A DUAL BAND MICROSTRIP PATCH ANTENNA WITH CIRCULAR POLARIZATION

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Abstract

This paper proposes design of a microstrip patch antenna having circular polarization. To achieve circular polarization two slots are created at 45^o and 135^o in 'X' shape, at centre of the patch. This antenna has dual band characteristics at 3.6GHz and 3.5GHz, the polarization at 3.6GHz is circular while at 3.5GHz is linear. A comparison between MPA having single-slot tilted at 45 degree and X-slot is done. The antenna with single-slot gives 170MHz bandwidth, while X-slot antenna provides 200MHz.

Keywords-Circular Polarization, microstrip patch, X-shape slot

1. Introduction

Micro-strip antenna have always been an attractive choice for the researchers, because of its numerous advantages such as light weight, low volume, low cost, conformal configuration compatibility with integrated circuits and so on. Usually micro-strip antennas are designed with linear polarization, but in some applications such as satellite communication, circular polarization is desired because of its insensitivity to transmitter or receiver orientation.

A micro-strip patch is one of the most widely used radiators for circular polarization generation. Circular polarized operation and polarization diversity are becoming major design considerations for practical applications of micro-strip antennas.

Circular polarization can be achieved by using circular, pentagonal (Haneishi 1989), equilateral triangle (Tsang 1998), ring (Suzuki 1988) or elliptical patches (Shen, Long 1981) truncating the corners of a square patch (Choi 2002), feeding a near square patch diagonally from any vertex with microstrip feed, feeding a patch with coaxial cable at a point on diagonal of the square patch(Sha Liu 2008), using dual orthogonal coaxial probe feed (Sharif 2005), using dual microstrip feed along with a 90^o phase shifter (Shakeeb 2010), etching a slot tilted at 45 degrees [2], or by using slots of different geometries and other methods.

In this paper, design and simulation of a micro-strip patch antenna designed at 3.6 GHz with linear polarization is presented. Two slots crossing each other in shape of 'X' are created at centre of the patch antenna. As a result, the linear polarization of the antenna changes and circular polarization is achieved. Cross slot has been used earlier in shape of Plus sign [3] and with coaxial probe, but in this paper X-shape is used and micro-stripline feed along with a Quarter Wave Transformer is used.

This antenna has dual band characteristics and shows two types of polarization, at 3.5GHz the polarization is linear while at 3.6 GHz is circular. This

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antenna will be referenced as X-Slot Antenna or XSA in this paper for convenience.

2. Antenna Design

Table 1 below, shows various dimensions of micro-strip patch antenna, list & properties of materials used and resulting polarization.

Table1. Various dimensions of Patch antenna

S.no.	Parameter	Value
1.	Frequency	3.6 GHz
2.	Dielectric constant of substrate	Duroid(tm) 2.2
2.	Width of patch	22.58 mm
3.	Length of patch	22.58 mm
4.	Width of quarter wave transformer	0.582 mm
5.	Length of QWT	20.8325 mm
6.	Width of 50 ohm transmission line	4.84 mm
7.	Length of 50 Ω TL	15 mm
8.	Slot length	8.6mm
9.	Slot width	0.86mm
10..	Polarization	Linear

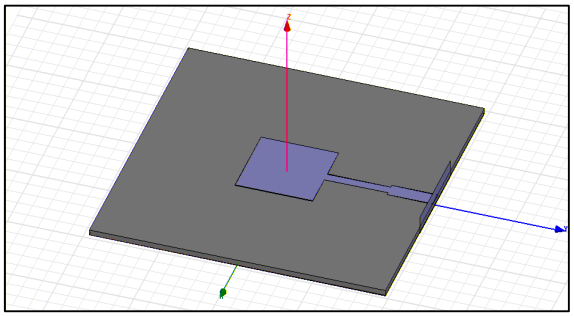

Fig.1(a) Microstrip Patch Antenna at 3.6 GHz

The patch antenna was designed on the basis of transmission line model (TLM). The width of the patch is calculated first, given by the formula,

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

where ε_r is the substrate dielectric constant, W is the width of the patch and h is the height of the substrate.
The patch we have used in our model is square patch, so the length and the width are the same. The dimensions of the patch are extended to account the fringing effect; the extension is given by,

