



# TEST REPORT

**Test Report No. :** UL-RPT-RP12185759JD08A V2.0

**Customer** : Apple Inc.  
**Model No.** : A1990  
**FCC ID** : BCGA1990  
**Technology** : *Bluetooth* – Basic Rate & EDR  
**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 2.0 supersedes all previous versions.

**Date of Issue:** 30 June 2018

**Checked by:**

Ben Mercer  
Senior Test Engineer, Radio Laboratory

**Company Signatory:**

Sarah Williams  
Senior Test Engineer, Radio Laboratory  
UL VS LTD



The *Bluetooth*® word mark and logos are owned by the *Bluetooth* SIG, Inc. and any use of such marks by UL VS LTD is under licence. Other trademarks and trade names are those of their respective owners.

---

## 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**

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

**Report Revision History**

<b>Version Number</b>	<b>Issue Date</b>	<b>Revision Details</b>	<b>Revised By</b>
1.0	27/06/2018	Initial Version	Ben Mercer
2.0	30/06/2018	Admin update	Sarah Williams

**Table of Contents**

<b>Customer Information.....</b>	<b>2</b>
<b>Report Revision History .....</b>	<b>2</b>
<b>1. Attestation of Test Results.....</b>	<b>4</b>
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
<b>2. Summary of Testing.....</b>	<b>5</b>
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
<b>3. Equipment Under Test (EUT) .....</b>	<b>9</b>
3.1. Identification of Equipment Under Test (EUT)	9
3.2. Modifications Incorporated in the EUT	10
3.3. Additional Information Related to Testing	10
3.4. Description of Available Antennas	10
3.5. Description of Test Setup	11
<b>4. Antenna Port Test Results .....</b>	<b>14</b>
4.1. Transmitter 20 dB Bandwidth	14
4.2. Transmitter Carrier Frequency Separation	18
4.3. Transmitter Number of Hopping Frequencies and Average Time of Occupancy	22
4.4. Transmitter Maximum Peak Output Power	24
<b>5. Radiated Test Results.....</b>	<b>31</b>
5.1. Transmitter Radiated Emissions <1 GHz	31
5.2. Transmitter Radiated Emissions >1 GHz	33
5.3. Transmitter Band Edge Radiated Emissions	36

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

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

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

### **1.2. General Information**

<b>Specification Reference:</b>	47CFR15.247
<b>Specification Title:</b>	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.247
<b>Specification Reference:</b>	47CFR15.209
<b>Specification Title:</b>	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.209
<b>Test Dates:</b>	20 December 2017 to 13 June 2018

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

<b>FCC Reference (47CFR)</b>	<b>Measurement</b>	<b>Result</b>
Part 15.247(a)(1)	Transmitter 20 dB Bandwidth	Complied
Part 15.247(a)(1)	Transmitter Carrier Frequency Separation	Complied
Part 15.247(a)(1)(iii)	Transmitter Number of Hopping Frequencies and Average Time of Occupancy	Complied
Part 15.247(b)(1)	Transmitter Maximum Peak 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. There are two vendors of the WiFi/*Bluetooth* radio modules, Vendor 1 and Vendor 2.

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

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

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

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

## **2. Summary of Testing**

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

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

Site 1	
Site 2	X
Site 17	X

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

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

<b>Reference:</b>	ANSI C63.10-2013
<b>Title:</b>	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

## **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
20 dB Bandwidth	2.4 GHz to 2.4835 GHz	95%	±4.59 %
Carrier Frequency Separation	2.4 GHz to 2.4835 GHz	95%	±4.59 %
Average Time of Occupancy	2.4 GHz to 2.4835 GHz	95%	±3.53 ns
Conducted Maximum Peak 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 26.5 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 Conducted Tests**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2037	Thermohygrometer	Testo	608-H1	45124925	27 Mar 2019	12
M199	Power Meter	Rohde & Schwarz	NRVS	827023/075	20 Apr 2020	24
M1276	Thermal Power Sensor	Rohde & Schwarz	NRV-Z52	100155	20 Apr 2020	24
G0614	Signal Generator	Rohde & Schwarz	SMB100A	177687	08 May 2020	36
M1794	Spectrum Analyzer	Rohde & Schwarz	FSU26	100027	28 Feb 2019	24
A2525	Attenuator	AtlanTecRF	AN18W5-10	832837#3	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)
M2016	Thermohygrometer	Testo	608-H1	45046428	26 Feb 2019	12
K0002	3m RSE Chamber	Rainford EMC	N/A	N/A	07 Feb 2019	12
M1874	Test Receiver	Rohde & Schwarz	ESU26	100553	28 Nov 2018	12
A3025	Pre-Amplifier	Com-Power Corp	PAM-118A	551126	12 Oct 2018	12
A255	Antenna	Flann Microwave	16240-20	519	07 Feb 2019	12
A256	Antenna	Flann Microwave	18240-20	400	07 Feb 2019	12
A2973	High Pass Filter	AtlanTecRF	AFH-03000	16080900032	24 Jan 2019	12
A2974	High Pass Filter	AtlanTecRF	AFH-06000	15032501232	21 Feb 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	18 Apr 2019	12
A2863	Pre-Amplifier	Agilent	8449B	3008A02100	19 Feb 2019	12
A2896	Pre-Amplifier	Schwarzbeck	BBV 9721	9721 - 023	20 Feb 2019	12
A490	Antenna	Chase	CBL6111A	1590	03 Apr 2019	12
A2889	Antenna	Schwarzbeck	BBHA 9120 B	BBHA 9120 B 653	19 Feb 2019	12
A2895	Antenna	Schwarzbeck	BBHA 9170	9170-728	20 Feb 2019	12
A2148	Attenuator	AtlanTecRF	AN18-06	090202-06	03 Apr 2019	12
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	21 Apr 2019	12
A2131	Low Pass Filter	AtlanTecRF	AFL-02000	JFB1004-002	22 Feb 2019	12
A2914	High Pass Filter	AtlanTecRF	AFH-03000	2155	22 Feb 2019	12

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

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2003	Thermohygrometer	Testo	608-H1	45046641	27 Feb 2019	12
K0017	3m RSE Chamber	Rainford EMC	N/A	N/A	20 Feb 2019	12
M1995	Test Receiver	Rohde & Schwarz	ESU40	100428	18 Apr 2019	12
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 Apr 2019	12



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

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

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1990
<b>Test Sample Serial Number:</b>	C02WC006JMFN ( <i>Conducted sample #1</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2033
<b>BT BB Version:</b>	v40
<b>FCC ID:</b>	BCGA1990

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1990
<b>Test Sample Serial Number:</b>	C02WC00DJMFL ( <i>Radiated sample #1</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2057
<b>BT BB Version:</b>	V45
<b>FCC ID:</b>	BCGA1990

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1990
<b>Test Sample Serial Number:</b>	C02WC003JMFN ( <i>Radiated sample #2</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2057
<b>BT BB Version:</b>	V45
<b>FCC ID:</b>	BCGA1990

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1990
<b>Test Sample Serial Number:</b>	C02VT01FJLG2 ( <i>Radiated sample #3</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2057
<b>BT BB Version:</b>	V45
<b>FCC ID:</b>	BCGA1990

**Identification of Equipment Under Test (EUT) (continued)**

<b>Brand Name:</b>	Apple
<b>Model Name or Number:</b>	A1990
<b>Test Sample Serial Number:</b>	C02WC006JTGW ( <i>Radiated sample #4</i> )
<b>Hardware Version:</b>	EVT
<b>Software Version:</b>	17G2033
<b>BT BB Version:</b>	v40
<b>FCC ID:</b>	BCGA1990

**3.2. Modifications Incorporated in the EUT**

No modifications were applied to the EUT during testing.

**3.3. Additional Information Related to Testing**

Tested Technology:	Bluetooth		
Power Supply Requirement:	Nominal	3.8 VDC via 120 VAC 60 Hz AC/DC Adapter	
Type of Unit:	Transceiver		
Channel Spacing:	1 MHz		
Mode:	Basic Rate	Enhanced Data Rate	
Modulation:	GFSK	$\pi/4$ -DQPSK	8DPSK
Packet Type: (Maximum Payload)	DH5	2DH5	3DH5
Data Rate (Mbps):	1	2	3
Maximum Conducted Output Power:	13.0 dBm		
Transmit Frequency Range:	2402 MHz to 2480 MHz		
Transmit Channels Tested:	Channel ID	Channel Number	Channel Frequency (MHz)
	Bottom	0	2402
	Middle	39	2441
	Top	78	2480

**3.4. Description of Available Antennas**

The radio utilizes an 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:

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

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

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

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

## **Operating Modes**

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

- Continuously transmitting at maximum power on bottom, middle and top channels in Basic Rate (DH5 packets) or EDR (2DH5 or 3DH5 packets) as required.
- Continuously transmitting at maximum power in hopping mode on all channels in Basic Rate (DH5 packets) or EDR (2DH5 or 3DH5 packets) as required.

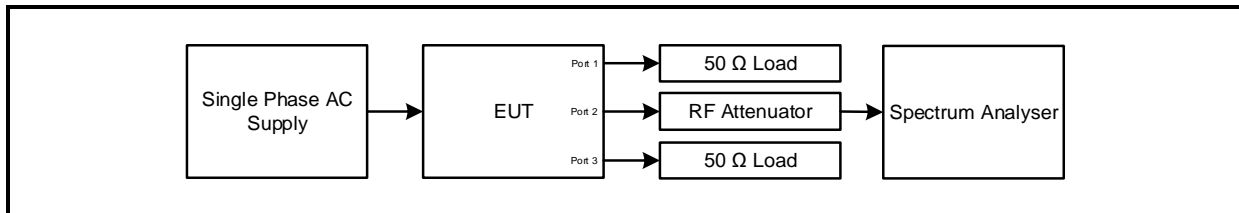
## **Configuration and Peripherals**

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

- Controlled in test mode using a set of commands entered into a terminal application on the EUT. The commands were used to enable a continuous transmission and to select the test channels as required. The customer supplied a document containing the setup instructions 'EUT\_BT\_BTLE\_CPM\_SOP v1.0.docx'.
- The EUT was powered from a 120 VAC 60 Hz single phase mains supply.
- Transmitter radiated spurious emissions tests were performed with the EUT transmitting in DH5 mode as this mode was found to transmit the highest power.
- Transmitter radiated spurious emissions tests were performed with the AC Charger and PHF connected to the EUT.

