Compact Tri-Stripped Rectangular Monopole Patch Antenna for UWB Application

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***Abstract*— In this paper a compact monopole antenna for Ultra-wideband (UWB) application is proposed in which three strips have been cut down at desired position from a rectangular patch to obtain operating bandwidth of 7.5 GHz from 3.1 GHz to 10.6 GHz, below – 10 dB of return loss. The proposed antenna is designed using Rogers RT/Duroid 5880 substrate of dielectric constant 2.2, with an overall dimension of 16 mm X 22 mm X 0.787 mm. To obtain the entire operational UWB bandwidth, optimization is done by changing the position of the feed line and distance between the ground plane and patch. The proposed antenna is relatively smaller than the antennas presented in recent past. The final optimized structure of the patch with simulated result shows that the proposed compact antenna has a stable and good radiation patterns across the operating band. This study could be helpful in product designing for the application like Body Area Network (BAN).**

Keywords- UWB antenna, rectangular UWB patch antenna, compact UWB patch antenna, monopole UWB patch antenna.

I. INTRODUCTION

UWB transmission is gaining popularity these days due to an increase in demand for high data transmission capability at low cost in communication systems. It can be used in many applications like health monitoring, data sensor networks and precise location-finding. According to current definition by the Federal Communications Commission (FCC), for UWB operation, the bandwidth of the transmitted signal from an antenna should be more than 500 MHz or 20% of the center frequency and – 10 dB below radiated transmission [1]. It operates in the range of 3.1 GHz – 10.6 GHz with an absolute bandwidth up to 7.5 GHz. This emerging radio technology is used to transfer information over a large bandwidth. Due to large bandwidth, it transmits lesser power over the short range. Large bandwidth available being the main advantages of UWB, other advantages are effective reduction in fading and interference problems, increase in SNR and channel capacity and hence this improves the overall UWB system performance. Despite of all these advantages, one of the challenges is to design an antenna that can work efficiently in the UWB operating range. Planar monopole antenna is preferred for UWB application, because of its stable radiation pattern and compact size [2].

This paper focuses on a patch antenna for UWB operation because of its compactness and low manufacturing cost. Though many patch antennas have been proposed in the recent past like the Swan shape [3] and a circular shape like antenna [4], but the proposed patch antenna presented in this paper has relatively smaller dimensions. The initial design starts with a rectangular monopole patch antenna and optimizes it by cutting rectangular strips and formatting its structure in such a way as to get the desired UWB characteristics which is discussed in section (2). Discussion and analysis of the simulation can be found in section (3). Finally conclusion is given in section (4).

II. ANTENNA DESIGN

The proposed antenna starts with a simple rectangular patch whose dimension parameter, length and width, are crucial in deciding antenna characteristics. The structural parameter of rectangular patch antenna having length (L) and width (W) can be determined from the following expressions [5]:

$$W = \frac{1}{2f_r\sqrt{\epsilon_o\mu_o}}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{r,eff}}\sqrt{\epsilon_o\mu_o}} - 2\Delta L \quad (2)$$

$$\epsilon_{r,eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (3)$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{r,eff}+0.3)\left(\frac{W}{h}+.264\right)}{(\epsilon_{r,eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

$$L_{eff} = L + 2\Delta L \quad (5)$$

$$f_r = \frac{c}{\lambda} \quad (6)$$

$$L_\lambda = \frac{\lambda}{4} \quad (7)$$

The first fundamental frequency f_1 is obtained by the given general equations. The actual length of the monopole antenna's arm is proportional to the operating wavelength, which decides the first fundamental frequency. The harmonics (f_2, f_3, f_4, …) are produced by the fundamental frequency f_1. The UWB characteristic can be obtained by the combination of these multiple resonant frequencies [6] generated by a patch antenna as shown in the Figure 1.

