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A SLEEVE MONOPOLE ANTENNA WITH WIDE IMPEDANCE BANDWIDTH FOR INDOOR BASE STATION APPLICATIONS

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Abstract—A sleeve monopole antenna, which has a wide impedance bandwidth for indoor base station applications, is successfully realized experimentally and numerically. The proposed antenna consists of dual sleeves, loaded circular disc and two shorted pins which are connected to the circular ground plane. The antenna possesses 14-dB impedance bandwidths of 30.3% and 46.5% at the lower and higher bands, respectively. And the 10-dB return loss bandwidth of the antenna is 128.2%, which is about 48 times that of the traditional monopolar wire-patch antenna. The antenna is successfully simulated, designed, and measured, showing dual-band and wide band characteristics, stable gain and good omni-directional radiation patterns.

1. INTRODUCTION

With the development of the wireless communication systems and services, the wideband antennas have attracted more attention in academic and industrial field. Especially, the third-generation mobile communication has been widely used all over the world. More and more wideband antennas have been designed to be mounted on the ceilings as indoor base station applications [1–3]. These antennas have the advantage of a lower profile than the conventional quarter-wavelength monopole antenna. But these antennas have large size and narrow impedance bandwidth. In order to enhance

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impedance bandwidth, bevel square monopole antenna [4], top loaded technology [5], monopolar patch monopole antenna with shorted pins [6–8], and parasitic element [9] are realized. However, the proposed antennas have large volume and complex structures. In [10], a dual-sleeve antenna with coaxial fed is presented. But the antennas are too large to meet the indoor base station applications. In [11–16], several printed sleeve monopole antennas are investigated. However, the proposed antennas have narrow bandwidth and large size. And these antennas always have horizontal polarization which is not suitable for indoor base station applications. In another design of sleeve based on end loaded planar has been proposed with an impedance bandwidth range from 750 to 1245 MHz for a VSWR less than 2, and the dimension of the antenna is more than 100 mm which is so large that it limits the antenna's applications [17]. Simultaneously, the bandwidth cannot meet the requirement of the mobile applications. A good design of sleeve monopole antenna shorted pins is presented in [18], and the experimental results show that impedance bandwidths of about 50% are obtained for the return loss less than −10 dB. Thus, it cannot cover GSM/DCS/PCS/CDMA2000/ WCDMA/ TD-SCDMA/WLAN operation bands.

The sleeve monopole antenna is an attractive candidate due to its wide impedance bandwidth, omni-directional pattern, but its bandwidth is not enough to meet the requirement of the mobile communications, and its height is fixed about quarter-wavelength at the desired frequency. For these reasons, a sleeve monopole antenna with dual-sleeves, a loaded disc and two shorted pins is proposed for indoor base station applications. With the antenna height about 0.16 times the free-space wavelength of the lowest operation frequency, the proposed antenna can achieve dual-band and wideband characteristics and possesses 14-dB return loss bandwidths of 30.3% and 46.5% at the lower and higher bands, respectively. The 10-dB return loss bandwidth of the antenna is 128.2%, which is about 48 times that of the traditional monopolar wire-patch antenna. Compared to the traditional antenna, the proposed antenna also has wider bandwidth and smaller size, which covers GSM, DCS, PCS, CDMA2000, UMTS, WCDMA, TD-SCDMA and WLAN applications. The antenna is successfully simulated, designed, and measured, and the experimental results validate the design procedure.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The proposed sleeve monopole antenna consists of dual sleeves which

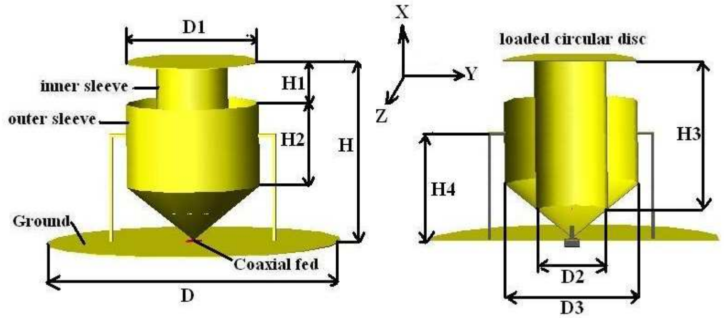


Figure 1. Geometry of the proposed antenna.

