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Metallic Rings Loaded Dielectric Rod Antenna with Enhanced Gain and Bandwidth

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***Abstract*-In this paper, a dielectric rod antenna with embedded metallic rings fed by circular waveguide operating from 10.9 to 14 GHz is proposed. Different from the traditional dielectric rod antenna, the proposed antenna uses embedded metallic rings to improve the antenna gain. According to the simulation verification, the antenna gain can be greatly improved by embedding several metallic rings with a decreasing radius in the dielectric rod. The simulated results indicate that the proposed antenna can achieve a gain enhancement of 1.4-5.5 dB in the operating frequency band of 10.9-12.5 GHz. Besides, the proposed antenna can attain a symmetric radiation pattern over the entire operating bandwidth.**

***Index Terms* —Circular waveguide, dielectric rod antenna, horn antenna.**

I. Introduction

Dielectric antennas are of increasing interests in millimeter-wave applications, where high antenna efficiency and high gain are required. Generally, antennas are made of metallic materials, such as copper. However, metallic antennas are vulnerable to corrosion and oxidation, and suffer from conductor losses.. As an alternative, dielectric antennas are free of these issues.

There are two common types of dielectric antennas, i.e., the dielectric resonator antenna (DRA) [1] and dielectric rod antenna. The diversity of feeding methods for DRAs facilitates the integration of DRAs and microwave circuits, which contributes to various applications such as radar [2], GPS navigation [3], mobile terminals and base stations. As for the dielectric rod antenna, it provides a wide bandwidth and high gain when utilized at microwave and millimeter-wave bands [4]-[7]. The radiation mechanism of uniform dielectric rod antenna can be explained by Zucker's discontinuity-radiation concept [8]. As is well known, the gradually decreasing of rod aperture can lead to the enhancement of the gain [9]-[11]. However, this will increase the fabrication complexity of dielectric rod antennas.

In this paper, a novel method to improve the gain of dielectric rod antennas by embedding metallic rings in the dielectric rod is presented. By loading six metallic rings with tapered diameters in the dielectric rod, the bandwidth and gain performance can be improved. The simulation results demonstrate that the proposed antenna can achieve an impedance bandwidth from 10.9 GHz to 14 GHz with a gain ranging from 8.6 dBi to 13.3 dBi. Moreover, the proposed antenna can keep symmetric radiation patterns across the entire operating band, making it suitable for various applications.

II. Antenna Configuration and Operating Principles

A. Antenna Configuration

The configuration of the proposed antenna is shown in Fig.1. As shown in Fig. 1, the proposed antenna is fed by a circular waveguide, and a metallic horn filled with dielectric connects to the waveguide. The cylindrical dielectric rod is embedded by three groups of metallic rings that are of progressively smaller diameters. High Temp V1 Full Cure is used as the dielectric material, which has a relative dielectric constant of 2.6 and a dissipation factor of 0.0114. Table I lists the dimensions of the proposed antenna.

Table I. Dimensions of the proposed antenna (Unit:mm).

