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# Analysis of a Rectangular Monopole Patch Antenna

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***Abstract*—A small printed monopole antenna for ultra wide band applications is proposed. The shape of the radiating patch considered is rectangular. The effect of the current distribution has been studied. The patch configuration is then modified to improve the impedance bandwidth. The dimensions of the patch and the distance between ground plane and radiating patch are optimized using the Genetic Algorithm. The 2:1 VSWR bandwidth of the proposed antenna covers the entire UWB application range specified by FCC that is from 3.1 GHz to 10.6 GHz.**

***Index Terms*— genetic algorithm, monopole antennas, ultra wideband antennas, patch antenna, current distribution**

## I. Introduction

With the rapid development of modern communication and semiconductor technologies, a wide variety of wireless services have been successfully introduced worldwide in the past few years. Ultra wideband (UWB) is one such technology, which promises extremely high transmission rates over a very short distance, high capacity and low power consumption. According to the regulation released by Federal Communications Commission (FCC), the UWB systems for indoor communication have been allocated to the frequency band of 3.1 to 10.6 GHz [1].

Antenna plays a vital role in any wireless communication. A well designed antenna relaxes the complexity and improves the performance of the receiver. The dimension, type and the configuration of the antenna depends on the application and the operating frequency. Due to the inherently ultra-wide operating bandwidth from 3.1 to 10.6 GHz, the circuit components to be implemented in an UWB radio face quite different challenges than those applied to a conventional narrowband system. The design of an antenna for the UWB devices is also a challenging issue. Within this operating range of frequency, the antenna should have stable response in terms of impedance matching, gain, radiation pattern polarization etc. At the same time it should be of small size, conformal, low cost and should be easily integrated into the RF circuits.

A variety of ultra broadband antennas exist for many years such as log periodic antenna and spiral antenna. But all these antennas tend to be unsuitable for short pulse applications, because log-periodic antenna and spiral antenna radiate different frequency components from different sections of the antenna, this distorts and stretches out the radiated waveform For UWB communications applications. Some prototypes have been reported for this purpose. [2-4]. A lot of work has been reported in the design of new types of planar structures some of which are the bow-tie antenna [5], the wide-slot antenna [6], fractal antennas [7], a planar monopole with the modified shape [8].

In this paper current distribution behavior of a rectangular monopole patch antenna for ultra wide band communication has been presented. The work starts with the design of simple rectangular monopole patch antenna. Then Genetic Algorithm Optimizer has been used to optimize the configuration of the patch so that one can get the optimized dimension for optimum current distribution within the specified range of the UWB application.

## II. Antenna Design

The antenna has been designed using the rectangular patch in monopole configuration. The monopole configuration provides impedance matching over the wide range of frequency. The initial Length (L) and width (W) of the patch has been determined using the following formulae [9]

$$W = \frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$L = L_{eff} - \Delta L \tag{2}$$

Where ,

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = h \times 0.412 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \text{ for } w/h \geq 1 \tag{5}$$

The antenna (Antenna1) was modeled with the calculated dimension of the patch in the IE3D, an Electromagnetic simulator [10] and analyzed. Most of the current was confined to the edge fed microstrip feed very less was fed to the Patch, which results in reduced efficiency and poor impedance matching.

To improve the impedance matching and current distribution over the desired range the edge feed was converted to the inset feed and a slit was introduced in ground plane (Antenna 2). There is no design formula available for the size of this slits, hence genetic algorithm has been utilized to optimize the dimension of the slit as well as the gap between the patch and the ground plane. Fig. 1 shows the simple rectangular patch without any optimization (Antenna 1) . Fig. 2 and Fig. 3 shows the top view of inset fed patch and modified ground plane with inserted slit. Further the notches were introduced at the four corners and all the dimensions were optimized once again. Final configuration of this patch (Antenna3) is shown in the Fig. 4 and the optimized dimensions are shown in the Table 1

