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Circular Polarization Techniques for Design of Monopole Antenna

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Abstract:
A retrospection of circular polarization techniques for monopole antenna is given in this paper. As circular polarization is gaining more importance now-a-days due to its flexible orientation and property to combat multipath fading effect, better orientation in signal reception between transmitter and receiver antenna, better weather penetration, line of sight and its application in mobile communication; GPS, RFID reader antenna, WLAN, portable hand handle devices and radio astronomy. An incisive explanation of circular polarization concept and then focus on most eloquent circular polarization feeding techniques which have been made in last few years.

Keywords: Axial ratio, Circular polarization, impedance bandwidth, single-feed and dual fed.

I. INTTRODUCTION

From the last decades wideband antennas have many researches due to spectrum allocation of ultra wideband by the national regulators [1].Monopole antennas is one of the category of antenna which have vast utilization in wireless and mobile communication. The simplest member of the monopole antenna family is quarter wave monopole antennas. The impedance bandwidth (BW) of the quarter wave monopole antenna is increases with the increase in radius of the cylindrical stub. This concept is when the stepped radius becomes abrupt from the feed probe to the cylindrical element. As this design has complex issues so a simple technique is given to replace the cylindrical stub by a planar element, which forms a planar monopole. 1968, Meinke and Gundlach first described the planar monopole and in 1976, Dubost and Zisler described it in details. In 1998 Agrawall discovered Circular and elliptical disk monopoles. A planar monopole antenna is formed by replacing a wire element of conventional monopole with a planar element, by this change of wire element to planar monopole surface area increases with various shapes, which has a direct impact on impedance bandwidth. Planar monopole antenna comprises of many conformation and geometry such as rectangular, circular, elliptical, square and hexagonal which provide wide range of impedance bandwidth. The radiation properties (pattern, directivity, input impedance) of thin wire antenna, when investigated by current distribution, which is most of the time sinusoidal is not realizable but can approximated. The radiation pattern, gain and impedance of such antennas are sensitive. For application that requires broad range of frequencies there are numerous types of antenna used such as arrays and broadband antenna [2]. Many antennas were developed with monopole antenna using micro strip patch in higher frequency application but these designed are limited to linear polarization only leaving enhancement in circular polarization (CP) behind.

A.Linear polarization-

Linear polarization or planar polarization is a confinement of electric field or magnetic fields are on same plane in direction of propagation. Several excellent design were developed in [3]-[10] for micro strip and monopole antennas having bandwidth enhancement. In 2009, A. Al-Zoubi, *et* al. proposed a ring-coupled circular patch antenna [11]. With a low profile of 0.028 0. The antenna provides a wide bandwidth of 12.8%. In 2013 a broadband circular patch antenna with shoring-vias loading [12]. The antenna has a simple structure and can be easily fabricated on any substrate. The coupling of the inherent TM02 mode in the non-loaded circular patch with respect to the definition in [13] and the TM01 mode generated by the shorting-vias . The antenna has a wide bandwidth of18% with a profile of 0.024 0.A circular monopole antenna loaded with shorting-vias and coupled with an annular ring [14]. By coupling three modes the ring-coupled and via-loaded circular patch antenna achieves an even wider bandwidth of 27.4% with a profile of 0.029 0. The monopole circular patch antenna with dual rings coupling [15] also had a triple resonance behavior. The antenna in has a Bandwidth of 27.1% with a profile of 0.027 0.

B.Circular Polarization-

Circular Polarization can be obtained if two orthogonal modes are excited with 90˚ phase shifts between them. This can be obtained by adjusting physical components of patch or by single and dual or more feed. Circular polarization can be easily achieve in square shape patch antennas shown in fig 1(a, b) to excite two orthogonal mode, to TM_{010} mode with the feed at one edge and TM_{001} at the other edge. A quadrature phase difference is provided by 90˚ power divider or 90˚hybrid couplers. For a circular patch, circular polarization for the TM^{Z}_{110} is achieved by using two feed with proper angular separation as shown in fig 1(c) where two coax feed is used which are 90˚ to each other and generate field which are orthogonal to each other[2].

