Polarization Reconfigurable Slot Antenna With a Novel Compact CPW-to-Slotline Transition for WLAN Application

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Abstract—A polarization reconfigurable slot antenna with a novel coplanar waveguide (CPW)-to-slotline transition for wireless local area networks (WLANs) is proposed and tested. The antenna consists of a square slot, a reconfigurable CPW-to-slotline transition, and two p-i-n diodes. No extra matching structure is needed for modes transiting, which makes it much more compact than all reference designs. The −10 dB bandwidths of an antenna with an implemented bias circuit are 610 (25.4%) and 680 MHz (28.3%) for vertical and horizontal polarizations, respectively. The radiation pattern and gain of the proposed antenna are also tested, and the radiation pattern data were compared to simulation results.

Index Terms—Compact, coplanar waveguide (CPW)-to-slotline transition, polarization reconfigurable, slot antenna.

I. INTRODUCTION

R ECENTLY, the polarization reconfigurable antennas have received significant attention for their intrinsic advantage in wireless communication. Such reconfigurable antennas can provide polarization diversity to mitigate multipath fading, even in near-line-of-sight (LOS) conditions. As mentioned in [1], dual linear polarizations switchable antennas are widely adopted in multiple-input–multiple-output (MIMO) systems for higher channel capacity than two antennas with identical linear polarization. In order to achieve switchable polarization, several methods have been studied in recent papers [2]–[4]. In [2], a polarization reconfigurable microstrip antenna with a piezoelectric transducer (PET) is proposed. Left-hand circular polarization (LHCP) and right-hand circular polarization (RHCP) can be switched by controlling the bias voltage of a PET. A quadric-polarization switchable patch antenna is studied in [3], where the polarization modes are controlled by two p-i-n diodes among LHCP, RHCP, and two orthogonal linear polarizations (LPs). In a study by Chen et al. [4], two p-i-n diodes are utilized to switch the polarization between LHCP and RHCP in a square slot antenna. However, the feed structures in [2]–[4] are not compact, and the bias circuits for PET [4] and p-i-n diodes [3], [4] are complicated. The antenna performance can be improved with simple bias circuits and compact feed structures.

In order to design a compact single-feed structure for polarization reconfigurable antennas, coplanar waveguide (CPW)-to-slotline transition is widely studied for its switchable dual mode applications: CPW mode and slotline mode. As proposed in [5], a λ/2 phase shifter is used to convert the CPW mode to slotline mode, and the transition bandwidth can be improved by adding air-bridges. A λ/4 transformer structure is often utilized for mode transitions [6], [7]. A slotline-radial-open with a radius of λ/4 is proposed in [6] for broadband application. In [7], the author made use of two twin-spirals as a modification of the λ/4 transformer for compactness. In order to achieve greater compactness and better performance, another CPW-to-slotline transition structure with a CPW series stub printed in the center conductor of the CPW has been analyzed. All the CPW-to-slotline transitions mentioned need extra structures to convert the mode, such as a λ/2 phase shifter [5], λ/4 transformer [6], [7], and series stub [8], which make the feed less compact.

In this letter, a slot antenna with switchable vertical and horizontal polarizations is proposed for WLAN application. The slot antenna is selected for its wide bandwidth and high isolation between dual polarizations [4], [9]. A novel compact CPW-to-slotline transition feed without any extra structures is controlled by two p-i-n diodes for polarization switching. The vertical polarization is excited by CPW mode with measured −10 dB bandwidth 2.17–2.78 GHz (25.4%), while the horizontal polarization is excited by slotline mode with measured −10 dB bandwidth 2.268 GHz (28.3%), both covering the WLAN band (2.4–2.484 GHz). The simulations and experimental results of return loss and radiation patterns agree well, and the gain of the proposed antenna is also measured.

II. ANTENNA CONFIGURATION AND DESIGN

The geometry of the proposed polarization reconfigurable antenna is shown in Fig. 1. The antenna is made of FR4 (εr = 4.4, tanδ = 0.01) of thickness 1 mm with the dimensions of 86 × 70 mm². A 48 × 48 mm² square slot is etched in the front side, whose dimension is chosen due to the preliminary study [10].
The width of square slot is approximately half of the resonant wavelength ($\lambda$) at working frequency ($f_0$), illustrated by (1).

$$L_{os} = W_s = \frac{\lambda}{2} = \frac{c}{2f_0 \cdot \sqrt{\varepsilon_{eff}}}$$

Where $c$ is the velocity of light in free space. A CPW feed structure is designed to excite vertical and horizontal polarizations of the slot. Two p-i-n diodes are implemented to control the operation modes of the CPW. The working configurations of two p-i-n diodes are listed in Table I. When PIN 1 is "ON" and PIN 2 is "OFF," vertical polarization is excited by a typical CPW mode; when PIN 1 is "OFF" and PIN 2 is "ON," the left slotline...
is shorted by PIN 2, and the center stub inside antenna radiation aperture is disconnected. A horizontal polarization, which is named slotline mode, is excited by the right slotline.

