SONOS

Antenna Test Report

June 5, 2024

FCC ID:	SBVRM045
IC:	5373A-RM045
Model:	S45
Product Description:	Radio 0: 802.11 a/ac/ax/b/g/n Client Device with BT and BLE Radio 1: 802.11 a/ac/ax/n Master Device
Test Engineer:	Gregory Best
Test Dates:	Jan 22 – Feb 9, 2024

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2 Avenue de Lafayette
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1. Measurement Method

Antenna Measurements in Anechoic Chambers The influence of atmospheric conditions and surrounding objects are non-ideal for accurate antenna measurements. An anechoic chamber offers a non-reflective, no-echo room for performing the antenna measurements. The anechoic chamber can simulate outer space, which is the most ideal location for antenna measurements. All gain measurements were performed in accordance with IEEE Std. 149 (IEEE Standard Procedures for Antenna Measurements). Losses of any test test cables were calibrated out post-measurement. Please refer to Figure 1 as the measurement chamber diagram.

1. Perform chamber calibration using reference antennas

2. Center the EUT in the chamber using the laser alignment system.

3. Connect the antenna micro-coax cable to the mast cable.

4. Capture antenna gain pattern using the automated measurement software.

5. Export the measurement data.

6. De-embed any additional cable losses in the setup (i.e., losses of any test cables that are not present in the actual product assembly).

7. Post-process measured data to extract the peak gain per antenna (take the maximum of the measured individual antenna pattern).

8. Combine antenna patterns per spatial point using the equations below (provided in KDB 662911, details outline in approved PAG submission) for correlated and uncorrelated gains, respectively

$$\text{Directional gain} = 10\log[(10^{G1/20} + 10^{G2/20} + \ldots + 10^{GN/20})^2 / N_{ANT}]\ \text{dBi}$$

Eq 1. Correlated Directional Gain Calculation

$$\text{Directional gain} = 10\log[(10^{G1/10} + 10^{G2/10} + \ldots + 10^{GN/10}) / N_{ANT}]\ \text{dBi}$$

Eq 2. Uncorrelated Directional Gain Calculation

9. Take the maximum of the combined directional gain pattern.

Example Math for ANT1 + ANT4 (at the spatial location where the highest combined gain occurs):

Directional Gain = 10*log((10^(3.1/20) + 10^(1.4/20))^2 / 2) dBi = 5.3 dBi

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2. Antenna Information

Antenna Designation	Sonos P/N	Band of Operation	Description
ANT1	105-00290	2.4, 5 & 6 GHz	Tri-band Monopole with coax cable, WLAN
ANT2	105-00289	2.4, 5 & 6 GHz	Tri-band Monopole with coax cable, WLAN
ANT3	105-00288	2.4, 5 & 6 GHz	Tri-band Monopole with coax cable, WLAN
ANT4	105-00291	2.4, 5 & 6 GHz	Tri-band Monopole with coax cable, WLAN
ANTF0	105-00294	5 & 6 GHz	Dual band Monopole with coax cable, WLAN
ANTF1	105-00292	2.4, 5 & 6 GHz	Tri-band Dipole with coax cable, WLAN, BT/BLE
ANTF2	105-00293	5 & 6 GHz	Dual band Monopole with coax cable, WLAN

