Compact and Broadband Circular Polarized Microstrip Antenna with Wideband Axial-Ratio Bandwidth

S. A. Malekabadi[1, 2], A. R. Attari[1], M. M. Mirsalehi[1]
[1]Electrical Engineering Department, Ferdowsi University of Mashhad, Mashhad, Iran.
[2]Communications and Computer Research Center, Ferdowsi University of Mashhad, Mashhad, Iran.
a.malekabadi@gamil.com

***Abstract*- In this paper, a novel stacked Microstrip Antenna (MSA) is proposed for wideband circular polarization. The antenna consists of two rectangular patches with two orthogonal slots at the center of each patch. The lower patch is excited with a coaxial line. The normalized bandwidths of the input impedance and Axial Ratio (AR) of the proposed antenna are found to be 17% and 13% respectively. Also, comparing the proposed antenna with a similar structure but without any slots, it is found to be 10% more compact. The proposed antenna is simulated using commercial electromagnetic software IE3D which is based on the Method of Moment (MoM).**

Keywords- stack microstrip antenna; circular polarization; axia-ratio bandwidth.

I. INTRODUCTION

Circular polarized antennas have various applications in communication systems like mobile GPS [1]. These antennas can have single or dual feeds [2, 3]. The single feed circular polarized structure has small occupied volume, less complexity and is desirable in situations where it is difficult to place dual orthogonal feeds. But, it suffers from some shortcomings, such as small axial ratio bandwidth [1]. Hence, the design of a broadband circularly polarized patch antenna that uses a single feed is in demand [5]. In [3], a three layer dual feed stacked microstrip antenna is presented with an impedance bandwidth of 10% and an AR bandwidth of 8.5%. However, this antenna has thickness of more than half a wavelength. Also, a wide-band almost square stacked patch antenna with an impedance bandwidth of 20% and an AR of 13% has been proposed [4]. In this antenna only a part of the two bandwidths are overlapped. Another design method for broadband circularly polarized microstrip antenna is reported which 8-17% AR bandwidth in the C and K frequency bands [5]. In this method two stacked square patches with cut edges are used and excited by a microstrip line. In [6], a reduced size stacked antenna using a single probe feed has been investigated. In [7], a novel technique is introduced to improve the AR bandwidth and the gain of the single feed circular polarized stacked microstrip antenna.

In this paper, a novel compact stacked microstrip antenna with two rectangular patches for achieving an impedance bandwidth of 17% and an AR bandwidth of 13% is proposed. Using two orthogonal slots in both upper and lower patches 10% compactness is achieved. The antenna is simulated using a commercial electromagnetic software IE3D base on Method of Moment (MoM) and simulation results are presented.

II. ANTENNA CONFIGURATION

Fig. 1 (a) shows the top and side views of the proposed antenna. The antenna consists of a stacked structure of a rectangular driven patch over a rectangular parasitic patch with dimensions of $L_1 \times W_1$ and $L_2 \times W_2$ respectively. The driven patch is fed by a coaxial line at (x, y) point and the parasitic patch is electromagnetically coupled to the driven patch. The driven patch is mounted on a dielectric substrate of 1.575 mm thickness and dielectric constant of $\varepsilon_r = 2.2$. A foam layer is sandwiched between the two patches. As shown in Fig. 2, in the center of each patch two orthogonal slots are inserted. The size of the crossed slot on the driven patch is smaller than the size of the crossed slot on the parasitic patch. It is found that these slots help to reduce the antenna size and increases axial-ratio bandwidth.

III. ANTENNA ANALYSIS AND PARAMETRIC STUDY

The analysis of the presented stacked patch antenna was performed by IE3D simulator. The maximum axial ratio bandwidth was obtained with patch dimensions of $L_1 = L_2 = 16$ mm and $W_1 = W_2 = 14$ mm, the slot dimensions of $l_1 \times w_1 = 7 \times 1$ mm^2 and $l_2 \times w_2 = 10.25 \times 1$ mm^2 and a foam layer height of $h_2 = 3.8$ mm. The impedance and axial ratio bandwidth of the antenna are 995 MHz and 765 MHz, respectively. The center frequency of the antenna is 5.9 GHz.

Parameters used for optimization of the antenna are feed position, foam layer height and slots dimensions. The proposed antenna was analyzed and optimized for achieving maximum axial ratio bandwidth.

