TEST REPORT

Test Report No. : UL-RPT-RP10950538JD11C

Manufacturer	:	Sigma Connectivity AB
Model No.	:	SSG-002
FCC ID	:	2AFCP-002
Technology	:	WLAN
Test Standard(s)	:	FCC Part 15.407(h)(2)

1. This test report shall not be reproduced in full or partial, without the written approval of UL VS LTD.
2. The results in this report apply only to the sample(s) tested.
3. The sample tested is in compliance with the above standard(s).
4. The test results in this report are traceable to the national or international standards.
5. Version 1.0.

Date of Issue: 13 October 2016

Checked by:

Ian Watch
Senior Engineer, Radio Laboratory

Company Signatory:

Steven White
Service Lead, Radio Laboratory
UL VS LTD

0644

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

UL VS LTD

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

This page has been left intentionally blank.

Table of Contents

1. Customer Information

Company Name:	Sigma Connectivity AB
Address:	Mobilevägen 10 223 62 Lund Sweden

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
FCCSite Registration:	209735
Location of Testing:	UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
Test Date:	09 March 2016

2.2. Summary of Test Results

FCC Reference (47CFR)	Measurement	Result
Part 15.407(h)(2)(iii)	Channel Closing Transmission Time and Channel Move Time	✓
Part 15.407(h)(2)(iv)	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 non-occupancy period 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 U-NII DFS Compliance Procedures New Rules v02 April 08, 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
Reference:	FCC KDB 905462 D03 U-NII Clients Without Radar Detection New Rules v01r02 August 22, 2016
Title:	U-NII Client Devices Without Radar Detection Capability

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:	Sensgate
Model Name or Number:	SSG-002
Test Sample Serial Number:	01001927 *(Conducted sample with RF port #1)*
Hardware Version:	Revision 2.0
Software Version:	Revision 219
FCC ID:	2AFCP-002

Brand Name:	Sensgate
Model Name or Number:	SSG-002
Test Sample Serial Number:	01001939 *(Conducted sample with RF port #2)*
Hardware Version:	Revision 2.0
Software Version:	Revision 219
FCC ID:	2AFCP-002

3.2. Description of EUT

The Equipment Under Test was a gateway in the SENS BY SIGMA system, collecting data from sensors and ensuring that all component parts are continuously under full control. The gateway communicates with the sensors via *Bluetooth* and is transmitting data to the Cloud via WiFi. SensGate is designed to be mounted in the ceiling or on the wall. It carries a battery for backup and is powered via the USB port.

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:	Unlicensed National Information Infrastructure Devices (U-NII)	
Type of Unit:	Transceiver	
Data Rates:	IEEE 802.11n HT40	Auto Rate
Power Supply Requirement(s):	Nominal	3.8 VDC
Transmit / Receive Frequency Range:	5150 to 5350 MHz 5470 to 5850 MHz	
Transmit / Receive Channels Tested at 40 MHz Bandwidth setting:	**Channel ID**	**Channel Centre Frequency (MHz)**
	134	5670

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:	Asus
Model Name or Number:	RT-AC68U
FCC ID:	MSQ-RTAC68U
Serial Number:	E2IU0H001767

Description:	Test Laptop (for controlling the Client)
Brand Name:	Hewlett Packard
Model Name or Number:	Compaq 6910p
Serial Number:	HUB7451SGN

Description:	Test Laptop (for controlling the Master)
Brand Name:	Lenovo
Model Name or Number:	ThinkPad L440
Serial Number:	R9-019E9Z

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:

