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MICROWAVE AND OPTICAL TECHNOLOGY LETTERS

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ISSN 0895-2477

MOTL 40(5) 349-442 (2004)

Volume 40, Number 5 was mailed the week of February 2, 2004

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finite-integration software to solve the microwave propagation for a microstrip device with such a photo-induced load.

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QUAD-BAND INTERNAL MONOPOLE MOBILE-PHONE ANTENNA

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Received 2 August 2003

ABSTRACT: A novel internal monopole antenna suitable for applications in AMPS/GSM/DCS/PCS quad-band mobile phones is presented. The antenna comprises two orthogonal wideband monopole elements for operation at about 900 and 1850 MHz, covering the APMS/GSM (824–894/890–960 MHz) and DCS/PCS (1710–1880/1850–1990 MHz) bands, respectively. The quad-band monopole antenna is also arranged in a compact structure such that it has a low profile (only 6 mm in this study) and protrudes from the top edge of the system ground plane of a communications device, thus making it very promising as an internal antenna, built-in within the device's casing. © 2004 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 40: 359–361, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11381

Key words: antennas; monopole antennas; quad-band antennas; mobile antennas

1. INTRODUCTION

A variety of low-profile planar monopole antennas for dual- or triple-band operation in the global system for mobile communication (GSM, 890–960 MHz), the digital communication system (DCS, 1710–1880 MHz) and personal communication system (PCS, 1850–1990 MHz) have recently been demonstrated [1–4]. These planar monopole antennas have the attractive feature of low profile in appearance, thereby making them very promising as internal antennas, built-in or concealed within the casing of a communications device. In this paper, we propose another novel dual-frequency planar monopole antenna for application as an

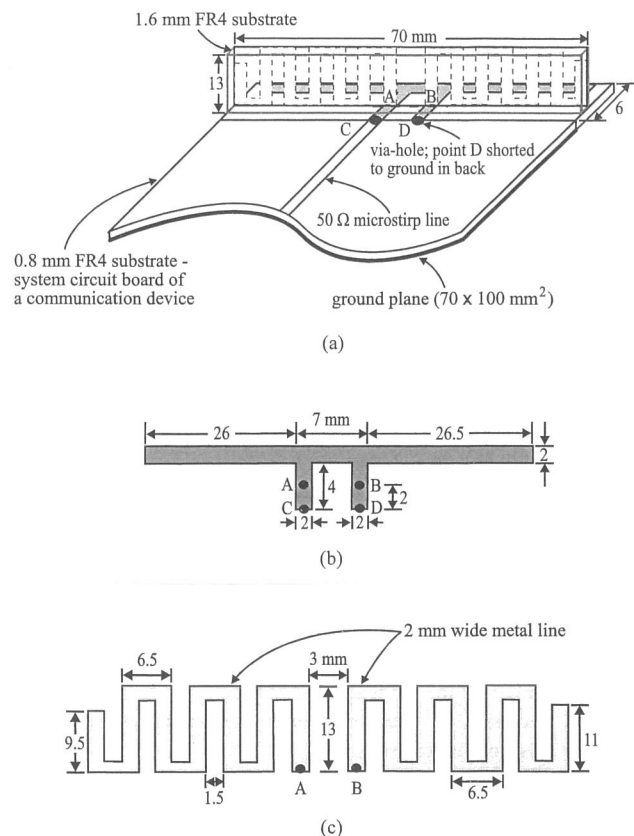


Figure 1 (a) Proposed quad-band internal monopole mobile-phone antenna mounted on the top portion (ungrounded portion) of the system circuit board of a communications device; (b) printed metal line on the system circuit board (high-frequency element); (c) printed metal line mounted vertically on the system circuit board (low-frequency element)

internal mobile-phone antenna. In addition, the proposed antenna has wide impedance bandwidths for both its two operating frequencies, thus making the antenna capable of quad-band operation in the advanced mobile phone system (APMS, 824–894 MHz), GSM (890–960 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz) bands. Details of the proposed antenna are described, and the experimental results of a constructed prototype are presented.

2. DESIGN CONSIDERATIONS

Figure 1(a) shows the geometry of the proposed antenna mounted on the top portion (ungrounded portion) of a grounded FR4 substrate, which has a size about that of the system circuit board of a communications device, such as a practical personal digital assistant (PDA) phone. A ground plane of size 70 × 100 mm², which does not cover the top portion (70 × 6 mm²) of the substrate that accommodates the proposed antenna, is printed on the back surface of the FR4 substrate.

