# TEST REPORT

## Test Report No. : UL-RPT-RP11265293JD07G V3.0

| | | |
|---|---|---|
| **Manufacturer** | : | Apple Inc. |
| **PMN** | : | Apple |
| **HVIN** | : | A1785 |
| **FCC ID** | : | BCG-E3088A |
| **ISED Certification No.** | : | IC: 579C-E3088A |
| **Technology** | : | WLAN |
| **Test Standard(s)** | : | FCC Part 15.407(h)(2) & ISED Canada RSS-247 6.3(iii) & 6.3(iv) |

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 3.0 supersedes all previous versions.

**Date of Issue:**      03 August 2016

**Checked by:**

Steven White
Service Lead, Radio Laboratory

**Company Signatory:**

Sarah Williams
Senior Engineer, Radio Laboratory
UL VS LTD

This laboratory is accredited by UKAS. The tests reported herein have been performed in accordance with its terms of accreditation.

**UL VS LTD**

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## Table of Contents

## 1. Customer Information

| Company Name: | Apple |
|---|---|
| Address: | 1 Infinite Loop<br>Cupertino, CA 95014<br>U.S.A |

## 2. Summary of Testing

### 2.1. General Information

| | |
|---|---|
| **FCC Specification Reference:** | 47CFR15.407 |
| **FCC Specification Title:** | Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart E (Unlicensed National Information Infrastructure Devices) - Section 15.407 |
| **FCC Site Registration:** | 209735 |
| **ISED Canada Specification Reference:** | RSS-210 Issue 8 December 2010 |
| **ISED Canada Specification Title:** | Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment |
| **ISED Canada Site Registration:** | 3245B-2 |
| **Location of Testing:** | UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom |
| **Test Dates:** | 13 July 2016 to 01 August 2016 |

### 2.2. Summary of Test Results

| FCC Reference (47CFR) | ISED Canada Reference | Measurement | Result |
|---|---|---|---|
| Part 15.407(h)(2)(iii) | RSS-247 6.3(iii) & 6.3(iv) | Channel Closing Transmission Time and Channel Move Time | ✅ |
| Part 15.407(h)(2)(iv) | RSS-247 6.3(2)(v) | Non-Occupancy Period | ✅ |
| **Key to Results** | | | |
| ✅ = Complied     ❌ = Did not comply | | | |

#### Note(s):

1. The manufacturer confirms that the information regarding the parameters of the radar waveforms is not available to the end user.

2. This test is not required for a client without radar detection according to Tables 1 and 2 of KDB 905462 D02, however it was performed to show compliance with KDB 905462 D02 5.1.2 e) and KDB 905462 D03, section (b)(5) and (b)(6).

### 2.3. Methods and Procedures

| | |
|---|---|
| **Reference:** | FCC KDB 905462 D02 UNII DFS Compliance Procedures New Rules v02 (April 8, 2016) |
| **Title:** | Compliance Measurement Procedures for Unlicensed-National Information Infrastructure Devices Operating in the 5250-5350 MHz and 5470-5725 MHz Bands Incorporating Dynamic Frequency Selection |

### 2.4. 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.

## 3. Equipment Under Test (EUT)

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

| | |
|---|---|
| **Brand Name / PMN:** | Apple |
| **Model Name / HVIN:** | A1785 |
| **Test Sample Serial Number:** | C39RW002HFML *(Conducted sample #48)* |
| **Hardware Version:** | REV 1.0 |
| **Software Version:** | 1.359 RC65.0 |
| **FCC ID:** | BCG-E3088A |
| **ISED Certification No.:** | IC: 579C-E3088A |

### 3.2. Description of EUT

The Equipment Under Test was a mobile phone with GSM/GPRS/EGPRS/UMTS/LTE/TD-SCDMA and CDMA technologies. It also supports IEEE 802.11a/b/g/n/ac, Bluetooth®, GPS and NFC. The rechargeable battery is not user accessible.

### 3.3. Modifications Incorporated in the EUT

No modifications were applied to the EUT during testing.

## 3.4. Additional Information Related to Testing

| Technology Tested: | WLAN (IEEE 802.11a,n,ac), Digital Transmission System | |
|---|---|---|
| Type of Unit: | Transceiver | |
| Modulation Types: | BPSK, QPSK, 16QAM, 64QAM & 256QAM | |
| Transmit / Receive Frequency Range: | 5250 to 5350 MHz<br>5470 to 5850 MHz | |
| Transmit / Receive Channels Tested at 80 MHz Bandwidth setting: | Channel ID | Channel Centre Frequency (MHz) |
| | 58 | 5320 |
| Transmit / Receive Channels Tested at 20 MHz Bandwidth setting: | Channel ID | Channel Centre Frequency (MHz) |
| | 100 | 5500 |

