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Research Article

Design and Fabrication of a 2.4 GHz Right Hand Circular Polarized Micro-Strip Patch Antenna

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Abstract: In this paper, we present a single feed circularly polarized microstrip patch antenna operating at 2.4 GHz WLAN frequency. A typical microstrip patch antenna is fabricated on a metal coated dielectric substrate where the metallic antenna patch is defined on the top of the substrate, whereas the bottom of the substrate acts as a ground plate. These antennas are typically used for civil and military communication purposes. Before fabrication, the presented antenna was first designed, simulated and optimized in CST Microwave studio. The circular polarization was achieved by perturbation of the edges, making the design optimization a bit challenging. The simulated and measured return loss of the proposed antenna is -27 dB and -13.34dB, respectively. Whereas, the gain came out to be 6 dB. The obtained results show that the presented antenna has the quality of right hand circular polarized antenna.

Keywords: Circular Polarization, Microstrip Patch Antenna, Antenna Gain, WLAN, Single Feed.

1. INTRODUCTION

The microstrip patch antenna structure, a very worthful and fascinating study, is currently vastly investigated to expand and explore its domain and reliability [1,2]. Microstrip patch antennas are now a days, used for a variety of wireless applications, ranging from WLAN communication [3,4] to Wi-Fi [5], Bluetooth [6] and many others. The first microstrip antenna was introduced in 1953 by Deschamps [7], but the fabrication for the first time took place in 1970's. Microstrip antenna is a low-profile antenna, its simple design/structure and low cost makes it one of the most appealing antennas. The fabrication process of the microstrip patch antennas is very economical which makes it suitable for mass production. The generation of linear and circular polarization and much more comes under its advantages [8].

Wave polarization is the orientation of the wave around a fixed point when travelling in space. The polarization plane contains electric and magnetic field vectors which are perpendicular to each other, the plane of polarization is always perpendicular to the propagation plane. Electric field vector tip draws a contour which is either circular, elliptical or linear and describes the wave polarization. The direction of the main beam is considered to be the direction of polarization [9].

In order to decrease transmission losses, the polarization matching between the transmitting and receiving antennas is very important. To attain the polarization match, circularly polarized antennas give interesting results by allowing the angle between transmitting and receiving antennas to be more flexible, minimizing multi path reflections effect, and allowing transmitter as well as receiver mobility [9].

Circular polarization takes place when Ex and Ey of the electric field vector have same magnitude and a phase shift of 90°. In the modern days of the antenna design industry, circulatory polarization is very important. It has diverse military and

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commercial applications, some of those applications include Global positioning system (GPS), Mobile satellite, Wireless local area network (WLAN) and Radio-frequency identification (RFID).

Single feeding techniques are often applied due to their simplicity, structure compactness, less expenses and facile manufacturing [7]. Among circular polarized microstrip patch antennas, the single fed antenna is the simplest one to generate circular polarization [10]. Circular polarization with single feed can be achieved by two degenerate modes of single feed, having equal amplitude and a phase difference of 90^{o}. Simple microstrip antenna with a basic shape is a linearly polarized antenna, to make it a circular polarized antenna some changes should be made to the structure of the antenna. Segments' perturbation is used for splitting the field into two identical modes with a phase shift of 90o, and thus the requirements of circular polarization and full filled.

A number of iterations should be carried out to optimize to perturbation segments to a degree where the fields are spilt into two identical modes with a phase difference of 90^{o} [7,11]. Truncating the corners of the square patch antenna is a basic perturbation approach to attain circular polarization.

The previously reported 2.4GHz antennas are either linearly polarized [12-14], or circular polarized with either complex geometry [15-17] or only simulation results [18-20]. This article presents a simple circular polarized antenna obtained through the truncation method. Truncating the corness of the square patch antenna is a basic perturation approach to attain circular polarizaton. Microstrip feeding process is used to investigate the radiation pattern, return loss and the axial ratio of the antenna using the commercial software CST and the results are validated with experimental measurements.

