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A Circular Ring Patch Antenna for Breast Cancer Detection Based on Return Loss and Voltage Standing Wave Ratio

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ABSTRACT The increasing number of breast cancer cases is a significant threat to women's health, emphasizing the importance of timely detection for successful treatment. Various medical imaging techniques, including magnetic resonance imaging, mammography, digital mammography, and computer-aided detection, are available for breast cancer detection. Among these methods, microwave imaging (MI) stands out due to its simplicity, effectiveness, and non-invasiveness. In this paper, a compact circular ring patch antenna with a partial ground plane is designed for detecting breast tumors using MI technique. The antenna operates at 5.2 GHz within the ultra-wideband frequency range of 3.1 – 10.6 GHz. It is made from Rogers RT/duroid 5880 material, with a dielectric constant of 2.2, a tangent loss of 0.02, and a thickness of 0.8 mm, featuring overall dimensions of 30 × 20 × 0.8 mm^3. High-Frequency Structure Simulator (HFSS) software is utilized to simulate the antenna, and breast phantoms with and without tumors. The simulation results reveal a return loss and VSWR value of –32.08 dB, – 40.30 dB, 1.0539, and 1.0198 without and with tumors, respectively. These findings demonstrate that the proposed antenna can accurately detect the presence of a tumor through variations in return loss and voltage standing wave ratio (VSWR), making it capable of detecting very small tumors (4 mm) due to its compact size and excellent impedance-matching characteristics. Overall, the study suggests that this compact antenna design shows promise in improving early detection of breast cancer, offering a simple yet effective solution in the field of microwave imaging.

INDEX TERMS Circular ring patch antenna, Return loss, VSWR, HFSS, Rogers RT/duroid 5880 (tm)

I. INTRODUCTION

Breast cancer is a significant global health issue with high rates of mortality and morbidity. Early detection is critical for improving patient outcomes through timely treatment. Several methods have been developed for early breast cancer detection, including biopsy, X-ray mammography, ultrasound, and tomography. Presently, mammography is considered the standard for breast imaging. The National Cancer Institute recommends that women aged 40 – 50 undergo mammograms twice annually and annually for those above 50. However, mammography has limitations, including a false-negative rate of 4 – 34% and exposure to ionizing radiation [1 – 3]. Biopsy-based methods are effective at detecting breast cancer cells, but they are invasive and require repeated procedures when the collected tissue sample is insufficient. These procedures are painful, time-consuming, and costly [4 – 6]. Other imaging methods, such as ultrasound and MRI, also suffer from high false-negative rates [7].

Microwave imaging (MI) techniques are emerging as a promising alternative for breast cancer detection. MI leverages the variations in dielectric properties between healthy and cancerous tissues, making it a safer and potentially more accurate diagnostic tool compared to conventional methods. Cancerous tissues generally exhibit higher dielectric properties than normal tissues, which can be detected using microwave signals [8 – 10]. This technique minimizes the risks associated with ionizing radiation exposure and offers a non-invasive diagnostic option. Biological tissue is highly non-homogeneous, comprising physical components with different permittivities and conductivities, which can be modeled homogeneously at specific frequencies. When breast tissue is placed close to the antenna, the antenna acts as a sensor, capturing variations in the electric properties of the breast tissue through transmission and reflection coefficients [11 – 13].

Microstrip patch antennas are commonly used in microwave imaging systems due to their practical advantages and cost-effectiveness. These antennas are compact, easy to fabricate, and can be integrated into wearable devices [14]. They are crucial in improving the accessibility of microwave imaging technology in clinical settings. Various antenna designs have been proposed, including a low-cost textile wearable antenna [15] and an ultra-wideband flexible antenna tested on breast phantoms [16]. These innovations aim to enhance the sensitivity and specificity of breast cancer detection, addressing some limitations of traditional mammography. Studies have explored different antenna configurations, such as circular arrays [17] and elliptical ring antennas [18], to enhance tumor detection in breast phantoms.

