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Design of Wearable UWB Microstrip Patch Antenna for Breast Cancer Tumor Detection

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ABSTRACT

A novel approach to detect breast cancer tumor is proposed in this paper. The UWB antennas are designed in the frequency range 3.3-10.6 GHz. The antennas show a return loss S11 less than -10 dB for the UWB frequency range and a maximum gain of 3.49 dB in this range. The designed UWB antennas can be placed on both sides of breast such that the signal scattered by the breast tumor can be detected by the receiving antenna. A breast model is designed which is simulated with UWB antenna on both sides, the variation of E field, H field and current density is shown with and without tumor for various position and size of the tumor, the difference between these values will detect the presence of tumor. The SAR is also simulated for different frequencies in UWB range with variation in size and position of the tumor. The simulated results can be observed and the presence of tumor can be detected.

Keywords:
E-field, H-field, SAR, Tumor , Ultra-Wide Band

1. Introduction

Breast cancer is a major cause of death among women nowadays [1]. It should be detected at a very early stage so that it can be treated otherwise the conditions can be very severe. It is basically a cell that grows very fast, the cancer cells can go to other parts of body also and affect them, these cells become longer and uncontrolled thus it becomes a tumor [2-3]. There are traditional methods to detect the cancer like ultrasound, X-ray, MRI, microwave imaging [4-5] but all these methods have certain restrictions and there is a need of such devices which can be implanted in the breast and which detect as soon as a tumor starts growing in the breast tissues. There can be a transmitting and receiving antenna. The transmitting antenna transmits electromagnetic signal which travels through skin, breast tissues and fat layers while the receiving antenna receives the scattered waves. The presence of tumor will affect the received signal on receiving antenna, thus it can be detected. [6-7]The scattered signal in the presence of tumor as compared to a normal breast will vary thus detecting the tumor presence. There are many approaches to detect the tumor in literature. The UWB is nowadays of great interest in biomedical applications [8-10]. The UWB antennas should be planar, compact with high radiation efficiency over the whole band. In this paper, a compact UWB antenna is designed, the antenna works for the entire UWB range which is obtained by using a partial ground plane. The designed UWB antennas are placed in a cover that can be worn such that the two UWB antennas are placed on both sides of breast. The transmitting and receiving antennas work in pair, the breast model is designed and it is simulated with antennas on its both sides. The electrical parameters including E field, H field current density and SAR values are simulated. The results are compared with and without tumor and this approach can be used for tumor detection. The variation in results with size and positions of tumor is also discussed.

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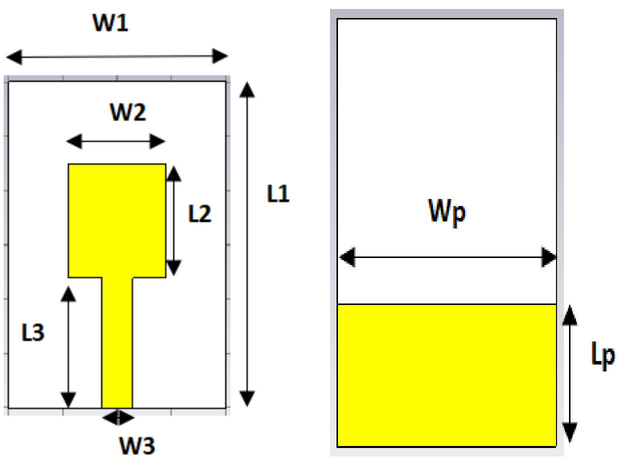
2. UWB antenna design

The antenna has been designed for UWB frequency range. The substrate used is FR4 having a dielectric constant of 4.4 and height 1.6 mm. The front view of the antenna is as shown in Fig. 1(a). The dimensions in mm are as given in Table 1. The back view is as shown in Fig. 1(b) where there is a partial ground plane to obtain UWB characteristics.