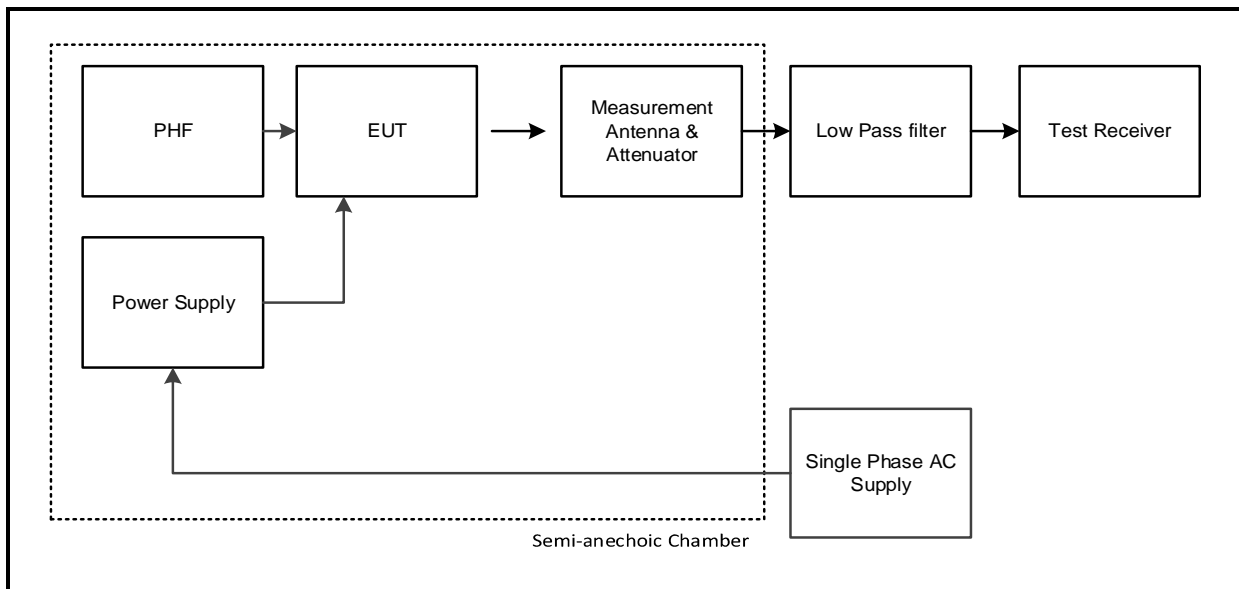
## **Test Setup Diagrams**

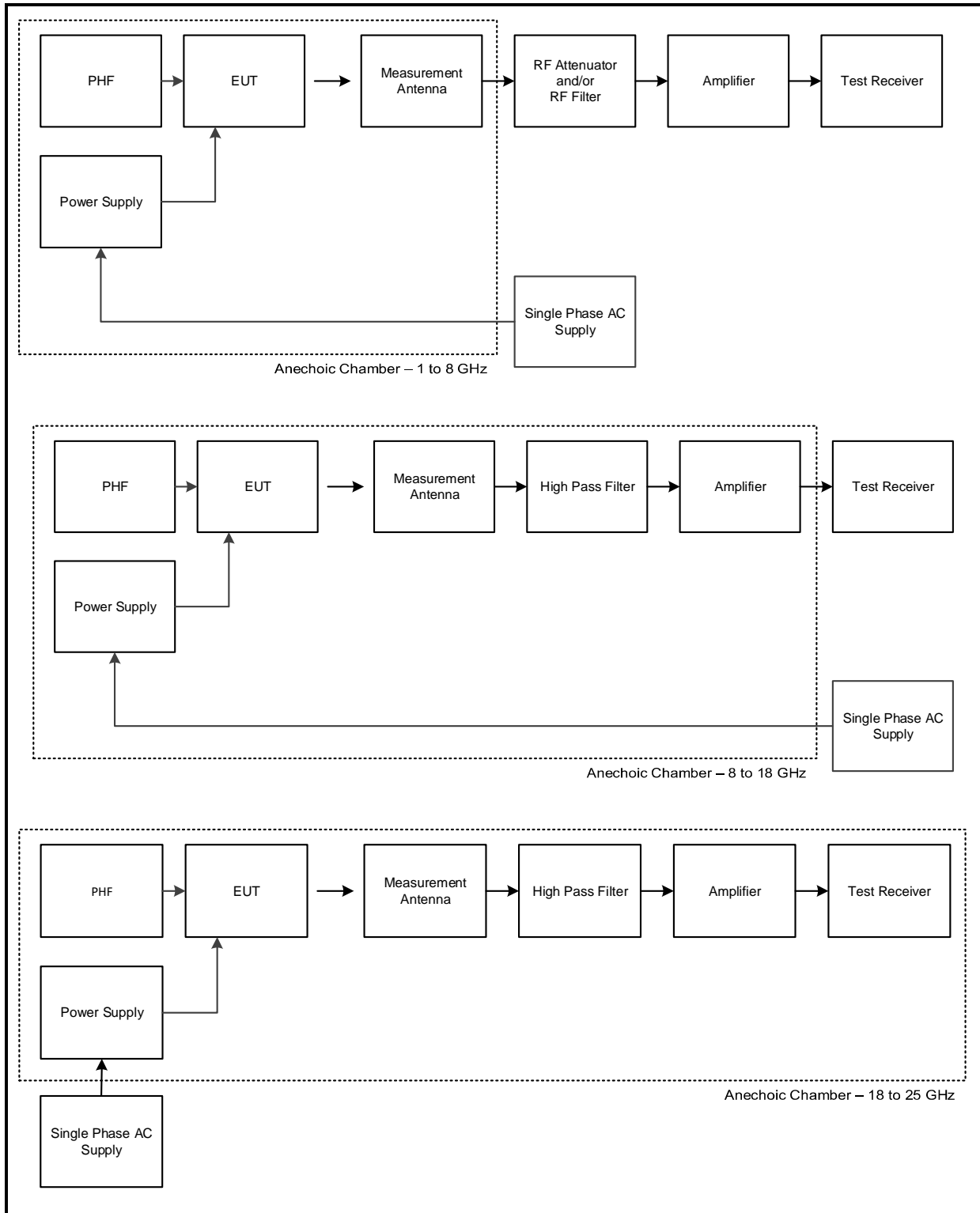
### **Test Setup for Conducted Tests**



### **Radiated 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 20 dB Bandwidth**

#### **Test Summary:**

<b>Test Engineer:</b>	Victor Carmon	<b>Test Dates:</b>	01 June 2018 & 13 June 2018
<b>Test Sample Serial Number:</b>	C02WC006JMFN		

<b>FCC Reference:</b>	Part 15.247(a)(1)
<b>Test Method Used:</b>	ANSI C63.10 Section 6.9.2

#### **Environmental Conditions:**

<b>Temperature (°C):</b>	23
<b>Relative Humidity (%):</b>	51 to 66

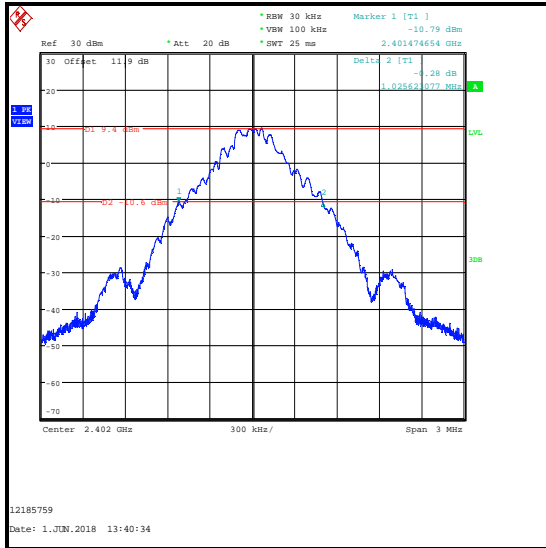
#### **Note(s):**

1. The spectrum analyser resolution bandwidth was set to 30 kHz and video bandwidth 100 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold. The span was set to 3.0 MHz. Normal and delta markers were placed 20 dB down from the peak of the carrier. These results are documented in the table below.
2. The spectrum analyser was connected to the RF port on the EUT using suitable attenuation and RF cable.

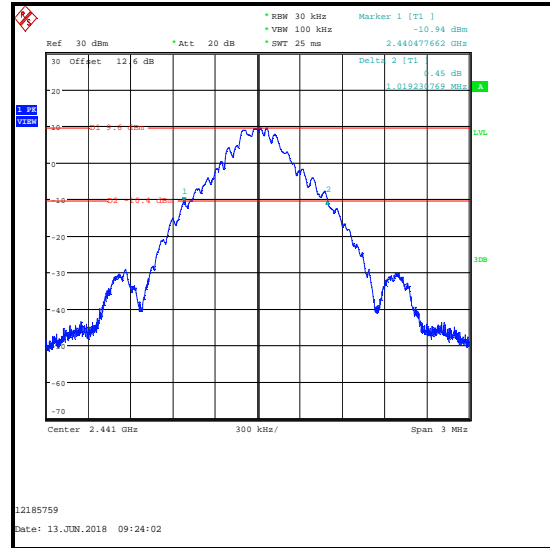
### Transmitter 20 dB Bandwidth (continued)

### Results DH5:

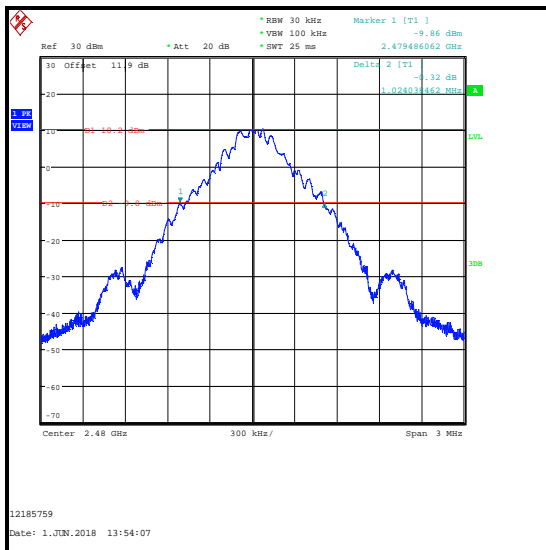
Channel	20 dB Bandwidth (kHz)
Bottom	1025.623
Middle	1019.231
Top	1024.038



