Circularly Polarized Aperture-Coupled Microstrip-Line Fed Array Antenna for WiMAX/C Bands Applications

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Abstract ─ In this paper, a new configuration of broad band circularly polarized (CP) array antenna is presented by a modified feeding network The proposed feed network includes two hybrid 90-degree branch line coupler and a 180-degree rat-race coupler. The feed network of array provides sequential rotation condition for consisting of four L-shaped microstrip lines which coupling through four ring-shaped slots. Each element of array is printed on two layer of substrate which connected together with a ring aperture. Employing wideband CP elements and feeding network structure causes the creation of innovation at CP array. The 3dB axial-ratio bandwidth of the array extends to approximately 650 MHz with impedance bandwidths of 24.7% for C-band applications and a relative high gain of about 10.2 dBic. The performance of the antenna has been approved by comparing between measurement and simulation results.

Index Terms ─ Aperture-coupled microstrip-line fed, array antenna, circularly polarized.

I. INTRODUCTION

Recently, the use of circularly polarized (CP) antennas have advantages such as: very effective in combating multipath interferences or fading, able to reduce the "Faraday rotation" effect due to the ionosphere and no strict orientation between transmitting and receiving antennas are required [1–15]. Therefore, circularly polarized antennas play a key role in many wireless applications, such as RFID systems, satellite communication and navigation systems. These antennas have more popularity because of their better mobility and weather penetration [1-7]. Microstrip technology with light weight and easy fabrication as a choice is constructed. But, the inherent narrow axial-ratio (AR) bandwidth and low gain of the microstrip antenna leads to limit their applications. The printed CP slot antennas attract much attention due to their capabilities of providing wide impedance and AR bandwidths while maintaining the low profile [1-15].

Hitherto, many attempts to improve them have been reported [2-7]. A feeding mechanism for patch antenna with circular polarization is proposed that has a feeding geometry, which is an integration of a hook shape feed line and four Γ-slots, a 2×2 sequentially rotated CP slot patch antenna array using a microstrip-line-to-asymmetric-CPW feeding network has been presented in [2]. In [5], a design of a circularly polarized array using a two section cascaded coupler feeding system for creating broadband circular polarization performance has been presented, which feeding network of the array is composed of a 180° ring hybrid coupler connected to the two branch-line couplers generating circular polarization. Despite the reported works can improve 3-dB AR bandwidth, they often suffer from large size and low gain.

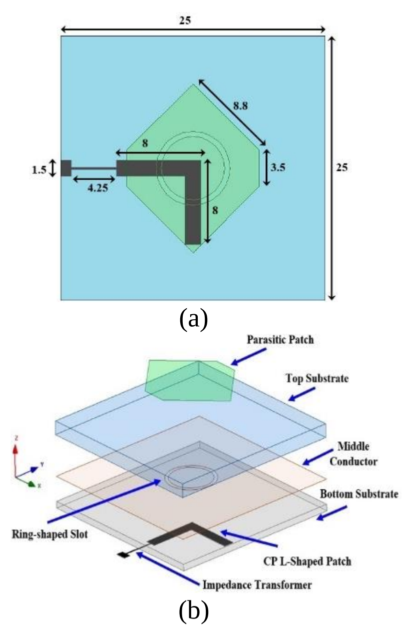

Fig. 1. Configuration of the proposed CP array antenna elements: (a) top view and (b) perspective view.

To addressed mentioned problems, in this paper a novel CP array antenna is presented. The proposed antenna consists of four single elements which each of

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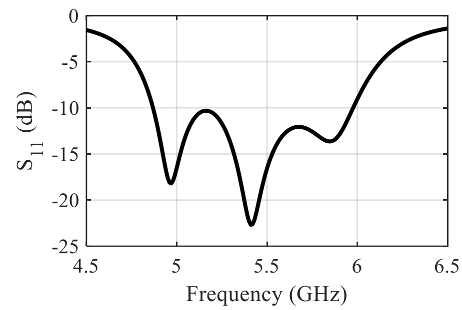
elements includes two layers of substrate which by a ring slot feed and radiation patch isolated from together. A cascade feed network includes two branch line and a rat-race coupler provide sequentially rotated conditions. Results and details of proposed antenna are discussed in following sections.

