Design and Development of Slotted Microstrip Patch Antenna for Breast Cancer Detection and Wireless Applications

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Abstract— In this paper, a novel monopole antenna is designed. The design consists of a microstrip patch which is fed by a microstrip feed line this patch is having a square slot and T-Slot the four sides are having corner cuts and the proposed antenna is showing good directivity. The dimensions of the proposed antenna are 29mm×30mm×1.9mm.The proposed antenna exhibits good impedance matching, high gain, and omnidirectional radiation patterns. The measurement results are presented to illustrate the performance of the proposed antenna. This antenna has been implemented in a designed system model with dielectric properties of a human breast capable to detect strange objects The results show that the localization of the tumor can be detected with high precision which remonstrance of the proposed antenna and the entire system. The proposed breast model system was developed using the commercial CST Microwave studio simulator

I. INTRODUCTION

Breast cancer is the most common non-skin-related malignancy and the second leading cause of cancer death among women in the world [1]. In 2014, an estimated 232,670 new cases of invasive breast cancer were expected to be diagnosed in women in the U.S., along with 62,570 new cases of non-invasive breast cancer as reported by the American Cancer Society, although some risk reduction might be achieved if they are detected in time. The current standard screening methods for detecting early-stage breast cancer are X-ray mammography, ultrasound techniques, and magnetic resonance imaging (MRI). X-ray mammography is proved to be the most widely used and effective modality for early breast cancer detection. It is clinically employed as a regular screening method. Despite its successful detection results compared to other screening tools, X-ray mammography also has its drawbacks: its failure to distinguish between benign and malignant tumors, high false-alarm rate, discomfort to patients, and difficulty to detect cancer in its initial formation state[2,3].

All these limitations provide motivation and encouragement for the development of a complementary breast-imaging tool as an appealing alternative to the previous techniques. One of the various alternatives proposed is microwave imaging, in particular, the ultra-wideband (UWB) frequency region. The principle that microwave imaging relies upon is the dielectric contrast between normal and cancerous human tissues[4]. The majority of the compact UWB antennas presented in the literature exhibit a large size with relatively low gain [5,6] which is suitable for specific communications. In this paper, we present a new design of compact UWB antenna for breast tumor detection system. The rectangular UWB antenna for breast imaging developed in this paper with a high gain, compact size, and relatively omnidirectional radiation patterns suitable for being placed directly on the target[5]. The antenna parameters such as return loss, gain, radiation pattern, and current distribution are discussed in detail.

The antenna is characterized by an ultra-wideband of 120% (3–12 GHz) and exhibits good gain and an omnidirectional pattern. The proptotype of the antenna for high frequencies can be found in the previous work[7] . It can be seen that the antenna is a good candidate for microwave imaging. As a second step, we design a tumor detection system with a breast model along with the proposed antenna. In fact, despite research that shows the ability of microwave detection technology, there is a lack of realistic breast models for testing. Then, our breast model includes heterogeneities that are similar to a real breast and represents all the important dielectric structure described in the literature.

The breast model with a skin layer of 2 mm and fat layer into the breast to get closer to reality are respectively considered. Detection capabilities provided by the whole system are also presented. The results show that the proposed detection system can achieve high accuracy with excellent performance

- Antenna Design Methodology:

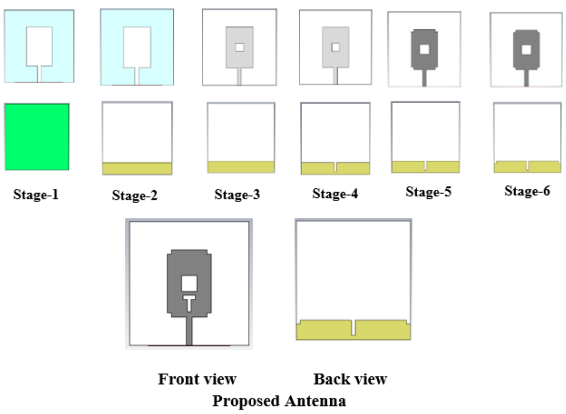


Fig-1: Stage wise development of antenna

The antenna is designed by using CST microwave studio. In the first step, a rectangular patch is taken and a microstrip is attached to it and the ground is also placed. These are stuck to material FR4. Then the ground is truncated for the antenna. In the next step, a square slot is made at the center of the rectangular patch, then a rectangular slit is made at the center of the truncated ground. In the next step of designing the proposed antenna, four corner cuts are made to the rectangular patch as shown in the figure. Then two corner cuts are made to the ground as shown in the figure. Finally, a T-slot is made in the rectangular patch of the antenna. The designing of the proposed antenna involves a total of 7 steps.

