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BUILT-IN DUAL FREQUENCY ANTENNA WITH AN EMBEDDED CAMERA AND A VERTICAL GROUND PLANE

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Abstract—A thin internal planar antenna for GSM/DCS with a hollow shorting cylinder suitable for integration with an embedded digital camera for a mobile phone is presented. A small vertical ground plane electrically connected to the system ground plane of the mobile phone is used. The vertical ground plane can function as an effective shield wall between the antenna and the nearby electronic elements in the mobile phone. The method of moments is used to simulate the antenna structure and calculate the radiation characteristics of the antenna.

1. INTRODUCTION

Planar antennas, including microstrip and printed antennas and other types of antennas that are flat in appearance and have a low profile, have recently received much attention for application in cellular communication systems, such as the global system for mobile communication (GSM), the digital communication system for mobile (DCS), personal communication system (PCS), the universal mobile telecommunication system (UMTS), and wireless local area networks (WLANs) in the 2.4 GHz and 5.2 GHz bands. Many novel designs of planar antennas for the above applications have been reported very recently [1–11]. The configuration of the conventional internal patch antenna, however allows the fringing electromagnetic (EM) fields to easily penetrate into the surrounding region of the antenna. In this case, some coupling between the antenna and the nearby electronic components will occur resulting in degrading effects on the performance of the antenna. To reduce this degrading coupling effect, an isolation distance of about 7 mm or larger between the antenna and the nearby electronic components is usually required for practical applications [3]. This isolation distance leads to an inefficient usage of the valuable board space of the system circuit board of the mobile device. In many wireless devices, a digital camera is usually embedded, preferably at the top portion of the device's system circuit board as well and thus competing for the very limited space of the system circuit board with the internal antenna.

In this paper, a thin GSM/DCS dual-band internal patch antenna with an air-layer substrate as in [5] is presented. Hollow shorting cylinder is used to accommodate the charge-coupled device (CCD) of an embedded digital camera in a mobile phone, thus leading to a compact integration of the antenna and CCD. The shorting cylinder also serves to support the proposed antenna firmly above the grounded substrate. Small vertical ground plane electrically connected to the system ground plane of the mobile phone is presented. The vertical ground plane can function as an effective shielding wall between the antenna and the nearby RF-shielding metal case or other associated elements in a mobile phone. In this case, the internal antenna can be compactly integrated within the mobile phone without degradation of the antenna performances.

2. ANALYSIS

The simulated results in this paper are obtained using the method of moments (MoM) [12]. The radiation characteristics of the antenna starting from the total field equation:

$$\overline{E}(r) = \overline{E}_i(r) + \int_s \overline{G}(r/r') \cdot \overline{J}(r') ds' \tag{1}$$

where $\overline{E}(r)$ is the total tangential field on the surface, $\overline{E}_i(r)$ is the incident field on the conducting surface, $\overline{G}(r/r')$ is the dyadic Green's function, and $\overline{J}(r')$ is the current distribution on the conducting surface S. For a typical highly conductive structure, the induces current is flowing on the conducting surface S of the antenna and boundary conditions

$$\overline{E}(r) = Z_s(r)\overline{J}(r), \quad r \in S \tag{2}$$

where $Z_s(r)$ is the surface impedance of the conductor. From Eqs. (1) and (2), then

$$Z_s(r)\overline{J}(r) = \overline{E}_i(r) + \int_s \overline{G}(r/r') \cdot \overline{J}(r')ds' \tag{3}$$

By assuming that the current distribution is represented by a set of complete basis functions:

$$\overline{J}(r') = \sum_n^N I_n \overline{B}_n(r'), \quad n = 1, 2, 3, \ldots \tag{4}$$

where, N is the number of finite terms. After some manipulations and using the test functions the same as the basis functions (Galerkin's method), Eq. (3) becomes an $N \times N$matrix equation,

$$[Z_{mn}][I_n] = [V_m] \tag{5}$$

where

$$Z_{mn} = \int_s Z_s(r)\overline{B}_m(r) \cdot \overline{B}_n(r)ds - \int_s ds \int_s \overline{B}_m(r) \cdot \bar{G}(r/r') \cdot \overline{B}_n(r')ds' \tag{6}$$

