A BOW-TIE ANTENNA DESIGN FOR BREAST CANCER DETECTION

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ABSTRACT: Breast cancer is the second in the causes of death ranks after cardiovascular diseases around the world. Early stage cancer detection is the most important in terms of reproducing of the malignant cells in an uncontrolled way and spreading to the other tissues. Microwave imaging is relatively easier compared to other types which are X-ray mammography, Magnetic resonance imaging (MRI) and ultrasound. They have some disadvantages. For example; X-ray mammography suffers from high missed-detection and false-detection rates. Also, it is ionizing and uncomfortable compression of the breast. Because of this, microwave imaging has the potential to overcome the some disadvantages of the X-ray mammography, MRI, and other existing known methods. In addition, Ultra-wide band (UWB) radar technique is a quite attractive technology for many applications, especially for early breast cancer detection. In this paper, both an UWB Bow-tie antenna with enhanced bandwidth and a 3D breast structure which has different permittivity and conductivity is modelled in CST software simulation tool to solve electromagnetic field values. Besides, The Federal Communications Commission (FCC) allowed frequency bandwidth of 3.1 to 10.6 GHz for this aim. Return loss, VSWR, and radiation pattern characteristics which are significant antenna parameters are simulated and obtained whether the antenna possess an efficient characteristic or not. Also, electric field values over the breast tissue with tumor and without tumor are evaluated.

Key words: Bow-tie antenna, breast cancer, microwave imaging, CST

INTRODUCTION

When uncontrolled growth (division beyond the normal limits) is occurred in a group of cells, this disease is called as cancer, invasion (intrusion on and destruction of adjacent tissues), and sometimes metastasis (spread to other locations in the body via lymph or blood) [1, 2]. Cancer cells which spread into different tissues cause various diseases; namely breast cancer, skin cancer, lung cancer, kidney cancer, prostate cancer, thyroid cancer etc. Breast cancer, which is a vital cause of death among women, is increasingly becoming a crucial interest around the world. Additionally, breast cancer usually occurs either in the cells of the lobules, or the ducts. However, every woman has her menstrual cycle due to the nature. In these cycles, breasts of women have different structures. At the same time, the structure of the breast tissue shows differences with age. For instance, breast tissue of young women has glands and milk ducts, but breast tissue of old women has mostly fatty tissue. There are also some external effects which causes breast cancer such as life-style, foods, contamination, stress, drugs, cigarette, alcohol and its derivatives etc. Therefore, early breast cancer detection is a big challenge task for the researchers and healthcare professionals in order to prevent the metastasis.

Hitherto; there have been a great many tools for early detections including mammogram, X-ray mammography, magnetic resonance imaging (MRI), ultrasound, electrical impedance tomography (EIT) etc.[3, 4] . X-ray mammography is one of the most widely-used detection technique [1, 5]. However the X-ray contrast between a tumor and the surrounding tissue is of the order of a few percent and as a result it suffers from relatively high missed-detection and false-detection rates. X-rays are also ionizing and not generally used to frequent screening. At the same time, X-ray mammography is uncomfortable compression of the breast. EIT which is one of the detection techniques has interested as a low-cost, non-invasive imaging tool for human body[6]. It is known that cancerous tissue has a much higher conductivity and permittivity than normal tissue. So, EIT may also be useful in the detection of breast cancer. These electrical properties (conductivity and permittivity) are changed very early in the cancerous cycle. Because of this, EIT may be used to detect cancer or tumor. However EIT would be acceptable on younger women. Conversely, these methods are not sufficient because of limitations. Recently, a novel method is Active Microwave Imaging (AMI) including Microwave Tomography and Ultra-Wideband (UWB) Radar based approach due to low cost and non-ionizing feature [1, 7, 8] . UWB radar based approach systems have attractive research area. Antenna structure is a key component in UWB applications. UWB antenna is also applied to define tumor in UWB Radar based approaches.

