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Design Analysis of Slotted Diagonal Shape Patch Antenna with Hybrid Coupler

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Abstract—In this paper hybrid coupler connected diagonal shaped patch antenna with slot is examined. Theoretical performance is carried out using advanced system design (ADS) software. Measurement of antenna parameters like return loss, standing wave ratio also have been presented in this article. The measured values for the antenna are taken by agilent E5062A network analyzer. Simulated and measured results are having good agreement. The effect of excited two orthogonal modes with equal amplitude and 90 degree phase shift coupler connected with patch will produce circular polarization. The antenna is having gain of 3.319dB and the directivity of 6.98dB. The proposed antenna can be useful in wireless applications.

Keywords— Advanced Design System, Circular Polarization, C band, Network Analyser, Patch antenna

I. INTRODUCTION

Microstrip patch antennas are placing vital role in personal communication systems because of its tremendous advantages of light weight, thin profile and low cost [1]. The other side micro strip patch antenna having great disadvantage is narrow bandwidth. Many techniques are introduced to improve the bandwidth for example multilayer, thick substrate [2]. Patch can be in any shape like rectangular, Circular, Square, Elliptical, Triangular etc [3]. Hybrid coupler implementation with Varactor diode and Pin diode is proposed by S. Cheng, K-O. Sun, [4 , 5] . Commercial wireless systems require low cost antenna with large bandwidth, slot antennas satisfying these requirements [6, 7]. By introducing Log periodic microstrip antennas [8,9], different types of feeding techniques [10-14] bandwidth is enhanced in wireless applications. Circular polarization antenna have been proposed and studied over the past few years [15-19]. In this design a new shaped microstrip antenna is introduced and the hybrid coupler is connected to get circular polarization. The design concept comes from circularly polarized antenna with conical beam [20].

II. MICROSTRIP ANTENNA

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. They are becoming very widespread within the mobile phone market. They are low cost, have a low profile and are easily fabricated. Discontinuities are present in microstrip antenna to produce electric and magnetic field distributions [21]. The fig 1 shows the geometry of the microstrip patch antenna. This patch antenna is having the ground plane and dielectric which would be underneath. The length L causes resonance at its half-wavelength frequency. The radiating edges are at the ends of the L-dimension of the rectangle, which sets up the single polarization. Radiation that occurs at the ends of the W-dimension is far less and is referred to as the cross polarization. The thickness of the ground plane is not critically important. Typically the height *h* is much smaller than the wavelength of operation. In GPS receivers the size of portable communication device is very important [22]. The square ring microstrip antenna design is having very small size of antenna proposed by J.S.Row [23]. To reduce the size of square patch antenna slits are introduced at the corner of antenna. Phase detection and the circularly polarized antenna is produced by a square patch antenna with feed point on the diagonal. Slot antennas will be having wider circular polarization bandwidth than single feed circularly polarized antenna. In this paper a novel design of microstrip octagonal shaped patch antenna is proposed for wireless applications.

III. HYBRID COUPLER DESIGN

Hybrid couplers normally split an input signal into two unequal amplitude outputs. It is a four port device with one input, two outputs and one isolated port. At ideal condition input port power is equal to sum of two output port power ie 90 degree phase shift between these ports. Termination impedance is connected with the isolated port. 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) is as follows

$$\frac{w}{d} = \begin{cases} \dfrac{8e^{A}}{e^{2A}-2} & \dfrac{w}{d} < 2 \\ \dfrac{2}{\pi}\left[B - 1 - \ln(2B-1) + \dfrac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B-1) + 0.39 - \dfrac{0.61}{\varepsilon_r}\right\}\right] & \dfrac{w}{d} > 2 \end{cases} \qquad \text{Eq. 1}$$

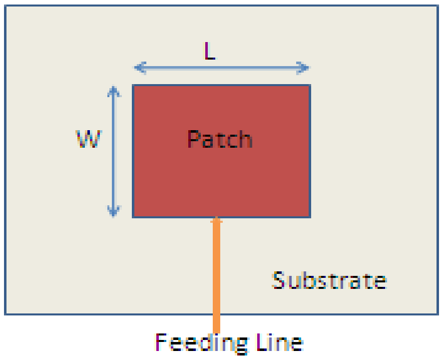

Fig 1 Geometry of Microstrip antenna

Consider $\frac{w}{d} > 2$ $\quad B = \frac{377\pi}{2z_0\sqrt{\varepsilon_r}}$

Dielectric constant (ε_e):