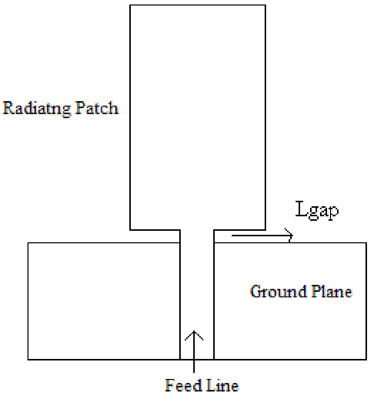



Figure 1. Rectangular Monopole Patch Antenna without any optimization (Antenna1)

## III. Results and Discussions

The current distribution and return loss characteristics of the simple rectangular patch are shown in Fig. 5 and Fig. 6 respectively. It is evident from the figure that the current distribution in the case of the simple rectangular monopole patch is confined to the edge fed microstrip line and very less amount of the current is fed to the radiating patch. The return loss characteristic for the un-optimized patch is very poor and is not covering the entire band of UWB communication. There is a region from 4 GHz to 5.3 GHz where the return loss is more than -10 dB. With inset feed it improves but not to the much extent (not shown). Insertion of the slit in the ground plane improves the current distribution as well as the return loss characteristics. The return loss characteristic for the modified and optimized patch is almost uniform and also covering the entire desired band, which is evident from the return loss characteristic curves shown in Fig. 6. Current distribution characteristics of Antenna 2 are shown in Fig. 7, which is much better compared to Antenna 1.

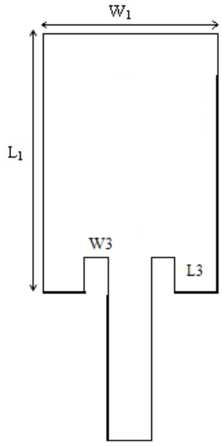



Figure 2. Inset fed top patch of rectangular monopole patch antenna (Antenna 2)

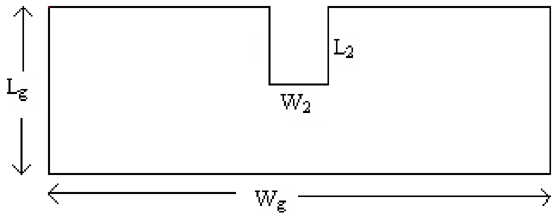



Figure 3. Modified ground plane of the monopole patch antenna (Antenna 2)

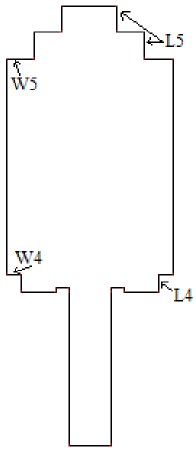



Figure 4. Final configuration (Antenna 3) of the top patch of modified rectangular monopole patch antenna

To further improve the notches were applied at the four corners of the patch. The return loss characteristic this patch has been shown in Fig. 6. It can be seen with the insertion of the notches at the four corners that the return loss characteristic has improved from 6 GHz to 9 GHz. Current distribution for this structure at 3.1 GHz and 7.9 GHz are shown in the Fig.8. The radiation pattern of this the final configuration at frequency 3.56GHz, 6.2 GHz and 9.8 GHz are shown in the Fig. 9

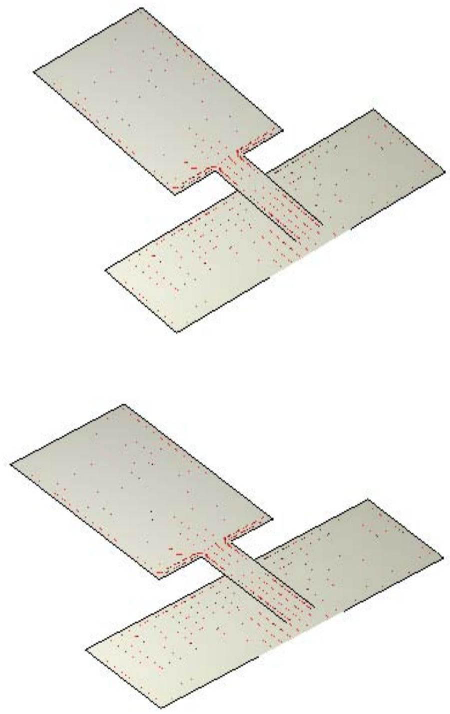


Figure 5. Current distribution characteristics antenna 1 at 3.1 GHz and 7.9 GHz respectively