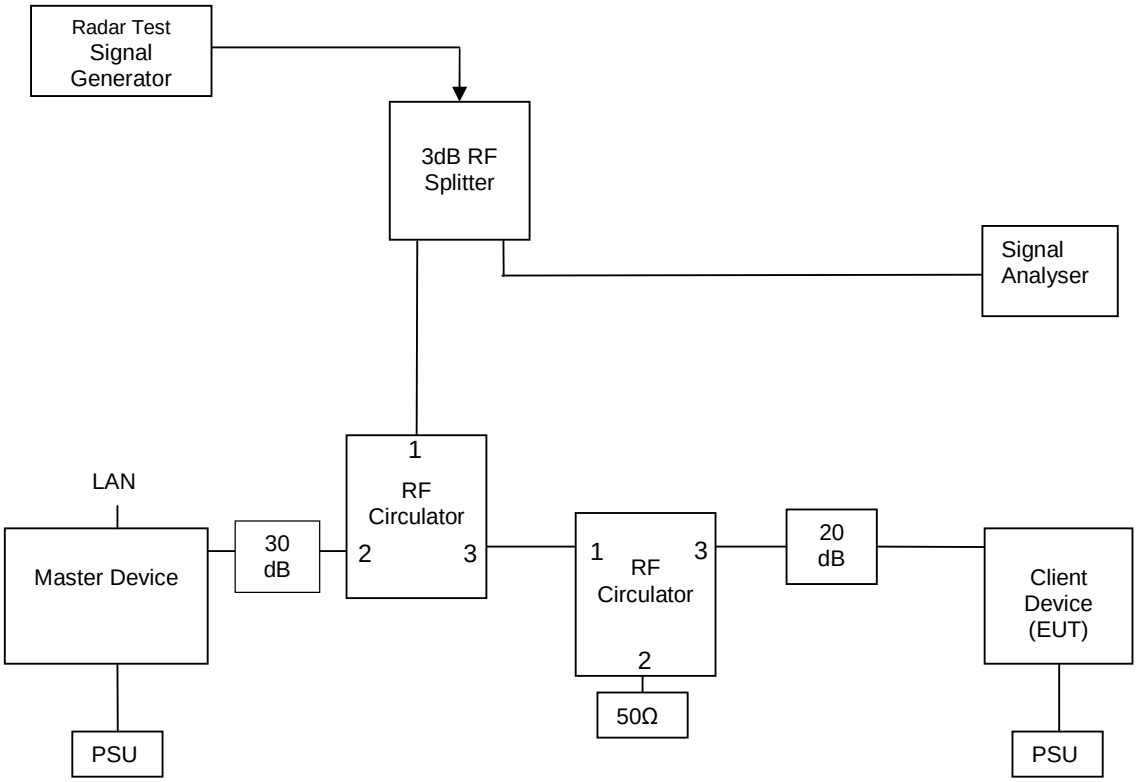
- Operating on a channel selected by the Master device in either UNII Band 2a or UNII Band 2c.
- The Master device controls the channel bandwidth and modulation of the EUT. The Master device was set to 802.11n / Auto Rate with 40 MHz channel bandwidth.
- For the required channel loading of >17% in KDB 905642 D02 7.7 c), a data transfer was performed between test laptops connected to the Master and the Client (EUT) respectively. This resulted in a channel loading (duty cycle) of 29.5%. See Appendix 3 *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 a commercially available DFS enabled router being used as the Master. A Radar Type 0 was injected to the Master to test the Clients Channel Move Time and Channel Closing Transmission Time after receiving the channel shutdown command from the Master.
- All measurements were made using a conducted link. The EUT had one external antenna port fitted for test purposes. System losses for the interconnecting hardware were measured and taken into consideration.
- The DFS detection threshold of -58.1 dBm (-62 + 3.9 dBi) was used at the Master device antenna port. Note this is not dependent on the EUT's EIRP, spectral density or antenna gain, only the 3.9 dBi 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 30 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 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.

Setup diagram for test of DFS Client without Radar Detection:



Rationale

The setup shown above ensures the waveforms indicated on the signal 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 signal 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 signal 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 signal 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 signal generator amplitude headroom and lower radar signal at the client.

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.

DFS Detection 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
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.
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:	Sandeep Bharat	**Test Date:**	09 March 2016
Test Sample Serial Number:	01001927		

FCC Reference:	Part 15.407(h)(2)(iii)
Test Method Used:	KDB 905462 D02 Section 7.8.3

Environmental Conditions:

Temperature (°C):	26
Relative Humidity (%):	30

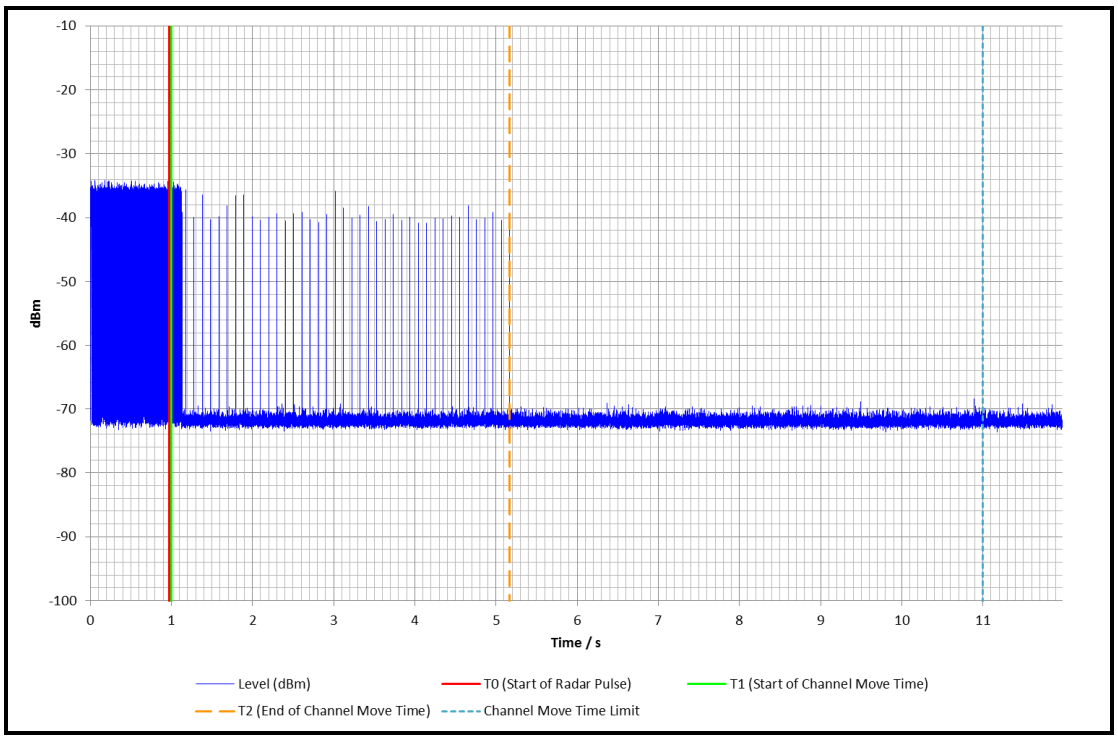
Note(s):

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

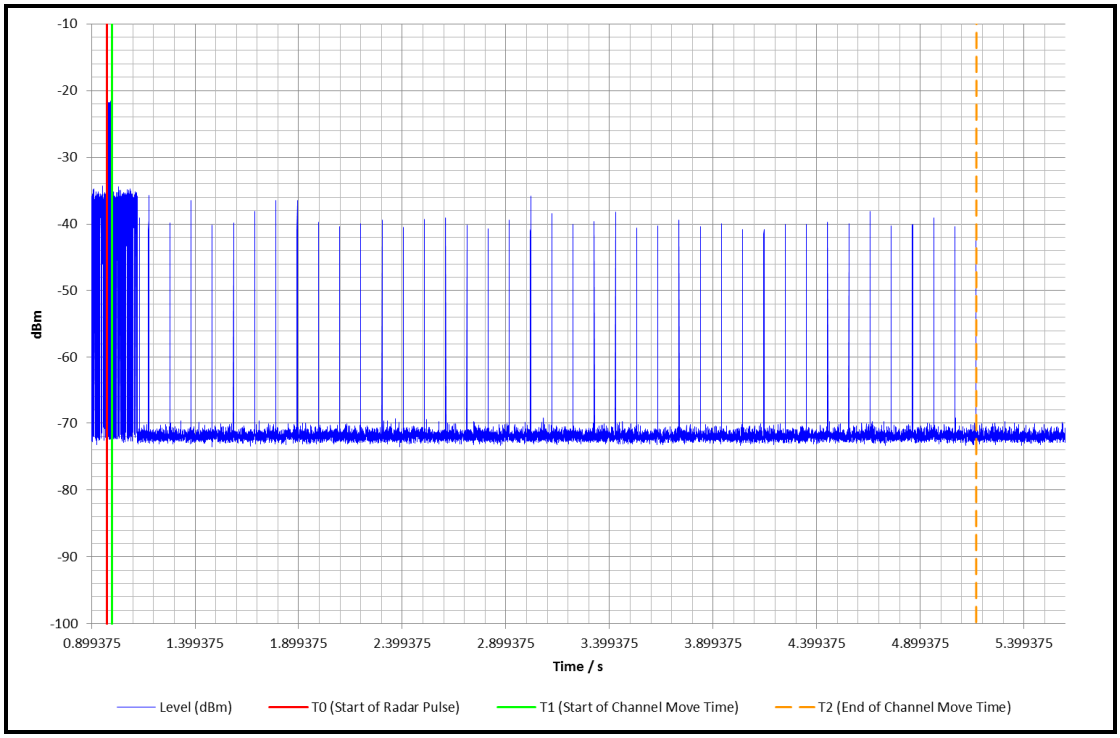
Results:

Channel Frequency (MHz)	Channel Move Time (ms)	Total Aggregate Channel Closing Time after first 200 ms (ms)	Limit (ms)	Margin (ms)	Result
5670	4170.4	-	10000	5829.6	Complied
5670	-	33.8	60	26.2	Complied

