Tonal

TEST REPORT FOR

Apollo Board
Model: 500-0806

Tested to The Following Standards:

FCC Part 15 Subpart E Section(s)

15.407 (h)(2)
Radar Detection Function of Dynamic Frequency Selection (DFS)

Report No.: 110285-38

Date of issue: November 27, 2024

This test report bears the accreditation symbol indicating that the testing performed herein meets the test and reporting requirements of ISO/IEC 17025 under the applicable scope of testing for CKC Laboratories, Inc.

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Test Certificate # 803.01

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Administrative Information

Test Report Information

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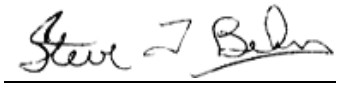
Project Number: 110285

DATE OF EQUIPMENT RECEIPT: October 14, 2024
DATE(S) OF TESTING: October 14-15, 2024

Report Authorization

The test data contained in this report documents the observed testing parameters pertaining to and are relevant for only the equipment provided by the client, tested in the agreed upon operational mode(s) and configuration(s) as identified herein. Compliance assessment remains the client's responsibility. This report may not be used to claim product endorsement by A2LA or any government agencies. This test report has been authorized for release under quality control from CKC Laboratories, Inc.



Steve Behm
Director of Quality Assurance & Engineering Services
CKC Laboratories, Inc.

Test Facility Information

Our laboratories are configured to effectively test a wide variety of product types. CKC utilizes first class test equipment, anechoic chambers, data acquisition and information services to create accurate, repeatable and affordable test results.

TEST LOCATION(S):
CKC Laboratories, Inc.
1120 Fulton Pl,
Fremont, CA 94539

Software Versions

CKC Laboratories Proprietary Software	Version
EMITest Emissions	5.03.19

Site Registration & Accreditation Information

Location	*NIST CB #	FCC	Canada	Japan
Canyon Park, Bothell, WA	US0103	US1024	3082C	A-0136
Brea, CA	US0103	US1024	3082D	A-0136
Fremont, CA	US0103	US1024	3082B	A-0136
Mariposa, CA	US0103	US1024	3082A	A-0136

*CKC's list of NIST designated countries can be found at: https://standards.gov/cabs/designations.html

Summary of Results

Standard / Specification: FCC Part 15 Subpart E - 15.407(h)(2) (UNII) 5.25-5.35 GHz and 5.47-5.725 GHz bands

Requirement	Test Procedure Clause	Description	Mods	Results
15.407(h)(2)	7.5	DFS Detection Threshold (master & client with radar detection)	NA	NA1
15.407(h)(2)	7.8.1	UNII Detection Bandwidth (master & client with radar detection)	NA	NA1
15.407(h)(2)(i)(A) 15.407(h)(2)(ii)	7.8.2.1 7.8.2.2 7.8.2.3	Channel Availability Check Time. (master & client with radar detection)	NA	NA1
15.407(h)(2)(i)(B) 15.407(h)(2)(iii)	7.8.3	Channel Move Time, Channel Closing Time (master, client with radar detection, client without radar detection)	NA	Pass
15.407(h)(2)(iv)	7.8.3	Non-Occupancy Period (master & client with radar detection client without radar detection)	NA	Pass
5.1 Table 2*	7.8.4	Statistical Performance Check (master & client with radar detection)	NA	NA1
7.7*	7.7	Channel Loading (master and client with radar detection)	NA	NA1

NA = Not Applicable
NA1 = The manufacturer declares test is not applicable because the device is not a Master nor Client with radar detection.
*KDB requirement.

ISO/IEC 17025 Decision Rule
The equipment sample utilized for testing is selected by the manufacturer. The declaration of pass or fail herein is a binary statement for simple acceptance rule (ILAC G8) based upon assessment to the specification(s) listed above, without consideration of measurement uncertainties. For performance related tests, equipment was monitored for specified criteria identified in that section of testing.

Modifications During Testing

This list is a summary of the modifications made to the equipment during testing.

Summary of Conditions
No modifications were made during testing.

Modifications listed above must be incorporated into all production units.

Conditions During Testing

This list is a summary of the conditions noted to the equipment during testing.

