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A Microstrip Patch Antenna for Breast Cancer Detection using Confocal Microwaves Imaging

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ABSTRACT

In this paper, UWB band microstrip patch antenna has been designed to detect an early stage of breast cancer detection by using confocal microwaves imaging technique. A patch antenna should be fabricated over FR-4 substrate, with dimensions of 22× 30 mm, having hexagonal circular patch with defected ground structure. The antenna has designed to achieved a moderate peak gain of 2.6 dB with average depth of -55 dB return loss at resonating frequency of 4.4 GHz. Antenna resonating at sharp 4.4 GHz with proper matching impedance with efficiency of 90% to penetrate the waves deep inside the breast to detect the correct location of cancer cell with high accuracy while maintaining low system cost and complexity. The UWB microstrip antenna are placed Infront of the breast model to transmit the EM waves and receive the scattered waves from tumor cell which having high dielectric property to absorbed the more energy than healthy cell. Finally, the scattered waves collected and proceed to Confocal Microwaves Imaging technique in MATLAB to regenerate the high resolution 2D image by using Delay-and-Sum Beamforming algorithm which represent the tumor position deep inside the breast. The regenerated image shows the high intensity of energy showing the more absorption of energy by tumor cell.

Keywords: Microstrip Patch Antenna, Breast phantom model, Confocal Microwave Imaging, MATLAB, -CST

I. INTRODUCTION

In this paper, we will discuss the most fatal world-wide disease which is secondary cause of death in women after the cervical's cancer is breast cancer [1]. A Harvard study showed that 70% of women who died from breast cancer were among 20% of women not screened due to unawareness and shy from family. Early detection significantly improves breast cancer survival, reducing the risk of dying of breast cancer by 40% [2]. 1 in 6 breast cancer occur in women at age of 40-49. X-Ray and mammography are the most common and low-cost Breast cancer detection, low resolution of image with ionizing technique and false-negative rates. Biopsies is the pain full method for breast cancer detection but MRI is better way to diagnose the early stage of breast cancer detection. Breast cancer [3],[4] is a common disease among women and death figure is continuing to increased. As there is no remedy in the late stage, Early breast cancer detection is crucid. That why we have to move some new approach with low cost, non-ionizing and comfort method for breast cancer detection is MWI microwaves imaging technique. For this the UWB/ISM is the promising candidate for its specification and lack of ionizing radiation. In my Literature review I will be presenting the performance analysis of different types of UWB antenna [5] for breast cancer detection. The antenna performance is comparison is based on the accuracy obtain from neural network (NN) module for each UWB antenna. These types of antennas taking into the account are UWB [6] Patch, UWB pyramidal and Horn antenna along with high gain Vivaldi antenna that design and fabricated over FR-4 substrate with low cost and compact in size. To measure the performance and accuracy of each antenna we observe that the pyramidal and Vivaldi antenna is 90 % better preform as compare to UWB/ISM microstrip patch antenna. High gain Vivaldi antenna [7] and more directional Horn antenna with proper 50Ω matching impedance to reduce the backscattering lobes and more transmission of energy. This antenna is placed in front the breast phantom model with embedded tumor cell according the given co-ordinate and counted both forward and backward scattering signal of monostatic antenna which act as transmitter and receiver used multiple time to multiple location to collect the scattered signal at different location of tumor inside the breast model. For high performance analysis we used multiple channels by placing the array of antenna around the breast model to collect the scattering energy of EM waves to detect the tumor position at different angle and location around the breast model, where one antenna act as transmitter and remaining antenna act as receiver of EM scattering waves from tumor cell. This scattered energy more reflected form high density tumor cell. Tumor cell having different dielectric property, such as permittivity and conductivity at different band of frequency range to fallow the skin depth effect. ISM band antenna operates at 2.4-2.45 GHz, where UWB antenna [8],[9] working frequency range at 3.1-10.6 GHz with wide channel bandwidth of 500 MHz

