Compact CPW-Fed Antenna with Circular Polarization Characteristics in WLAN Frequency Band

M. Majidzadeh, J. Nourinia, and Ch. Ghobadi

Department of Electrical Engineering
Urmia University, Urmia, Iran
Maryam_Majidzadeh37@yahoo.com, J.Nourinia@urmia.ac.ir, Ch.Ghobadi@urmia.ac.ir

Abstract **─** A novel co-planar waveguide (CPW)-fed antenna with circular polarization (CP) characteristics in the 5.1 GHz − 5.8GHz is presented. By adding a vertical stub and a rotated L shaped stub to the antenna structure, a bandwidth of 5 GHz – 8GHz (46 %) for S_{11} < -10 dB is achieved and also circular polarization characteristics is generated in the 5.1 GHz − 5.8 GHz, which completely covers the wireless local area network (WLAN) frequency band. The antenna has a very simple structure and occupies a compact area of 25 × 25 × 1 mm^3. The very simple structure and small size are of the marvelous merits of the proposed antenna. The antenna design process, impedance bandwidth and axial ratio (AR) bandwidth enhancement process are discussed in detail.

Index Terms - Circular polarization, CPW-feed line, and WLAN applications.

I. INTRODUCTION

Communication industry has experienced sea-change during the last decades. One of the key components of every communication system is the antenna, which has not been an exception and has undergone great changes over the years of its progress. With the assignment of 3.1 GHz – 10.6 GHz as UWB frequency band, which caused the accelerating growth of communication systems, the need for novel antennas with compact size, low weight, high efficiency, and good radiation properties have been emerged. An antenna, if properly designed, can be highly impressive in the performance of a communication system. Hence, a lot of effort has been put into designing antennas and considerable valuable works have been reported in the literature. Microstrip-fed antennas [1-4] and CPW-fed antennas [5-8] are of the most common antenna types that are designed to be used in communication appliances. One of the important issues in communication systems is the provision of right orientation between the transmitter and receiver antennas. Circularly polarized antennas are good solutions to this problem. By the use of CP antennas, there will be no need to consider the orientation between the transmitter and receiver. Apart from this, overcoming the multipath fading problem, higher performance, and better mobility and weather penetration with respect to the linearly polarized (LP) antennas are of the admirable CP antennas features [9, 10]. Recently, a lot of CP antennas have been proposed. For instance in [11], a CPW-fed CP antenna is presented that has a 48.8 % axial ratio. In [12], the authors propose an antenna with C-shaped grounded strips aiming at generating CP characteristics. An antenna with enhanced axial ratio is introduced in [13]. In [14], an annular ring antenna with microstrip feed line is presented.

In this paper we propose a novel antenna structure. The proposed antenna is fed by a 50 Ω CPW feed line. The antenna is printed on a 25×25×1 mm^3 FR4 substrate and operates over the frequency band of 5 GHz – 8 GHz for S_{11} < -10 dB, which is achieved by the inclusion of a vertical stub and a rotated L-shaped stub in the antenna structure. The addition of a rotated L-shaped element, also creates the circular polarization characteristics in the frequency band of 5.1 GHz – 5.8 GHz (WLAN). The proposed antenna with the circular polarization property is a suitable candidate for communication systems,

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which are to be used in WLAN frequency band. The most salient feature of the presented work which differentiates it from the previously designed antennas is the very simple structure and small size. The remainder of the paper is outlined as follows: the structure and design process of the antenna are discussed in section II. The simulation results of parametric study, measured results, and their comparison are presented in section III. Eventually, section IV concludes the paper.

