TEST REPORT

Test Report No. : UL-RPT-RP12185759JD09C

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 1.0

Date of Issue: 27 June 2018

Checked by:

Ben Mercer
Senior Test Engineer, Radio Laboratory

Company Signatory:

Sarah Williams
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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	27/06/2018	Initial Version	Ben Mercer

Table of Contents

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:	17 February 2018 to 13 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):

1. For the data rates declared as worst cases 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.
2. 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	
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

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

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
A3005	RePlay Test Rack	N/A	N/A	N/A	Calibration not required	-

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
A2863	Pre-Amplifier	Agilent	8449B	3008A02100	19 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
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	21 Apr 2019	12
A2914	High Pass Filter	AtlanTecRF	AFH-03000	2155	22 Feb 2019	12
A3014	High Pass Filter	AtlanTecRF	AFH-06000	17042400007	22 Feb 2019	12
A2947	High Pass Filter	AtlanTecRF	AFH-07000	1601900001	22 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
A2131	Low Pass Filter	AtlanTecRF	AFL-02000	JFB1004-002	22 Feb 2019	12
A490	Antenna	Chase	CBL6111A	1590	03 Apr 2019	12
A2895	Antenna	Schwarzbeck	BBHA 9170	9170-728	20 Feb 2019	12

Test and Measurement Equipment (continued)

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
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 *(Conducted sample #1)*
Hardware Version:	EVT
Software Version:	17G2057
FCC ID:	BCGA1990

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

Brand Name:	Apple
Model Name or Number:	A1990
Test Sample Serial Number:	C02VT01FJLG2 *(Radiated sample #2)*
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 (SISO)	1, 2, 5.5 & 11 Mbps
	802.11g (SISO)	6, 9, 12, 18, 24, 36, 48 & 54 Mbps
	802.11n HT20 (SISO)	MCS0 to MCS7
Power Supply Requirement(s):	Nominal	3.8 VDC via 120 VAC 60 Hz AC/DC Adapter
Maximum Conducted Output Power:	22.2 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 Antenna

The radio utilizes 1 integrated antenna, with the following maximum gain:

Frequency Range (MHz)	Antenna Gain (dBi)
2400 - 2480	2.1

3.5. Description of Test Setup

Support Equipment

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

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

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

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

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

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

Operating Modes

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

- Continuously transmitting with a modulated carrier at maximum power on the relevant channels as required using the supported data rates/modulation types.

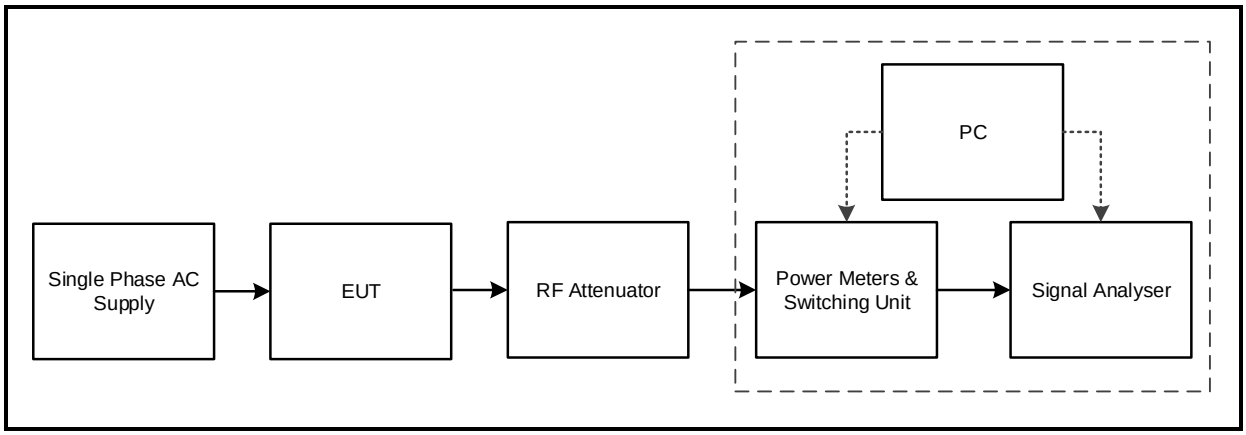
Configuration and Peripherals

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

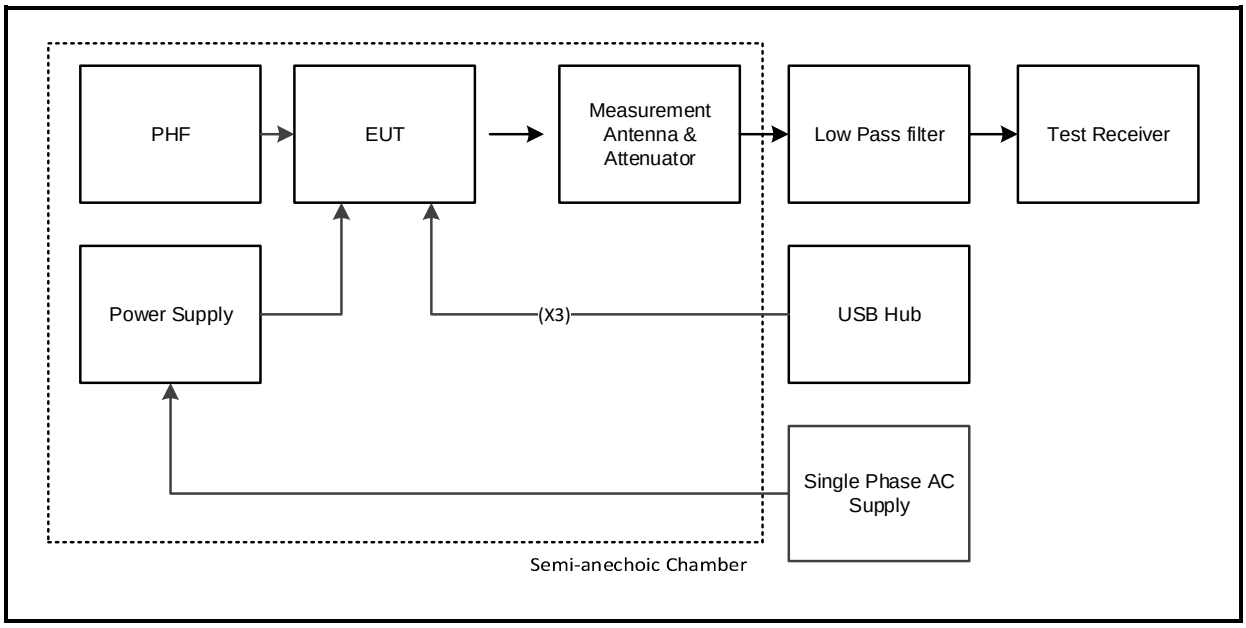
- Controlled in test mode using a software application on the EUT supplied by the customer. The application was used to enable a continuous transmission and to select the test channels as required. The customer supplied a document containing the setup instructions 'EUT_EVT_wlan_setup_v1.sh'.
- The customer declared the following data rates to be used for all measurements as:
    - 802.11b – DBPSK / 1 Mbps
    - 802.11g – BPSK / 6 Mbps
    - 802.11n HT20 – BPSK / MCS0
- Transmitter spurious emissions were performed with the EUT transmitting 802.11b / DBPSK / 1 Mbps. This was found to be the worst case modulation scheme with regards to emissions after preliminary investigations and, as this mode emits the highest output power level, it was deemed to be the worst case.
- Transmitter radiated spurious emissions tests were performed with the AC Charger, USB cable 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

Test Setup for Transmitter Conducted Tests

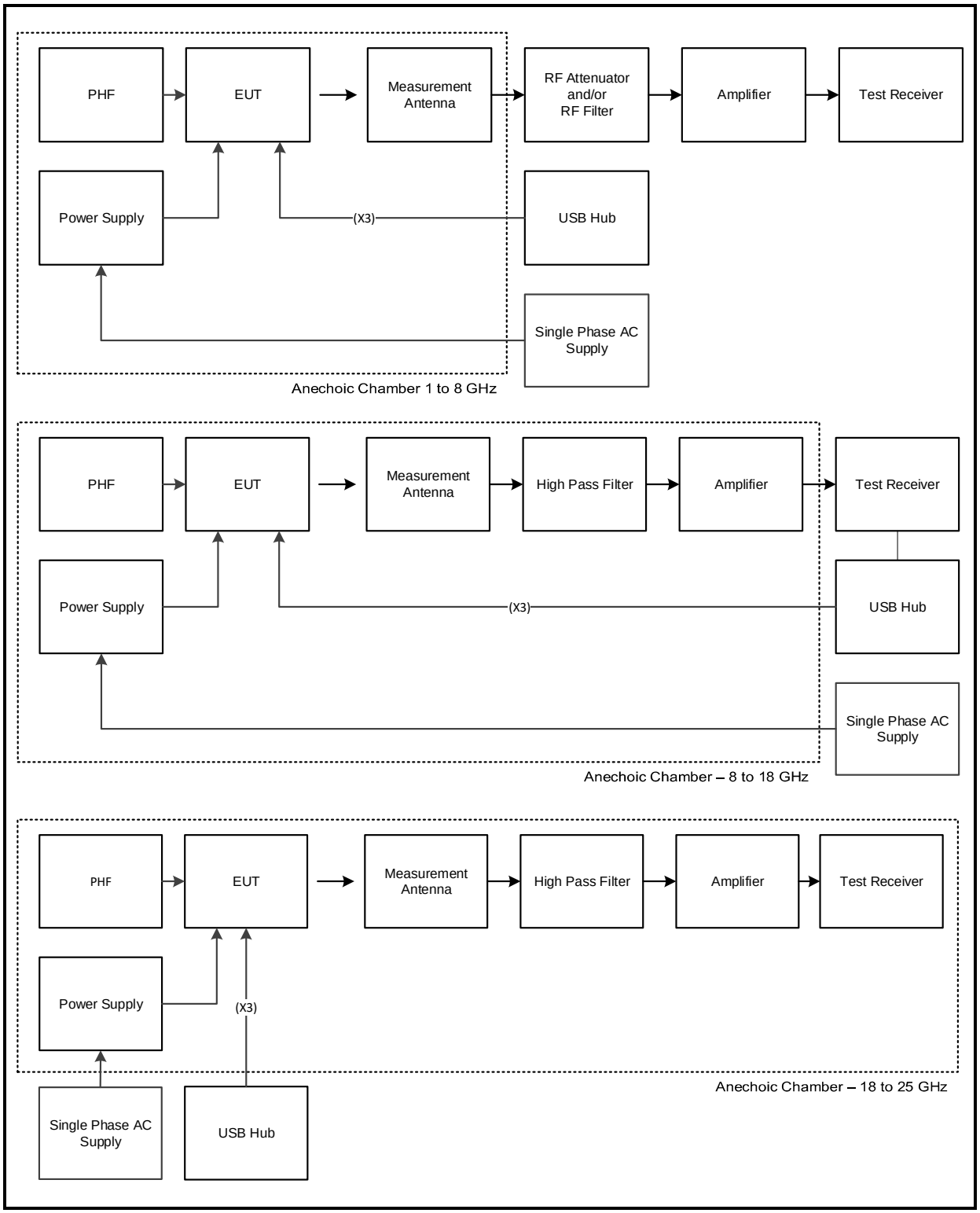


Test Setup for Transmitter Radiated Emissions



Test Setup Diagrams (continued)

Test Setup for Transmitter Radiated Emissions (continued)



4. Antenna Port Test Results

4.1. Transmitter Minimum 6 dB Bandwidth

Test Summary:

Test Engineer:	Max Passell	**Test Date:**	01 June 2018
Test Sample Serial Number:	C02WC003JMFN		

FCC Reference:	Part 15.247(a)(2)
Test Method Used:	FCC KDB Section 8.1 and Notes below

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	51

Note(s):

1. The customer declared the following data rates to be used for all measurements as:
    - 802.11b – DBPSK / 1 Mbps / Core 2
    - 802.11g – BPSK / 6 Mbps / Core 2
    - 802.11n HT20 – BPSK / MCS0 / Core 2
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.

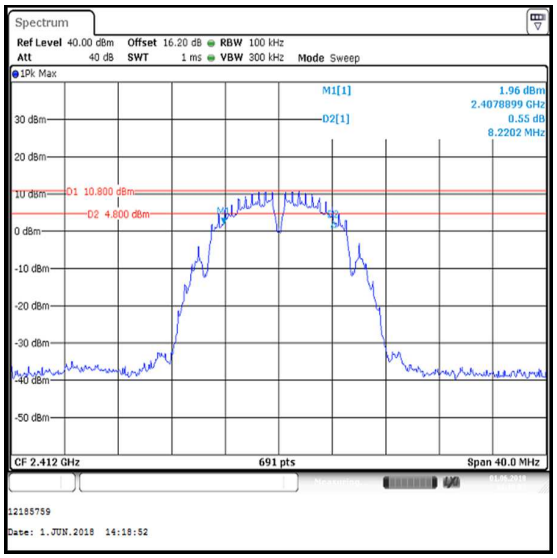
Transmitter Minimum 6 dB Bandwidth (continued)

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

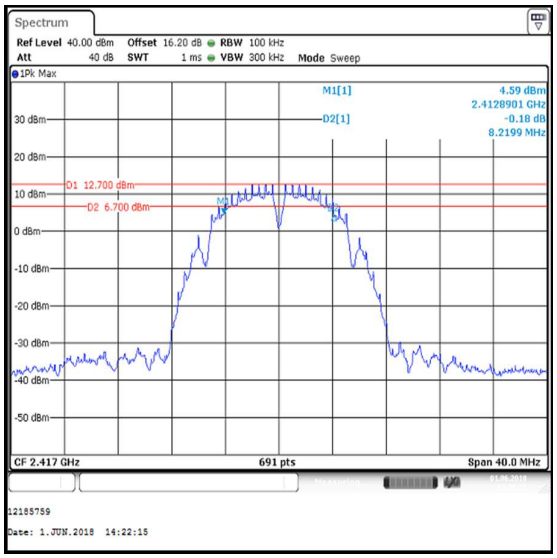
Channel	6dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	8220	≥500	7720	Complied
2	8220	≥500	7720	Complied
3	9146	≥500	8646	Complied
6	8220	≥500	7720	Complied
7	9146	≥500	8646	Complied
11	8683	≥500	8183	Complied
12	9146	≥500	8646	Complied
13	8220	≥500	7720	Complied

Transmitter Minimum 6 dB Bandwidth (continued)

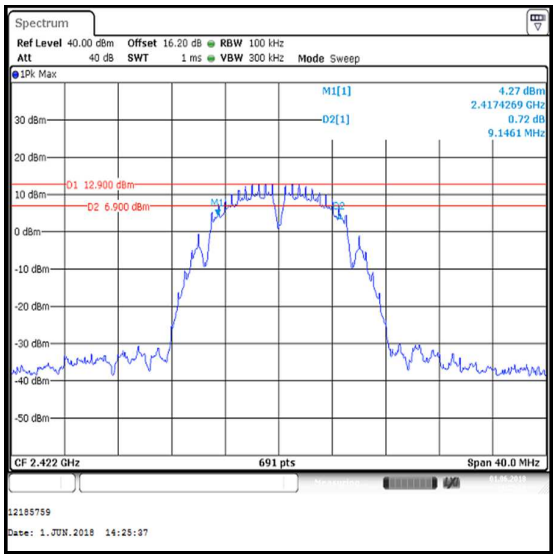
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 2