## 3.5. Support Equipment

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

| | |
|---|---|
| **Description:** | Wireless Dual Band Router (DFS Master) |
| **Brand Name:** | Cisco |
| **Model Name or Number:** | AIR-CAP3702E-A-K9 V04 |
| **FCC ID:** | LDK102087 |
| **ISED Canada Certification No:** | IC: 2461B-102087 |
| **Serial Number:** | FJC1938F3G6 |

| | |
|---|---|
| **Brand Name:** | Lenovo |
| **Description:** | Laptop Computer (*UL Computer Name: GBRAD004*) |
| **Model Name or Number:** | Thinkpad L440 |
| **Serial Number:** | R9019EA4 |

| | |
|---|---|
| **Brand Name:** | Apple |
| **Description:** | Video Streaming Box |
| **Model Name or Number:** | Apple TV (3rd generation) |
| **Serial Number:** | C07JV34NFF54 |

| | |
|---|---|
| **Brand Name:** | Logik |
| **Description:** | Television |
| **Model Name or Number:** | L22FE12A |
| **Serial Number:** | 1309020661 |

## 4. Operation and Monitoring of the EUT during Testing
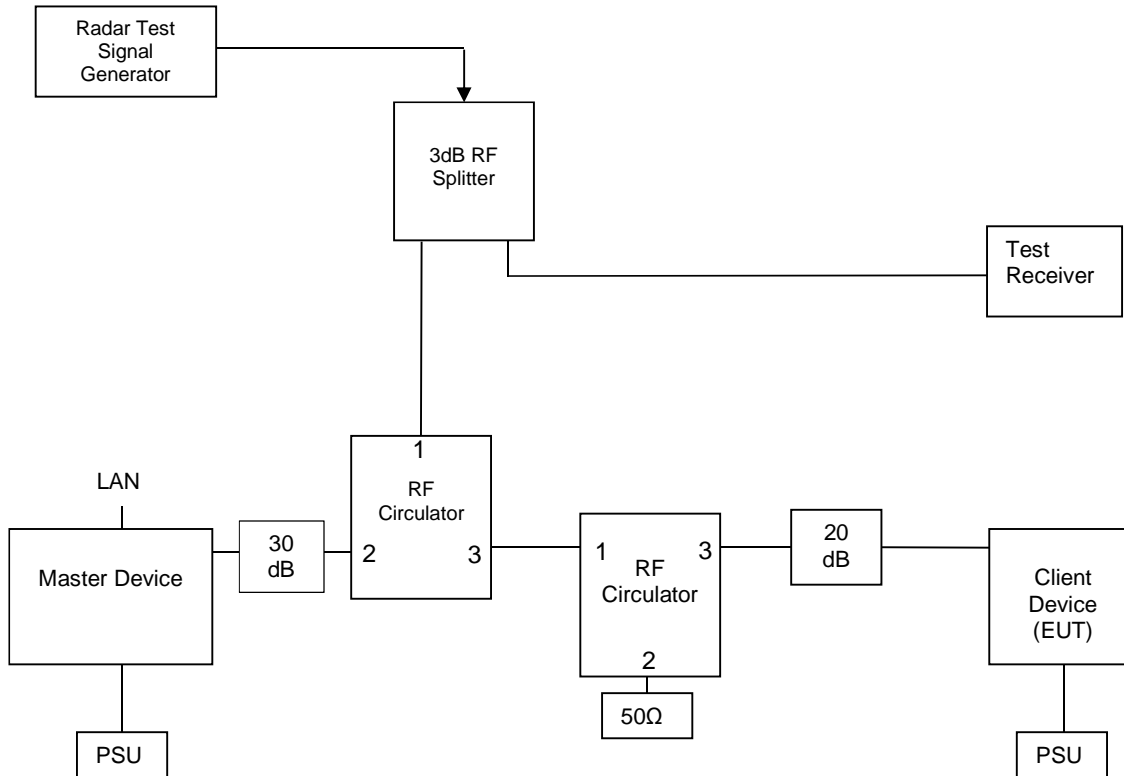
### 4.1. Operating Modes

The EUT was tested in the following operating modes, unless otherwise stated:

- Operating on the channel selected by the Master device in either UNII Band 2a or UNII Band 2c.

- The Master device controls the channel bandwidth and modulation of the EUT. The EUT was forced to 802.11ac / VHT80 / MCS0x1 / SISO mode, so the channel loading would not fluctuate during testing.

- KDB 905462 D02 *UNII DFS Compliance Procedures* states in Table 2 the EUT should be tested at maximum channel bandwidth (80 MHz for 802.11ac mode). However, the exception for 802.11ac client devices in KDB 905462 D03 U-NII *Client Devices Without Radar Detection Capability* was used to test the client device at 40 MHz channel bandwidth due to limited availability of FCC approved DFS-capable 802.11ac routers.

- For the required channel loading of >17% in KDB 905642 D02 7.7 c), a data transfer was performed between a test computer and the EUT. This gave a channel loading (duty cycle) of 37.0 % at the modulation scheme and bandwidth above. See Appendix 4 *Channel Loading* for further details.