### Bottom Channel



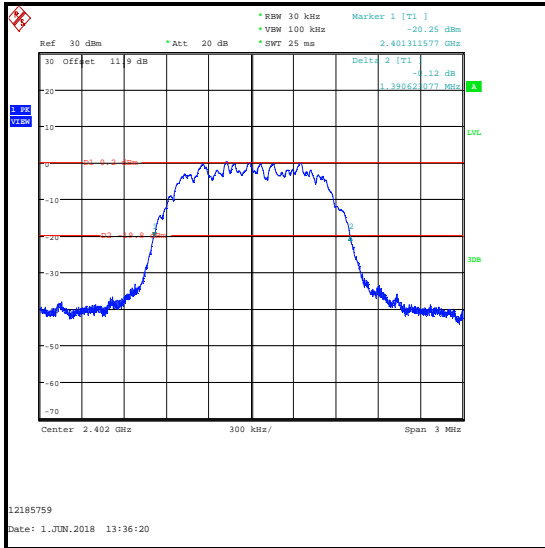
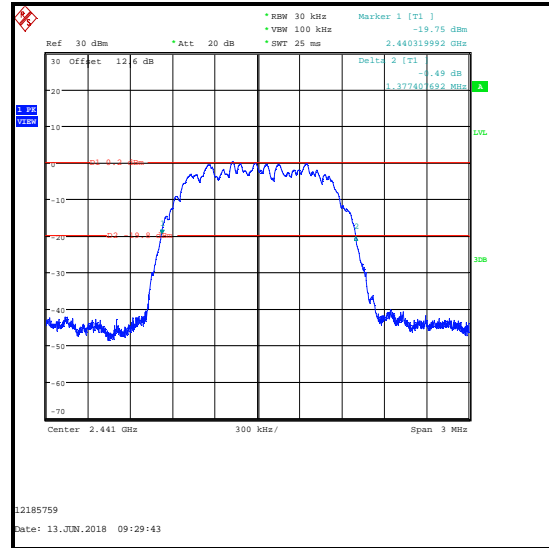
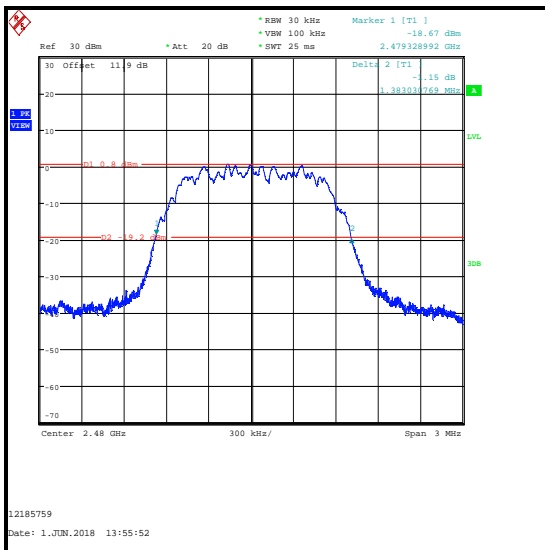
### Middle Channel



### Top Channel

**Transmitter 20 dB Bandwidth (continued)****Results 2DH5:**

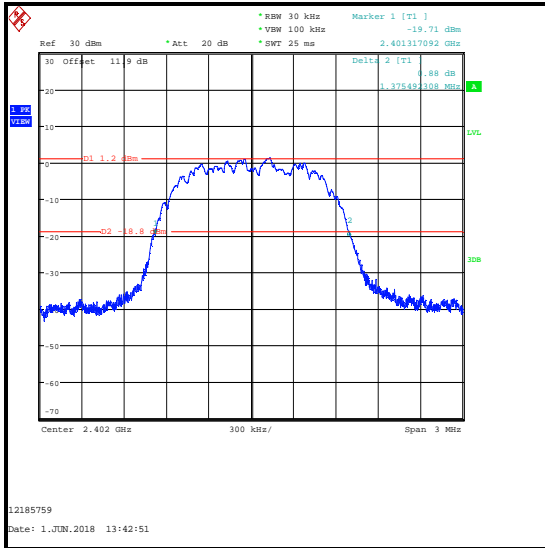
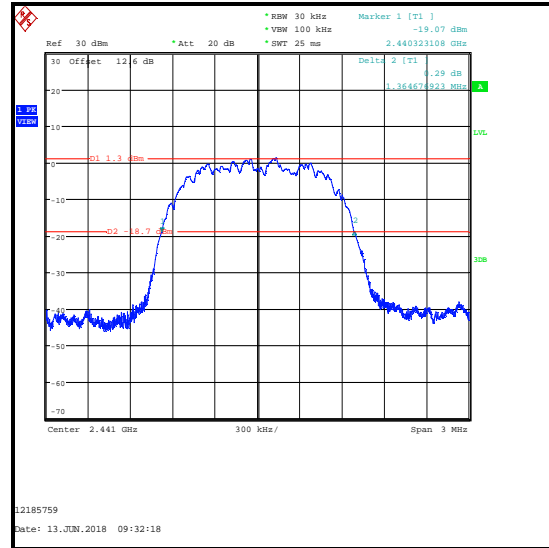
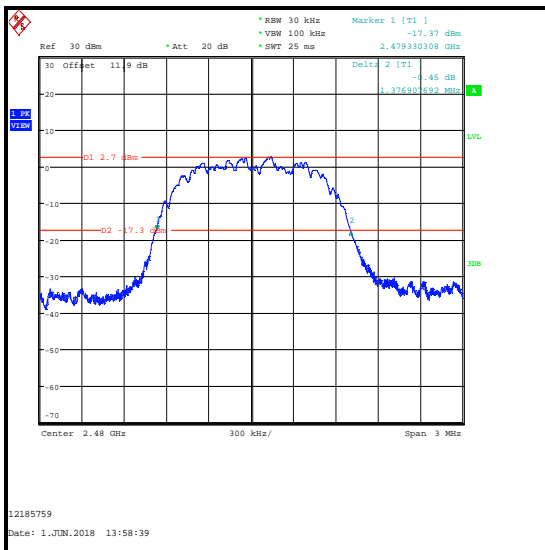
Channel	20 dB Bandwidth (kHz)
Bottom	1390.623
Middle	1377.408
Top	1383.031

**Bottom Channel****Middle Channel****Top Channel**



**Transmitter 20 dB Bandwidth (continued)****Results 3DH5:**

Channel	20 dB Bandwidth (kHz)
Bottom	1375.492
Middle	1364.677
Top	1376.908

**Bottom Channel****Middle Channel****Top Channel**

**4.2. Transmitter Carrier Frequency Separation****Test Summary:**

<b>Test Engineer:</b>	Victor Carmon	<b>Test Dates:</b>	31 May 2018 & 01 June 2018
<b>Test Sample Serial Number:</b>	C02WC006JMFN		

<b>FCC Reference:</b>	Part 15.247(a)(1)
<b>Test Method Used:</b>	ANSI C63.10 Section 7.8.2

**Environmental Conditions:**

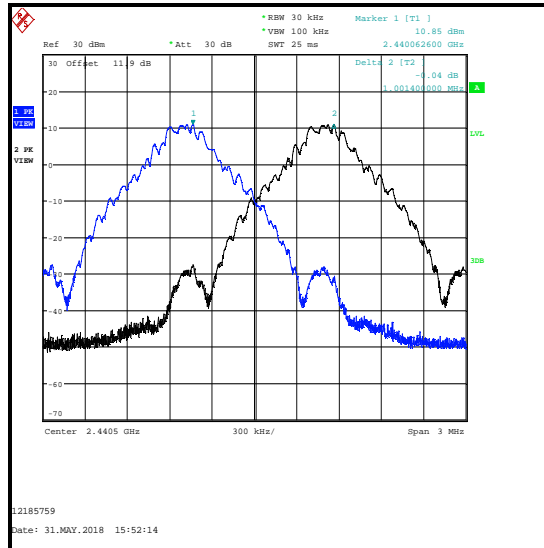
<b>Temperature (°C):</b>	23
<b>Relative Humidity (%):</b>	60 to 66

**Note(s):**

1. The 20 dB bandwidth measured for the middle channel operating at 2441 MHz was used to calculate the limit.

**Transmitter Carrier Frequency Separation (continued)****Results: DH5**

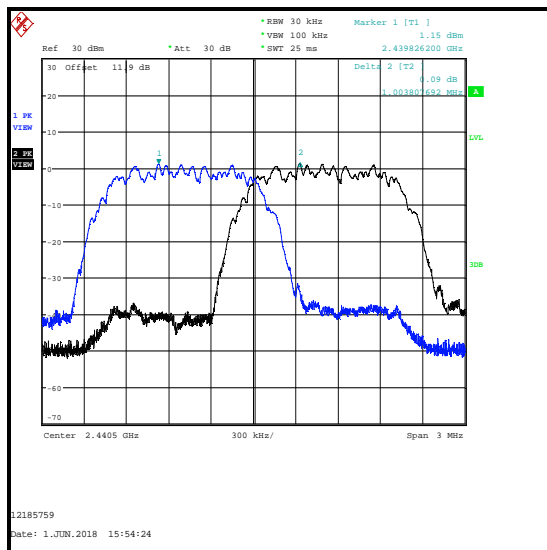
Carrier Frequency Separation (kHz)	Limit ( $\frac{2}{3}$ of 20 dB BW) (kHz)	Margin (kHz)	Result
1001.400	681.641	319.759	Complied