II. ANTENNA DESIGN

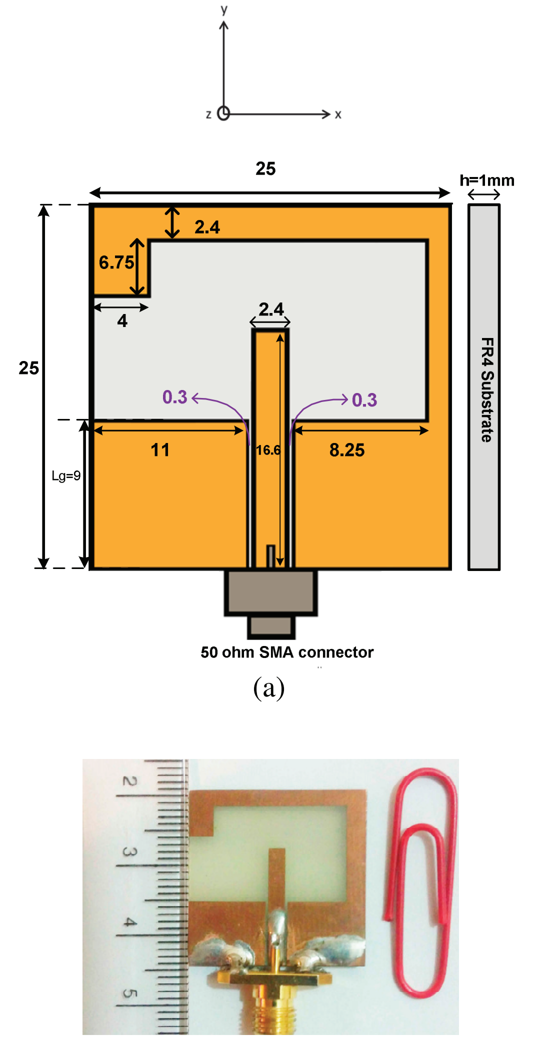
The schematic of the proposed CP antenna is shown in Fig. 1 (a). The fabricated antenna is also shown in Fig. 1 (b). The proposed antenna is printed on a cheap FR4-epoxy substrate with permittivity of 4.4, loss tangent of 0.002 and thickness of 1 mm. A CPW feed line with the length and width of 16.6 mm and 2.4 mm respectively, is adopted to feed the study antenna. First, a basic structure is designed as the main topology. Then a vertical stub is added to the basic antenna structure to enhance the impedance bandwidth and then a rotated L-shaped stub is included to both, enhance the impedance bandwidth and generate the CP property. What makes this antenna distinctive from the conventional CP antennas is the simple structure respect to the other CP antennas. Also, small area of the antenna is an important feature that makes the antenna design process easy and cost effective as well as making its installation easy and economical on the communication equipment. The values of all the antenna parameters are given in detail in Fig. 1.

III. RESULTS AND DISCUSSIONS

The performance of the CP antenna has been investigated using Ansoft High Frequency Structure Simulator (HFSS). The impedance bandwidth, axial ratio, gain, and radiation pattern of the proposed antenna have been measured and analyzed. The measured results are obtained using the Agilent 8722ES network analyzer.

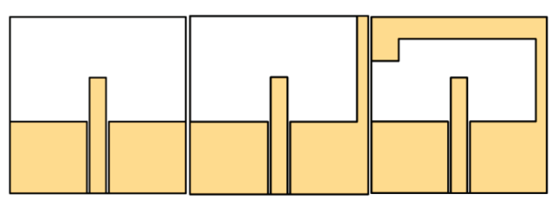
A. Antenna design steps

To better understand the antenna performance and analyze the effect of different parts on its performance, the design process is divided into three steps. In each step, one part is added to the antenna to reach the final design. The three steps are shown in Fig. 2. S_{11} and axial ratio curves for the antennas in Fig. 2 are shown in Fig. 3 (a) and (b).



(b)

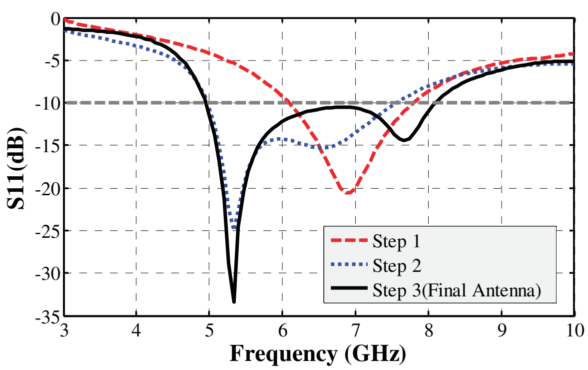
Fig. 1. (a) The schematic geometry of the proposed antenna and (b) the fabricated antenna.