(a) (b)

Fig.1. Front and back view of antenna

Table 1. Dimensions of Antenna (mm)

W1	20	**L1**	30
W2	9	**L2**	10.5
W3	2.9	**L3**	12
Wp	20	**Lp**	10

The antenna design is simulated and return loss (S11 (dB)) results are plotted with frequency as shown in Fig. 2 It can be observed that S11<-10 dB for the frequency range 3.3 to 10.6 GHz that lies in the Ultra-wide band range and the minimum attenuation is obtained at a frequency of 9.344 GHz in the UWB range.

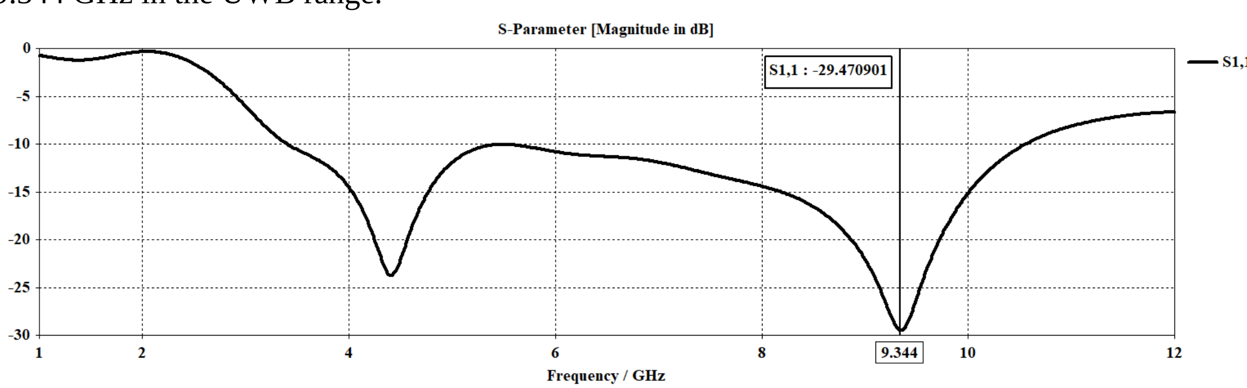


Fig.2. S11 vs frequency plot

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The plot for gain is also simulated with frequency as in Fig. 3, it can be seen that a peak gain of 3.49 dB can be obtained at a frequency of 7.3 GHz in the UWB range.