### 4.2. Configuration and Peripherals

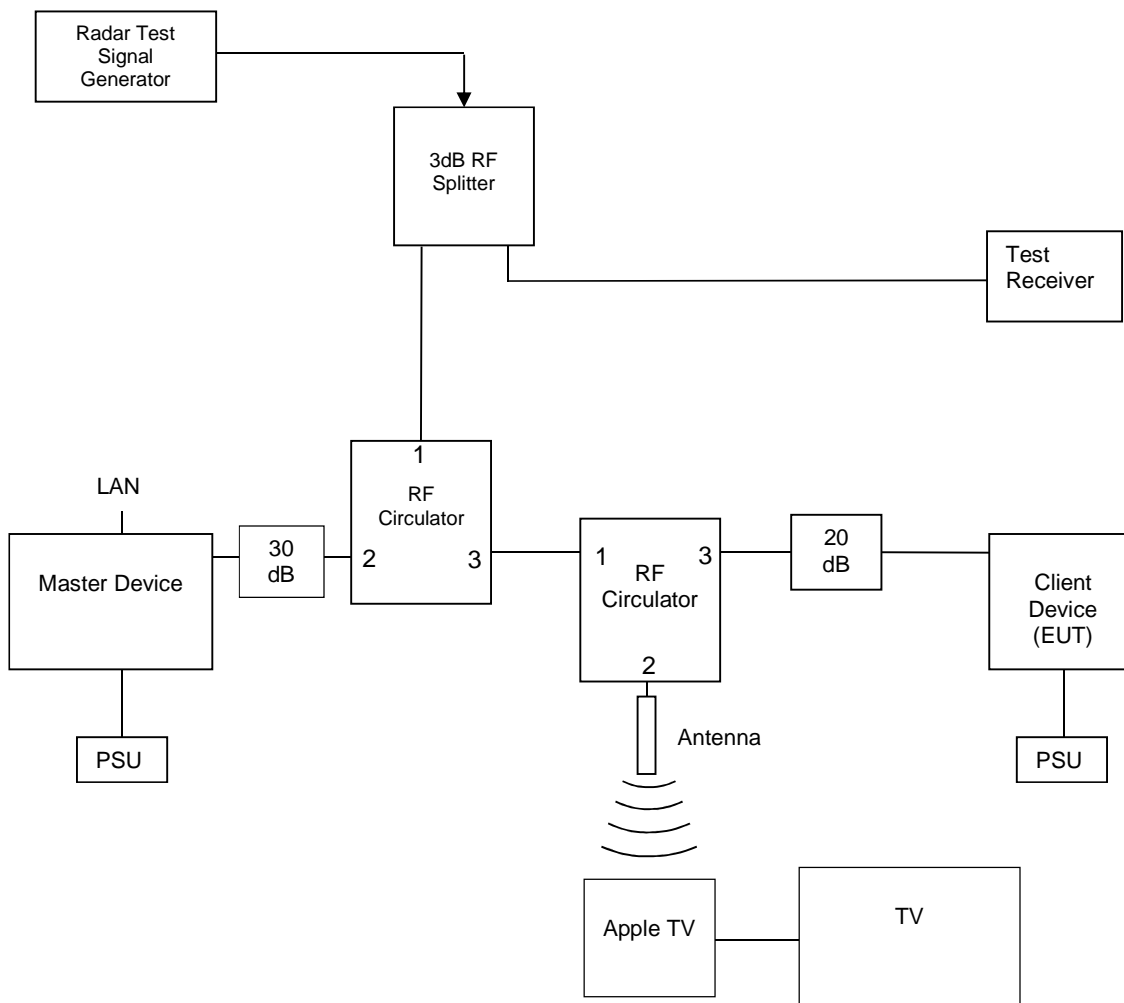The EUT was tested in the following configuration(s):

- The EUT is a DFS client without Radar Detection capability. It was tested in combination with an FCC/ ISED Canada certified Cisco DFS enabled router being used as the Master (see *Section 3.5: Support Equipment* for further details). A Radar Type 0 was injected to the Master to test the client's Channel Move Time and Channel Closing Transmission Time after receiving the channel shutdown command form the Master.

- All measurements were made using a conducted link. The EUT has two external antenna ports fitted for test purposes. 'Port 1' was tested. System losses for the interconnecting hardware were measured and taken into consideration.

- The Radar test platform used was the Aeroflex DFS Radar 110105 Simulator and Analyser which has been verified and accepted by Andrew Leimer of the FCC/NTIA on the 23rd of September 2011. Refer to Appendix 2 of this Test Report for the original confirmation email.

- The DFS detection threshold of -61.0 dBm (-62 dBm + 1 dB + 0 dBi) was used at the Master device antenna port. Note this is not dependent on the EUT EIRP, Spectral Density or EUT antenna gain, only the antenna gain of the master device, as the EUT does not have radar detection.

