

1. OTA PASSIVE ANTENNA TEST REPORT

Date of Report	7/08/2025	Client's Contact person:	Jouni Lifländer
Number of pages:	15	Responsible Test engineer:	Veli-Matti Niemitalo
Testing laboratory:	Verkotan Oy Elektroniikkatie 17 90590 Oulu Finland	Client:	Haltian Oy Yrttipellontie 1 D3 90230 Oulu Finland
Tested devices	Sonos Large Sonos Small		
Testing has been carried out in accordance with:	Passive measurements per customer request		
Documentation:	The test report must always be reproduced in full; reproduction of an excerpt only is subject to written approval of the testing laboratory.		
Test Results:	The test results relate only to devices specified in this document		

Date and signatures:



07.08.2025 Jani Kallankari
Chief Scientist

2. SUMMARY

2.1 Test Details

Devices under Test (DUT):

Product:	Sonos Large
Note	-
Manufacturer info:	-
SW Info:	-
DUT number:	23
Tested Frequencies [MHz]	2300-2600 in 5 MHz steps



Figure 1 Sonos Large front



Figure 2 Sonos Large back

Product:	Sonos Small
Note	-
Manufacturer info:	-
SW Info:	-
DUT number:	22
Tested Frequencies [MHz]	2300-2600 in 5 MHz steps



Figure 3 Sonos Small front



Figure 4 Sonos Small back

Testing information:

Testing performed:	08.05.2025, 15.05.2025
Notes:	-
Document name:	Passive_OTA_test_report_ID5993_Sonos_07082025
Temperature °C / Humidity RH%	22±2 / 25%±10%
Measurement performed by:	Veli-Matti Niemitalo
Document history:	07.08.2025 Non-draft version 15.05.2025 Sonos Large remeasured, results updated 12.05.2025 Draft version

TABLE OF CONTENTS

1. OTA PASSIVE Antenna Test Report..... 1

2. Summary 2

 2.1 Test Details 2

3. Test Equipment..... 6

4. Test setup 8

5. RESULTS 9

 5.1 Passive OTA measurements 9

 5.1.1 Maximum gain and efficiency 9

 5.1.2 Maximum gain (graphs) 13

 5.1.3 Efficiency (graphs) 13

6. Antenna Patterns 14

3. TEST EQUIPMENT

Main used test equipment is listed below. For full equipment list and calibration intervals, please contact the testing laboratory.

Type of Equipment	Type	Manufacturer	Calibration date	Calibration period	Calibration due	Purpose
Diagonal Dual Polarized Horn Measurement Antenna	114960	ETS	Included in range calibration	Included in range calibration	Included in range calibration	Probe antenna
Positioning Controller	2090	EMCO	n/a	n/a	n/a	DUT alignment
3D Positioner	Custom made	ETS-Lindgren	n/a	n/a	n/a	DUT alignment
Anechoic Chamber	4	ETS-Lindgren	12.02.2025	1 year	12.02.2026	Test range
Switching System	MSN-6TD-06-DEC-SP	American Microwave	Included in range calibration	Included in range calibration	Included in range calibration	Probe selection
Switching System	SW6AD-A61	Pulsar	Included in range calibration	Included in range calibration	Included in range calibration	Probe selection
Network Analyzer	E5071C	Agilent	20.05.2024	1 year	20.05.2025	Measurement transmitter / receiver
Dual-Ridge Horn Antenna	SH600	MVG	20.08.2020	n/a	n/a	Calibration antenna 1-9 GHz