2. MATERIALS AND METHODS

2.1 Antenna Design

A square microstrip patch antenna is presented in this article. A basic microstrip patch antenna is presented in Figure 1, which reveals the elemental geometry of a rectangular patch antenna fed from quarter wave transformer transmission line, the quarter wave transformer is used for impedance matching. The antenna is generally operated at or near the resonance frequency to acquire real valued input impedance.

Different techniques and models are at hand to determine the resonant frequency, with cavity model normally producing accurate results [22]. Fringing fields comes to an action to extend the patch's length called the effective length. Thus, the length of the half wavelength of the substrate dielectric material is slightly larger than the half-wave patch. The size of length reduction in half wave path depends on dielectric constant ϵ_r, height of substrate h and width of the patch W. Different approaches can be used from the available ones to approximate the resonant length, still empirical adjustments are often needed in practice [23]. The initial approximate value of width and length calculated for the resonant patch antenna to operate at 2.4 GHz is [24].

$$L = 0.49\lambda_d = 0.49\frac{\lambda}{\sqrt{\epsilon_r}} \tag{1}$$

where λ being the free-space wavelength, λ_d is the wavelength in the dielectric, and ε_r the substrate dielectric constant. The design uses (FR-4) substrate with a height of 1.6 mm, while the dielectric constant and tangent loss are 4.4 and 0.01 respectively.

Standard input impedance at the edge of a resonating rectangular patch is ranging from 100 Ω to 400 Ω. A general expression to calculate the input impedance (we only have resistance term as reactance is minimum i.e. zero, at resonance) of an edge fed resonant half wavelength patch is [15]:

$$Z_A = 90\frac{\epsilon_r^2}{\epsilon_r - 1}\left(\frac{L}{W}\right)^2 \tag{2}$$

From equation (2), we can see that the input resistance (impedance) is proportional to the length and width of the patch. By enlarging the width of the patch, the input resistance can be reduced.

It is important to match the input impedance of the patch antenna to the transmission line impedance, which means that the input impedance Z_A of the patch antenna needs to be matched to the characteristic impedance Z_0 of the transmission line (typically 50 Ω). A quarter wave transformer method is applied for the impedance matching purpose. The quarter wave transformer is a section of transmission line having length of a quarter-wavelength to the wavelength in the transmission line. The characteristic impedance of the matching segment is given by equation (3).

$$Z_{qw} = \sqrt{Z_0 Z_A} \quad (3)$$

Generally, as shown in Equation (2) the characteristic impedance of a microstrip line is inversely proportional to the width of the microstrip patch, as resistance is inversely proportional to the diameter of wire. In other words, the broader the strip, the lower the characteristic impedance. Another important aspect is picking of the dielectric substrate as it plays a great role in calculating the length (1) and input impedance (2) of the patch.

The final optimized parameters for designing the antenna are summarized in (Table 1). Note that the length and width of the quarter wave transmission line are determined to match the antenna's impedance to that of the 50Ω coaxial cable. A square patch antenna is designed and presented in this work instead of rectangular, still all the concepts of the rectangular patch are applicable except that we have a length equal to Width (L=W, patch is square). The offset position of the feed point is at a distance of 15 mm from the microstrip patch. The feeding is done by using the coaxial feeding method.

The fabricated microstrip patch antenna is shown in Figure 2. The Figure shows a square patch and a quarter wave transmission line on a dielectric substrate. The bottom of the dielectric substrate is fully covered by copper, serving as a ground plane.

Table 1: Proposed Antenna Parameters

Parameter	Value
Length/Width of the Patch (L=W)	28.8 mm
Substrate Thickness (h)	1.6 mm
Copper layer Thickness	0.035 mm
Quarter Wave Transmission Line Length	15 mm
Quarter Wave Transmission Line Width	0.8 mm

The patch's size is compact compared to the size of substrate and ground. The size of the resonating patch and ground depends upon the resonance frequency and ε_r. The circular polarization in the single feed square antenna is obtained by truncating the square patch from the top right and bottom left corners as shown in Figure 2. This truncated and optimized design resulted in right hand circular polarization at 2.4 GHz frequency.

