



TEST REPORT

Test Report No. : UL-RPT-RP12505086JD09A

Customer : Apple Inc.

Model No. : A2116

FCC ID : BCGA2116

Technology : WLAN

Test Standard(s) : FCC Parts 15.209(a) & 15.247

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

1. This test report shall not be reproduced in full or partial, without the written approval of UL VS LTD.
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: 04 January 2019

Checked by:

Sarah Williams
Senior Test Engineer, Radio Laboratory

Company Signatory:

Ben Mercer
Senior Test Engineer, Radio Laboratory
UL VS LTD



UL VS LTD

Pavilion A, Ashwood Park, Ashwood Way, Basingstoke, Hampshire, RG23 8BG, UK
Telephone: +44 (0)1256 312000
Facsimile: +44 (0)1256 312001

Customer Information

Company Name:	Apple Inc.
Address:	One Apple Park Way Cupertino, California 95014 U.S.A.
Contact Name:	Stuart Thomas

Report Revision History

Version Number	Issue Date	Revision Details	Revised By
1.0	04/01/2019	Initial Version	Sarah Williams

Table of Contents

Customer Information.....	2
Report Revision History	2
1. Attestation of Test Results.....	4
1.1. Description of EUT	4
1.2. General Information	4
1.3. Summary of Test Results	4
1.4. Deviations from the Test Specification	4
2. Summary of Testing.....	5
2.1. Facilities and Accreditation	5
2.2. Methods and Procedures	5
2.3. Calibration and Uncertainty	6
2.4. Test and Measurement Equipment	7
3. Equipment Under Test (EUT)	9
3.1. Identification of Equipment Under Test (EUT)	9
3.2. Modifications Incorporated in the EUT	9
3.3. Additional Information Related to Testing	10
3.4. Description of Available Antennas	10
3.5. Description of Test Setup	11
4. Antenna Port Test Results	19
4.1. Transmitter Duty Cycle	19
4.2. Transmitter Minimum 6 dB Bandwidth	21
4.3. Transmitter Power Spectral Density	31
4.4. Transmitter Maximum (Average) Output Power	78
5. Radiated Test Results.....	126
5.1. Transmitter Radiated Emissions <1 GHz	126
5.2. Transmitter Radiated Emissions >1 GHz	128
5.3. Transmitter Band Edge Radiated Emissions	130
Appendix 1	159

1. Attestation of Test Results

1.1. Description of EUT

The equipment under test was a desktop computer with WLAN and BT radios.

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:	621311
Location of Testing:	UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
Test Dates:	14 October 2018 to 10 December 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):

1. The measurement was performed to assist in the calculation of the level of maximum conducted output power, power spectral density and emissions. The EUT cannot transmit continuously and sweep triggering/signal gating cannot be implemented.
2. 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.
3. 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	-
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 15.247 Meas Guidance v05 August 24, 2018
Title:	Guidance for Compliance Measurements on Digital Transmission System, Frequency Hopping Spread Spectrum System, and Hybrid System Devices Operating Under Section 15.247 of the FCC Rules
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)
M2042	Thermohygrometer	Testo	608-H1	458046425	26 Feb 2019	12
A3027	Attenuator	Broadwave Technologies	351-311-006	#1	Calibrated before use	-
A3028	Attenuator	Broadwave Technologies	351-311-006	#2	Calibrated before use	-
A3029	Attenuator	Broadwave Technologies	351-311-006	#3	Calibrated before use	-
A3004	RF Switch	Pickering Interfaces	64-102-002	XZ363230	Calibrated before use	-
M2033	Signal Analyser	Rohde & Schwarz	FSV13	101667	31 May 2019	12
G0607	Signal Generator	Rohde & Schwarz	SMU200A	100943	10 May 2019	36
A3005	RePlay Test Rack	N/A	N/A	N/A	Calibration not required	-

Test Equipment Used for Transmitter Conducted Tests (TxBF)

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2042	Thermohygrometer	Testo	608-H1	458046425	26 Feb 2019	12
M1835	Signal Analyser	Rohde & Schwarz	FSV30	103050	19 Mar 2019	12
G0615	Signal Generator	Rohde & Schwarz	SMBV100A	260473	08 May 2020	36
A2097	Power Splitter	Mini-Circuits	ZN4PD1-63W-S+	SUU98701205	Calibrated before use	-
A1535	Variable Attenuator	Hewlett Packard	8495B/8494B	00007	Calibrated before use	-
A2505	Directional Coupler	Atlan TecRF	CDC-003060-20	1101230	Calibrated before use	-
A2536	Directional Coupler	Atlan TecRF	CDC-003060-20	14041701720	Calibrated before use	-
A2534	Directional Coupler	Atlan TecRF	CDC-003060-20	14041701718	Calibrated before use	-
A2098	Power Splitter	Mini-Circuits	ZN4PD1-63-S+	SF210501205	Calibrated before use	-
A3160	RF Switch	Pickering Interface	60-102B-001	XZ370188	Calibrated before use	-

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)
M2040	Thermohygrometer	Testo	608-H1	45124934	27 Mar 2019	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	16 Oct 2019	12
M2044	Test Receiver	Rohde & Schwarz	ESU26	100122	17 Apr 2019	12
A3154	Pre-Amplifier	Com-Power Corp	PAM-103	18020012	14 Sep 2019	12
A553	Antenna	Chase	CBL6111A	1593	08 Oct 2019	12
A3085	Low Pass Filter	AtlanTecRF	AFL-02000	AFL-02000	26 Jun 2019	12
A3112	Attenuator	AtlanTecRF	AN18-06	219706#2	08 Oct 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
M1995	Test Receiver	Rohde & Schwarz	ESU40	100428	10 Aug 2019	12
A2863	Pre-Amplifier	Agilent	8449B	3008A02100	19 Feb 2019	12
A2891	Pre-Amplifier	Schwarzbeck	BBV 9718	9718-306	20 Feb 2019	12
A2896	Pre-Amplifier	Schwarzbeck	BBV 9721	9721-023	20 Feb 2019	12
A2889	Antenna	Schwarzbeck	BBHA 9120 B	BBHA 9120 B 653	19 Feb 2019	12
A2890	Antenna	Schwarzbeck	HWRD 750	014	19 Feb 2019	12
A2895	Antenna	Schwarzbeck	BBHA 9170	9170-728	20 Feb 2019	12
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	21 Feb 2019	12
A2914	High Pass Filter	AtlanTecRF	AFH-03000	2155	22 Feb 2019	12
A2947	High Pass Filter	AtlanTecRF	AFH-07000	1601900001	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)
M2040	Thermohygrometer	Testo	608-H1	45124934	27 Mar 2019	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	04 Oct 2019	12
M2044	Test Receiver	Rohde & Schwarz	ESU26	100122	17 Apr 2019	12
A3155	Pre Amplifier	Com-Power Corp	PAM-118A	18040037	14 Sep 2019	12
A3138	Antenna	Schwarzbeck	BBHA 9120B	00702	03 Oct 2019	12
A2523	Attenuator	AtlanTecRF	AN18W5-10	8328727#1	23 Feb 2019	12

Test Measurement Software/Firmware Used

Name	Version	Release Date
UL VS LTD Replay	v.11	22 Nov 2018
iPerf	2.0.9	01 Jun 2016

3. Equipment Under Test (EUT)

3.1. Identification of Equipment Under Test (EUT)

Brand Name:	Apple
Model Name or Number:	A2116
Test Sample Serial Number:	C02X2007KFLX (<i>Conducted sample #1</i>)
Hardware Version:	EVT
Software Version:	18A334
FCC ID:	BCGA2116

Brand Name:	Apple
Model Name or Number:	A2116
Test Sample Serial Number:	C02WW00WKFMM (<i>Conducted sample #2</i>)
Hardware Version:	EVT
Software Version:	18A334
FCC ID:	BCGA2116

Brand Name:	Apple
Model Name or Number:	A2116
Test Sample Serial Number:	C02WW00PKFMM (<i>Radiated sample #1</i>)
Hardware Version:	EVT
Software Version:	18E110z
FCC ID:	BCGA2116

Brand Name:	Apple
Model Name or Number:	A2116
Test Sample Serial Number:	C02X200XKFLX (<i>Radiated sample #2</i>)
Hardware Version:	EVT
Software Version:	18E110z
FCC ID:	BCGA2116

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, MIMO with CDD)
	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 with or without TxBF) MCS16 to MCS23 (3 spatial streams on 3 transmit chains with or without TxBF)
Power Supply Requirement(s):	Nominal	120 VAC 60 Hz
Maximum Conducted Output Power:	26.8 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)	$G_{\text{Antenna 1 / Core 0}}$ (dBi)	$G_{\text{Antenna 2 / Core 1}}$ (dBi)	$G_{\text{Antenna 3 / Core 2}}$ (dBi)
2400 - 2480	3.7	4.8	4.3

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:

Description:	Test Laptop
Brand Name:	Apple
Model Name or Number:	MacBook Pro
Serial Number:	C025200CHH5Q

Description:	Test Laptop
Brand Name:	Apple
Model Name or Number:	MacBook Pro
Serial Number:	C02S200EHH5Q

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

Description:	USB Keyboard
Brand Name:	Apple
Model Name or Number:	A1243
Serial Number:	CC2438202G4DQW0AC

Description:	USB Mouse
Brand Name:	Apple
Model Name or Number:	A1152
Serial Number:	CC2446203PNDNYPAJ

Description:	USB-C Adapter
Brand Name:	Apple
Model Name or Number:	A1632
Serial Number:	Not marked or stated

Description:	Laptop PC
Brand Name:	Dell
Model Name or Number:	GBITL003
Serial Number:	76487-641-1766771

Support Equipment (continued)

Description:	USB Hub
Brand Name:	Hama
Model Name or Number:	00078498
Serial Number:	09825891600

Description:	Ethernet Router
Brand Name:	Netgear
Model Name or Number:	DG834G
Serial Number:	1JX167B008C4A

Description:	Ethernt cable. Length 2.0 metres. Quantity 1
Brand Name:	Not marked or stated
Model Name or Number:	Not marked or stated
Serial Number:	Not marked or stated

Description:	USB Cable. Length 3.0 metres. Quantity 4
Brand Name:	Not marked or stated
Model Name or Number:	Not marked or stated
Serial Number:	Not marked or stated

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

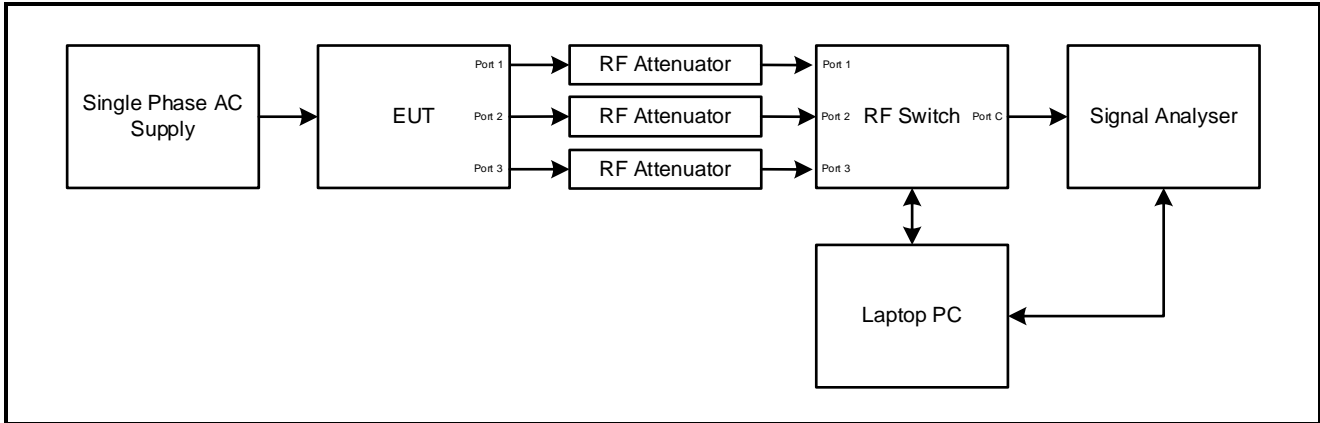
The EUT was tested in the following configuration(s):

- 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.
- For TxBF modes, the EUT was communicating via a conducted or 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_v1.2.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. Core 0, Core 1 and Core 2 correspond to antenna 1, antenna 2 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 USB Keyboard, USB Mouse and PHF connected to the EUT. The remaining USB ports were connected with a USB cable to a hub. The USB-C ports were connected via a USB C-A adaptor and USB cable to a hub. The ethernet port was terminated into a router. The router and hub were placed under the floor inside the chamber.
- The EUT was powered from a 120 VAC 60 Hz single phase mains supply.

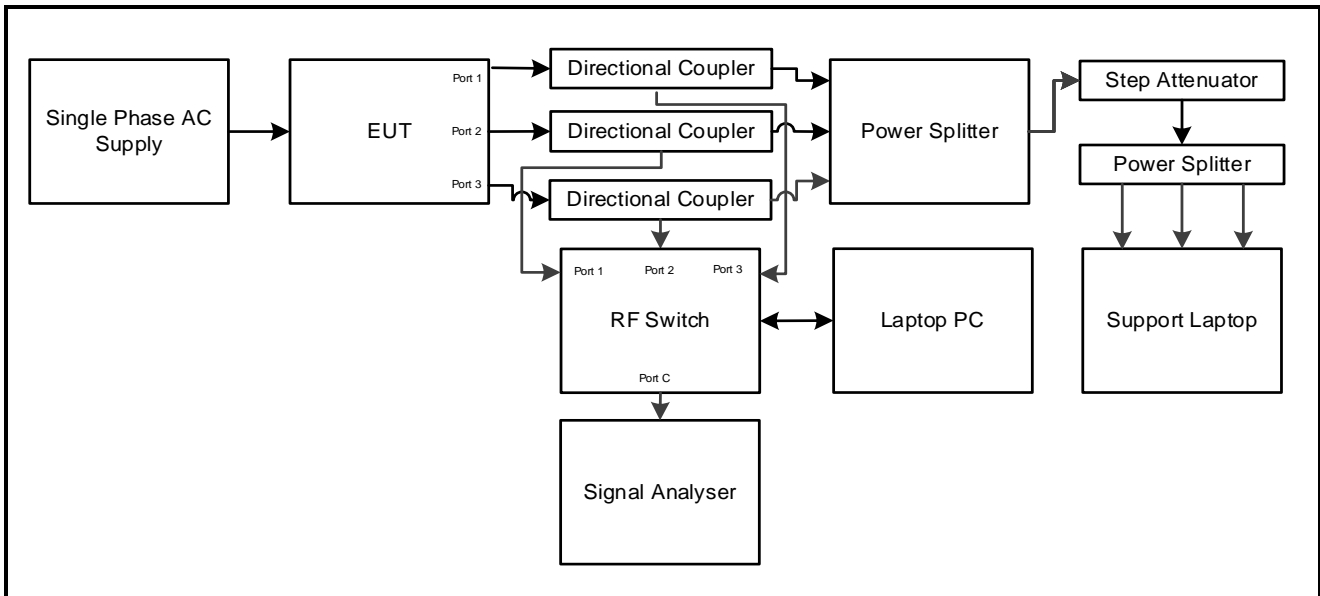
Test Setup Diagrams

Conducted Tests:

Test Setup for Transmitter Conducted Tests (non TxBF)



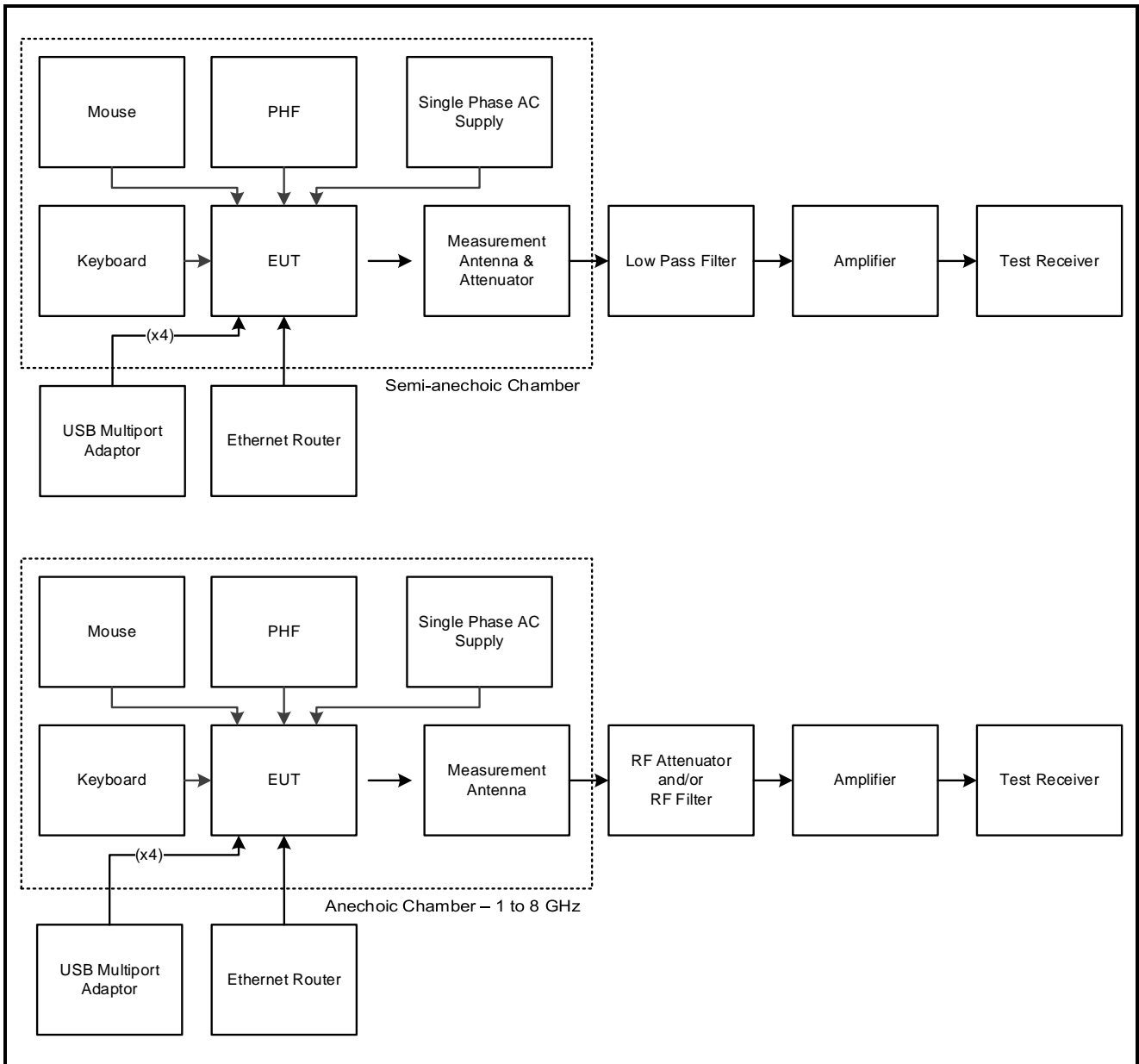
Test Setup for Transmitter Conducted Tests (TxBF)



