# Low-Loss Dual-Wideband Circularly-Polarized Antenna With Using Loading Technology

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***Abstract*—A millimeter-wave novel loading method to realize dual-wideband circularly-polarized (CP) performance based on a low-loss waveguide radiating antenna is proposed in this paper. The band-notching and CP characteristics can be achieved respectively by the simple loadings of non-radiating grooves and radiating stubs, while good impedance-matching is also achieved in a wide range. It can be seen from the simulated results that the proposed dual-wideband circularly-polarized antenna has the impedance bandwidths of 37% (25.3~34GHz) and 7.8% (37.49~39.77 GHz), and 3 dB axial ratio (AR) bandwidths of 29.6% and 5.95% in the lower- and higher-bands. Since the position of the introduced notch can be independently controlled by adjustable parameters, the bandwidth of the two frequency bands can be adjusted according to different applications. Besides, the simulated gains at 28 GHz and 38 GHz are 7.6 dBi and 6.9 dBi, respectively.**

***Keywords—Circularly-polarized antenna, loading technique, millimeter-wave，multi-band***

## I. Introduction

Low-loss antennas are typically devices used for transmitting and receiving electromagnetic waves in millimeter-wave wireless radio frequency systems. For most modern communication systems, multi-band technology is often required in satellite communications, while using a single antenna to achieve different working bands. In addition, considering the increasingly complex electromagnetic environment, the advantages of circularly-polarized antennas in signal transmission and resistance to multi-path effects are becoming more prominent. Therefore, achieving multi-band and circularly-polarized performance in one antenna is of great significance.

Throughout these years, CP antennas have been widely studied. In[1], traditional patch antennas achieve CP by altering the shape of the elements. However, these antennas typically have narrow axial ratio bandwidths and low gains. SIW technology is also applied to CP antennas, but these structures face issues such as dielectric loss, dissipative loss, and surface wave leakage at high frequencies[2]. To reduce losses, several CP antennas based on waveguide structures have emerged, including open-ended circular waveguides with short stubs[3], and CP slot waveguide antennas[4].

Although these waveguide structures have the advantage of low loss, they either lack sufficient impedance bandwidth and 3 dB AR bandwidth or are difficult to construct into easily integrated and low-loss arrays. Many studies have achieved multiple frequency bands through methods such as slot cutting or adding short stubs. Therefore, to meet specific needs, this paper proposes a new method that combines open-ended waveguides with loading techniques to achieve dual-band wideband CP performance in the millimeter wave band.

A compact dual-band wideband circularly-polarized waveguide antenna using a loading technique that combines radiating and non-radiating stubs from field and circuit aspects is proposed in this paper. The low loss of waveguides makes it more suitable for the mm-Wave band. Compared with other studies, the proposed structure has wider impedance and axial-ratio bandwidths in each band, and is easy to form arrays with larger size. Additionally, the use of vertical feeding waveguide significantly reduces the aperture size, making it possible to put the radiating elements and feeding network in the same layer.

## II. Design Principles

An open-ended waveguide with the advantage of low loss is an ideal choice for millimeter-wave applications. Fig.1 shows the electric-field distribution of an open-ended waveguide with an vertical feeding waveguide. To achieve broadband bandwidth and an extra resonant point, an E-plane waveguide impedance transformer is added between the vertical feeding waveguide and the open-ended waveguide unit cavity.

To achieve CP characteristics, a radiating stub is first loaded on the wide side of the waveguide cavity. By etching the current on the wide arm, the $TE_{01}$ mode is excited in this stub and the related radiation is generated with the direction of the electric-field component is perpendicular to that of the cavity radiating aperture. By adjusting the length $l_1$, width $w_1$, depth $h_1$, and distance of the radiating stub from the center of the long radiating edge of the waveguide unit $w_{off1}$, the amplitude and phase of the $TE_{01}$ mode are controlled, thereby producing left-hand CP polarization at a specific

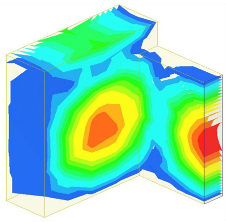

Fig. 1. Electric-field distribution of open-ended waveguide with vertical feed waveguide

