Evaluation of Breast Tumor with Antipodal Vivaldi Antenna

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ABSTRACT:
Subsurface scanning problems, which both it is one of microwave imaging techniques and there are applications in various fields, has become a very interesting topic today. Many methods have been developed to detect cancer cells. The electrical properties of malignant cancer cells compared to normal cells indicate significant differences at microwave frequencies. Since breast tissue according to such as brain and muscle tissues is permeable than these tissues, this case supports the idea of imaging of cancerous cells in the microwave range. Various techniques such as mammography for breast cancer diagnosis are inadequate in detecting malignant cells, have high cost, and also patients are exposed harmful rays. Because of these, it is not a desirable situation. Therefore, non-ionizing electromagnetic waves used to detect cancerous cells in the human body has been widely used in biomedical applications nowadays. In this paper, both an antipodal Vivaldi 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. 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.

KEYWORDS: antipodal Vivaldi antenna, breast cancer, computer simulation technology (CST), dielectric properties.

1. INTRODUCTION

Detection of cancerous cells in the human body by non-ionizing electromagnetic waves is used in many biomedical applications. Many methods have been developed to detect cancerous cells. In 1998, Hagness et al. [1] developed a method of using UWB radars for the detection of malignant cells. In microwave frequencies, the electrical properties of malignant cancer cells show significant differences compared to normal cells. Even at these frequencies, breast tissue is more permeable than other tissues, such as the brain and muscle [2], supports the idea that electromagnetic waves can be used to image cancerous cells. There is a question like this whether other techniques can be developed since a mammogram, which is an X-ray imaging technique used to screen and diagnose breast cancer, is insufficient for detecting malignant cells [3]. On the other hand, it is not desirable that the cost of MRG is very high and the patient is exposed to X-ray during measurement.

The answer to the question of how a good breast imaging device is listed as follows: (prepared by U. S. Institute of Medicine [3]

- Do not harm human health
- Must be sensitive to all masses and distinguish malignant cells
- Must be able to provide diagnosis during treatment
- Practice should be comfortable
- The cost should be low

Early diagnosis is very important, and it is clear that new methods are required even for the detection of very small malignant tissues [3].

In this article, the presence of different tumor sizes was investigated by using antipodal Vivaldi antenna. This study is a preliminary study to determine the importance of tumor sizes or very small malignant tissues.

2. MATERIAL AND METHOD

In this part, antenna model and breast model processes were given in detail.

2.1. Antenna Model

In communication, fixed base stations, radar systems, and so on, directional antennas are needed in applications where intensification of a certain direction of electromagnetic wave is desired. The design of an antenna with stable radiant performance in ultra wideband (UWB) applications is a bit difficult because of the variation of the current distribution in the radiating planes. Conical slot antennas, considered as traveling wave antennas, can achieve a constant radiant performance over a wide working bandwidth. There are Vivaldi antenna designs with different constructions in the literature. Vivaldi antennas [4, 5] can be examined in three main groups as Vivaldi, Antipodal Vivaldi and Balanced Antipodal Vivaldi.). The reason for choosing this antenna in this study achieves ultra-wideband operation with acceptable efficiency, gain, and directivity [6].

An antipodal Vivaldi antenna was used in this study. This antenna was put into Computer Simulation Technology (CST) platform from Antenna Magus Software, a tool for modeling and designing antennas (Figure 1). Features of the antenna are shown in Table 1. On the other hand, antipodal Vivaldi with breast model was designed in CST and simulation was performed in CST Design Studio.

Table 1. Features of used antenna

Parameter	Values
Dielectric substrate	4.4
Inner flare height	17.20 mm
Outer flare height	39.56 mm
Inner flare length	31.12 mm
Outer flare length	17.60 mm
Feed-line length	1.553 mm
Feed-line width	1.338 mm
Ground plane width	1.338 mm
Substrate height	1.4 mm

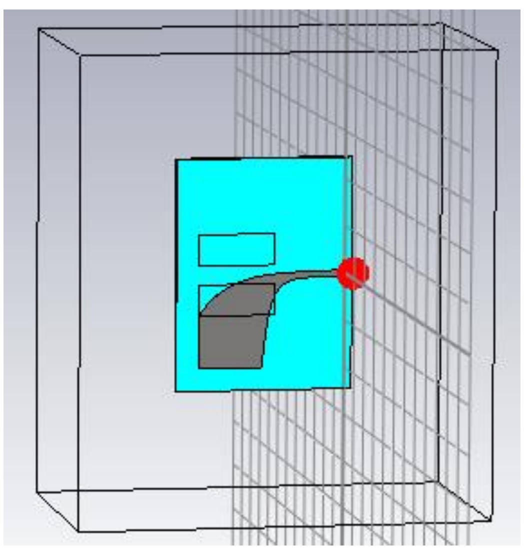

Fig. 1. Antenna Structure in Antenna Magus Software.

