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A Triangular Patch Antenna for Wireless Applications

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***Abstract*— A coplanar waveguide feed (CPW) triangular patch antenna is designed for wideband circular polarization and experimentally validated. The square slot is excited using a stepped feed line terminated on a triangular shaped tuning stub. To achieve circular polarization, inverted L shape strip are attached to the ground plane at the opposite corners while a rectangular slit is cut in the triangle patch. The proposed antenna provides a wide bandwidth of 3.4GHz (3.1GHz-6.5GHz) under simulation. The gain of the antenna is enhanced by using a double layered square loop frequency selective surface (FSS). The FSS is used as a reflector placed beneath the antenna at on optimum distance. The gain improvement is about 4dB at most of the operating band. From experimental results, it is found that the gain of the antenna is improved and the FSS is found to be in good agreement**.

***Index Terms*—Circular Polarization, CPW feed, Frequency Selective Surface, High Gain.**

I. INTRODUCTION

Today's remote shopper gadgets, intended for indoor correspondence needs high information rate. In addition, therefore correspondence like Bluetooth, WLAN, WiMAX, and HIPERLAN-2 needs the compact antenna with wide bandwidth. The channel capacities with wide bandwidth improve the date rate of compact antennas. Slot antenna has attractive features such as wider bandwidth, low profile, easy integration with monolithic microwave integrated circuits, low cost and easy fabrication. A circularly polarized antenna gives a flexible orientation of the transceiver and it also helps to combat multi-path fading effects in a diverse environment [1]. A number of printed antennas displaying the circular polarization (CP) have been discussed in the literature. In particular, the coplanar waveguide (CPW) fed slot antenna are preferred for wider bandwidth and it is a cost efficient uniplanar structure. The uniplanar structure also reduces the misalignment errors to a large extent [2]. In addition, the CPW feed is characterized by easily integrated with monolithic microwave integrated circuitry, less dispersion and low radiation loss. Some of the slotted antennas recently reported for circular polarization are listed in Refs. [3-8]. The wideband rectangular slot antenna was notched at the frequency from 3.4 - 3.6GHz and the slot dimension is 16.5x30mm^2 [9].

Along with a desired polarization profile, another property of the antenna which is quite important in many applications is the gain or directionality property [10]. As against the micro strip fed antennas, the CPW fed or slots suffer from degradation in gain due to the absence of ground backing. The Omni-directional radiation patterns of these antennas imply wastage of power for application such as point to point communication or object tracking. The applications such as microwave imaging, bio-medical imaging, nondestructive detection and ground penetrating radars also require high gain or uni-directionality. The uni-directional feature improves the signal to noise ratio. One solution to improve the gain of the CPW feed antenna is to provide a metallic reflector beneath the antenna which can also act as a shield for the adjustment electronic circuitry. The metallic shield causes image current to appear and the out of phase reflection results in deterioration in the impedance matching and far field radiation pattern [11]. Another solution to improve gain is to use frequency selective surface (FSS) just like a reflector. The FSS, also called as a high impedance surface (HIS),when placed properly, it can offer in-phase reflection over a wide band and improves the impedance matching [12].

In this paper, a compact slot antenna utilizing CPW feed is outlined. Geometry of the slot is rectangular with perturbation applied for getting circularly polarized behavior. To improve gain of the antenna, the frequency selective surface has been designed and implemented. The FSS is a square loop printed on both sides of the substrate and placed beneath the antenna to act as a reflector. The double layer is chosen as the multi layer FSS offers wider bandwidth and sharper roll off [13].The software used for simulation is high frequency structure simulator. In the following sections, the antenna geometry, simulated results and FSS design for gain enhancement are discussed.

