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# YAGI UDA SHAPED DUAL RECONFIGURABLE ANTENNA

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***Abstract***

***In this paper, YagiUda shaped rectangular microstrip patch antenna fed by inset feed is designed to operate for frequency and polarization reconfigurability is presented. It consists of a square patch with four corners truncated and three parasitic patches placed on top. It operates as a frequency and polarization, reconfigurable antenna. Switches are placed in the gaps of truncated corners to obtain switching between Linear, Circular polarizations. The proposed antenna also switches between two frequencies by controlling current path between main and parasitic patches through switches. Its performance evaluation is carried out with the help of simulation and physical verification and the results are presented.***

***Keywords:***

***Yagi-Uda, Polarization, Parasitic, Truncation***

## 1. INTRODUCTION

Recent communication systems demand for transfer of information at high speed almost in all areas of communications. Achieving the requirements becomes more challenging when the fading rate is high thus the system is expected to be versatile and dynamic. Various diversity schemes, polarization diversity, frequency diversity has been proposed in literature to increase the capacity. Implementation of diversity schemes requires switching between polarizations and frequencies [1]. Also, due to the advent of modern wireless communications such as Cognitive Radio where frequency switching is required, reconfigurable antennas have received much attention. Various applications require antennas with adaptable characteristics of antennas. A single antenna should have the capability of switching its operating characteristics such as frequency, polarization and its radiation pattern.

To obtain polarization reconfigurability, several patch antenna configurations have been proposed and investigated [2]-[4]. A truncated cornered microstrip antenna has been proposed for switchable polarization [2]-[5]. It has been shown that it can switch between linear and two circular polarizations which is limited to only polarization switching. This paper presents Yagi Uda shaped structure antenna with frequency and polarization reconfigurablility. The antenna configuration and the design concept are described in section 2. The antenna operating mechanism, simulated and measured return loss results and simulated axial ratio (AR) are presented in section 3. Finally, a conclusion is presented in section 4 followed by references.

## 2. ANTENNA DESIGN

The theoretical background for the proposed antenna is as followed. The fundamental frequency of the antenna totally depends on the effective length of the current path and is determined using Eq.(1). To obtain the desired frequency shift from the fundamental frequency, parametric and optimization analysis were carried out using Yagi Uda principle and simulation software Ansoft HFSS12.0 by manipulating the length and width dimensions of parasitic elements $P1$, $P2$ and $P3$. In Yagi Uda antenna, generally length of the directors is 8% to 15% less than the previous directors. It also observed during simulation that spacing between the main patch and parasitic patch $G1$ and between parasitic patches $G2$ and $G3$ mainly affects the impedance matching and is optimized using trial and error method.

$$f_r = \frac{c}{2\left(L+2\Delta L\right)\sqrt{\varepsilon_{reff}}} \tag{1}$$

$$\Delta L = 0.412h\frac{\left(\varepsilon_r+3\right)\left(\dfrac{w}{h}+0.264\right)}{\left(\varepsilon_r-3\right)\left(\dfrac{w}{h}+0.8\right)} \tag{2}$$

$$\varepsilon_{reff} = \frac{\left(\varepsilon_r+1\right)}{2}+\frac{\left(\varepsilon_r-1\right)}{2}\left[1+12\frac{h}{w}\right]^{-1/2} \tag{3}$$

where,

$\varepsilon_r$ = Dielectric constant

$f_r$ = Resonating frequency

$c$ = Velocity of light

$\varepsilon_{reff}$ = Effective dielectric constant

$\Delta L$ = Fringing length

$L$ = Length of main patch

Length of the parasitic element $P1$ = 0.93 × Length of main patch.

Length of the parasitic element $P2$ = 0.82 × Length of parasitic element $P1$.

Length of the parasitic element $P3$ = 0.83 × Length of parasitic element $P2$.

The geometry of the proposed reconfigurable antenna is shown in Fig.1. It consists of a square patch of 40.8 × 40.8mm, three parasitic patches placed above the square patch with the gaps $G1$ = 2mm, G2 = $G3$ = 1mm as shown in Fig.1. The dimensions of the patches are $P1$ = 37.8 × 4mm, $P2$ = 31 × 2.6 mm, $P3$ = 25.82 × 2.6mm.