### Transmitter Carrier Frequency Separation (continued)

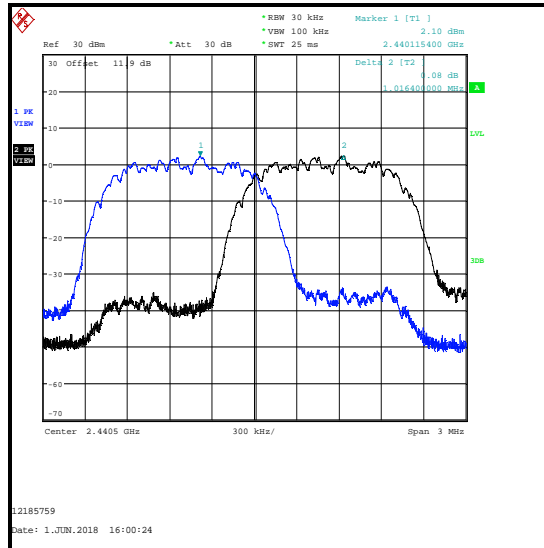
### Results: 2DH5

Carrier Frequency Separation (kHz)	Limit (2/3 of 20 dB BW) (kHz)	Margin (kHz)	Result
1003.808	920.975	82.833	Complied



**Transmitter Carrier Frequency Separation (continued)****Results: 3DH5**

Carrier Frequency Separation (kHz)	Limit ( $2/3$ of 20 dB BW) (kHz)	Margin (kHz)	Result
1016.400	909.261	107.139	Complied



**4.3. Transmitter Number of Hopping Frequencies and Average Time of Occupancy****Test Summary:**

<b>Test Engineer:</b>	Victor Carmon	<b>Test Date:</b>	31 May 2018
<b>Test Sample Serial Number:</b>	C02WC006JMFN		

<b>FCC Reference:</b>	Part 15.247(a)(1)(iii)
<b>Test Method Used:</b>	ANSI C63.10 Sections 7.8.3 & 7.8.4

**Environmental Conditions:**

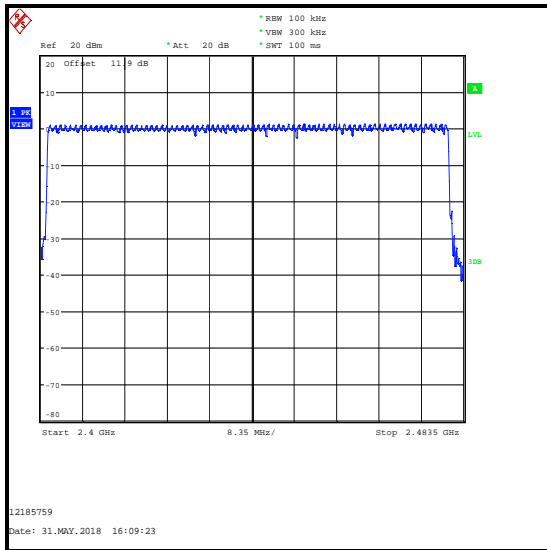
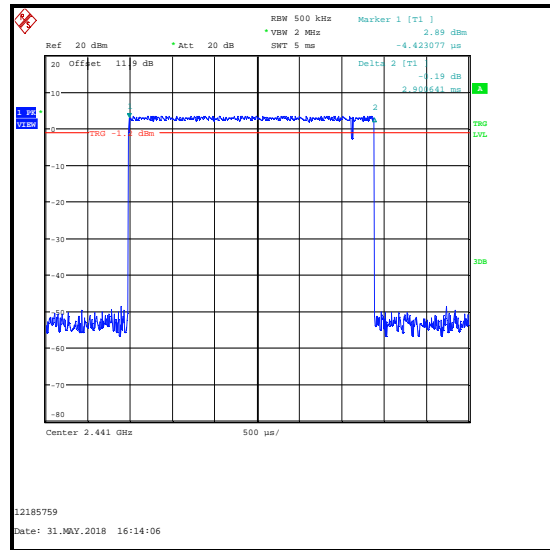
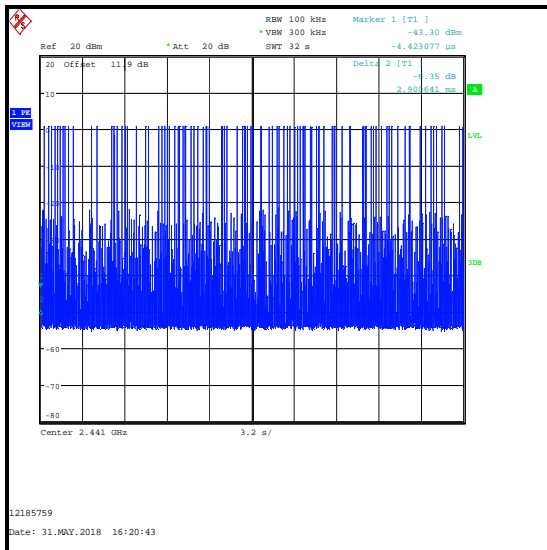
<b>Temperature (°C):</b>	23
<b>Relative Humidity (%):</b>	66

**Note(s):**

1. Tests were performed to identify the average time of occupancy in number of channels (79) x 0.4 seconds. The calculated period is 31.6 seconds.
2. The spectrum analyser was set up for the Number of Hopping Frequencies measurement as follows: the resolution bandwidth was set to 100 kHz and video bandwidth of 300 kHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The span was set to 83.5 MHz.
3. The spectrum analyser was set up for the Emission Width measurement as follows: the resolution bandwidth was set to 500 kHz and video bandwidth 2 MHz. A peak detector was used and sweep time was set to auto with a span of zero Hz. The spectrum analyser was set to trigger at 1 ms, with a marker placed at the start of the emission and a delta marker placed at the end of the emission. The emission width is recorded in the table below.
4. The spectrum analyser was set up for the Number of Hopping Frequencies in 32 seconds measurement as follows: the resolution bandwidth was set to 100 kHz and video bandwidth of 300 kHz. A peak detector was used and sweep time was set to 32 seconds. The EUT was set to transmit in a hopping frequency mode with zero span. The total numbers of hopping frequencies were recorded in the table below.
5. The spectrum analyser was connected to the RF port on the EUT using suitable attenuation and RF cable

**Transmitter Number of Hopping Frequencies and Average Time of Occupancy (continued)****Results:**

Emission Width ( $\mu$ s)	Number of Hops in 31.6 Seconds	Average Time of Occupancy (s)	Limit (s)	Margin (s)	Result
2900.641	105	0.307	0.400	0.093	Complied

**Number of Hopping Frequencies****Emission Width****Number of Hopping Frequencies in 32 s**

**4.4. Transmitter Maximum Peak Output Power****Test Summary:**

<b>Test Engineer:</b>	Victor Carmon	<b>Test Dates:</b>	31 May 2018, 01 June 2018 & 13 June 2018
<b>Test Sample Serial Number:</b>	C02WC006JMFN		

<b>FCC Reference:</b>	Part 15.247(b)(1)
<b>Test Method Used:</b>	ANSI C63.10 Section 7.8.5

**Environmental Conditions:**

<b>Temperature (°C):</b>	23
<b>Relative Humidity (%):</b>	51 to 66

**Note(s):**

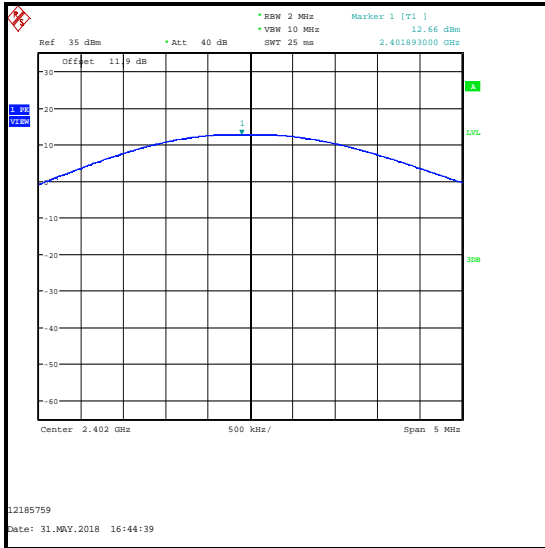
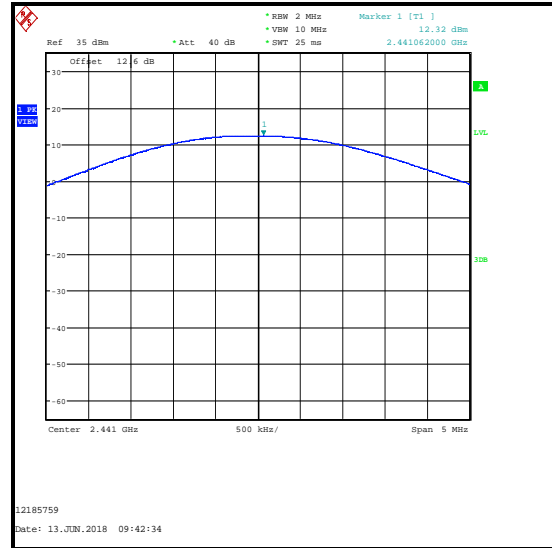
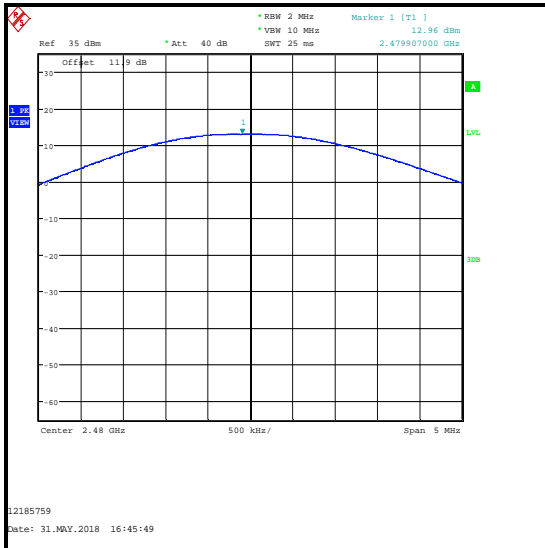
1. The signal analyser resolution bandwidth was set to 2 MHz (> 20 dB bandwidth) and video bandwidth of 10 MHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The span was set to 5 MHz (approximately five times the 20 dB bandwidth). A marker was placed at the peak of the signal and the results recorded in the tables below.
2. The declared antenna gain was added to the conducted peak power to obtain the EIRP.
3. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable. An RF offset level was entered on the signal analyser to compensate for the loss of the attenuator and RF cable.



