



Renesas DA14870

Antenna characterization

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Revision History

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3 Acronyms, Abbreviations and Definitions

Table 1. Acronyms

Acronym	Description
WSI	Wireless System Integration
VSWR	Voltage Standing Wave Ratio
PCB	Printed Circuit Board



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4 Introduction

This paper presents antenna measurements for the Renesas DA14870 BLE module when positioned on a reference test board. The module has an internal PCB integrated antenna supporting the 2.4GHz frequency band.

5 Antenna measurements

The BLE antenna performance is characterized in terms of *Voltage Standing Wave Ratio (VSWR)*, *antenna efficiency* and *radiation patterns*.

The antenna performances have been evaluated for the BLE module when positioned at three locations; left, middle and right on a reference test board with dimensions 89mm x 35mm.

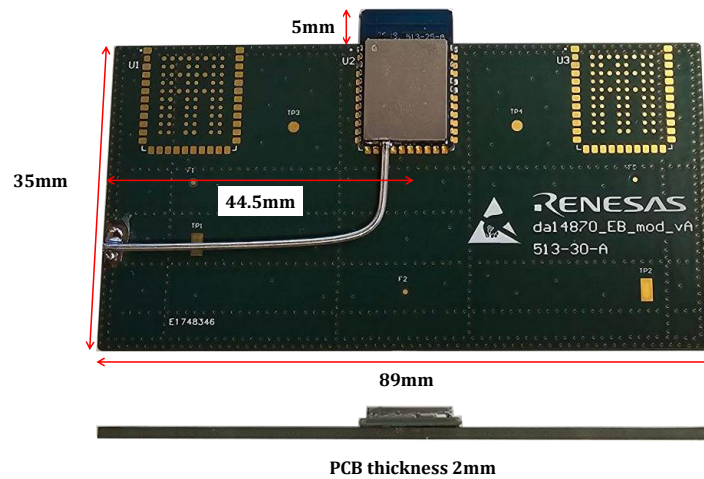


Figure 1. The DA14870 BLE module is positioned at right, middle and left position on a reference board with dimension 89mm x 35mm.

5.1 Voltage Standing Wave Ratio

Voltage Standing Wave Ratio (VSWR) is a measure of how well an antenna is impedance matched to the system impedance. A VSWR of one means a perfect match where all the available power is delivered to the antenna and an infinite VSWR means a short or an open circuit where all the energy is reflected.