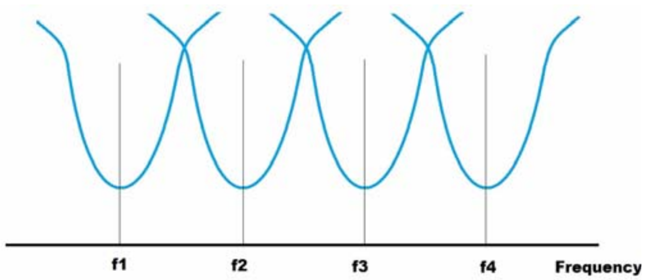

Figure 1. Combination of Multi Resonance frequency.

A rectangular substrate of Rogers RT/Duroid 5880 having length L_S and width W_S is used with a dielectric constant ε_r = 2.2 and loss tangent σ = 0.0009 of thickness h. The width and length of the rectangular patch is taken as W_P and L_P as shown in Figure 2.

An excitation is given through a 50 Ω microstrip feed line with a width W_M from the edge center of the substrate. To optimize the antenna characteristics, three strips have been cut off from the rectangular patch at different positions (P_1, P_2 and P_3), with each strip having length L_K and width W_E as shown in Figure 3. The removed strips increase the current path length [7], [8].

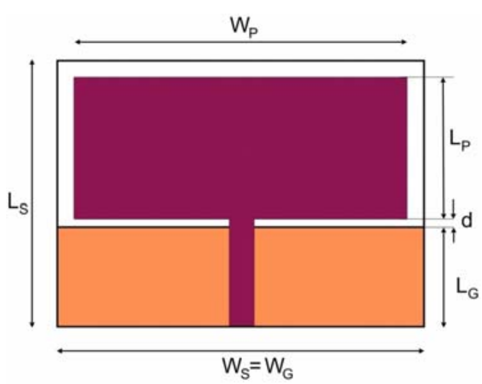

Figure 2. Simple Rectangular Patch.

The design is shown in Figure 3, where P is the position of microstrip line from the center of the width of substrate [9]. The ground plane is provided below a height h from the patch plane which is of length L_G and width W_G. The distance between the planes of the ground and the patch is d.

The optimized dimensions of proposed antenna are L_S = 16 mm, W_S = 22 mm, L_P = 8.6 mm, W_P = 20 mm, W_M = 1.5 mm, L_K = 7.1 mm, W_E = 1.5 mm, L_G = 6 mm, W_G = 22 mm, P = 2 mm, h = 0.787 mm and d = 0.4 mm.

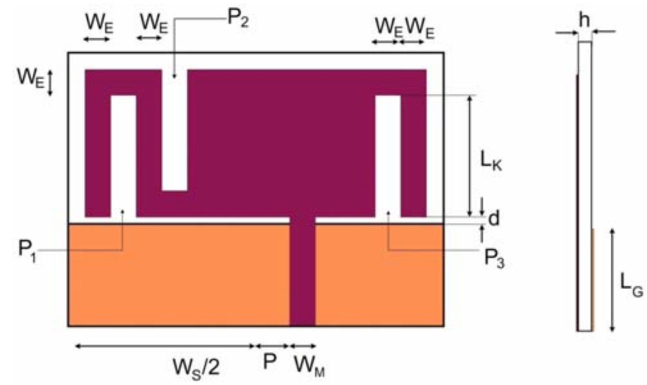

Figure 3. The optimized structure of proposed Antenna.

III. SIMULATION ANALYSIS AND DISCUSSION

All simulations are done using Ansoft HFSS Version 13 Simulation Software [10] and results are analyzed. The return loss characteristic of the un-optimized simple rectangular patch of Figure 2 is shown in Figure 4 with different values of d. The first resonance at 3.42 GHz is obtained with d = 0.4 mm having its harmonic at 10.27 GHz. It can be observed from the graph that the return loss characteristic does not converge to UWB, due to the lack of proper current path length [4],[8],[11].