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\frac{1}{1 + \frac{12d}{w}}} \qquad \text{Eq. 2}$$

Length of the hybrid (l):

$$l = \frac{90^0(\pi \times 180^0)}{\sqrt{\varepsilon_e} \times k_0} \qquad \text{Eq. 3}$$

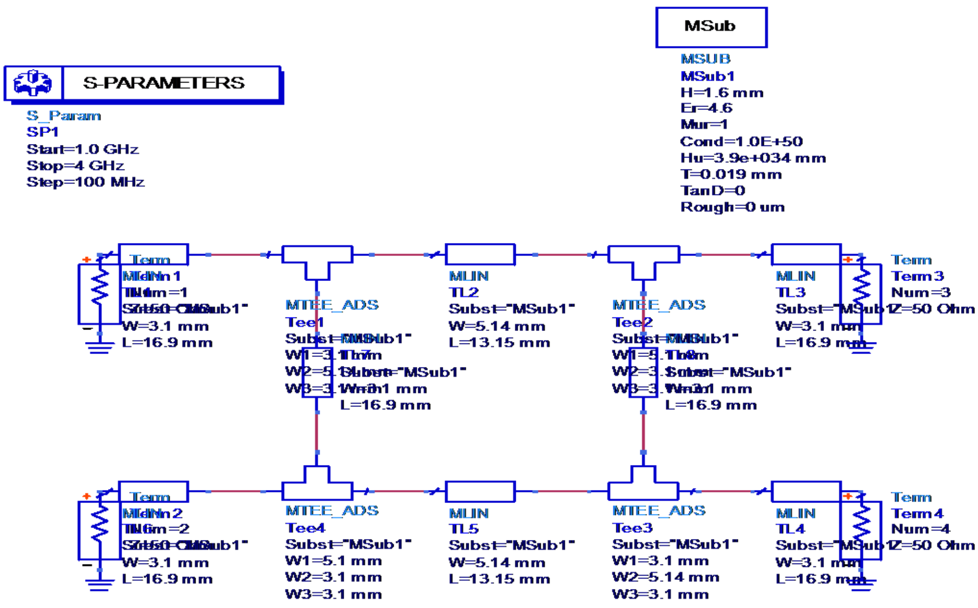

Fig 2 Schematic diagram of Hybrid coupler

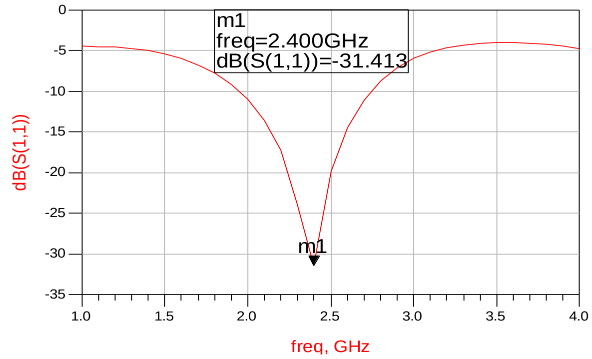

Fig 3 Return loss Vs frequency

Normal hybrid coupler has been modified to get optimum result for 2.4GHz hybrid coupler. Each input line used 2.96 mm for the width and 16.66 mm for the length. While the main line used 5.15 mm for the width and 12.9 mm for the length. And for the shunt arm dimension is 2.96 mm for the width and 16.66 mm for the length. The figure 2 and 3 shows schematic and return loss diagram of hybrid coupler. The hybrid coupler is terminated by 50Ω impedance. Magnitude response is calculated theoretically for 2.4GHz and simulation is done using the software ADS shows coupler is having -31.9dB return loss at 2.4GHz.

