TEST REPORT

Covering the
DYNAMIC FREQUENCY SELECTION (DFS)
REQUIREMENTS
OF

FCC Part 15 Subpart E (UNII)

Sonos, Inc.
Model(s): PLAY:3

COMPANY:	Sonos, Inc. 25 First Street, Suite 300 Cambridge, MA, 02141
TEST SITE:	Elliott Laboratories 41039 Boyce Road Fremont, CA 94538
REPORT DATE:	May 26, 2011
FINAL TEST DATE:	March 21, 2011
TEST ENGINEER:	David Bare
AUTHORIZED SIGNATORY:	Mark Hill Senior EMC Engineer

Testing Cert #2016.01

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REVISION HISTORY

Rev #	Date	Comments	Modified By
-	05-26-2011	Initial release	-

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SCOPE

Test data has been taken pursuant to the relevant DFS requirements of the following standard(s):

- FCC Part 15 Subpart E Unlicensed National Information Infrastructure (U-NII) Devices.

Tests were performed in accordance with these standards together with the current published versions of the basic standards referenced therein as outlined in Elliott Laboratories test procedures. The test results recorded herein are based on a single type test of the Sonos, Inc. model PLAY:3 and therefore apply only to the tested sample. The sample was selected and prepared by Mark Keefe of Sonos, Inc.

OBJECTIVE

The objective of the manufacturer is to comply with the standards identified in the previous section. In order to demonstrate compliance, the manufacturer or a contracted laboratory makes measurements and takes the necessary steps to ensure that the equipment complies with the appropriate technical standards. Compliance with some DFS features is covered through a manufacturer statement or through observation of the device.

STATEMENT OF COMPLIANCE

The tested sample of the Sonos, Inc. model PLAY:3 complied with the DFS requirements of nd FCC Part 15.407(h)(2).

Maintenance of compliance is the responsibility of the manufacturer. Any modifications to the product should be assessed to determine their potential impact on the compliance status of the device with respect to the standards detailed in this test report.

DEVIATIONS FROM THE STANDARD

No deviations were made from the test methods and requirements covered by the scope of this report.

EQUIPMENT UNDER TEST (EUT) DETAILS

GENERAL

The Sonos, Inc. model PLAY:3 is a wireless audio speaker that is uses a 802.11agn 3x3 radio.

The sample was received on March 21, 2011 and tested on March 21, 2011. The EUT consisted of the following component(s):

Manufacturer	Model	Description	Serial Number
Sonos	PLAY:3	Wireless speaker	1101 00-0E-58-70-01-F4-3

The manufacturer declared values for the EUT operational characteristics that affect DFS are as follows:

Operating Modes (5250 – 5350 MHz, 5470 – 5725 MHz)

- ☐ Master Device 5250-5350 MHz
- ☐ Master Device 5470-5725 MHz
- ☐ Master Device 5470-5725 MHz (excluding 5600-5650 MHz)
- ☒ Client Device (no In Service Monitoring, no Ad-Hoc mode)
- ☐ Client Device with In-Service Monitoring

Channel Protocol

- ☒ IP Based
- ☐ Frame Based
- ☐ OTHER ____________________

ENCLOSURE

The EUT enclosure measures approximately 27 by 16 by 13 centimeters. It is primarily constructed of uncoated plastic.

MODIFICATIONS

The EUT did not require modifications during testing in order to comply with the requirements of the standard(s) referenced in this test report.

SUPPORT EQUIPMENT

The following equipment was used as support equipment for testing:

Manufacturer	Model	Description	Serial Number	FCC ID
Cisco Systems	*AIR-AP1242AG-A-K9*	*Access Point*	*FTX1446B0UY*	*LDK102055*
Dell	P05G	Laptop	29717068285	DoC
Netgear	GS105	Network Hub	2731043S06ED3	-

The italicized device was the master device.

INTERFACE PORTS

The I/O cabling configuration during testing was as follows:

Port	Connected To	Cable(s)		
		Description	Shielded or Unshielded	Length (m)
EUT Ethernet	Remote Hub	Cat 6	Unshielded	15.2
Access Point Ethernet	Remote Hub	Cat 6	Unshielded	15.2

EUT OPERATION

The EUT was operating with the following software. The software is secured by only allowing the user to update software when provided by Sonos. This software includes anti cloning protection. These features prevent the user from disabling the DFS function.