Test Setup Diagrams (continued)

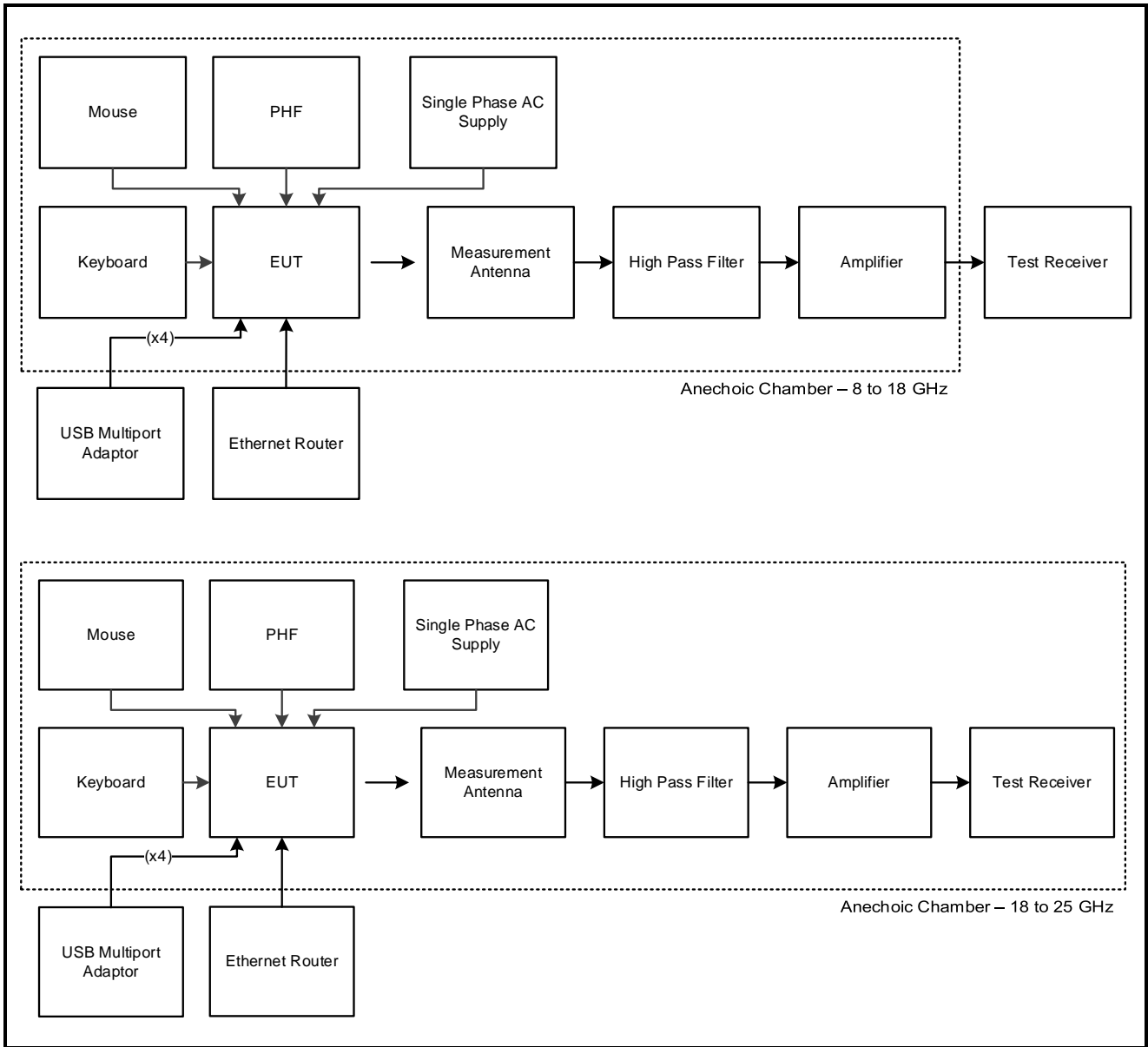
Radiated Tests:

Test Setup for Transmitter Radiated Emissions (non TxBF)



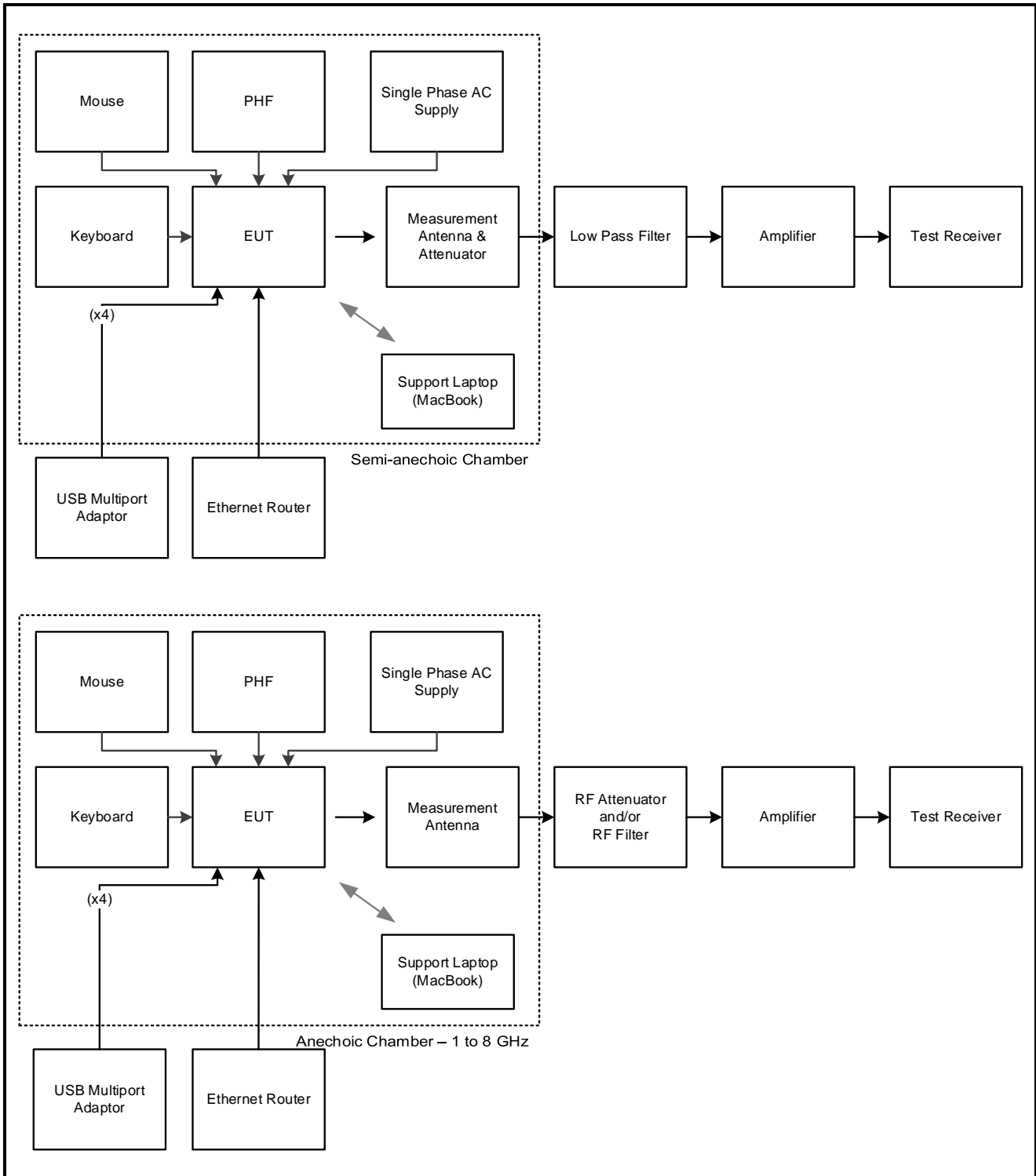
Test Setup Diagrams (continued)

Test Setup for Transmitter Radiated Emissions (non TxBF) (continued)



Test Setup Diagrams (continued)

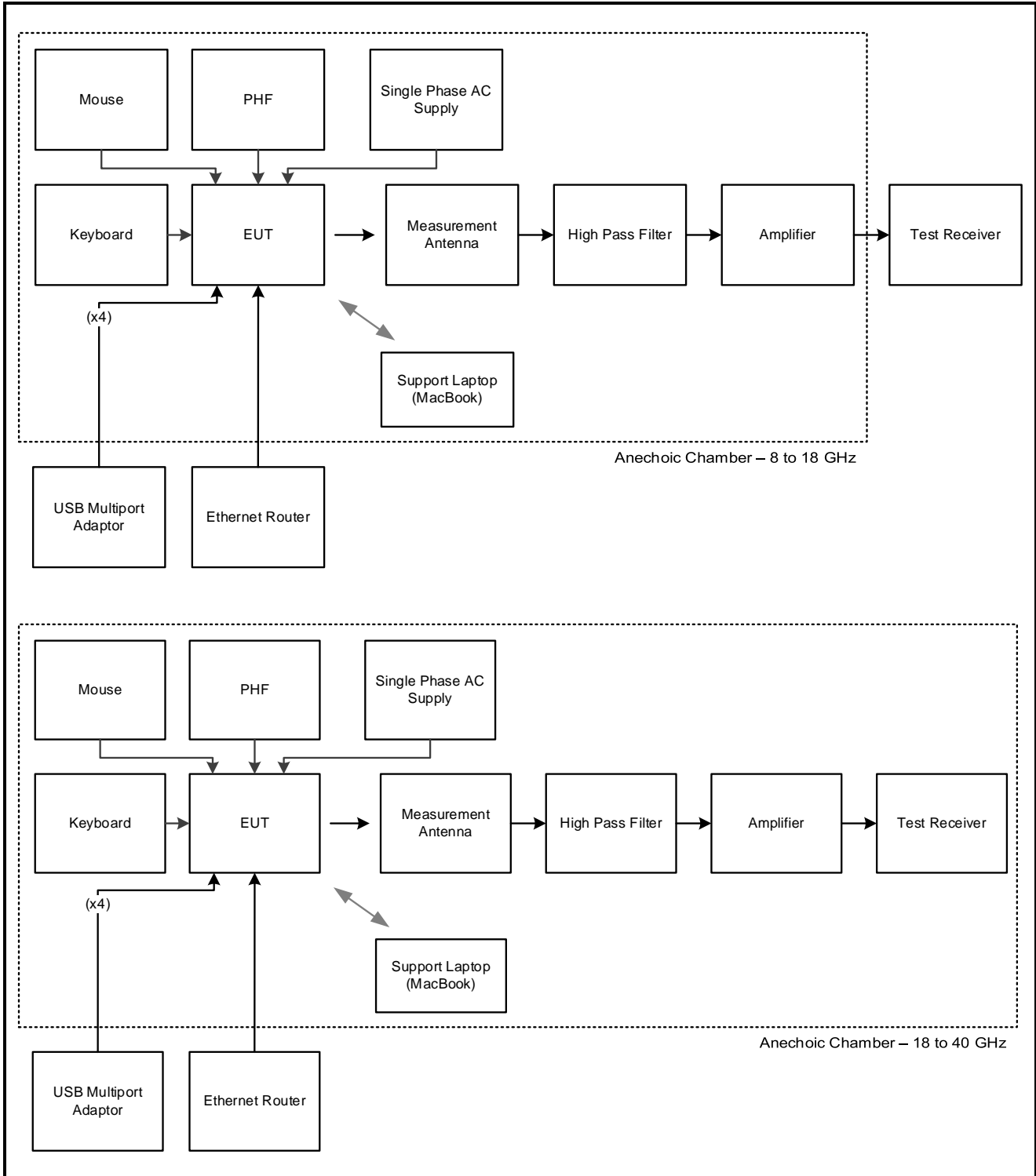
Test Setup for Transmitter Radiated Emissions (TxBF)



Test Setup Diagrams (continued)

Radiated Tests:

Test Setup for Transmitter Radiated Emissions (TxBF) (continued)



4. Antenna Port Test Results

4.1. Transmitter Duty Cycle

Test Summary:

Test Engineers:	Victor Carmon & Matthew Botfield	Test Dates:	26 November 2018 & 03 December 2018
Test Sample Serial Number:	C02WW00WKFMM		

FCC Reference:	Part 15.35(c)
Test Method Used:	FCC KDB 558074 Section 6 referencing ANSI C63.10 Section 11.6

Environmental Conditions:

Temperature (°C):	22 to 23
Relative Humidity (%):	39 to 45

Note(s):

- 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 by using the following calculation:

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

$$802.11n / HT20 / MCS0 / MIMO / 2Tx TxBF / \text{Core 1 duty cycle: } 10 \log (1 / (4.7536/4.8986)) = 0.1 \text{ dB}$$

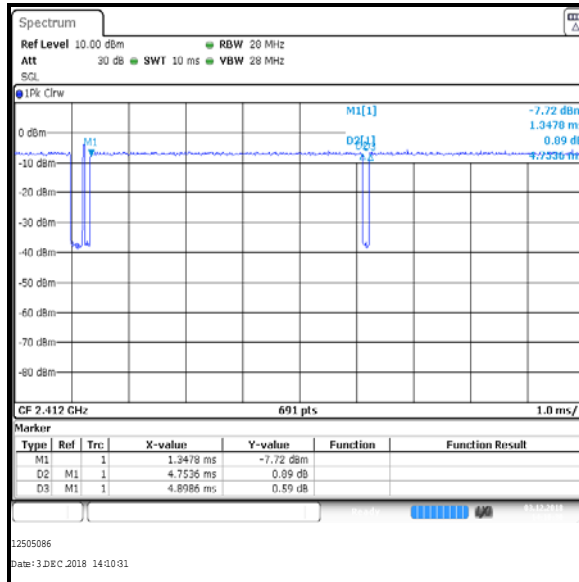
$$802.11n / HT20 / MCS0 / MIMO / 3Tx TxBF / \text{Core 0 duty cycle: } 10 \log (1 / (3.8440/3.9480)) = 0.1 \text{ dB}$$

- 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)

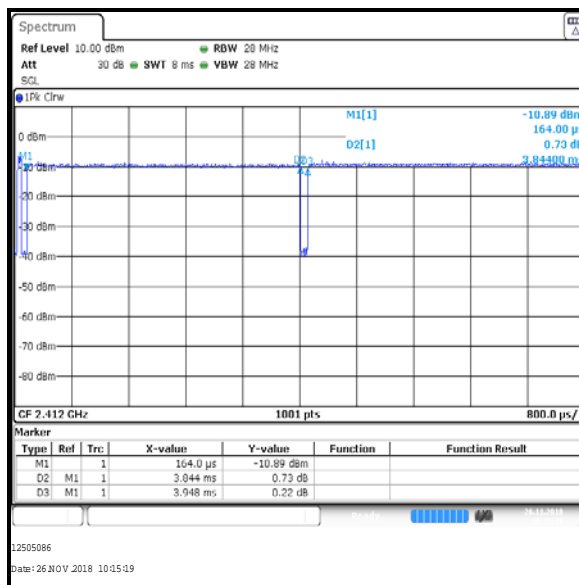
Results: 802.11n / HT20 / MIMO / 2Tx TxBF / MCS0 / Core 1

Pulse Duration (ms)	Period (ms)	Duty Cycle (dB)
4.7536	4.8986	0.1



Results: 802.11n / HT20 / MIMO / 3Tx TxBF / MCS0 / Core 0

Pulse Duration (ms)	Period (ms)	Duty Cycle (dB)
3.8440	3.9480	0.1



4.2. Transmitter Minimum 6 dB Bandwidth

Test Summary:

Test Engineer:	Max Passell	Test Dates:	21 November 2018 & 28 November 2018
Test Sample Serial Number:	C02X2007KFLX		

FCC Reference:	Part 15.247(a)(2)
Test Method Used:	FCC KDB 558074 Section 8.2 referencing ANSI C63.10 Section 11.8.1

Environmental Conditions:

Temperature (°C):	20 to 23
Relative Humidity (%):	38 to 50

Note(s):

1. The customer declared the following data rates to be used for all measurements as:

- 802.11b – DBPSK / 1 Mbps / Core 1
- 802.11g – BPSK / 6 Mbps / Core 1
- 802.11n HT20 – BPSK / MCS0 / Core 1

Only SISO modes are reported since the bandwidth does not change depending on chains used.

