Broadband Circularly Polarized Cylindrical Dielectric Resonator Antenna

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Abstract

A circularly polarized quadruple strip feed cylindrical dielectric resonator antenna utilizing a pair of 90° hybrid couplers is investigated experimentally. The antenna is shown to deliver an impedance bandwidth (S_{11} < -10 dB) of 34.52%, from 1.75 to 2.48 GHz, and an axial-ratio bandwidth (AR < 3 dB) of 25.86%, from 1.65 to 2.14 GHz. The gain and radiation pattern are found to be stable within the passband.

1. INTRODUCTION

Dielectric resonator antennas (DRAs) [1] have been widely investigated as viable alternatives to conventional metallic antennas in the past two decades [2]. The DRA avoid the inherent disadvantages of the metallic antenna including high conduction loss at millimeter-wave frequencies and low efficiency due to surface wave excitation. Furthermore, the DRA enjoys several attractive features such as low cost, compact size, light weight, and ease of coupling to most transmission lines.

Prior studies on the DRA were primarily focused on those producing linear polarization [1]-[5]. However, circular polarization allows for greater flexibility in the orientation angle between transmitter and receiver, better mobility and weather penetration, and greater reduction in multipath reflections and other kinds of interference. Consequently, the circularly polarized DRA has received more attention in recent years [7]-[14].

In this paper, we introduce a circularly polarized quadruple strip feed cylindrical DRA utilizing a pair of 90° hybrid couplers. To improve the coupling between the microstrip feed line and the DRA, we positioned four vertical conformal strips around the circumference of the DRA as in [15]. To improve the quality of circular polarization, we supplied the four vertical strip feeds with balanced power and relative excitation phases of 0°, 90°, 180°, and 270° as in [16]. Measured results of return loss, axial ratio, radiation pattern, and gain are presented.

2. ANTENNA CONFIGURATION

Fig. 1 shows the circularly polarized quadruple strip feed cylindrical DRA utilizing a 90° hybrid coupler pair. The cylindrical dielectric resonator, of radius $r = 20$ mm, height $h = 20$ mm and relative permittivity $\varepsilon_r = 9.5$, was positioned at the center of a Rogers RO4003 dielectric substrate of length $L = 200$ mm, thickness $t = 0.8$ mm and relative permittivity $\varepsilon_r = 3.38$. The four vertical strip feeds, of length $s = 16$ mm and width $w = 1.85$ mm, were aligned along the z-axis, 90° apart from one another around the circumference of the cylindrical dielectric resonator.

To achieve dual-fed type circular-polarization, the four orthogonally-orientated vertical strips were supplied equal-amplitude power and relative excitation phases of 0°, 90°, 180°, and 270°. The feed network comprises of a 180° phase shifter cascaded with a pair of 90° hybrid couplers.

3. RESULTS AND DISCUSSION

For this paper, the simulations were performed using Ansoft HFSS, a commercially available 3-D electromagnetic field solver based on the Finite Element Method (FEM). The input impedance and radiation pattern measurements were taken using the HP8510C vector network analyzer, and aided by the MiDAS near-field and far-field measurement software package. The input and output ports of the feed network were each set to 50 Ω.

Fig. 2 shows the simulated and measured return loss for the circularly polarized quadruple strip feed cylindrical DRA utilizing the 90° hybrid coupler pair. The DRA exhibits a simulated impedance bandwidth (S_{11} < -10 dB) of 38.46%, from 1.68 to 2.48 GHz, and a measured impedance bandwidth (S_{11} < -10 dB) of 34.52%, from 1.75 to 2.48 GHz. Fig. 3 shows the simulated and measured axial-ratio at the boresight ($\theta = 0$) for the circularly polarized quadruple strip feed cylindrical DRA utilizing the 90° hybrid coupler pair. The DRA exhibits a simulated 3-dB axial-ratio bandwidth of 28.87%, from 1.63 to 2.18 GHz, and a measured 3-dB axial-ratio bandwidth of 25.86%, from 1.65 to 2.14 GHz. The DRA shows a minimum measured boresight axial-ratio of 0.3 dB at 1.8 GHz. It is observed that the simulated and measured results are in good agreement.

Fig. 4 shows the measured spinning linear radiation pattern at 1.9 GHz for the circularly polarized quadruple strip feed cylindrical DRA utilizing the 90° hybrid coupler pair, on the X-Z and Y-Z planes. A rotating transmit horn was used to measure the circular polarized waves. On both principle planes, the axial-ratio is observed to be less than 3 dB across a 60° beamwidth. The ripple in the envelope of the measured radiation pattern can be attributed to the diffracted fields from the edges of the finite ground plane [17]. The slight dip in gain at the boresight, as seen in Fig. 4 (b), can be explained by the dependence of the gain on the ground plane size [18]. Fig. 5 shows the measured peak gain for the circularly polarized quadruple strip feed cylindrical DRA utilizing the 90° hybrid coupler pair. The DRA exhibits a 3-dB gain bandwidth of 24%, from 1.65 to 2.1 GHz, with its highest gain of 4.95 dBi at 1.9 GHz.

Combining the measured results, the DRA is observed to deliver sufficiently low return loss ($S_{11} < -10$ dB), adequately low axial-ratio (AR < 3 dB), and reasonable gain, over a bandwidth of 24% from 1.65 to 2.1 GHz. This setup lends itself to cellular-phone base station applications providing circularly polarized coverage wide enough to include the GSM1800, GSM1900 and UMTS2000 bands.

4. Conclusion

In this paper, we have demonstrated a wideband circular polarization for the cylindrical dielectric resonator antenna (DRA) with four vertical strip feeds excited in phase quadrature (90°).

