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BROADBAND THIN INTERNAL PLANAR ANTENNA FOR MOBILE PHONE

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1. Introduction

Planar antennas such as planar inverted-F antenna (PIFAs) have been found to be very attractive for application as an internal mobile phone antenna, and many promising related designs have been reported [1-9]. These related internal planar antennas usually show a thickness of about 6 ~ 10 mm for operating in the 900 MHz band and are mounted directly on the system circuit board or ground plane of a mobile phone for practical applications. In this case such an internal planar antenna usually occupies a certain board space of the system circuit board of a mobile phone, and no other components of the mobile phone can be placed between the internal antenna and the system circuit board.

In this paper we propose a novel broadband thin planar antenna suitable for application as an internal mobile phone antenna that is suitable to be mounted over board components and does not occupy the board space of the system circuit board. For operating in the 900 MHz band, the proposed antenna has a very low profile of 3 mm only, less than one half of that (6 ~ 10 mm) of conventional internal PIFAs [1]. Owing to its very low profile, relatively much smaller than that of most mobile phones (generally larger than 10 mm), the proposed internal planar antenna is very promising to be mounted above the system circuit board, without occupying any board space (see Fig. 1). The unoccupied board space beneath the proposed internal antenna can be used to accommodate other possible components, such as the front-end modules and filters, of the mobile phone. In addition to its very low profile, the proposed antenna shows a wide operating bandwidth of about 25% with respect to the center frequency 900 MHz, which makes it easily cover the operating bandwidths of the AMPS (Advanced Mobile Phone System, 824–894 MHz) and GSM (Global System for Mobile Communication, 890–960 MHz) bands. Prototypes of the proposed antenna have been constructed and studied.

2. Antenna Design

Fig. 1 shows the geometry of the proposed broadband thin internal planar antenna mounted above the system circuit board of a mobile phone. In this study a ground plane of dimensions 45 × 120 mm^2 (layer 3 in the figure) represents the system circuit board, which is a typical size for many practical mobile phones. The proposed planar antenna comprises a shorted top patch of width 45 mm and length t_1 (layer 1 in the figure) and an antenna's ground plane of width 45 mm and length t_2 (layer 2 in the figure). The antenna thickness or the distance between the top patch and the antenna's ground plane is denoted as h (foam supporter between the top patch and the antenna's ground plane is not shown in the figure).

Note that the shorting and feeding points are both along the centerline of the top patch, and the shorting point is fixed at the center of the top edge of the top patch. In this case impedance matching is easily achieved for the proposed antenna by adjusting the width (w) of the feeding strip and the distance (S) of the feeding point to the shorting point. In addition, with the shorting and feeding points located along the centerline of the top patch, the excited surface currents on the top patch are expected to be symmetric with respect to the centerline, that is, more uniform excited surface current distributions can be achieved, which is helpful in achieving a wide impedance bandwidth for the proposed antenna.

Also note that, at the top edge of the antenna's ground plane, a shorting plate (size 45 mm × d) short-circuits the antenna's ground plane to the system ground plane. This shorting plate and a plastic supporter (not shown in the figure) at the other edge of the antenna's ground plane support the

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proposed antenna above the system ground plane with a height of *d*. With this arrangement, the proposed internal planar antenna is mounted above the system ground plane or circuit board and does not occupy the board space. Some possible components or additional circuit board for the mobile phone can thus be located in the board space beneath the antenna's ground plane; the related effects on the antenna performance are explored with the aid of Fig. 6 in Section III.

