Review of Circular Polarization techniques for design of Microstrip Patch Antenna

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***Abstract*—This paper is a review of the techniques used to generate circular polarized radiation with reference to the feeding techniques. Circular polarized antennas are increasingly gaining importance in wireless communication. The usable bandwidth is the overlap of axial ratio bandwidth and impedance bandwidth. Cross polarization is a measure of the polarization purity of circular polarized antenna. Dual circular polarization is the generation of both RHCP (Right handed circular polarized radiation) and LHCP (Left handed circular polarization) using the same antenna for either frequency reuse or diversity applications.**

***Index Terms*—Circular polarization, axial ratio, impedance bandwidth, single-feed, dual fed, orthogonal.**

I. Introduction

Microstrip patch antennas are most popular antennas for wireless communication, as they offer the benefits of low profile, light weight, compact, conformable to surfaces, easy fabrication. Microstrip antennas have the inherent disadvantages of low gain and narrow bandwidth. Several techniques to increase the impedance bandwidth of patch antennas, such as aperture coupled feed [1], L-shaped probe feed [2], U-slotted patch [3], have been proposed.

Circular Polarized antennas (referred to as CP antennas hereafter) are increasingly gaining importance in wireless communications since they allow signal reception irrespective of the orientation of the receive antenna with respect to the transmit antenna, and also have the ability to suppress multipath interference. Linear polarized antennas require transmit and receive antennas to be of the same polarization, hence require accurate alignment of the antennas. Circular polarized microstrip patch antennas are widely used in portable/ hand held devices, for example RFID reader antenna, WLAN, GPS, rectenna for energy harvesting, mobile phone antenna, etc.

Generating circular polarized radiation involves exciting two equal amplitude orthogonal modes. Feed position and feed technique decides the impedance bandwidth of the antenna. The usable bandwidth of a CP patch antenna is the overlapping bandwidth of Impedance bandwidth (VSWR<2 or S_{11}<-10 dB) and axial ratio bandwidth (AR<3 dB).

A number of techniques to generate circular polarized radiation are available in literature. Circular polarization techniques may be classified as single- feed and dual-feed.

II. Single feed configuration

Single-feed configuration involves slightly perturbing the antenna structure at appropriate locations with respect to the feed to excite modes with 90° phase-shift for circular polarized radiation. Commonly used perturbation techniques for single-feed configuration are the insertion of cross or Y-shaped slots, , truncating corners[3], slits[2], spur lines, loading stubs[5] in the boundary. The single feed circular polarized antennas are fed at 45° with respect to the perturbation.

Different types of feed techniques may be used for the CP microstrip patch antenna. Coaxial probe feed [3-5,8,12] though simple, provides only narrow bandwidth. In [1], a Γ-shaped feeding structure and two meandering strips are used to feed a wideband unidirectional patch antenna. The antenna exhibits wide impedance bandwidth of 54.2%, cross polarization level of -27 dB and gain of 9 dBi over the entire operating frequency range.

By introducing asymmetrical slits in diagonal direction of the square microstrip patches[2], the single coaxial-feed microstrip patch antenna is realized for circularly polarized radiation with compact antenna size. The impedance and axial ratio bandwidths are small around 2.5% and 0.5%.

In [5] circularly polarized patch antenna with loaded parasitic shorting elements to obtain size reduction. The parasitic loaded elements are shorted to the ground plane. The parasitic shorting strips provide a capacitive and inductive loading to the patch so that the current from the patch is concentrated along the shorting strip. The proposed antenna exhibits low impedance bandwidth and axial ratio bandwidth of 3.25% and 0.682% respectively, and low gain of 3.8 dBi.. In [3], a single fed truncated corner square patch to generate circular polarization characteristics. The antenna incorporates the use of U-slot to increase bandwidth, offers low gain (4.5 dBi), and axial-ratio bandwidth is 3.2%.

Single-fed techniques for CP generation are compact and simple, but provide only narrow axial ratio bandwidth. The impedance bandwidth can be enhanced, but the designs either cause low antenna gain (less than 6 dBi) or low axial-ratio bandwidth.

