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CPW-Fed Square Slot Antenna With Reconfigurable Circularly Polarization Characteristics For Wideband Application

Rohit Kumar Saini

Assistant Professor & Faculty of Engineering & Teerthanker Mahaveer University, Moradabad,Uttar Pradesh, India

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Abstract - *A CPW-Fed square slot antenna with circular polarization and reconfigurable function is proposed, and its performance is verified experimentally. The circular polarization characteristic is realized by using a cross-shaped feed line and L-shaped grounded strip. The reconfigurable function is realized by integrating two switches into L-shaped grounded strips. Switches are used to ground one of the L- shaped strip at a time. The proposed antenna is designed, simulated, optimized, and fabricated. The simulated and measured results show that the proposed antenna has wide circular polarization bandwidth and reconfigurable function, making it suitable for the wideband application. By adjusting the length of the strip, the circularly polarized bandwidth is obtained as high as 28.98% (1.47GHz-1.97GHz) with AR ≤ 3dB. Impedance bandwidth of 87.28% (1.33GHz-3.38GHz) with VSWR ≤ 2 is achieved.*

Keywords — *Slot Antenna, Axial Ratio (AR), Circular Polarization, Reconfigurable Antenna, Switchable Polarization, L-shaped Grounded Stub, and CPW-feed.*

I. INTRODUCTION

Polarization diversity is one of the most promising techniques in the future. In modern wireless communication systems, the polarization diversity of antennas may be utilized to alleviate the channel deterioration caused by multipath fading effects. In recent research studies, several antenna architectures offering polarization diversity have been proposed [1, 2]. They implement shorting pin diodes on the antenna structures to switch the far-field polarization. In Ref. 1, a microstrip patch antenna that allows switching between two circular polarizations (CPs) has been presented. The switching is achieved using two pin-diodes mounted on the center of the two orthogonal slots. By turning the pin-diodes on or off using a DC-bias circuit, the antenna can operate with right-hand circular polarization (RHCP) or left-hand circular polarization (LHCP). In Ref. 2, a square patch is excited by a pair of crosswise-oriented slots, which is illuminated underneath by a microstrip. The switching between RHCP and LHCP is obtained for the antenna by turning on/off two pairs of beam-lead pin-diodes soldered across the coupling slots. However, this type of antennas may hardly operate with dual CP radiations simultaneously, and the 3-dB axial ratio (AR) bandwidths are usually narrow. To improve the operating bandwidth, using a printed slot antenna is a possible method [3, 4]. In Ref. 3, the square-slot CP antenna fed by coplanar-waveguide (CPW) has reached a 3-dB AR bandwidth of more than 18% (with respect to the center frequency of 2 GHz). In Ref. 4, The CP bandwidth of about 22% has been achieved for a microstrip-line-fed wide-slot antenna, which is very wide as compared with those of other single-port CP antennas [5, 6]. With the rapid progress in wireless communication, circularly polarized (CP) antennas have received considerable attention for deploying a transmitter and a receiver without causing a polarization mismatch between them. Circular Polarization (CP) can be obtained when the antenna radiates two orthogonal field vectors having equal amplitude and 90-degree phase difference. On the other hand, the antenna having wide bandwidth is very much promising for high data rate wireless technology. In the light of the above views, broadband circularly polarized antennas are becoming very important. Single fed and single-element antennas have advantages of small volume and do not need power divider circuits in comparison to multi fed and array antennas. Printed circularly polarized slot antennas having inherent wideband characteristics are found in various applications as they have numerous advantages such as lightweight, low volume, and low cost. Having various advantages of low radiation loss, less dispersion, and scope of easy integration with solid-state devices, coplanar waveguide (CPW) feed becomes more attractive than microstrip feed [1]. Therefore, CPW fed circularly polarized slot antenna have drawn more attraction recently [2]-[11], where wideband circular polarization was achieved by protruding a metallic strip from the signal line of the feeding CPW into the slot. The axial ratio bandwidth is within 50% in [1]-[12], while that in [13] is 85%. However, the size of the antenna in [13] is 60X60mm^2 on FR4 substrate of thickness 0.8mm.