The key problem with the antenna design procedure is that the proposed antenna bandwidth should comply with the UWB requirements [9]. As a drawback from the previous chapter (Half wave dipole), bandwidth of half wavelength dipole is narrow. Thus, quite a few design techniques might be used to increase the bandwidth. One of the techniques for the half wavelength dipole antenna is to modify the structure of the dipole. A considerable amount of antenna shape has been designed and investigated in the literature [10-14]. The different antenna configurations, especially dipole configurations, are taken into account for the UWB requirements i.e circular, square, triangular, other shapes which have two metal sheets such as bow tie. Modified dipole configurations are generally preferred to get the broadband characteristic. The main point is that the antenna features should be light weight, low cost, ease of fabrication during the modification process. As mentioned before, the bow tie antenna is definitely one of the dipole configurations. Bow tie antenna has wider bandwidth than half wave dipole despite the simplicity structure.

In this paper, bow-tie antenna is designed for the purpose of microwave imaging over detecting cancerous tissue into breast structure and also, a simple 3D breast structure is modelled to define cancerous tissue. Different simulations such as breast tissue with tumor and without tumor are implemented in CST Microwave Studio. Obtained simulation graphics are evaluated according to electric field values.

BREAST STRUCTURE

By using the CST Software, data for the UWB microwave imaging techniques are obtained from numerical breast phantoms [2, 3]. There have been several breast phantom models in the literature, including cylindrical, hemispherical, and MRI-derived models. In this paper, a hemispherical breast is modelled as shown in Figure 1. Diameters and thicknesses of breast model are shown in Table 1. Also, the tumor radius size ranges from 0.2 cm to about 1.5 cm. Tumor is modelled as a spherical structure and is placed in the breast tissue (fibro glandular tissue). Structures such as skin, fatty breast tissue, tumor have different dielectric properties (permittivity, conductivity) have different electromagnetic field values. Differences of dielectric properties provide opportunity for detecting of tumor. The dielectric properties are given in Table 2 [15].

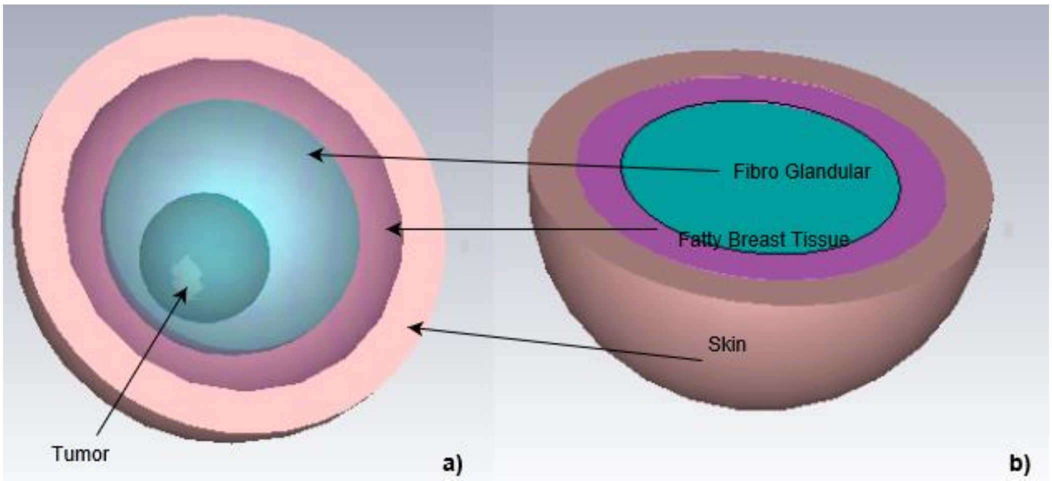

Figure 1. 3D Breast Structure, a) top view b) side view

Table 1. Dimensions of parts of the breast

Model Part	Diameter	Thickness
Skin	10mm	2mm
Fatty Breast	8mm	2mm
Fibro Glandular	6mm	2mm

Table 2. Debye parameters at 6 GHz UWB Centre Frequency [15]

Tissue	ε_∞	ε_s	σ_s	τ(ps)
Skin	4.00	37.00	1.10	7.37
Fatty breast tissue	6.57	16.29	0.23	7.00
Fibro glandular	5.28	35.14	0.46	7.0
Tumor	3.99	54.00	0.70	7.23

