E-shaped Patch Antenna with Reconfigurable Circular Polarization for Wireless Applications

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Abstract: Polarization reconfigurable capability has been successfully added to a conventional E-shaped patch antenna. It allows switching between right hand circular polarization (RHCP) and left hand circular polarization (LHCP). Antenna reconfiguration is enabled with the aid of two RF switches inserted in appropriate locations on each slot of the E-shaped patch. If one switch is ON and the other is OFF, the two slot lengths will become effectively unequal and circular polarization will be obtained. If the states are reversed, circular polarization (CP) with opposite orientation will be obtained at the same frequency band. The antenna with integrated DC biasing circuit for the switches is designed to cover IEEE802.11b/g band (2.4-2.5GHz).

Keywords: Reconfigurable Antennas, Polarization Agility, RF Switches, Circular Polarization

1. Introduction

Polarization reconfigurable microstrip antennas have received much interest in the last decade. These microstrip antennas can alter their polarization characteristics, that is why they are sometimes called “polarization agile microstrip antennas”. They are desired for wireless applications because they double the system capacity through frequency reuse with two different polarizations. In addition, they enable diversity in establishing radio links which combat signal fading and enhance the overall performance. Moreover, they allow users of mobile devices to roam on different wireless systems without the need of several individual antennas integrated in their devices. Hence, they are useful for the compactness and light weight of these wireless devices. Also, polarization reconfigurable antennas have potential applications in multiple-input multiple-output (MIMO) systems. In the literature, different methods and techniques are reported for such aim; the most recent among them are reported in [1-6]. In this paper, a new antenna design is proposed for polarization reconfigurable single-feed single-layer microstrip antenna with switchable RHCP/LHCP covering IEEE802.11b/g band (2.4-2.5GHz). The proposed structure exhibits design simplicity and wide effective bandwidth (impedance, axial ratio, and gain overlapped bandwidth). Simulation results for S11, axial ratio, and gain radiation pattern are presented.

2. Reconfigurable Antenna Configuration

Antenna’s geometry is shown in Fig.1. It is a conventional E-shaped patch antenna of length L=40 mm and width W=77 mm with equal parallel slots of lengths Ls=31 mm and widths Ws=7 mm. The antenna is printed over substrate of εr=2.2, thickness t=0.787 mm, and dimensions Lsub=140 × Wsub=80 mm. This structure is then mounted 10mm above the ground plane whose dimensions are 200×200 mm²
via the coaxial probe feed as shown in Fig.1(b). The excitation pin is placed at Yf=16 mm. The rest of the structure’s dimensions are S=0.5mm, l=10mm, dx=30mm, dy= 20mm. E-shaped patch is used because of its wide band characteristics [7].

Two RF switches are inserted on the two slots of an E-shaped patch at Y=12.5mm. The RF switch used is the PIN diode, which is modeled as a 4Ω resistor in the forward bias (ON state) and parallel RC circuit in the reverse bias (OFF state), whose values are 4kΩ for the resistor and 0.03pf for the capacitor as shown in Fig. 2. This model mimics the behavior of the real commercial PIN diode MA4AGBLP912 available in market. In order to function properly as switches, PIN diodes need a special DC biasing circuit to be integrated with the antenna structure for practical applications. The positive terminal of the DC is fed through the coaxial pin with the RF signal using a Tee bias. This is a section used to superimpose the DC voltage with the RF signal using lumped inductor and capacitor as shown in Fig.1(b). A narrow slit of 0.5mm is incorporated to connect the two parallel slots of the E-shaped patch in order to divide the E-shaped patch into two parts (part 1 and part 2) to avoid a DC short when connected across the diode’s nodes. Part 1 is connected to the pin of the coaxial probe, while part 2 is grounded through a via connected to a strip line of 1mm width and lumped inductor act as RF choke (100 uH) as shown in Fig.1. Part 1 and Part 2 need to be RF shorted to maintain the performance of the original structure. Three 50 pF capacitors are inserted across the narrow slit to shorten it for the RF signal and block the DC connected across the two parts of the antenna. By this, a complete DC biasing circuit is integrated within the antenna structure with common ground for both DC and RF signal and full isolation between them.

3. Operation Principle

Due to the presence of two diode switches within the antenna structure, the antenna has four possible configurations tabulated in Table 1. In state 1, switch 1 (D1) is ON while switch 2 (D2) is OFF. Therefore, the upper slot of the E-patch is now effectively shorter in length than the lower slot and the antenna will look as shown in Fig. 3(a). This yield a LHCP as discussed in [8]. State 2 is the reverse of state 1 as shown in Fig. 3(b), and hence, RHCP is achieved. In states 3 and 4, since both switches are OFF or ON, the two slots of the E-shaped patch will have the same length. Therefore, linear polarization will be excited in these two states.

4. Simulation Results And Discussion

Ansoft HFSS and in house developed FDTD code are used, for simulation of the proposed design in both states 1 and 2. Reflection coefficient and axial ratio results are shown in Figs. 4 and 5. Both antenna states provide 8.16% impedance bandwidth defined by -10db level of (2.35-2.55GHz) and 7% axial ratio bandwidth defined by 3dB level of (2.38-2.55GHz). The overlapped bandwidth among both of them (effective bandwidth) covers the desired band (2.4-2.5GHz) for IEEE 802.11b/g WLAN application. Also, realized gain patterns in xz and yz plane at 2.45GHz are shown in Fig. 6, respectively. It is observed from the results that the antenna polarization changes from LHCP in state 1 to RHCP in state 2. Due to the symmetry of the structure, gain radiation patterns of the two states are the same in yz plane which is a virtue of this design. While in xz plane, they are the mirror of each other around the 0º degree axis.

5. Conclusions

E-shaped microstrip patch antenna with switchable LHCP/RHCP is proposed. Reconfigurable capability is achieved using two RF switches (PIN diodes), with simple DC biasing circuit integrated within antenna structure. Antenna covers the frequency band (2.4-2.5GHz) for 802.11b/g WLAN, and maintains the same pattern in yz plane on both polarization states. Proposed design is a polarization agile antenna candidate for wireless applications. The fabrication and measurements of the proposed design will be conducted in future work.
Fig. 1. Antenna geometry (a) Top view, (b) Side view.

- RF choke coil
- DC block capacitor
- PEC
- Substrate

Fig. 2. Lumped element models of a beam lead PIN diode (MA4AGBLP912) in ON/OFF state.
Fig. 3. States of E-shaped patch antenna (a) state 1, (b) state 2, (c) state 3, (d) state 4.

Table 1: Antenna possible configurations

<table>
<thead>
<tr>
<th>State</th>
<th>Switch 1</th>
<th>Switch 2</th>
<th>Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ON</td>
<td>OFF</td>
<td>LHCP</td>
</tr>
<tr>
<td>2</td>
<td>OFF</td>
<td>ON</td>
<td>RHCP</td>
</tr>
<tr>
<td>3</td>
<td>ON</td>
<td>ON</td>
<td>LP</td>
</tr>
<tr>
<td>4</td>
<td>OFF</td>
<td>OFF</td>
<td>LP</td>
</tr>
</tbody>
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Fig. 4. Simulated $S_{11}$ for the two antenna states.

Fig. 5. Simulated axial ratio for the two antenna states.
Fig. 6. Simulated gain patterns at the two principle plane cuts for the two antenna states at 2.45GHz.

References