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Circularly Polarized Cylindrical Dielectric Resonator Antenna with Different Shapes Cross Slot

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ABSTRACT

A cross slot coupled cylindrical dielectric resonator antenna (CDRA) operating in the X-band (8GHz -12GHz) frequency range is studied. The proposed CP designs are achieved by implementing a suitable crossslot on the ground plane (in the case of aperture coupled feed method), which results in excitation of two near degenerate orthogonal modes of near equal amplitudes and 90° phase difference. Attempts are madeto change the geometry of slots ends to introduce a novel structure in order to achieve a better impedance bandwidth with an improved 3dB axial ratio (AR) bandwidth. It is found that the hourglass of cross slot has a great effect on the strength of coupling between the feed line and the dielectric resonator antenna.In simulation an impedance bandwidth of 46.15% and axial ratio bandwidth of 22% has been achieved with the above geometry. An improvement of 12% in impedance bandwidth and 11.2% in Axial ratio bandwidth is obtained over conventional rectangular cross slot.

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1. INTRODUCTION

During the past two decades, dielectric resonator antenna (DRA) has been widely explored. These antennas have several advantages such as small size, light weight, ease of excitation and high gain [1], [2]. Dielectric resonators of different shapes have various modes of resonances. With the proper excitation of certain modes, these resonators can actually become efficient radiatorsinstead of energy storage devices [1]. Primary conducted studies on DRA have been mainly focused on the linear polarization applications, bandwidth enhancing techniques such as excitation of higher order modes, combination of hybrid modes and array applications [3], [4]. Nevertheless, designing a wideband circularly polarized (CP) DRA is still a challenging task.It is difficult to simultaneously obtain wide impedance and axial ratio (AR) bandwidths. Circularly polarized (CP) DRA has received tremendous attention [5]-[10], mainly due to its ability to reduce the polarization mismatch.

A Circular polarization (CP) operation was achieved through complex geometries of the DRA [5], [6] or through the attachment of parasitic patches [7], [8]. In designs [5], [6] make use of slots on the side walls of DRAs to excite degenerate modes, for generation of CP fields with 3dB AR bandwidth of 8.2. In [9], another design was proposed, in which dual-band CP operation was accomplished by using a cross slot coupled to couple energy from a microstrip line to a rectangular DRA. The 3-dB axial-ratio (AR) bandwidths dB obtained 19.8% and 6.2% for the lower and upper bands, respectively. Recently, in [10] the cross slot coupled cylindrical DRA with wide impedance and AR bandwidth has been proposed. It was demonstrated that the bandwidth of cross slot coupled DRA can be increased substantially by stacking two DRs vertically. For this antenna axial ratio bandwidth obtained 16.0%.

In this paper, a singly-fed cross slot coupled cylindrical DRA with different shapes of crossslot consist of rectangular, dog bone, and hourglass is studied. It is found that the hourglass of cross slot has a great effect on the strength of coupling between the feed line and the dielectric resonator antenna. It gives an optimum impedance bandwidth with an improved 3 dB axial ratio (AR) bandwidth. The 3dB AR bandwidths are 10.8%, 13.6%, and 22% for the rectangular, dog bone, and hourglass cross slot, respectively. In comparison with similar works, these proposed antennas offer relatively wide AR bandwidth, high gain, and simple structure. Also employing FR4 substrate makes these also a low cost structure. Other advantages of the proposed antenna is using only one port for achieve wideband circular polarization at all frequency bands. The return losses, axial ratios, radiation patterns and antenna gains were studied using Ansoft HFSS.

2. CDRA MODELLING AND DESIGN

The aperture-coupled excited cylindrical DRA through the rectangular, dog bone, and hourglass crossslots was designed and is shown in Figure 1. The crossslots are in the ground plane, and the DR on top of the slots. The slots are centered with each other and with the DR in the ground plane and substrate.It is etched on a 22mm × 22 mm FR4 (ε_r =4.4, tanδ = 0.002) substrate with a thicknessof S=0.8mm. The microstrip feed line of W_m= 1.6mm and L_m = 14mm is printed on a substrate. A small rectangular stub of 1.6mm × 5mm is used at the centered below the DR which aids in the impedance matching. The DR element is made of Rogers RT6010 (ε_r =10.2, tanδ = 0.0023) with the radius a=4.32 mm and height h=3.1 mm. The DR is excited in the fundamental $HEM_{11\delta}$ mode. The dimensions of the crossslots, the DR, and the ground plane determining the antenna performance are labeled in Figure 1.