ANTENNA STRUCTURE

Arrangement and dimensions of the bow tie antenna is depicted in Figure 2.The proposed antenna is printed on substrate with dielectric constant of 2. The thickness of the substrate is 0.5 mm. The all length of proposed antenna must be slightly equal to λ/2 for perfectly radiation efficiency .The antenna is composed of two dielectric metal sheets that have 55 mm length per sheet. The bowtie antenna is represented by two metal sheets which have lengths l_e (55 mm) and separated by feeding gap (0.66 mm).Flare angle (α) is 60^o which is determined the distance between two metal sheets. Any changes in antenna size affect the performance of antenna parameters. Therefore, any antenna size should be fixed by varying another antenna size in order to obtain bandwidth enhancement. The design parameters such as arm length, substrate width, feed gap, permittivity and flare angle are optimized to obtain the better bandwidth and gain characteristics by antenna designers as in [13]. Substituting the value of the lower frequency and the upper frequency into Equation (1), the center frequency is computed. The bowtie antenna presented this section has been designed using dimensions in Figure 2. CST Microwave Studio is used to simulate this bow tie model with bow-tie antenna and breast structure as shown in Figure 3.

$$f_{center} = \frac{f_{upper} + f_{lower}}{2} \quad (1)$$

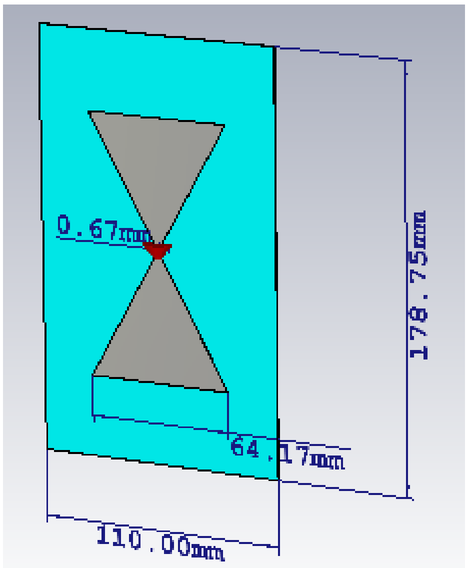

Figure 2. Proposed Antenna Structure (Bow-Tie Antenna)

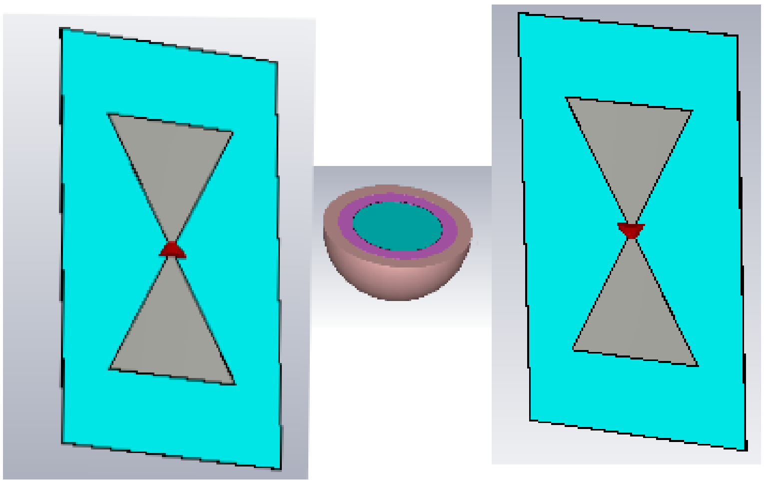

Figure 3. Design with proposed antenna and breast structure

SIMULATION RESULTS

Analysis of proposed antennas are carried out and presented. Parameters which are analyzed are return loss, radiation pattern and VSWR. The proposed antenna's -10 dB bandwidth which spans in 3.1-10.6 GHz is achieved as given in Figure 4. These frequency range meets the requirements for UWB imaging systems which is especially used for early breast cancer detection. Additionally, VSWR of the proposed antenna illustrates in Figure 5. VSWR has also desired characteristic in the frequency of interest.