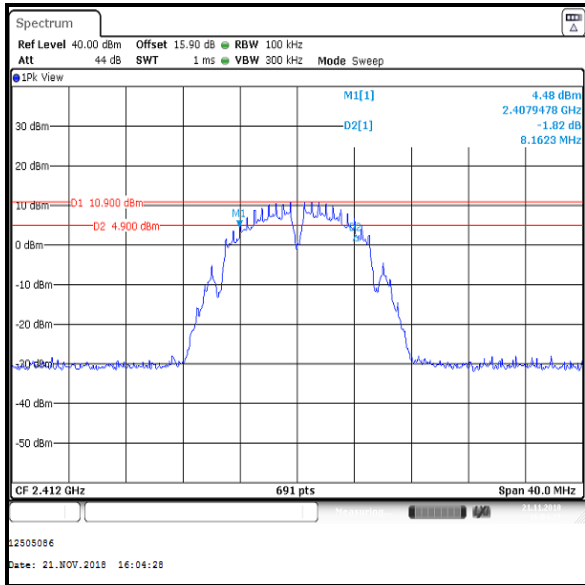
2. Final measurements were performed using the above configurations on the relevant channels in accordance with ANSI C63.10 Section 11.8.1 Option 1 measurement procedure. Additional channels were tested as requested by the customer. The signal analyser resolution bandwidth was set to 100 kHz and video 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 1**

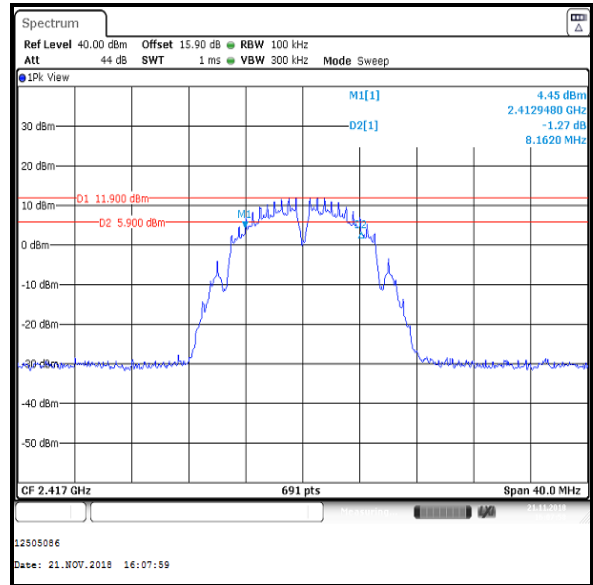
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	8162	≥500	7662	Complied
2	8162	≥500	7662	Complied
3	8162	≥500	7662	Complied
6	8220	≥500	7720	Complied
7	8220	≥500	7720	Complied
11	8162	≥500	7662	Complied
12	8162	≥500	7662	Complied
13	8220	≥500	7720	Complied

Transmitter Minimum 6 dB Bandwidth (continued)

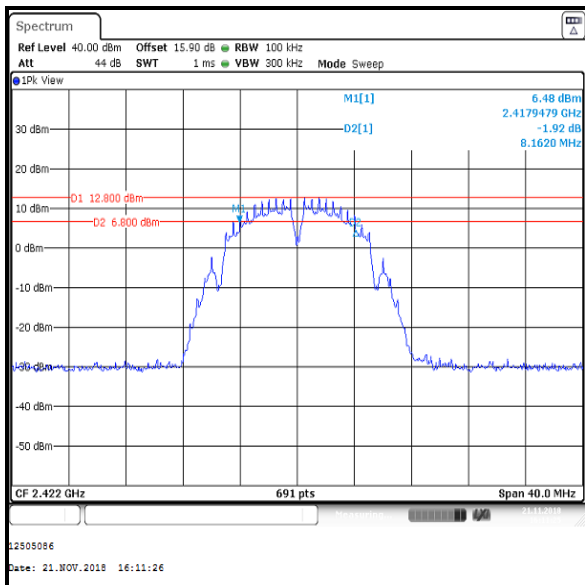
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 1



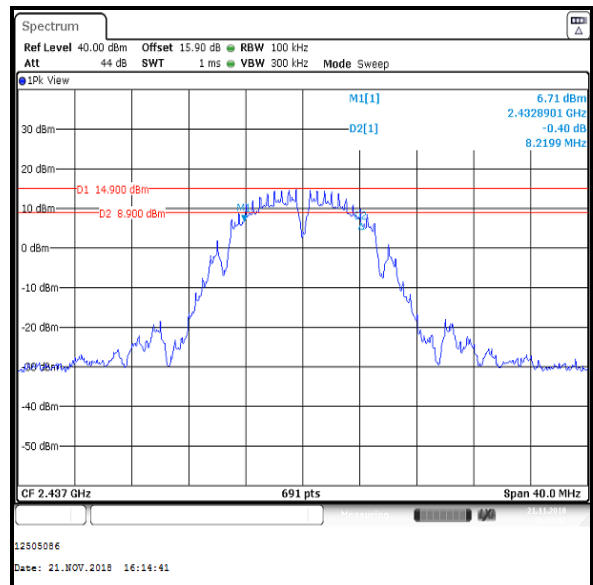
Channel 1



Channel 2



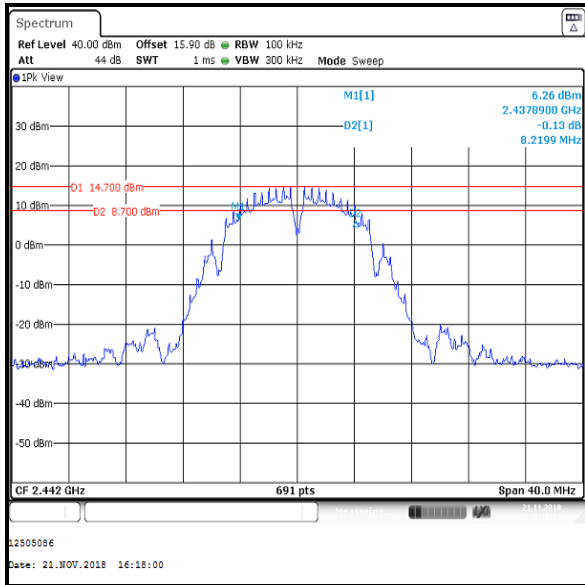
Channel 3



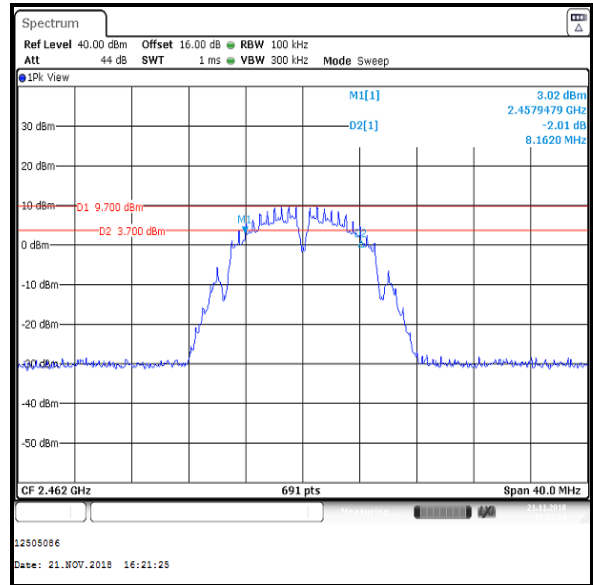
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)

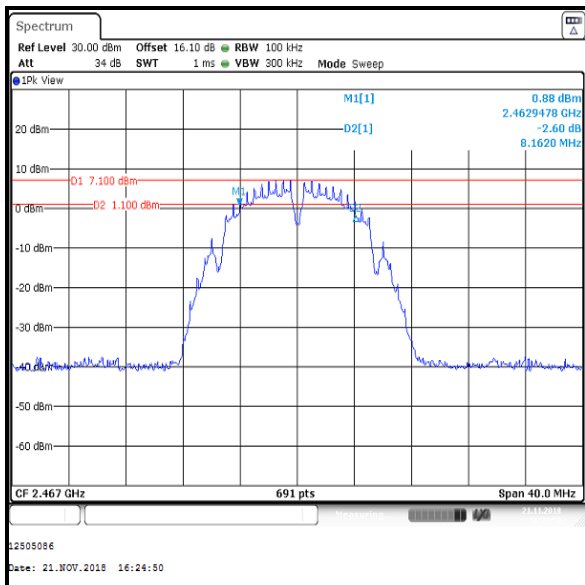
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 1



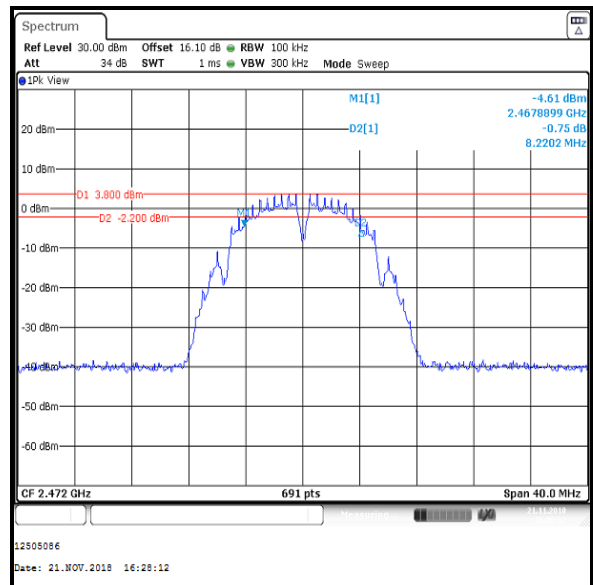
Channel 7



Channel 11



Channel 12



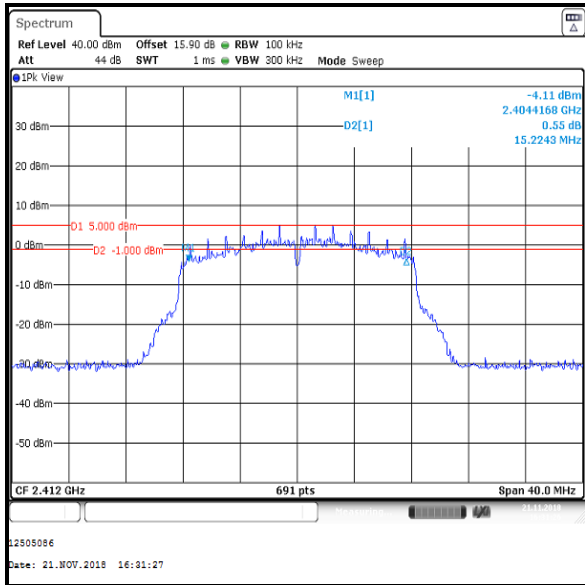
Channel 13

Transmitter Minimum 6 dB Bandwidth (continued)**Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 1**

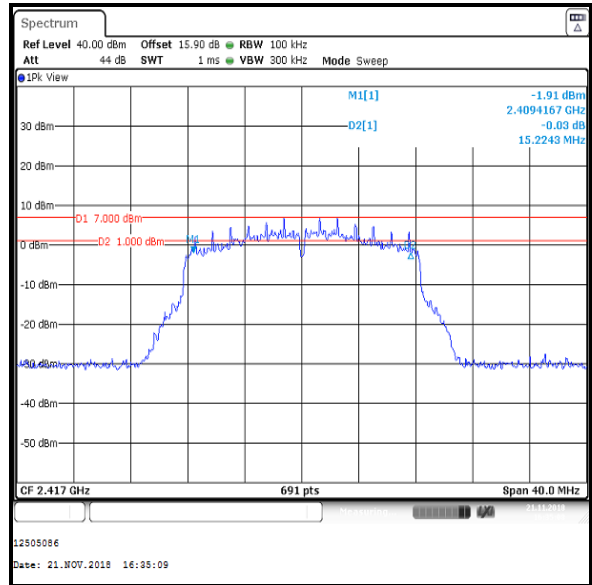
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	15224	≥500	14724	Complied
2	15224	≥500	14724	Complied
3	15166	≥500	14666	Complied
6	15167	≥500	14667	Complied
7	15224	≥500	14724	Complied
11	15166	≥500	14666	Complied
12	15109	≥500	14609	Complied
13	15167	≥500	14667	Complied

Transmitter Minimum 6 dB Bandwidth (continued)

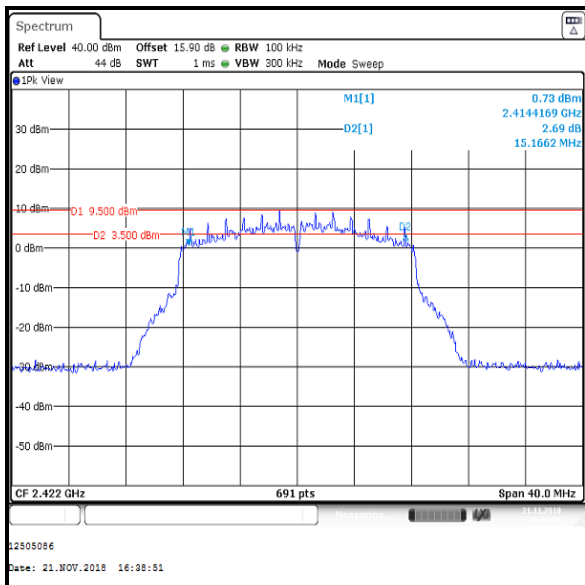
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 1



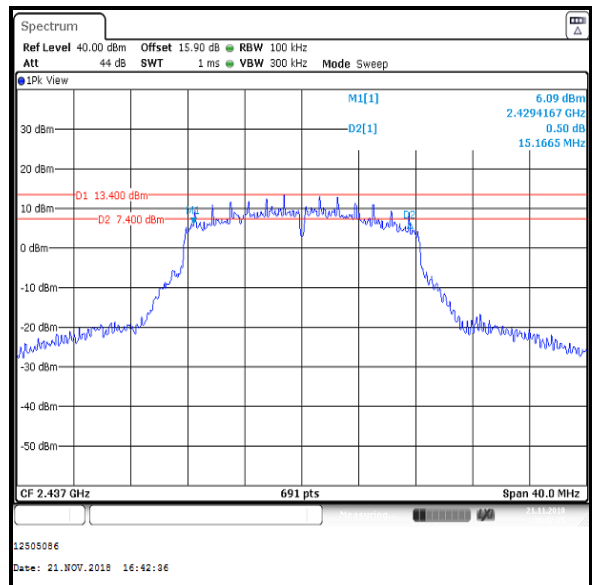
Channel 1



Channel 2



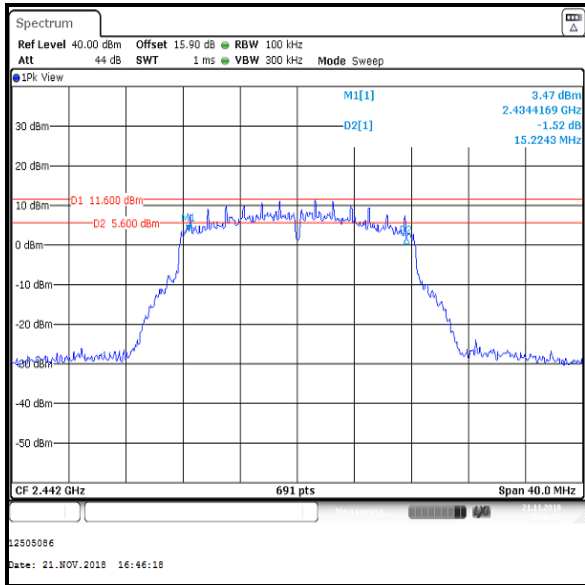
Channel 3



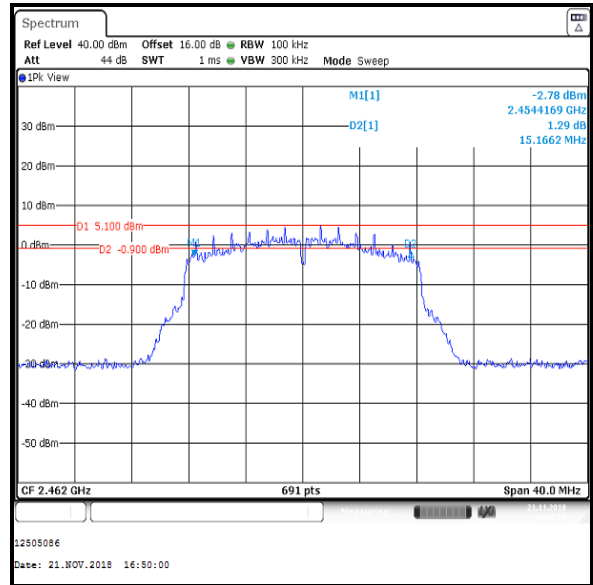
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)

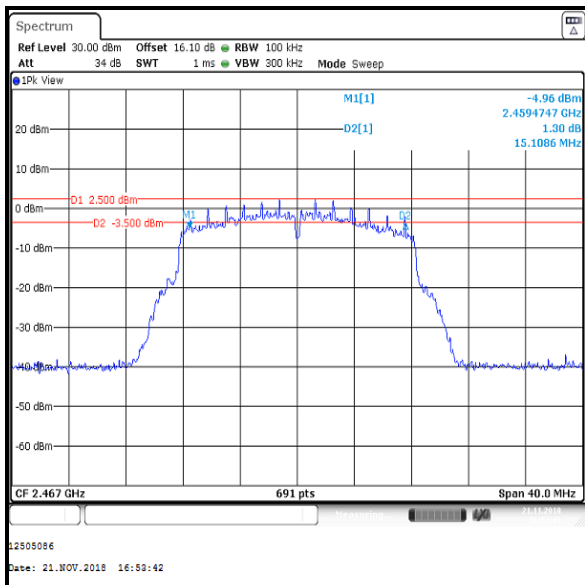
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 1



