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# UWB Microstrip Antenna Design for Microwave Imaging Systems

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***Abstract -*** In this work, an ultra-wide band (UWB) microstrip antenna is designed which can be used for microwave imaging applications such as breast cancer detection. Proposed antenna is operating in between 2.01GHz to 7.64GHz with a Fractional Bandwidth (FBW) of 116%. Antenna is using low cost low profile substrate with 38 × 40mm$^2$ dimensions and thickness of 1.6mm. This antenna can provide maximum gain of 9.4dB, which is considerably a good result for microwave imaging purpose.

***Keywords -*** *Ultra-wide band (UWB), microstrip antenna, microwave imaging, breast cancer detection*

## 1. Introduction

Recently, many researchers are focusing on the wide use of ultra-wide band (UWB) antennas because of ability for using in many applications such as Medical and Military Purpose, Radar and Communication Systems. According to the Federal Communication Commission (FCC) that device where the fractional bandwidth is greater than 109% (3.1GHz – 10.6GHz) while according to European Telecommunications Standards Institute (ETSI) the fractional bandwidth is more than 85.7% (3.4GHz – 8.5GHz) is considered as ultra-wide band devices. Designing UWB antenna, we are required to keep several parameters in specific range and values. For instance, the most important parameter is frequency bandwidth, voltage standing wave ratio (VSWR), gain, and directivity. Even in some applications, we require to have good penetration depth such as through-wall imaging systems [1-2] and [14-15].

UWB antennas are widely used in microwave imaging for cancer detection purposes [3]. Compact antennas exhibiting ultra-wide bandwidth is considerably possessing low gain and omni-directional radiation pattern which is commonly used for short distance and low resolution [4]. This type of antenna could be used in the g round-penetrating radar (GPR) application also [16-21]. While on the other hand, use of UWB antennas for detection purpose in microwave imaging systems, requires somewhat better gain and radiation pattern.

Microwave imaging is considered as one the most interested field in terms of research, as they have many advantages such as detecting cancerous tissues. In medical purpose, microwave imaging basically finding out the electrical property distribution of body [5]. The difference between normal tissues and cancer affected tissues helps in detection of cancer. It is moving towards popularity for cancer detection and other medical purposes at the present time because of easy layout and simplicity in configuration.

In this paper, we proposed the microstrip patch antenna designed which is applicable in ultra-wide band. This frequency range is considered as a better solution for detecting breast cancer. Also, we improved the gain and directivity to get high resolution data. High frequency structure simulator (HFSS) is used for simulation to design the antenna structure and analyze the measurement and properties.

In section 2, we discussed the design of antenna thoroughly, which includes size and dimensions. Section 3 includes simulation results and detailed discussion while in the end; we conclude the paper with conclusion.

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## 2. Geometry of Proposed Antenna

Ultra-wide band can be obtain by keeping a specific dimension of radiating patch such that length and width, also we used different slits and extended stubs to get considerable simulation results. Proposed microstrip antenna consist of optimal substrate thickness (FR4) substrate thickness of 1.6mm with the relative permittivity, $\varepsilon_r$=4.4 and loss tangent $\delta$=0.02. The length and width of substrate is 40mm and 38mm respectively.

Radiating patch is most important part of every antenna because the design parameters of patch manage the properties of antenna. Resonant frequency is depending on the length of patch while width of patch gives us good radiation efficiencies [6], which are the reasons that we focus on the calculated and compact size of patch. The length of patch, denoted by $L_p$, is 23.5mm and width, $W_p$ size is 12mm. In the beginning, we designed a very simple structure of patch without having any gaps and slits in the patch which later on improved by adding I shaped slits in the right side of patch [7]. First of all, we used a simple design to observe the changes in radiation pattern and S11, which is mentioned in Figure 1(a), (b), (c) and (d).