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3).(W/h + 0.264)}{(\varepsilon_{eff} - 0.258).(W/h + 0.8)} \qquad (2)$$

Since the length has been extended by Δ on each side of the patch, the effective length is given by,

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \qquad (3)$$

Patch resonant length L is given by,

$$L = L_{eff} - 2\Delta \qquad (4)$$

Using the formulas given by TLM approximation, parameters for the antenna were calculated at 3.6GHz frequency. The material used as substrate is Duroid (ε_r = 2.2) with height h = 1.57 mm.
A Quarter wave transformer (QWT) is used to match the impedance of patch antenna with that of 50Ohm transmission line. QWT is a useful and practical circuit for impedance matching and also provides a simple transmission line circuit that further illustrates the properties of standing waves on a mismatched line.

Therefore, when it is desired to match a load resistance R_L with a feed line of characteristic impedance Z_0, a piece of lossless transmission line of characteristic impedance Z_1 and λ/4 length is used to connect them, to make the reflection coefficient Γ=0 looking into the λ/4 matching section. The matching impedance Z_1 is given by,

$$Z_1 = \sqrt{Z_0 * R_L} \qquad (5)$$

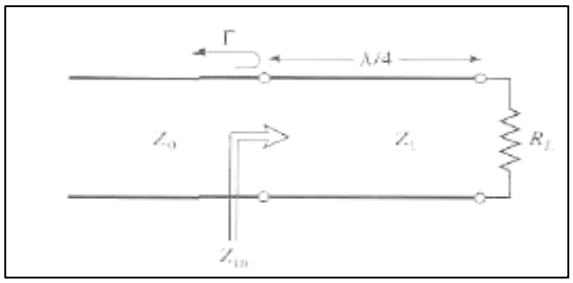

Fig. 1(b) Quarter wave matching transformer

The length of the transformer is λ/4 or 20.8325 mm and the width of the conductor is given by the formula

$$\frac{w}{h} = \frac{8\exp(A)}{\exp(2A) - 2} \qquad (6)$$

for $Z_0(\varepsilon_r)^{1/2} > 89.91$, that is A > 1.52 and for $Z_0(\varepsilon_r)^{1/2} <= 89.91$, that is A <= 1.52

$$\frac{w}{h} = \frac{2}{\pi}\left\{B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} \qquad (7)$$

where,

$$A = \frac{Z_0}{60}\left\{\frac{\varepsilon_r + 1}{2}\right\}^{1/2} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left\{0.23 + \frac{0.11}{\varepsilon_r}\right\} \quad (8)$$

The width of 50-ohm transmission line is calculated by eq. (7) and comes out be 4.84mm.
The dimensions of the ground plane were taken according to the length of the patch, quarter wave transformer and the 50-Ohm transmission line. So the length of the ground plane, will be given by;

$$L_g = L + L_{QWT} + L_{TL} \quad (9)$$

where L is the length of the patch, L_{QWT} is the length of the quarter wave transformer; L_{TL} is the length of the 50-Ohm transmission line.

The Patch antenna and ground plane are made of copper sheet; the thickness of copper sheet is taken to be 0.1 mm. The antenna is fed RF signals ranging from 2 to 5GHz with the help of a wave-port as shown in fig.1. This antenna without any slot shows linear polarization. To change the polarization of this antenna from linear to circular, a slot tilted at an angle of 45degrees is etched at the centre of the Patch [2]. The dimensions of the slots being calculated according to the following equation given below [2]

Length a = length of patch / 10 (10)
Width b = a / 10 (11)

The structure of micro-strip patch antenna with tilted-slot is shown in figure 2.

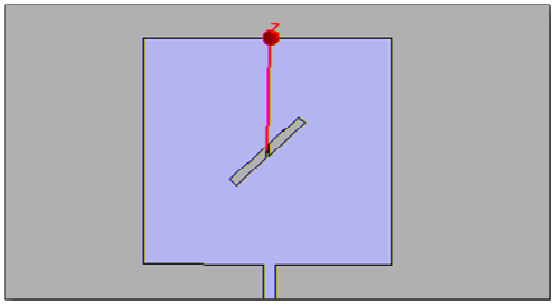

Fig.2 Patch antenna with tilted slot

The tilted slot changes the polarization of the antenna from linear to circular and may be verified by plotting the axial ratio as shown in fig 3. For circular polarization the axial ratio should be 1. The axial ratio of single tilted slot antenna is 1.01 which confirms circular polarization.