An on-body microstrip antenna operating in the S-band (1.5 to 3 GHz) was developed and compared in performance between free space and a breast model affected by cancer. This development aims to enable the early diagnosis of breast cancer [19]. Additionally, a 16-printed log periodic antenna array with metamaterial loading showed significant potential in microwave imaging for breast tumor detection, offering enhanced properties such as radiation pattern and gain crucial for accurate imaging [20]. A compact ultrawideband slotted patch antenna was designed for early-stage breast tumor detection applications, demonstrating efficient performance based on the electrical characteristics of breast cancer cells [21]. Microwave breast imaging using CPW antenna structures demonstrates superior performance in terms of return loss, which is essential for precise breast cancer detection [22]. Furthermore, ultra-wideband microstrip patch antennas and circular slotted UWB monopole antennas were proposed for breast cancer detection, emphasizing the importance of antenna design in improving detection accuracy and reliability [23 – 24]. A flexible and wearable microstrip patch antenna was developed for breast cancer detection via a circular slit [25]. A unique ultra-wideband (UWB) patch antenna design, specifically for detecting breast tumors, was created [26].This new design features a partially ground plane and slots to enhance performance in a compact size. The breast cancer detection system, operating within the ISM Band, was established through an analysis of the specific absorption rate (SAR) using a multi-slotted patch antenna [27]. A microstrip patch antenna was engineered to operate within the ISM frequency range with the aid of CST Studio Suite software [28]. Subsequently, it underwent testing with two different 3D breast phantom models. The expression of a preference for radiation-free methods in the early detection of breast tumors, especially in earlier decades, was stated [29]. An innovative idea was introduced for an ultra-wide-band (UWB) microstrip antenna that aims to identify breast cancer in its initial phase. This unique design incorporates a partial ground technique, which effectively improves the antenna's bandwidth. The proposal is grounded on a comprehensive analysis of the specific absorption rate (SAR) [30]. A rectangular microstrip patch antenna with a T-shaped slot and symmetrical rectangular slots was developed for breast cancer detection [31]. An investigation was conducted on inset-fed rectangular microstrip antenna structures for microwave imaging aimed at early breast cancer diagnosis [32]. This involved modifying the ground plane and introducing slots on the microstrip patch. A specifically designed I-shaped dual C-slotted microstrip patch antenna was developed for the detection of cancer tumors in the breast at a frequency of 10 GHz [33]. The proximity of the antenna to the human breast without any distance between them was considered for tumor detection, which could pose a risk to human skin tissue [31 – 33].

Overall, the advancements in microwave imaging and antenna technology hold great promise for improving the early detection and diagnosis of breast cancer, potentially leading to better patient outcomes.

Several antenna configurations have been proposed in the literature [25, 27 – 30] for the purpose of breast cancer detection. However, these antennas are characterized by their large size and the need for enhancements in terms of return loss and design simplicity to render them suitable for medical applications. This study aims to contribute to breast cancer detection by creating a small and efficient circular microstrip patch antenna that uses ring slots and a partial ground plane to address these challenges. This antenna is positioned 10 mm away from the skin of the breast, making it safe for human skin tissue, and it serves as a sensor for microwave imaging for breast cancer detection. A beneficial aspect of this antenna is that it does not require a coupling liquid during operation. Additionally, precautions will be taken to minimize the potential negative effects of ionizing radiation on healthy tissue. By surmounting the limitations associated with prior antenna configurations concerning dimensions, return loss, and design complexity, the suggested antenna opens up promising opportunities for improving the suitability of antennas in medical settings, especially in the early detection of breast cancer The contributions of the paper are summarized as follows:

1. The study presents a small circular microstrip patch antenna with ring slots and a partial ground plane. This antenna is designed for detecting breast tumors using a microwave imaging technique. The design aims to overcome the limitations of traditional medical imaging techniques and size constraints that have restricted the use of antennas in medical applications, especially in the detection of breast cancer.
2. The antenna is designed to operate at a safe distance of 10 mm from breast tissue to ensure human skin safety and eliminate the need for coupling liquids. This design improvement significantly enhances its practicality and safety in medical diagnostics.
3. The antenna design has been optimized to improve return loss and voltage standing wave ratio (VSWR), while also simplifying its design complexity. These enhancements address key challenges in modern microwave imaging technology and can lead to more accurate and efficient breast cancer detection. This may potentially improve patient outcomes and advance the use of microwave imaging in medical diagnostics.