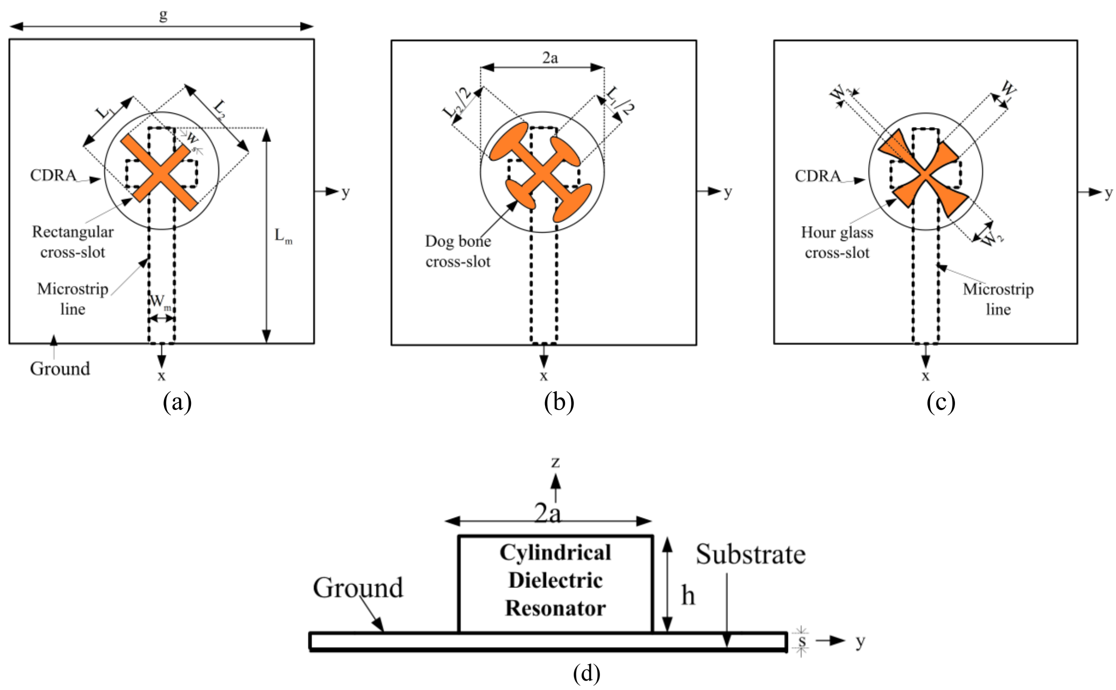

Figure 1. Configuration of the antenna: (a) Top view of rectangular cross slot (b) Top view of dog bone cross slot (c) Top view of hourglass cross slot (d) side view.

2.1. Slot Effect Characterization

The shape and size of cross slot may affect the coupling between the slot and CDRA. In order to efficiently couple the electromagnetic energy from aperture to CDRA, this parameter has optimized. The slot should be made no larger than is required for impedance matching. For maximum coupling, the DR should be centered over the cross slot.

A thin rectangular cross slot gives much stronger coupling. The coupling can be increased by using longer or wider rectangular cross slot. For a simple rectangular cross slot, the transverse electric field must vanish at the end of the aperture. By adding a ellipticalslot at the end of the rectangular aperture (Dog bone-shaped) the field becomes nearly uniform along the aperture and hence the coupling increases [11]. A bowtie or butterfly shaped cross slot, also gives more coupling and higher resonant impedance as compared the rectangular cross slot. An hourglass shaped cross slot uses the features of both the dog bone- and the bowtie-shaped cross slots without any sharp edges and hence give maximum coupling.The width of the rectangular cross slot (Figure 1(a)) is W_s= 0.5mm, and the arms lengths are chosen to be L_1= 5mm and L_2= 7mm. Figure 1(b) and 1(c) show other parameters of dog bone and hourglass cross slot. The arms width of hourglass cross slot are selected to beW_1= 1.2mm, W_2= 2.2mm, and W_3= 0.5mm.