TABLE 1
DIMENSIONS OF THE ANTENNA 1, ANTENNA 2 AND ANTENNA 3

| Dimensions in mm | Antenna 1 (Un-optimized) | Antenna2 (Optimized) | Antenna 3 (Optimized) |
|---|---|---|---|
| $L_1$ | 20.0 | 18.75 | 20.8 |
| $W_1$ | 12.0 | 12.0 | 12.0 |
| $L_g$ | 10.25 | 10.25 | 10.25 |
| $W_g$ | 30.0 | 30.25 | 30.25 |
| $L_{gap}$ | 1.25 | 2.5 | 1.258 |
| $L_2$ | - | 4.75 | 4.75 |
| $W_2$ | - | 2.05 | 2.05 |
| $L_3$ | - | 0.6 | 0.09 |
| $W_3$ | - | 1.0 | 1.025 |
| $L_4$ | - | - | 0.84 |
| $W_4$ | - | - | 1.025 |
| $L_5$ | - | - | 1.85 |
| $W_5$ | - | - | 2.025 |

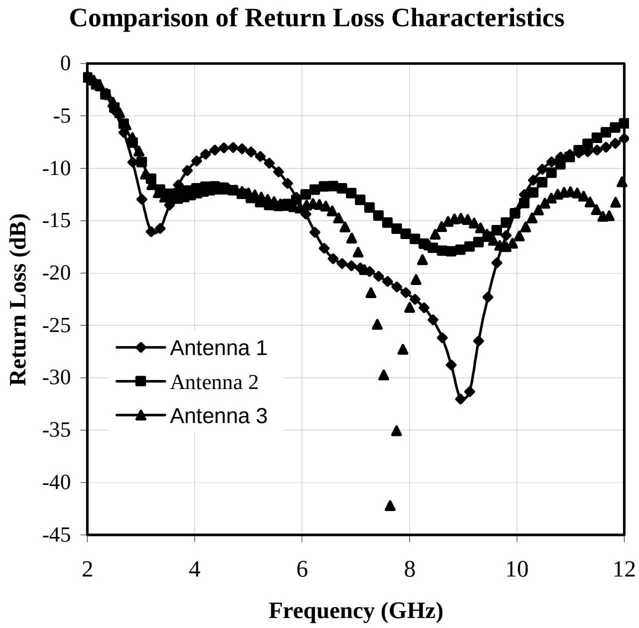



Figure 6. Comparison of return loss characteristics of Antenna 1, Antenna 2 and Antenna 3.

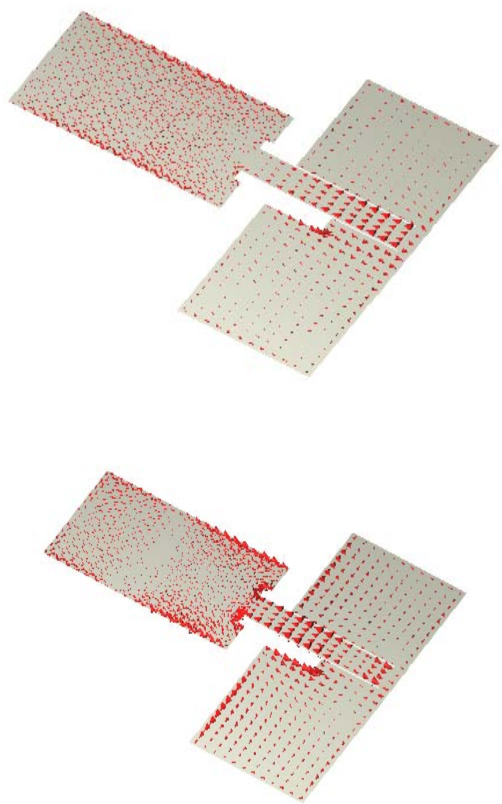


Figure7. Current distribution characteristics Antenna 2 at 3.1 GHz and 7.9 GHz respectively

