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Square Patch Antenna for Breast Cancer Diagnosis at 2.45 GHz

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Abstract

This paper presents a model of cancer diagnosis using principal electrical parameters of tumor cells such as the relative permittivity and the conductivity. The proposed model involves a square microstrip antenna and breast phantom comprising a tumor cell. The radiation properties of the designed antenna at the ISM bands, such as the Return Loss (RL), the current density, the electrical field and the Specific Absorption Rate (SAR) are exploited for diagnosing purposes. The Ansoft HFSS (13.0) simulated results show that the difference in terms of the RL, the current density, the electrical field and the SAR is higher than 2 dB, 40 A/m^2, 100 V/m and 20 W/kg respectively, once the tumor exists inside the breast model. This proposed technique in turn can be exploited to distinguish malignant cells inside the women breast in earlier stages as compared to other traditional techniques such as mammography, X-ray, ultrasound, tomography and MRI.

Keywords

Breast Cancer, Tumor Cells, Microstrip Antenna, Cancer Detection

1. Introduction

On the whole, 17 million cancer cases were reported worldwide in 2018 by Cancer Research UK [1]. These cancerous cases consist of breast cancer, lung cancer, bowel and prostate cancer. Unfortunately, it is expected to be 27.5 million new cancerous cases annually by 2040 [1]. In 2018, World Health Organization [2] reported that there were about 2.09 million breast cancer cases whereas the death cases were 0.627 million by such a type of cancer. A huge number of women that belong to the age group of 25 - 40 years, suffer from breast cancer leading to the need for the initial detection [3] [4] [5]. There are a set of different methods of breast cancer identifications such as mammogram, x-ray, ultrasound, tomography and magnetic resonance imaging (MRI). However, these techniques have some undesired results and painful which are not favored by younger age group. This can be overcome to some extent by the latest emergent techniques and technologies such as microwave breast imaging (MBI), wireless monitoring system, and medical implants.

Unfortunately, these techniques use bulky communication antenna systems. Currently, the exploited technology for detecting the breast cancer is the MBI [6] [7]. However, the initial or the early detection is a prerequisite to distinguish between the benign and malignant cells inside the breast. In this paper, a microstrip antenna is designed to detect tumor cells, using primary parameters of tumor cells such as the relative permittivity and the conductivity.

2. Microwave Antenna Design

The current section aims to design a square microstrip patch antenna at the industrial, scientific and medical (ISM) radio band. The ISM band refers to a group of radio bands or parts of the radio spectrum at 27 MHz, 434 MHz, 915 MHz and 2450 MHz. Hence the designed antenna must be able to operate in this frequency range. The three important parameters, for designing a microstrip patch antenna, are the operation frequency, the substrate height and the substrate dielectric constant. The selected operating frequency for the designed antenna is 2.45 GHz which is suitable for medical applications such breast cancer detection and treatment. For the microstrip patch antenna to be used in medical applications, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.57 mm. To reduce the dimensions of the antenna, the dielectric material selected for this design is Rogers RT/Duroid 5880 substrate with a dielectric constant of 2.2. The configuration of the proposed antenna is shown in **Figure 1**.

The optimum dimension of the patch length and the patch width are similar. This means that the metallic patch has a square shape, leading to a symmetric radiation pattern. The selected substrate is square in dimension with 100 mm^2 as similar to the ground underneath. In order to match the applied power, the height and the width of wave port are carefully chosen. The key parameter to investigate the antenna performance is the return loss (S11), which is shown in

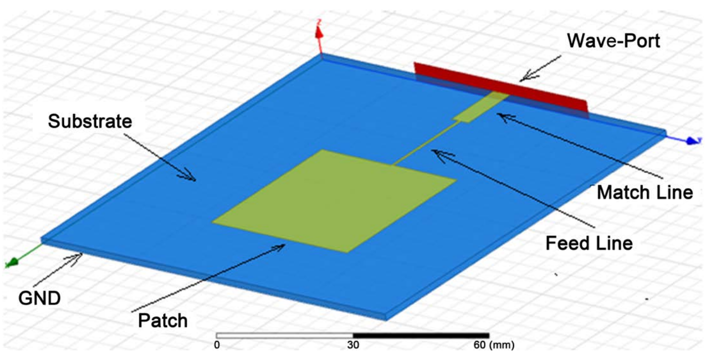

Figure 1. The designed patch antenna configuration.