3. RESULTS AND ANALYSIS

Analysis of cylindrical DRA at 10 GHz has done by taking rectangular, dog bone, and hourglass of cross slot having dielectric constant 10.2, keeping the slot position same. The simulated return loss and AR bandwidth for these three cases are shown in Figure 2. As it can be found out from Figure 2(a), the simulated −10dB impedance bandwidths of rectangular, dog bone and hourglass cross slot CDRAs are 34.14% (8.5–12GHz), 42.42% (7.8–12GHz) and 46.15% (7.5–12 GHz), respectively. Figure 2(b) shows the simulated AR for all of the three cases in the boresight direction (θ= 0°). The CDRA has 3dB AR bandwidths 10.8% (8.8–9.8 GHz), 13.6% (9.6–11 GHz), and 22% (8.9–11.1 GHz), forrectangular, dog bone and hourglass cross slot respectively. With reference to the figure, maximum return loss and 3dB AR bandwidth is achieved by using hourglass of cross slot CDRA. Only 10.8% 3dB AR bandwidth is achieved when we use rectangular shape cross slot. The simulated antenna gains for these three cases are shown in Figure 3. With reference to the figure, similar results are found for all of the three cases. It can be seen the simulated antenna gain varies between 0dB and 6.5dB.

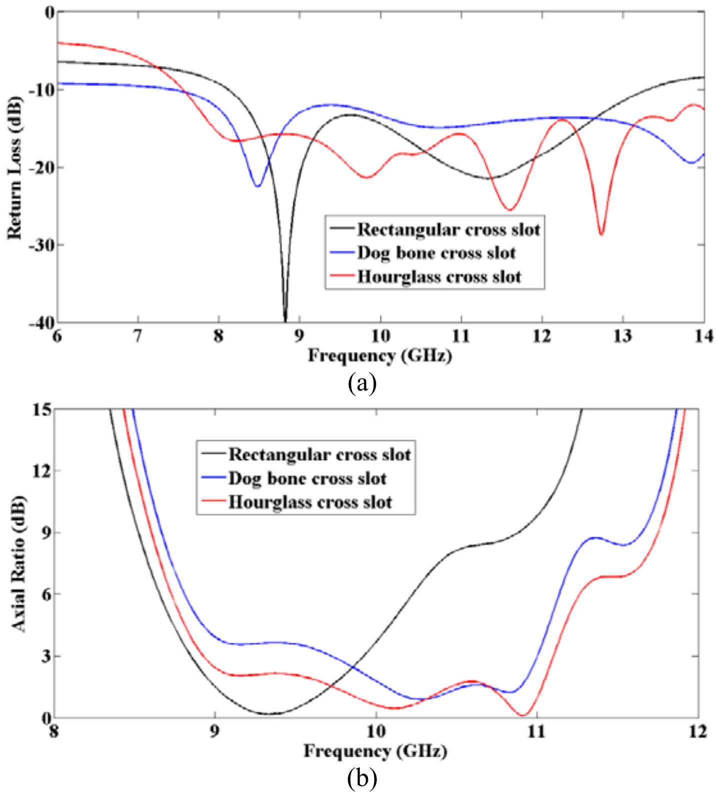

Figure 2. Simulated Return Loss and Axial ratioof the CP CDRA with different shape cross slot (a) Return Loss, (b) Axial ratio

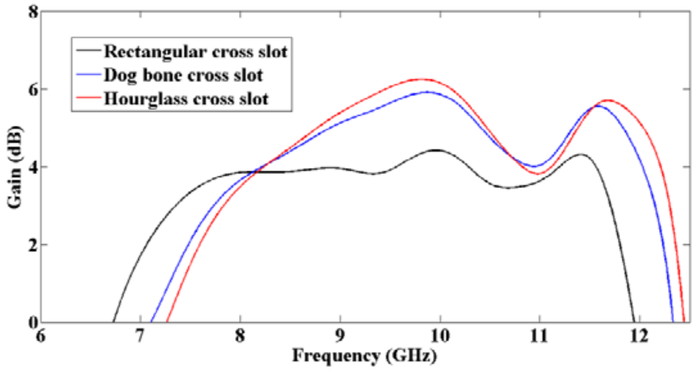

Figure 3. Simulated gains of the CP CDRA with different shape cross slot

Figure 4 represents the simulated radiation patterns for three cases at 9.3 GHz, 10.3 GHz, and 10.2 GHzfor *xz*-planes. With reference to this figure, the LHCP fields are stronger than RHCPs.

