Circularly Polarized Microstrip Patch Antenna for Wireless Communication

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***Abstract*—In recent years, compact circularly polarized microstrip antennas (CPMAs) have received much attention in the wireless communication systems. This paper describes the design of microstrip stacked patch antenna with circular polarization (CP). This antenna is designed for ISM band applications (2.4GHz). The proposed antenna is fed by a new S-shaped impedance matching network (IMN). The proposed antenna has two stacked patches. For making the size of antenna compact additionally, four symmetric L narrow slots on the patches are added. For matching antenna, parameters of S shaped impedance matching network are regulated. The peak gain is optimized in the frequency range from 2.31 to 2.56 GHz of larger than 6 dBi, and it achieves 6.32 dBi in the center frequency 2.45 GHz.**

***Index Terms*-Circular polarization (CP), microstrip antenna, Impedance Matching Network, patch antenna.**

I. INTRODUCTION

With the emerging use of wireless applications, there is always a continuous need for RF community to design low cost, light weight, and miniature antennas which can easily be integrated with small size communication systems. Generally, a single feed patch antenna generates a linearly polarized wave, unless some perturbation is introduced in the radiator structure to excite the two orthogonal modes with 90 phase difference for achieving the CP radiation. This is usually achieved by chamfering the square patch radiator corners or making slots or slits with respect to suitable feeding location [1]. The design of a circularly polarized antenna with broadband characteristic is presently one of the most challenging topics. This is because the use of commercial RFID system in practical situation for indoor or outdoor environment usually requires a CP reader antenna for orientation diversity. The CP antennas are classified as a single feed type or dual feeds type depending on the number of feed point necessary to generate the CP waves [2].

The single feed antennas are smaller in size as compared to dual feed antennas because dual feed antennas need larger ground plane structure than single feed antenna [3]. Different methods for the single-feed CPMAs have been published in the literature. In 1983, Sharma and Gupta [4] proposed a method to generate CP radiation of the square patch using the truncated corners method. A dual frequency microstrip antenna with CP capabilities has been also introduced in [5] by stacking two different corner-truncated square patches on the dielectric layer. Wireless system is composed of antennas & microwave devices. These microwave devices generates harmonics. In [6] the harmonic suppression characteristic is realized by introducing the circularly symmetrical slot near the coaxial feed location on the microstrip antenna radiation patch. In modern wireless communication systems for spectrum sensing or communication frequency reconfigurable antennas are needed. In [7] frequency reconfigurable microstrips patch which is capable of switching at nine different frequency bands between 1.98 and 3.59 GHz.

In this paper, a new type of feed technology for a microstrip antenna is proposed, in which the S shaped impedance matching network technology is used. The proposed antenna has two stacked patches. These patches have two resonant frequency points which are made closer so as to obtain resonant circuit. For improving the gain of antenna, an air dielectric layer and the parasitic patch with a lower dielectric substrate is used.

II. ANTENNA DESIGN

Fig. 1(a) shows the geometry of a compact & broadband circularly polarized microstrip patch antenna with two stacked patches.

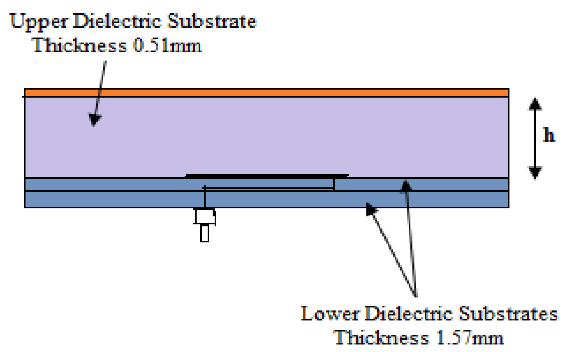

Fig. 1 a) Geometry of proposed antenna

The conductor was fabricated on the three layers square substrate, whose width is G=58mm, with a dielectric constant of 10, and substrate thickness of h1=1.6mm for the first and second dielectric layers. The dielectric constant of the third dielectric layer is 4.4, and the thickness of the substrate is h2=0.51mm. In addition, with an additional air layer of the thickness h between the second layer and the third layer, and by adjusting the thickness h, the wider impedance bandwidth and higher gain could be obtained.

For feeding antenna a single strip S shaped impedance matching network is used. The width of strip is Ws and x – direction length is S_x and y-direction length is S_y, as shown in Fig. 1(b). One end of the S-shaped IMN was connected to the main radiating patch by a probe, whereas the other end was connected to a coaxial connector.

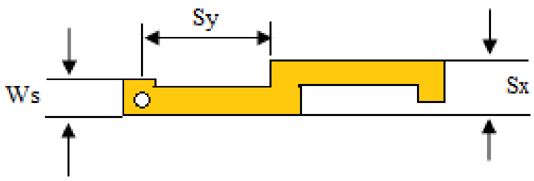

Fig. 1 b) S Shaped Impedance Matching Network

The square radiation patch implemented on the second dielectric substrate. It is connected to the S-shaped IMN by a probe. The width of the patch to resonate at the center frequency of 2.45 GHz and two centrosymmetric diagonal comers of the right-angled isosceles triangle were truncated. Four additional symmetrical-L narrow slots placed on the patch. This could improve the circular polarization characteristic. With the structure, the proposed antenna obtains a wide impedance bandwidth and a high gain performance.

