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# Low-Profile Dual-Polarized Omnidirectional Antenna for Broadband Indoor Distributed Antenna System

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**Abstract**—A low-profile dual-polarized omnidirectional antenna with an overall height of 80 mm is presented in this paper for broadband indoor distributed antenna system (IDAS). The proposed antenna consists of an improved discone antenna for vertical polarization (VP) and a printed dipole array with five pairs of dipoles for horizontal polarization (HP). The VP element is a combination of three radiation patches, a cone-shaped feeding structure, a circular shorted loading patch and a coupling ring. By loading the shorted patch and coupling ring over the top and at the bottom of the radiation patches, the bandwidth for VP is significantly enlarged while the antenna height is reduced. Simulated and measured results indicate that the operating bands of 0.86–5.62 GHz for VP and 1.62–2.71 for HP are realized. Omnidirectional radiation patterns in horizontal plane for HP and VP, good port isolation of greater than 26 dB, low cross-polarization level, and stable gain (2.6–5.6 dBi for VP and 2.8–4.2 dBi for HP) are achieved during the operating bands, which demonstrate the proposed antenna can be widely used for broadband IDAS.

## 1. INTRODUCTION

Nowadays, the demands for high speed and broadband data services for mobile users are growing dramatically, such as high-speed surfing, high-definition video, video call and so on. According to statistics, more than 80% mobile data traffic is originated in the indoor environments, for instance, commercial buildings and airports. Thus, the indoor distributed antenna systems (IDAS) which are employed to provide wireless communication coverage in high-traffic indoor areas are becoming more and more important [1, 2]. An IDAS is a network of compact wideband antennas which connected to a common source via coaxial-cables to enhance the coverage performance. Several vertical polarized antenna designs for IDAS have been proposed and discussed in open literatures [3, 4]. For most of the antennas for IDAS are mounted on the ceilings of indoor areas, they are required to have a low profile. So the design of low-profile distributed antenna has become one of the most important research aspects.

To increase the channel capacity, enhance spectrum efficiency, and combat the multipath fading in complex indoor environments, polarization diversity technology has been widely applied to IDAS. Therefore, dual-polarized distributed antennas which consist of a vertically polarized element and a horizontally polarized element are investigated [5–8, 12]. Furthermore, more and more frequency bands have been designed and commercially used for different communication systems to provide better communication services, such as 4G, 5G, WiMAX and WLAN. So low-profile broadband dual-polarized distributed antennas which can simultaneously cover multiple service bands are in great demand. In [8], an omnidirectional dual-polarized antenna is presented. The antenna consists of a printed dipole array for horizontal polarization (HP) and an asymmetric biconical for vertical polarization (VP). Good

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antenna performances are obtained for HP element and VP element during 1.8–2.7 GHz and 0.81–3 GHz bands respectively. However, the overall height of the antenna is as large as 117 mm, which greatly limits its application to IDAS. To reduce the antenna height and enlarge the bandwidth, an improved distributed antenna is demonstrated in [9]. By combining four pairs of flag-shaped dipoles for HP and a discone antenna for VP, the antenna with a height of 102.6 mm could operate from 1.7 to 3.0 GHz for HP while from 0.671 to 3.58 GHz for VP. In [10], though the bandwidths for VP and HP antennas are enlarged to 152% (0.82–6 GHz) and 63% (1.53–2.95 GHz), the antenna height is still 97.5 mm. By using a circular planar loop antenna for HP and a modified low-profile monopole for VP, the height of the antenna illustrated in [11] is reduced to 72.8 mm. But the antenna bandwidths are only 27.8% (1.7–2.25 GHz) for VP and 25.6% (1.7–2.2 GHz) for HP, which is not wide enough for the broadband or multiband IDAS.

In this paper, a low-profile dual-polarized omnidirectional antenna is studied for broadband IDAS. The proposed antenna consists of an improved discone antenna for VP and a printed dipole array with five pairs of dipoles for HP. By loading a circular shorted patch over the top and a coupling ring at the bottom of three radiation patches, the VP antenna's bandwidth is effectively improved while the antenna height keeps small. By installing the HP element over the VP element, a low-profile structure with a height of 80 mm, wide bandwidths of 0.86–5.62 GHz for VP and 1.62–2.71 GHz for HP are realized.

## 2. ANTENNA DESIGN

The geometry of the proposed low-profile dual-polarized distributed antenna with detailed dimensions is illustrated in Figure 1. By using three dielectric cylinders, the circular dipole array for HP is installed over the top of the improved discone antenna for VP.