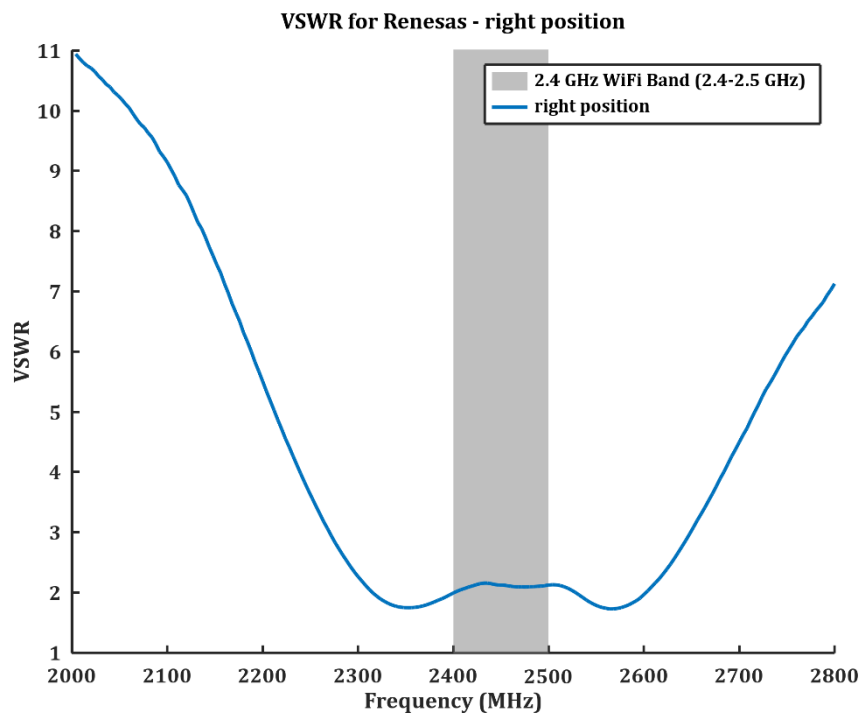


Figure 2. VSWR Renesas DA14870 BLE module antenna. Module in right position.

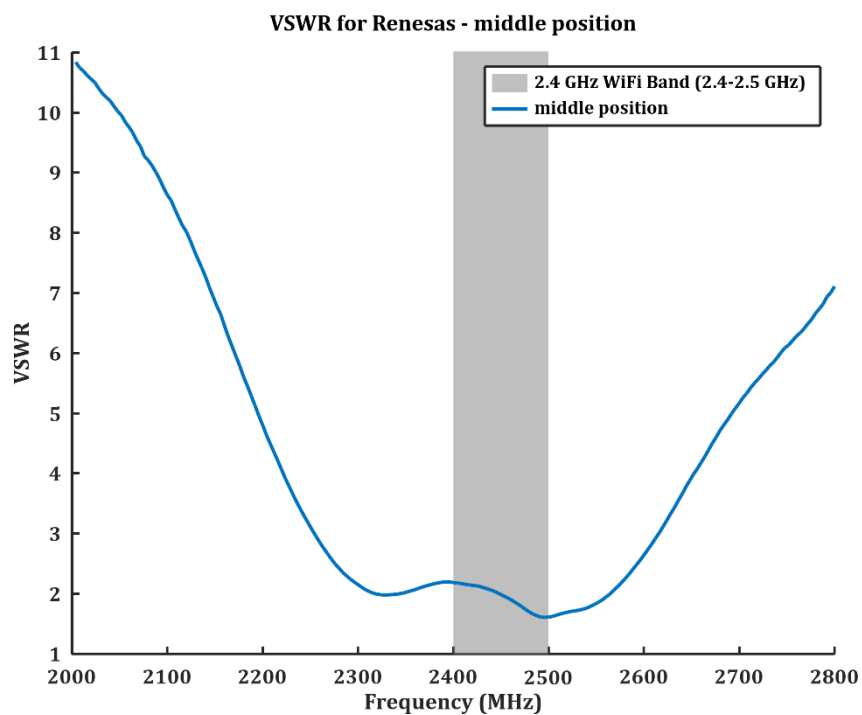


Figure 3. VSWR Renesas DA14870 BLE module antenna. Module in middle position.