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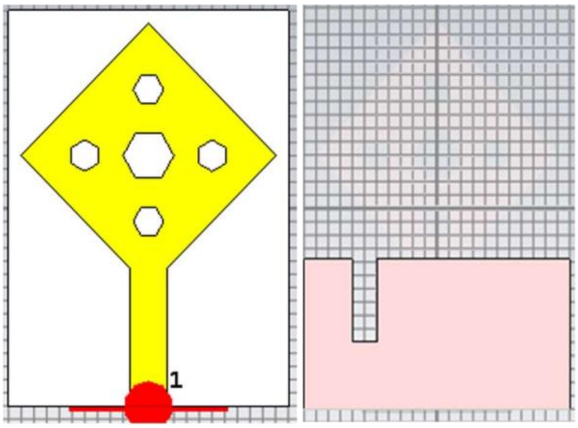
This spectrum is used for high-speed data transmission, short-range and precise location tracking applications. Due to difference in permittivity and conductivity medium of breast, the ISM frequency have more energy to penetrate deep inside the breast model to collect and detect the location of cancer cell but low resolution of image, at the same time UWB frequency have low penetration of waves but high resolution of image is reconstructed by proceeding the scattering signal in MATLAB by using Delay-and-Sum beamforming [10],[11] algorithm in confocal microwaves imaging technique.

The paper is organized as follows: Section II describes the design and measurement of UWN Antenna. Section III describe the breast phantom model. Section IV provides the simulation results and the observations. Section V mainly deal with Confocal Microwave Imaging Algorithm to reconstruction of high resolution 2-D Image.

II. ANTENNA DESIGN

A simple, low-cost ISM band antenna with radiating patch on top side and slotted ground plane antenna shown in Fig.1



(a) Radiating Patch. (b) Slotted Ground Plane

Fig. 1. Proposed microstrip slotted ground antenna.

TABLE I
LIST OF PAPRAMETER VALUES

PARAMETER	VALUE
Substrate length L_S	22
Substrate width W_S	30
Height of substrate h_S	1.6
Patch Square L_p	10
Hexagonal radius r	1.2
Ground Plane $l_g \times w_g$	22 × −15 × 3.5
Slotted cut $L_{slotted}$ × w_{sl}	-10× −3.5

Below -10 dB the magnitude shows the max amount of energy transmitted with minimum loss of energy to reduce back lobes at optimum gain of 2.5 dB at resonating frequency of 4.4 GHz with radiating efficiency of 90% as shown in fig 4.

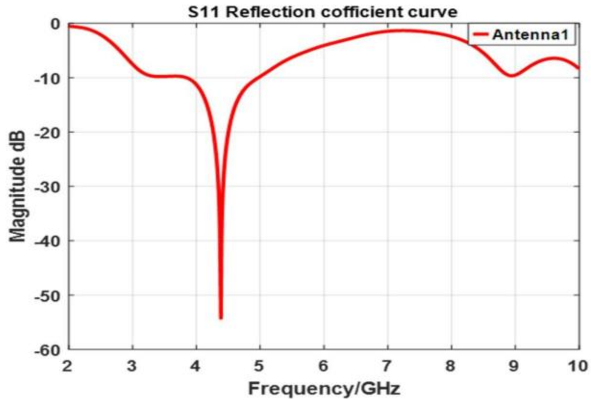


Fig. 2. S11 Reflection coefficient curve of proposed Antenna-1 at resonating frequency 4.4 GHz

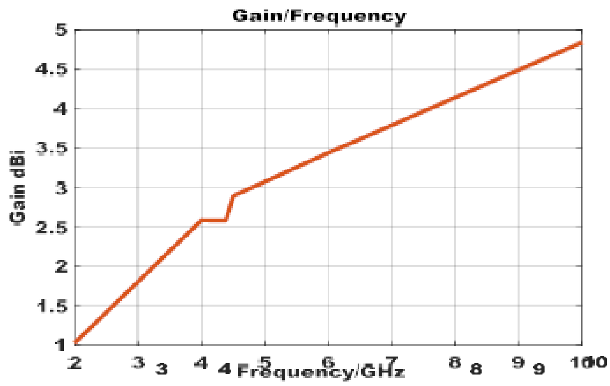


Fig. 3. Gain of proposed antenna-1 at 4.4 GHz.

The input impedance of square patch is given by:

$$Z_{in} = \frac{60\lambda_0}{l_p} \quad (1)$$

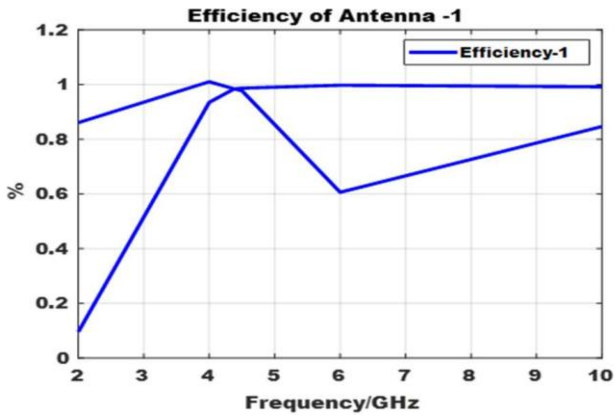


Fig. 4. Radiation Efficiency of Antenna-1

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$$Z_o = \sqrt{50 \text{ x } Z_{in}} \quad (2)$$

