

Report on the Radio Testing
For
Ocado Innovation Limited
on
RCOM Bot Communication Module
Report no. TRA-048486-45-10A
16th September 2021

RF929



Report Number: TRA-048486-45-10A
Issue: A

REPORT ON THE RADIO TESTING OF A
Ocado Innovation Limited
RCOM Bot Communication Module
WITH RESPECT TO SPECIFICATION
DFS requirements of FCC 47CFR15E

TEST DATE: 2021-08-04

Written by:

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Date: 16th September 2021

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[2] THE RESULTS CONTAINED IN THIS DOCUMENT RELATE ONLY TO THE ITEM(S) TESTED

RF929

1 Revision Record

<i>Issue Number</i>	<i>Issue Date</i>	<i>Revision History</i>
A	16th September 2021	Original

2 Summary

TEST REPORT NUMBER:	TRA-048486-45-10A
WORKS ORDER NUMBER	TRA-048486-02
PURPOSE OF TEST:	Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J.
TEST SPECIFICATION:	47CFR15.407(h)
EQUIPMENT UNDER TEST (EUT):	RCOM Bot Communication Module
FCC IDENTIFIER:	2AGHF-RCOMBCM002
EUT SERIAL NUMBER:	P3631-BCM-A3158
MANUFACTURER/AGENT:	Ocado Innovation Limited
ADDRESS:	Trident Place, Hatfield Business Park, Mosquito Way, Hatfield, Hertfordshire, AL10 9UL United Kingdom
CLIENT CONTACT:	Ed Briggs ☎ 07557 860903 ✉ Ed.Briggs@Ocado.com
ORDER NUMBER:	IT-200528
TEST DATE:	2021-08-04
TESTED BY:	A Longley Element

2.1 Test Summary

Test Method and Description	Requirement Clause	Applicable to this equipment	Result / Note
	47CFR15		
TPC and DFS	15.407(h)	☒	PASS
U-NII detection bandwidth	15.407(h)(2)	☐	Note1
CAC	15.407(h)(2)(ii)	☐	Note1
In-service monitoring	15.407(h)(2)(iii) & 15.407(h)(2)(iv)	☒	PASS
Statistical performance check	-	☐	Note1

Notes:

1. This test was not applicable to a client device without radar detection.

The results contained in this report relate only to the items tested, in the condition at time of test, and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.

The apparatus was set-up and exercised using the configurations, modes of operation and arrangements defined in this report only. Any modifications made are identified in Section 8 of this report.

Particular operating modes, apparatus monitoring methods and performance criteria required by the standards tested to have been performed except where identified in Section 5.2 of this test report (Deviations from Test Standards).

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4 Introduction

This report TRA-048486-45-10A presents the results of the Radio testing on an Ocado Innovation Limited, RCOM Bot Communication Module to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Ocado Innovation Limited by Element, at the address detailed below.

☒	Element Hull Unit E South Orbital Trading Park Hedon Road Hull HU9 1NJ UK	☐	Element Skelmersdale Unit 1 Pendle Place Skelmersdale West Lancashire WN8 9PN UK
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This report details the configuration of the equipment, the test methods used and any relevant modifications where appropriate.

FCC Site Listing:

The test laboratory is accredited for the above sites under the US-EU MRA,

Designation number(s)

Element Hull	UK2007
Element Skelmersdale	UK2020

The test site requirements of ANSI C63.4-2014 are met up to 1GHz.

The test site SVSWR requirements of CISPR 16-1-4:2010 are met over the frequency range 1 GHz to 18 GHz.

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- FCC KDB Publication 905462 D02 v01r02 – Compliance measurement procedures for unlicensed-national information infrastructure devices operating in the 5250-5350 MHz and 5470-5725 MHz bands incorporating dynamic frequency selection.

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

§	denotes a section reference from the standard, not this document
AC	Alternating Current
ANSI	American National Standards Institute
BW	bandwidth
C	Celsius
CAC	Channel Availability Check
CFR	Code of Federal Regulations
CW	Continuous Wave
dB	decibel
dBm	dB relative to 1 milliwatt
DC	Direct Current
DFS	Dynamic Frequency Selection
DSSS	Direct Sequence Spread Spectrum
EIRP	Equivalent Isotropically Radiated Power
ERP	Effective Radiated Power
EUT	Equipment Under Test
FCC	Federal Communications Commission
FHSS	Frequency Hopping Spread Spectrum
Hz	hertz
IC	Industry Canada (now ISED)
ISED	Innovation, Science and Economic Development Canada
ITU	International Telecommunication Union
LBT	Listen Before Talk
LE-LAN	Licence-Exempt Local Area Network
m	metre
max	maximum
MIMO	Multiple Input and Multiple Output
min	minimum
MRA	Mutual Recognition Agreement
N/A	Not Applicable
PCB	Printed Circuit Board
PDF	Portable Document Format
Pt-mpt	Point-to-multipoint
Pt-pt	Point-to-point
PSD	Power Spectral Density
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
Rx	receiver
s	second
SVSWR	Site Voltage Standing Wave Ratio
TPC	Transmitter Power Control
Tx	transmitter
UKAS	United Kingdom Accreditation Service
U-NII	Unlicensed-National Information Infrastructure
V	volt
W	watt
Ω	ohm