Table 1. Antenna pattern measurement equipment, Anechoic Chamber 4

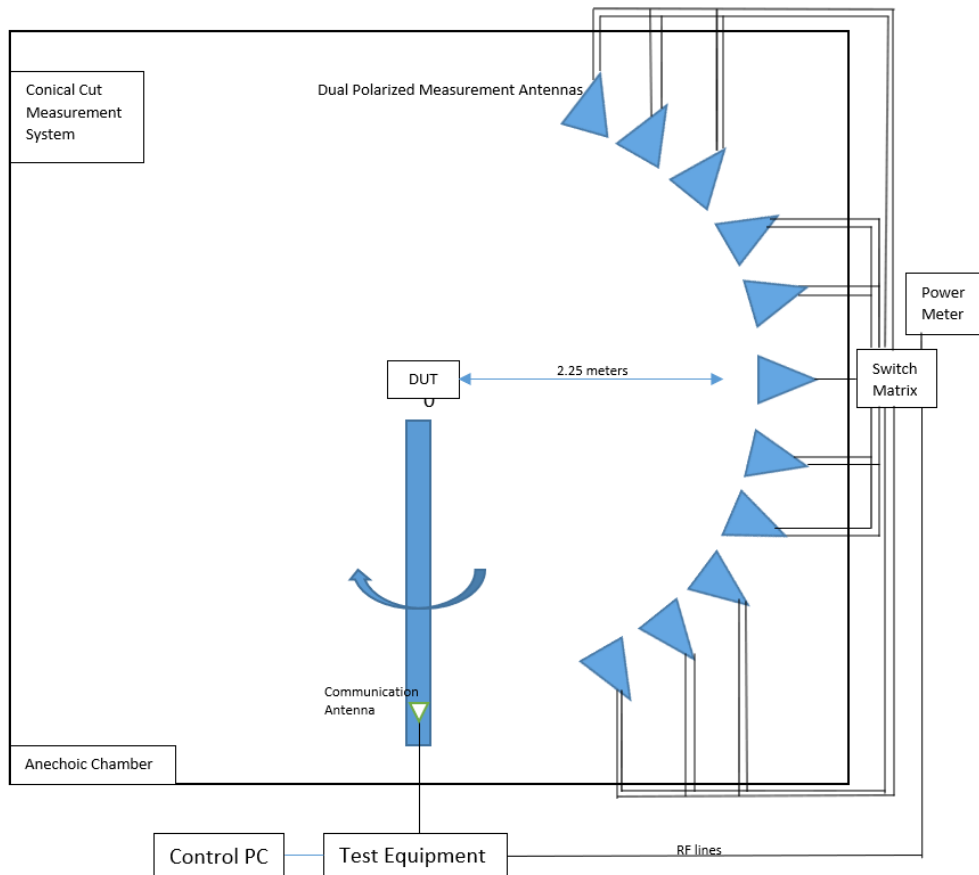


Figure 5. Laboratory 4 chamber schematic.

4. TEST SETUP

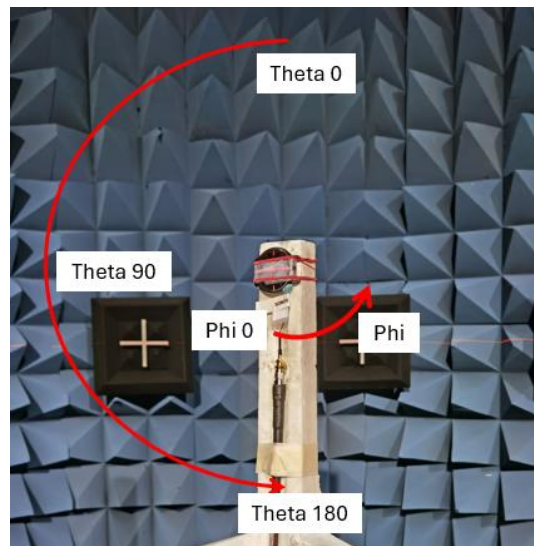


Figure 6 Sonos Large in FS passive measurement and coordinate system

Vertical laser in DUT setup position denotes $\phi=0$, horizontal laser denotes $\theta=90$. Theta 0 is directly up from DUT, and theta 180 is down from DUT.

