Circularly polarized DRA antenna: Design and Developments

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Abstract— This paper describes basic of circular polarization, fundamental concepts, theory and review study of the circularly polarized dielectric resonator antenna (CP DRA) over the last three decades. The latest techniques for generating the circular polarization as well as enhancing the performance are also covered. CP DRA catches the potential application in the Satellite communication, mobile communication, GPS, WLAN, WIMAX, Mobile communication and Radar system. This paper also presents a design of polarization reconfigurable, left hand and right hand switchable cylindrical DRA ,by using two crossed slots of unequal length to couple energy from an aperture coupled microstrip line. Right hand circular polarization or left hand circular polarization can be achieved with a single feeding structure in the designed antenna. The designed antenna minimises fading caused by multipath effect.

Key words: Dielectric resonator antenna (DRA), Circular polarization, Feed excitation

I. Introduction

There is a need of antenna with polarization diversity in todays wireless communication system. As per the literature survey, most of the research on polarization diversity has been done on patch antennas. Over the past decades, significant research work has been done on the linearly polarized (LP) antenna and the result shows that there is not so much work carried out on circularly polarized dielectric resonator antenna (CP DRA). CP DRA fascinated too many scientific groups due to its very powerful features like it provides more agility between transmitter and receiver orientation angle, enhanced mobility, improved weather. penetration and very less multipath reflections and other type of interference as compared to linear polarization [1–5]. The operation of circular polarized DRAs has been in focus of a number of researches in the recent past. Complicated feeding network is required to excite two orthogonal modes with a 90 degree phase difference [6]. In the earlier work ,by making use of complex geometries of the DRA or through the attachment of parasitic patches, truncating patch antenna or loading the antenna/ground with slots, stubs, slits and shorting walls ,circular polarization (CP) operation was achieved [7]. Several techniques such as proximity coupling, stacked CP patches or sequential rotation array, Circular slot antennas using L-shaped probe for broadband circular polarization, have been proposed . In modern wireless system, circularly polarized antennas are widely used because they can suppress multipath interferences, free from the alignment requirement for the transmitting and receiving antenna, insensitive to transmitter and receiver orientation. In addition, CP fields are less sensitive to the propagation effect than LP fields. Due to these numbers of attractive features, the CP system is widely used in satellite communications, mobile communication, navigation systems, radar system and global positioning system [8–11].

The proposed work has the novelty of polarization control DRA antenna with frequency reuse. The designed antenna can achieve right hand circular polarization or left hand circular polarization with a single feeding structure.

The capability of switching from LHCP to RHCP and vice versa can be used to reduce polarization mismatch losses in portable devices.

II. Mathematical Modelling

The instantaneous field of a plane wave, travelling in the negative z- direction, can be written as .

$$\mathcal{E}(z;t) = \hat{a}_x\,\mathcal{E}_x(z;t) + \hat{a}_y\,\mathcal{E}_y(z;t)$$

The instantaneous components are related to their complex counterparts by

$$\mathcal{E}_x(z;t) = Re\left[E_x^- \,e^{j(\omega t+kz)}\right] = Re\left[E_{xo}\,e^{j(\omega t+kz+\phi_x)}\right] = E_{xo}\cos(\omega t + kz + \phi_x)$$

$$\mathcal{E}_y(z;t) = Re\left[E_y^- \,e^{j(\omega t+kz)}\right] = Re\left[E_{yo}\,e^{j(\omega t+kz+\phi_y)}\right] = E_{yo}\cos\left(\omega t + kz + \phi_y\right)$$

where E_{xo} *and* E_{yo} are, respectively, the maximum magnitudes of the x *and* y components

For the wave to have linear polarization, the time-phase difference between the two components must be

$$\Delta\phi = \phi_y - \phi_x = n\pi\,, \qquad n = 0, 1, 2, 3 \ldots$$

Circular polarization can be achieved only when the magnitudes of the two components are the same and the time-phase difference between them is odd multiples of $\pi/2$. That is,

$$|\mathcal{E}_x| = |\mathcal{E}_y| \Rightarrow E_{xo} = E_{yo}$$

$$\Delta\phi = \phi_y - \phi_x =$$

$$\begin{cases} +\left(\frac{1}{2}+n\right)\pi;\, n = 0, 1, 2 \ldots \quad for\ CW & (7.6) \\ -\left(\frac{1}{2}+n\right)\pi;\, n = 0, 1, 2 \ldots \quad for\ CCW & (7.7) \end{cases}$$

Where

CW is clockwise and CCW is counter- clockwise rotation

III. Circular polarization generation techniques

To generate the circular polarization while using DRA various techniques have been offered. They can be divided on the basis of different feeding methods which are single feed , multiple feeds and sequential rotation methods . By exciting two quasi-degenerate orthogonal modes which are in phase quadrature, a single feeding technique for generating the circular polarization is obtained. In the dual feeding method two orthogonal degenerate modes excited by the two quadrature signals are fed into the DRA. The feeding network of single fed CP DRA is very simple as compared to dual fed CP DRA because in dual fed CP DRA an external quadrature coupler is required to generate two quadrature signals and therefore system becomes very complex. In single point feed DRA, four techniques are used for generating the circular polarization i.e. different geometrical DRA shapes , slot excitation technique , strip and patch excitation technique and slot with strip excitation technique . The research on DRA while using circular polarization with single-point feed started with configurations such as the rectangular DR with truncated corners as shown in Fig. 1 [12-14]. In this design two diagonal corners removed from a square cross-section DRA and DRA is excited with a probe. To achieve a better impedance match the location and height of the probe are varied.