These three patches combined together operate as Yagi Uda antenna when connected by a switch between the square patch and parasitic elements. Controlling the switch $FS1$, it can operate at two frequencies 4.7GHz and 5.19GHz, which becomes a frequency reconfigurable antenna. The inset feed technique is used to feed the main patch antenna with a metal strip of width 3.52mm and length 18mm. The location of inset cut point is adjusted to match with its input impedance (usually 50Ω). The proposed antenna is printed on FR4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.54mm. The ground plane dimensions are 59.2 × 75.52mm.

Perturbation is obtained by cutting the four corners of square patch with equal side lengths and circular polarization is achieved. Polarization reconfigurability is achieved by controlling the switches *PS*1, *PS*2, *PS*3 and *PS*4 placed in the truncated corners.

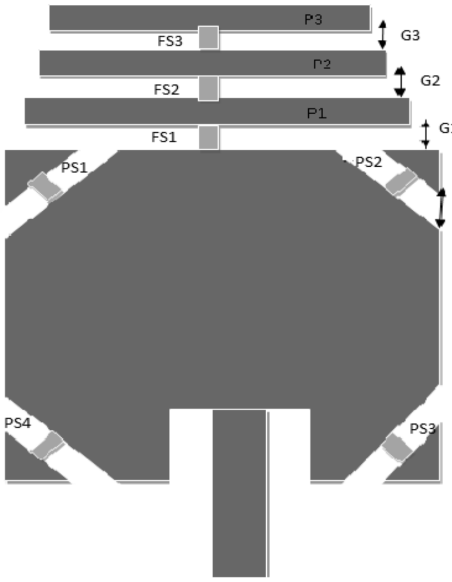



Fig.1. Geometry of the proposed antenna

## 3. SIMULATED AND EXPERIMENTAL RESULTS

The proposed structure has been simulated using HFSS and the return loss characteristics and axial ratio results are presented in Fig.3, Fig.5, Fig.6, Fig.7 and Fig.8. It has also been fabricated and return loss characteristics are measured for various switching positions using automatic Vector Network Analyzer is shown in Fig.2. The measured results of return loss characteristics are shown in fig.4.

### 3.1. FREQUENCY RECONFIGURABILITY

In simulation, the switches are modeled by choosing the capacitance of 0.25pF for OFF state and 1.5Ω resistances for ON state. In OFF state switch provides high impedance in their conducting paths. In the physically fabricated antenna, the switching between the two different frequencies is achieved by using switches of metal strip with dimensions 1mm × 1mm.

The optimum separation between the parasitic patches is found during simulations. The presence and absence of these metal strips correspond to the ON and OFF state of ideal switches. The measurements are performed with these ideal switches of metal strips.

The Fig.3 and Fig.4 shows the simulated and measured return loss characteristics of proposed antenna. The proposed antenna is designed to obtain good return loss characteristics well below -10dB. When all the *FS*1, *FS*2 and *FS*3 switches are OFF, antenna resonates at fundamental frequency of 5.19GHz as shown in Fig.3 and Fig.4.

As switches *FS*1-*FS*3 are ON there is conducting path between parasitic patches *P*1-*P*3 and main patch hence the resonating frequency of the antenna is according to equivalent electrical length of main and *P*1-*P*3 patches and antenna resonates at the frequency of 4.7GHz as shown in Fig.3 and Fig.4. The return loss is obtained below -20dB for both the frequencies hence the frequency reconfigurability is achieved.