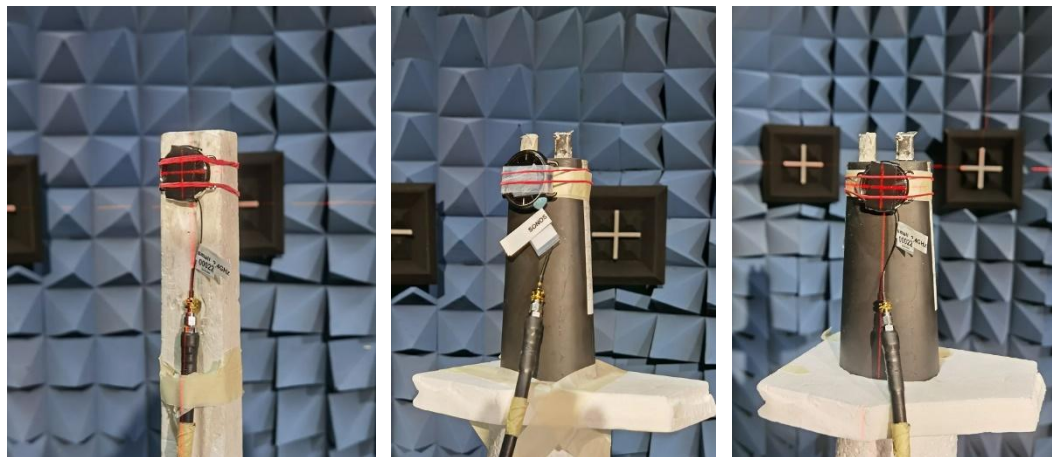


Figure 7 Setup pictures: Sonos Small FS, Sonos Large on wrist phantom, Sonos Small on wrist phantom

5. RESULTS

5.1 Passive OTA measurements

5.1.1 Maximum gain and efficiency

5.1.1.1 Free Space, Sonos Large

Frequency [MHz]	Max gain [dBi]	Efficiency [dB]	Frequency [MHz]	Max gain [dBi]	Efficiency [dB]
2300	-8.9	-15.4	2455	-5.5	-11.4
2305	-8.6	-15.0	2460	-5.6	-11.6
2310	-8.5	-14.7	2465	-5.5	-11.6
2315	-8.5	-14.5	2470	-5.5	-11.6
2320	-8.3	-14.2	2475	-5.6	-11.6
2325	-7.8	-13.7	2480	-5.6	-11.6
2330	-7.5	-13.4	2485	-5.7	-11.7
2335	-7.0	-13.1	2490	-5.8	-11.7
2340	-6.7	-12.9	2495	-5.9	-11.7
2345	-6.4	-12.7	2500	-6.1	-11.9
2350	-6.3	-12.4	2505	-6.2	-11.9
2355	-6.1	-12.2	2510	-6.2	-11.9
2360	-5.8	-12.0	2515	-6.2	-11.9
2365	-5.5	-11.7	2520	-6.3	-12.0
2370	-5.2	-11.4	2525	-6.6	-12.3
2375	-5.0	-11.1	2530	-6.6	-12.3
2380	-4.8	-11.0	2535	-6.5	-12.3
2385	-4.8	-10.9	2540	-6.7	-12.4
2390	-4.7	-10.7	2545	-6.7	-12.5
2395	-4.7	-10.6	2550	-6.8	-12.6
2400	-4.6	-10.6	2555	-6.8	-12.5
2405	-4.6	-10.6	2560	-6.7	-12.4
2410	-4.7	-10.7	2565	-6.9	-12.5
2415	-4.7	-10.7	2570	-6.8	-12.5
2420	-4.7	-10.7	2575	-6.7	-12.4
2425	-4.7	-10.7	2580	-6.7	-12.3
2430	-4.9	-10.8	2585	-6.6	-12.2
2435	-5.0	-11.0	2590	-6.8	-12.4
2440	-5.1	-11.1	2595	-6.8	-12.3
2445	-5.2	-11.1	2600	-6.7	-12.2
2450	-5.3	-11.2			

