UWB Bowtie Slot Antenna for Breast Cancer Detection

N. Seladji-Hassaine, L. Merad, S.M. Meriah, and F.T. Bendimerad

***Abstract*—**UWB is a very attractive technology for many applications. It provides many advantages such as fine resolution and high power efficiency. Our interest in the current study is the use of UWB radar technique in microwave medical imaging systems, especially for early breast cancer detection. The Federal Communications Commission FCC allowed frequency bandwidth of 3.1 to 10.6 GHz for this purpose.

In this paper we suggest an UWB Bowtie slot antenna with enhanced bandwidth. Effects of varying the geometry of the antenna on its performance and bandwidth are studied. The proposed antenna is simulated in CST Microwave Studio. Details of antenna design and simulation results such as return loss and radiation patterns are discussed in this paper. The final antenna structure exhibits good UWB characteristics and has surpassed the bandwidth requirements.

***Keywords*—**Ultra Wide Band (UWB), microwave imaging system, Bowtie antenna, return loss, impedance bandwidth enhancement.

I. Introduction

ULTRA Wide Band is a promising technology in data transmission domain. Advantages of such technology are high data rate and low energy density. Initially reserved to military applications in Radar systems, it is nowadays used in a lot of emerging applications since 2002, for instance, wireless communications, Ground penetrating Radar, through wall radar and medical imaging systems [1]. Our interest is focused on UWB imaging systems, essentially their use in breast cancer detection. The fact is that at microwave frequencies, the electrical properties' contrast between normal and cancerous tissues is significant. It means that when illuminating the breast with narrow pulses from an UWB antenna, the treatment of the backscattered signals recorded by receiving antennas allow the detection and the localization of the tumor even in early stage [2-6].

This technique offers good resolution, uses non-ionizing radiation and is relatively low cost and more comfortable, in comparison with the traditional X-ray mammography [7].

The frequency range allowed by the American commission of communications FCC for this kind of application is [3.1-10.6] GHz.

UWB antennas used in medical imaging should be planar, compact, with high radiation efficiency and stability over the entire operation band. Most of UWB antennas presented in the literature exhibit omnidirectional radiation patterns with low gain. Several kinds of antennas can be used, for instance, microstrip, Vivaldi and Bowtie antennas. [8-12].

In this paper, we propose a Bowtie slot antenna fed by a coplanar waveguide CPW. From an initial configuration of triangular symmetric bowtie antenna, UWB bandwidth enhancement is achieved by rounding the ends of the antenna an applying progressive feed line. The commercial software CST Microwave Studio is employed for simulations. In the next section, we describe the steps followed in antenna design. The third section discusses the simulation results of the different studied antennas performances.

This study is a part of an Algerian national research project. The optimized antenna will be implemented in a microwave Imaging System considering a model of breast with tumor. The entire system is analyzed using CST MWS [13].

II. Antenna Design

The design of an UWB antenna for imaging system presents a real challenge. The geometries of three proposed UWB configurations are presented in Fig. 1.

A conventional bowtie slot antenna is shown in Fig. 1(a). In the second configuration which is presented in Fig. 1(b), each arm of the antenna is extended by a rounded end. This may lead to increase the bandwidth of the antenna. In the last structure (Fig. 1(c)), we apply a progressive variation of the feed line.

The antenna is realized on FR-4 substrate with dielectric permittivity $\varepsilon r = 3.34$ and thickness $h = 0.794$mm. Its length and width denoted by L and W are respectively 44mm and 24mm. The antenna is fed by a coplanar waveguide, the width of the coplanar lines is wa = 1.5mm, separated by a distance of 1mm. Following are the other geometrical parameters of the different structures shown in Fig. 1: Lt = 20mm, Wt = 18mm, O1(0, 13)mm, R1 = 7.25mm, O2 (3.7, 3.7)mm, R2 = 1.7mm, O3 (3.5, 6.6)mm, R3 = 6mm. The origin of the coordinate system is taken at the center of the structure.

All simulations are made in CST Microwaves Studio environment.

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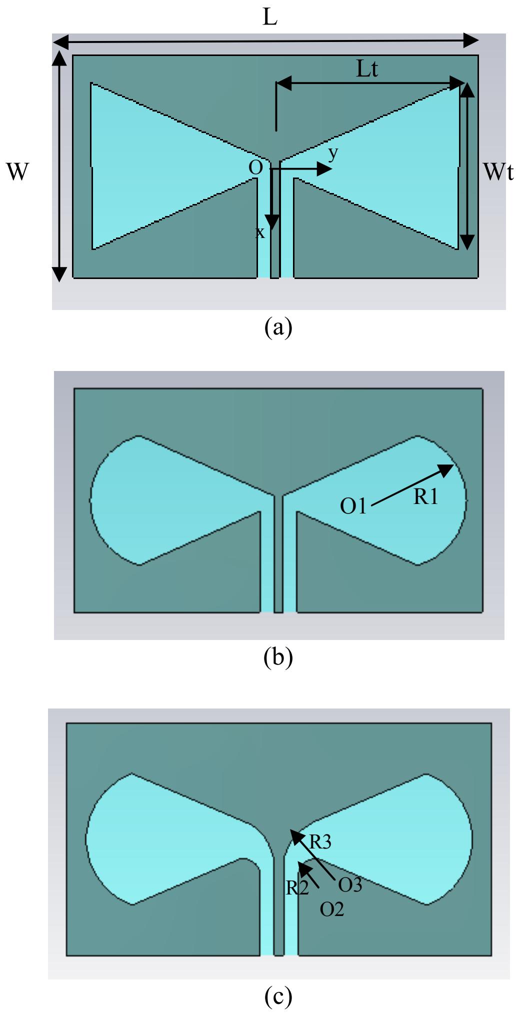