As demonstrated in Figure 1(a), the VP element is composed of three radiation patches which are arranged concentrically with an interval of 120 degrees, a circular loading patch, a coupling ring and a cone-shaped feeding structure. Since the three radiation patches have an external profile of a discone-shape and the electric currents mainly flow along the edges of the patches, the VP element here is employed as a discone antenna and its overall height $H_1$ is designed to be close to a quarter wavelength of the center frequency around 2.8 GHz. A circular patch, which is mounted on and shorted to the ground plane by three shorting strips, is loaded over the radiation patches with a small gap. By loading the circular patch, the distributed antenna's impedance matching at lower bands is improved effectively. Meanwhile, a coupling ring is loaded on the ground plane to mainly improve the impedance matching at higher operation bands. A novel cone-shaped feeding structure is used to feed the VP element. While the top surface of the feeding structure is attached to the three radiation patches, the bottom surface is directly joined to a 50 $\Omega$ coaxial cable.

Figure 1(b) shows the perspective view of the HP element. It can be seen that the HP element is made up of five pairs of concentrically arranged electrical dipoles and a five-way power divider which are printed on the opposite sides of the substrate. The length of each electric dipole's arm is designed close to a quarter wavelength corresponding to the desired resonant frequency. The five-way power divider is employed to excite the dipoles with signals having equal amplitude and phase, so that omnidirectional radiation patterns in azimuth plane can be achieved. Five pairs of parasitical strips are printed on the edge of the substrate for bandwidth improvement. As shown in Figure 1(c), a 50 $\Omega$ coaxial cable which is attached to one of the shorting strips is used to feed the HP element. One end of the cable is connected to HP element's feeding point while the other end is joined to the HP port. The angles $\theta_1$ and $\theta_2$ which are corresponding to the lengths of the parasitical strips and dipoles are set to be 60.5° and 55° respectively.

As indicated in Figure 2, the current distribution of the printed array with five pairs of dipoles is illustrated to further explain the HP element's operation principle. It can be observed that clockwise currents with equal amplitude and coincident phase are generated. Therefore, omnidirectional radiations are obtained for HP elements in a horizontal plane.

By using HFSS software, the configuration parameters are simulated and optimized. The optimal dimension values for the low-profile dual-polarized antenna are listed in Table 1.