II. MATERIALS AND METHODS

A. ROGERS RT/DUROID 5880 MATERIAL:

Rogers RT/duroid 5880 is a high-frequency laminate material recognized for its outstanding electrical and mechanical characteristics, which establish it as a favored option in microwave and millimeter-wave circuits, such as high-performance antennas like microstrip patch antennas. Featuring a dielectric constant of 2.20 ± 0.02, this material effectively reduces signal distortion and loss, guaranteeing efficient signal transmission in high-frequency scenarios. Its low loss tangent of 0.0009 at 10 GHz aids in diminishing signal attenuation, thereby upholding signal integrity over extended distances and at elevated frequencies. Moreover, the material showcases remarkable thermal stability, showcasing minimal alterations in dielectric constant and loss tangent over a broad temperature spectrum, which is essential for applications exposed to diverse operating conditions. Furthermore, its mechanical durability, dimensional steadiness, ease of manufacturing, and resistance to chemicals render it appropriate for deployment in challenging environments, ensuring sustained performance throughout manufacturing procedures and device longevity.In the proposed antenna design, this material with a dielectric constant of 2.2 and a thickness of 0.8 mm is chosen for its favorable electrical properties. The low dielectric constant helps in achieving higher radiation efficiency and wider bandwidth, while the specific thickness provides mechanical stability and ease of fabrication [34].

B. CIRCULAR RING SLOT IN PATCH:

A circular ring slot in a patch antenna refers to a circular-shaped slot cut out from the patch. This design can be used to achieve specific resonant frequencies and improve the bandwidth of the antenna. The circular ring slot can also help in controlling the radiation pattern and impedance matching of the antenna. By adjusting the dimensions of the slot, designers can fine-tune the antenna's performance for specific applications [35].

C. PARTIAL GROUND PLANE:

A partial ground plane is a technique where the ground plane of the antenna is not fully extended under the entire patch. Instead, it covers only a portion of the substrate. This approach can be used to enhance the bandwidth and radiation efficiency of the antenna. By optimizing the size and position of the partial ground plane, designers can achieve better impedance matching and improve the overall performance of the antenna [36].

D. MICROSTRIP FEEDLINE TECHNIQUE:

A microstrip feedline is a type of transmission line used to feed the antenna. It consists of a conducting strip separated from a ground plane by a dielectric substrate. The microstrip feedline is widely used due to its simplicity and ease of integration with other microwave components. The width of the microstrip feedline and the properties of the dielectric substrate determine the characteristic impedance of the feedline, which is crucial for impedance matching with the antenna [36].

When designing an antenna using these techniques and materials, the circular ring slot in the patch can be used to achieve the desired resonant frequency and bandwidth. The partial ground plane can be optimized to enhance the radiation efficiency and impedance matching. The microstrip feedline provides a convenient and effective way to feed the antenna, ensuring proper impedance matching with the rest of the RF circuitry. The utilization of Rogers material, possessing a dielectric constant of 2.2 and a thickness of 0.8 mm, ensures that the antenna exhibits minimal loss and maintains stable performance across a broad range of frequencies. In general, these techniques and materials are widely employed in advanced antenna designs to achieve superior performance, reliability, and efficiency in various applications, such as wireless communication, radar systems, and medical imaging.

E. FUNDAMENTAL PRINCIPLES OF MICROWAVE IMAGING

Microwave imaging operates on the fundamental concept of transmitting microwave signals into the human body and examining alterations in the reflection of these signals, which indicate variations in the electrical characteristics of tissues. The distinct changes in the reflected signals can be utilized to detect abnormal tumor cells within the breast, as these cells typically have a higher dielectric constant compared to surrounding healthy breast tissues. The dielectric properties of a simulated breast tissue alter upon the introduction of a tumor cell, and the effective dielectric constant of the tissue with the tumor can be determined by applying the widely recognized Maxwell Garnett Eq. (1) [37].

$$\varepsilon_{reff} = \varepsilon_m + 3\varepsilon_m \phi_v \frac{(\varepsilon_p - \varepsilon_m)}{2\varepsilon_m + \varepsilon_p - \phi_v\,(\varepsilon_p - \varepsilon_m)} \quad (1)$$

where, ε_m and ε_p represent the permittivity of the host and inclusion respectively, and ϕ_v is the volume fraction of the inclusion. In this context, the host material is represented by the phantom, while the inclusion is represented by the tumor. The change in permittivity of the phantom due to the presence of the tumor is a critical factor in microwave imaging systems. Therefore, it is essential to have a sensor with sufficient sensitivity to detect this permittivity variation.