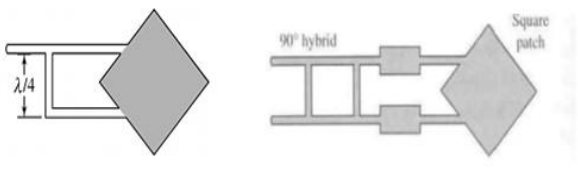

Figure.1. (a) Square patch driven at adjacent side through power dividers (b) Square patch driven at adjacent side through hybrid couplers [2].

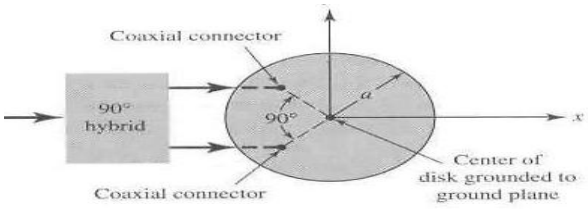

Figure.1. (c) Circular patch with coax feed [2].

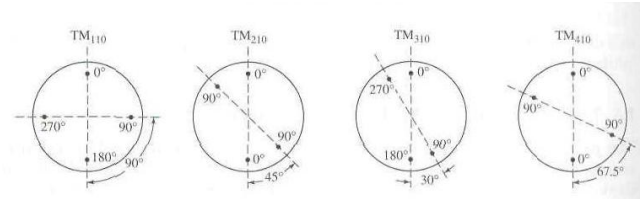

Figure.1. (d) Circular patch with TM_{110} mode with higher modes [2].

Circular polarization antenna (CP) is gaining more importance in wireless communication because it allow flexible orientation in signal reception between transmitter and receiver antenna, better weather penetration, line of sight and also combat multipath fading. In Linear polarized antennas transmitter and receiver should be in same polarization and also posses same orientation. Circular antennas are widely used in mobile communication; GPS, RFID reader antenna, WLAN, portable hand handle devices and radio astronomy. Those applications requests antenna researchers some requirements on CP antennas such as small/compact size, wideband or multiband characteristics, wide CP beam, reconfigurable performances etc. Circular polarization of an electromagnetic wave is in polarization when each point of the electric field magnitude has a constant value but different in phase by 90˚. Circular polarization comes in two variations as Right hand polarized and Left hand polarized. Feed techniques and position gives impedance bandwidth of a antenna. The desired parameters of a circular polarized antenna are axial ratio, tilt angle and sense of rotation [2, 16]. When the Axial Ratio becomes infinite or zero and with tilt angle defining orientation linear polarization occur. The quality of linear polarization is detected by the level of cross polarization. Axial ratio at unity defined perfect circular polarization which defined the quality of circularly polarized waves .For circular polarization .The desire parameters of a circular polarized antenna is VSWR<2 and S11< -10db and Axial Ratio ≤ 3db [17].

II. FEEDING TECHNIQUES FOR CIRCULAR POLARIZATION-

There are many techniques for generation of circular polarization; mainly single feed, dual feed and triple feed are classified.

A. Single feed configuration –

Single feed configuration antenna structure is slightly perturb with respect to the feed position to give 90˚phase shift for proper circular polarization. Many perturbation techniques are used for the single feed circular polarization like insertion of cross or Y shaped slots, truncating corners, slits, spur lines and loading stubs. Different types of feed techniques may be used for the CP microstrip patch antenna. Coaxial probe feed [18- 22] though simple, provides only narrow bandwidth. In [23] a circular microstrip antenna with partial ground, some cross slots and additional slot is used give good circular polarization at 3 dB axial ratio bandwidth is higher than 87.8% and achieved impedance bandwidth of 158.8% (1.4–12.2 GHz). This is shown in fig 2. In [26] a antenna is made with circular patch and defected ground is made to achieve circular polarization shown in fig 3. Proposed RSMA with partial and defected ground design, UWB response (i.e. 3.1GHz – 10.6 GHz) with reference to VSWR<2 is achieved**.** The design was implemented on the substrate RT/Duroid5880 with dielectric constant 2.2 with thickness 0.785 mm and small modifications to the ground plane to improve the dual polarization as well as UWB characteristics. The gain variation is between 2-5 dB in UWB frequency range For UWB response the required minimum radius of circular monopole antenna is deduced by Following equation [24-25]