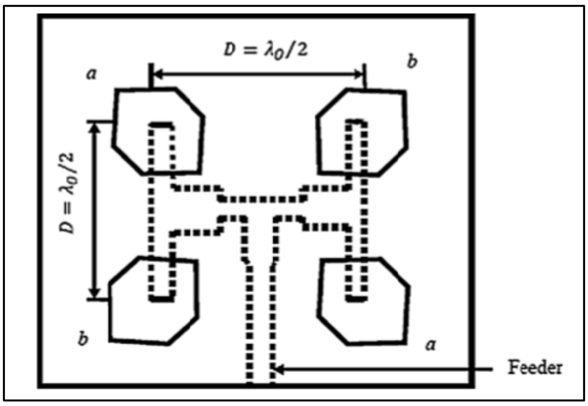

Fig. 1: Rectangular DRA with truncated corners

The first designed on circularly polarized rectangular DRA was reported in 1995, a rectangular DRA which was excited by single slot feed [15]. In this case to generate CP, feeding can be achieved either a probe or through a single aperture as shown in Fig. 2.

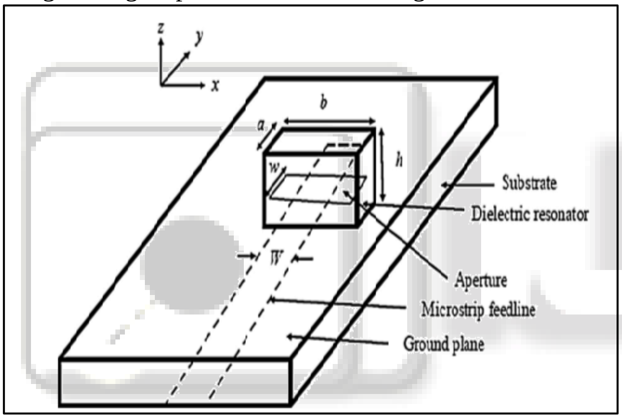

Fig. 2: Configuration of the aperture fed CP rectangular DRA

In the other design, to achieve a wide band CP DRA a narrow rectangular slot makes an angle of 45 degree with respect to the sides of the DRA is used to excite the stair DRA as shown in Fig. 3

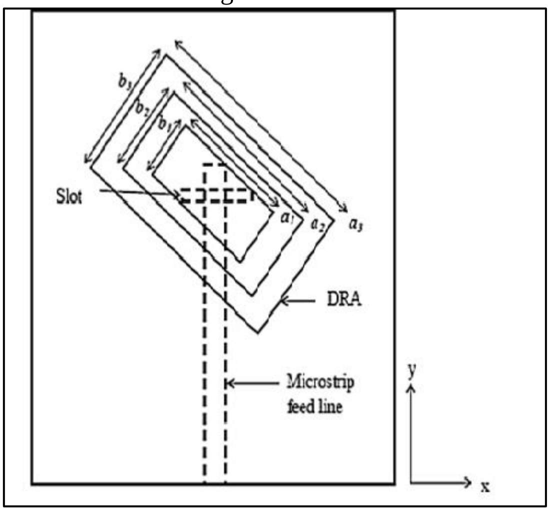

Fig. 3: Configuration of the CP rectangular stair DRA

For improving the polarization quality, slot fed DRAs are used because it reduces the radiation from the feeding circuit. Also in the feed design more degree of freedom can be obtained by using a slot coupling feed. Slot coupling is the most popular excitation technique for the DRA design due to its direct integration with monolithic microwave integrated circuits (MMICS). In slot fed DRAs, by using different slot sizes wide frequency-band selections are achieved for a DR element. To achieve wider impedance bandwidth annular slot is better than the rectangular slot excitation technique. There are several advantages of cross slot feeding mechanism in the DRA design for circular polarization. If we compare feeding mechanism of microstrip antenna with the DRA, the arm-length variation of the coupling cross slot of DR element is more sensitive than that of the microstrip one due to smaller required arm length ratio of the cross slot in case of DR element. As the length of the coupling slot is increasing, the resonant frequency of the microstrip patch is decreasing. The slightly lower resonant frequency of the resonant mode will be obtained in the perpendicular direction of the longest slot as compared to the perpendicular direction of the shortest slot.