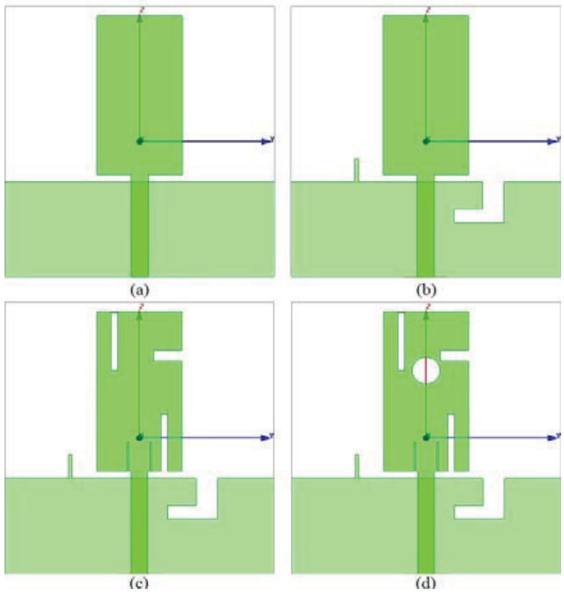


**Figure 1.** (a) Simple design (b) I shaped stub and L shaped slit in ground (c) Modified patch (d) Proposed antenna design

Changes occurred because of altering and modification in antenna design effect the return loss, S11 parameter of antenna which can be observed in Figure 2.

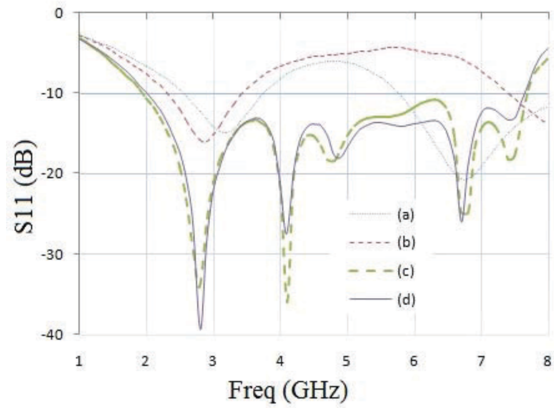


**Figure 2.** Variation in S11 with changing design of Antenna i-e; (a), (b), (c) and (d)

There is very slight difference in S11 of antenna (c) and (d) but we can find out a huge difference in gain. Gain of proposed antenna with the varying design (a), (b), (c) and (d) is shown in Figure 3.

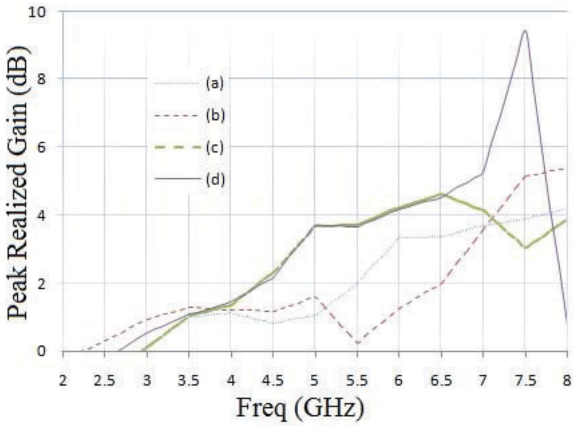


**Figure 3.** Gain (dB) with the varying design of antenna (a), (b), (c) and (d)

Ground is on the lower side of substrate with the length, $L_g$ and width of 14×38mm$^2$, while from the Figure 1, it is quite visible that there is I shaped stub on the left side which is inserted on the particular place to increase the bandwidth and gain for ultra-wide band purpose. I shape stub has the size of 3.5×0.5mm$^2$, also there is L shaped slit on the right side of the ground. Figure 4 shows the complete design parameters of antenna.

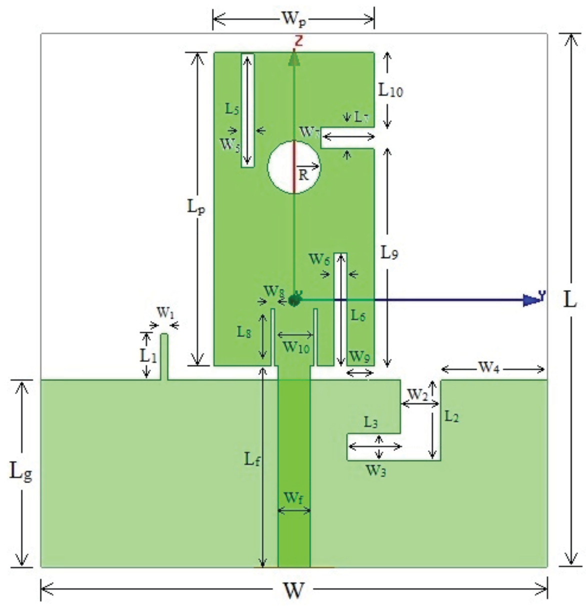


**Figure 4.** Complete Design Parameters of Antenna

From Figure 4, Patch structure can be seen clearly as its shape is consisting of rectangular shape. $L_p$ denotes the length of patch and $W_p$ is width of patch, which is responsible for the bandwidth. Inset feed of width, $W_f$ and length, $L_f$ is used to achieve 50Ω impedance. Effect of inset feed is discussed briefly in the section 3. The structure has been simulated in high frequency structure simulator (HFSS) which helped us to understand the detailed characteristics of antenna.

