A Low-Profile Planar Monopole Antenna for Multiband Operation of Mobile Handsets

Kin-Lu Wong, *Senior Member, IEEE*, Gwo-Yun Lee, and Tzung-Wern Chiou

***Abstract*—A novel planar monopole antenna with a very low profile (antenna height less than 0.04 times the operating wavelength in the free space) and capable of multiband operation is proposed. The proposed antenna has a planar rectangular radiating patch in which a folded slit is inserted at the patch's bottom edge. The folded slit separates the rectangular patch into two subpatches, one smaller inner subpatch encircled by the larger outer one. The proposed antenna is then operated with the inner subpatch resonating as a quarter-wavelength structure and the outer one resonating as both a quarter-wavelength and a half-wavelength structure. The proposed antenna, 12 mm in height and 30 mm in width has been constructed, and the obtained bandwidths cover the global system for mobile communication (890–960 MHz), digital communication system (1710–1880 MHz), personal communication system (1850–1990 MHz), and universal mobile telecommunication system (1920–2170 MHz) bands. Details of the proposed design and obtained experimental results are presented and discussed.**

***Index Terms*—Antennas, mobile antennas, monopole antennas, multifrequency antennas.**

I. INTRODUCTION

BROAD-BAND or dual-band planar monopole antennas [1]–[6] with a reduced antenna height are very attractive for mobile handset antenna applications. For the planar monopole antennas reported in [1] and [2], the radiating element is a circular disc or an elliptical disc, and a very wide bandwidth has been shown. However, the antenna height of such planar monopole antennas is larger than about $0.15\lambda_0$ (λ_0 is the operating wavelength in free space), which makes it less attractive to be employed in mobile handsets. To achieve a reduced antenna height for broad-band or dual-band planar monopole antennas, a variety of designs have also been demonstrated [3]–[6]. These designs include introducing a shorting pin to the planar monopole antenna [3], fabricating the radiating strip of the monopole antenna on a substrate of very high relative permittivity (about 80) [4], using a stacked planar monopole consisting of a top-loaded element and a parasitic square element [5], modifying the geometry of a bent folded monopole/loop antenna [6]. However, the antenna height for these designs is still greater than $0.1\lambda_0$.

In this paper, we propose a novel planar monopole antenna design with a very low antenna height less than $0.04\lambda_0$ (the total antenna height is only 12 mm for operating at the 900-MHz band). In addition, the proposed antenna is also capable of multiband operation, covering the 900-MHz-band global system for mobile communication (GSM), 1800-MHz-band digital communication system (DCS), 1900-MHz-band personal communication system (PCS), and 2050-MHz-band universal mobile telecommunication system (UMTS). The proposed design is described in detail in this paper, and experimental results of the constructed prototype are presented and discussed.

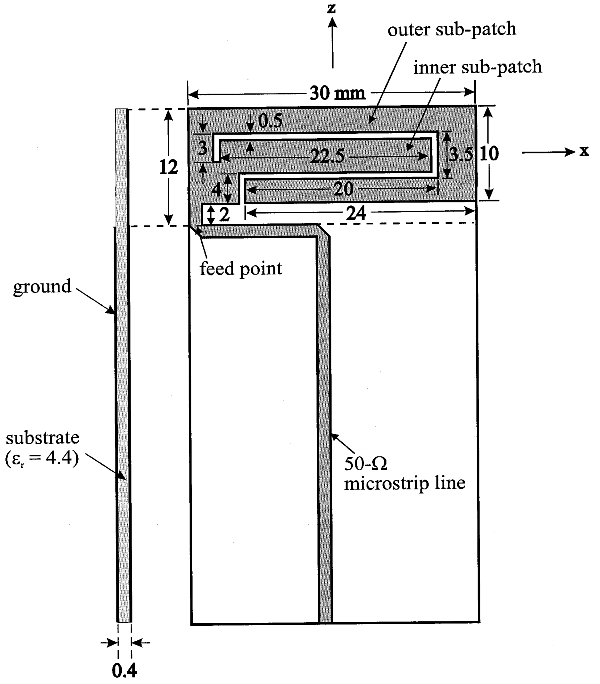

Fig. 1. Geometry and dimensions of the proposed low-profile planar monopole antenna for GSM/DCS/PCS/UMTS operation.

