http://dx.doi.org/10.35596/1729-7648-2026-24-3-29-35

UDC 621.396.677

USING A MICROSTRIP ANTENNA TO DETECT BREAST CANCER

HESHAM AYAD, SAJA SWISSI, RIHAM MADI, REHAB ALHATAB

University of Zawia (Az-Zawiya, Libya)

Abstract. This article discusses the design of a Vivaldi microstrip antenna operating at 7 GHz. Its broadband characteristics and high directivity make it ideal for use in a variety of applications. The design utilizes FR4 material, known for its excellent electrical properties. The antenna's performance was analyzed using S-parameters, which demonstrated good stability and high power transfer efficiency. Testing the antenna on healthy and diseased breast tissue revealed significant energy absorption, indicating the antenna's effectiveness in detecting changes in tissue electrical properties.

Keywords: Vivaldi microstrip antenna, FR4, S-parameters, transmitter, receiver.

Conflict of interests. The authors declare that there is no conflict of interests.

For citation. Ayad H., Swissi S., Madi R., Alhatab R. (2026) Using a Microstrip Antenna to Detect Breast Cancer. *Doklady BGUIR*. 24 (3), 29–35. http://dx.doi.org/10.35596/1729-7648-2026-24-3-29-35.

ИСПОЛЬЗОВАНИЕ МИКРОПОЛОСКОВОЙ АНТЕННЫ ДЛЯ ОБНАРУЖЕНИЯ РАКА МОЛОЧНОЙ ЖЕЛЕЗЫ

Х. АЙАД, С. СВИССИ, Р. МАДИ, Р. АЛЬХАТАБ

Университет Аль-Завия (Эз-Завия, Ливия)

Аннотация. В статье рассмотрена конструкция микрополосковой антенны Вивальди, работающей на частоте 7 ГГц, с широкополосными характеристиками и высокой направленностью, что делает ее идеальной для применения в различных областях. В конструкции использовался материал FR4, известный отличными электрическими свойствами. Характеристики антенны анализировались с помощью S-параметров, которые показали хорошую стабильность и высокую эффективность передачи мощности. При испытании антенны на здоровых и пораженных тканях молочной железы было выявлено значительное поглощение энергии. Это указывает на эффективность антенны в обнаружении изменений электрических свойств тканей.

Ключевые слова: микрополосковая антенна Вивальди, FR4, S-параметры, передатчик, приемник.

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

Для цитирования. Использование микрополосковой антенны для обнаружения рака молочной железы / Х. Айад [и др.] // Доклады БГУИР. 2026. Т. 24, № 3. С. 29–35. http://dx.doi.org/10.35596/1729-7648-2026-24-3-29-35.

Introduction

Antennas are metallic devices used to transmit and receive electromagnetic waves, acting as an interface between outer space and communication equipment. Antennas come in various types and applications, and among these, microstrip antennas are of particular importance [1, 2]. A microstrip antenna consists of a conductive material placed on an insulating surface and mounted on a ground-level support structure [3]. Microstrip antennas are characterized by their small size, ease of manufacture, and relatively low cost [4]. In addition to their radiation characteristics, these antennas offer better directionality, higher gain, and longer transmission range with reduced interference compared to other types of antennas [5, 6].

Breast cancer is the most common cancer among women worldwide, accounting for 23 % of all female cancers. Early detection of breast cancer in asymptomatic women is crucial for saving lives and preserving breast health [7, 8]. However, many patients find it difficult to undergo regular screenings, as most monitoring and follow-up systems are complex and immobile [9, 10]. The flexible and efficient properties of microstrip antennas make them very suitable for imaging and diagnostic applications [11].

Conducting an experiment

Tab. 1 lists the structural characteristics of the breast and their acceptable values. The structure of the mammary gland tissue is shown in Fig. 1.