- Fabricated Antenna Front view and back view:

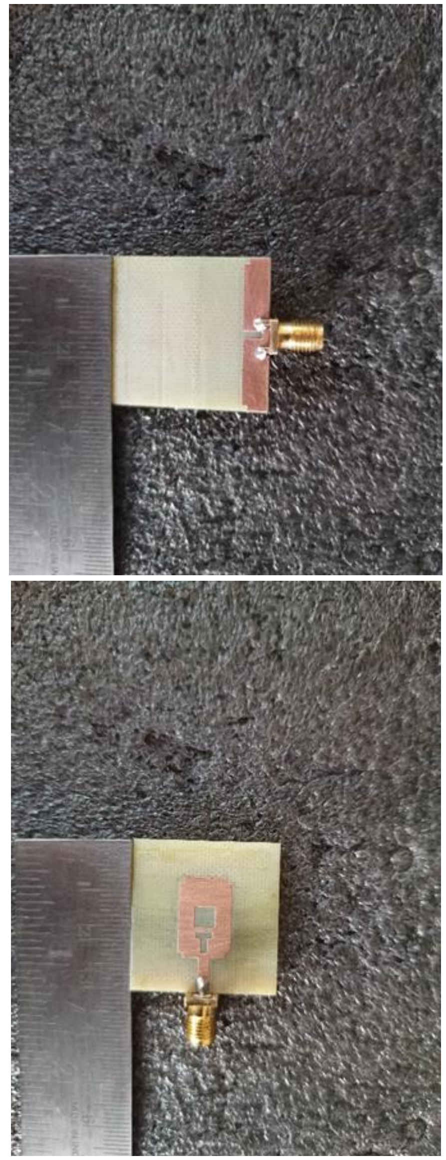


Fig-2: Fabricated prototype of proposed antenna

- Final dimensions of all Parameters:

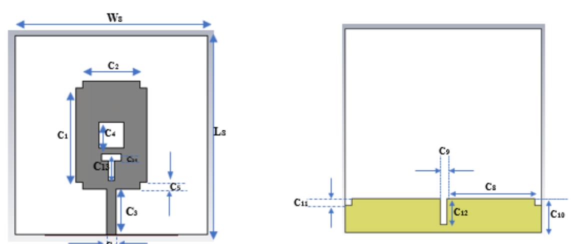


Fig-3: Front view and back view of the proposed antenna with dimension identifications

The below-mentioned Table-1 will give the complete dimensions of the front view and back view of the proposed antenna.

Table-1: All dimensions of proposed antenna

Symbol	Dimension(mm)	Symbol	Dimension(mm)
Ls	30	C6	2.5
Ws	29	C8	13
Ts	1.6	C9	1
C1	14.2	C10	5
C2	8.7	C11	1
C3	6.9	C12	3.8
C4	3.8	C13	4
C5	1	C14	3

II. RESULTS AND DISCUSSIONS

In this segment, insights concerning the simulation and measurement results of the designed antenna will be explored. The proposed monopole UWB antenna is simulated on CST. An antenna is fabricated using a photolithographic etching process and measured for its S11, radiation pattern, and gain.

- Simulated and Measured S11 Parameters:

The reflection coefficient is an essential criterion to characterize the antenna bandwidth for Ultrawideband (UWB) microwave imaging and it must be lower than -10 dB in the entire frequency band.