Summary of Conditions
The EUT 's PCB is placed on the test bench. The RF connector is connected to support DFS master via RF combiner and attenuators network. Attenuators were adjusted to present best signal to noise ratio and clarity to identify signal from master, client and radar pulse.
See Appendix A and B for Test Setup Block Diagrams

Test Procedure
The DFS testing presented in this report is perform in accordance with the following test procedure to meet the requirement. 905462 D02 UNII DFS Compliance Procedures New Rules v02. April 8, 2016. Each clause of the test procedure is identified in specific section of this report.

Equipment Under Test (EUT)

During testing, numerous configurations may have been utilized. The configurations listed below support compliance to the standard(s) listed in the Summary of Results section.

Configuration 1

Equipment Tested:

Device	Manufacturer	Model #	S/N
Apollo Board	Tonal	500-0806	NA

Support Equipment:

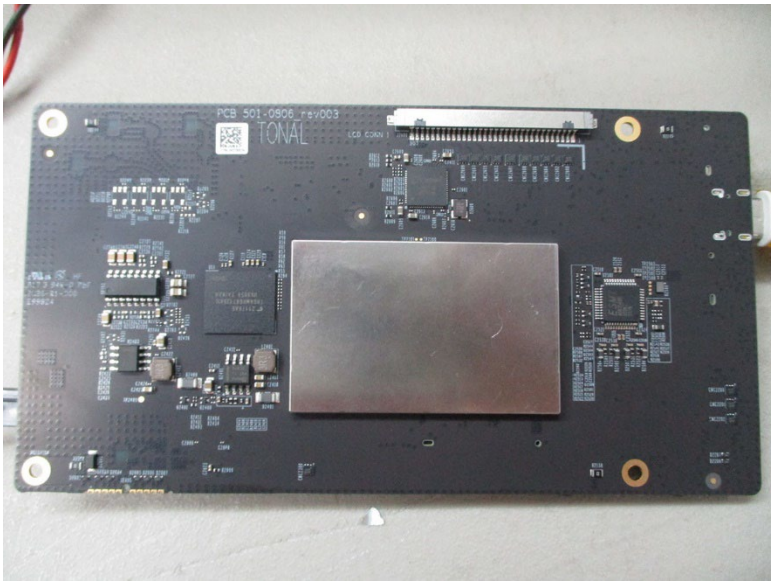
Device	Manufacturer	Model #	S/N
Laptop	Dell	XPS	22E00911
Laptop	Lenovo	R61	L3—B7192
Laptop	Lenovo	E530	AN03319
Wireless Router	Netgear	R7800	NA

General Product Information:

Product Information	Manufacturer-Provided Details
Equipment Type:	Stand-Alone Equipment
Operational Mode(s):	☐ Master ☐ Client with Radar Detection ☒ Client without Radar Detection
FCCID of Master Used for Testing:	Client mode was tested with FCCID: PY315100319
Network Type:	☐ Bridge ☐...Mesh ☒ Access Point
System Architecture:	802.11a/n20/n40/20ac/40ac/80ac
Operating Frequency Range(s):	☒ 5150-5250 MHz ☒ 5250-5350 MHz ☒ 5470-5725 MHz ☒ 5725-5850 MHz
Modulation Type(s):	802.11a (BPSK, QPSK,16QAM,64QAM) 802.11n HT20 (BPSK, QPSK, 16QAM,64QAM) 802.11n HT40 (BPSK, QPSK, 16QAM,64QAM) 802.11ac VHT20 (BPSK, QPSK, 16QAM,64QAM, 256QAM) 802.11ac VHT40 (BPSK, QPSK, 16QAM,64QAM, 256QAM) 802.11ac VHT80 (BPSK, QPSK, 16QAM,64QAM, 256QAM)
Channel bandwidth(s):	☒ 20 MHz ☒ 40 MHz ☒ 80 MHz ☐ 160MHz contiguous ☐ 80 MHz+80MHz noncontiguous
Maximum Duty Cycle:	100%
Number of TX/RX Chains:	2 Note: The manufacturer declared MIMO is not enabled, completely uncorrelated transmission.
Antenna Type(s) and Gain:	External 4.66dBi
Antenna cable loss	NA
Beamforming Capable:	NA
Antenna Connection Type:	External Connector
Antenna Impedance (ohm):	50
Nominal Input Voltage:	12Vdc
Manufacturer Statement:	The manufacturer has confirmed that information regarding the parameters of the detected Radar Waveforms is not available to the end user.
Firmware / Software used for Test:	QRCT (Qualcomm Radio Control Toolkit) Version 4
The validity of results is dependent on the stated product details, the accuracy of which the manufacturer assumes full responsibility.	

