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MICROSTRIP PATCH ANTENNA FOR BREASTCANCER DETECTION

RAJESH KUMAR S [1], Prakash N [2], Poovarasan M [3] , Ramkumar M [4] and Naveen T R [5]

[1] Assistant Professor, Electronics and Communication Engineering College, VSB Engineering College, Karur, Tamilnadu.
[2] Student, Electronics and Communication Engineering College, VSB Engineering College, Karur, Tamilnadu.
[3] Student, Electronics and Communication Engineering College, VSB Engineering College, Karur, Tamilnadu.
[4] Student, Electronics and Communication Engineering College, VSB Engineering College, Karur, Tamilnadu.
[5] Student, Electronics and Communication Engineering College, VSB Engineering College, Karur, Tamilnadu.

Abstract— Breast cancer is a prevalent cancer type among women worldwide. Medical imaging techniques, such as X-ray mammography, magnetic resonance imaging (MRI), and ultrasound, have their limitations. The objective of this study was to develop a new method to detect the presence of malignant tumors using a microstrip patch antenna designed in the ISM frequency range, along with two types of 3D breast phantoms. The study aimed to identify cancerous tumors in the breast phantom by analyzing the variation of S11 parameters. The efficiency and reflection parameters were evaluated. This technique is advantageous because it uses microwaves, which are non-ionizing and do not harm biological tissues. By detecting changes in the reflection coefficient and observing higher S11 values in the presence of a tumor, this method can detect breast tumors effectively.

Keywords – tumor; microstrip patch antenna; S11 parameters ;

INTRODUCTION

Breast cancer is a common form of invasive cancer among women and is responsible for a significant number of cancer-related deaths, second only to lung cancer in women. Detecting breast tumors early is crucial to ensuring accurate and efficient treatment. Traditional techniques like X-ray mammograms, MRI, ultrasound, and biopsy are used for breast cancer detection. In recent years, ultra-wideband (UWB) technology has gained popularity in wireless communication systems, and UWB microwave imaging has proven effective in medical diagnostic fields. UWB antennas are utilized in medical imaging due to their compact size, stability over the entire active band, and high radiation efficiency. Microwave imaging can be used to detect the presence of breast tumors because the conductivity and permittivity of cancerous tissue differs from that of normal breast tissue. Microwave imaging techniques require very little energy absorption by the breast, which poses minimal health risks to patients. Therefore, UWB microwave imaging has become a promising technology for non-destructive evaluation of biological tissues, and it can help accurately locate small tumors in the early stages of breast cancer.

X-ray mammography is a widely used breast cancer detection technique but suffers from a high missed detection rate due to the limited contrast between tumors and surrounding tissues, and the ionizing radiation exposure poses health risks to patients. Additionally, breast compression during the procedure can cause discomfort. Ultrasound is a less painful technique that helps evaluate tumors in dense breasts that are difficult to see on X-ray, but it also fails to distinguish between fatal and benign tumors. MRI is useful for detecting breast cancer in younger women and those with breast implants, but it can give false-positive test results and cannot differentiate between cancerous and noncancerous abnormalities. Biopsy is another screening method, but it has some drawbacks such as misdiagnosis due to false-negative results and the need for repeated procedures as the amount of extracted tissue may not be sufficient. Antennas used for medical diagnosis and treatment should function in the ISM band, which is a frequency range reserved worldwide for industrial, scientific, and medical applications other than telecommunications. In medical applications, radio waves in the ISM bands are used for shortwave and microwave diathermy equipment to administer deep warmth to the body, promoting healing and relaxation. Hyperthermia therapy is a recently developed technique that uses microwaves to heat tissue, killing cancer cells.

In this paper, a microstrip patch antenna was designed using CST Studio Suite and tested with two different 3D breast phantom models. The antenna was designed to operate within the ISM frequency band. Simulation results showed that the presence of tumors was detectable in both breast phantoms. The paper is organized as follows: Section II details the antenna design, Section III describes the breast phantom design, Section IV presents the simulation and results, and Section V contains the conclusion.