Analysis of proposed antennas are carried out and presented. Parameters which are analyzed are return loss, and VSWR. The proposed antenna's -10 dB bandwidth which spans in 3-12 GHz is achieved as given in Figure 2. 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 3. VSWR has also desired characteristic in the frequency of interest. Figure 5 illustrates the radiation pattern characteristic of the proposed antenna at four different frequencies 3, 6.8571, 9.428, 12 GHz respectively.

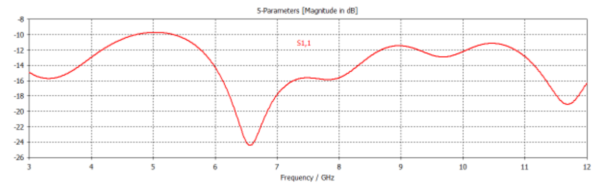

Fig. 2. Graphic of S-parameter (S_{11}) of Vivaldi antenna.

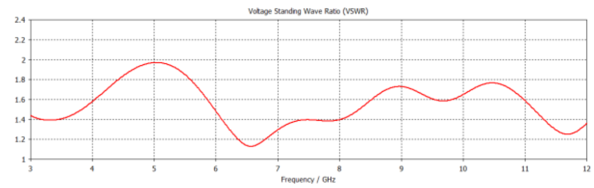

Fig. 3. Graphic of Voltage Standing Wave Ratio of Vivaldi antenna.

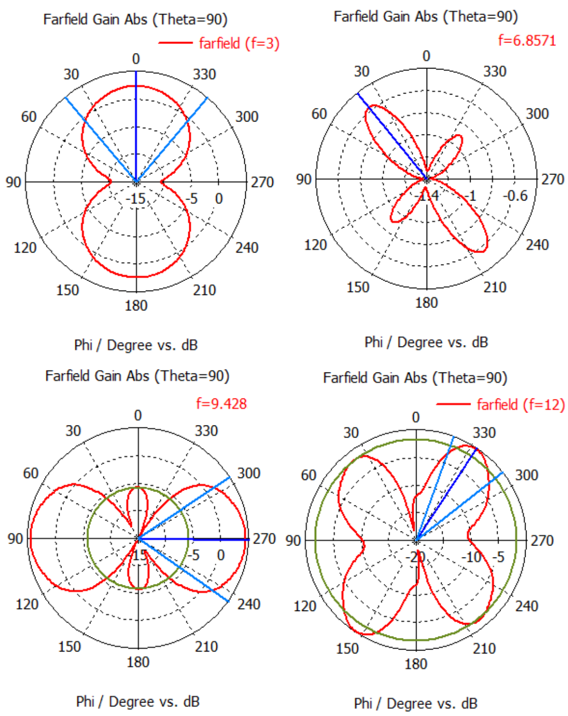

Fig. 5. Radiation pattern of Vivaldi antenna at different frequencies 3, 6.8571, 9.428, 12 GHz respectively.

2.2. Breast Model

The breast model is shown in the Figure 6 with the skin, fat and tumor parts from outside to inside. The dielectric properties of each tissue are shown in Table 2 [8]. One of the dielectric properties is the conductivity (σ), other is the relative permittivity (ε_r).