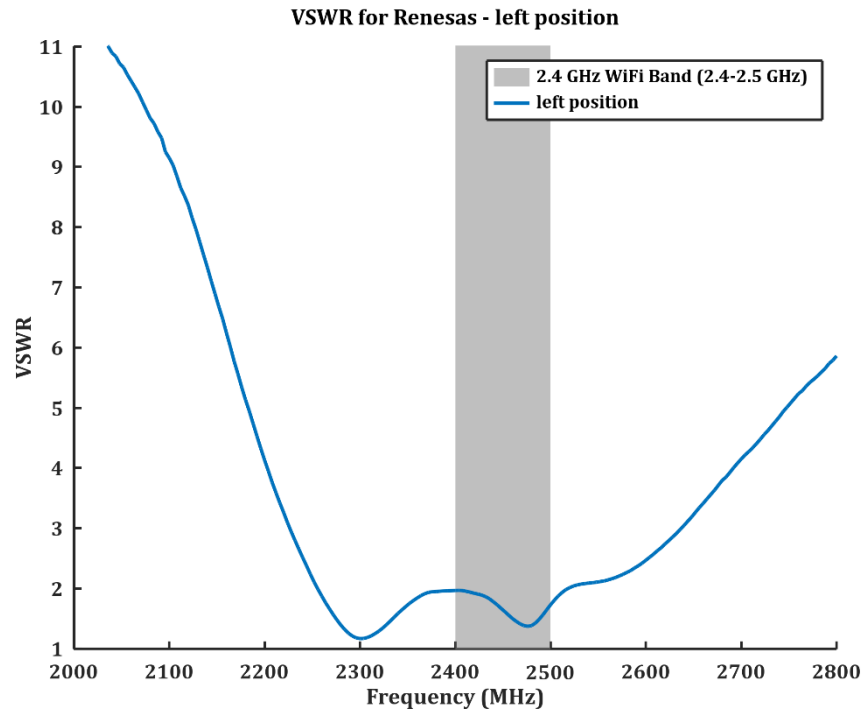


Figure 4. VSWR Renesas DA14870 BLE module antenna. Module in left position.

5.2 Antenna efficiency

The antenna efficiency measurements are carried out in a Satimo SG-23 6 GHz Stargate Antenna Test Chamber. The antenna efficiency, ε_T , is the ratio of the power delivered at the 50 Ω antenna interface, P_t , relative to the power radiated from the antenna, $P_{radiated}$.

$$\varepsilon_T = \frac{P_{radiated}}{P_t}$$

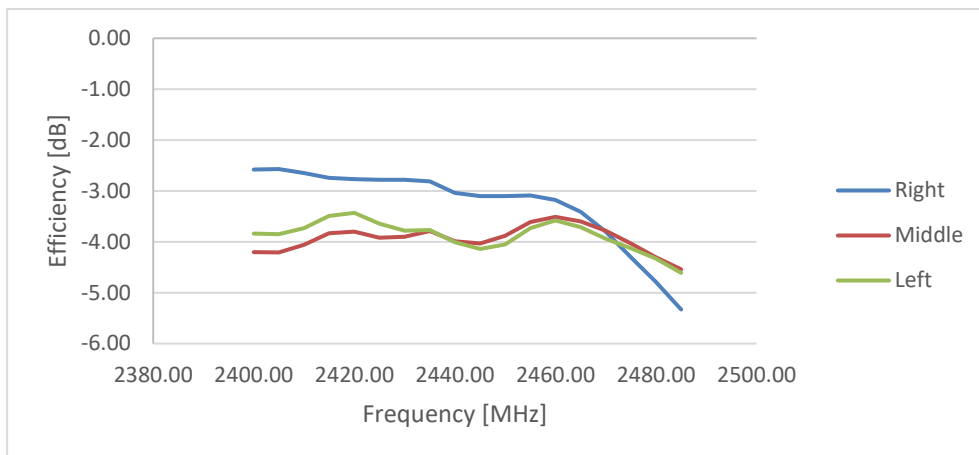


Figure 5. Antenna efficiency for the Renesas BLE module located at right, middle and left position at reference test board.

Table 2. Antenna efficiency for 2.4GHz band. Renesas DA14870 BLE module located at right, middle and left position at reference test board.

Frequency [MHz]	Right position	Middle position	Left position
	Antenna efficiency [dB]		
2400.00	-2.58	-4.20	-3.84
2405.00	-2.57	-4.21	-3.85
2410.00	-2.65	-4.06	-3.73
2415.00	-2.74	-3.83	-3.49
2420.00	-2.77	-3.80	-3.43
2425.00	-2.78	-3.92	-3.64
2430.00	-2.78	-3.90	-3.78
2435.00	-2.81	-3.79	-3.77
2440.00	-3.04	-3.99	-4.01
2445.00	-3.10	-4.03	-4.14
2450.00	-3.10	-3.88	-4.05
2455.00	-3.09	-3.61	-3.73
2460.00	-3.18	-3.51	-3.58
2465.00	-3.41	-3.60	-3.71
2470.00	-3.80	-3.78	-3.94
2475.00	-4.30	-4.03	-4.13
2480.00	-4.79	-4.30	-4.33
2485.00	-5.33	-4.54	-4.61