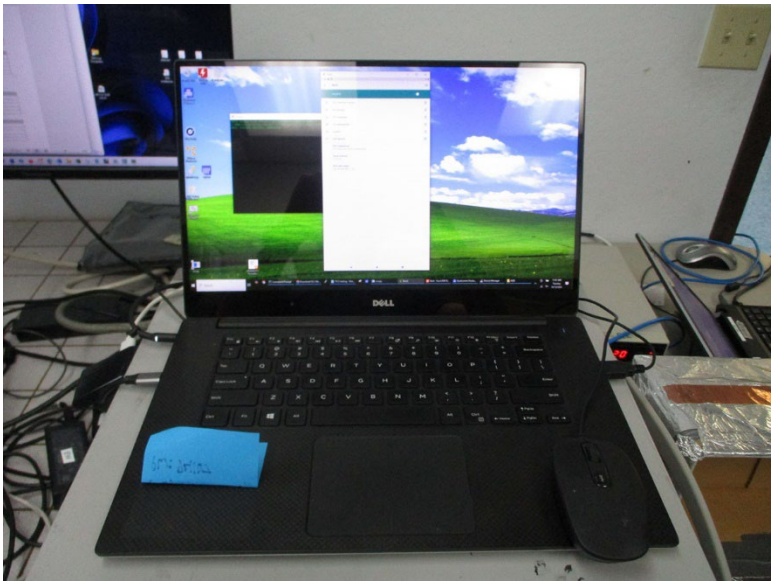
EUT and Support Equipment Photo(s)

EUT, View 1



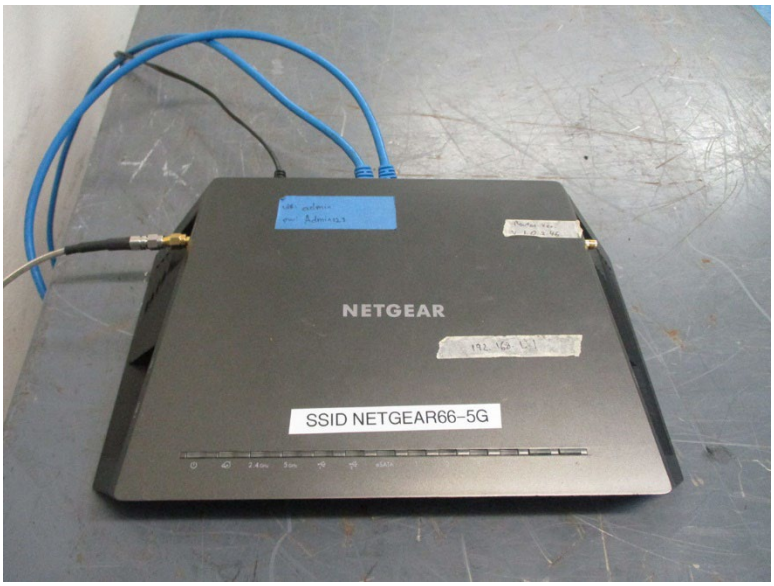
EUT, View 2

Support Equipment Photo(s)



Support Equipment, Laptop #1

Support Equipment, Laptop #2



Support Equipment, Wireless Router

Test Equipment					
Asset#	**Description**	**Manufacturer**	**Model**	**Cal Date**	**Cal Due**
03592	Vector Signal Generator	Keysight	N5182B	1/26/2024	1/26/2026
02660	Spectrum Analyzer	Agilent	E4446A	12/6/2022	12/6/2024
03011	Cable	AstroSteel	32022-2-2909K-24TC	3/23/2023	3/23/2025
P07697	Cable	Huber+Suhner	32022-29094K-29094K-72TC	08/16/2024	8/16/2026
P07134	Attenuator	Weinschel	3M10	NCR	NCR
P07135	Attenuator	Weinschel	3M10	NCR	NCR
P07181	Attenuator	Weinschel	3M30	NCR	NCR
P07182	Attenuator	Weinschel	3M30	NCR	NCR
P08023	Power Divider	Anaren	41130	8/10/2023	8/10/2025
P08024	Power Divider	Anaren	40510	8/10/2023	8/10/2025

NCR = No Calibration Required

Environmental Conditions			
Temperature (ºC)	24	Relative Humidity (%):	49

Unless otherwise noted, all test performed under the listed environmental condition.

