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Circularly Polarized Dielectric Resonator Antenna Excited by a Conformal Wire

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***Abstract*—A conformal spiral wire has been used to feed a dielectric resonator antenna to obtain a circular polarization. The parameters of the spiral have been optimized numerically so that minimum axial ratio (AR) and return losses are achieved. The method of moments (MoM) has been used in the analysis and the results have been validated against those from a commercial software package with a good agreement.**

***Index Terms*—Conformal antennas, dielectric antennas, spiral antennas.**

I. Introduction

DESIGN of a dielectric resonator antenna (DRA) to achieve a circular polarization radiation is an issue that has received considerable attention over the last few years. A circularly polarized rectangular DRA has been reported in [1] where a single slot feed has been used. An elliptical DRA with a circular polarization radiation has been investigated in [2] using a single probe feeding. In [3], a circularly polarized cylindrical DRA with a microstrip line feeding has been presented where circular polarization is achieved by adding two metal strips on the cylinder. A spiral slot has been used to feed a hemispherical dielectric resonator for minimum axial ratio (AR) and return losses [4]. A parasitic conformal patch has been used to generate orthogonal, nearly degenerate modes that produce a circular polarization radiation from a hemispherical DRA [5]. In [6], additional parasitic patches have been added to facilitate the frequency tuning of both linearly and circularly polarized dielectric resonators.

In this letter, a new method to design a circularly polarized DRA is proposed. This is based on using a single conformal Archimedean spiral arm for excitation. Moment method analysis of a spiral that is printed on a dielectric sphere has been recently reported [7]. Such an analysis has been followed in this study. The spiral has been optimized numerically to minimize both AR and return losses. The radiation characteristics of the DRA have been investigated and the computed results have been validated using the computer simulation technology (CST) microwave studio [8].

II. Formulation

A hemispherical dielectric resonator with a conformal antenna feed is shown in Fig. 1. The presence of the perfectly conducting ground plane has been modeled using the image theory.

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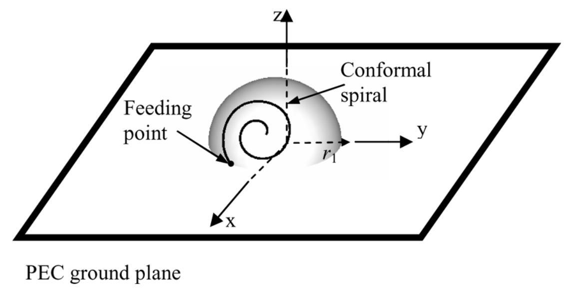

Fig. 1. Antenna's geometry.

Throughout the analysis, the thin wire approximation has been implemented and ten current pulses have been used to compute the method of moments (MoM) impedance matrix elements. An additional half-current pulse has been used to represent the connection of the spiral's outer end to the ground plane, where a delta gap voltage source is used to feed the antenna. Once a traveling current distribution is achieved along the wire, a circular polarization can be obtained [9]. Optimization using marginal distribution (OMD) algorithm [10] has been adopted where a total of seven generations and forty populations have been used throughout the optimization process.

The spiral arm's starting point coordinates are (r_1, θ_s, ϕ_s) where r_1 is the hemisphere radius, $\phi_s = 0$, and θ_s is determined by the optimizer. Other parameters that have been optimized are the spiral constant a and the winding constant ρ_o. These parameters have been optimized so that a minimum broadside AR as well as a minimum return loss (S_{11}) is achieved. During optimization, the frequency is varied between 3.3 and 4 GHz.

The CST microwave studio has been used with a waveguide excitation port, 45 mesh lines per wavelength and an accuracy of -60 dB. The PEC ground plane has been simulated using a boundary condition that forces the tangential electric field to vanish at $\mathrm{z} = 0$ in the CST transient solver.

III. Results

The dielectric resonator has a radius of $r_1 = 1.25$ cm and a relative permittivity of $\varepsilon_\mathrm{r} = 9.5$ [4]–[6]. The optimized parameters of the spiral arm are found to be $\rho_o = 0.1415$ cm, $a = 0.0676$ cm, $\theta_\mathrm{s} = 1$ rad at a frequency of 3.85 GHz. A wire of radius 0.25 mm has been assumed.

The calculated input impedance compared to that obtained using CST is shown in Fig. 2 with a good agreement. Fig. 3 shows the return losses calculated using MoM and CST, where it can be seen that a 10 dB bandwidth of 12% has been achieved. There is a reasonable agreement between the results of the two solutions with a slight discrepancy that could be attributed to the difference in the excitation mechanisms.

