Hexagonal Shaped Ultra Wide Band Patch Antenna with a Square Fractal in Ground Plane for Breast Cancer Detection

Astt.Prof. Abhishek Choubey, Rachna Pal
Department of Electronics and communication Engineering, RKDFIST, RGTU, Bhopal (M.P.)

Abstract

A hexagonal patch microstrip antenna with a square fractal in ground plane composed by coaxial-feed is proposed. This antenna is used in ultra-wideband microwave imaging systems aimed for early breast cancer detection. The antenna is designed to operate across the ultra-wideband frequency band in the air. The proposed geometry is simulated with IE3D and in results Return Loss, Gain, and VSWR are calculated. The simulated results are shown to illustrate the performances of the proposed antenna.

1. Introduction

Among the all detected types of cancers breast cancer is the most common type of cancer found in women, but fortunately breast cancer can be early detected and treatment can be started in early stages which improve the survival rate. Ultrasound, mammography and magnetic resonance imaging (MRI) are commonly used clinically for breast cancer detection and diagnosis [1]. But these techniques have many limitations, such as high rate of missed detections, ionizing radiation (mammography), too expensive to be widely available, and so on. The conventional mammography is an ionizing technique and microwave imaging of breast tumors is a non-ionizing technique, potentially low-cost, comfortable and safe alternative [2]. The high contrast of the dielectric property between the malignant tumor and the normal breast tissue should manifest itself in terms of lower numbers of missed detections and false positives [3, 4]. The microwave breast tumor detection also has the potential to be both sensitive and specific, to detect small tumors, and to be less expensive than methods such as MRI.

Breast tumor detection using ultra-short pulses presents advantages over other techniques such as x-ray mammography, and the possibilities of this new technique are presently under study [4–6].The problem basically involves the interaction of transient electromagnetic waves with human breast tissue and the analysis of the backscattered signals from the tumor, whose dielectric properties present a significant contrast with respect to normal tissue. The range of frequencies used to obtain a high resolution is typically in the interval 4–8 GHz.

In this paper, a novel design of printed hexagonal disc monopole antenna fed by coupled feeding method is proposed. The parameters which affect the operation of the antenna in terms of its frequency domain characteristics are analyzed numerically and simulated with IE3D in order to understand the operation of the antenna. It has been demonstrated that the optimal design of this type of antenna can achieve an ultra wide bandwidth with satisfactory radiation properties.

Furthermore, the simulations have also shown that the proposed monopole antenna is ultrawide band with radiation band from 1.5 GHz to 2.5 GHz, which is a band of 1 GHz and 50 % of center frequency and 4 GHz to 8 GHz which is a band of 4 GHz and 66% of center frequency.

The paper is organized in the following sections. Section-2 describes the antenna design and return loss bandwidth obtained less than -10 dB for an optimal design. Section-3 analyzes the characteristics of the antenna. Section-4 summarizes and concludes the study.

2. Antenna Structure and Mechanism

As we know, rectangular shaped patch antennas have received more attention due to their ultra-wideband characteristic. They are very popular for volume-limited and wideband applications. The structure of the proposed UWB antenna is shown in Fig.-1. This antenna is printed on a FR-4 substrate with relative permittivity 4.4 and thickness of 1.6 mm. The antenna is hexagonal shaped copper patch grown on FR-4 material. The antenna has two layers, the top layer and the bottom layer. On the bottom layer there is a square shape ground with side of length 50mm and having beveled shaped cut of length 4mm. So remained length of sides is 46 mm. According to Babinet's theory, the slot antenna can be solved through

analyzing its complementary antenna. So the hexagonal shaped antenna with square slot in ground plane presented in this paper can be seen as equivalent to a disk monopole antenna which is already studied [11, 12]. The antenna presented here has wideband characteristic covering from 1.5 to 2.5 GHz and 4 to 8 GHz.

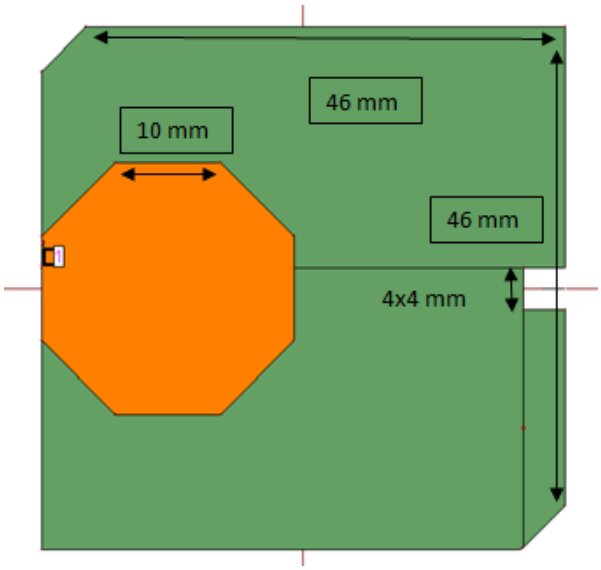

Figure 1: The geometry of the proposed antenna

Figure-2 shows the return loss of the antenna with a hexagonal patch and square fractal in ground plane. Thus the proposed antenna has ultra-wideband characteristic.

