Square Microstrip Antenna with Frequency and Polarization Reconfigurability

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Abstract- The design of a microstrip square patch antenna with dual reconfigurability is presented in this paper. Reconfigurability in terms of frequency and polarization is called dual reconfigurability. It has been designed for 1.7 GHz and 2.2 GHz and also for circular and linear polarization. The U-slot is inserted in the square patch and PIN diodes are placed on the slot. By switching the PIN diodes on the slot from ON to OFF state, frequency diversity is achieved. The corners of the square patch are truncated and the PIN diodes are placed on the truncated corners. By switching the diodes placed on truncated corners from ON to OFF state, the polarization diversity from linear polarization to circular polarization is achieved. The reconfigurable antenna was designed and simulated using HFSS v13 on FR4 epoxy substrate of dielectric constant 4.4 and height of substrate equal to 1.6 mm. The square patch antenna was excited by quarter wave transformer feeding method.

Keywords-PIN diodes, polarization, reconfigurability

I. INTRODUCTION

With the rapid development of wireless communication, reconfigurable antennas is gaining huge demand. Different antenna characteristics such as polarization and frequency can be reconfigurable through the change of the structures. They are lighter in weight, smaller in dimension and lower in price [1]. The fixed and reconfigurable designs giving frequency diversity are studied and experimented over simulation, in which the switching of PIN diodes give frequency reconfigurability and multibands for the patch antenna[2]. The frequency reconfigurability can be achieved on monopole to cover either the 3–5 GHz or the 5–8 GHz bands is studied using computer simulation and experimental results are also calculated[3]. A reconfigurable patch antenna consisting of a square patch with two cross-shaped diagonal slots is presented. The use of two pairs of switches in order to obtain both frequency and polarization reconfigurability is made. Specifically, three different polarization states have been obtained: a Right-Hand Circular Polarization, a Left-Hand Circular Polarization and a Linear Polarization [4]. A reconfigurable microstrip patch antenna with frequency and polarization diversities is studied. A U-slot is incorporated into a square patch, and a PIN diode is utilized to switch the slot ON and OFF, which realizes the frequency diversity characteristic. The polarization diversities among linear polarization (LP), right-hand circular polarization (RHCP), and left-hand circular polarization (LHCP) are also obtained by switching three PIN diodes on the slot and the truncating corners of a square patch ON and OFF[5].

Basically, in this paper, the square Microstrip patch with quarter wave transformer fed is designed using computer simulation, i.e. HFSSv13. The design is made for centre frequency 2.4GHz. Then the U-slot is inserted in the square patch, and two PIN diodes are placed on the slot. The PIN diodes on the slot are switched from ON to OFF state to give frequency reconfigurability. The corners of the square patch are truncated at all the four ends. The two PIN diodes are placed at the two opposite corners of the truncated square patch, whose switching from ON to OFF state gives polarization diversity from linear to circular polarization. Thus, all the four diodes on the square patch are switched to achieve dual reconfigurability.

II. MICROSTRIP PATCH ANTENNA DESIGN

The Microstrip Patch Antenna has been designed with center frequency of 2.4 GHz on a FR4 Epoxy substrate with the relative permittivity ($\varepsilon_r$) 4.4. substrate. For simplicity in the design quarter wave transformer feed was used for proper impedance matching. The Patch was designed using conventional formulas as shown below [6].
Width of the Patch is calculated using,

\[ W = \frac{1}{2f_c \sqrt{\varepsilon_{\text{eff}}}} \sqrt{\frac{2}{\varepsilon_{\text{eff}} + 1}} = \frac{\lambda_0}{2f_c \sqrt{\varepsilon_{\text{eff}}} + 1} \]  

Eq. 1

Length of the Patch is calculated using,

\[ L = \frac{1}{2f_c \sqrt{\varepsilon_{\text{eff}}}} \sqrt{\frac{2}{\varepsilon_{\text{eff}} + 1}} - 2\Delta L \]  

Eq. 2

Where,

\[ \Delta L = 0.412 \frac{(\varepsilon_{\text{eff}} + 0.3) (\frac{W}{h} + 0.204)}{(\varepsilon_{\text{eff}} - 0.3) (\frac{W}{h} + 0.8)} \]  

Eq. 3

\[ \varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12h}{W}\right)^{-0.5} \]  

Eq. 4

Using the above equation the dimensions for the patch antenna were calculated, optimized and are given below, \( W = 40\) mm, \( L = 40 \) mm.