- The Master device used for test was set to 17 dBm / 50 mW with TPC enabled.

- Plots and data were captured using a Rohde and Schwarz FSV Signal Analyser. The number of data points was increased to maximum and the trace data exported so it could be analysed in far greater detail than available on the built-in display.

- The Channel Move Time was the time taken from the end of the radar waveform to the time the client (EUT) ceased transmissions. The Channel Closing Transmission Time was calculated to the nearest sample from any additional pulses occurring >200 ms after the end of the radar.

- The EUT was also tested in a second setup where it was directly exchanging data with another client associated with the same network using Apple's AirPlay protocol. Both setups are explained with diagrams in the following section.

## Setup diagram for test of DFS Client without Radar Detection: Setup 1

Radar Test Signal Generator

3dB RF Splitter

Test Receiver

LAN

RF Circulator — 1, 2, 3

Master Device — 30 dB

RF Circulator — 1, 3, 2

20 dB

Client Device (EUT)

50Ω

PSU

PSU

### Rationale

The setup shown above ensures the waveforms indicated on the spectrum analyser are in order of magnitude. The circulators have typically 18 dB attenuation in the reverse direction. The left-hand circulator directs the radar towards the master, ensuring there is not an overly large radar pulse into the client (EUT) even though there is the same attenuation between the client and the radar generator. The radar signal should be approximately 26 dB smaller at the client antenna port than at the master. The right-hand circulator is to give the same path loss between master and client in both directions of the 802.11 communications link.

The Radar signal is most predominant on the spectrum analyser, coming straight through a 3 dB splitter. The client is 2nd largest, being attenuated by the 20 dB, and the (typically 18 dB) isolation from the directional splitter. The smallest signal is the master, being attenuated by 30 dB from the attenuator and approximately 18 dB from the left-hand circulator and 18 dB across the splitter.

The RF path from the radar generator to the DFS Master crosses no isolated ports of any splitters or circulators and any change of impedance in load between calibration and test is isolated from any circulators by 50 Ω attenuators which further minimises mismatch. This setup therefore meets the requirements of KDB 905462 D02 clause 7.2 points (1) and (2) whilst providing greater radar generator amplitude headroom and lower radar signal at the client.

## Setup diagram for test of DFS Client without Radar Detection: Setup 2



### Rationale

This setup is exactly the same as the previous one, except the EUT is also communicating with the Apple TV on the same network. A movie was streamed directly to the Apple TV from the client, using Apple's AirPlay technology. The Apple TV was placed close enough to the antenna to make sure that the link between EUT and the Apple TV is stronger than the link between the EUT and the Master device. This was also achieved by controlling the attenuation in the network. The transmit duty cycle of the EUT could not be directly controlled, but a high-quality 1080p movie was used to maximize the transmission duty cycle and create the worst-case scenario.

**Applicability of DFS requirements prior to use of a channel**

| Requirement | Operational Mode | | |
|---|---|---|---|
| | Master | Client Without Radar Detection | Client With Radar Detection |
| *Non-Occupancy Period* | Yes | Not required | Yes |
| *DFS Detection Threshold* | Yes | Not required | Yes |
| *Channel Availability Check Time* | Yes | Not required | Not required |
| *Uniform Spreading* | Yes | Not required | Yes |

**Applicability of DFS requirements during normal operation**

| Requirement | Operational Mode | |
|---|---|---|
| | Master Device or Client with Radar Detection | Client Without Radar Detection |
| *DFS Detection Threshold* | Yes | Not required |
| *Channel Closing Transmission Time* | Yes | Yes |
| *Channel Move Time* | Yes | Yes |
| *U-NII Detection Bandwidth* | Yes | Not required |

| Additional requirements for devices with multiple bandwidth modes | Master Device or Client with Radar Detection | Client Without Radar Detection |
|---|---|---|
| *U-NII Detection Bandwidth and Statistical Peformance Check* | All BW modes must be tested | Not required |
| *Channel Move Time and Channel Closing Transmission Time* | Test using widest BW mode available | **Test using the widest BW mode available for the link** |
| *All other tests* | Any single BW mode | Not required |
| **Note:** Frequencies selected for statistical performance check (Section 7.8.4) should include several frequencies within the radar detection bandwidth and frequencies near the edge of the radar detection bandwidth. For 802.11 devices it is suggested to select frequencies in each of the bonded 20 MHz channels and the channel center frequency. | | |

**Interference Threshold values, Master or Client incorporating In-Service Monitoring**

| Maximum Transmit Power | Value (see notes) |
|---|---|
| EIRP ≥ 200 milliwatt | -64 dBm |
| EIRP < 200 milliwatt and power spectral density < 10 dBm/MHz | -62 dBm |
| EIRP < 200 milliwatt that do not meet the power spectral density requirement | -64 dBm |
| **Note 1:** This is the level at the input of the receiver assuming a 0 dBi receive antenna<br>**Note 2:** Throughout these test procedures an additional 1dB has been added to the amplitude of the test transmission waveforms to account for variations in measurement equipment. This will ensure that the test signal is at or above the detection threshold level to trigger a DFS response.<br>**Note 3:** EIRP is based on the highest antenna gain. For MIMO devices refer to KDB Publication 662911 D01. | |