F. ANTENNA DESIGN MODELING

The study introduces a compact and efficient circular microstrip patch antenna operating at 5.2 GHz. This antenna utilizes ring slots and a partial ground plane. It is essential to carefully select the dimensions of the dielectric substrate, ground plane, and radiating patch to achieve the desired antenna performance.The following equations are employed for determining the dimensions of the proposed antenna.

Step-1: The dimensions of the circular patch are calculated in Eq. (2) [38].

$$r = \frac{F}{\sqrt{1+\frac{2h}{\pi\varepsilon_r F\left[ln\left(\frac{F\pi}{2h}\right)+1.7726\right]}}} \quad (2)$$

Where, h refers to the substrate thickness

F = effective radius of the circular patch = $\frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$

ε_r represents the relative dielectric constant of the substrate

f_r is the operating frequency

Step-2: The length of the substrate $(\boldsymbol{L_s})$ is equal to the length of the ground plane $(\boldsymbol{L_g})$ and the width of the substrate $(\boldsymbol{W_s})$ is equal to the width of the ground plane $(\boldsymbol{W_g})$, as stated in Eqs. (3 – 4) [39].

$$L_s = L_g = 6h + r \quad (3)$$

$$W_s = W_g = 6h + r \quad (4)$$

Step-3: The feedline length $(\boldsymbol{L_f})$ and feedline width $(\boldsymbol{W_f})$ can be expressed by Eqs. (5 – 6) [40].

$$\boldsymbol{L_f} = \frac{\boldsymbol{\lambda_g}}{\boldsymbol{4}} \quad (5)$$

Where, $\boldsymbol{\lambda_g}$= guided wavelength = $\frac{\lambda}{\sqrt{\varepsilon_{reff}}}$

$\boldsymbol{\lambda}$ = free space wavelength = $\frac{c}{f_r}$

$\boldsymbol{c}$ = speed of light = $\boldsymbol{3 \times 10^8}$ m/sec

$\boldsymbol{\varepsilon_{reff}}$ = substrate effective relative dielectric constant

$$= \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w_f}\right]^{-1/2}$$

$$\boldsymbol{W_f} = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (6)$$

G. PROPOSED ANTENNA DESIGN

The primary objective of developing the circular microstrip patch antenna is to achieve an effective ultra-wideband (UWB)

operation at a frequency of 5.2 GHz. To enhance its performance and minimize losses, the design of the circular microstrip patch antenna incorporates a ring slot. This addition ensures that the antenna maintains its desired characteristics even when connected to a breast phantom model, making it ideal for use with such models. During the design process of this antenna, special consideration is given to the dielectric properties of Rogers RT/duroid 5880(tm) material. The substrate thickness (h) is set at 0.8 mm, and the dielectric constant (ε_r) is specified as 2.2. To further optimize its performance, a loss tangent (tanδ) value of 0.02 is utilized.
The substrate used for this antenna has a length (L_S) of 30 mm and a width (W_S) of 20 mm. On the backside of the substrate, a partial ground plane made of copper is placed. The dimensions of this partial ground plane are 13 mm for length (Lg) and 20 mm for width (Wg), with a thickness of zero. The copper patch responsible for the antenna's operation is attached to the substrate on the opposing side, with a radius (r) of 7 mm. Excitation of the patch is achieved through a microstrip feedline that has a characteristic impedance of 50 Ω. The feedline itself has a length (L_f) of 14 mm and a width (W_f) of 2 mm. To provide a visual representation, FIGURE 1 depicts the structure of the proposed antenna. For additional details, please refer to TABLE 1, which provides a comprehensive overview of the specifications associated with the designed antenna.

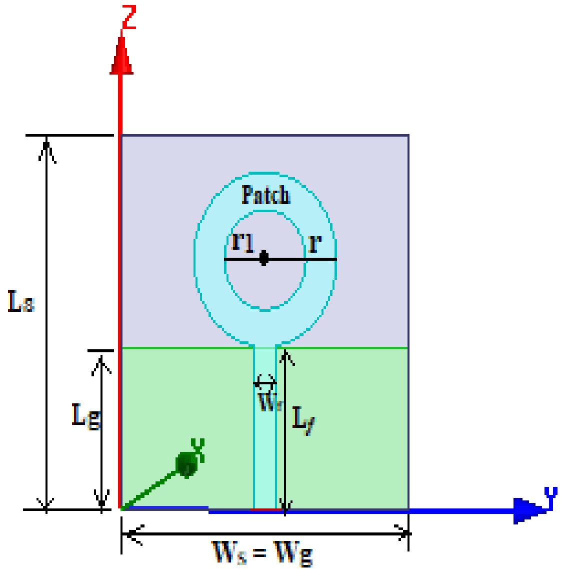


FIGURE 1. Structure of the proposed antenna

TABLE 1
Specifications of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
Ls	30	Wg	20
Ws	20	L_f	14
h	0.8	W_f	2
ε_r	2.2	r (radius)	7
Lg	13	r1 (ring slot)	4

