

ADDENDUM - DFS

Test of: Sonos Inc S23

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1. TEST SUMMARY

List of Measurements for Client Device

Test Header	Result	Data Link
Dynamic Frequency Selection (DFS) – Client Device	Complies	--
Channel Availability Check	Not Tested	--
Initial CAC	Not Tested	--
Beginning CAC	Not Tested	--
End CAC	Not Tested	--
Channel Close / Transmission Time	Complies	View Data
Non-Occupancy Period	Complies	View Data
Probability of Detection	Not Tested	--
Detection Bandwidth	Not Tested	--

2. DYNAMIC FREQUENCY SELECTION (DFS)

2.1. Overview

2.1.1 Test Requirements

A U-NII network will employ a DFS function to detect signals from radar systems and to avoid co-channel operation with these systems. This applies to the 5250-5350 MHz and/or 5470-5725 MHz bands. 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. The following tables summarize the requirements.

Requirement	Master Device or Client with Radar Detection	Client without Radar Detection
	Operational Mode	
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 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.

The operational behavior and individual DFS requirements associated with these modes are as follows:

2.1.2 Client Devices

- a) A Client Device will not transmit before having received appropriate control signals from a Master Device.
- b) A Client Device will stop all its transmissions whenever instructed by a Master Device to which it is associated and will meet the Channel Move Time and Channel Closing Transmission Time requirements. The Client Device will not resume any transmissions until it has again received control signals from a Master Device.
- c) If a Client Device is performing In-Service Monitoring and detects a Radar Waveform above the DFS Detection Threshold, it will inform the Master Device. This is equivalent to the Master Device detecting the Radar Waveform and d) through f) of section 5.1.1 apply.
- d) Irrespective of Client Device or Master Device detection the Channel Move Time and Channel Closing Transmission Time requirements remain the same.
- e) The client test frequency must be monitored to ensure no transmission of any type has occurred for 30 minutes. Note: If the client moves with the master, the device is considered compliant if nothing appears in the client non-occupancy period test. For devices that shutdown (rather than moving channels), no beacons should appear.

2.1.3 DFS Detection Thresholds

The table below provides the DFS Detection Thresholds for Master Devices as well as Client Devices incorporating In-Service Monitoring.

DFS Detection Thresholds for Master Devices and Client Devices with Radar Detection

Maximum Transmit Power	Value (see Notes 1, 2 and 3)
EIRP \geq 200 milliwatt	-64 dBm
EIRP 200 milliwatt and power 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.

NOTE 3: EIRP is based on the highest antenna gain. For MIMO devices refer to KDB Publication 662911 D01.

2.1.4 Response Requirements

The following table provides the response requirements for Master and Client Devices incorporating DFS.

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.

2.1.5 Radar Test Waveforms

This section provides the parameters for required test waveforms, minimum percentage of successful detections, and the minimum number of trials that must be used for determining DFS conformance. Step intervals of 0.1 microsecond for Pulse Width, 1 microsecond for PRI, 1 MHz for chirp width and 1 for the number of pulses will be utilized for the random determination of specific test waveforms.

2.1.5.1 Short Radar Pulses

Short Pulse Radar Test Waveforms

Radar Type	Pulse Width (μS)	PRI (μS)	Number of Pulses	Minimum Percentage of Successful Detection	Minimum 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	Roundup $\left\{ \left(\frac{1}{360} \right) \cdot \left(\frac{19 \cdot 10^6}{\text{PRI}_{\mu\text{sec}}} \right) \right\}$	60%	30
		Test B: 15 unique PRI values randomly selected in the range 518-3066 μS, with a minimum increment of 1 μS, excluding PRI values selected in Test A			
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 Radar Pulse Type 0 should be used for the Detection Bandwidth test, Channel Move Time and Channel Closing Time tests					

A minimum of 30 unique waveforms are required for each of the Short Pulse Radar Types 2 through 4. If more than 30 waveforms are used for Short Pulse Radar Types 2 through 4, then each additional waveform must also be unique and not repeated from the previous waveforms. If more than 30 waveforms are used for Short Pulse Radar Type 1, then each additional waveform is generated with Test B and must also be unique and not repeated from the previous waveforms in Tests A or B.