Table 1: Comparison of the proposed antenna size and measured characteristics with other references; the impedance bandwidth is for a frequency range where the VSWR ≤ 2, and ARBW is the 3-dB axial-ratio bandwidth

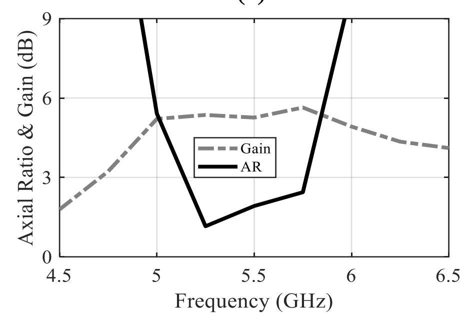
Ref.	Size (mm^3)	BW (GHz)	3dB ARBW (GHz)	Peak Gain (dBic)
[8]	70×70×1.60	0.85 (1.75-2.6)	0.4 (1.7-2.1)	3.7
[9]	70×70×1.60	0.20 (1.5-1.7)	0.3 (1.5-1.8)	3.5
[10]	70×70×1.60	0.80 (1.6-2.4)	0.2 (1.8-2.0)	3.5
[11]	60×60×0.76	0.80 (1.7-2.5)	0.7 (1.8-2.5)	3.5
[12]	60×60×0.74	1.40 (1.6-3.0)	0.7 (2.3-3.0)	4.0
[15]	30×30×0.80	1.2 (4.9-6.1)	0.5 (5.25-5.75)	3.7
This work	25×25×1.4	1.11(4.87-5.98)	0.63 (5.17-5.8)	5.8

II. ANTENNA ELEMENTS

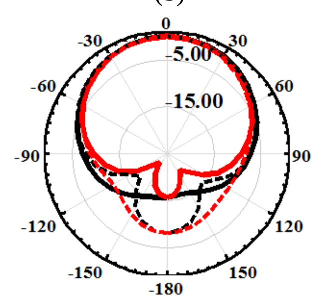
Construction of CP array elements is displayed in Fig. 1. The proposed elements are consisted of two layers of FR4 substrate with relative permittivity of (ε_r=) 4.4 and loss tangent of (tanδ=) 0.02. In order to reduce radiation loss and improvement of radiation characteristics of the patch, the thicknesses of bottom and top substrates are chosen to be 0.8 mm and 1.6 mm, respectively (Figs. 1 (a), (b)). At the bottom side of the array elements, a thin microstrip line with a length of 4.25 mm and width of 0.2 mm acts as an impedance transformer between the CP L-shaped antenna and the 50 Ω microstrip line along the y-axis. Between the two substrates, a metallic layer including a ring-shaped slot which performs as an aperture slot is created. The bottom layer of single element consists of a L shape feed line which among a ring aperture slot between two substrates couples to upper patch. The size of ring aperture is regulated so that provides a 90-degree phase difference in two point of excitation by L-shape feed toward top patch. At top layer, in order to improve CP features two opposite corner of rectangular patch is chamfered. The results of single element are illustrated in Fig. 2. As it is shown, the impedance bandwidth is 4.87 to 5.98 GHz (Fig. 1 (a)) with 630 MHz 3-dB AR bandwidth (Fig. 1 (b)). The proposed antenna with an almost constant gain in all of IBW generates a broadside pattern (Fig. 1 (c)), as expected. The proposed single element has an area of 625 mm^2 (25 mm × 25 mm), which is significantly less than the previously published slot antennas as summarized in Table 1. Compared to other types of CP slot antennas fabricated on the same substrate the proposed antenna exhibits an impedance bandwidth which is significantly larger and with no reduction in the gain performance, as well as having a larger circular polarization bandwidth. The gain is comparable to previous designs.