7 Equipment Under Test

7.1 EUT Identification

- Name: RCOM Bot Communication Module
- Serial Number: P3631-BCM-A3158
- Model Number: BCM
- Software Revision: v10.0.73
- Build Level / Revision Number: A. 3

7.2 System Equipment

Equipment listed below forms part of the overall test setup and is required for equipment functionality and/or monitoring during testing. The compliance levels achieved in this report relate only to the EUT and not items given in the following list.

Lenovo Laptop and Netgear Ethernet Switch.

7.3 EUT Mode of Operation

7.3.1 Transmission

The EUT was set to transmit on the required channel.

7.3.2 Reception

The EUT was set to receive on the required channel.

7.4 EUT Radio Frequency Parameters

7.4.1 General

Frequency of operation:	5470 MHz – 5725 MHz
Modulation type(s):	OMDMA
Occupied channel bandwidth(s):	10 MHz
Channel spacing:	10 MHz
ITU emission designator(s):	8M97W7D
Declared output power(s):	21 dBm EIRP
Nominal Supply Voltage:	24 Vdc
Location of notice for license exempt use:	Label / user manual / both.
Method of prevention of use on non-US frequencies:	Country code in firmware (factory set)

7.4.2 Antennas

Frequency range:	5470 MHz to 5725 MHz
Impedance:	50 Ohm
Gain:	4 dBi (including loss of antenna assembly cable)
Polarisation:	Linear
Connector type:	SMA (reverse polarity)
Environmental limits:	0°C to 45°C
Mounting:	External

7.4.3 Product specific declarations

Multiple antenna configuration(s), e.g. MIMO:	Single Transmit antenna (dual receive antennas)
Fixed pt-pt operations (yes/no):	No

DFS Parameters:	
Antenna used for testing:	None (Antenna port A)
Antenna port impedance:	50 ohms
Channel loading / test file:	Master device used in test loaded to 47.5% duty
TPC description:	TPC at full power during test
System architectures, data rates, U-NII channel bandwidths:	Frame based proprietary
Clients: Radar detection Master U-NII Device FCC ID	2AGHF-RCOMBS002

7.5 EUT Description

The EUT is part of a point to multipoint short range radio communications system, identified as RCOM, which operates in the frequency band 5470MHz to 5725MHz. The wireless part of this system comprises of two parts, the BS – Base Station (EUT) and the BCM – Bot Control Module. One Base Station can be connected to many BCMs at any one time. The purpose of this radio system is to provide a low data rate, bi-directional, wireless connection to a large number of low speed factory floor machineries which transport goods, in a controlled manner, around the facility. These machineries are unmanned and the purpose of the wireless connection is to issue commands to the machineries and relay status information back, from each of the machineries, to a central point in the factory.