**DFS Response requirement values**

| Parameter | Value |
|---|---|
| *Non-occupancy period* | Minimum 30 minutes |
| *Channel Availability Check Time* | 60 seconds |
| *Channel Move Time* | 10 seconds   See Note 1. |
| *Channel Closing Transmission Time* | 200 milliseconds + an aggregate of 60 milliseconds over remaining 10 second period. See Notes 1 and 2. |
| *U-NII Detection Bandwidth* | Minimum 100% of the U-NII 99% transmission power bandwidth. See Note 3. |
| **Note 1:** *Channel Move Time* and the *Channel Closing Transmission Time* should be performed with Radar Type 0. The measurement timing begins at the end of the Radar Type 0 burst. **Note 2:** The *Channel Closing Transmission Time* is comprised of 200 milliseconds starting at the beginning of the *Channel Move Time* plus any additional intermittent control signals required to facilitate a *Channel* move (an aggregate of 60 milliseconds) during the remainder of the 10 second period. The aggregate duration of control signals will not count quiet periods in between transmissions. **Note 3:** During the *U-NII Detection Bandwidth* detection test, radar type 0 should be used. For each frequency step the minimum percentage of detection is 90 percent. Measurements are performed with no data traffic. | |

**Short Pulse Radar Test Waveforms**

| Radar Type | Pulse Width (Microseconds) | PRI (Microseconds) | Pulses | Minimum Percentage of Successful Detection | Minimum Trials |
|---|---|---|---|---|---|
| 0 | 1 | 1428 | 18 | See Note 1 | See Note 1 |
| **Note 1:** should be used for the detection bandwidth test, channel move time and channel closing time tests. | | | | | |

## 5. Measurements, Examinations and Derived Results

### 5.1. General Comments

Measurement uncertainties are evaluated in accordance with current best practice. Our reported expanded uncertainties are based on standard uncertainties, which are multiplied by an appropriate coverage factor to provide a statistical confidence level of approximately 95%. Please refer to *Section 6 Measurement Uncertainty* for details.

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.

## 5.2. Test Results

### 5.2.1. Channel Closing Transmission Time and Channel Move Time

**Test Summary:**

| Test Engineer: | Philip Harrison | Test Dates: | 13 July 2016 & 14 July 2016 |
|---|---|---|---|
| Test Sample Serial Number: | C39RW002HFML | | |

| | |
|---|---|
| FCC Reference: | Part 15.407(h)(2)(iii) |
| ISED Canada Reference: | RSS-247 6.3(iii) & 6.3(iv) |
| Test Method Used: | KDB 905462 D02  Section 7.8.3 |

**Environmental Conditions:**

| | |
|---|---|
| Temperature (°C): | 21 |
| Relative Humidity (%): | 63 |

**Note(s):**

1. The channel move time is the time taken from the end of the radar burst to the ceasing of transmissions of the EUT.

2. The Total Aggregate Channel Closing Transmission Time shown in the table below was measured from 200 ms after the end of the radar burst and compared to the 60 ms limit.

3. The smaller transmissions seen in the plot that are not included in the move time come from the Master device and not from the client, these transmissions can be ignored for the below results.