Table 2. Dielectric Properties of Breast Tissues and Tumor [7]

Tissue Portion	Conductivity (S/m)	Relative Permittivity
Skin	1.49	37.9
Fat	0.14	5.14
Tumor	1.4	50

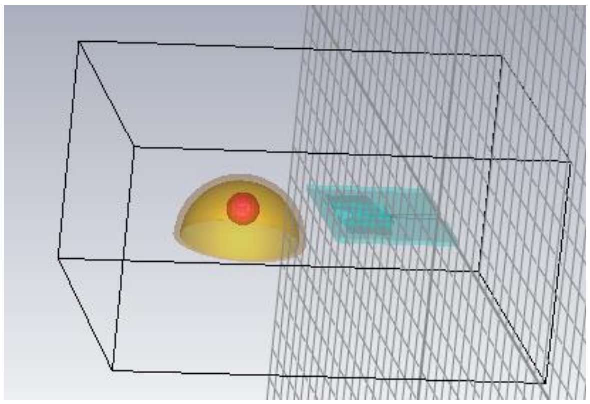

Fig. 6. Breast Structure in CST Microwave Studio.

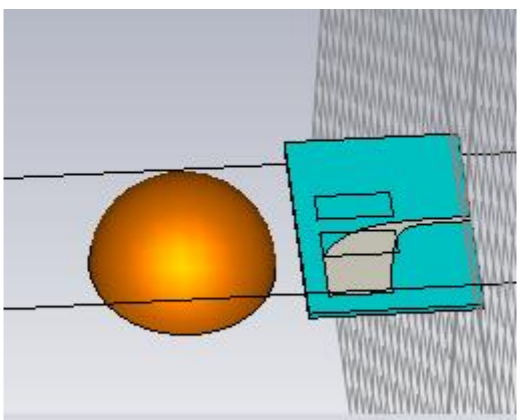

Fig. 7. Measurement setup for data collection process in CST.

While Figure 8 shows the maximum electric field value of the breast model without tumor, Figure 8, 9, 10, and 11 show the maximum electric field value of the breast model with different tumor diameters. It is clear from the graphs that there is a difference between the breast model without tumor and the breast model with tumor, also at different tumor diameters.

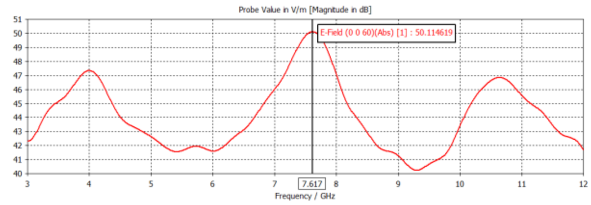

Fig. 8. Graphic of electric field of breast tissue without tumor

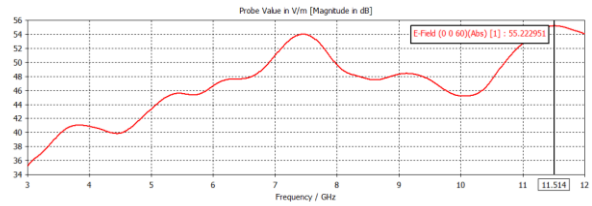

Fig. 9. Graphic of electric field of breast tissue with tumor (tumor radius is 4mm).

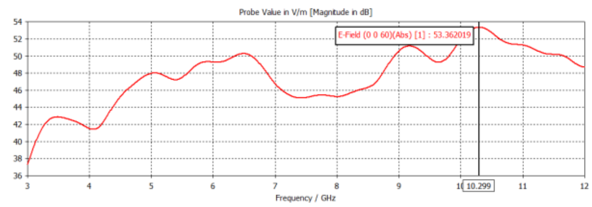

Fig. 10. Graphic of electric field of breast tissue with tumor (tumor radius is 5mm).

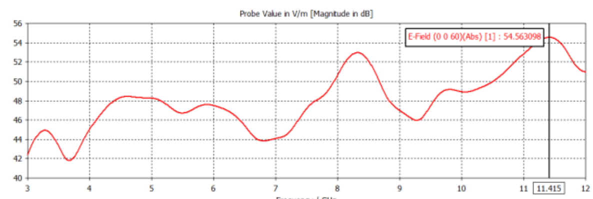

Fig. 11. Graphic of electric field of breast tissue with tumor (tumor radius is 6mm).

3. CONCLUSION

In this paper, an antipodal Vivaldi is used to detection tumor due to its efficiency, gain, and directivity. As a first step, an antipodal Vivaldi antenna is designed via the Antenna Magus Software in order to cover UWB frequency range (3-12 GHz). Secondly, a 3D breast structure which is made up of skin layer, and fatty layer is created. In the next step, this antenna structure and breast structure with or without tumor are simulated in CST software simulation tool to detection 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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