r_0	r_1	r_2	r_3	r_4	h_0	h_1	d_1	d_2	a_0	t_0
5	12	6	5.5	5	12	58	32	5	1	0.5

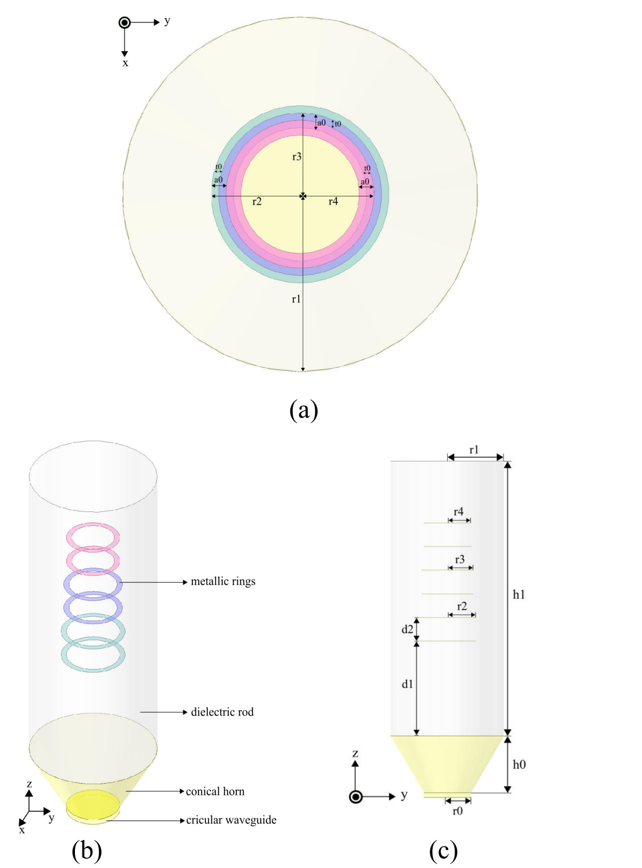


Fig. 1. Geometry of proposed antenna. (a) Top view, (b) Perspective view, (c) Side view.

B. *Operating Principle*

A circular waveguide is used to feed the proposed antenna for achieving symmetric radiation patterns. The single-mode (TE_{11}) transmission bandwidth is 10.9-14.2GHz, which can be calculated from the following equation:

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\varepsilon}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\varepsilon}} \quad (1)$$

By observing the simulated phase constant curve shown in Fig.2, the single-mode operating frequency band of the circular waveguide is from 10.9 GHz to 14 GHz, which further verifies the above calculation.

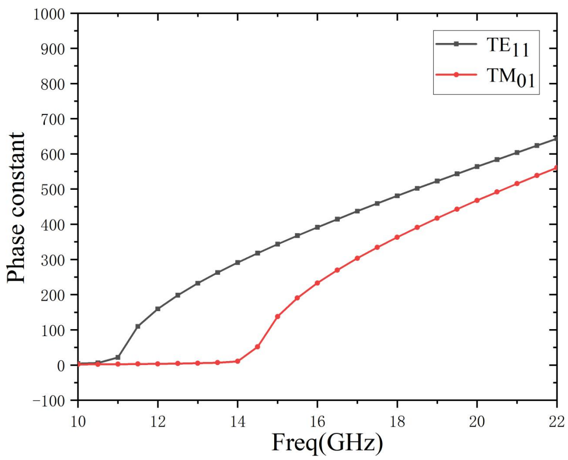
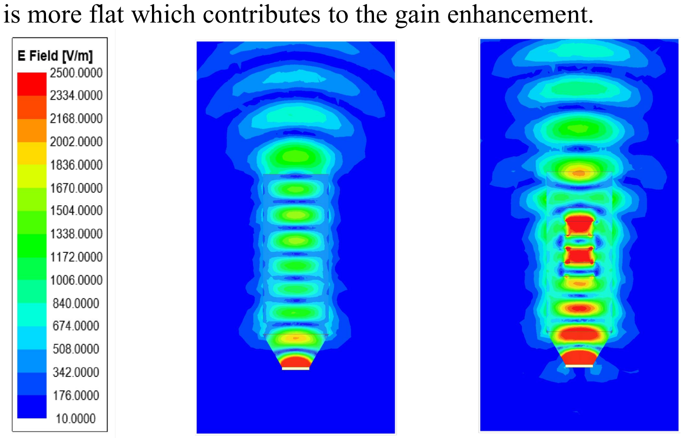


Fig. 2. Simulated phase constant of the circular waveguide with a size of r0=5mm.

Fig. 3 shows the E-field distribution of the proposed antenna with and without the loaded metallic rings. It can be observed from Fig. 3(a) that the wave propagates along the dielectric rod and radiates as a spherical wave at the end of the dielectric rod. When the metallic rings are embedded in the dielectric rod, intensive fields are observed around these rings, which increase the field intensity on the radiating aperture (the interface between the dielectric rod and air). With the enhanced field intensity on the radiating aperture, the radiated wavefront is more flat which contributes to the gain enhancement.



(a) (b)

Fig. 3. The E-field distributions of the proposed antenna at 11.5GHz (a) without metallic rings, (b) with metallic rings.

III. Results and Discussion

Fig. 4 shows the simulated $|S_{11}|$ and gain of the proposed antenna with and without embedded rings. As can be seen from Fig. 4 (a), the impedance bandwidth is improved by around 0.5 GHz when loaded with metallic rings. In addition, the gain is improved by 1.4-5.5 dB with the presence of metallic rings.