The primary consideration for assessing the performance of the constructed antenna is the return loss (S_{11}). The evaluation is depicted in FIGURE 2, where the simulated results not only exhibit an impressive performance surpassing – 39.74 dB of the S_{11} at 4.80 GHz but also achieve a bandwidth of 2.5 GHz (below -10 dB) from 4 GHz to 6.50 GHz. These results indicate a satisfactory impedance matching, ensuring effective radiation through the ring-slotted circular patch design. Consequently, this favorable performance will be utilized for tumor detection, which will be elaborated upon in the upcoming sections.

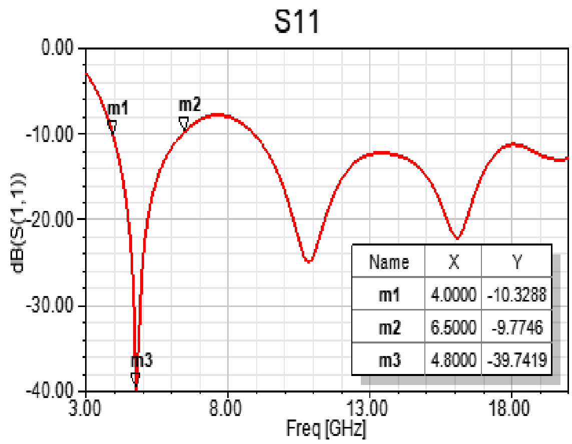


FIGURE 2. The performance of return loss at a frequency of 4.80 GHz

H. BREAST PHANTOM DESIGN

FIGURE 3 depicts the configuration of the breast model. In this model, a cone-shaped breast is covered by breast skin, breast tissue, and a sphere-shaped tumor. The breast phantom is composed of skin that has a radius of 0 mm at the lower cone and 11 mm at the upper cone. The healthy tissue, also referred to as fatty tissue, has a lower cone radius of 0 mm and an upper cone radius of 9 mm. There is a 2 mm separation between the skin and healthy tissue on both sides. The cone shape of this breast model is not an exact representation; however, it is suitable for conducting feasibility studies on breast cancer detection. The tumor in this model has a diameter of 4 mm, signifying that it is in the early stages of cancer. TABLE 2 provides all the relevant parameters of the breast phantom model. The breast skin has a diameter of 22 mm, while the breast tissue has a diameter of 18 mm. The breast phantom model is positioned at a distance of 10 mm from the antenna's center, as depicted in FIGURE 4. FIGURE 5 portrays the schematic diagram of the proposed work. It visually presents the overall concept and design of the study.

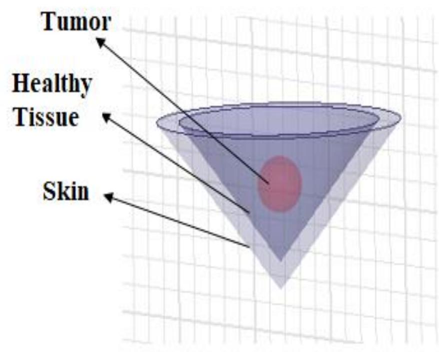


FIGURE 3. The design of the breast phantom model

TABLE 2
Dielectric Characteristics of Breast Tissue

Tissue	Dielectric permittivity, ε_r	Conductivity (S/m)	Diameter (mm)
Normal breast tissue	10.4	0.4	18
Breast Skin	36	4	22
Tumor	50	4	4