Table 2 Sonos Large maximum gain and efficiency, Free space

5.1.1.2 Free Space, Sonos Small

Frequency [MHz]	Max gain [dBi]	Efficiency [dB]	Frequency [MHz]	Max gain [dBi]	Efficiency [dB]
2300	-17.4	-25.6	2455	-6.2	-14.2
2305	-16.7	-25.0	2460	-6.4	-14.3
2310	-16.3	-24.4	2465	-6.2	-14.2
2315	-16.0	-24.1	2470	-5.9	-14.2
2320	-15.9	-23.9	2475	-5.7	-14.2
2325	-15.5	-23.5	2480	-5.8	-14.2
2330	-14.8	-22.9	2485	-6.0	-14.4
2335	-14.1	-22.4	2490	-6.1	-14.4
2340	-13.5	-22.0	2495	-6.3	-14.5
2345	-13.0	-21.6	2500	-6.7	-14.7
2350	-12.5	-21.1	2505	-6.9	-14.9
2355	-12.0	-20.5	2510	-7.1	-15.1
2360	-11.8	-20.1	2515	-7.0	-15.1
2365	-11.6	-19.7	2520	-7.0	-15.3
2370	-11.0	-19.1	2525	-7.4	-15.7
2375	-10.3	-18.4	2530	-7.8	-15.9
2380	-9.6	-17.9	2535	-8.2	-16.2
2385	-9.1	-17.5	2540	-8.4	-16.3
2390	-8.7	-17.2	2545	-8.7	-16.5
2395	-8.1	-16.7	2550	-8.9	-16.9
2400	-7.6	-16.2	2555	-9.0	-17.0
2405	-7.5	-15.9	2560	-8.8	-17.0
2410	-7.4	-15.7	2565	-9.0	-17.2
2415	-7.2	-15.4	2570	-9.1	-17.4
2420	-6.8	-15.1	2575	-9.5	-17.6
2425	-6.4	-14.8	2580	-9.8	-17.7
2430	-6.2	-14.7	2585	-10.0	-17.8
2435	-6.1	-14.6	2590	-10.4	-18.2
2440	-5.9	-14.4	2595	-10.5	-18.4
2445	-5.8	-14.3	2600	-10.7	-18.6
2450	-6.0	-14.2			

Table 3 Sonos Small maximum gain and efficiency, Free space

5.1.1.3 Wrist phantom, Sonos Large

Frequency [MHz]	Max gain [dBi]	Efficiency [dB]	Frequency [MHz]	Max gain [dBi]	Efficiency [dB]
2300	-11.2	-17.6	2455	-6.9	-12.8
2305	-10.9	-17.2	2460	-7.0	-13.0
2310	-10.5	-16.9	2465	-7.0	-12.9
2315	-10.1	-16.6	2470	-7.1	-12.9
2320	-9.6	-16.2	2475	-7.2	-13.0
2325	-9.1	-15.7	2480	-7.3	-13.0
2330	-8.7	-15.3	2485	-7.4	-13.0
2335	-8.5	-15.0	2490	-7.4	-13.1
2340	-8.4	-14.8	2495	-7.5	-13.1
2345	-8.2	-14.5	2500	-7.7	-13.3
2350	-7.9	-14.2	2505	-7.6	-13.3
2355	-7.5	-13.9	2510	-7.5	-13.3
2360	-7.2	-13.7	2515	-7.6	-13.3
2365	-6.9	-13.4	2520	-7.8	-13.4
2370	-6.5	-13.0	2525	-8.2	-13.7
2375	-6.3	-12.8	2530	-8.4	-13.7
2380	-6.2	-12.6	2535	-8.4	-13.7
2385	-6.3	-12.5	2540	-8.6	-13.8
2390	-6.2	-12.4	2545	-8.6	-13.8
2395	-6.3	-12.3	2550	-8.7	-13.9
2400	-6.2	-12.2	2555	-8.6	-13.9
2405	-6.0	-12.1	2560	-8.4	-13.7
2410	-5.9	-12.1	2565	-8.5	-13.9
2415	-5.8	-12.1	2570	-8.4	-13.8
2420	-5.7	-12.0	2575	-8.2	-13.8
2425	-5.8	-12.0	2580	-8.2	-13.8
2430	-6.1	-12.2	2585	-8.1	-13.7
2435	-6.5	-12.4	2590	-8.2	-13.8
2440	-6.7	-12.5	2595	-8.1	-13.7
2445	-6.8	-12.6	2600	-8.1	-13.6
2450	-6.8	-12.7			