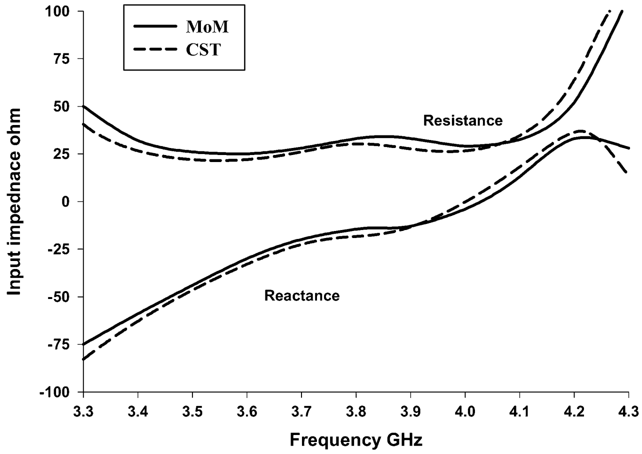

Fig. 2. Input impedance as a function of frequency.

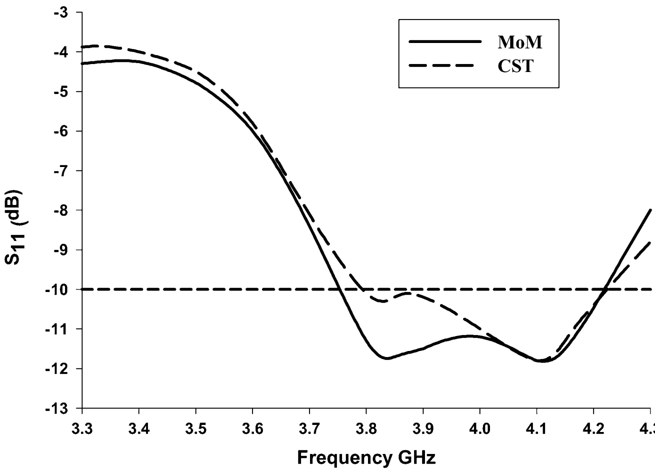

Fig. 3. Return losses as a function of frequency.

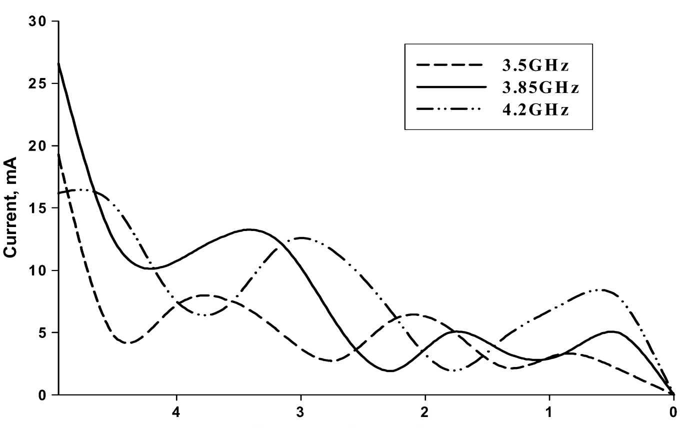

Fig. 4. Current distribution along the spiral arm at different frequencies.

The current distribution along the spiral arm is shown in Fig. 4, where it is evident that at 3.85 GHz, a traveling wave distribution has been achieved. Such a distribution is required to produce a circular polarization. At other frequencies, standing wave current distribution exists along the wire, which increases the AR. This agrees well with the results shown in Fig. 5 where it can be seen that a minimum AR of 1.2 dB has been obtained at 3.85 GHz. The calculated AR is in good agreement with that obtained from a CST simulation.

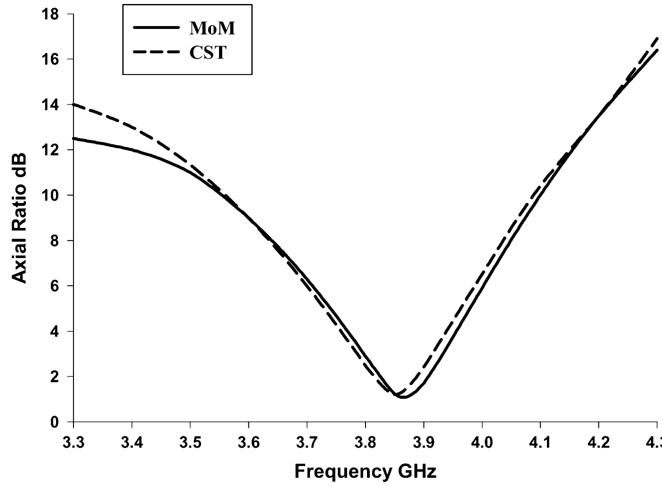

Fig. 5. Axial ratio of the dielectric resonator antenna.