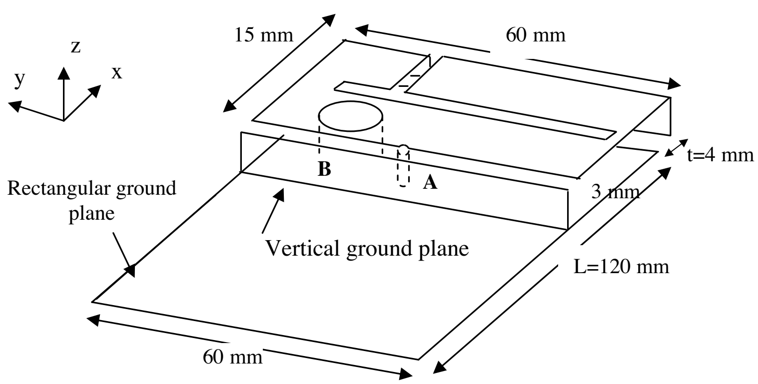
$$V_m = \int_s \overline{E}_i(r) \cdot \overline{B}_n(r)ds \tag{7}$$

The solutions of Eq. (5) are the coefficients of the expanded current distribution in Eq. (4).

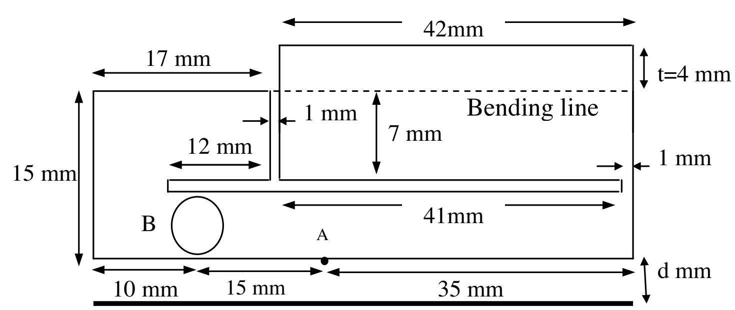
In this analysis roof-top functions are used to approximate the current distribution on the antenna. A roof-top function is a ramp in the longitudinal direction and constant on the transverse direction. After the current distribution is solved, the antenna parameters can be calculated.

3. NUMERICAL RESULTS

Figure 1 shows the geometry of the antenna mounted at the top portion of the system ground plane of a mobile phone (size $60 \times 120\,\text{mm}^2$). The antenna uses a hollow shorting cylinder of diameter 6 mm in place of a conventional shorting pin to contain the lens of a practical embedded digital camera. The occupied volume of the antenna is about the same as that in [5]. The vertical ground has the same height (3 mm) as the antenna thickness and at a distance $d = 0.5$ mm from the antenna. Before extensive numerical calculations are performed, the radiation characteristics of the internal GSM/DCS patch antenna for a portable mobile terminal as in [5, Figure 1] were calculated to verify the accuracy of the computer program. Figure 2 depicts the variation of the return loss in dB versus the frequency for the antenna structure. The radiation characteristics of the antenna are compared with the measurements in Figures 3 at frequency $f = 925$ and $f = 1795$ MHz. Good agreement is observed between the simulated results and the measured results. The hollow shorting cylinder of diameter 6 mm is used as a first modification for the antenna structure in [5]. The position of the feeding pin is modified as in Figure 1 to keep the same resonant frequencies approximately the same as in [5]. The effect of the hollow shorting cylinder on the return loss and on the radiation characteristics are depicted on Figures 4 and 5. The radiation patterns with and without the hollow shorting cylinder are almost identical. Figure 6 shows the simulated results of the return loss after adding the vertical plane at a distance $d = 0.5$ mm from the edge of the antenna



(a)



(b)

Figure 1. (a) Geometry of the mobile-phone antenna. (b) Top view.