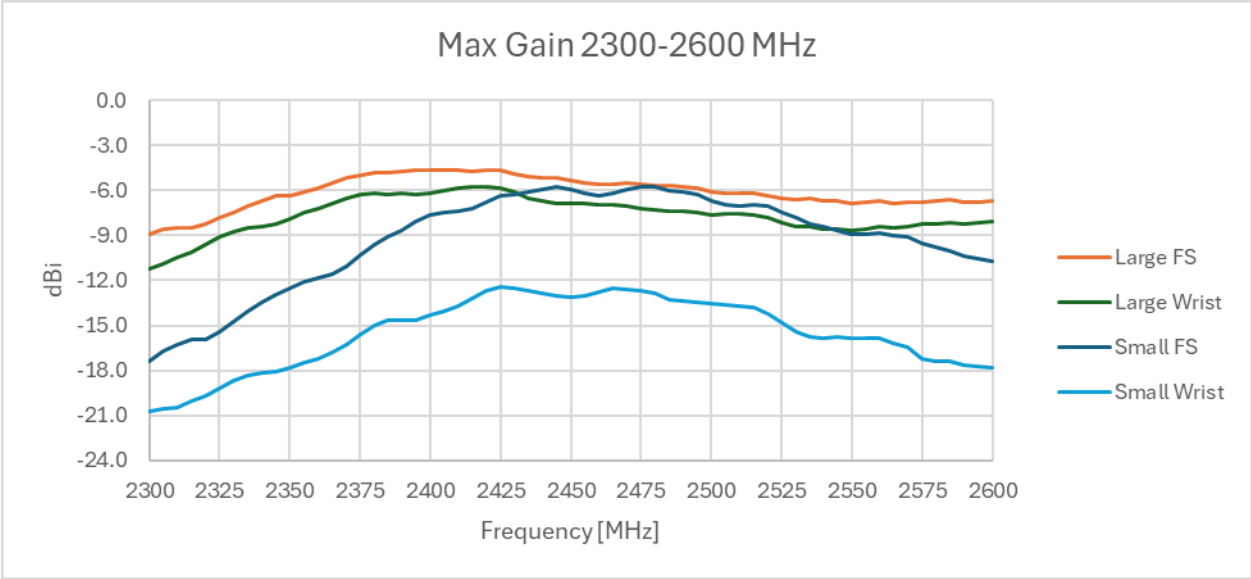
Table 4 Sonos Large maximum gain and efficiency, Wrist phantom

5.1.1.4 Wrist phantom, Sonos Small

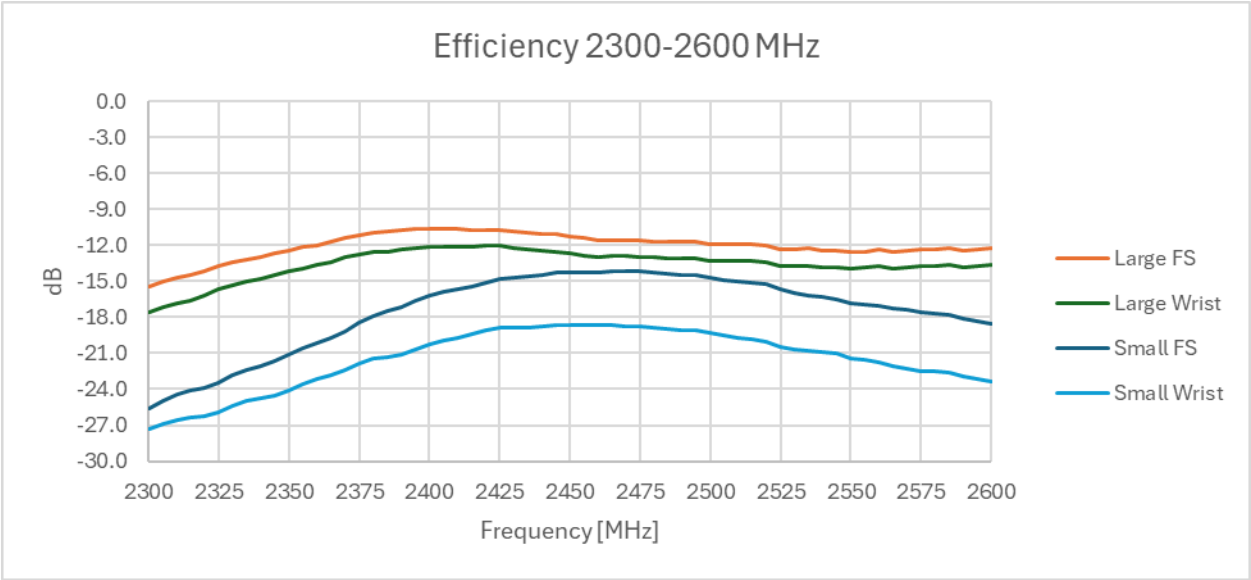
Frequency [MHz]	Max gain [dBi]	Efficiency [dB]	Frequency [MHz]	Max gain [dBi]	Efficiency [dB]
2300	-20.7	-27.3	2455	-13.1	-18.6
2305	-20.5	-26.9	2460	-12.8	-18.7
2310	-20.5	-26.6	2465	-12.5	-18.7
2315	-20.0	-26.3	2470	-12.6	-18.7
2320	-19.7	-26.2	2475	-12.7	-18.8
2325	-19.2	-25.9	2480	-12.9	-18.9
2330	-18.7	-25.4	2485	-13.3	-19.0
2335	-18.3	-25.0	2490	-13.4	-19.0
2340	-18.1	-24.8	2495	-13.4	-19.1
2345	-18.1	-24.5	2500	-13.6	-19.3
2350	-17.8	-24.1	2505	-13.6	-19.5
2355	-17.5	-23.6	2510	-13.7	-19.7
2360	-17.2	-23.2	2515	-13.8	-19.9
2365	-16.8	-22.8	2520	-14.2	-20.1
2370	-16.3	-22.4	2525	-14.8	-20.5
2375	-15.6	-21.8	2530	-15.4	-20.7
2380	-15.0	-21.4	2535	-15.8	-20.8
2385	-14.7	-21.3	2540	-15.8	-20.9
2390	-14.7	-21.1	2545	-15.8	-21.1
2395	-14.7	-20.7	2550	-15.8	-21.4
2400	-14.3	-20.3	2555	-15.8	-21.6
2405	-14.1	-19.9	2560	-15.9	-21.7
2410	-13.7	-19.7	2565	-16.2	-22.0
2415	-13.2	-19.4	2570	-16.5	-22.2
2420	-12.7	-19.1	2575	-17.2	-22.5
2425	-12.4	-18.9	2580	-17.4	-22.5
2430	-12.5	-18.9	2585	-17.4	-22.6
2435	-12.7	-18.9	2590	-17.7	-22.9
2440	-12.8	-18.8	2595	-17.8	-23.1
2445	-13.1	-18.7	2600	-17.8	-23.4
2450	-13.1	-18.6			