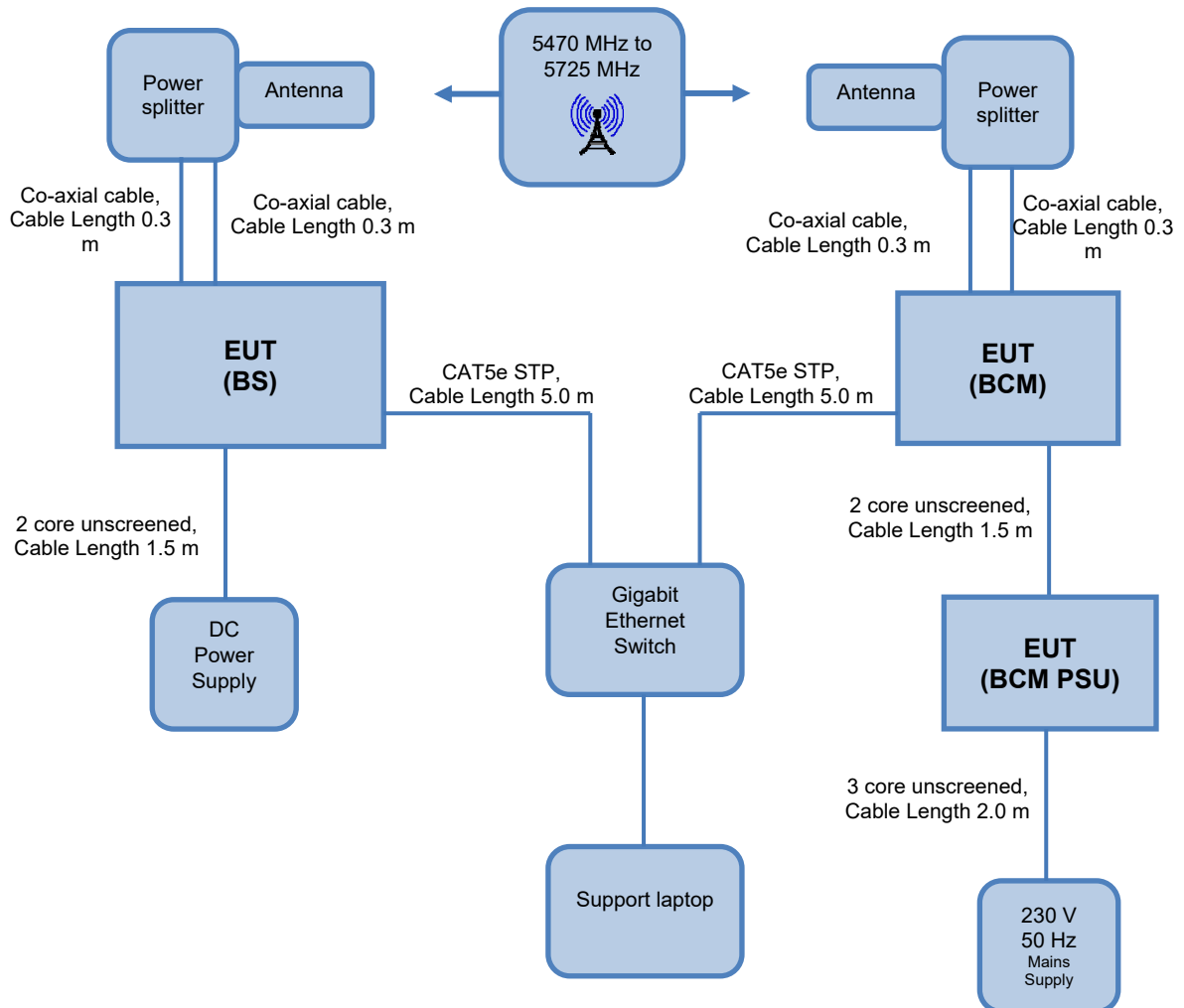
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

9.1 Block Diagram

The following diagram shows basic EUT interconnections with cable type and cable lengths identified:



10 General Technical Parameters

10.1 Normal Conditions

The E U T was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 24 Vdc from a bench top power supply connected to 230 Vac, 50 Hz from the mains.

10.2 Varying Test Conditions

No varying test conditions were used during these tests.

11 Dynamic Frequency Selection (DFS)

11.1 General

An U-NII network will employ a Dynamic Frequency Selection (DFS) function to detect interference from radar systems (radar detection) and to avoid co-channel operation with these systems.

Within the context of the operation of the DFS function, a U-NII device will operate in either *Master Mode* or *Client Mode*. U-NII devices operating in *Client Mode* can only operate in a network controlled by a U-NII device operating in *Master Mode*.

11.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	KDB 905462 D02, Clause 7.8
EUT Tested Channel Bandwidths:	10 MHz
EUT Test Channel Loading:	Test Master: Internal data pattern repeated every 20ms, 47.5% duty.
EUT Output Power Setting:	Max.
EUT Tested Modes:	Client
Deviations From Standard:	None
Temperature Extreme Environment Test Range:	N/A
Voltage Extreme Environment Test Range:	N/A

Environmental Conditions (Normal Environment)

Temperature: 23 °C	Usually: +15 °C to +35 °C
Humidity: 48 %RH	Usually: 20%RH to 75%RH
Supply: 24 Vdc	

11.3 Test Equipment

Equipment Description	Manufacturer	Equipment Type	Element No	Due For Calibration
Spectrum Analyser	Agilent	N9030A	REF2167	2021-08-19
DFS Test System	Aeroflex	PXI-1042	REF2152	Calibrate in Use

Test Limits

Refer to individual tests for applicable tables, as defined below.

Table 3: Interference threshold values

Maximum Transmit Power	Value (see notes 1, 2 and 3)
EIRP $\geq$ 200 mW	-64 dBm
EIRP < 200 mW and PSD < 10 dBm/MHz	-62 dBm
EIRP < 200 mW that do not meet the PSD 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 1 dB 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 2:	EIRP is based on the highest antenna gain. For MIMO devices refer to KDB Publication 662911 D01.

Table 4: DFS requirement values

Parameter	Value
Non-Occupancy Period	Min. 30 minutes
Channel Availability Check Time	60 s
Channel Move Time	10 s (see note 1).
Channel Closing Transmission Time	200 ms + an aggregate of 60 ms over remaining 10 s period (see notes 1 & 2).
U-NII Detection Bandwidth	Min. 100 % of the U-NII 99% transmission power bandwidth (see note 3).
Maximum Off-Channel CAC Time	4 hours (see note 2)
NOTE 1:	<i>Channel Move Time</i> and the <i>Channel Closing Transmission Time</i> should be performed with Radar Type 0. The measurement timing begins at the end of the Radar Type 0 burst.
NOTE 2:	The <i>Channel Closing Transmission Time</i> is comprised of 200 ms starting at the beginning of the <i>Channel Move Time</i> plus any additional intermittent control signals required to facilitate a channel move (an aggregate of 60 ms) during the remainder of the 10 s period. The aggregate duration of control signals will not count quiet periods in-between transmissions.
NOTE 3:	During the <i>U-NII Detection Bandwidth</i> detection test, radar type 0 should be used. For each frequency step the minimum percentage of detection is 90 %. Measurements are performed with no data traffic.