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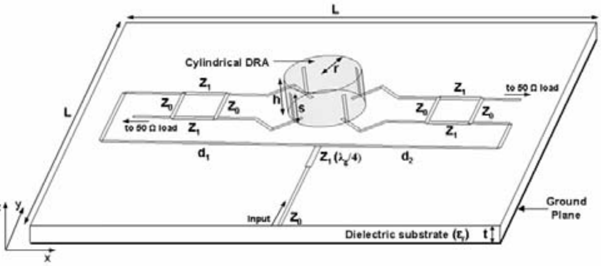


Fig. 1 Geometry of the circularly polarized quadruple strip feed cylindrical dielectric resonator antenna utilizing the 90° hybrid coupler pair.

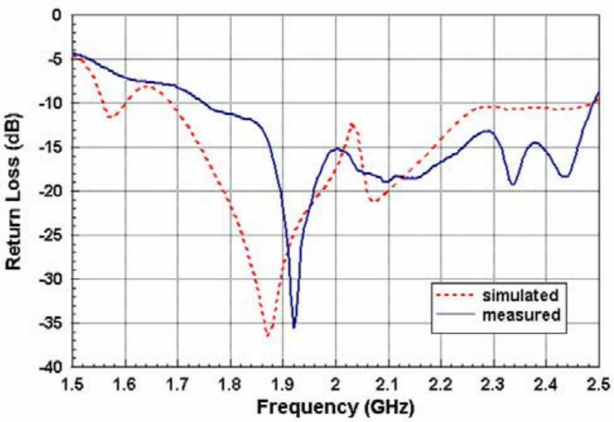


Fig. 2 Return loss (simulated and measured) for the circularly polarized quadruple strip feed cylindrical dielectric resonator antenna utilizing the 90° hybrid coupler pair.

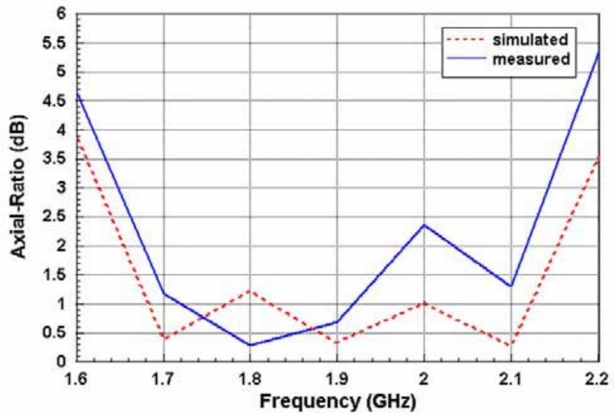
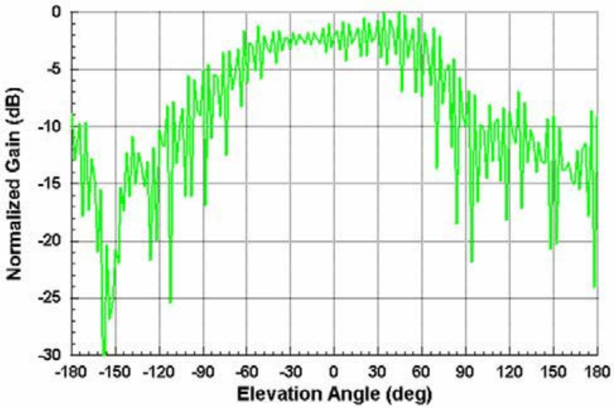
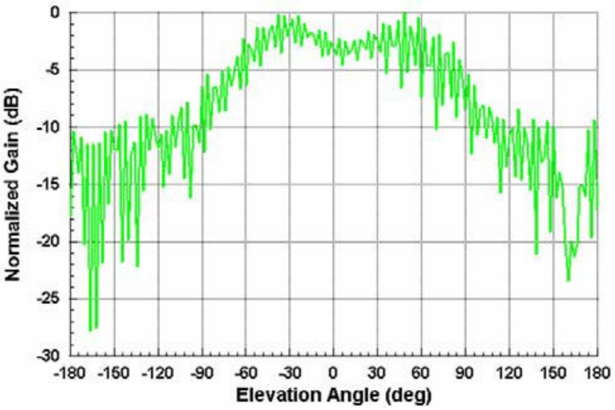


Fig. 3 Axial-ratio (simulated and measured) for the circularly polarized quadruple strip feed cylindrical dielectric resonator antenna utilizing the 90° hybrid coupler pair.



(a)



(b)

Fig. 4 Spinning linear radiation pattern (measured) at 1.9 GHz for the circularly polarized quadruple strip feed cylindrical dielectric resonator antenna utilizing the 90° hybrid coupler pair on the (a) X-Z plane; and (b) Y-Z plane.

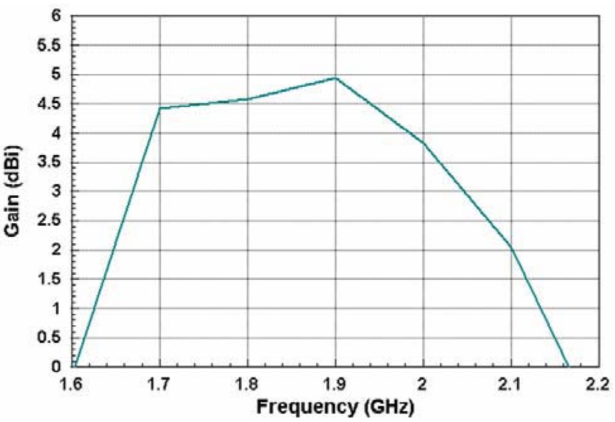


Fig. 5 Gain (measured) for the circularly polarized quadruple strip feed cylindrical dielectric resonator antenna utilizing the 90° hybrid coupler pair.