Table 5 Sonos Small maximum gain and efficiency, Wrist phantom

5.1.2 Maximum gain (graphs)



5.1.3 Efficiency (graphs)



6. ANTENNA PATTERNS

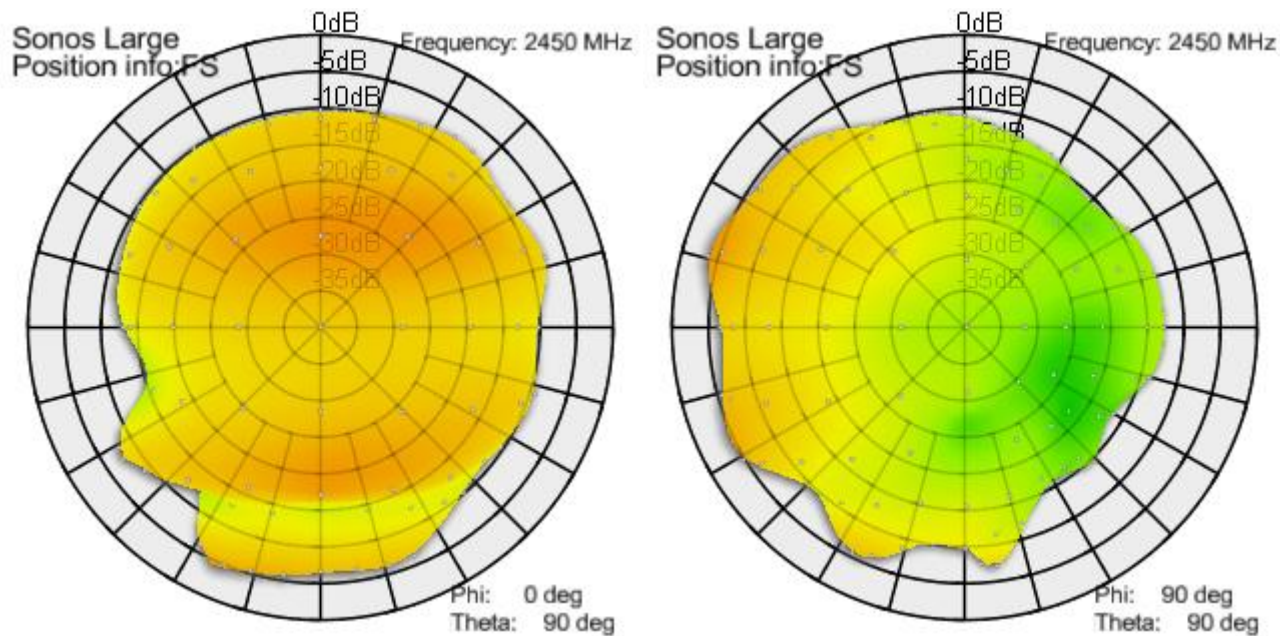


Figure 8 Antenna pattern at 2450 MHz, Sonos Large, FS

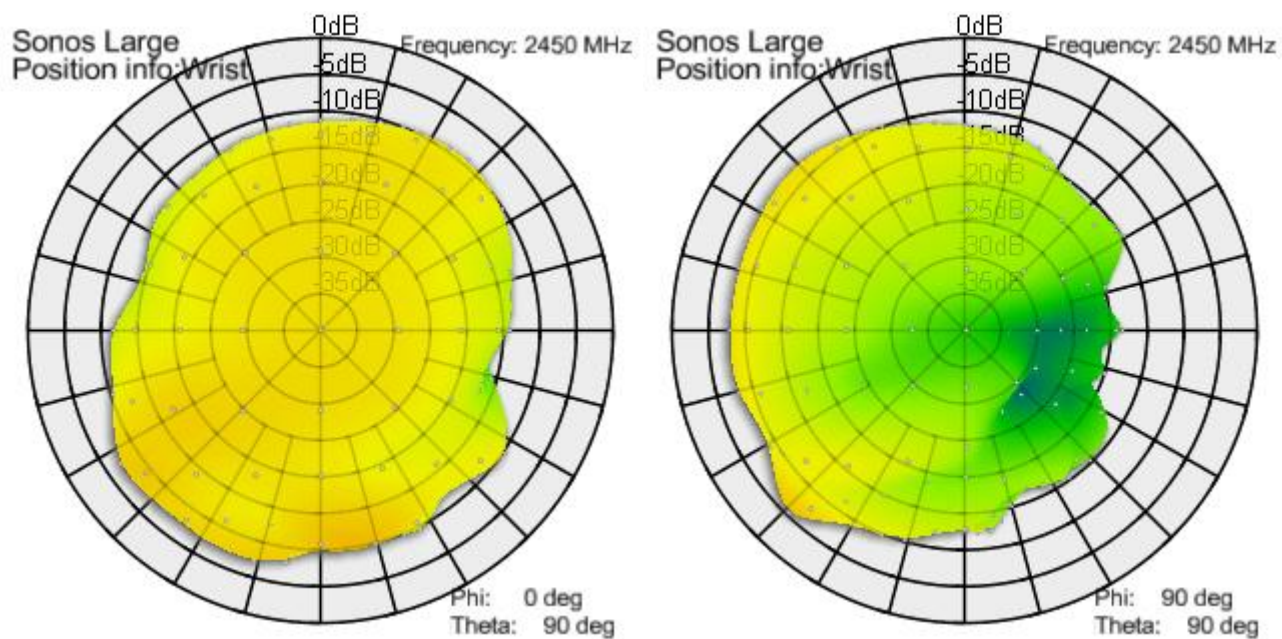


