The Analysis of Element Shape for Multi-Band Antenna Applications

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Abstract- *A multi-band microstrip antenna is proposed in this paper. The antenna structure is made to resonate at multiple frequencies by introducing two small rectangular strips attached vertically at the edge of a conventional rectangular patch antenna. The designed antenna resonates at S and C bands. The final optimized dimensions of the basic rectangular patch antenna are 40 x 15 mm and two rectangular strip lines are spaced at 2.5 mm with different dimensions. The simulated antenna shows that the return loss of the proposed antenna at resonant modes are lower than -10 dB. For multi-band applications, the simulation results provide good performance in term of return loss as well as radiation pattern.*

I. INTRODUCTION

Recent advancements in the field of wireless communication systems require a compact multi- band antenna that supports diverse applications at different frequencies. The study of multi-band antennas is crucial owing to its increasing demand in the sophisticated systems. Many techniques have been proposed to relax the system burdens. By miniaturization of patch antenna size will open up ways of solving problems for mobile communications. However, conventional ways of size reduction in patch antenna are shorting post, slots etc.

Antenna optimization for compact size and achieving multi-band using coplanar waveguide feeding technique is investigated by Jagath K. H. Gamage1 et al [1] for WLAN applications. Antenna which consists of a square radiating stub and a ground plane with a pair of L-shaped parasitic structures and an inverted T-shaped strips is suggested for multi-band operation [2]. Here, the L and inverted T-shaped strips are responsible for multi-band radiation. A rectangular radiating patch with symmetrical L and U-shaped slots is proposed for multi-band operation [3] at WLAN / WiMAX applications. For all these antennas [1-3] resonant frequencies of multi-band are controlled by the dimensions of the inserted strips. Single feed stacked patch antenna for triple band operation is presented by O. P. Falade et al [4]. However, fabrication complexity increases with stacked layers. The multi-band using fractals self- affine property is thoroughly investigated by Sachindra et al [5]. By replacing one of the radiating edge of the rectangular patch with E-shaped fractal and a simple probe feed, multi-band operation is achieved [6]. By cutting U-slots on the patch and feeding with L-probe, dual and triple band antenna is designed. The number of resonance bands are equivalent to the number of U-slots inserted on the patch [7].

Microstrip antennas perform multiple functions with the use of a single antenna aperture, thus increasing the antenna efficiency. The proposed antenna has been designed to operate at dual and triple bands. The presented antenna operates at the resonant frequencies of 2.4 GHz, 3.8 GHz, 4.7 GHz, 4.8 GHz, 5.1, 5.8 GHz, 6.5 GHz, and 7.4 GHz is useful for Wi-Fi, WLAN, Hiperlan, WiMAX applications.

II. THE RECTANGULAR SHAPED PATCH ANTENNA DESIGN

The geometry and configuration of the multi-frequency planar antenna is illustrated in Fig. 1. Initially a single rectangular patch without strip lines is designed to resonate at a frequency of 2.45 GHz. After that, two strip lines are added and the patch resonates at triple-band. Here, for parametric study dimensions of the two strip lines are used. The position of the probe feed is optimized at different positions for all patches for better return loss.

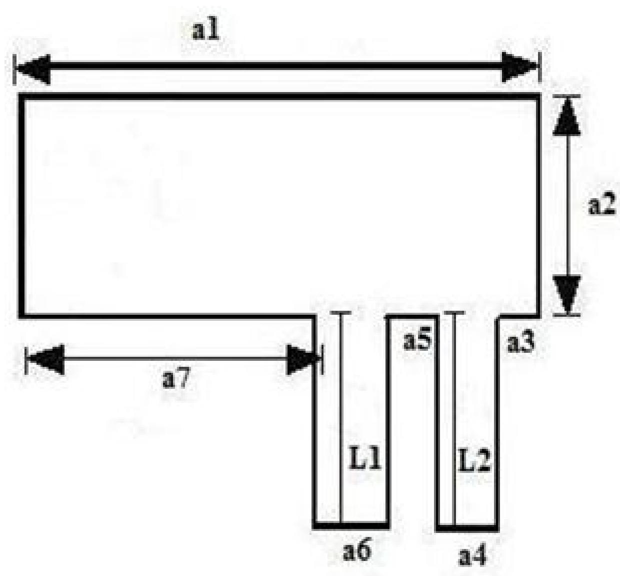

Fig -1 Geometry of the proposed rectangular patch antenna

Table-1 Dimensions of the Patch antenna

Parameter	Values (mm)
a1	40
a2	15
a3	2.5
a4	5
a5	2.5
a6	5
a7	25

The dimensions of the antennas are tabulated in Table 1.

Design Parameters:

The length and width of the basic patch according to the desired frequency are as follows.

Width of the patch (W):

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

Length (L) is given by,

$$L = \frac{\lambda_0}{2\sqrt{\varepsilon_{reff}}} - 2\,\Delta L \quad (2)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.262\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.813\right)} \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-1/2} \quad (4)$$

The resonant frequency occurs at multiple bands by varying the approximate lengths of the strip line and width value for the strip is 5 mm. The position of the probe feed is optimized for four different patches.