Table 5: Short pulse radar test signals

Radar type	Pulse width (μs)	PRI (μs)	Number of pulses	Min. % of successful detection	Min. number of trials
0	1	1428	18	See Note 1	See Note 1
1	1	Test A: 15 unique PRI values randomly selected from the list of 23 PRI values in Table 5a Test B: 15 unique PRI values randomly selected within the range of 518-3066 μ s, with a minimum increment of 1 μ s, excluding PRI values selected in Test A	Roundup: $1/360 \times 19.10^6/\text{PRI}$	60%	30
2	1-5	150-230	23-29	60%	30
3	6-10	200-500	16-18	60%	30
4	11-20	200-500	12-16	60%	30
Aggregate (Radar Types 1-4)				80%	120
NOTE 1: Short pulse radar type 0 should be used for detection bandwidth test, channel move time and channel closing time tests.					

Table 5a: Pulse repetition intervals for test A

<i>Pulse repetition frequency number</i>	<i>Pulse repetition frequency (pulses / s)</i>	<i>Pulse repetition interval (μs)</i>
1	1930.5	518
2	1858.7	538
3	1792.1	558
4	1730.1	578
5	1672.2	598
6	1618.1	618
7	1567.4	638
8	1519.8	658
9	1474.9	678
10	1432.7	698
11	1392.8	718
12	1355	738
13	1319.3	758
14	1285.3	778
15	1253.1	798
16	1222.5	818
17	1193.3	838
18	1165.6	858
19	1139	878
20	1113.6	898
21	1089.3	918
22	1066.1	938
23	326.2	3066

Table 6: Long pulse radar test signal

<i>Radar type</i>	<i>Pulse width (μs)</i>	<i>Chirp width (MHz)</i>	<i>PRI (μs)</i>	<i>Number of pulses per burst</i>	<i>Number of bursts</i>	<i>Min. % of successful detection</i>	<i>Min. number of trials</i>
5	50-100	5-20	1000-2000	1-3	8-20	80%	30

Table 7: Frequency hopping radar test signal

<i>Radar type</i>	<i>Pulse width (μs)</i>	<i>PRI (μs)</i>	<i>Pulses per hop</i>	<i>Hopping rate (kHz)</i>	<i>Hopping sequence length (ms)</i>	<i>Min. % of successful detection</i>	<i>Min. number of trials</i>
6	1	333	9	0.333	300	70%	30

11.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure i, the wanted signal (Gen A) was set to establish a reliable link (approx. 10 dB above receiver threshold). The interfering signal (Gen B) was then introduced at the specified Radar Detection Threshold level, plus 1dB.