Table 1. Breast characteristics

Layer	Dielectric constant *εr*	Tangent loss tanδ
Skin	17.7	0.93
Fat	3.4	0.16
Fibro-globular tissue	16	0.94
Tumor tissue	20	1.05

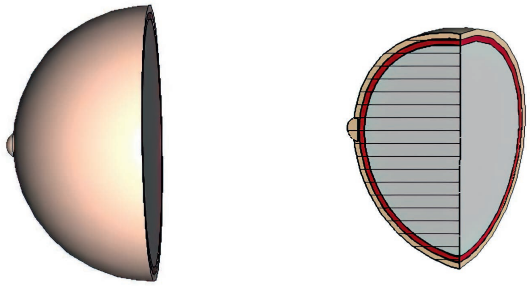

Fig. 1. Breast tissue structure

In the studies conducted for breast cancer detection, the Vivaldi antenna was used. It has excellent ultra-wideband (UWB) characteristics, high directivity, compact size, and a simple planar structure (Fig. 2). These properties make it suitable for biomedical imaging applications, including breast cancer detection. The Vivaldi antenna is capable of generating directional beams and operating over a broad frequency spectrum, penetrating deep into tissue, and detecting changes with high resolution [12, 13].

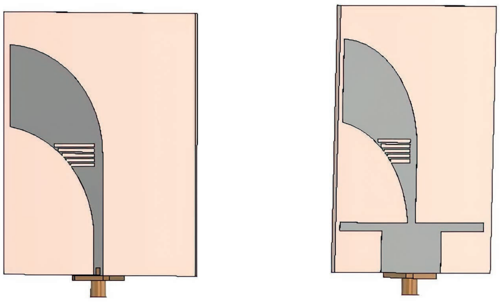

Fig. 2. Vivaldi slot antenna

Design of a Vivaldi microstrip antenna operating at 7 GHz

To design a small Vivaldi slot antenna, the substrate thickness *h*, dielectric constant *εr*, and center frequency response *fr* in hertz must be determined. The antenna dimensions *W* and length *L* are then defined. In this design, an operating frequency of 7 GHz was used because it offers several important technical advantages for advanced communication applications. FR4 material was chosen due to its suitability for microwave and millimeter wave applications, its lightweight nature, availability, and ease of fabrication. It has a dielectric constant ε = 2.33 and a thickness of 0.127 mm. It also has a loss shadow tanδ = 0.0005. Fig. 3 shows the construction of the Vivaldi slot antenna.

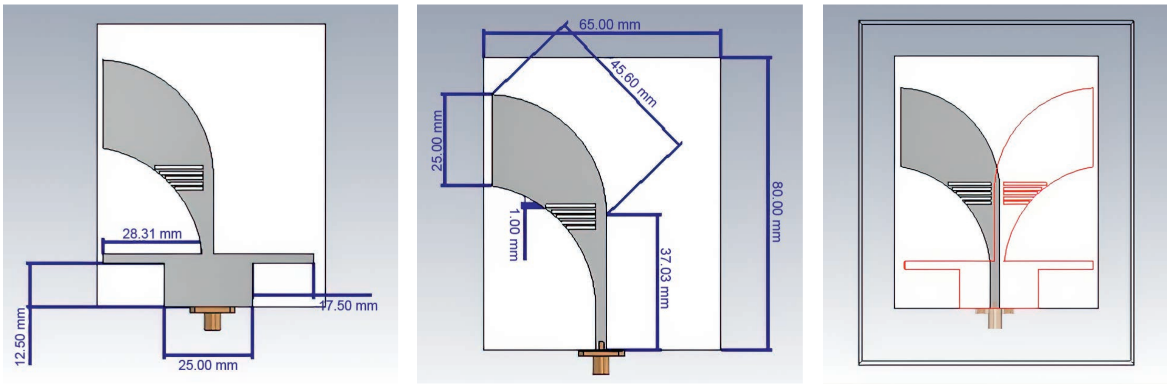

Fig. 3. Construction of the Vivaldi slot antenna

The system is designed with a transmitter and receiver at a frequency of 7 GHz. A sensor system based on experimental construction measurements (S2,1) was designed and analyzed to detect the electromagnetic radiation generated in the medium between two opposing antennas (transmitter and receiver) at a frequency of 7 GHz. The global system operates on the electromagnetic spectrum generated by the antenna, which is generated by the receiving antenna. The characteristics of the transmitter and the antenna separation are shown in Fig. 4.