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3. Antenna Gain

Antenna Gains: Radio 0

Radio 0					
	SISO Gain		MIMO Correlated Gain		MIMO Un-Correlated Gain
	Chain	Highest Peak (dBi)			
	BT	3.1			
	Chain	Highest Peak (dBi)	Ant Combo	Highest Peak (dBi)	Highest Peak (dBi)
2400 - 2483 MHz	ANT3	4.7	ANT3+ANT2	6.6	3.6
	ANT2	3.6	ANT3+ANT1	4.9	2.1
	ANT1	3.8	ANT2+ANT4	2.9	0.9
	ANT4	2	ANT1+ANT4	5.3	2.3
U-NII 1: 5150-5250 MHz	ANT3	5.3	ANT3+ANT2	6.1	3.2
	ANT2	4.6	ANT3+ANT1	4.7	2.5
	ANT1	3.8	ANT2+ANT4	3.8	1.8
	ANT4	1.7	ANT1+ANT4	4.8	1.9
U-NII 2A: 5250-5350 MHz	ANT3	5.3	ANT3+ANT2	6.8	3.9
	ANT2	4.6	ANT3+ANT1	4.4	2.4
	ANT1	4.1	ANT2+ANT4	3.4	1.8
	ANT4	2.3	ANT1+ANT4	5.2	2.3
U-NII 2C: 5470-5725 MHz	ANT3	7.3	ANT3+ANT2	7.8	5
	ANT2	4.9	ANT3+ANT1	5.4	4.4
	ANT1	4.3	ANT2+ANT4	3.5	1.9
	ANT4	2.1	ANT1+ANT4	5.5	2.6
U-NII 3: 5725-5850 MHz	ANT3	6.8	ANT3+ANT2	7.5	4.7
	ANT2	4.6	ANT3+ANT1	4.9	3.9
	ANT1	3.9	ANT2+ANT4	3.5	1.6
	ANT4	1.9	ANT1+ANT4	5.4	2.4

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U-NII 5: 5925-6425 MHz	ANT3	6.6	ANT3+ANT2	7.3	4.5
	ANT2	4.8	ANT3+ANT1	5	3.7
	ANT1	3.5	ANT2+ANT4	2.9	1.8
	ANT4	1.9	ANT1+ANT4	5	2.1
U-NII 6: 6425-6525 MHz	ANT3	6.3	ANT3+ANT2	7.2	4.4
	ANT2	4	ANT3+ANT1	5.3	3.3
	ANT1	2.9	ANT2+ANT4	2.7	1
	ANT4	1.2	ANT1+ANT4	3.5	0.2
U-NII 7: 6525-6875 MHz	ANT3	6.6	ANT3+ANT2	7.2	4.5
	ANT2	3.5	ANT3+ANT1	5.6	3.6
	ANT1	4.6	ANT2+ANT4	3.1	0.9
	ANT4	1.7	ANT1+ANT4	4.2	1.8
U-NII 8: 6875-7125 MHz	ANT3	6.1	ANT3+ANT2	6.4	3.9
	ANT2	3.4	ANT3+ANT1	5.8	3.5
	ANT1	4.2	ANT2+ANT4	3	0.8
	ANT4	1.5	ANT1+ANT4	4.7	2.1

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Antenna Gains: Radio 1

Radio 1					
	SISO Gain		MIMO Correlated Gain		Mimo Un-Correlated Gain
	Chain	Highest Peak (dBi)	Ant Combo	Highest Peak (dBi)	Highest Peak (dBi)
U-NII 1 5150 - 5250 MHz	ANTF2	4.2	ANTF2+ANTF0+ANTF1	4.8	0.8
	ANTF0	2.3			
	ANTF1	4.3			
U-NII 2A 5250 - 5350 MHz	ANTF2	4	ANTF2+ANTF0+ANTF1	4.9	0.8
	ANTF0	1.9			
	ANTF1	4.1			
U-NII 2C	ANTF2	3.1	ANTF2+ANTF0+ANTF1	6.1	2.2
	ANTF0	1.9			
	ANTF1	5.4			
U-NII 3	ANTF2	2.6	ANTF2+ANTF0+ANTF1	5.8	1.8
	ANTF0	1.9			
	ANTF1	5.2			
U-NII 5: 5925-6425 MHz	ANTF2	3.5	ANTF2+ANTF0+ANTF1	6	2.2
	ANTF0	3.3			
	ANTF1	5.7			
U-NII 6: 6425-6525 MHz	ANTF2	3.6	ANTF2+ANTF0+ANTF1	5.8	1.3
	ANTF0	4.3			
	ANTF1	4.3			
U-NII 7: 6525-6875 MHz	ANTF2	3.7	ANTF2+ANTF0+ANTF1	5.8	1.5
	ANTF0	4.8			
	ANTF1	4.3			
U-NII 8: 6875-7125 MHz	ANTF2	4.4	ANTF2+ANTF0+ANTF1	5.5	1.7
	ANTF0	5			
	ANTF1	3.6			