Waveform information.
The waveforms used are commercially available pre-defined DFS waveform per Agilent N7607B Signal Studio for DFS radar profile. The waveforms meeting the following requirement.
USA : FCC15.407, FCC-13-22

FCC Part 15 Subpart E

Requirements

Table 1: 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
U-NII Detection Bandwidth	Yes	Not required	Yes

Table 2: 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 Performance 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.		

Table 3: DFS Detection Thresholds for Master Devices and Client Devices with Radar Detection

Maximum Transmit Power	Value (See Notes 1, 2, and 3)
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 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. **Note3:** EIRP is based on the highest antenna gain. For MIMO devices refer to KDB Publication 662911 D01.	

Table 4: 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.	

15.407(h)(2)(i)(B) Channel Move Time, Channel Closing Time
15.407(h)(2)(iv) Non-Occupancy Period

Channel Move / Closing Time and Non-Occupancy Period

Master

Client with Radar Detection

Client without Radar Detection

Test Setup/Conditions			
Test Location:	Fremont Lab Bench	Test Engineer:	E. Wong
Test Method:	7.8.3	Test Date(s):	10/14/2024
Configuration:	Configuration 1		
Test Setup:	Conducted In-Service Monitoring was evaluated as illustrated in test setup diagram. The Test frequency contains control signals. A spectrum analyzer with Peak detector activated, set at zero span and RBW and VBW >3 MHz. Except for Non-Occupancy time, In-Service monitoring was evaluated with the Widest bandwidth mode available for the link. (in this case, BW= 20MHz) Radar burst at required test level was triggered and the time to vacate the channel and remained unoccupied was evaluated. Plot and Spectrum analyzer trace data was captured with maximum available BIN, the trace data is imported to Analysis application to detect channel move time and channel closing time. Time above Threshold (T1 to T1+200ms) and (T1+200ms to Ts+10s) meet required maximum timing requirements. Test performed with widest BW mode available for the link with the support Access point, which is 20MHz, radar inject and monitored at 5280MHz, the service channel is set at 5280MHz. For Channel move and Channel closing time Sweep at 11sec, there was no transmission detected after 1 second, second acquisition performed at 2 second sweep time. Time analyses perform with 2 sec sweep. DFS channel 56, 5280MHz, Channel loading 31%, 10Mb file. For non-occupancy period time plot, 1080 P video file was used for higher data visibility.		