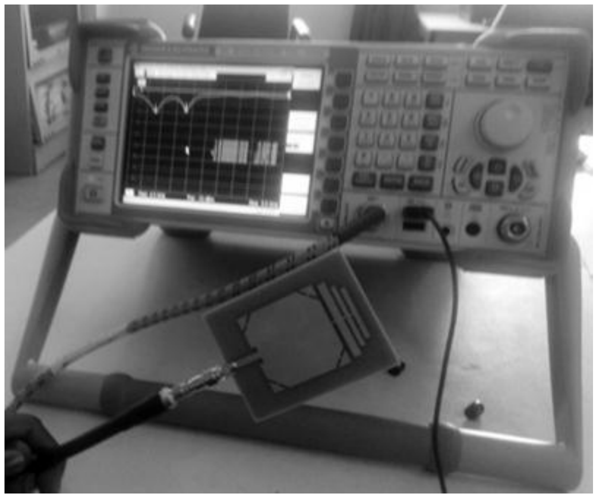


Fig.2. Photo copy of fabricated antenna with practical setup

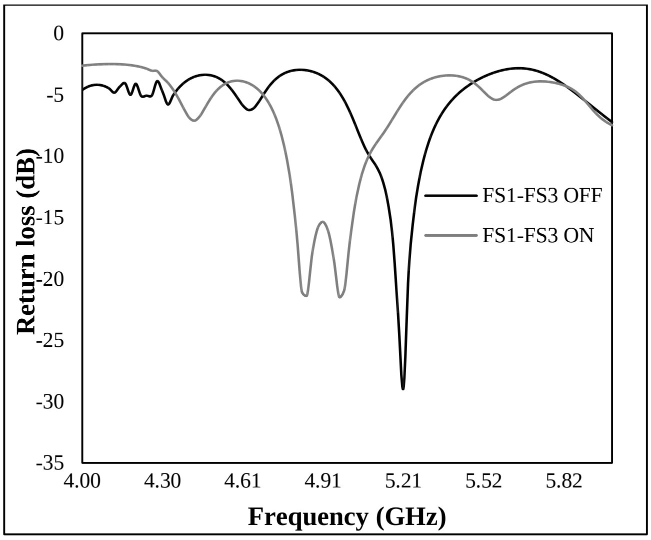



Fig.3. Simulated return loss characteristics of the antenna

### 3.2. POLARIZATION RECONFIGURABILITY

The patch antenna can be described as a cavity with $TM_{01}$ and $TM_{10}$ modes [6]. When $TM_{10}$ and $TM_{01}$ are well designed with equal amplitudes and 90 degrees phase difference, the LHCP or RHCP can be generated. The most important parameters affecting the polarization are the SMA feed location and the shapes of the main patch antenna and its truncating corners. $TM_{10}$ and $TM_{01}$ modes are created with variation in resonant frequencies by truncating the corners of main patch. At the mean of these two frequencies the circular polarization frequency is occurred.

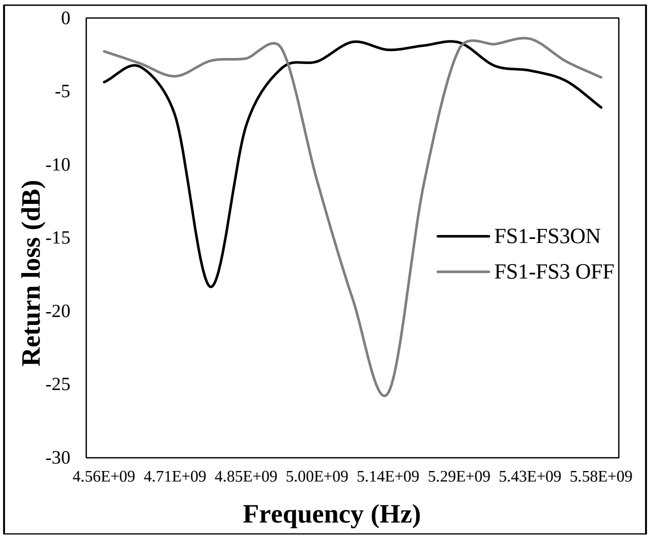



Fig.4. Measured return loss characteristics of the antenna

In the proposed antenna circular polarization is obtained at the desired resonant frequency is by adjusting the truncating corner lengths and gap '*T*' between truncated corners and main patch. In the case of RHCP, the electric current flows along the *y*-direction through the *PS*1 and *PS*3 to the two corners, resulting in longer resonant length than the current flowing along *x* direction in the main patch only. This shows that the *x* polarized field lags the y-polarized field. In contrast, in the case of LHCP the *y*-polarized field lags the *x*-polarized field. Finally, when the *x*-polarized field and the *y*-polarized field are in-phase, the type of polarization of the proposed antenna is linear polarization (LP).

Polarization reconfigurability for the proposed antenna is achieved by changing the states of the four switches which are placed at corner of the main patch. OFF state of switch (*PS*1-*PS*4) indicates that corresponding corner triangle is disconnected from the main patch. Polarization states of proposed antenna for different switching states are described in Table.1.

The return loss characteristics are verified at fundamental frequency 5.19GHz for the three polarization states. The simulated and measured -10dB impedance bandwidth for LP, LHCP and RHCP is obtained around 40MHz is shown in Fig.5. The small variation between resonance frequencies of LP antenna and CP antenna has been observed from Fig.5 is due to change in the antenna structure.

