A Novel Wideband Printed Diversity Antenna for Mobile Handsets

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ABSTRACT—A novel printed compact wide-band diversity antenna for mobile handsets is proposed in this paper. The antenna comprises two back-to-back G-shaped monopoles placed symmetrically with respect to a T-shaped and dual inverted-L-shaped ground plane. The measured results show that the proposed diversity antenna operates in a very wide bandwidth of 1200 MHz starting from 1700 MHz to 2900 MHz. In the above bands, the isolations of the prototype are better than -15 dB. The antenna can provide pattern diversity to combat multipath fading.

Key words: diversity antenna; monopole antenna; wideband;

INTRODUCTION

With the rapid development of mobile wireless communication technology, high-capacity information transmission has become more and more important. MIMO system has been regarded as a promising solution, as it can increase channel capacity without sacrificing additional spectrum or transmitted power[1]. In MIMO multi-antenna systems, antenna diversity can be widely used for reducing multipath fading and in-channel interference[2]. In a cellular communication system, the base station side is very easy to implement the antenna away from each other with a few wavelengths. In the mobile handset, however, how to install in its limited space with more than two antennas is a recognized difficulty.

Most of antennas used for MIMO systems in mobile handsets were composed of several monopole antennas[3]. In addition, the mobile terminal device miniaturization, making the spacing between multi-antenna elements decreases, and the mutual coupling between antenna elements has become a problem affecting the antenna MIMO system performance. As a leader of the small, integrated antenna, microstrip patch antenna with its flexible three-dimensional structure were widely used for various design goals [4].

Dongya Shen et al. in [5] proposed a broadband antenna with a shorted-patch. In [6], a MIMO antenna with two closely-positioned PIFAs for WLAN is proposed. Both of the two antennas had a large volume, which greatly restricted their applications in mobile handsets. [7] and [8] proposed a 2.4/5.2 GHz, GSM 900/1800 MHz dual-band antenna, respectively, Also, [9] proposed a 2.4/5.2/5.8GHz triple-band monopole antenna, but all of them can not overcome multipath fading, and multipath fading are widely present in the real working environment.

Some related antenna designs used for MIMO terminals have been reported. [10] proposed a antenna with three equilateral triangular microstrip patches as the antenna elements to combat the multipath fading problem. In [11] K. Chung et al proposed a MIMO antenna with high isolation characteristic. Also, [12] proposed a compact MIMO antenna. In 2010, [13] proposed a low profile co-located MIMO antenna structure with high port isolation. [10]-[13] proposed the MIMO antennas operating in a single band. In [14] and [15] , a dual-band printed diversity antenna for 2.4/5.2-GHz WLAN operations was proposed. The two antennas consist of two orthogonal C-shaped and F-shaped monopoles, respectively. A protruding T-shaped stub at the ground plane is used to increase the isolation between two elements. In [16], based on the deep study on bandwidth enhancement and size reduction of the microstrip slot antenna, a diversity antenna of dual L-shaped slots with a bandwidth of 2.52 to 6.4 GHz was presented, and [17] also proposed a wide band planar diversity antenna from 1890 to 2310 MHz. All of above antennas isolation between two ports across the whole bandwidth is controlled well. Unfortunately, antennas proposed in [14]-[17] cannot cover the most usual bands, such as UMTS and 2.4 GHz WLAN, in the limited antenna volume.

In this paper, a dual-band printed diversity antenna for mobile handsets is proposed. The antenna with two back-to-back monopoles is printed on a printed circuit board (PCB). Several ground branches are introduced to increase the isolation or adjust the resonant frequency. The measured bandwidth (S11＜-10 dB) is 1700 to 2900 MHz with acceptable isolation for frequencies across the DCS, PCS, PHS, UMTS, WLAN band.

In Section II, the geometry of the proposed dual-band diversity antenna with some detailed dimensions is provided. In Section III, the effects of some important parameters of the proposed antenna are fully discussed to show how this diversity antenna works. And the average current distributions on the monopoles and ground plane at resonant frequency are also illustrated and studied. In Section IV, the scattering parameters and the far-field radiation patterns of the proposed antenna are obtained. Results show that the proposed antenna is a good candidate for diversity system. Finally, a conclusion is given in Section V.