I. ANTENNA DESIGN

The microstrip patch antenna is a type of antenna with a simple physical geometry, commonly used at higher frequencies, especially in the microwave frequency range. It is available in different shapes, including rectangular, circular, square, dipole, elliptical, and triangular. Among these, rectangular and circular patch microstrip antennas are the most widely used [2]. The rectangular patch antenna offers higher return loss compared to the circular patch antenna. However, the rectangular patch antenna has a higher VSWR value than the circular patch antenna. On the other hand, the circular patch antenna has a higher bandwidth than the rectangular patch antenna [5].

To detect the presence of cancerous tumors in a breast phantom, a rectangular microstrip patch antenna operating in the ISM frequency range was designed. To improve the performance of the antenna in terms of resonant frequency and return loss, the antenna was cut into different slots. However, this resulted in a reduction in bandwidth. In order to enhance the gain and S11 parameters of the antenna, semi-circular and rectangular cutting slots were introduced on both sides of the antenna.

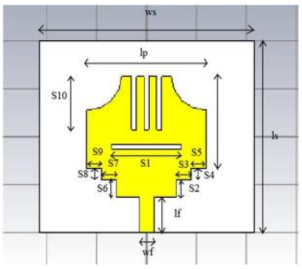
arrangement has the advantage of being able to etch the feed on the same substrate, resulting in a planar structure.

The proposed antenna allows for breast tumor detection by analyzing the variation of the reflection coefficient and SAR (specific absorption rate) analysis, as SAR values tend to be higher for tumor cells. The antenna operates within the ISM frequency band, and SAR analysis was conducted specifically for this frequency range. Copper was chosen as the material for the ground and patch of the antenna due to its superior conductivity and high reactivity, allowing for effective distribution of electrical energy. Additionally, copper is harder and cheaper than other materials such as silver or gold.

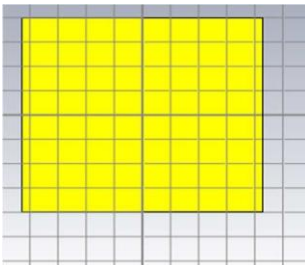
The antenna substrate was made from FR-4 material, which was chosen due to its relatively low cost and higher fabrication tolerance. The use of a microstrip antenna for microwave imaging has several benefits, including non-ionizing nature, low cost, and harmlessness. Both the antenna and the human breast phantom model were created using CST Studio Suite.

The final rectangular microstrip patch antenna was designed using the dimensions calculated from the relevant equations, with all of the materials mentioned above.

the width w of the antenna is calculated by [2]



(a)



(b)

Fig. 1. Structure of the created antenna (a) Front View (b) Back View

RF power is delivered straight away to the radiating patch using a microstrip line conducting element in this manner. This type of feed

$$W = \frac{c}{2f_o\sqrt{\frac{(sr+1)}{2}}} \qquad (2)$$

Where,

s_r = Relative permittivity of the substrate

c = Speed of the light in free space

f_o = Resonant frequency

The effective dielectric constant (s_{reff}) is calculated by

$$s_{reff} = \frac{s_r+1}{2} + \frac{s_r-1}{2}\left[1 + 12\,\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (3)$$

Where, h = Height of dielectric substrate

The effective length (L_{eff}) equation is given as

$$L_{eff} = \frac{c}{2f_o\sqrt{s_{reff}}} \qquad (4)$$

The length extension (ΔL) is calculated by

$$\Delta L = 0.412h\,\frac{(s_{reff}+0.3)(\frac{W}{h}+0.264)}{(s_{reff}-0.258(\frac{W}{h}+0.8)} \qquad (5)$$

The actual length of the patch (L) is given as

$$L = L_{eff} - 2\Delta L \qquad (6)$$

The dimension of the proposed antenna was measured to be 40×43×1.6 mm^3.