include inner sleeve and outer sleeve, loaded disc, two shorted pins and a circular ground plane. The two shorted pins are located at the opposite positions, around the center of the outer sleeve, symmetrically. The circular disc is loaded at the top of the inner sleeve, which can enhance the impedance and improve the radiation pattern of the lower band. A coaxial probe is used to feed this sleeve monopole antenna. The dimensions of this antenna are: height of the sleeve antenna (H) is 65 mm; the distance between the loaded circular disc and outer sleeve (H1) is 15 mm; height of the outer sleeve (H2) is 30 mm; height of the inner sleeve (H3) is 50 mm; height of the shorted pin (H4) is 32 mm; diameter of the ground plane (D) is 110 mm; diameter of the loaded circular disc (D1) is 50 mm; diameter of the inner sleeve (D2) is 27 mm; diameter of the outer sleeve (D3) is 50 mm; the separation of each shorting pins from the center of the sleeve is 39 mm. The distance between the bottom of sleeve monopole antenna and the ground plane is 1 mm. The thickness of the sleeve antenna and the loaded circular disc is 0.5 mm. The thickness of the ground plane is 2 mm.

3. PARAMETRIC STUDY

To obtain enough information of the proposed antenna, the effects of the geometric parameters on antenna bandwidth are investigated by using electro-magnetism simulation software CST. Since the height of the outer sleeve (H2), height of the inner sleeve (H3), height of the two shorted pins (H4), diameter of the ground plane (D), diameter of the loaded circular disc (D1), diameter of the inner sleeve (D2), diameter of the outer sleeve (D3) are important to the proposed antenna, the above parameters are selected in the parametric study. In order to obtain accurate effects of these parameters on its impedance bandwidth, only