Channel Closing Transmission Time and Channel Move Time (continued)



Setup 1 Channel Move Time 5670 MHz – Short Radar (Type 0) – Full 10 seconds



Setup 1 Channel Move Time 5670 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)
M1783	Thermohygrometer	JM Handelspunkt	30.5015.13	None stated	23 Apr 2016	12
M1835	Signal Analyser	Rohde & Schwarz	FSV30	103050	26 Feb 2017	12
G0615	Vector Signal Generator	Rohde & Schwarz	SMBV100A	260473	22 May 2017	36
A163	Step Attenuator	Narda	743-80	01344	Calibrated before use	-
A248	Step Attenuator	Narda	743-60	01411	Calibrated before use	-
A1536	Step Attenuator	Hewlett Packard	8495B/8494B	3308A3080/ 3308A19649	Calibrated before use	-
A2120	Power Splitter	Mini-Circuits	ZN2PD-63-S+	SUU12701203	Calibrated before use	-
A2179	Coaxial Circulator	AtlanTecRF	ACC-20130-SF-SF-SF	120409230	Calibrated before use	-
A2180	Coaxial Circulator	AtlanTecRF	ACC-20130-SF-SF-SF	120409233	Calibrated before use	-
A2181	Coaxial Circulator	AtlanTecRF	ACC-20130-SF-SF-SF	120409229	Calibrated before use	-
S021	Power Supply Unit	TTI	CPX200	061034	Calibrated before use	-
M122	Multimeter	Fluke	77	64910017	22 Apr 2016	12

5.2.2.Non-Occupancy Period

Test Summary:

Test Engineer:	Sandeep Bharat	**Test Date:**	09 March 2016
Test Sample Serial Number:	01001939		

FCC Reference:	Part 15.407(h)(2)(iv)
Test Method Used:	KDB 905462 D02 Section 7.8.3

Environmental Conditions:

Temperature (°C):	26
Relative Humidity (%):	30

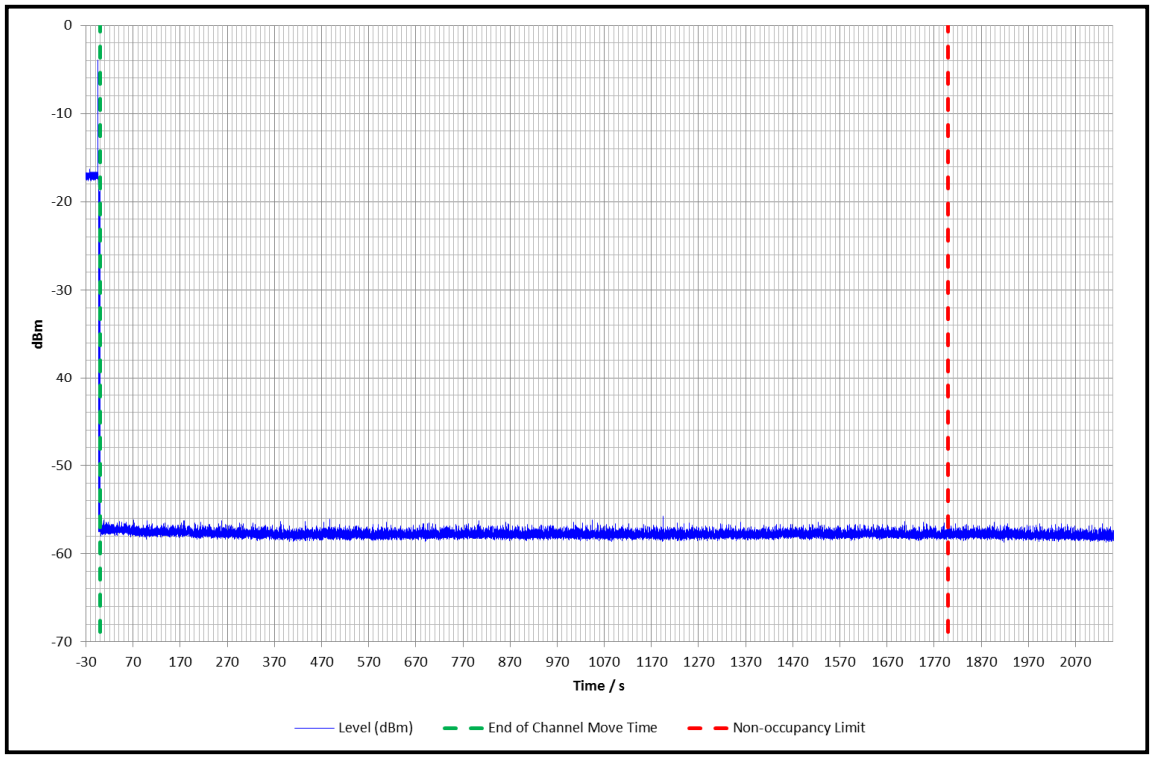
Notes:

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 a 40 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.
3. The noise floor remains below the -27 dBm/MHz spurious limit for the 30 minute (1800 second) non-occupancy period. Therefore the EUT is deemed to comply.