Fig. 1 Antennas geometry (a) triangular bowtie (b) with rounded ends (c) with rounded ends and progressive feed line

III. Results and Discussions

The different simulations of the return loss parameter S11 for the three structures are plotted in Fig. 2. As we can see, the first antenna presents a multiband behavior, but the 10 dB return loss bandwidth in the UWB frequency range extends only from 3.63 to 8.31 GHz. Whereas it extends from 3.67 to 16.47GHz for the second one, covering the required UWB band. It displays resonant frequencies at 5.65 GHz with S11 of -24.7dB, 11.75GHz with S11 of -25dB and 15.5GHz with S11 of -13dB. This result shows that for the same dimensions of the structure, we can improve the impedance bandwidth of the antenna by rounding antenna's ends.

The simulated result for the third case displays an impedance bandwidth from 3.95GHz to more than 25 GHz. A first resonance occurred at 6.3 GHz with S11 of -22.2dB.

Other resonant frequencies are observed at 14.35 GHz, 16.57 GHz and 22.9 GHz with S11 of -24dB, -30.4dB and -27.5 dB respectively.

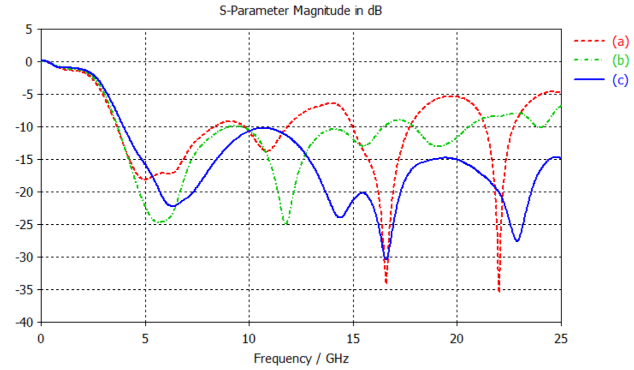


Fig. 2 Simulated Return Loss S11 (dB) against frequency (GHz) for the three antennas

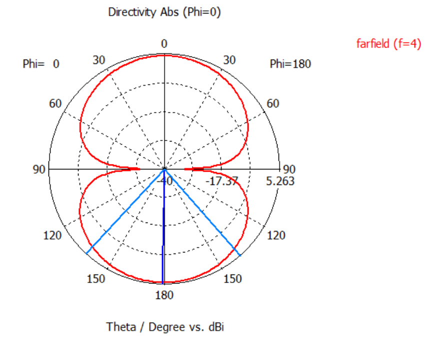
Bowtie antenna is well known for its multiband performance. The results presented here attest that the application of curved ends and a progressive transition in the feed system of the bowtie antenna allow us to improve the impedance matching so that we enhance the bandwidth, which is suitable in UWB applications.

The far field radiation patterns of the final structure (c) are also simulated by CST MWS. They are illustrated by Fig. 3 for the frequencies 4GHz, 6GHz, 8GHz and 10GHz in the E-plane.

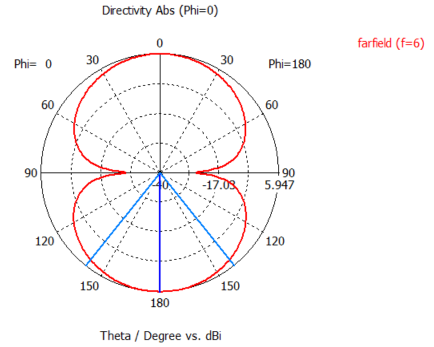
It can be noticed that the radiation is symmetric bi-directional and almost similar at the specified frequencies. The main lobe is directed at 0° and 180°. The radiation is suppressed at 90° and 270°. The main lobe magnitudes are 4.5dBi, 5.9dBi, 6dBi and 5.5dBi for the corresponding frequencies. The half power beam widths HPBW are 85°, 77°, 70° and 65° respectively.

Fig. 4 illustrates the radiation patterns in the H-plane at the same frequencies. It is observed that the radiation patterns exhibit an omni-directional behavior.