IV. ANTENNA DESIGN

Working at microwave frequencies requires proper selection of the substrate. Microstrip bends at high frequencies start to radiate and hence do not transmit much of the input power. A circuit like butler matrix, which has numerous bends in its physical layout, looses most of input power if proper substrate is not selected. A proper substrate is selected for a resonant frequency of 2.4GHz with a substrate of $\varepsilon r = 4.6$ and a thickness is about 1.6 mm with FR4 board. With the available facilities, working with such thin substrates is very difficult, but any further increase in the thickness of the substrate would cause higher radiation losses at each microstrip line bend. This has significant impact on the response of butler matrix as it has numerous bends. There are many methods of analysis used with patch antennas. One of the popular is the method of moment model, which is based on equivalent magnetic current distribution around the patches edge. Initially rectangular patch is drawn by using the following equations, then slot is introduced in the square patch and the simulation was performed by using ADS software. The fundamental mode of a patch antenna is TM_{01} mode. The subscript depicts the orientation along y-axis of the two radiating slots, or voltage maximums. To excite the length L, should be slightly less than $\lambda_g/2$, where λ_g is defined by

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{re}}} \qquad (4)$$

Where ε_{re} is effective dielectric constant and is calculated as follows

$$\varepsilon_{re} = \left[\frac{\varepsilon r+1}{2}\right] + \left[\frac{\varepsilon r-1}{2}\right]\left[1+\frac{12h}{W}\right]^{-1/2} \qquad (5)$$

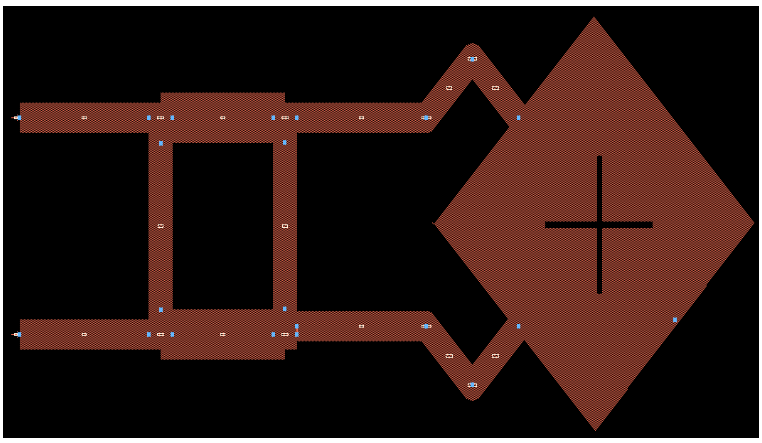

Fig 4 Geometry of proposed antenna

W is taken as being equal to a half-wavelength corresponding to the average of the two dielectric mediums i.e. substrate and air.

$$W = \frac{C}{2f_o\sqrt{\frac{\varepsilon r+1}{2}}} \tag{6}$$

Generally the resonance frequency of the patch can be calculated by the excited mode TM_{mn} is given by

$$f_o = \frac{c}{2\sqrt{\varepsilon_r}} \left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2} \tag{7}$$

Finally coupler and patch is connected to achieve the desired characteristics. Figure 4 illustrate the geometry of proposed antenna.

V. SIMULATED AND MEASURED RESULTS

The return loss for the proposed antenna is -15.65dB at 2.417GHz as shown in figure 5 and 6. The simulated and measured results are having good agreement. Measured value of VSWR is shown in figure 7. The measured VSWR is less than two for resonant frequency. The phase change characteristic is shown in figure 8. The phase is getting changed exactly at 2.417GHz. Polarization shows the electric filed distribution of antenna, here the proposed antenna is having circular polarization, it is produced by directly connecting the hybrid coupler to radiating element and it is shown in figure 9.

