Study, Design and Fabrication of a CPW Fed Compact Monopole Antenna with Circular Polarization for Ultra Wide Band Systems Application

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Abstract **─** A compact circularly polarized square slot antenna (CPSSA) is presented in this paper, which is appropriate for UWB applications requiring high data rate transmission. This antenna operates across 2.8 GHz to 10.8 GHz with an impedance bandwidth (IBW) of 117.6% for VSWR $\leq$ 2. The antenna consists of a trapezoidal shaped radiation patch which is fed through a coplanar waveguide (CPW) and includes two inverted L-shaped ground arms at the two opposite corners of the slot to excite two orthogonal resonant modes for circular-polarization (CP) radiation. Furthermore, two square slits at the two other opposite corners of the slot are applied to enhance its IBW. The antenna exhibits CP bandwidth of 50.5% across 3.7 GHz-6.2 GHz, which is suitable for WLAN, WiMAX and C-bands. In addition, the antenna has a considerably compact volume of 25×25×0.8 mm^3. The measured and simulated results confirm the usefulness of the antenna for practical applications.

Index Terms **─** CPW-fed, circularly polarized, UWB application.

I. INTRODUCTION

Circularly polarized signals are used in modern systems such as wireless communications, radar and satellite to provide better mobility and weather penetration than linearly polarized ones. This is because CP prevents severe polarization mismatch between transmitter and receiver, which is otherwise encountered in such systems. In particular, fast growing communication systems require compact, low cost, CP antennas with a high data rate capability to be used in wireless applications. Despite low profile CP microstrip based antennas with high-Q are the best option for aforementioned requirement [1]. Circular-polarization can be implemented using various types of techniques such as: loading a cross patch at the center of the square slot [2], using asymmetric CPW-fed square slot antenna [3], applying a crane-shaped strip in the ground plane [4], and opening the radiation slot at the lower left side of the slot [5].

Attributes of such CPSSA include: (a) broadband performance, (b) construction on a single layer for low cost production, (c) low profile, and (d) compatibility for integration with monolithic microwave integrated circuit (MMIC) technologies. These characteristics afforded by such antennas have made them increasingly popular for applications such as imaging, vehicular radar, and communications [6–7].

The CPSSA structures reported in recent literature have a simple slot structure, which can be implemented in various ways, namely, by: (a) embedding two inverted L grounded strips around two opposite corners of the slot [7], (b) inserting a lightning-shaped feed-line and inverted L grounded strips [8], (c) embedding a T-shaped grounded metallic strip that is perpendicular to the axial direction of the coplanar waveguide feed-line [9], (d) utilizing a spiral slot in the ground-plane [10], and (e) utilizing embedded arc-shaped grounded metallic strip for circular and linear polarization [11].

In order to distribute the magnetic currents in the slots so that the two orthogonal resonant modes with an equal magnitude and 90° phase difference can be excited. The CPSSA structure needs to be constructed in one of the following ways: (a) by loading in the square slot a crisscross patch [12], (b) in order to realize the proposed antenna, miniature circular polarized square slot antenna is used with L-shape and crooked T-shape grounded strips located at the slots opposite corners to reduce cross-polarization [13], (c) by protruding into the square slot a meandering [14] or inverted L-shaped [15] conducting strip connected to the signal strip of the CPW, or (d) by loading the CPW-fed antenna with an inductive slot [16]. On the other hand, in order to achieve wide impedance bandwidth, we need UWB antennas which includes planar monopole antennas (PMAs). Ease of fabrication and appropriate radiation properties are some of these antennas advantages [17–20].

In this paper, we present a significantly compact and structurally simple CPSSA exhibiting an impedance bandwidth of 117.6% that extends from 2.8 GHz-10.8 GHz and CP bandwidth of 50.5% across 3.7 GHz-6.2 GHz.

II. ANTENNA DESIGN

The geometry of the proposed single-layer CPW-fed CPSS antenna is shown in Fig. 1. The antenna consists of a square ground plane, two identical inverted L-shaped

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ground strips at the two opposite corners of the slot, two square slits at the two other opposite corners of the slot, and a trapezoidal shaped radiation patch connected to the feed-line. Furthermore, a rectangular-shaped tuning stub attached to the feed-line.