Non-occupancy Period (continued)

Results:

Channel (MHz)	Trial	Non-Occ (min)	Limit (min)	Margin (min)	Result
5670	1	>36.0	30	>6.0	Complied



Limits:

A channel that has been flagged as containing a radar system, either by a channel availability check or in-service monitoring, is subject to a non-occupancy period of at least 30 minutes. The non-occupancy period starts at the time when the radar system is detected.

KDB 905462 D02 Table 4: DFS Response Requirement Values

Parameter	Value
Non-occupancy period	Minimum 30 minutes

Non-occupancy Period (continued)

Test Equipment Used:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M1783	Thermohygrometer	JM Handelspunkt	30.5015.13	None stated	23 Apr 2016	12
M1835	Signal Analyser	Rohde & Schwarz	FSV30	103050	26 Feb 2017	12
G0615	Vector Signal Generator	Rohde & Schwarz	SMBV100A	260473	22 May 2017	36
A163	Step Attenuator	Narda	743-80	01344	Calibrated before use	-
A248	Step Attenuator	Narda	743-60	01411	Calibrated before use	-
A1536	Step Attenuator	Hewlett Packard	8495B/8494B	3308A3080/ 3308A19649	Calibrated before use	-
A2120	Power Splitter	Mini-Circuits	ZN2PD-63-S+	SUU12701203	Calibrated before use	-
A2179	Coaxial Circulator	AtlanTecRF	ACC-20130-SF-SF-SF	120409230	Calibrated before use	-
A2180	Coaxial Circulator	AtlanTecRF	ACC-20130-SF-SF-SF	120409233	Calibrated before use	-
A2181	Coaxial Circulator	AtlanTecRF	ACC-20130-SF-SF-SF	120409229	Calibrated before use	-
S021	Power Supply Unit	TTI	CPX200	061034	Calibrated before use	-
M122	Multimeter	Fluke	77	64910017	22 Apr 2016	12

6. 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 of the measurand (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
DFS Radar Amplitude	5.15 GHz to 5.825 GHz	95%	±2.17 dB
DFS Channel Shutdown Timing	5.15 GHz to 5.825 GHz	95%	±0.45 ms
DFS Non-Occupancy Timing	5.15 GHz to 5.825 GHz	95%	±79.25 ms

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.

7. Report Revision History

Version Number	Revision Details		
	Page No(s)	Clause	Details
1.0	-	-	Initial Version