Client Device: Version 3.5 build 15139020

The streamed file was the NTIA approved audio test file. The laptop was using a UPnP application to stream the file to the EUT through the access point. See Appendix D for the FCC's Permit-But-Ask approval of the alternate test method.

RADAR WAVEFORMS

Table 1 FCC Short Pulse Radar Test Waveforms

Radar Type	Pulse Width (μsec)	PRI (μsec)	Pulses / burst	Minimum Detection Percentage	Minimum Number of Trials
1	1	1428	18	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

Table 2 FCC Long Pulse Radar Test Waveforms

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

Table 3 FCC Frequency Hopping Radar Test Waveforms

Radar Type	Pulse Width (μsec)	PRI (μsec)	Pulses / hop	Hopping Rate (kHz)	Hopping Sequence Length (msec)	Minimum Detection Percentage	Minimum Number of Trials
6	1	333	9	0.333	300	70%	30

TEST RESULTS

TEST RESULTS SUMMARY – FCC Part 15, CLIENT DEVICE

Table 4 FCC Part 15 Subpart E Client Device Test Result Summary

Description	Radar Type	Radar Frequency	Measured Value	Requirement	Test Data	Status
Channel closing transmission time	Type 1	5300 MHz	1.1 ms	< 60 ms	Appendix B	Pass
Channel move time	Type 1	5300 MHz	590 ms	< 10 s	Appendix B	Pass
Non-occupancy period - associated	Type 1	5680 MHz	> 30 minutes	> 30 minutes	Appendix B	Pass
Passive Scanning	N/A	N/A	Refer to manufacturer attestation			

Notes:
1) Tests were performed using the radiated test method.
2) Channel availability check, detection threshold and non-occupancy period are not applicable to client devices.

MEASUREMENT UNCERTAINTIES

ISO/IEC 17025 requires that an estimate of the measurement uncertainties associated with the emissions test results be included in the report. The measurement uncertainties given below are based on a 95% confidence level, with a coverage factor (k=2) and were calculated in accordance with UKAS document LAB 34.

Measurement	Measurement Unit	Expanded Uncertainty
Timing (Channel move time, aggregate transmission time)	ms	Timing resolution +/- 0.24%
Timing (non occupancy period)	seconds	5 seconds
DFS Threshold (radiated)	dBm	1.6
DFS Threshold (conducted)	dBm	1.2

DFS TEST METHODS

RADIATED TEST METHOD

The combination of master and slave devices is located in an anechoic chamber. The simulated radar waveform is transmitted from a directional horn antenna (typically an EMCO 3115) toward the unit performing the radar detection (radar detection device, RDD). Every effort is made to ensure that the main beam of the EUT's antenna is aligned with the radar-generating antenna.