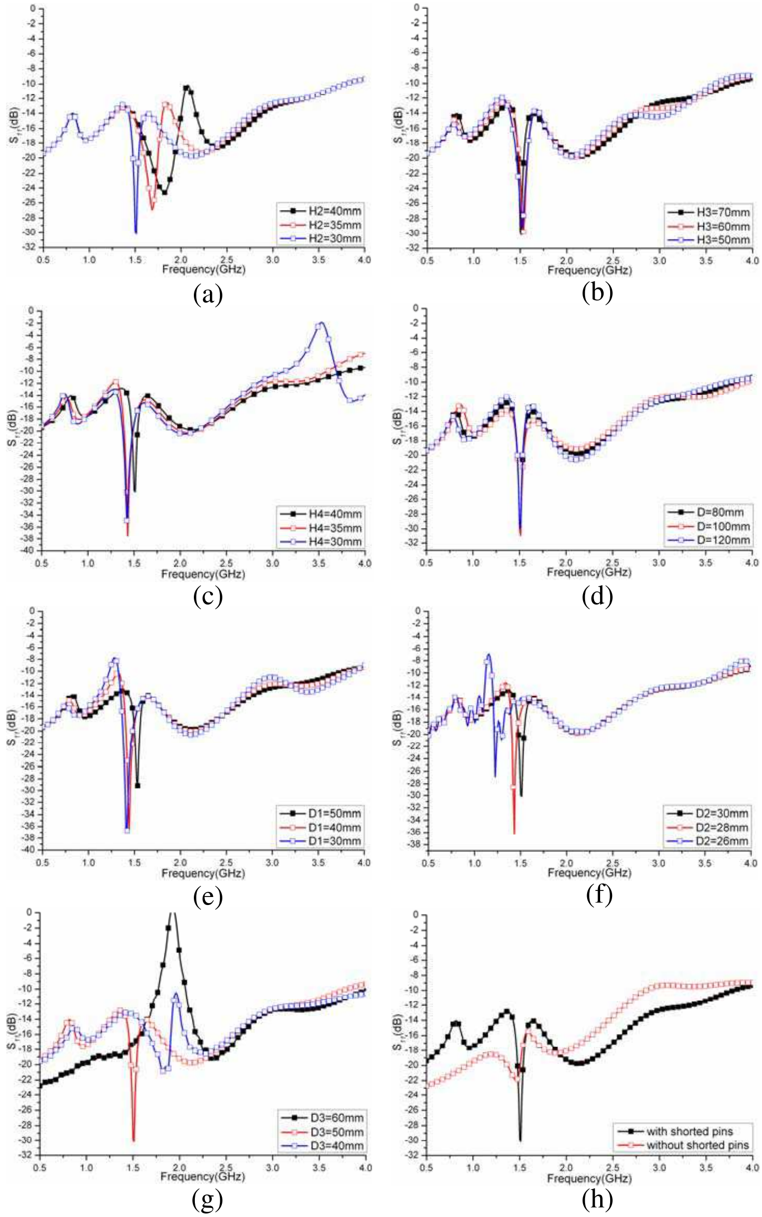


Figure 2. Return loss vs. frequency with various parameters. (a) H2, (b) H3, (c) H4, (d) D, (e) D1, (f) D2, (g) D3, (h) shorted pins.

one parameter is changed at each time while other parameters are kept constant.

The effects of the parameters H2, H3, H4, D, D1, D2, D3 and the shorted pins on the return loss vs. frequency are plotted in Figs. 2(a)–(h), respectively. It can be seen from Fig. 2(a) that the -14 dB impedance bandwidth expands with the decrease of the height H2, whereas the radiation pattern at the operation band is almost unchanged. Fig. 2(b) shows that with the increase of the height H3, the -14 dB impedance bandwidth is almost invariable. But the height can improve the bandwidth and radiation pattern of the lower band. The return loss at the lower band is getting better by increasing the height of the inner sleeve H3. Fig. 2(c) indicates that with the increase of the height of the two shorted pins H4, the return loss changes rapidly. But the height of the shorted pins cannot increase unlimitedly. When the height of the shorted pins is equal to the height of the outer sleeve, the return loss gets worse. The ground plane can affect the impedance bandwidth of the proposed antenna. It can be seen from Fig. 2(d) that the return loss gets worse when the diameter of the ground plane D is increased. So the ground can be optimized further. The diameter of the ground plane D also affects the radiation pattern. Fig. 2(e) shows the influence of the loaded circular disc. It shows that the return loss changes quickly at the lower band and is almost unchanged at the higher band. The radiation pattern in the operation band is almost unchanged. Fig. 2(f) describes the effects of the diameter of the inner sleeve, and the return loss of the lower band changes quickly while the return loss is almost constant at the higher band. Fig. 2(g) shows the effects of the diameter of the outer sleeve, and the return loss of the lower band changes quickly while the return loss is almost unchanged at the higher band. The impedance bandwidth is improved by decreasing the diameter of the outer sleeve. It may be caused by the coupling between the inner and outer sleeves. The coupling enhances the bandwidth effectively. Fig. 2(h) indicates the influence of the shorted pins, and the return loss changes quickly. The shorted pins can improve the impedance bandwidth, but it deteriorates the return loss of the lower band. It implies that the proposed antenna is mainly determined by the geometry model and dimensions of the antenna. As the electrical size has more effect on impedance bandwidth, they can be optimized by tradeoff. Based on the parameters study above, the proposed antenna for indoor base station and WLAN applications is optimized and manufactured after several adjustments of different parameters.