Appendix 1. Radar Calibration

Test Setup Photographs

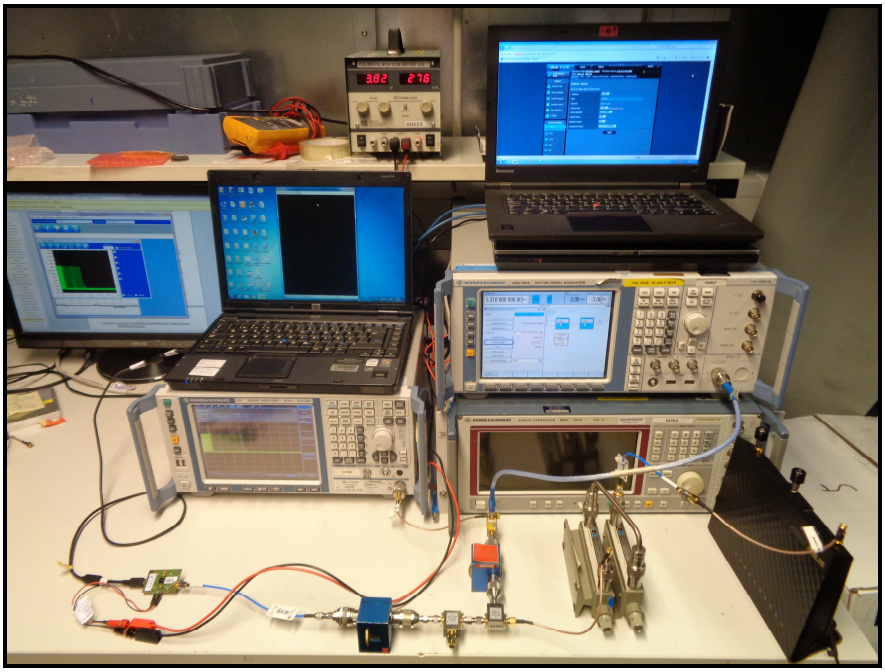


Photo 1

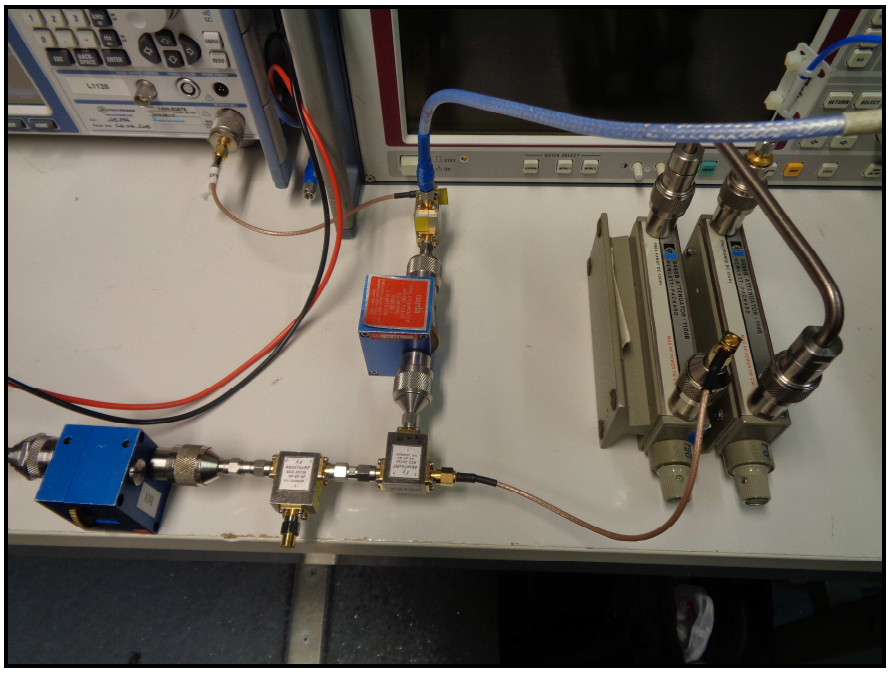


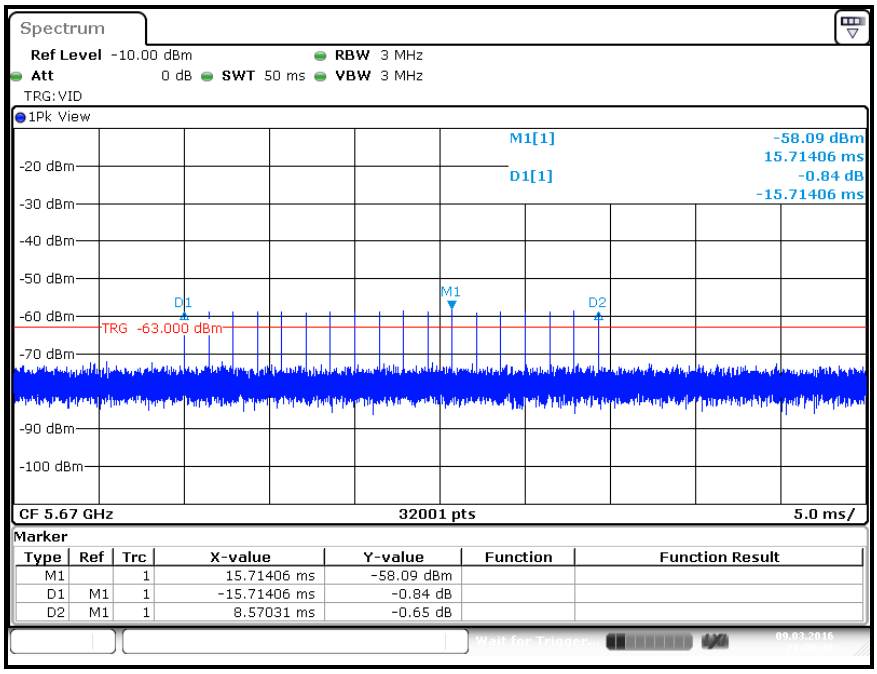
Photo 2

Radar calibration procedure

The system was configured as shown in section 4.2, but with the signal analyser node terminated into a 50Ω load, and the signal analyser connected to the master port instead. The radar was then replayed by the radar signal generator, the waveform captured, and the amplitude adjusted until correct.