Microstrip-line-fed CP annular-ring slot antenna (ARSA) with inverted-L shaped modified feed [6] to obtain high axial ratio bandwidth of the order of 46% and 56%, respectively in L and S bands is proposed.The two hat-shaped patches perturb the magnetic current distribution in the ring slot so as to produce two equal-amplitude orthogonal resonant modes.

Antenna arrays may be used to improve the antenna gain. SRRs are integrated with a 2x2 E-shaped microstrip patch antenna array[7] in order to reduce cross-polarization and achieves a bandwidth of 8.5% and achieve a gain of 12.60 dBi.

Some structures like defected ground structure, different meta-structures or resonators integrated with microstrip antenna, perturb or suppress some property of the antenna are also employed to generate CP radiation in conjunction with patch antenna[8,9] . A low-profile metamaterial-loaded patch antenna [8] is proposed to generate circularly-polarized radiation. It is a single-fed configuration, is loaded with the composite right/left-handed (CRLH) mushroom-like structures and a reactive impedance surface (RIS) for miniaturization purpose. The CP radiation is realized by exciting two orthogonally-polarized modes simultaneously which are located in the left-handed (LH) region. The CRLH mushroom-like structure is capacitively coupled to the outside patch by a small gap. It resonates at a lower frequency compared to the microstrip patch. Circular polarization can be obtained by either changing the configuration of the mushroom-like structure or the patch, mainly the width-to-length ratio. Use of coaxial feed implies low impedance & axial ratio bandwidths are 4.6% and 1.46% respectively. Gain of the proposed antenna is low, 2.98 dBi only.

It has been proved in [9], that the arc-shaped DGS is highly efficient for suppression of cross-polarization radiation by 10–12 dB. Only E-plane cross polar radiation levels are greatly affected by feed positions.

Stacked patch may be used to reduce antenna size, but it causes undesired coupling that degrades bandwidth as well as axial ratio. In [10], single feed patch antenna consisting of low profile stacked radiators is used to obtain dual-frequency circular polarization. Stub and slit loaded patch along the diagonal are used to obtain CP radiation. The design has poor CP bandwidths less than 1 % and low antenna gains 2.3 dBi , 2.4 dBi in GPS & SDMB bands.

In [11], 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. CP radiation is achieved using a single-feed only.

III. DUAL FEED CONFIGURATION

Dual-feed configuration is based on the sequential phase-rotation technique to generate CP radiation with low cross polarization and higher axial ratio bandwidth. Dual-feed configuration provides greater axial ratio bandwidth at the cost of increased size of ground plane to accommodate the feed network, as compared to single-feed circular polarization techniques.

In [1], a simple aperture-coupled hook shaped microstrip line feed is used to feed the square patch through four Γ-shaped slots to generate four sequentially phased sources to excite the single layer patch antenna. The antenna provides peak gain of 7.4 dB*ic* at 2.55 GHz & cross-polarization radiation is below 15 dB. Though the design ensures wide impedance bandwidth, and wide axial ratio bandwidth, the front-to-back ratio is only 5 dB. The front-to-back ratio may be increased by use a reflector, but this would cause an increase in size of antenna.

The sequential rotation technique is used to achieve dual circular polarization properties of a 2 x 2 array of dual-frequency ACMAs. The proposed design [10] uses stripline feed and Wilkinson power dividers to achieve AR<1.2 dB & isolation between the two modes is larger than 26 dB.

A circular patch antenna with dual capacitively coupled feeds connected to a Wilkinson power divider with a 90° phase shift between its two output feed lines are used for broadband operation [12]. A 100-ohm chip resistor is added in the power divider for achieving good isolation between the two feeds. A 7.0 dBi gain & axial ratio bandwidth 35 % (relative to center frequency 1843 MHz) is obtained.

For applications that demand polarization diversity or enhance the spectrum efficiency by means of frequency reuse, it is desirable to design dual circular polarized antennas. In [13], a compact dual-feed, dual-polarized patch antenna for GPS applications (at center frequency of 1575.42 MHz) 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 [14], a 2.45-GHz rectenna using a compact circular polarized square patch antenna with an RF–dc power conversion circuit is proposed for RF energy harvesting for WSN. The antenna is aperture-coupled fed through a crossed-slot etched on the ground plane & uses a band pass filter for harmonic rejections. Two linear polarized signals with a 90° phase shift are used to obtain circular polarization characteristics, and the antenna generates LHCP. The cross-polar radiation level is below the co-polar radiation by 0.7 dB at broadside.