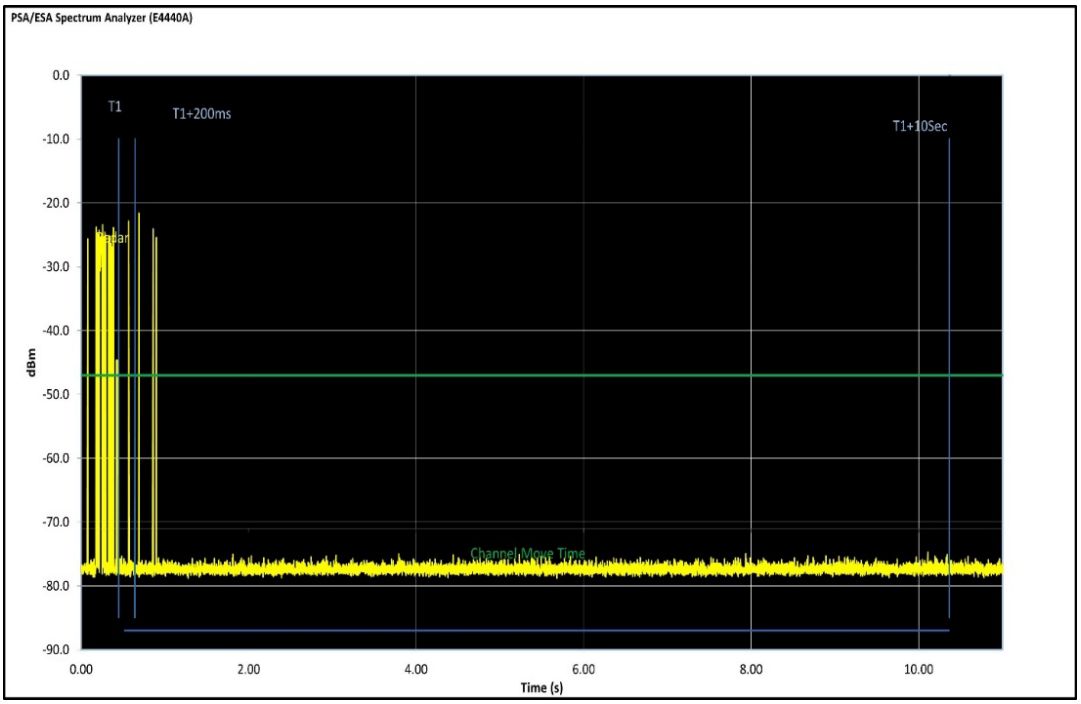
Test Data Summary						
Frequency (MHz)	**Protocol**	**Waveform Type**	**Channel Test**	**Measured Time**	**Limit**	**Results**
5280	802.11n20	0	Move[1]	1.2ms	<10 s	Pass
5280	802.11n20	0	T1 - Closing[1,2]	1.2 ms	<200ms	Pass
5280	802.11n20	0	CS - Closing[1,2]	3.2 ms	<60 ms/10s	Pass
5280	802.11n20	0	Non-Occupancy[3]	NA	>30 min	Pass

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. This test is required for Master and Client with Radar Detection.

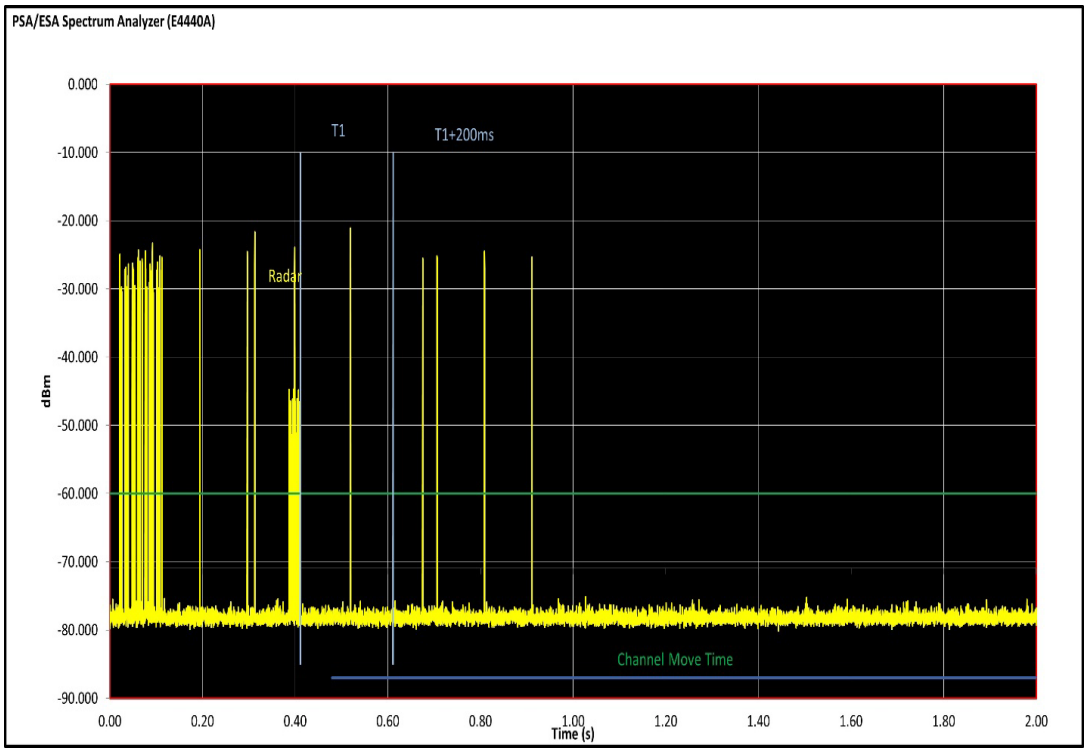
Fail: Transmission detected within 30 minutes after Radar burst.