4. The path loss from the EUT to the spectrum analyser were added to the were added as an offset to the plots.

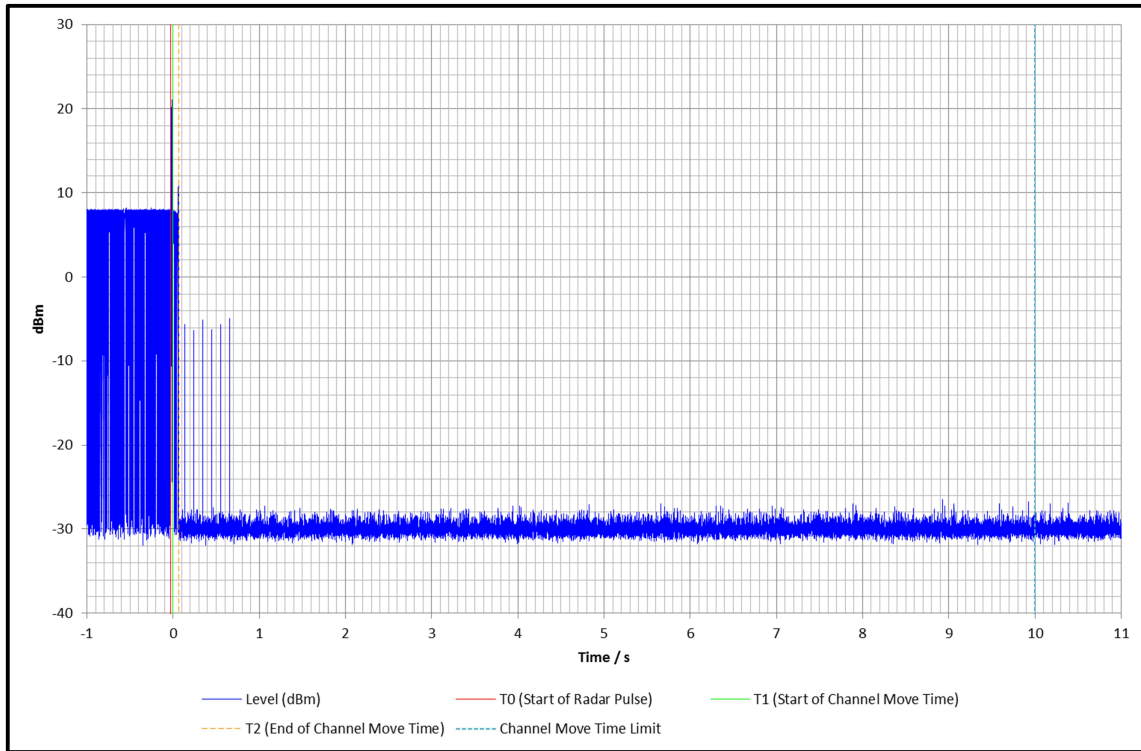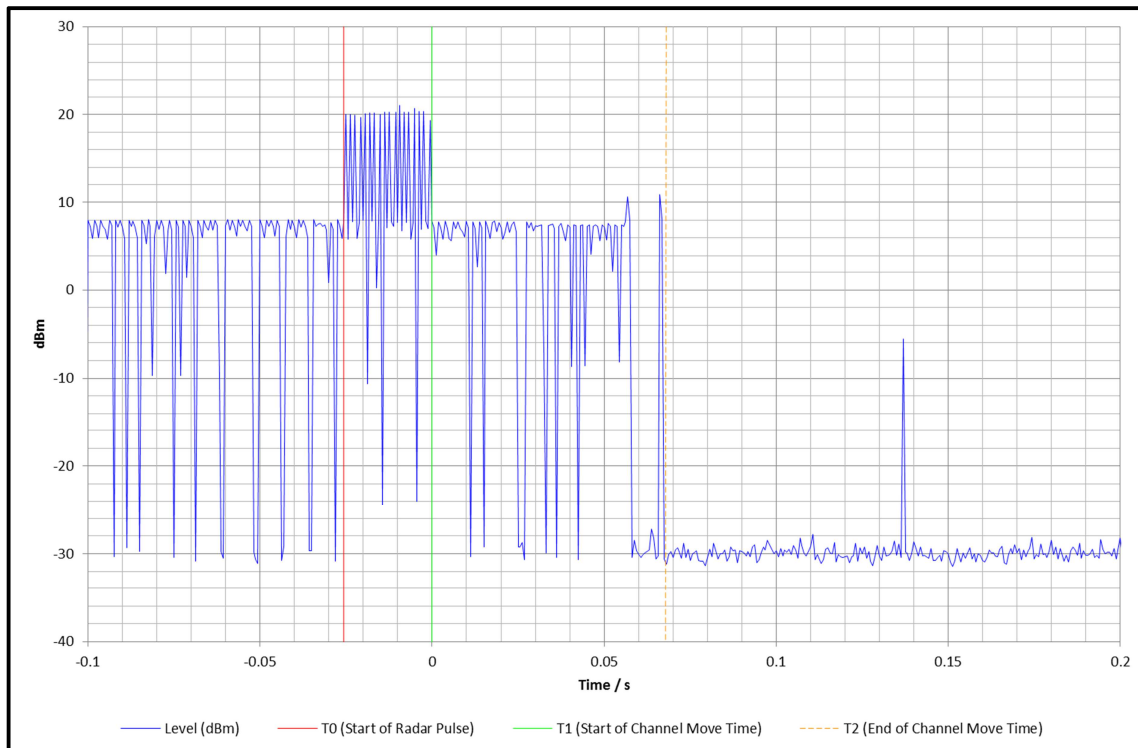5. All