Simulation Measurement for Detection of the Breast Tumors by Using Ultra-Wideband Radar-Based Microwave Technique

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Abstract - *It is known that early detection of the breast tumors increases the success rate in the treatment of cancer. Therefore, a number of diagnostic methods have been developed to detect tumors that are small in size and deep in location. As well as the positive aspects of each methods, there are also some negative aspects. For this reason, works for the development of new methods are ongoing. Using of the microwaves for detection of the breast cancer tumors has been a subject of intense research in recent years. Because, there are significant differences in the electrical properties of the malignant breast tumors and normal breast tissue in the microwave frequencies. By using these differences, anyone can have knowledge about the existence, dimension and position of the tumor. There are many methods that microwaves are used, and the most popular and successful method is the ultra-wideband radar-based method. In this method, the breast is illuminated with ultra-wideband microwave signals and the scattering parameters (S_{11}) of the reflected signals from the breast are recorded. The differences of the reflected signals for tumorous and non-tumorous cases indicate the presence of tumor. In this paper, a hemi-spherical breast phantom that consisted low relative permittivity and conductivity material to represent the healthy tissue and high relative permittivity and conductivity material to represent the malignant breast tumor is formed by using High Frequency Structural Simulator software (HFSS). An ultra-wideband and directional antenna that designed before is used for the simulation measurements. According to simulated results, S_{11} values increase when the tumor-mimicking object is present. Also, S_{11} increases as the antenna gets close to the object.*

Key Words: Breast cancer, Microwave techniques, HFSS, Ultra-wideband, Radar-based.

1. INTRODUCTION

The detection of the breast cancer at the early stages provides decreasing the rates of death from this disease [1]. It is known that the tumor tissue occurs when malignant cells multiply uncontrolled. Then, it may spread to other part of the body and prevent them from functioning. For this reason, detecting the malignant tumors when they are small in size and deep in location is very critical for the successful treatment. There are many breast tumors detecting techniques such as X-ray mammography, magnetic resonance imaging, ultrasound technique and digital tomosynthesis [2,3].

Although these methods are very important and effective, but they don't meet the ideal requirements which can be summarized as low health hazard, sensitivity to malignant tumor, determining the disease at a medicable stage, screening as fast as possible and involving minimal discomfort [4]. Hence, researchers work to develop new methods for breast cancer detection.

Because of the microwave signals are non-ionizing, and microwave detection system is non-destructive, safer and less expensive than existing methods, ultra-wideband (UWB) radar-based microwave technique that proposed by Hagness et al has been one of the emerging electromagnetic methods last decades [5]. This technique is based on determining the differences in electrical properties (relative permittivity and conductivity) of malignant tumors and healthy breast tissue [6].

In this method, the breast is illuminated with ultra-wideband microwave signals. The lower frequency band ensures enough penetration depth, and the higher band provides sufficient resolution for the created images. Thus, deeply buried and small size tumor can be detected based on the lower and higher frequency of the UWB bands [7].

UWB radar-based microwave technique is classified as monostatic, bistatic and multistatic systems according to the measurement configurations. The representative view of a monostatic measurement is shown in Figure 1 as an example. In this measurement type, the same antenna is used to send and receive the signals, and target is positioned for illumination.

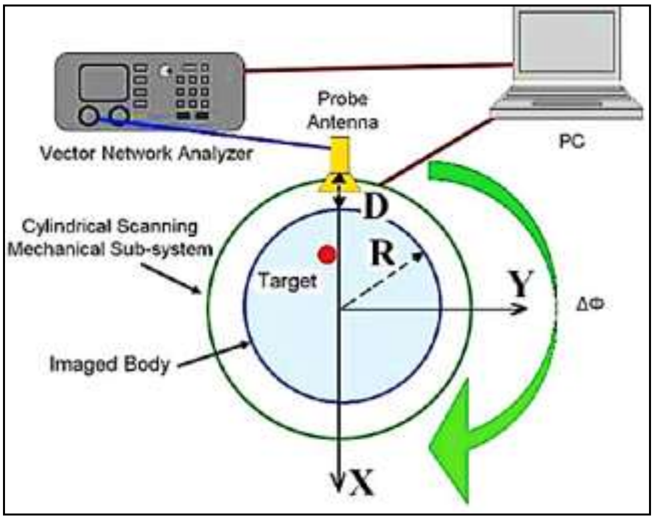

Fig -1: Example of a monostatic measurement [8]

2. SIMULATION MEASUREMENT

2.1 UWB Directional Antenna

In this study, the using of the monostatic measurement configuration is preferred and the system is developed by using High Frequency Structural Simulator (HFSS) software. HFSS is based on full-wave finite elements method and widely used in the analysis of electromagnetic structures is utilized [9]. The key component of the UWB radar-based microwave technique is the antenna that is used to radiate and receive the UWB pulses. This system requires compact, UWB, stable and high directive antennas as their radiating and receiving sensors [10].