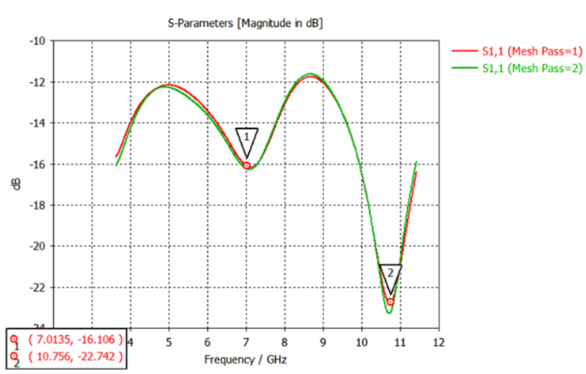


Fig-4 Simulated S11 parameters of the proposed antenna

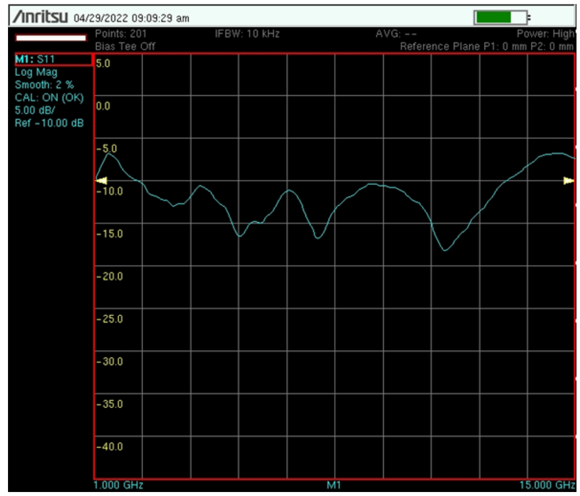


Fig-5: Measured S11 parameters of proposed antenna

A slight deviation in operating frequency bands is seen, which may be caused due to the antenna's fabrication process, measuring cable of VNA, and soldering of the SMA connector However, the designed antenna bandwidth meets the necessity of breast cancer detection i.e., to provide a wide bandwidth as higher frequencies are needed for good resolution and lower frequencies for deeper penetration which is the major necessary objective.

- Simulated 3-D Gain:

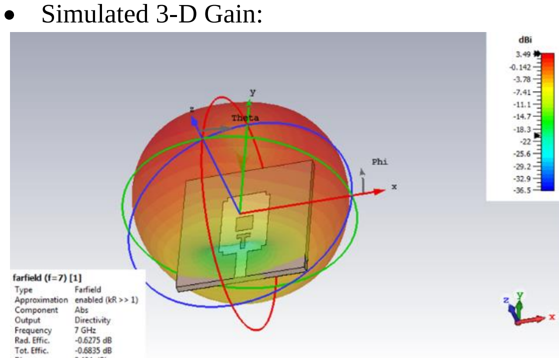


Fig-6: 3-D Radiation pattern at 7GHz

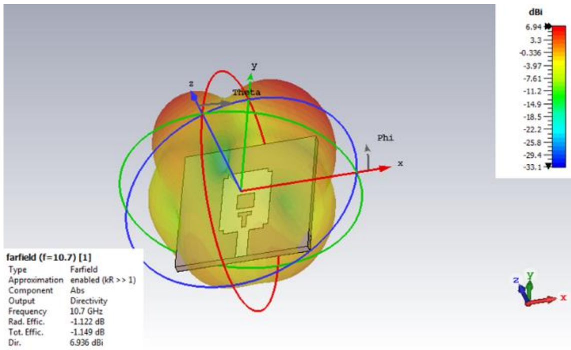


Fig-7: 3-D Radiation pattern at 10.7GHz

The simulated 3D polar gain plot of the proposed antenna at the resonance frequencies of 7 and 10.7 GHz is depicted below. It can be seen that the radiation pattern at 7GHz is directional with a total gain of 3.49dB. At the second resonance 10.7GHz, the pattern is directional and is having a total gain of 6.94GHz.