(see Figure 1). The impedance bandwidth, defined by 2.5:1 VSWR (about 7.3 dB return loss) is 94 MHz for the GSM band and 189 MHz for DCS band. Figure 7 shows the radiation patterns of the antenna at 925 MHz and 1795 MHz in different plane. Stable radiation patterns are noticed.

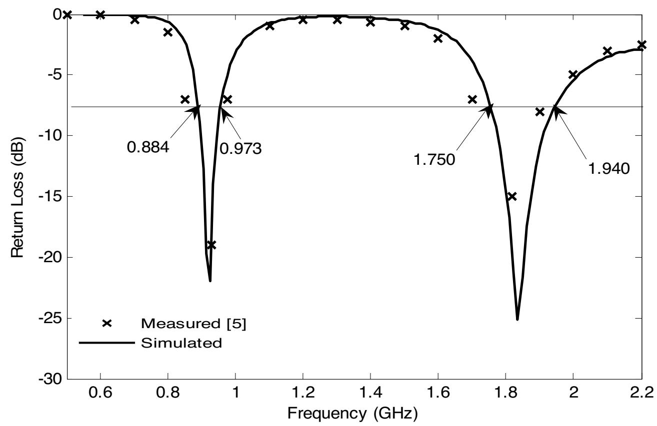
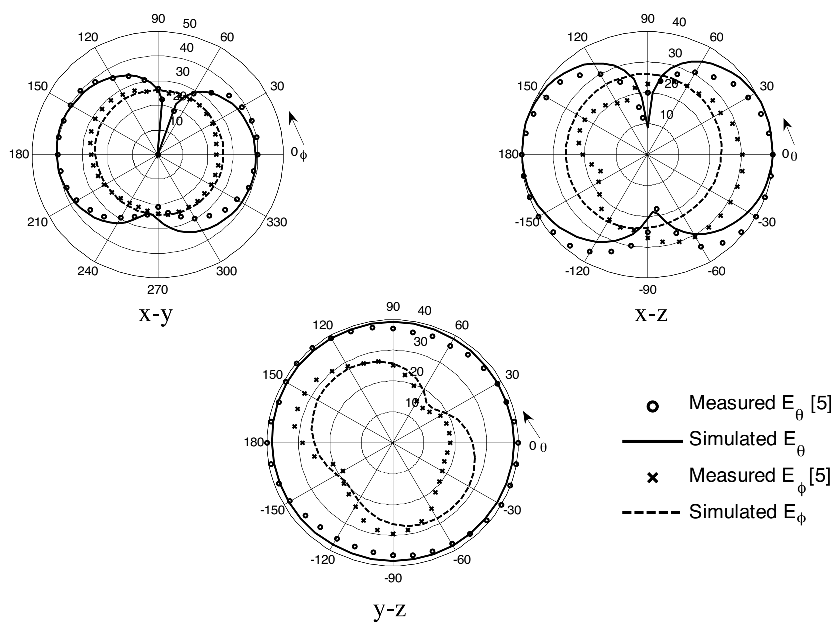
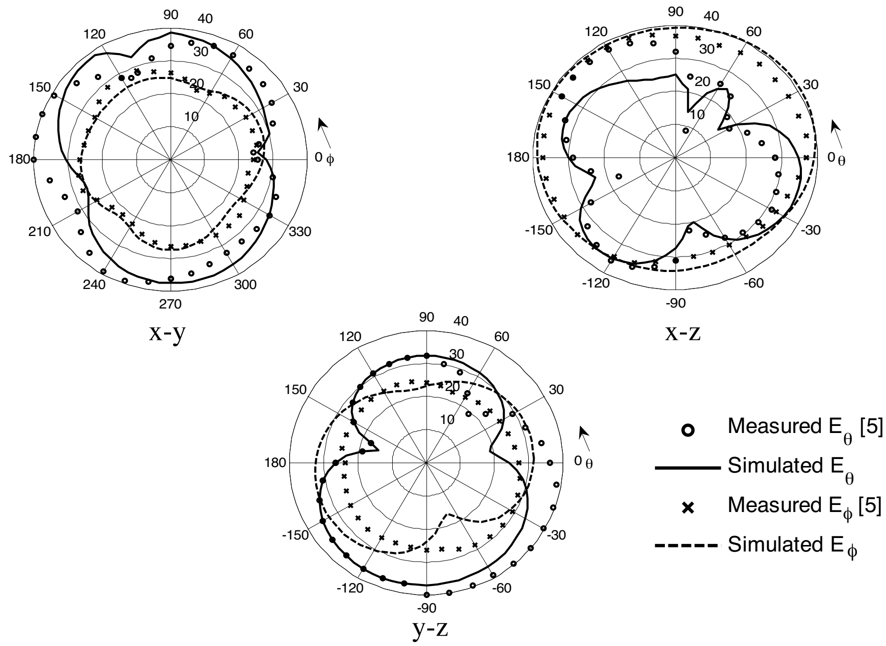