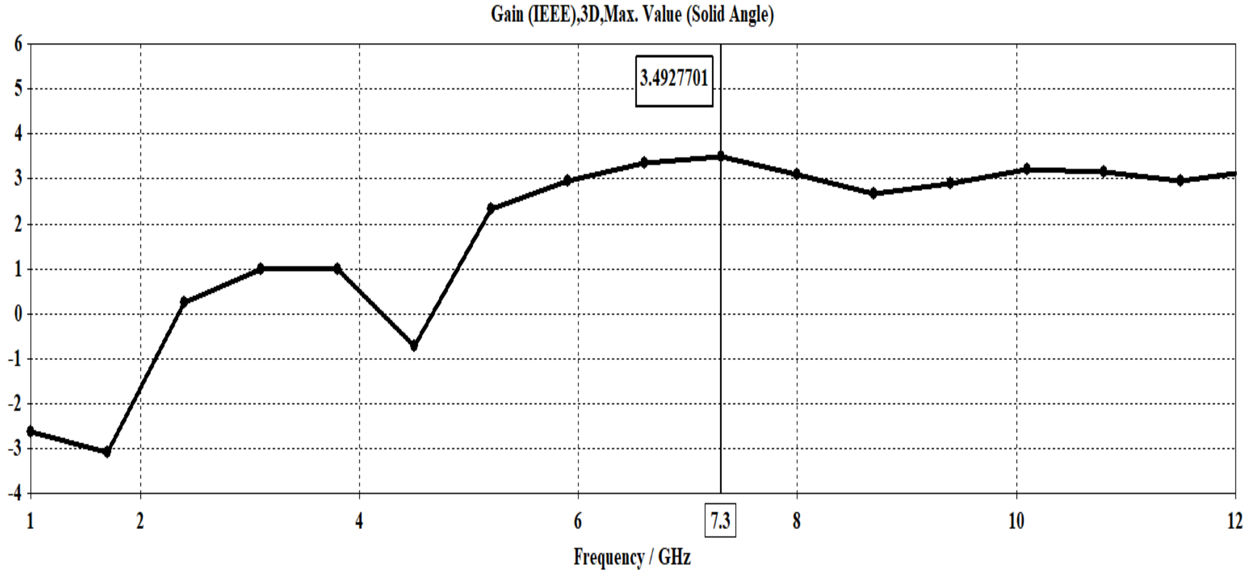

Fig.3 Gain vs Frequency plot

3. Breast model design

A breast model in conical form will be designed and the above designed antenna will be placed on both sides of the breast to detect the presence of tumor. The model is designed in a conical form as shown in Fig. 4. The outer layer is skin, then fat layer, then breast tissue layer. The tumor is taken as a sphere which is placed inside the breast at different positions. The relative permittivity and conductivity of different layers are as shown in Table 2.

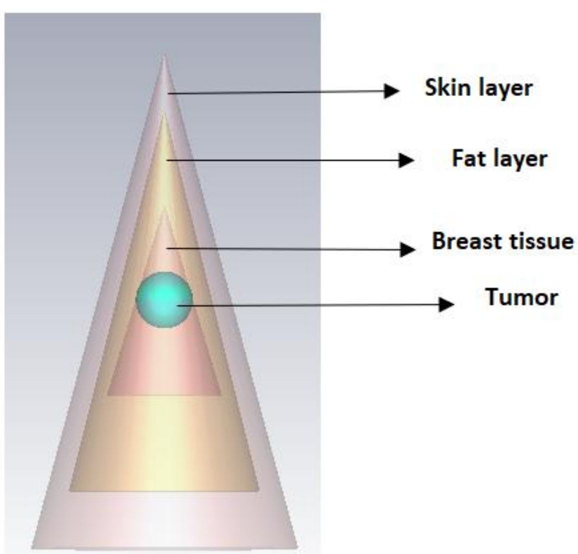

Fig.4. Breast model

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Table 2. Permittivity and Conductivity of different layers

	Permittivity(ε_r)	Conductivity(S/m)
Skin	38	1.46
Fat	5.28	0.1
Breast tissue	4.49	0.59
tumor	50	4

4. Breast tumor detection

The designed UWB antennas are placed on both sides of the breast as shown in Fig. 5.The signal is transmitted from one antenna inside the breast and the scattered signal is received at the receiver.

First of all the peak electric field, magnetic field and current density without tumor inside the breast and then with tumor for different radius and with different positions of tumor from the breast tip is simulated as in Table 3.