$F_L=\frac{7.2}{2.25R+\varepsilon}GHz$

Where e is the gap between radiating patch and ground plane and F_L is the lowest resonant frequency corresponding to UWB frequency band i.e. 3.1 GHz

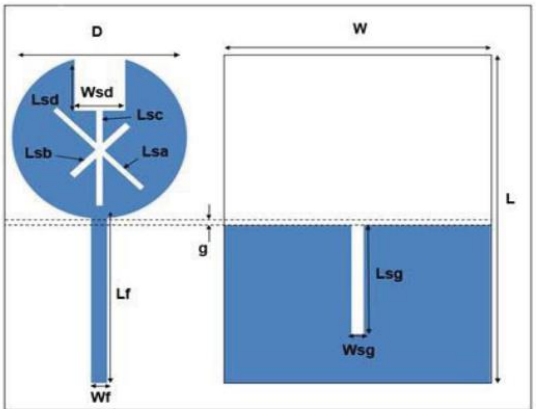

Figure. 2. Circular monopole antenna [23].

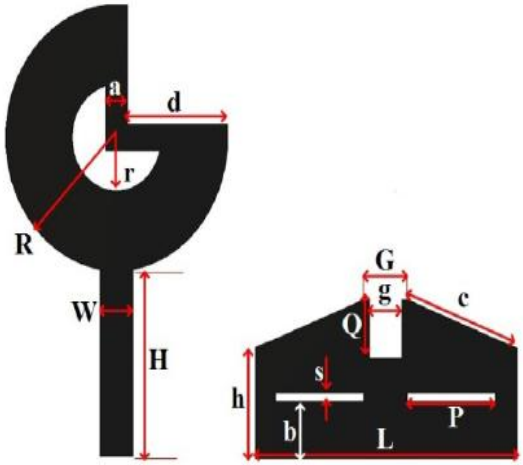

Figure. 3. Geometry of proposed RSMA [26].

In [42] equilateral triangle patch is used with defected ground to achieve circular polarization. A thin layer coating of Indium Tin Oxide (ITO) is used in patch and is feed with the CPW feed. Two L shaped slot is cut in the ground to achieve circular polarization. Bandwidth of 1.96 GHz and impedance of -56 ohm at designing frequency 2.19 GHz for S band application is design which is shown in fig 4. The fundamental mode resonant frequency of equilateral triangular patch antenna is given [43]

$f_0=\frac{2c}{3a\sqrt{\varepsilon}}$

Where, `a' is side length of triangle. In this equation the effects of fringing fields are not considered. The resonant frequency may be determined with better accuracy.

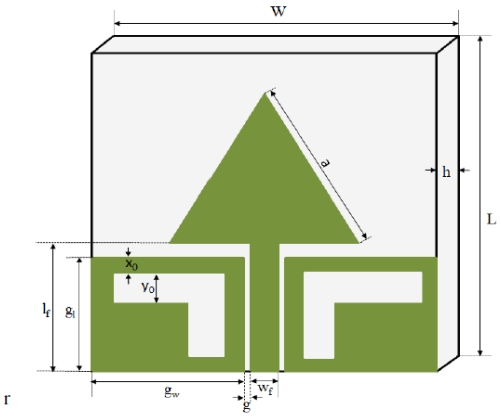

Figure.4. Geometry of equilateral triangular patch[42].