II. ANTENNA DESIGN

Fig. 1 shows the proposed low-profile planar monopole antenna. The radiating element is a rectangular patch with a folded slit inserted at its bottom edge, and is printed on an inexpensive FR4 substrate (thickness 0.4 mm, relative permittivity 4.4) as shown in the figure. A 50-Ω microstrip line is used to feed the monopole antenna, and is printed on the same substrate. On the other side of the substrate, there is a ground plane below the microstrip feed line. This ground plane was selected to be 30×60 mm^2 in the experiment, which can be considered to be the ground plane of a practical mobile handset.

The radiating rectangular patch has dimensions of 10×30 mm^2 and is placed on top of the ground plane with a distance of 2 mm. The dimensions of the folded inserted slit are shown in the figure. The major effect of the folded slit is to separate the rectangular patch into two subpatches,

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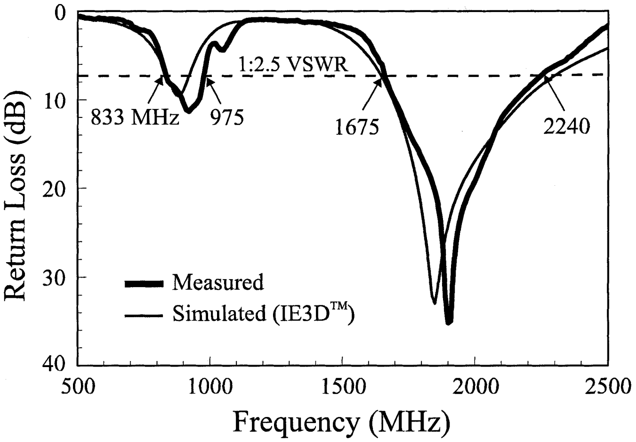


Fig. 2. Measured and simulated return loss for the proposed antenna.

one smaller inner subpatch and one larger outer subpatch. It should be noted that the open end of the folded slit at the patch's bottom edge is placed close to the feed point, and the other end inside the patch is also designed to be close to the feed point. In this case, the smaller inner subpatch is encircled by the outer one, which leads to two possible excited surface current paths inside the rectangular patch. The longer path starts from the feed point and follows the folded slit to the open end of the slit at the patch's bottom edge, while the shorter one is from the feed point to the end of the inner subpatch encircled by the folded slit. It can be seen that the length of the longer path is much greater than the length of the rectangular patch, which makes the fundamental resonant frequency of the proposed antenna greatly lowered. In the proposed design shown in Fig. 1, this length is about 70 mm, which is slightly less than one-quarter wavelength of the operating frequency at 900 MHz. This difference is largely due to the effect of the supporting FR4 substrate, which reduces the resonant length of the radiating element [3].

On the other hand, the length of the shorter path in the proposed design is about 30 mm, which makes it possible for the excitation of a quarter-wavelength resonant mode at about 2000 MHz. This resonant mode incorporating the second-higher (half-wavelength) resonant mode of the longer path, which is expected to be at about 1800 MHz, forms a wide impedance bandwidth covering the bandwidths of the 1800-, 1900-, and 2050-MHz bands for the proposed antenna. A prototype of the proposed antenna shown in Fig. 1 was constructed, and experimental results are shown in Section III.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Fig. 2 shows the measured return loss of the proposed antenna. It is clearly seen that two wide operating bandwidths are obtained. The lower bandwidth, determined by 1 : 2.5 VSWR, reaches 142 MHz and covers the GSM band (890–960 MHz). On the other hand, the upper band has a bandwidth as large as 565 MHz and covers the DCS (1710–1880 MHz), PCS (1850–1990 MHz), and UMTS (1920–2170 MHz) bands. The measured data in general agree with the simulated results. The excited surface current distributions, obtained from the IE3D simulation, on the radiating patch for the proposed antenna at 900, 1800, 1900, and 2050 MHz are also presented in Fig. 3. For the 900-MHz excitation, a larger surface current distribution is observed for the longer path along the outer subpatch. This suggests that the outer subpatch is the major radiating element for the proposed antenna at the 900-MHz band, and the outer sub-patch is operated as a quarter-wavelength structure as discussed in Section II. For the 1800-, 1900-, and 2050-MHz operation, it is observed that the surface current distribution in the inner subpatch gradually increases. This also indicates that the inner subpatch is the major radiating element for the higher operating frequencies of the antenna's upper band, especially in the 2050-MHz band, and is also operated as a quarter-wavelength structure. As for the lower operating frequencies of the antenna's upper band, it is largely related to the outer subpatch operated as a half-wavelength structure. This can be explained that the current distributions in the outer subpatch are larger for the 1800- and 1900-MHz operations than for the 2050-MHz operation.