II. ANTENNA DESIGN AND DESIGN PROCESS

The geometry of the triangular patch antenna is placed in the co-ordinate system as shown in Fig.1. For simulating the antenna, glass epoxy (FR4) substrate of relative permittivity ϵ_r=4.4, loss tangent tanδ=0.02 and thickness 1.6mm is used. The ground plane is imprinted on one side of the substrate with the dimension of W x L mm^2.A square slot is etched on the ground plane which has dimension of L_s x W_s mm^2.The width of the surrounding spaced slot is “q” mm for horizontal section and the “p” mm for vertical section. The square slot is excited by a CPW whose feed line is stepped for impedance

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matching. The widths of the two section of the feed line are indicated by w1 and w2 whereas the length of the section closed to the port is denoted by 'l_s'. The feed is terminated on a triangular shaped patch protruding into the slot centre. The triangle patch has a side length of r mm.

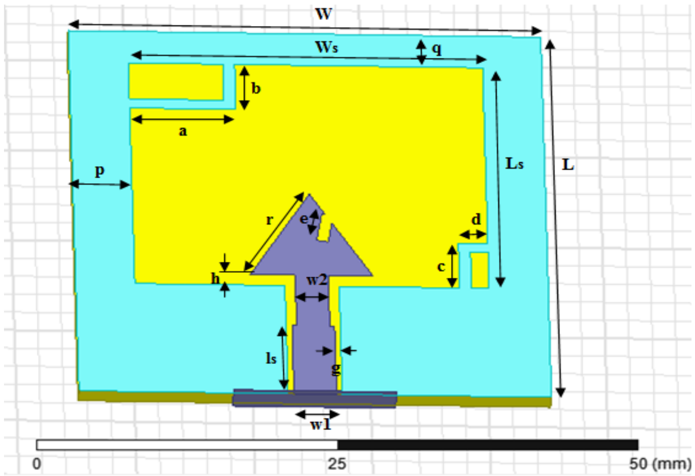

Fig.1 Geometry of the proposed antenna

For obtaining circular polarization, inverted L-shaped strip of 1mm wide are attached to the ground plane at the opposite corner of the square slot. The lengths of the various section of these strips are indicated by 'a', 'b', 'c' and'd'. Further, a vertical rectangular slit is cut in the triangular shaped patch. The slit is 1mm in width, 3mm in length and from vertex to rectangular slit distance is 2.79mm. The dimensions of the proposed antenna are as follows (in millimeter): L=40, W=40, L_s=24.5, W_s=30, p=5, q=3.5, w1=3.6, w2=2.8, l_s=7.6, a=9, b=5, c=5, d=2.5, e=3, r=6, h=1.2, g=0.5.

III. SIMULATED RESULTS

The proposed antenna is simulated on HFSS and their corresponding reflection coefficients are shown in Fig.2. The impedance bandwidth seen from the reflection coefficient (for S11>-10dB) starts from 3.2GHz and extends well beyond 6.4GHz.From the reflection coefficient, resonance can be noted at 3.2GHz (3.2GHz-6.4GHz). The first resonance is controlled by wide slot of dimensions W_s x L_s. The slot perimeter being approximately equals to one guide wavelength at this frequency. The triangle at the end of the CPW feed line acts like a monopole and results in the second resonance due to the open slit cut in the triangular patch and the inverted L shaped strip is attached at the corners of the rectangular slot.

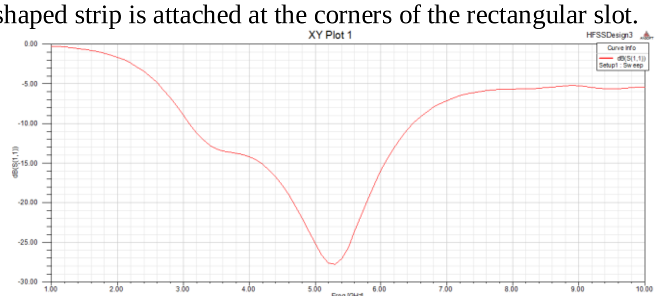

Fig.2 Reflection coefficient of the proposed antenna (without FSS)