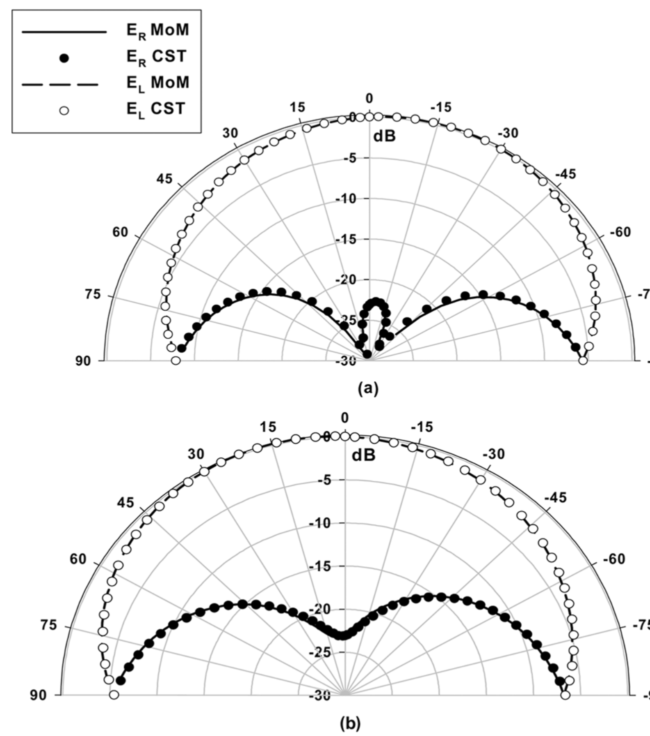

Fig. 6. Radiation patterns at 3.85 GHz. (a) $\phi = 0^\circ$ plane. (b) $\phi = 90^\circ$ plane.

A comparison of Fig. 3 to Fig. 5 shows that circular polarization has been achieved within an acceptable impedance matching bandwidth. The 3–dB AR bandwidth has been calculated as 3.9%. Although the achieved impedance and AR bandwidths are acceptable for a DRA with a single feed, these results show that the bandwidth of a spiral antenna has been reduced significantly owing to the frequency response of the dielectric resonator.

The calculated radiation patterns are shown in Fig. 6 where it can be seen that an isolation of 23 dB between the copolarization and cross-polarization field components has been achieved. It can be seen from Fig. 6 that this is a left-hand polarized DRA. However, numerical investigations have shown that a right-hand polarization can be achieved if the spiral's winding changes

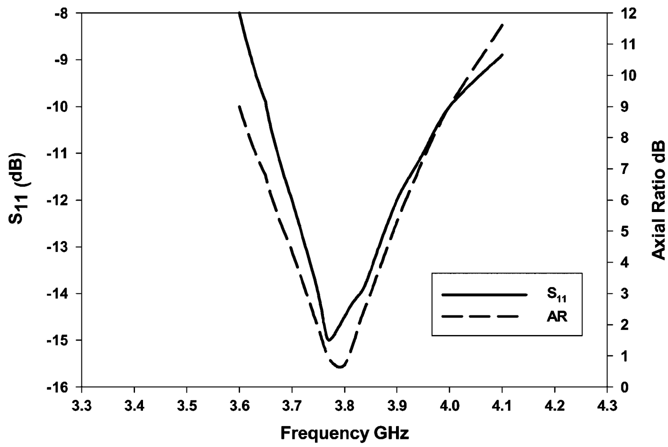

Fig. 7. Frequency responses of return losses and axial ratio.

from counterclockwise to clockwise direction. Calculated field patterns using MoM and CST agree well with each other.

The significance of changing the spiral's dimensions has been investigated using $\rho_o = 0.275$ cm, $a = 0.0618$ cm and $\theta_s = 0.95$ rad. The resulting axial ratio and return losses are shown in Fig. 7 where it can be seen that optimum values have been achieved at a frequency of 3.8 GHz with an impedance matching bandwidth of 9% and a 3-dB AR bandwidth of 3.4%. This shows that the operating frequency can be varied using different optimized parameters of the feeding spiral.

IV. Conclusion

A circularly polarized dielectric resonator antenna has been designed using a single feed wire. The feed is an optimized spiral arm with a traveling current distribution. An impedance matching bandwidth of 12% has been achieved with a 3 dB AR bandwidth of 3.9% at the same frequency range. Good agreement with CST results has been obtained. The presented approach can be used to achieve circularly polarized dielectric resonator antennas of other geometric shapes such as rectangular or cylindrical.

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