TABLE I. CREATED ANTENNA DIMENSION

Parameter Name	Dimension(mm)
Substrate Width (ws)	43
Substrate Length (ls)	40
Patch Length (lp)	25
Patch width (wp)	24
Feed Line Length (lf)	10
Feed Line Width (wf)	3
Patch Height (hp)	0.035
Substrate Height (hs)	1.6
Ground Height (hg)	0.035
S1	14
S2, S6	4.5
S3, S7	3.5
S4, S8	2.5
S5, S9	3

II. BREAST PHANTOM DESIGN

To simulate the antenna, a human breast phantom was created using breast tissues and skin with varying parameter values. Two different breast phantom models were developed. The first model was created to analyze the results when the phantom incorporates the entire antenna. In the second model, the antenna's response was analyzed when applied to a real biological breast phantom.

Table II. BREAST PHANTOM MODEL SIZE

Tissues	Outer Radius (mm) For model 1	Outer Radius (mm) For model 2
Skin	2	55
Adipose	8	53
Glandular	20	45
Tumor	6	6

Table III. BREAST PHANTOM MODEL ELECTRICAL PROPERTIES OF DIFFERENT TISSUES WITH TUMOR

Tissues	Electrical properties					
	Dielectric (ε_r)	***Conductivity*** σ (s/m)	***Mass density*** (Kg/m3)	***Thermal Conductivity [W/K/m]***	***Heat Capacity [KJ/K/Kg]***	***Mue***
Skin	36.7	2.34	1109	0.37	3.391	1
Adipose	4.84	0.262	911	0.21	2.348	1
Glandular	50	3.46	1041	0.33	2.960	1
Tumor	50.9	4	1058	_	_	1

In the first breast phantom model, the phantom was created to incorporate the entire antenna, with the same dimensions as the antenna itself. An air gap of 10mm was included between the antenna and the breast phantom.

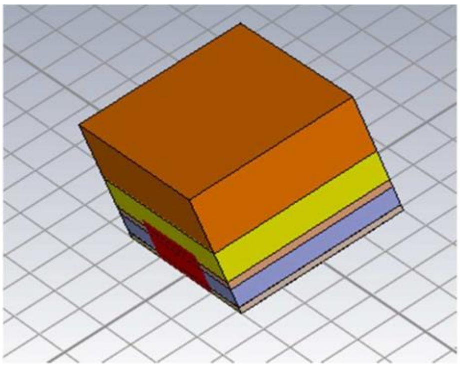


Fig.2. Breast phantom model 1 without tumor

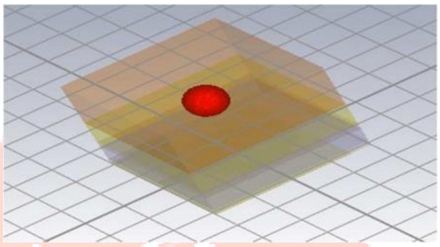
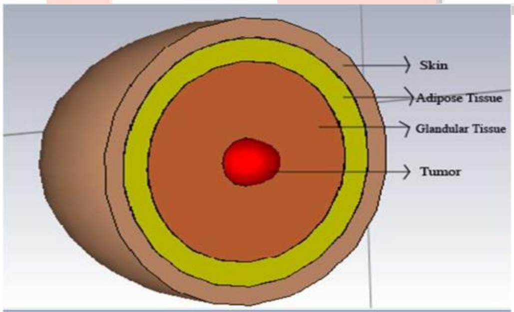


Fig.3. Breast phantom model 1 with tumor



The second breast phantom model was designed to closely represent a real biological human breast and was created in the shape of a half-sphere.

Fig.4. Different layers of breast phantom model

The layers shown in the figure are identical for both breast phantom models, and the properties of skin, adipose, and glandular tissues are also the same for both phantoms.

