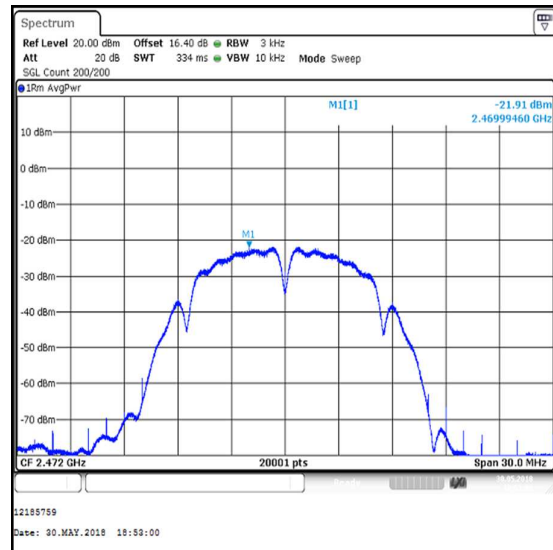
Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps**

Channel	PSD at Core 1 (dBm / 3 kHz)	PSD at Core 0 (dBm / 3 kHz)	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-12.3	-12.2	-9.2	8.0	17.2	Complied
2	-12.3	-12.1	-9.2	8.0	17.2	Complied
3	-11.0	-11.3	-8.3	8.0	16.3	Complied
6	-9.6	-9.6	-6.7	8.0	14.7	Complied
7	-9.5	-9.2	-6.5	8.0	14.5	Complied
11	-14.9	-14.9	-12.2	8.0	20.2	Complied
12	-18.9	-18.4	-15.8	8.0	23.8	Complied
13	-21.8	-21.9	-19.0	8.0	27.0	Complied

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

Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Core 0****Channel 7****Channel 11****Channel 12****Channel 13**

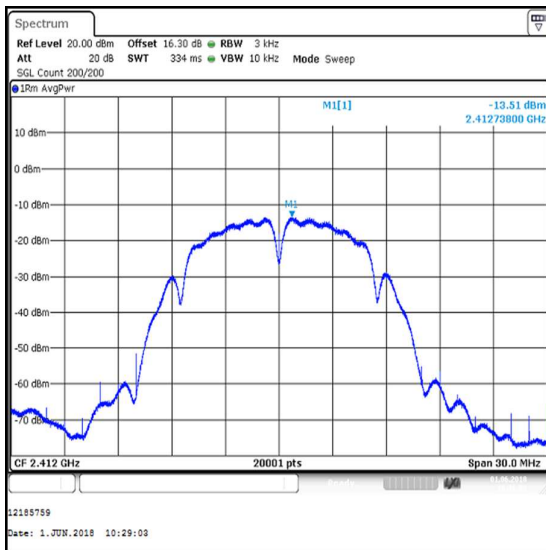
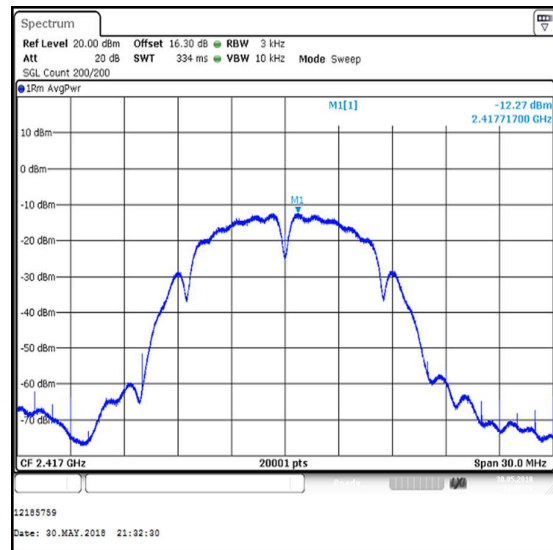
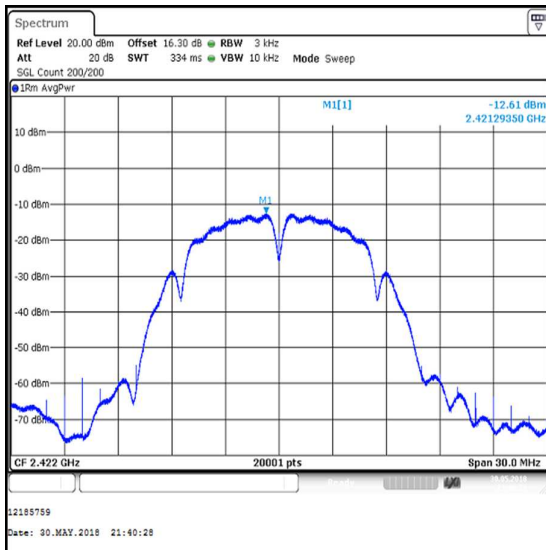
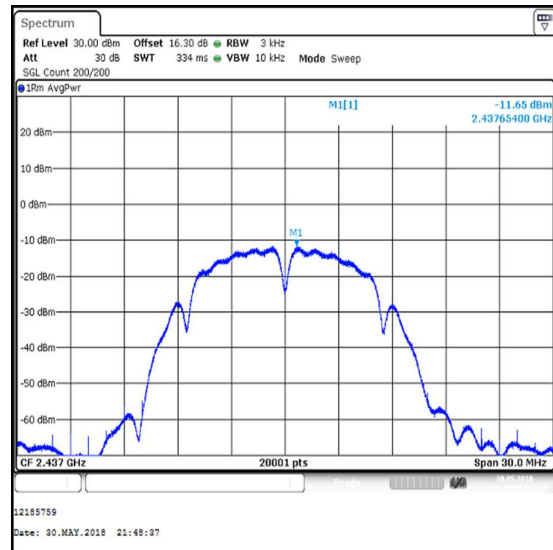
Transmitter Power Spectral Density (continued)**Results 802.11b / 20 MHz / 2Tx CDD / DBPSK / 1 Mbps / Core 0****Channel 1****Channel 2****Channel 3****Channel 6**