### III. DUAL RECONFIGURABLE ANTENNA DESIGN AND RESULT

To allow the operating frequencies and the bandwidths to be reconfigurable, switching components are normally used. PIN diodes, varactor diodes or MEMS switches are the most frequently used components in the design of reconfigurable antennas. The frequency reconfigurable feature is due to change in current distribution caused on the Microstrip patch due to some switching elements like PIN diodes[2]. A quarter wave transformer fed square patch of 40x40 mm is designed using computer simulation, i.e. HFSSv13. A U-slot is being incorporated in the square patch and PIN diodes are used to switch the frequency, thus causing change in current distribution and resulting in frequency diversity. There are 2 PIN diodes placed on the U-slot, whose switching from ON to OFF state result in frequency response variation. In computer simulation, these two diodes are modelled using the resistance, inductance, and capacitance (RLC) boundary sheet which gives 0.9 \( \Omega \) as the impedance value of the PIN diode in the ON state and 0.3 pF as the capacitance value in the OFF state[2]. Using the impedances, widths of the microstrip line are calculated which are further optimized to get the desired response.

The polarization diversity is achieved by truncating the four corners. Two PIN diodes are placed on two opposite corners to switch the polarization from linear to circular polarization state. Again, in computer simulation, these two diodes are modelled using the resistance, inductance, and capacitance (RLC) boundary sheet which gives 0.9 \( \Omega \) as the impedance value of the PIN diode in the ON state and 0.3 pF as the capacitance value in the OFF state.
The Antenna is simulated using Ansoft’s HFSS 13. Figure 2 show the simulated return loss of the patch antenna.

The return loss obtained is 12 dB at 1.7 GHz as shown in Fig2.
The Axial Ratio for the states of diodes D1, D2, D3, D4 all in ON state is 7.48 dB which indicates linearly polarized antenna, and axial ratio for the states of diodes D1, D2 ON and D3, D4 OFF is 1.8 dB which indicates circularly polarized antenna. The axial ratio for linear and circular polarized antenna is shown in Fig 3.

Fig 4 shows the change in frequency response with change in switching states of diodes D1 and D2 from ON to OFF state. That means frequency diversity is achieved.

The table 1 shows the comparative results of different switching states of all four diodes from ON to OFF state resulting in dual reconfigurability.

<table>
<thead>
<tr>
<th>Diode Switching States</th>
<th>Return Loss (dB)</th>
<th>Axial Ratio (dB)</th>
<th>Freq. GHz</th>
<th>Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1, D2, D3, D4 ON</td>
<td>-12</td>
<td>7.48</td>
<td>1.7</td>
<td>Linear</td>
</tr>
</tbody>
</table>
image and original image with various watermark image, where our watermarked images peak signal to noise ratio has a better performance than others.

### IV. CONCLUSION

The proposed dual reconfigurable square Microstrip patch antenna has been designed. The developed patch has good return loss and change in Axial ratio indicating polarization diversity by switching the PIN diodes from ON to OFF state or vice versa. Also, the designed patch provides with change in frequency response yielding frequency diversity due to switching the PIN diodes. From the analysis it has been pointed out that the PIN diodes placed on U-slot of the patch change the current distribution of the patch on switching the diode states from ON to OFF. Also, the polarization has been reconfigured due to switching of the PIN diodes placed on truncated corners from ON to OFF state.

### REFERENCES