I. ANTENNA CONFIGURATION

Fig.1 shows the geometry of the proposed diversity antenna. Fig.1(a) shows the geometry with some detailed dimensions of the proposed diversity antenna printed on a substrate with dimensions 55 mm×99 mm, which can be considered as the circuit board of a mobile handset. The substrate has a thickness of 1.6 mm and a relative permittivity of 4.4. The diversity antenna consists of two symmetric back-to-back G-shaped monopoles (dark color) printed on the front side of the substrate. Each monopole is directly fed by a 50 Ω microstrip feeding line printed on the front side of the substrate. The detailed dimensions of one monopole are illustrated in Fig. 1(b). The design of two monopoles adopts folded techniques to reduce the occupied area. There are two resonant paths in this G-shaped monopole: the longer one, starting from the feed point to the opening end OA 1, generates the lower operating band; the shorter one, starting from the feed point to the opening end OA 2, controls the upper operating mode. The lengths from the feeding point to the end of the metal are smaller than one-quarter wavelength of a conventional straight monopole in free space. This behavior is largely due to the effect of the microwave substrate supporting the proposed monopole, which leads to decrease resonant length for the proposed monopole. This effect is also helpful for achieving a smaller antenna size for a fixed operating frequency.

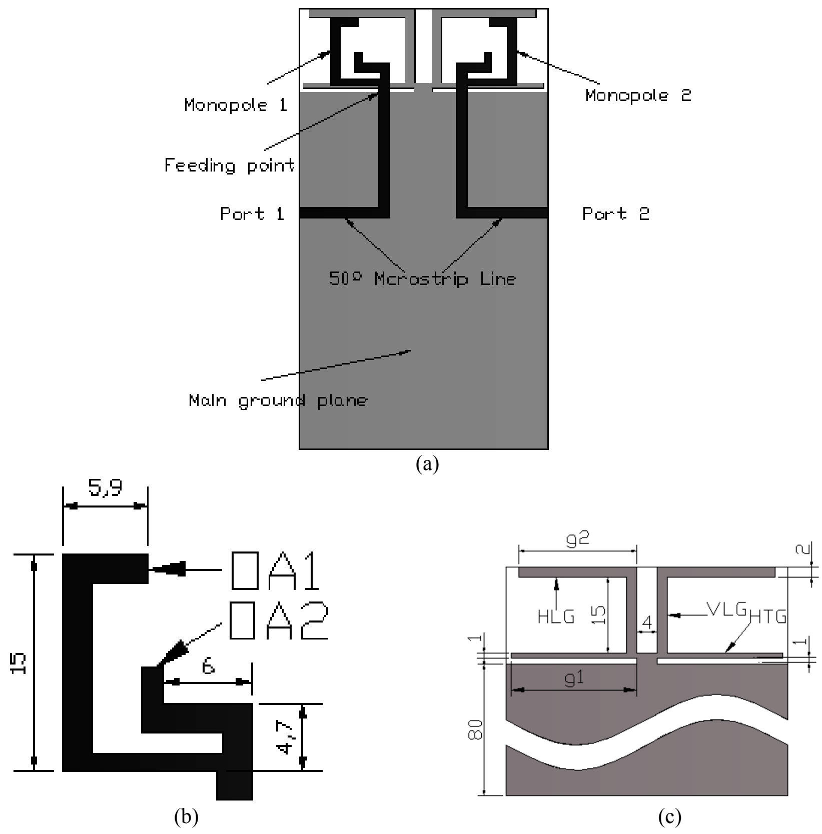


Fig.1. Geometry of the proposed diversity antenna (a) General view, (b) Dimensions of monopole, and (c) Dimensions of the ground plane

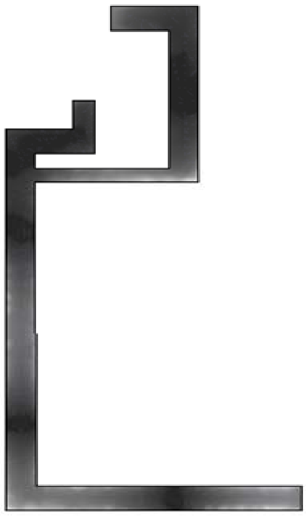
On the back side of the substrate, the main ground plane with the dimensions 55 mm × 80 mm can be considered the whole circuit part in a mobile handset. The other part of the ground plane protruding from the main ground plane can be divided into two parts: one part is dual inverted-L-shaped ground plane (LG) and the other is a T-shaped ground plane (TG). The detailed dimensions of the ground plane are illustrated in Fig.1(c). The widths of the LGs including the horizontal parts (HLG) and the vertical parts (VLG) are all 2 mm. The distance between the two LGs is 4 mm, and the width of the vertical part of the T-shaped ground plane (VTG) also is 4 mm. The horizontal part of the T-shaped ground plane (HTG) has the width 1 mm. The slot between the HTG and the main ground plane is 1 mm. The length g1 of the HLG and the length g2 of the HTG have large role in tuning resonant frequencies and improving the isolation, which will be discussed in the next section.

