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UWB antenna for Microwave screening of Breast Cancer

Philip Cherian, Alka Jasmine

Abstract— A novel, coplanar, ultra-wideband, directional antenna having a size of 24mm× 25mm printed on a 1.5mm thick FR4 substrate for microwave screening of breast cancer is presented. To reduce the complexity in shape, exponential flares and curves are used in the geometry .The ground plane has been extended in both sides. Optimization is done for the gap between the ground planes. Special features for bandwidth enhancement includes rectangular slot towards bottom, rectangular and circular projections and a unique structure in the gap. The dimensions of the slot and projection has been optimized. The antenna has a near-field pattern in the end-fire direction which makes it a suitable candidate for medical imaging. The antenna is capable for wideband operation to cover 2.89-11.2GHz which includes the whole ultra-wideband frequency range.

Index Terms— Breast cancer detection, coplanar, microwave imaging, ultra-wideband (UWB) antenna , near-field ,directional ,HFSS

1 Introduction

Microwave breast imaging has been proposed to assist in the early detection of breast cancer [1].Radar- based microwave breast imaging approaches involve illuminating the breast with an ultra-wideband pulse of microwaves and detecting reflections[2]. The reflections are then processed to create images that indicate the presence and location of tumors in the breast. Ultra-wideband (UWB) systems offers the advantage of greater tissue penetration at low frequencies and good imaging resolution at high frequencies. A key component of these systems is the antenna that is used to radiate and receive the ultra-wideband pulses[3].

Since the purpose of the antenna is to transmit a short pulse in time it needs to be broadband, so a reflection coefficient (S_{11}) less than -10dB over the frequency range from 2 to 12GHz is required. Moreover, it requires that the radiation pattern to be endfire-directed with a narrow beamwidth.Given Fthat the antenna is placed very close to the breast, all of the radiation requirements need to be fulfilled in the near field region. Since the system uses an array of antennas to radiate the breast, the antenna designed should be low profile, to make the system compact. Proper substrate selection for the design also makes the system low cost.

In recent years, there is a growing interest in the design of ultra-wideband antennas particularly for medical imaging applications. The balanced antipodal Vivaldi antenna (BAVA) [3] has proven its imaging ability, efficiency and directivity, however the multi-layered geometry and the large size of the antenna (74mm×44mm) is a disadvantage. The BAVA-D [4] antenna improves the efficiency but the inclusion of director makes the system more complex. Other antennas for radar based breast imaging include the ridged pyramidal horn antenna with curved launching plane [5], the stacked patched antenna [6] developed at the University of Bristol and finally a planar tapered slot antenna [7].

In this paper a coplanar 24mm× 25mm×1.5mm antenna printed on a low cost FR4 substrate to cover 2.89-11.2GHZ band having flared geometry is investigated. Its geometry, the design process and its performance characterization in the near-field are presented. Simulated results for S_{11} are also provided.

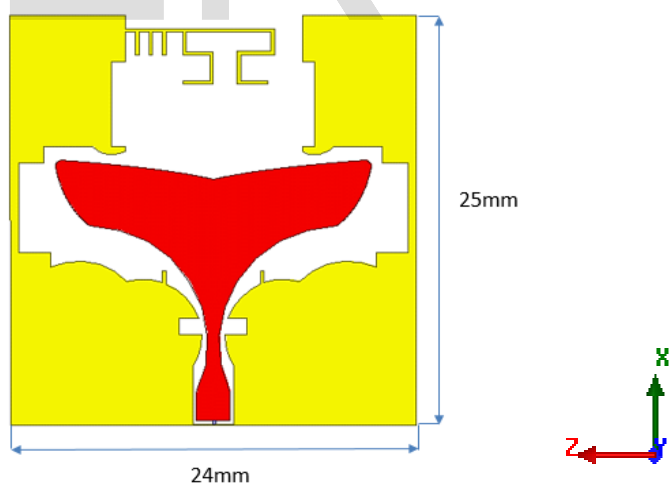

Fig. 1. Proposed antenna

2 Antenna Design

Fig.1 shows the proposed antenna that is printed on a thin (0.5-mm) FR4 substrate with relative permittivity 4.4 and loss tangent 0.02.The proposed antenna has a rectangular shape of 24mm× 25mm.As depicted in the figure, the antenna consists of two major section, namely a signal path and a ground plane.

