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Miniaturized UWB Microstrip Antenna with T-Slot for Detecting Malignant Tumors by Microwave Imaging

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***Abstract*- A miniaturized microstrip antenna that meets the requirements of UWB systems in terms of bandwidth and reflection coefficient is presented in this paper. This antenna is designed for a system to detect malignant tumors by microwave imaging. We use certain miniaturization techniques of slots and partial ground plane for expansion of bandwidth in order to achieve our intention. The proposed antenna exhibits good UWB characteristics and has the capability of operating from 2.85GHz to 13.21GHz. The antenna has an ordinary rectangular radiating patch, therefore displays a good omnidirectional radiation pattern. The detailed design and the results are shown and discussed in this paper.**

***Index Terms*- Ultra Wide Band (UWB), microstrip antenna, miniaturization, microwave imaging**

I. INTRODUCTION

Recent research suggests the use of microwaves for breast tumor detection, in particular the Ultra Wide Band (UWB) frequency region, offering a promising trade-off between imaging resolution and tissue penetration depth. Microwave UWB imaging is currently a very promising technology for wireless communications son very high speed, high precision radars and imaging systems [1]. This method involves transmitting UWB signals through the breast tissue and records the received signals from different locations.

The UWB systems use short pulses (of the order of picoseconds), repeated with a certain rate of up to several giga-pulses per second, providing a wide bandwidth with a level of transmit power very low. This offers the possibility to UWB systems to coexist with other electronic systems [2]. Since the release by the Federal Communications Commission (FCC) of a bandwidth of 7.5GHz for UWB wireless communications, UWB has been rapidly evolving as a potential wireless technology and UWB antennas have consequently drawn more and more attention from both academia and industries worldwide. The commission has established some regulations regarding the frequency bands and transmission power limits allocated to different UWB applications. UWB is defined as any wireless scheme that occupies either a fractional bandwidth greater than 20% or more than 500MHz of absolute bandwidth [3].

Among the UWB applications, microwave imaging has attracted considerable interest in recent years. The spectrum that was allocated by the FCC for this kind of applications is 3.1GHz to 10.6GHz [3-4]. This technique could be very effective in the detection of malignant tumors, the contrast in electrical properties between normal tissue and malignant tissue becomes very significant [5-6]. We focus primarily on the application of this technique in the detection of breast cancer. The idea is to illuminate the breast by short pulses of microwave energy at low power and reap the waves scattered or reflected by one or more receiving antennas. The processing of information received allows the detection and location of the tumor, knowledge of its size, shape and electrical properties and could be exploited for the establishment of a three-dimensional image.

Such systems require the UWB antennas that meet their requirements in terms of bandwidth design, gain and stability of radiation, but also compact antenna for better system integration, which is a real challenge. The microstrip

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antennas seem to be ideal candidates and are frequently encountered in UWB applications, including medical imaging. This is due to their low profile, low cost and ease of integration [7]. Various wideband (WB) and UWB antennas have been proposed for microwave imaging. Most of the antennas present in the literature show omnidirectional radiation pattern with low gain [8-9].

The aim of this paper is to design an antenna with the UWB features that will be included in a system for detecting breast cancer and simulated with HFSS and CST software's. The microstrip antenna that we propose is miniaturized rectangular shape and has desirable performance for UWB antennas.

The interest is to achieve increased bandwidth. The reduction in size is also a consideration to be taken into account in the design of this antenna, which would be more easily integrated into the system and reduce clutter. For this some techniques are used [10-13]. Among these techniques, we will use the insertion of the slots at the radiating element and cutting in "stair steps" in this element [14]. The use of a partial ground plane promotes the enlargement of the bandwidth [15]. Insert a slot in the partial ground plane can also have a significant effect on the performance of our antenna [16-17].

II. MODEL AND GEOMETRY OF THE PROPOSED ANTENNA

The design of an UWB antenna for imaging system presents a real challenge. Figure 1 shows the schematic of the proposed antenna. The geometry of the studied microstrip antenna is shown in Figure 2. The antenna is a rectangular patch that has undergone a number of changes in order to overcome the limitation of narrow bandwidth at the origin. The patch (l=8mm, w=12mm) is formed on a substrate of FR-4 (dielectric permittivity ε_r=4.4, thickness h=0.8mm), dimensions are L=25mm and W=16mm. Two rectangular slots are inserted on the radiating element (0.5×6mm^2) ensuring miniaturization. Antenna feeding is performed by microstrip line with dimensions of width w=1.6mm in order to adapt to 50Ω.