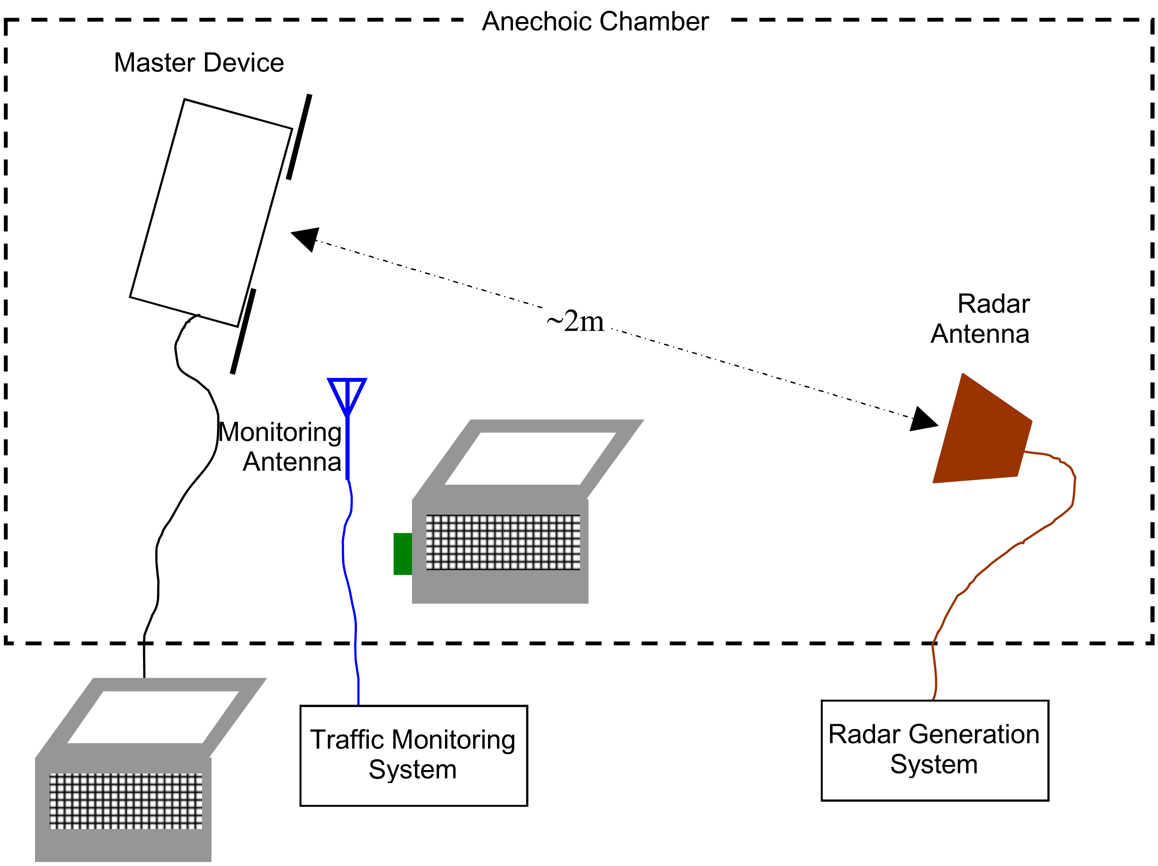

Figure 1 Test Configuration for radiated Measurement Method

The signal level of the simulated waveform is set to a reference level equal to the threshold level (plus 1dB if testing against FCC requirements). Lower levels may also be applied on request of the manufacturer. The level reported is the level at the RDD antenna and so it is not corrected for the RDD's antenna gain. The RDD is configured with the lowest gain antenna assembly intended for use with the device.

The signal level is verified by measuring the CW signal level from the radar generation system using a reference antenna of gain G (dBi). The radar signal level is calculated from the measured level, R (dBm), and any cable loss, L (dB), between the reference antenna and the measuring instrument:

Applied level (dBm) = R – GREF + L

If both master and client devices have radar detection capability then the device not under test is positioned with absorbing material between its antenna and the radar generating antenna, and the radar level at the non RDD is verified to be at least 20dB below the threshold level to ensure that any responses are due to the RDD detecting radar.

The antenna connected to the channel monitoring subsystem is positioned to allow both master and client transmissions to be observed, with the level of the EUT's transmissions between 6 and 10dB higher than those from the other device.

DFS MEASUREMENT INSTRUMENTATION

RADAR GENERATION SYSTEM

An Agilent PSG is used as the radar-generating source. The integral arbitrary waveform generators are programmed using Agilent's "Pulse Building" software and Elliott custom software to produce the required waveforms, with the capability to produce both un-modulated and modulated (FM Chirp) pulses. Where there are multiple values for a specific radar parameter then the software selects a value at random and, for FCC tests, the software verifies that the resulting waveform is truly unique.

With the exception of the hopping waveforms required by the FCC's rules (see below), the radar generator is set to a single frequency within the radar detection bandwidth of the EUT. The frequency is varied from trial to trial by stepping in 5MHz steps.

Frequency hopping radar waveforms are simulated using a time domain model. A randomly hopping sequence algorithm (which uses each channel in the hopping radar's range once in a hopping sequence) generates a hop sequence. A segment of the first 100 elements of the hop sequence are then examined to determine if it contains one or more frequencies within the radar detection bandwidth of the EUT. If it does not then the first element of the segment is discarded and the next frequency in the sequence is added. The process repeats until a valid segment is produced. The radar system is then programmed to produce bursts at time slots coincident with the frequencies within the segment that fall in the detection bandwidth. The frequency of the generator is stepped in 1 MHz increments across the EUT's detection range.