III. SIMULATION RESULTS

RT/Duroid 5880 planar substrate with a 1.57 mm thickness is used. A standard 50 Ω microstrip probe fed is used to excite the multiple resonant bands, with good matching. The feeding point is set up at the optimized point from the ground plane.

The parameters values are:

1. Dielectric constant ( ) =2.2.
2. Center Frequency (fo) = 2.45 GHz
3. Substrate Height (h) = 1.57 mm

Multi-band resonant frequencies are observed in the simulated return loss curve due to the increase of electrical length of the patch

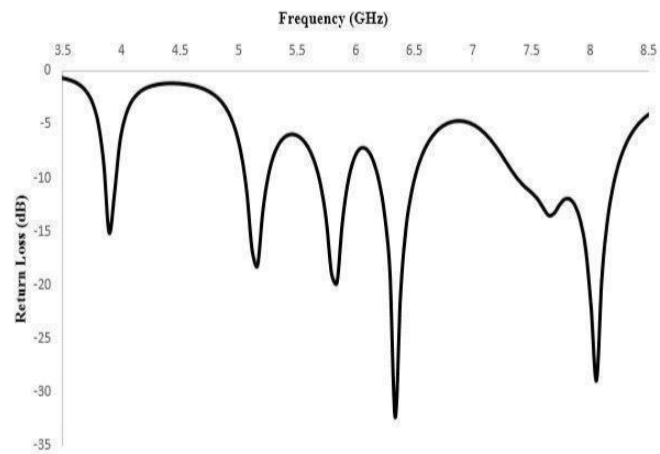

Fig-2 Return Loss of Patch 1

Table-2 Dimensions of the strip lines with corresponding RL and 10 dB Impedence BW (%) results.

Strip Lines Length (mm)	Freq (GHz)	RL (dB)	10 dB Impedance BW (%)
Patch 1	3.8	-15	2.5
L1=29.75	5.1	-18.2	4.87
L2= 1.25	5.8	-19	4.46
	6.3	-32.34	4.57
Patch 2 L1 =10	5.3	-19.5	2.8
L2 =10	7.6	-15.6	3.9
Patch 3	2.4	-40.7	2.12
L5 =6.75 L6 =2.75	4.7	-11.7	2.5
Patch 4	4.8	-26.6	3.25
L7 =4.75	6.5	-22.9	3.87
L8 =4.75	7.4	-19.86	4.2