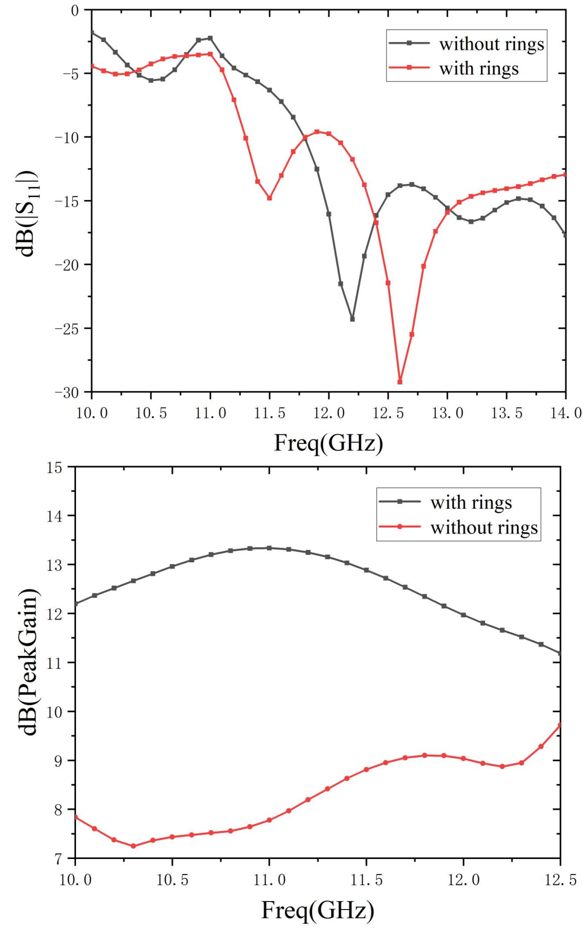


Fig. 4. Simulated (a) $|S_{11}|$ and (b) Peak gain of the proposed antenna.

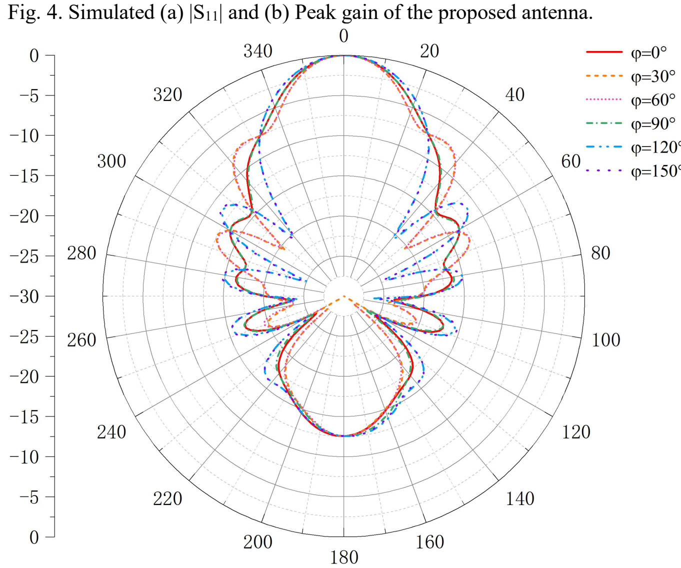


Fig. 5. Simulated pattern of the proposed antenna at Φ=0°, 30°, 60°, 90°, 120°, 150°.

Fig. 5 shows the simulated radiation patterns of the proposed antenna in different azimuth angles at 12 GHz. As can be seen from Fig. 5, the proposed antenna can keep relatively symmetric radiation patterns in different azimuth angles, with half-power beamwidth nearly unchanged.

IV. Conclusion

This paper presents a dielectric rod antenna loaded with metallic rings. By embedding metallic rings with tapered radius in the dielectric rod, the fields concentrate around the metallic rings which increase the field intensity on the radiating aperture of the dielectric rod. The intensive fields on the radiating aperture flatten the wavefront of the radiated wave, leading to gain improvement for the proposed antenna. Moreover, the radiation pattern is rather symmetric over the entire bandwidth of 10.9-14 GHz. With high gain, wide bandwidth, and symmetric radiation patterns, the proposed antenna would be a promising candidate for various wireless applications.

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