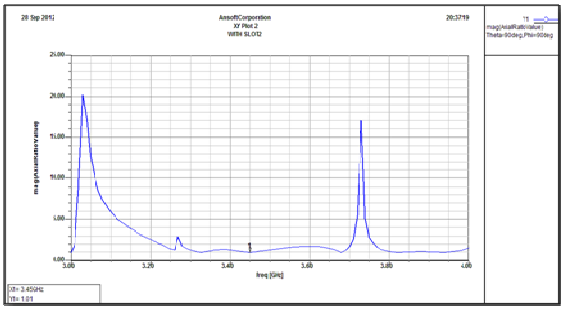

Fig.3.Axial ratio of single tilted slot etched patch antenna

The s-parameter plot of antenna with tilted slot is shown in figure 4. The bandwidth of the antenna may be measured with the help of this plot and is found to be 170MHz.

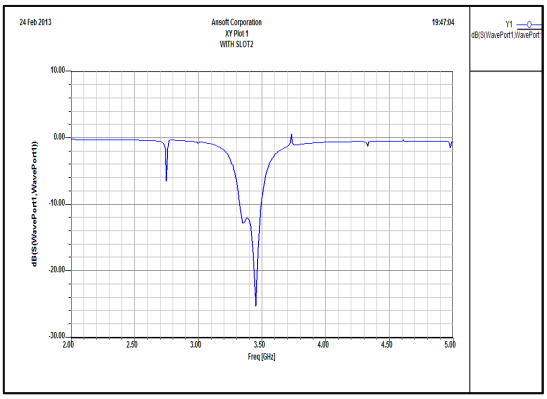

Fig.4 S11 plot of single slot patch antenna

Next step is to create another slot at an angle of 135 degrees crossing the first slot in the shape of 'X'. This 'X' shape slot also gives circular polarization. Circular polarization can be observed by plotting axial ratio. The design of X slot antenna (XSA) is shown in fig.5 given below

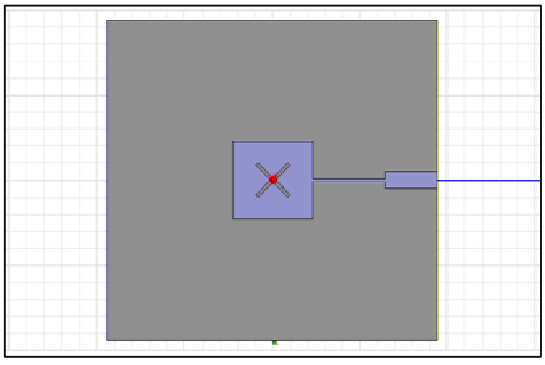

Fig.5 Micro-strip patch antenna with X slot

The XSA provides better bandwidth as compared to patch antenna with single tilted slot. The comparison of bandwidth between these two patch antennas is shown in next section.

The bandwidth may be found in terms of VSWR (VSWR<2) or S11 parameter (S11<-10dB). In this paper it is calculated in terms of S11 parameters.