2.1.5.2 Long Radar Pulse Test

Long Pulse Radar Test Waveforms

Radar Type	Pulse Width (µsec)	Chirp Width (MHz)	PRI (µsec)	Number of Pulses per Burst	Number of Bursts	Minimum Percentage of Successful Detection	Minimum Trials
5	50-100	5-20	1000-2000	1-3	8-20	80%	30

The parameters for this waveform are randomly chosen. Thirty unique waveforms are required for the Long Pulse radar test signal. If more than 30 waveforms are used for the Long Pulse radar test signal, then each additional waveform must also be unique and not repeated from the previous waveforms.

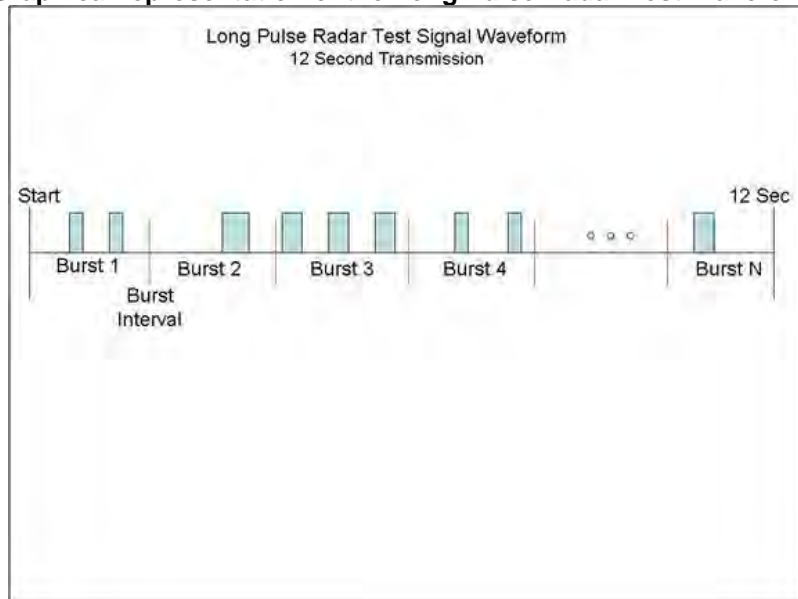
Each waveform is defined as follows:

1. The transmission period for the Long Pulse Radar test signal is 12 seconds.
2. There are a total of 8 to 20 Bursts in the 12 second period, with the number of Bursts being randomly chosen. This number is Burst Count.
3. Each Burst consists of 1 to 3 pulses, with the number of pulses being randomly chosen. Each Burst within the 12 second sequence may have a different number of pulses.
4. The pulse width is between 50 and 100 microseconds, with the pulse width being randomly chosen. Each pulse within a Burst will have the same pulse width. Pulses in different Bursts may have different pulse widths.
5. Each pulse has a linear FM chirp between 5 and 20 MHz, with the chirp width being randomly chosen. Each pulse within a Burst will have the same chirp width. Pulses in different Bursts may have different chirp widths. The chirp is centered on the pulse. For example, with a radar frequency of 5300 MHz and a 20 MHz chirped signal, the chirp starts at 5290 MHz and ends at 5310 MHz.
6. If more than one pulse is present in a Burst, the time between the pulses will be between 1000 and 2000 microseconds, with the time being randomly chosen. If three pulses are present in a Burst, the time between the first and second pulses is chosen independently of the time between the second and third pulses.
7. The 12 second transmission period is divided into even intervals. The number of intervals is equal to Burst_Count. Each interval is of length $(12,000,000 / \text{Burst_Count})$ microseconds. Each interval contains one Burst. The start time for the Burst, relative to the beginning of the interval, is between 1 and $[(12,000,000 / \text{Burst_Count}) - (\text{Total Burst Length}) + (\text{One Random PRI Interval})]$ microseconds, with the start time being randomly chosen. The step interval for the start time is 1 microsecond. The start time for each Burst is chosen independently.