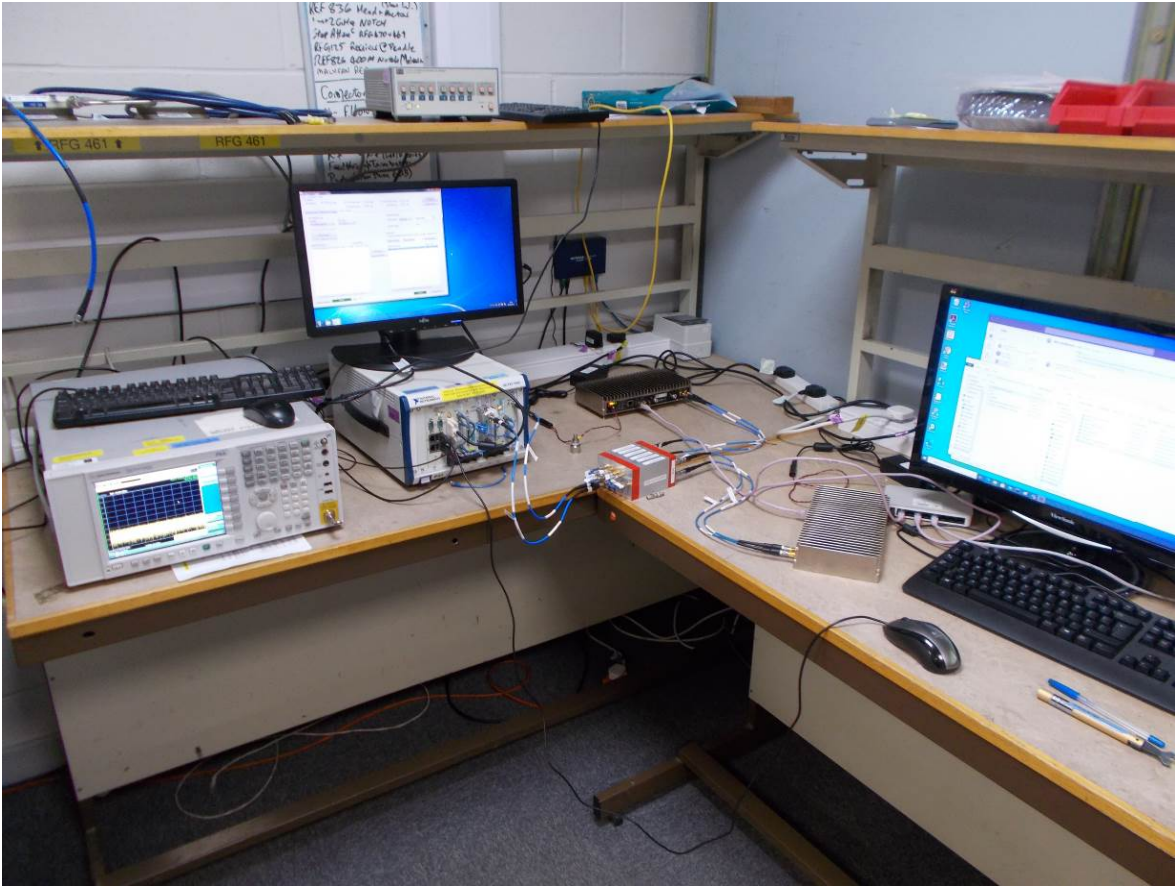
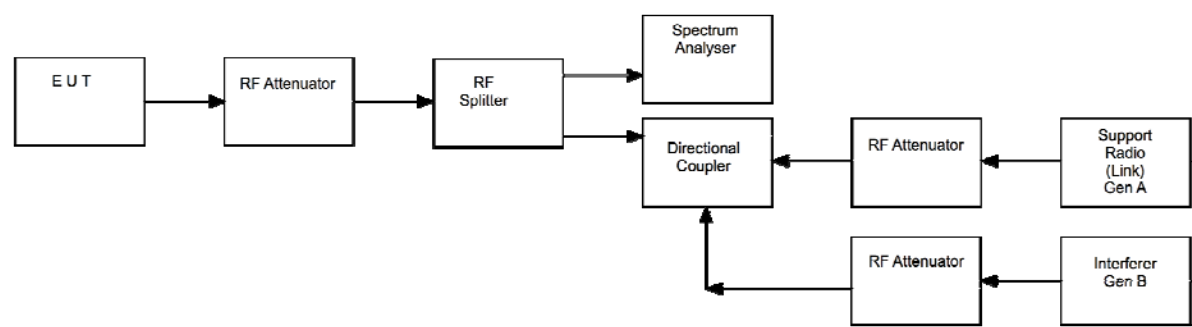
[1] Conducted method

Received power was measured at the antenna port. For multiple port devices, equal splitting was employed to ensure the same level was received at each antenna port.

[2] Radiated method

Received power was measured at the centre of the EUT.

Figure i Test Setup



11.5 Calibration

Antenna Gain

Declared antenna gain = 4 dBi (including loss of antenna assembly cable).

DFS Radar Waveforms

The RF attenuator nearest the EUT was set to provide sufficient attenuation not to overload the analyser whilst the EUT was at maximum power. The RF attenuator nearest the support radio was then set by increasing to the point where the EUT could no longer receive the signal (receiver threshold), then backing off 10dB. The RF attenuator nearest the signal generator was then set to provide sufficient isolation between the generator and the support radio.

The interferer (Gen B) was set to the centre of the test channel, Ch_r , in CW mode. The EUT was replaced with the spectrum analyser, whilst the analyser was replaced with a 50 ohm load. The level of the generator was adjusted to find the appropriate DFS threshold +1dB, adjusted for declared antenna gain 4dB, measured on the spectrum analyser. The analyser and EUT were then returned to position and an offset added to the analyser to read the same level as measured at the EUT.

Each radar signal required was then observed on the spectrum analyser in a 3MHz RBW with peak detector.

12 In-Service Monitoring

12.1 Definition

12.1.1 Channel Closing

The *Channel Closing* is defined as the process initiated by the U-NII device on an *Operating Channel* after a radar signal has been detected during the *In-Service Monitoring* on that channel.

The master device shall instruct all associated slave devices to stop transmitting on this channel, which they shall do within the *Channel Move Time*.

Slave devices with a Radar Interference Detection function, shall stop their own transmissions on an *Operating Channel* within the *Channel Move Time* upon detecting a radar signal within this channel.

The aggregate duration of all transmissions of the U-NII device on this channel during the *Channel Move Time* shall be limited to the *Channel Closing Transmission Time*. The aggregate duration of all transmissions shall not include quiet periods in-between transmissions.