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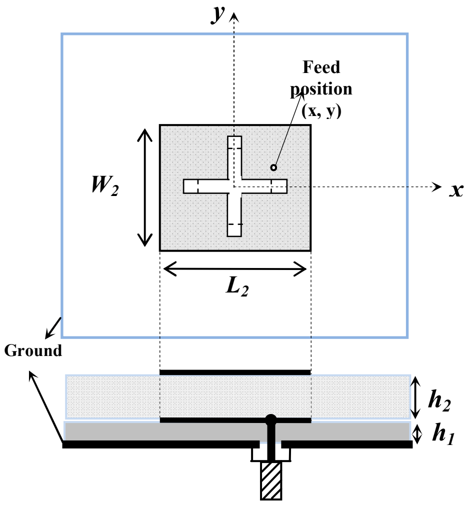

Fig. 1. Top and side views of the proposed antenna.

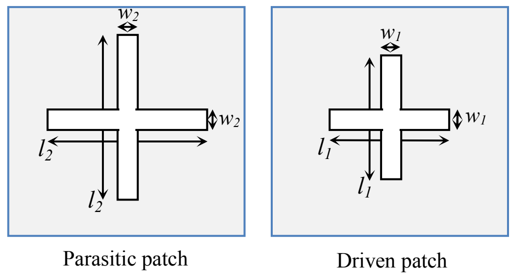

Fig. 2. Driven and parasitic patches of the reported antenna.

A. *Effects of Feed Position*

Several simulations for different values of feed position, with constant slot dimensions and foam layer height, were carried out. The effect of feed position on the performance of the proposed antenna was studied. The objective was to achieve maximum impedance and axial ratio bandwidth. Return loss and axial ratio of the proposed antenna for three different values of feed position are depicted in Fig. 3 (a) and (b), respectively. More detailed information is presented in Table 1. It can be seen that the maximum impedance and axial ratio bandwidth can be achieved with the feed position placed at (4, 2) mm.

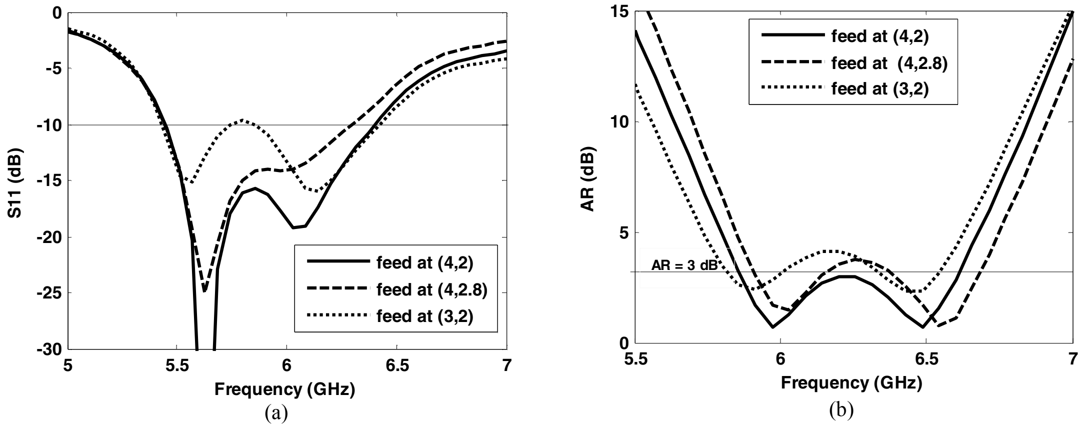

Fig. 3. (a) Return loss and (b) axial ratio of the proposed antenna for different values of feed position.

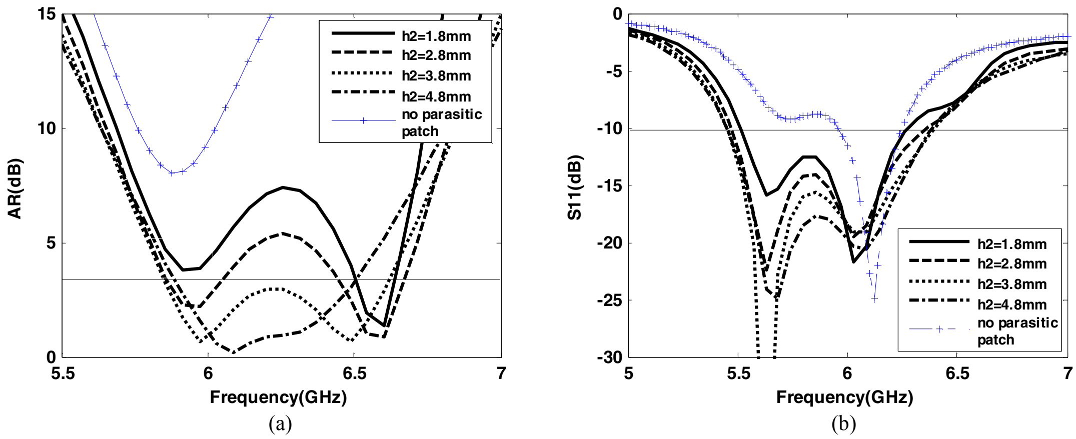

Fig. 4. (a) Return loss and (b) axial ratio of the proposed antenna for different values of foam layer height.