In the measurement, a planar monopole antenna which was developed in [11] is used to perform the task of both sending and receiving the microwave signals. This antenna is a modified square planar monopole antenna having broad frequency range and high directivity properties, and it has been proposed for using in UWB radar-based microwave imaging. The design parameters and top view of the fabricated antenna are shown in Figure 2.

The return loss and radiation pattern results of the antenna are given in Figure 3 and 4, respectively. As it is shown from these figures, the size of the proposed antenna is 50x40 mm2. It has broad frequency range between 3 and 8 GHz, and in this frequency it has stable and directive radiation patterns.

2.2 Measurement Configuration

A simple hemi-spherical phantom structure with 6 cm radius is created to mimic the breast tissue, and a spherical structure with 5 mm radius is inserted in the phantom to mimic the tumor by using the HFSS program. The dielectric constants (εr) of the healthy breast tissue and tumor are 64 and 4.8, respectively, and the conductivity (σ) of the healthy breast tissue and tumor are 0.5 S/m and 11 S/m, respectively, for the constant 7 GHz frequency [12,13]. These values are taken as the reference in this study.

The view of the measurement system having antenna and simulated breast phantom with tumor is given in the Figure 5. It is seen from this figure that the phantom is placed so that the direction of the main radiation lobe of the antenna is as perpendicular as to the phantom.

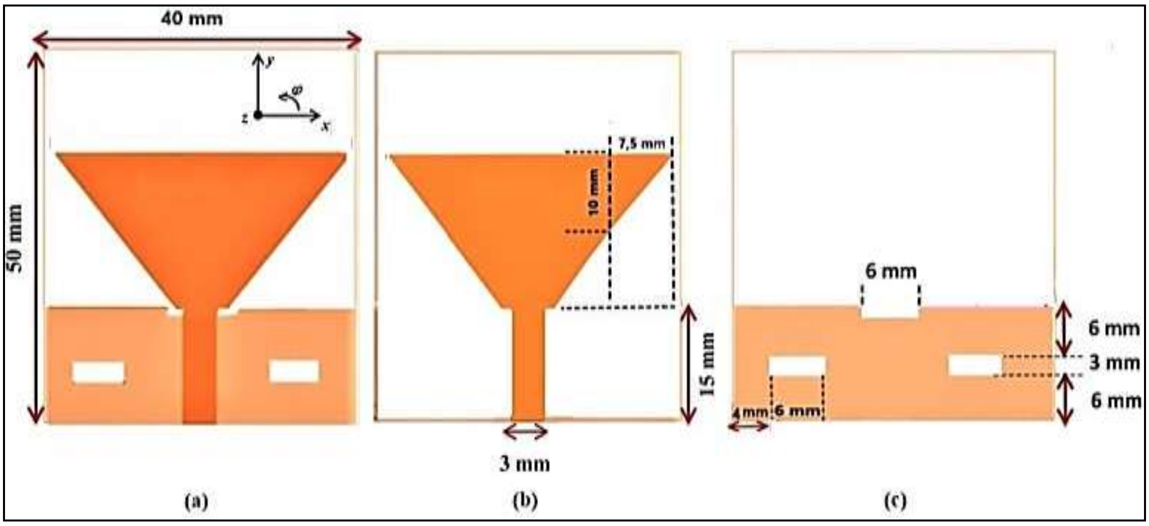

Fig -2: Design parameters of the used antenna [11]