For equipment having simultaneous transmissions on multiple (adjacent or non-adjacent) operating channels, only the channel(s) containing the frequency on which radar was detected is subject to the *Channel Closing* requirement. The equipment is allowed to continue transmissions on other *Operating Channels*.

12.1.2 Non-Occupancy Period

The *Non-Occupancy Period* is defined as the time during which the U-NII device shall not make any transmissions on a channel after a radar signal was detected on that channel.

For equipment having simultaneous transmissions on multiple (adjacent or non-adjacent) operating channels, only the channel(s) containing the frequency on which radar was detected is subject to the *Non-Occupancy Period* requirement. The equipment is allowed to continue transmissions on other *Operating Channels*.

After the *Non-Occupancy Period*, the channel needs to be identified again as an *Available Channel* before the U-NII device may start transmitting again on this channel.

12.2 Additional Test Parameters

EUT Test Channels, Ch _r .	5592.5 MHz
EUT Operating Channels / Bandwidths:	10 MHz
Master Uniform Spreading:	Disabled

Test Limits

The *Channel Move Time* shall not exceed the limit defined in table 4.

The *Channel Closing Transmission Time* shall not exceed the limit defined in table 4.

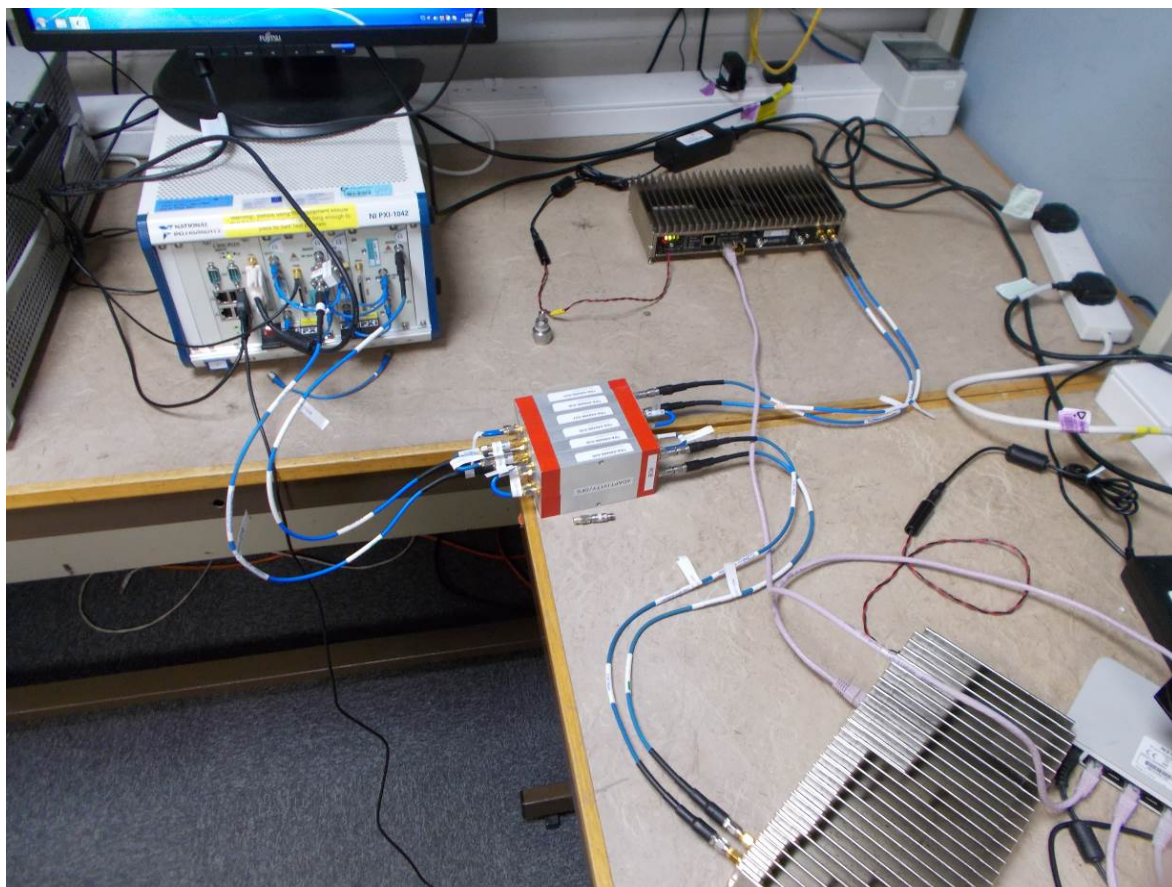
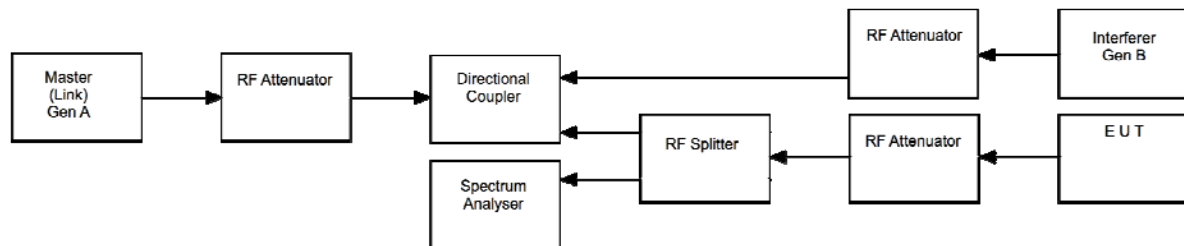
The *Non-Occupancy Period* shall not be less than the value defined in table 4.

