

Design of Hybrid Coupler Connected Square Array Patch Antenna for Wi-Fi Applications

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ABSTRACT

Microstrip patch antennas being popular because of light weight, low volume, thin profile configuration which can be made conformal. Wireless communication systems applications circular polarization antenna is placing vital role. In this study we introduce a new technique to produce circular polarization. Hybrid coupler is directly connected to microstrip antenna to get circular polarization. Also gain is further increased by introducing antenna array technique. Each square in array having length of 4.6mm patch is having thickness of 0.381mm and the dielectric material used FR4. The designed antenna having high gain of 6.26dB and directivity of 5.11dB at the resonant frequency of 3.7GHz. Simulation results shows that the designed antenna characteristic is suitable for Wi-Fi applications.

Keywords: Array Antenna, Circular Polarization, Directivity, Hybrid Coupler, Radiation Pattern

1. INTRODUCTION

Planar configurations of microstrip technology is placing vital role in the field of antenna (Sarin *et al.*, 2009). Microstrip antenna provides high repeatability of parameters to increase the gain, band width and the size reduction is achieved by using small substrate. Patch can be in any shape like rectangular, circular, square, elliptical and triangular. Hybrid coupler implementation with Varactor diode and Pin diode is proposed by Sun *et al.* (2005). Different feeding techniques for UWB antenna are investigated and fabricated (Guo *et al.*, 2002). **Figure 1** show the fields associated with an antenna (Yang *et al.*, 2001). Electromagnetic energy coupling in and around patch is done by dielectric material. The electric field is maximum at one end of patch and minimum in other end. This maximum and minimum end will depends the applied signal but electric field at the center of patch is always zero. Electric field in the patch is extended outside patch is causing radiation in a patch and this extended field is known as fringing field (Martin *et al.*, 2007). The proposed antenna is in square array shape with 0.381mm and it resonates at 3.7GHz which includes Wi-Fi and Wi-Max.

1.1. Dual-Fed Circular Polarization Patch Antenna

Polarization of an antenna is defined as the polarization of the wave transmitted (radiated) by the antenna, whereas polarization of radiated wave is defined as property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric-field vector; specifically, the figure traced as a function of time by the extremity of the vector at fixed location in the space and the sense in which it is traced, as observed along the direction of propagation. Polarization may be classified as linear, circular and elliptical. The proposed antenna having circular polarization and is achieved by dual feed in patch antenna. **Figure 2** shows the general configuration of dual feed patches (Guo *et al.*, 2004). External polarizer used to categories the dual-fed CP patch antenna they are 3dB hybrid type and the other is an offset-line coupler are used and it produces of equal amplitude but 90° out of phase at its centre frequency. **Figure 3 and 4** shows internal diagram and simulated diagram of 3db hybrid coupler.

1.2. Hybrid Coupler Design

Generally branch-line couplers are 3dB, four ports directional couplers having a 90° phase difference between its two output ports named through and coupled arms. Branch-line couplers (also named as Quadrature Hybrid) are often made in microstrip line form.

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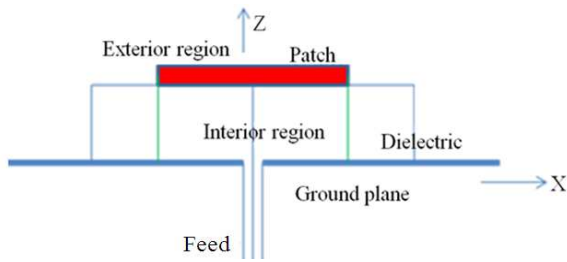


Fig. 1. Division of fields is associated with an antenna into an interior fields and exterior fields