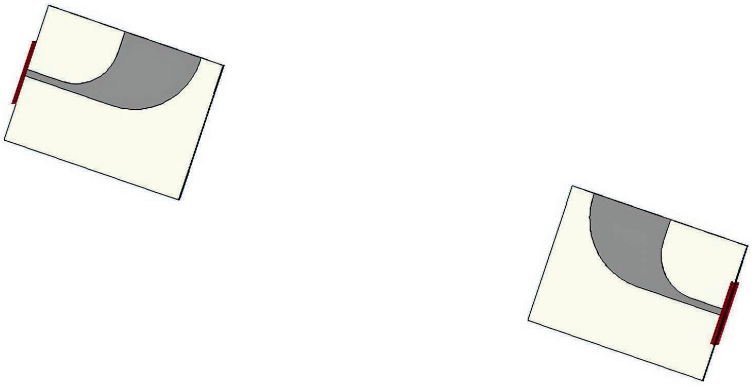

Fig. 4. A system with a transmitter and receiver

Results and its discussion

The S1,1 parameter graph (Fig. 5) shows stable performance across frequencies from 6.0 to 8.0 GHz. At –15 dB, the S1,1 value is –13.570864, indicating low reflections and efficient energy transfer. The smooth response suggests the component operates effectively without significant fluctuations. These results are ideal for RF applications where minimizing reflections is crucial. Overall, this performance reflects high quality and efficiency in signal transmission within the specified frequency range.

The S2,1 parameter graph (Fig. 6) shows the performance of an RF component across frequencies from 6.0 to 8.0 GHz. It displays a gradual decrease in the S2,1 = –34.92752value with increasing frequency, indicating improved transmission efficiency. Negative values suggest low reflections, reflecting good performance. These results are ideal for use in wireless communication systems. Overall, the component operates with high efficiency in the specified frequency range.

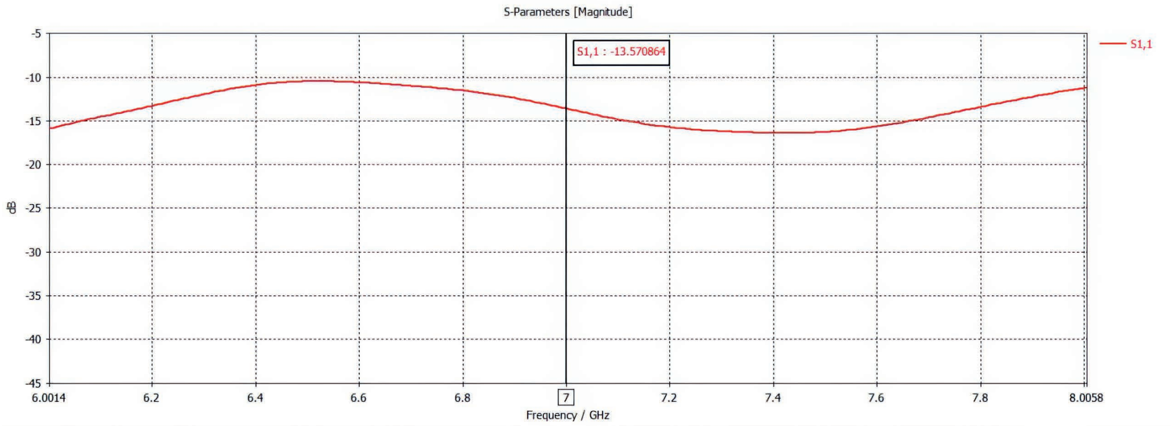

Fig. 5. Reflection coefficient at port 1 in the frequency range from 6.0 to 8.0 GHz