transmissions after the reported channel move time were from the router or Apple TV.
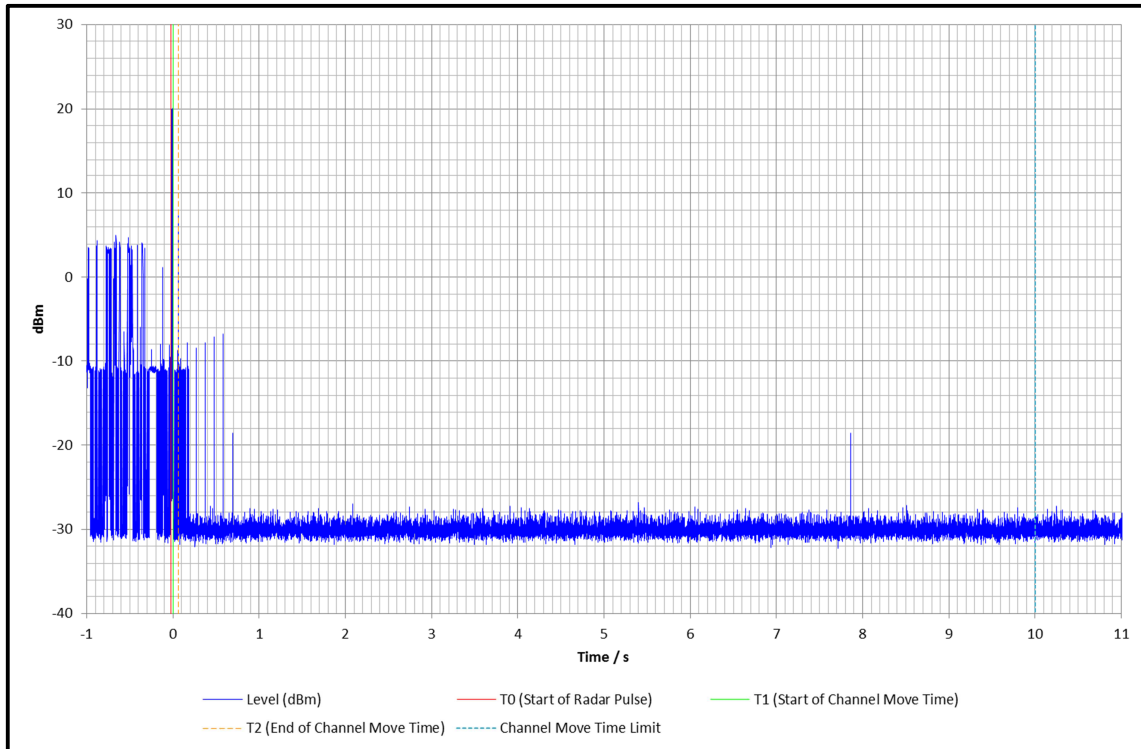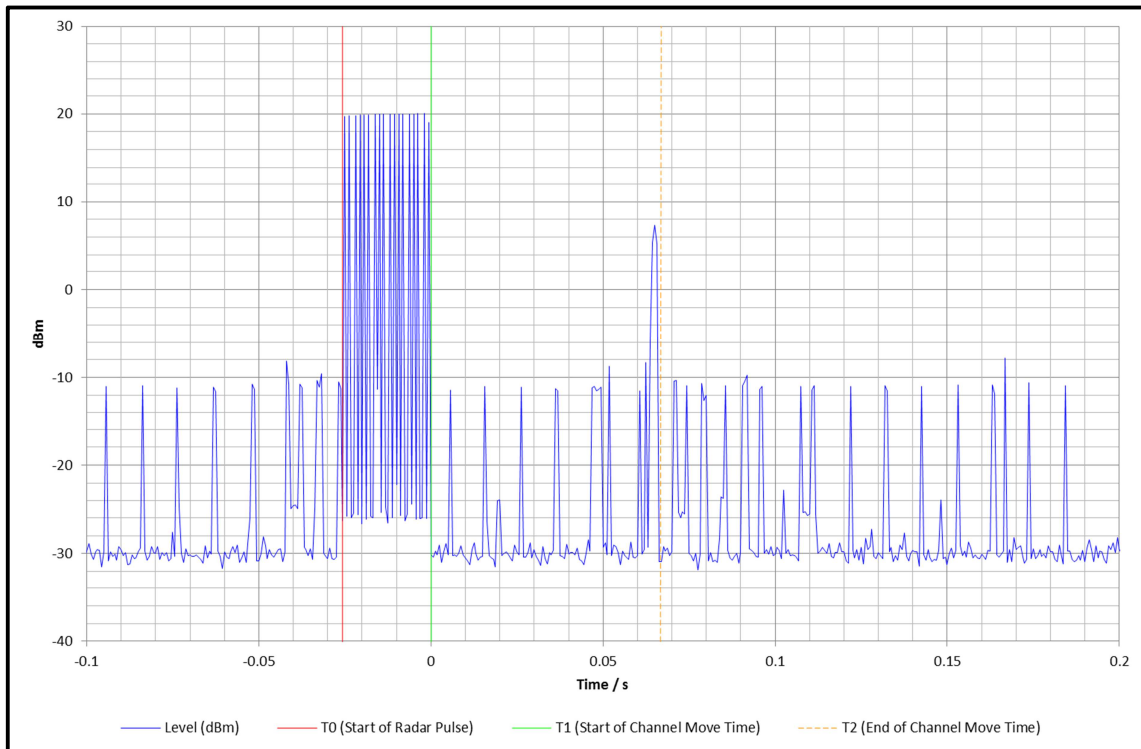
**Results: Setup 1**