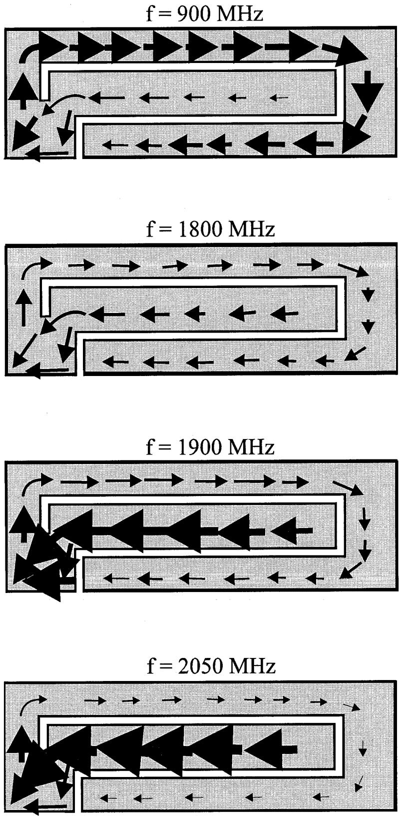


Fig. 3. Simulated IE3D results of the surface current distributions on the radiating patch for the proposed antenna at 900, 1800, 1900, and 2050 MHz.

Figs. 4 and 5 plot the measured radiation patterns in the xy plane (azimuthal direction) and yz plane (elevation direction) for the proposed antenna at 900, 1800, 1900, and 2050 MHz. Although the obtained radiation patterns are not as good as those of a conventional simple monopole antenna having a very good azimuthal omni-directional pattern and null radiation along the antenna axis ($\theta = 0^\circ$), the proposed antenna in general shows a monopole-like radiation pattern. Fig. 6 shows the measured antenna gain against frequency for the proposed antenna. For the 900-MHz band, a peak antenna gain of about 2.9 dB is observed,

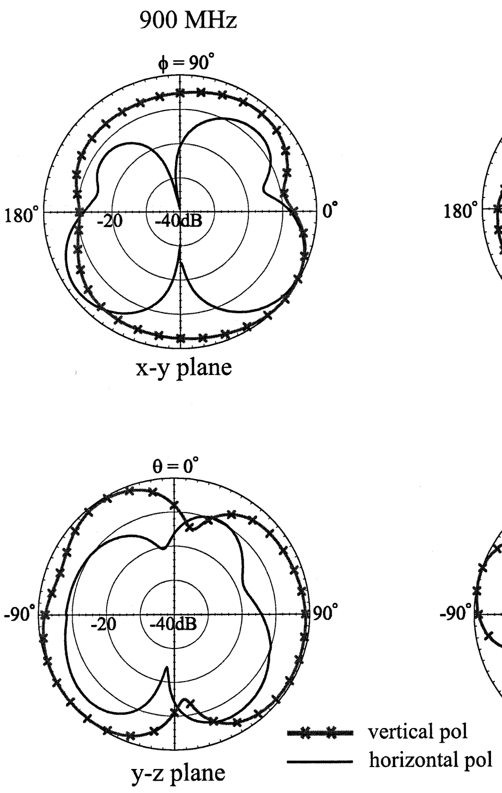


Fig. 4. Measured radiation patterns for the proposed antenna at: (a) 900 MHz and (b) 1800 MHz.