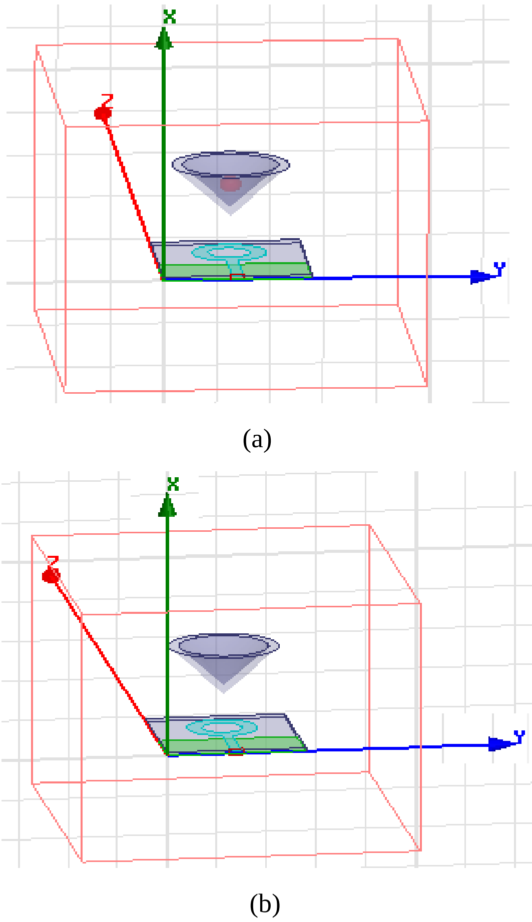


FIGURE 4. **Breast representation featuring an antenna (a) with a tumor and (b) without a tumor**

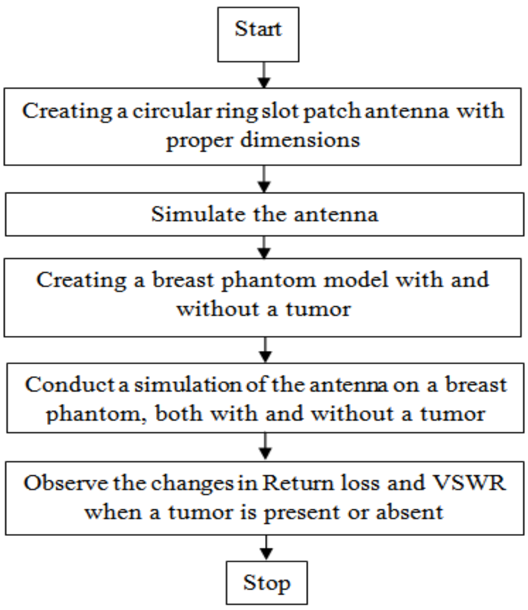


FIGURE 5. **Illustrative diagram portraying the outline of the intended research project**

I. PROPOSED METHOD

The reflected wave from the phantom will be detected by the antenna, encompassing both malignant and nonmalignant tissues. The presence of a foreign body or tumor cell in the breast region can be determined by analyzing the difference in their reflected power. This technique is not limited to the breast region and can be applied to other areas of the body as well. The dissimilarity in the reflected power is attributed to the distinct electrical properties of malignant and nonmalignant tissues, specifically their dielectric constants and conductivities. Malignant tissues typically exhibit higher dielectric constants and conductivities compared to healthy tissues, resulting in noticeable disparities in the reflected signals.

III. RESULTS

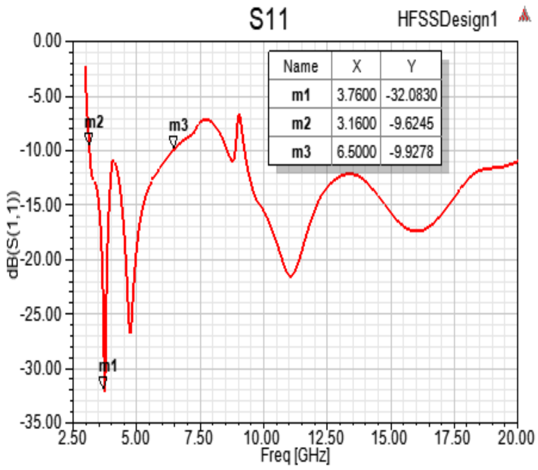
The antenna has been fine-tuned to resonate precisely at a frequency of 5.2 GHz. The assessment of its effectiveness will be conducted by analyzing the return loss and VSWR parameters. This evaluation will be based on the presence or absence of a tumor, as depicted in Figures 4(a) and 4(b) respectively. To simulate the antenna's performance, the High Frequency Structure Simulator (HFSS) software has been utilized.