In [27] circular polarization is achieved in microstrip antenna with tilted ground plane and period pattern ground plane. The microstrip patch is kept in 90˚ phase shifts along with travelling wave microstrip feed line by which circular polarization is achieved. The designed antenna exhibits a maximum gain of 3.2dB with beam pointing angle at 30° and operates over a bandwidth of around 8% for a VSWR < 2. Circular polarization beam width for axial ratio <3dB is around 44°. In [28] CP radiation is achieved using a single-feed only with the etched hole in truncated square patch allows the positive mode to have decreased resonance frequency, the negative mode is achieved by using the 2x 2 triangle mushroom antenna. In [29] circular polarization is achieved by microstrip-line-fed in annular-ring slot antenna (ARSA) with inverted-L shaped modified feed to obtain high axial ratio bandwidth of 46% and 56%.The two hat-shaped patches perturb the magnetic current distribution in the ring slot so as to produce two equal-amplitude orthogonal resonant modes. In [30] broadband and circular polarization is obtained in the open slot and patch protruded feed. The open slot is formed by an L-shape conducted strip asymmetrically connected at the edge of the ground plane. After optimization, the final structure which measured 3 dB axial-ratio bandwidth for left-hand circular polarization is 2.47 GHz from 2.00 to 4.47 GHz.

A. Dual feed configuration-

In dual feed configuration sequential phase rotating technique is used to generate circular polarization. In this type of feed there is higher axial ratio bandwidth with low cross polarization. In dual feed configuration higher axial ratio is achieved but the size of ground plane is increased as compare to single feed. In[31]dual fed with aperture coupling is used in microstrip patch antenna to achieve circular polarization. The gain is good and axial ratio nearly 3db by maintaining the proper spacing between the feeds. The figure of dual feed configuration is shown below in fig 6(a, b).

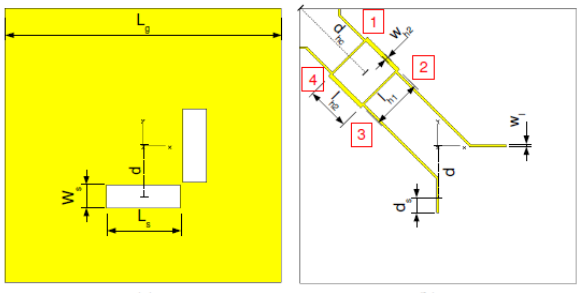

Figure.6. (a) Ground plane: (a) front view of the upper layer (ground + slots),(b) back view (horizontally flipped) of the down layer (feeding lines) [31].

In [32] Flower shaped antenna for multi-polarization microstrip patch antenna with improved gain and bandwidth is made by using the coaxial probes in center patch. Antenna is mainly made for radar and s band applications. The VSWR is 1.01 and gain is at 13db as shown in fig 7.

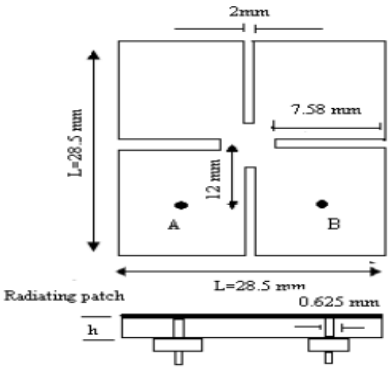

Figure.7. Geometry of proposed square-fed flower –shaped Microstrip patch antenna [32].

In [33] a novel design with dual slot coupling is used to achieve circular polarized by making array and is feed through two micro strip lines, which are 90˚ out of phase shown in fig 8. The square patch is connecting with feed lines by square ring slot. By this excellent axial ratio (AR) performance is achieved in the WiMax band (AR≤1.35 dB at broadside) and for any direction in the antenna main beam (AR<2.25 dB at 3.55 GHz). Actually, the 3-dB AR bandwidth is larger than the WiMax frequency band.