**Transmitter Maximum Peak Output Power (continued)****Results: DH5**

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	12.7	30.0	17.3	Complied
Middle	12.3	30.0	17.7	Complied
Top	13.0	30.0	17.0	Complied

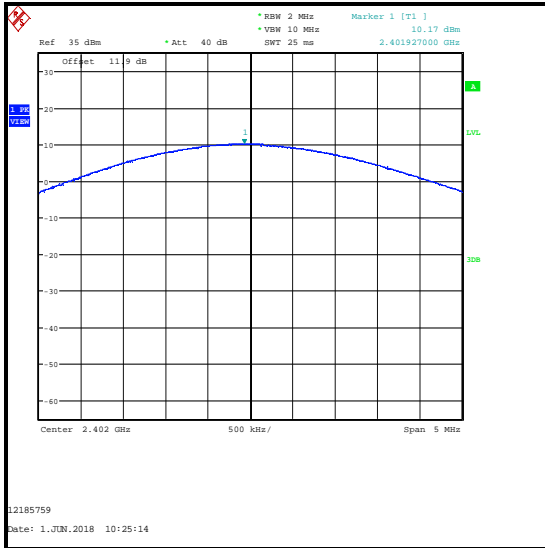
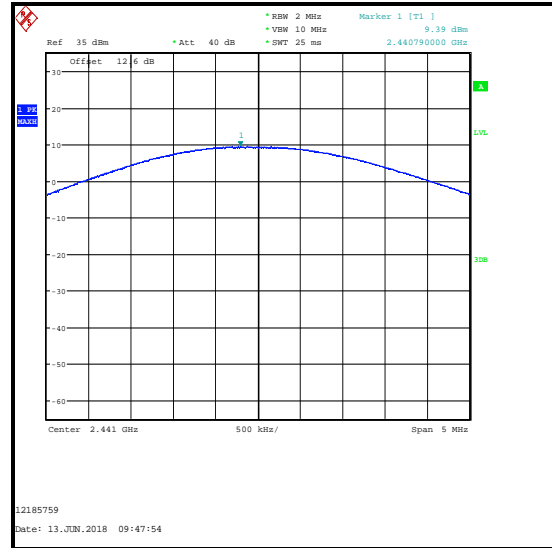
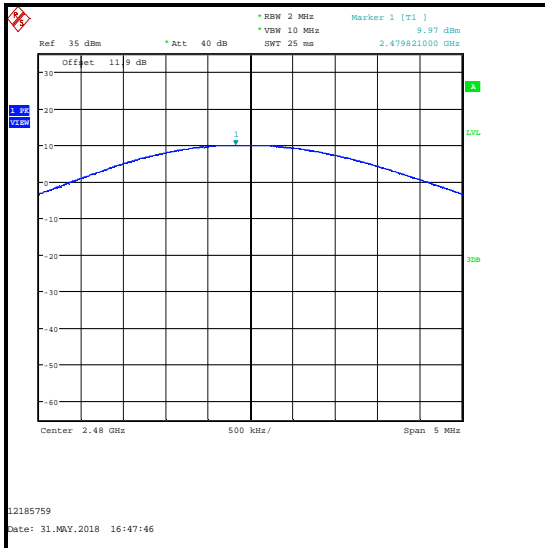
Channel	Conducted Peak Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	12.7	2.1	14.8	36.0	21.2	Complied
Middle	12.3	2.1	14.4	36.0	21.6	Complied
Top	13.0	2.1	15.1	36.0	20.9	Complied

**Transmitter Maximum Peak Output Power (continued)****Results: DH5****Bottom Channel****Middle Channel****Top Channel**

**Transmitter Maximum Peak Output Power (continued)****Results: 2DH5**

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	10.2	30.0	19.8	Complied
Middle	9.4	30.0	20.6	Complied
Top	10.0	30.0	20.0	Complied

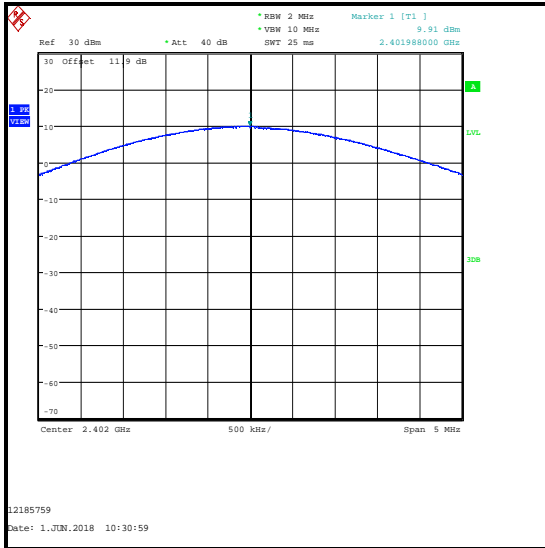
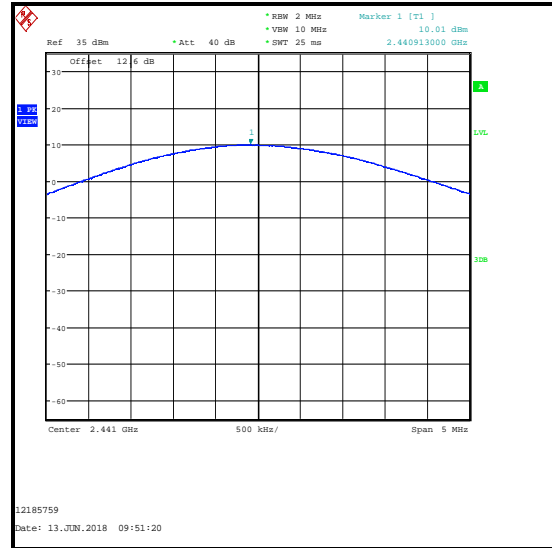
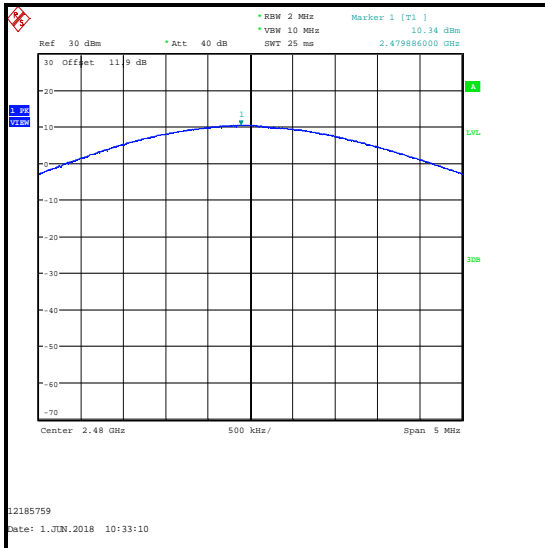
Channel	Conducted Peak Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	10.2	2.1	12.3	36.0	23.7	Complied
Middle	9.4	2.1	11.5	36.0	24.5	Complied
Top	10.0	2.1	12.1	36.0	23.9	Complied

**Transmitter Maximum Peak Output Power (continued)****Results: 2DH5****Bottom Channel****Middle Channel****Top Channel**

**Transmitter Maximum Peak Output Power (continued)****Results: 3DH5**

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	9.9	30.0	20.1	Complied
Middle	10.0	30.0	20.0	Complied
Top	10.3	30.0	19.7	Complied

Channel	Conducted Peak Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	9.9	2.1	12.0	36.0	24.0	Complied
Middle	10.0	2.1	12.1	36.0	23.9	Complied
Top	10.3	2.1	12.4	36.0	23.6	Complied

**Transmitter Maximum Peak Output Power (continued)****Results: 3DH5****Bottom Channel****Middle Channel****Top Channel**

## **5. Radiated Test Results**

### **5.1. Transmitter Radiated Emissions <1 GHz**

#### **Test Summary:**

<b>Test Engineer:</b>	Alan Withers	<b>Test Date:</b>	16 May 2018
<b>Test Sample Serial Number:</b>	C02WC00DJMFL		

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

#### **Environmental Conditions:**

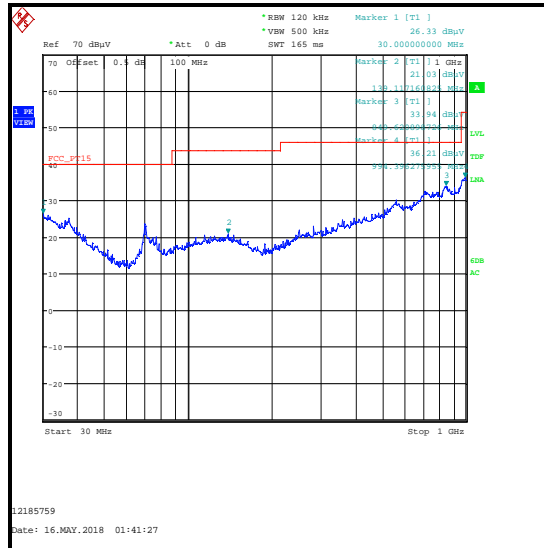
<b>Temperature (°C):</b>	23
<b>Relative Humidity (%):</b>	41

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

1. Transmitter radiated spurious emissions tests were performed with the EUT transmitting in DH5 mode as this was found to transmit the highest power and therefore deemed worst case.
2. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
3. All emissions shown on the pre-scan plot 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. 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.
5. 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.
6. 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: Peak / DH5**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
994.396	Vertical	36.2	54.0	17.8	Complied





**5.2. Transmitter Radiated Emissions >1 GHz****Test Summary:**

<b>Test Engineers:</b>	David Doyle, Nick Steele & Andrew Edwards	<b>Test Dates:</b>	20 December 2017, 14 May 2018 & 16 May 2018
<b>Test Sample Serial Number:</b>	C02WC003JMFN & C02WC00DJMFL		

<b>FCC Reference:</b>	Parts 15.247(d) & 15.209(a)
<b>Test Method Used:</b>	ANSI C63.10 Sections 6.3 and 6.6
<b>Frequency Range</b>	1 GHz to 25 GHz