Figure 2. Simulated and measured return loss.



(a)



(b)

Figure 3. Simulated and measured radiation pattern in different planes. (a) at $f = 925\,\text{MHz}$, (b) at $f = 1795\,\text{MHz}$.

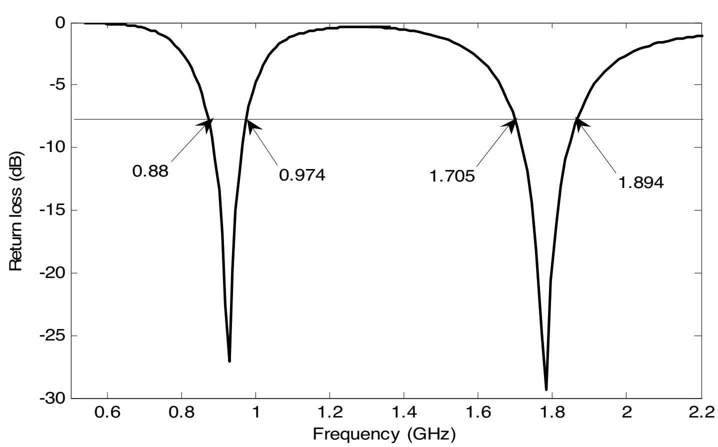


Figure 4. Simulated return loss after acting the hollow shorting cylinder.

