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Planar Patch Antenna Mountable Above the System Ground Plane of the Mobile Device for GSM/DCS Operation

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1. Introduction

The conventional planar inverted-F antenna (PIFA) has been widely applied in mobile devices as an internal antenna for GSM (Global System for Mobile Communication, 890 ~ 960 MHz) and DCS (Digital Communication System, 1710 ~ 1880 MHz) operation [1]. This kind of conventional PIFA, however, mainly occupies a certain portion of the system circuit board or ground plane of the mobile device, and uses it as the antenna ground plane. Hence, when such a conventional PIFA is employed in the mobile device, valuable board space is occupied. This limits the efficient integration of the employed internal antenna and the electronic components in the mobile device.

In this paper, we present a novel planar patch antenna suitable to be mounted above the system ground plane of the mobile device, without occupying the valuable space of the system ground plane. The proposed antenna mainly comprises a bottom antenna ground portion and a top radiating portion (see Fig. 1). When applied in the mobile device, the antenna ground portion, which encircles the top radiating portion in this design, is supported by conducting pins and mounted above the system ground plane. Note that the antenna ground portion has a three-dimensional structure consisting of a planar ground plane and a vertical ground wall. The latter is expected to function as an effective shielding wall to suppress the antenna's possible fringing electromagnetic (EM) fields from entering the interiors of the mobile device [2]-[3]. In this case, the possible coupling between the proposed antenna and the conducting elements mounted on the portion of the system ground plane below the antenna can be eliminated or greatly suppressed, thus resulting in very slight or no variations in the antenna performances.

2. Antenna Design

A design example of the proposed antenna for GSM/DCS operation in the PDA phone or smart phone is demonstrated. Fig. 1(a) shows the configuration of the antenna mounted above the system ground plane of the PDA phone with a height of 5 mm, and detailed dimensions of the metal pattern of the antenna unfolded into a planar structure is given in Fig. 1(b); the configuration indicates that the antenna can be fabricated from a single metal plate. The antenna has two major portions: a bottom antenna ground portion and a top radiating portion. The antenna ground portion is supported by three conducting/grounding pins of length 5 mm and mounted above the system ground plane. This configuration allows the space in between the antenna and the system ground plane reusable for accommodating associated components of the PDA phone. The antenna is also protruded over the top edge of the system ground plane with a small length of 3 mm, and the antenna ground portion is flushed to the top edge of the system ground plane. This small protrusion can effectively improve the operating bandwidths of the antenna [4]; in this case, although the thickness of the antenna is 5 mm only, which is smaller than that of general PIFAs for mobile phones [1], the obtained bandwidths of the antenna can cover the GSM and DCS operations.

In the study, the dimensions of the system ground plane are selected to be 70×100 mm^2, which are reasonable dimensions of general PDA phones. For the top radiating portion, it consists of a first radiating patch and a second radiating patch. Their detailed dimensions are given in Fig. 1(b). The two radiating patches share a common shorting strip of length 4 mm and width 2 mm, which short-circuits the two patches to the antenna ground portion. The two patches can generate a

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lower band at about 900 MHz and an upper band at about 1800 MHz for GSM/DCS operation. The first radiating patch mainly controls the upper band, while the second radiating patch mainly controls the lower band. In the design, the length of the open end of the second radiating patch is first adjusted to let the antenna's lower band occurred at about 900 MHz for GSM operation. Then, the length of the first radiating patch is adjusted to let the antenna's upper band occurred at about 1800 MHz for DCS operation. Also notice that the outer part of the first radiating patch is bent downward to achieve a compact structure of the antenna.

The antenna ground portion has a three-dimensional structure consisting of a major ground plane (size 17×60 mm^2) parallel to the top radiating portion and two vertical ground planes (sizes 5×20 mm^2 and 5×60 mm^2) parallel to the side surfaces of the antenna. The two vertical ground planes are used to shield the antenna's EM fringing fields from entering the interiors of the PDA phone. In this case, when there are conducting elements placed below the antenna, small effects on the performances of the antenna can be obtained. Related results of placing a RF shielding metal case (shown in Fig. 1(a) with a volume of $70 \times 25 \times 4.5$ mm^3) below the antenna will be discussed with the aid of Fig. 4. This metal case can provide a coupling-free space for accommodating the associated electronic components of the PDA phone.