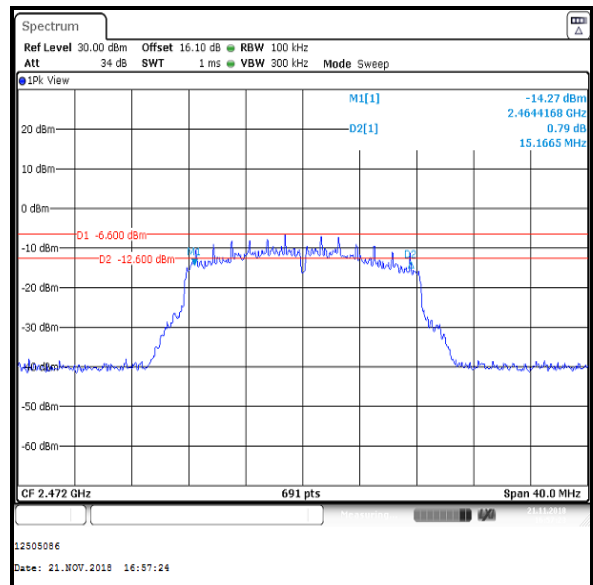
Channel 7



Channel 11



Channel 12



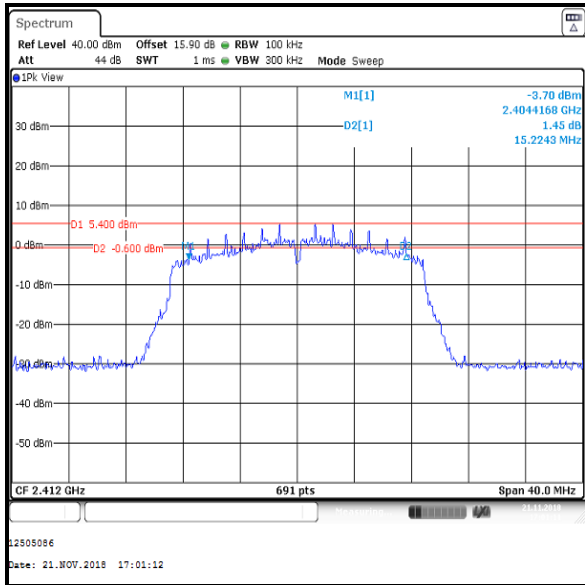
Channel 13

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

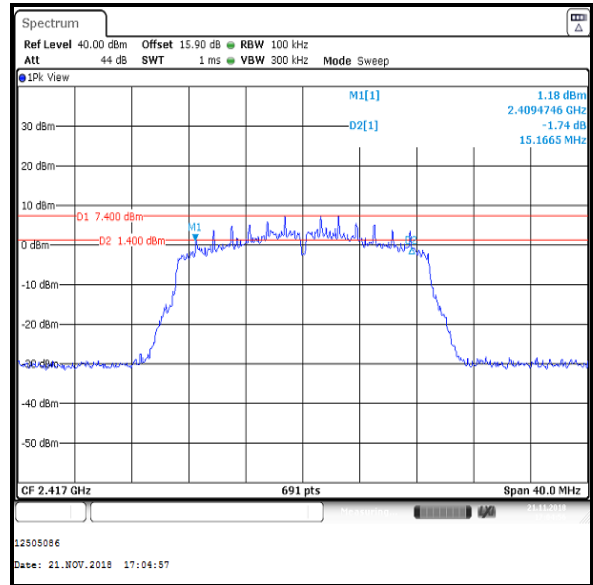
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	15224	≥500	14724	Complied
2	15167	≥500	14667	Complied
3	15166	≥500	14666	Complied
6	15167	≥500	14667	Complied
7	15224	≥500	14724	Complied
11	15166	≥500	14666	Complied
12	15167	≥500	14667	Complied
13	15167	≥500	14667	Complied

Transmitter Minimum 6 dB Bandwidth (continued)

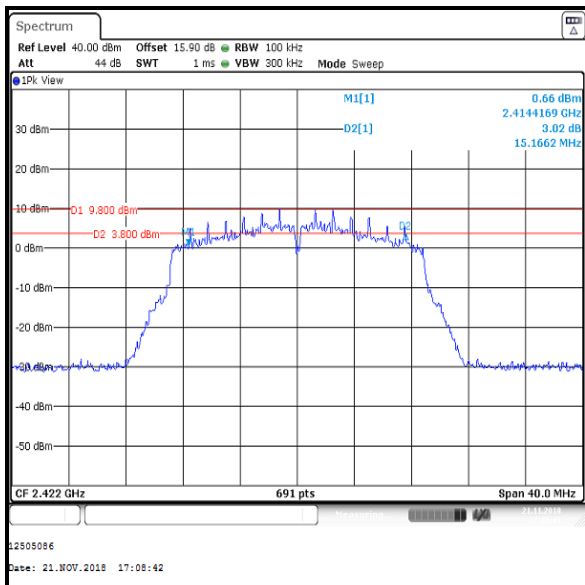
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 1



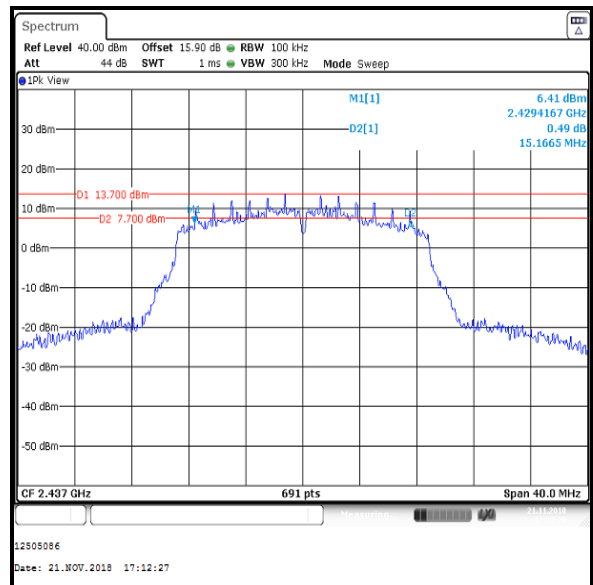
Channel 1



Channel 2



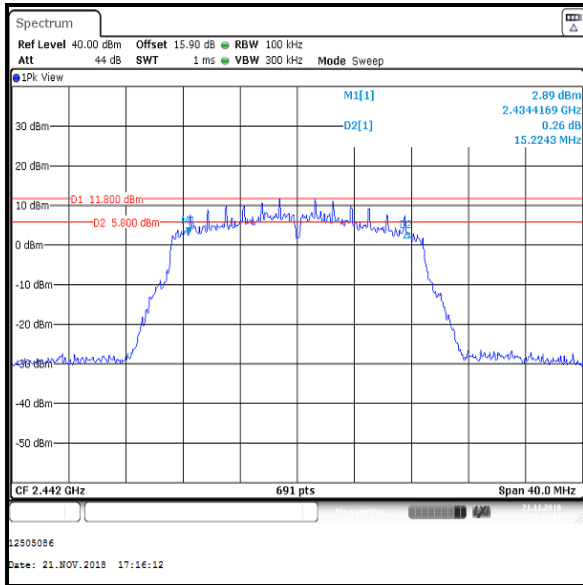
Channel 3



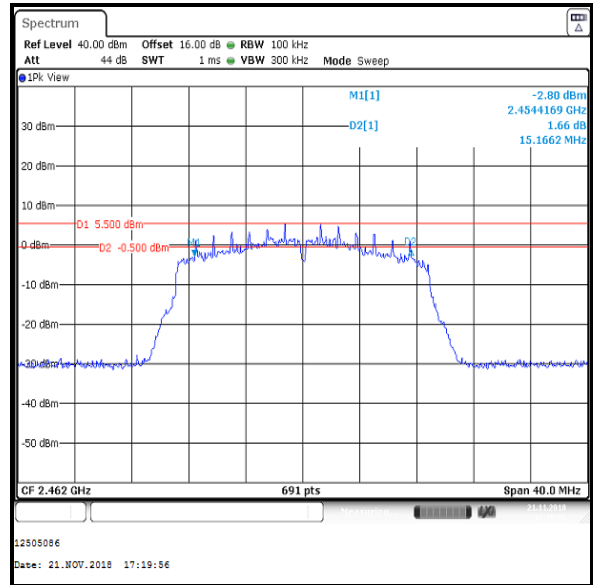
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)

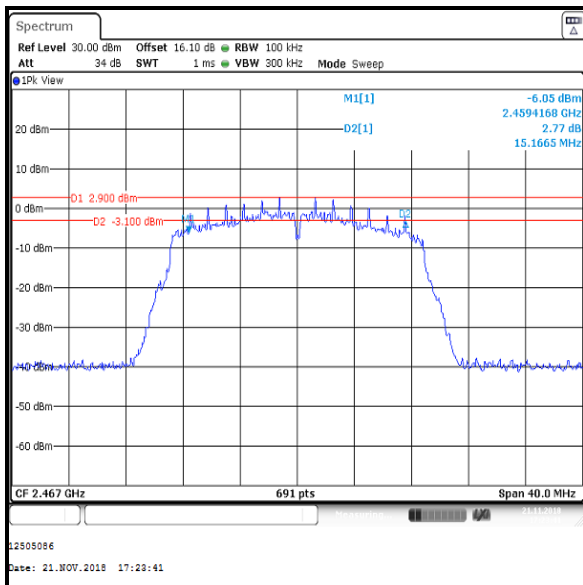
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 1



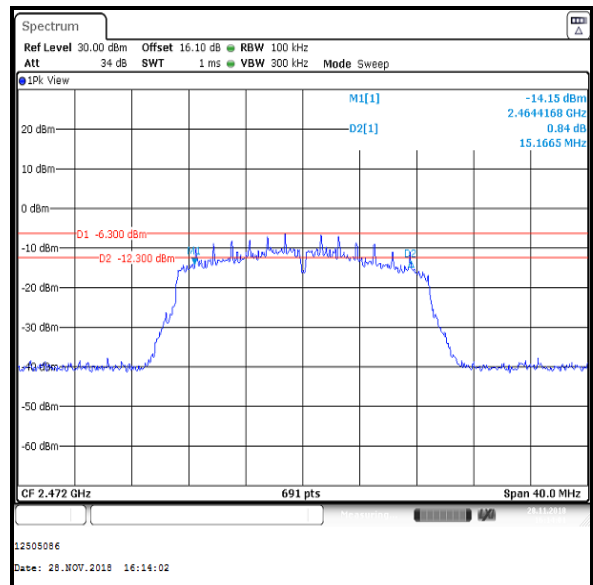
Channel 7



Channel 11



Channel 12



Channel 13

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

Test Engineers:	Max Passell, Victor Carmon & Matthew Botfield	Test Dates:	21 November 2018 to 30 November 2018
Test Sample Serial Numbers:	C02X2007KFLX & C02WW00WKFMM		

FCC Reference:	Part 15.247(e)
Test Method Used:	FCC KDB 558074 Section 8.4 referencing ANSI C63.10 Sections 11.10.3 & 11.10.5

Environmental Conditions:

Temperature (°C):	20 to 23
Relative Humidity (%):	38 to 51

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

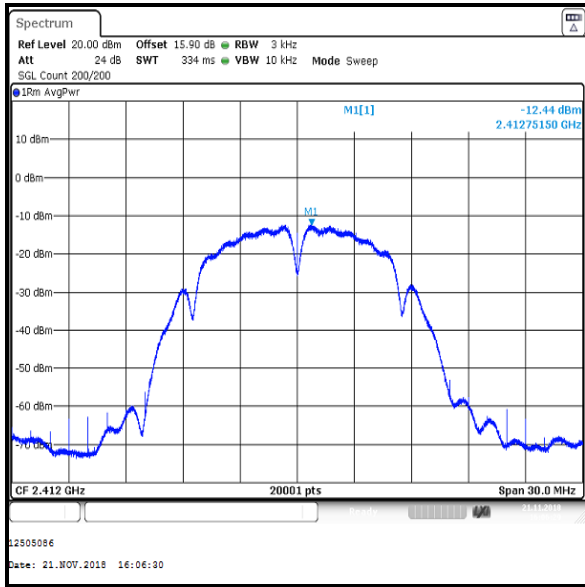
1. The customer declared the following data rates to be used for all measurements as:
 - 802.11b – DBPSK / 1 Mbps / Core 1
 - 802.11g – BPSK / 6 Mbps / Core 1
 - 802.11n HT20 – BPSK / MCS0 / Core 1
 - 802.11b – DBPSK / 1 Mbps / MIMO / 2Tx CDD / Core 1 & Core 2
 - 802.11b – DBPSK / 1 Mbps / MIMO / 3Tx CDD / Core 0, Core 1 & Core 2
 - 802.11n HT20 / MIMO / 2Tx CDD / BPSK / MCS0 / Core 1 & Core 2
 - 802.11n HT20 / MIMO / 3Tx CDD / BPSK / MCS0 / Core 0, Core 1 & Core 2
 - 802.11n HT20 / MIMO / 2Tx TxBF / BPSK / MCS0 / Core 1 & Core 2
 - 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-Tx BF modes, the EUT was transmitting at >98% duty cycle and testing was performed in accordance with ANSI C63.10 Section 11.10.3 Method AVGPSD-1. The signal analyser resolution bandwidth was set to 3 kHz or 100 kHz and video bandwidth 10 kHz or 300 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 Tx BF modes, the EUT was transmitting at <98% duty cycle and testing was performed in accordance with ANSI C63.10 Section 11.10.5 Method AVGPSD-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 200 traces. The span was set greater than 1.5 times the 99% emission bandwidth.
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 Tx BF, 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 C02X2007KFLX was used for non-Tx BF tests, the EUT with serial number C02WW00WKFMM was used for Tx BF tests.

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

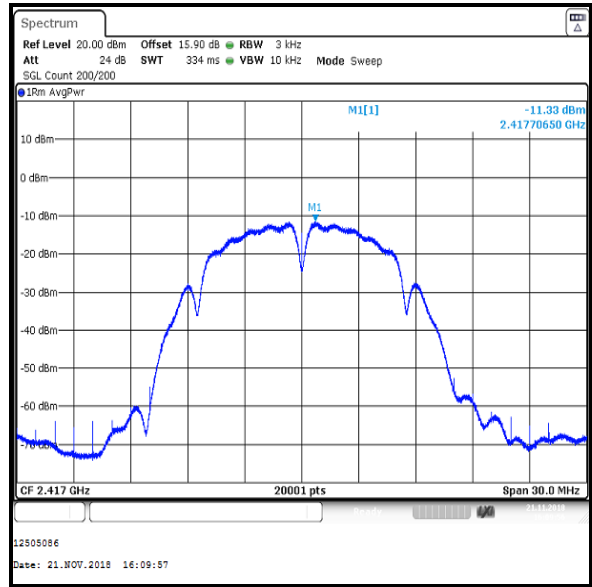
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
1	-12.4	8.0	20.4	Complied
2	-11.3	8.0	19.3	Complied
3	-10.2	8.0	18.2	Complied
6	-8.4	8.0	16.4	Complied
7	-8.8	8.0	16.8	Complied
11	-13.5	8.0	21.5	Complied
12	-16.0	8.0	24.0	Complied
13	-19.4	8.0	27.4	Complied

Transmitter Power Spectral Density (continued)

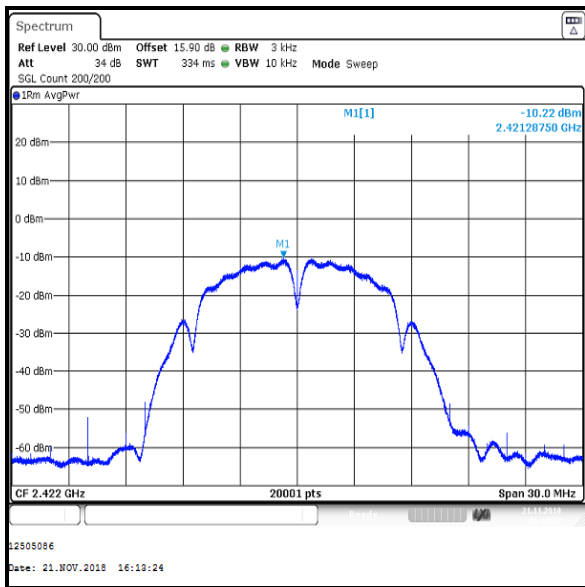
Results: 802.11b / 20 MHz / SISO / DBPSK / 1 Mbps / Core 1



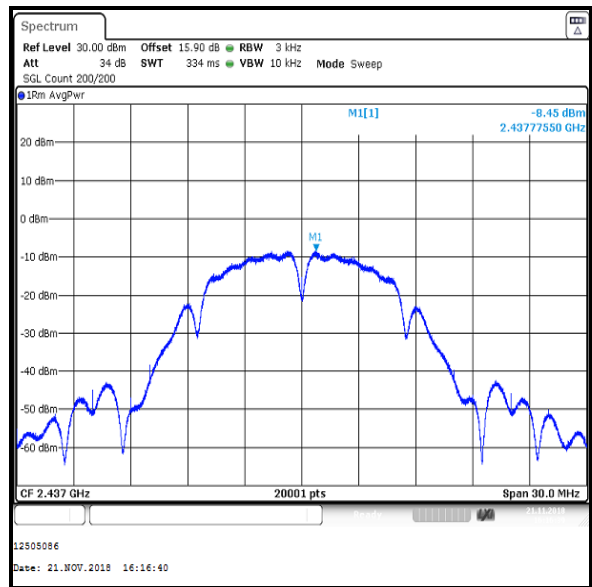
Channel 1



Channel 2



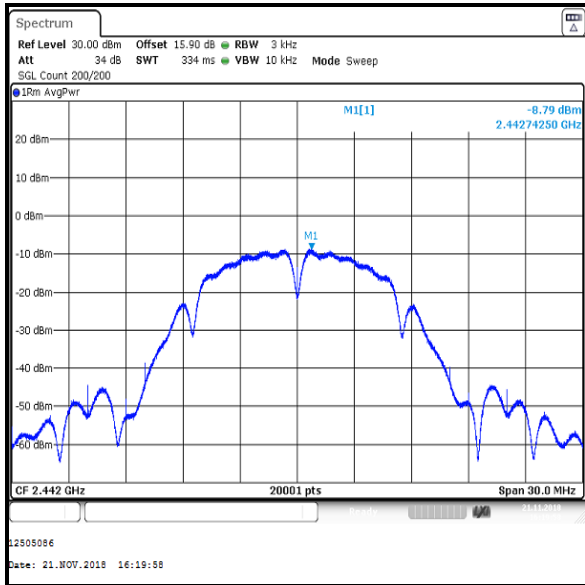
Channel 3



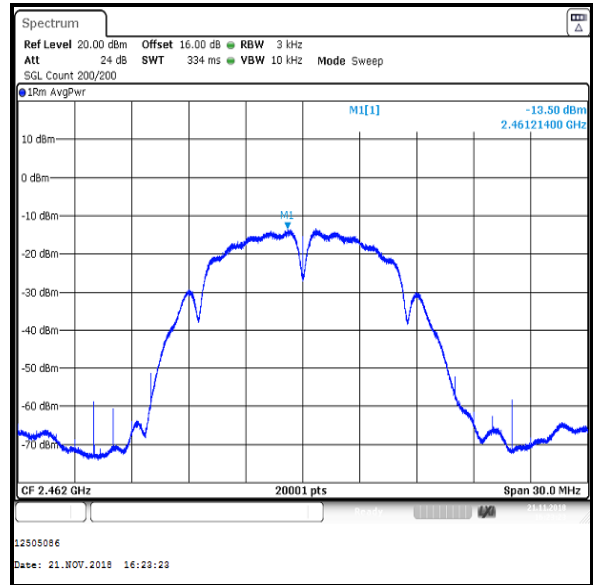
Channel 6

Transmitter Power Spectral Density (continued)

