Research Article

Wideband Circularly Polarized Dielectric Rod Antenna

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A new dielectric rod antenna (DRA) is introduced to produce circular polarization (CP) over a wide frequency band without a complex feed network. Along with the simulated results, measured results of the antenna prototype are presented, showing a 3 dB axial ratio (AR) CP bandwidth of 17.7%. The radiation characteristics of the fabricated antenna are also demonstrated showing the measured gain of better than 6.2 dBi. Moreover, the measured impedance bandwidth ($VSWR \leq 2$) reaches 20.1%, from 8.75 GHz to 10.7 GHz, while the CP beamwidth ($AR \leq 3$ dB) at the central frequency is measured over 120° .

1. Introduction

Circularly polarized waves are often used to offer better propagation characteristics through the atmosphere and reduced multipath effect as well as the flexibility of orientation between the transmitting and receiving antennas. Satellite CP systems require antennas exhibiting an excellent axial ratio over a wide frequency band and over a wide beamwidth to realize low power signal reception at low elevation angle. The CP approach includes two categories: single feed and multipoint feed. The single feed is of simplicity advantage of not requiring an external polarizer such as 90° hybrid coupler, but it usually leads to a limited AR bandwidth in the range of a few percentage. For instance, a single-fed elliptical dielectric resonator antenna is proposed with a circular polarization bandwidth of 3.5% [1]. In [2], a rectangular dielectric resonator antenna outer-fed by a square spiral strip provides CP operation over a broad CP bandwidth of 14% with an impedance bandwidth of 11%. The multipoint feed is of a wider CP bandwidth, but an external feeding circuit is required.

The surface wave antenna, employing a dielectric rod, is popular because of its wide bandwidth, agility in controlling the radiation pattern shape, ease of fabrication and low cost [3, 4]. In lower microwave range, this antenna may be used as a feed system for reflector antennas [5] and at the millimeter wave range, it can be integrated directly with the

monolithic integrated circuits [6, 7]. In recent years, ultra-wideband (UWB), dual-band, and dual-polarized dielectric rod antennas have been investigated [8–10]. A number of theoretical and experimental studies [11] have been carried out to understand the radiation mechanism with linearly polarized operation. Lately, more attentions have been paid to the circularly polarized DRA due to its wider applications, especially in the satellite communication systems.

In this paper a single-fed CP DRA is presented, where the phase transformer is made by introducing a dielectric sheet in the circular feed waveguide. This CP design does not require a complex feed network or special configuration of the radiating element. The measured results show a circular polarization bandwidth of 17.7%, which is greater than the bandwidths reported in the literature for single-fed CP DRAs. Reasonable agreement between the simulation and the measurement is obtained. Details of the proposed antenna design are described and experimental results of its CP performance are presented and discussed.

2. Antenna Design

The geometry of proposed DRA is shown in Figure 1. The diameter a_1 of the feed waveguide is mainly determined by the cutoff frequency of TE_{11} mode and is chosen as 16.4 mm to operate at X-band with a frequency range of 9.0 GHz to 11.5 GHz. In the circular feed waveguide, a centered

FIGURE 1: Geometry of dielectric rod antenna.

dielectric sheet with relative permittivity $\epsilon_r = 2.05$ is located, which consists of a phase-shift segment and two matching segments in two ends. To produce CP radiation, the dielectric rod should be excited by two orthogonal electric field components, $\vec{E}_x$ and $\vec{E}_y$, with equal amplitude and 90-degree phase difference. The probe of coaxial feed is oriented by 45° to form two orthogonal electric field components with equal amplitude, as shown in the Figure 1(b), which is for LHCP operation, while for RHCP operation the probe in the other diagonal is required.

Based on the microwave waveguide theory, the phase difference between two orthogonal electric field components $\vec{E}_x$ and $\vec{E}_y$ is given by

$$\Delta\phi = \frac{2\pi L \sqrt{\epsilon_{rx} - (\lambda_0/\lambda_c)^2} - \sqrt{\epsilon_{ry} - (\lambda_0/\lambda_c)^2}}{\lambda_0}, \quad (1)$$

where L is the length of dielectric sheet, λ_0 is the free-space wavelength, and λ_c is the cut-off wavelength. The effective relative permittivity of y direction is

$$\epsilon_{ry} = \epsilon_r. \quad (2)$$

The effective relative permittivity of x direction is

$$\epsilon_{rx} = 1 + \frac{(\epsilon_r - 1)A_1}{A_0}, \quad (3)$$

where A_1 is the cross area of the circular waveguide and A_0 is the cross area of the dielectric sheet.

3. Experimental Results

The proposed antenna prototype has been fabricated and measured to verify its CP operation, whose parameters are optimized by using the simulation software HFSS 11

FIGURE 2: Simulated and measured VSWR characteristics.

with the final optimized parameters: $a_1 = 16.4$ mm, $a_2 = 12.2$ mm, $a_3 = 9.6$ mm, $d = 13.3$ mm, $d_1 = 73.1$ mm, $d_2 = 34$ mm, $d_3 = 6.8$ mm, and $d_4 = 6.8$ mm. Figure 2 displays the simulated and measured VSWR curves of the antenna. The measured impedance bandwidth is 20.1% for VSWR less than 2, covering the frequency range from 8.75 GHz to 10.7 GHz. Figure 3 shows the simulated and measured axial ratio against frequency and angle. The simulated CP bandwidth of 3 dB axial ratio is 2.2 GHz or 22.8% with the minimum AR of 0.29 dB at 11.1 GHz. The measured 3 dB axial-ratio CP bandwidth is 2.75 GHz or about 17.7% with the central frequency 9.875 GHz, which may be the widest one for single-fed CP DRAs in the open literature. The difference between simulated and measured bandwidths is probably due to the tolerance of DRA permittivity and

(a) axial ratio against frequency

(b) axial ratio against angle

FIGURE 3: Simulated and measured axial ratio.

(a) x-z plane

(b) y-z plane

FIGURE 4: Simulated and measured radiation patterns at central frequency.

dimensions. Figure 4 displays simulated and measured radiation patterns at central frequency, showing fine agreement. The measured half-beamwidth in x - z plane is 69.66° , and the half-beamwidth in y - z plane is 68.87° . The measured antenna gain is over 6.2 dBi and approximately constant over a wide bandwidth, as shown in Figure 5. The CP beamwidth ($AR \leq 3$ dB) at central frequency is measured over 120° .

4. Conclusion

A new single-fed DRA without a 90-degree hybrid coupler has been introduced to realize a wide CP bandwidth. The

CP operation is easily obtained by controlling the length and width of the dielectric sheet in the circular feed of waveguide. The antenna is compact in structure, because, that it consists of only a cylindrical DRA with radius of 16.4 mm, length of 75 mm, and a feed waveguide. The measured CP bandwidth is 17.7% with a measured axial ratio minimum of 0.869 dB and a CP beam width of 120° . The proposed antenna exhibits an impedance bandwidth of 20.1% around the same frequency range. With these features, this antenna is attractive for the satellite communication applications.

FIGURE 5: Simulated and measured gains at $\theta = \varphi = 0^\circ$.

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