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Directional versus Omni Directional Antennas for UWB Imaging

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Abstract:- Biomedical applications necessitate some restrictions on the type of devices to be used. When Ultra-Wide Band signals are used, the antenna is better to be directional and small in size. This paper presents a modified directional patch antenna design and fabrication which was used in real breast cancer detection experiments using breast phantom. It shows optimistic results.

Keywords:- Patch antenna, breast cancer detection, UWB imaging, Neural Network.

I. INTRODUCTION

Currently, Ultra Wideband (UWB) imaging is considered a promising method since the power level is below the noise floor, it is easy and safe to be built and used [1]-[4]. In this method, UWB signals are transmitted through the breast tissues from one side and the scattered signals are received from other sides. Usually, these scattered signals are very weak but they contain the tumor existence signature. For these requirements, it is preferable to use directional antennas for medical applications since it is desirable to focus the power toward the receiver [5]-[7]. Antennas with some degree of directionality show better performance for biomedical applications including tumorous cancer detection. Also, successful detection using only one pair of antennas rather than multiple antennas reduces the cost. Another important feature is the size of the antenna. It is clear that it is better to be as small as possible.

II. DETECTION ENHANCEMENT USING DIRECTIONAL ANTENNA

Breast tumor detection experiments both in simulation and experimental were previously done [8]. For conducting the experimental work, we used the setup shown in Fig. 1. We used Time Domain product called PulsOn evaluation kit [9]. It works at a center frequency of 4.7 GHz with 3.2 GHz bandwidth. The transmitter and receiver use Omni directional antennas. They are also relatively large for such types of experiments.

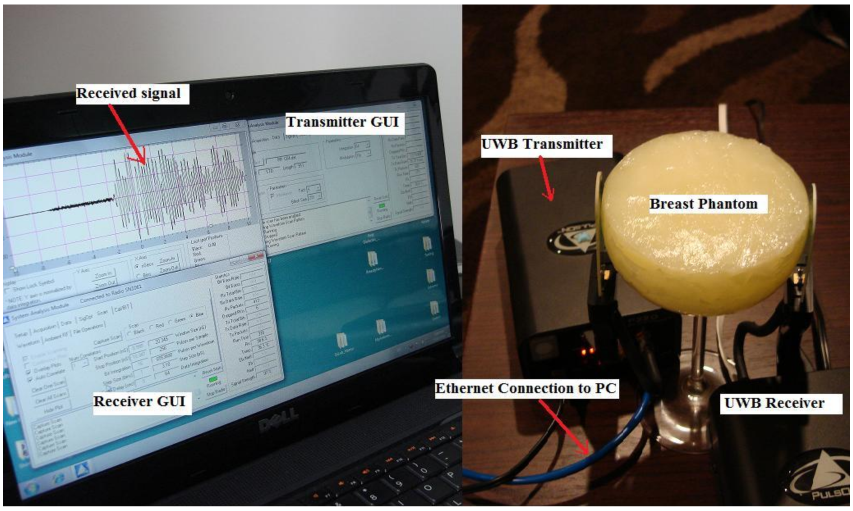

Fig. 1: Experiment setup as of [8].

In this research, we have decided to replace the Omni directional antenna with directional one. The goal of using this antenna is to discover the difference in performance between the Omni-directional and directional patch antennas in this kind of applications. It was not intended to show better design in terms of different antenna parameters. A smaller and modified version of the antenna presented in Reference [10] was designed and fabricated to be used in this experimental work. Fig. 2 and Fig. 3 show the designed and fabricated antenna. The performance of this antenna was obtained using CST software. Fig. 4 shows the return loss, which indicates its correct UWB behavior. The measured return loss is less than −10 dB in the frequency range of 3.5–5.5 GHz, which gives 2 GHz bandwidth. The antenna gain is shown in Fig. 5. The gains for frequencies less than 5 GHz were not calculated by CST since there is no resonance at those frequencies. Fig. 6 shows the 3D radiation pattern of the antenna at 5.5 GHz.