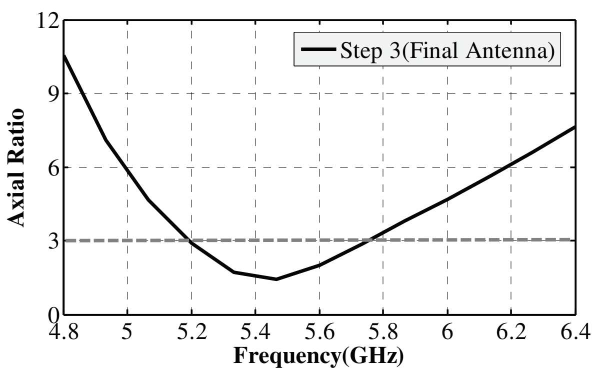
(a) (b) (c)

Fig. 2. The geometry of the three design steps of the proposed antenna; (a) step 1, (b) step 2, and (c) step 3.

As it is seen from Fig. 2, three geometries are considered until reaching the final antenna structure. In step 1, which is shown in Fig. 2 (a), just a simple feed line and two rectangular parts as the ground plane are included in the antenna body. From the simulated results in Fig. 3, this antenna operates over the frequency band of 6.1 GHz – 7.9 GHz and there is no circular polarization. In step 2, a vertical stub is added to the right side of the ground plane. The addition of this stub, creates a new path for the current and excites a new resonance in the 5.3 GHz, leading to bandwidth enhancement. The bandwidth of the antenna in this step extends from 5 GHz to 7.5 GHz. Still, no circular polarization is seen. Finally, in step 3, which is the final structure, a rotated L-shaped stub is also included. With this change, the bandwidth has reached to 5 GHz – 8 GHz. Apart from the bandwidth enhancement obtained by the modification made in last step, circular polarization is also generated in the frequency band of 5.2 GHz – 5.8 GHz.



(a)



(b)

Fig. 3. (a) S_{11} curve of the three proposed antennas in Fig. 2 and (b) the axial ratio of the proposed antennas in Fig. 2.

B. The CP mechanism

To explain the CP operation mechanism of the proposed antenna, surface current distribution is simulated on the antenna at the frequency of 5.5 GHz and in four phases of 0º, 90º, 180º, and 270º. The simulated results are shown in Fig. 4. As it is clear from this figure, in 0º phase, the dominant current on the antenna flows in +y direction. In 90º phase, the current changes its direction and flows in the –x direction. In 180º and 270º, the magnitude of the current is the same as 0º and 90º, respectively, but its orientation is reverse, that is –y and +x. Based on the simulated surface current distribution, it is seen that the current turns counter clockwise as the phase increases from 0º to 270º by a step of 90º. This shows that the presented CP antenna generates RHCP in +z direction and LHCP in –z direction.

C. The ground plane length

The ground plane length that is named as L_g in Fig. 1, is the parameter that is studied in this section. Figure 5 shows the effect of this parameter on the antenna performance. Three values are chosen for L_g and the S_{11} and AR bandwidths are simulated and shown in Fig. 5 (a) and (b). It is clear that the lower edge frequency band of both S_{11} and AR have shifted towards higher frequencies as the L_g increases from 8 mm to 10 mm with a step of 1 mm. The higher edge has also been influenced by this change and has shifted to higher frequencies. Only when L_g is 9 mm, highest impedance bandwidth and a complete CP coverage of 5.2 GHz – 5.8 GHz (WLAN) is covered. In fact, when this parameter is varied, the coupling of the ground plane with the feed line and the rotate L-shaped element is influenced, which affects the antenna performance.

D. Simulated and measured results

The antenna with the given values in Fig. 1 has been fabricated and tested. Figure 6 shows the simulated and measured S_{11} and axial ratio bandwidth. It is seen that the simulated and measured S_{11} curves are in good agreement and the small difference is due to the soldering and fabrication faults. Also, the measured axial ratio bandwidth is slightly more than the AR obtained from simulation. According to the measured results, the frequency band of 5 GHz – 8 GHz is completely covered by the antenna and the axial ratio is extended from 5.1 GHz – 5.8 GHz, which is about 13 %.