A. RETURN LOSS (S_{11})

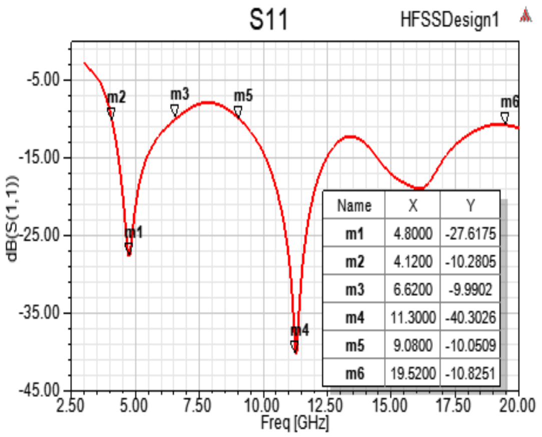
The evaluation of an antenna's performance requires attention to the return loss, often denoted as S_{11}. This parameter quantifies the power that is reflected back from the antenna compared to the power incident upon it. In an ideal scenario, where there are no losses and perfect impedance matching, the return loss would be infinitely negative. This would signify that the antenna absorbs all the power without any reflection. However, practical situations involve losses and imperfections that prevent S_{11} from achieving negative infinity. The objective of antenna design is to achieve the most optimal impedance matching, resulting in a significantly negative return loss (S_{11}). A substantial negative S_{11} indicates that the antenna efficiently absorbs most of the incident power while minimizing reflections. Consequently, this enhances the antenna's efficiency and overall performance. Through the optimization of the design and careful tuning of parameters such as dimensions and matching networks, engineers strive to attain the desired highly negative S_{11}. This ensures that the antenna operates at its peak performance by minimizing power losses and reflections. To summarize, although an ideal return loss (S_{11}) would be infinitely negative, the practical goal is to achieve a significantly negative S_{11} to ensure impeccable impedance matching and minimal power reflections.

In the context of detecting breast cancer, the change in return loss values can indicate the presence of malignancy within the breast. The return loss plot of the designed antenna without and with a tumor, as shown in Figures 6 (a) and (b), illustrates this change. The return loss without a tumor is reported as –32.08 dB, while in the presence of a tumor, it is – 40.30 dB. This decrease in return loss indicates a change in the impedance matching and can be indicative of the presence of malignancy within the breast. By monitoring changes in return loss values, it may be possible to detect and analyze abnormalities in breast tissue, potentially aiding in the diagnosis or monitoring of breast cancer.

B. VOLTAGE STANDING WAVE RATIO (VSWR):

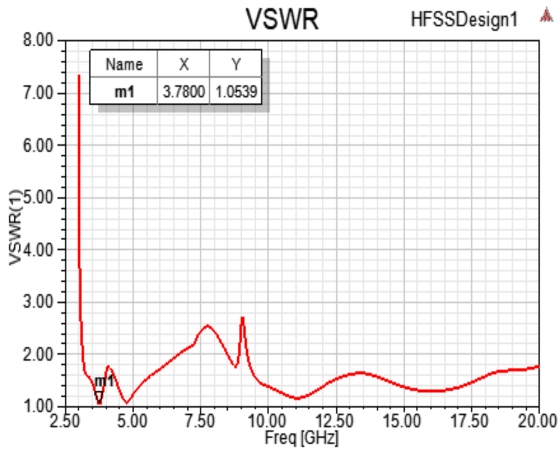


(a)

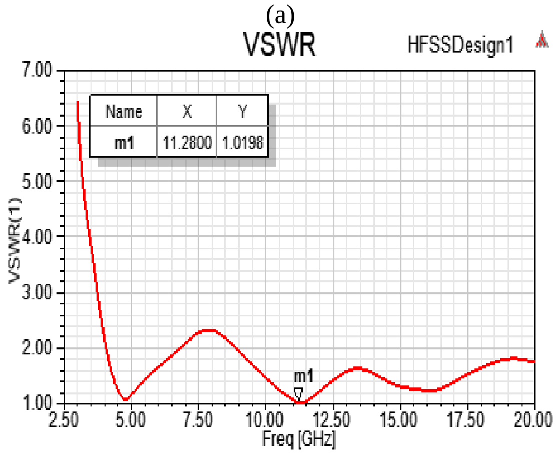


(b)

FIGURE 6. The return loss (S_{11}) performance in the absence and presence of a tumor (a) absence of tumor, (b) presence of tumor