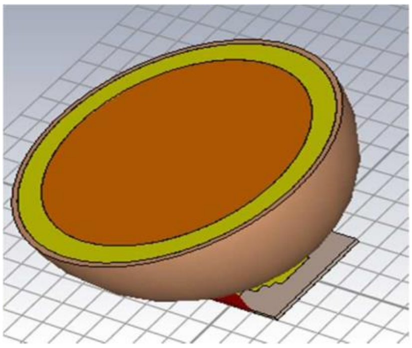


Fig.5. Breast phantom model 2 without tumor

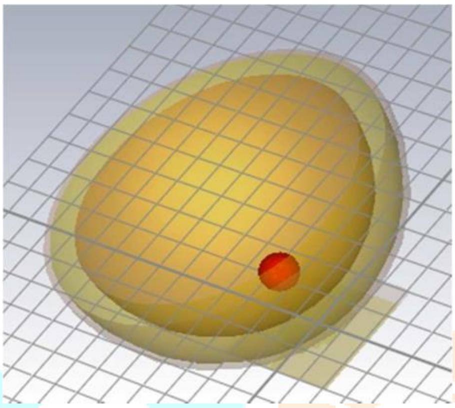


Fig.6. Breast phantom model 2 with tumor

III. SIMULATION AND RESULTS

The input-output relationships between ports or terminals are represented by the S-parameters. The reflection coefficient, often known as S11, is a measurement of how much power an antenna reflects. At first, the antenna was simulated in the free space. The resonant frequency was 2.445 GHz and the reflection coefficient was -36.334625 dB.

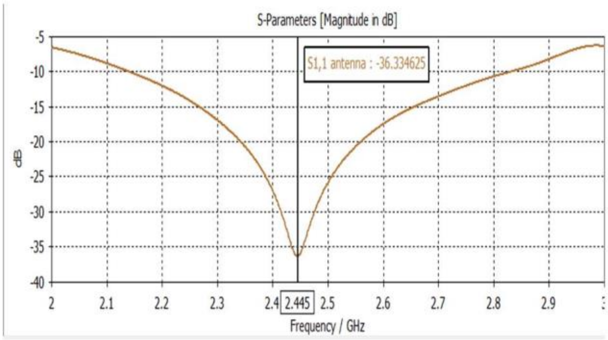


Fig.7. S_{11} of the antenna without breast phantom

A breast phantom model was created by putting the antenna at the top of the breast skin. After simulating the resonant frequency was found at 2.358 GHz while the reflection coefficient had been reduced to -17.50214 dB as shown in figure 8.

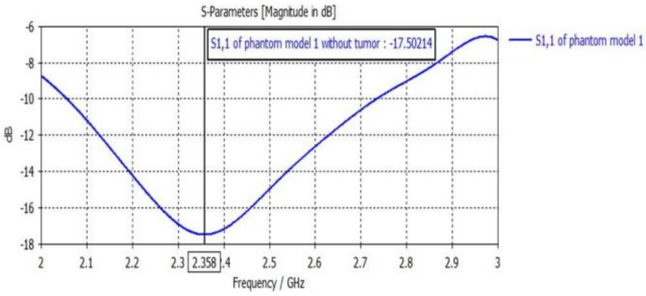


Fig.8. S_{11} of breast phantom model 1 without tumor

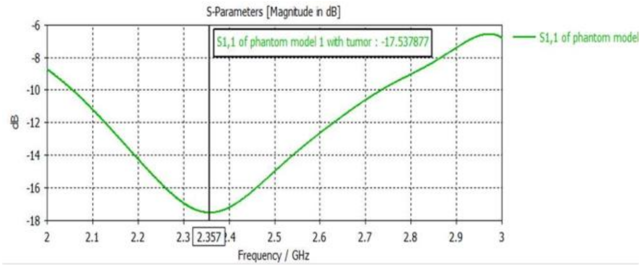


Fig.9. S_{11} of breast phantom model 1 with tumor

When the breast phantom model 1 with tumor from figure 8 is examined, it is discovered that the reflection coefficient decreases slightly as the tumor appears. When comparing the two curves in Figures 8 and 9, we can see that the curve with the tumor is slightly lower than the one without the tumor. -17.537877 dB is the new reflection coefficient value.