Figure 2. From this, it can be seen that the return loss presents a great result at the desired frequency (2.45 GHz) with better than −30 dB. This means that most the incident power transfer to the square patch making the antenna radiates efficiently. Also, this provides around 30 MHz bandwidth at the operating frequency.

Figure 3 and Figure 4 show the radiation patterns in the E-plane and H-plane of the designed antenna at 2.45 GHz, respectively. These planes are also known in respective as the Azimuth plane and Elevation plane. By observing, it can be seen that the antenna has a similar beam width, with about 74˚ in azimuth plane whereas in elevation plane is 75˚. Also, it is obvious from these radiation patterns that the Gain is better than 7 dB, which is shown individually in a 3D pattern in Figure 5.

3. Breast Cancer Detection

This section presents the key objective of the current paper, introducing the whole proposed model for diagnosing the breast cancer using the radiation

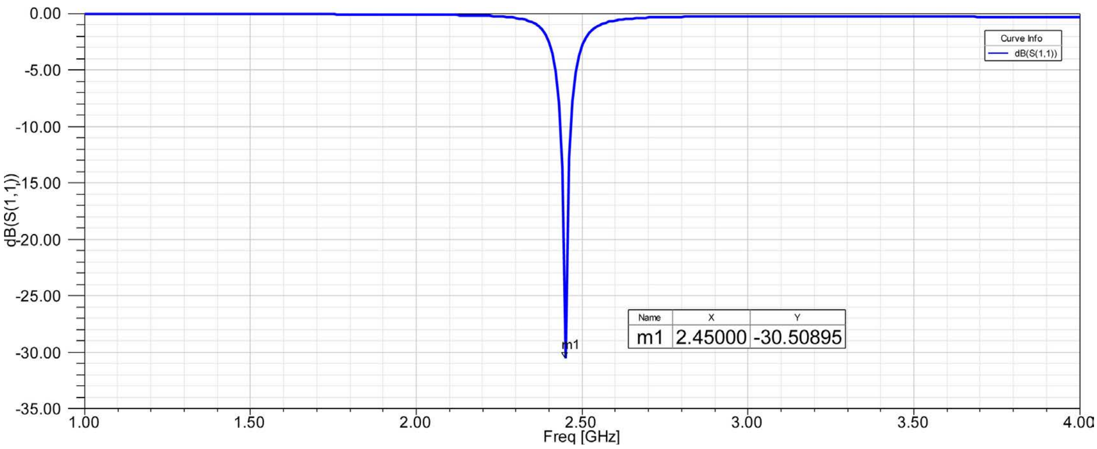

Figure 2. The performance in terms of the return loss.

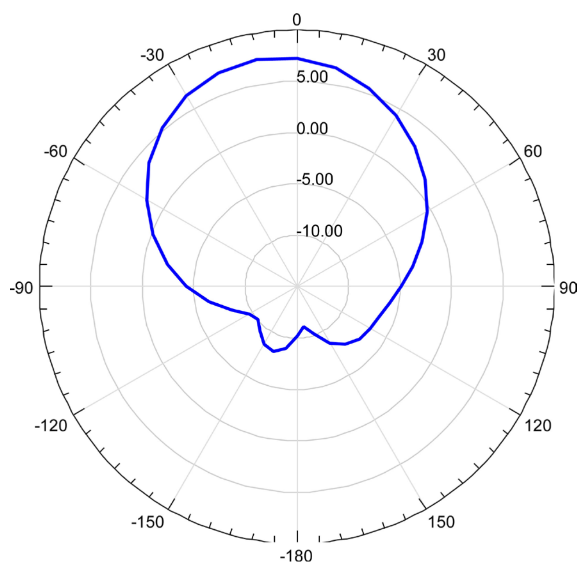

Figure 3. Radiation pattern in E-Plane/Azimuth plane.

