Breast Cancer Detection Method Utilizing UWB Patch Antenna

Ennam Govinda *1, Dr. Vemuri B.S.S. Indira Dutt *2

*1 ECE Department, Ph.D. scholar, GITAM deemed to be University, India, ennamgovinda19@gmail.com
*2 ECE Department, GITAM deemed to be University, India, srilatha06.vemuri@gmail.com

ABSTRACT

The common image restoration approach utilized in a medical device used for early breast cancer diagnosis is ultrawideband (UWB) microwave imaging. A patch antenna created to detect breast cancer has a low complexity, high accuracy rate, is easy to identify tumors, and produces a low-cost output. The 3D homogeneous breast phantom and its interactions with the Ansoft HFSS software were utilized for numerical design and assessment of the electrical characteristics of the Patch antenna system. The operational bandwidth of the proposed antenna ranges from 3.3 GHz to 8.1 GHz. During construction, the performance of the antenna unit was evaluated using two different dielectric materials that comprised the antenna patch system. The electrical characteristics of the antenna created as a consequence of the numerical measurement are then compared to determine the best radiator construction outcome. Its numerical calculations were carried out by placing the best radiator alone on the breast skin in order to evaluate the magnetic field, electrical fields, and current density in normal and malignant tissue created for the breast phantom. The numerical experiments were carried out to evaluate the impacts of different tumor sizes (5 mm, 10 mm), as well as the influence of distance variations between the breast phantom surface and the tumor site. In terms of return loss, electric field, magnetic field, radiation pattern, gain, and frequency, simulation results were given to confirm the utility of the suggested design. The simulation findings demonstrate that as tumor size increases, the reflected power received decreases.

Keywords: UWB Microwave imaging, Breast cancer, Patch antenna, Ansoft high frequency simulation software (HFSS).

I. INTRODUCTION

Breast cancer is one of the world's deadliest female cancers. A malignant tumor grown from breast cells is defined in the word "breast cancer." Over time, the cancer cells can occupy nearby healthy breast tissue and reach the lymph node in the armpits. A wide range of cancer scans have been published, and other types of breast identification. These techniques are currently used, however, but they are still poor. For primary tumor detection, Positron emission tomography (PET) is not successful. The breast cancer diagnosis is known as mammogram, but, for younger women and people with dense breasts it is ineffective. X-rays are causing the rupture of the human body's cells and tissue, and magnetic resonance rays are poorly able to capture images of superficial soft tissues [1],[2]. Microwave imaging (MI) is an effective approach to solve problems. It is not ionizing with low-cost radiation, has high tumor sensitivity and offers comfort to the patient. MI is using the tumor detection microband patch antenna. Tomography and radar-based microwave imagery fall into two groups. The MWI consists of a microwave transmission system to transmit signals to the breast and a recipient to detect backscattered signals after their breast contact. The MWI theory is the comparison between tumour tissue dielectric and healthy breast tissue.
II. PROPOSED METHODOLOGY

The transmitter antenna sends signals in the proposed antenna system, then illuminates the breast Phantom and the receive antenna picks up the back-scattered waves from the breast Phantom. Upon the back-scatter signal, the UWB breast cancer image is created shown in Figure.1. A Rectangular Patch Antenna was designed with slot less microband architecture. The creation of a model of the human breast phantom is therefore also being built for cancer and non-cancer tumor. The antenna being proposed is kept in HFSS for breast cancer detection at a distance of around 5 mm from the breast phantom. The antenna substratum is FR-4. Copper is the patch, the field, the antenna power supply (annealed).

![Fig.1. UWB breast cancer detection](image)

III. UWB PATCH ANTENNA DESIGN

The simplest form of the microstrip patch antenna, as seen in Figure 2, is the radiation region of dielectric substrate on one side and the ground plane on the other. Patches are usually "made of conductive materials such as gold and copper. Usually, the beam region and the power lines are photographed in the dielectric layer.