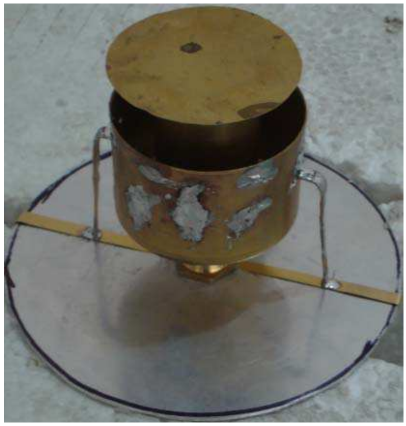


Figure 3. The photograph of the antenna.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

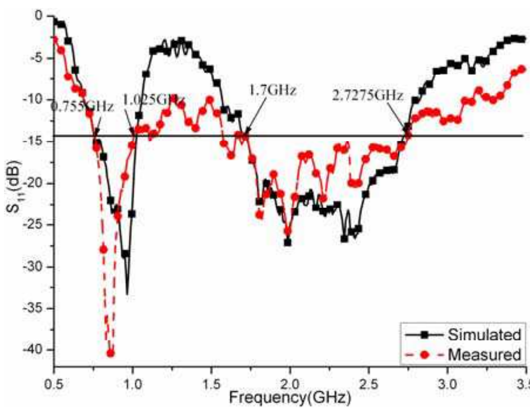
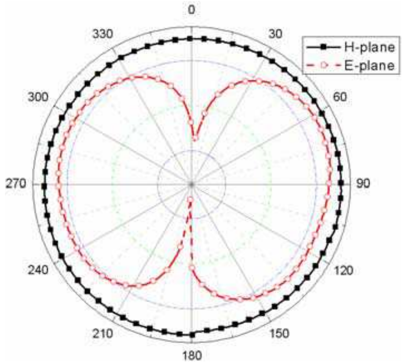
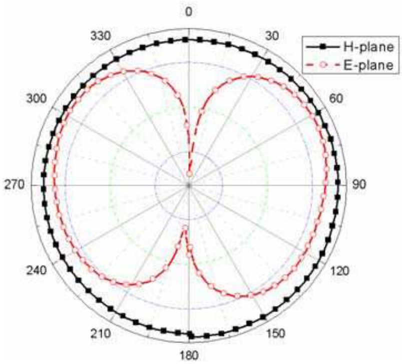


Figure 4. Return loss of the proposed antenna.

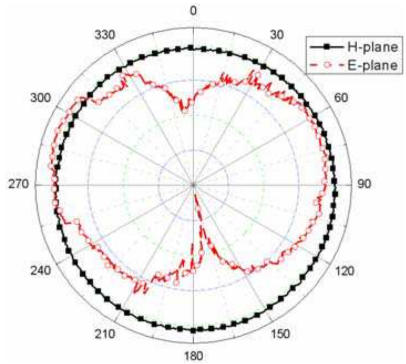
To evaluate the performance of the optimized antenna, the proposed antenna is implemented and tested. In the experiment, the ground is made up of aluminum. In order to fix the shorted pins, a copper strip is employed to connect the outer sleeve to the circular ground plane. The photograph of the proposed antenna is shown in Fig. 3. In this section, the simulated and measured return loss, gain and the measured radiation pattern of the proposed antenna are presented and discussed. The simulations are given by using CST. The



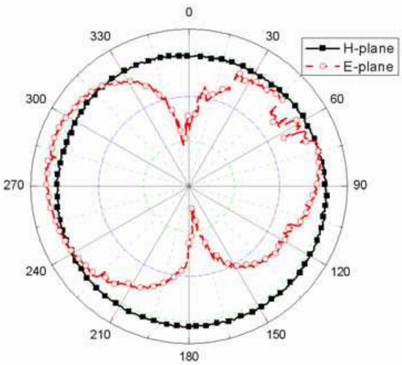
(a)



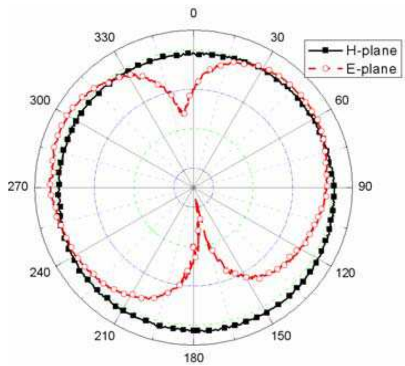
(b)