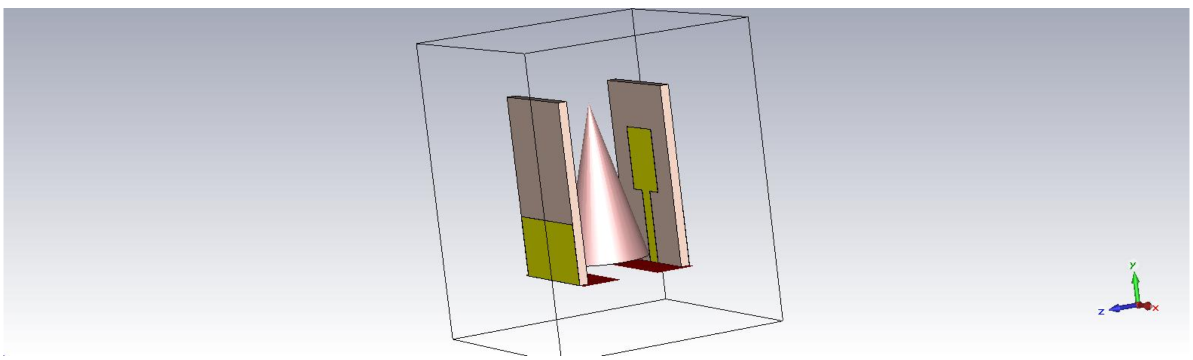

Fig.5. Placement of two antennas on both side of breast

Table 3. Simulated results for electrical parameters

Without Tumor			Radius of Tumor	Distance of Tumor from tip					
				10.75 mm			13 mm		
E field (V/m)	**H field (A/m)**	**Current density (A/m2)**		**E field (V/m)**	**H field (A/m)**	**Current density (A/m2)**	**E field (V/m)**	**H field (A/m)**	**Current density (A/m2)**
16577	70.1	1661	1.5 mm	16530	71.3	1828	16610	71.4	1857
			2 mm	16496	71.6	1916	16617	71.8	2006
			2.5 mm	16490	72.2	2069	16673	72.7	1935

The results can be observed without tumor and compared to with tumor results. It can be seen that there is a decrease in E field in the presence of tumor when it is at a distance of 10.75 mm from the top but if the tumor position becomes more deep the E field value increases, in the same way there is an increase in H field and current density in the presence of tumor. The difference in values are more when the tumor is more deep inside the breast and can be detected easily, also when the size of tumor is more the difference between values is more, so a larger tumor can be detected easily as compared to a smaller tumor. The simulated results for E field, H field and current density for without tumor are as shown in Fig. 6