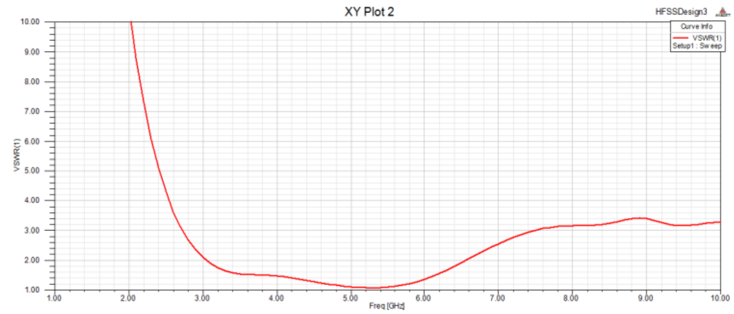

Fig.3 VSWR of the proposed antenna (without FSS)

IV. FSS DESIGN FOR GAIN ENHANCEMENT

A 6x6 square loop FSS is designed to improve the gain of the proposed antenna. The FSS is formed by printing metallic loops on both sides of FR4 substrate. The substrate has a relative permittivity ε_r= 4.4 and thickness 1.6mm. A schematic of the FSS is shown in Fig.4. The loop type FSS combines the characteristic of the patch type FSS and the slot type FSS and is chosen for its broadband operation. By using a double layer structure with these square loop FSS, ultra wide bandwidth can be realized. A double layer square loop FSS structure is shown in Fig.4. An equivalent circuit for the square FSS is shown in Fig.5. The substrate with its characteristic impedance Z_{sub} is sandwiched between the two FSS section, each represented by a lumped inductance and capacitance in series. Z_o is the characteristic impedance of air. The values of L and C can be computed using Eqs. (1)-(4) [13]

$$\omega L = \frac{d}{p}F(p,2w,\lambda) \quad (1)$$

$$\omega C = 4\varepsilon_r\frac{d}{p}F(p,g,\lambda) \quad (2)$$

$$F(p,2w,\lambda)=\frac{p}{\lambda}[\ln(\mathrm{cosec}\frac{\pi(2w)}{2p}+G(p,w,\lambda)] \quad (3)$$

$$F(p,g,\lambda)=\frac{p}{\lambda}[\ln(\mathrm{cosec}\frac{\pi(g)}{2p}+G(p,g,\lambda)] \quad (4)$$

Here ωL is the inductive associated with L and ωC is the capacitive susceptance associated with C and G is a correction factor. The admittance of the shunt branch FSS is represented as,

$$Y=(j\omega L+\frac{1}{j\omega C}) \quad (5)$$

The magnitude of the transmission coefficient for a single layer FSS is given by

$$|\tau|^2=\frac{4}{4+|Y|^2} \quad (6)$$

The resonance frequency can be obtained as follows,

$$\omega L=\frac{1}{\omega C} \quad (7)$$

For a single layer, square loop FSS substrate is ε_r=2.7 (the mean of air and FR4), the value of ωL is 5.2416λ^{-1}, ωC is 440.929 λ^{-1}. With these values and Eq. (7), the calculated

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resonance comes out to be 6.24GHz which matches well the simulated values of 6.27GHz. Also, the transmission coefficient magnitude $|\tau|$ is calculated using (5) and (6).

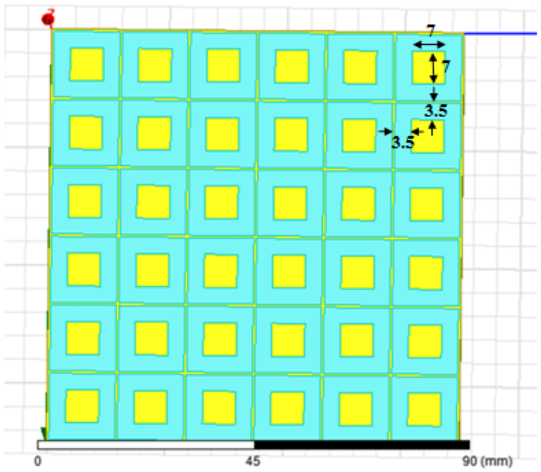

Fig.4 FSS Structure of the proposed antenna

The separation from the antenna at which the FSS screen is to be placed is decided from the reflection phase behavior. The separation should allow for constructive interference between the radiation reflected from the FSS and the antenna radiation. For this requirement, a simple expression can be written as given in Eq.(8).