A representative example of a Long Pulse radar test waveform:

1. The total test signal length is 12 seconds.
2. 8 Bursts are randomly generated for the Burst_Count
3. Burst 1 has 2 randomly generated pulses.
4. The pulse width (for both pulses) is randomly selected to be 75 microseconds.
5. The PRI is randomly selected to be at 1213 microseconds.
6. Bursts 2 through 8 are generated using steps 3 – 5.
7. Each Burst is contained in even intervals of 1,500,000 microseconds. The starting location for Pulse 1, Burst 1 is randomly generated (1 to 1,500,000 minus the total Burst 1 length + 1 random PRI interval) at the 325,001 microsecond step. Bursts 2 through 8 randomly fall in successive 1,500,000 microsecond intervals (i.e. Burst 2 falls in the 1,500,001 – 3,000,000 microsecond range).

Graphical representation of the Long Pulse Radar Test Waveform.



2.1.5.3 Frequency Hopping Radar Test Waveform

Radar Type	Pulse Width (μsec)	PRI (μsec)	Pulses per Hop	Hopping Rate (kHz)	Hopping Sequence Length (msec)	Minimum Percentage of Successful Detection	Minimum Trials
6	1	333	9	.333	300	70%	30

For the Frequency Hopping Radar Type, the same Burst parameters are used for each waveform. The hopping sequence is different for each waveform and a 100-length segment is selected from the hopping sequence defined by the following algorithm:

The first frequency in a hopping sequence is selected randomly from the group of 475 integer frequencies from 5250 – 5724 MHz. Next, the frequency that was just chosen is removed from the group and a frequency is randomly selected from the remaining 474 frequencies in the group. This process continues until all 475 frequencies are chosen for the set. For selection of a random frequency, the frequencies remaining within the group are always treated as equally likely.

2.6.6 Radar Waveform Calibration

The following equipment setup was used to calibrate the Radar Waveform. A spectrum analyzer was used to establish the test signal level for each radar type. During this process there were no transmissions by either the Master or Client Device. The spectrum analyzer was switched to the zero span (Time Domain) mode at the frequency of the Radar Waveform generator. Peak detection was utilized. The spectrum analyzer resolution bandwidth (RBW) and video bandwidth (VBW) were set to 3 MHz.

The signal generator amplitude was set so that the power level measured at the spectrum analyzer was equal to the DFS detection threshold +1dB (Ref Section 9.2).

2.1.6 Test Program Details

EUT Type: Client, no radar detection

Frequency band(s): 5,250 - 5,350 MHz and 5,470 – 5,725 MHz

Uniform Loading: For the above frequency band(s) the manufacturer declared that the device provides an aggregate uniform loading of the spectrum across all devices by selecting an operating channel among the available channels using a random algorithm.

Test Environment: Conducted

Antenna Gain used for Testing: Client Device Only dBi

Radio parameters: Transmit Power: Maximum Data Rate: 6 Mbit/s Duty Cycle: 18%

Number of Antenna Chains: 4

Test Communication Throughput Methodology

The requisite MPEG video file ("TestFile.mpg" available on the NTIA website at the following link <http://ntiacsd.ntia.doc.gov/dfs/>) is used during this video stream.

EUT Software Version: 52.10-64150-1-29

EUT Build number: Information not available

Test Environmental Conditions - Ambient:

Temperature: 17 to 23 °C

Relative humidity: 31 to 57%

Pressure: 999 to 1012 mbar

2.1.7. Test Results

2.1.7.1. Channel Close / Transmission Time

The steps below define the procedure to determine the above-mentioned parameters when a radar burst with a level of up to 10 dB above the DFS Detection threshold is injected on the Operating Channel of the EUT.

Observe the transmissions of the EUT at the end of the radar Burst on the Operating Channel for duration greater than 10 seconds. Measure and record the transmissions from the EUT during the observation time (Channel Move Time). Compare the Channel Move Time and Channel Closing Transmission Time results to the limits defined in the DFS Response requirement values table.