5.3 Antenna peak gain

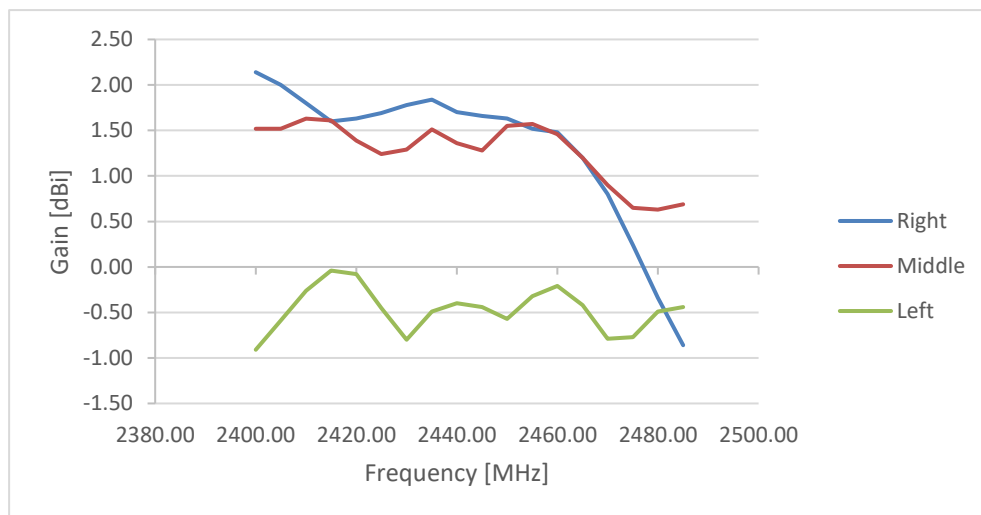


Figure 6. Antenna peak gain for the Renesas DA14870 BLE module located at right, middle and left position at reference test board.

Table 3. Antenna peak gain for 2.4GHz band. Renesas DA14870 BLE module located at right, middle and left position at reference test board.

Frequency [MHz]	Right position	Middle position	Left position
	Antenna peak gain [dBi]		
2400.00	2.14	1.52	-0.91
2405.00	2.00	1.52	-0.59
2410.00	1.80	1.63	-0.26
2415.00	1.60	1.61	-0.04
2420.00	1.63	1.39	-0.08
2425.00	1.69	1.24	-0.45
2430.00	1.78	1.29	-0.80
2435.00	1.84	1.51	-0.49
2440.00	1.70	1.36	-0.40
2445.00	1.66	1.28	-0.44
2450.00	1.63	1.55	-0.57
2455.00	1.52	1.57	-0.32
2460.00	1.48	1.46	-0.21
2465.00	1.20	1.20	-0.42
2470.00	0.80	0.90	-0.79
2475.00	0.24	0.65	-0.77
2480.00	-0.34	0.63	-0.49
2485.00	-0.86	0.69	-0.44

5.4 2D Radiation patterns

The antenna radiation pattern measurements are carried out in a Satimo SG-23 6GHz Stargate Antenna Test Chamber. Radiation patterns are presented for three measurement planes: XY-, XZ- and YZ-planes.



Figure 7. Satimo SG-23 6 GHz Stargate Antenna Test Chamber.