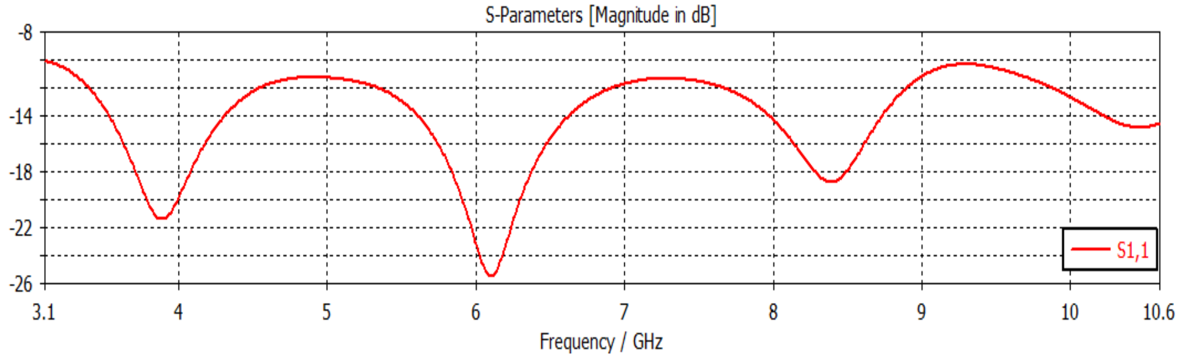

Figure 4. Graphic of S-parameter (S_{11}) of designed Bow-tie antenna

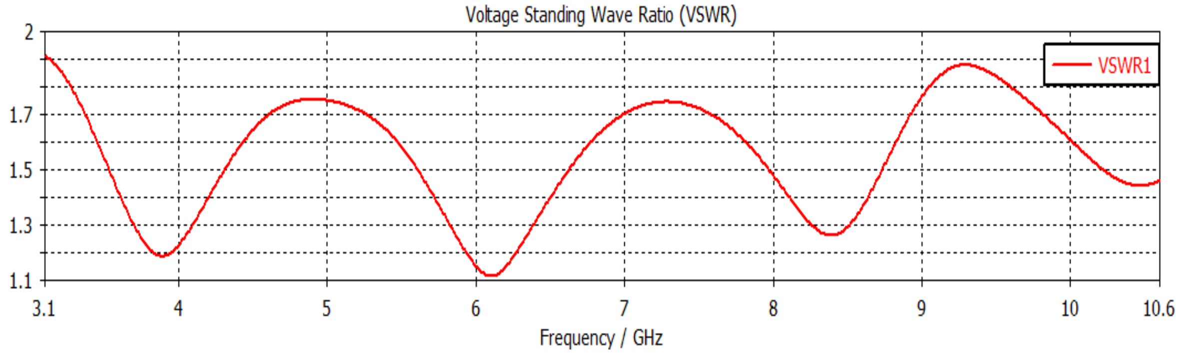

Figure 5. Graphic of Voltage Standing Wave Ratio of designed Bow-tie antenna

Figure 6 illustrates the radiation pattern characteristic of the proposed antenna at four different frequencies 3, 4.5, 7.5, 9 GHz respectively. Four of them has omnidirectional radiation pattern characteristics which is acceptable feature for a better coverage of the breast surface.

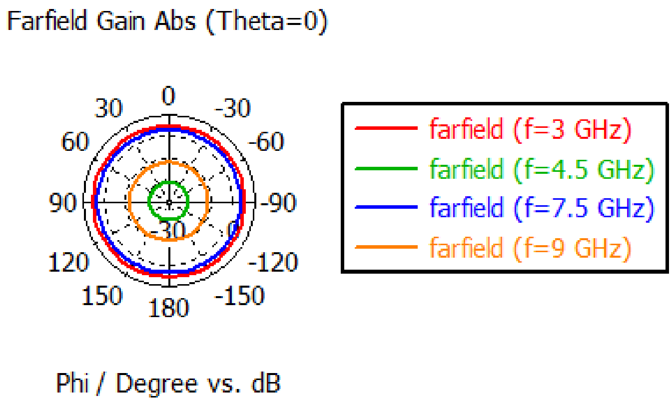

Figure 6. Radiation pattern of designed Bow-tie antenna at different frequencies 3, 4.5, 7.5, 9 GHz respectively