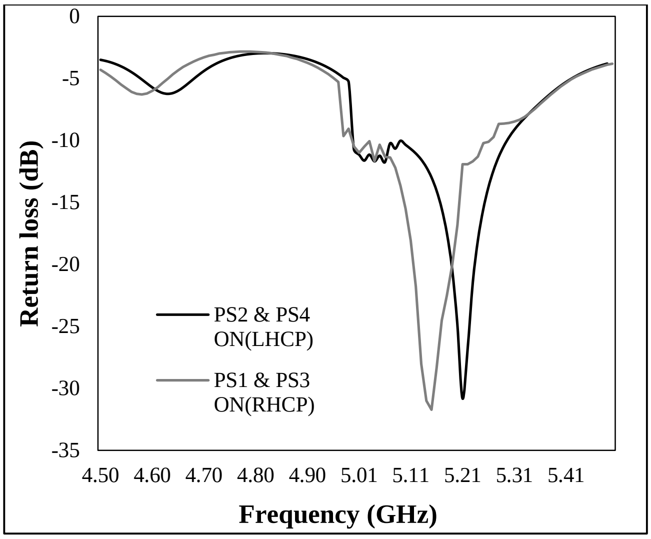



Fig.5. Simulated return loss characteristics of the antenna for LHCP & RHCP

Proposed antenna is simulated at fundamental frequency 5.19GHz and axial ratio characteristics are plotted in Fig.6-Fig.8 for all three polarization states. Axial ratio is obtained above 5dB from $\theta$ = 0º to 360º indicating antenna exhibits linear polarization is shown in Fig.6. Axial ratio of 1.67dB is obtained for RHCP from $\theta$ = 45º to 120º is shown in Fig.7 and axial ratio of 1.5dB is obtained for LHCP from $\theta$ = -10º to 80º respectively. The Fig.7 and Fig.8, shows that proposed antenna exhibits circular polarization characteristics hence Polarization reconfigurability is verified.

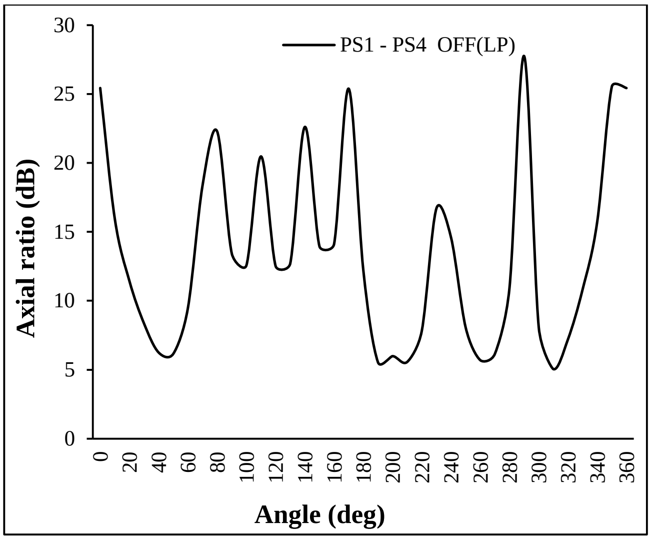



Fig.6. Simulated axial ratio characteristics of the antenna for LP

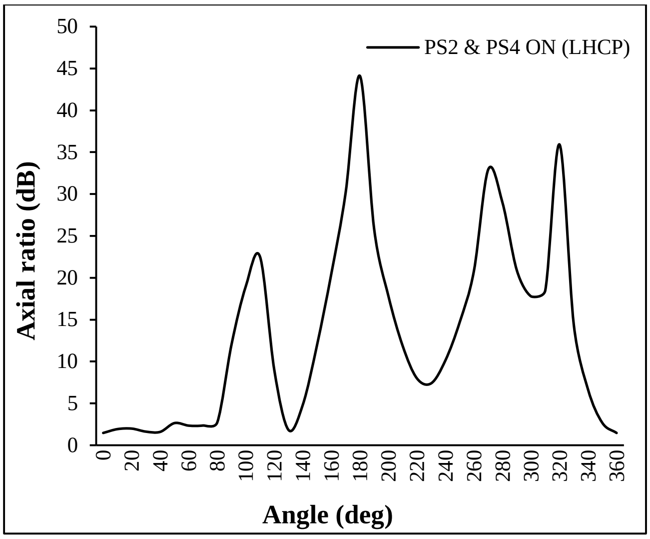



Fig.7. Simulated axial ratio characteristics of the antenna for LHCP

The radiation patterns of the proposed antenna for three polarization states at frequency 5.19GHz are illustrated in Fig.9. For the LP state, the peak gain is 5dBi and the peak gain for RHCP and LHCP is around 2dBi is obtained.