3. Experimental Results and Conclusion

Prototypes of the proposed antenna for operating in the 900 MHz band were constructed and studied. Note that, in the experiments, a via-hole in the system ground plane was cut to allow the use of a 50 Ω mini coaxial line for testing [see Fig. 1(b)]. The case with equal lengths of the top patch and the antenna's ground plane is first studied. Fig. 2 shows the measured and simulated return loss for the proposed antenna with h = 3 mm, d = 7 mm, $t_1 = t_2$ = 55 mm, S = 8 mm, w = 2 mm. Good agreement between the measured data and the simulated results obtained using Ansoft HFSS (High Frequency Structure Simulator) simulation software is obtained. In this design the proposed antenna is with a very low profile (3 mm), which is relatively much smaller than that of most mobile phones (generally larger than 10 mm). In addition, the measured impedance bandwidth (10 dB return loss) reaches 225 MHz (822–1047 MHz), which is 25% referenced to 900 MHz and covers the AMPS (824–894 MHz) and GSM (890–960 MHz) bands.

Fig. 3 shows the measured antenna gain across the operating bandwidth. An antenna gain level of about 0.9–2.0 dBi is obtained. Fig. 4 plots the measured radiation patterns at 900 MHz for the antenna studied in Fig. 2. Note that the antenna radiation shows larger forward radiation in the $-y$ direction than backward radiation in the y direction. This behavior is largely because the system ground plane (layer 3 in Fig. 1) in this design performs more like a reflector than a radiator. (For conventional internal PIFA designs [1], the system ground plane is used as the antenna's ground plane of the internal PIFA and is performed as a part of radiator, thus omnidirectional radiation patterns in the azimuthal plane (x–y plane here) are usually observed for operating in the 900 MHz band.) Other frequencies across the operating bandwidth were also measured, and the results obtained are similar to that shown here.

Effects of the design parameters of the proposed antenna were also studied. Measured return loss for the proposed antenna as a function of antenna thickness (h) is shown in Fig. 5. Results indicate that h has a critical value of about 3 mm. When h is decreased to 2 mm, the impedance bandwidth is quickly degraded. On the other hand, by increasing h from 3 mm to 4 mm, a slight increase (about 15 MHz) in the impedance bandwidth is seen.

Effects of the distance (d) between the antenna's ground plane and the system ground plane on the impedance bandwidth of the proposed antenna were also studied. From the results, it is fount that the variations in the obtained impedance bandwidths are small for d varied from 5 to 8 mm. The effects of the antenna's ground plane length (t_2) on the impedance bandwidth of the proposed antenna were also investigated. The obtained results indicate that the length t_2 affects the resonant frequencies and impedance matching of the two excited resonant modes that form the wide impedance bandwidth for the proposed antenna, and there exists an optimal value of t_2 (57 mm in this study) for achieving a maximum impedance bandwidth (about 238 MHz for this study).

Fig. 6 shows the measured return loss for the proposed antenna with a dielectric slab (3.2 × 55 × 45 mm^3 or 4.8 × 55 × 45 mm^3, ε_r = 4.4) placed between the antenna's ground plane and the system ground plane [a distance of 7 mm (d) in this case]. The dielectric slab here represents the additional circuit board or some possible components to be located in the board space beneath the antenna's ground plane. From the results obtained, it indicates that, when the dielectric slab has a thickness smaller than about half (3.5 mm in this study) of the distance d, the antenna performance is slightly affected (10 dB return-loss bandwidth remains about the same). It is thus very promising that additional circuit boards or some possible components can be located in the board space beneath the antenna's ground plane. In addition, it is also expected that, when additional circuit boards are with a lower dielectric constant (ε_r < 4.4), smaller effects than that shown in Fig. 6 can be obtained. More experimental and simulation results will be given in the presentation.