**Table 1.** Values of Antenna Parameters

| Parameter | Values (mm) | Parameter | Values (mm) |
|---|---|---|---|
| L | 40 | $W_4$ | 8 |
| W | 38 | $L_5$ | 8.5 |
| Height | 1.6 | $W_5$ | 1 |
| $L_g$ | 14 | $L_6$ | 8.5 |
| $L_1$ | 3.5 | $W_6$ | 1 |
| $W_1$ | 0.5 | $L_7$ | 1.6 |
| $L_2$ | 6 | $W_7$ | 4 |
| $W_2$ | 3 | $L_8$ | 4.3 |
| $L_3$ | 2 | $W_8$ | 0.2 |
| $W_3$ | 4 | $L_9$ | 16.3 |
| $L_p$ | 23.5 | $W_9$ | 2 |
| $W_p$ | 12 | $L_{10}$ | 2.3 |
| $L_f$ | 15.1 | $W_{10}$ | 3 |
| $W_f$ | 2.4 | | |

In references, there are few antennas which are compared with our proposed antenna in terms of dimensions and the operating frequency range which is listed below in Table 2.

**Table 2.** Proposed Antenna Dimension Comparison with Reference Antennas

| References | Dimensions ($mm^3$) | Freq Range (GHz) | Gain |
|---|---|---|---|
| [3] | 50×50×1.6 | 3.1–11 (112%) | 9 dB |
| [9] | 35×30×1.6 | 3.2–12 (115.7%) | 5 dB |
| [10] | 34×36×1.6 | 4.6–9.6 (70%) | 5 dB |
| [12] | 35×30×1.6 | 3.2–15.7 (132%) | 7.5 dB |
| [13] | 50×30×1.57 | 4.8–6.1 (23.8%) | 11 dB |
| Proposed Antenna | 38×40×1.6 | 2.01–7.64 (116%) | 9.4 dB |

## 3. Results and Discussion

Proposed antenna is designed in high frequency structure simulator (HFSS). Operating frequency is in between 2.01GHz to 7.64GHz which is considered as better frequency range for microwave imaging purpose. The most important part is fractional bandwidth (FBW), formula used for FBW is shown in equation (1).

$$FBW = \frac{f_h - f_l}{f_h + f_l}\, 200\% \qquad (1)$$

Antenna has 116% fractional bandwidth, as lower frequency $f_l$ is 2.01GHz while higher frequency $f_h$ is 7.64GHz. Return loss, S11 of designed antenna is shown in Figure 5.

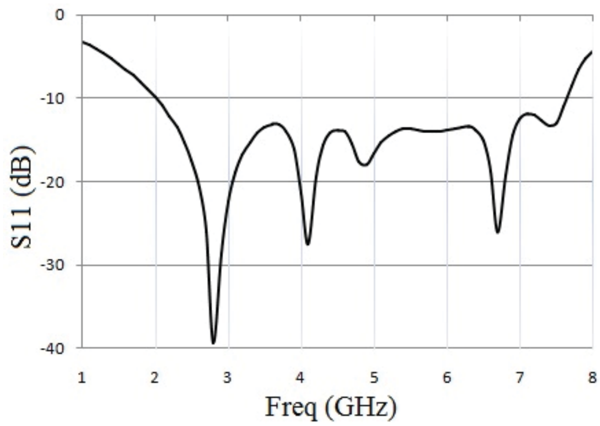


**Figure 5.** Return Loss, S11 of Proposed Antenna

After simulating the designed antenna, we got several results that are important to show and discuss in this paper. Voltage standing wave ratio (VSWR) is basically describes the power reflected from antenna and should be less than 2 [8], as we can see in Figure 6, in between the range of 2.01GHz to 7.64GHz.