The patch is typically circular, square, rectangular, triangular and elliptical are the regular shapes used to evaluate and predict results. Patch length L is usually $0.333 \lambda_0 < L < 0.5 \lambda_0$ in a rectangular patch. The patch thickness ‘t<<\lambda_0’ is selected. The dielectric substrate height ‘h’ is $0.003\lambda_0<h<0.05\lambda_0$. The substrate dielectric constant(\varepsilon_r) is usually $2.2<\varepsilon_r<12$.

Microstrip patch antennas mostly radiate due to the fringing fields between the patch edge and the ground plane. For better antenna performance, a thick dielectric substrate with a low dielectric constant is needed. This increases productivity, bandwidth and system radiation. This design, on the other hand, raises the antenna's size. Using a high dielectric constant substrate to build a compact microstrip antenna. This lowers efficiency and reduces bandwidth. A balance between antennasize and antenna efficiency must therefore be achieved.
When compared all other antenna, the microstrip rectangular patch antenna was perfectly operated at UWB frequency from 3.1 to 10.6 GHz seen in Fig.3.

![Rectangular Patch antenna structure](image)

Fig. 3 Rectangular Patch antenna structure

The design formulas of Microstrip Patch antennas are

1. To find the width (W)

\[
(W) = \frac{c}{2f_0 \sqrt{\varepsilon_{eff} + 1}}
\]

2. To find the Effective dielectric constant (\(\varepsilon_{eff}\))

\[
\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \sqrt{1 + \frac{12}{\varepsilon_r + 1}}
\]

3. To find the Fringing Length (\(\Delta L\)):

\[
\Delta L = 0.412h \left( \frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258} \right) \left( \frac{W}{h} + 0.26 \right)
\]

To find the effective Length (Leff):

\[
L_{eff} = \frac{c}{2f_0 \sqrt{\varepsilon_{eff}}}
\]

4. To find the Actual Length (L):

\[
L = L_{eff} - 2\Delta L
\]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Patch (L_p)</td>
<td>22mm</td>
<td>(\varepsilon_r(Fr4))</td>
<td>4.4</td>
</tr>
<tr>
<td>Width of the Patch (W_p)</td>
<td>20mm</td>
<td>Resonant frequency (Fr)</td>
<td>3.23GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
Comparison Study Results:

Modeling of the UWB breast cancer diagnosis device with the ANSOFT high frequency 3D modeling platform HFSS. The antenna unit that works in the microwave as a radiating part of the electronic breast cancer detection device. The two separate dielectric patch antennas were examined to analyze and placed on the skin of the breasts in order to define the better antenna as a perfect response to various levels of magnetic fields, electric fields and the present breast tissue density.

Return Loss:

During construction two dielectric materials that formed the patch frame antenna were used to measure the efficiency of the antenna device. The electrical characteristics produced by the digital calculation antenna are compared to authenticate the best radiator design result. The initial test was performed using a dielectric patch substrate, FR4 Epoxy material with relative permittivity is 4.4 and 0.02 tangent loss. However, second test used Arlon CLTE-XT material with 2.94 relative permittivity and 0.005 tangent loss. Figure 3. shows the fundamental antenna structure and size. This UWB patch antenna is 24 mm x 22 mm in size. The quantitative test results of the antenna with two different dielectric materials are shown in Table 1. Using FR4 epoxy materials as an antenna construction substrate, the radiator may be required to work within a frequency range of 3.1 to 8.2 GHz (5100 MHz bandwidth). When utilizing Arlon CLTE-XT content as dielectric substratum of a patch antenna system, the process would have the outstanding operating range of 3.9 to 9.8 GHz (5900 MHz bandwidth) as seen in Figure 4. The evaluation of the two materials with HFSS simulator shows that antenna's performance works over broad band width and meets UWB technology standard's specifications. The antenna was developed with biomedical applications in mind, especially when breast cancer is detected.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Length of feedLf</td>
<td>10mm</td>
</tr>
<tr>
<td>Height of substrateH</td>
<td>1.58mm</td>
</tr>
<tr>
<td>Width of feedWf</td>
<td>5mm</td>
</tr>
<tr>
<td>Length of slot Sl</td>
<td>44 mm</td>
</tr>
<tr>
<td>Width of slot Sw</td>
<td>40mm</td>
</tr>
</tbody>
</table>