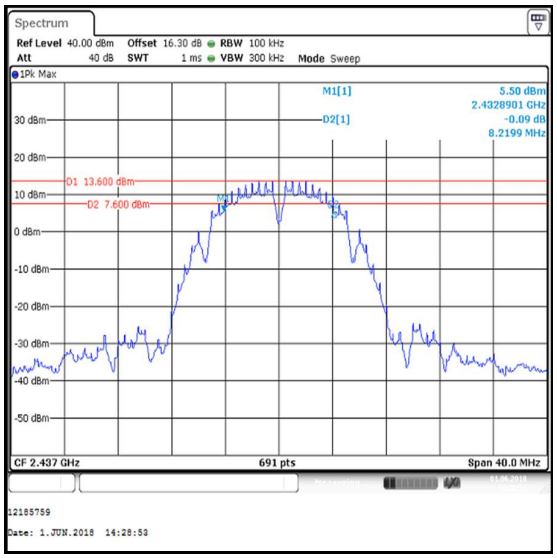
Channel 1



Channel 2



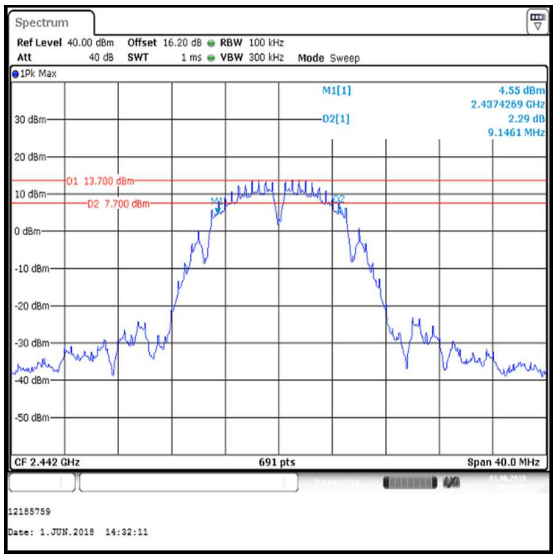
Channel 3



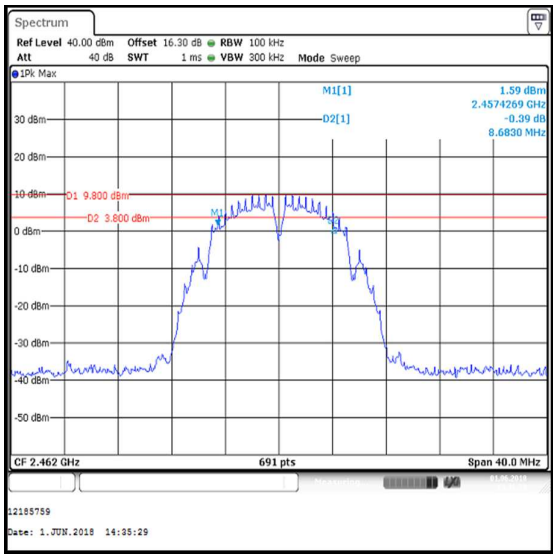
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)

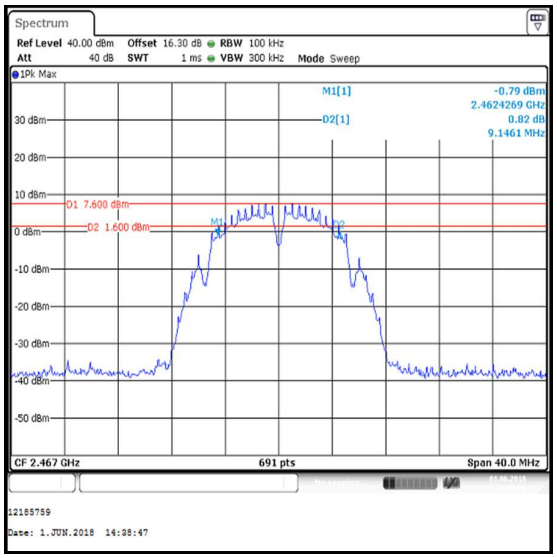
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 2



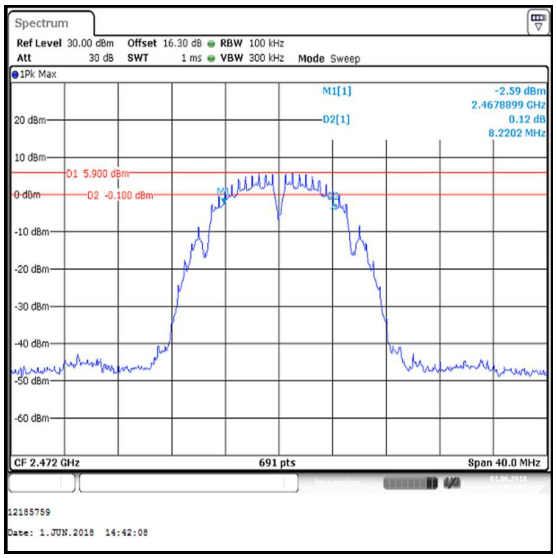
Channel 7



Channel 11



Channel 12



Channel 13

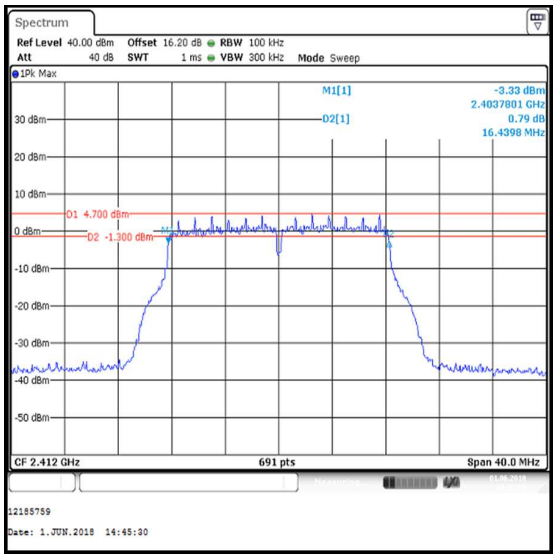
Transmitter Minimum 6 dB Bandwidth (continued)

Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2

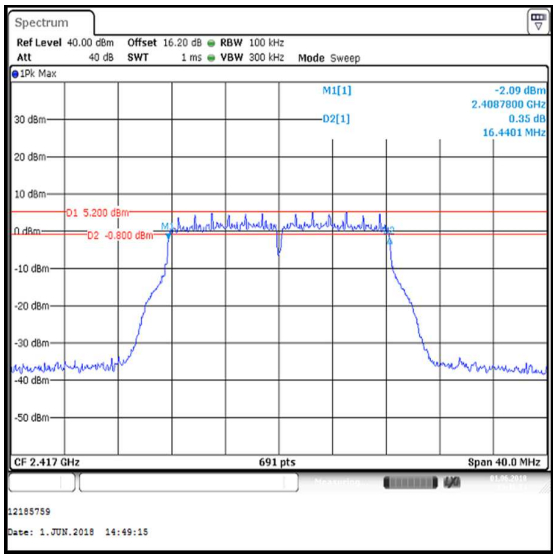
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	16440	≥500	15940	Complied
2	16440	≥500	15940	Complied
3	16440	≥500	15940	Complied
6	16440	≥500	15940	Complied
7	16440	≥500	15940	Complied
11	16440	≥500	15940	Complied
12	16440	≥500	15940	Complied
13	16440	≥500	15940	Complied

Transmitter Minimum 6 dB Bandwidth (continued)

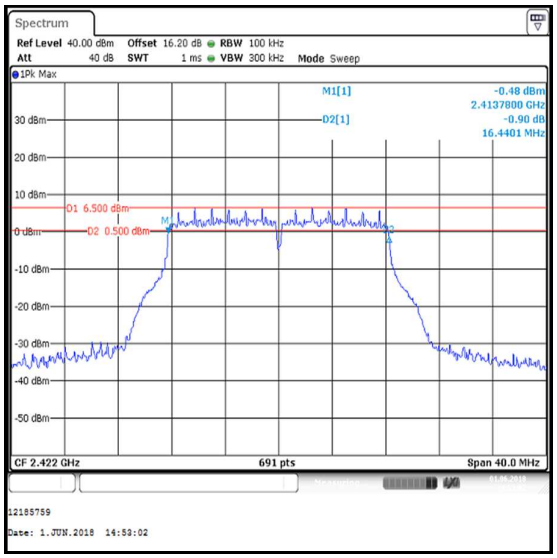
Results: 802.11g / 20 MHz BPSK / 6 Mbps / Core 2



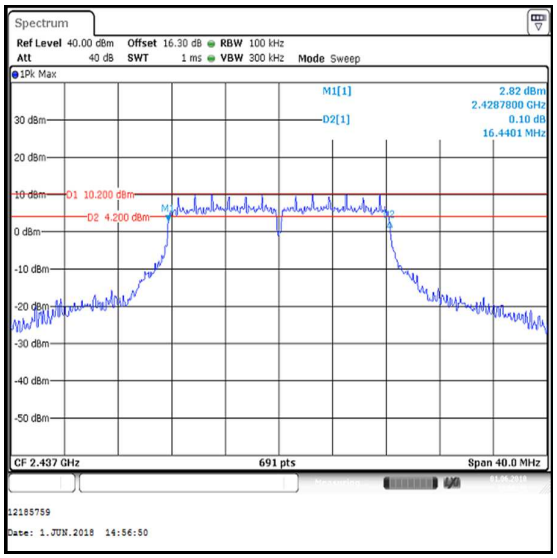
Channel 1



Channel 2



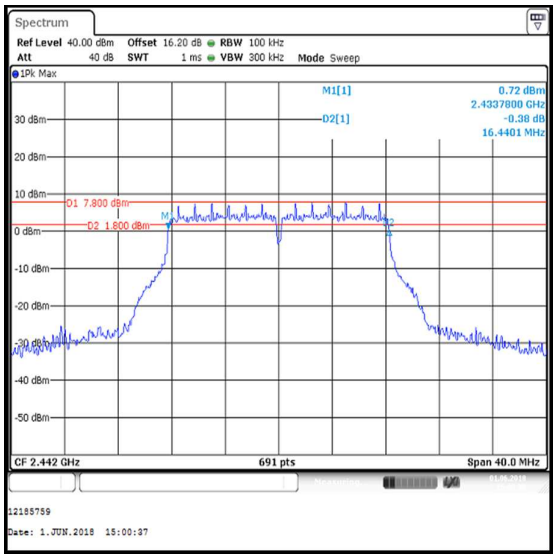
Channel 3



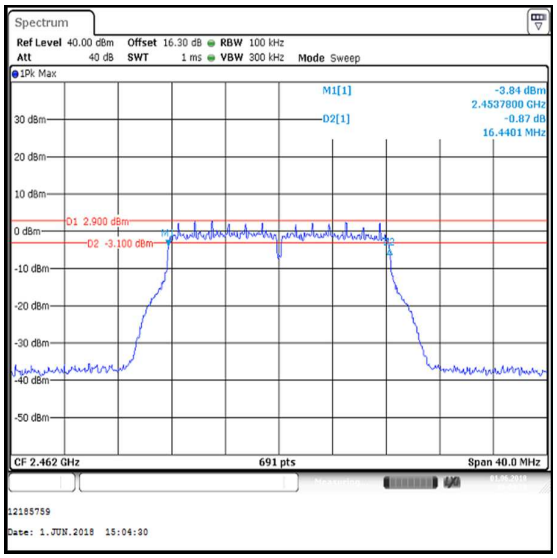
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)

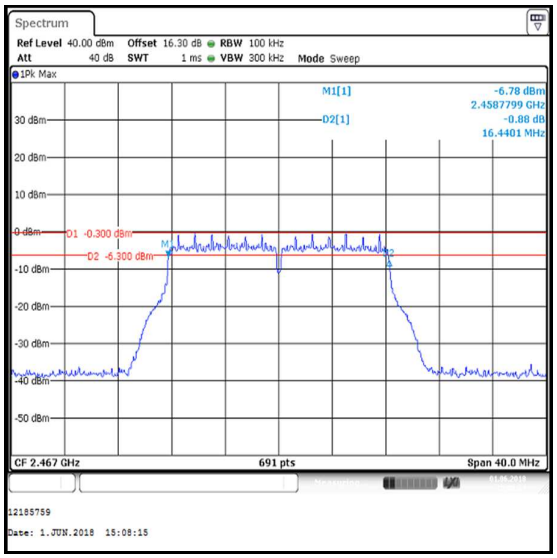
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2



Channel 7



Channel 11



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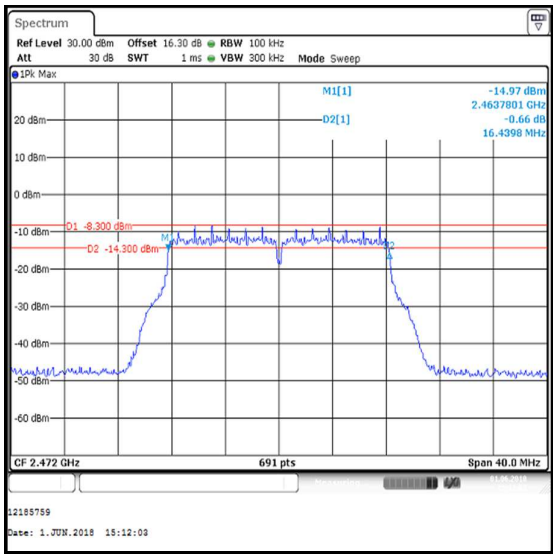


Channel 13

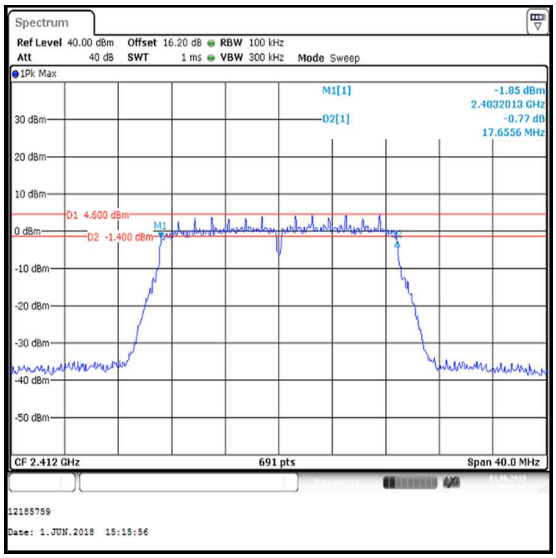
Transmitter Minimum 6 dB Bandwidth (continued)

Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2

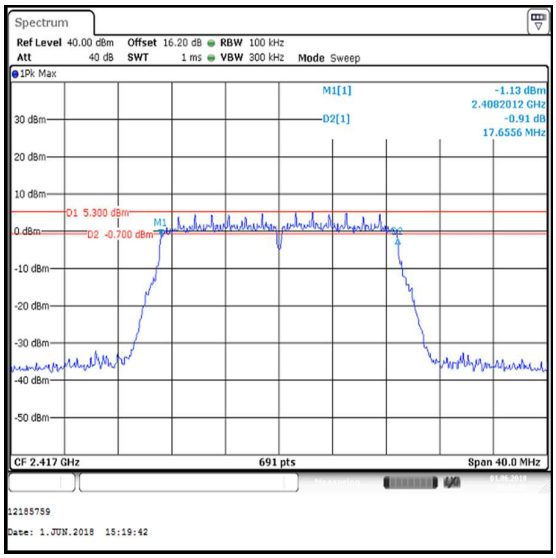
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
1	17656	≥500	17156	Complied
2	17656	≥500	17156	Complied
3	17713	≥500	17213	Complied
6	17713	≥500	17213	Complied
7	17713	≥500	17213	Complied
11	17713	≥500	17213	Complied
12	17713	≥500	17213	Complied
13	17714	≥500	17214	Complied

Transmitter Minimum 6 dB Bandwidth (continued)

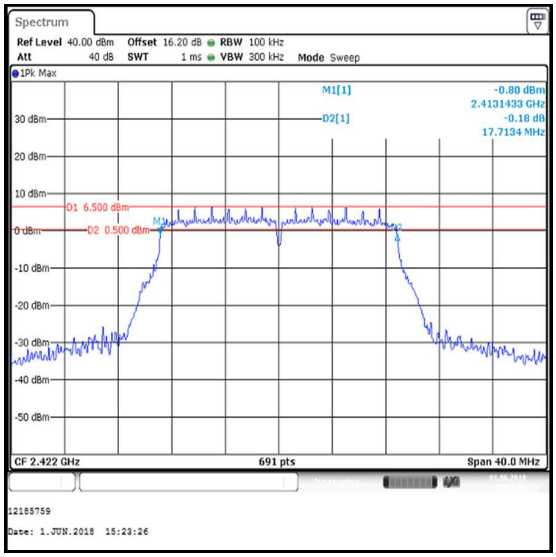
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2