Fig. 2. Dual-fed CP patches

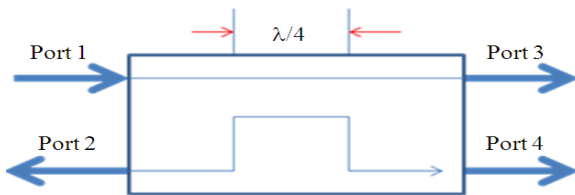


Fig. 3. Internal diagram of 3dB quad hybrid Coupler

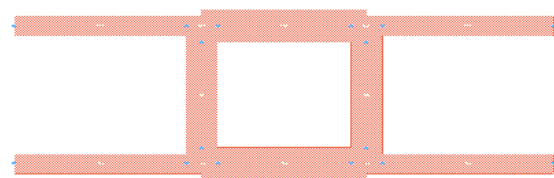


Fig. 4. Simulated Hybrid Coupler

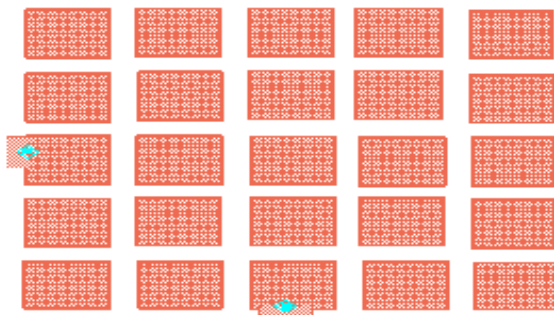


Fig. 5. Square patch antenna arrays

Power dividers and directional couplers, are passive devices used in the field of radio technology such as power division or power combining (Tang *et al.*, 2006). A 3 dB, 90° hybrid coupler is a four-port device, that is used either to equally split an input signal with a resultant 90° phase shift between output signals or to combine two signals while maintaining high isolation between them. However, in a practical device the amplitude balance is frequency dependent and departs from the ideal 0dB difference.

All 90° Power Dividers/Combiners, also known as quadrature hybrids or simply quad hybrids, are reciprocal four port networks (Targonski *et al.*, 1998; Mak *et al.*, 2000). The hybrid coupler or 3 dB directional coupler, in which the two outputs are of equal amplitude, takes many forms. It is beginning with quadrature (90°) 3 dB coupler coupling with outputs 90° out of phased. Now any matched 4-port with isolated arms and equal power division is called a hybrid or hybrid coupler. Today the characterizing feature is the phase difference of the outputs. If 90°, it is a 90° hybrid. If 180°, it is a 180° hybrid. In this study 90° coupler is designed and connected with antenna to produce circular polarization. According to the impedance choice of the series and stub microstrip transmission lines we can calculate the w/d ratios of those lines in microstrip form by using the following formulas.

Width of Hybrid (w) Eq. 1:

$$\frac{w}{d} = \begin{cases} \frac{8a^4}{8^{24-2}} & \frac{w}{d} < 2 \\ \frac{2}{\pi} \left[\begin{matrix} B-1 - \ln(zB-1) \\ \ln(B-1) + 0.39 - \frac{0.61}{6} \end{matrix} \right] & \frac{w}{d} > 2 \end{cases} \quad (1)$$

Consider Eq. 2:

$$\frac{w}{d} > 2 \quad \text{and} \quad B = \frac{377\pi}{2z_0\sqrt{s_c}} \quad (2)$$

Dielectric constant (ϵ_c) Eq. 3:

$$s_c = \frac{s_r + 1}{2} + \frac{s_r - 1}{2} \sqrt{\frac{1}{1 + \frac{12d}{w}}} \quad (3)$$

Length of the hybrid (l) Eq. 4:

$$l = \frac{90^\circ(\pi \times 180^\circ)}{\sqrt{s_c} \times k_0} \quad (4)$$

1.3. Radiation Element Design

Microstrip antennas that operate as a single element usually have a relatively large half Power beamwidth, low gain and low radiation efficiency. Initially the square patch is designed with each side of 4.2 mm. This patch is arranged to form an array to improve parameters like gain and Range of the radiating structure shows **Figure 5**. By considering all the elements are placed at regular interval, all the elements are identical, all the elements have uniform (equal) amplitude excitation there can be a linear relative phasing between the elements in the two orthogonal directions the analysis is done. The effect of mutual coupling is depends on antenna type and its design parameters, relative positioning of the elements in the array, feed of the array elements (Chair *et al.*, 2005).