$$\Phi_{FSS}-2\beta h=2n\pi, \quad n = \ldots.-2,-1,0,1,2,\ldots.. \qquad (8)$$

In Eq.(8), Φ_{FSS} is the reflection phase of the FSS. h is the distance at which the FSS is to be placed and the free space propagation constant β is given by $2\pi/\lambda$. If the reflection phase is chosen to be 0, from Eq.(1), the optimal height will be $h=\lambda/2$. Hence, the optimal height can be taken equal to half of the wavelength at that particular frequency where the reflection phase of the FSS is zero. Hence, the optimal height is calculated as 21mm. The geometry of the proposed antenna with FSS is shown in Fig.6. The reflection coefficient of the antenna without the FSS is shown in Fig.2 and with the double layer square loop FSS is shown in Fig.7.

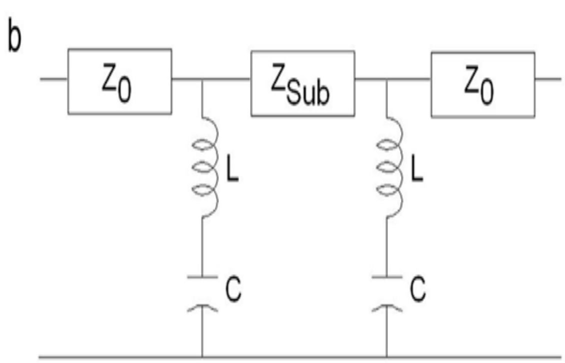

Fig.5 Equivalent circuit for double layer, square loop FSS

Fig.3 and Fig.8 show the simulated VSWR for with and without FSS antenna. It can be seen from Fig.7, that the impedance bandwidth is more or less same after the application of the FSS screen. However, at frequency 9GHz, the impedance matching somewhat deteriorates in the presence of the FSS. In case of without FSS, the deterioration results and is not so evident. It is to be noted here that the working region of the FSS is from 3.4GHz (3GHz-6.4GHz) and 9GHz (Fig.7). The simulated radiation patterns of the proposed slot antenna with the FSS are shown in Fig.12, Fig.13 and Fig.14.