Channel 1



Channel 2



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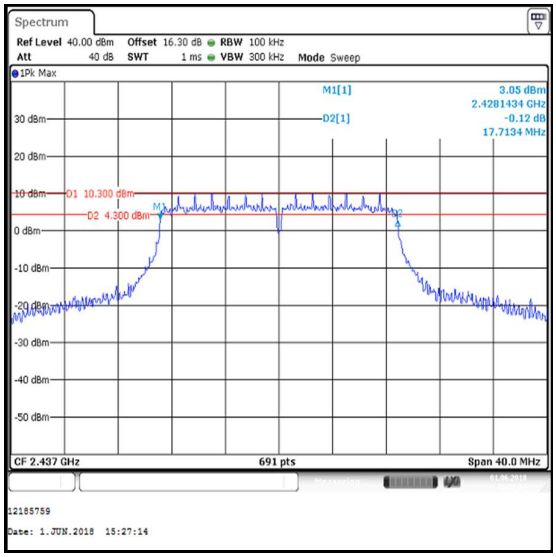
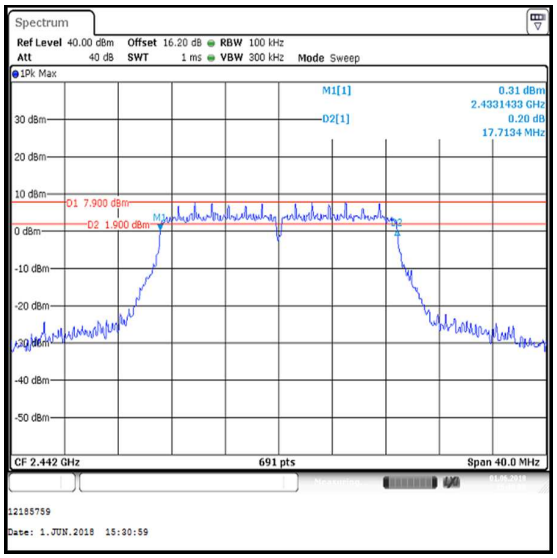


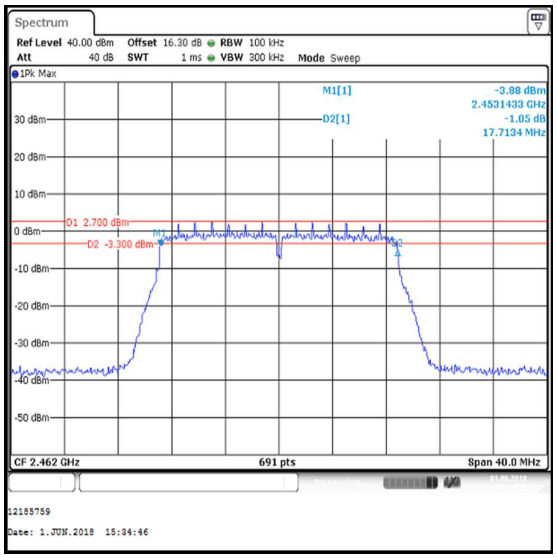
Channel 6

Transmitter Minimum 6 dB Bandwidth (continued)

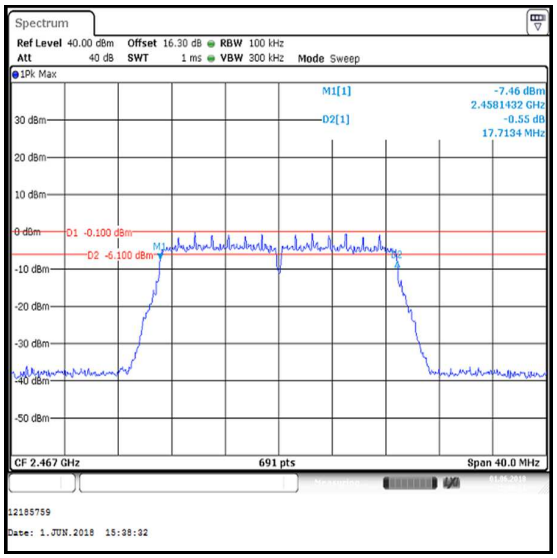
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2



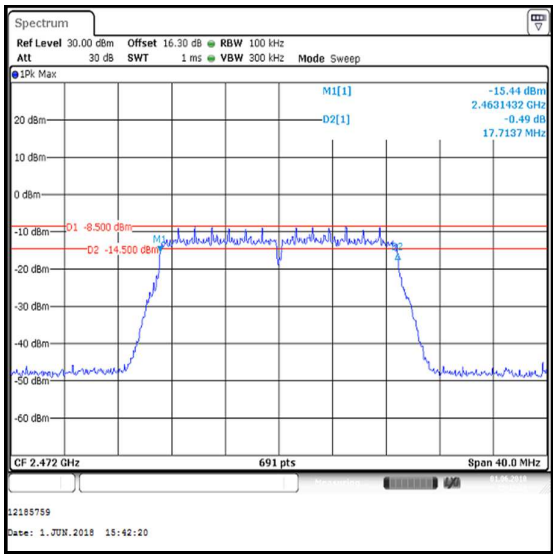
Channel 7



Channel 11



Channel 12



Channel 13

4.2. Transmitter Power Spectral Density

Test Summary:

Test Engineer:	Max Passell	**Test Date:**	01 June 2018
Test Sample Serial Number:	C02WC003JMFN		

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

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	51

Note(s):

1. The customer declared the following data rates to be used for all measurements as:
    - 802.11b – DBPSK / 1 Mbps / Core 2
    - 802.11g – BPSK / 6 Mbps / Core 2
    - 802.11n HT20 – BPSK / MCS0 / 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. The EUT was transmitting at >98% duty cycle and testing was performed in accordance with KDB 558074 Section 10.3 Method AVGPSD-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. 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.

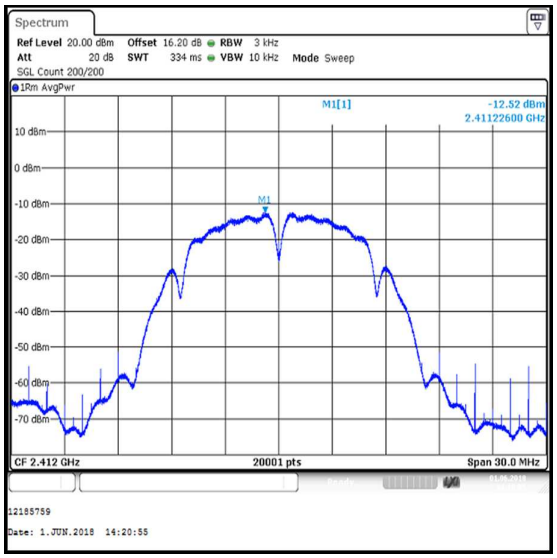
Transmitter Power Spectral Density (continued)

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

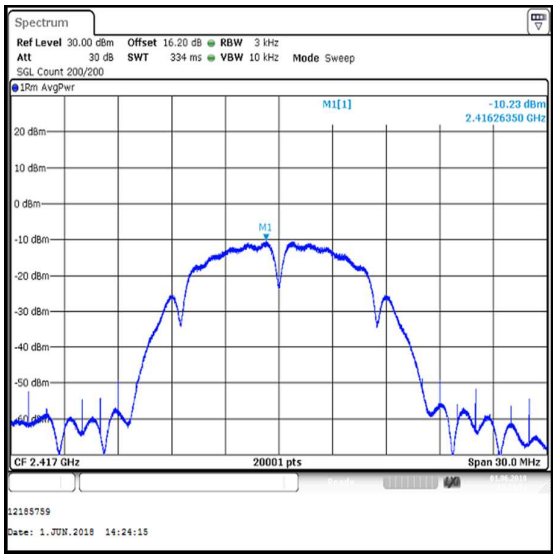
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3kHz)	Margin (dB)	Result
1	-12.5	8.0	20.5	Complied
2	-10.2	8.0	18.2	Complied
3	-10.5	8.0	18.5	Complied
6	-9.7	8.0	17.7	Complied
7	-9.4	8.0	17.4	Complied
11	-13.1	8.0	21.1	Complied
12	-15.4	8.0	23.4	Complied
13	-17.7	8.0	25.7	Complied

Transmitter Power Spectral Density (continued)

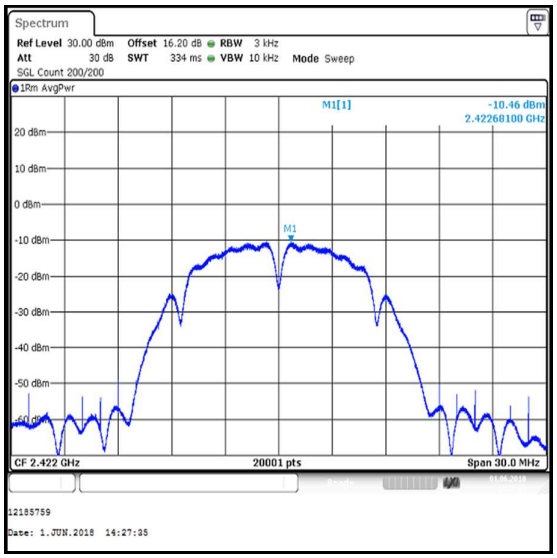
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 2



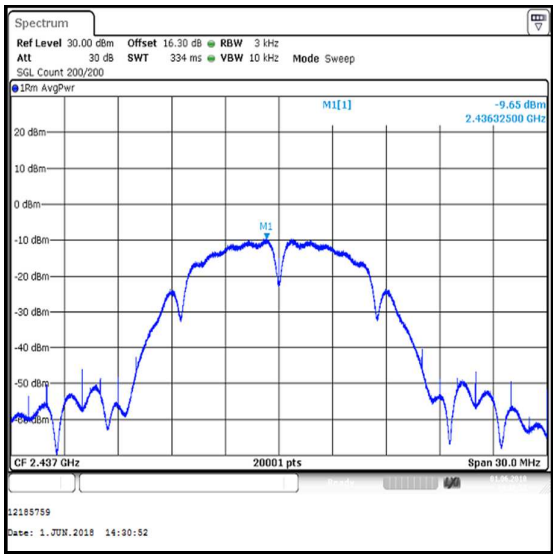
Channel 1



Channel 2



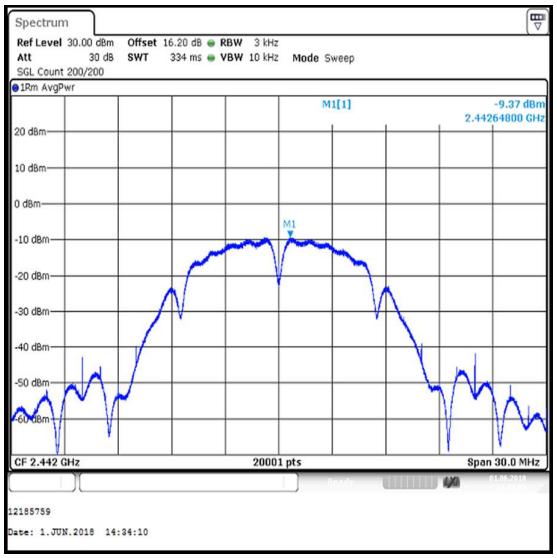
Channel 3



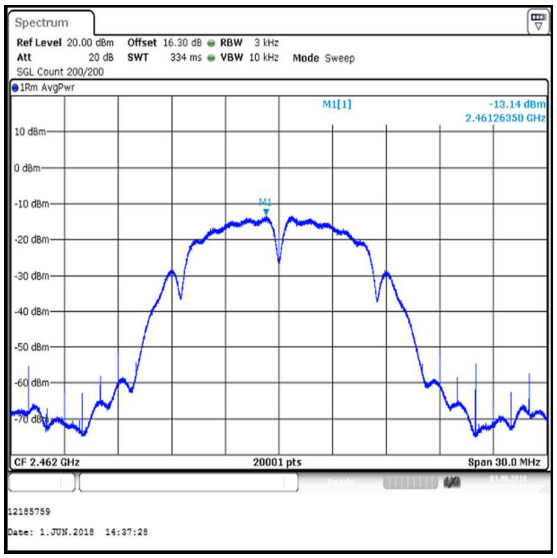
Channel 6

Transmitter Power Spectral Density (continued)

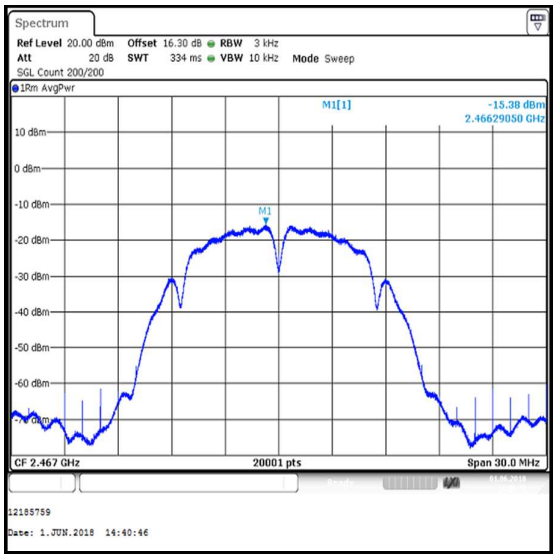
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 2



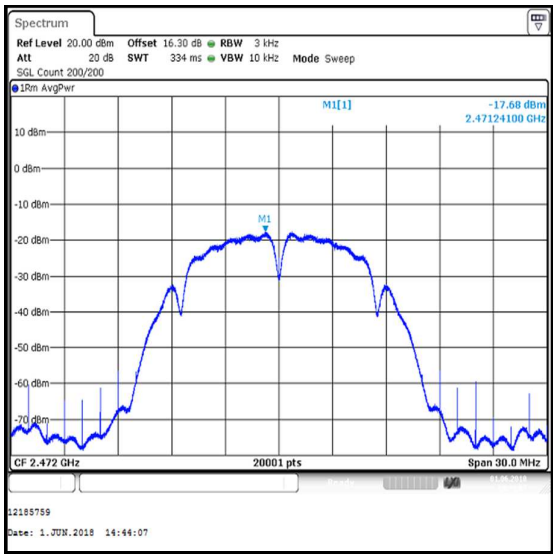
Channel 7



Channel 11



Channel 12



Channel 13

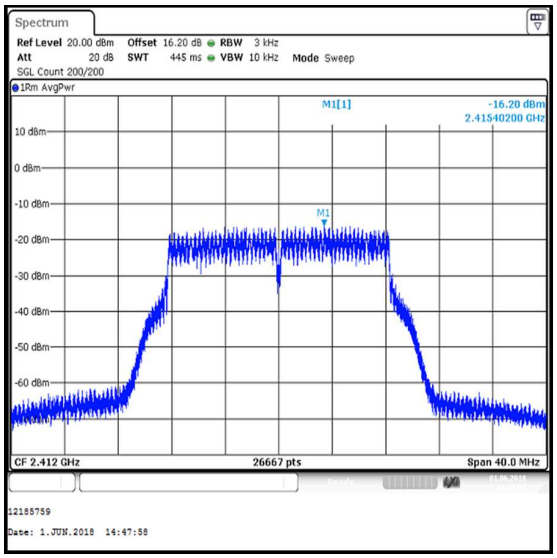
Transmitter Power Spectral Density (continued)

Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2

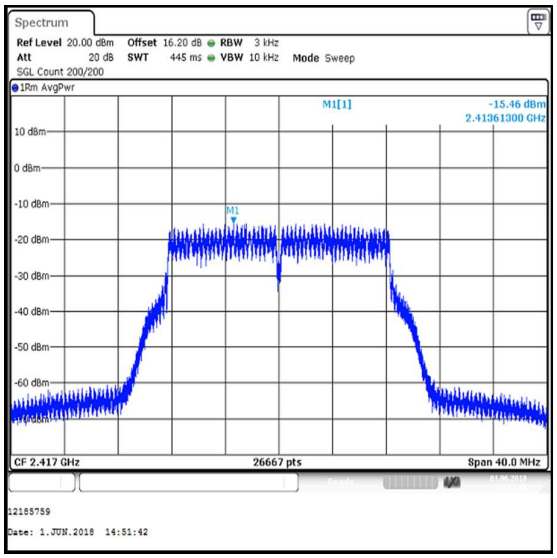
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Result
1	-16.2	8.0	24.2	Complied
2	-15.5	8.0	23.5	Complied
3	-14.0	8.0	22.0	Complied
6	-10.6	8.0	18.6	Complied
7	-12.7	8.0	20.7	Complied
11	-17.4	8.0	25.4	Complied
12	-20.5	8.0	28.5	Complied
13	-28.3	8.0	36.3	Complied

Transmitter Power Spectral Density (continued)

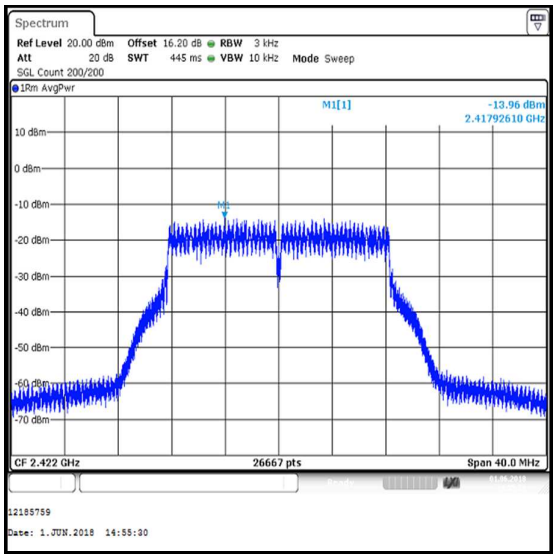
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2



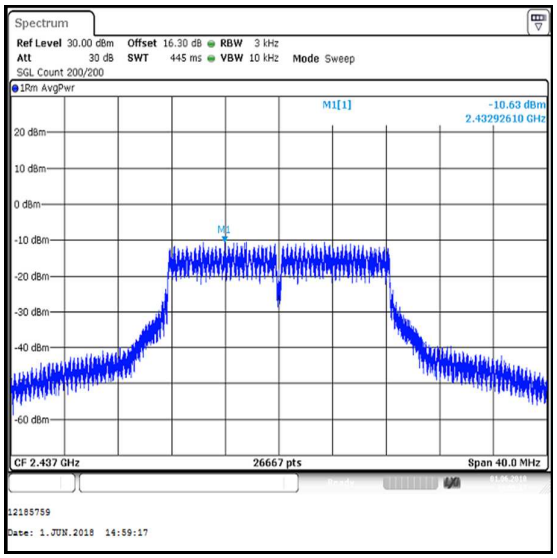
Channel 1



Channel 2



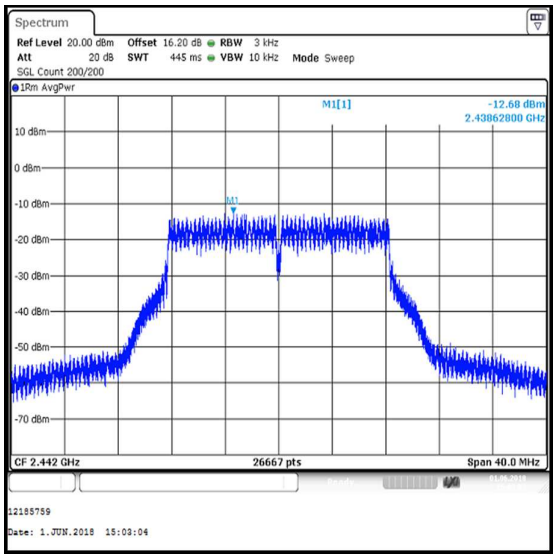
Channel 3



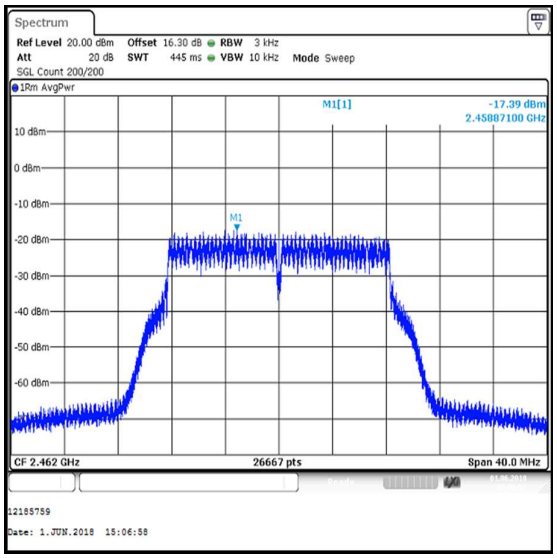
Channel 6

Transmitter Power Spectral Density (continued)

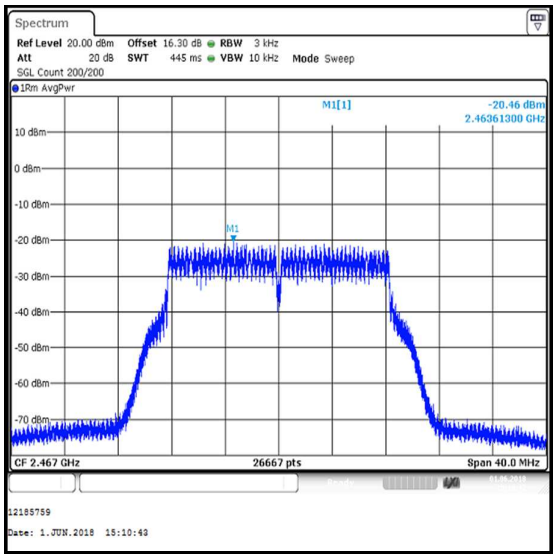
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2



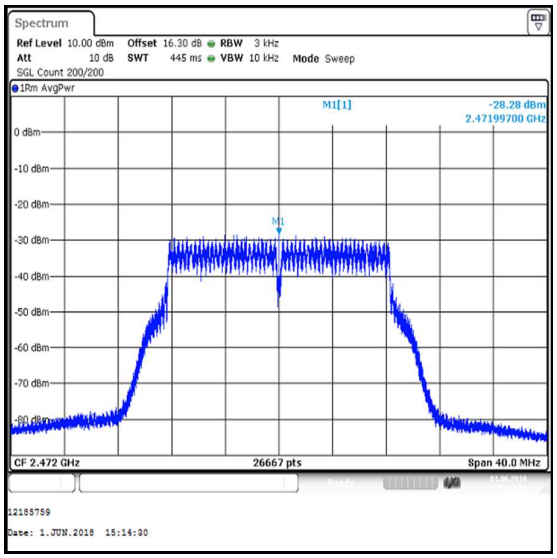
Channel 7



Channel 11



Channel 12



Channel 13

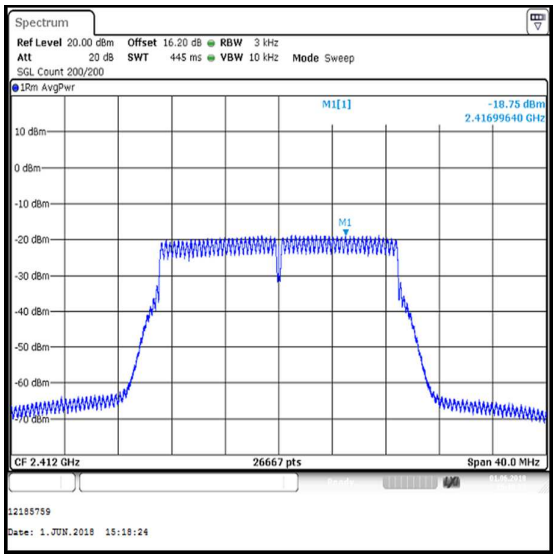
Transmitter Power Spectral Density (continued)

Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2

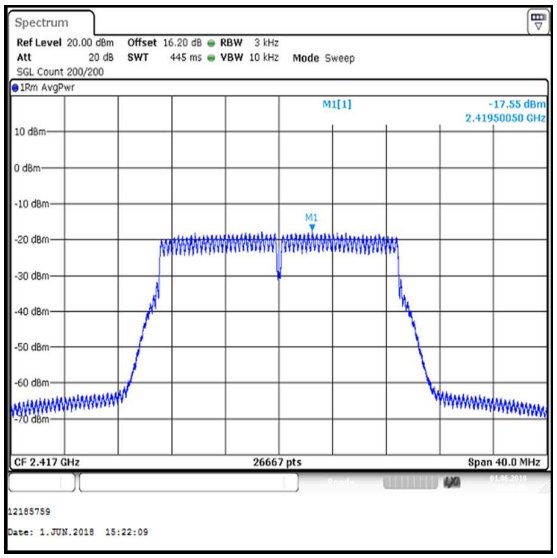
Channel	Output Power (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Result
1	-18.8	8.0	26.8	Complied
2	-17.6	8.0	25.6	Complied
3	-16.8	8.0	24.8	Complied
6	-13.3	8.0	21.3	Complied
7	-15.4	8.0	23.4	Complied
11	-20.2	8.0	28.2	Complied
12	-23.6	8.0	31.6	Complied
13	-30.4	8.0	38.4	Complied

Transmitter Power Spectral Density (continued)

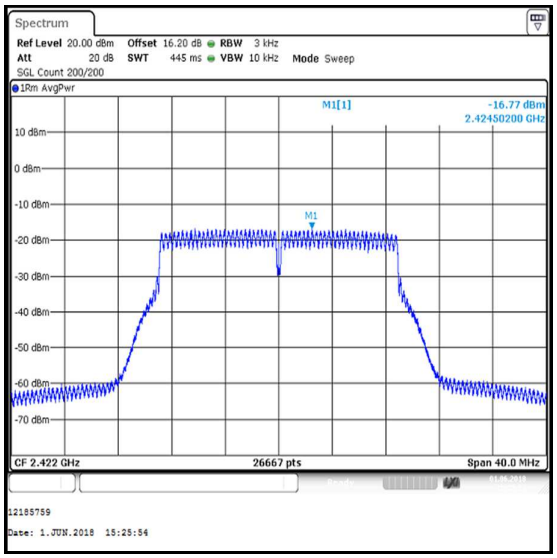
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2



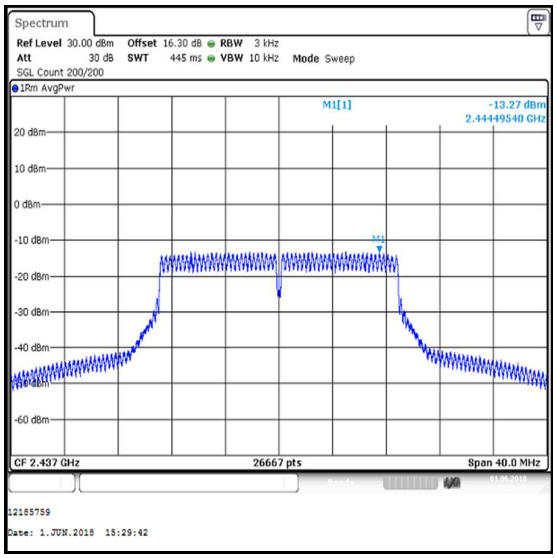
Channel 1



Channel 2



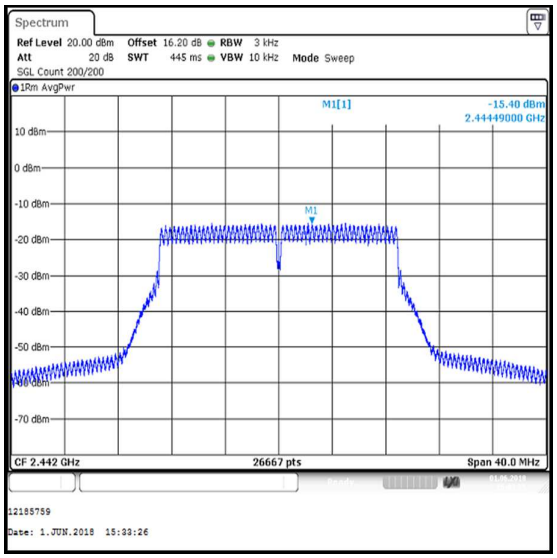
Channel 3



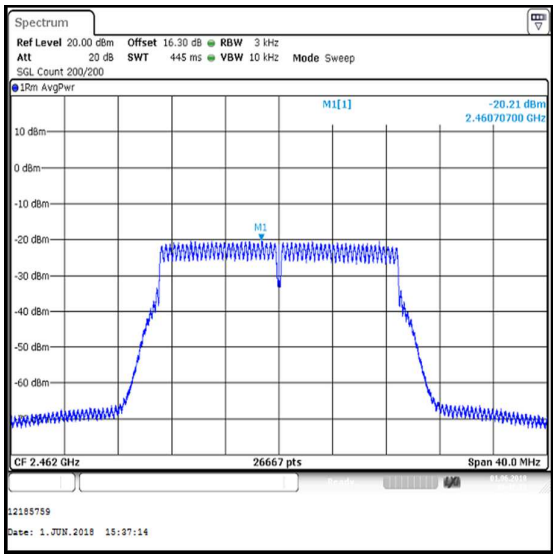
Channel 6

Transmitter Power Spectral Density (continued)

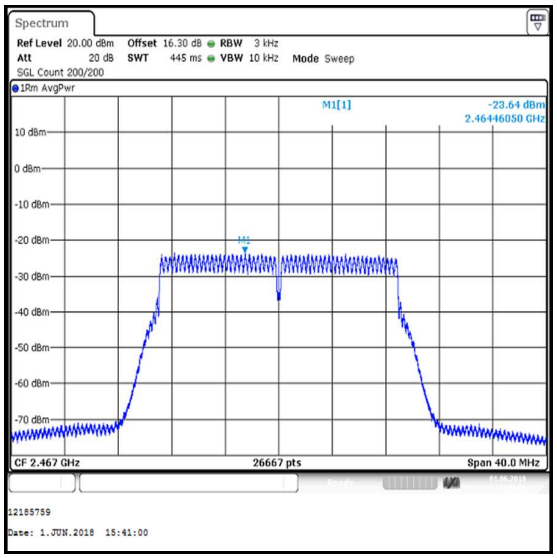
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2



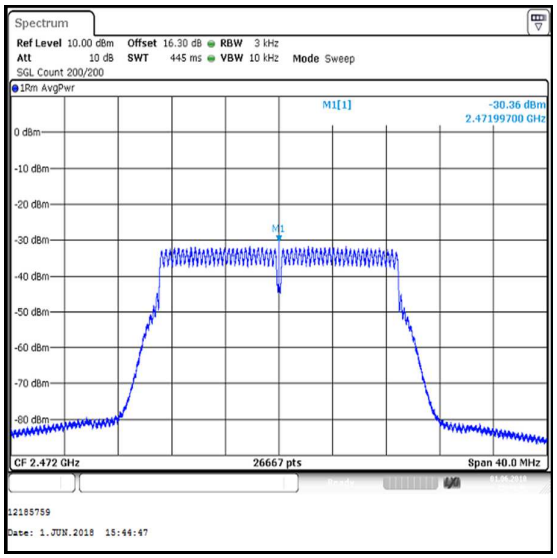
Channel 7



Channel 11



Channel 12



Channel 13

4.3. Transmitter Maximum (Average) Output Power

Test Summary:

Test Engineer:	Max Passell	**Test Date:**	01 June 2018
Test Sample Serial Number:	C02WC003JMFN		

FCC Reference:	Part 15.247(b)(3)
Test Method Used:	FCC KDB 558074 Sections 9.2.2.2

