Design of Dual-Band Microstrip Patch Antenna with Chair Shape Slot for Wireless Application

Avneet Kaur[1], Davinder Prakash[2]
Professor,
Electronics & Communication Engineering,
Chandigarh Engineering College, Landran, Mohali

Abstract- **This paper presents rectangular microstrip patch antenna for wireless applications. The proposed microstrip patch antenna has dual frequency band i.e. S and C. Moreover gain has obtained having range 3.41dBi to 7.93dBi. The antenna is fed by co-axial feed line technique and comprises of Roger RT/duroid 5870.To understand the characteristics of the proposed antenna the parametric study is to be performed. In addition, under the operating band good antenna characteristics observed like radiation pattern, gain and return loss. The proposed antenna is simulated and designed using HFSS.**

Keywords – Microstrip antenna, Dual band, Chair-shape patch, Gain.

I. INTRODUCTION

Mostly, microstrip patch antennas are used due to the low cost, low weight, and ease of fabrication [1-3]. But, with the advantages of these microstrip patch antenna suffer from disadvantages like narrow bandwidth and low gain [2-5]. But the narrow bandwidth is needed in many applications such as in government security systems. The rectangular microstrip patch antenna can be designed in many shapes such as square, circular, triangular, elliptical etc [1]. There are many techniques, are used to extend the efficiency and bandwidth by increasing the height of substrate. But, there is a problem by increasing the height of substrate, undesirable surface wave entered, which extract power from the total available for direct radiation. Usually, in the microstrip patch antenna the patch is mounted on the top of the substrate [8]. For the microstrip patch antenna the dielectric substrate Roger RT/duroid 5870 is used. There are many types of feeding methods such as proximity coupled feed; coaxial feed, microstrip feed, and aperture coupled feed [9]. However, the coaxial feeding is used in slotted rectangular microstrip patch antenna.

II. DESIGN & PARAMETRIC STUDY

Design of microstrip patch antenna must be in a way so that its pattern maximum is normal to the patch. Microstrip patch antenna has very small thickness as compared to wavelength i.e. $t \ll \lambda_o$ & its height is very small with wavelength, usually $0.003\lambda_o \leq h \leq 0.05\lambda_o$ [6-7]. The length L of the element is typically $\lambda_o/3 < L < \lambda_o/2$ used for a rectangular patch [1]. For the design of microstrip patch antennas, many types of substrates can be used and their dielectric constants are usually in the range of $2.2 \leq \varepsilon_r \leq 12$.

The effective dielectric constant are referred to as the static values for low frequencies which is given by [10-11] :

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

ϵ_{reff} = Effective dielectric constant

ϵ_r = dielectric constant of substrate

h = Height of substrate

W = Width of patch

Electrically patch of microstrip antenna look larger than its physical dimensions because of fringing effect. Patch dimensions with its length have been extended on both ends with ΔL, which is function of both dielectric constant and width of height ratio (W/h) [3-4].

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (2)$$

After extension length of patch is now described as effective length of patch and described below,

$$L_{eff} = L + 2\Delta L \quad (3)$$

Effective length for resonance frequency f_o is denoted as,

$$L_{eff} = \frac{c}{2f_o\sqrt{\epsilon_{reff}}} \quad (4)$$

Resonant frequency of microstrip antenna is described below,

$$(f_r)_{010} = \frac{1}{2L\sqrt{\epsilon_r}\sqrt{\mu_o\epsilon_o}} = \frac{v_o}{2L\sqrt{\epsilon_r}} \quad (5)$$

Width W is described for effective radiation,

$$W = \frac{c}{2f_o\sqrt{\frac{\epsilon_r+1}{2}}} \quad (6)$$

The length and width of the ground plan can be calculated as [3]:

$$L_g = 6(h) + L \quad (7)$$

$$W_g = 6(h) + W \quad (8)$$

Where L is the length of the substrate and W is the width of the substrate.

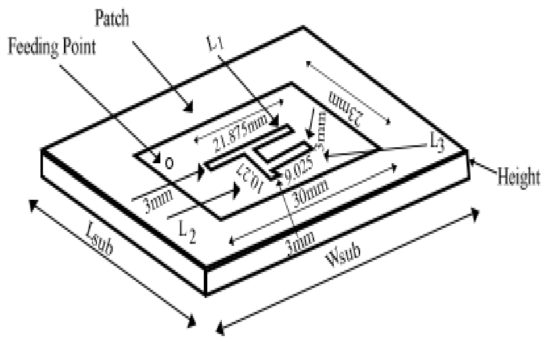

Figure 1- Schematic diagram of proposed chair shape antenna

The rectangular patch is mounted on the standard substrate Rogers RT/duroid 5870 with the dielectric constant ε_r=2.3 and thickness 3.17 mm. The substrate dimensions are W_{sub} & L_{sub} and with the co-axial feeding. To calculate the physical characteristics of microstrip patch antenna with width W = 30mm and length L = 23mm [3]. The rectangular microstrip patch antenna attains the resonance frequency 3.90 GHz. The dual operating band is achieved by placing the three vertical slots on the patch, by adjusting the length and width of the slots.