The breast structure is simulated with an excitation signal from the bowtie antenna and the electric fields values are obtained for different tumor size such as 2, 3, 4 mm respectively in order to detect the cancerous cells. Additionally, it is observed that both breast tissues with tumor and without tumor have significantly difference in the electric field. Figure 7 illustrates the maximum electric field value of the breast tissue without tumor at given position (0, 5, 10. 95). Figure 8,9,10 show the maximum electric field value of the breast structure with different tumor sizes. Furthermore, Table 3 shows electric field values for breast tissue with different radius tumors and without tumor. Differences between values of breast structure with tumor and without tumor are clearly shown in Table 3.After all, tumor in the breast structure can be detected due to the electric field difference.

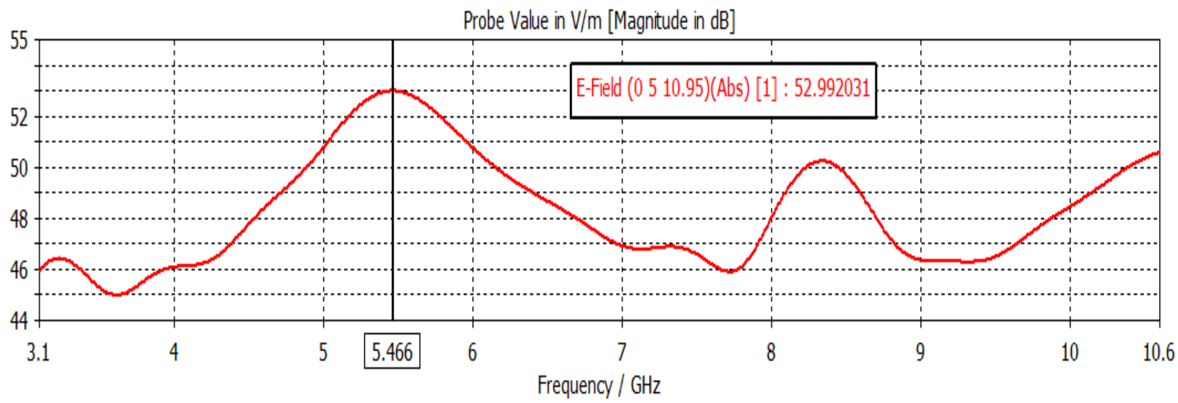

Figure 7. Graphic of electric field of breast tissue without tumor

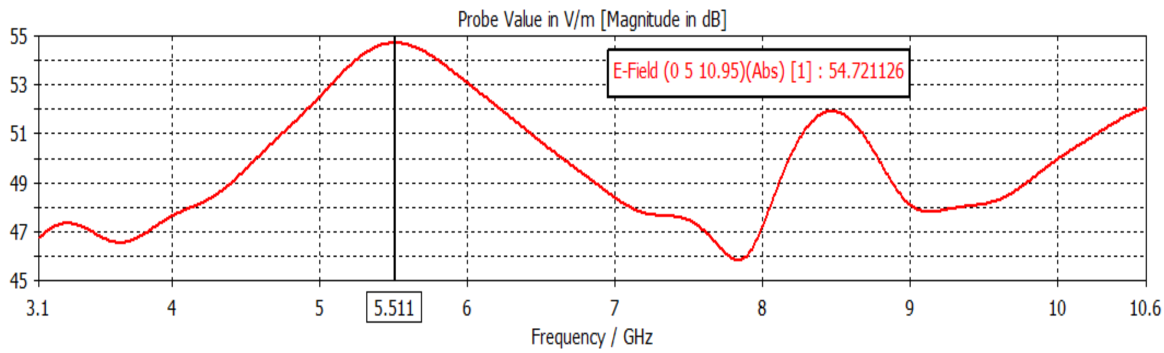

Figure 8. Graphic of electric field of breast tissue with tumor (tumor radius is 2mm)