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	51

Note(s):

1. The customer declared the following data rates to be used for all measurements as:
    - 802.11b – DBPSK / 1 Mbps / Core 2
    - 802.11g – BPSK / 6 Mbps / Core 2
    - 802.11n HT20 – BPSK / MCS0 / Core 2
3. Final measurements were performed using the above configurations on the relevant channels. Additional channels were tested as requested by the customer.
4. The power has been integrated over the 99% emission bandwidth. Plots for the occupied bandwidth are archived on the company server and available for inspection upon request.
5. The EUT was transmitting at >98% duty cycle and testing was performed in accordance with KDB 558074 Section 9.2.2.2 Method AVGSA-1. The signal analyser's integration function was used to integrate across the 99% emission bandwidth. For 802.11b, the signal analyser resolution bandwidth was set to 300 kHz and video bandwidth 1 MHz. For 802.11g and 802.11n, the signal analyser resolution bandwidth was set to 500 kHz and video bandwidth 2 MHz. An RMS detector was used and sweep time set manually to perform trace averaging over 200 traces. The span was set to at least 1.5 times the 99% emission bandwidth.
6. 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 Maximum (Average) Output Power (continued)

Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / SISO / Core 2

Conducted Peak Limit Comparison

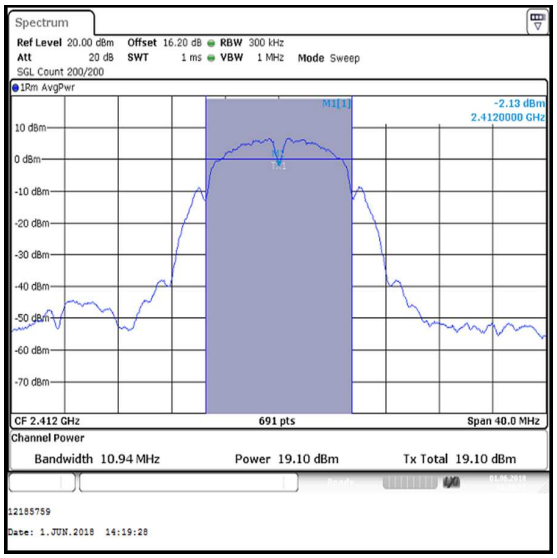
Channel	Conducted Power (dBm)	Conducted Power Limit (dBm)	Margin (dB)	Result
1	19.1	30.0	10.9	Complied
2	21.1	30.0	8.9	Complied
3	21.2	30.0	8.8	Complied
6	22.1	30.0	7.9	Complied
7	22.2	30.0	7.8	Complied
11	18.3	30.0	11.7	Complied
12	15.7	30.0	14.3	Complied
13	13.9	30.0	16.1	Complied

EIRP Limit Comparison

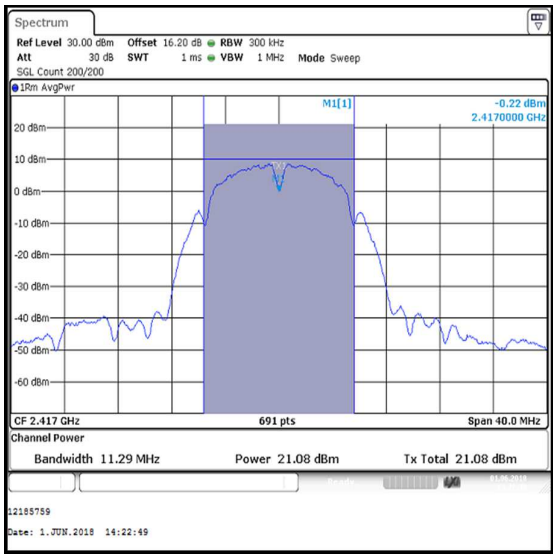
Channel	Conducted Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
1	19.1	2.1	21.2	36.0	14.8	Complied
2	21.1	2.1	23.2	36.0	12.8	Complied
3	21.2	2.1	23.3	36.0	12.7	Complied
6	22.1	2.1	24.2	36.0	11.8	Complied
7	22.2	2.1	24.3	36.0	11.7	Complied
11	18.3	2.1	20.4	36.0	15.6	Complied
12	15.7	2.1	17.8	36.0	18.2	Complied
13	13.9	2.1	16.0	36.0	20.0	Complied

Transmitter Maximum (Average) Output Power (continued)

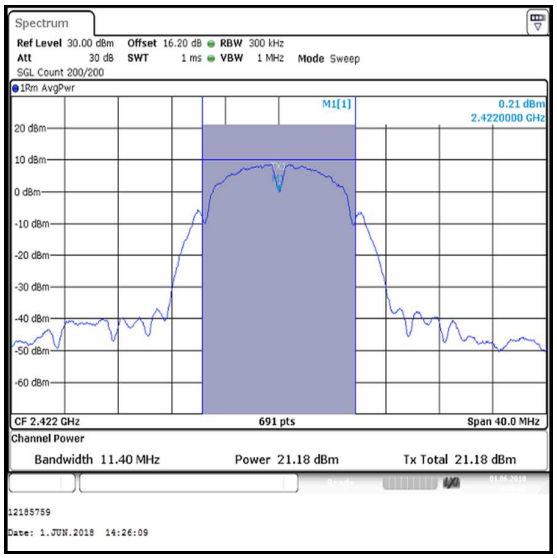
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 2



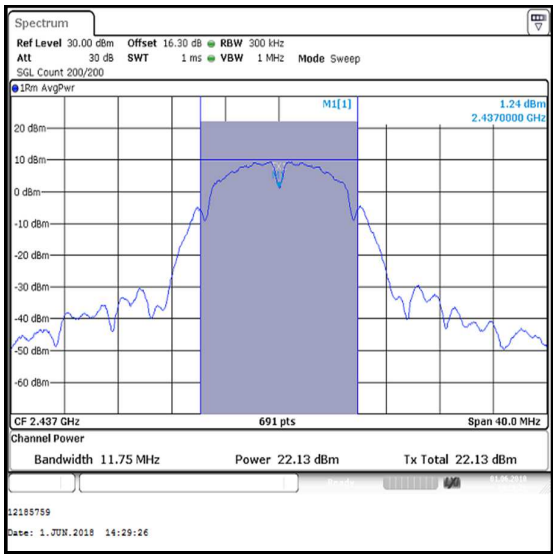
Channel 1



Channel 2



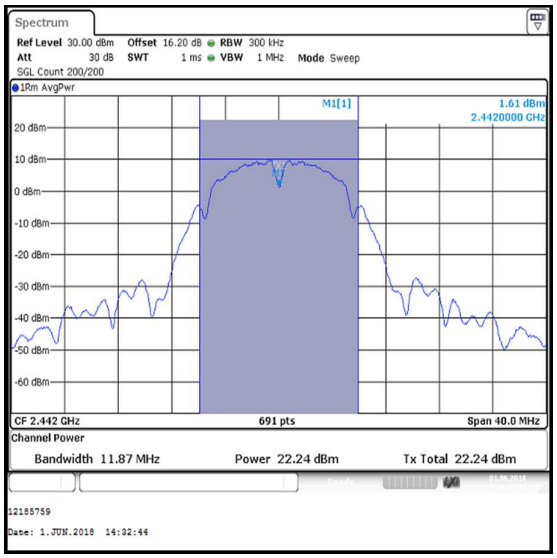
Channel 3



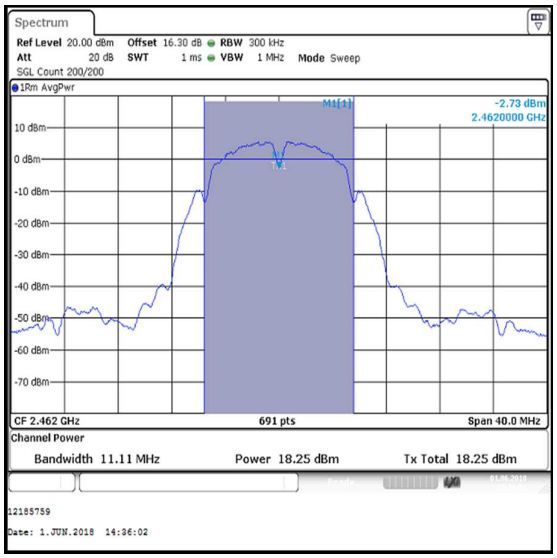
Channel 6

Transmitter Maximum (Average) Output Power (continued)

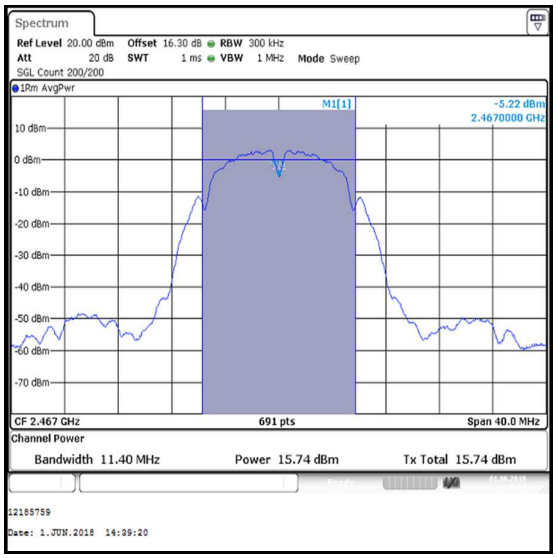
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps / Core 2



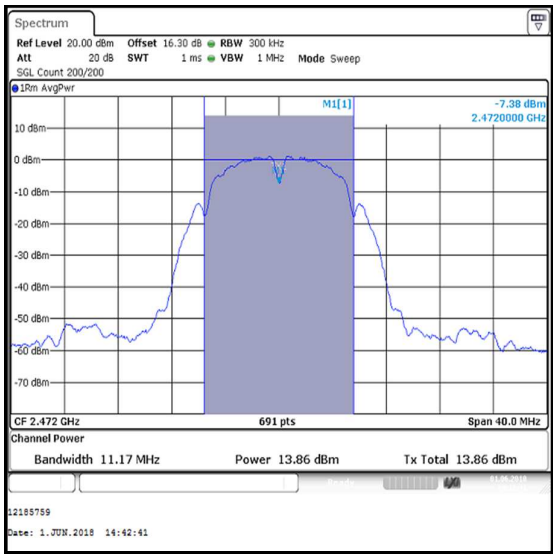
Channel 7



Channel 11



Channel 12



Channel 13

Transmitter Maximum (Average) Output Power (continued)

Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2

Conducted Peak Limit Comparison

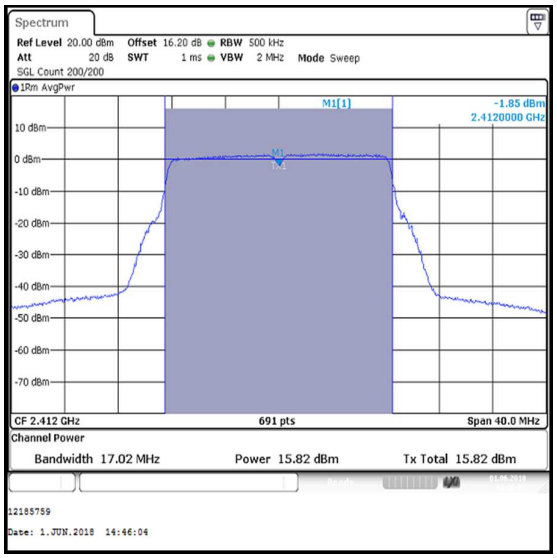
Channel	Conducted Power (dBm)	Conducted Power Limit (dBm)	Margin (dB)	Result
1	15.8	30.0	14.2	Complied
2	16.4	30.0	13.6	Complied
3	17.7	30.0	12.3	Complied
6	21.2	30.0	8.8	Complied
7	19.2	30.0	10.8	Complied
11	14.1	30.0	15.9	Complied
12	10.9	30.0	19.1	Complied
13	2.9	30.0	27.1	Complied

EIRP Limit Comparison

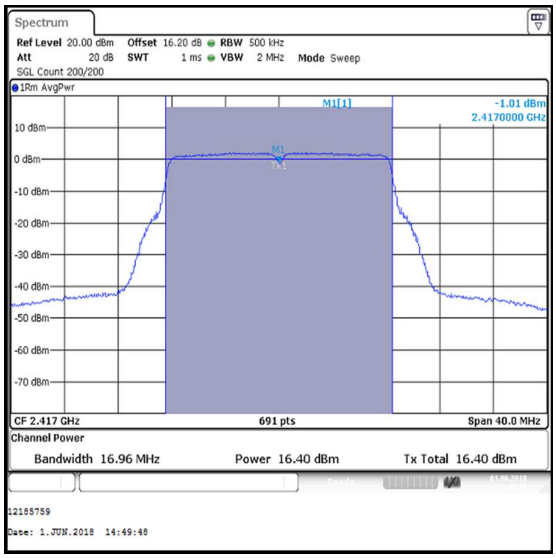
Channel	Conducted Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
1	15.8	2.1	17.9	36.0	18.1	Complied
2	16.4	2.1	18.5	36.0	17.5	Complied
3	17.7	2.1	19.8	36.0	16.2	Complied
6	21.2	2.1	23.3	36.0	12.7	Complied
7	19.2	2.1	21.3	36.0	14.7	Complied
11	14.1	2.1	16.2	36.0	19.8	Complied
12	10.9	2.1	13.0	36.0	23.0	Complied
13	2.9	2.1	5.0	36.0	31.0	Complied

Transmitter Maximum (Average) Output Power (continued)

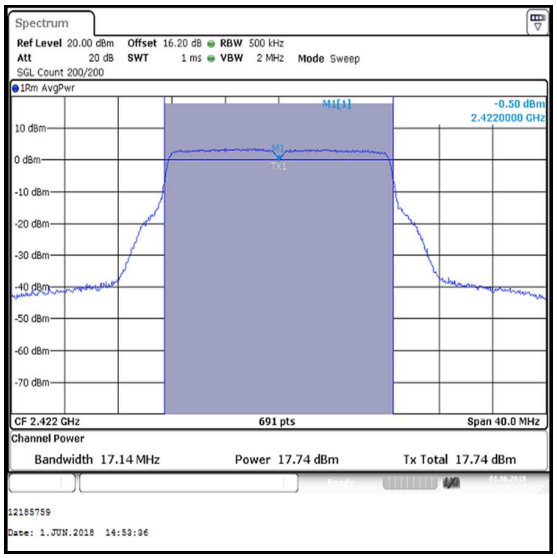
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2