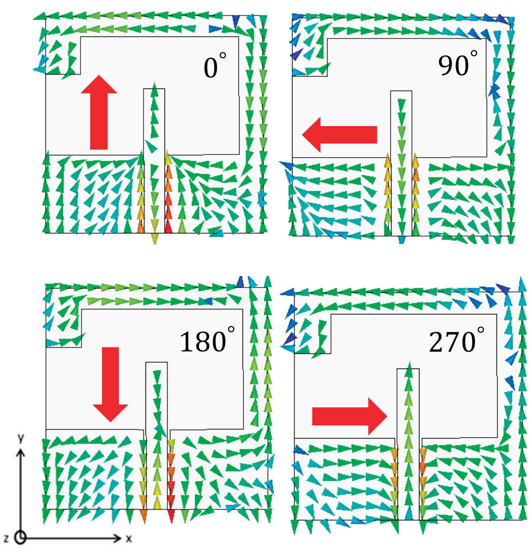
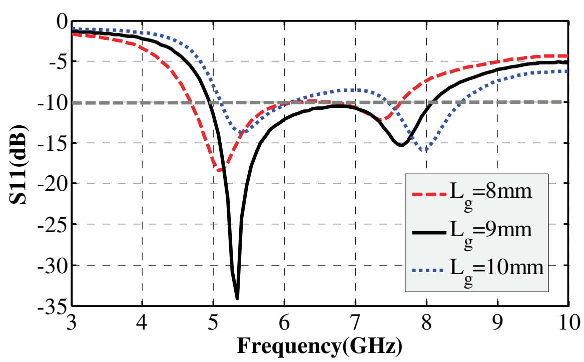
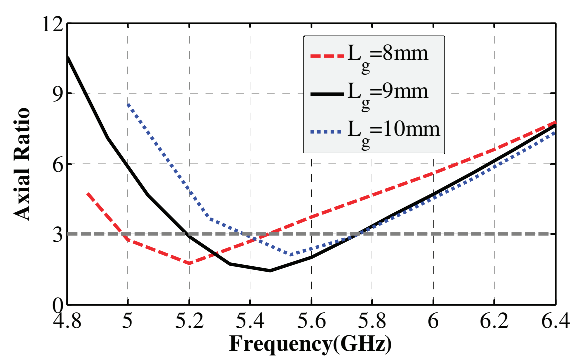


Fig. 4. Surface current distribution on the antenna at 0º, 90º, 180º, and 270º.

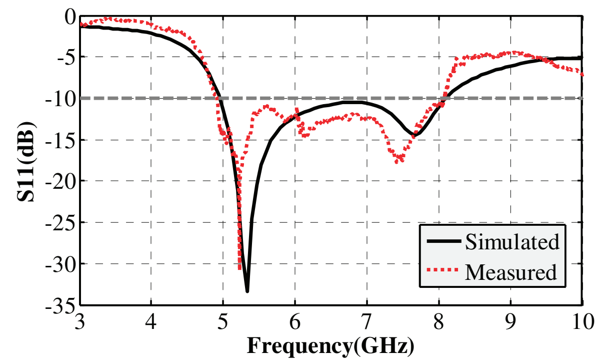


(a)

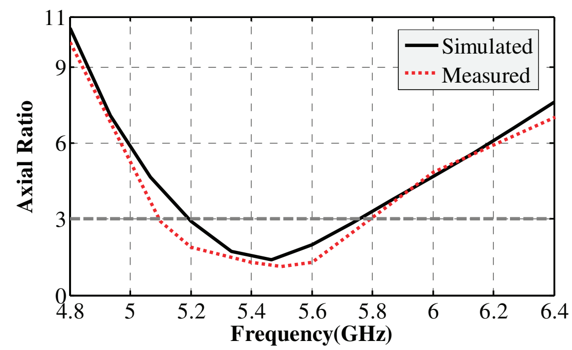


(b)

Fig. 5. (a) S_{11} curves and (b) axial ratio for different values of L_g.



(a)



(b)

Fig. 6. (a) Simulated and measured S_{11} and (b) simulated and measured AR.

The antenna gain is also measured and compared with the simulated results in Fig. 7. It is seen that the measured gain is acceptable in the frequency band of 5.1 GHz – 5.8 GHz, where the CP property is achieved. The measured RHCP and LHCP radiation patterns of the antenna at 5.5 GHz in the xz- and yz-plane are plotted in Fig. 8. Acceptable radiation pattern is obtained for the antenna, making it suitable for communication industry.