Pass: No transmission within 30 minutes after Radar burst.

Plot(s)



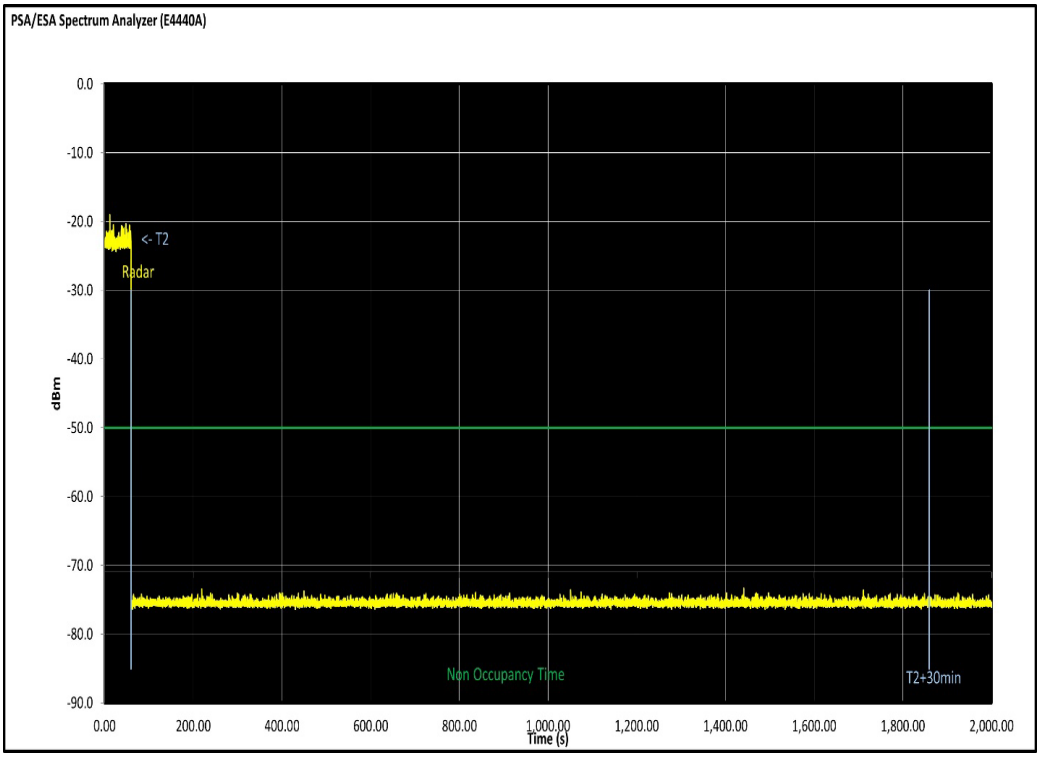
Transmission with radar pulse at T1, 466ms, 11 sec sweep