(a)



(b)

FIGURE 7. The VSWR performance in the absence and presence of a tumor (a) absence of tumor, (b) presence of tumor

The measurement of how well an antenna is connected to the transmission line it is attached to can be determined by the process of impedance matching. This measurement is commonly known as the Voltage Standing Wave Ratio (VSWR). VSWR indicates the level of match between the antenna and the transmission line by calculating the ratio between the highest and lowest voltages along the transmission line. For optimal performance, a VSWR value below 2 is preferable, as it signifies low reflection and efficient power transfer. A VSWR value of 1 signifies a flawless match without any signal reflections, whereas higher values indicate a poorer match and increased signal reflections (FIGURE 6).

In the specific context of detecting breast cancer, the presence of tumors can cause variations in VSWR values. Observing FIGURES 7 (a) and (b), one can see how simulated VSWR values behave both with and without a tumor. Without a tumor, the VSWR is measured at 1.0539, indicating a relatively good impedance match. However, with the presence of a tumor, the VSWR decreases to 1.0198, suggesting an even better impedance match and reduced signal reflections. These fluctuations in VSWR values can potentially serve as an indicator of the presence of breast cancer. By carefully monitoring changes in VSWR, it may be feasible to identify and analyze abnormalities in breast tissue, which could assist in the diagnosis or continuous monitoring of breast cancer. It is essential to note that while VSWR can provide valuable information, it is most effective when utilized alongside other diagnostic techniques and medical expertise to ensure accurate diagnoses.

IV. DISCUSSION

The proposed ultra-wideband (UWB) antenna for breast tumor detection, as evaluated through a comprehensive simulation study using HFSS software, demonstrates excellent performance metrics with a return loss of – 32.08 dB without tumors and – 40.30 dB with tumors, and Voltage Standing Wave Ratio (VSWR) values of 1.0539 and 1.0198 without and with tumors, respectively. This antenna's compact design, exceptional impedance matching, and non-invasive nature at a 10 mm distance from the breast skin make it a promising tool for early breast cancer detection, addressing the limitations of prior designs [25, 27 – 30] in terms of size, return loss, and complexity. By offering enhanced sensitivity and safety in microwave imaging applications, this antenna presents a practical and user-friendly solution for medical diagnostics, enabling the accurate identification of very small tumors (4 mm) through monitoring variations in return loss and VSWR. Despite the promising results, the proposed antenna has some limitations, particularly in terms of bandwidth. The antenna's bandwidth is relatively narrow, which could affect the resolution and accuracy of the imaging in detecting tumors of varying sizes. This limitation highlights the need for further optimization to ensure the antenna can perform effectively across a broader frequency range.

In future work, the research focuses on fabricating and testing the proposed antenna for Microwave Breast Imaging (MBI) systems, aiming to compare the performance of simulated and fabricated antennas. This study represents a significant advancement in MBI, emphasizing the optimization of antenna design to enhance sensitivity and resolution, seamless integration of antennas into MBI systems, and the necessity of conducting thorough clinical trials to evaluate the system's accuracy and effectiveness in real-life scenarios. By combining innovative antenna designs with comprehensive MBI systems and rigorous clinical validation, this research paves the way for the practical implementation of advanced MBI technologies, offering promising prospects for improved breast cancer detection and diagnosis.

V. CONCLUSION

Microwave breast imaging (MBI) has recently attracted considerable attention. This research explores the potential of using a circular ring patch microstrip antenna with a partial ground plane technique for Ultra-Wideband (UWB) applications in detecting breast cancers. The absence of tumor tissues results in a return loss and Voltage Standing Wave Ratio (VSWR) of –32.08 dB and 1.0539, respectively. Conversely, when tumor tissues are present, these values change to – 40.30 dB and 1.0198, respectively. Variations in these parameters act as indicators of tumor presence. Additionally, the proposed antenna exhibits an impressive impedance bandwidth of 2.5 GHz (4 GHz – 6.5 GHz), covering the UWB range of 3.1 – 10.6 GHz. This wide bandwidth is essential for capturing detailed tissue characteristics. The antenna is known for its compact size and simple design, making it suitable for integration into various medical imaging systems without adding bulk or complexity. Its excellent impedance matching ensures efficient signal transmission and reception, enhancing the accuracy of tumor detection. Consequently, this antenna is an essential component for microwave imaging systems.

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