An increase in stair steps between feeding and antenna allows a better adaptation and development of the resonance. The steps width are 1.5mm, their lengths are w_1=w_2=1.5mm and L_3=10mm, w_3=1mm; L_4=7mm, w_4=0.75mm. The length of the feeding line and the width of the slots at the entrance of the patch were optimized using software simulation, in order to obtain a better adaptation.

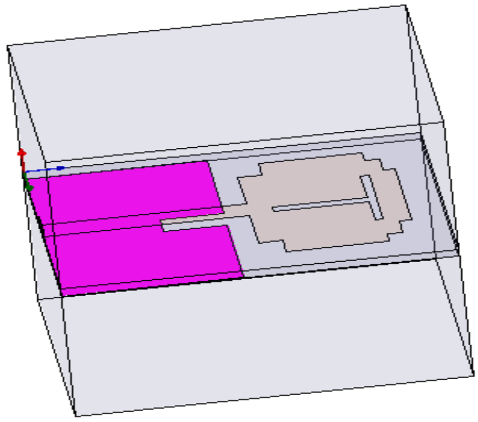

Fig.1. Schematic of the proposed antenna

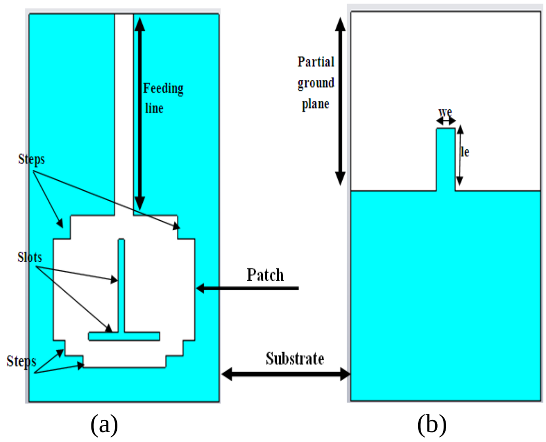

Fig.2. Antenna geometry (a) Top view (b) Bottom view

A partial ground plane, which was inserted a slot, is printed on the bottom surface of the substrate. Its length L is 11.5mm; it is the same width as the substrate (16mm). The slot has the dimensions le=4mm and we=1.6mm. The structure is

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simulated in HFSS whose numerical analysis is based on the finite element method (FEM).

III. RESULTS AND DISCUSSIONS

Figure 3 shows the reflection coefficient of this antenna according to the frequency. This result shows the presence of a resonance frequency at 6.09GHz with a level of S_{11} parameter at -51.36dB.
Bandwidth measured at -10dB ranges from 2.85GHz to 13.21GHz, presented a width of 10.36GHz

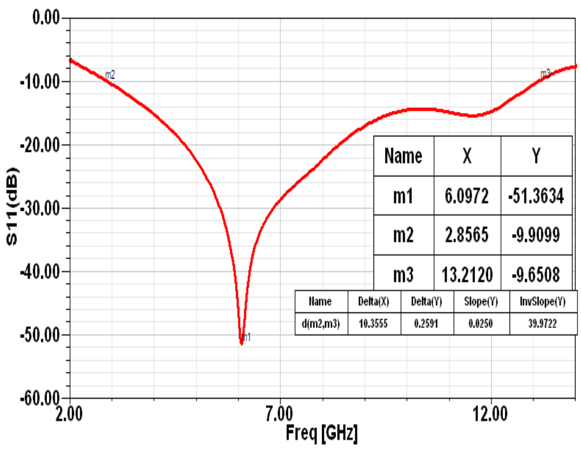

Fig.3. Simulated reflection coefficient S_{11} against frequency

We compare this result to the case of a single antenna with a full ground plane and partial ground plane without slot and with a slot as shown in figure 4. We thus show the influence of these parameters on the behavior of the structure. Bandwidth narrow for a full ground plane is about 8.19GHz (between 3.45GHz and 11.64GHz) relative to the resonant frequency and level of S_{11} not exceed -20dB for a part ground plane without slot and about 10.36GHz for a part ground plane with a slot. We can conclude that the presence of the slot and the gap between the part ground plane and radiating element allowed us to greatly expand the frequency band and the level of S_{11} and hence get a better structure UWB.