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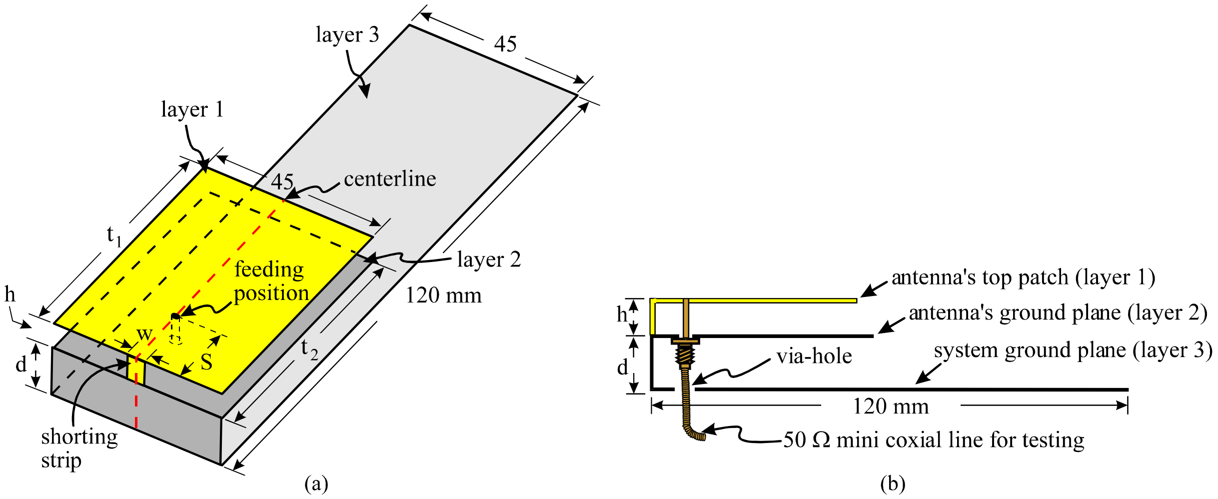

Fig. 1 (a) Geometry of the proposed broadband thin internal mobile phone antenna.
(b) Cross-sectional view along the centerline of the mobile phone.

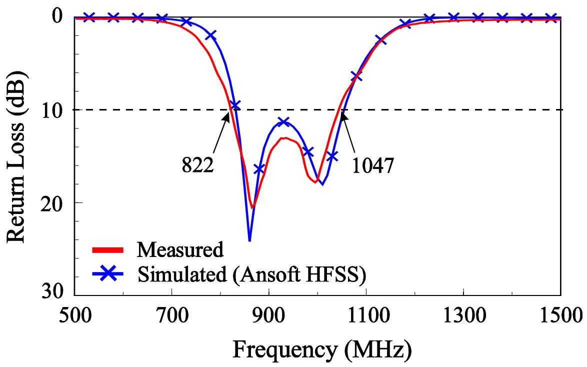

Fig. 2 Measured and simulated return loss for the proposed antenna with h = 3 mm, d = 7 mm, $t_1 = t_2$ = 55 mm, S = 8 mm, w = 2 mm.

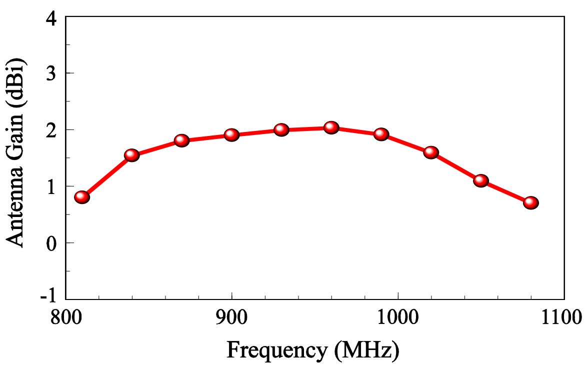

Fig. 3 Measured antenna gain for the proposed antenna studied in Fig. 2.