Channel Closing Transmission Time - Measurement

The reference radar signature was introduced to the EUT, from which a 11 second transmission record was captured, as well as 1000ms of pre-trigger data. The Reference radar type was triggered to play at the exact time allowing the end of the pulse to occur at time $t=0$.

The system was setup to capture data for all transmission events above a given threshold level as determined and adjusted by the test engineer. The system time stamps all captured events with respect to T0 (zero time indicating the start of the measurement sequence) starting at the end of the radar pulse indicated by the purple vertical marker line in the Plot (on the next page).

The system captured data over a 12 second period at 10 points per microsecond. The data is analyzed by counting all "bursts" that occur above the threshold limit and aggregating the time each burst is on. The data is then compressed for presentation in one 12 second segment showing all of the activity recorded over the period.

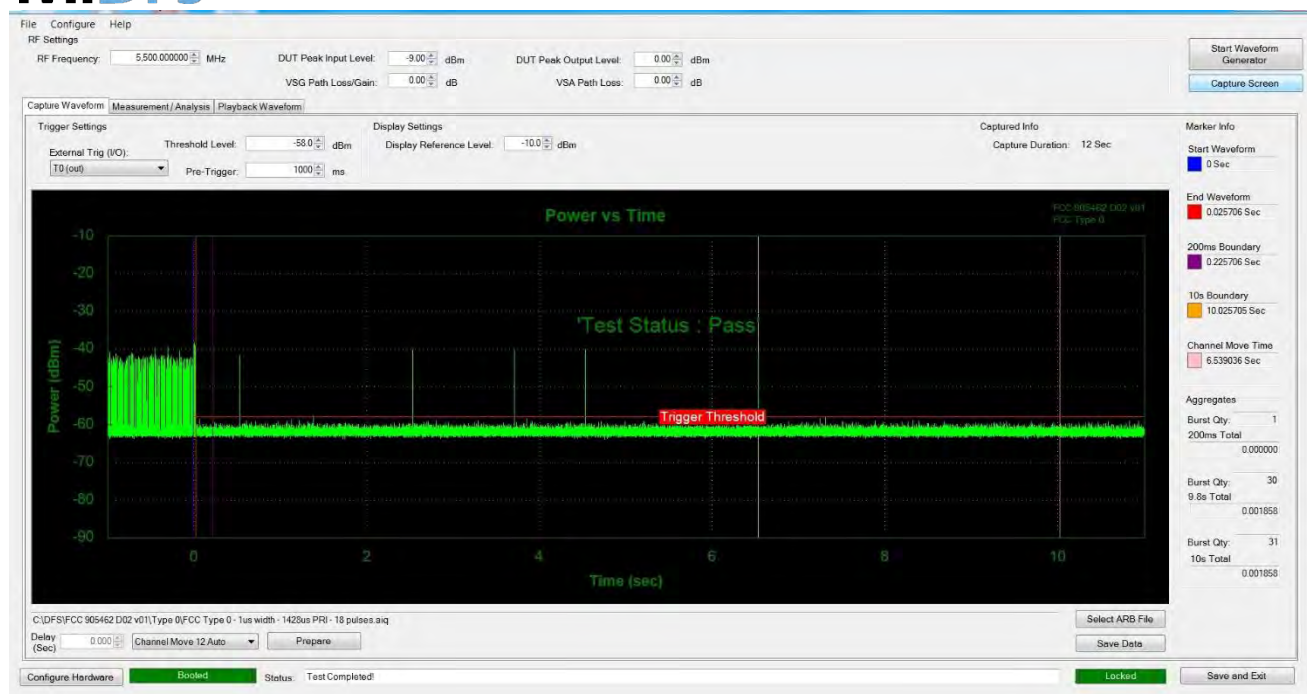
802.11a Channel 5500 MHz; Observed Frequency 5500 MHz

The system measures and aggregates the pulses occurring after the end of the radar pulse to determine the following parameters: -