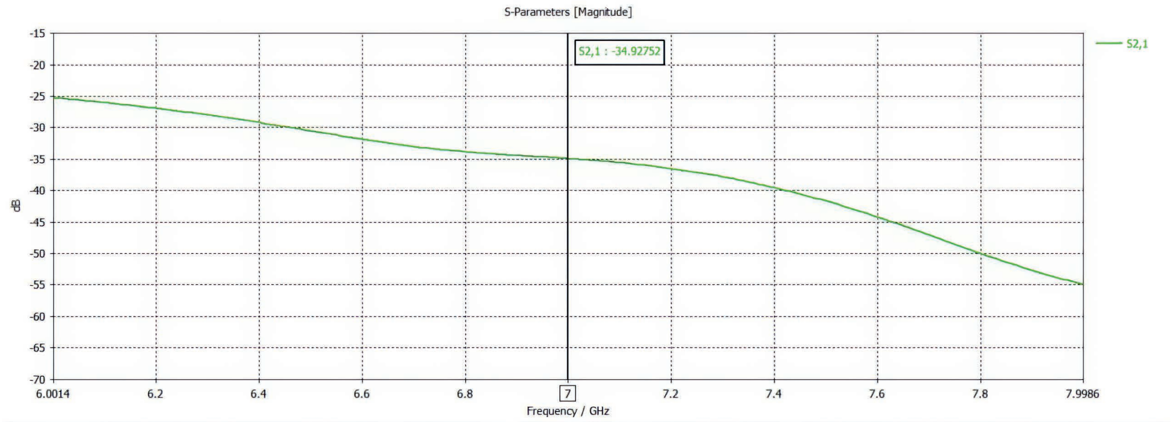

Fig. 6. Transition factor from port 1 to port 2 in the frequency range from 6.0 to 8.0 GHz

The S2,2 parameter graph (Fig. 7) shows stable performance across frequencies from 6.0 to 8.0 GHz. At –15 dB, the S2,2 value is –13.571697, indicating low reflections and efficient energy transfer. The smooth response suggests the component operates effectively without significant fluctuations. These results are ideal for RF applications where minimizing reflections is crucial. Overall, this performance reflects high quality and efficiency in signal transmission within the specified frequency range.

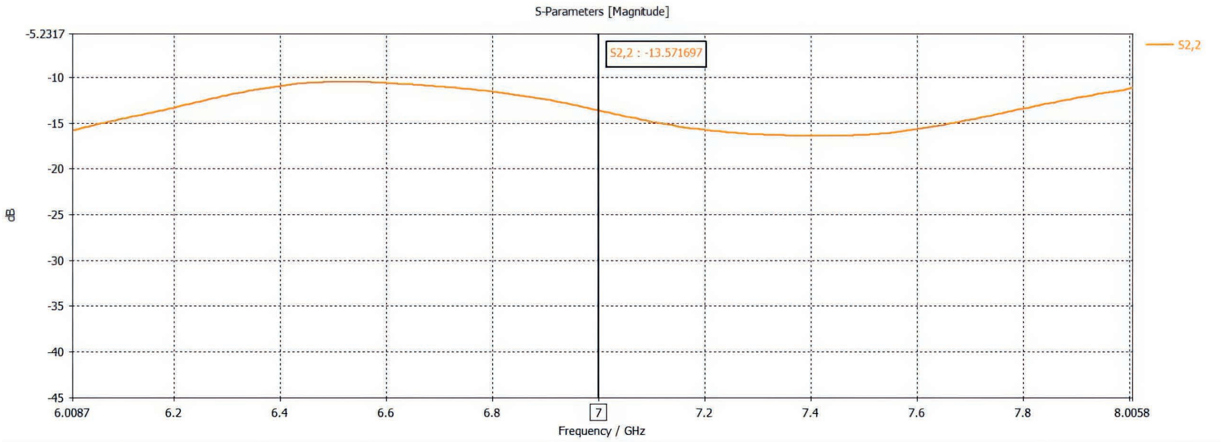

Fig. 7. Reflection coefficient at port 2 in the frequency range from 6.0 to 8.0 GHz

The S1,2 parameter graph (Fig. 8) shows the performance of an RF component across frequencies from 6.0 to 8.0 GHz. It displays a gradual decrease in the S1,2 = –34.92752 value with increasing frequency, indicating improved transmission efficiency. Negative values suggest low reflections, reflecting good performance. These results are ideal for use in wireless communication systems. Overall, the component operates with high efficiency within the specified frequency range.