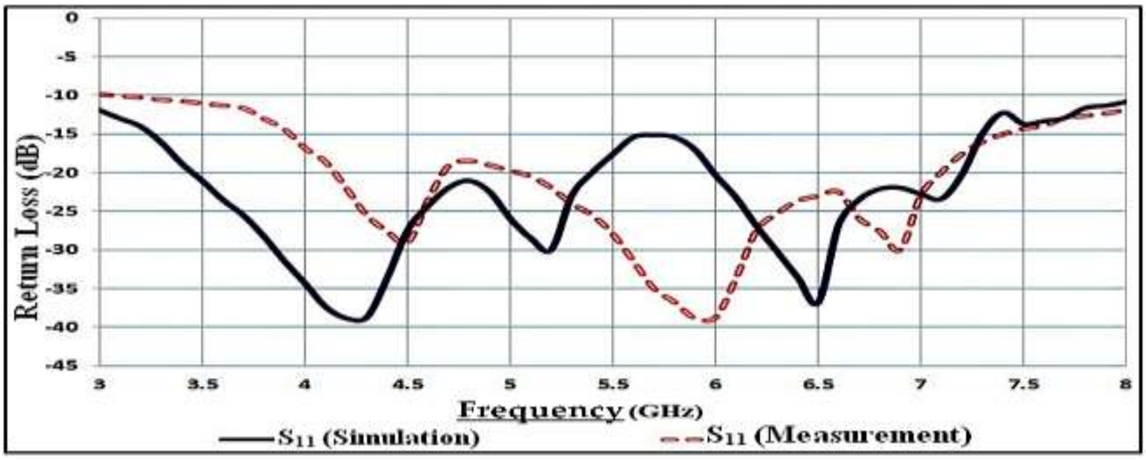

Fig -3: Return loss of the used antenna

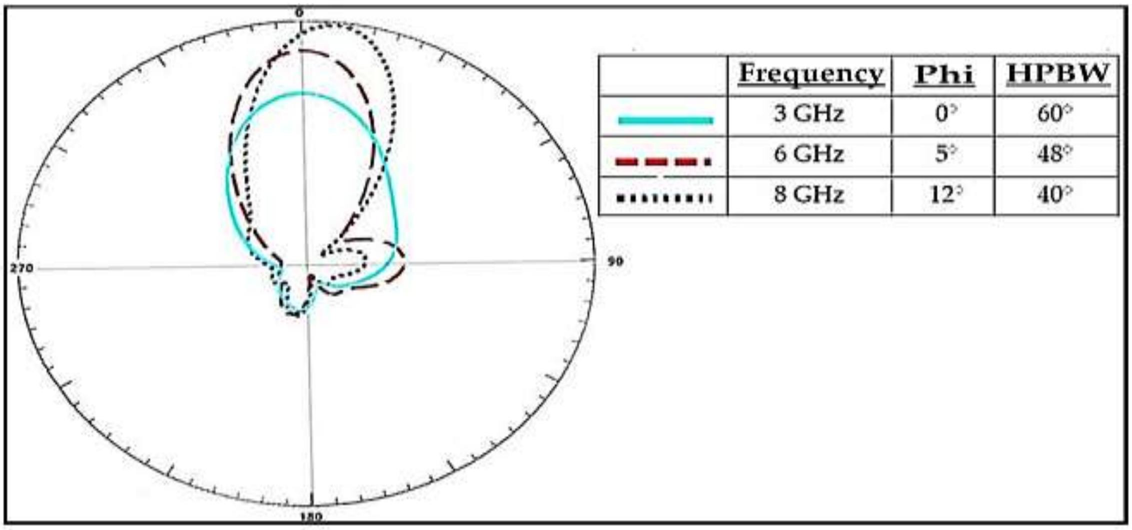

Fig -4: Radiation patterns of the used antenna

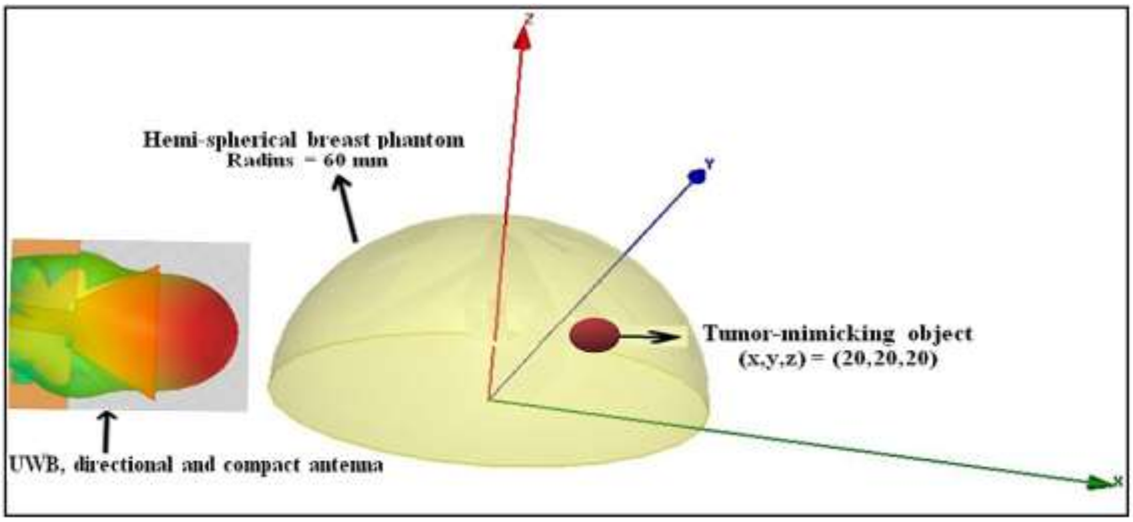

Fig -5: The view of the system when tumor is at the (x=20mm, y=20mm, z=20mm) points

3. RESULTS AND DISCUSSIONS

Since S11 and the reflection coefficient (Γ) are related to each other according to the Equation 1, the smaller the magnitude of S11, the larger the reflection becomes [14].

$$S_{11}(dB) = 20 \log_{10} \Gamma \qquad (1)$$

According to the simulated return loss (S11) results for tumorous and non-tumorous situations are given in Figure 6. It is clearly seen that the reflection is higher when there is tumor in the breast phantom. Furthermore, the antenna is rotated around the phantom in order to scan at a 360 degree angle.

In the Figure 6, also the S11 results are given for the situations where the antenna is the closest and farthest to the tumor. As expected, it is seen that reflection increases as the antenna approaches to the tumor.

4. CONCLUSIONS