Parameters	Values	
Length of substrate (L_{sub})	42.29	
Width of substrate (W_{sub})	48.66	
Height of Substrate	3.17	
Length of Patch	23	
Width of Patch	30	
Slots	Length(l)	Width(w)
L_1	21.875	3
L_2	10.27	3
L_3	9.025	3

Table 1 – List of different parametric values

III. SIMULATION RESULTS AND DISSCUSSION

The return loss obtained after the analysis of antenna is -29.38 dB at 2.59 GHz and -13.40 dB at 5.69 GHz. It shows the reflected signals with respect to incident signal.

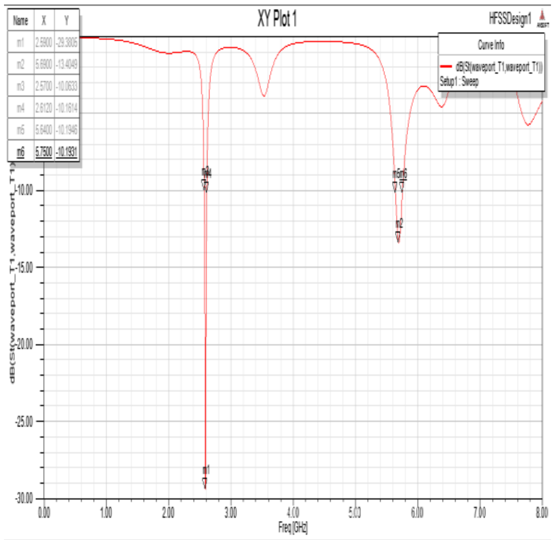

Figure 2 -Return Loss for Dual band

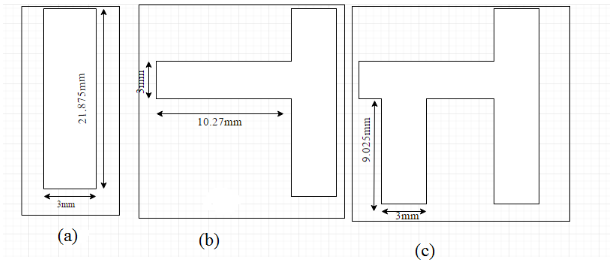

Figure 3- The transformation of I shaped and inverted T shaped slots into chair shaped structure.(a) I shaped slot i.e. L_1 (b) inverted T shaped slot i.e. L_2 (c) proposed chair shaped structre.

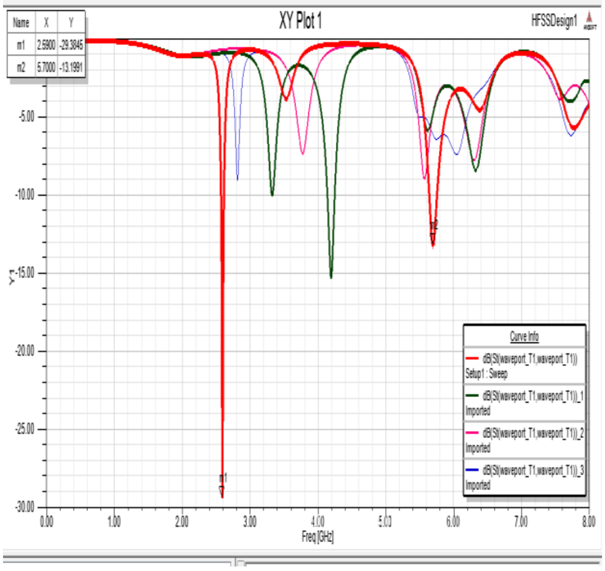

Figure 4 – Comparison of Return loss (a) return loss of proposed antenna (b) return loss of plane patch without slots (c) return loss of I shape slot (d) return loss of inverted T shape slot

From the graph in figure 4, it is clear that the return loss of proposed antenna is better. When the simple substrate is used means without slots then the very low value return loss are obtained. Therefore, chair shaped slots on the substrate are improves the antenna performance