(a)



(b)



(c)

Fig. 2. Results of the proposed CP array antenna elements (solid lines are CP right hand, dash lines are CP left hand, blue lines are at φ=0° and red lines are at φ=90°). (a) The simulated S_{11}, (b) the simulated gain and axial ratio, and (c) a normalized simulated radiation pattern at 5.5 GHz.

III. ARRAY ANTENNA DISCUSSION

The feed network and array antenna designed and optimized by using Agilent Advanced Design system (ver.2012) and Ansys HFSS (ver. 13), respectively. In order to enhance the 3-dB axial ratio bandwidth and pattern balance, elements rotations must be changed as much as 90° between the adjacent elements and 180° between the opposite ones, and phase delay of the feed line has to be changed according to the elements rotations, respectively. The details of the configuration and feed network of the proposed CP array antenna are displayed in Fig. 3. As shown in Fig. 3 (a), the feed network uses a 180° ring hybrid coupler to realize a 3 dB power split, equal in magnitude, but 180° out of phase. Two branch-line hybrid couplers then divide the signal energy into two paths and give the signal to each of the output branches with the same amplitude, but phase-shifted by 90°, wherein the relative phases at four feed points are 0°, 90°, 180° and 270°.

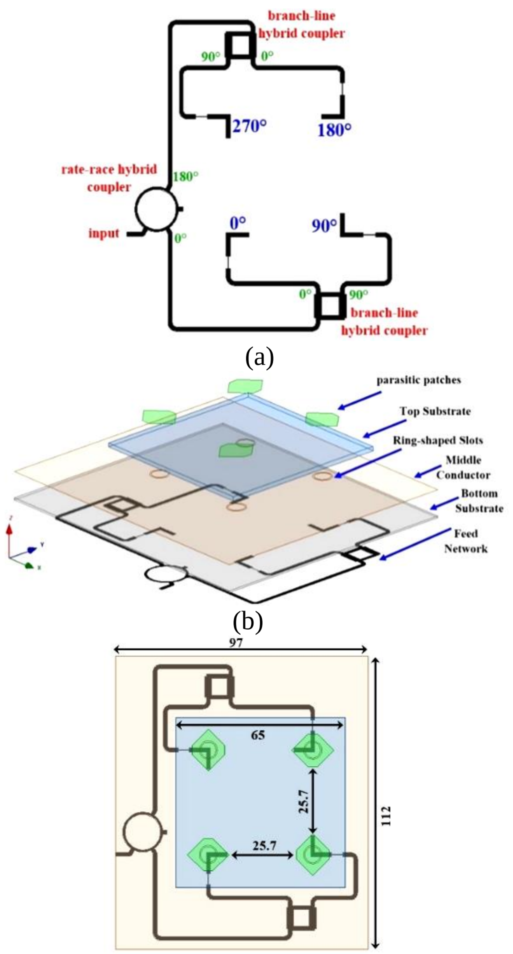


Fig. 3. A configuration and feed network of the proposed CP array antenna: (a) top view of feed network, (b) perspective view of the proposed CP array antenna, and (c) top view of the proposed CP array antenna.

A perspective and top view of the proposed CP array antenna are shown in Fig. 3 (b) and Fig. 3 (c) respectively. The scattering parameter of the proposed array antenna is measured by the Agilent™ 8722ES vector network analyzer. The CP array antenna achieves measured impedance bandwidths from 4470 to 6670 MHz for C-band applications with S_{11}<-10 dB, as demonstrated in Fig. 4 (a). The comparison between simulated and measured AR and gain of the proposed array antenna are shown in Fig. 4 (b). The measured AR bandwidth of the array is 650 MHz between 4870 MHz to 5520 MHz. Minimum point of the axial-ratio curve is at 5000 MHz with a magnitude of 1.67 dB. The proposed array has a peak gain of 9.85 dBic at 6.24 GHz. A standard linearly polarized waveguide BJ320 was used to measure the total gain characteristics. The measured results of the normalized radiation patterns of the array at 5 GHz are presented in Fig. 4 (c). The RHCP and LHCP radiation patterns of the array are obtained at φ=0° and φ=90°. The array antenna size is 97 mm × 112 mm. Also a photograph of the fabricated antenna is shown in Fig. 5.