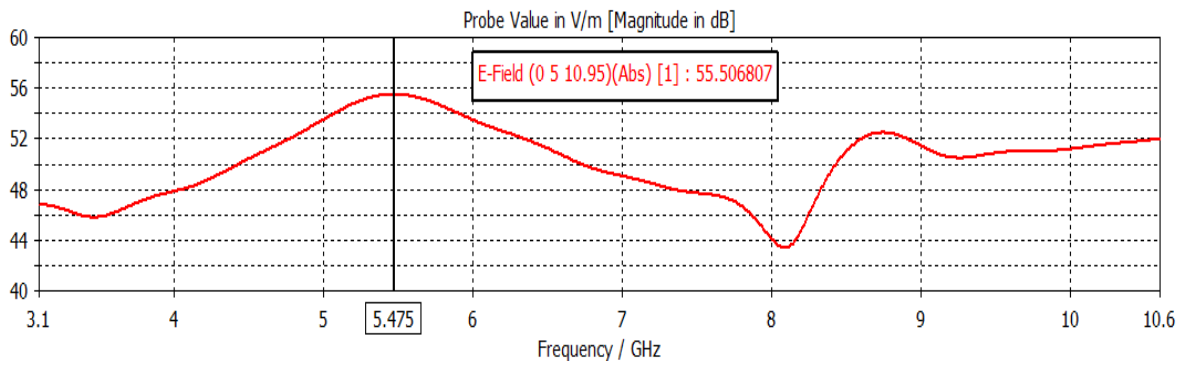

Figure 9. Graphic of electric field of breast tissue with tumor (tumor radius is 3mm)

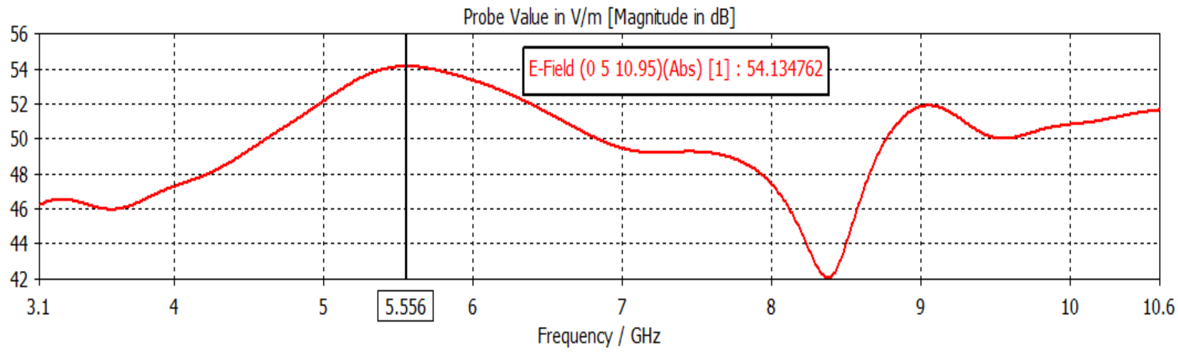

Figure 10. Graphic of electric field of breast tissue with tumor (tumor radius is 4mm)

Table 3. Obtained electric field values according to breast tissue with tumor and without tumor

Tumor Radius	E_{max}(with tumor)	E_{max} (without tumor)
2 mm	54.72 V/m	52.99 V/m
3 mm	55.51 V/m	52.99 V/m
4 mm	54.14 V/m	52.99 V/m

CONCLUSION

In this paper, a bow-tie antenna is used to diagnose tumor due to its low profile, high bandwidth and omnidirectional radiation pattern. Firstly, a bow-tie antenna is designed in order to cover UWB frequency range (3.1-10.6 GHz). Secondly, a 3D breast structure which is made up of skin layer, fatty layer and fibro glandular layer is obtained. Then, this antenna structure and breast structure are simulated in CST software simulation tool to diagnose the tumor cells. Finally, the electric fields values are measured with different tumor size. All these values are acceptable for detecting breast tumor.

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