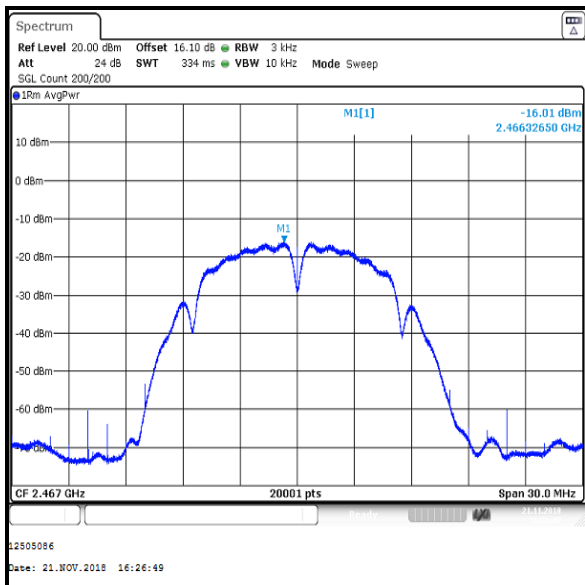
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 1



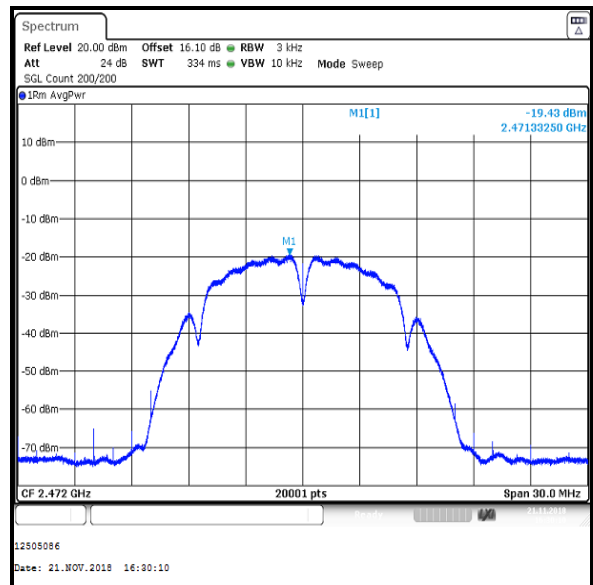
Channel 7



Channel 11



Channel 12



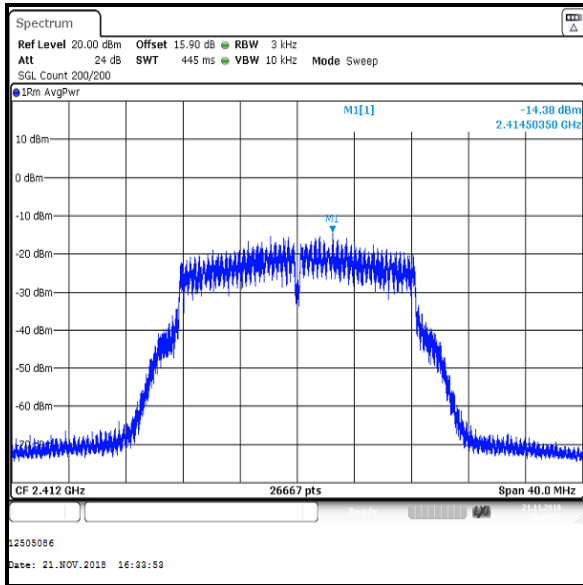
Channel 13

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

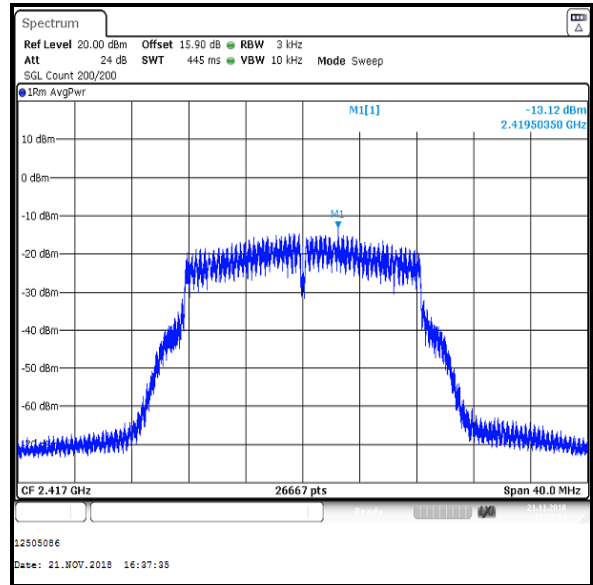
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
1	-14.4	8.0	22.4	Complied
2	-13.1	8.0	21.1	Complied
3	-10.7	8.0	18.7	Complied
6	-6.7	8.0	14.7	Complied
7	-8.4	8.0	16.4	Complied
11	-14.9	8.0	22.9	Complied
12	-18.3	8.0	26.3	Complied
13	-27.4	8.0	35.4	Complied

Transmitter Power Spectral Density (continued)

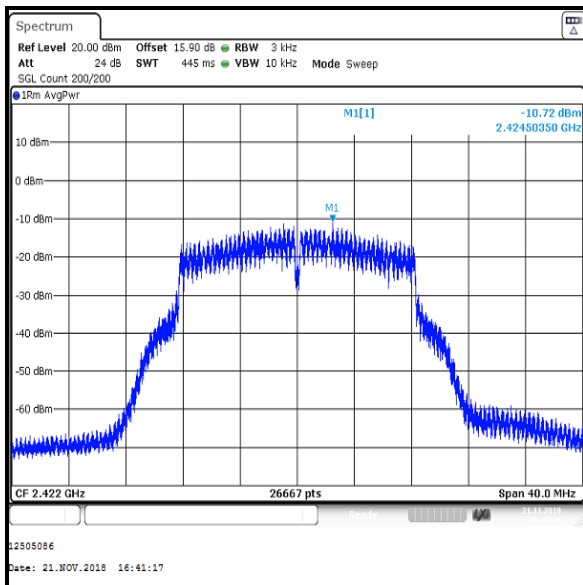
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 1



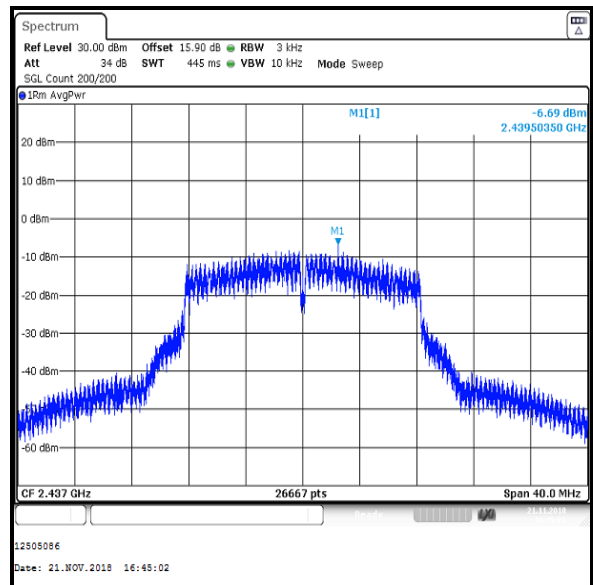
Channel 1



Channel 2



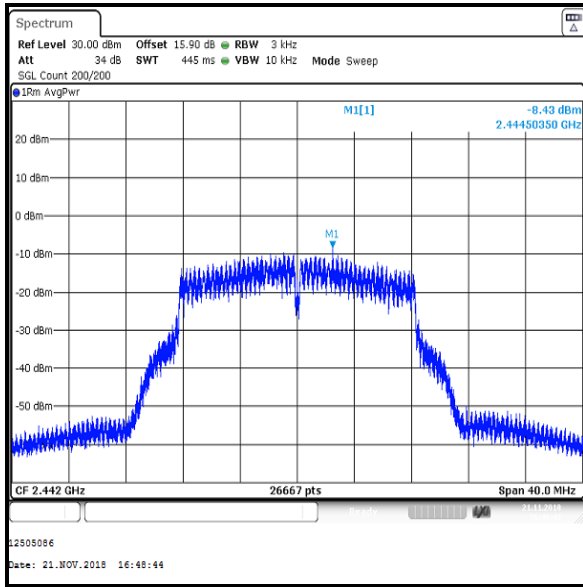
Channel 3



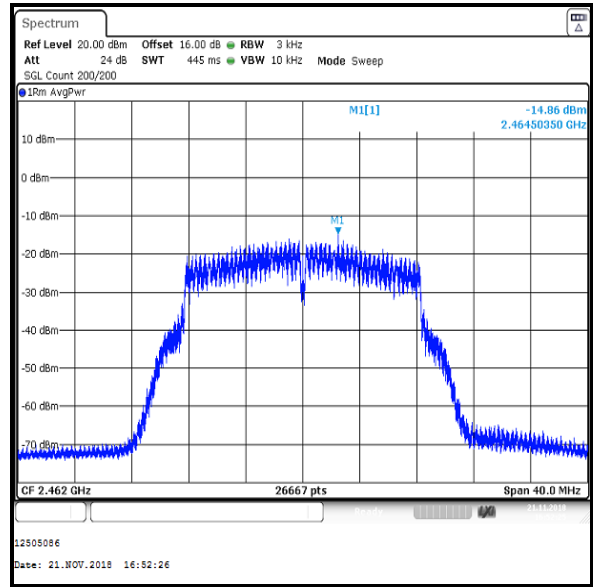
Channel 6

Transmitter Power Spectral Density (continued)

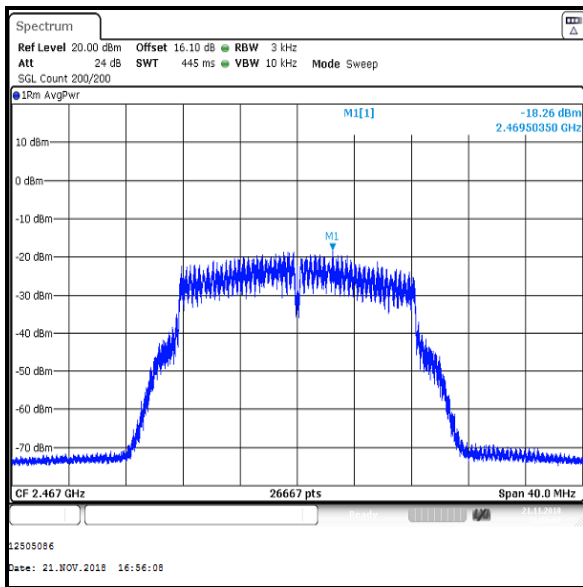
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 1



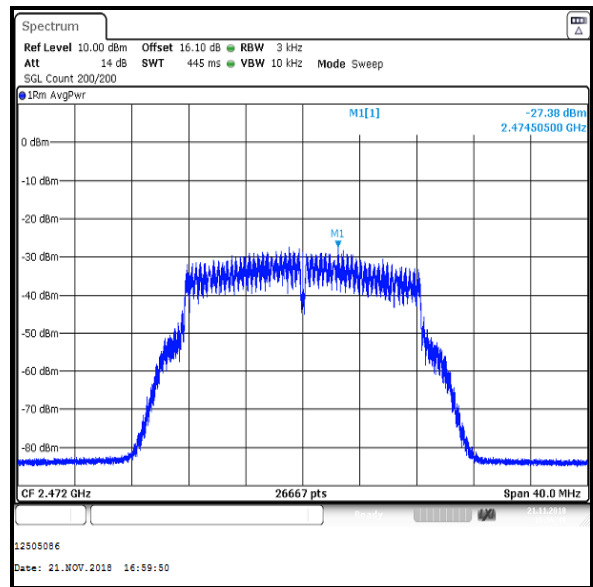
Channel 7



Channel 11



Channel 12



Channel 13

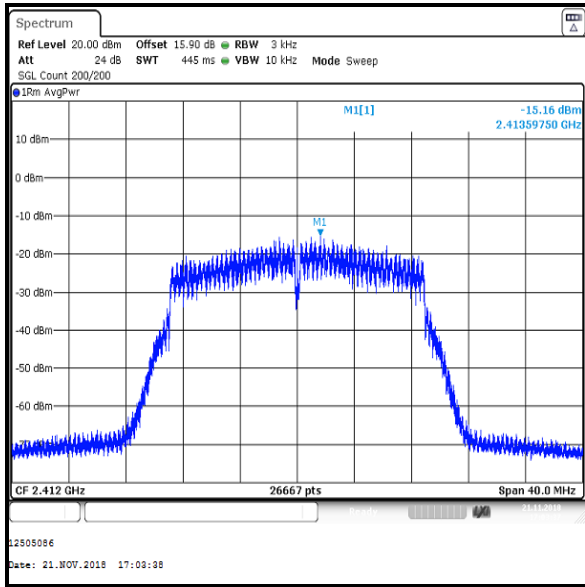
Transmitter Power Spectral Density (continued)**Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 1**

Channel	Output Power (dBm/3 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
1	-15.2	8.0	23.2	Complied
2	-13.0	8.0	21.0	Complied
3	-10.8	8.0	18.8	Complied
6	-7.5	8.0	15.5	Complied
7	-9.1	8.0	17.1	Complied
11	-15.3	8.0	23.3	Complied
12	-18.2	8.0	26.2	Complied

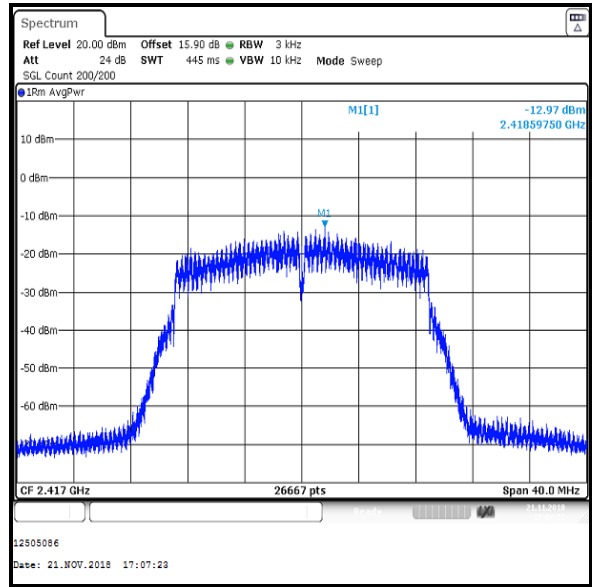
Channel	Output Power (dBm/100 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
13	-16.0	8.0	24.0	Complied

Transmitter Power Spectral Density (continued)

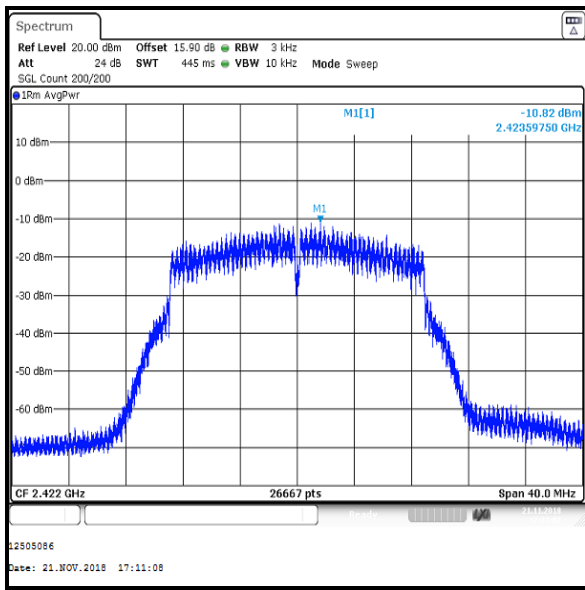
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 1