- *Philip Cherian is working as Associate Professor in department of Electronics engineering in College of Engineering,Chengannur ,India*
  E-mail: philipcherian@ceconline.edu
- *Alka Jasmine is currently pursuing masters degree program in Electronics engineering in College of Engineering,Chengannur,India*
  E-mail: alkaj9@gmail.com

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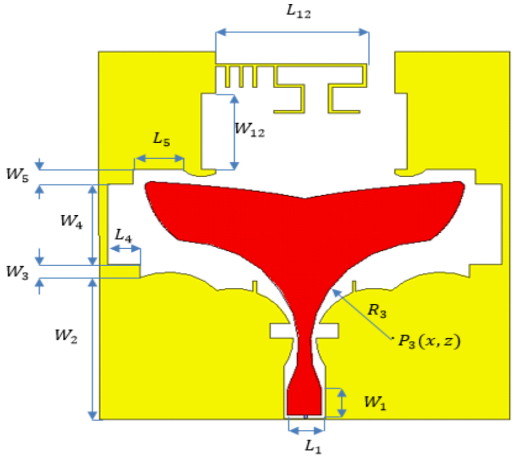


Fig. 2. Antenna with the signal path and ground plane

TABLE 1
DIMENSIONS OF MAJOR FEATURES (IN MM)

L_1	L_4	L_5	L_{12}	W_1	W_2
2	1.9	1.5	8.8	1.74	10.5
W_3	W_4	W_5	W_{12}	$P_3(x,z)$	R_3
0.8	5.5	1	5.2	(5,7.5)	7.16

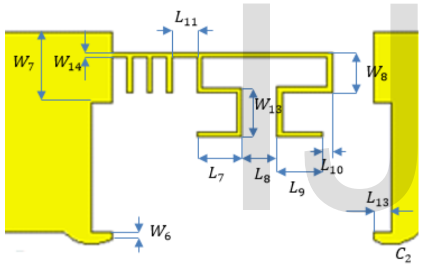


Fig. 3. Labeled design of top features

TABLE 2
DIMENSIONS OF TOP FEATURES (IN MM)

L_7	L_8	L_9	L_{10}	L_{11}	L_{13}
1.9	1.5	8.8	0.4	1	0.7
W_6	W_7	W_8	W_{13}	W_{14}	C_2
0.8	2.8	1.8	2	0.2	1.5

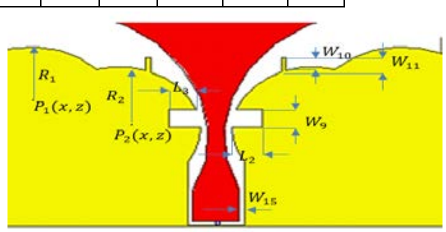


Fig. 4. Labeled design of bottom features

TABLE 3
DIMENSIONS OF BOTTOM FEATURES (IN MM)

L_2	L_3	W_9	W_{10}	W_{11}
24	2	1	0.7	0.8
W_{15}	$P_1(x,z)$	$P_2(x,z)$	R_1	R_2
0.2	(5.4,4.2)	(6,8)	3.5	4

The feed has a length of 2mm, up to 1.74mm and then begins a circular flare of radius 7.16mm.The structure is symmetric in the x-z plane. The circular flares are then joined by exponential curves. The curves are defined by the following equation:

$$z = \pm A * e^{P*(x-B)} + C \quad (1)$$

Where A is the scaling factor the exponential rate the shifting value C the offset and L the length. These parameters are defined for each curves in Table 4, where (x_1, z_1) , (x_2, z_2) are the coordinates.