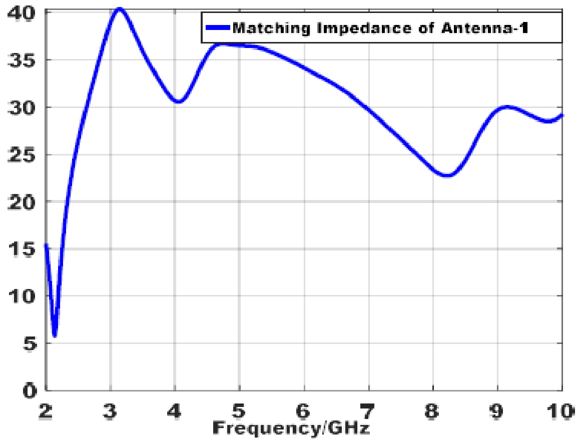

Fig. 5. Matching Impedance of Antenna-1

III. BREAST-IMAGING SYSTEM

In figure.6 show the core concept of breast-imaging system by using CMI confocal microwaves imaging. The simulation setup is most common breast imaging method in which proposed antenna are placed 40 mm distance from the surface of breast phantom model with tumor embedded inside the breast along Z-axis at co-ordinate (0,0,50) of radius 5 mm.

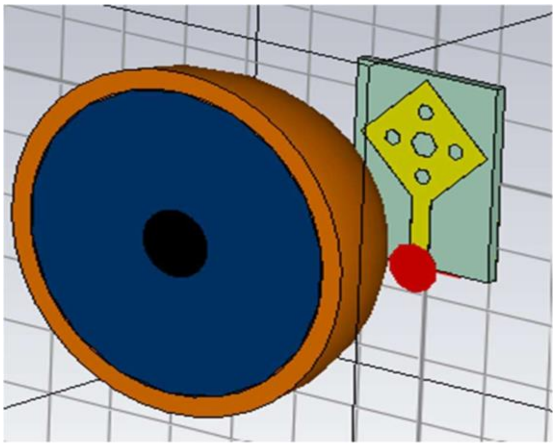

Fig. 6. Breast-Imaging model with embedded tumor (0,0,50). placed in-front of proposed antenna-1.

TABLE II

Parameter	ε_o	σ (S/M)	ρ (kg/m³)	Radius	x, y, z mm
Skin	36.7	2.35	1109	26	0, 0,50
Fat	4.85	0.262	911	23	0, 0, 50
Tumor	55	4	1060	5	0, 0, 50

In near field region, the proposed antenna resonating at 4.4 GHz with high directivity and moderate gain for breast cancer detection. Highly efficient antenna transmitted more power in given direction and the directivity increased the scattering energy rebounced back from the tumor cell of the breast tissue. This rebounced energy was collected by monostatic antenna which seen in term of S11 reflection coefficient curve as shown in figure.7. S11 magnitude of curve below -10 dB up to -25dB show maximum transfer of energy from radiating patch of antenna to breast model.

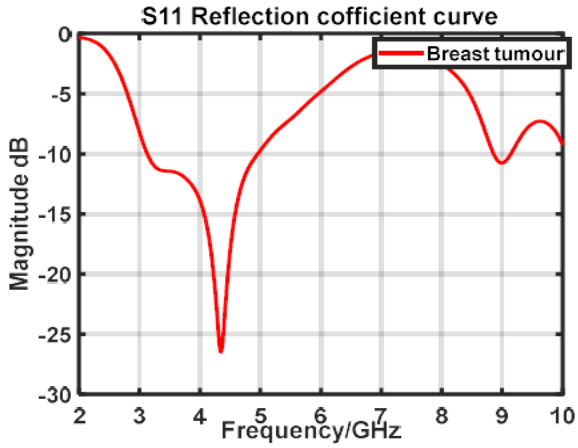

Fig. 7. Return loss when breast placed Infront of antenna.1

Due to different conductivity and permittivity of breast skin and fat are calculated in Table-II which show that different parameter of skin and fat have more reflection of waves from the surface of skin which also act as noise and clutter. This noise and clutter should be removed by averaging the S11signal in Delay-and-Sum beamforming algorithm by using confocal microwaves Imaging in MATLAB [12]. The tumor cell has high density of water content which absorbed more energy from radiating antenna when placed Infront of breast phantom model at a distance of 50 mm. By changing the position of antenna-1 or distance between the breast phantom and antenna, we saw slightly shifting of S11 reflection coefficient curve as shown in fig.8