In this communication, we describe a new CPW- feed square slot antenna with circular polarization characteristic as well as reconfigurability function, which has different polarization (LHCP/RHCP) characteristics and simpler configurations as compared to those reported by the previous article [11]. The circular polarization is achieved by inserting a cross-shaped feed line, two square-shaped parasitic patches, and L-shaped grounded strip. In addition, the reconfigurable function is realized by integrating two ideal switches between the ground plane of the slot and L- shaped grounded strips. Switches are used to ground one of the L-shaped strips at a time into Slot, respectively. The simulated and measured results show that the proposed antenna has wide impedance as well as axial ratio bandwidth, and it offers the reconfigurable function in polarization (LHCP/RHCP) as well. These attributes make the design suitable for Polarization diversity. In this study, the presence of a metal bridge represents the ON state, and the absence of a metal bridge represents the OFF state for designing the ideal switches [11–13]. The perturbation is constructed by a strip of width 0.5mm on the rectangular-shaped parasitic element. The axial ratio bandwidth can be tuned by varying lengths of the strip, as shown in fig.1. The proposed antenna will generate right- and left-hand circularly polarized (RHCP and LHCP) radiation in +z- and –z-directions when the switch-1 (SW1) is in on, and switch-2 (SW2) is in off condition and vice versa. According to measured results, the proposed antenna is found to possess an impedance bandwidth of 87.28% (1.33GHz-3.38GHz), entirely covering the 3dB ARBW 28.98% (1.47GHz-1.97GHz). The size of the antenna is 60X60mm^2. Therefore, the proposed antenna has a low profile, compact size, and simple feeding structure [14-23].

II. ANTENNA STRUCTURE

The configuration of the proposed antenna with polarization diversity functions is shown in Figure 1. The antenna is printed on a substrate FR4 with a relative permittivity of 4.4, loss tangent of 0.002, and substrate thickness of 1.6 mm. The proposed antenna with polarization diversity functions, shown in Figure 1. It is comprised of a wide slot of square shape in the CPW ground plane, a cross-shaped signal line, a pair of rectangle-shaped parasitic patches, a pair of inverted L-shaped grounded stubs, and a CPW ground plane together with a CPW feed structure.

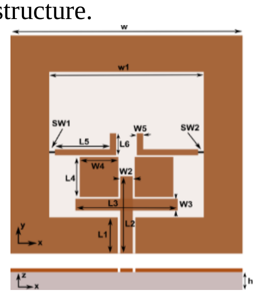


Fig.1. The geometry of the proposed reconfigurable square slot antenna.

The feed structure consists of a CPW-fed transmission line with a width of 3.2 mm, and the gap between the CPW-fed transmission line and the CPW ground plane is 0.7 mm. Two ideal switches, namely, switch-1 (SW1) and switch-2 (SW2), are used and to realize the reconfigurable polarization characteristic. In this design, the circular polarization characteristic is achieved by using an inverted L-shaped grounded stub into the slot, a pair of the rectangular-shaped parasitic patch, and the Cross-shaped signal line perturbed from the 50Ω CPW-fed transmission line, whereas the reconfigurability function is achieved by integrating two ideal switches into the slot and one switch open at a time. Furthermore, the wide axial ratio bandwidth is achieved by adjusting the dimensions of the inverted L-shaped grounded stub. To evaluate the performance of the proposed antenna, a commercial electromagnetic solver, High-Frequency Structure Simulator (HFSS-14), is used to create the antenna. The optimized parameters of the designed antenna are as follows: W=60mm, W1=40 mm, W2=3.2mm, W3=3.2mm, W4=10mm, W5=1.6mm, L1=10mm, L2=21.3mm, L3=26.4mm, L4=11mm, L5=14.2mm, L6=6mm, and h=1.6mm.

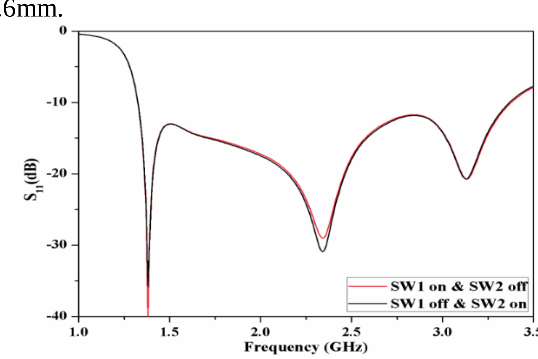


Fig. 2. Impedance bandwidth of the proposed antenna.

III. FABRICATION AND MEASUREMENT

To study the performance of the proposed reconfigurable CP slot antenna, the circular polarization characteristic and the reconfigurable function are investigated and analyzed by using HFSS. When the switch-1 (SW1) is in on condition, the current flows on the left inverted L-shaped grounded strip.

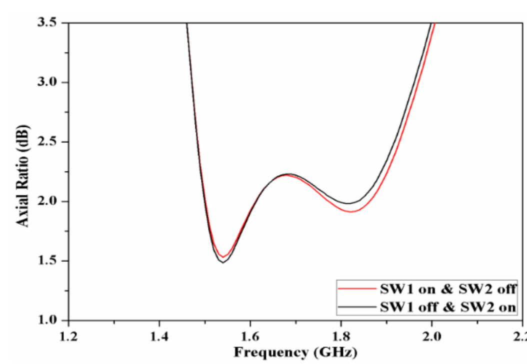


Fig. 3. Axial ratio bandwidth of the proposed antenna.