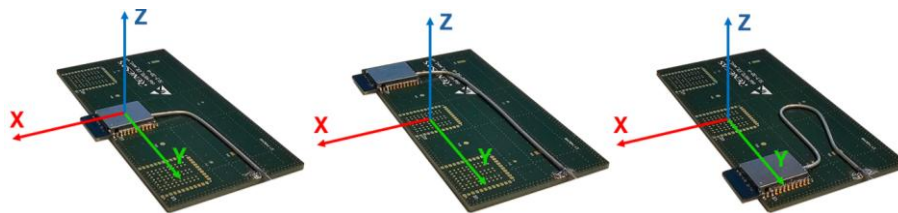
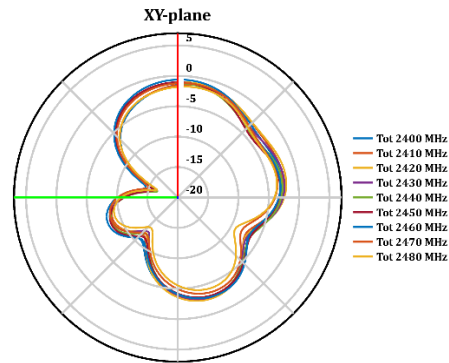


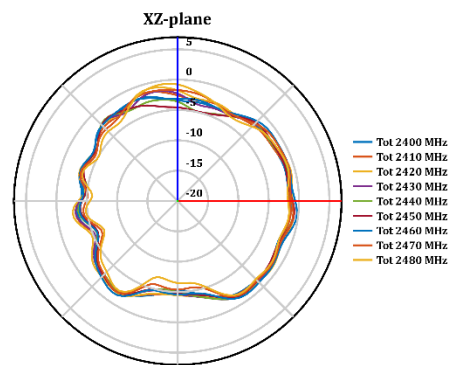
Figure 8. Measurement plane definitions.

5.4.1 2.4GHz: Module in right position



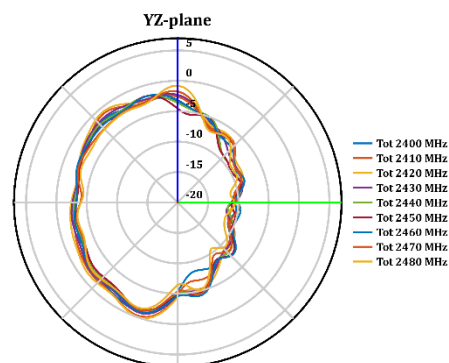
Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	-1.2	-4.5
2410	-1.3	-4.5
2420	-1	-4.1
2430	-1.2	-4.4
2440	-1.2	-4.5
2450	-1.1	-4.5
2460	-0.6	-4.2
2470	-1.2	-4.8
2480	-1.7	-5.3

Figure 9. Radiation patterns for Renesas DA14870 BLE module located at right position in XY-plane.



Freq [MHz]	Peak [dBi]	Avg [dBi]
2410	-1.3	-2.7
2420	-0.7	-2.3
2430	-0.8	-2.6
2440	-0.8	-2.9
2450	-0.7	-2.9
2460	-0.2	-2.4
2470	-0.8	-2.7
2480	-0.6	-3

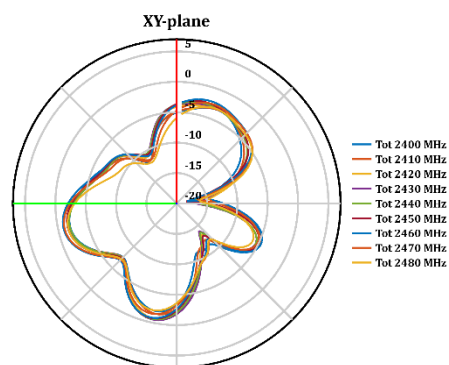
Figure 10. Radiation patterns for Renesas DA14870 BLE module located at right position in XZ-plane.



Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	-0.9	-4.3
2410	-0.3	-3.9
2420	-0.1	-3.5
2430	-0.8	-3.9
2440	-1.3	-4.3
2450	-1.4	-4.5
2460	-1	-4.1
2470	-1.3	-4.3
2480	-0.8	-4.6

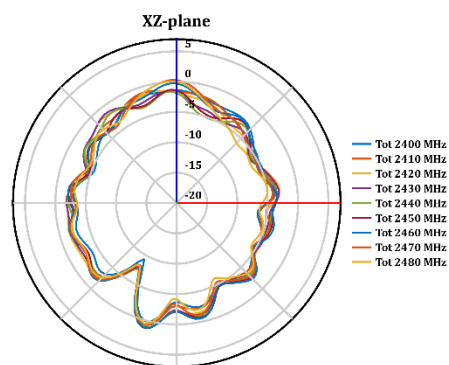
Figure 11. Radiation patterns for Renesas DA14870 BLE module located at right position in YZ-plane.

5.4.2 2.4GHz: Module in middle position



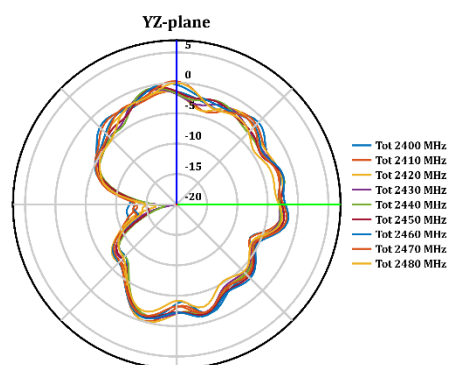
Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	-2	-5.7
2410	-1.5	-5.5
2420	-0.7	-5.1
2430	-0.5	-5.1
2440	-0.6	-5.2
2450	-0.7	-5.1
2460	-0.8	-4.8
2470	-1.1	-5.2
2480	-1.7	-5.8

Figure 12. Radiation patterns for Renesas DA14870 BLE module located at middle position in XY-plane.



Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	0.2	-3.4
2410	0.8	-3.1
2420	1.3	-2.8
2430	1.2	-2.9
2440	1.2	-3
2450	1.3	-3
2460	1.2	-2.7
2470	0.8	-2.9

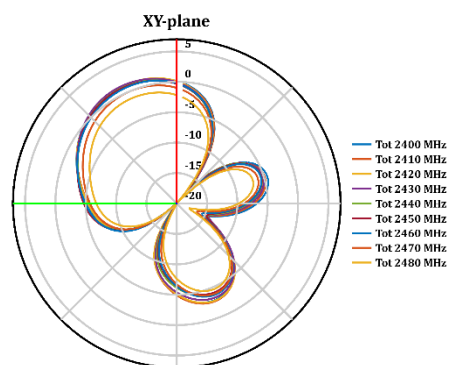
Figure 13. Radiation patterns for Renesas DA14870 BLE module located at middle position in XZ-plane.



Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	-0.8	-3.4
2410	-0.1	-3.4
2420	0	-3.4
2430	-0.8	-3.6
2440	-0.4	-3.7
2450	-0.5	-3.5
2460	0	-3
2470	0.3	-3.3
2480	0	-4

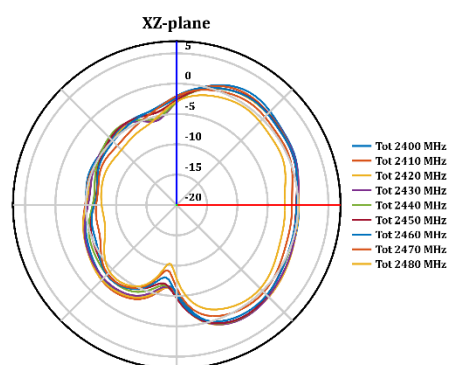
Figure 14. Radiation patterns for Renesas DA14870 BLE module located at middle position in YZ-plane.