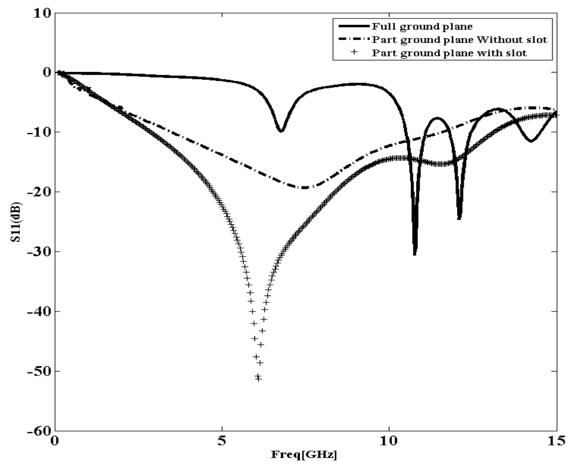

Fig.4. Comparison between the reflection coefficients S_{11} against frequency

On the other hand, it is find that the largest dimension of the patch (12mm) is 0.14λ if we refer to the lowest frequency of the spectrum (λ is the wavelength in free space). It is indeed a miniature antenna which is a difficult task to achieve in the case of UWB antennas.

To validate our use of design software HFSS, we designed and simulated the same structure as CST whose numerical analysis is based on the method of the Finite Integration Technique (FIT). Figure 5 illustrates the reflection coefficient obtained by both simulation tools. We note a good agreement between the simulated results. There is a slight difference if we consider the resonant frequency, that is, in terms of bandwidth results are very comparable. As shown in table 1.

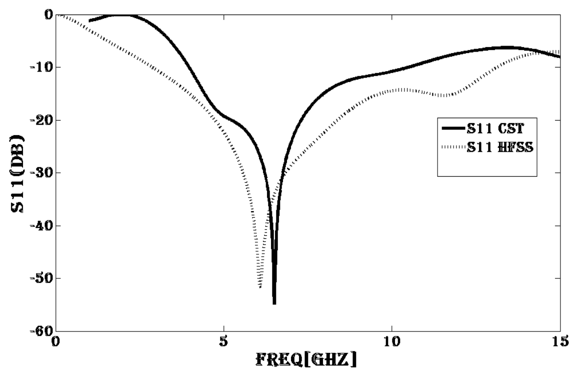

Fig.5. Comparison between the reflection coefficients obtained by both HFSS and CST software

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Table 1: Comparison results between CST and HFSS

Bandwidth		Resonant frequency	Level S_{11}
HFSS	2.85GHz-13.21GHz	6.09 GHz	-51.38dB
CST	3.92GHz-10.6GHz	6.5 GHz	-54.88dB

Figure 6 shows the variation of voltage standing wave ratio of the antenna according to the frequency. We observe that the value of VSWR in the band is less than the value 2, which is sufficient to cover the band allocated by the FCC. The radiation pattern of the antenna, characterized the variation of the radiation intensity at large distance in the different directions of space. To show the radiation from our antenna, we illustrate in figure 7 the radiation pattern in 3D at frequencies 4GHz, 6GHz, 8GHz and 10GHz. We can say that the radiation is focused on both sides of the antenna.