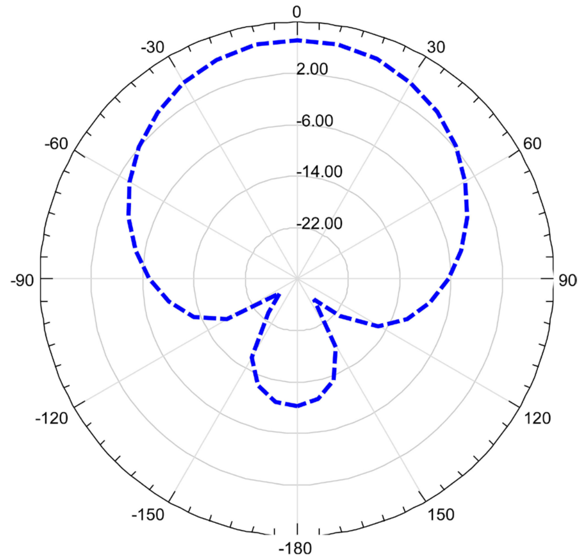

Figure 4. Radiation pattern in H-Plane/Elevation plane.

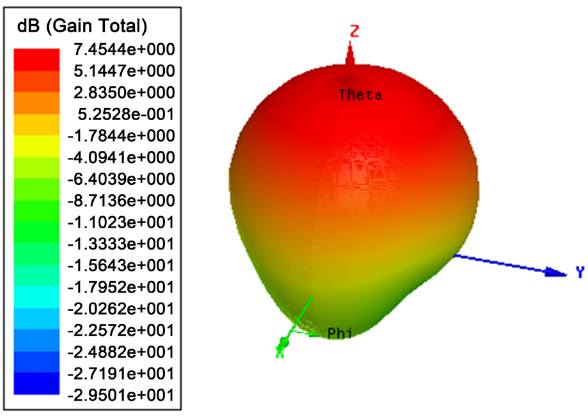

Figure 5. 3D-Gain radiation pattern.

properties of the designed antenna in the previous section. In principle, the designed antenna will be used to radiate a signal towards the breast. The radiation properties of the antenna, such as the return loss, the volume current density [A/m^2], the electrical field and the Specific Absorption Rate (SAR), are valuable for diagnosing of the breast cancer. The SAR is an index that quantifies the rate of radio frequency (RF) energy absorption in a biological tissue. It is the power absorbed per unit of volume. The main concept behind the detection of cancer using this model is the difference values of these parameters once the tumor is presented, where the hey properties of the tumor such as relative permittivity and conductivity primarily determine or distinguish the type of tumor (*i.e.*, malignant or benign). The relative permittivity and conductivity are a function of frequency, and for the current work the tumor with relative permittivity of 50 F/m and conductivity of 2.1 S/m is carefully considered for achieving the detection at 2.45 GHz.

A simple 3D-design of the breast phantom is modelled by a cone, with relative permittivity of 9 F/m and conductivity of 0.4 S/m. The breast phantom is placed 10 mm distant from the designed microstrip antenna. However, a 2 mm diameter sphere, representing the tumor, is placed inside of the cone model as shown in **Figure 6**. The structure without tumor and with tumor are modelled and simulated, and the potential results are discussed in the next section.

4. Results and Discussion

It is expected that the simulated results will show different values once the tumor considered inside the phantom. The results will be estimated by observing the return loss, the volume current density [A/m^2], the electrical field and the SAR, respectively. **Figure 7** shows the effect of the tumor on the return loss. There is a slight increasing around 2 dB at the planned frequency when the tumor is placed inside the breast model.

Figure 8(a) shows the current density distribution in the breast without a tumor.