3. RESULTS AND DISCUSSION

3.1 Simulation Results

The simulations were carried out using CST STUDIO SUITE, and the results are presented in this section. For better accuracy of the simulation results, a very fine mesh consisting of as many as 48,975 mesh cells is used. Note that the more mesh cells used in the simulation, the longer time the simulation takes but, the more realistic results obtained. Figure 3 shows the radiation pattern of

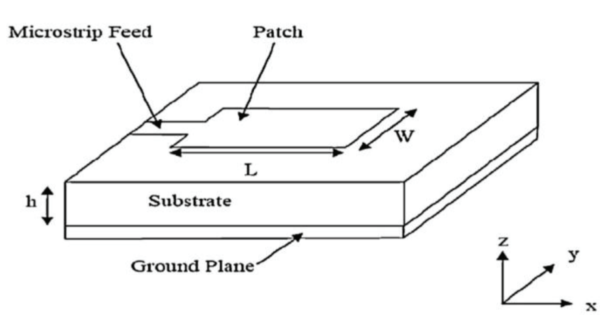

Fig. 1. A typical patch antenna. Reprinted from [21]

the simulated antenna. As we can see from Figure 3, the antenna radiation is mostly upward. This is because of the ground placed at the bottom side of the antenna, which acts as a reflector. A total gain of 6 dB is observed in the positive z direction.

In Figure 4, the S11 parameter is shown in dB as a function of the frequency. As noticed from the Fig., S11 deeply drops at frequencies 2.4 GHz and 2.44 GHz. It is also seen that 10 dB band is slightly more than 100 MHz.

In Figure 5, axial ratio in dB is plotted with respect to ϕ. Axial ratio is a parameter from which we can check the circular polarization. In the circular polarization case, the minor and major axis should be equal, that is to say, the axial ratio is 0 dB.

3.2 Experimental Results

In this section, we present the actual performance of the fabricated antenna. The antenna radiates perpendicular to the patch, so recording the measurements at different cuts is important. We have used three settings for our measurements. In these settings (setting A, B and C, respectively), we have measured the antenna performance for ϕ=0,ϕ=45,and ϕ= 90 to characterize the performance at different angles. We have looked at these measurements' efficiency, gain, and radiated power. Figures 7 to 12 show the respective scenarios with (Figure) captions describing which setting they correspond to. We provide the antenna's actual/ measured S11 performance in Figure 6.

3.2.1 Measurements at ϕ= 0

Figure 7 shows 3D plot of all values obtained at different θ for a fixed ϕ (fixed at ϕ = 0) and 2D plots of amplitudes attained at θ= 0 and θ=90. Whereas,(Figure 8) gives the achieved gain and radiated power at a range of frequencies for ϕ= 0.

3.2.2 Measurements at ϕ= 45

In (Figure 9) the 3D measurements for all θ values for ϕ= 45 can be seen. The 2D plots of implies to