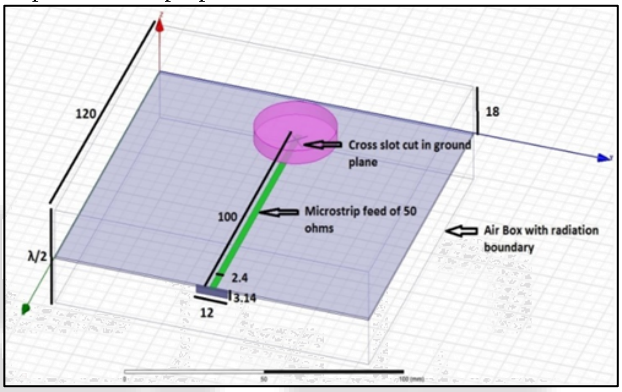

Fig. 4: DRA for circular polarization

IV. CIRCULAR POLARIZED DRA ANTENNA DESIGN

The antenna deign consists of copper ground plane of 120*120 mm2. The substrate consists of Roger RT Duroid 5880 of permittivity 2.2 and dimensions 120*120*0.7874 mm3. The cylindrical DRA of 5.1 mm height and 15.2 mm radius was used, as shown in Fig. 4 and Fig. 5

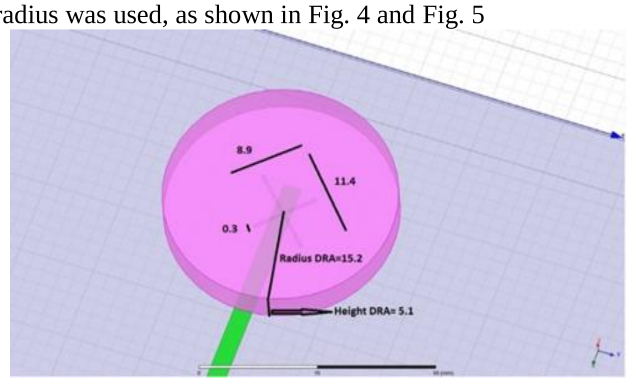

Fig. 5: Cross Coupled DRA for Circular Polarization

The circular operation of antenna is achieved by using two crossed slots of unequal lengths. The energy is coupled from an aperture coupled microstrip line to a cylindrical DRA. Both slots were oriented at 90 degrees with respect to each other and their centres were at the same position, centred underneath the dielectric resonator (DR), as depicted in Fig.5

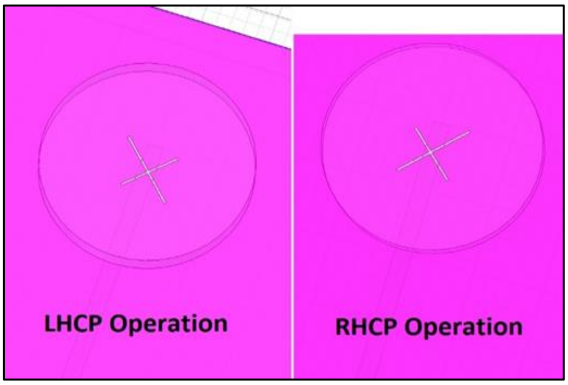

Fig. 6: LHCP and RHCP Circular Polarization

The 90 degree angle crossing of the slots, shown in Fig. 6, prevents the coupling between the two excited orthogonal modes and therefore, the investigation for each slot resonance may even be conducted separately. Their lengths were unequal, so that two near-degenerate orthogonal modes of equal amplitude and 90 degree phase difference are excited at frequencies close to that of the fundamental mode of the DRA. The dimensions of the Slot 1 and Slot 2 were 11.4*0.3 mm2 and 8.9*0.3 mm2 respectively

V. Conclusion

This paper provides a detail evolution and advancement in the design technique and working of CP DRAs, in order to focus on the high degree of flexibility and versatility that CP DRAs can provide. Feeding techniques is the most important design mechanism for CP operation; the observation shows that microstrip-feed line and slot excitation techniques are the most efficient feeding method available for CP operations. A circularly polarized DRA antenna for polarization diversity has been designed. To achieve the circular polarization two crossed slots of unequal length to couple energy from an aperture coupled microstrip line have been used. The designed antenna can achieve right- hand circular polarization or left -hand circular polarization with a single feeding structure. The quality of polarization has been estimated by measuring the axial ratio, input impedance, VSWR, co and cross polarization gain. In the designed antenna, switching between RHCP and LHCP is achieved at the same frequency. Circularly polarized wave is robust as compared to linearly polarized wave, hence antenna misalignment can be compensated with the use of circular polarization. The designed antenna can be used to impart secrecy and polarization diversity by specific switching between RHCP and LHCP. As a future work, investigations can be done on other resonator geometries like elliptical, octagon, and hexagon for wideband performance analysis. Several feeding mechanisms can be used (like slots, probes, microstrip lines, dielectric image guide, and coplanar waveguide lines) to efficiently excite antenna design

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