![Fig. 4 Simulation results of S11 characteristics](image)

**Antenna Gain:**

![Fig. 5 Comparisons of Antenna gains (FR4 Epoxy and Arlon CLTE-XT)](image)

As a feature of frequency operation, the gain output of every antenna design, whether or not mistreatment Arlon CLTE-XT or FR4-Epoxy, exhibited 2 separate gain characteristics shown in Figure 5. Inserting FR4-Epoxy because the patch’s dielectric stratum will cause the antenna to work higher on lower waveband than those utilized...
by Arlon CLTE-XT. Using Arlon CLTE-XT will attract the cancer monitoring system to operate at a higher frequency range to be more powerful. The resonant frequency 3.9 GHz should reach the gain of more than 7 dB. The antenna gain provided while using FR4-Epoxy is about 3.16 dB at the 3.3 GHz resonant frequency.

The UWB microstrip antenna design’s 3D radiation pattern with two different dielectric materials showed in a particular direction very good power radiation. The 3D-pattern properties are seen in Figure.6.

![Fig(a)](image1)
![Fig (b)](image2)

**Fig. 6 Radiation patterns of Patch antennas: (a) FR4 epoxy material (b) Arlon CLTE-XT material**

It is analysed that inset fed rectangular microstrip antenna’s structure are investigated with two different dielectric materials to provide UWB signals for diagnose breast cancer early. In the simulation it is identified that Fr4 dielectric rectangular microstrip antenna is best radiator. The simulation antenna i.e. FR4 dielectric rectangular microstrip has an operating frequency spectrum of 3.1 to 8.2 GHz and 3.16 dB gain at 3.3 GHz.

**Realistic Breast Phantom:**

The breast model was created using the HFSS software shown in Figure 8. The model of the breast is an approximate replication of a human breast. Different prototypes of breasts phantoms have been used by researchers [6]. Many of these phantoms are distinguished by the critical electrical properties that are the relative permittivity εr and the conductivity ‘σ’.

![Fig. 7 Breast model with tumor](image3)

**Fig. 7 Breast model with tumor**

The numerical control is used to determine how the breast cancer screening program performs the difficult and extremely challenging task of tumor recognition. As can be clearly observed from the image shown in Figure 7 and 8. The geometry of the Microstrip Antenna and the homogeneous 3D model of the breast phantom consisting of a sheet of skin, adipose tissue and tumor were determined using different dielectric properties. The dielectric properties table of concept was developed as a hemisphere with a 3mm thick surface layer and an outer radius of 25mm. Inside the skin layer is a layer of fibro glandular adipose tissue of the breast with a radius of 22 mm. A plane wave is incident towards the model through the z axis and the field is located at 4 mm. The plane wave is transmitted through the unit and then sent from the ground. Several features of the model have been mentioned. The damaged cell is located as a 10 mm diameter ring inside the fibro glandular adipose tissue membrane.
I. BREAST MODELING

Modeling of the structure of the breast tissue in Figure 8 was done using the dielectrical properties from Debye model [10] shown in Table 2. The geometric characteristics, spatial arrangement of various constituent tissues, and dispersive properties of the breast must all be used in practical models. This study uses the ANSOFT HFSS simulation program to create 3-D anatomically accurate FDTD-based breast models based on the UWCEM MRI breast cancer repository. The breast model consists of 3 kinds of fatty tissue and 3 kinds of fibro glandular tissue, in addition to the skin layer and malignant tumour.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\varepsilon$</th>
<th>$\sigma$ (S/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>36.58</td>
<td>2.3404</td>
</tr>
<tr>
<td>Tumour</td>
<td>67</td>
<td>49</td>
</tr>
<tr>
<td>Fatty Tissue</td>
<td>4.8393</td>
<td>0.26229</td>
</tr>
</tbody>
</table>