Due to the difficulty of measuring the 1 µs burst accurately across the duration of a radar pulse sequence the output of the radar signal generator with both CW and test Radars has been correlated. The test network loss is then calibrated using a CW signal from the radar signal generator, and an offset put into the radar generation software. All radars are then generated at the correct level at the Master device antenna port.

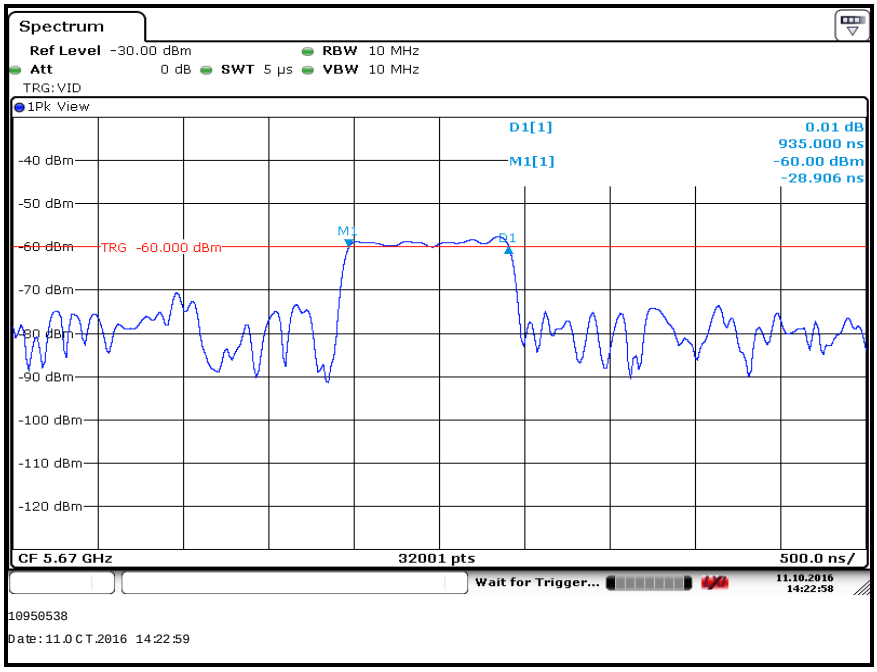
Below is an example plot of the type 0 radar burst at the DFS master port of the attenuation network. The signal generator was set to -14.8 dBm output and the correct path loss offset applied.



Type 0 Radar

Radar Verification

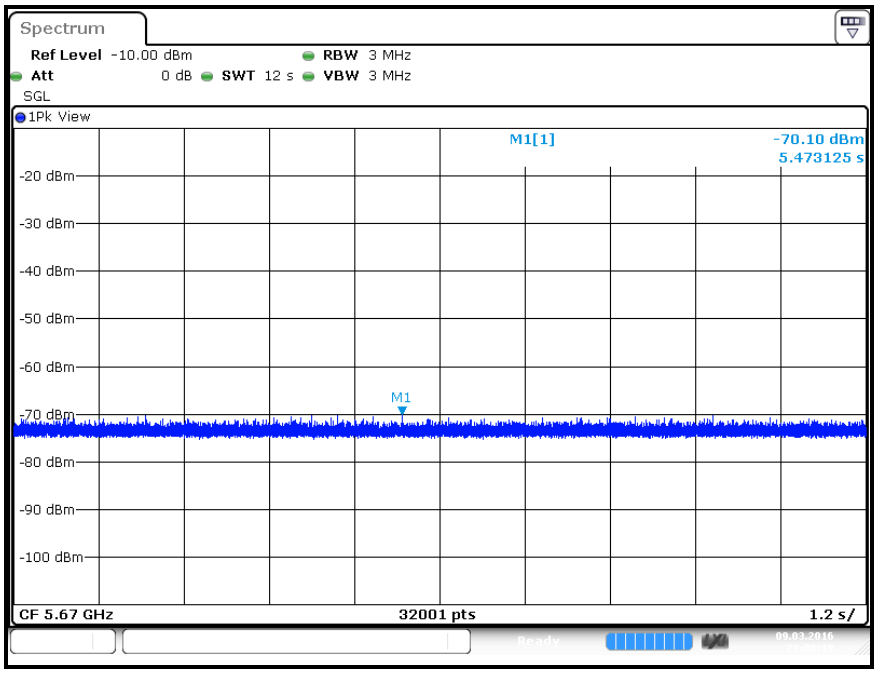
Below is a sample plot for Type 0 Radar. Note the timing of the pulses in the waveform may give slightly inaccurate amplitudes or durations due to the pulse desensitisation of the filters of the spectrum analyser which was used for testing. They are therefore accurate only as an example radar overview and for basic validation. A more accurate validation has been performed previously with more suitable equipment.