3. Results and Discussion

In the experiment, a 50-Ω mini coaxial line is used to feed the antenna across the feeding point (point A) and the grounding point (point B) shown in Fig. 1. Fig. 2 shows the measured and simulated return loss for the fabricated prototype without the presence of the shielding metal case. The simulated results are obtained using Ansoft simulation software HFSS, and agreement between the measurement and simulation is seen. Two operating bands of the antenna are excited with good impedance matching. The lower band is formed by the quarter-wavelength resonant mode generated by the second radiating patch and has an impedance bandwidth, defined by 3:1 VSWR or 6 dB return loss, of 90 MHz, which allows the antenna to easily cover the GSM operation. Note that the bandwidth definition of 3:1 VSWR is generally used for mobile phone antennas for practical applications. The upper band shows an impedance bandwidth of 253 MHz, allowing it to easily cover the DCS operation. The upper band is formed by two adjacent resonant modes. The one at about 1700 MHz is a quarter-wavelength mode generated by the first radiating patch and the other one at about 1900 MHz is the higher-order mode generated by the second radiating patch.

Effects of a nearby conducting element on the performances of the antenna are studied. Fig. 3 shows the experimental photo of the antenna with the shielding metal case placed below it. The measured return loss for the antenna with and without the shielding metal case is presented in Fig. 3. Small effects on the measured return loss are obtained. This behavior can be explained from the simulated surface current distributions on the antenna and the system ground plane shown in Fig. 4 for the proposed antenna and the reference antenna (the case without the presence of the antenna ground portion). On the portion of the system ground plane near the antenna the surface current distribution is seen to be much smaller for the proposed antenna than for the reference antenna. Thus, with the metal case placed below the proposed antenna, small effects on the antenna performances can be expected.

Radiation characteristics of the antenna are also studied. Measured radiation patterns in three principal planes at 925 and 1795 MHz (center frequencies of the GSM and DCS bands) are plotted in Fig. 5, respectively. Results for other frequencies over the GSM and DCS bands are also studied, which are found to be similar to the patterns plotted here and are thus not shown for brevity. At 925 MHz, monopole-like radiation pattern is generally obtained, and near-omnidirectional radiation pattern in the *x-y* plane (azimuthal plane) is seen. At 1795 MHz, more variations in the radiation patterns compared to those at 925 MHz are seen. These radiation patterns show no special distinctions compared to those of the conventional mobile phone antennas [1]. Fig. 6 shows the measured antenna gain and simulated (HFSS) radiation efficiency for the antenna studied in Fig. 2. Over the GSM band shown in Fig. 6(a), the antenna gain is varied from about 1.0 to 2.1 dBi, and the radiation efficiency is all larger than 70%. Over the DCS band shown in Fig. 6(b), the antenna gain is about 3.0 ~ 3.4 dBi and the radiation efficiency is all larger than 80%.

4. Conclusion

A planar dual-band patch antenna mounted above the system ground plane of the mobile phone for GSM/DCS operation has been proposed. The antenna does not directly occupy the valuable space on the system ground plane, and a usable space below the antenna for accommodating the conducting elements or electronic components is provided. In addition, owing to the use the proposed ground portion that encircles the antenna's top radiating portion, the performances of the antenna are found to be very slightly affected by the conducting element placed below the antenna. This behaviour can lead to a compact integration of the antenna employed in the mobile device.

References

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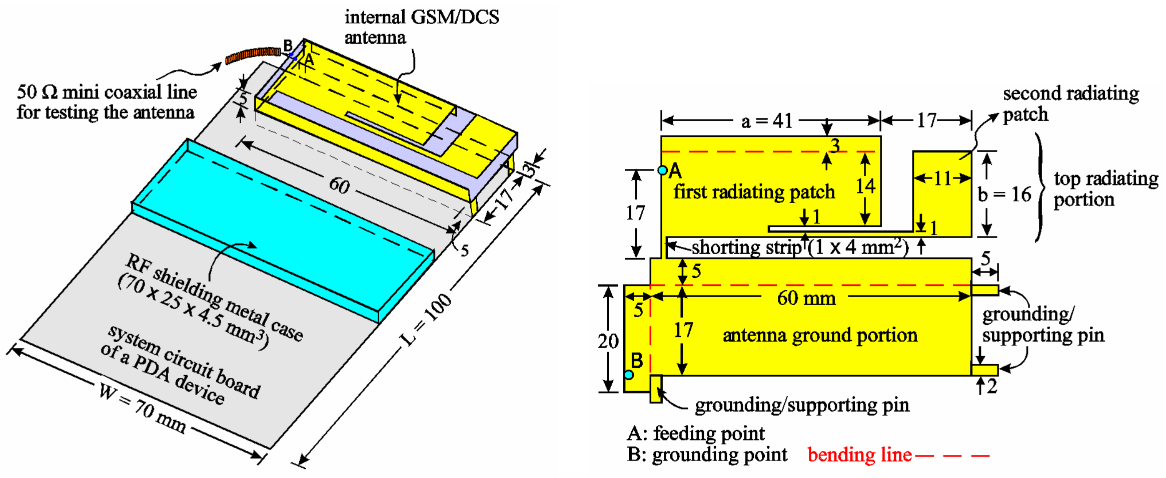