The radar signal level is verified during testing using a CW signal with the AGC function switched on. Correction factors to account for the fact that pulses are generated with the AGC functions switched off are measured annually and an offset is used to account for this in the software.

The generator output is connected to the coupling port of the conducted set-up or to the radar-generating antenna.

CHANNEL MONITORING SYSTEM

Channel monitoring is achieved using a spectrum analyzer and digital storage oscilloscope. The analyzer is configured in a zero-span mode, center frequency set to the radar waveform's frequency or the center frequency of the EUT's operating channel. The IF output of the analyzer is connected to one input of the oscilloscope.

A signal generator output is set to send either the modulating signal directly or a pulse gate with an output pulse co-incident with each radar pulse. This output is connected to a second input on the oscilloscope and the oscilloscope displays both the channel traffic (via the if input) and the radar pulses on its display.

For in service monitoring tests the analyzer sweep time is set to > 20 seconds and the oscilloscope is configured with a data record length of 10 seconds for the short duration and frequency hopping waveforms, 20 seconds for the long duration waveforms. Both instruments are set for a single acquisition sequence. The analyzer is triggered 500ms before the start of the waveform and the oscilloscope is triggered directly by the modulating pulse train. Timing measurements for aggregate channel transmission time and channel move time are made from the oscilloscope data, with the end of the waveform clearly identified by the pulse train on one trace. The analyzer trace data is used to confirm that the last transmission occurred within the 10-second record of the oscilloscope. If necessary the record length of the oscilloscope is expanded to capture the last transmission on the channel prior to the channel move.

Channel availability check time timing plots are made using the analyzer. The analyzer is triggered at start of the EUT's channel availability check and used to verify that the EUT does not transmit when radar is applied during the check time.

The analyzer detector and oscilloscope sampling mode is set to peak detect for all plots.

DFS MEASUREMENT METHODS

DFS – CHANNEL CLOSING TRANSMISSION TIME AND CHANNEL MOVE TIME

Channel clearing and closing times are measured by applying a burst of radar with the device configured to change channel and by observing the channel for transmissions. The time between the end of the applied radar waveform and the final transmission on the channel is the channel move time.

The aggregate transmission closing time is measured in one of two ways:

FCC/KCC Notice No. 2009-22 – the total time of all individual transmissions from the EUT that are observed starting 200ms at the end of the last radar pulse in the waveform. This value is required to be less than 60ms.

ETSI the total time of all individual transmissions from the EUT that are observed from the end of the last radar pulse in the waveform. This value is required to be less than 260ms.

DFS – CHANNEL NON-OCCUPANCY AND VERIFICATION OF PASSIVE SCANNING

The channel that was in use prior to radar detection by the master is additionally monitored for 30 minutes to ensure no transmissions on the vacated channel over the required non-occupancy period. This is achieved by tuning the spectrum analyzer to the vacated channel in zero-span mode and connecting the IF output to an oscilloscope. The oscilloscope is triggered by the radar pulse and set to provide a single sweep (in peak detect mode) that lasts for at least 30 minutes after the end of the channel move time.

For devices with a client-mode that are being evaluated against FCC rules the manufacturer must supply an attestation letter stating that the client device does not employ any active scanning techniques (i.e. does not transmit in the DFS bands without authorization from a Master device).

DFS CHANNEL AVAILABILITY CHECK TIME

It is preferred that the EUT report when it starts the radar channel availability check. If the EUT does not report the start of the check time, then the time to start transmitting on a channel after switching the device on is measured to approximate the time from power-on to the end of the channel availability check. The start of the channel availability check is assumed to be 60 seconds prior to the first transmission on the channel.

To evaluate the channel availability check, a single burst of one radar type is applied within the first 2 seconds of the start of the channel availability check and it is verified that the device does not use the channel by continuing to monitor the channel for a period of at least 60 seconds. The test is repeated by applying a burst of radar in the last 2 seconds (i.e. between 58 and 60 seconds after the start of CAC when evaluating a 60-second CAC) of the channel availability check.