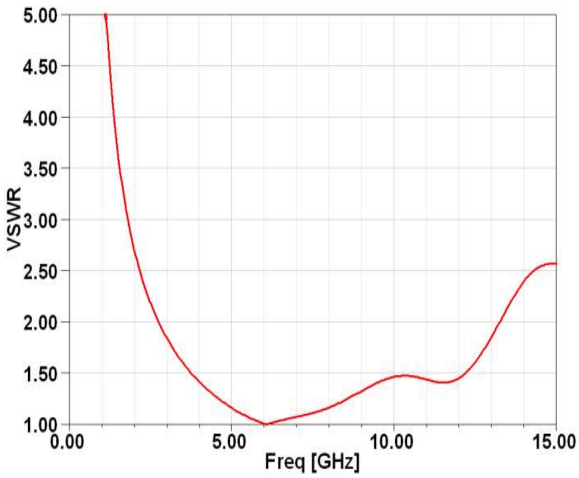
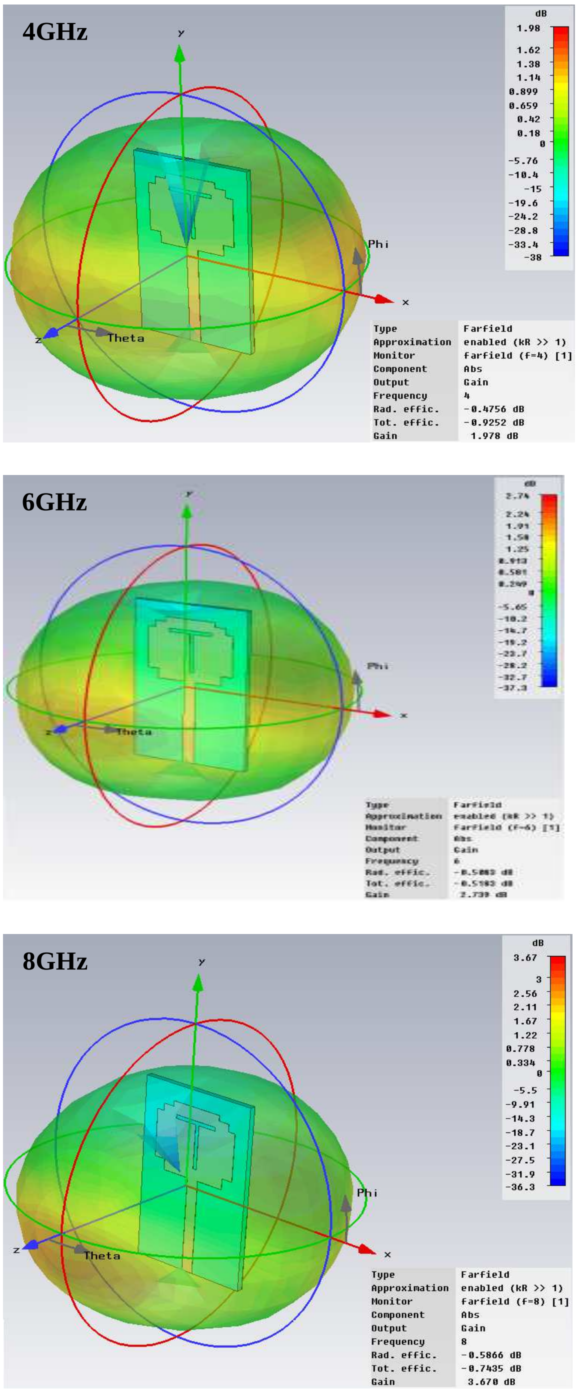