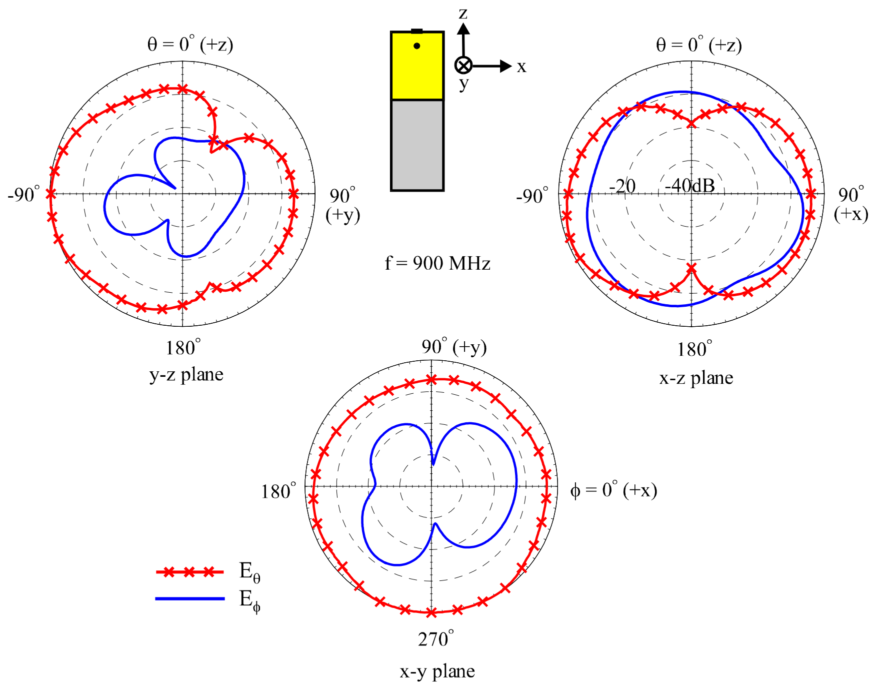

Fig. 4 Measured radiation patterns for the proposed antenna studied in Fig. 2; f = 900 MHz.

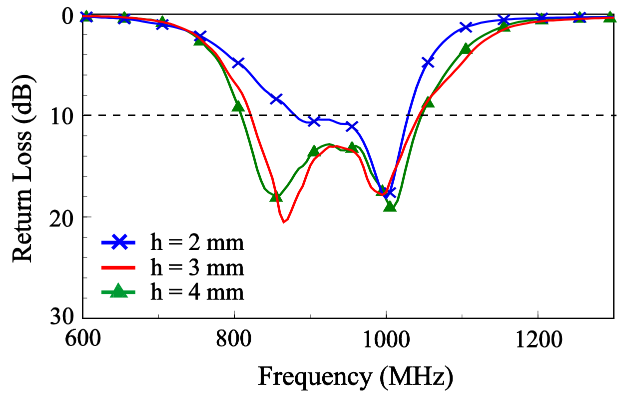

Fig. 5 Measured return loss for the proposed antenna with various values of h;

d = 7 mm, t_1 = t_2 = 55 mm, S = 8 mm, w = 2 mm.

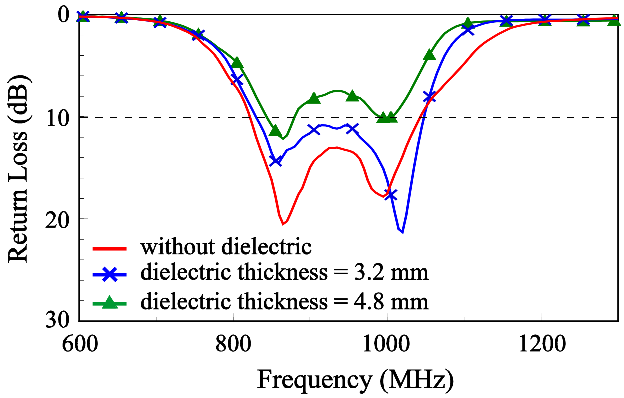

Fig. 6 Measured return loss for the proposed antenna with a dielectric slab ($3.2 \times 55 \times 45$ mm^3, ε_r = 4.4 or $4.8 \times 55 \times 45$ mm^3, ε_r = 4.4) placed between the antenna's ground plane and the system ground plane.