3. Simulation Results

The proposed structure is simulated in IE3D a product of Zeland Software Company. The detailed dimensions can be found in previous section. The measured 10 dB return loss bandwidths are from 1.5GHz to 2.5 GHz, and 4 GHz to 8 GHz which covers an ultra-wideband. At the first resonant point on 2.0 GHz the bandwidth is about 50% and at the other resonant point at 6 GHz bandwidth is 66 % the combined average bandwidth is approximately 58% which is sufficient for making the antenna suitable for breast cancer detection applications. Figure-3 shows the simulated gain of antenna. Figure-4 and figure-5 shows VSWR and Axial Ratio respectively.

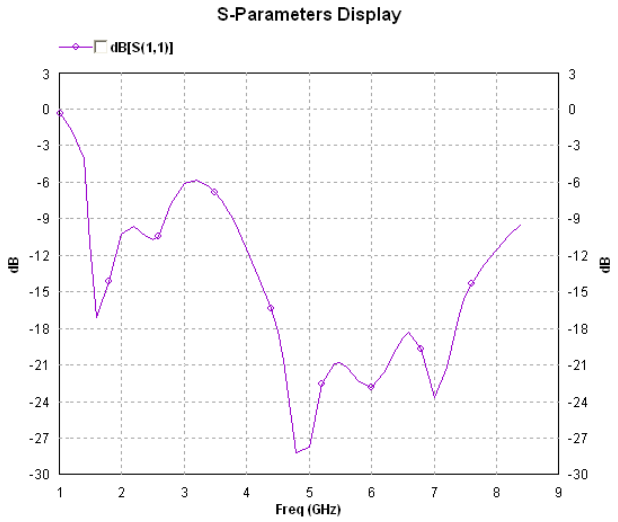

Figure 2: Return loss for proposed antenna

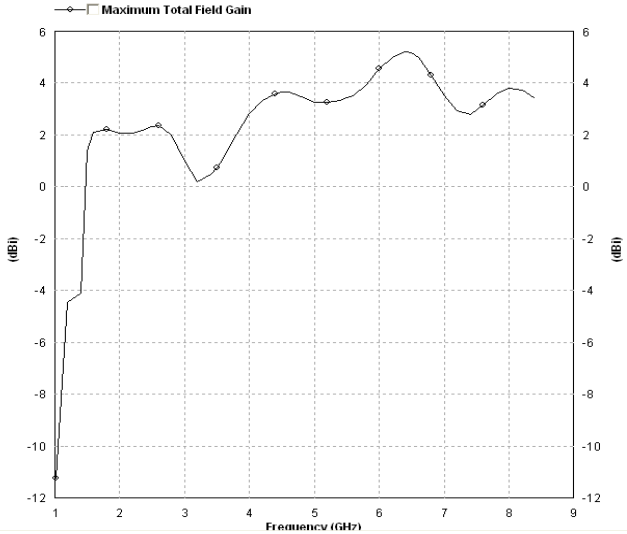

Fig – 3 Simulated Gain for proposed antenna

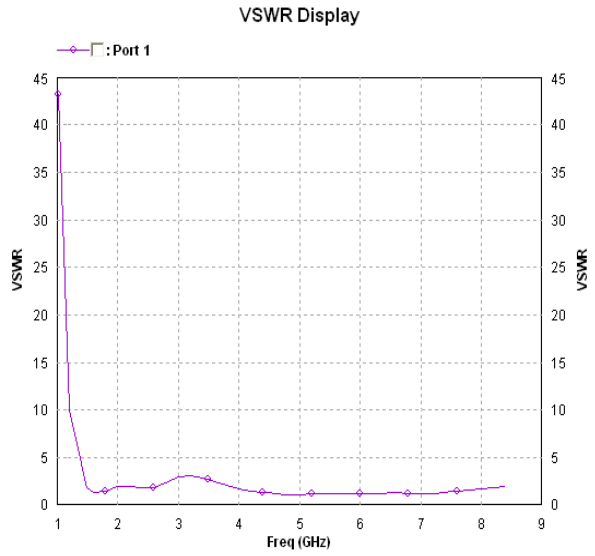

Fig – 4 VSWR

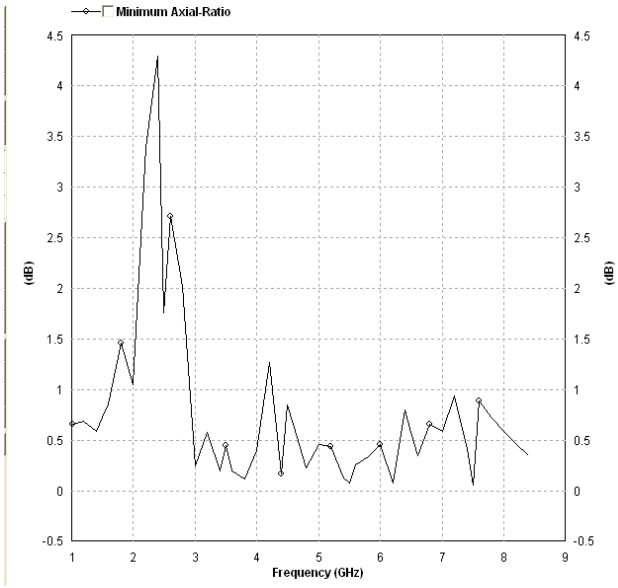

Fig – 5 Axial Ratio

4. Conclusion

Using a new configuration of coupling slots, the design and measured results for a hexagonal shaped radiating plane and fractal ground plane antenna is presented. The antenna exhibits measured -10dB Return Loss bandwidth of 50% and 66% for the two frequencies ranges. A study of Gain, VSWR and axial ratio with respect to frequency is also carried out.

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