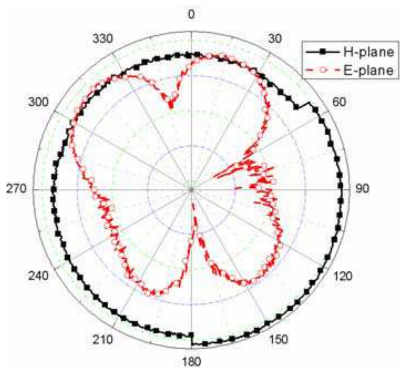
(c)



(d)



(e)



(f)

Figure 5. The photograph of the antenna. (a) 0.824 GHz, (b) 0.96 GHz, (c) 1.71 GHz, (d) 2.17 GHz, (e) 2.45 GHz, (f) 2.7 GHz.

measurement is achieved by using HP8756A scalar network analyzer, and the radiation pattern is obtained in the anechoic chamber. The proposed antenna is smaller than traditional monopolar wire-patch antenna, and the bandwidth is also enhanced. The antenna is reduced by 38.9% compared to the monopolar proposed in [2–4, 6, 17–18], which is more suitable for the indoor base station applications mounted on ceiling and suburban area. The size is reduced by using the shorted pins and loaded circular disc, which improves the impedance matching characteristic and decreases the electrical size effectively. The impedance bandwidth is also enhanced by using the shorted, and the loaded circular disc is shown in Fig. 4. It can be seen from Fig. 4 that the antenna has a dual-band and wide bandwidth characteristic which covers the GSM, DCS, PCS, WCDMA, CDMA2000, TD-SCDMA and WLAN bands. The simulated and measured return loss shows that the antenna possesses bandwidth of 30.3% and 46.5% at the lower and higher bands, respectively. The measured 10-dB return loss bandwidth of the antenna is 128.2%, which is about 48 times that of the traditional monopolar wire-patch antenna [1]. The measured return loss of the antenna has similar impedance characteristic to that in the simulated results, which agrees well with that in the operation band. The difference may come from the fed technology employed in the experiment and copper strip used in the circular ground plane. The simulated and measured results satisfy the indoor base station applications.

Figure 5 shows the measured radiation pattern of the proposed antenna at 0.824 GHz, 0.96 GHz, 1.71 GHz, 2.17 GHz, 2.45 GHz, 2.7 GHz, respectively. It can be seen from Fig. 5 that the antenna has good omni-directional radiation pattern in the impedance bandwidth in the H-plane. In the E-plane, the radiation pattern of the antenna is monopole-like, which is in bidirectional radiation pattern. The E-plane at 2.7 GHz has some change caused by the influence of the fed line at high frequency and the copper strip employed in the experiment.

The gain of the proposed antenna is similar to the traditional monopole antenna. The gain is approximately 2 dBi in the operation band and has little ripples. So the gain is not given in this paper.

5. CONCLUSION

In the paper, a sleeve monopole antenna that utilizes a bandwidth broadening technique is investigated experimentally and numerically. A loaded circular disc and two shorted pins are employed to obtain wider bandwidth. The antenna has simple structure and smaller size. The height of the antenna is only 0.16 times the free-space wavelength of the lowest operation frequency. The proposed antenna has a dual-band and wideband characteristic and possesses 14-dB return loss bandwidths of 30.3% and 46.5% at the lower and higher bands, respectively. The measured 10-dB return loss bandwidth of the antenna is 128.2%, which is about 48 times that of the traditional monopolar wire-patch antenna. Simulated and measured results indicate that the antenna can meet the GSM, DCS, PCS, WCDMA, CDMA2000, TD-SCDMA, UMTS and WLAN indoor base station applications.

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