Assuming single mode operation the terminal voltage of one element in terms of current flowing in the others can be written as Eq. 5:

$$V_{mn} = \sum_p \sum_q Z_{mn, pq} I_{pq} \tag{5}$$

where, $Z_{mn, pq}$ defines the terminal voltage at antenna mn due to a unity current in element pq when the current in all the other elements is zero. Thus the $Z_{mn, pq}$ terms represent the mutual impedances when the indices mn and pq are not identical. The driving impedance of the mnth element is defined as Eq. 6:

$$Z_{Dmn} = \sum_p \sum_q Z_{mn, pq} e^{j(p-m)\beta x e^j (q-n)\beta y} \tag{6}$$

Incident and reflected waves for E and H field can be written as Eq. 7-10:

$$E^i = E_0^i (\hat{a}_y \cos \theta_i - \hat{a}_z \sin \theta_i) e^{+jk_z (y \sin \theta_i + z \cos \theta_i)} \tag{7}$$

$$H^i = \hat{a}_x H_0^i e^{+jk_0 (y \sin \theta_i + z \cos \theta_i)} \tag{8}$$

$$E^r = E_0^r (\hat{a}_y \cos \theta_r - \hat{a}_z \sin \theta_r) \theta^{-jk_0 (-y \sin \theta_r + z \cos \theta_r)} \tag{9}$$

$$H^r = -\hat{a}_x H_0^r e^{-jk_0 (-y \sin \theta_r + z \cos \theta_r)} \tag{10}$$

The tangential components of electric and magnetic field is:

$$\eta_0 = \frac{E_{tan}}{H_{tan}}$$

Reflection coefficient of a transmission line with normalized coefficient Z_L is given by:

$$\Gamma = \frac{\bar{Z}_L - 1}{\bar{Z}_L + 1}$$

2. MATERIALS AND METHODS

The ideal method for analysis microstrip antenna are Transmission line model, cavity model and Methos of moment techniques (Targonski *et al.*, 1998; Mak *et al.*, 2000).

2.1. Transmission Line Model

In this model microstrip antenna is represented by two slots of width W and height h, separated by a low impedance transmission line of length L. Some electric field lines are travelling outside the substrate resulting fringing effect that is changing effective dielectric constant. It is a function of the dimensions of the patch and the height of the substrate. Transmission line model is easy to design but it is having less accurate.

2.2. Cavity Model

Transmission line model ignores field variations along the radiating edges. This model provides a better way to model the radiation patterns and is closer in the physical interpretation of the antenna characteristics. The normalized fields within the dielectric can be found more accurately by treating the region as a cavity bounded by electric conductors (above and below) and by magnetic walls along the perimeter of the patch. The disadvantage of this method is complex in nature.

2.3. Method of Moment

In this method, the surface currents are used to model the microstrip patch and the volume polarization currents are used to model the fields in the dielectric slab. The basic form of the equation to be solved by the Method of Moment is:

$$F(g) = h$$

Where:

F = A known linear operator

g = An unknown function

h = The source or excitation function

The aim here is to find g, when F and h are known.

Here we used ADS software for analysing proposed antenna. ADS is used to compute S, Y, Z parameters of general planar circuits. Microstrip topology is analysed quickly and accurately with momentum using ADS. The simulator is based on the Method of Moments (MoM) technology that is particularly efficient for analysing planar conductor and resistor geometries.

3. RESULTS

A simulator Advanced Design System based on Method of Moment has been used to calculate return loss, radiation pattern. Geometry of proposed antenna is shown in **Figure 6**. Using the above equations dimensions of hybrid coupler, patch is calculated and the simulation is done using ADS software. **Figure 7** shows return loss for proposed antenna and 3-D radiation pattern of hybrid coupled microstrip rectangular patch antenna is shown in **Fig. 8** and it is showing the proposed antenna is having circular polarization.

4. DISCUSSION

Reflection coefficient (S11) or return loss is defined as the ratio of reflected power to the incident power. Simulated return loss in hybrid coupled microstrip antenna is -24.083 db at resonant frequency 3.688 GHz.