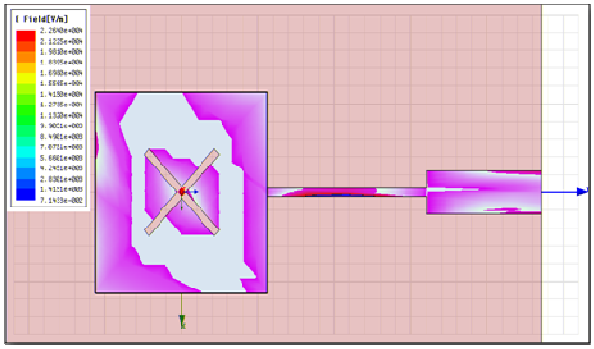

Fig.6 Electric field distribution for XSA

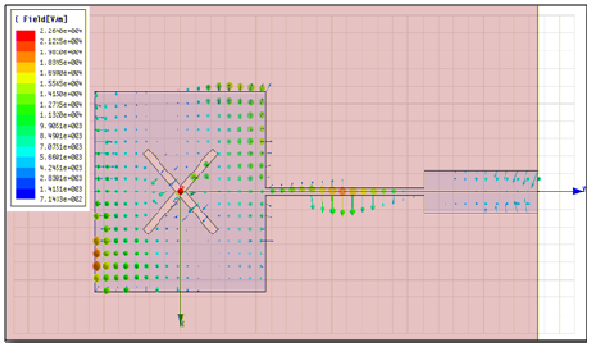

Fig.7. Distribution of Vector and Magnitude of Electric Field

3. **Result & Analysis**

3.1 Software and settings

This Circularly polarized antenna was simulated on EM solver Ansoft HFSS (High Frequency Structure Simulator), the radiations were measured with the help of an infinite sphere setup in far field. The RF Signals were setup from 2 GHz to 5 GHz, simulated adaptively.

3.2 Analysis of results

The simulation results are shown in figures below; from figure 8 to 12. It can be observed that the S11 for circularly polarized antenna with X slot when compared to the S11 of patch antenna with single tilted slot provides improved bandwidth.

XSA has dual band characteristics, showing resonance at frequencies 3.5GHz and 3.6GHz. Figure 10 shows the axial ratio for XSA, as desired, its magnitude is 1.01, which shows that this antenna has circular polarization.

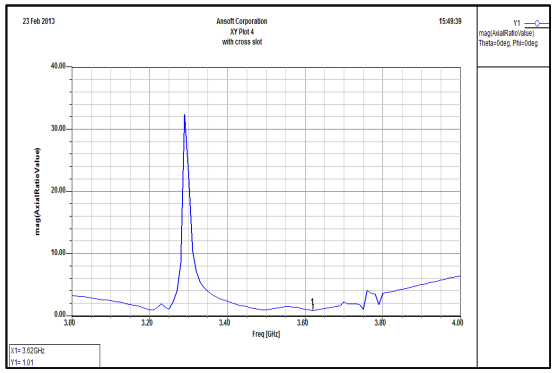

Fig.8 Axial ratio of XSA

Gain and radiation pattern of XSA are shown in figure 9 and 10 respectively. From Fig.9 a maximum gain of 5.54dB is reported.

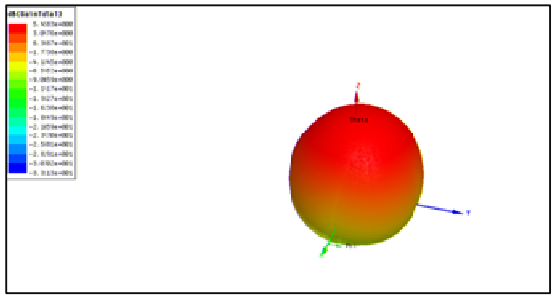

Fig. 9 Gain of XSA

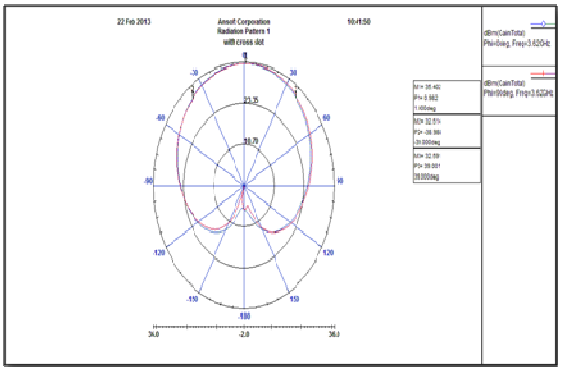

Fig. 10 Radiation Pattern of XSA

XSA provides wide bandwidth and is observed to be 200MHz with the help of s-parameter as shown in

fig.11, while the single-slot antenna shows a bandwidth of 170MHz as was shown in fig. 4.