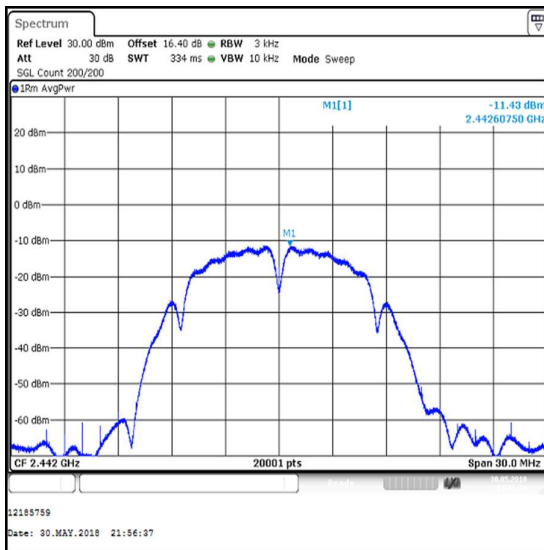
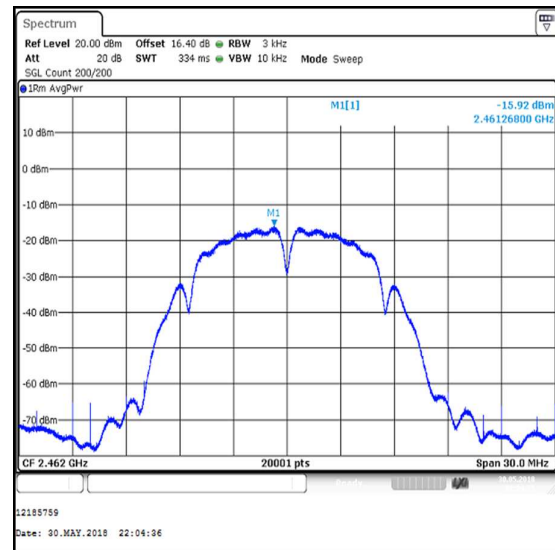
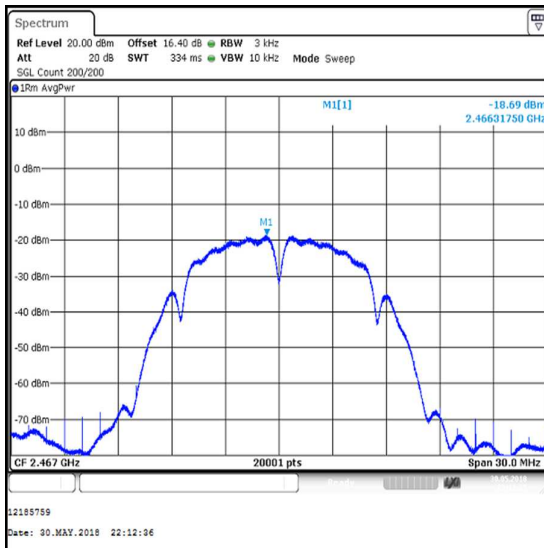
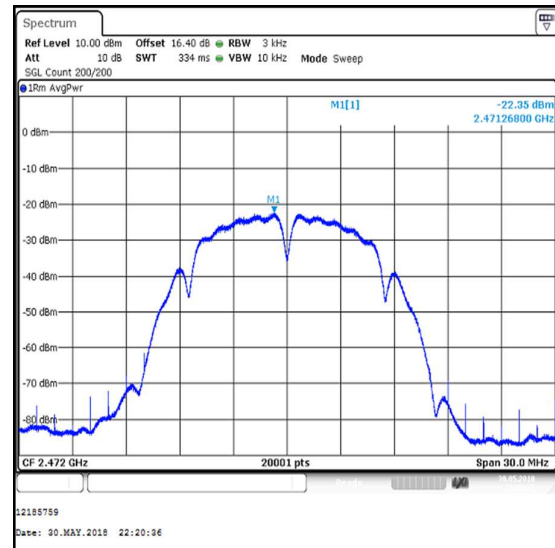
Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Core 0****Channel 7****Channel 11****Channel 12****Channel 13**

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

Channel	PSD on Core 1 (dBm / 3 kHz)	PSD on Core 0 (dBm / 3 kHz)	PSD on Core 2 (dBm / 3 kHz)
1	-13.5	-13.4	-13.5
2	-12.3	-12.1	-11.9
3	-12.6	-12.4	-12.4
6	-11.6	-11.6	-11.4
7	-11.4	-11.3	-11.3
11	-15.9	-16.0	-15.9
12	-18.7	-18.3	-18.5
13	-22.3	-22.5	-22.3

Channel	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-8.7	8.0	16.7	Complied
2	-7.8	8.0	15.8	Complied
3	-8.0	8.0	16.0	Complied
6	-7.1	8.0	15.1	Complied
7	-6.9	8.0	14.9	Complied
11	-11.4	8.0	19.4	Complied
12	-13.9	8.0	21.9	Complied
13	-18.1	8.0	26.1	Complied

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

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