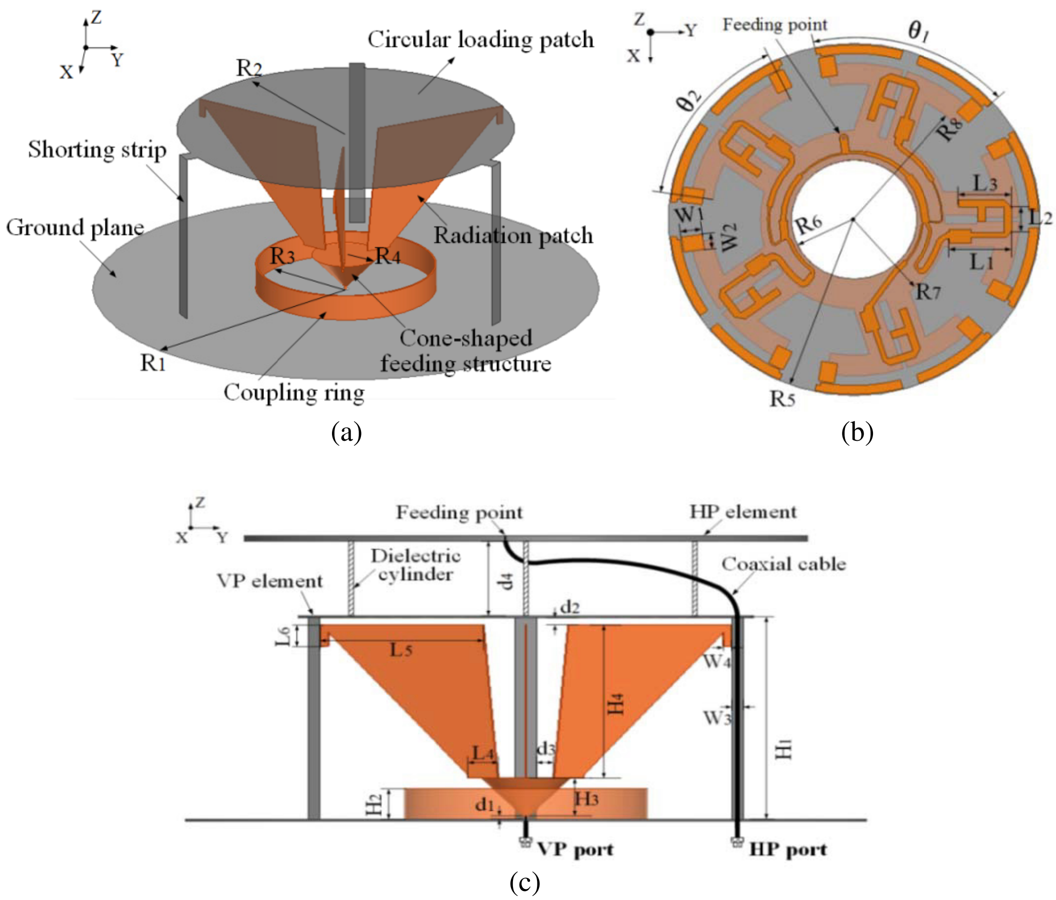


**Figure 1.** Geometry of the distributed antenna: (a) 3D view of VP element; (b) Perspective view of HP element; (c) Side view of the proposed antenna.

**Table 1.** The optimal dimension values (unit: mm).

| Dimension | Value | Dimension | Value | Dimension | Value | Dimension | Value |
|---|---|---|---|---|---|---|---|
| $R_1$ | 84 | $R_8$ | 53.5 | $W_1$ | 7.8 | $H_4$ | 42.8 |
| $R_2$ | 56 | $L_1$ | 23.3 | $W_2$ | 6 | $d_1$ | 1 |
| $R_3$ | 29.5 | $L_2$ | 9.7 | $W_3$ | 5.2 | $d_2$ | 2 |
| $R_4$ | 11.2 | $L_3$ | 19.8 | $W_4$ | 2 | $d_3$ | 8 |
| $R_5$ | 69.5 | $L_4$ | 8.4 | $H_1$ | 56.5 | $d_4$ | 21.3 |
| $R_6$ | 23.5 | $L_5$ | 46 | $H_2$ | 8.5 | | |
| $R_7$ | 35.2 | $L_6$ | 6 | $H_3$ | 10.7 | | |

## 3. RESULTS AND DISCUSSIONS

According to the analysis and simulation above, a prototype of the low-profile dual-polarized distributed antenna has been fabricated, and a photograph is exhibited is Figure 3. The VP element is fabricated with a 0.5 mm copper sheet, and the HP element is printed on an FR4 substrate with a thickness of 1.5 mm. The HP element is mounted over the VP element by three dielectric cylinders.

To better demonstrate the design steps of the VP element and the effects of the circular loading patch and coupling ring, the comparison between simulated return loss curves of the antenna without circular loading patch, the antenna without coupling ring, and the proposed antenna is given in Figure 4. It can be found that the circular shorted loading patch can effectively expand the bandwidth at lower

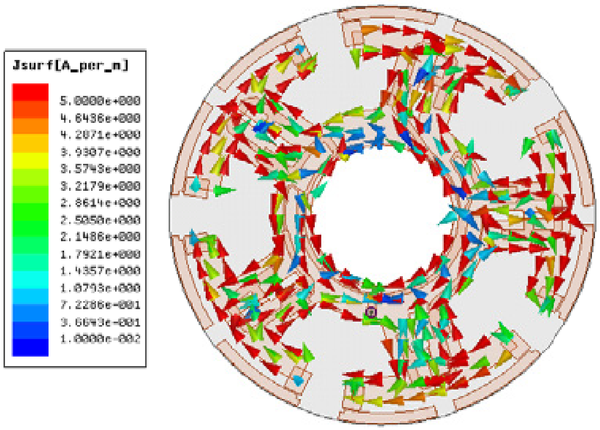


**Figure 2.** Current distribution of HP element at 1.8 GHz.

**Figure 3.** Picture of the manufactured antenna.

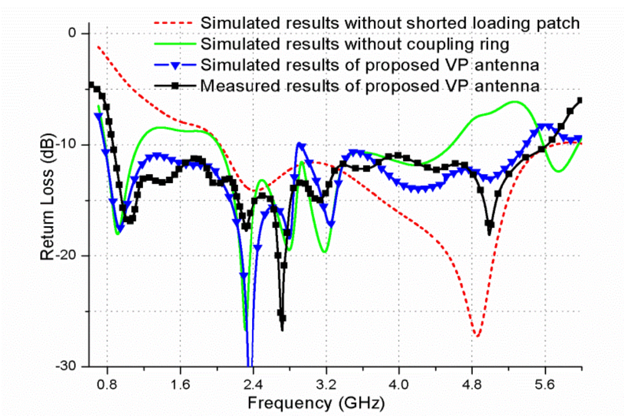


**Figure 4.** Return loss curves of the antenna without shorted loading patch, the antenna without coupling ring, and the proposed VP antenna.