Transmission with radar pulse at 411ms 2 sec sweep

BIN T1+200ms	5
Time T1+200ms ms	1.2

BIN after T1+200ms to 10sec	13
Aggregate time (T1+200ms, to 10 sec) ms	3.2



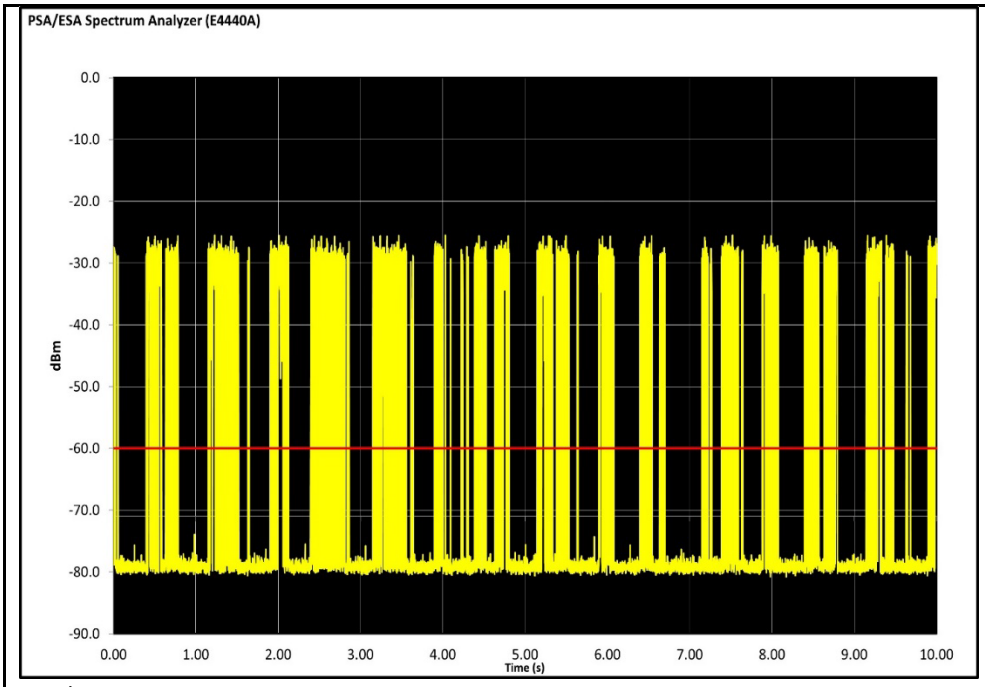
Non-Occupancy time 2000sec sweep

Channel Loading

Test Setup/Conditions			
Test Location:	Fremont Lab Bench	Test Engineer:	E. Wong
Test Method:	7.7	Test Date(s):	10/15/2024
Configuration:	1		
Test Setup:	Conducted Channel loading was measured as illustrated in test setup diagram. A spectrum analyzer with Peak detector activated, set at zero span and RBW and VBW >3 MHz. Channel loading of each protocol is evaluated. Data transfer: MPEG file is loaded on Laptop1 which is connected to the Ethernet port of a host with the Master device installed. Laptop 2 is connected to the client device via Ethernet port. Communication established between the master and client, Scrcpy App installed in a laptop with the EUT connected (client device) plays the MPEG file stored in laptop1 (Master device) via steaming mode. Filename: DFS Video 10 Mbps. Trace captured and analyzed with excel spread sheet. Channel loading is measured by Time On/ (Time On + Time Off), equivalently (BIN above Threshold/ total BIN)		

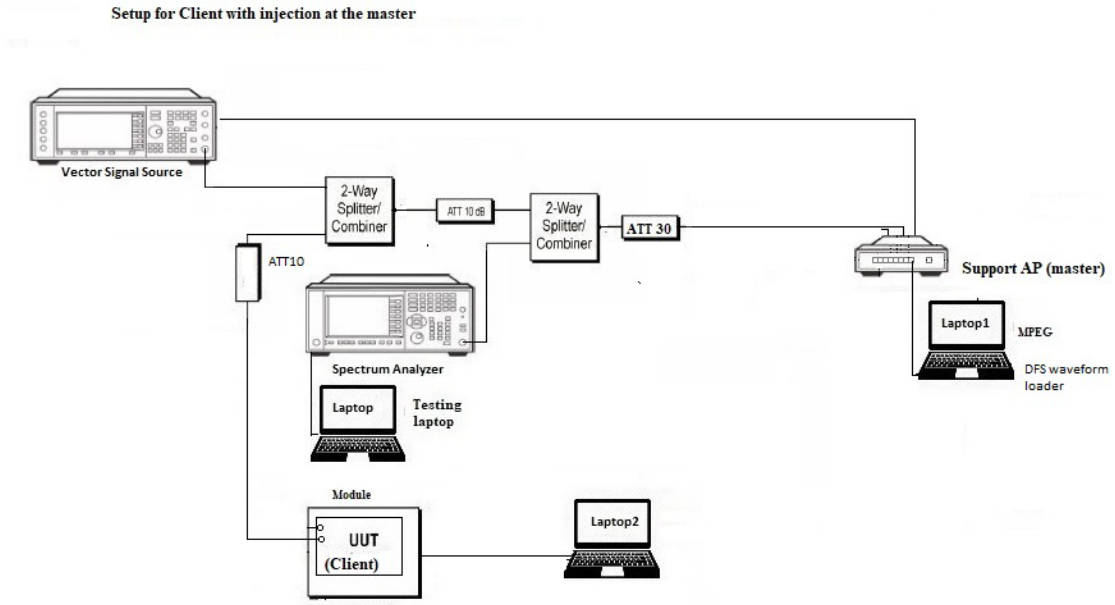
Test Data Summary				
Frequency (MHz)	**Protocol**	**Loading (%)**	**Limit (%)**	**Results**
5280	802.11n20, 10Mbs	31.5	> 17	Pass