ANSMIT POWER CONTROL (TPC)

Compliance with the transmit power control requirements for devices is demonstrated through measurements showing multiple power levels and manufacturer statements explaining how the power control is implemented.

SAMPLE CALCULATIONS

DETECTION PROBABILITY / SUCCESS RATE

The detection probability, or success rate, for any one radar waveform equals the number of successful trials divided by the total number of trials for that waveform.

HRESHOLD LEVEL

The threshold level is the level of the simulated radar waveform at the EUT's antenna. If the test is performed in a conducted fashion then the level at the rf input equals the level at the antenna plus the gain of the antenna assembly, in dBi. The gain of the antenna assembly equals the gain of the antenna minus the loss of the cabling between the rf input and the antenna. The lowest gain value for all antenna assemblies intended for use with the device is used when making this calculation.

If the test is performed using the radiated method then the threshold level is the level at the antenna.

Appendix A Test Equipment Calibration Data

Manufacturer	Description	Model #	Asset #	Cal Due
Hewlett Packard	EMC Spectrum Analyzer, 9kHz - 6.5GHz	8595EM	780	28-Dec-11
EMCO	Antenna, Horn, 1-18 GHz	3117	1662	04-May-12
Tektronix	500MHz, 2CH, 5GS/s Scope	TDS5052B	2118	29-Sep-11
Agilent	PSG, Performance Signal Generator, (installed options, HEH, HEC, 602, 420)	E8267C	2200	05-May-11

Appendix B Test Data Tables and Plots for Channel Closing

PART 15 SUBPART E Channel Closing Measurements

Table 5 FCC Part 15 Subpart E Channel Closing Test Results

Waveform Type	Channel Closing Transmission Time [1]		Channel Move Time		Result
	Measured	Limit	Measured	Limit	
Radar Type 1	1.1 ms	60 ms	590 ms	10 s	Pass