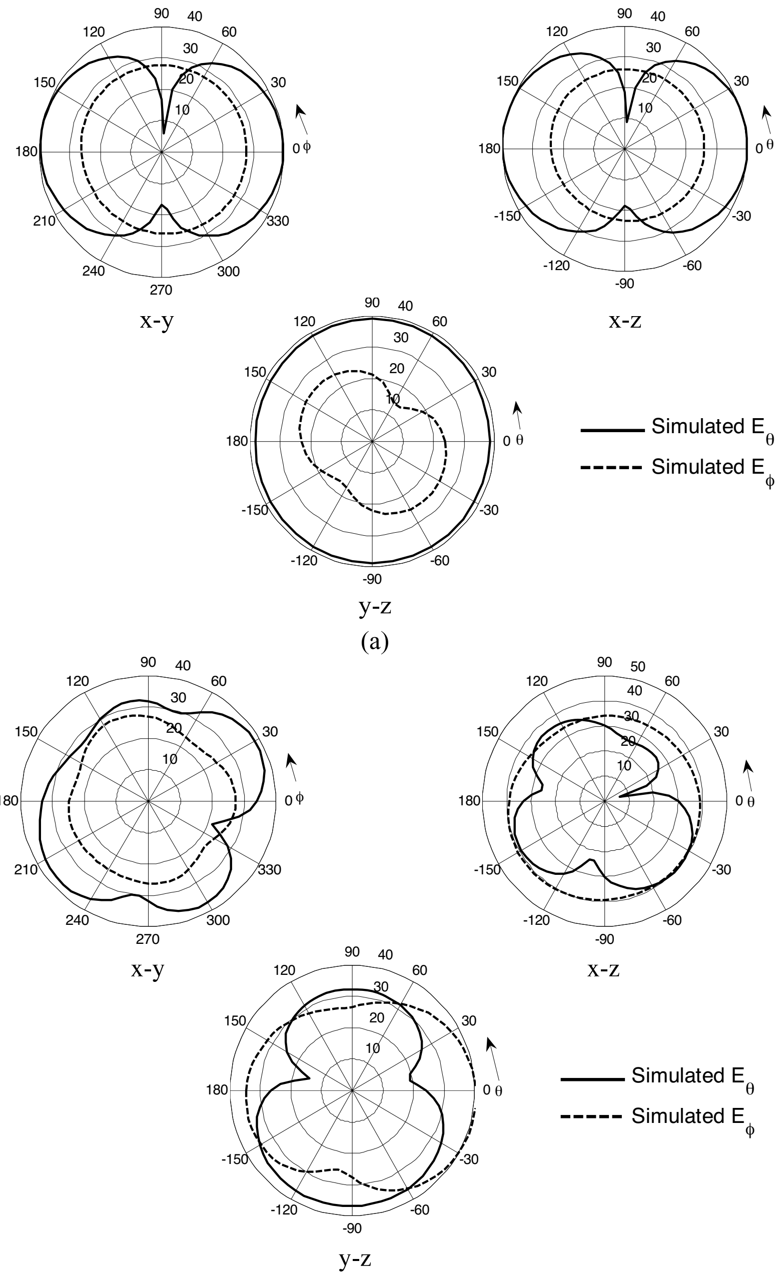


Figure 5. Simulated radiation pattern in different planes after adding the hollow shorting cylinder. (a) $f = 925\,\text{MHz}$, (b) $f = 1795\,\text{MHz}$.

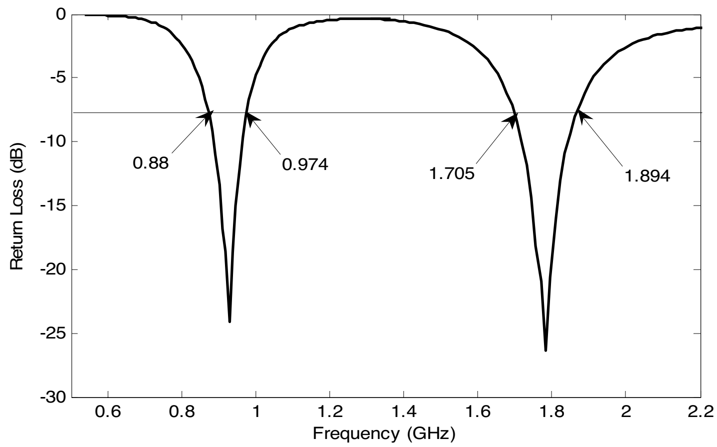
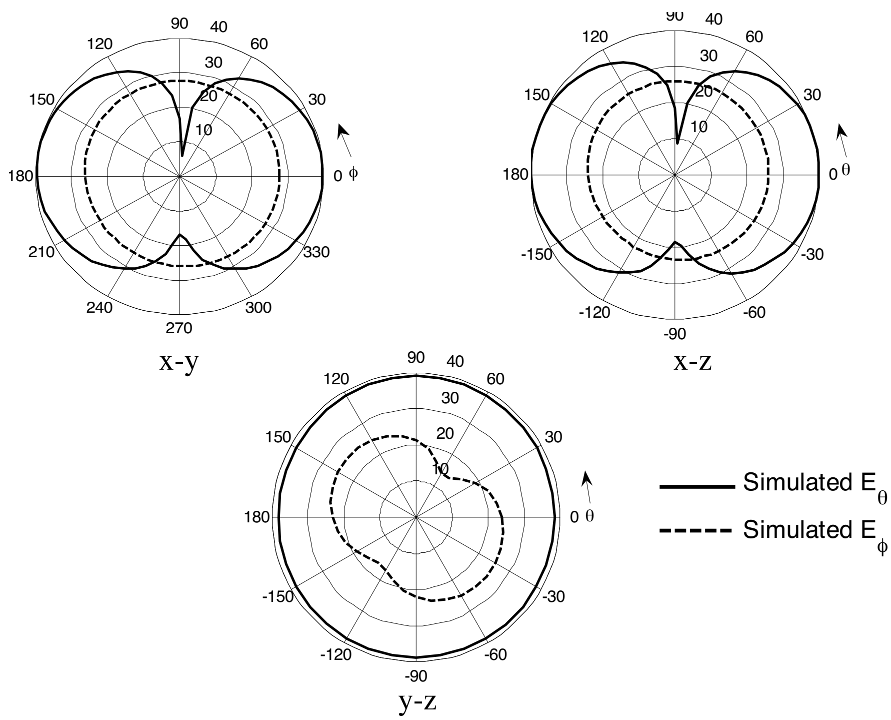