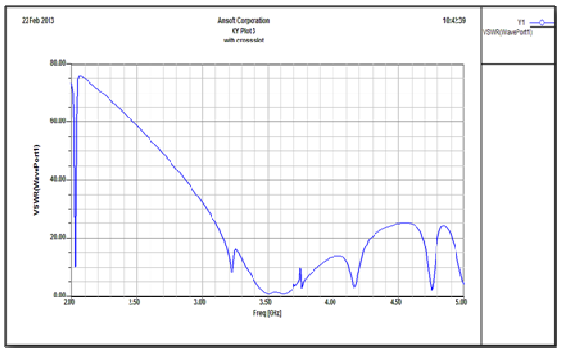

Fig.11 VSWR of XSA

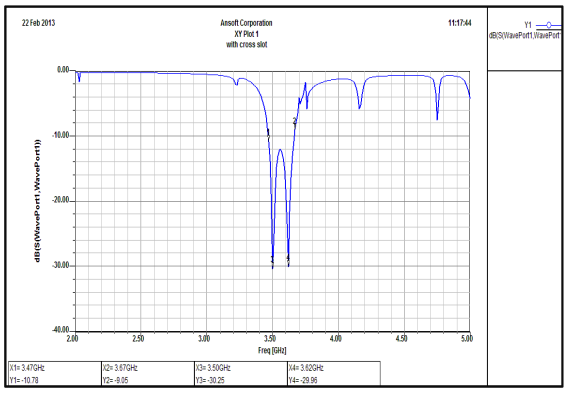

Fig.12. S-parameter of XSA

Circular polarization can be verified with help of E(Θ) and E(Φ), both of these quantities takes maximum and minimum values alternately i.e. when E(Θ) is maximum E(Φ) takes minimum value and vice-versa. The plot for single-slot antenna is shown in Fig.13, which confirms this pattern and thus confirms circular polarization. Fig.14 shows similar plot for XSA, which is also showing circular polarization.

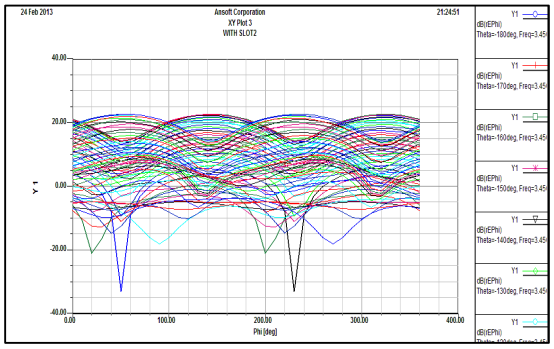

Fig. 13 E(θ) and H(Φ) plot of single tilted slot etched antenna

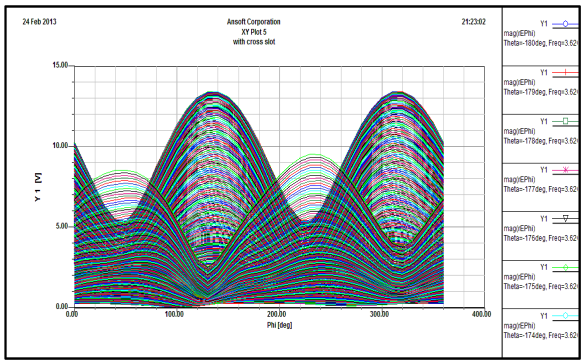

Fig. 14 E(θ) and H(Φ) plot of X slot etched antenna

Conclusion and Future scope

The design of a circularly polarized is presented in this paper, first a single slot tilted at 45 degrees was etched and results were analyzed, then the effect of etching two slots at 45 and 135 degrees in shape of 'X' was studied.

A comparison between the two was also done. It was found that Patch antenna with X-slot or X-shape slot showed better performance than patch with single tilted slot in terms of bandwidth. Both of these antennas successfully showed circular polarization; which was confirmed with help of axial ratio or by noting the behavioral pattern of theta and phi components of Electric field.

The proposed antenna is suitable for use in communication, defense applications, surveillance and countermeasures etc.

In future this antenna may be made reconfigurable in frequency and polarization. Also work could be done in order to improve its bandwidth.

Acknowledgement

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