(a) (b)

Figure 1: (a) Geometry of the proposed antenna mounted above the system ground plane of the PDA phone. (b) Detailed dimensions of the antenna unfolded into a planar structure.

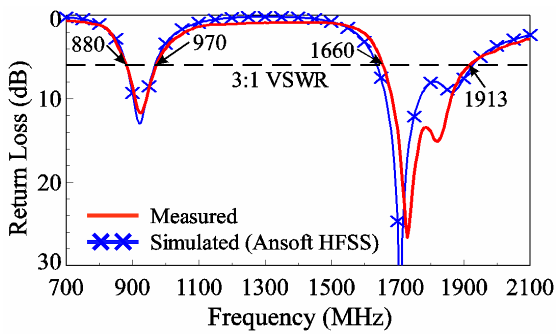

Figure 2: Measured and simulated return loss; the RF shielding metal case shown in Fig. 1 is not present.

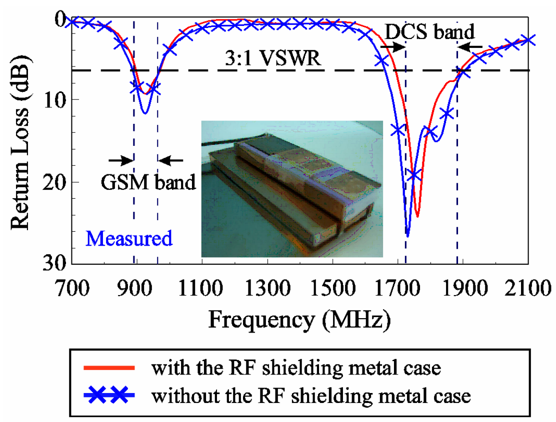

Figure 3: Measured return loss for the antenna with and without the RF shielding metal case.

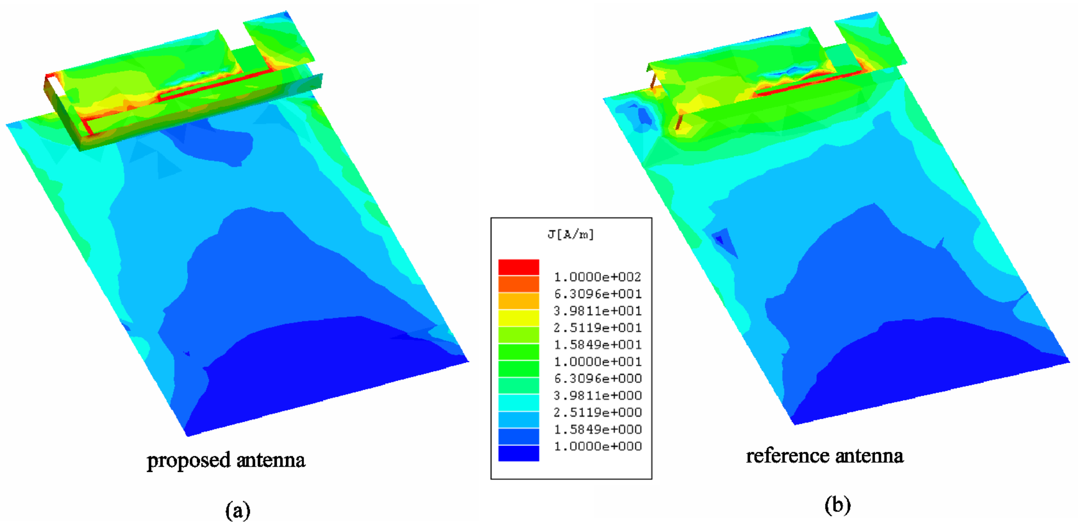

Figure 4: Simulated surface current distributions on the antenna and the system ground plane at 925 MHz for the case studied in Fig. 2. (a) The antenna with h = 5 mm studied in Fig. 2. (b) The top radiating portion directly mounted above the system ground plane with a height of 8 mm (the antenna ground portion not present).