Fig.6. Variation of the VSWR



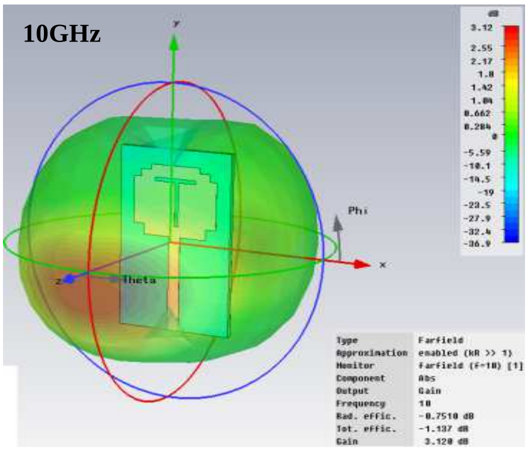
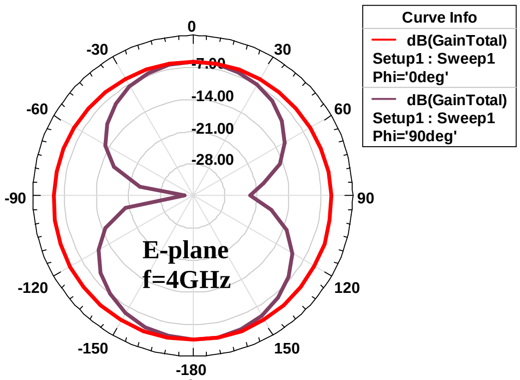
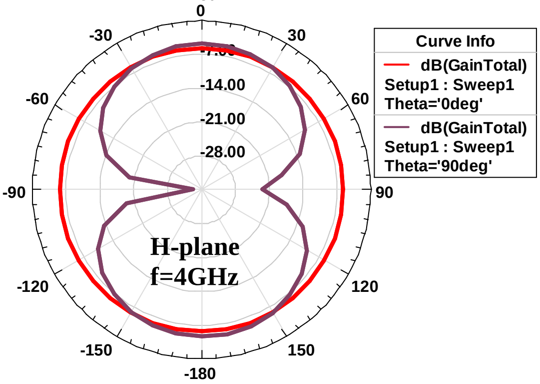
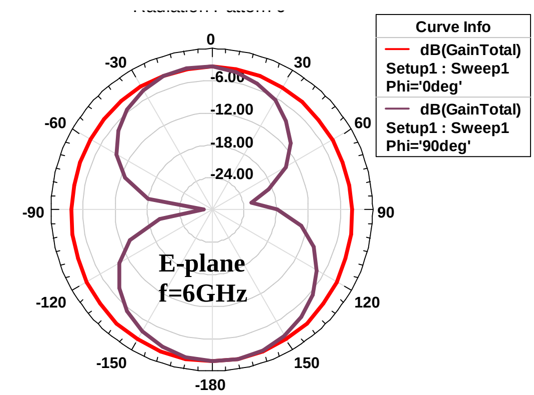
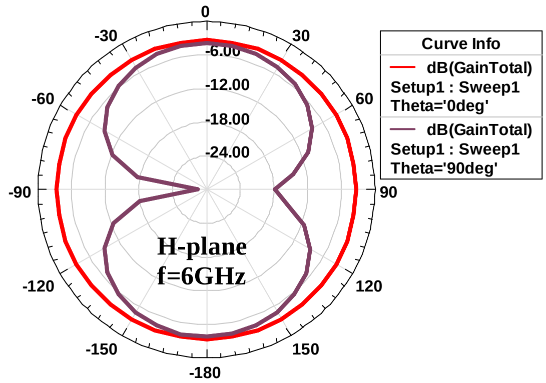