IV. RESULTS AND DISCUSSIONS

In this method, we used the high directional monostatic antenna-1 radiating at 4.4 GHz frequency with moderate gain. The antenna is placed at a distance of 50 mm from breast to detect the exact location of tumor inside the breast by measuring the S11 return loss power from tumor cell. For high resolution of image and exact location of tumor we rotate the antenna around the breast model at different position and compare the S11 radiation pattern of tumor.

The proposed approach is used to detect the tumor of radius of 5 mm embedded inside the breast model. The same approach is applied at different size of tumor in

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different co-ordinate system of breast model and measured the S11 curve for different size of tumor cell by changing the distance between the breast and antenna along the z-axis.

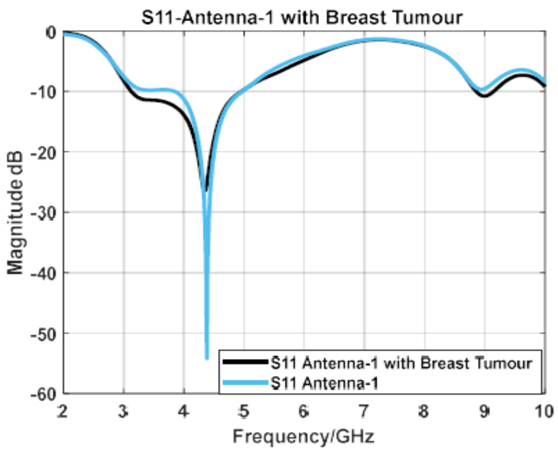

Fig. 8. Comparison of S11Return loss curve with tumor and without tumor at resonating frequency at 4.4 GHz.

Which represent the correct location of tumor co-ordinate in high resolution image. While measuring the S11 for different size and location of tumor we see slightly shifting of frequency band at 4.4 GHz frequency shown in fig.9 and more absorption of energy by tumor cell which identified by high resolution of 2D image in confocal microwaves imaging process in MATLAB code.

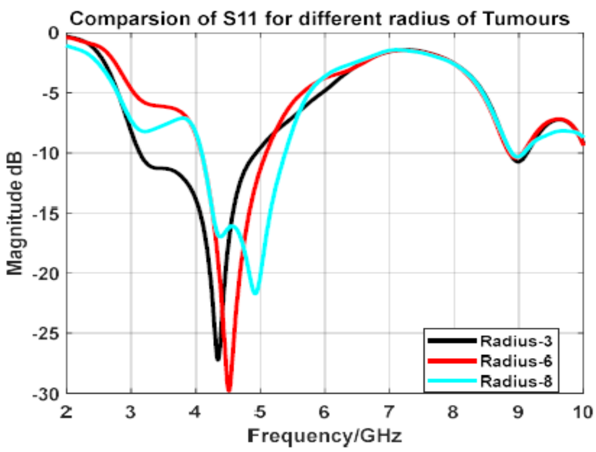

Fig. 9. Comparison of Bandwidth and S11Return loss with different tumor size and distance between breast and antenna-1 at resonating frequency at 4.4 GHz.

Table III show the different size of tumor cell inside the breast at calculative distance between breast and antenna.

TABLE III

Position of breast	Radius of Tumor	Co-ordinate x, y, z
50	3	5, 10, 45 mm
35	6	10, 15, 32 mm
30	8	-10, 15, 25 mm

V. CONFOCAL MICROWAVES IMAGING

For image reconstruction, the gaussian pulse at center frequency of 4.4 GHz should fallow the skin depth process and penetrate at a depth of few centimeters inside the breast without attenuation of signal. Finally, the scattered signal form tumor is collected and procced for image reconstruction [13].

Table III show the location of different size of tumor and distance between the breast and antenna to obtain the frequency domain signal. At different location, the frequency domain signal of the tumor-free breast and breast with tumor model are simulated by using CST software.

By using Delay-and-Sum [14] Algorithm and developed MATLAB code we can generate the high-resolution image, the location of tumor is determined by subtracting the time domain signal received from a tumor-free from those of breast with tumor. Before proceeding the time domain signal, first we have to remove the noise and clutter which added from reflection of waves at the surface of skin. To removed clutter, first averaging the signal and then proceed to MATLAB Code to reconstruct the high resolution of image with high intensity around the tumor [15].