5.4.2.1 2.4GHz Module in left position



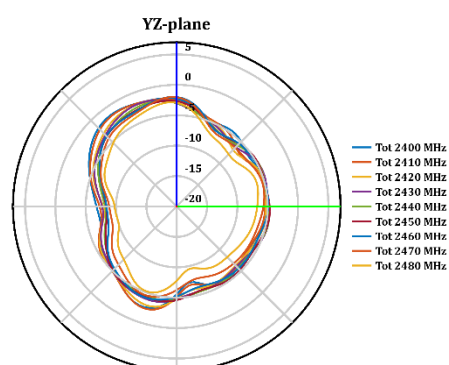
Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	1.2	-3.9
2410	1.1	-3.9
2420	1.2	-3.9
2430	1.3	-4
2440	1	-4.2
2450	1	-4.3
2460	0.8	-4.3
2470	0	-5
2480	-1.2	-6.1

Figure 15. Radiation patterns for Renesas DA14870 BLE module located at left position in XY-plane.



Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	2.1	-1.1
2410	1.6	-1.1
2420	1.6	-1.2
2430	1.7	-1.3
2440	1.5	-1.5
2450	1.5	-1.5
2460	1.4	-1.6
2470	0.7	-2.2

Figure 16. Radiation patterns for Renesas DA14870 BLE module located at left position in XZ-plane.



Freq [MHz]	Peak [dBi]	Avg [dBi]
2400	-1.4	-4.3
2410	-1.6	-4.5
2420	-2	-4.8
2430	-2	-4.7
2440	-2.4	-4.9
2450	-2.5	-4.9
2460	-2	-5
2470	-2	-5.6
2480	-2.8	-6.5

Figure 17. Radiation patterns for Renesas DA14870 BLE module located at left position in YZ-plane.



A. Antenna measurement system

All radiated measurements were performed using the measurement setup described in this appendix.

Table 4. List of equipment in antenna measurement system.

Item	Vendor	Model/Version
3D measurement chamber	Satimo	SG-23
Network Analyzer	Rohde & Schwarz	ZNB-8
Software	MVG	Wave Studio 22.5.6
Last calibration	MVG	2025-08

B. 3D antenna radiation patterns

B.1 Renesas DA14870 BLE module located in right position

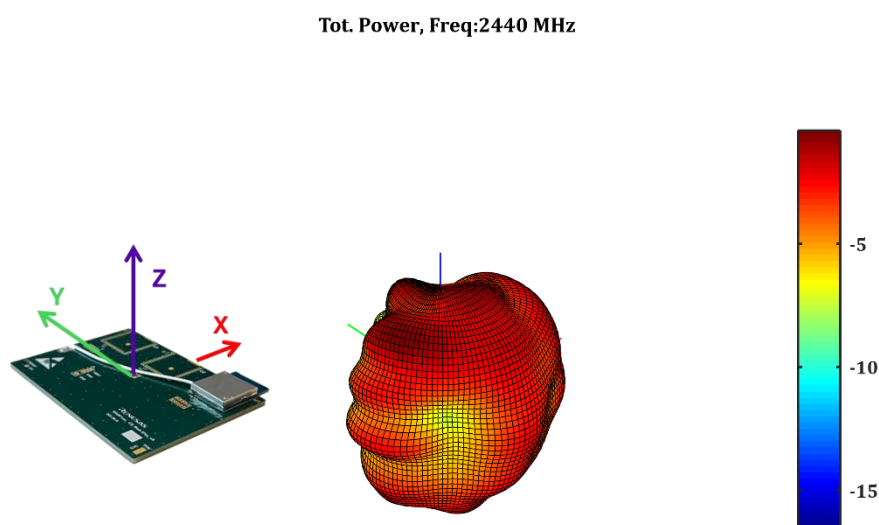


Figure 18. 3D plot in right position.

Table 5. Gain and efficiency for 3D plots in right position.