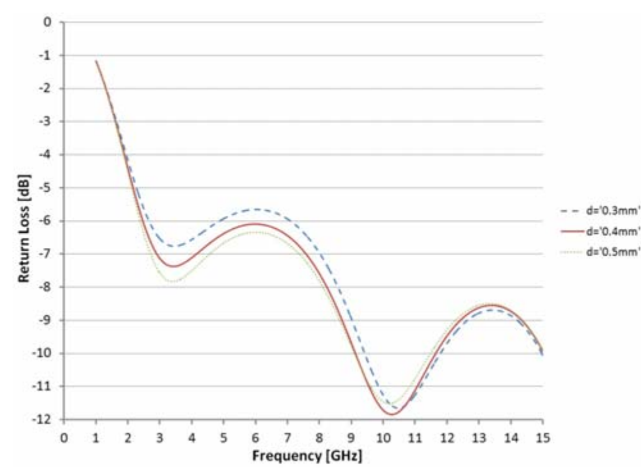

Figure 4. Return loss of Simple Rectangular Patch.

To increase the effective current path length, the first strip has been cut from position P_1 and a bandwidth range of 2.60 GHz – 5.60 GHz is observed below – 10 dB. When the second strip is cut from position P_2, a bandwidth range of 2.60 GHz – 5.60 GHz and 9.60 GHz – 16.49 GHz is observed below – 10 dB. After cutting the last strip from position P_3, a range from

2.65 GHz and above 10.60 GHz is observed below – 10 dB covering the entire UWB range.

By removing three strips as shown in Figure 3, the simulated return loss results are obtained by optimizing parameters d and P. It is evident from the Figure 5 and Figure 6 that good return loss characteristic is produced, which is below – 10 dB and covering the whole UWB range of 3.1 GHz – 10.6 GHz. It is also concluded that d = 0.4 mm and P = 2 mm are the optimized positions for this patch.

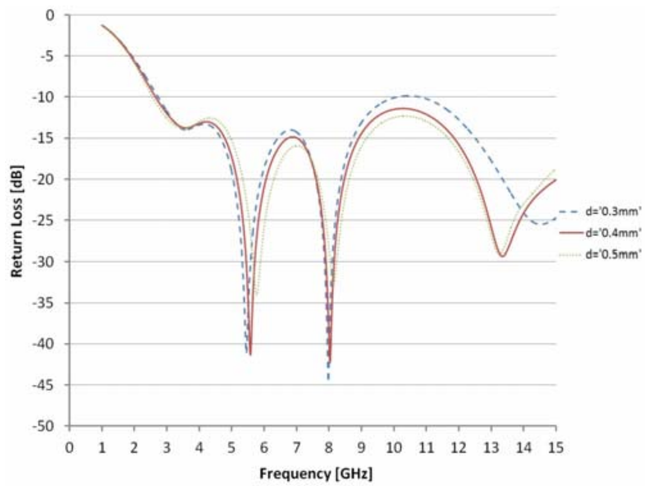

Figure 5. Return loss variation with different values of d.

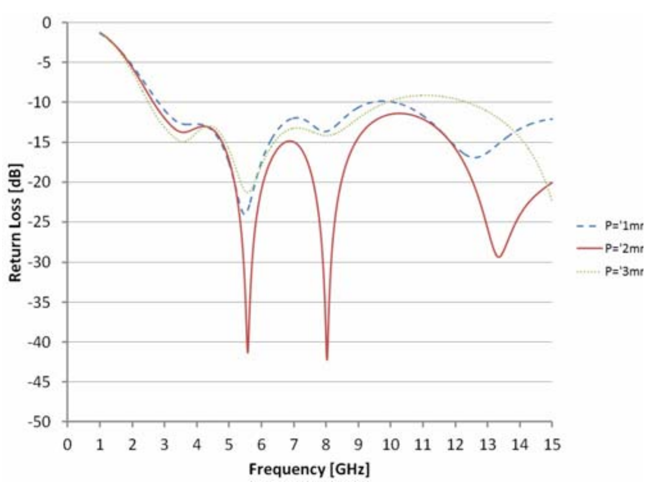

Figure 6. Return loss variation with different values of P.

Multiple resonances occur at 3.58 GHz, 5.57 GHz, 8.02 GHz and 13.34 GHz. The vector current distributions at these four different frequencies are shown in Figure 7 (a), (b), (c) and (d). At the first resonant frequency there is not much variation in current distribution along the arm length but it is observed that there is an alternate change in current distribution along the patch arm as higher resonant frequencies are encountered.