Therefore, RHCP in the front-side can be obtained (slot antenna is a bidirectional radiator with reversed CPs in front- and back-side). On the other hand, if switch-2 (SW2) is in on condition, LHCP can be obtained. Second, a cross-shaped signal line, a pair of rectangular-shaped parasitic patches, and dimension of inverted L-shaped grounded stub are optimized to effectively improve the circular polarization bandwidth. The proposed antenna can operate with broadband dual CP radiations. Because of the symmetry, antenna 1 in RHCP (SW1 on & SW2 off) and LHCP (SW1 off & SW2 on) states has very similar return loss and CP performance. The measured S_{11}(dB) versus frequency are shown in Figure 2. The measurement was made with a Wiltron 37269A network analyzer.

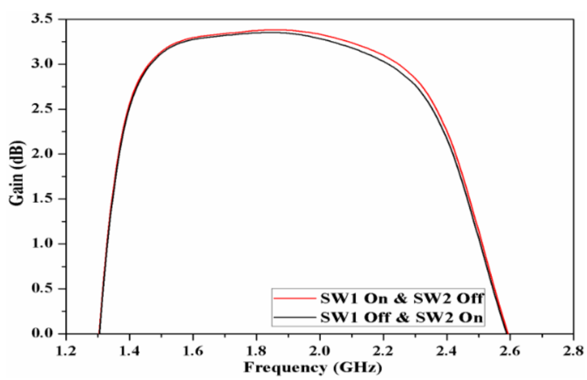
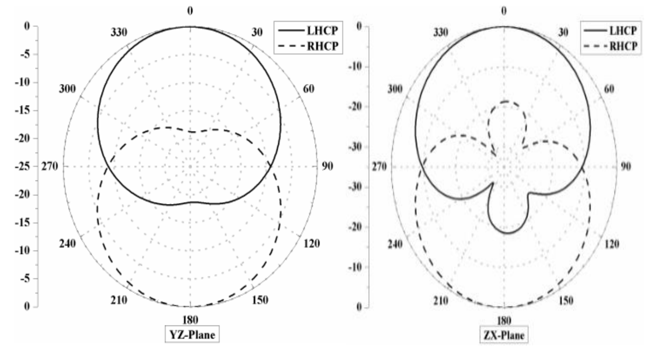
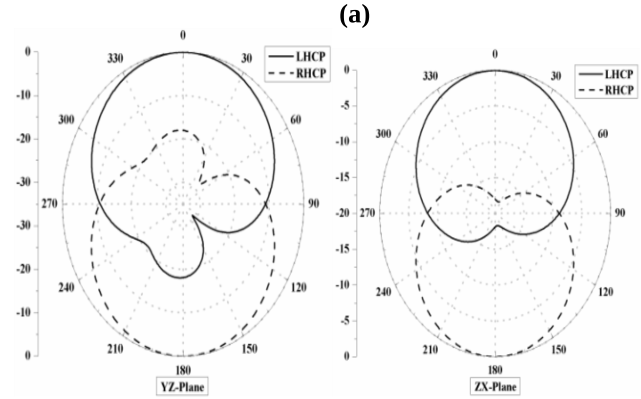


Fig. 4. The simulated gain in the +z direction of the proposed antenna.

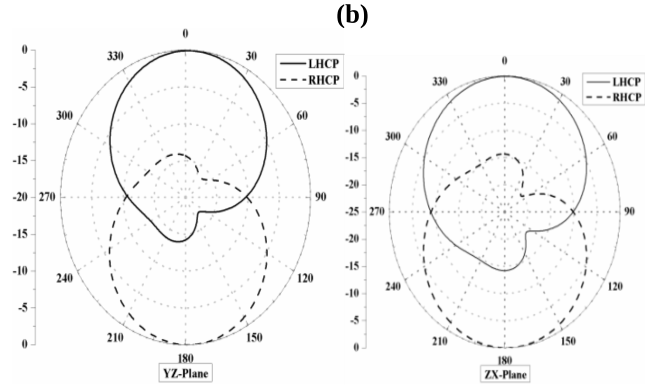
From the measured results, it is clear that by loading the inverted L-shaped grounded strip in the slot, circular polarization has been achieved. The impedance bandwidth of antenna prototypes can cover the frequency range from 1.33GHz to 3.38GHz. Figure 3 shows the measured AR with respect to frequency in the +z direction. The CP bandwidth determined by the 3-dB AR is about 500 MHz or 28.98% (1.47GHz – 1.97 GHz), respectively. Both the impedance and CP bandwidths cover the same band. It is evident that the length L_2 of the inverted L-shaped grounded strip has a larger effect on the axial ratio bandwidth but has less effect on the impedance bandwidth. As for the antenna with inverted L-shaped stub length (L_1+$L_{2=}$ mm), both impedance matching (referred to ≤10 dB return loss) and wide axial ratio bandwidth (referred to ≤3 dB) are achieved with the polarization diversity function. Figure 4 depicts the simulated and measured gain against frequency, which varies from 2.5dBi to 3.9dBi in 3-dB axial ratio bandwidth.