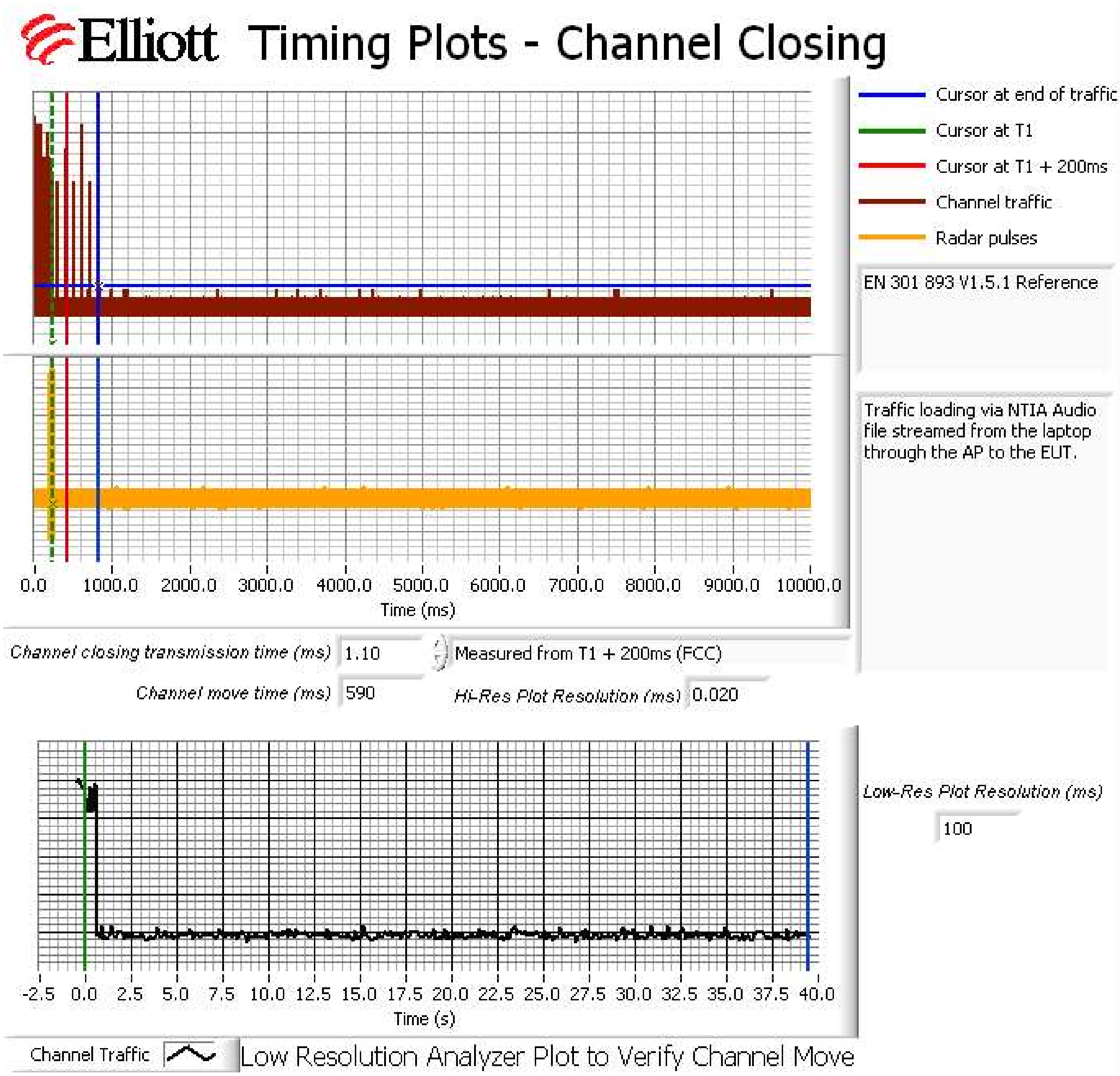

Figure 2 Channel Closing Time and Channel Move Time – 10 and 40 second plots

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[1] Channel closing time for FCC measurements is the aggregate transmission time starting from 200ms after the end of the radar signal to the completion of the channel move.