- Polar plots at 7 and 10.7 GHz:

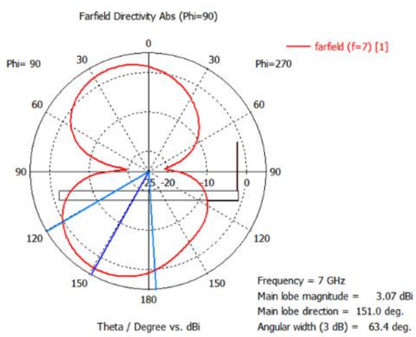


Fig-8: Polar plot at 7GHz

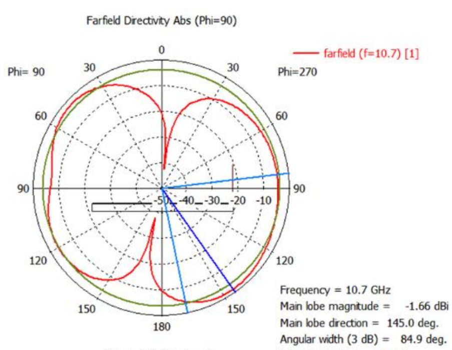


Fig-9: Polar plot at 10.7GHz

- Simulated gain:

The simulated gain of the monopole antenna is illustrated for the entire operating bandwidth, the antenna simulated gain ranges from 2.7dB to 7.15 dB. Gain increases linearly with the frequency which is nothing but higher gains are achieved at higher frequencies except at frequencies between 9.5 and 11 GHz. The maximum simulated peak gain of about 7.15 dB is seen at 11.42 GHz and a minimum peak gain of about 2.7 dB is noticed at 3.62 GHz.

- Frequency Vs Gain:

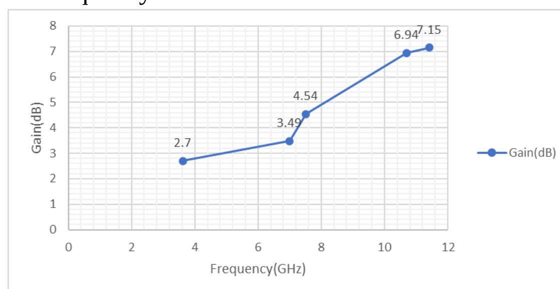


Fig-10: Frequency Vs Gain

Table-2: Gain at different Frequencies

Frequency (GHz)	Gain(dB)
3.62	2.7
7	3.49
7.52	4.54
10.7	6.94
11.42	7.15

- Surface Current distribution at 7 GHz and 10.7GHz:

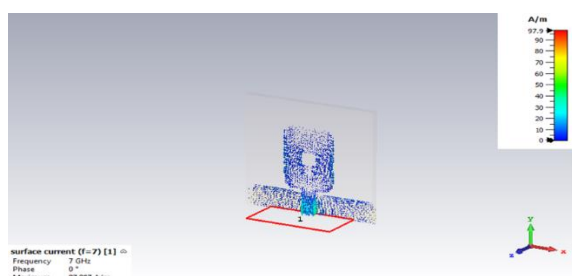


Fig-11: Surface current distribution at 7GHz

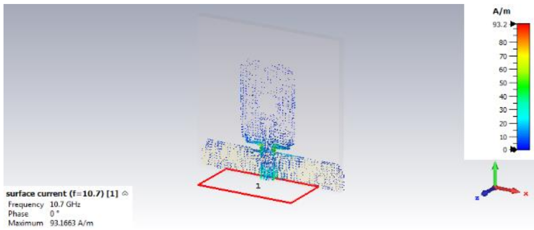
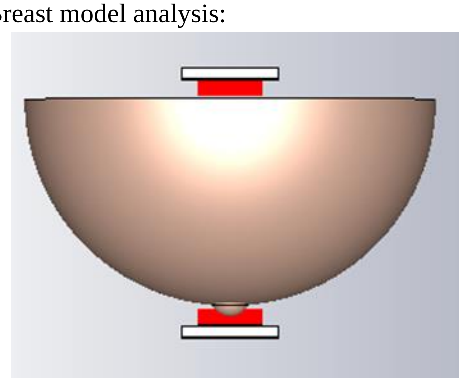


Fig-12: Surface current distribution at 10.7GHz

The surface current distribution of the proposed antenna observed at 7Ghz which is 97.9A/m in Fig-11 and also observed at 10.7 GHz which is 93.2 A/m in Fig-12 which is very good at resonant frequencies.