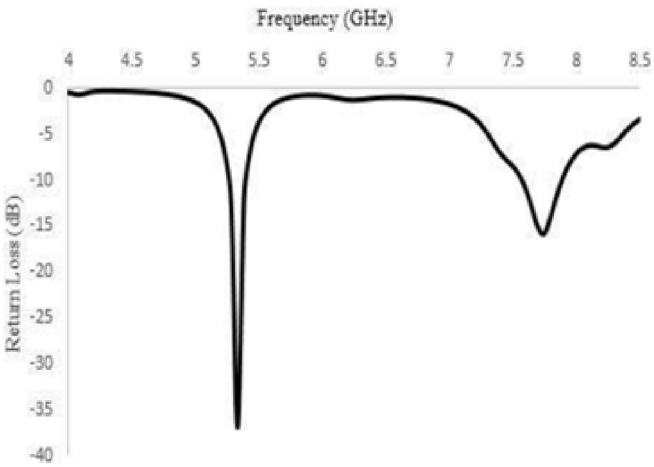

Fig-3 Return Loss of Patch

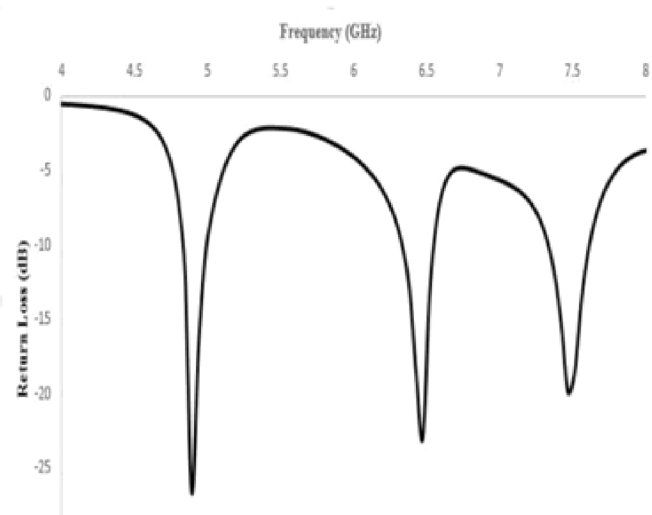

Fig-4 Return Loss of Patch 4

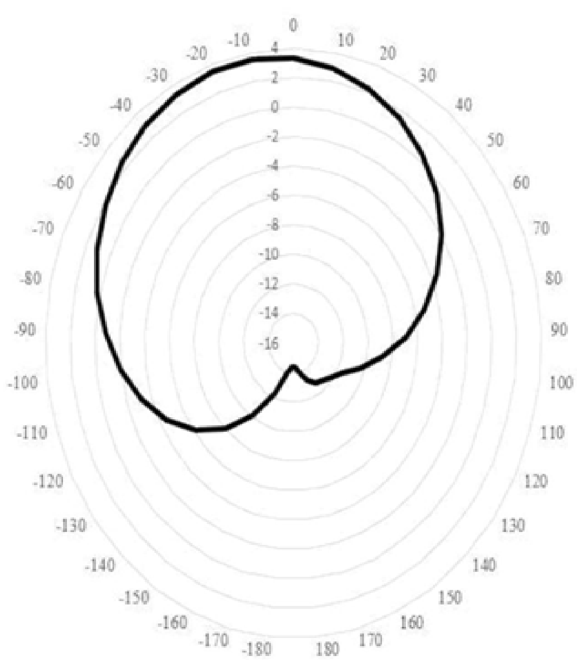

Fig-5 Radiation Pattern at 2.4 GHz

Fig-6 Radiation Pattern at 4.8 GHz

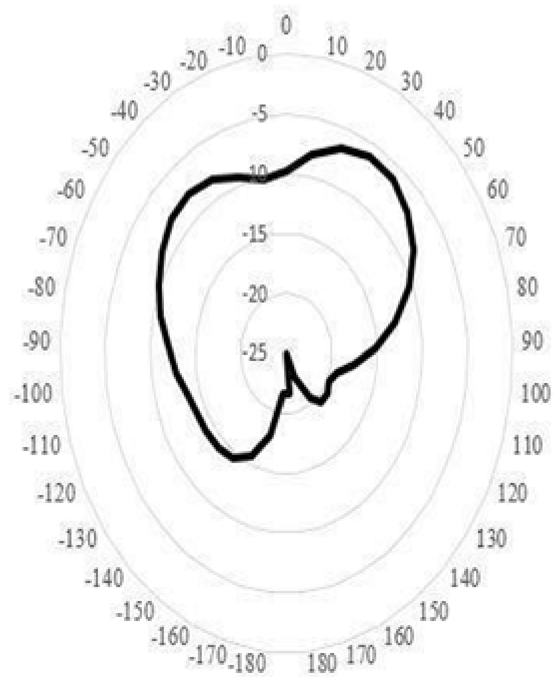

Fig-7 Radiation Pattern at 5.1

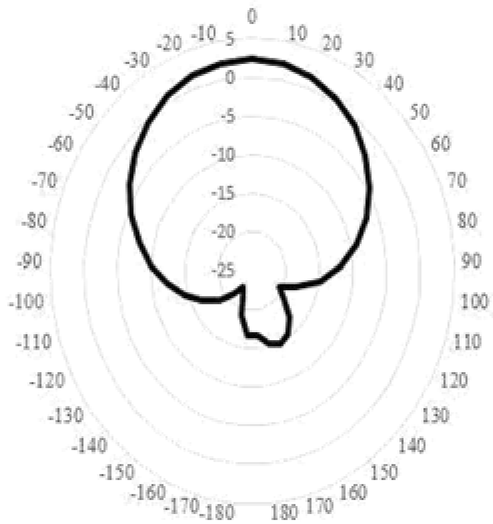

Fig-8 Radiation Pattern at 7.4 GHz

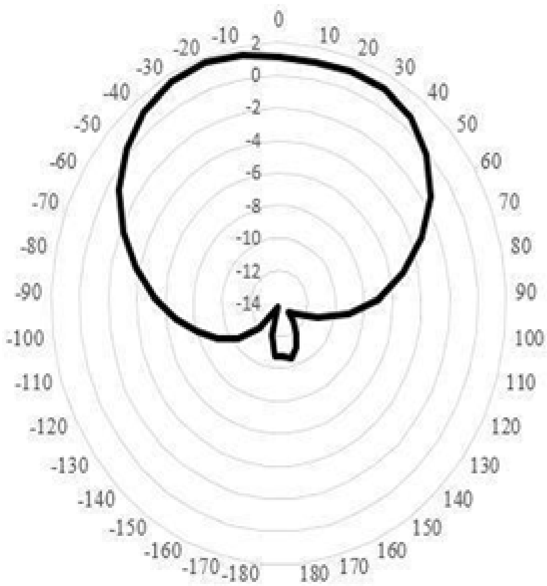

Fig-9 Radiation Pattern at 7.4 GHz

The radiation pattern at resonant frequencies are shown in Fig 6-12, calculated beam width is in the range of 80^{o} - 90^{o}.

The antenna simulated in HFFS 15.0 (high frequency structural simulator) and the performance is verified at S and C Band frequencies. The results show that the rectangular shaped structure can be used at multiple operating frequencies with extended lines.

IV. CONCLUSIONS

In this paper, we have successfully exhibited a new conception of the rectangular antenna structure with two strip lines attached for S and C band frequencies. Finally, the proposed antenna has been simulated to perform the Wi-MAX and WLAN applications.

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