4. Antenna Test Chamber Details

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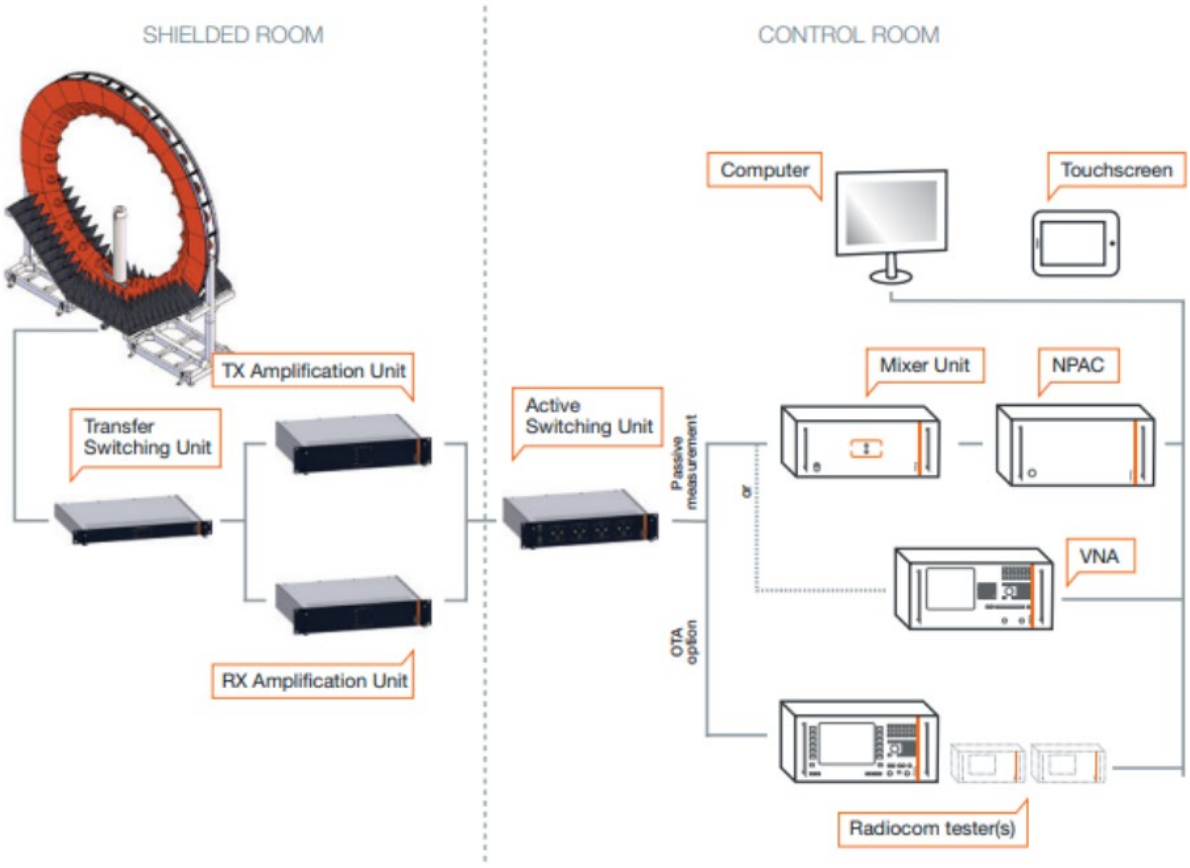

Figure 1. Measurement Chamber Diagram

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Test Location

Sonos Antenna Chamber, 2 Avenue de Lafayette, Boston, MA 02111 USA.

Peak Gain was measured using the antenna test chamber. The antennas for S45 were measured in the full product assembly.