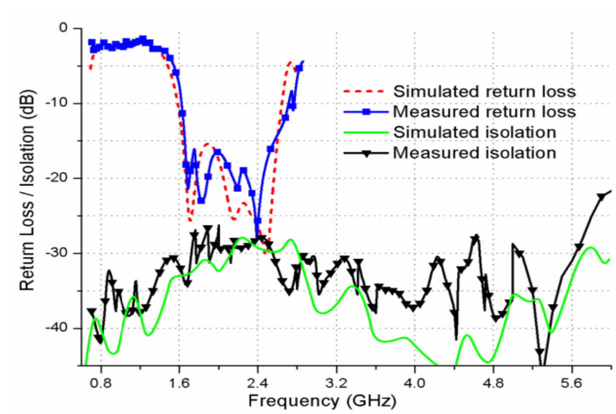


**Figure 5.** Return loss for the HP element and Isolation between the HP and VP ports.

bands. On the contrary, the coupling ring is mainly employed to enlarge the antenna's bandwidth at higher bands. The measured return loss shows that a broad bandwidth ranging from 0.86–5.62 GHz is achieved for the VP element.

As can be seen in Figure 5, the simulated and measured return loss curves for the HP antenna as well as the simulated and measured isolation curves between the HP and VP ports are exhibited. The simulated and measured results are in good agreement with each other. And the results show that the operation band of 1.62–2.71 GHz is realized for HP and the isolation values are large than 26 dB during the whole operation bands.

The measured normalized far-field radiation patterns of the low-profile dual-polarized antenna are plotted in Figure 6. Omnidirectional radiation patterns for both HP and VP in horizontal plane ($XY$-plane) are observed. Though there is some deterioration for the $H$-plane patterns of the VP element at 5.5 GHz, the omnidirectional characteristic can still be found. Low cross-polarization levels of no more than $-15$ dB in the $H$-plane are achieved as well.

As shown in Figure 7, measured and simulated antenna gains are presented and show good agreement with each other. Measured results illustrate that the gains for VP range from 2.6 to 5.6 dBi while the gains for HP vary from 2.8 to 4.2 dBi.