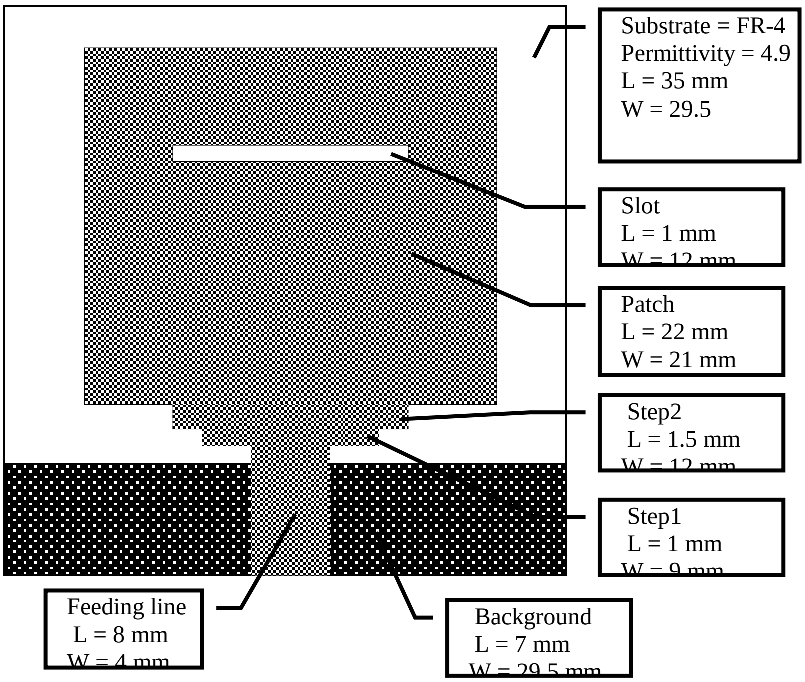

Fig. 2: Geometry of the antenna

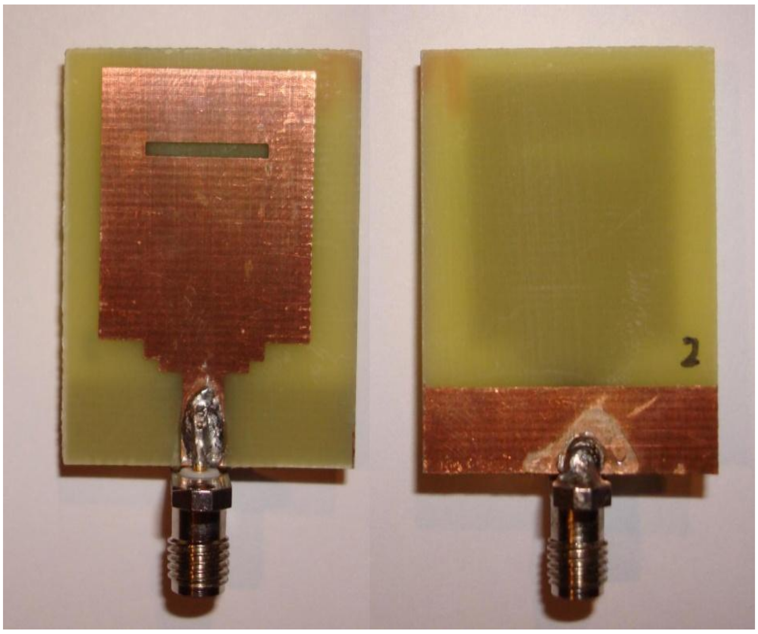

Fig. 2: Front and back photos of the antenna

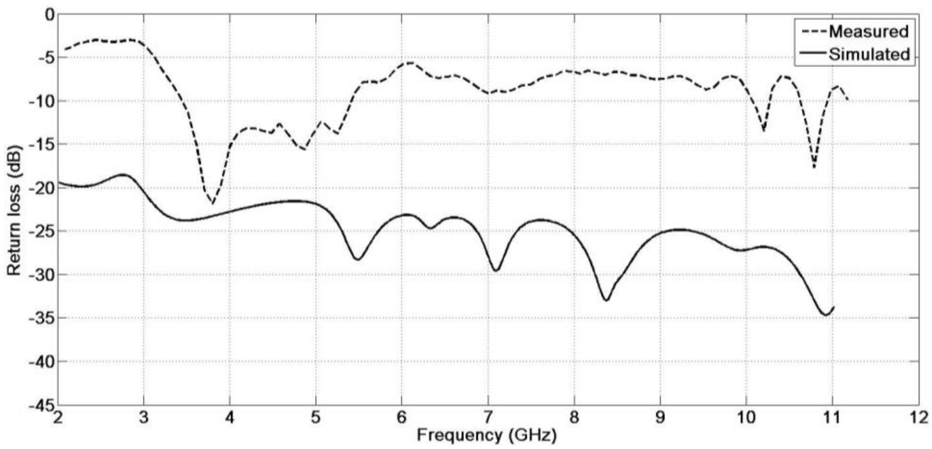

Fig. 3: Measured and simulated return loss of the antenna

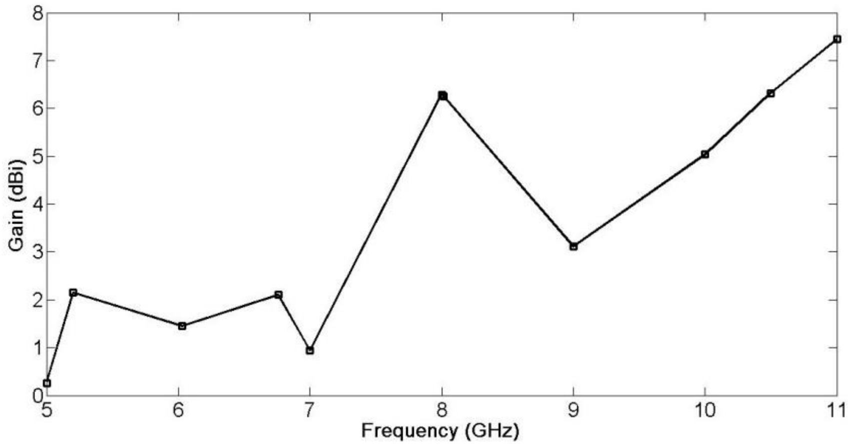