1. Take the absolute value of signals.

The reflection coefficient are frequency domain signals and further convert to absolute signal in term of

S_{11} Reflection coefficient for breast without tumor

SB_{11} Reflection coefficient for breast with tumor

2. Transformation of signals.

First convert the frequency domain signal to time domain signals by applying the IFFT in Equ. (3) and (4).

$$S_{11} = \mathrm{IFFT}(S_{11}) \quad (3)$$

$$SB_{11} = \mathrm{IFFT}(SB_{11}) \quad (4)$$

3. Calibration of signal

The time domain signal of breast with tumor is subtracted from the time domain signal without tumor. The subtracted signal indicated the exact location of tumor.

$$C11s(t) = SB11s(t) - S11s(t) \quad (5)$$

4. Clutter/Noise removal

The C11s(t) signal contain some reflected signal from surface of skin and antenna also. To remove this reflected signal first we calibrated the signal by averages method, then subtracted from calibrated signal. Where N denote number of antenna position around the breast model.

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$$\mathrm{Axy}(t) = \frac{\sum_{Y=1}^{N} C_{11s(t)}}{N} \quad (6)$$

$$\mathrm{Pxy}(t) = C_{11}s(t) - \mathrm{Axy}(t) \quad (7)$$

5. Synthetic focusing.

Let the area of 100 × 100 mm is considered and the distance from each antenna position XY to each pixel (xi and yi) is calculated. Hence, the distance between the antenna and the pixel are same. Because of this the distance DXY (xi, yi) is multiple by 2 in Equ.9. which represent the round-trip time for signal to reach back to the antenna by using doppler effect.

$$D_{XY}(x_i, y_i) = 2\sqrt{(X - x_i)^2}\text{-}(Y - y_j)^2 + d^2 \quad (8)$$

$$t_{XY}(xi, y_i) = \frac{D_{xy}\,(x_i - y_j)}{c/\sqrt{\varepsilon_r}} \quad (9)$$

6. 2-D Image generation

The intensity value of high-resolution image can we calculated for each pixel by proceeding signal PXY(t) at a time tXF (xi, yj) in Equ. 10. Where r = total no of antenna position in row, c = total no of antenna position in column and I (xi, yj) represent the intensity value of pixel of generated image.

$$I(x_i, y_j) = \left[\sum_{X=1}^{r} \sum_{Y=1}^{c} P_{xy}\,(x_i y_j)\right]^4 \quad (10)$$

Figure.10 show the image generated by using confocal Microwaves Imaging by applying Delay-and-Sum algorithm in MATLAB code. The same image can be generated by using Python code by using the S11 reflection coefficient frequency domain signal.

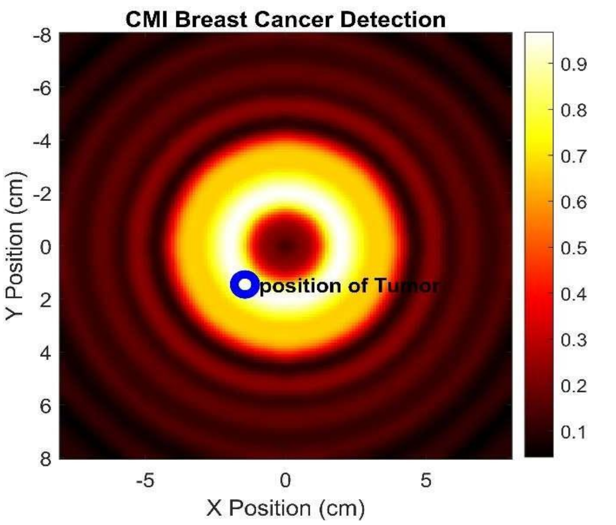

Fig. 10. represent the high intensity 2-D Image showing the accurate position of tumor inside the breast.

VI. CONCLUSION

In this paper, we represent the (CMI) Confocal Microwaves Imaging technique for breast cancer detection by modified (DAS) Delay-and-Sum beamforming to calculate the exact location of tumor inside the breast by generating the high intensity image. For generation of image, we design high directional antenna with moderate gain of 2.4 dB at resonating frequency 4.4 GHz. The experimental setup developed in CST software by me searing the S11 frequency domain signal for different size of tumor embedded ins side the different co-ordinate inside the breast from different distance from antenna position.

Further, we notice an accurate high-resolution image can be generated in MATLAB code and in Python code by suppressing the noise and clutter from reflected waves.

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