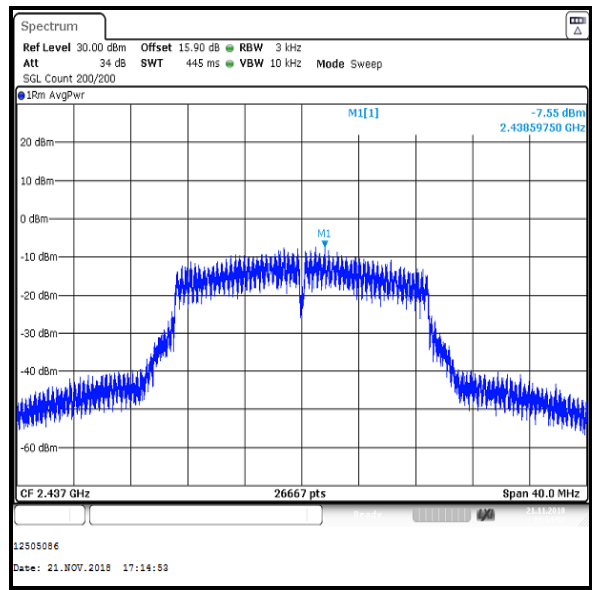
Channel 1



Channel 2



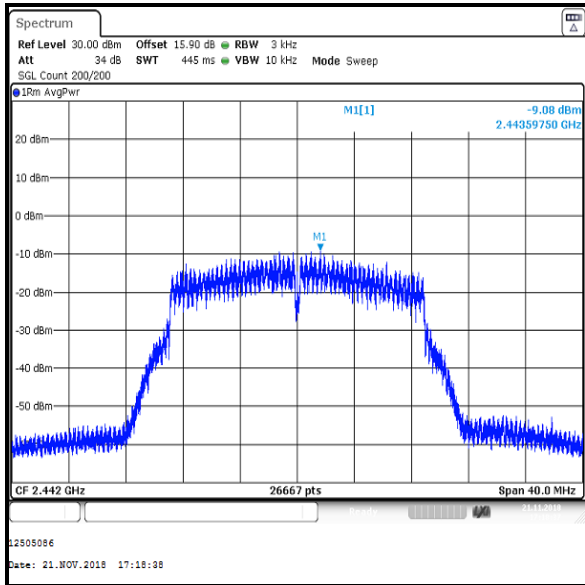
Channel 3



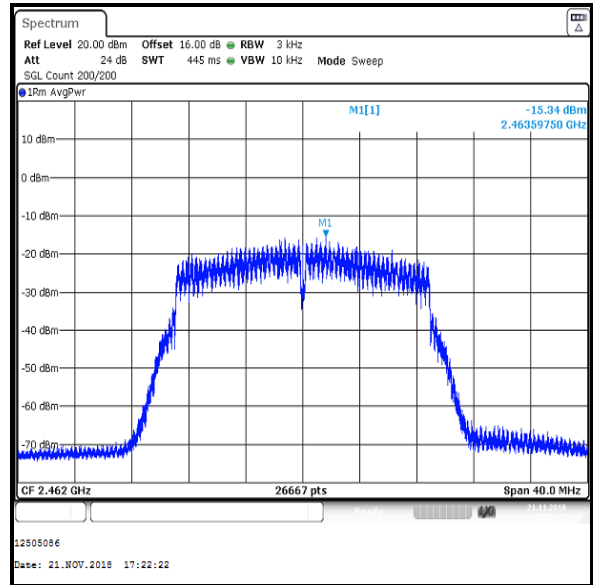
Channel 6

Transmitter Power Spectral Density (continued)

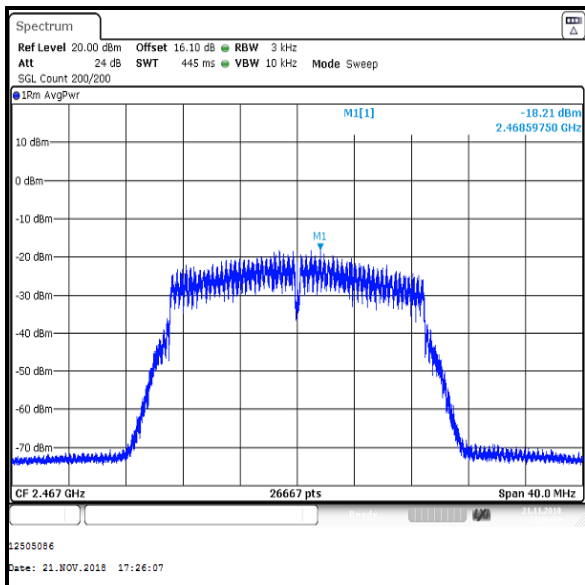
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 1



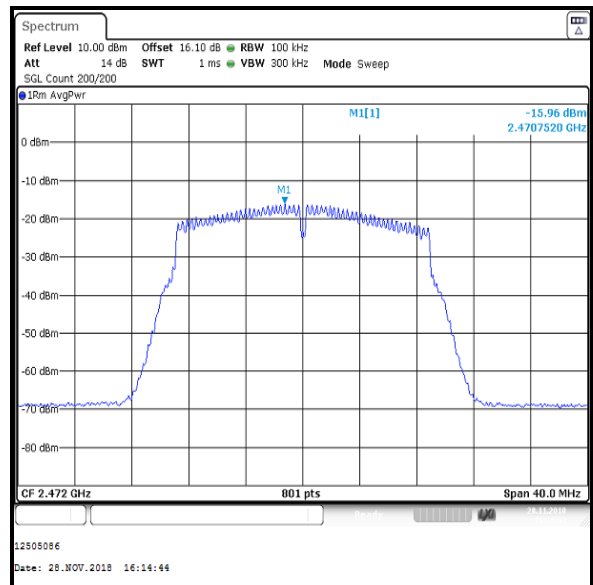
Channel 7



Channel 11



Channel 12



Channel 13

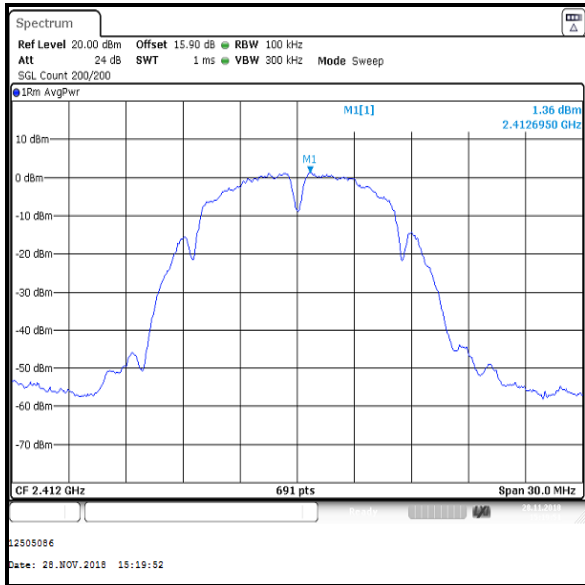
Transmitter Power Spectral Density (continued)**Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps**

Channel	PSD at Core 1 (dBm / 100 kHz)	PSD at Core 2 (dBm / 100 kHz)	Combined PSD (dBm / 100 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	1.4	1.4	4.4	8.0	3.6	Complied

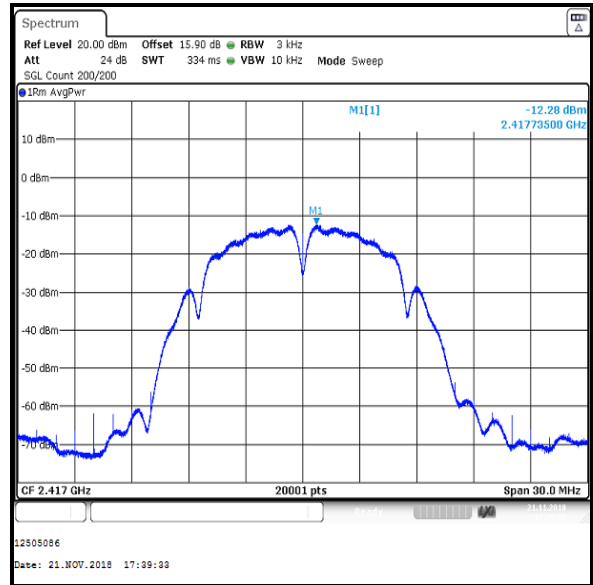
Channel	PSD at Core 1 (dBm / 3 kHz)	PSD at Core 2 (dBm / 3 kHz)	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
2	-12.3	-12.4	-9.5	8.0	17.5	Complied
3	-11.3	-11.5	-8.5	8.0	16.5	Complied
6	-8.3	-8.4	-5.6	8.0	13.6	Complied
7	-8.4	-8.5	-5.6	8.0	13.6	Complied
11	-15.3	-15.2	-12.6	8.0	20.6	Complied
12	-17.1	-17.2	-14.3	8.0	22.3	Complied
13	-20.5	-20.5	-17.8	8.0	25.8	Complied

Transmitter Power Spectral Density (continued)

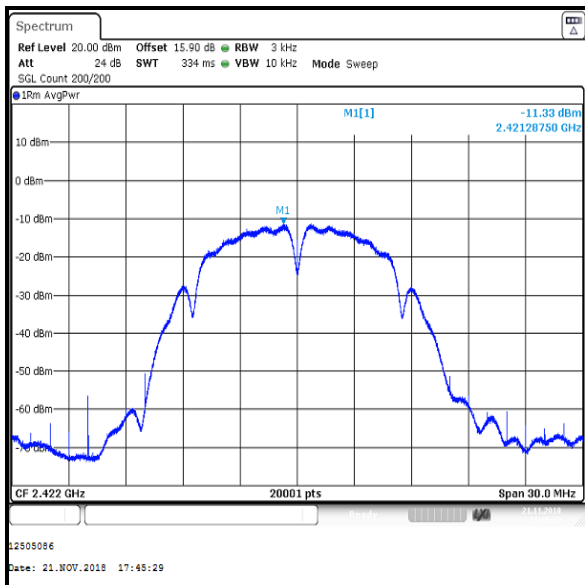
Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Core 1



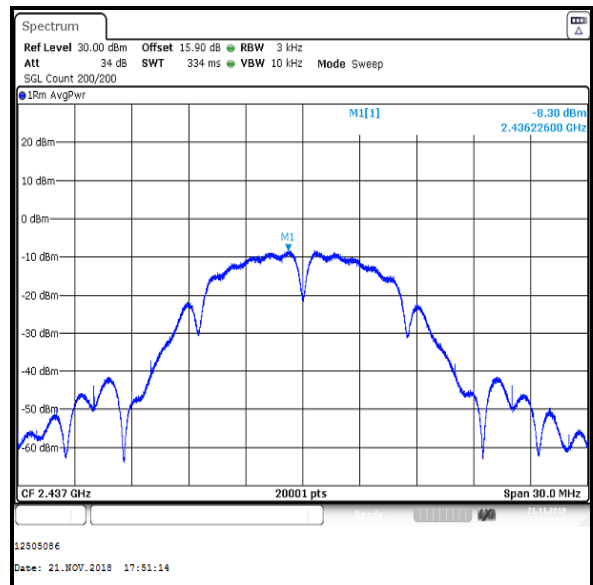
Channel 1



Channel 2



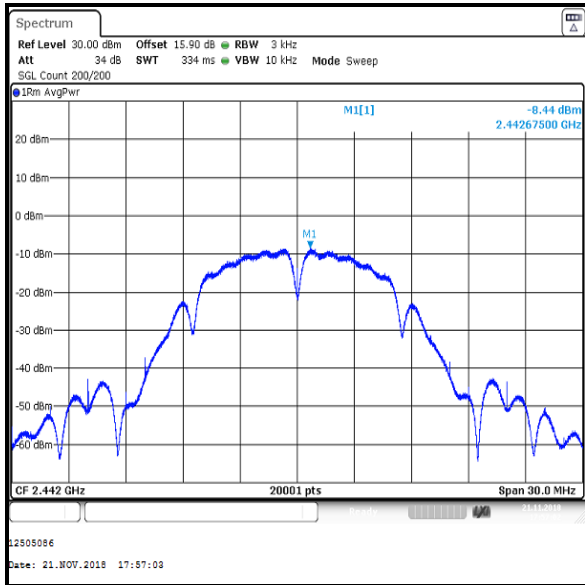
Channel 3



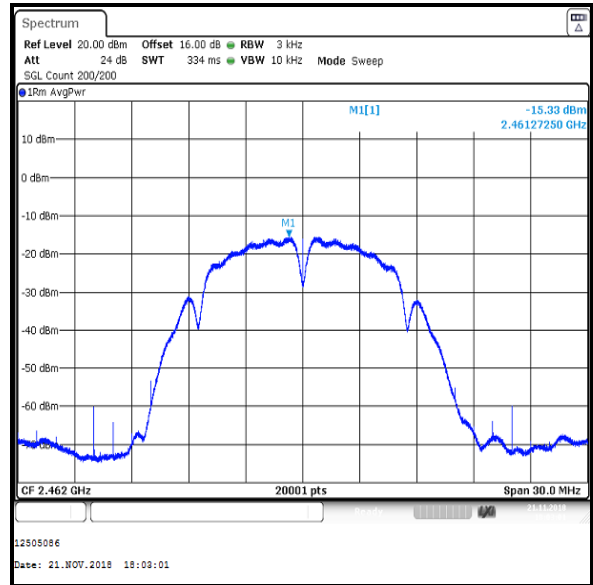
Channel 6

Transmitter Power Spectral Density (continued)

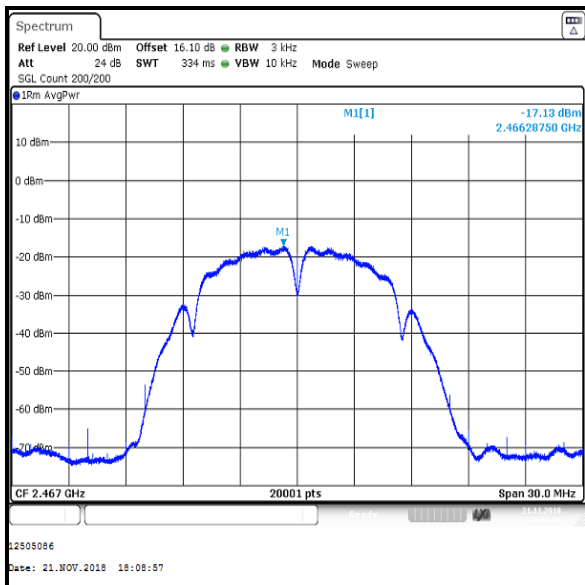
Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Core 1



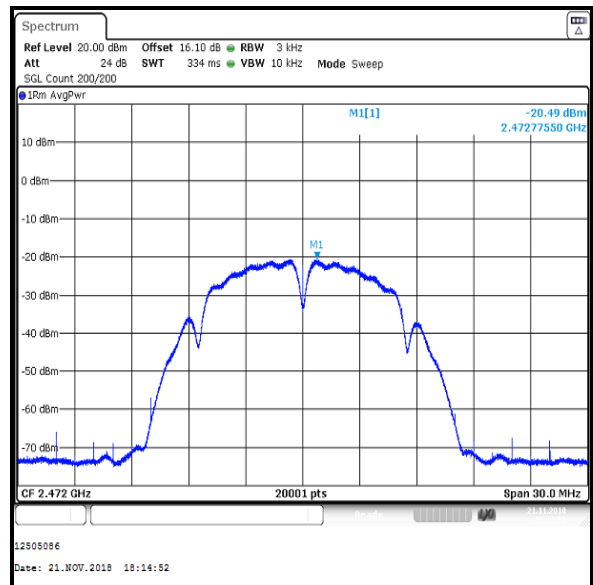
Channel 7



Channel 11



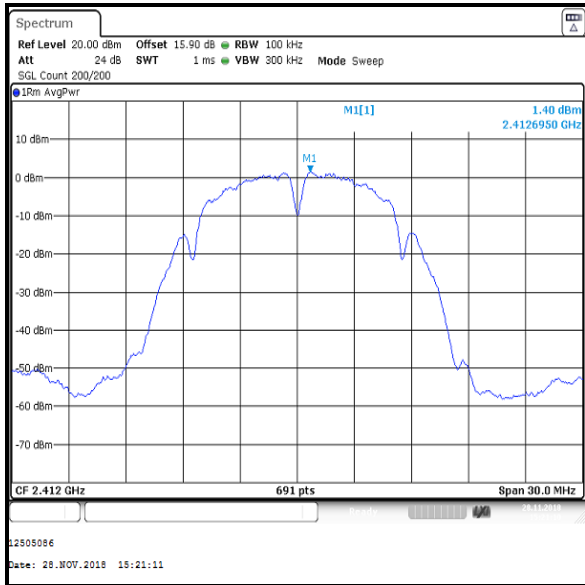
Channel 12



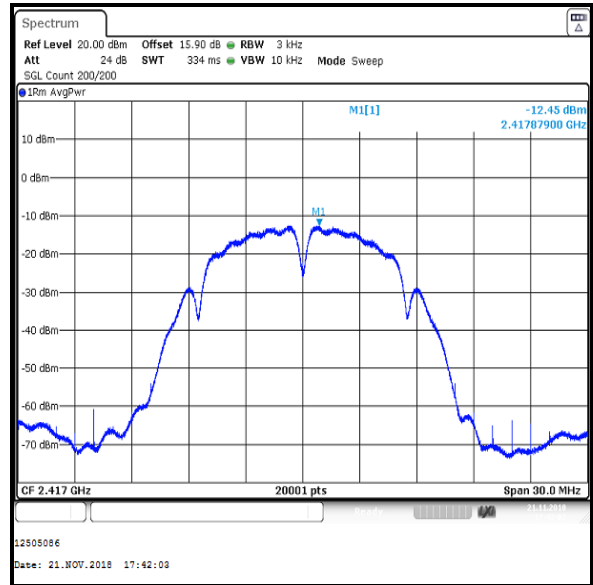
Channel 13

Transmitter Power Spectral Density (continued)