Type 0 Radar – Zoomed on a Pulse

Appendix 2. System Noise Floor Reference Plots

As required by Section 8.3.4(iii) of KDB 905462 D02, the following plot shows the reference noise floor of the system used during measurement. It also shows compliance with Section 8.3.7 of KDB 905462 D02 when the path loss of the coupling network shown in Section 4.2 *Configuration and Peripherals* is added to the noise floor.



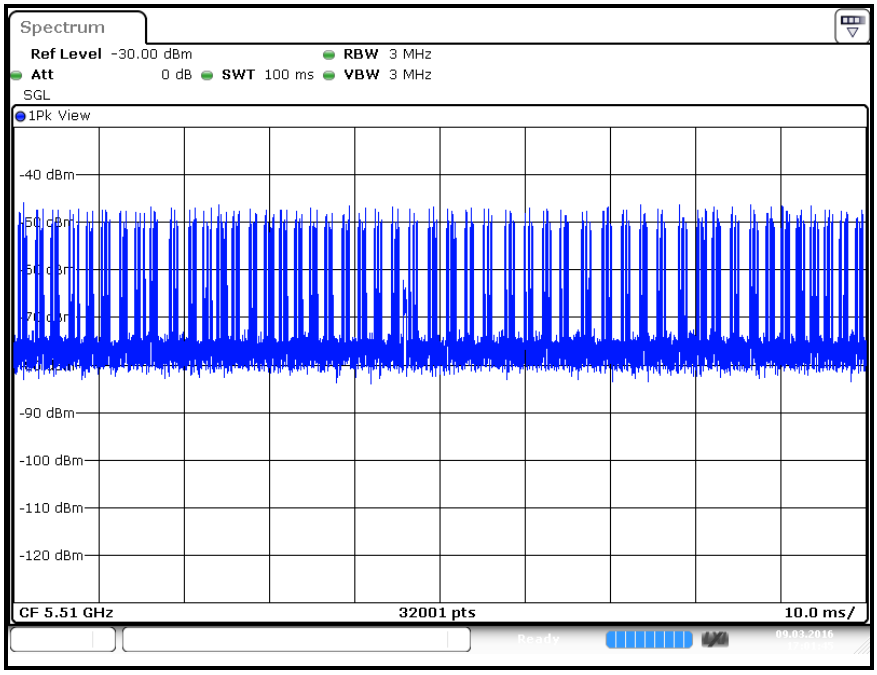
Noise Floor of Signal Analyser

Appendix 3. Channel Loading

As required by Section 8.3. 3 f) of KDB 905462 D02, the following plot and calculations shows the duty cycle of the channel used during testing.

Streaming representative file types as defined in Section 7.7 a) of KDB 905462 D02, were found not to produce a high enough duty cycle of >17%, as required by 7.7 c), on a 40 MHz channel bandwidth. This included lowest data rate with modulation coding scheme MCS0, maximum video size (1080p) and the minimum video compression ratio during encoding. Therefore alternative pseudo-random data transfer as per 7.7 b) was streamed to simulate data transfer. A suitable duty cycle was obtained with the link using a throughput-limited file transfer.

The duty cycle was calculated over 100 ms. This was captured on a signal analyser in the time domain using a 0 Hz span and 32001 sweep points to ensure it included any longer term variations whilst maintaining accurate to a 3.125 µs sample size.



The number of samples greater than -70 dBm were compared to the total number of samples to calculate the duty cycle. The EUT and test router were found to be transmitting above this threshold for 29.5 % of the total, and hence meeting the requirement of greater than 17 % channel loading.

Appendix 4. Channel/Frequency plan

Wi-Fi Supported Channels		
Country	**Channels**	
United States	20 MHz	40 MHz
	1 - 13 36 - 48 52 – 64 100 – 144 149 - 165	38 & 46 54 & 62 102 – 142 151 & 159
Canada	1 - 13 36 – 48 52 – 64 100 – 116 & 132 - 140 149 - 165	38 & 46 54 & 62 102, 110 & 134 151 & 159

Note(s):

1. FCC: Channels 120 – 128: Only used if DFS Master allows
2. Channels 36 – 48: Set to Indoor use only for Canada
3. The following channels are set to Active/Passive in FCC domain:

2.4 GHz Band
Channels 1 – 11: Active
Channels 12 – 13: Passive

5 GHz Band
Channels 36 – 48: Active
Channels 52 – 144: Passive DFS
Channels 149 – 165: Active

--- END OF REPORT ---