| Channel Frequency (MHz) | Channel Move Time (ms) | Total Aggregate Channel Closing Time after first 200 ms (ms) | Limit (ms) | Margin (ms) | Result |
|---|---|---|---|---|---|
| 5530 | 67.5 | - | 10000 | 9932.5 | Complied |
| 5530 | - | 0 | 60 | 60 | Complied |

**Results: Setup 2**

| Channel Frequency (MHz) | Channel Move Time (ms) | Total Aggregate Channel Closing Time after first 200 ms (ms) | Limit (ms) | Margin (ms) | Result |
|---|---|---|---|---|---|
| 5530 | 66.3 | - | 10000 | 9933.7 | Complied |
| 5530 | - | 0 | 60 | 60 | Complied |

Radar burst type 0 was detected and channel move occurred.

## Channel Closing Transmission Time and Channel Move Time (continued)



**Setup 1 Channel Move Time 5530 MHz – Short Radar (Type 0) – Full 10 seconds**



**Setup 1 Channel Move Time 5530 MHz – Short Radar (Type 0) – Zoomed Plot**

## Channel Closing Transmission Time and Channel Move Time (continued)



**Setup 2 Channel Move Time 5530 MHz – Short Radar (Type 0) – Full 10 seconds**



**Setup 2 Channel Move Time 5530 MHz – Short Radar (Type 0) – Zoomed Plot**

### Channel Closing Transmission Time and Channel Move Time (continued)

### Test Equipment Used:

| Asset No. | Instrument | Manufacturer | Type No. | Serial No. | Date Calibration Due | Cal. Interval (Months) |
|---|---|---|---|---|---|---|
| M1631 | DFS Test System | Aeroflex | PXI 3000 | 300110/291 | 09 Jul 2017 | 24 |
| M1883 | Signal Analyser | Rohde & Schwarz | FSV-30 | 103084 | 09 May 2017 | 12 |
| A1535 | Step Attenuator | Hewlett Packard | 8495B/8494B | 00007 | Calibrated before use | - |
| A1536 | Step Attenuator | Hewlett Packard | 8495B/8494B | 3308A30801 / 3308A19649 | Calibrated Before Use | - |
| A2181 | Coaxial Circulator 4 – 18 GHz | Atlantec | ACC-20130-SF-SF-SF | 120409229 | Calibrated Before Use | - |
| A2183 | Coaxial Circulator 4 – 18 GHz | Atlantec | ACC-20130-SF-SF-SF | 120409232 | Calibrated Before Use | - |
| A2910 | Power Splitter | Mini-Circuits | ZN4PD1-63-S+ | SUU50001612 #2 | Calibrated before use | - |
| A162 | 50Ω Termination | Narda | 3768NM | 5204 | Calibrated Before Use | - |
| A2491 | 50Ω Termination | Narda | TA06W5-M | 121813#2 | Calibrated Before Use | - |
| A2494 | 50Ω Termination | Narda | TA06W5-F | 082013#2 | Calibrated Before Use | - |
| M2001 | Thermohygrometer | Testo | 608-H1 | 45041824 | 02 Apr 2017 | 12 |

### 5.2.2. Non-Occupancy Period

**Test Summary:**

| Test Engineer: | Philip Harrison | Test Date: | 01 August 2016 |
|---|---|---|---|
| Test Sample Serial Number: | C39RW002HFML | | |

| FCC Reference: | Part 15.407(h)(2)(iv) |
|---|---|
| ISED Canada Reference: | RSS-247 6.3(2)(v) |
| Test Method Used: | KDB 905462 D02 Section 7.8.3 |

**Environmental Conditions:**

| Temperature (°C): | 22 |
|---|---|
| Relative Humidity (%): | 63 |

**Notes:**

1. This test is not required for a client without radar detection according to Tables 1 and 2 of KDB 905462 D02, however it was performed to show compliance with KDB 905462 D02 5.1.2 e) and KDB 905462 D03, section (b)(5) and (b)(6). Therefore no specified bandwidth requirement is given and so was performed using an 80 MHz channel bandwidth; as used for *Channel Closing Transmission Time and Channel Move Time*.

2. Radar burst type 0 was detected and the channel was vacated for >1800 seconds. Since the client has no radar detection and is therefore not performing an 'intelligent' blacklisting of the channel, the device was shown not to transmit for greater than 30 minutes after its own shutdown time, not the shutdown of the DFS master or the second client in the peer-to-peer set-up.

3. The noise floor remains below the -27 dBm/MHz spurious limit for the 30 minute (1800 second) non-occupancy period, except where the other devices are still transmitting and are yet to have shutdown. Therefore the EUT is deemed to comply.

## Non-occupancy Period (continued)

## Results: Set-up 1

| Channel (MHz) | Trial | Non-Occ (min) | Limit (min) | Margin (min) | Result |
|---|---|---|---|---|---|
| 5500 | 1 | >32.8 | 30 | >2.8 | Complied |