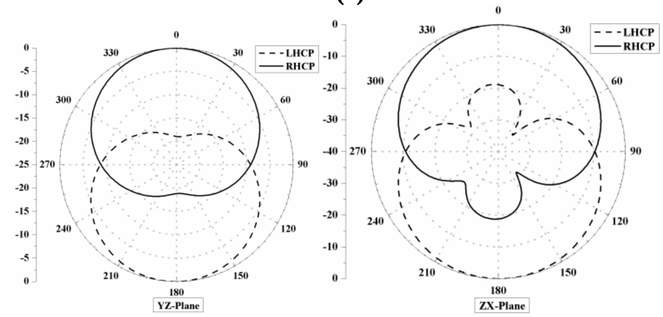
(a)



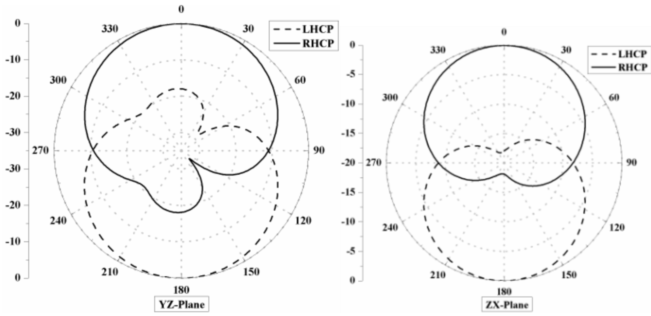
(b)



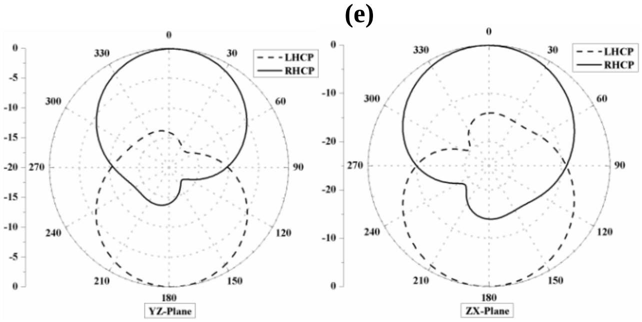
(c)



(d)



(e)



(f)

Fig. 5. Simulated radiation patterns at (a) 1.5GHz, (b) 1.7GHz, and (c) 1.9GHz in both planes (YZ-plane and XY-plane) of the proposed antenna (SW1 on & SW2 off) and (d) 1.5GHz, (e) 1.7 GHz, and (f) 1.9GHz in both plane of the proposed antenna (SW1 off & SW2 on).

Figures 5 (a), (b) & (c) show the measured far-field radiation patterns of the antenna at 1.5GHz, 1.7GHz & 1.9GHz in the LHCP and RHCP operation when the switch SW1 is on. At 1.7 GHz & 1.9GHz, it shows a good cross-polarization level of approximately ≥ 20dB in measured far-field radiation patterns of the antenna at 1.7 GHz in the LHCP and RHCP operation. It is observed that the cross-polarization levels are about 26 dB in the broadside direction in both states. It should be noted that the backside radiation pattern is a mirror image of the front pattern, and the polarization senses of both sides are opposite to each other. The antenna radiates almost the same amount of energy to both sides.

VI. CONCLUSIONS

A rectangular slot antenna fed by a 50ΩCPW for wideband applications is presented. The circular polarization characteristic is realized by using a cross-shaped feed line and L-shaped grounded strip. The reconfigurable function is realized by integrating two switches into L-shaped grounded strips. Switches are used to ground one of the L- shaped strip at a time. The proposed antenna is designed, simulated, optimized, and fabricated. Wide impedance bandwidth of 87.28% (1.33GHz-3.38GHz) and ARBW of 28.98% (1.47GHz-1.97GHz) have been achieved. An antenna gain varies from 2.5dBi to 3.9dBi in the axial ratio bandwidth of the proposed antenna. Therefore, this proposed antenna is suitable for wireless communication for circular polarization from 1.47GHz to 1.97GHz band applications.

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