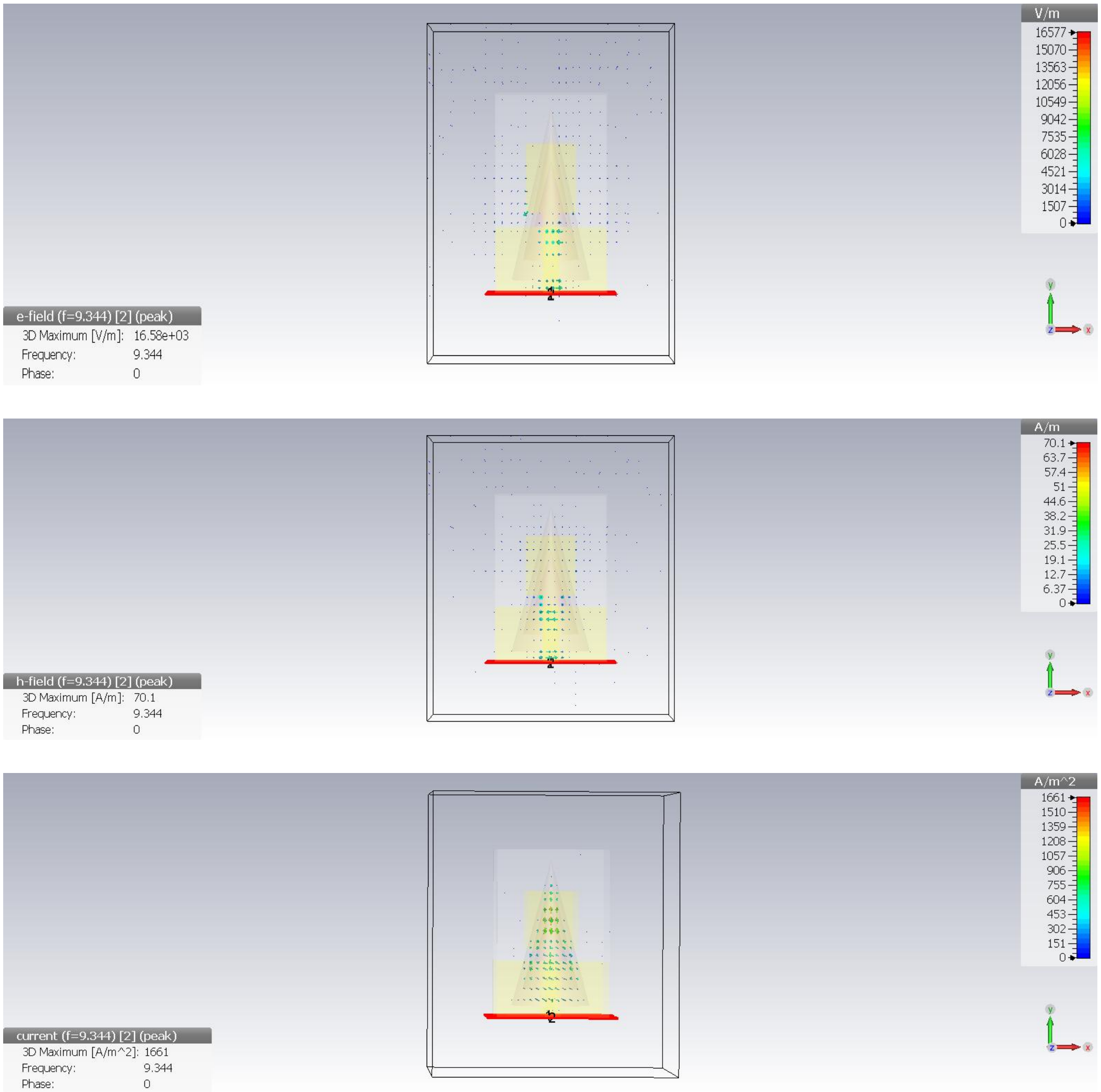

Fig.6. E field, H field and current density for without tumor

The results for E field, H field and current density when radius of