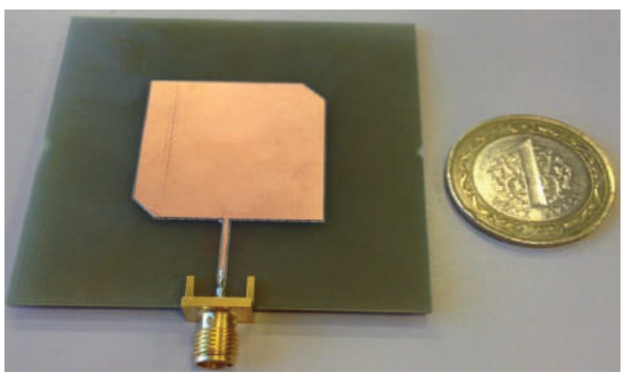

Fig. 2. The final fabricated antenna

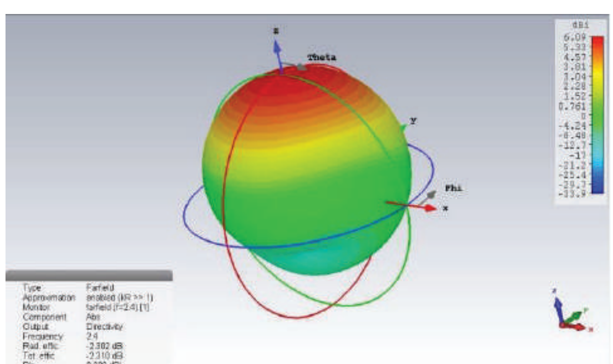

Fig. 3. The radiation pattern of the proposed antenna

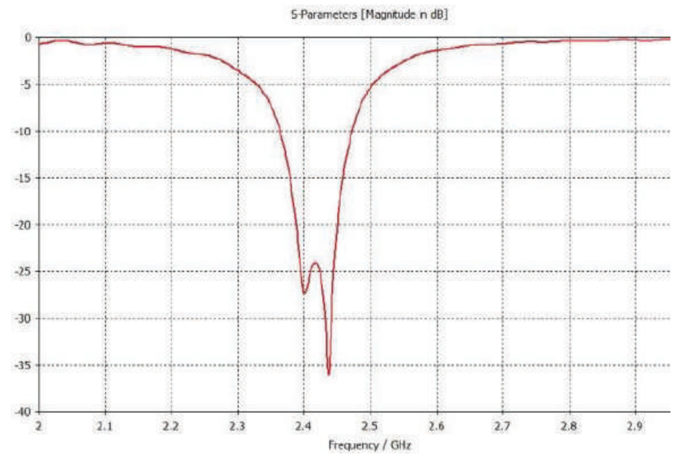

Fig. 4. Simulated S11 Parameters

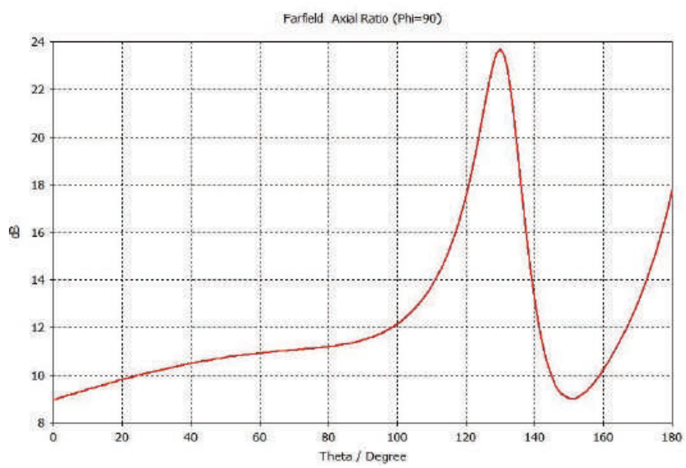

Fig. 5. Axial ratio (simulated).

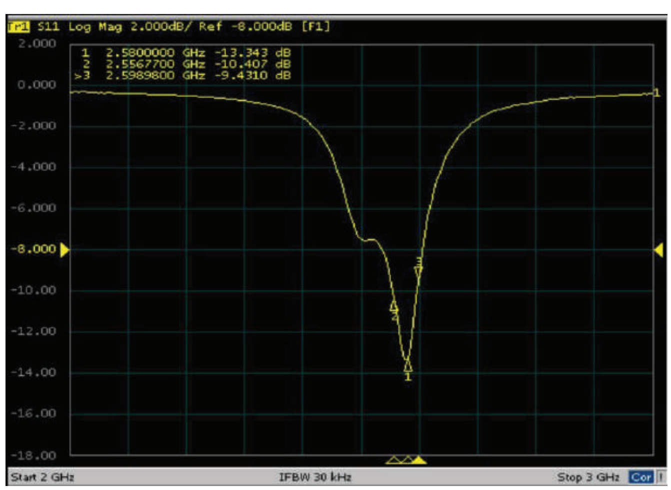

Fig. 6. Experimental S11 parameter of the fabricated antenna.