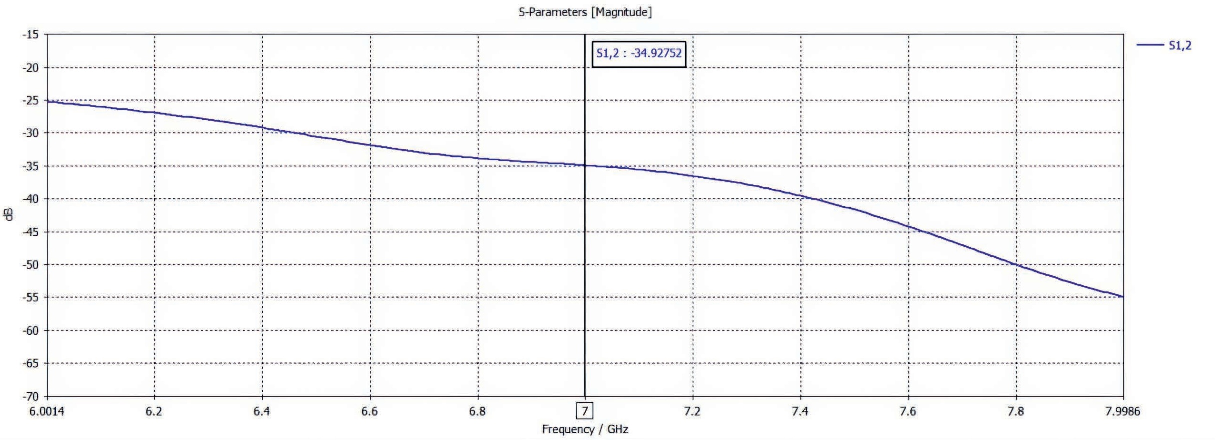

Fig. 8. Transition factor from port 2 to port 1 in the frequency range from 6.0 to 8.0 GHz

In Fig. 9, the breast was placed between two Vivaldi slot antennas design at 7 GHz for the purpose of detecting changes in the transmission coefficient (S2,1; S1,2). Fig. 10, 11 show the results of S1,2 = –42.908394 and S2,1 = –42.908438. It is clear that there is a significant loss in the signal, indicating significant absorption or dispersion of energy through the breast tissue.