tumor is 2 mm and distance of tumor from tip is 13 mm is as shown in Fig.7.

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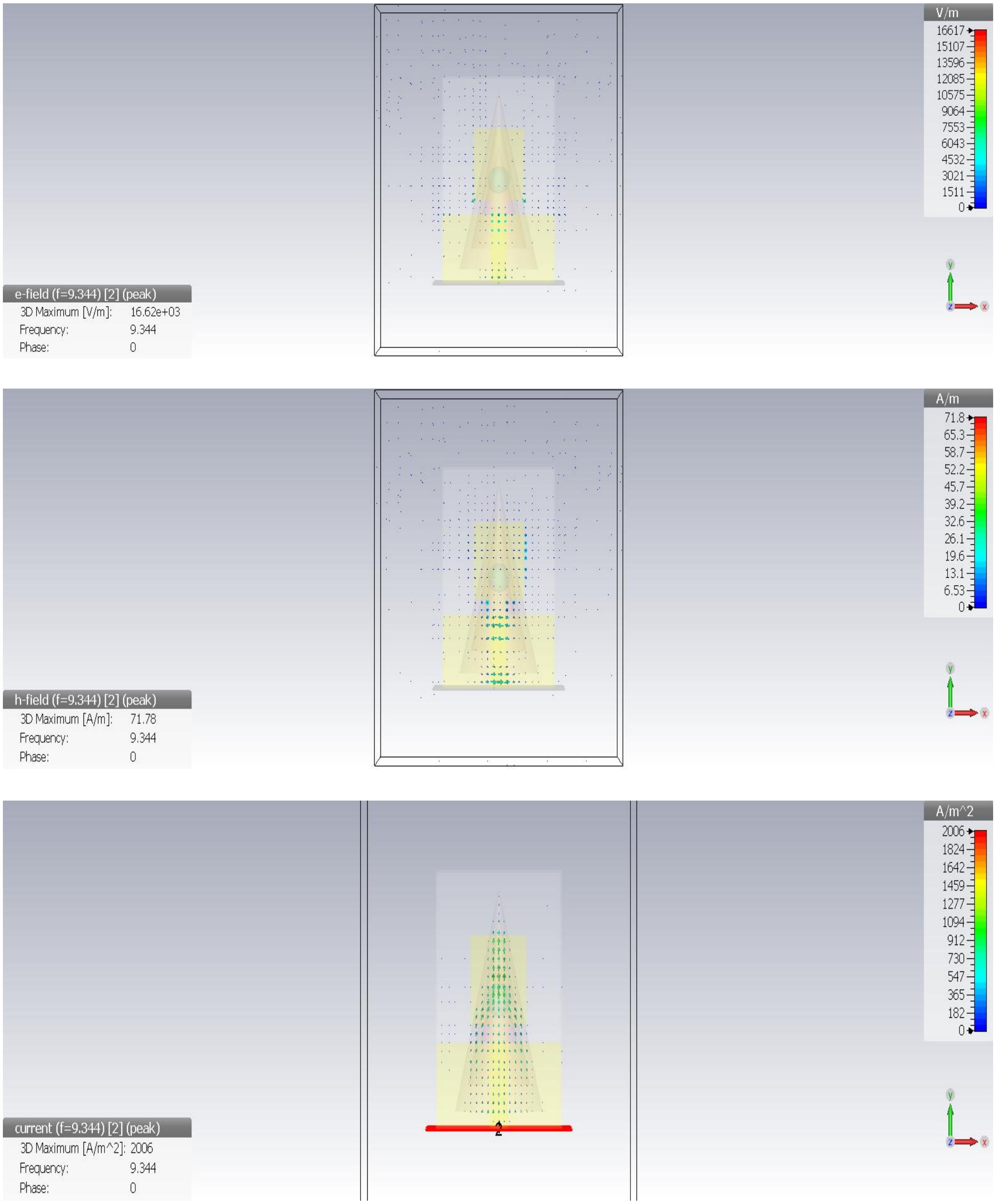