TABLE 4
EQUATION PARAMETERS

Curve	A	P	B	C
E	$\frac{z_2 - z_1}{2 * (e^{P*L} - 1)}$	P	x_1	$z_1 - A$

The ground plane follows a circular path,and has been extended towards the +ve x-direction.A rectangular gap is provided between the two ground planes.Special features has been added in the ground plane for bandwidth enhancement.The rectangular slot (length L_3 and width W_9) towards bottom ground plane,a rectangular notch (length 0.2mm and width W_{11}) and the finger like structures appended to ground plane are a few.Optimization analysis for the rectangular slot and the notch resulted in a dimension of 1.1 mm× 1mm and 0.2mm × 0.8mm respectively.All the individual fingers in the gap have a width of 0.2mm.

3 SIMULATION RESULTS

The antenna is simulated by employing the commercially available software High Frequency Structure Simulator (HFSS).The performance of the antenna is evaluated in terms of: S_{11} and near-field directivity.

For this design, S_{11} is below -10dB above 2.89GHz as shown in Fig.5.The bandwidth extends up to 11.2GHz.The total near-field directivity at different frequencies of analysis are presented in Fig.6.

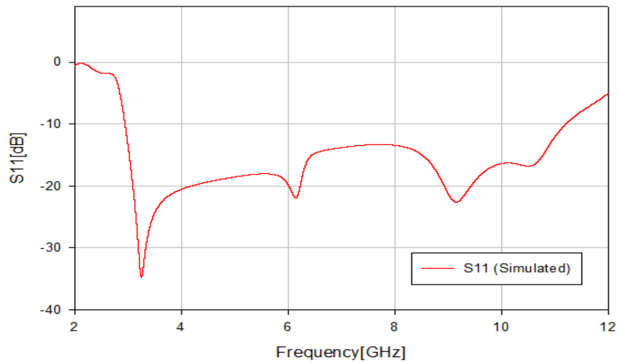


Fig. 5. Simulated reflection coefficient (S_{11})