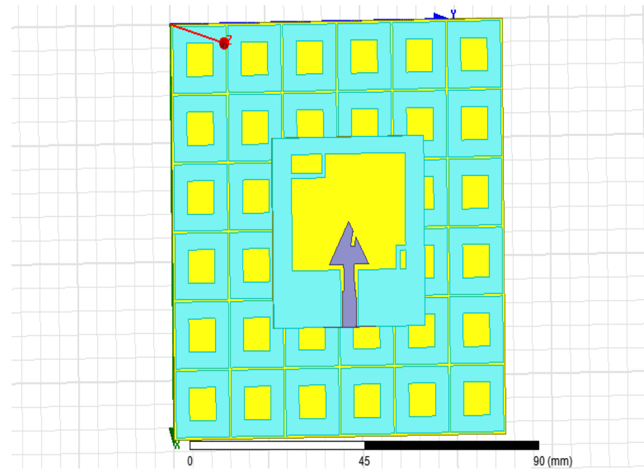

Fig.6 Geometry of the proposed antenna with FSS

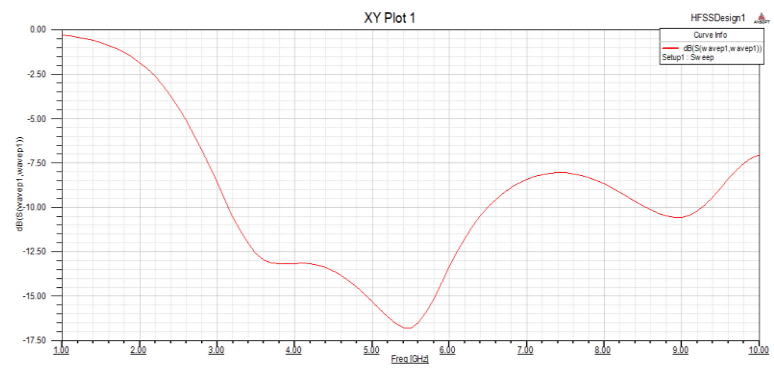

Fig.7 Reflection coefficient of the proposed antenna with FSS

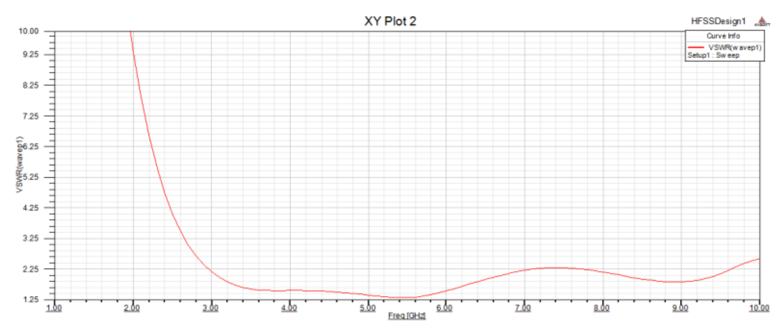

Fig.8 VSWR of the proposed antenna with FSS

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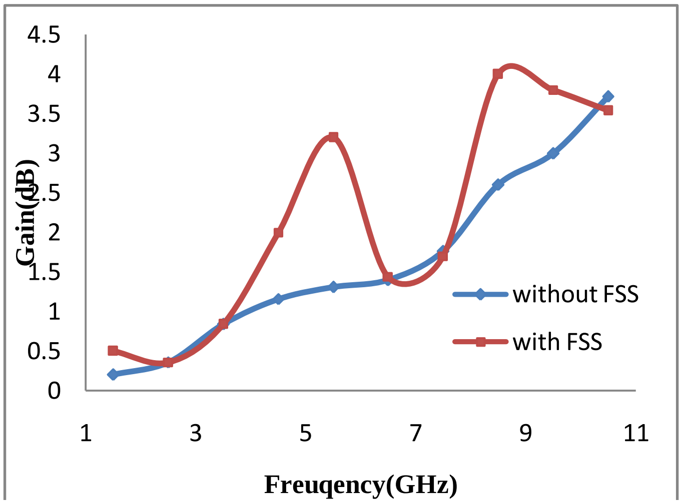

Fig.9 Gain

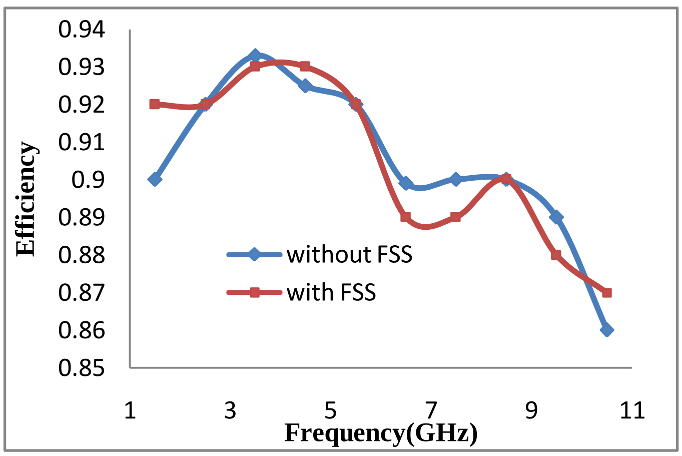

Fig.10 Radiation Efficiency

The comparison between the simulated peak gain for the antenna with and without FSS is shown in Fig.9. The increase in the gain basically results from an increase in the directivity also. On an average, the improvement in the peak gain is seen to be about 4dB. It is also observed from the Fig.9 that the gain for without FSS is approximately 2dB and for with FSS the gain is approximately 4dB. The comparison between the simulated efficiency for the antenna with and without FSS is shown in Fig.10. Nonetheless, the efficiency stays above 75% in the operating band.

The radiation pattern is plotted for selected frequencies in the two principal planes (XZ, phi=0 degree and YZ, phi=90degree). From figure, it is seen that the E-plane (XZ plane) radiation patterns look like dumb bell shape whereas the H-plane patterns are quasi-omni directional in nature. There is a good agreement in the simulated radiation pattern with the slight difference caused due to assembly misalignments. Likewise, most of the patterns seem to be reasonably stable with respect to frequency.