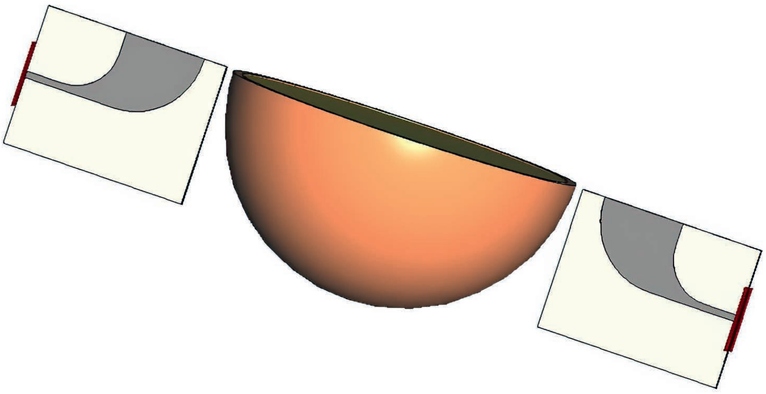

Fig. 9. Healthy breast between the two antenna

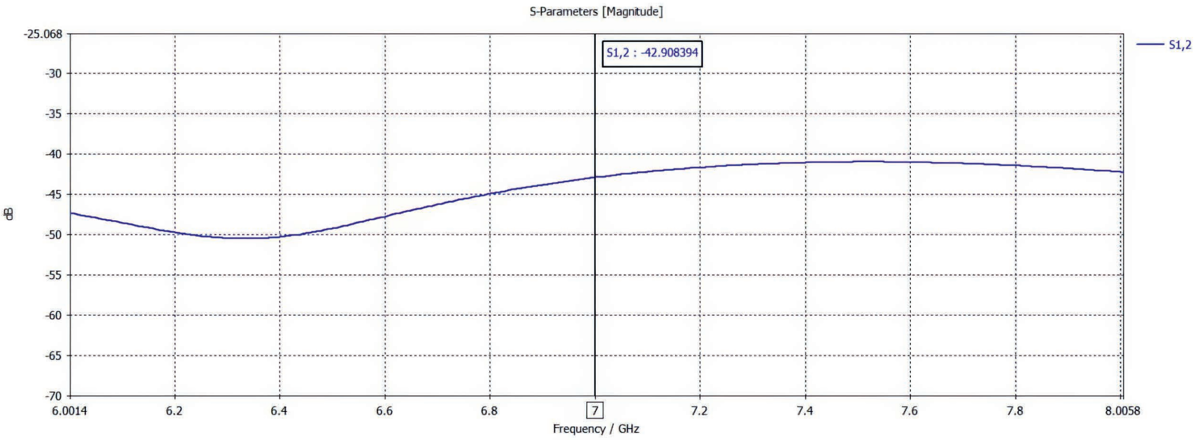

Fig. 10. Transition factor from port 2 to port 1 in the frequency range from 6.0 to 8.0 GHz for the healthy breast

In Fig. 12, the affected breast was placed between two Vivaldi slot antennas at 7 GHz to detect changes in the transmission coefficient (S2,1; S1,2). Fig. 13, 14 show the results for S1,2 = –45.288975 and S2,1 = –45.288976. Significant signal loss is evident, indicating significant absorption or dissipation of energy across the breast tissue.

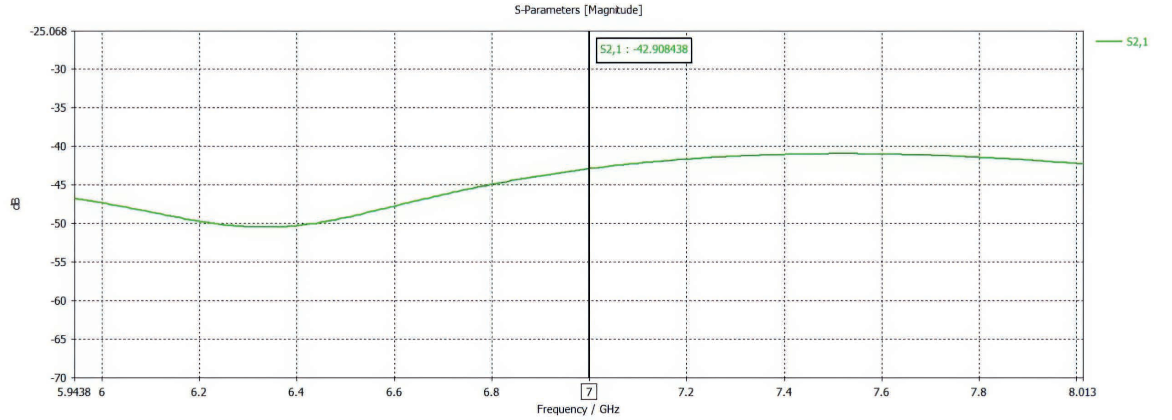

Fig. 11. Transition factor from port 1 to port 2 in the frequency range from 6.0 to 8.0 GHz for the healthy breast