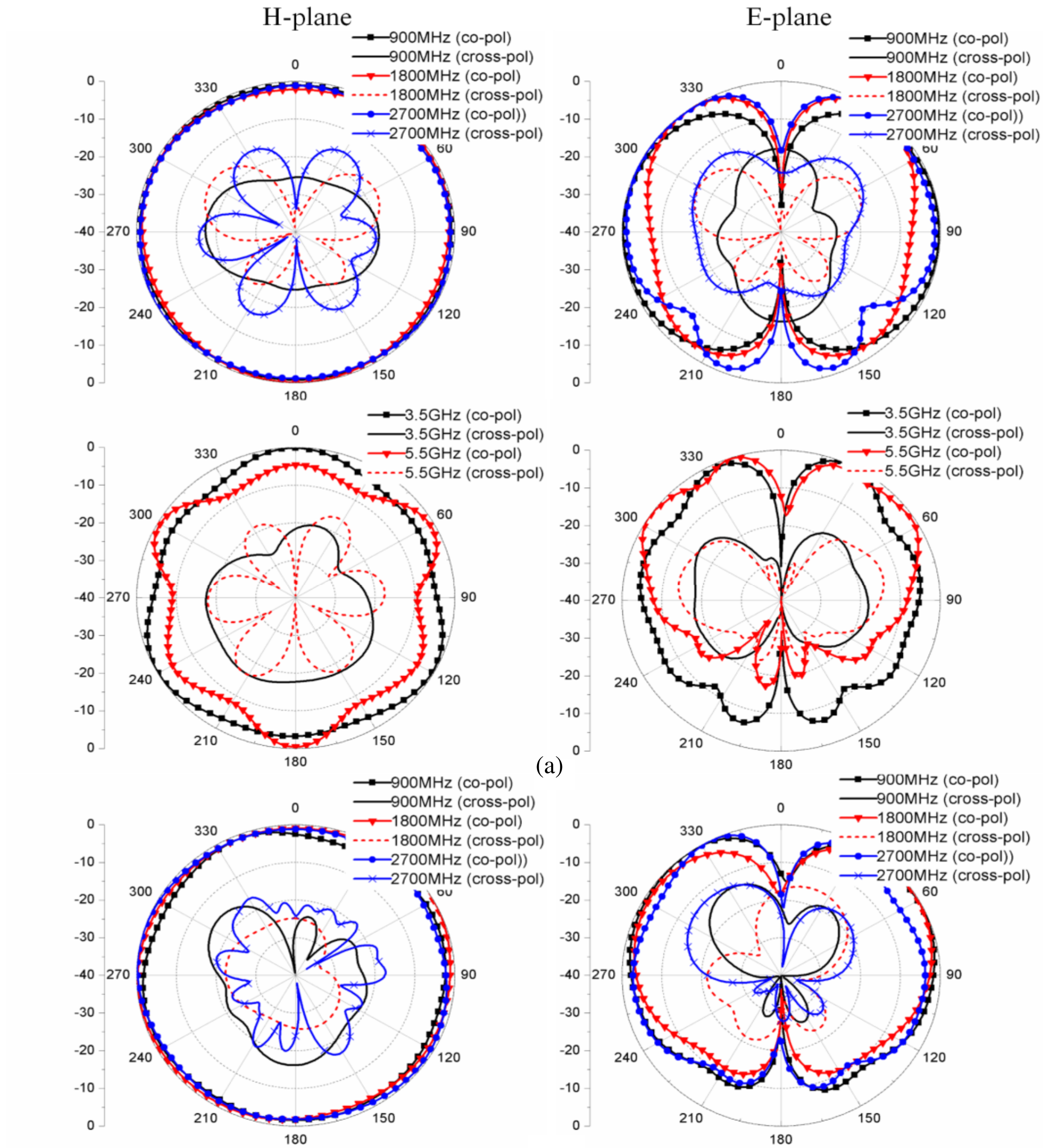


**Figure 6.** Measured normalized far field radiation patterns for the low-profile dual-polarized antenna: (a) VP element; (b) HP element.

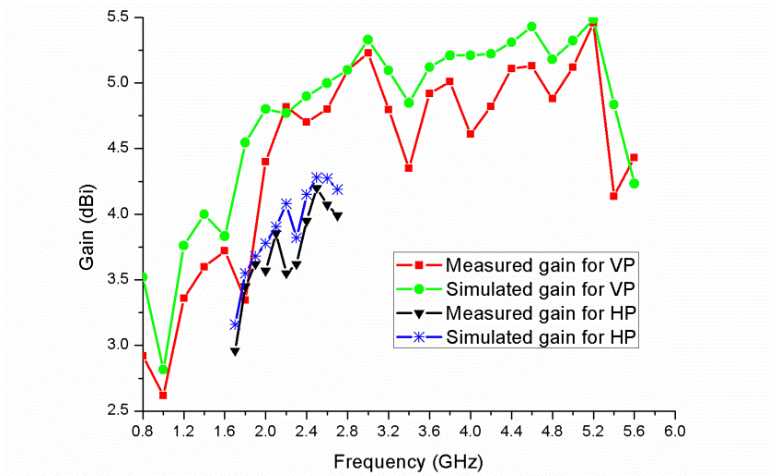


**Figure 7.** Measured and simulated gains of the low-profile dual-polarized antenna.

## 4. CONCLUSION

In this paper, a low-profile dual-polarized omnidirectional antenna is studied for broadband IDAS. A small overall antenna height of 80 mm is realized by combing a printed dipole array with five pairs of dipoles for HP and an improved discone antenna for VP. The VP element is composed of three radiation patches which are fed by a novel cone-shaped feeding structure, a circular shorted loading patch and a coupling ring. By employing the two loading structures, the bandwidth for VP is expanded and antenna height reduced simultaneously. Broad bandwidths of 0.86–5.62 GHz for VP and 1.62–2.71 GHz for HP, omnidirectional radiation patterns in horizontal plane, good port isolation, low cross-polarization level, and stable gain are obtained, which indicate that the proposed antenna is a good candidate for broad IDAS.

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