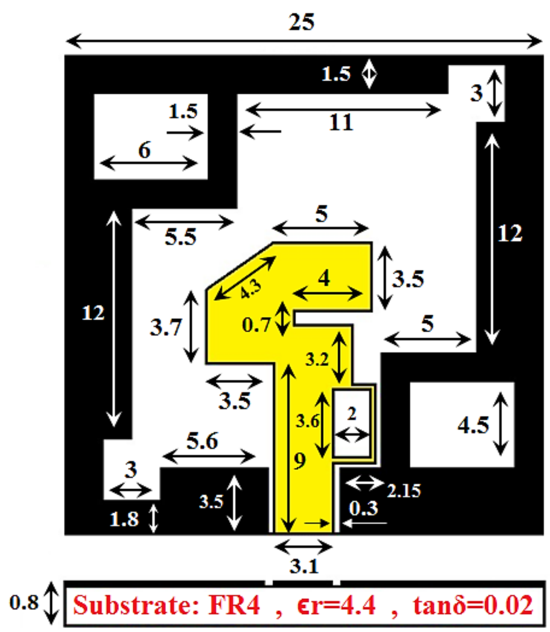

Fig. 1. Geometry of the proposed CPW-fed CPSSA. (All dimensions in millimeters).

The proposed CPSSA has been constructed on a commercially available FR4 dielectric substrate with a loss tangent of 0.02, permittivity of 4.4 and dimension of $25\times25\times0.8$ mm^3. To achieve 50Ω characteristic impedance, the width and length of the coplanar waveguide feed-line is 3.1 mm and 9 mm, respectively.

The gap between the feed-line and the ground-plane is 0.3 mm. The length of the feed-line structure affects the field distributions in the antenna aperture. The feed-line is extended from the CPW section to control the antenna's impedance match. The sizes of the inverted L-shaped strip arms are 6 mm and 4.5 mm. Other dimensions are given in Fig. 1. Additionally, to understand how this antenna design is achieved, Fig. 2 displays the four designing steps to realize the proposed antenna. The antenna in step-1 consists of a rectangular strip as the feed-line and the ground plane with a rectangular slot.

In step-2, a trapezoidal-shaped radiation patch and a rectangular-shaped tuning stub are attached to the feed line. In step-3 and step-4, two identical inverted L-shaped ground strips at the two opposite corners of the slot and the two square slits at the two other opposite corners of the slot are applied to the ground plane.

These modifications result in the improvement of the antenna's IBW and ARBW, as shown in Fig. 3 and Fig. 4.

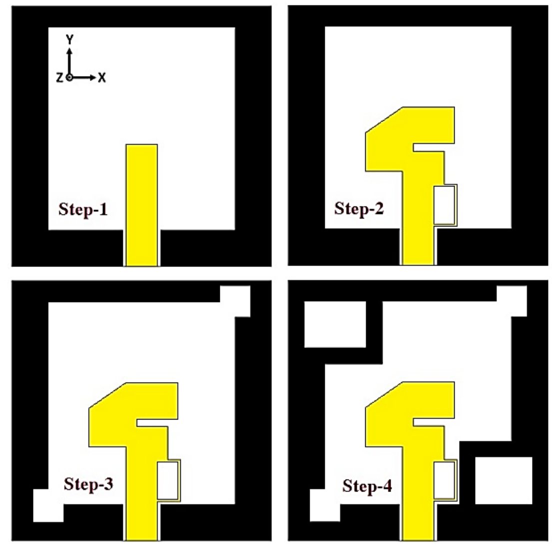

Fig. 2. Four designing steps to accomplish the proposed CP antenna.

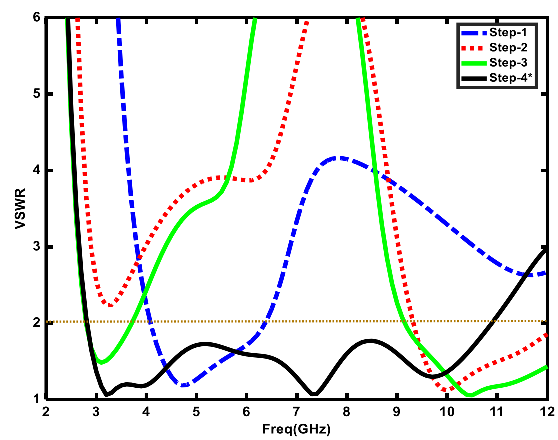

Fig. 3. VSWR responses for the designing steps of the proposed antenna.

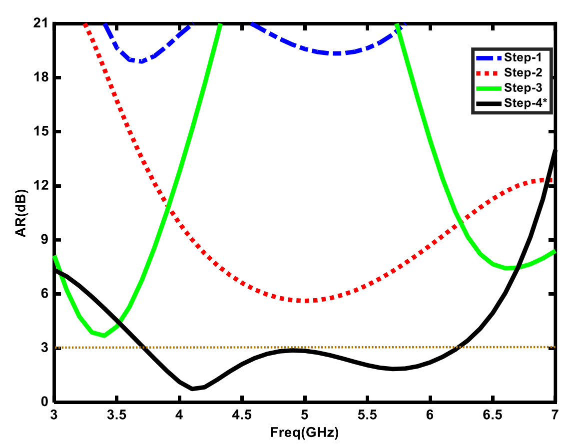

Fig. 4. AR curves for the designing steps of the proposed antenna.