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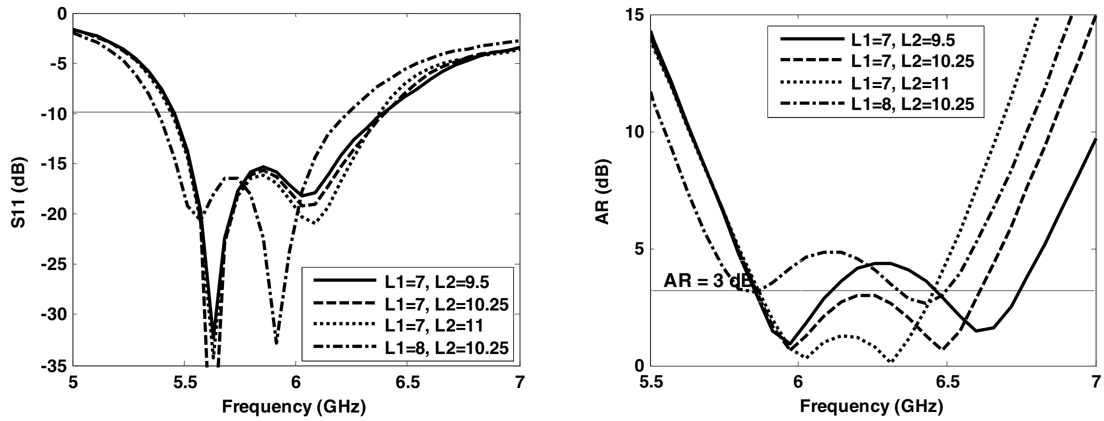

(a) (b)

Fig. 5. (a) Return loss and (b) axial ratio of the proposed antenna for different values of slots dimensions.

B. *Effects of Foam Layer Height*

In this part the effect of h_2 parameter on the performance of the antenna is studied. This is the foam layer height which is sandwiched between the driven and parasitic patches. The feed position and slot dimensions are constant in this investigation. Antenna is fed at (4, 2) mm and the slots dimensions are $l_1 \times w_1 = 7 \times 1$ mm^2 and $l_2 \times w_2 = 10.25 \times 1$ mm^2. Return loss of the antenna for different values of h_2 is illustrated in Fig. 4 (a). It is observed that, the return loss of the antenna is not dependent on the h_2. Also, the axial ratio of this antenna is depicted in Fig. 4 (b). It is seen that, the maximum axial ratio bandwidth is obtained for h_2 = 3.8 mm.

As shown in Fig. 4 (a) and (b), in the case of $h_2 \rightarrow \infty$ (without parasitic patch) the return loss indicates two resonances approximately similar with proposed stack structure but the minimum axial ratio is about 7.5 dB which corresponds to linear polarization. It is observed that the second minimum point in the axial ratio diagram is due to the parasitic patch.

TABLE I

EFFECTS OF THE FEED POSITION ON THE PERFORMANCE OF THE REPORTED ANTENNA.

Feed Position *(x, y)$_{mm}$*	***f_r*** **(GHz)**	**S_{11}-BW (MHz)**	**AR-BW (MHz)**
(4, 1.5)	5.855	855	390
(4, 1.8)	5.885	955	680
(4, 2)	**5.90**	**995**	**765**
(4, 2.3)	5.94	985	620
(4, 2.8)	6.01	860	515
(3, 2)	5.91	830	255
(3.5, 2)	5.93	957	642
(4.5, 2)	5.93	943	647
(5, 2)	5.96	853	662

C. *Effects of Slot Dimensions*

Effects of slots dimensions on the return loss and axial ratio of the proposed antenna are presented in Table 2. Antenna is fed at (4, 2) mm and the foam layer height is h_2 = 3.8 mm. It has been found that these slots improve the axial ratio bandwidth and reduce the antenna size. As seen in the Table 2, the maximum impedance and axial ratio bandwidth is achieved for l_1 = 7 and l_2 = 10.25 mm.