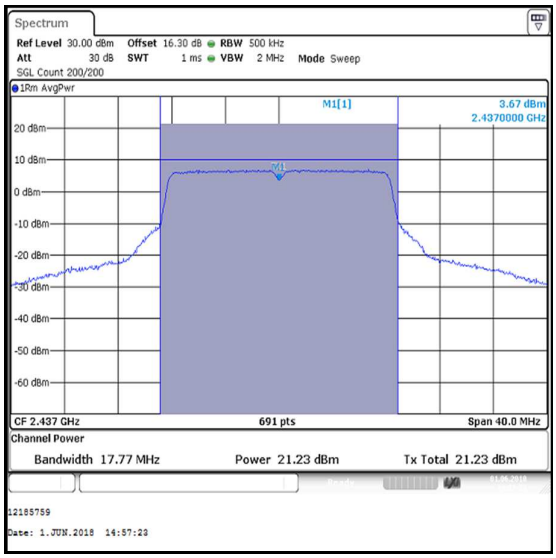
Channel 1



Channel 2



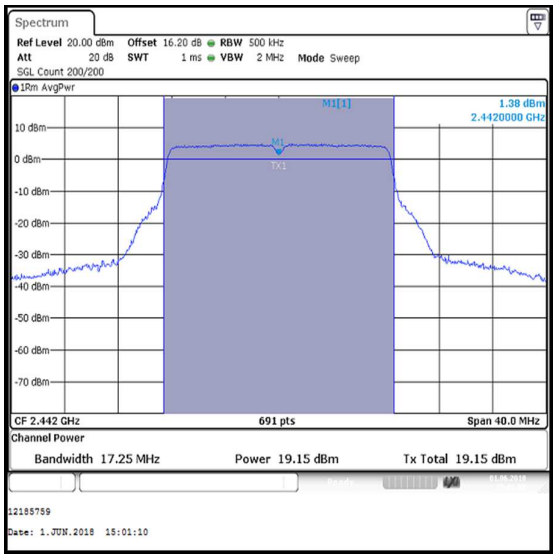
Channel 3



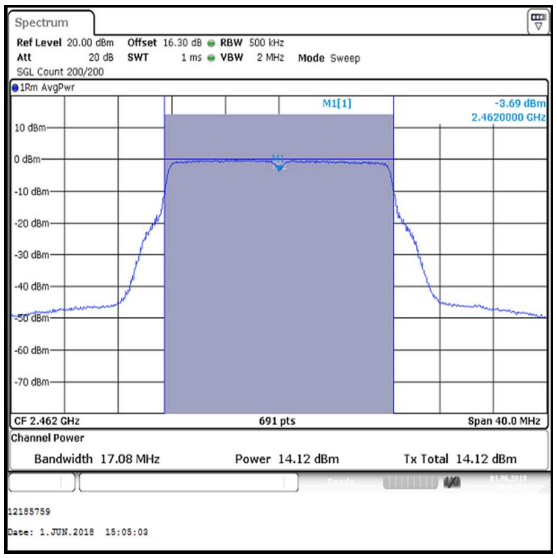
Channel 6

Transmitter Maximum (Average) Output Power (continued)

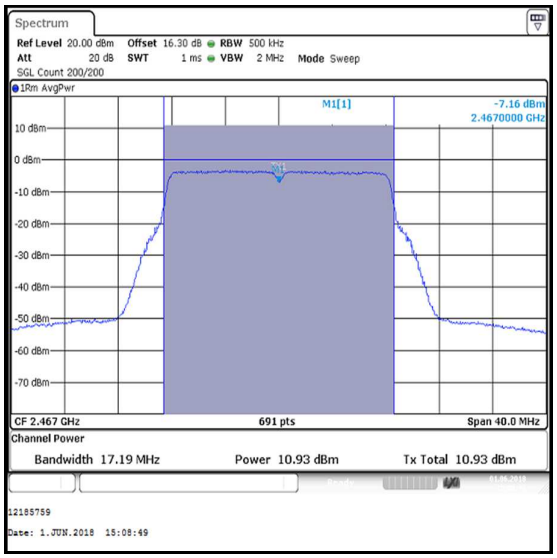
Results: 802.11g / 20 MHz / BPSK / 6 Mbps / Core 2



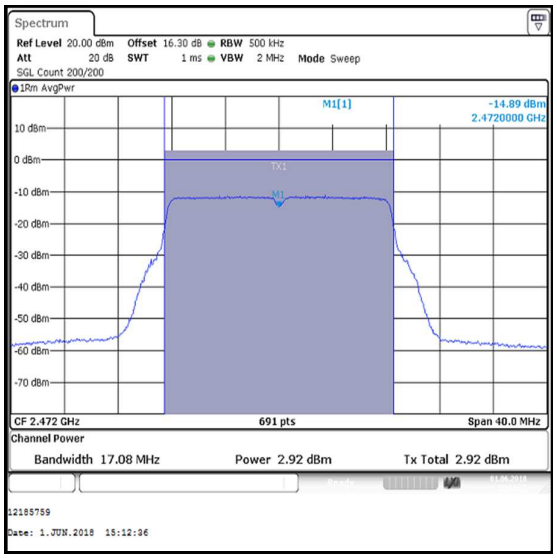
Channel 7



Channel 11



Channel 12



Channel 13

Transmitter Maximum (Average) Output Power (continued)

Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2

Conducted Peak Limit Comparison

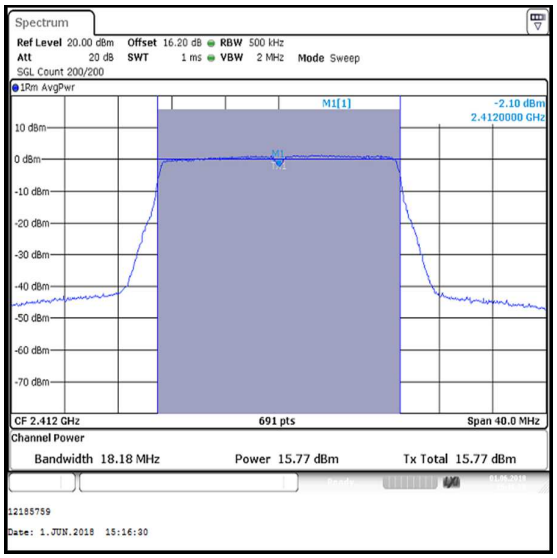
Channel	Conducted Power (dBm)	Conducted Power Limit (dBm)	Margin (dB)	Result
1	15.8	30.0	14.2	Complied
2	16.4	30.0	13.6	Complied
3	17.9	30.0	12.1	Complied
6	21.4	30.0	8.6	Complied
7	19.2	30.0	10.8	Complied
11	14.1	30.0	15.9	Complied
12	11.0	30.0	19.0	Complied
13	3.0	30.0	27.0	Complied

EIRP Limit Comparison

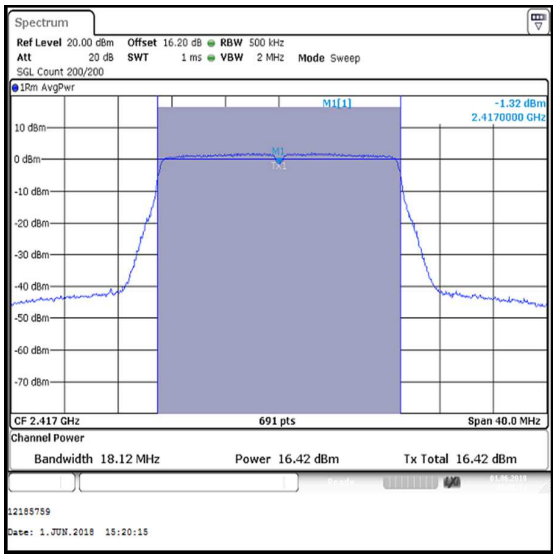
Channel	Conducted Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
1	15.8	2.1	17.9	36.0	18.1	Complied
2	16.4	2.1	18.5	36.0	17.5	Complied
3	17.9	2.1	20.0	36.0	16.0	Complied
6	21.4	2.1	23.5	36.0	12.5	Complied
7	19.2	2.1	21.3	36.0	14.7	Complied
11	14.1	2.1	16.2	36.0	19.8	Complied
12	11.0	2.1	13.1	36.0	22.9	Complied
13	3.0	2.1	5.1	36.0	30.9	Complied

Transmitter Maximum (Average) Output Power (continued)

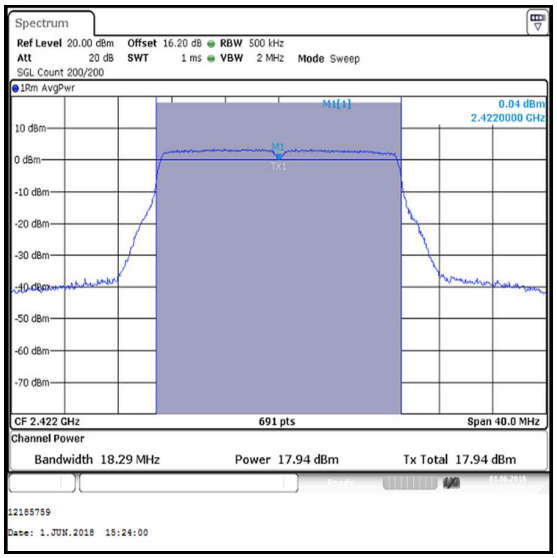
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2



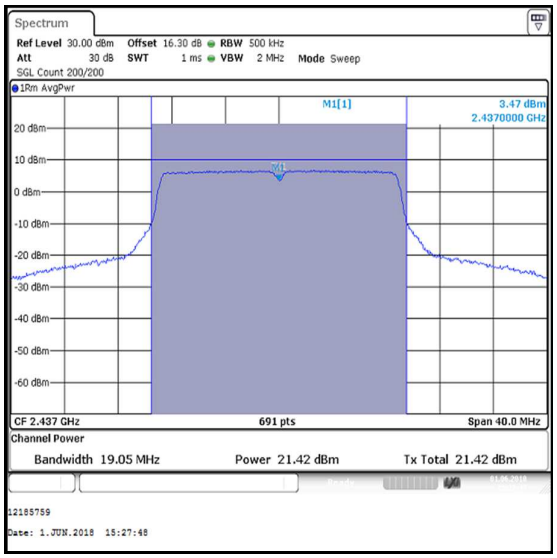
Channel 1



Channel 2



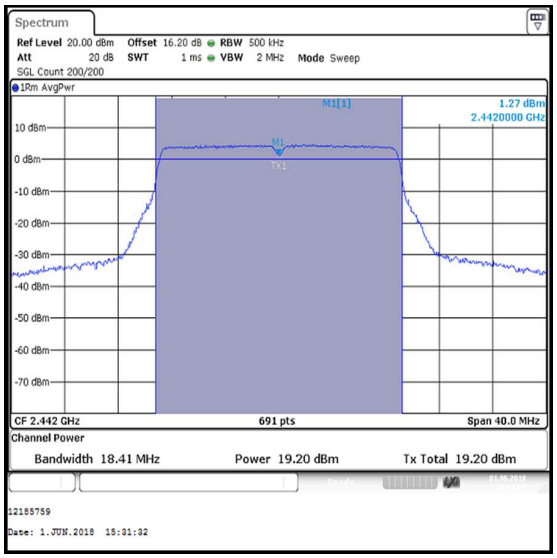
Channel 3



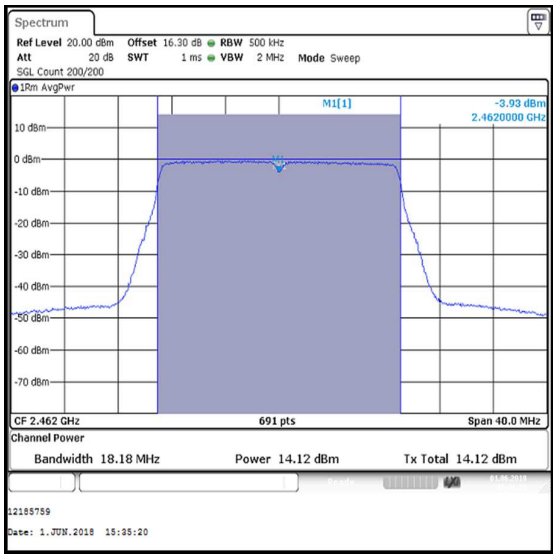
Channel 6

Transmitter Maximum (Average) Output Power (continued)

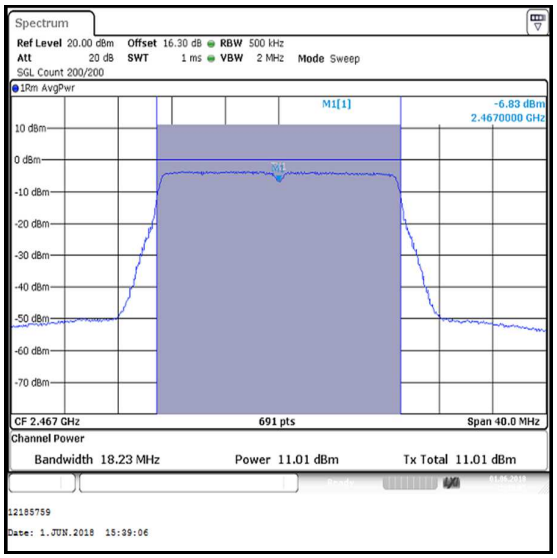
Results: 802.11n / HT20 / SISO / BPSK / MCS0 / Core 2



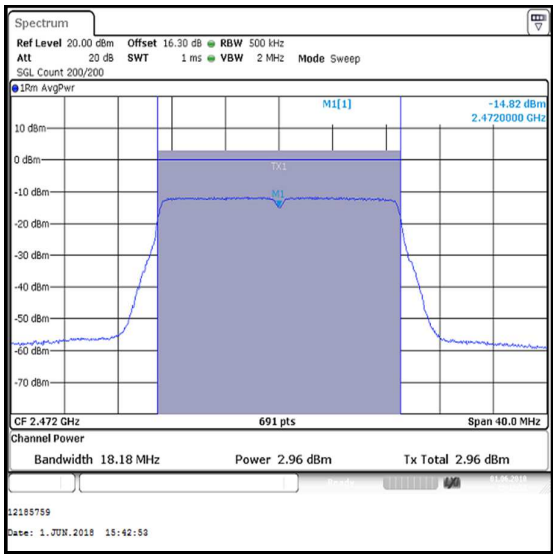
Channel 7



Channel 11



Channel 12



Channel 13

5. Radiated Test Results

5.1. Transmitter Radiated Emissions <1 GHz

Test Summary:

Test Engineer:	Alan Withers	**Test Date:**	16 May 2018
Test Sample Serial Number:	C02WC006JTGW		

FCC Reference:	Parts 15.247(d) & 15.209(a)
Test Method Used:	ANSI C63.10 Sections 6.3 and 6.5
Frequency Range	30 MHz to 1000 MHz

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	39

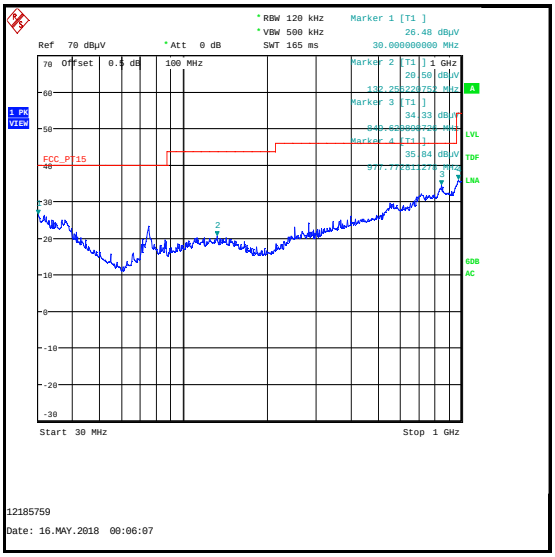
Note(s):

1. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
2. The preliminary scans showed similar emission levels below 1 GHz, for each channel of operation. Therefore final radiated emissions measurements were performed with the EUT set to the middle channel only.
3. All emissions shown on the pre-scan plots were investigated and found to be ambient, or >20 dB below the applicable limit or below the measurement system noise floor. Therefore the highest peak noise floor reading of the measuring receiver was recorded in the table below.
4. Measurements below 1 GHz were performed in a semi-anechoic chamber (Asset Number K0017) at a distance of 3 metres. The EUT was placed at a height of 80 cm above the reference ground plane in the centre of the chamber turntable. Maximum emission levels were determined by height searching the measurement antenna over the range 1 metre to 4 metres.
5. Pre-scans were performed and markers placed on the highest measured levels. The test receiver resolution bandwidth was set to 120 kHz and video bandwidth 500 kHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold.