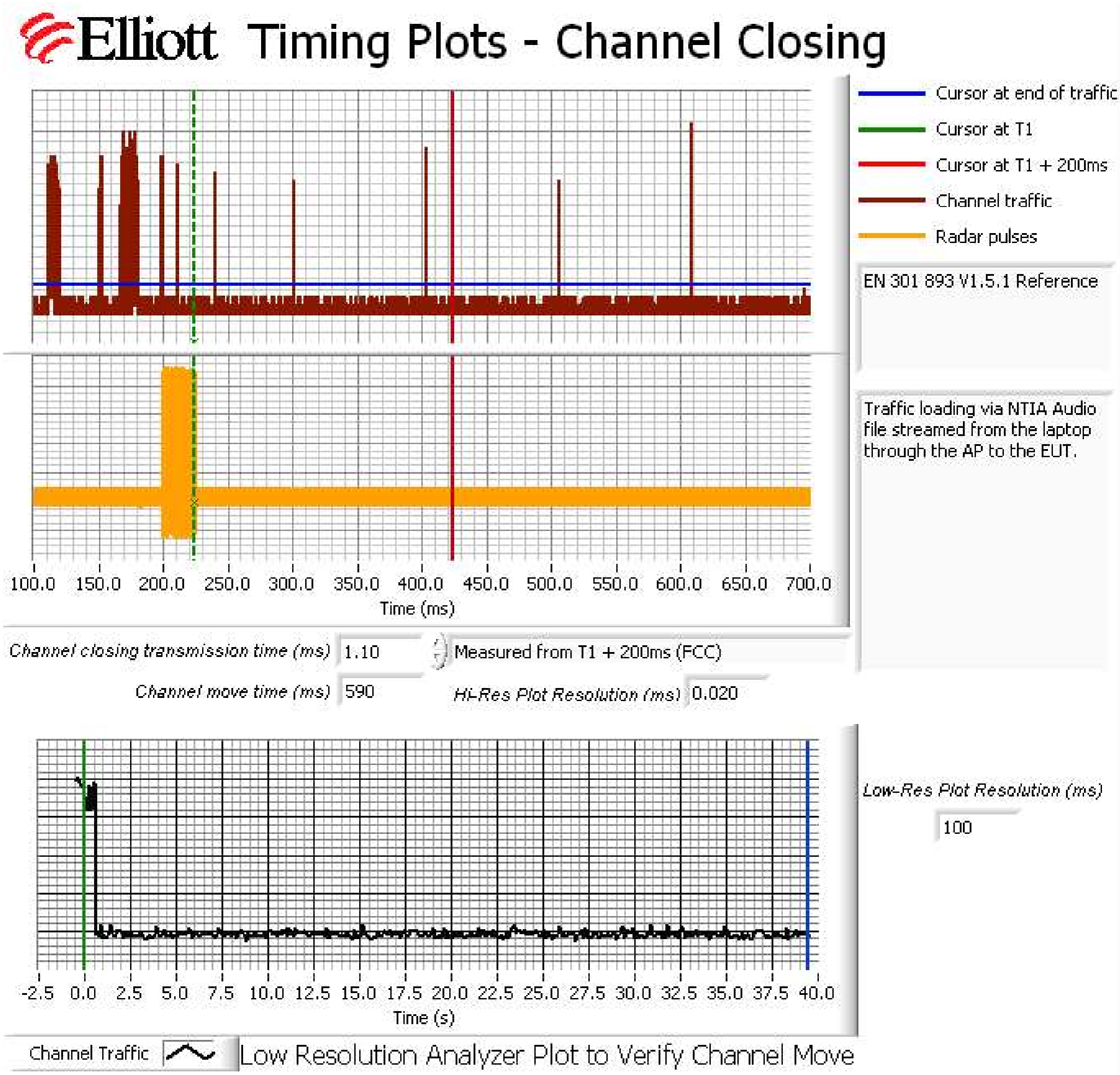

Figure 3 Close-Up of Transmissions Occurring More Than 200ms After The End of Radar

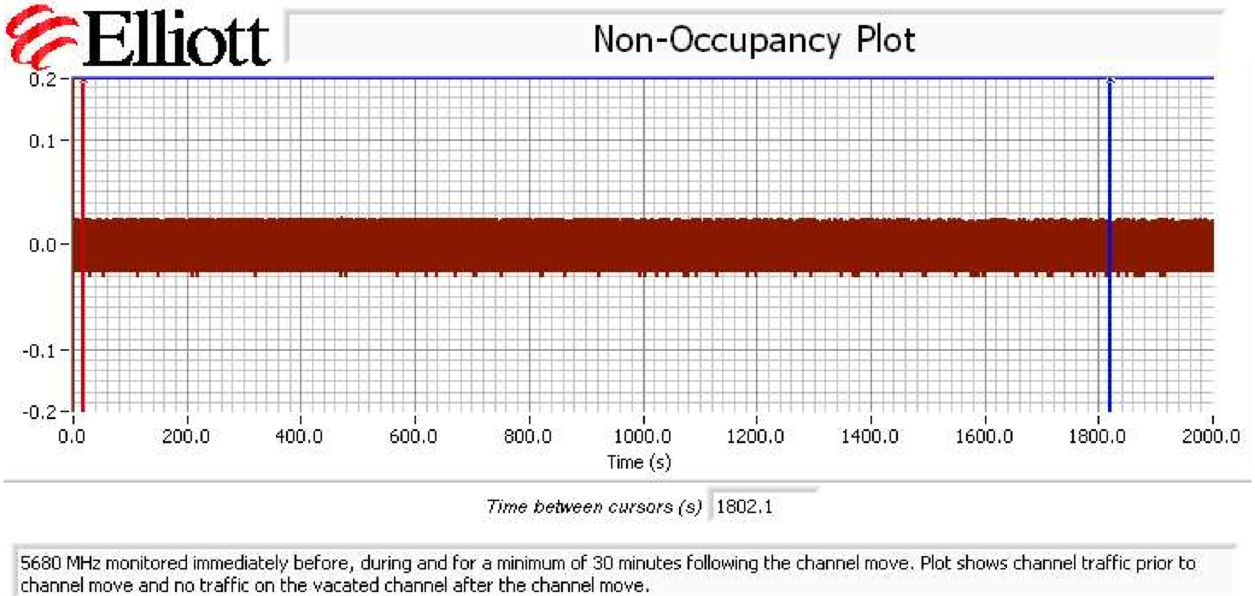

Figure 4 Radar Channel Non-Occupancy Plot

The non-occupancy plot was made over a 30-minute time period following the channel move time with the analyzer IF output connected to the scope and tuned to the vacated channel. No transmissions were observed after the channel move had been completed.