This paper has demonstrated the performance of the ultra-wideband radar-based microwave technique for the detection of the breast tumor by using HFSS software. A simple simulation system including a hemi-spherical breast phantom which has the similar electrical properties with the breast fat and tumor has been designed to achieve purpose. An UWB planar monopole antenna which is compact and has directional radiation pattern has been used in the simulation measurements.

Based on the return loss results, it is concluded that the reflection increases when the antenna gets close to the tumor; it decreases when the antenna is away from the tumor. Therefore, it can be said that the UWB radar-based microwave technique for detecting the tumor tissue is a successful method, and the compact, UWB, directive antennas are good choices for using in this system.

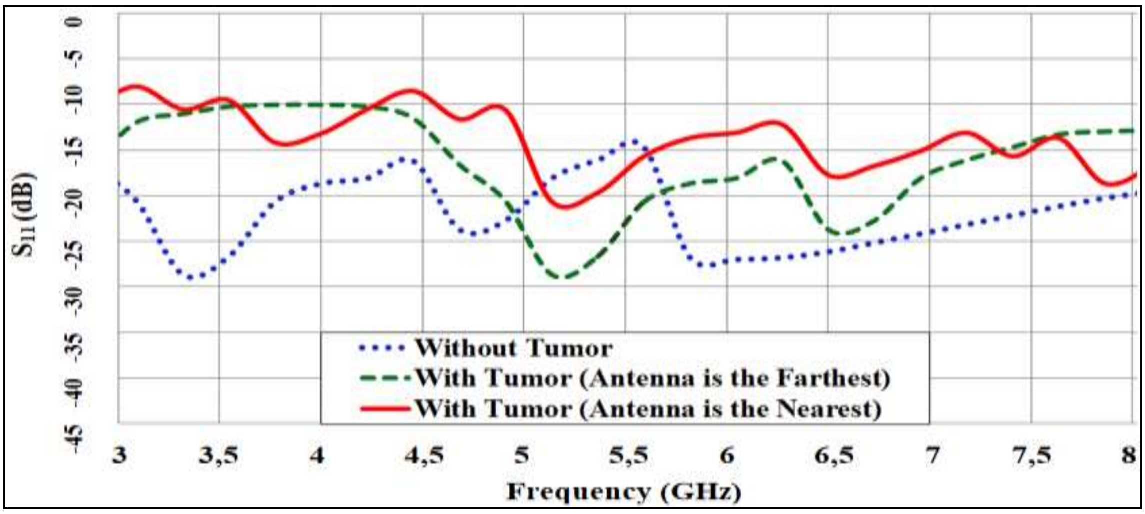

Fig -6: Return loss results of tumorous and non-tumorous situation

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BIOGRAPHY

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