Transmitter Radiated Emissions (continued)

Results: Middle Channel / 802.11b / 20 MHz / 1 Mbps / SISO

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
977.773	Vertical	35.8	54.0	18.2	Complied



5.2. Transmitter Radiated Emissions >1 GHz

Test Summary:

Test Engineers:	John Ferdinand & Alan Withers	**Test Dates:**	14 May 2018, 15 May 2018 & 13 June 2018
Test Sample Serial Number:	C02WC006JTGW		

FCC Reference:	Parts 15.247(d) & 15.209(a)
Test Method Used:	ANSI C63.10 Sections 6.3 and 6.6 & FCC KDB 558074 Sections 11, 12.2.4 & 12.2.5.2
Frequency Range	1 GHz to 25 GHz

Environmental Conditions:

Temperature (°C):	22 to 24
Relative Humidity (%):	42 to 45

Note(s):

1. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
2. All other emissions shown on the pre-scan plot were investigated and found to be ambient or >20 dB below the appropriate limit or below the measurement system noise floor.
3. The emission shown approximately at 2442 MHz on the 1 GHz to 3 GHz plot is the EUT fundamental.
4. In accordance with ANSI C63.10 Section 6.6.4.3 (Note 1), if the peak measured value complies with the average limit, it is unnecessary to perform an average measurement.
5. Pre-scans above 1 GHz were performed in a fully anechoic chamber (Asset Number K0017) at a distance of 3 metres. The EUT was placed at a height of 1.5 metres above the test chamber floor in the centre of the chamber turntable. All measurement antennas were placed at a fixed height of 1.5 metres above the test chamber floor, in line with the EUT.
6. Final measurements above 1 GHz were performed in a fully anechoic chamber (Asset Number K0017) at a distance of 3 metres. The EUT was placed at a height of 1.5 m above the reference ground plane in the centre of the chamber turntable. Maximum emission levels were determined by height searching the measurement antenna over the range 1 metre to 4 metres.
7. Pre-scans were performed and a marker placed on the highest measured level of the appropriate plot. The test receiver resolution bandwidth was set to 1 MHz and video bandwidth 3 MHz. The sweep time was set to auto.
8. *-30 dBc limit applies in non-restricted bands as the conducted average maximum output power was previously measured.
9. The reference level for emissions in non-restricted bands was established following KDB 558074 Section 11.2 procedure.

Transmitter Radiated Emissions (continued)

Results: Peak / Bottom Channel

Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Peak Limit (dBµV/m)	Margin (dB)	Result
9647.937	Vertical	51.1	73.1*	22.0	Complied

Results: Peak / Middle Channel

Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Peak Limit (dBµV/m)	Margin (dB)	Result
9767.958	Vertical	51.6	79.0*	27.4	Complied

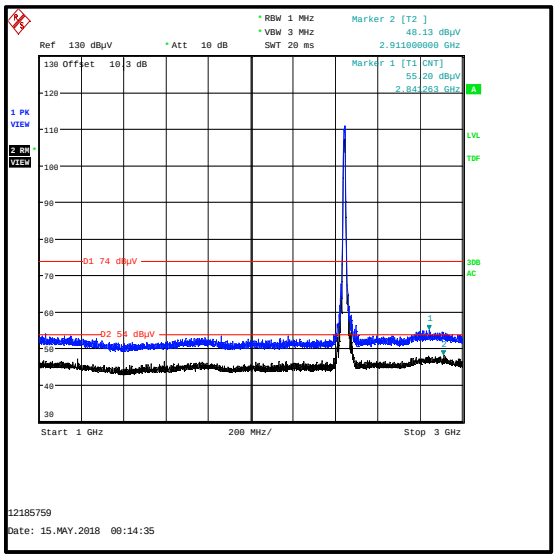
Results: Peak / Top Channel

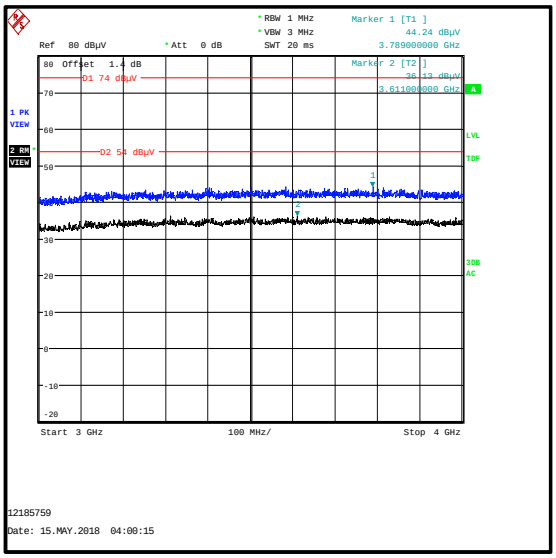
Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Peak Limit (dBµV/m)	Margin (dB)	Result
11254.000	Vertical	46.9	74.0	27.1	Complied

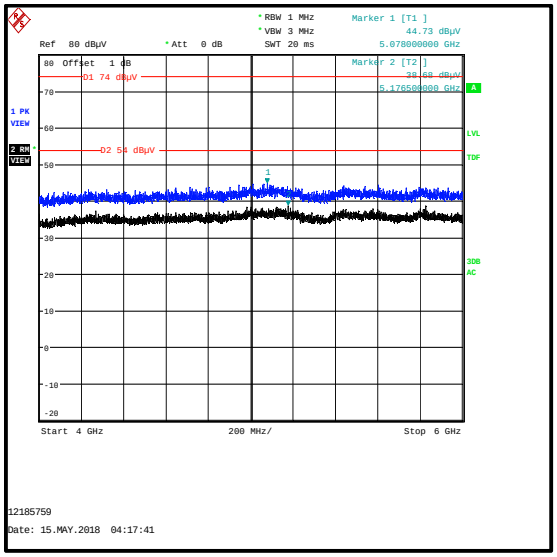
Results: Average / Top Channel

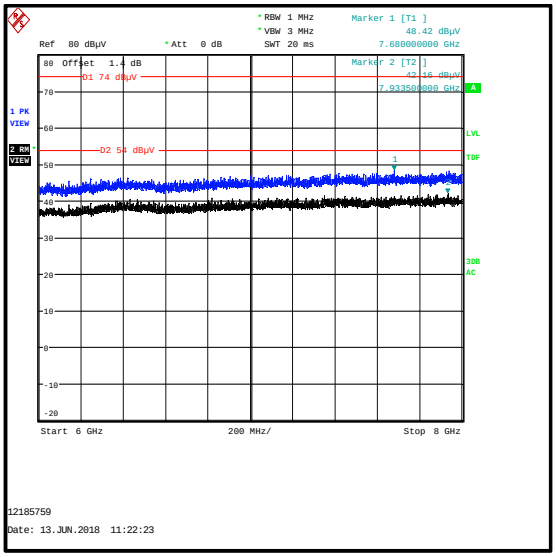
Frequency (MHz)	Antenna Polarity	Average Level (dBµV/m)	Average Limit (dBµV/m)	Margin (dB)	Result
11398.500	Vertical	40.9	54.0	13.1	Complied

Transmitter Radiated Emissions (continued)

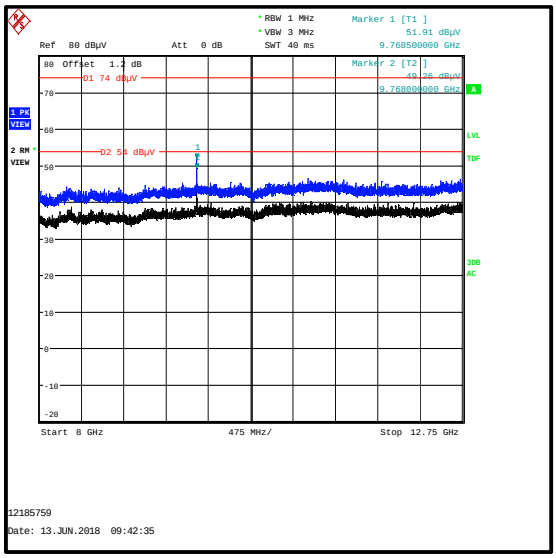


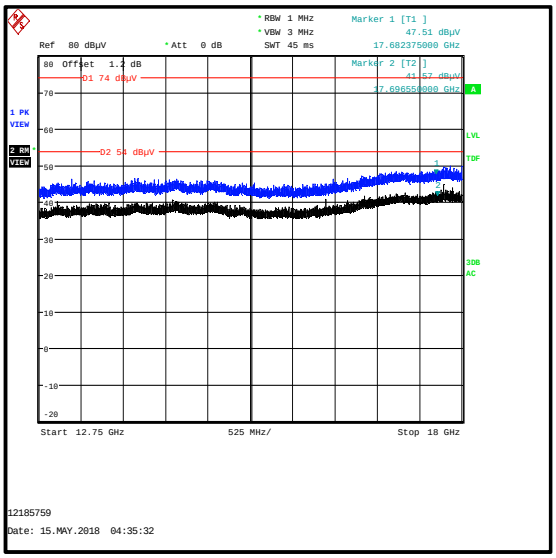


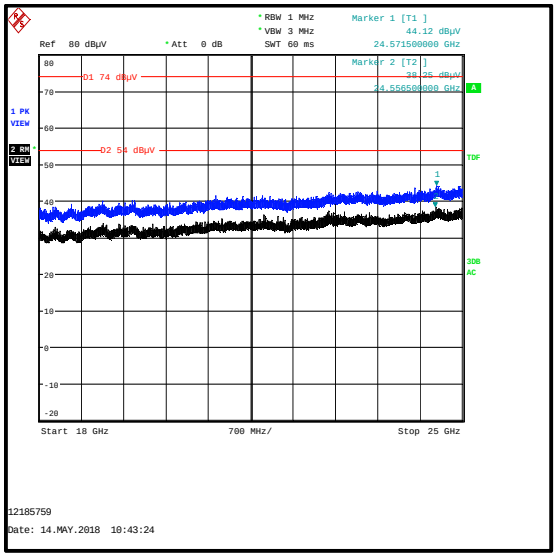




Transmitter Radiated Emissions (continued)







Note: These plots are pre-scans and for indication purposes only. For final measurements, see accompanying tables.

5.3. Transmitter Band Edge Radiated Emissions

Test Summary:

Test Engineers:	Andrew Edwards & John Ferdinand	**Test Dates:**	17 February 2018 to 30 May 2018
Test Sample Serial Numbers:	C02VT01FJLG2 & C02WC006JTGW		

FCC Reference:	Parts 15.247(d) & 15.209(a)
Test Method Used:	ANSI C63.10 Section 6.10 & FCC KDB 558074 Sections 11 & 12

Environmental Conditions:

Temperature (°C):	22 to 25
Relative Humidity (%):	38 to 44

Note(s):

1. The customer declared the following data rates to be used for all measurements as:
    - 802.11b – DBPSK / 1 Mbps / SISO / Core 2
    - 802.11g – BPSK / 6 Mbps / SISO / Core 2
    - 802.11n HT20 – BPSK / MCS0 / SISO / Core 2

    Final measurements were performed with the above configurations.
2. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
3. The maximum conducted (average) output power was previously measured. In accordance with FCC KDB 558074 Section 11.1(b), the lower band edge measurement should be performed with a peak detector and the -30 dBc limit applied.
4. As the lower band edge is adjacent to a non-restricted band, only peak measurements are required. In accordance with FCC KDB 558074 Section 11.1, the test method in Section 11.3 was followed: the test receiver resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The test receiver was left to sweep for a sufficient length of time in order to maximise the carrier level and out-of-band emissions. A marker and corresponding reference level line were placed on the peak of the carrier. As the maximum conducted (average) output power was measured using an RMS detector in accordance with FCC KDB 558074 Section 9.2.2.4 an out-of-band limit line was placed 30 dB (FCC KDB 558074 Section 11.1(b)) below the peak level. A marker was placed on the band edge spot frequencies and a second marker placed on the highest emission level in the adjacent non-restricted band of operation (where a higher level emission was present). Marker frequencies and levels were recorded.
5. As the upper band edge is adjacent to a restricted band both peak and average measurements were recorded by placing a marker at the edge of the band. For peak measurements the test receiver resolution bandwidth was set to 1 MHz and the video bandwidth 3 MHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. For average measurements the test receiver resolution bandwidth was set to 1 MHz and the video bandwidth 3 MHz. An RMS detector was used, sweep time was set to auto and trace mode was trace averaging over 300 sweeps. A marker was placed on the band edge spot frequencies and a second marker placed on the highest emission level in the adjacent restricted band of operation (where a higher level emission was present). Marker frequencies and levels were recorded.
6. There is a restricted band 10 MHz below the lower band edge. The test receiver was set up as follows: the RBW set to 1 MHz, the VBW set to 3 MHz, with the sweep time set to auto couple. Peak and average measurements were performed with their respective detectors. Markers were placed on the highest point on each trace.

Transmitter Band Edge Radiated Emissions (continued)

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

Results: Lower Band Edge / Channel 1

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	-30 dBc Limit (dBµV/m)	Margin (dB)	Result
2398.958	Vertical	62.2	76.2	14.0	Complied
2400.000	Vertical	53.1	76.2	23.1	Complied

Results: Upper Band Edge / Peak / Channel 11

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	62.4	74.0	11.6	Complied
2485.856	Vertical	63.9	74.0	10.1	Complied

Results: Upper Band Edge / Average / Channel 11

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	50.6	54.0	3.4	Complied

Results: Upper Band Edge / Peak / Channel 12

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	61.7	74.0	12.3	Complied
2484.942	Vertical	64.4	74.0	9.6	Complied

Results: Upper Band Edge / Average / Channel 12

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	50.6	54.0	3.4	Complied

Results: Upper Band Edge / Peak / Channel 13

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	64.5	74.0	9.5	Complied
2485.263	Vertical	64.6	74.0	9.4	Complied

Results: Upper Band Edge / Average / Channel 13

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	50.1	54.0	3.9	Complied
2486.865	Vertical	50.2	54.0	3.8	Complied

Transmitter Band Edge Radiated Emissions (continued)

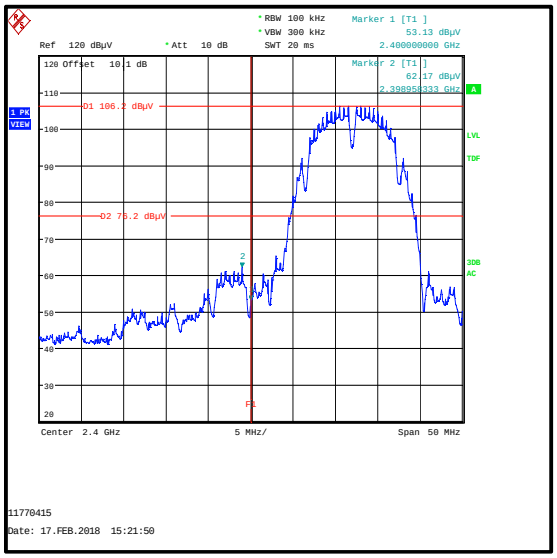
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps

Results: 2310 MHz to 2390 MHz Restricted Band / Peak

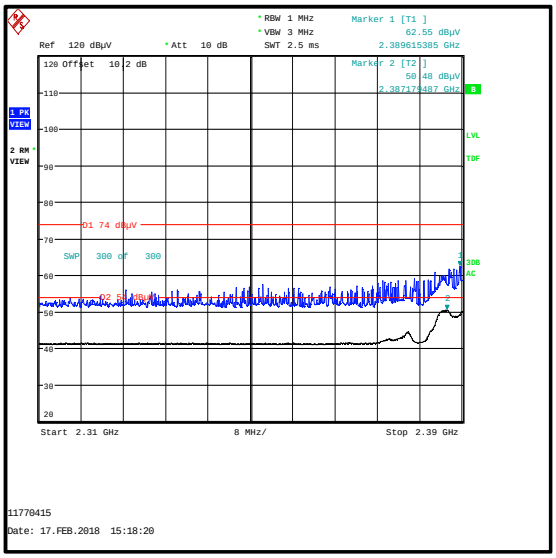
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2389.615	Vertical	62.6	74.0	11.4	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Average

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2387.179	Vertical	50.5	54.0	3.5	Complied