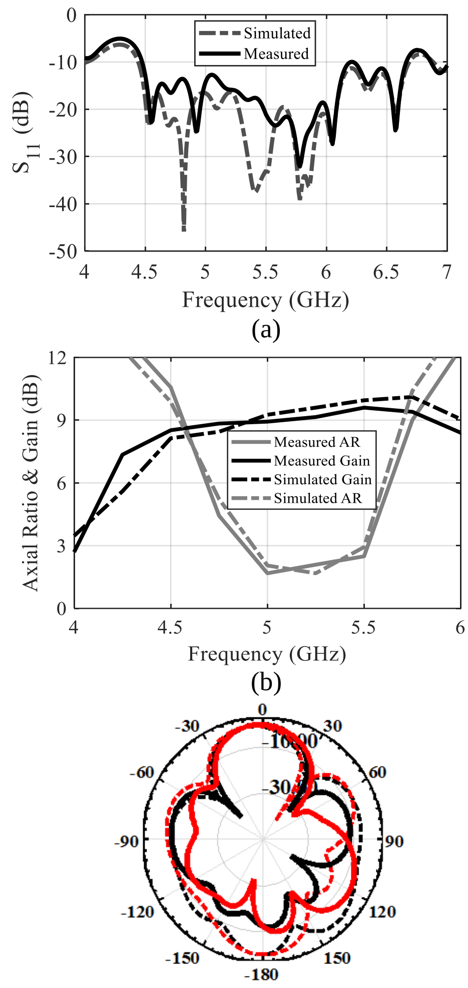


Fig. 4. Results of the proposed CP array antenna (solid lines are CP right hand, dash lines are CP left hand, blue lines are at φ=0° and red lines are at φ=90°). (a) Comparison between the simulated and measured S_{11}, (b) comparison between the simulated and measured gain and axial ratio, and (c) normalized measured radiation pattern at 5.5GHz.

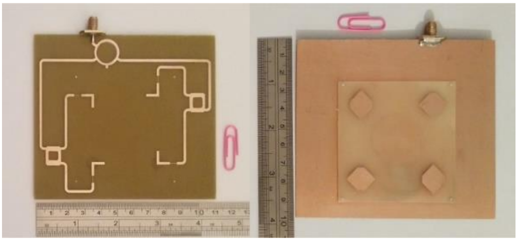


Fig. 5. Photograph of the fabricated antenna.

The design when compared with the previous CP array structures with sequential feed network and arc feed-line presented in Table 2 show significantly increased impedance bandwidth and axial-ratio bandwidth, i.e., the impedance and AR bandwidth are, respectively, more than three and two fold wider than the previous designs.

Table 2: Comparison of the proposed feed network structure and measured characteristics with other array antennas

Ref.	Feed Network	Impedance BW	ARBW	PG (dBic)	Substrate
[13]	Asymmetric CPW	0.80 (1.1-1.9)	0.80 (1.1-1.9)	~7.5	FR4
[14]	Aperture Coupled	0.80 (1.6-2.4)	0.60 (1.7-2.3)	~15	Rogers 5880
[15]	Symmetric Microstrip	1.7 (4.5-6.2)	1.47 (4.75-6.22)	7.2	FR4
This work	Cascade	2.2 (4.47-6.67)	0.65 (4.87-5.52)	10.2	FR4

IV. CONCLUSION

In this paper, a two layers CP array antenna using the cascade feed network for C-band application is presented. The feed network by special structure which consists of two 90-degree couplers and a 180 degree couplers can be realized a broadband sequentially rotated condition. The single elements of antenna have been designed on two layer which isolated feed network and radiating patch by a ring slot. The patch of antenna to provide better CP feature was chamfered in two opposite corner. Proposed antenna compared with other works and indicated that proposed antenna is better than they from most aspects.

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