12.3 Test Method

The EUT channel for both data and control signals, Ch_r , was selected, then transmissions to the paired device commenced. The interferer (Gen B) was set to the same frequency, Ch_r , and a radar test signal of table 5 (to appear at the Master at the threshold level + 1dB) then muted. The spectrum analyser was set to time domain (zero span) with sufficient bandwidth to capture all intentional emissions from the EUT. The analyser was then synchronised to the switching of the interferer – the interferer (Gen B) level was unmuted for a single burst. Transmissions from the EUT continued to be observed for a further 30 min.

Note, the set-up of figure ii was required to test slave mode, where the master is not the EUT.

Figure ii Test Setup



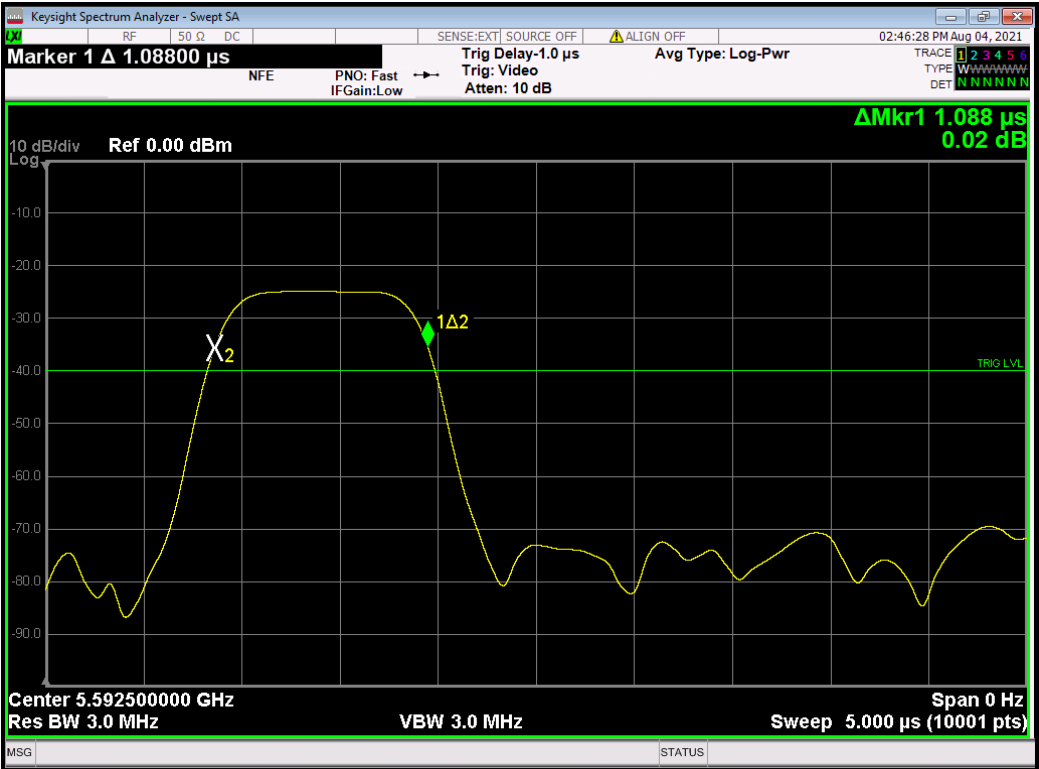
12.4 Test Equipment

<i>Equipment Description</i>	<i>Manufacturer</i>	<i>Equipment Type</i>	<i>Element No</i>	<i>Last Cal Calibration</i>	<i>Calibration Period</i>	<i>Due For Calibration</i>
DFS Test System	Aeroflex	PXI-1042	REF2152	2017-06-27	12	Calibrate in Use
Spectrum Analyser	Agilent	N9030A	REF2167	2020-08-19	12	2021-08-19