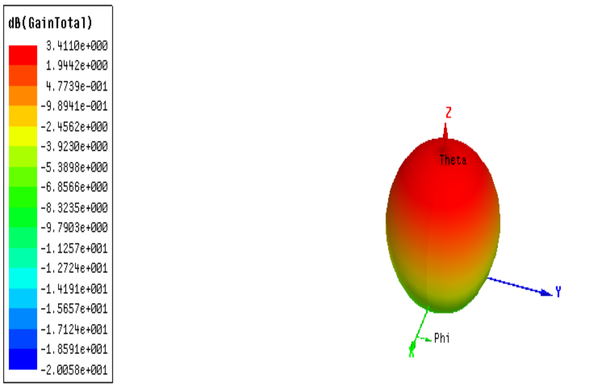

Figure 5 (a) –3D Gain observed 3.41dBi at 2.59GHz

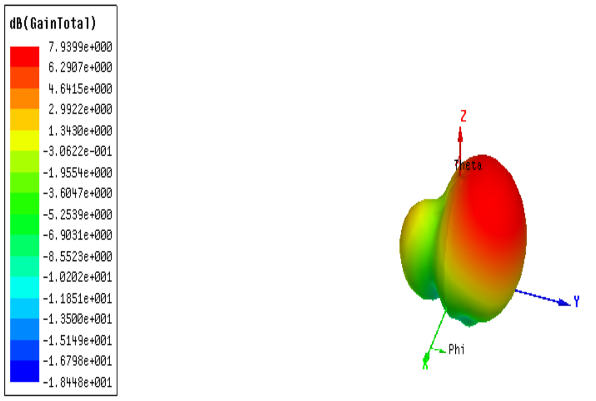

Figure 5(b) – 3D Gain observed 7.93dBi at 5.69GHz

Radiation pattern

The radiation pattern of the proposed antenna are measured at normalized E-plane (*yz-plane*, $\Phi = 90^{\circ} plane$) and H-plane ($xz - plane, \Phi = o^{\circ}\ plane$) at their central frequencies 2.59GHz and 5.69GHz as shown in below figure 6(a) & 6(b) respectively . These far-field radiation patterns are simulated at HFSS software.

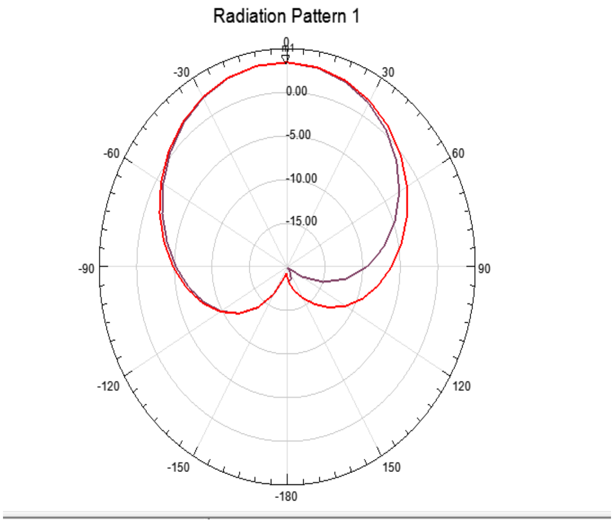

Figure 6(a) –Radiation pattern at 2.59GHz

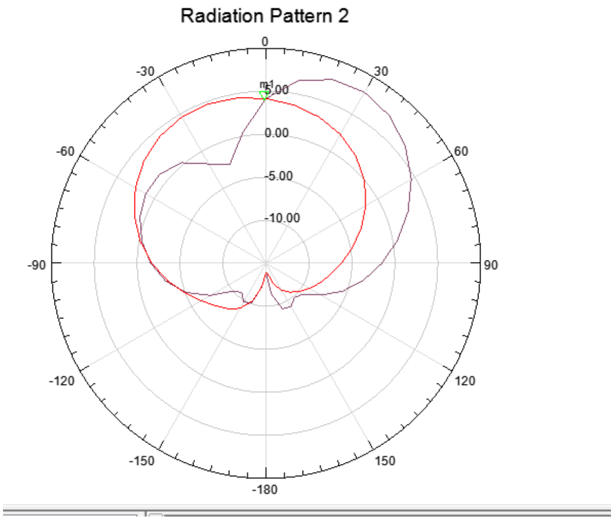

Figure 6(b) – Radiation pattern at 5.69GHz

V. CONCLUSION

The proposed antenna has simple design and simple geometry. The simulated results are obtained in HFSS 13. The rectangular patch antenna contains bandwidth 1.64 % (40MHz) at 2.59 GHz for S band and 1.93% (110MHz) at 5.69GHz for c band. These bands can be used for satellite communication and Wi-Fi devices. Moreover, the proposed antenna has many advantages like small size, higher gain (3.41dBi at 2.59GHz & 7.93dBi at 5.69GHz) & outstanding radiation pattern.

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