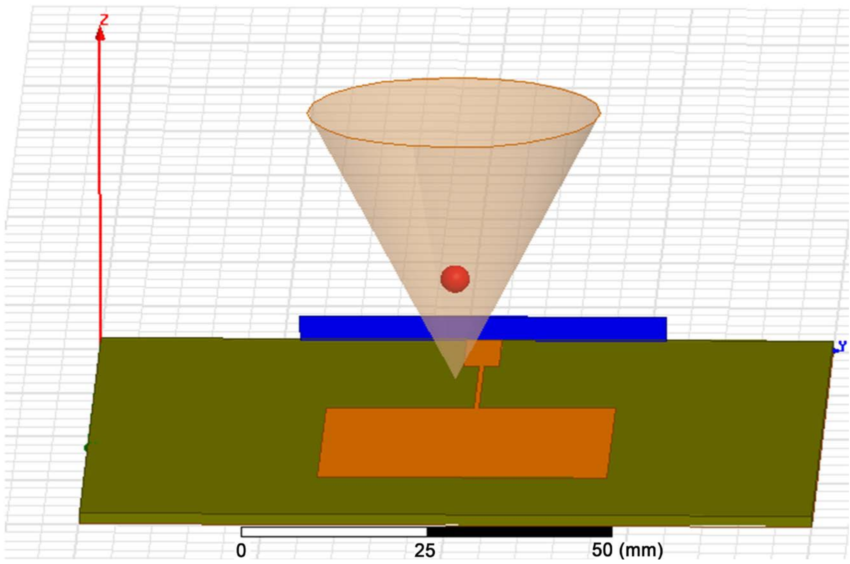

Figure 6. Breast phantom including a tumor.

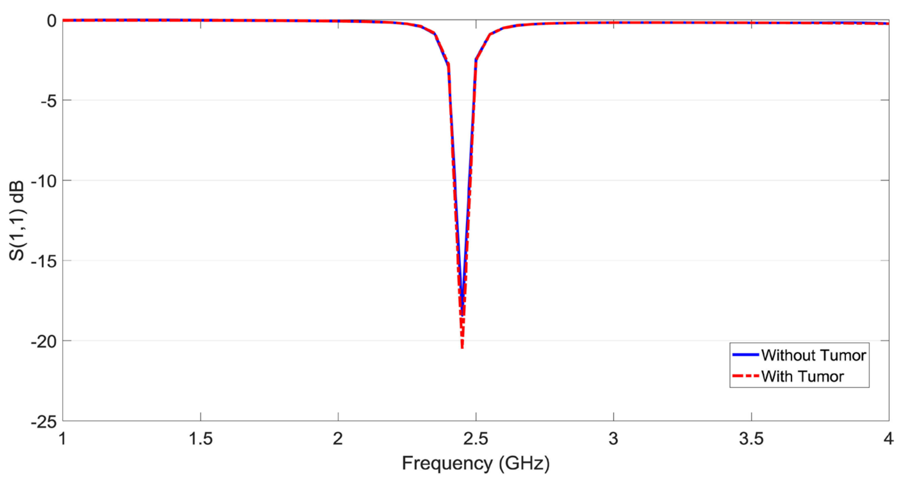

Figure 7. Tumor effect on the return loss.