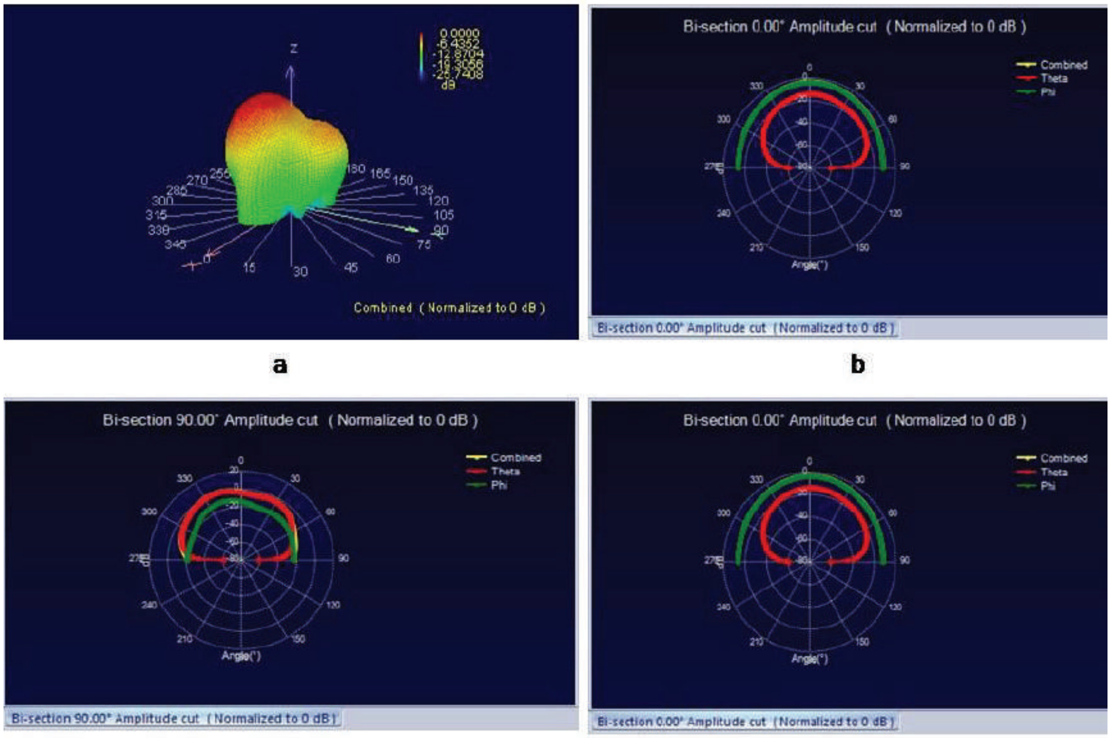

Fig. 7. Measurement @ ϕ= 0, a) Combined Pattern b) Bisection combined chard c) Bi-section cut at 0^o d) Bi-section cut at 90^0.