Fig. 4: The antenna gain in frequency range 5–11 GHz using CST

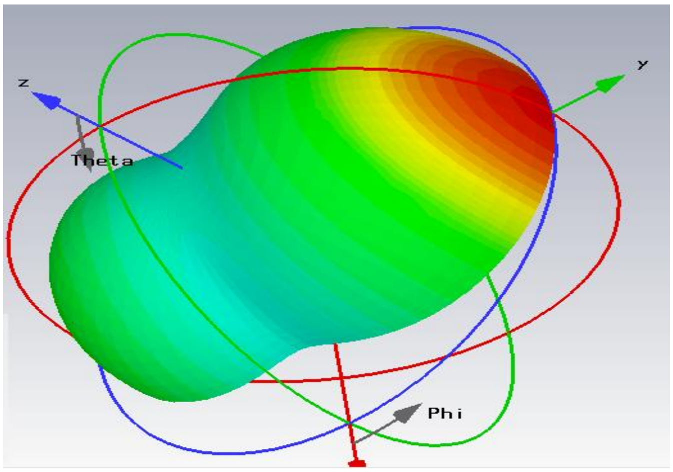

Fig. 5: Radiation pattern of the antenna at 5.5 GHz

Fig. 7 and Fig. 8 show the UWB signals received using both types of antennas. It can be noticed that the behavior of the antennas are generally similar.