The ratio of the radiated power to the accepted power in the direction of the maximum radiation gives the radiation efficiency of an antenna. The Table.2 shows that the simulated radiation efficiency of the proposed antenna is above 90% for all polarization states for entire frequency band of antenna.

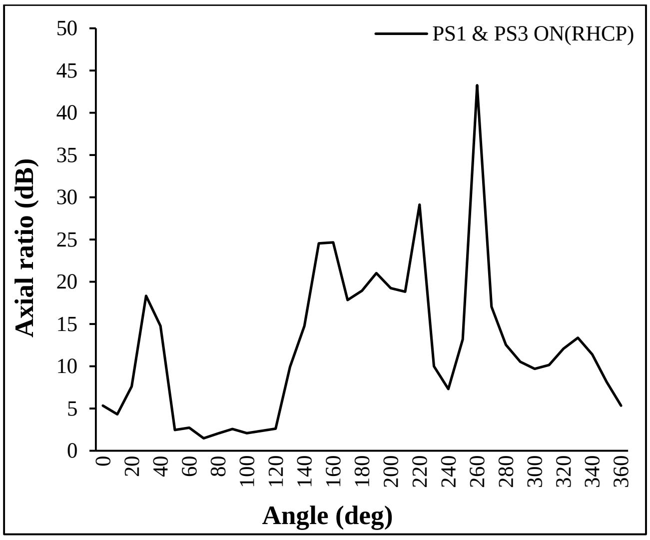



Fig.8. Simulated axial ratio characteristics of the for RHCP

Table.2. Radiation efficiency and Gain for three cases of antenna

| S.No. | Antenna state | Radiation efficiency (%) | Gain (dBi) |
|---|---|---|---|
| 1 | LP | 90 | 5 |
| 2 | RHCP | 92 | 2 |
| 3 | LHCP | 96 | 3 |

