Monopole Antenna using Switchable PIN Diode for WLAN

Application

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Abstract:
In this paper, the Reconfigurable concept has been used to produced dual polarized wideband monopole antenna for WLAN Applications. Conducting Upper edge strips are used to connect to the partial ground plane providing the necessary additional modes for circular polarization. Linear polarization, right-hand circular (RHCP) or left-hand circular (LHCP) polarization can be realized using only two PIN diodes, which connect to the ground plane, minimizing their effect on Radiation characteristics. The antenna has been designed on FR4-epoxy substrate of dielectric constant is 4.4 and thickness is 1.53mm & it's dimension is 48mm × 48mm × 1.6 mm. The antenna has an excellent axial ratio bandwidth (< 3 dB) of 8.1%. The proposed antenna exhibits a much higher impedance bandwidth (1.682- 3.22GHz) of about 58.33% (S11 < −10 dB) and also yields return loss better than −15dB in the useful range of circular polarization. The simulated radiation of antenna in azimuth plane is nearly omnidirectional. The radiation pattern, Axial ratio, Return loss, VSWR and Bandwidth of the proposed antenna are described and simulated using HFSS software package.

Keywords: Monopole antennas, Polarization, Reconfigurable, WLAN, Circular Polarization (CP).

I. INTRODUCTION
In recent years, demand for broad-band antennas has increased for use in high frequency and high speed data communication. Printed antennas are economical and can be accommodated in the device packages. Microstrip antennas are best form of printed antennas because they are light weight, low profile, low cost, easy to analyze and fabricate and are compatible with the integrated circuit. In this paper, dual-polarized and dual frequency design of a single-feed rectangular microstrip antenna with a rectangular slots i.e approximate to square slot is placed Close to its probe feeding point. The two operating frequencies, having different radiation characteristics and different polarization planes i.e. one is linear polarization and other is circular polarization. Here dual-polarized radiation can be obtained with a reduced antenna size at a fixed operating frequency. Many prototypes of the proposed compact dual polarized by exciting the patch using a coaxial probe feed along the diagonal line of the rectangular patch, it is seen that dual-frequency operation [1,2] based on the two resonant Frequencies f1 and f2 of the perturbed TM10 and TM01 modes can be generated. Linear polarization is used for mobile communication and circular polarization used for satellite communication. The dual-polarized patch antenna has been a popular research topic during recent years; the proposed antenna can double the capacity of communication systems by means of frequency reuse, and reduce the multipath fading of the received signals in land-based mobile-communication systems by means of polarization diversity. The new proposed design has the greater area reduction compared to the placard-shaped [5], arrow-shaped [6], slotted square shaped [7] antennas which reported earlier. Two parameters affect the resonant frequency of the antenna, slot width and slot length structure and changes VSWR position. Here, the low-frequency ratio and the area reduction mainly depended on the slot parameters. The design has been implemented and simulated results are presented.

In this communication, we proposed a dual polarized reconfigurable printed monopole antenna for WLAN applications. It provides RHCP and LHCP as well as linear polarization. The planar monopole is augmented by conducting strips, which connected to the ground plane using PIN diodes. It is less complex and has the advantage of avoiding diodes in the radiating element, with the benefit of using only two PIN diodes and a simple feed arrangement. To explain the CP mechanism and antenna concept, two copper pads are used initially. The pads has been used to connect PIN diodes at ground and the antenna is slightly modified to minimize axial ratio and Associated circuit effects. Key parameters are studied that show how polarization configurability is optimized.

II. ANTENNA DESIGN AND ANALYSIS
The dielectric chosen is FR4-epoxy substrate having relative permittivity of 4.4 and the thickness of 1.53mm. The dimension of patch is approximated by using basic design approach described for microstrip patch antenna as listed below:

Step 1: Calculation of Lambda (λ0)-

\[ \text{Lambda} (\lambda_0) = \frac{c}{f} = \frac{3 \times 10^8}{2.4 \times 10^9} \]

(λ0)=125mm at 2.4 GHz

Step 2: Calculation of monopole length (L)-
The frequency of operation of the patch antenna is determined by the length L.
The center frequency will be given by:

\[ F_c = \frac{c}{2L \sqrt{\varepsilon_r}} \]

\[ L = \frac{c}{2F_c \sqrt{\varepsilon_r}} \]

……………..(1)
Where $f_c$ is centre freq = 2.4GHz
$\varepsilon_r = 4.4$ and $c = 3 \times 10^8$
$L = 30\text{mm}$

Step 3: Calculation of monopole Width ($W$)-

$$W = \frac{c}{2Fr} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad \text{...............(2)}$$

For $c = 3 \times 10^8 \text{m/s}, f_r = 2.4, \varepsilon_r = 4.4$
We get $W = 38.03 \text{mm}$.

Step 4: Calculation of monopole Ground Length (GL)-

$$(GL) = \frac{\lambda}{4} \sqrt{\varepsilon_r} = 14.5\text{mm}$$

GL = 14.5 mm

Step 5: Calculation of monopole Ground Width (GW)-

$$(GW) = \frac{\lambda}{2} \sqrt{\varepsilon_r} = 30\text{mm}$$

GW = 30 mm

Step 6: Calculation of feed point-

Feed point $(y_0)$ = $\frac{30}{4} \times 7\text{mm}$
$y_0 = 7.5\text{mm}$

Feed width calculate by using

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln \left(8 \left(\frac{H}{W}\right) + 0.25 \left(\frac{W}{H}\right)\right) \quad \text{...............(3)}$$

We get $W = 2.84\text{mm}$

The length of quarter-wave transformer is,

Feed Length $(FL) = \frac{\lambda_r}{4/\sqrt{\varepsilon_r}} = 14.89\text{mm}$

Fl = 14.89 mm

A. Antenna Structure and CP Mechanism

Fig. 1 shows the proposed dual polarized antenna geometry. The antenna is printed on a FR4 substrate of dimension 48.0 mm × 48.0 mm × 1.6 mm with $\varepsilon_r = 4.4$ and $\tan = 0.0027$. The antenna consists of a rectangular-shaped planar monopole arm and a rectangular-shaped ground plane. The ground plane is augmented with two 2-mm wide strips ($S_l$ and $S_r$) and separated by 1.5 mm ($g$) from the upper edge of the ground plane. A small upper strip of width 3 mm & length is 11 mm is used to reconfigure polarization by connecting the ground plane to the strips. The antenna is fed with a 50-Ω microstrip line (2.8 mm wide) and optimized for Circular Polarization at 2.4 GHz.