The identification method is carried by designed to simulate an antenna with a 25 mm diameter sinusoidal pattern. The antenna is situated at the top of the sine form at a distance of 5 mm simulated with frequency band 3.1 GHz to 8.2 GHz. Figure 10 shows the SAR value reached without a tumor that already matches the breast safety standard.
Specific absorption rate (SAR) of the antenna for cancer-free skin and adipose tissue. SAR value refers to average strength of tissue. For healthy breasts, it is clear that the actual levels of SAR in skin and adipose tissue are low. This study shows that the proposed antenna can be used to detect breast cancer effectively. This work is a test of concepts that need to be experimentally tested. The range of detection sensitivity of the antenna can be greatly improved.

**Back Scattering Signals**

The tumor detection procedure using the integrated breast cancer detection system was mathematically validated by obtaining S11 reflected power at each antenna position. The antenna system rotated slightly during the operation and the h dimension remained stable to cover the entire surface of the breast shown in figure 13.

It should be noted that, while the breast cancer detector is form of a FR4 epoxy substrate. The key concern of breast cancer detector research is its findings using FR4-Epoxy. The simulations were performed by altering the distance (h) between the surface of the breast phantom and the tumor at the actual cutoff of the breast size, using two zones of tumor sizes, using two zones of tumor sizes (5mm and 10mm) to determine and interpret the strongest resonant frequency observed return loss values. The size of the tumor would have a direct effect on changes in the return loss values. The bigger the size of the tumour, the more incident energy that illuminated the antenna device requires to consume more energy. As a result, the obtained reflected power would be less. The simulation results shows that the effective distance of just under 2cm from the surface of the breast phantom makes it possible to detect the existence of tumors in the phantom by measuring value of the return loss.
The effect of the size of the tumor and distance ‘h’ between the phantom surface of the breast and tumor can be managed on the basis of the electrical field distribution model developed to obtain reflex return loss observations. This trend can be fully taken into account when using the HFSS method. The fascinating example of the E-field distribution pattern reported in the numerical demonstration as seen in Figure 14 shows that the tumor with a tumor size of 10 mm located at a distance ‘h’ of 1 cm can still consume all the radiation energy. When moving the position of the tumor by 3 cm h on the z axis, the power obtained in the tumor is less than 1 cm of h.

![Fig 14 (a) Tumor size of 10 mm at 3 mm distance (b) Electric field (c) Magnetic fields](image)

**II. UWB BREAST CANCER IMAGE FORMATION**

Evaluating and determining the proper location and size of the tumor is one of the most difficult challenges in the use of the UWB microwave imaging method to verify the efficiency of the breast cancer screening and tracking device. In order to resolve the problem of breast cancer modelling, several holistic methods have recently been proposed. For example, the final research report applied mammography technology using a Robust Artifact resistant (RAR) [13] algorithm to minimizes effects of incident signal volume and skin system reflexes. The algorithm was used to accurately reproduce the 3D breast image by extracting the unwanted signal from the reflected signal to achieve a better 3D breast image quality.

Easy and specific algorithms can, however, be used to accomplish the key purpose of diagnosing and detecting cancer, which is to predict and classify the location and scale of the tumor within the anatomy of the breast. The digital experiment was performed systematically to calculate the predicted reflective power obtained over the entire surface of the breast. Figure 3.14 is the breast area (top view) scanned by the UWB microwave imaging system used. A realistic evaluation would show the whole area and the corresponding S11 values are plotted in to various pixels (15x15 pixels). For each power obtained, a particular color code will be assigned.

Current empiric regulation takes into account the direction of the tumor midpoint (X, Y, Z axis=0 mm). The location and scale of tumor can be accurately measured using the simple reflective power imaging technique obtained as the image of Figure 15.
Fig. 15 Position of tumor existed inside the breast image (2D Image) (a)Topview of breast model (b) 2D Image for each breast tissue for different value of reflected power S11 value.