After the channel move the client re-associated with the master device on the new channel. After the channel move the client device stopped transmitting.

Appendix D FCC PBA for Alternate DFS method

1) A brief description of the device

The principal component of the Sonos S3 is the CPU board with Freescale MPC8314E 400 MHz microprocessors that performs the digital to analog converter, which allows digital files to be converted to analog signals and played through the 3 channel Class-D amplifiers. The Sonos S3 communicates via standard 802.11 wire Ethernet or 802.11a/g/n wireless LAN. The internal wireless LAN card is Alpha Networks WMC-ND02 capable of operating in the 5 GHz U-NII bands on the Dynamic Frequency Selection (DFS) channels.

The Sonos S3 operating system is a proprietary Linux based software application. The Sonos S3 cannot produce audio without the product specific software application and Ethernet (wire or wireless) TCP/IP connection to a media content server.

With the Sonos S3 installed in various rooms, an end user can play the same digital sound files in different rooms or different digital sound files in different rooms. As many as thirty-two (32) Sonos products may be operated and manipulated with the use of a single handheld controller, which is sold separately from the Sonos S3.

The Sonos S3 system allows the user to wirelessly stream data, including digital music files and related metadata in multiple rooms. It allows files to be played from storage on a personal computer and network storage facility, and also play content from select music services ripping, downloading, or personal computer interaction required. The Sonos system requires a wire Ethernet connection to a router and typically connects to a high speed Internet connection via a personal computer. The initial Sonos S3 in the system is connected to a broadband router and computer software must be installed for the connection to work. Thus the Sonos S3 is merely a machine for reception, conversion and transmission of voice or other data. After the initial Sonos S3 is connected to a router or network, additional Sonos products may be installed wirelessly in a thirty-two (32) different rooms creating a network.

The user creates the Sonos network by installing the first Sonos S3 in the network into a wire Ethernet connection and activating a desktop configuration program and a handheld wireless controller (purchased separately). The Sonos S3 and controller contain wireless network cards that establish their own secure wireless mesh network. Any additional installed Sonos products will automatically become part of the wireless mesh network. By “wirelessly” it is meant that after the initial Sonos S3 is connected to a router and network; additional Sonos products may be installed without a wired connection to the network.

The Sonos S3 employ a Sonos Net software solution, secured AES encrypted peer to peer wireless mesh network interface, which ensure synchronous music playback. In a Sonos networks, the same digital music file may be played in multiple rooms or zones without echoes or delays (multi-zone synchronous playback). Alternatively, the system can play different digital sound files simultaneously in different zones (multi-stream playback). The Sonos S3 is a point to point device; outsiders cannot listen into the audio files of the Internet web streams because the proprietary Sonos software is designed to prevent intrusion by persons outside the Sonos network.

2) The reason you cannot stream the NTIA MPG or WAV file

The Sonos S3 is an audio only device therefore it cannot decode or display the NTIA MPEG test file as specified in the DFS test procedure. The proposed alternative method is to follow the NTIA recommendation and stream the 5_GHz_Audio_Test_file.WAV test file located at the following website http://ntiacsd.ntia.doc.gov/dfs/

3) A description on how you propose to do the data streaming.

The NTIA 5_GHz_Audio_Test_file.WAV test file is located on a laptop running an http server. The said laptop is connected via wire Ethernet CAT5 cable to a Cisco AIR-AP1262N-A-K9 access point which will serve as the DFS mater device. The Sonos S3 establishes a 5 GHz wireless LAN connection to the laptop via the Cisco access point. The NTIA test file is streamed to the Sonos S3 where the WAV file is decoded and played through the internal audio amplifier and speakers. Please reference the attached block diagram.

4) An estimate of the percentage of channel loading. Explain how you derived this estimate.

The NTIA 5_GHz_Audio_Test_file.WAV test file streams at 1.4 Mbps. By limiting the traffic to 6Mb/s, a channel loading of ~26% could be achieved. This was measured prior to testing. See below plot.

5) Timing plots