III. RESULTS AND DISCUSSION

The main objectives of developing the antenna design have been to enhance its impedance bandwidth, generate CP, and expand the polarization bandwidth. Fig. 5 and Fig. 6 show the measured and simulated IBW and ARBW of the proposed antenna. It's demonstrated in these figures that by adjusting the sensitive parameters of the antenna and applying the optimal values the wide IBW and ARBW of 117% and 50.5%, respectively, can be achieved.

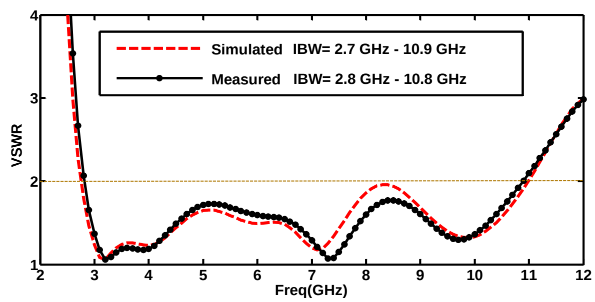

Fig. 5. Measured and simulated VSWR response of the proposed antenna.

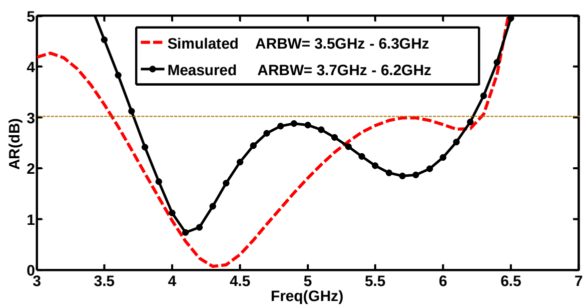

Fig. 6. Measured and simulated CP AR of the proposed antenna.

Indeed, by applying the inverted L-shaped grounded strips, and providing redistribution of the magnetic currents in the slots so that the two orthogonal resonant modes with equal amplitude and 90° phase difference can be excited. It is lead to a wide ARBW. The structure of inverted L grounded strips has been first proposed in [7]. In addition, by carving the two square slits at the two other opposite corners of the slot and providing more current paths, the wide IBW is achieved. The correlation between the simulated and measured results of the final antenna prototype is excellent as shown in the figures. The numerical results have been accomplished by using the Ansoft High Frequency Structure Simulator (HFSS Ver.11). For more understanding about the CP radiation, the surface current distribution of the antenna is discussed.

The surface current distribution over the antenna at 4.5 GHz, at the minimum point of AR, is shown in Fig. 7. It is observed that the surface current distribution at 180° and 270° is equal in the magnitude and opposite in the phase at 0° and 90°. When the current rotates in the clockwise/counter clockwise direction, the antenna correspondingly radiates in the RHCP/LHCP. The proposed CPSSA is able to generate an RHCP in the +z direction, whereas an LHCP is produced in the -z direction. Also, the normalized right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) radiation patterns of the CPSSA at the frequencies of 5 GHz and 6 GHz are given in Fig. 8.

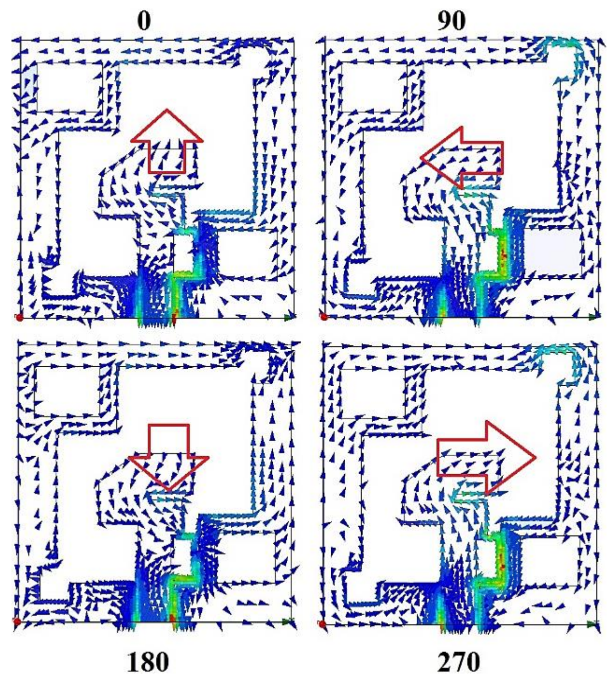

Fig. 7. Distribution of the surface current on the CPSS antenna at 4.4 GHz in 0°, 90°, 180°, and 270°.