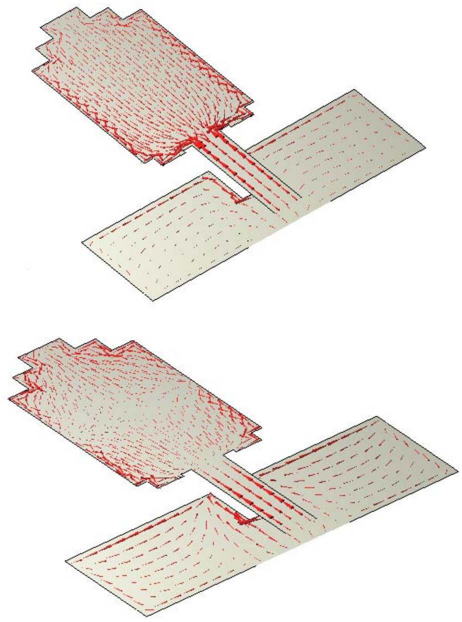
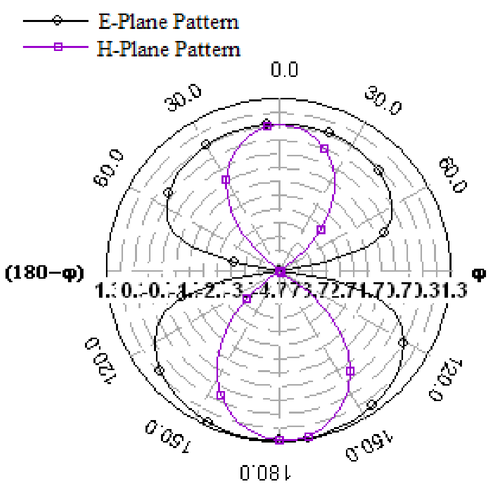


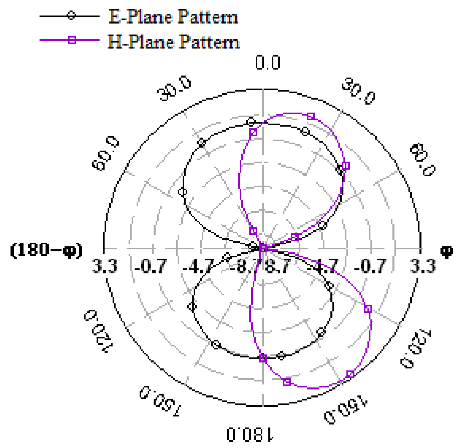
Figure 8. Current distribution characteristics antenna 3 at 3.1 GHz and 7.9 GHz respectively

## IV. CONCLUSIONS

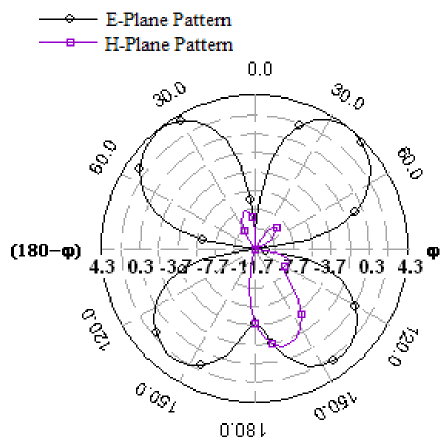
A monopole patch antenna for the UWB application has been proposed. The current distribution characteristic of the monopole patch has been studied, which in turn affects the other performance parameter of the antenna. To improve the impedance bandwidth three techniques, inset feeding, slit in the ground plane and notches at the four corner of the patch has been introduced. Further their dimensions have been optimized using the GA. The inset feeding not as effective as in the case of the conventional rectangular microstrip patch antenna. Antenna 2 shows improvement at the lower frequency around 4 GHz to 5 GHz. Antenna 3 shows improved impedance band width and covers the entire range of UWB application.




(a). at 3.56 GHz




(b). at 6.2 GHz




(c). at 9.8 GHz

Figure9. Radiation pattern of antenna 3 at 3.56 GHz and 6.2 GHz and 9.8 GHz respectively

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