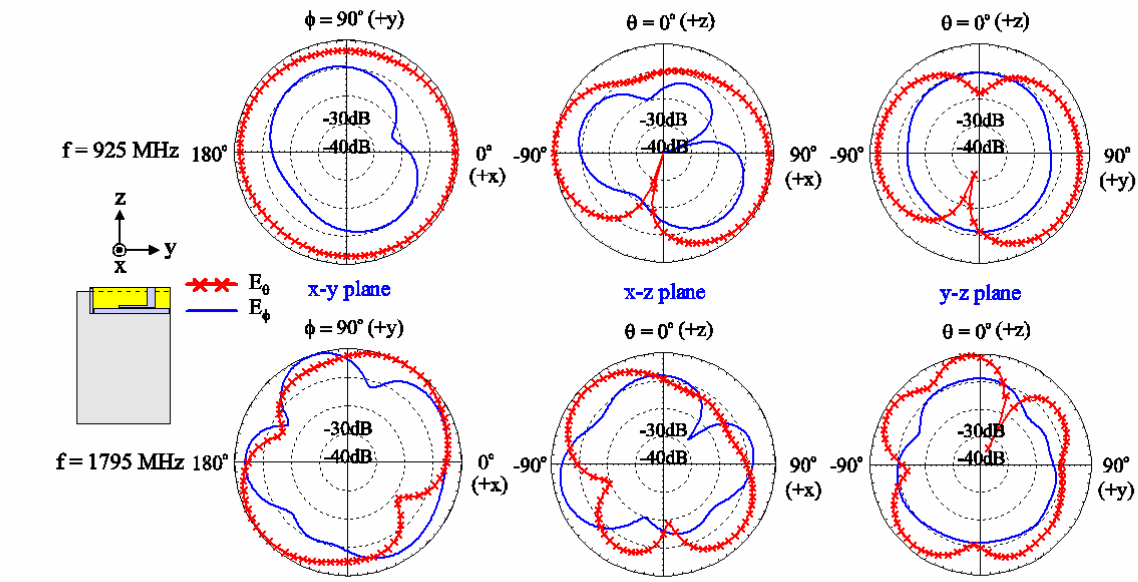

Figure 5: Measured radiation patterns at 925 and 1795 MHz for the antenna studied in Fig. 2.

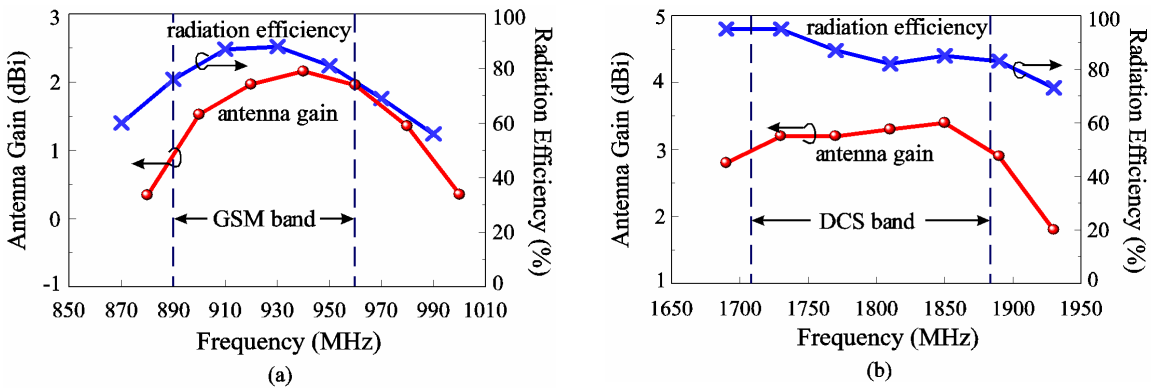

Figure 6: Measured antenna gain and simulated radiation efficiency for the antenna studied in Fig. 2. (a) The GSM band. (b) The DCS band.