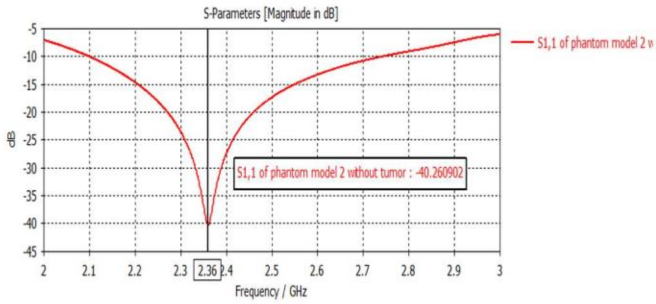


Fig.10. S_{11} of breast phantom model 2 without tumor

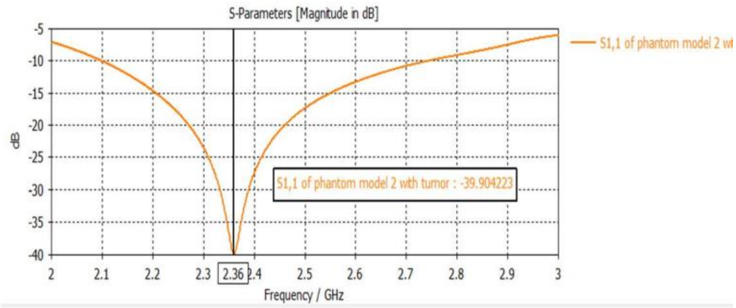


Fig.11. S_{11} of breast phantom model 2 with tumor

The simulation this time was for a replica of a real biological breast phantom. This results in a 2.36 GHz operating frequency and a reflection coefficient of -40.260902 dB.

The new reflection coefficient value in the presence of a tumor is -39.904223dB. As a result of the rise in reflection coefficient, we may say that the curves in Figures 10 and 11 are incompatible.

Table IV. COMPARISON CHART BETWEEN BREAST PHANTOM MODEL 1 & BREAST PHANTOM MODEL 2.

		Breast Phantom Model 1	**Breast Phantom Model 2**
Without Tumor	Resonant Frequency	2.358 GHz	2.36 GHz
	Reflection Coefficient	-17.50214 dB	-40.260902 dB
With Tumor	Resonant Frequency	2.357 GHz	2.36 GHz
	Reflection Coefficient	-17.537877 dB	-39.904223 dB

The ratio of power radiated in all directions to the power given to the antenna is known as antenna efficiency. The ratio of the antenna's highestradiation intensity to the isotropic antenna's radiation intensity is known as antenna directivity. For breast phantom model 2, the directivity of the antenna was found to be 5.59dB.

The total efficiency of this antenna was measured to be -11.957226 dB, while the radiation efficiency was found to be-11.867837 dB.

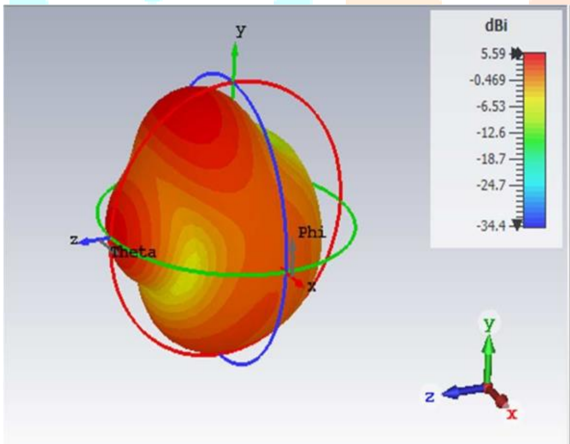


Fig.12. 3D Far field Analysis

The Specific Absorption Rate (SAR) quantifies EM radiation absorption by tissues and represents the amount of energy per unit mass of biological tissue. For breast phantom model 2, the maximum SAR for 1g and 10g tissue was computed. The W/Kg bar in the figure depicts the amount of intensity for SAR. For 1g and 10g of tissues, the maximal SAR values were 0.72 W/Kg and 0.261 W/Kg, respectively. The location of the tumor was (0,0,25).