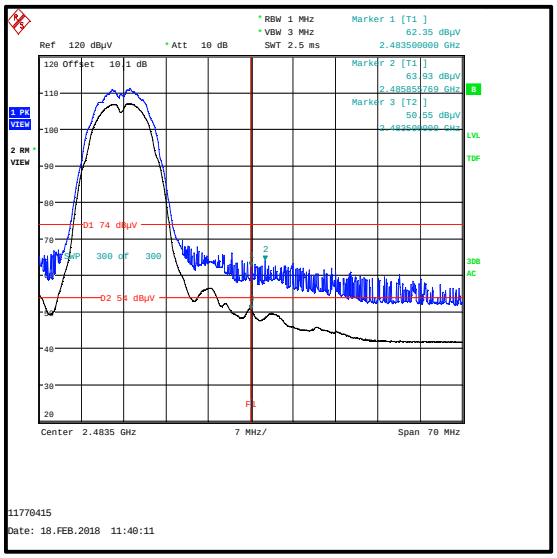
Lower Band Edge
Channel 1



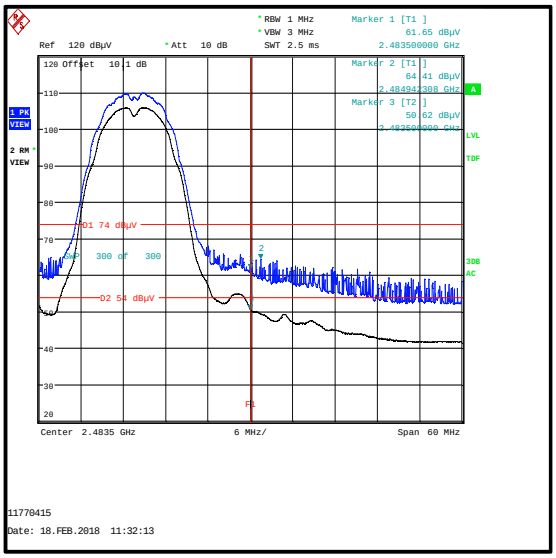
2310 MHz to 2390 MHz Restricted Band

Transmitter Band Edge Radiated Emissions (continued)

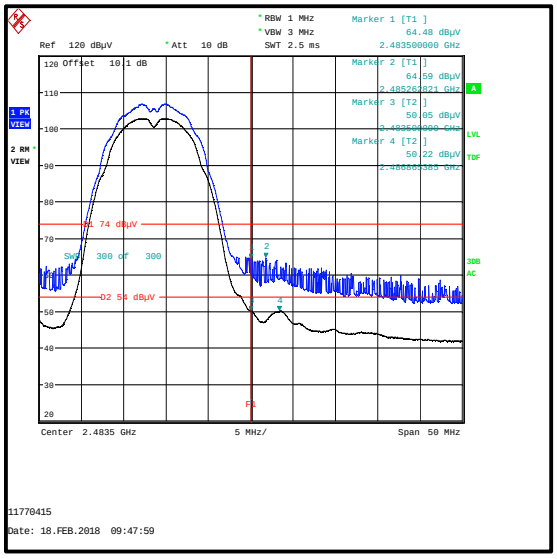
Results: 802.11b / 20 MHz / DBPSK / 1 Mbps



Upper Band Edge
Channel 11



Upper Band Edge
Channel 12



Upper Band Edge
Channel 13

Transmitter Band Edge Radiated Emissions (continued)

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

Results: Lower Band Edge / Channel 1

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	-30 dBc Limit (dBµV/m)	Margin (dB)	Result
2397.900	Vertical	61.2	69.8	8.6	Complied
2400.000	Vertical	59.5	69.8	10.3	Complied

Results: Upper Band Edge / Peak / Channel 11

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	62.2	74.0	11.8	Complied
2484.622	Vertical	62.3	74.0	11.7	Complied

Results: Upper Band Edge / Average / Channel 11

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	48.8	54.0	5.2	Complied

Results: Upper Band Edge / Peak / Channel 12

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	63.8	74.0	10.2	Complied
2485.231	Vertical	64.9	74.0	9.1	Complied

Results: Upper Band Edge / Average / Channel 12

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	51.2	54.0	2.8	Complied

Results: Upper Band Edge / Peak / Channel 13

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	68.7	74.0	5.3	Complied

Results: Upper Band Edge / Average / Channel 13

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	50.8	54.0	3.2	Complied

Transmitter Band Edge Radiated Emissions (continued)

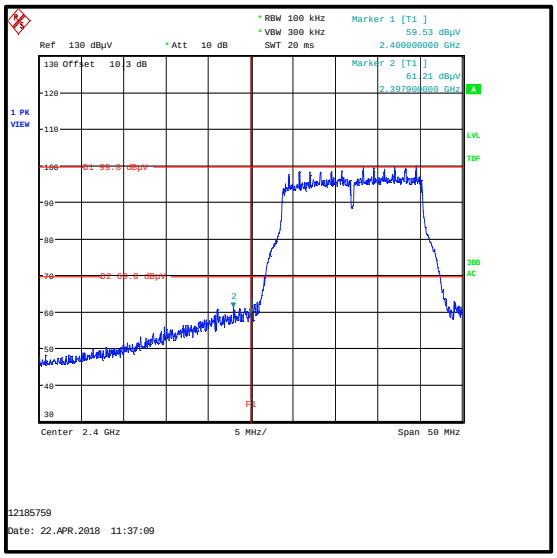
Results: 802.11g / 20 MHz / BPSK / 1 Mbps

Results: 2310 MHz to 2390 MHz Restricted Band / Peak

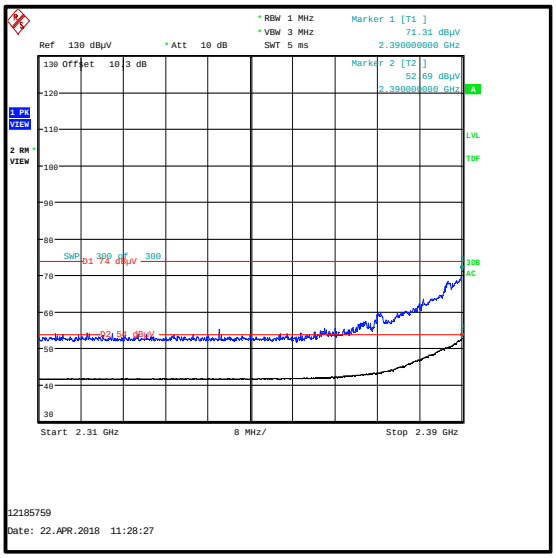
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2390.000	Vertical	71.3	74.0	2.7	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Average

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2390.000	Vertical	52.7	54.0	1.3	Complied



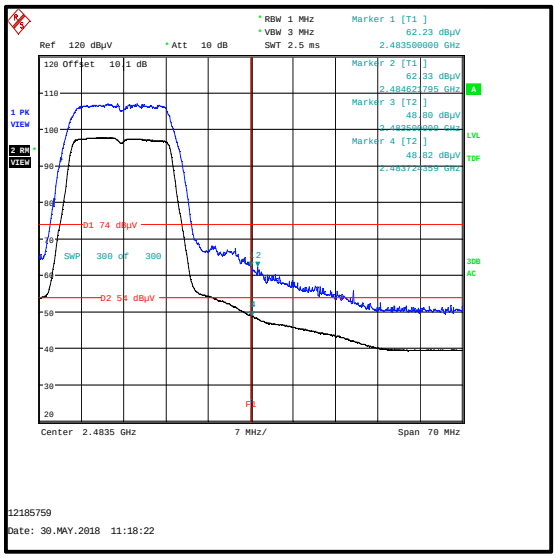
Lower Band Edge
Channel 1



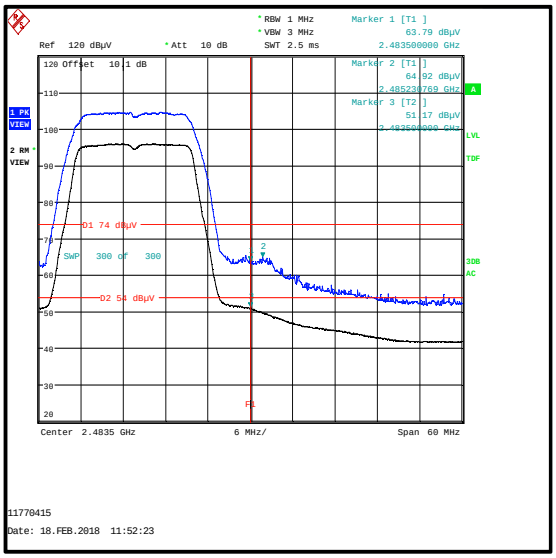
2310 MHz to 2390 MHz Restricted Band

Transmitter Band Edge Radiated Emissions (continued)

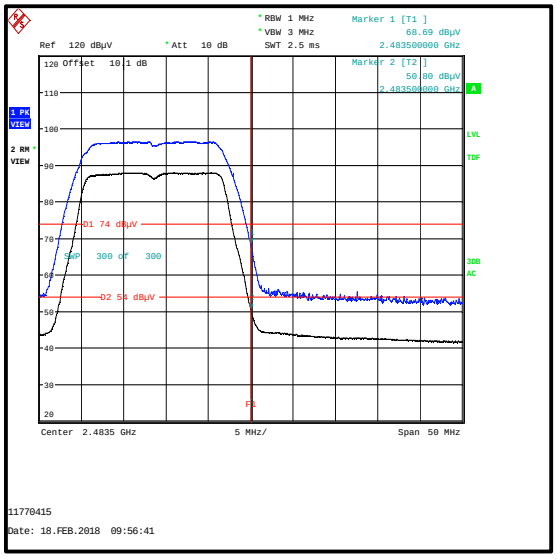
Results: 802.11g / 20 MHz / BPSK / 1 Mbps



Upper Band Edge
Channel 11



Upper Band Edge
Channel 12



Upper Band Edge
Channel 13

Transmitter Band Edge Radiated Emissions (continued)

Results: 802.11n HT20 / SISO / BPSK / MCS0

Results: Lower Band Edge / Channel 1

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	-30 dBc Limit (dBµV/m)	Margin (dB)	Result
2399.038	Vertical	60.1	68.2	8.1	Complied
2400.000	Vertical	59.0	68.2	9.2	Complied

Results: Upper Band Edge / Peak / Channel 11

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	68.8	74.0	5.2	Complied
2483.900	Vertical	71.6	74.0	2.4	Complied

Results: Upper Band Edge / Average / Channel 11

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	52.3	54.0	1.7	Complied

Results: Upper Band Edge / Peak / Channel 12

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	61.8	74.0	12.2	Complied
2487.731	Vertical	64.3	74.0	9.7	Complied

Results: Upper Band Edge / Average / Channel 12

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	48.1	54.0	5.9	Complied

Results: Upper Band Edge / Peak / Channel 13

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	68.8	74.0	5.2	Complied

Results: Upper Band Edge / Average / Channel 13

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Vertical	51.2	54.0	2.8	Complied

Transmitter Band Edge Radiated Emissions (continued)

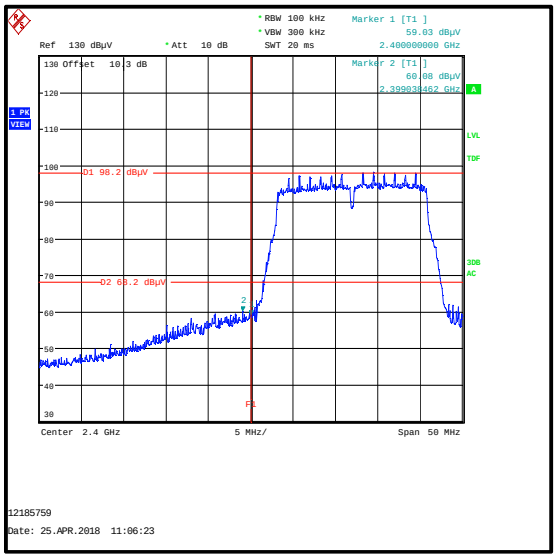
Results: 802.11n HT20 / SISO / BPSK / MCS0

Results: 2310 MHz to 2390 MHz Restricted Band / Peak

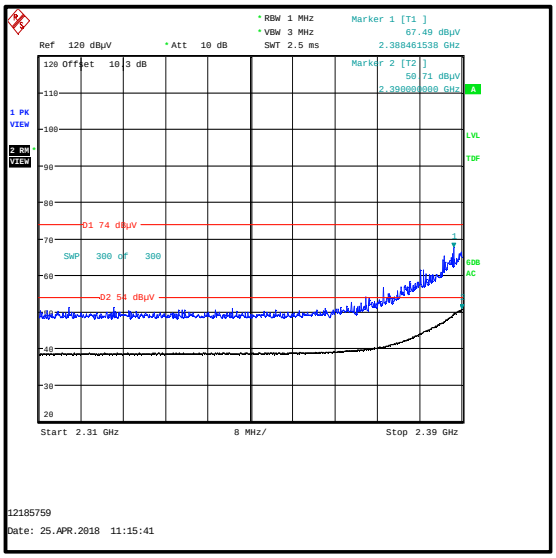
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2388.462	Vertical	67.5	74.0	6.5	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Average

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2390.000	Vertical	50.7	54.0	3.3	Complied



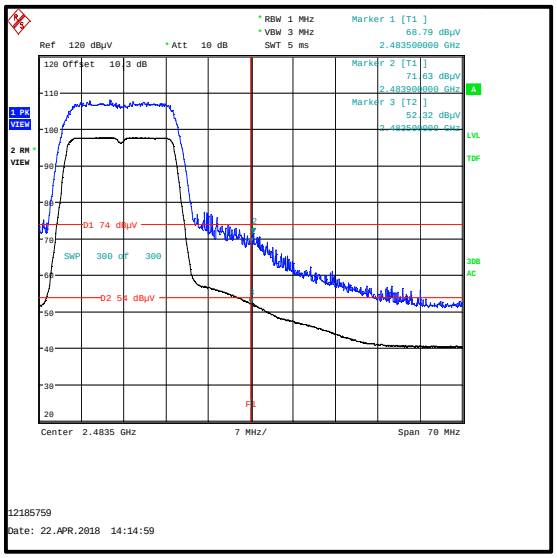
Lower Band Edge
Channel 1



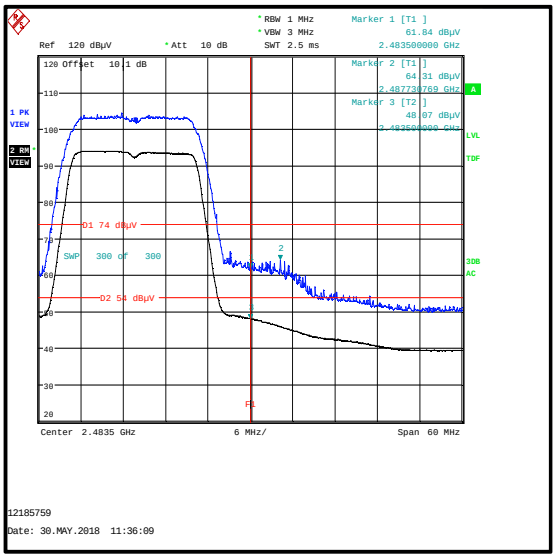
2310 MHz to 2390 MHz Restricted Band

Transmitter Band Edge Radiated Emissions (continued)

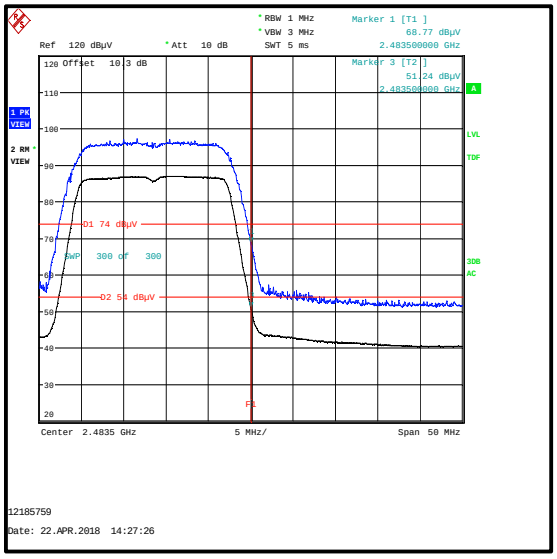
Results: 802.11n HT20 / SISO / BPSK / MCS0



Upper Band Edge
Channel 11



Upper Band Edge
Channel 12



Upper Band Edge
Channel 13

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