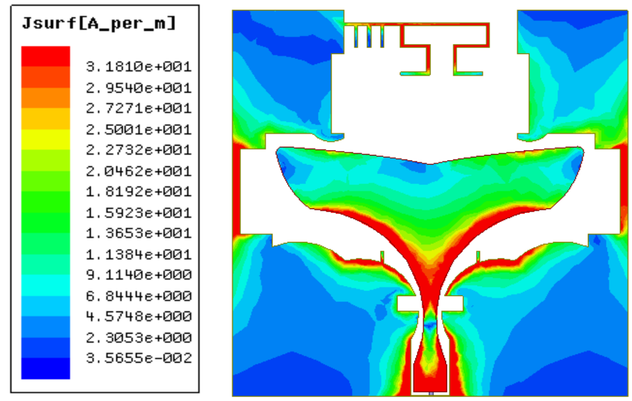


Fig. 7. Simulated surface current density

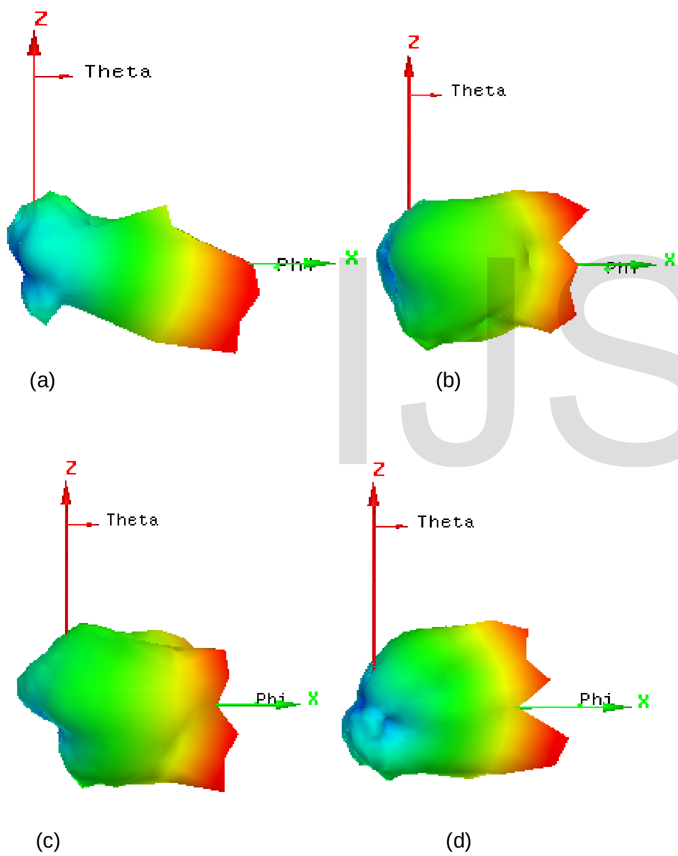


Fig.6. Simulated Near-Field directivity. (a) 3GHz (b) 7GHz (c) 9GHz (d) 11GHz

Surface current density of the design at a frequency of 7GHz is shown in Fig.7. From the figure it is evident that more current is concentrated in the exponential curves of the signal path.The current follows a smooth path and is terminated at the cross over between the two flares.The finger like geometry in the top also contributed for the resonance at the lower frequencies

The antenna has a near-field pattern in the end-fire direction which makes it a suitable candidate for medical imaging.Near-field pattern at different frequencies of analysis are shown in Fig. 6.The side lobes and back lobes are reduced.

4 PARAMETRIC STUDY AND DESIGN PROCESS

To facilitate the design, a parametric study has been carried out. Through extensive parametric analysis it has been concluded that the finger like structures, the rectangular notch (W_{11}), the rectangular slot (W_9) in the bottom ground plane, the rectangular slot in the top ground plane (L_{13}) are the critical features of the design particularly in the lower frequencies. The resonances in the higher frequencies are mainly contributed by the exponential flares.

By the inclusion of the finger like structures in the top, the bandwidth extended towards lower frequencies. Without the structure the band obtained was 3.5GHz-11.6GHz.

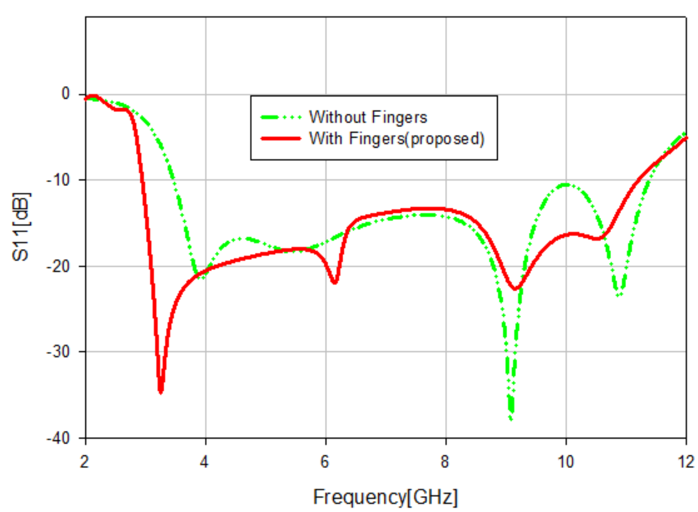


Fig. 8. Simulated reflection coefficient (S_{11})

The influence of (W_{11}) is critically important in the design. Increasing or decreasing W_{11} alters the band and creates a notch in the low frequency.