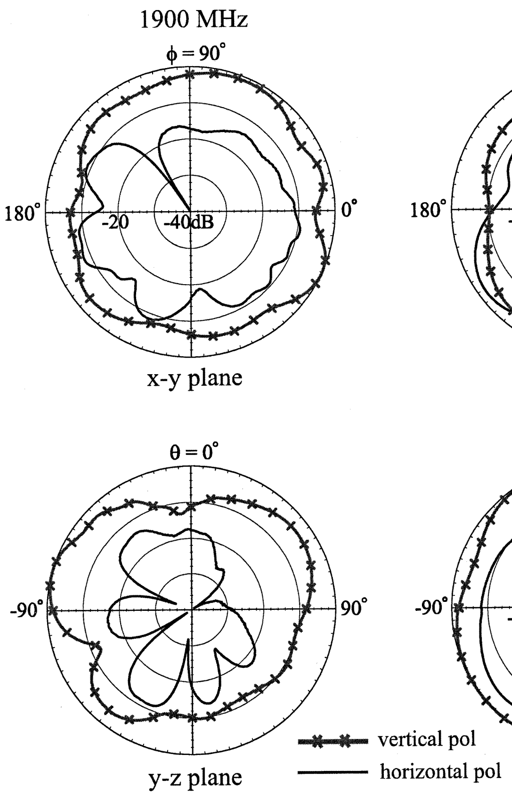
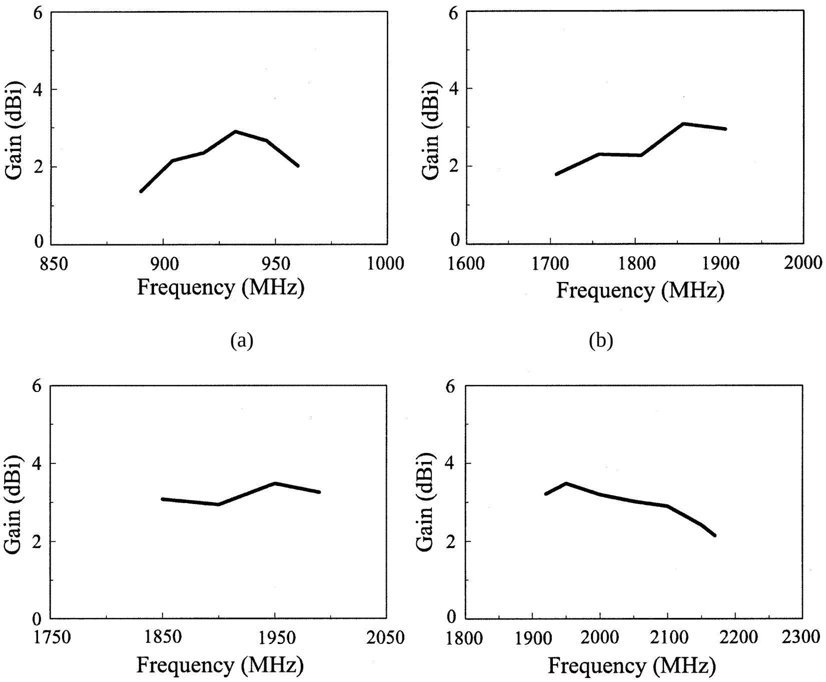


Fig. 5. Measured radiation patterns for the proposed antenna at: (a) 1900 MHz and (b) 2050 MHz.

with gain variations less than 1.5 dB. For the 1800-, 1900-, and 2050-MHz bands, the peak antenna gain observed is 3.0, 3.4, and 3.4 dB, respectively, and the gain variations are also less than 1.5 dB.



(a) (b)

(c) (d)

Fig. 6. Measured antenna gain for the proposed antenna. (a) The GSM band (890–960 MHz). (b) The DCS band (1710–1880 MHz). (c) The PCS band (1850–1990 MHz). (d) The UMTS band (1920–2170 MHz).

IV. CONCLUSION

A novel low-profile planar monopole antenna suitable for multiband operation of mobile handsets has been proposed. A prototype of the proposed antenna has been successfully implemented, and the antenna occupies a small area of 12×30 mm^2. The obtained bandwidths meet the bandwidth requirements of the GSM, DCS, PCS, and UMTS cellular systems.

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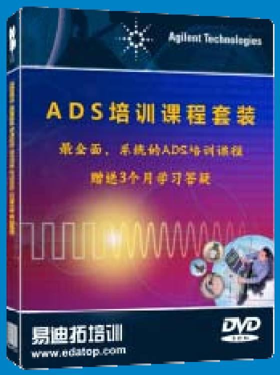

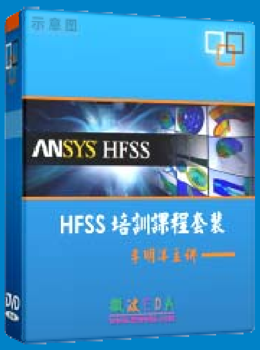

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