Test Heading	Time (Secs)	Limit (Secs)	Status
Channel Closing Transmission Time	0.001858	0.260	Complies
Channel Move Time	6.539036	10.0	Complies

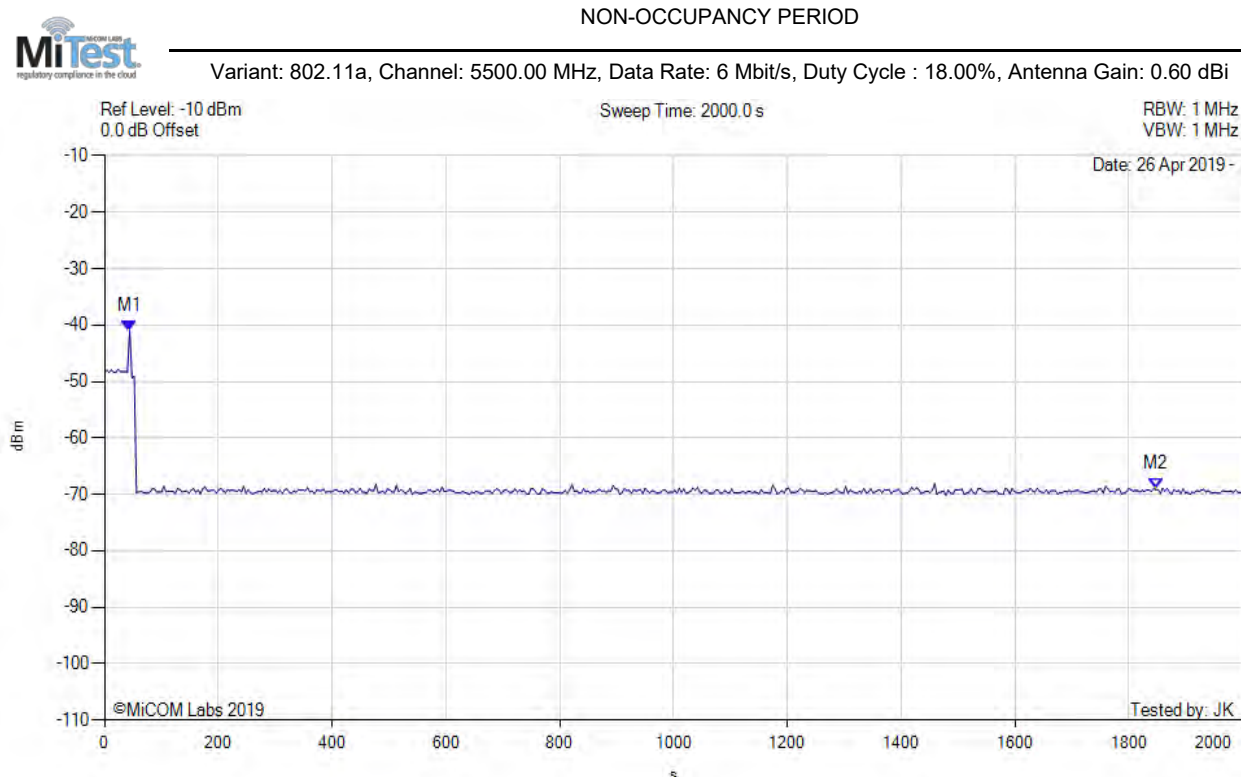


Channel Move Time, Channel Closing Transmission Time 0-12 Second Capture



2.1.7.2. Non-Occupancy Period

The EUT is monitored for more than 30 minutes following the channel close/move time to verify no transmissions resume on this Channel. There should be no transmissions on the frequency of interest during the non-occupancy period.



Analyzer Setup	Marker:Time:Amplitude	Test Results
Detector = MAX PEAK Sweep Count = 0 RF Atten (dB) = 10 Trace Mode = MAX HOLD	M1(5500.00 MHz) : 44.088 s : -40.974 dBm M2(5500.00 MHz) : 1847.695 s : -69.119 dBm	Channel Frequency: 5500.00 MHz



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