Fig. 5 shows three dimensional view of the radiation pattern at 8GHz. The concentration of the field focuses on the two sides of the bowtie antenna. One perspective would be to concentrate the radiation to only one side of the antenna and to increase the HPBW for a better coverage of the breast surface.



(a)



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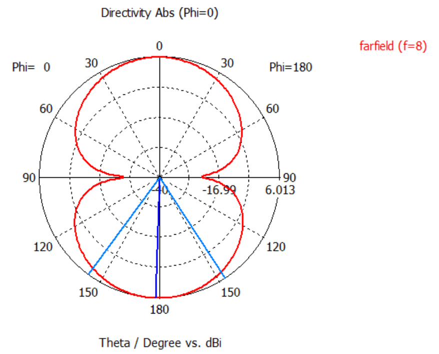
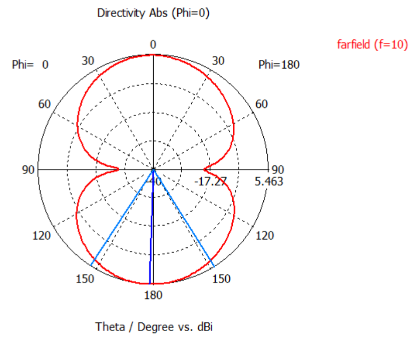
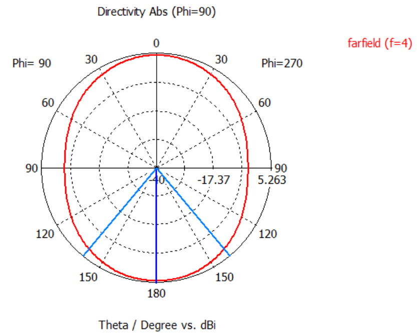


(c)

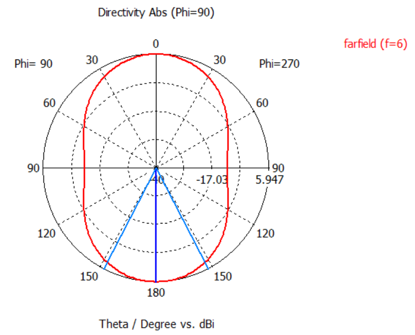


(d)

Fig. 3 Simulated radiation patterns in the E-plane at (a) 4GHZ (b) 6 GHz (c) 8 GHZ and (d) 10 GHZ



(a)



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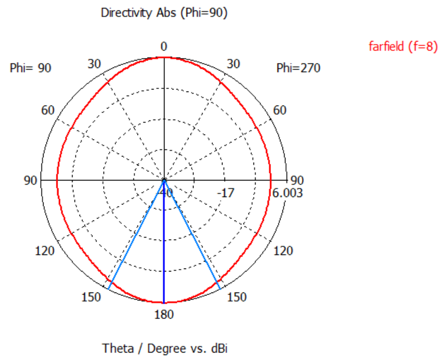
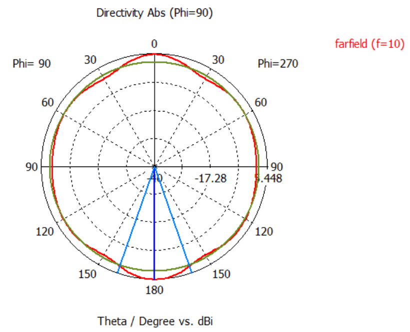


(c)



(d)

Fig. 4 Simulated radiation patterns in the H-plane at (a) 4GHZ (b) 6 GHz (c) 8 GHZ and (d) 10 GHZ

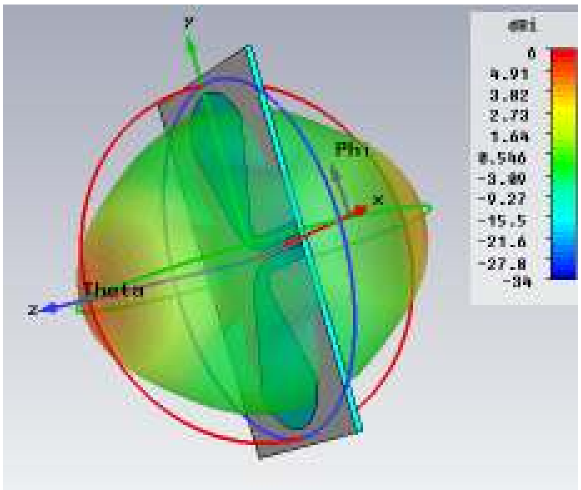


Fig. 5 3D radiation pattern at 8 GHz

IV. Conclusion

In this paper, a CPW-fed bowtie slot antenna is proposed for breast cancer imaging. We demonstrate that rounding ends and curved feed lines could have significant impact on the bandwidth of the structure. The proposed antenna has achieved enhanced bandwidth which covers and surpassed the UWB band of 3.1-10.6GHz.

The simulated E and H plane radiation patterns of the bowtie antenna show good stability almost over the entire operation frequency band. The final structure has good UWB characteristics with a moderate gain and can be suitable for microwave imaging systems.

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