Freq [MHz]	Peak [dBi]	Efficiency [dB]
2400	-0.9	-3.8
2410	-0.3	-3.7
2420	-0.1	-3.4
2430	-0.8	-3.8
2440	-0.4	-4
2450	-0.6	-4
2460	-0.2	-3.6
2470	-0.8	-3.9
2480	-0.5	-4.3

B.2 Renesas DA14870 BLE module located in middle position

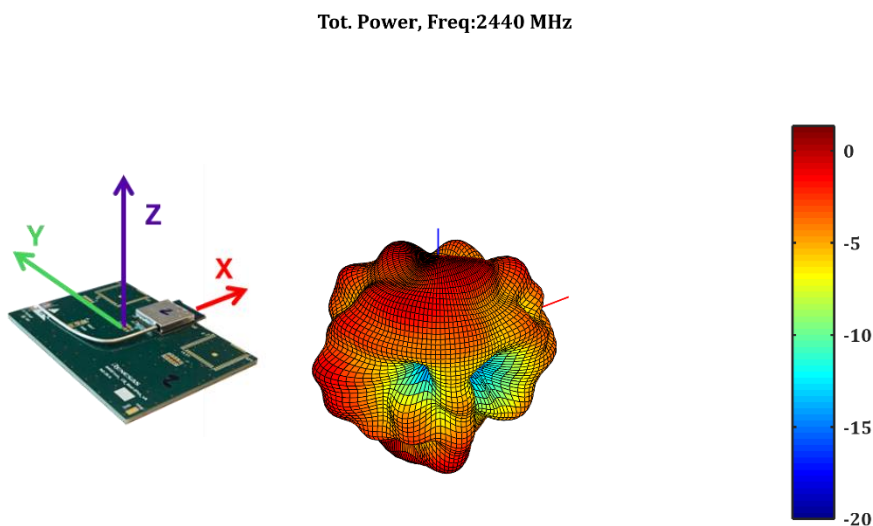


Figure 19. 3D plot in middle position.

Table 6. Gain and efficiency for 3D plots in middle position.

Freq [MHz]	Peak [dBi]	Efficiency [dB]
2400	1.5	-4.2
2410	1.6	-4.1
2420	1.4	-3.8
2430	1.3	-3.9
2440	1.4	-4
2450	1.5	-3.9
2460	1.5	-3.5
2470	0.9	-3.8
2480	0.6	-4.3

B.3 Renesas DA14870 BLE module located in left position

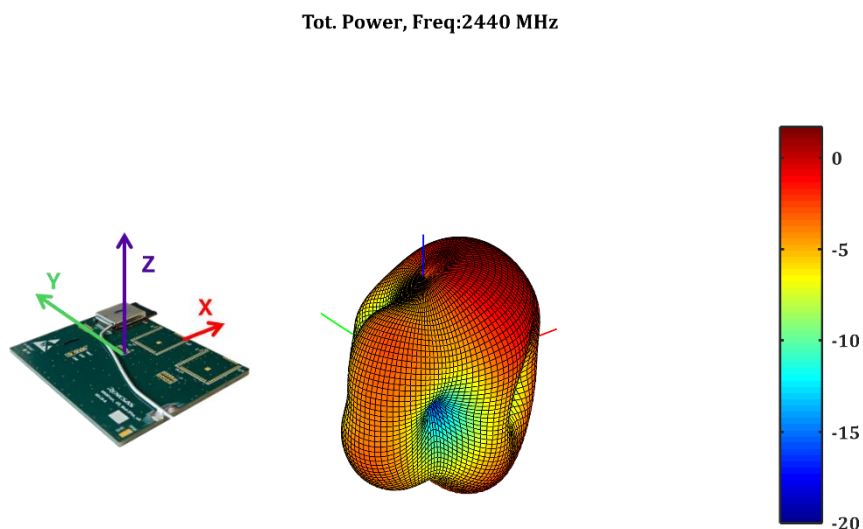


Figure 20. 3D plot in left position.

Table 7. Gain and efficiency for 3D plots in left position.

Freq [MHz]	Peak [dBi]	Efficiency [dB]
2400	2.1	-2.6
2410	1.8	-2.6
2420	1.6	-2.8
2430	1.8	-2.8
2440	1.7	-3
2450	1.6	-3.1
2460	1.5	-3.2
2470	0.8	-3.8
2480	-0.3	-4.8