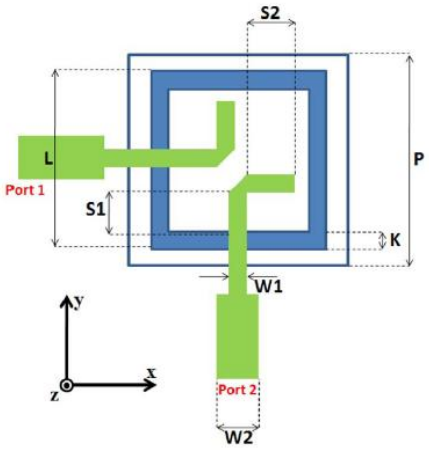

Figure. 8. Geometry of square patch with dual feed [33].

In [34] equilateral triangular micro strip patch with hybrid feed is used to achieve polarization. Vertical polarization in patch is due to aperture coupling and horizontal polarization is due to proximity coupling. Array of triangular patch is orthogonally arranged at 60˚ to give circular polarization at designing frequency 10.6 GHz shown in fig 9(a, b). The detailed dimensions of the dual-LP equilateral triangular patch antenna are given in Fig.9. The initial dimension of the side length of the equilateral triangular patch is calculated
by using the formulas given in [35].

$$f_{mn}=\frac{2c}{3a\varepsilon_r^{-\frac{1}{2}}}\sqrt{(m^2+mn+n^2)}$$

where c is the speed of light, a represents the side length of the equilateral triangular patch, "r is the relative dielectric permittivity of the substrate and mn refers to the TMmn modes.

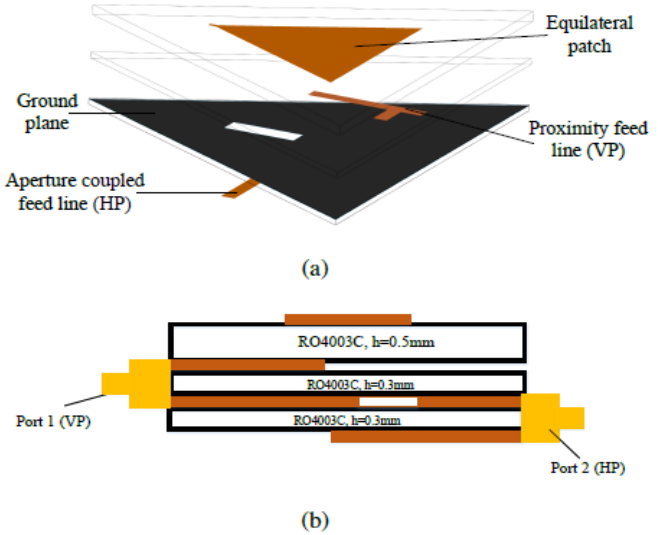

Figure.9. The (a) exploded and (b) side view of the dual-LP equilateral patch antenna. Both feed lines share a same ground plane [34].

A novel design to achieve circular polarization in [36] a planar annual ring antenna with RFID UWB application is made by using Wilkinson power divider feed network with dual L shaped strip. Impedance bandwidth (RL ≧10 dB) of about 246 MHz and the 3 dB axial-ratio (AR) bandwidth of about 180 MHz for UHF RFID applications. Bandwidth is approx. 925 MHz of this antenna. The demand of polarization diversity or enhance the spectrum efficiency by means of frequency reuse in many applications, it is desirable to design dual circular polarized antennas. In [37], a compact dual-feed, dual-polarized patch antenna for GPS applications is proposed. The orthogonal feed excites two linearly polarized waves with a phase shift of 90°. A high permittivity substrate, & four bent (L-shaped) embedded slots at center of the square patch that cause meandering of current path are employed to obtain a reduction in antenna size at the cost of antenna gain and impedance bandwidth. In [38] a compact wideband patch antenna utilizing a quad-feed network and quadruple semi fan-annulus patches is used to improve the Circular Polarization bandwidth to 72 %. The quad feed networks provide good impedance matching. Patches can expand the CP Bandwidth & reduce the size of the antenna effectively. Circular polarization is achieved by a serial aperture-coupled feed with two patches in [39]. The antenna comprises of a square patch enclosed in a square-shaped ring patch. The diamond-shaped slot couples to the ring and cross-slot couples's energy to the patch. The structure operates as dual band CP antenna to cover the 0.915 GHz and 2.45 GHz bands.