II. EFFECTS OF THE GEOMETRICAL PARAMETERS OF THE PROPOSED ANTENNA

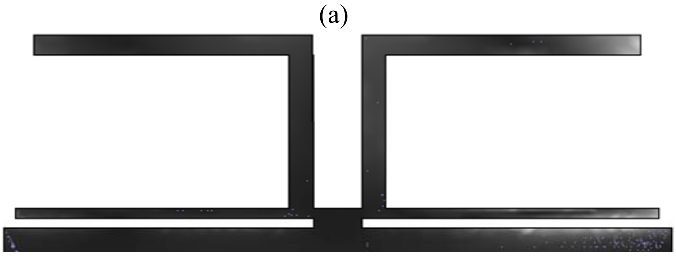
Among the geometry of the diversity antenna as shown in Figure 1, the dimensions of the monopoles are given, whose length from feeding point to OA 1 is about a quarter of the wavelength in the free space at the desired centre frequency. By tuning the length, the resonant frequency is quite easily achieved. In this letter, the resonant frequency is about 2.4 GHz and the dimensions are fixed as shown in Fig.1 (b). The part from feeding point to OA 2 adjusts the matching characteristics a little in the low frequency. The length and width of the main ground plane are limited by the practical mobile handset. The widths of the LGs and TG do not affect the antenna performance much. Only the parameters g1 and g2 have more effects on the S11 and S21.

To choose the optimal lengths g1 and g2 of the HLG and HTG shown in Figure 1(c), respectively, we need to know how the two branches affect the return loss and the mutual coupling of the proposed diversity antenna. To describe how the proposed antenna works, we give the average current distributions of the monopole and ground plane at two resonant frequencies based on the optimal dimensions. The simulated results are obtained using Ansoft Simulation Software HFSS 11.0 (High Frequency Structure Simulator). Because of the symmetric configuration of the diversity antenna, S22 (S12) is consistent with S11 (S21), and only S11 and S21 are discussed in the following text, under a selected combining scheme (that is to say, when the first element is fed, the other one is terminated to a 50 Ω impedance).

Considering the S11 and S21 synthetically, the optimal dimension g1 is chosen as 24.5mm and g2 23 mm.



(a)



(b)

Fig.2 the average current distributions for the proposed antenna with Port 2 excited at 2.4 GHz (the light color means large current density): (a) the monopole 2; (b) the main ground

On the basis of the optimal values of g1 = 24.5 mm and g2 = 23mm, the average current distributions on the monopoles and ground plane at two resonant frequencies are illustrated and studied. Fig.2 gives the monopole and the average ground current distribution respectively. The current on the monopole is mainly concentrated on the longer path from the feeding point to OA 1 as shown in Figure1(b), and in the ground plane, the current is mainly concentrated on the VLGs and the HTG especially the slot part between the HTG and the main ground plane. It is revealed that the low-resonant frequency is affected largely by the path from the feeding point to OA 1.

III. EXPERIMENTAL RESULTS AND DISCUSSION

With the dimensions shown in Figure 1 (g1, g2) = (24.5 mm, 23 mm), a prototype of the proposed diversity antenna was constructed.

The S11 and S21 are simulated using the HFSS 11.0. The simulated results of the S11 and S21 are shown in Fig.3. Because of the symmetric structure of the two monopoles, the simulated S22 and S12 are almost the same with S11 and S21 respectively, and are thus not shown in the figure for brevity. The obtained impedance bandwidth (S11 $<$ −10 dB) reaches about 1500 MHz from 1400 to 2900 MHz. In addition, across the operating band, acceptable isolation between the two ports is obtained (S21$<$ −25dB).

The S11 and S21 are also measured using Agilent E5071C vector network analyzer. The measured results of the S11 and S21 are shown in Fig.3. The obtained impedance bandwidth (S11<−10 dB) reaches about 1200 MHz from 1700 to 2900 MHz. In addition, across the operating band, acceptable isolation between the two ports is obtained.

The simulated radiation patterns of Port 1 and Port 2 excited at 2400MHz are given in Fig. 4 and Fig.5, respectively. Comparing Figures 4 and 5, one can find that the simulated patterns tend to cover complementary patterns, which provide pattern diversity for the system operation. This can overcome the multipath fading problem and enhance the system's performance.