**Environmental Conditions:**

<b>Temperature (°C):</b>	23 to 24
<b>Relative Humidity (%):</b>	48 to 49

**Note(s):**

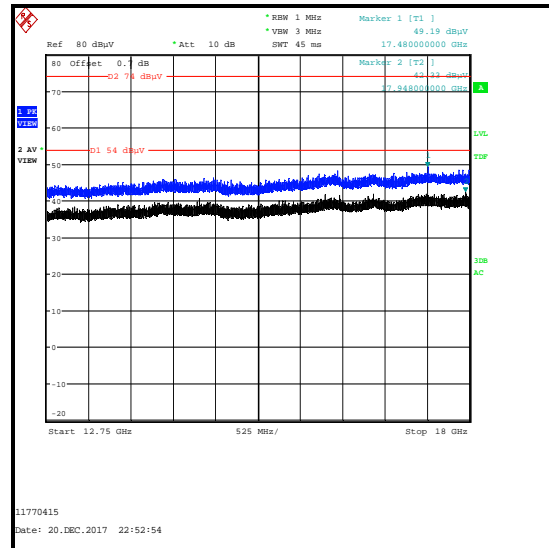
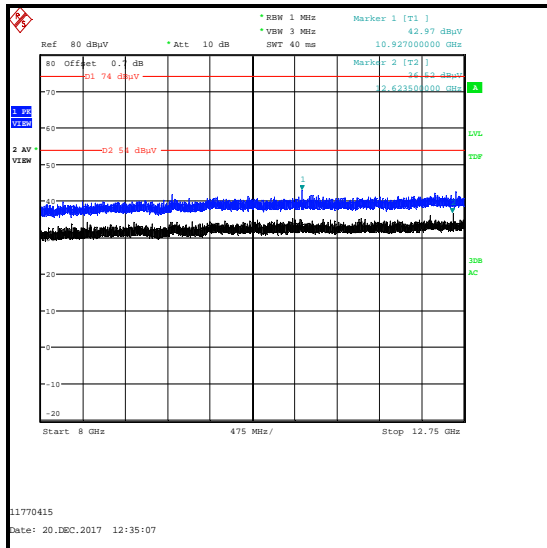
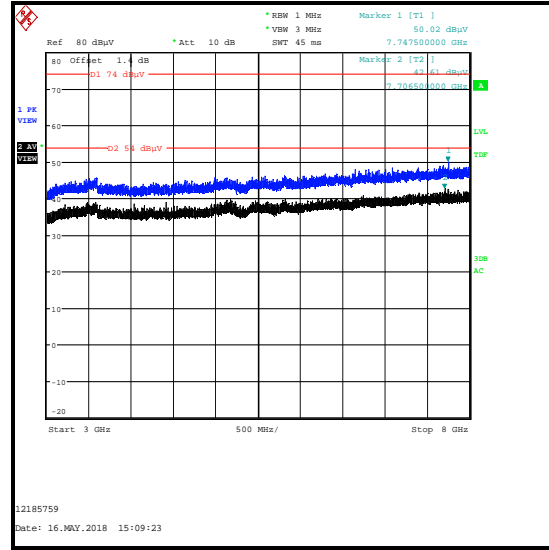
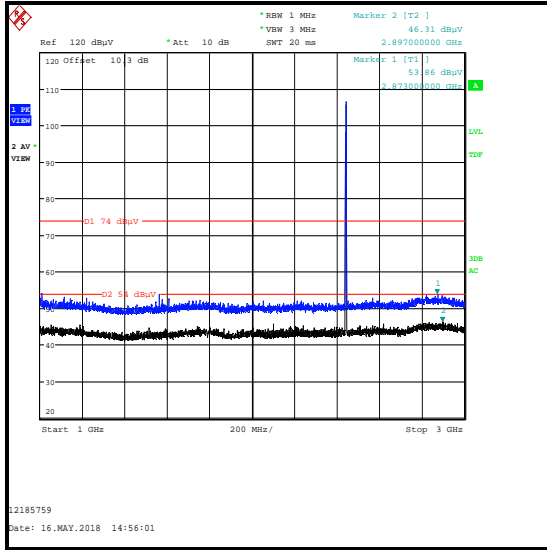
1. Transmitter radiated spurious emissions tests were performed with the EUT transmitting in DH5 mode as this was found to transmit the highest power and therefore deemed worst case.
2. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
3. The emission shown on the 1 GHz to 3 GHz plot is the EUT fundamental.
4. All emissions shown on the pre-scans were investigated and found to be ambient, > 20 dB below the appropriate limit or below the noise floor of the measurement system. The highest peak and average noise floor readings of the measuring receiver were therefore recorded in the tables below.
5. Pre-scans above 1 GHz were performed in a fully anechoic chamber (Asset Numbers K0002 & 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. 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. Peak and average measurements were performed with their own appropriate detectors during the pre-scan measurements.

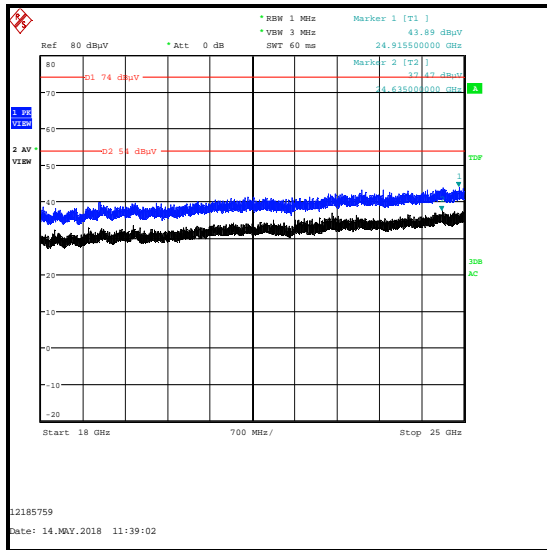
**Results: Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2873.000	Vertical	53.9	74.0	20.1	Complied

**Results: Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2897.000	Vertical	46.3	54.0	7.7	Complied

**Transmitter Radiated Emissions (continued)**

**Transmitter Radiated Emissions (continued)**

### **5.3. Transmitter Band Edge Radiated Emissions**

#### **Test Summary:**

<b>Test Engineers:</b>	Andrew Edwards & Stuart Martin	<b>Test Dates:</b>	14 January 2018 & 17 May 2018
<b>Test Sample Serial Numbers:</b>	C02VT01FJLG2 & C02WC006JTGW		

<b>FCC Reference:</b>	Parts 15.247(d) & 15.209(a)
<b>Test Method Used:</b>	ANSI C63.10 Section 6.10

#### **Environmental Conditions:**

<b>Temperature (°C):</b>	24 to 26
<b>Relative Humidity (%):</b>	39 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. The lower band edge is adjacent to a non-restricted band. 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. A marker was placed on the band edge spot frequencies and a second marker placed on the highest emission level in the adjacent band (where a higher level emission was present). Marker frequencies and levels were recorded.
3. The upper band edge is adjacent to a restricted band. The test receiver resolution bandwidth was set to 1 MHz and video bandwidth 3 MHz. Peak and average measurements were performed with their respective detectors, 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 was placed on the band edge spot frequencies and a second marker placed on the highest emission level in the adjacent band (where a higher level emission was present). Marker frequencies and levels were recorded.
4. 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.
5. \* -20 dBc limit.

**Transmitter Band Edge Radiated Emissions (continued)****Results: Static Mode / DH5**

Frequency (MHz)	Antenna Polarity	Peak Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2399.920	Vertical	42.1	85.1*	43.0	Complied
2400.000	Vertical	41.3	85.1*	43.8	Complied
2483.500	Vertical	52.2	74.0	21.8	Complied

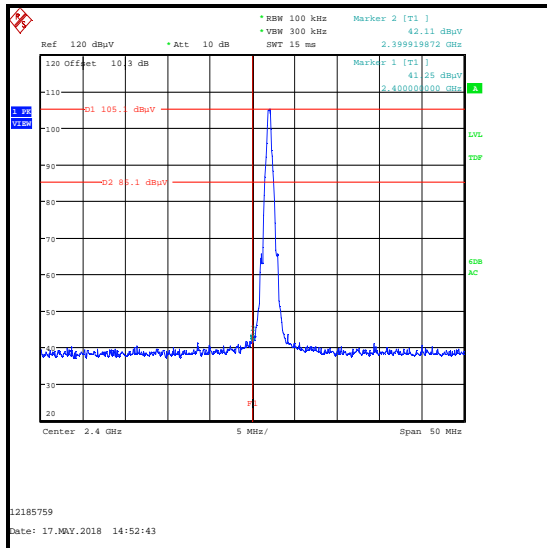
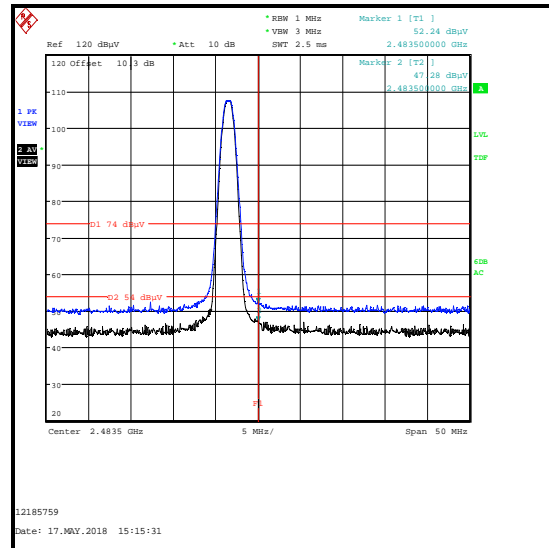
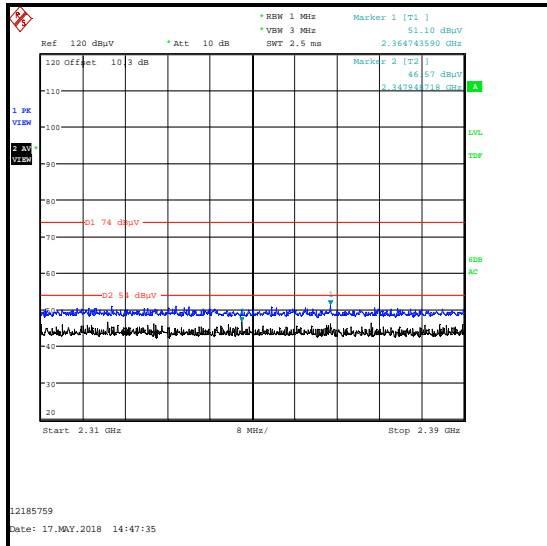
Frequency (MHz)	Antenna Polarity	Average Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2483.500	Vertical	47.3	54.0	6.7	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2364.744	Vertical	51.1	74.0	22.9	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2347.949	Vertical	46.6	54.0	7.4	Complied