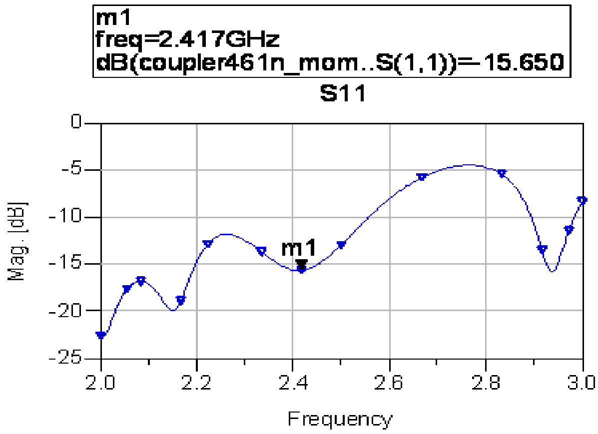

Fig 5. Simulated graph of return loss Vs Frequency

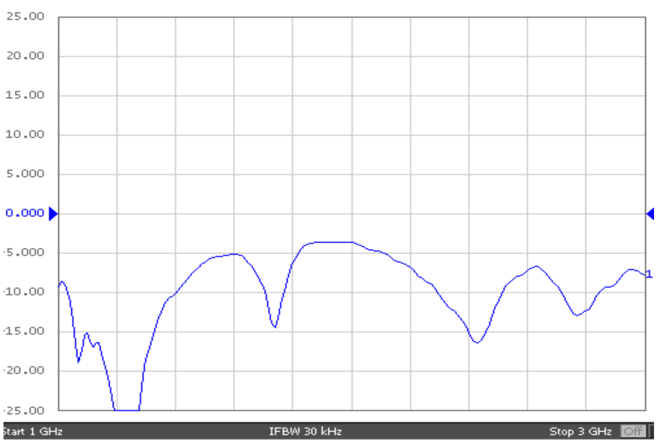

Fig 6. Measured graph of return loss Vs Frequency

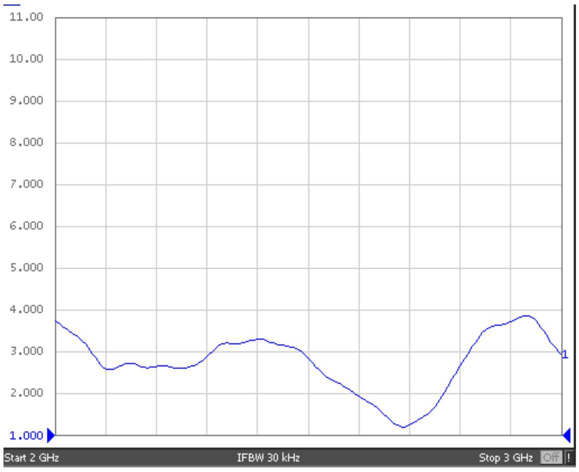

Fig 7 Measured Characteristic of VSWR

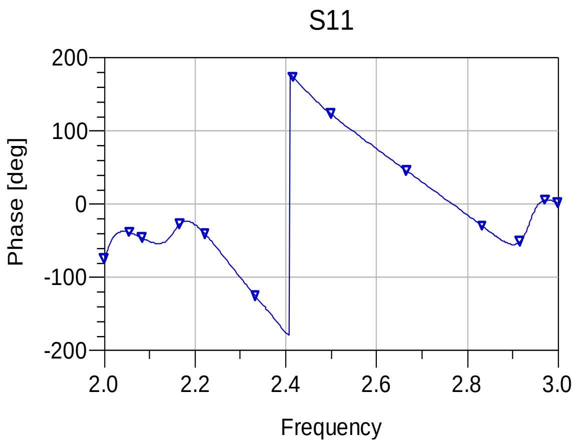

Fig 8 Phase Characteristic of proposed antenna

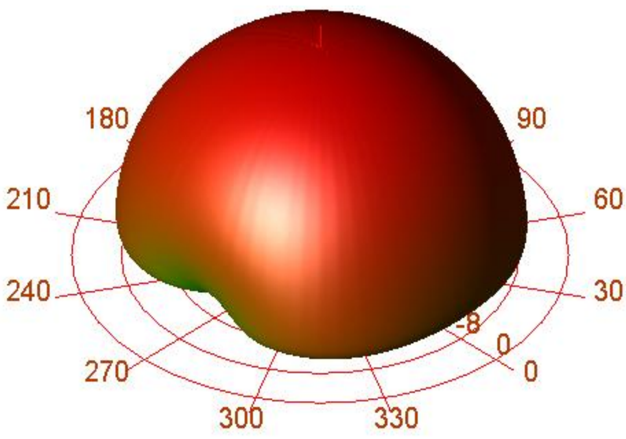

Fig 9 Radiation pattern of proposed antenna

VI. CONCLUSION

A new feeding technique is introduced in this paper. Circular polarization is achieved by connecting directly hybrid coupler to radiating element. The return loss value is greater than -10dB so the proposed antenna can be useful in the field of wireless application. Proposed antenna also having high directivity.

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