The operating modes of CPW-to-slotline transition and equivalent transmission line models are shown in Fig. 2. Fig. 2(a) describes the CPW mode. The length of the CPW ($L_1$) and the length of the exciting stub in the antenna ($L_2$) are tuning parameters to achieve a good match. Ansoft High Frequency Structure Simulator (HFSS) is used for parameter optimization, and $\lambda/5$ is set as the starting value for $L_1$ and $L_2$. While in the slotline mode, which is shown in Fig. 2(b), the right slotline is used to feed the horizontal polarization, and the shorted left slotline serves as a matching branch. The impedance of slotline $Z_{\text{slot}}$ is determined by the value of $S_3$. The equivalent impedance of the shorted branch at the feed point is $jZ_{\text{slot}} \tan(\beta_{\text{slot}} L_2)$, serving as a shunt inductance when $L_1 < \lambda/4$. As a result, optimized $L_1$ realizes the impedance match between 50 $\Omega$ and the radiation resistance $R_{\text{Focal}}$ of the horizontal polarization. The detailed optimized values of each parameter in Fig. 1 are listed in Table II. The simulated electric field distribution in the slot for the two modes is shown in Fig. 3. In Fig. 3(a), the vertical polarization in the slot is excited by CPW mode. And in Fig. 3(b), horizontal polarization is excited by slotline mode.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$L$</th>
<th>$L_G$</th>
<th>$L_S$</th>
<th>$L_1$</th>
<th>$L_2$</th>
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<td>Value(mm)</td>
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<td>27</td>
<td>48</td>
<td>22</td>
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<tr>
<td>Parameter</td>
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<td>$W_S$</td>
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<td>Value(mm)</td>
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<td>48</td>
<td>0.8</td>
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<td>2</td>
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</table>

III. EXPERIMENT RESULTS

Fig. 4 shows the construction of the proposed antenna and bias circuit for PIN 1 and PIN 2 (Philips BAP64-03). The “ON” and “OFF” states of the two p-i-n diodes are controlled by $V_{\text{Contr,1}}, V_{\text{Contr,2}},$ and $V_{\text{Contr,3}}$. The bias circuit consists of two RF choke inductances ($L_{\text{ch1}}$ and $L_{\text{ch2}}$, 12 nH), a dc block capacitance ($C_0$, 120 pF), a RF shorted capacitance ($C_3$, 470 pF), and a bias resistance ($R$, 46 $\Omega$).

The simulated and measured S-parameters for vertical and horizontal polarizations are shown in Fig. 5. The simulated and measured data agree well, and a frequency shift in horizontal polarization in measurement is mainly caused by the effect introduced by the bias circuit. The return loss for bandwidths of $-10$ dB are 610 MHz (2.17–2.78 GHz, 25.4%) and 680 MHz (2.68 GHz, 28.3%) for vertical and horizontal polarizations, respectively. Both polarizations can cover the WLAN band (2.4–2.484 GHz) with $S_{11} < -13.8$ dB.

The simulated and measured normalized radiation patterns of the proposed antenna for vertical and horizontal polarizations at 2.4 GHz are shown in Figs. 6 and 7. Bidirectional radiation is achieved on the $y$ and $-y$ axis, and asymmetric patterns are contributed to by the bias structure. In Fig. 6, the 3-dB beamwidths in the E-plane ($y$-direction) are $70^\circ$ ($y$-direction) and $80^\circ$ ($y$-direction), while $70^\circ$ ($y$-direction) and $90^\circ$ ($y$-direction) in the H-plane ($xy$ plane). In Fig. 7, the 3-dB beamwidths in the E-plane ($xy$ plane) are $60^\circ$ ($y$-direction) and $70^\circ$ ($y$-direction) in the H-plane ($xy$ plane). The cross-polarization levels are lower than 9 dB in the $y$- and $-y$-directions, which are not as good as the simulated values. High level of cross polarization is mainly introduced by the parasitic parameters of p-i-n diodes. An experiment was carried out by using metallic strip instead of the p-i-n diodes at their “ON” state. Almost the same results as simulation are achieved, and it is proven that the deterioration of cross polarization comes from the p-i-n diodes.
High-quality p-i-n diodes with low parasitic parameters can suppress cross polarization.

Gain of the proposed antenna was also measured, and results are shown in Fig. 8. In the WLAN band of 2.4–2.484 GHz, the gain is better than 3 and 2.8 dBi for each polarization.

**IV. CONCLUSION**

In this letter, a polarization reconfigurable slot antenna with a switchable compact CPW-to-slotline transition is proposed for WLAN application. Dual orthogonal polarizations can be switched by converting CPW mode to slotline mode. The proposed CPW-to-slotline transition has the advantages of compactness and easy implementation. A prototype of the antenna was built and tested. The −10 dB bandwidths of two polarizations are 610 (25.4%) and 680 MHz (28.3%) for each polarization. The measured radiation patterns agree well with the simulation ones. The measured gain is better than 3 and 2.8 dBi. The nonideal p-i-n diodes introduce higher cross polarization than in the simulation. Potential application of this bidirectional pattern antenna is serving as an access point for WLAN (2.4–2.484 GHz).

**REFERENCES**