Finally, Table 1 shows a comparison of the different shape cross slot of CP DRA and other Published CP DRA results in terms of the -10 dB impedance bandwidth, 3dB AR bandwidth, and gain. The characteristics of the different shape cross slot antennas can be summarized as follows: impedance bandwidth, 3 dB axial ratio bandwidth and antenna gain is improved when hourglass shape cross slot is used instead of the antenna with rectangular and dog bone shape cross slot. It is because that the hourglass makes the fields on the slots more uniform than the other cases. When hourglass cross slot is used, the axial ratio bandwidth increases above 22% as compared to rectangular cross slot, which gives a bandwidth of 10.8%. Also, compared with other CP DRA published such as [9] and [10], our proposed antenna has a better performance, low-cost and simple structure.

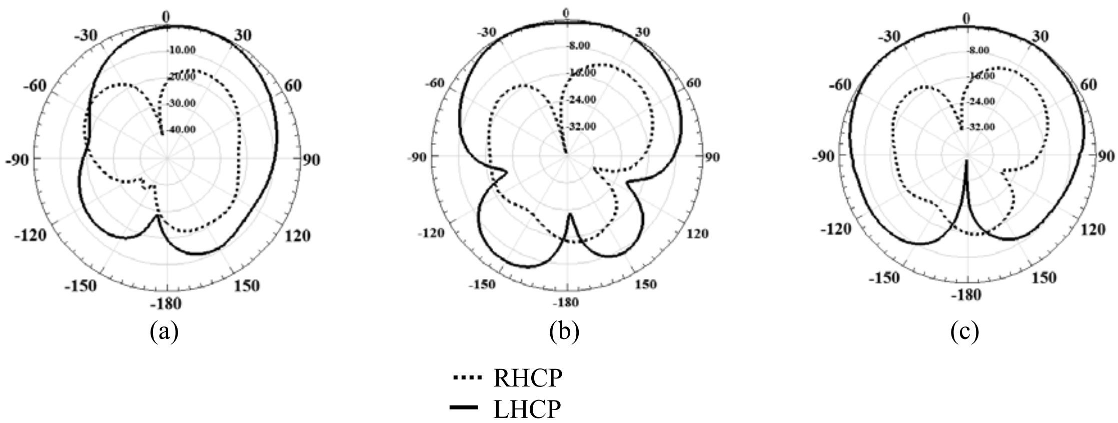

Figure 4. Simulated radiation patterns (LHCP and RHCP) of the different shape cross slot CP CDRA. (a) Rectangular cross slot at 9.3GHz, (b) Dog bone cross slot at 10.3GHz (c) Hourglass cross slot at 10.2GHz

Table 1. Performance of Different Shape Cross Slot of CP DRA as Compared to other Published CP DRA

	This work	This work	This work	Ref [9]	Ref [10]
	RectangularCross slot shape	Dog bone Cross slot shape	Hourglass Cross slot shape	2014	2013
-10dB impedance bandwidth	34.14%	42.42%	46.15%	24.3%	100%
3dB AR bandwidth	10.8%	13.6%	22%	19.8%	16%
Gain	4.5 dB	5.9 dB	6.2 dB	2.3 dBi	5 dB

4. CONCLUSION

This paper describes the results for circularly polarized CDRA structure with different geometry on the cross-slots. An aperture-coupled CDRA operating in X-band has been presented which is driven from a single feed and excited through a rectangular, dog bone, and hourglass crossslots. It is found that the maximum return loss and 3dB AR bandwidth is achieved by using hourglass of cross slot CDRA. It is because that the hourglass makes the fields on the slots more uniform than the other cases. When hourglass cross slot used, the axial ratio bandwidth increased as compared to rectangular cross slot. By adjusting the length, width and position of the hourglass shaped cross slot, best antenna performance obtained.

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