IV. RADIATION PATTERNS

The radiation patterns in two orthogonal planes ($\varphi = 0^{\circ}$ and $\varphi = 90^{\circ}$) are plotted in Fig. 6 for two frequencies (6.0 and 6.4 GHz). As seen in the patterns, the radiation of the antenna is in the broadside ($\theta = 0^{\circ}$) direction.

V. CONCLUSIONS

In this paper, a new stacked microstrip antenna for achieving CP is reported. The obtained impedance and axial ratio bandwidths are 995 MHz (17%) and 765 MHz (13%), respectively. The center frequency of the proposed antenna is 5.9 GHz which shows 10% compactness compared with unslotted stacked antenna with the center frequency of 6.57 GHz. Parametric study on all parameters of the proposed antenna is carried out for achieving maximum axial ratio bandwidth.

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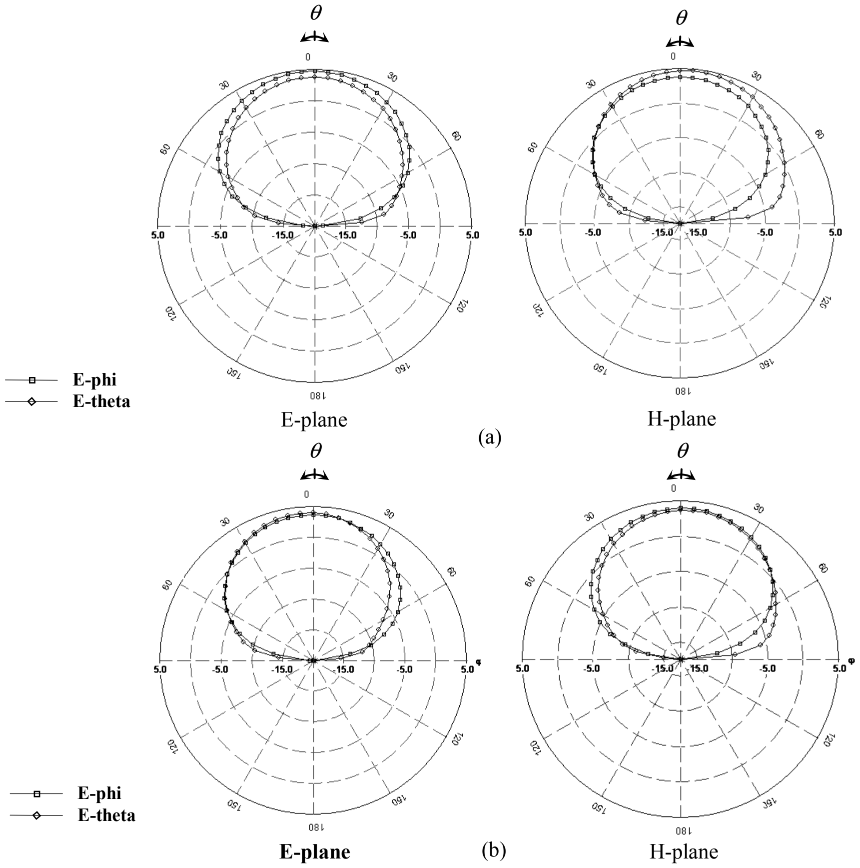

Fig. 6. *E*-plane (φ = 0°) and *H*-plane (φ = 90°) radiation patterns of the proposed antenna with $L_1=L_2=16$ mm and $W_1=W_2=14$ mm, the slot dimensions of $l_1\times w_1=7\times 1$ mm^2 and $l_2\times w_2=10.25\times 1$ mm^2 and a foam layer height of $h_2=3.8$ mm for two frequencies: (a) f = 6.0 GHz and (b) f = 6.4 GHz.

TABLE II
CENTER FREQUENCY, IMPEDANCE AND AXIAL RATIO BANDWIDTH OF THE PROPOSED ANTENNA FOR DIFFERENT VALUES OF SLOT DIMENSIONS.

Slot Dimensions		f_r (GHz)	S_{11}-BW (MHz)	AR-BW (MHz)
l_1 (mm)	l_2 (mm)			
7	9.5	5.92	950	560
7	10	5.91	935	610
7	**10.25**	**5.90**	**995**	**765**
7	10.5	5.93	945	710
7	11	5.93	935	545
5	10.25	6.09	1048	541
6	10.25	6.01	1003	661
8	10.25	5.8	810	430
9	10.25	5.65	725	255

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