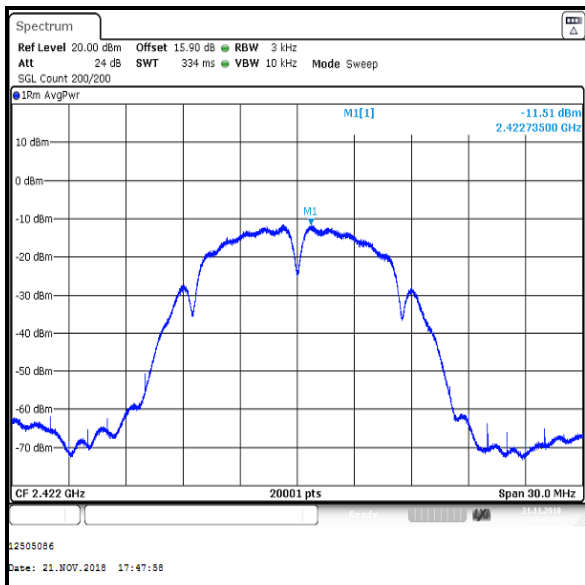
Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Core 2



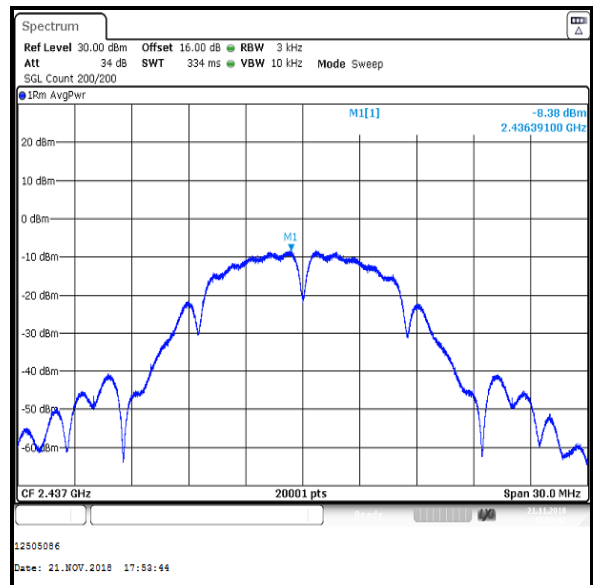
Channel 1



Channel 2



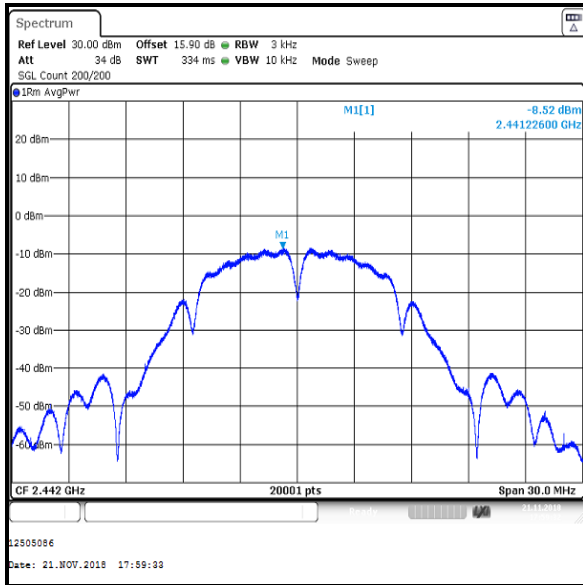
Channel 3



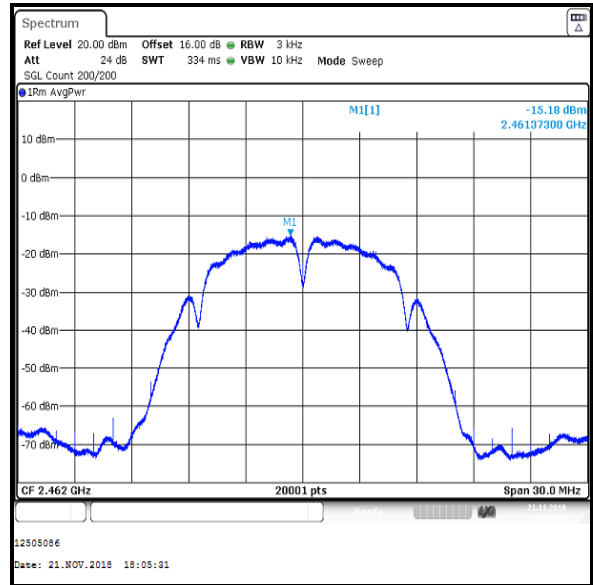
Channel 6

Transmitter Power Spectral Density (continued)

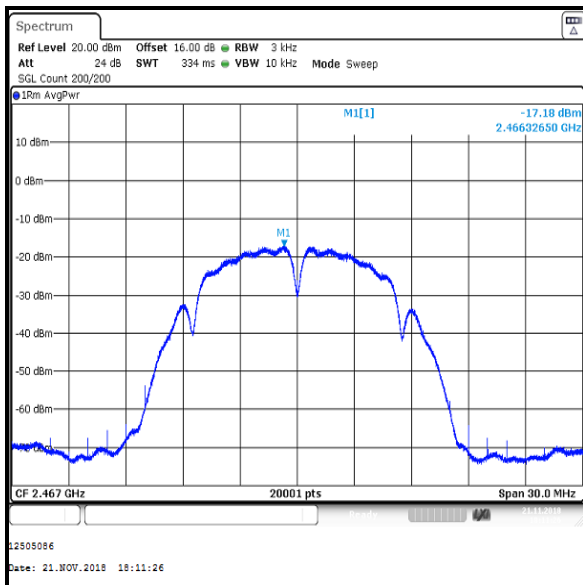
Results: 802.11b / 20 MHz / MIMO / 2Tx CDD / DBPSK / 1 Mbps / Core 2



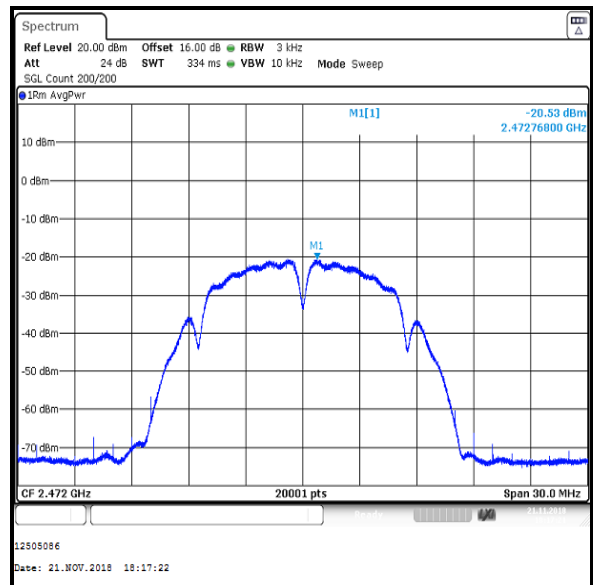
Channel 7



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 0 (dBm / 3 kHz)	PSD on Core 1 (dBm / 3 kHz)	PSD on Core 2 (dBm / 3 kHz)
1	-14.5	-15.0	-15.1
2	-13.4	-13.5	-13.5
3	-11.5	-11.6	-11.8
6	-9.4	-9.8	-9.7
7	-9.6	-9.5	-9.9
11	-16.4	-16.6	-16.5
12	-16.8	-17.2	-17.0

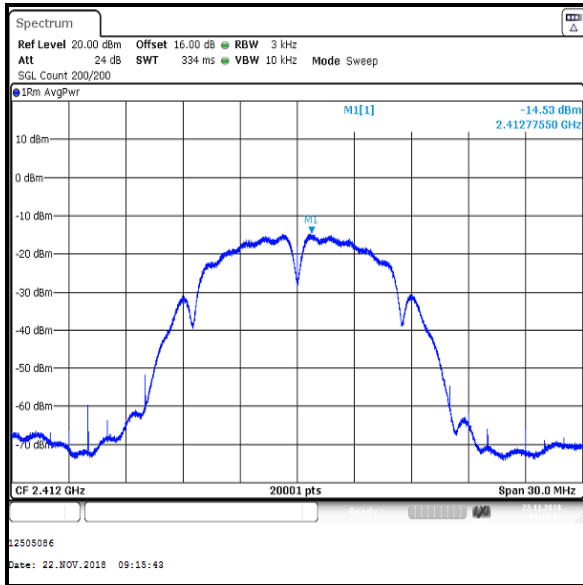
Channel	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-10.4	8.0	18.4	Complied
2	-9.0	8.0	17.0	Complied
3	-7.2	8.0	15.2	Complied
6	-5.1	8.0	13.1	Complied
7	-5.2	8.0	13.2	Complied
11	-11.9	8.0	19.9	Complied
12	-12.5	8.0	20.5	Complied

Channel	PSD on Core 0 (dBm / 100 kHz)	PSD on Core 1 (dBm / 100 kHz)	PSD on Core 2 (dBm / 100 kHz)
13	-6.4	-6.5	-6.5

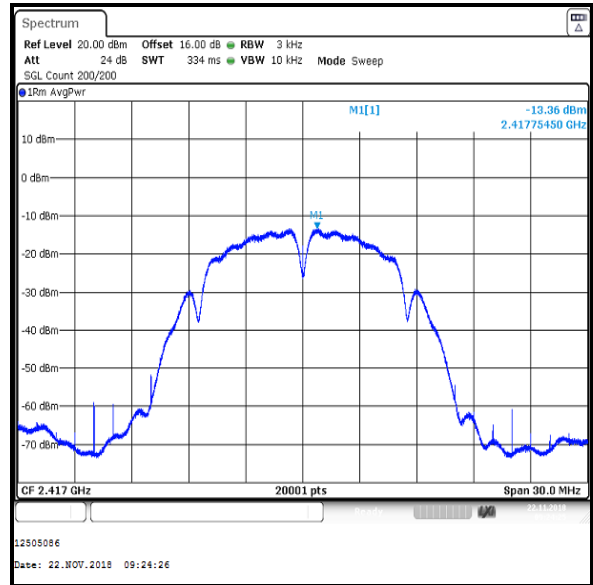
Channel	Combined PSD (dBm / 100 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
13	-1.8	8.0	9.8	Complied

Transmitter Power Spectral Density (continued)

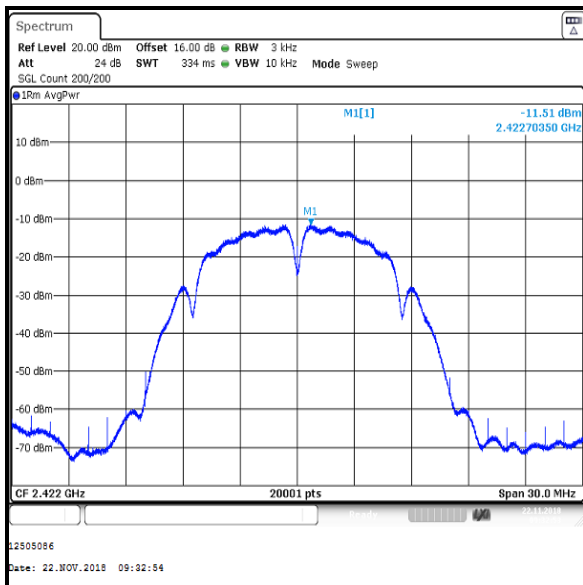
Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Core 0



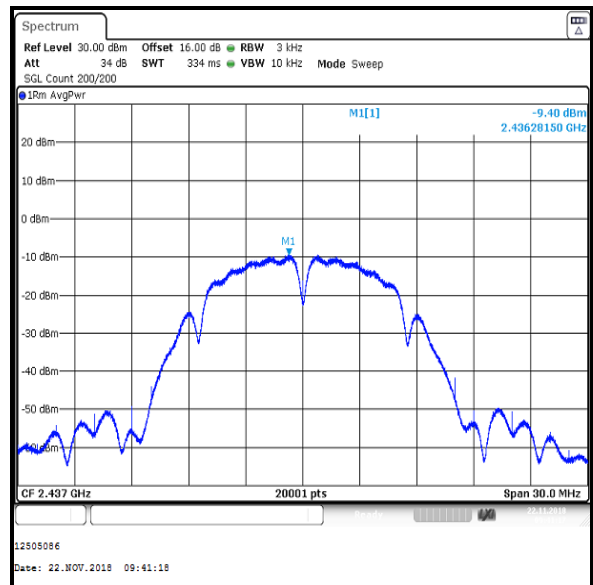
Channel 1



Channel 2



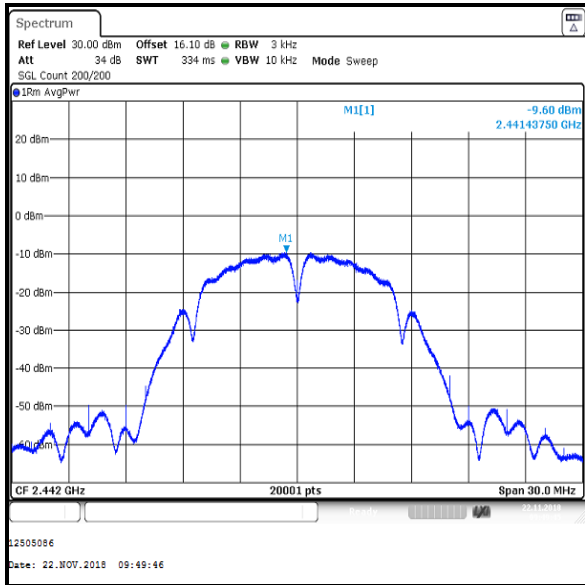
Channel 3



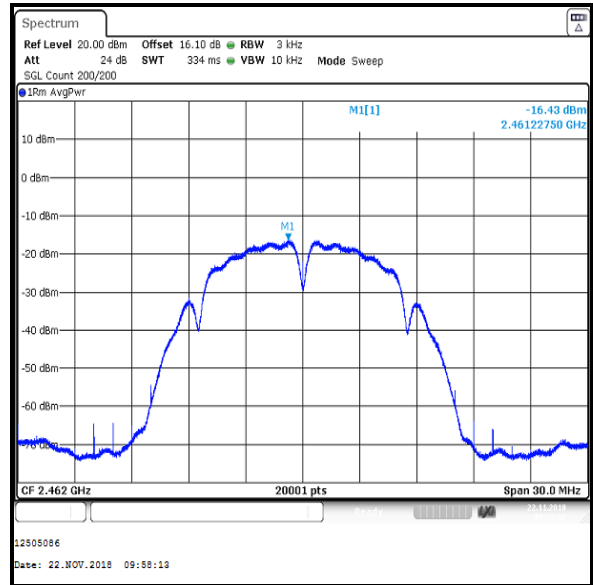
Channel 6

Transmitter Power Spectral Density (continued)

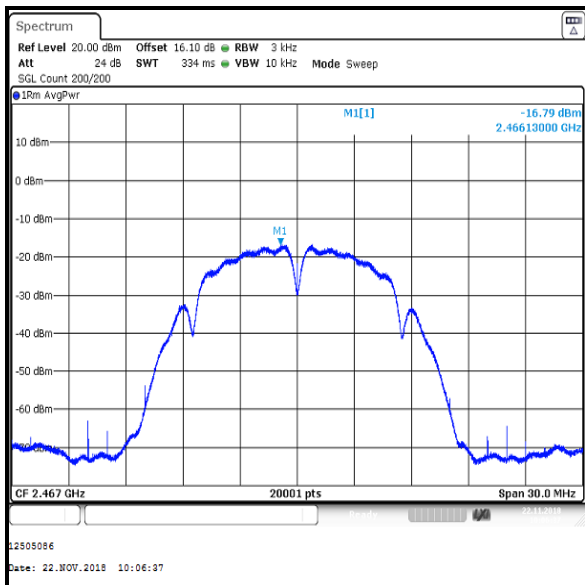
Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Core 0



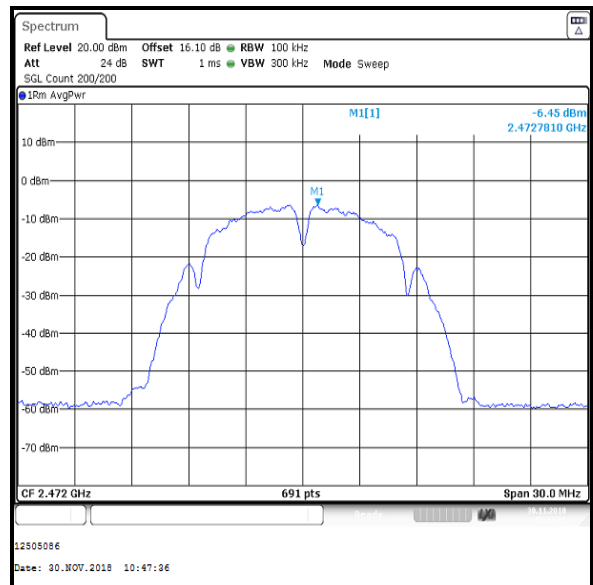
Channel 7



Channel 11



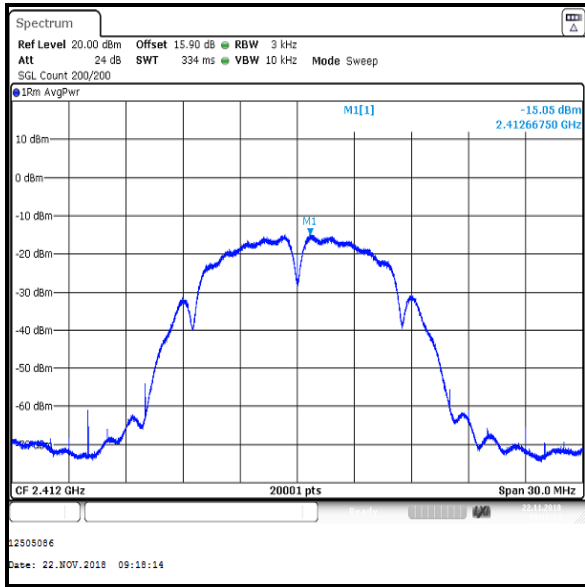
Channel 12



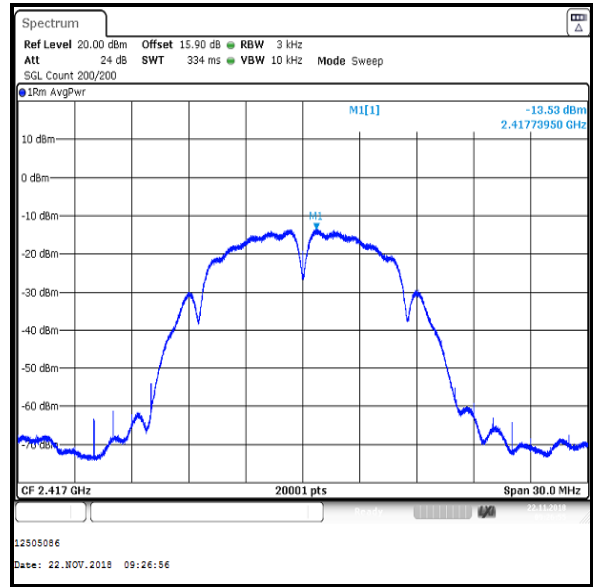
Channel 13

Transmitter Power Spectral Density (continued)