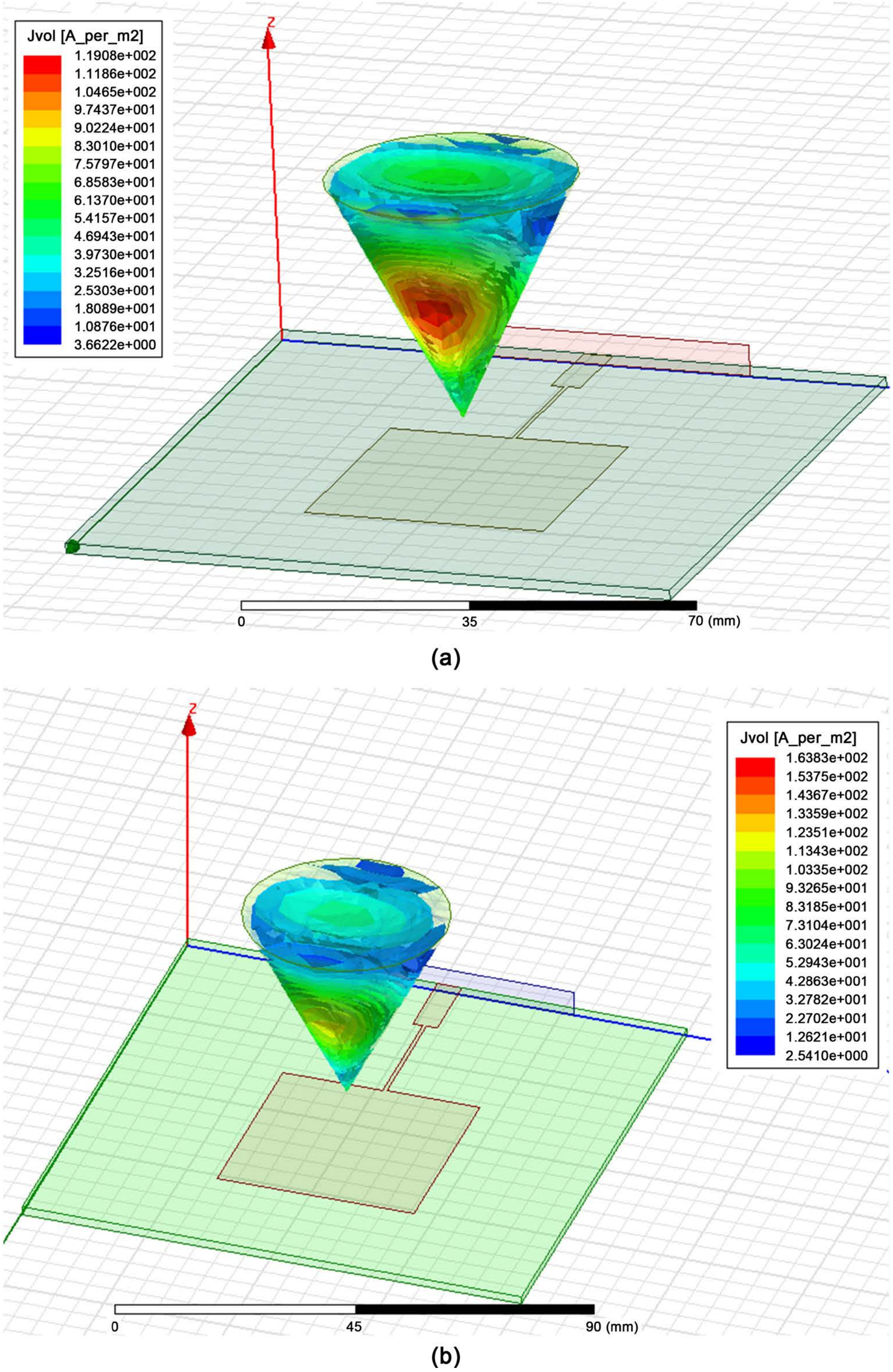

Figure 8. Tumor effect on the volume current density. (a) The breast model without a tumor; (b) The breast model with a tumor.

It can be easily observed that the maximum current density in the breast is 119 A/m^2. After placing a tumor with 2 mm radius and simulate the designed model, the maximum current density of the breast is 163 A/m^2 as shown in **Figure 8(b)**.

The difference in terms of the current density is higher than 40 A/m^2 when the tumor exists. This means that the breast has more composition as compared to the breast without tumor.