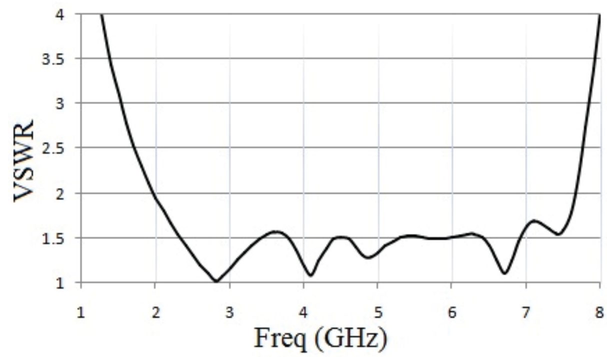


**Figure 6.** Voltage Standing Wave Ratio (VSWR) of Proposed Antenna

Antenna pattern give us more detail about the radiation characteristics. The pattern of designed antenna at frequency of 5.9GHz is shown in Figure 7.

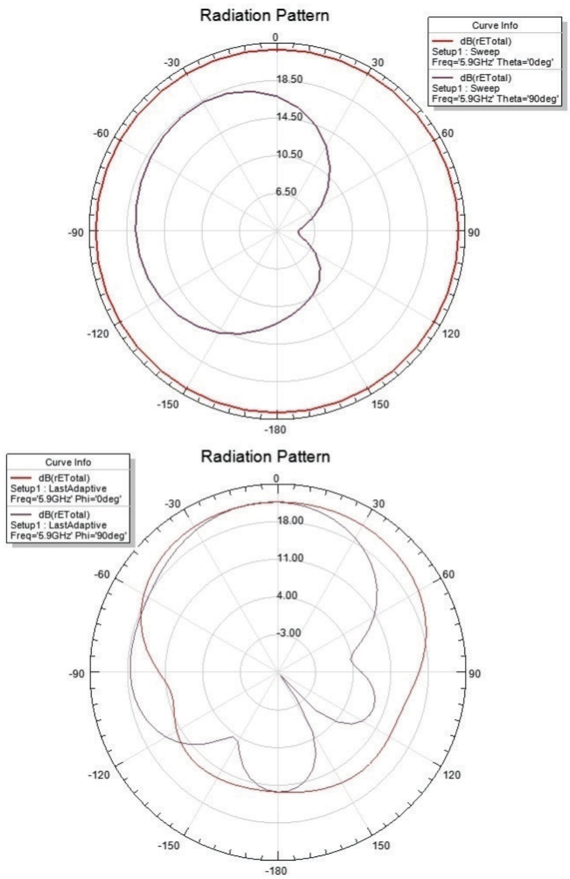


**Figure 7.** Radiation pattern at 5.9 GHz at phi=0˚ and theta=90˚

Also, we focused on increasing the gain as much as possible with the compact size of antenna. The maximum gain is 9.4dB at frequency 7.5GHz, which is quite better result. Figure 8 shows graphical representation of antenna gain.

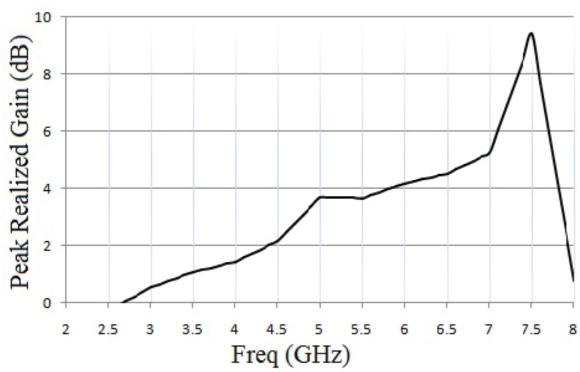


**Figure 8.** Graphical representation of Antenna Gain

## 4. Conclusion

In this paper, we designed a simple ultra-bide band (UWB) microstrip patch antenna with the fractional bandwidth (FBW) of 116%. Substrate used in proposed antenna is FR4 with the thickness of 1.6mm having relative permittivity, $\varepsilon_r$ of 4.4 and loss tangent, $\delta$ equals to 0.02. Dimension of the substrate is 38 × 40mm$^2$ which is low profile comparatively to other antennas. Microstrip feed line is used to provide 50Ω High frequency structure simulator (HFSS) is used for designing and simulation. Return loss, S11 is lesser than -10dB in the range 2.01GHz to 7.64GHz with the improved maximum gain of 9.4dB, which is considered as sufficient results. In short, a very compact design of antenna is proposed to use in microwave imaging applications such as breast cancer detection. As compared to other cancer detection techniques it is considered as one of the most efficient technique because of high sensitivity.

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