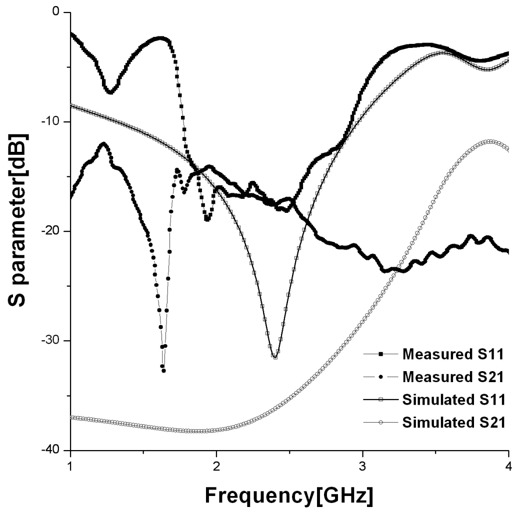
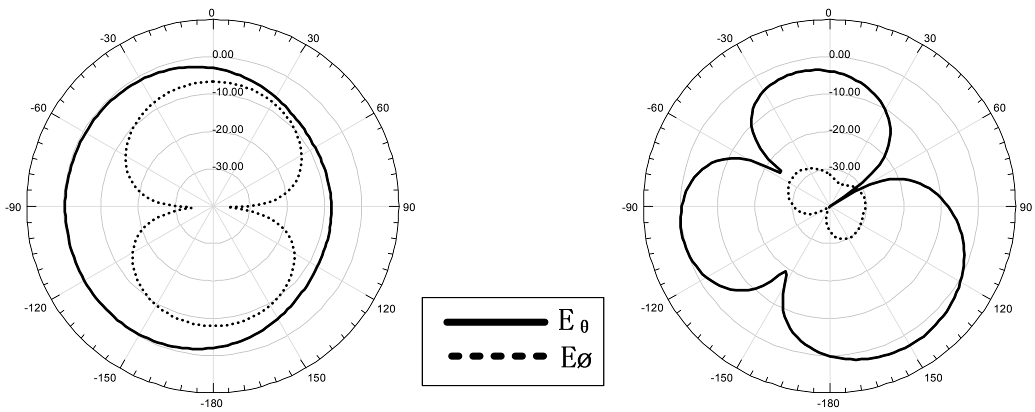
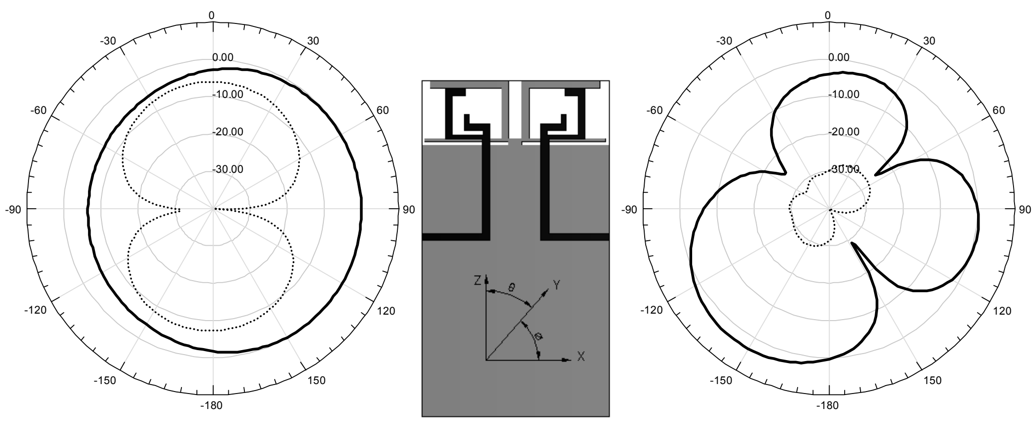


Fig.3 Simulated and measured S parameter



XOY-plane ZOX-plane

Fig.4 simulated radiation for Port1 excited at 2.4GHz



XOY-plane ZOX-plane

Fig.5 simulated radiation for Port2 excited at 2.4GHz

IV.CONCLUSION

A novel compact wideband printed diversity antenna has been proposed and studied in this paper. On the basis of simulated results, the optimal values of the parameters are chosen and the radiation mechanisms are also studied. The final measured bandwidth (S11<-10 dB) is 1700 to 2900 MHz with acceptable isolation for frequencies across the DCS, PCS, PHS, UMTS, WLAN band. Compared with similar products, the proposed antenna can provide pattern diversity to help combat multipath fading in real environment and is very suitable for mobile handsets.

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