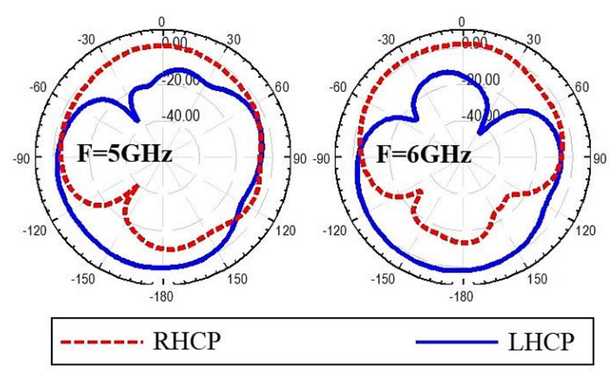

Fig. 8. Simulated radiation patterns of the proposed antenna at 5 and 6 GHz.

It shows the antenna exhibits omnidirectional radiation characteristics, but whose gain variation is evident over certain angular directions. For more explanation about the antenna radiation, 3D polar plot of antenna gain in RHCP/LHCP states are given in Fig. 9. Furthermore, the simulated and measured gain curves of the proposed antenna are shown in Fig. 10.

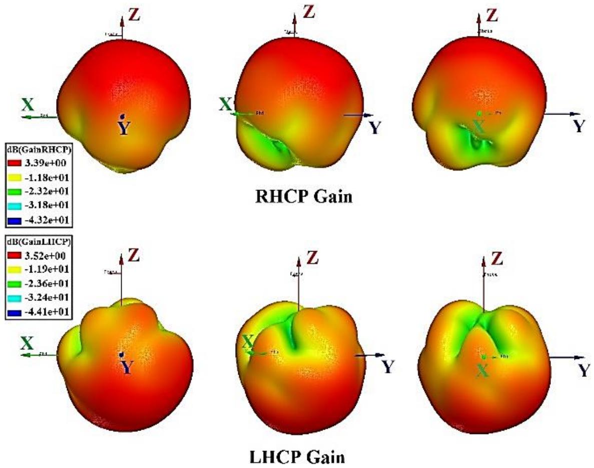

Fig. 9. Simulated 3D RHCP/LHCP gain of the proposed antenna at 4.4 GHz.

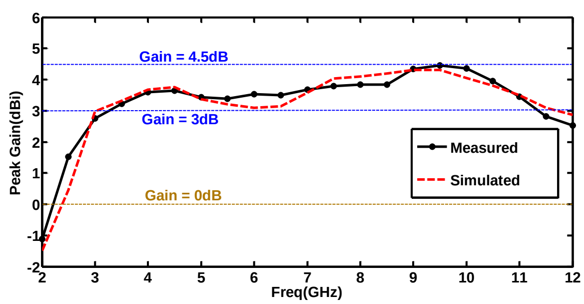

Fig. 10. Measured and simulated gain of the proposed antenna.

It shows a well agreed simulated and measured antenna gains in the antenna band whose maximum gain is about 4.5 dBi and its fluctuation is between 3 dBi and 4.5 dBi. Photograph of the fabricated antenna is shown in Fig.11.

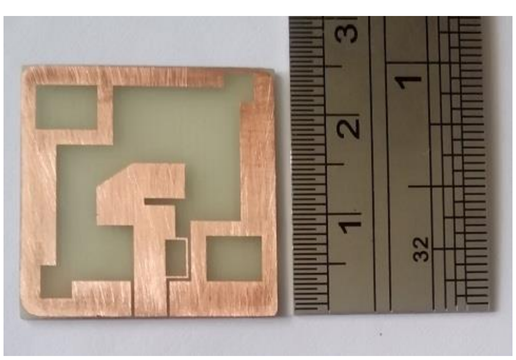

Fig. 11. Photograph of the fabricated antenna prototype.

IV. CONCLUSION

A new CPW-fed CPSSA has been proposed. The measured AR bandwidth can be enhanced to over than 50.5% with a wide IBW of greater than 117.6% that exactly covers the UWB band. The designed antenna has a very compact size of 25 × 25 × 0.8 mm^3.

According to the impedance bandwidth and axial ratio bandwidth, the proposed antenna is suitable for WLAN, WiMAX and C-bands systems application.

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