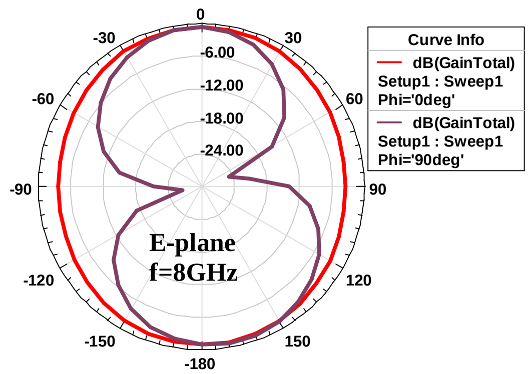
Fig.7. 3D radiation pattern

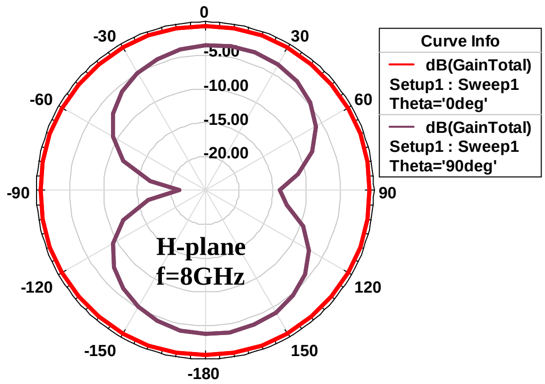












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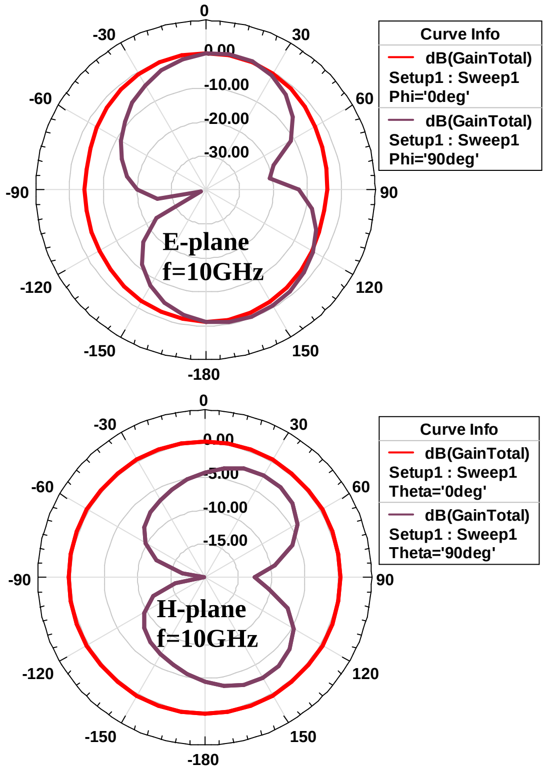

Fig.8. Simulated radiation patterns of the UWB patch antenna

The x-z plane elevation plane with some particular azimuth angle φ is the principle E-plane while for the x-y plane azimuth plane with some particular elevation angle θ is the principle of H-plane [18-19]. Figure 8 shows the simulated two dimensional radiation patterns (E-plane, H-plane) of the antenna at four frequencies 4GHz, 6GHz, 8GHz and 10GHz. In the E-plane, the value of azimuth angle φ of 0° and 90° and in H-plane, the value of elevation angle θ of 0° and 90° are taken into consideration.

The radiation is symmetric and bidirectional. The radiation is relatively stable across the frequency band coveted. Also, an omnidirectional, more or less stable behavior can be seen on the whole frequency band.

Like most UWB planar structures, our antenna behaves like a dipole in viewpoint of radiation (bidirectional in a main plane and omnidirectional in the other). The gain on the frequency range is shown in Figure 9. The gain shows some stability to the frequency band, and has a peak value of 4.33dBi. A gain is relatively good and can be improved by any networking of our antenna.

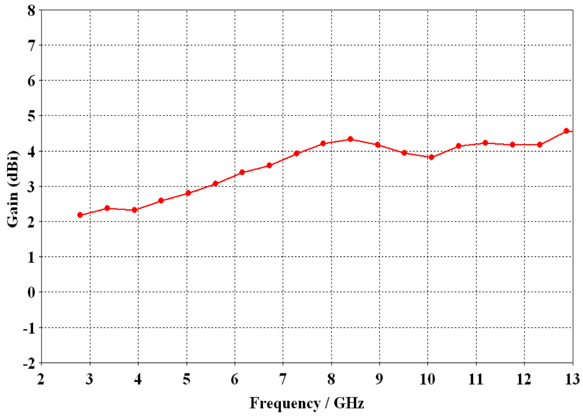

Fig.9. Gain in dBi against frequency

IV. CONCLUSION

In this paper, we proposed a miniature microstrip antenna for application in medical imaging which is the detection of breast cancer. The antenna satisfactorily meets the requirements and has an UWB attitude. Indeed, the simulations in HFSS software led to a reflection coefficient of -10dB from 2.85GHz to 13.21GHz, with good results in comparison with CST software, which we give a good performance for the spectrum allocated to the UWB by the FCC commission.

We have demonstrated in this study that the size and shape of the ground plane could have a significant impact on the bandwidth of the antenna. It is the presence of a slot in this ground plane. A good adaptation is obtained between the antenna and its feeding through gradual transition through stairs steps.

The radiation of this antenna was analyzed. It has good stability over the entire frequency band coveted and that in the two principal planes E and H. The gain is good and sufficient for the intended application, it could be improved by a possible network of the proposed antenna. This simple, miniaturized antenna structure might be a good application for a system of detection of malignant tumors by microwave imaging.

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