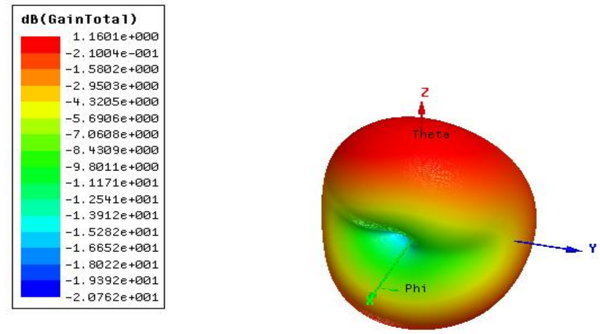

Fig.11 Radiation pattern in 3D

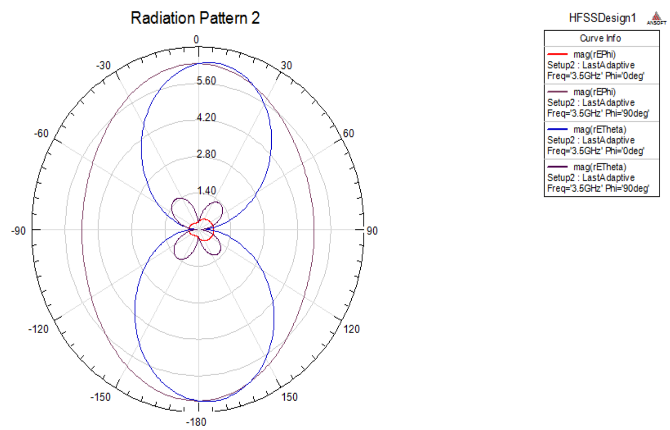

Fig.12 Radiation pattern at 3.5GHz

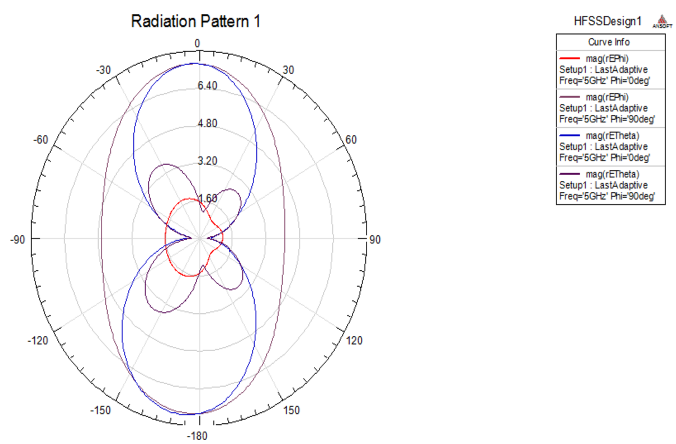

Fig.13 Radiation pattern at 5GHz

The H-plane pattern at 3 GHz shows the pinch-off along the end-fire directions (ϴ = 90). This is because of the increased cross polarization at this frequency. The simulated radiation patterns (3D) for the antenna with the FSS are shown in Fig.11. As expected the radiation becomes unidirectional in nature and the back lobes (alongϴ = 180) are considerably reduced. This indicates a reduction in the cross polar component after the application of FSS. The E-Plane and H-

Plane at 5GHz and 9GHz are more or less similar to 3GHz radiation pattern.

V. CONCLUSION

In this paper, the design of a circularly polarized triangular patch antenna is proposed and the performance is experimentally validated. The radiating element in the proposed triangular patch antenna is a rectangular slot which is excited using the stepped coplanar waveguide. The feed line is terminated on a triangular shape protrusion. For achieving circular polarization, inverted L-shaped strips are attached to the rectangular slot while a slant rectangular slit is cut on the triangular. The impedance bandwidth is 3.2GHz (3.2-6.4GHz). To improve the gain of the antenna, the frequency selective surface is designed. A square loop FSS is designed at the center frequency of 9GHz which improves the antenna gain by about 4 dB.

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