The proposed antenna comprises two orthogonal wideband monopole elements for operation at about 900 and 1850 MHz, respectively. The first wideband monopole element [high-frequency element, see Fig. 1(b)] is printed on the system circuit board and is a shorted π-shape monopole formed by a π-shape matching bridge connecting two metal lines of different lengths (26 and 26.5 mm, in this study) extended in opposite directions. These two metal lines of different lengths provide two resonant paths of slightly different lengths. This condition effectively results in the excitation of two closely spaced resonant modes at

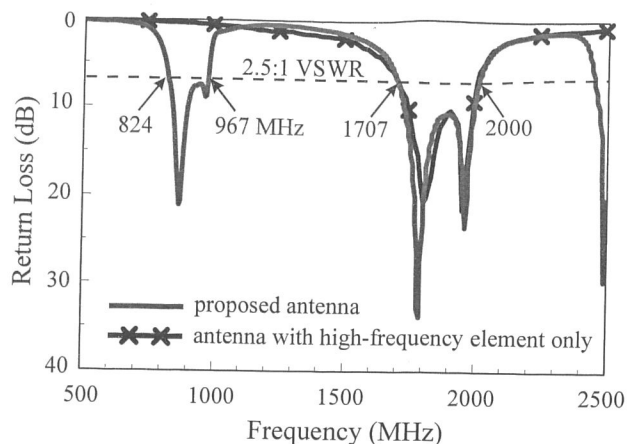


Figure 2 Measured return loss for the proposed antenna and the antenna with the high-frequency element only

about 1850 MHz, in this design, which lead to a wide operating band covering the DSC and PCS bands. For the π -shape matching bridge, its open end at point C is connected to a 50Ω microstrip feed line printed on the front surface of the FR4 substrate, and the open end at point D is short-circuited to the ground plane in back through a via-hole in the substrate.

The second wideband monopole element [low-frequency element, see Fig. 1(c)] is printed on a 1.6-mm FR4 substrate, which serves as a supporter for the second element, and then is mounted orthogonally and connected to the matching bridge of the first element at points A and B. The second element also has two metal lines of slightly different lengths, which are meandered to achieve a compact structure, extended in opposite directions for providing two closely spaced resonant modes in order to form a wide operating band at about 900 MHz. This obtained low-frequency operating band covers the AMPS and GSM bands in this design. Also note that, through controlling the size of the π -shape matching bridge [its optimal dimensions are given in Fig. 1(b)], good impedance matching for both the low- and high-frequency operating bands of the proposed antenna is easily achieved.