Figure 9(a) shows the electrical field distribution in the breast without a

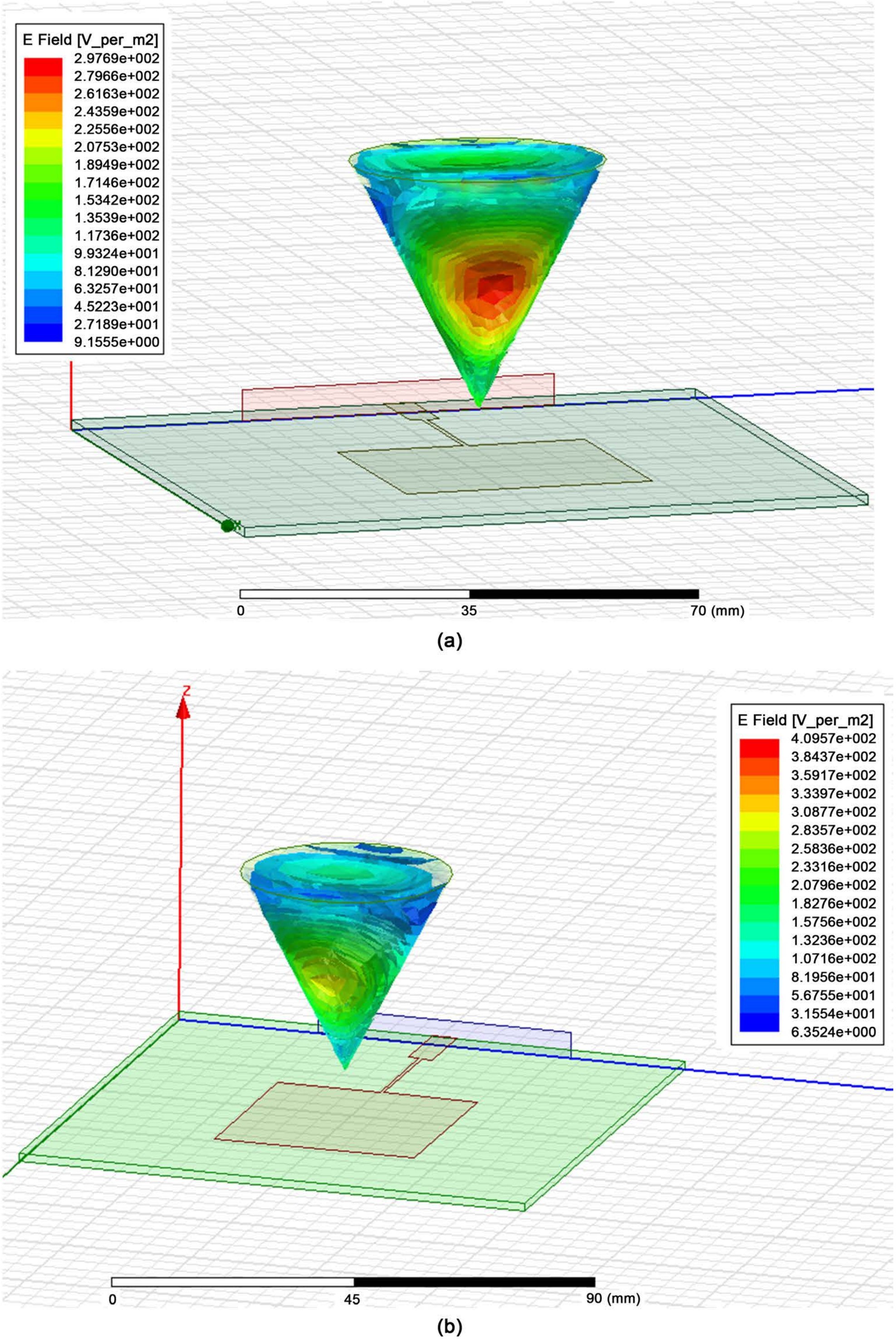

Figure 9. Tumor effect on the electrical field. (a) The breast model without a tumor; (b) The breast model with a tumor.