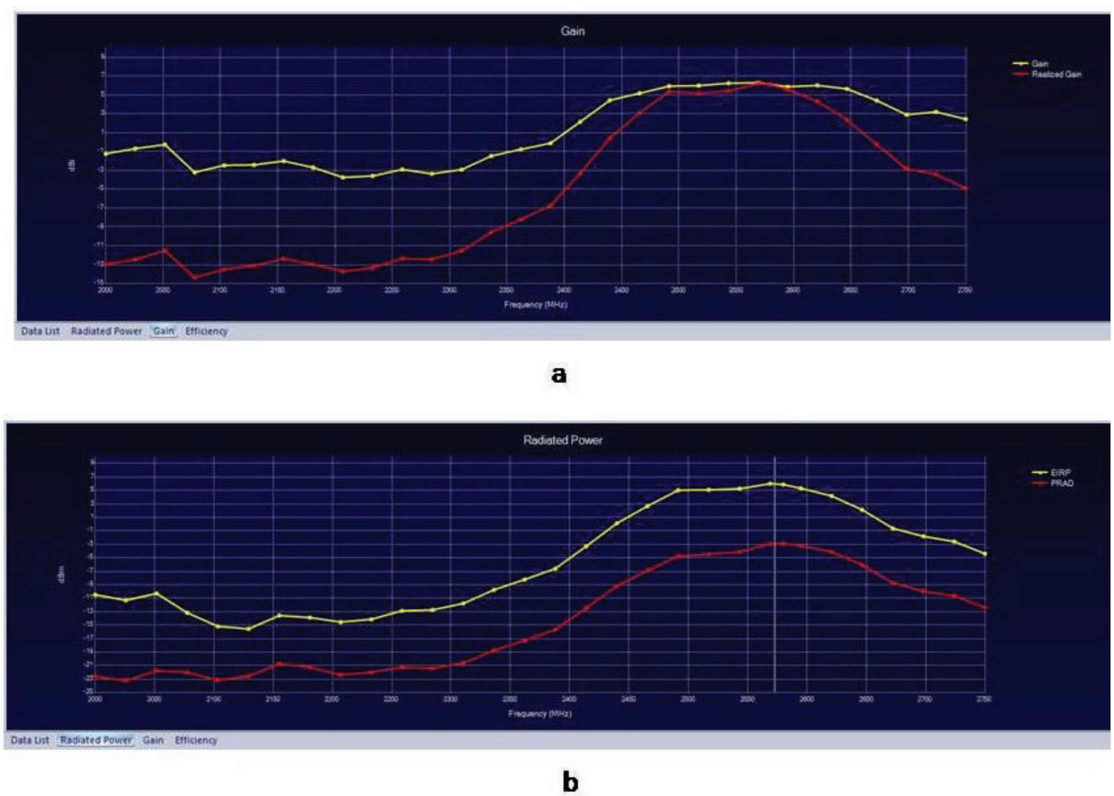

Fig. 8. Measurement @ ϕ = 0; a) Gain b) Radiated power

the amplitudes attained at θ = 0 and θ = 90 for same ϕ= 45. The gain, efficiency and radiated power for ϕ= 45 at different frequencies are shown in Figure 10.

3.2.3 Measurements at ϕ= 90

In (Figure 11) the 3D measurements for all θvalues for ϕ= 90 can be seen. The 2D plots of implies to the amplitudes attained for all angles and at θ = 0 and θ = 90 for same ϕ= 90. The gain, efficiency and radiated power given in (Figure 12) are obtained for different frequencies at ϕ= 90.

The simulated and measured return loss of the proposed antenna is -27 dB and -13.34dB, respectively. Whereas, the gain came out to be 6 dB. These results are comparable to a RHCP antenna array of 4 cells [25] and better than that of a complex CP antenna [15]. The gain of all three cuts is almost equal, confirming that the design antenna is circular polarized.

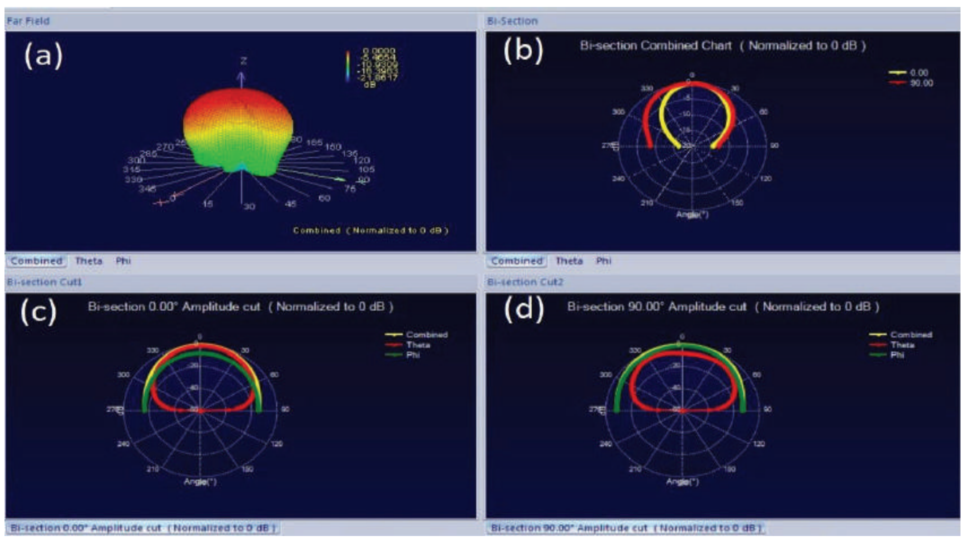

Fig. 9. Measurement @ ϕ = 45; a) Combined Pattern b) Bi-section combined chard c) Bi-section cut at 0o d) Bi-section cut at 900.