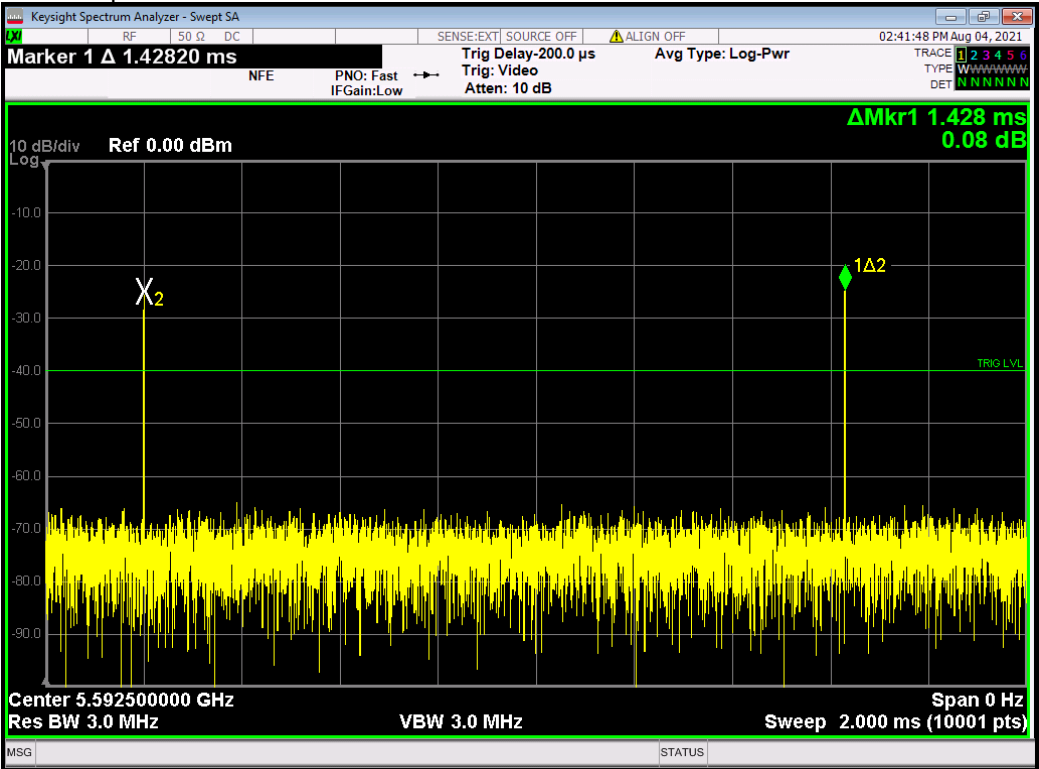
12.5 Test Results

Test signal plots for Type 0 pulse:

Pulse Width:



Pulse Repetition:



Bandwidth: 10 MHz					
Channel (MHz)	Interference level (dBm)	Channel move time (s)	Channel Closing Transmission Time (ms)	Transmissions during non-occupancy period	Result
5592.5	-48.5	0.105	2.52	None	PASS



13 Measurement Uncertainty

Radio Testing – General Uncertainty Schedule

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence where no required test level exists.

Reference No.	Parameter	Description	Value	Unit
1	Adjacent Channel Power	Uncertainty in test result	1.86	dB
2	Carrier Power	Uncertainty in test result (Power Meter)	0.070	dB
		Uncertainty in test result (Spectrum Analyser)	3.11	
3	Effective Radiated Power	Uncertainty in test result	4.71	dB
4	Radiated Spurious Emissions	Uncertainty in test result 30 MHz to 1 GHz	4.75	dB
		1 GHz to 18 GHz	4.46	
5	Maximum Frequency Error	Uncertainty in test result (CMTA)	113.441	Hz
6	Radiated Emissions, Field Strength OATS 9 kHz – 110 GHz Electric Field	Uncertainty in test result (9 kHz – 30 MHz)	2.3	dB
		Uncertainty in test result (30 MHz – 1 GHz)	4.75	
		Uncertainty in test result (1 GHz – 18 GHz)	4.46	
		Uncertainty in test result (18 GHz – 26 GHz)	3.2	
		Uncertainty in test result (26 GHz – 40 GHz)	3.3	
		Uncertainty in test result (40 GHz – 50 GHz)	3.5	
		Uncertainty in test result (50 GHz – 75 GHz)	3.6	
		Uncertainty in test result (75 GHz – 110 GHz)	3.6	
7	Frequency Deviation	Uncertainty in test result	3.7	%
8	Magnetic Field Emissions	Uncertainty in test result	2.3	dB
9	Conducted Spurious	Uncertainty in test result Up to 26 GHz	0.921	dB
10	Channel Bandwidth	Uncertainty in test result	15.71	%

Reference No.	Parameter	Description	Value	Unit
11	Spectrum Mask Measurements	Uncertainty in test result (frequency)	2.59	%
		Uncertainty in test result (amplitude)	1.32	dB
12	Adjacent Sub Band Selectivity	Uncertainty in test result	1.24	dB
13	Receiver Blocking – Listen Mode, Radiated	Uncertainty in test result	3.23	dB
14	Receiver Blocking – Talk Mode, Radiated	Uncertainty in test result	3.36	dB
15	Receiver Blocking – Talk Mode, Conducted	Uncertainty in test result	1.24	dB
16	Receiver Threshold	Uncertainty in test result	3.42	dB
17	Transmission Time Measurement	Uncertainty in test result	4.40	%