C.Triple feed configuration-

The feed structure in shown in fig 10(a) is triple feed configuration made of micro trip line. This type of feed give better performance than any other type of micro strip feed .In simple type of structures antenna arrays and additional matching circuits are required by this insertion, fading loss increases with increase undesired radiation. But micro strip-slot feed circuit needs no impedance matching circuits [40]. In this type of circuit a feed is given to a micro strip line that is coupled by the slot lines to ensure the triple feeding mechanism. The impedance of the slot line is kept 50 ohm and 100 ohm of micro strip line. To understand the working of triple feeding name is given to different points 1,2,3and 4.The structure is shown is fig 10(b) .It shows impedance matching with different four ports [41].

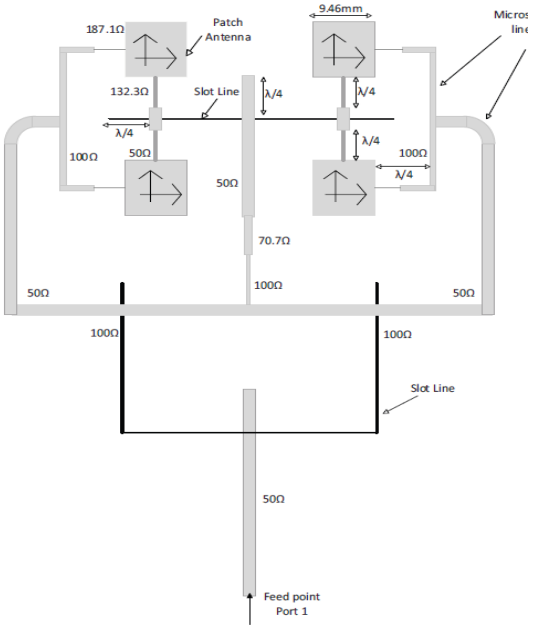

Figure.10. (a) Geometry of array antennas with feed.

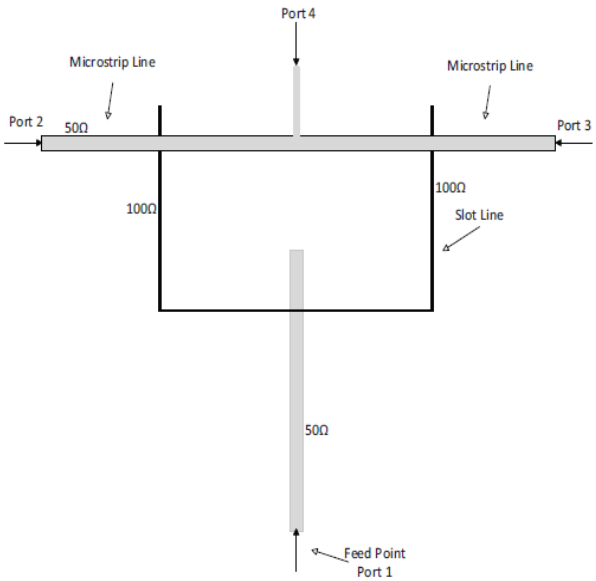

Figure.10. (b) Basic configuration of triple feed structure.

III.CONCLUSION

This paper mainly focused on circular polarization and its techniques for designing monopole antennas. Circular polarization feeding techniques are single double and triple which have discussed briefly in paper. Dual feed configuration have wider future scope due to its advantage of higher axial ratio ,random alignment of transmitter and receiver antenna, improved gain impedance and other parameter of antenna. Triple feed configuration is a novel idea and also carry wide scope of researches in achieving circular polarization.

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