**Transmitter Band Edge Radiated Emissions (continued)****Results: Static Mode / DH5****Lower Band Edge****Upper Band Edge****2310 MHz to 2390 MHz Restricted Band**

**Transmitter Band Edge Radiated Emissions (continued)****Results: Hopping Mode / DH5**

Frequency (MHz)	Antenna Polarity	Peak Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2397.596	Vertical	43.0	86.0*	43.0	Complied
2400.000	Vertical	41.1	86.0*	44.9	Complied
2483.500	Vertical	51.7	74.0	22.3	Complied
2500.728	Vertical	52.6	74.0	21.4	Complied

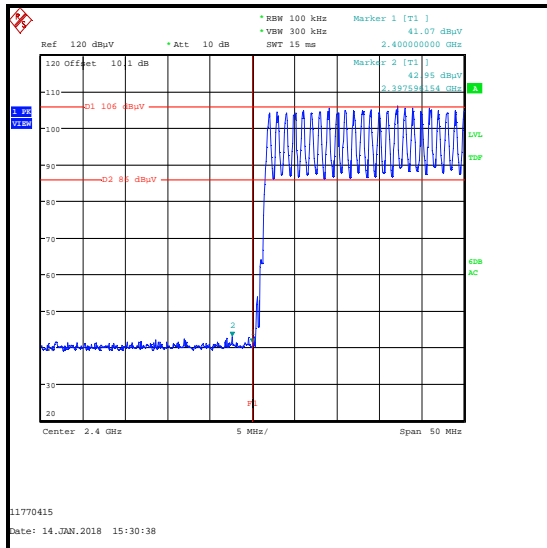
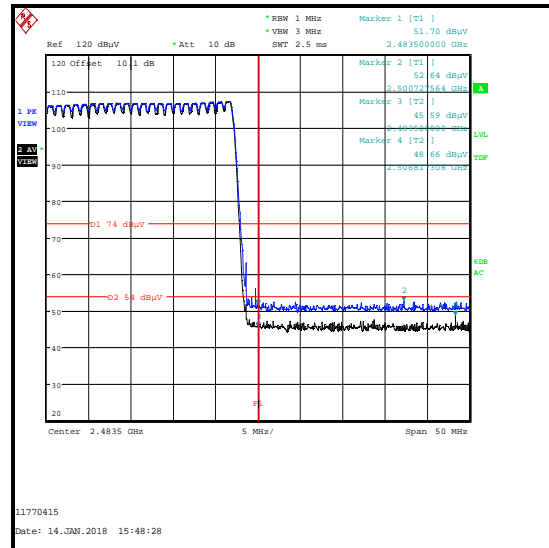
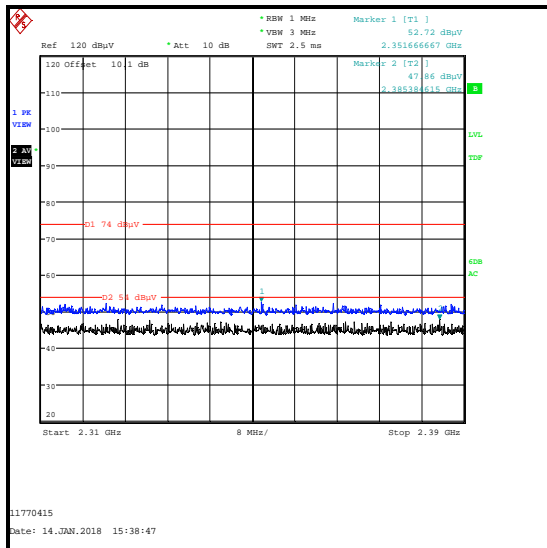
Frequency (MHz)	Antenna Polarity	Average Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2483.500	Vertical	45.6	54.0	8.4	Complied
2506.817	Vertical	48.7	54.0	5.3	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2351.667	Vertical	52.7	74.0	21.3	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2385.385	Vertical	47.9	54.0	6.1	Complied

**Transmitter Band Edge Radiated Emissions (continued)****Results: Hopping Mode / DH5****Lower Band Edge****Upper Band Edge****2310 MHz to 2390 MHz Restricted Band**



**Transmitter Band Edge Radiated Emissions (continued)****Results: Static Mode / 2DH5**

Frequency (MHz)	Antenna Polarity	Peak Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2399.679	Vertical	44.9	78.4*	33.5	Complied
2400.000	Vertical	44.6	78.4*	33.8	Complied
2483.500	Vertical	52.9	74.0	21.1	Complied
2483.580	Vertical	53.4	74.0	20.6	Complied

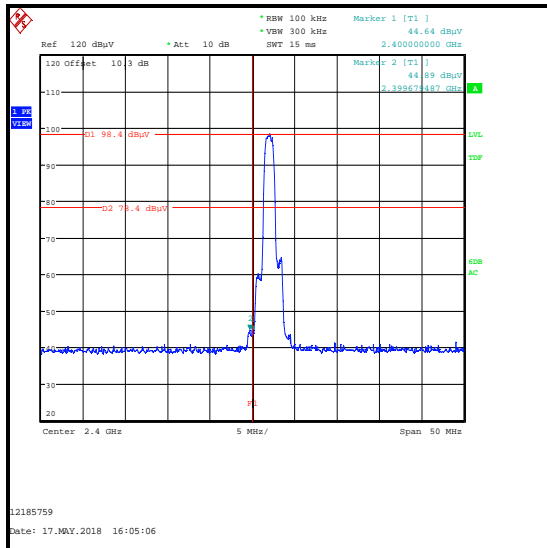
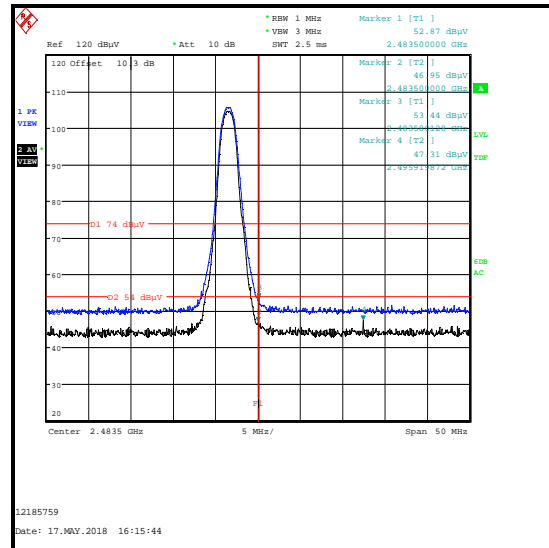
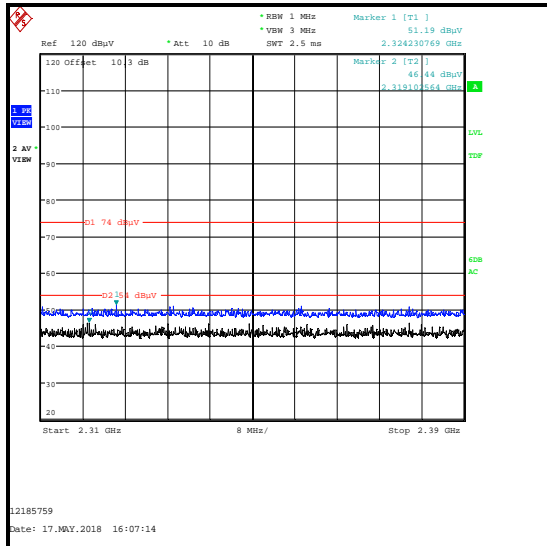
Frequency (MHz)	Antenna Polarity	Average Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2483.500	Vertical	47.0	54.0	7.0	Complied
2495.920	Vertical	47.3	54.0	6.7	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2324.231	Vertical	51.2	74.0	22.8	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2319.103	Vertical	46.4	54.0	7.6	Complied

**Transmitter Band Edge Radiated Emissions (continued)****Results: Static Mode / 2DH5****Lower Band Edge****Upper Band Edge****2310 MHz to 2390 MHz Restricted Band**

**Transmitter Band Edge Radiated Emissions (continued)****Results: Hopping Mode / 2DH5**

Frequency (MHz)	Antenna Polarity	Peak Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2395.513	Vertical	41.2	86.0*	44.8	Complied
2400.000	Vertical	40.2	86.0*	45.8	Complied
2483.500	Vertical	50.5	74.0	23.5	Complied
2487.837	Vertical	51.2	74.0	22.8	Complied