Fig.7. E field, H field and current density for with tumor

Next the SAR results are simulated which is the specific absorption rate, this is an important parameter as it tells the radiations absorbed by the body from antenna which should be minimum. The simulated results for SAR are as shown in Table 4.

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Table 4. SAR results

		Distance of Tumour from tip	
		10.75 mm	13 mm
Radius of Tumor (mm)	**Frequency (GHz)**	**SAR (W/Kg)**	
1.5	4.41	3.35	3.33
	9.344	1.27	1.32
2	4.41	3.35	3.43
	9.344	1.15	1.29
2.5	4.41	3.49	3.27
	9.344	1.06	1.19

The variation of SAR is done for two different frequencies in the UWB range and with varying size and position of the tumor. It can be seen that SAR values are more for the frequency of 4.41 GHz. The values are minimum when the size of tumor is more, thus a larger tumor can be detected without much radiation absorption by the body. The simulated results of SAR are shown when radius of tumor is 2.5 mm and distance from tip is 13 mm as in Fig.8.

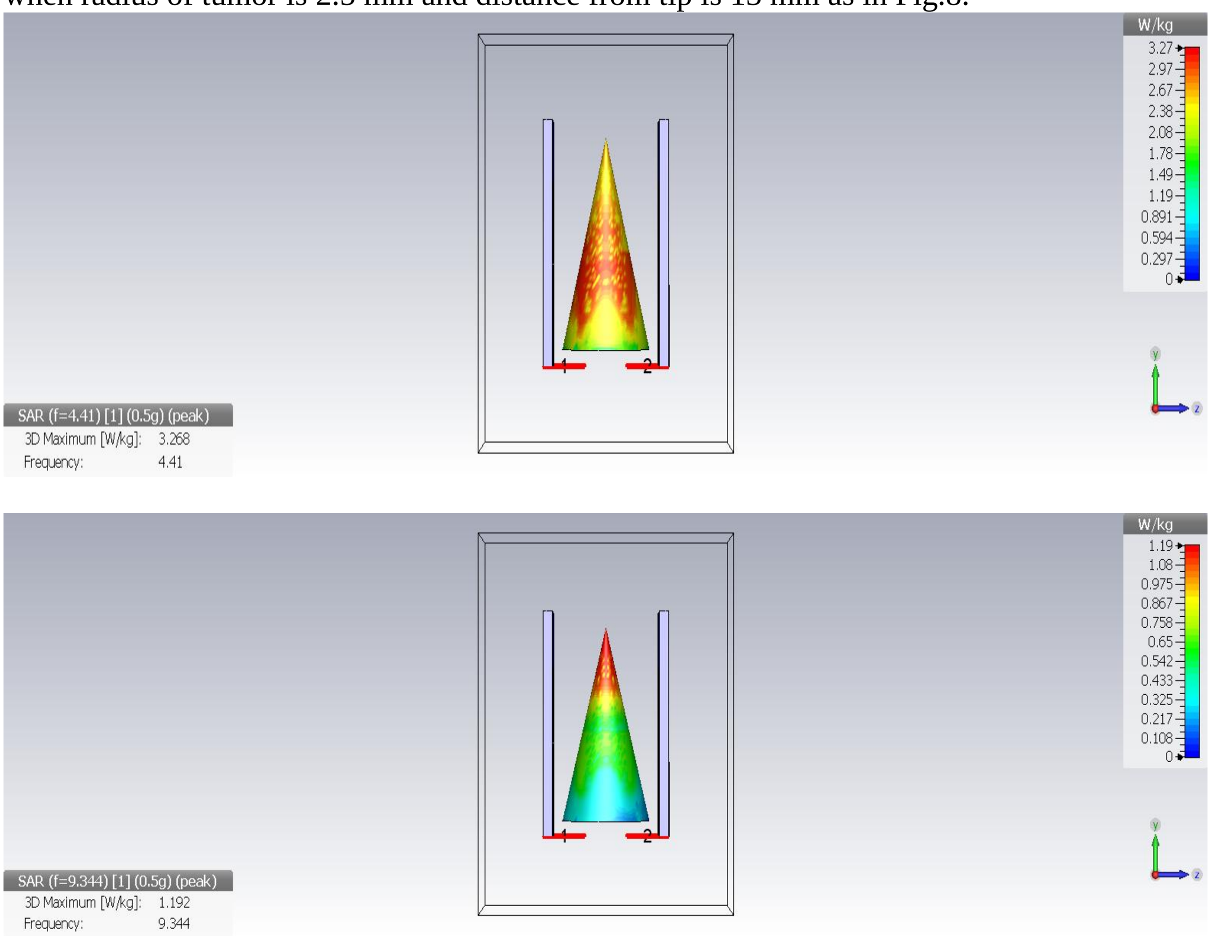

Fig.8. Simulated SAR results

Comparison of proposed antenna with other antennas in literature for this application is done in Table 5. It can be observed that the proposed antenna is compact and results are more accurate in UWB range 3.1-10.6 GHz.

Table.5. Comparison results

	Dimension (mm)	**Frequency range (GHz)**	**Gain (dB)**
[11]	35 X 20 X 1.6	3-12	5.2
[12]	70 X 35 X 1	2.3-12.2	4.25
[13]	70 X 60 X 1.6	1.6 -11.2	6.17
Proposed antenna	30 X 20 X 1.6	3.3-10.6	3.48

5. Conclusion

A breast model has been designed and an approach to detect the presence of tumor is carried out, the antennas can be inserted in a phantom which can be worn such that the two antennas are placed on both sides of breast. The electrical parameters vary due to the presence of tumor which depends on both size and position of the tumor. The difference in electrical parameter values with and without tumor illustrates that a large tumor can be easily detected compared to a smaller tumor and also when the position of tumor is at the direction of maximum radiation of the antenna.

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