- Breast model analysis:



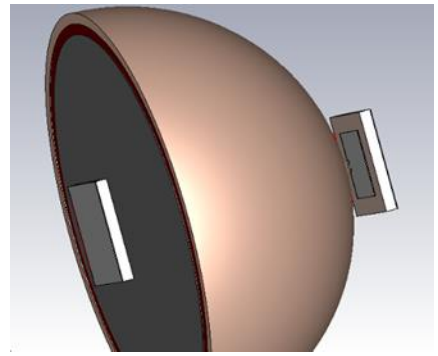


Fig-13: Arrangement of antennas around the breast model

The breast model is designed by using CST Microwave studio software and placed on either side of the breast and the tumor is placed inside with 15mm size and measured the scattering parameters of the proposed model in Fig-13.

- Electrical material property of breast tissue for Electromagnetic simulation:

Fig-14: Model breast developed in CST Microwave studio

Table-3: Properties of Breast Tissues

Tissue	Permittivity	Tangent loss
Skin	17.7	0.93
Fat	3.4	0.16
Fibro-glandular	16	0.94
Tumor	18	1.05

- S_{11} Parameters of the proposed Breast model:

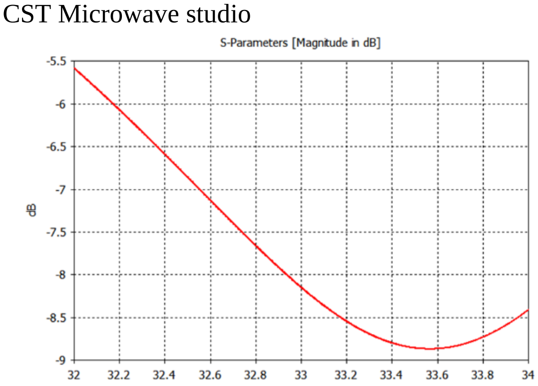


Fig-15: S_{21} Parameters of proposed Breast model

In Fig-15 the S-parameters of the proposed breast model is represented and it is shoeing good characteristics in the graph.

- Radiation pattern of Breast Model:

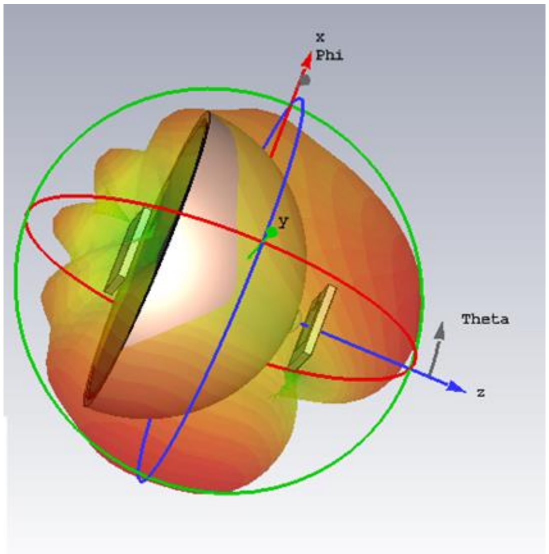


Fig-16: Radiation pattern of Breast model

The 3-D radiation pattern is observed for the proposed breast model is shown in Fig-16 and from that observed the directional characteristics of antenna on either side

- Polar plot of Breast Model:

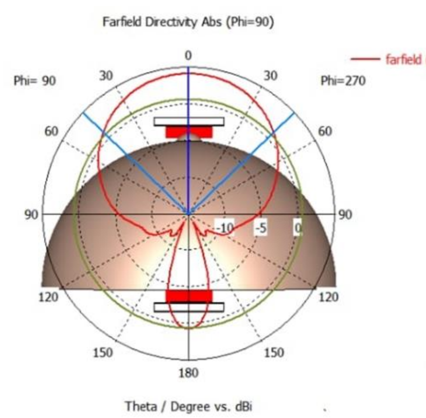


Fig-17: Polar plot of Breast Model

In fig-17 the polar plot is represented. In this it is showing clearly the orientation of the main lobe.

CONCLUSION

This paper presents a novel method for locating a tumor using a new breast model system based on a UWB antenna. The antenna performs reasonably well in terms of VSWR, gain, and radiation pattern. To test the efficiency of our system, a breast model with dielectric properties of a human breast is designed. Simulation of the rectangular patch antenna in our system demonstrates that the breast tumors can be detected by considering the difference between the power absorbed in normal tissue and malignant tissue.

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