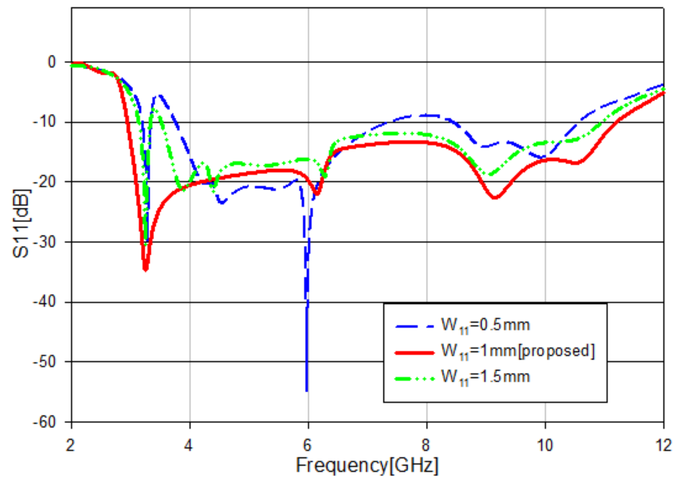


Fig 9. Optimization results of rectangular notch (W_{11})

The rectangular slot in the bottom ground plane (W_9) also influences the low frequency result.

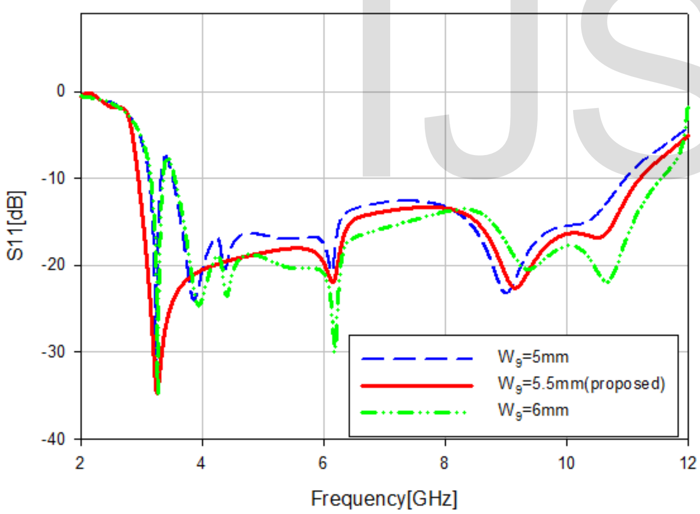
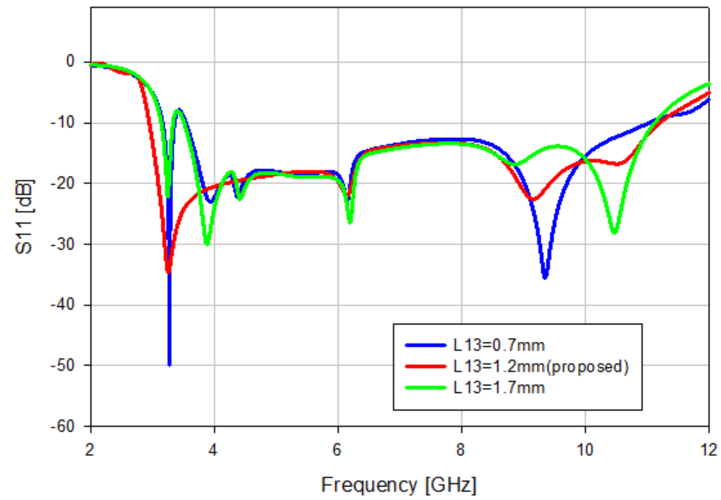


Fig 10. Optimization results of rectangular notch (W_9)

The presence of L_{13} influences the overall bandwidth of the antenna. Without the slot, the return loss is raised and both the higher as well as lower frequencies are affected. Increasing or decreasing L_{13} creates notch in the low frequency.

Fig 11. Optimization results of rectangular notch (L_{13})



4 CONCLUSION

In this paper, a novel, cost effective, low profile, coplanar antenna suitable for the application of microwave screening of breast cancer is presented. The antenna has a bandwidth extending from 2.89GHz to 11.2GHz.The antenna has a near-field pattern in the end-fire direction which makes it a suitable candidate for medical imaging. The radiation patterns are promising for further investigations to develop a pencil beam pattern .The bandwidth can also be extended to lower frequencies to include the GSM,GPS and ISM bands.

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