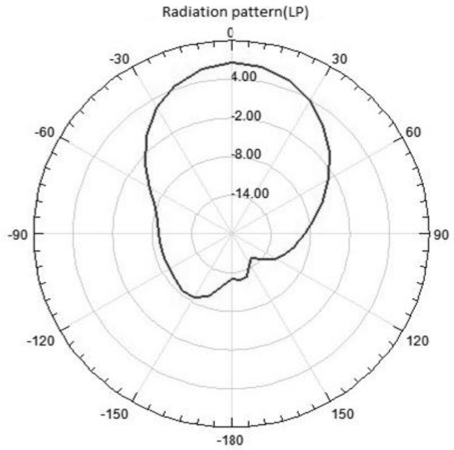



Fig.9(a). Radiation pattern of the proposed antenna for LP case

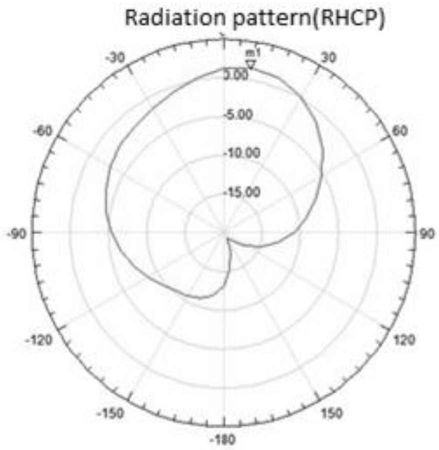



Fig.9(b). Radiation pattern of the proposed antenna for RHCP case

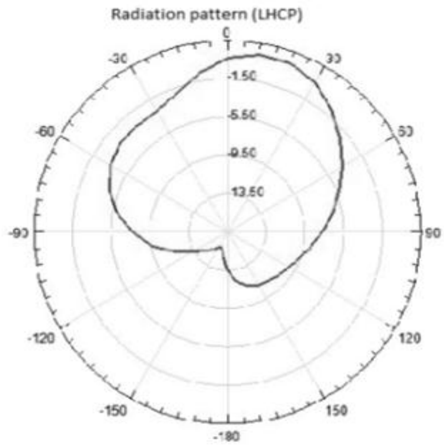
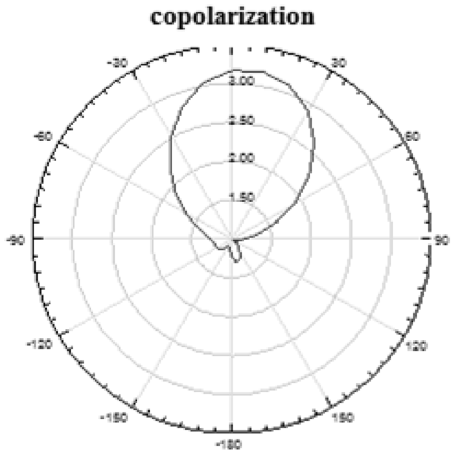
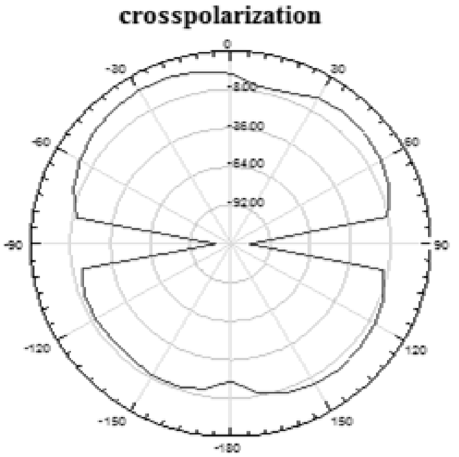



Fig.9(c). Radiation pattern of the proposed antenna for LHCP case

The Fig.10 shows that simulated co polarization ($E_\theta$) and cross polarization ($E_\phi$) levels of proposed antenna at frequency 5.19GHz for LP case and observed that cross polarization levels are well below the -10dB and shows good linear polarization performance. Cross polarizations levels of RHCP are more than 20dB below the co polarization of LHCP from -60º to 60º is shown in Fig.11 and it concludes that cross polarization field levels for LP and CP cases are less than -10dB and no interference between the polarization states.




(a)




(b)

Fig.10. Simulated results of (a). Copolarization and (b). Cross polarization of proposed antenna for LP case at 5.19MHz

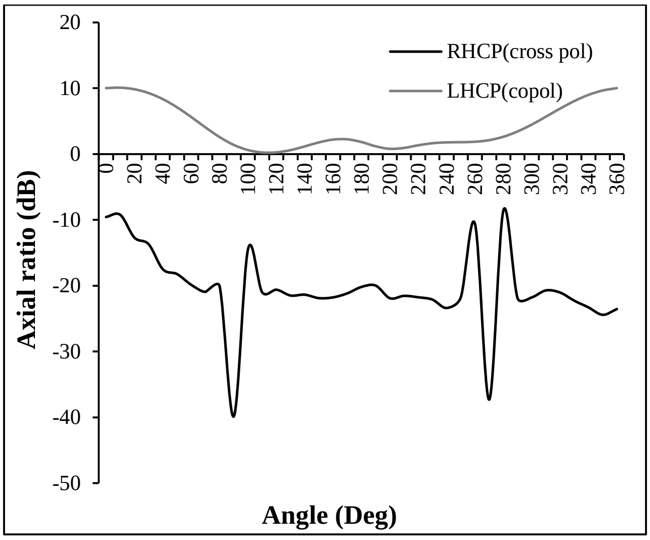



Fig.11. simulated results of co polarization (LHCP) and cross polarization (RHCP) of proposed antenna for CP case at 5.19MHz

## 4. CONCLUSION

A Yagi-Uda shaped structure antenna with frequency and polarization reconfigurability has been presented in this paper. It was shown that by controlling the states of the diagonally placed switches the polarization can be switched between circular and linear polarization or between two circular polarizations. With this proposed method a minimum axial ratio of 1.67dB for RHCP and 1.5dB for LHCP is obtained. Return loss of -20dB is obtained for both the resonating frequencies. The proposed antenna achieved -10dB impedance bandwidth of 40MHz for the three polarization states and 3dB axial ratio beam width of 75º for RHCP and 90º for LHCP. The proposed single antenna element is very much suitable for implementation of polarization and frequency diversity schemes for wireless applications.

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