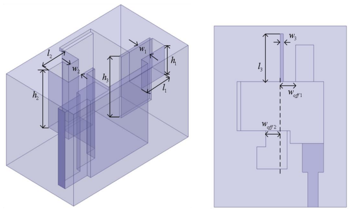

Fig. 2. model diagram (unit: *mm*, $w_1$=1.2, $w_2$=2.6, $w_3$=2.5, $l_1$=0.4, $l_2$=8.64, $l_3$=3, $h_1$=4.72, $h_2$=1.8, $h_3$=11, $w_{\text{off1}}$=1, $w_{\text{off2}}$=0.95, $w_{\text{off3}}$=0)

frequency. However, the loading of this radiating stub only acts at higher-band. To achieve CP performance at lower-band, a second radiating stub is loaded on the opposite side. Similarly, by controlling the parameters $l_2$, $w_2$, $h_2$, and $w_{\text{off2}}$, left-hand CP polarization can be achieved at lower frequencies. At the same time the second radiating stub is bent into an L-shape to save space. It was unexpectedly found that after the second radiating stub was bent into an L-shape, the horizontal part played a guiding role, further enhancing the field strength at the longitudinal slot.

Unlike the above-mentioned radiating stub, to modulate the frequency response of the open-ended waveguide antenna and to achieve dual-band characteristics, we loaded a non-radiating groove on the side of the first radiating stub. This non-radiating groove is set at a certain distance below the radiation aperture, thus, it will not impact the field distribution across the aperture surface. The overall structure is shown in Fig.2.From the circuit perspective; it is equivalent to connecting an reactance in series with the main waveguide. At a certain frequency, this reactance approaches infinity, and the transmission approaches zero, thus producing a notch. By controlling the parameters $l_3$,$w_3$,$h_3$and $w_{\text{off3}}$,the position of the notch point is controlled, achieving a dual-frequency effect.

## III. Simulation and Analysis

The simulated reflection coefficient and realized gains of the dual-wideband CP antenna designed in this paper are shown in Fig. 3. It indicated that the return loss is below -10 dB within the frequency bands of 24.18~35.16 GHz and 37.49~40.56 GHz. The relative bandwidths are 37% and 7.8%, respectively. The gain is relatively flat within the operating frequency bands, with simulated gains of 7.6 dBi at 28 GHz and 6.9 dBi at 38 GHz. Fig. 4 shows the simulated 3-dB axial ratio (AR) bandwidth of 29.6%, ranging from 25.26 to 34.04 GHz, and the simulated 3-dB AR bandwidth of 5.95%, ranging from 37.47 to 39.77 GHz. Fig.5 respectively display the normalized radiation patterns in the yoz and xoz planes at 28 GHz for both simulated and measured results.

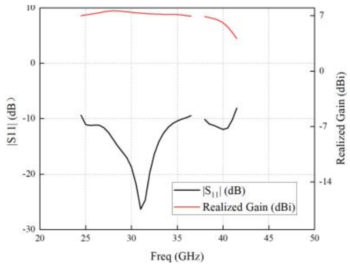


Fig. 3. Simulated reflection coefficients and realized gains of the proposed antenna

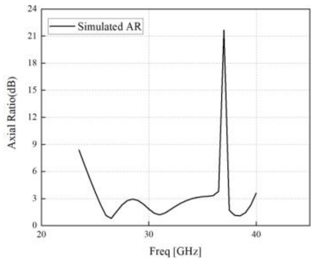


Fig. 4. Simulated AR results of the proposed antenna

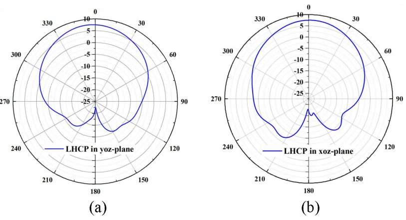


Fig. 5. Simulated LHCP at 28 GHz.(a) in the yoz-plane. (b) in the xoz-plane

## IV. Conclusion

Loadings combining field-circuit processing is designed to realize low-loss dual-wideband circularly-polarized antenna. The antenna is suitable for millimeter-wave satellite communication and can be further extended to higher frequency bands. The simulated antenna is only an example and the proposed can be further expanded in future work to meet the requirements for multi-frequency, dual circular-polarization, or other specifications.

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