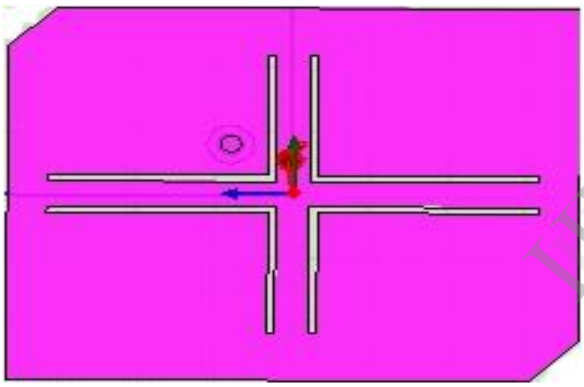
Fig. 1 c) Structure of antenna

Instead of using conventional impedance matching technique, the antenna's impedance matching is mainly achieved by adjusting the size of the S-shaped Impedance Matching Network: W_s, S_x and S_y. In the simulated return loss of the proposed antenna with different S_x, we observed that with S_x decreasing ($S_{y=}$8mm is constant.) the antenna's impedance matching was better and better and the voltage standing wave ratio (VSWR)< 2 impedance bandwidth was wider and wider.

Also, in the return loss of the proposed antenna with different S_y, we observed that with S_y increasing (S_x=2.5 mm is constant), the antenna's impedance matching was better and better, but the VSWR<2 impedance bandwidth was narrower and narrower. Therefore, the S_x and S_y mainly influenced the antenna's matching characteristic and impedance bandwidth and had a little effect on the resonant frequency.

III. DESIGN SPECIFICATIONS

Step 1: Calculation of the Width (W)
The width of the Microstrip patch antenna is given as:

$$W = \frac{c}{f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

Substituting c = 3.00e^{+8} m/s, εr = 4.4 and fr = 2.45 GHz, we get: W = 38.22mm.

Step 2: Calculation of Effective dielectric constant (εreff):
The effective dielectric constant is given by:

$$\varepsilon_{eff} = \left(\frac{\varepsilon_r+1}{2}\right) + \left(\frac{\varepsilon_r+1}{2}\right) . \frac{1}{\sqrt{1+12\frac{h}{W}}} \qquad (2)$$

Substituting εr = 4.4, W = 38.22mm and h = 1.6 mm we get εreff = 3.99.

Step 3: Calculation of the Effective length (Leff)
The effective length is:

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \qquad (3)$$

Substituting εreff = 3.99, c = 3.00e^{+8} m/s and fr = 2.45 GHz we get: Leff = 30.25mm.

Step 4: Calculation of the length extension (ΔL)
The length extension is:

$$\frac{\Delta l}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (4)$$

Substituting εreff = 3.99, W = 38.22mm and h = 1.6mm we get: ΔL = 0.70 mm.

Step 5: Calculation of actual length of patch (L):
The actual length is obtained by:

$$\mathbf{L = L_{eff} - 2\Delta L} \qquad (5)$$

Substituting Leff =30.25mm and ΔL = 0.70 mm we get: L = 28.4mm.
Step 6: Calculation of the ground plane dimensions (Lg and Wg):
The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. Hence, for this design, the ground plane dimensions would be given as:

$$Lg = 6h + L = 6(1.6) + 39 = 59mm \qquad (6)$$
$$Wg = 6h + W = 6(1.6) + 30 = 50mm \qquad (7)$$

For this feed would be given L/4 distance.i.e 6.5mm.

IV. EXPERIMENTAL RESULTS

The software used to model and simulate the Microstrip patch antenna is Ansoft HFSS. It analyzes 3D and multilayer structures of general shapes. Fig.2 shows the measured return loss of the proposed compact antenna. The antenna has the resonance at the center frequency of 2.45 GHz and obtained the reflection characteristic of less than 10 dB in the bandwidth of about 370 MHz. The center frequency is selected as the one at which the return loss is minimum. This wideband characteristic of the measured return loss was obtained by the S-shaped IMN technology and the stacked patches.

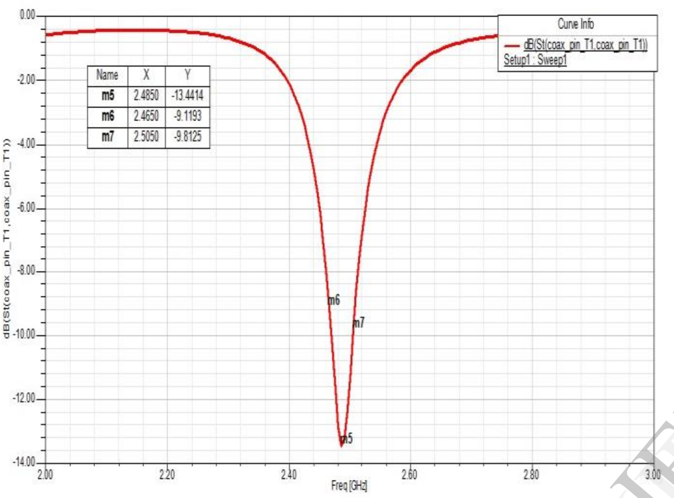

Fig.2 Measured return loss of the proposed compact antenna.