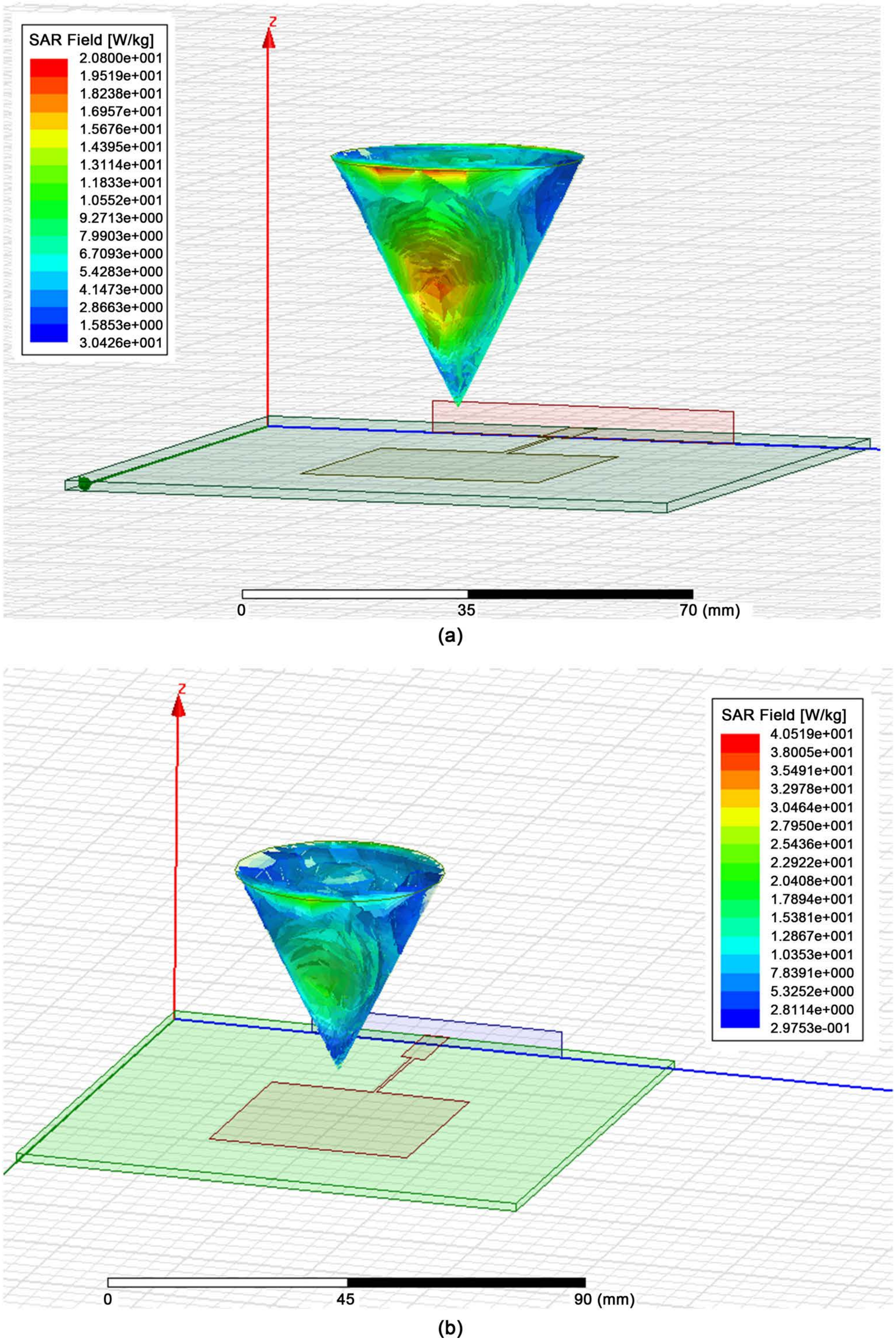

Figure 10. Tumor effect on the SAR. (a) The breast model without a tumor; (b) The breast model with a tumor.

tumor. It can be noticed that the maximum electrical field in the breast is 297 V/m. After adding the tumor and simulate the designed model, the electrical field distribution is shown in **Figure 9(b)**. The maximum electrical field of the breast is 409 V/m, at which the difference in terms of the electrical field is higher than 100 V/m when the tumor is presented inside the breast phantom.

Figure 10(a) shows the SAR field in the breast without a tumor. It can be seen that the maximum SAR in the breast is 20.8 W/kg. By counting the tumor and simulate the designed model, the maximum SAR of the breast is 40.5 W/kg as shown in Figure 10(b). The difference in terms of the SAR is around 20 W/kg when the tumor is presented inside the breast model.

The current results of this work give a good indication to only use a single array as ultimate goal, leading to come with a low cost and less complexity. In other words, a number of published studies are employed two antennas, instead of a single antenna (current paper), to make a detection where the function of the first antenna is to send an electromagnetic radiation whereas the second one is to receive this radiation. Consequently, the approach is based on using S21 instead of S11 (current paper).

5. Conclusion

The prospect of using a microstrip patch antenna at the ISM band to detect the breast tumor was investigated in this work. More investigation in terms of antenna shapes, tumor and phantom properties as a function of frequency, is required as the ultimate goal is to realize efficient and low reflection antenna array. Steps to fabricate and measure the current antenna are presently underway to confirm the current simulated results.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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