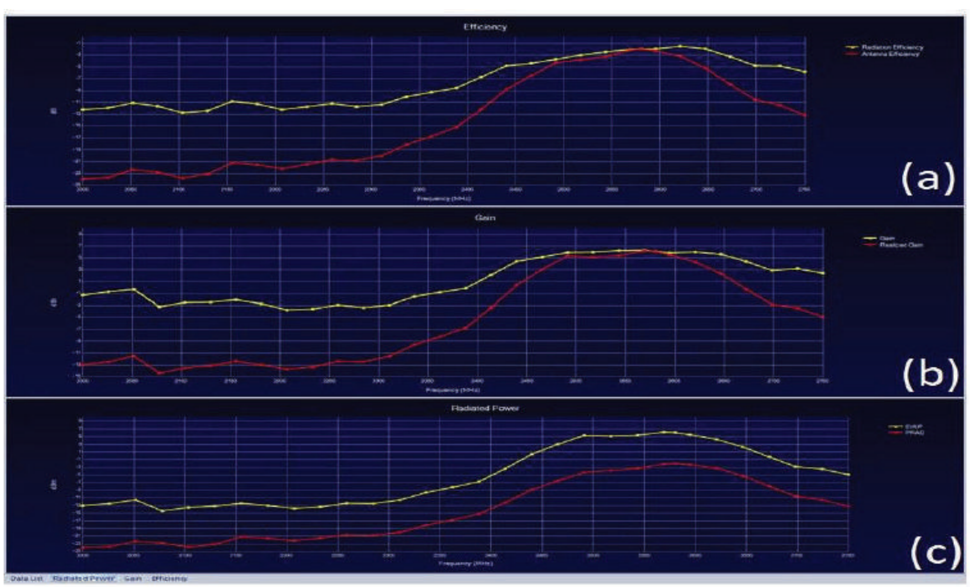

Fig. 10. Measurement @ ϕ = 45; a) Efficiency b) Gain c) Radiated power

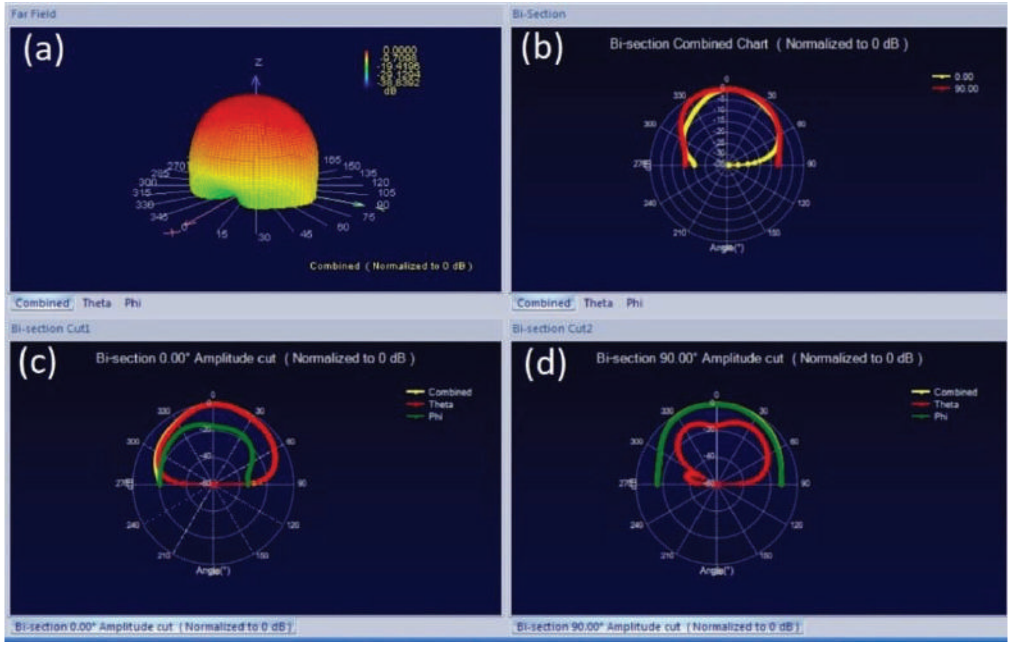

Fig. 11. Measurement @ ϕ = 90; a) Combined Pattern b) Bi-section combined chard c) Bi-section cut at 0° d) Bi-section cut at 90°