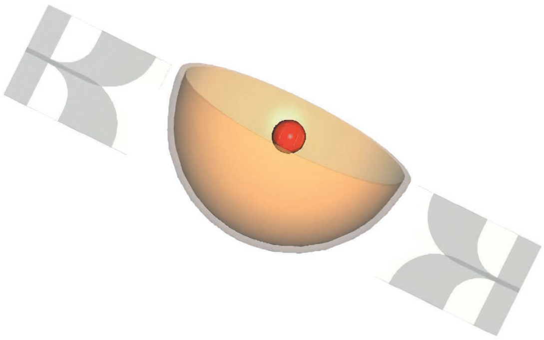

Fig. 12. Place the affected breast between the antenna

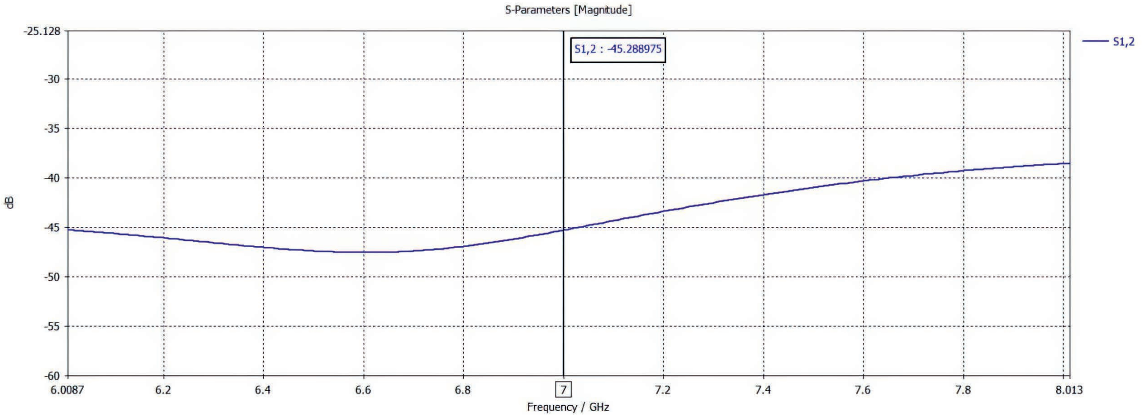

Fig. 13. Transition factor from port 2 to port 1 in the frequency range from 6.0 to 8.0 GHz for the affected breast

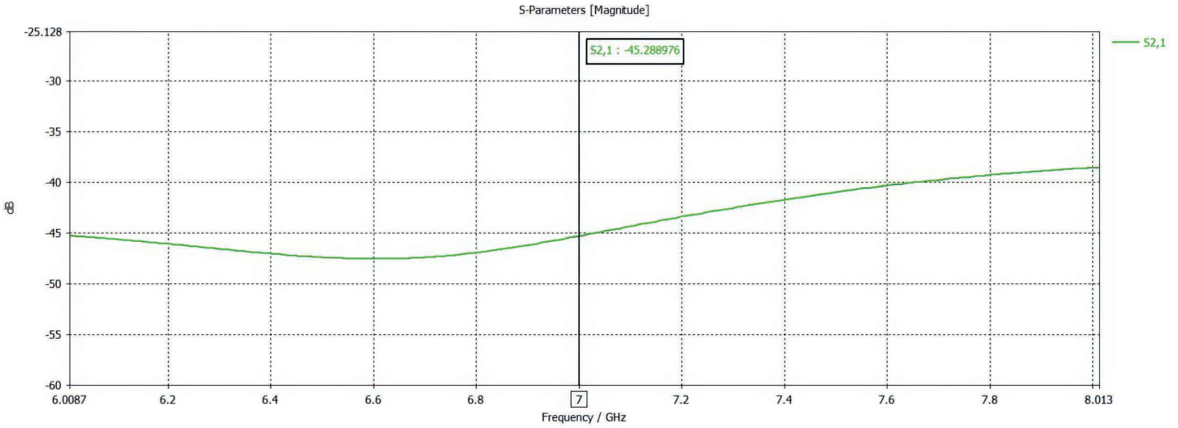

Fig. 14. Transition factor from port 1 to port 2 in the frequency range from 6.0 to 8.0 GHz for the affected breast

Conclusion

1. The Vivaldi antenna design features high efficiency within a specific frequency range, a significantly reduced reflectance coefficient, and negative S-values.

2. The results indicate good signal transmission performance, making the antenna an effective tool in medical applications, such as early breast cancer detection. This design opens new avenues for its use in modern medical imaging technologies.

3. Recommendations of the obtained results development are the following:
– test a wider range of frequencies;
– design a system consisting of more than two antennas to increase accuracy;
– explore broader applications for the designed system, such as detecting other types of tumors;
– integrate artificial intelligence techniques into data analysis.

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Received: 4 December 2025
Accepted: 17 April 2026

Authors' contribution

The authors contributed equally to the writing of the article.

Information about the authors

Ayad H., PhD, Lecturer of Electrical Engineering and Electronics Department, University of Zawiya (UZ)

Swissi S., Student, UZ

Madi R., Student, UZ

Alhatab R., Student, UZ

Address for correspondence

16418, Libya, Zawiya
University of Zawiya
Tel.: +218 92 7405417
E-mail: h.ayad@zu.edu.ly
Ayad Hisham