Figure 9 Antenna pattern at 2450 MHz, Sonos Large, Wrist

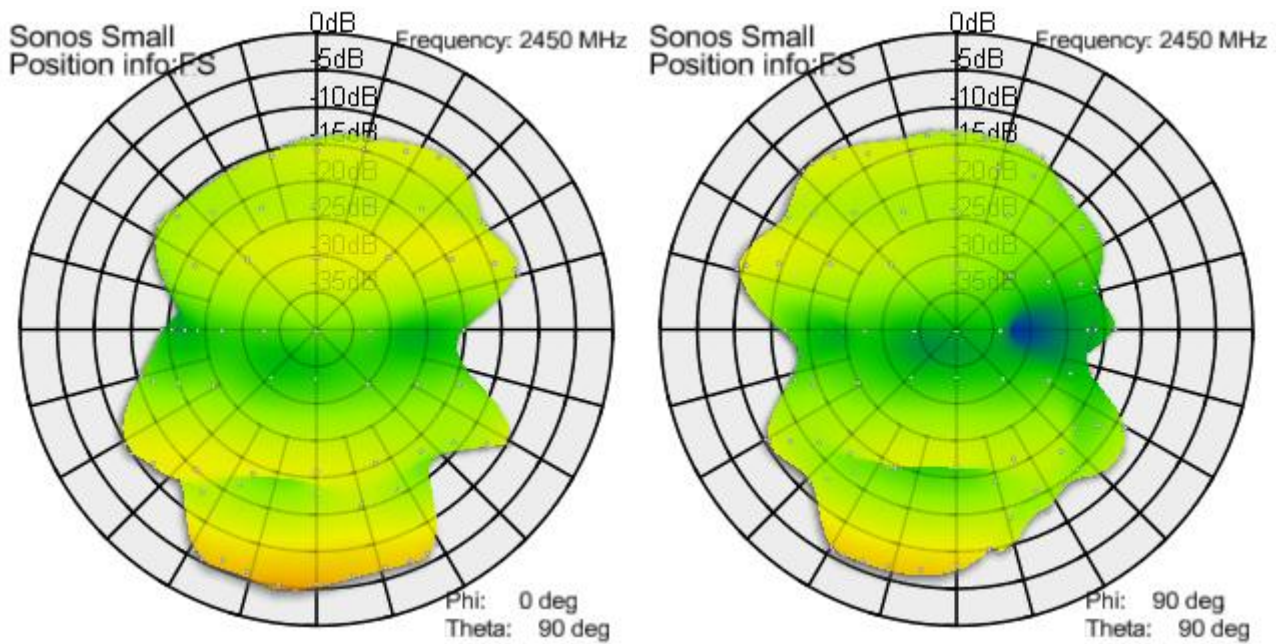


Figure 10 Antenna pattern at 2450 MHz, Sonos Small, FS

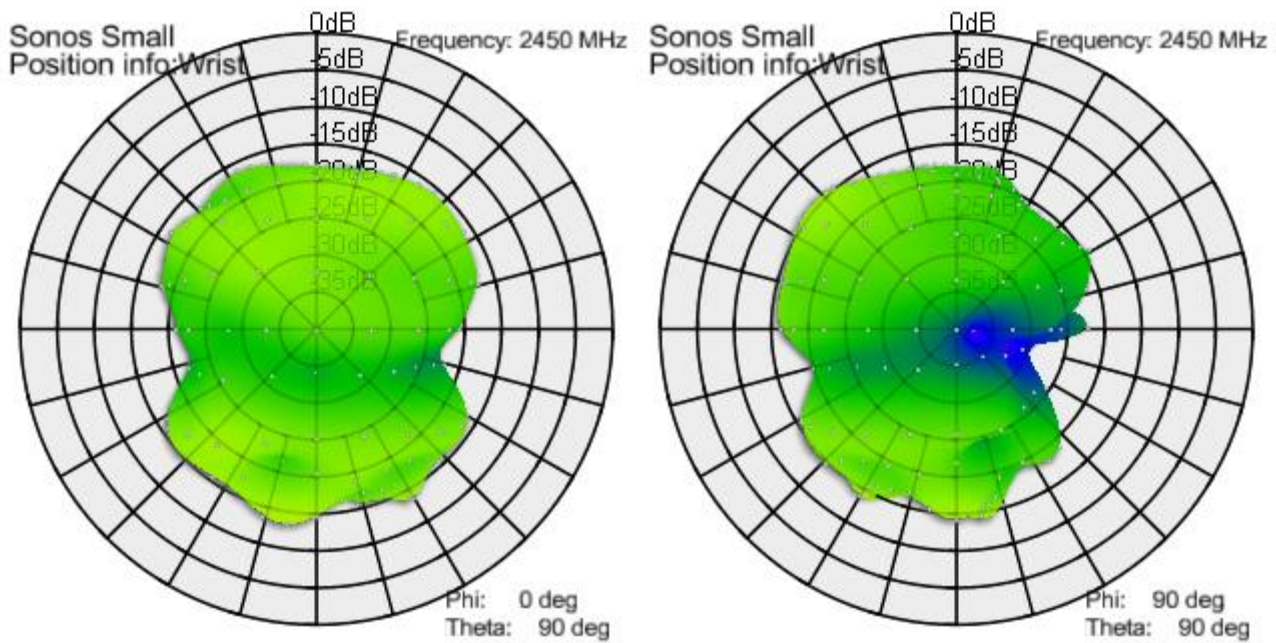


Figure 11 Antenna pattern at 2450 MHz, Sonos Small, Wrist