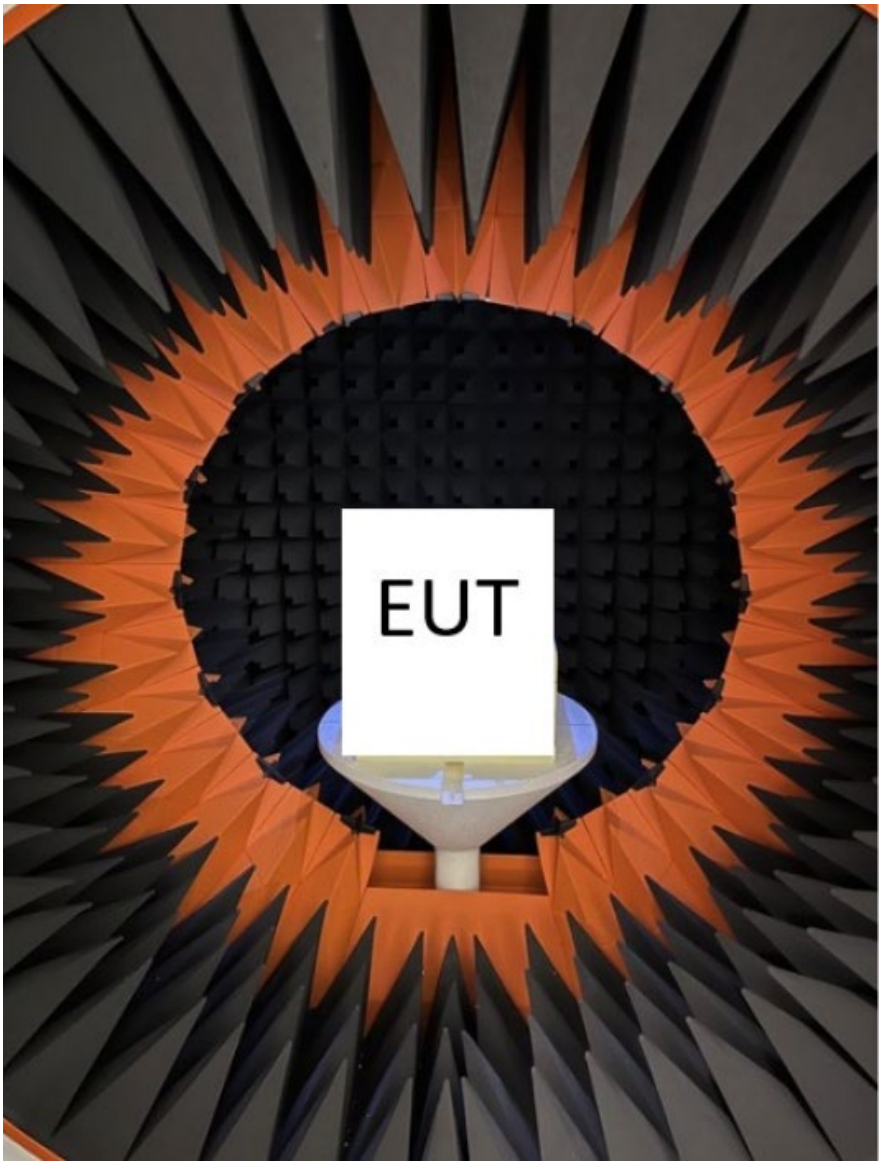

Figure 2.EUT placed inside the test chamber

5. Test Equipment/Software

Hardware

Description	Manufacturer	Model	Calibration Interval
Antenna Measurement Probe (Multi-Probe System)	MVG	SG24S	Yearly
Vector Network Analyzer	Agilent	ENA E5071C	Yearly
Reference Dipole	MVG	SD2450	Yearly
		SD5150	Yearly
		SD5650	Yearly
		WD6000	Yearly

Software

Description	Manufacturer	Model	Calibration Interval
Data Processing Software	MVG	SatEnv	N/A
Test Chamber Automation Software	MVG	WaveStudio	N/A
Data Processing Software	Mathworks	MATLAB R2022b	N/A

-END-