Normalized scaling allows the Smith Chart to be used for problems involving any characteristic impedance or system impedance, although by far the most commonly used is 50 ohms. Fig.3 show that the input impedance of the port is matched with the normalized Zc value of 80 at the frequency 2.408 GHz, which is near the operating frequency of 2.45 GHz.

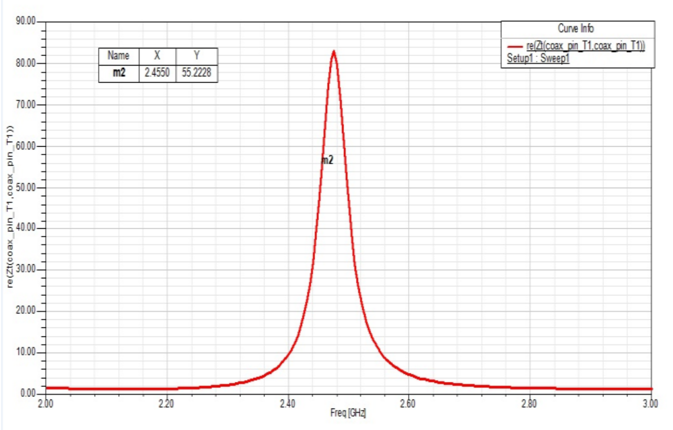

Fig. 3: Z-parameter plot for Input impedance (Zc)

The axial ratio was less than about 5 dB in the measured frequency range from 2.40 to 2.42 GHz as shown in Fig. 5, and with a minimum AR of 0.53 dB. The bandwidth of the peak gain was quite wide, but the bandwidth of the axial ratio was narrower than the bandwidth of the return loss. Although the bandwidth of the axial ratio was narrower, it could sufficiently be used in the 2.45-GHz RFID band.

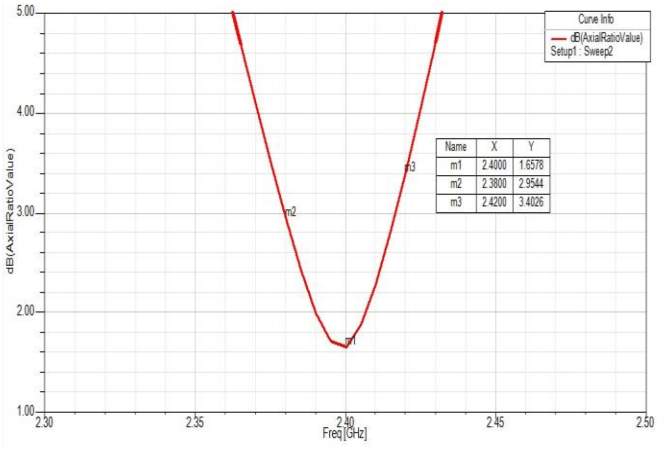

Fig. 4: Axial Ratio v/s frequency plot

An impedance of exactly 80 Ohm can only be practically achieved at one frequency. The VSWR defines how far the impedance differs from 80 Ohm with a wide-band antenna. The power delivered from the transmitter can no longer be radiated without loss because of this incorrect compensation. VSWR must lie in the range of 1-2 which is achieved in fig.5 for the frequency 2.408 GHz, near the operating frequency value.

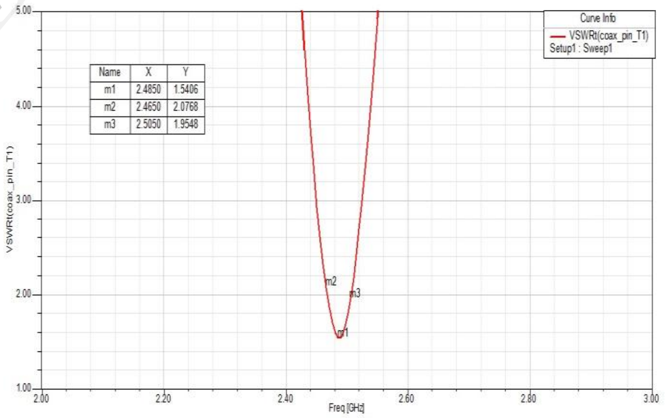

Fig. 5: VSWR v/s frequency plot

V. CONCLUSION

The microstrip patch antenna has been studied for Circular Polarization with compact size. The nearly square and truncated corners square patch radiators have also been studied for Circular Polarization. S-shaped IMN technology is used for feeding microstrip antenna due to which a good impedance matching and symmetrical broadside radiation pattern is obtained. The antenna has a gain of 6.32dB and bandwidth about 370 MHz, which makes it suitable for wireless communication systems, such as Wi-Fi. The proposed antenna can be made frequency reconfigurable which is capable of operating at different frequency bands.

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