TABLE V. SAR ANALYSIS OF 1G & 10G TISSUE

Frequency	**Tissue**	**Max. coordinates**	**Max. SAR**
2.36 GHz	1g	-0.125, -3.25, 20.2083	0.720336
2.36 GHz	10g	-0.125, -1.00, 17.299	0.261041

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Following Federal Communications Commission (FCC), in order to avoid harmful effects in the human body, in a 1g tissue cube, the maximum value of SAR should be less than 1.6 W/ Kg.

Thus, this antenna is totally biocompatible for its small size and it satisfies Specific Absorption Rate (SAR) to prevent hazardous heating of the biological tissues. In comparison to other antennas, it demonstrates decreased return loss, good impedance matching, and high gain, as well as a very low SAR value. The lower the SAR value the more compatible is the antenna for biomedical application.

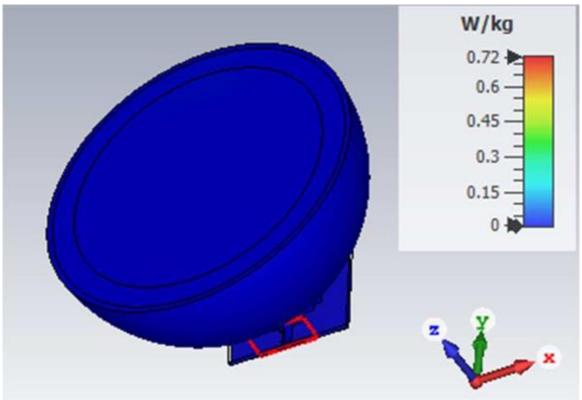

Fig.13. SAR Distribution in 1g Tissue

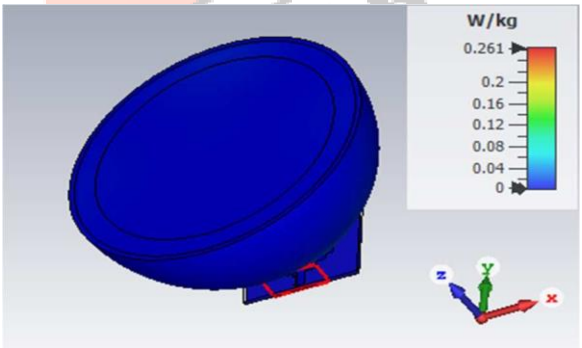

Fig.14. SAR Distribution in 10g Tissue

IV. CONCLUSION

In this paper, a microstrip patch antenna was constructed and simulated in the ISM frequency range, and it was found to be a favorable choice due to its small size and biocompatibility. Two different breast phantoms were generated to analyze the simulated results, both with and without tumors.

Based on the findings, it was possible to determine the presence of malignant tumors. In breast phantom model 1, the presence of a tumor caused the reflectance coefficient to decrease from -17.50214 dB to -17.537877 dB, while in breast phantom model 2, the change in reflection coefficient from -40.260902 dB to -39.904223 dB indicated the presence of a malignant tumor.

Various parameters such as directivity, reflection coefficient, far-field, radiation efficiency, total efficiency, and maximum SAR were simulated in the virtual environment. The SAR analysis showed that the maximum coordinates of the tumor were very close to the actual location of the tumor. These results demonstrate that the antenna can identify malignant tumors in the virtual breast phantom that was created.

Furthermore, this antenna can be used in microwave imaging and other biomedical applications. Although it cannot be implanted inside the human body, by using flexible and conductive materials in the future, it can also be employed in several implantation scenarios.

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