Figure 6. Simulated return loss after acting the hollow shorting cylinder and vertical plate.



(a)

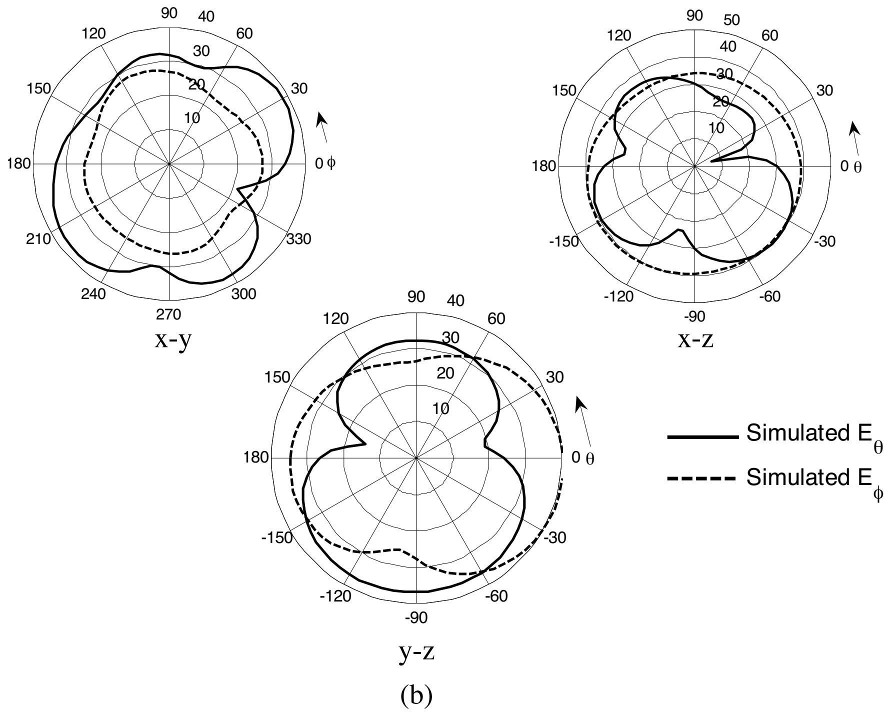


Figure 7. Simulated and measured radiation pattern in different planes after adding the hollow cylinder and vertical plate. (a) at $f = 925\,\text{MHz}$, (b) at $f = 1795\,\text{MHz}$.

4. CONCLUSIONS

A built-in dual frequency antenna with an embedded camera and a vertical ground plane is investigated. A vertical-ground plane is used. Hollow shorting cylinder is proposed to embedded the digital camera inside the antenna structure. Good isolation behavior between the antenna and a nearby element such as the RF-shielding metal case inside the mobile phone has been achieved. Good radiation characteristics has been observed.

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