Loading a pair of L-shaped stubs on adjacent edges of a corner truncated patch [15] (truncating opposite corners) is used to excite an outer mode & an inner mode respectively to obtain unidirectional dual-band circular polarized characteristics. The antenna has lower circular polarization bandwidth, is fed by a meandering probe. The frequency ratio is varied by changing the length of stubs.

A dual-band single-fed CP, S-shaped slotted patch antenna (for dual band) with a small frequency-ratio is proposed for GPS applications in [16]. A single microstrip feed-line is underneath the center of coupling aperture ground-plane. Asymmetrical S -shaped slot acts as a perturbation of the patch to excite the two orthogonal modes for CP operation at the lower-band. The S-shaped slot itself resonates at the upper-band & generates CP radiation for the upper-band. Both the GPS bands are covered with less than 3-dB AR. A branch-line coupler [17] is used to feed a dual CP microstrip patch antenna with wideband isolation for RFID application between transmit and receive ports. The BLC provide dual CP radiation by coupling to the patch through H-shaped slots. BLC is located below the ground and maintains the CP purity because of its separation from the ground plane. A stacked patch antenna with a perpendicular feed substrate [18] is proposed to generate CP characteristics. Coupling from the stacked patch to the perpendicular microstrip feed is through a slot in the ground plane of both the stacked patch & perpendicular substrate. The limitations of the design are the non-planar structure, the sensitivity to the gap between the orthogonal substrates. The feed network uses Wilkinson power dividers to increase isolation between the outputs. An eight-element array is used to increase the gain and obtain wide angle scanning capability, but only a low CP bandwidth (2.8 %) is achieved.

In [19], dual-band CP with a small frequency ratio of 1.18 is achieved by employing a circular patch below the rotated rectangular patch. The circular patch provides resonance a higher frequency band, and gives capacitive loading and hence tunes the operating frequency of the lower band. The rectangular patch & circular patch can be arranged on opposite sides of a thin substrate & fed by a single slot. A serial aperture-coupled feed is used to feed the two patches in [20]. 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 energy to the patch. The structure operates as dual band CP antenna to cover the 0.915 GHz and 2.45 GHz bands.

In [21], a compact wideband CP patch antenna utilizing a quad-feed network and quadruple semi fan-annulus patches to improve the CP bandwidth to 72 % is proposed. The quad feed network provide good impedance matching. QSFA patches can expand the CP BW & reduce the size of the antenna effectively. In [23], CP DRA loaded with a modified circular patch is proposed for dual-band applications. The antenna is centrally fed by a coaxial probe, giving omnidirectional patterns with different senses of CP in two bands. Circular patch has four identical arc-shaped curved branches (oriented in a counterclockwise direction) to generate RHCP for patch & LHCP for DRA band. The patch not only functions as a polarizer that converts the omnidirectional LP fields of DRA mode into CP fields, but it also provides another resonance mode to realize a dual-band operation.

In [24], an omnidirectional dual-band dual CP antenna with wide beam radiation patterns using TM01 & TM02 modes is investigated. The proposed antenna is composed of a circular patch with eight curved slots & a disk-loaded coaxial probe, which are employed for generating horizontal & vertical polarizations, resp .An annular ring slot is used to get a good impedance matching at both resonant modes. Moreover, eight curved slots are symmetrically loaded on the patch, and each curved slot consists of two slots. Due to symmetrical structure, the phase difference between the vertical & horizontal polarizations is 90°. Hence, good omnidirectional CP properties in the azimuth plane at the cost of gain are obtained. The gains at lower and upper frequency are 0.1 dBic & 1.1 dBic, respectively.

IV. CONCLUSION

The use of dual polarized antennas to achieve frequency diversity or frequency reuse, brings about the need for design of dual circularly polarized antennas for wireless communication, where the orientation of the receiver being random with respect to that of receiver limits the use of linearly polarized antennas. Extensive research is being carried out for the design of dual circularly polarized microstrip patch antennas with special emphasis on enhancement of circular polarized bandwidth, gain, unidirectional radiation pattern and cross polarization reduction.

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