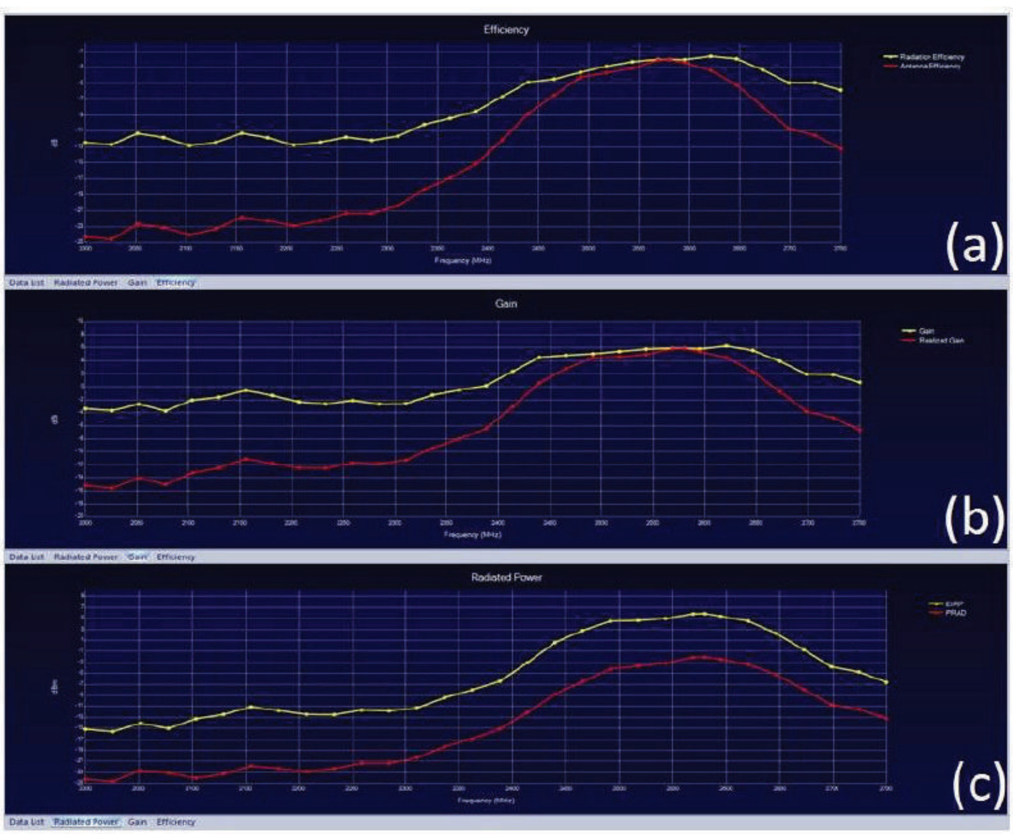

Fig. 12. Measurement @ ϕ = 90; a) Efficiency b) Gain c) Radiated power.

4. CONCLUSION

This paper presents a successful design and fabrication of the micro-strip patch antenna with circular right-hand polarization for WLAN applications. The operating frequency is 2.4 GHz. It is an electrically small antenna and comfortably handle-able. As discussed in the above section, the gain for different values of θ are identical so we have circular polarization. A good gain of 6 dB was obtained. The simulated 10 dB bandwidth was recorded to be almost 100 MHz, whereas, the experimental 10 dB bandwidth turned out to be 50 MHz. Although measured performance is slightly different from simulation results, the antenna meets the requirement for a typical WLAN application.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

The authors declare no potential conflict of interests.

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