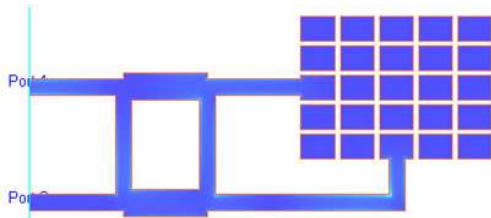


Fig. 6. Geometry of proposed antenna

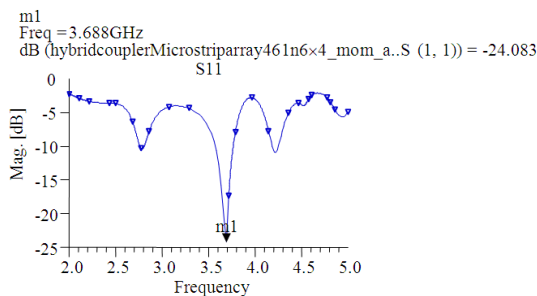


Fig. 7. Return loss characteristics

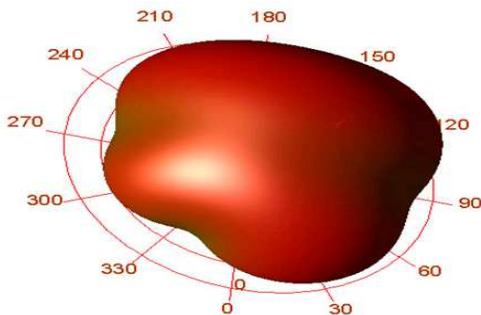


Fig. 8. Radiation pattern

The radiated energy in a particular direction is measured in terms of field strength at a point which is at particular distance from the antenna. Radiation pattern is a graph which shows the variation of actual field strength of electromagnetic field at all points which are at equal distance from antenna. So the graph of radiation pattern will be three dimensional. Here the simulated result of radiation pattern shows proposed antenna is having circular polarization.

5. CONCLUSION

Design of hybrid coupled square microstrip patch array antenna is presented and discussed in this study having return loss is -24.083 db at resonant frequency 3.688 GHz. Circular Polarization is also achieved by using hybrid coupler. Proposed antenna is suitable for wireless applications at 3.7GHz.

6. REFERENCES

- Chair, R., C.L. Mak, K.F. Lee, K.M. Luk and A.A. Kishk, 2005. Miniature wide-band half U-slot and half E-shaped patch antennas. *IEEE Trans. Antennas Propag.*, 53: 2645-2652. DOI: 10.1109/TAP.2005.851852
- Guo, Y.X., K.M. Luk, K.F. Lee and R. Chair, 2002. A quarter-wave U-shaped patch antenna with two unequal arms for wideband and dual-frequency operation. *IEEE Trans. Antennas Propag.*, 50: 1082-1087. DOI: 10.1109/TAP.2002.801285
- Guo, Y.X., M.Y.W. Chia, Z.N. Chen and K.M. Luk, 2004. Wide-band L-probe fed circular patch antenna for conical-pattern radiation. *IEEE Trans. Antennas Propag.*, 52: 1115-1116. DOI: 10.1109/TAP.2004.823971
- Mak, C.L., K.M. Luk, K.F. Lee and Y.L. Chow, 2000. Experimental study of a microstrip patch antenna with an L-shaped probe. *IEEE Trans. Antennas Propag.*, 48: 777-783. DOI: 10.1109/8.855497
- Martin, M.A., B.S. Sharif and C.C. Tsimenidis, 2007. Probe fed stacked patch antenna for wideband applications. *IEEE Trans. Antennas Propag.*, 55: 2385-2388. DOI: 10.1109/TAP.2007.901924
- Sarin, V.P., N. Nassar, V. Deepu, C.K. Ananadan and P. Mohahana *et al.*, 2009. Wideband printed microstrip antenna for wireless communications. *IEEE Antennas Wireless Propag. Lett.*, 8: 779-781. DOI: 10.1109/LAWP.2009.2026193
- Sun, K.O., C.C. Yen and D.V. Weide, 2005. A size reduced reflection-mode phase shifter. *Mic. Opt. Technol. Lett.*, 47: 457-459. DOI: 10.1002/mop.21198
- Tang, C.W., M.G. Chen, Y.S. Lin and J.W. Wu, 2006. Broadband microstrip branch-line coupler. *Elec. Lett.*, 42: 1458-1460. DOI: 10.1049/el:20063025
- Targonski, S.D., R.B. Waterhouse and D.M. Pozar, 1998. Design of wide-band aperture-stacked patch microstrip antennas. *IEEE Trans. Antennas Propag.*, 46: 1245-1251. DOI: 10.1109/8.719966
- Yang, F., X.X. Zhang, X. Ye and Y. Rahmat-Samii, 2001. Wide-band E-shaped patch antennas for wireless communications. *IEEE Trans. Antennas Propag.*, 49: 1094-1100. DOI: 10.1109/8.933489