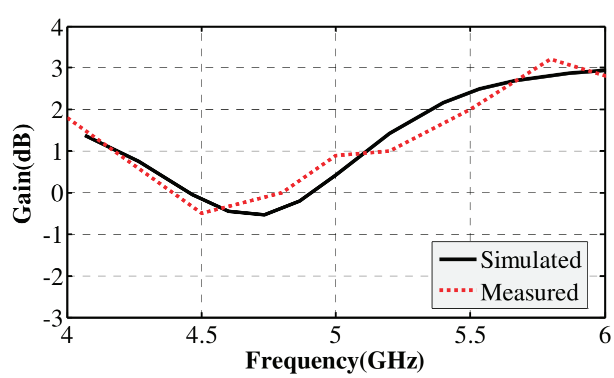


Fig. 7. Simulated and measured antenna gain.

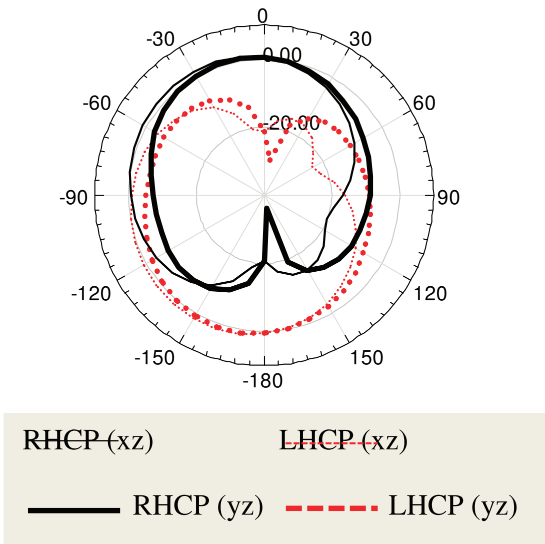


Fig. 8. Measured RHCP and LHCP radiation pattern of the CP antenna in the xz- and yz-plane at 5.5 GHz.

IV. CONCLUSION

A novel compact CPW-fed antenna with CP characteristics in WLAN frequency band is introduced in this work. The antenna has admirable characteristics making it a suitable option for communication systems. Small size and very simple structure are of the clear advantages of this antenna over the previously designed CP antennas. Also, acceptable gain and good radiation properties are other features of the presented antenna. The study antenna exhibits impedance bandwidth between 5 GHz to 8 GHz and its axial ratio extends from 5.1 GHz to 5.8 GHz, completely covering the WLAN frequency band. The agreement of the simulated and measured results show that the presented structure is a good candidate for communication systems.

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Maryam Majidzadeh was born on 18 September, 1987 in Urmia, Iran. She received her B.S. and M.Sc. degrees in Electrical Engineering from Urmia University in 2009 and 2012, respectively. She is currently a Ph.D. student in Electrical Communication Engineering at the same university. Her research interests are in designing of UWB antenna, bandwidth enhancement and antenna miniaturization techniques, Circular Polarized antennas and numerical method in electromagnetics.

Javad Nourinia received his B.Sc. in Electrical and Electronic Engineering from Shiraz University and M.Sc. degree in Electrical and Telecommunication Engineering from Iran University of Science and Technology, and Ph.D. degree in Electrical University of Science and Technology, Tehran Iran in 2000. From 2000, he was an assistant professor and now he is a professor in the Department of Electrical Engineering of Urmia University, Urmia, Iran. His primary research interests are in antenna design, numerical methods in electromagnetic and microwave circuits.

Changiz Ghobadiwas born on 1 June, 1960 in Iran. He received the B.S. degree in Electrical and Electronic Engineering and M.S. degree in Electrical and Telecommunication Engineering from Isfahan University of Technology, Isfahan, Iran and Ph.D. degree in Electrical-Telecommunication from University of Bath, Bath, UK in 1998. From 1998 he was an Assistant Professor and now is a professor in the Department of Electrical Engineering, of Urmia University, Urmia, Iran. His primary research interests are in antenna design, radar and adaptive filters.