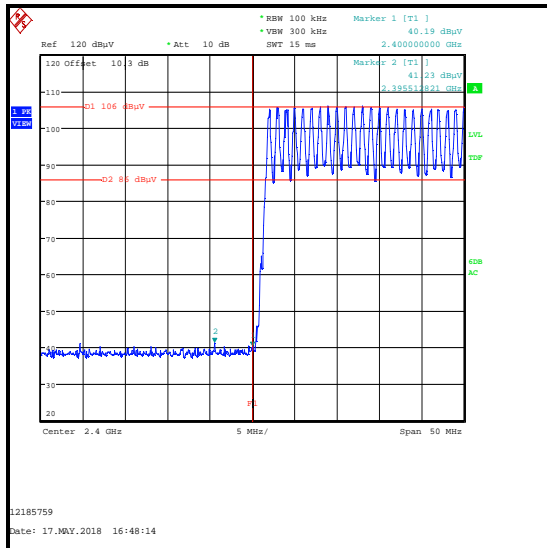
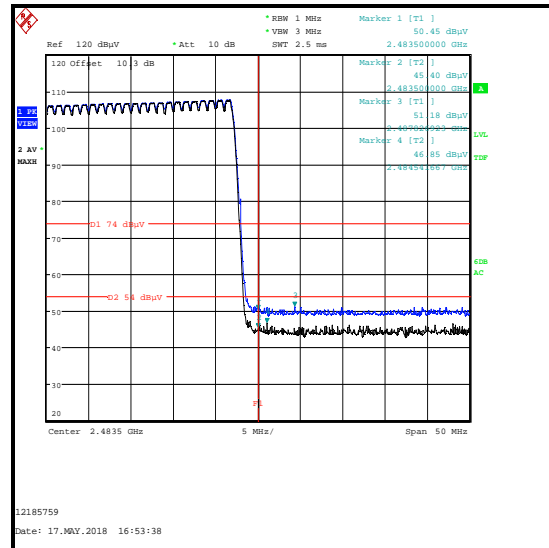
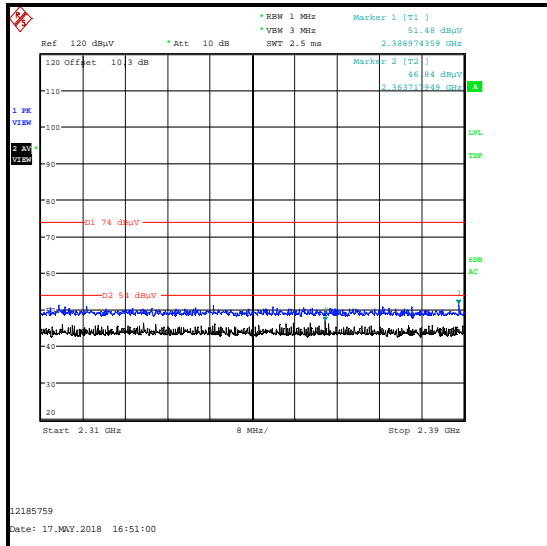
Frequency (MHz)	Antenna Polarity	Average Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2483.500	Vertical	45.4	54.0	8.6	Complied
2484.542	Vertical	46.9	54.0	7.1	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2388.974	Vertical	51.5	74.0	22.5	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2363.718	Vertical	46.8	54.0	7.2	Complied

**Transmitter Band Edge Radiated Emissions (continued)****Results: Hopping Mode / 2DH5****Lower Band Edge****Upper Band Edge****2310 MHz to 2390 MHz Restricted Band**

**Transmitter Band Edge Radiated Emissions (continued)****Results: Static Mode / 3DH5**

Frequency (MHz)	Antenna Polarity	Peak Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2399.760	Vertical	46.4	79.2*	32.8	Complied
2400.000	Vertical	45.5	79.2*	33.7	Complied
2483.500	Vertical	52.0	74.0	22.0	Complied
2483.580	Vertical	52.6	74.0	21.4	Complied

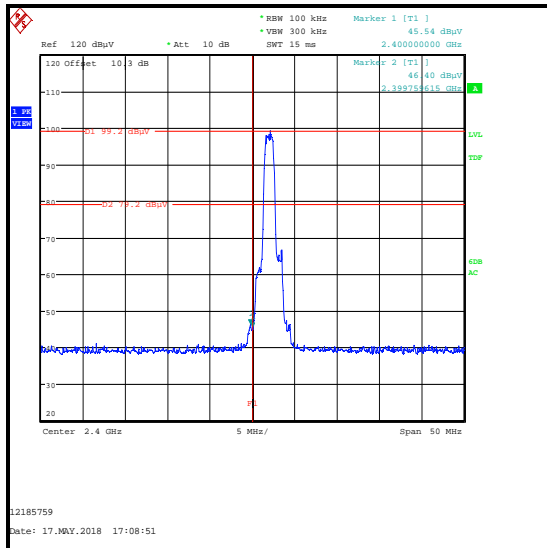
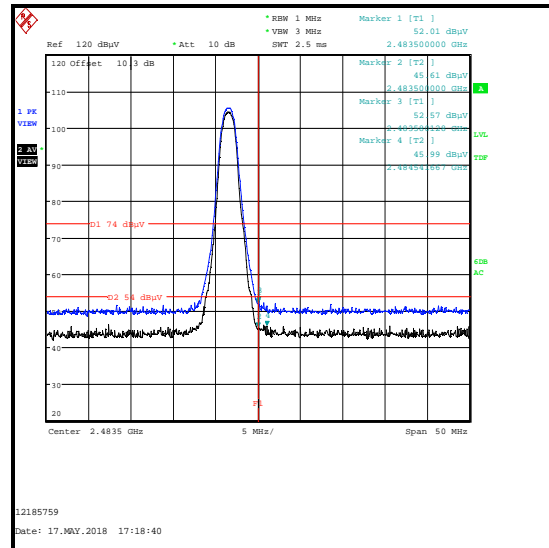
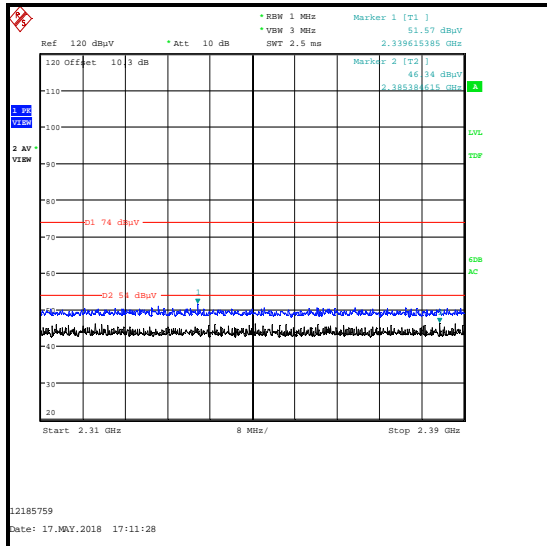
Frequency (MHz)	Antenna Polarity	Average Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2483.500	Vertical	45.6	54.0	8.4	Complied
2484.542	Vertical	46.0	54.0	8.0	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2339.615	Vertical	51.6	74.0	22.4	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2385.385	Vertical	46.3	54.0	7.7	Complied

**Transmitter Band Edge Radiated Emissions (continued)****Results: Static Mode / 3DH5****Lower Band Edge****Upper Band Edge****2310 MHz to 2390 MHz Restricted Band**

**Transmitter Band Edge Radiated Emissions (continued)****Results: Hopping Mode / 3DH5**

Frequency (MHz)	Antenna Polarity	Peak Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2399.599	Vertical	41.3	86.4*	45.1	Complied
2400.000	Vertical	39.8	86.4*	46.6	Complied
2483.500	Vertical	51.7	74.0	22.3	Complied

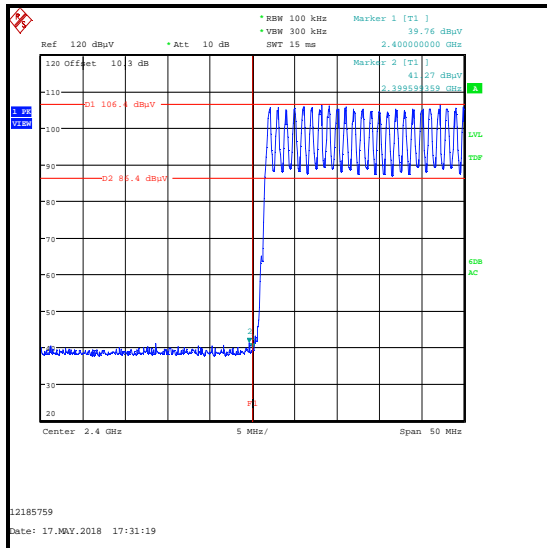
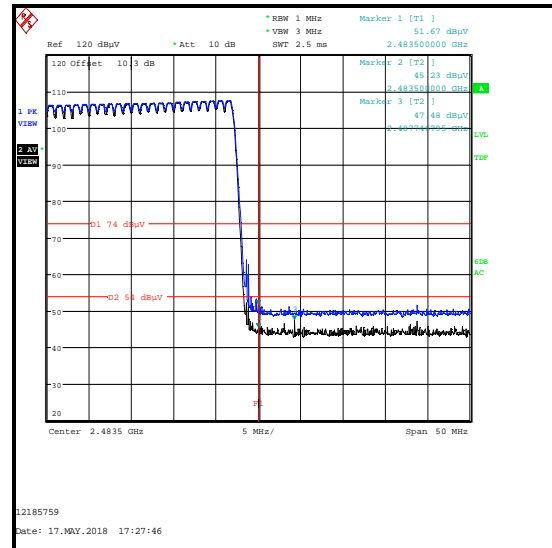
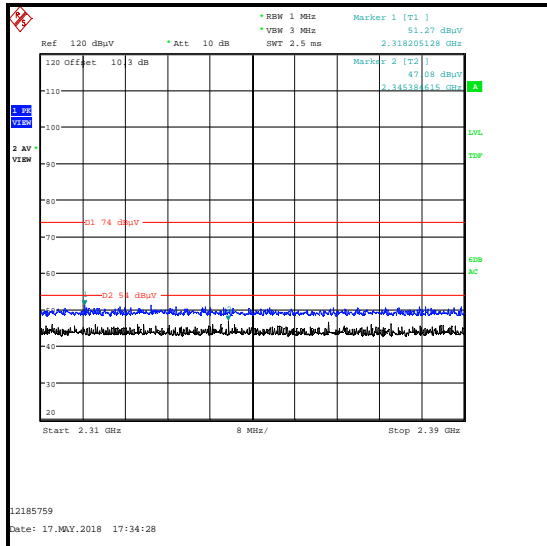
Frequency (MHz)	Antenna Polarity	Average Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2483.500	Vertical	45.2	54.0	8.8	Complied
2487.747	Vertical	47.5	54.0	6.5	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Peak**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2318.205	Vertical	51.3	74.0	22.7	Complied

**Results: 2310 MHz to 2390 MHz Restricted Band / Average**

Frequency (MHz)	Antenna Polarity	Level (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Result
2345.385	Vertical	47.1	54.0	6.9	Complied

**Transmitter Band Edge Radiated Emissions (continued)****Results: Hopping Mode / 3DH5****Lower Band Edge****Upper Band Edge****2310 MHz to 2390 MHz Restricted Band****--- END OF REPORT ---**