Plot(s)



Total BIN	8192
BIN above Threshold	2567
Channel loading	31.3%

Appendix A: Test Equipment Setup Block Diagram



Appendix B: Detection Threshold Diagram

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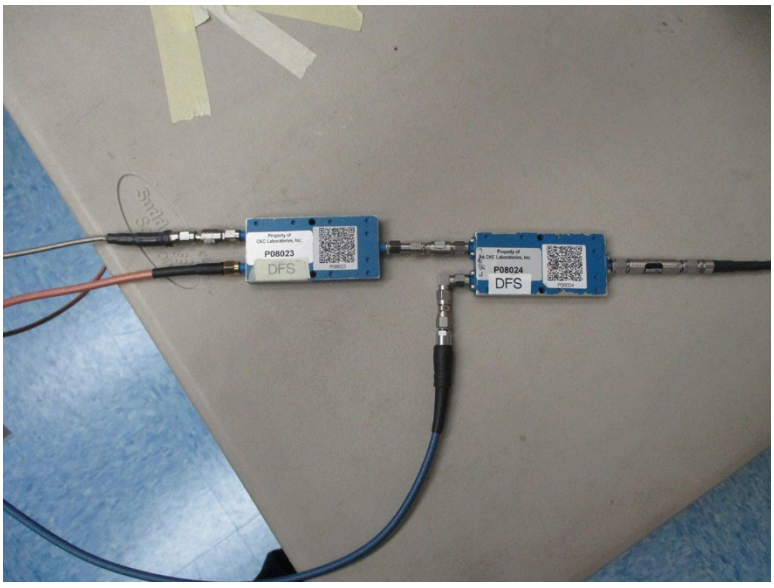
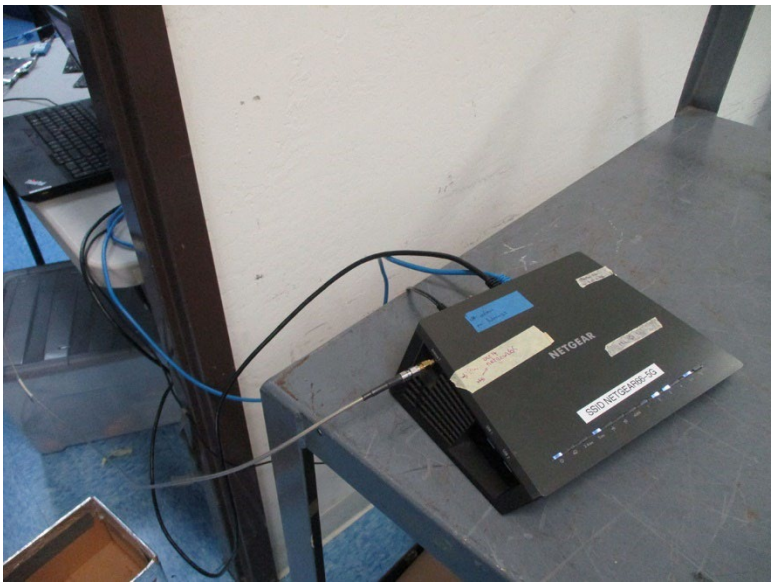
Appendix C: Test Setup Photos

Test Setup, View 1



Test Setup, View 2



Test Setup, View 3

Appendix D: Statistical Performance Test Waveform Radar Type 1-6 for 20MHz, 40 MHz and 80MHz

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Appendix E: Radar Waveform Requirement

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Appendix F: Measurement Uncertainty

Measurement Uncertainty

Uncertainty Value	Parameter
4.73 dB	Radiated Emissions
3.34 dB	Mains Conducted Emissions
3.30 dB	Disturbance Power

Uncertainties reported are worst case for all CKC Laboratories' sites and represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor of k=2.

End of Report