![Figure 1](image1)

**Figure 1. Antenna Reconfigurable Geometry (a) Front View, (b) Side View**

B. Antenna With PIN Diodes and Biasing Circuit

PIN diodes of type SMP 1320 series are used as switches in this design. According to their datasheet, the diode is equivalent to a 0.9ohm resistor in the “ON” status, and a 0.3-pF capacitor in the “OFF” status. When the diode P1 is off and P2 is on, the upper left loop slot does work, whereas the upper right loop slot has little effect on the patch’s current distribution, resulting in an LHCP wave. Similarly, an RHCP wave can be excited when the diode P1 is on and P2 is off. The antenna radiates linearly polarized wave when both switches OFF. A 1.5-V button battery is used to power the diode.

IV. SIMULATION RESULTS

Simulation of this antenna has been carried out in HFSS. The simulation results are given in the following section:

![Simulation Results](image2)

**Figure 2. Antenna surface current (a) both switches OFF, (b) right switch ON**

When the ground plane and strips are not connected, the induced surface current on the ground plane horizontal edges and the strips are in phase but oppositely directed, therefore cancel, leaving only the vertical surface currents on the monopole arm and ground plane, generating a linearly polarized wave. When the ground plane is connected to one of the strips, the surface current on the ground plane and the strips are rearranged, so that the resultant currents on the strip upper edge and ground plane lower edge are in the same direction (strip lower edge current cancels with ground plane upper edge) and form the horizontal component needed for Circular Polarization generation. Figure 2 shows the antenna surface currents with and without the copper strip (p). When the ground plane is connected to the right strip ($Sr$), the antenna realizes RHCP in the $+Z$ direction. When connected to the left strip ($Sl$), LHCP is achieved in the same direction. Because the location of the connection (p) is symmetric with respect to the center of the coordinate system of the RHCP and LHCP antennas are the same except radiation patterns which are mirrored.

![Simulation Results](image3)

**Figure 3. VSWR**
From the Figure 3 we can be seen that the VSWR lies below the value 2 from 1.68 GHz to 3.22 GHz frequency.

**Figure 4. Return loss**

Return loss is a parameter similar to VSWR to indicate how well the matching between transmitter and antenna has taken place. Ideal value of return loss is around -10 dB which corresponds to VSWR of less than 2. As shown in Figure 4 the value of Return loss is -16.22 dB. The proposed antenna exhibits a much higher impedance bandwidth (1.68-3.22 GHz) of about 58.33% (S11 < -10 dB).

**Figure 5. Axial ratio when right switch is ON**

Figure 5 depicts the simulated axial ratio (AR) at the Right switch ON of the reconfigurable antenna. The Simulated 3-dB AR bandwidth is 180 MHz. The simulated 3-dB AR for both RHCP and LHCP configurations is 8.1% (2.5–2.7 GHz).

**Figure 6. E & H Plane radiation pattern**

Fig. 6 It is observed that the radiation patterns of antenna are omnidirectional in H-plane and bidirectional in E-plane over the entire operating freq band.

**Figure 7. Gain**

The simulated gain of the antenna at 2.45 GHz is presented in Figure 7 and it is perceived that the stable gain across the operating freq. The maximum gain is 2.0 dBi at 2.45 GHz.

### V. COMPARISON TABLE

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Switch Conditions</th>
<th>Freq (GHz)</th>
<th>Return loss (dB)</th>
<th>VSWR</th>
<th>BW (MHz)</th>
<th>Axial Ratio (dB)</th>
<th>Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Right Switch ON</td>
<td>2.48</td>
<td>-20.95</td>
<td>1.19</td>
<td>1140</td>
<td>0.67</td>
<td>2.1</td>
</tr>
<tr>
<td>2.</td>
<td>Left Switch ON</td>
<td>2.48</td>
<td>-20.98</td>
<td>1.19</td>
<td>1140</td>
<td>0.78</td>
<td>2.1</td>
</tr>
<tr>
<td>3.</td>
<td>Both left right Switch OFF</td>
<td>2.42</td>
<td>-16.22</td>
<td>1.32</td>
<td>1450</td>
<td>25</td>
<td>2.0</td>
</tr>
</tbody>
</table>

To improve the compact size of this antenna, partial ground techniques are introduced. As seen from the table, when right switch is ON then we got RHCP and left switch ON then we got LHCP. If both switch OFF conditions means it is linear polarized because axial ratio is greater than 3.

### VI. CONCLUSION

A simple low-cost wideband dual-polarized reconfigurable antenna for WLAN applications in the 1.62–3.2 GHz frequency band. The antenna has an approximately BW of 58.33% and the peak gain of 2.0 dBi for both polarizations is proposed. It can provide LP Switch OFF as well as RHCP or LHCP with switch ON conditions configurations using only two PIN diodes. The diodes connect to the partial ground plane minimizing their influence on radiation characteristics. The antenna has a measured Axial Ratio Bandwidth of 180 MHz for CP configuration.

### VI. REFERENCES