### III. BREAST CANCER DETECTION SIMULATION RESULTS

Simulation results in terms of Electric field, return loss, magnetic field, radiation pattern, gain and frequency for given FR4 patch antenna with realistic breast phantom were presented to validate the usefulness of the proposed design. The simulation study reveals that the reflected power obtained declines as the tumor size rises. The Simulation results of FR4 patch type realistic breast model without tumour is as shown Figure 16.

The Simulation results of realistic breast model with 5 mm tumour is shown in figure: 17

The Simulation results of realistic breast model with 10 mm tumour is as shown in Figure 18.
The figure shows a simulation of a real breast model with 10mm tumor. The HFSS software tool compares the electric, magnetic, inverse, current density, phantom amplification results of a real breast with 5mm and 10 mm FR4 tumor patches with cancerous tumours. It is simulated in the foreground as shown in Table 3. The table indicates that the return loss increases with the tumour size.

Table 3. Results for Realistic breast phantom with 5mm and 10mm breast tissue

<table>
<thead>
<tr>
<th>Patch antenna</th>
<th>Electric field (Volts per meter)</th>
<th>Magnetic field (Ampere per meter)</th>
<th>Current density (Ampere per meter²)</th>
<th>S11 Returnloss (dB)</th>
<th>F (GHz)</th>
<th>Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without tumor</td>
<td>1.4648e+003</td>
<td>4.915</td>
<td>5.153</td>
<td>12.148</td>
<td>3.4</td>
<td>3.7</td>
</tr>
<tr>
<td>5mm tumour</td>
<td>1.4233e+003</td>
<td>5.05</td>
<td>6.0002</td>
<td>17.344</td>
<td>3.3</td>
<td>3.25</td>
</tr>
<tr>
<td>10mm tumour</td>
<td>1.4879e+003</td>
<td>4.92</td>
<td>5.567</td>
<td>17.482</td>
<td>3.3</td>
<td>3.24</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

It is argued that two different dielectric materials are being used to study the structure of rectangular microstrip insert antennas to deliver UWB signals to diagnose early-stage breast cancer. The FR4 rectangular dielectric microstrip antenna is the perfect radiator for the simulation. The FR4 dielectric rectangular microstrip simulation antenna has operating frequency spectrums of 3.1-8.2 GHz and a gain of 3.7 dB in resonant frequencies of 3.4 GHz. Reasonable tumor identification for diagnosis of breast cancer centered on study of intensity of the breast tissue illuminated. The ANSOFT HFSS was used as a homogeneous 3D breast phantom and antenna. The simulations show that the greater the tumor size in the breast, the higher the return loss. The extra reflex strength from both adipose and tumor tissue may be several potential causes that can explain this phenomenon. The effective distance is less than 1cm between the skin phantom and the breast tumor. The designed antenna features UWB advantages, conservative size, minimum cost, good directions.

REFERENCES


AUTHORS PROFILE

Ennam Govinda post graduated from JNTU Hyderabad with his M. Tech in DSCE. He graduated from V. R Siddhartha engineering college, BZA, Andhra Pradesh, with a B. Tech degree in ECE. He took up his current position at Avanthi Engineering College, Visakhapatnam as associate professor of ECE. Besides this, he is doing a Ph.D. at GITAM deemed to be University, Visakhapatnam, A.P, India.

Dr. B.S. Vemuri Srilatha Indira Dutt currently works as a professor in the ECE department of GITAM University, Visakhapatnam. She did her B.Tech. from Siddhartha College of Engineering in ECE and M. Tech from Andhra University. She received her Ph.D from Andhra University, Visakhapatnam. She is an experienced faculty member in microwave and radars, with over 20 years of experience. More than 30 research papers were written by her in various International and National conferences. She is a life member of different professional bodies, such as ISTE, CSI, IEEE.