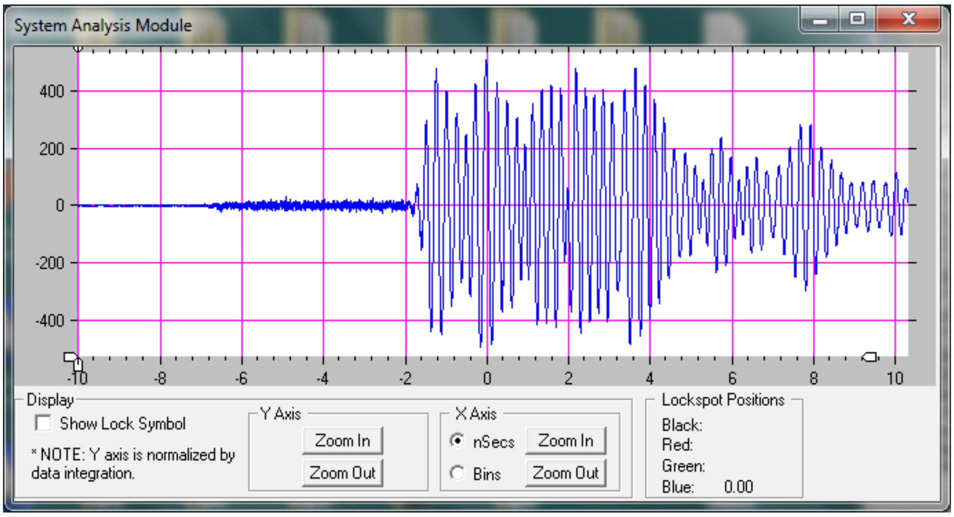

Fig. 6: Received signal waveform using our directional antenna

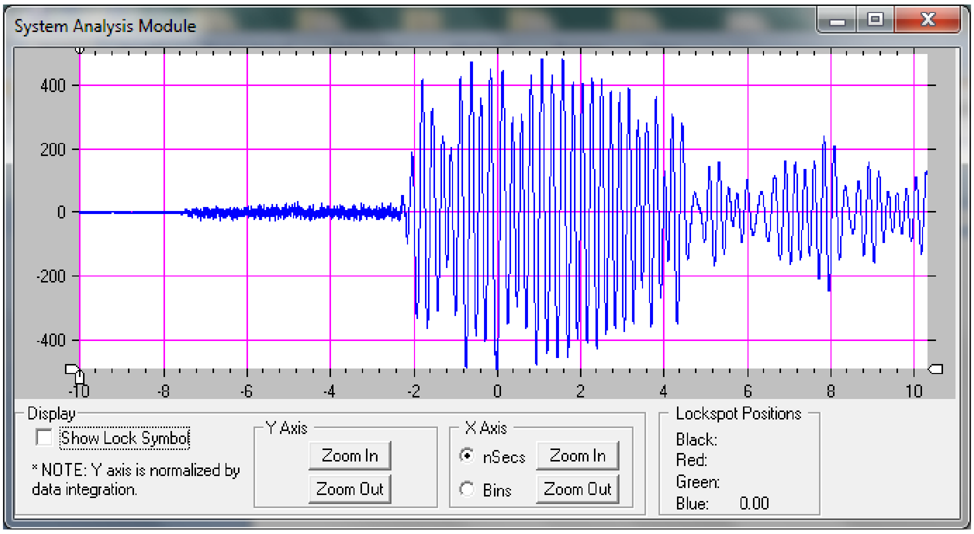

Fig. 7: Received signal waveform using PulsOn antenna

The same experiment setup and procedure for data collection when using PulseOn transceivers were repeated. The only difference is the replacement of the Omni direction antenna by our directional antenna. Fig. 9 and Fig. 10 show the antennas being used in the experiment. The experiment setup is as in Fig. 1 [8]. The steps are:

1) Place a transmitter-receiver pair at opposite sides of the breast phantom.
2) Place a tumor at any location l along the x-axis in the model.
3) Transmit first a UWB signal using PulsOn transceiver.
4) Receive the signal on the opposite side.
5) Change the tumor location and repeat steps 2–4 many times.
6) Calculate the Discrete Cosine Transform (DCT) of all signals.

The same steps were followed with the change of tumor size and fixing the location at the center of the breast phantom. Using MatLab software , neural network was used as the detection tool similar to the work done in [8]. It was trained with these DCT values. Table I shows the NN parameters.

Fig. 8: The directional antennas during experiment setup

Fig. 9: Transmitter antenna and tumor placed inside breast phantom

Table I: Neural Network Parameters

NN parameters used in MATLAB	NN parameters
Number of nodes in Input layer	251
Number of nodes in Hidden layer	3
Number of nodes in Output layer	1
Transfer function	tansig
Training function	traingdm
Learning rate	0.009
Momentum constant	0.6
Maximum number of Epochs	400000
Minimum performance gradient	1e-25

III. DETECTION RESULTS

Using the proposed directional patch antenna improved the tumor size detection. But it showed slightly less performance accuracy in tumor location detection. However, the tumor existence detection rate remains up to 100%. The average performance accuracies were 97.4% and 91.8% for tumor size and location detection respectively. Table II shows the performance differences between Omni directional and directional antennas.

Table II: Comparison Performance Results of Omni Directional and Directional Patch

Type of work	Detection type	
	Size	Location
Experiment using homogeneous breast phantom and Omni directional antenna	95.8 %	94.3%
Experiment using homogeneous breast phantom and directional antenna	97.4 %	91.8%

IV. CONCLUSIONS

The effect of using a directional patch antenna was presented. A modified patch antenna was designed and fabricated. It was used in breast cancer detection experiments. The results were close to the Omni-directional antenna. However, the compactness and simplicity of fabricated design of the directional were obvious in the case of the directional patch antenna.

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