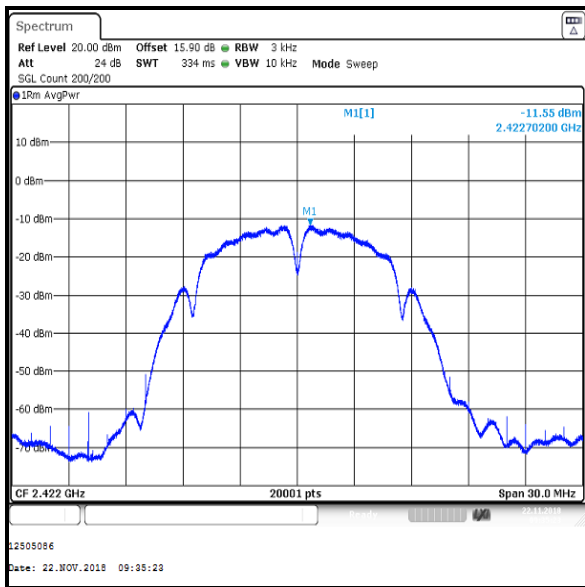
Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Core 1



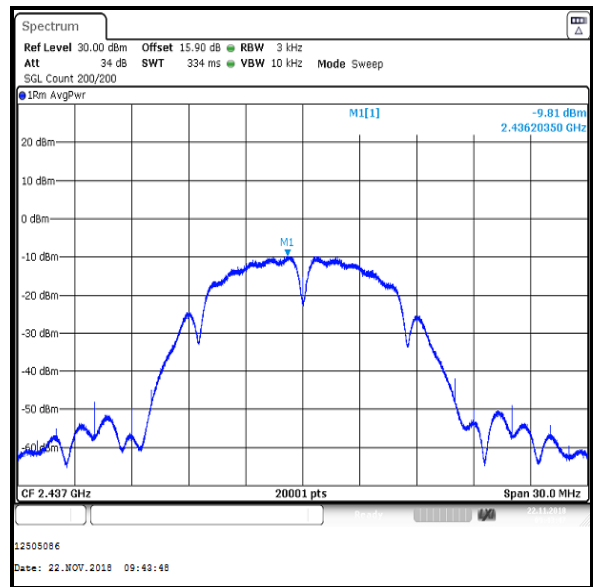
Channel 1



Channel 2



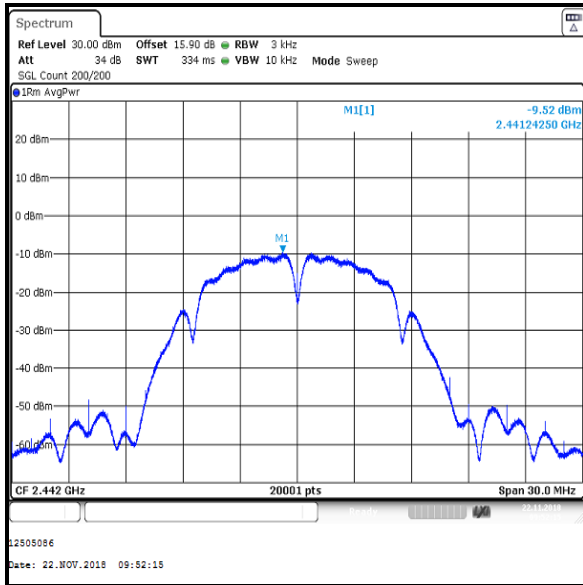
Channel 3



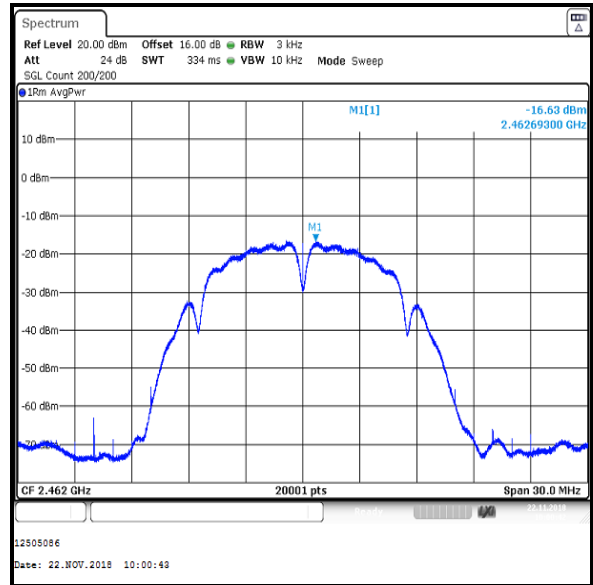
Channel 6

Transmitter Power Spectral Density (continued)

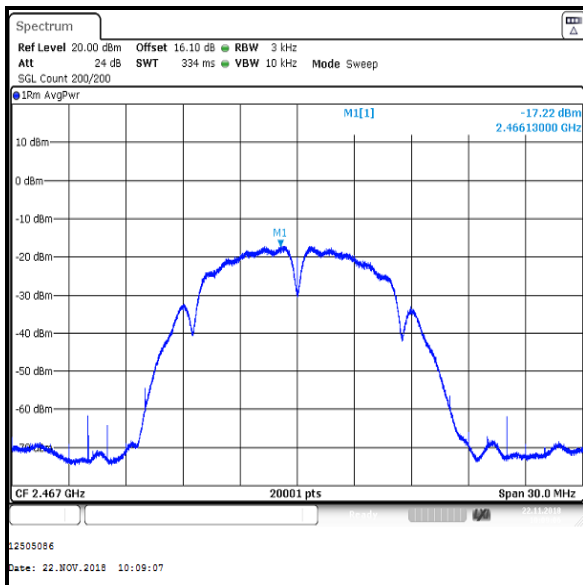
Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Core 1



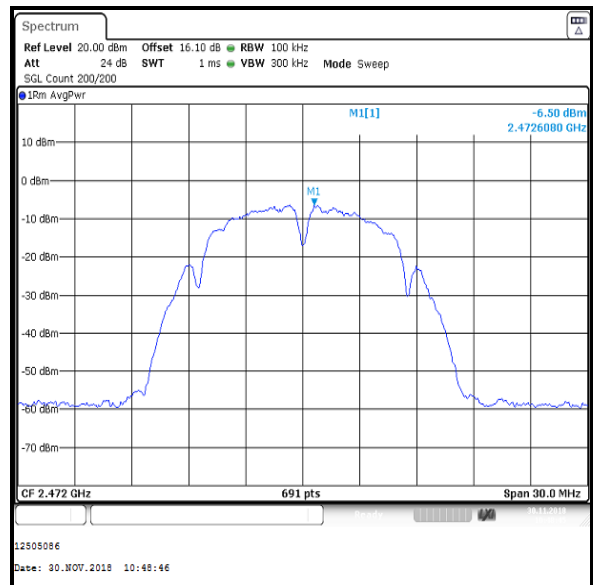
Channel 7



Channel 11



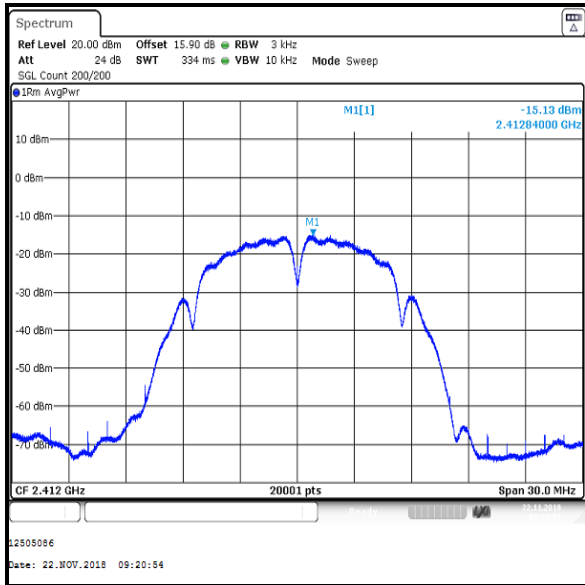
Channel 12



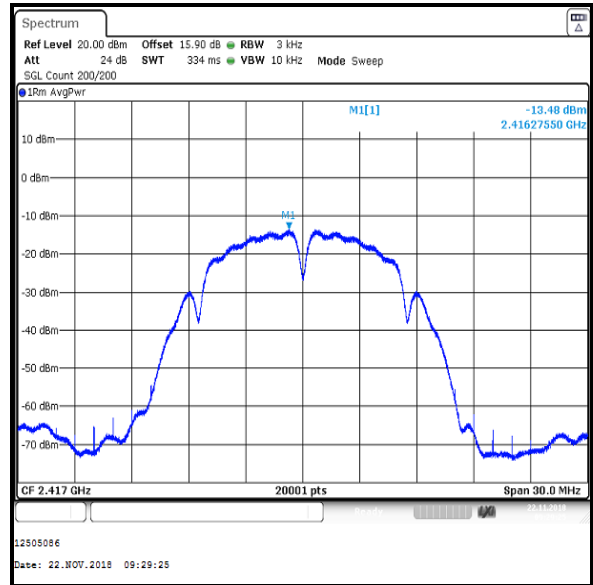
Channel 13

Transmitter Power Spectral Density (continued)

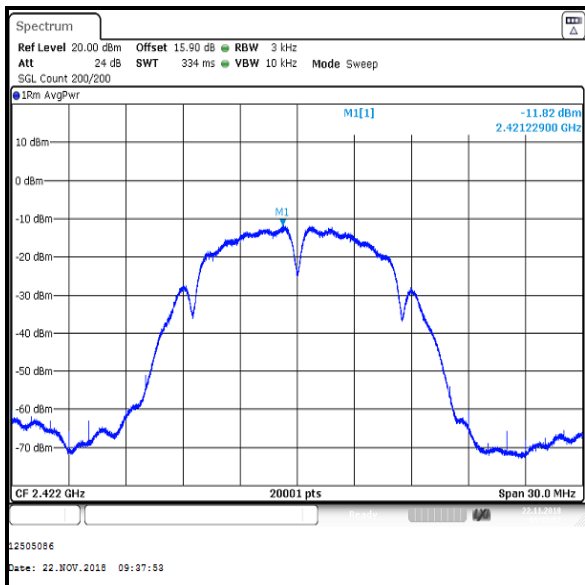
Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Core 2



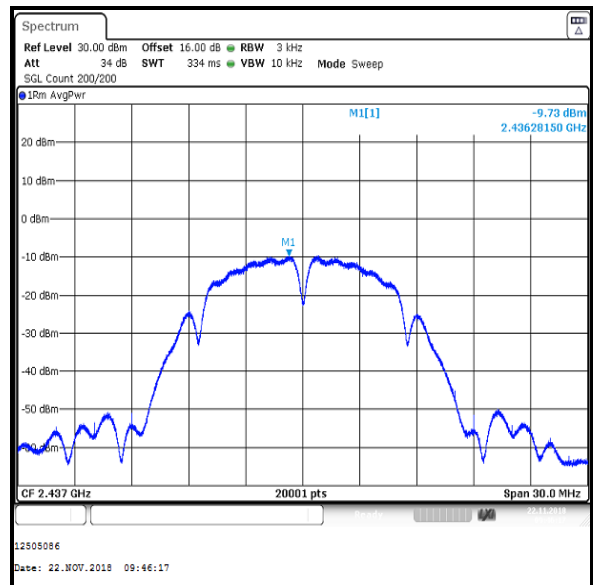
Channel 1



Channel 2



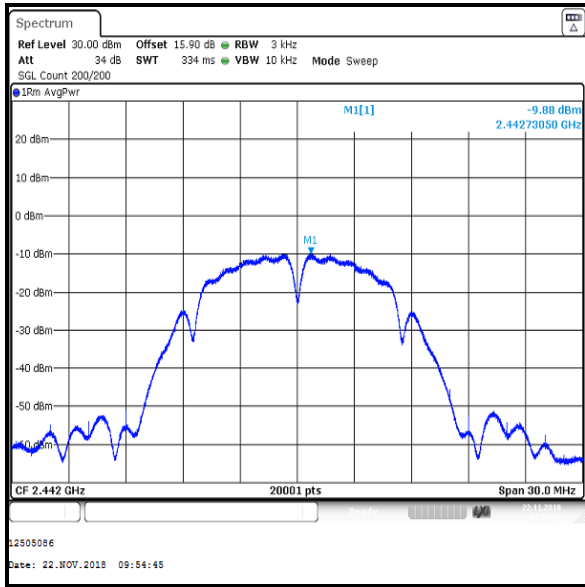
Channel 3



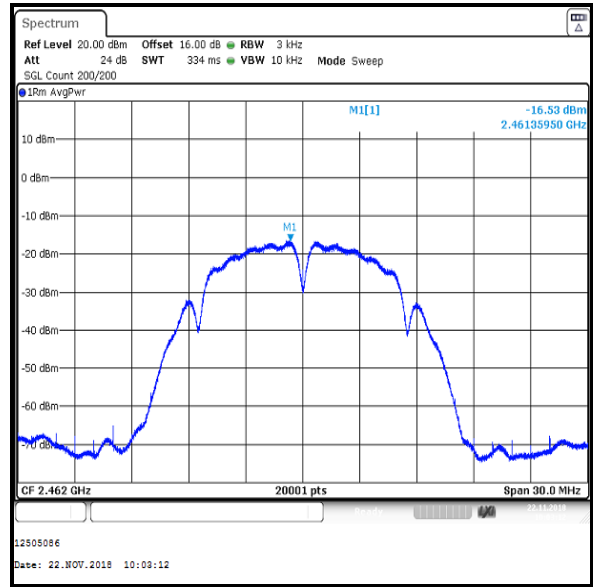
Channel 6

Transmitter Power Spectral Density (continued)

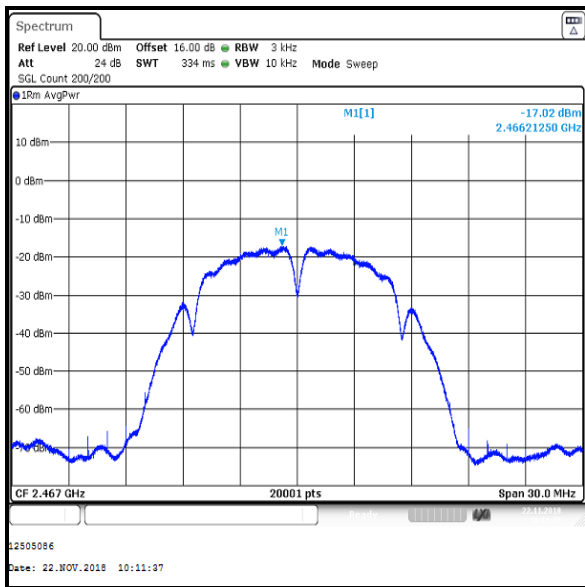
Results: 802.11b / 20 MHz / MIMO / 3Tx CDD / DBPSK / 1 Mbps / Core 2



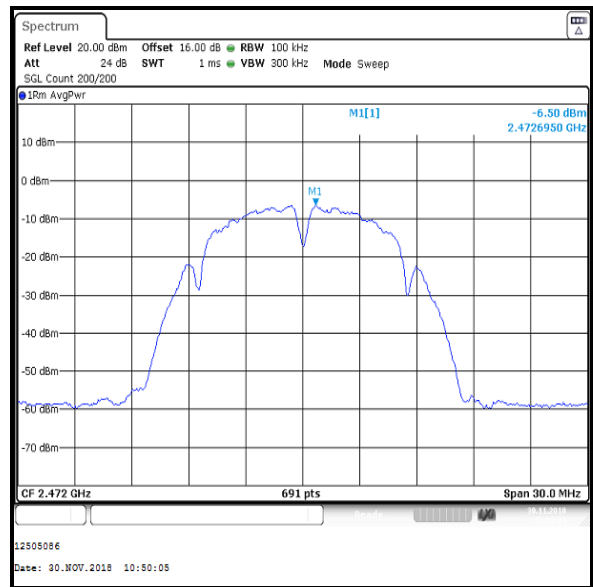
Channel 7



Channel 11



Channel 12



Channel 13

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

Channel	PSD at Core 1 (dBm / 3 kHz)	PSD at Core 2 (dBm / 3 kHz)	Combined PSD (dBm / 3 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
1	-15.6	-15.4	-12.6	8.0	20.6	Complied
2	-13.5	-13.7	-10.6	8.0	18.6	Complied
3	-10.8	-11.2	-8.0	8.0	16.0	Complied
6	-8.6	-9.0	-5.8	8.0	13.8	Complied
7	-10.2	-10.2	-7.2	8.0	15.2	Complied
11	-16.4	-16.1	-13.5	8.0	21.5	Complied
12	-19.8	-19.6	-16.8	8.0	24.8	Complied

Channel	PSD at Core 1 (dBm / 100 kHz)	PSD at Core 2 (dBm / 100 kHz)	Combined PSD (dBm / 100 kHz)	PSD Limit (dBm / 3 kHz)	Margin (dB)	Result
13	-16.4	-16.2	-13.5	8.0	21.5	Complied