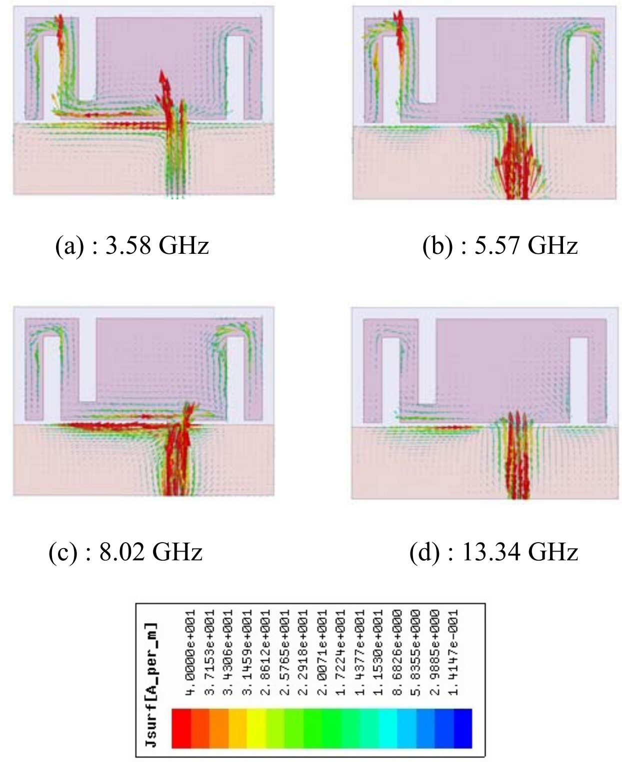

Figure 7. Vector current distribution at different frequencies.

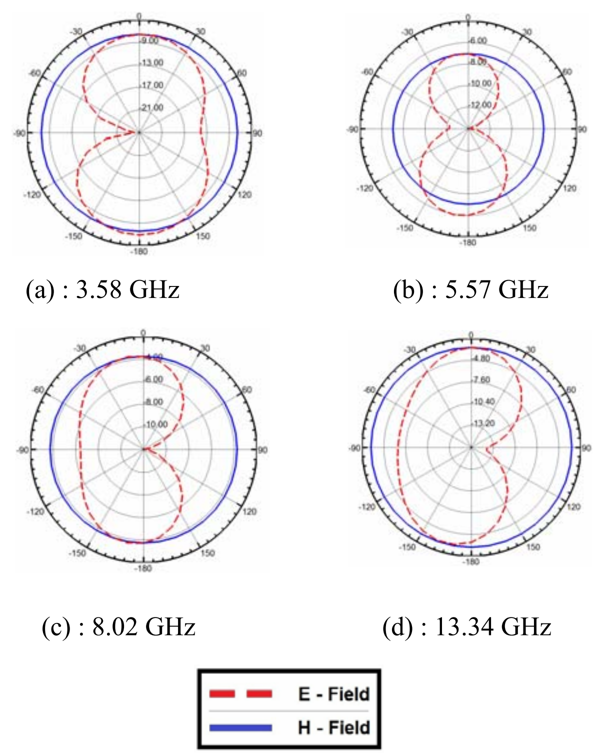

Figure 8. E and H Radiation Pattern at different frequencies.

It is concluded from the results that after increasing the current path length, the return loss characteristics of the antenna gets better with near multiple resonances due to which the entire UWB range is covered [6],[8]. The Electromagnetic patterns of the presented antenna at different resonant frequencies are shown in Figure 8 (a), (b), (c) and (d).

IV. CONCLUSION

This paper presents a UWB antenna which is relatively smaller in dimensions and simple in structure. It is observed that return loss variation with frequencies is below – 10 dB throughout the entire UWB frequency range. It is seen that increasing the current path by cutting off strips from a rectangular patch at desired positions shifts the first resonance at a lower frequency, whose harmonics can be controlled by varying patch parameters and converge the antenna to work in UWB operating range. The desired UWB characteristics are obtained by optimization of antenna parameters like position of the feed line and distance between the ground plane and patch. The simulated result indicates an omnidirectional radiation pattern over the operating frequency band hence the proposed antenna can be an ideal candidate in various UWB application.

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