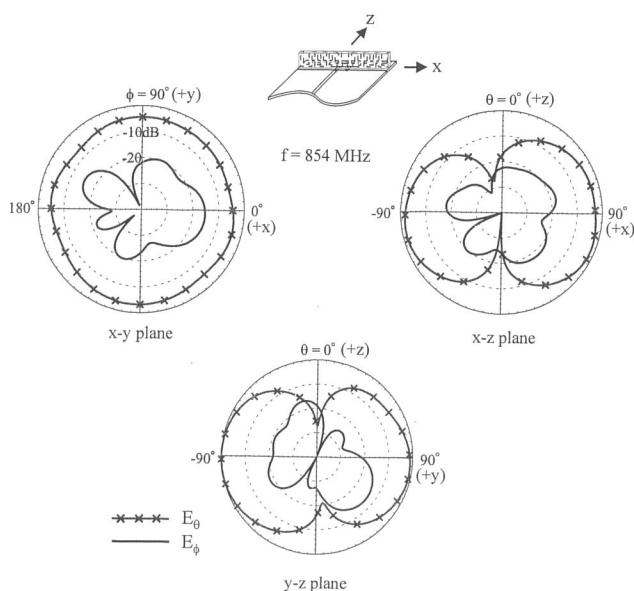


Figure 3 Measured radiation patterns at 854 MHz

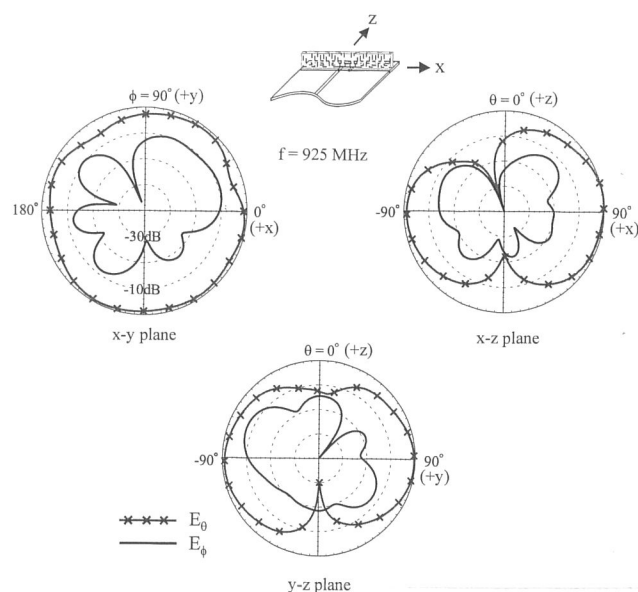


Figure 4 Measured radiation patterns at 925 MHz

3. EXPERIMENTAL RESULTS AND DISCUSSION

Based on the design dimensions shown in Figure 1, which are obtained with the aid of the Ansoft simulation software high-frequency structure simulator (HFSS), a prototype of the proposed antenna was constructed and tested. Figure 2 shows the measured return loss of the constructed prototype. The result for the case with the presence of the high-frequency element only is also shown for comparison. From the results it is clearly seen that, as designed, each monopole element in the proposed antenna generates two closely spaced resonant modes to form a wide operating band at about 900 or 1850 MHz. The impedance bandwidths (2.5:1 VSWR) obtained for the two operating bands cover the required bandwidths of the APMS/GSM and DCS/PCS bands.

The radiation characteristics were also studied. Figures 3–6 show the measured radiation patterns at center frequencies (854, 925, 1795, and 1920 MHz) of the AMPS, GSM, DCS, and PCS

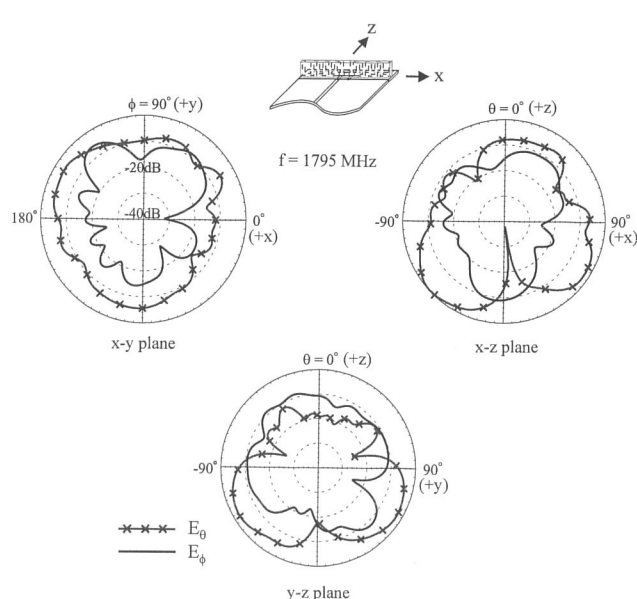


Figure 5 Measured radiation patterns at 1795 MHz

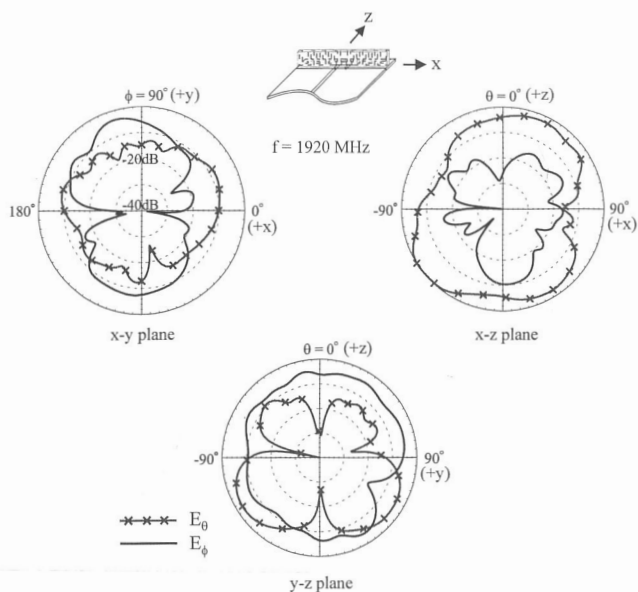
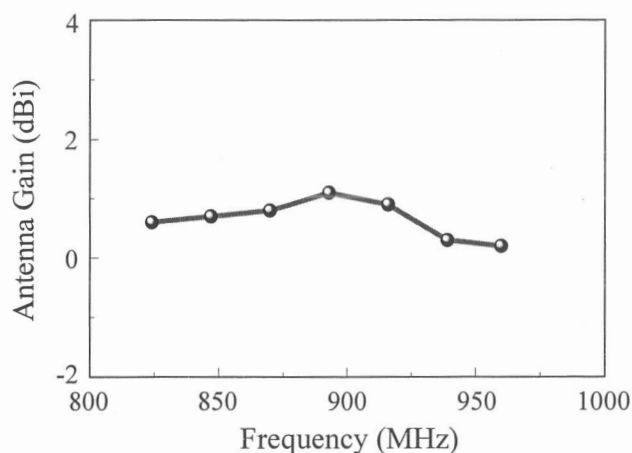
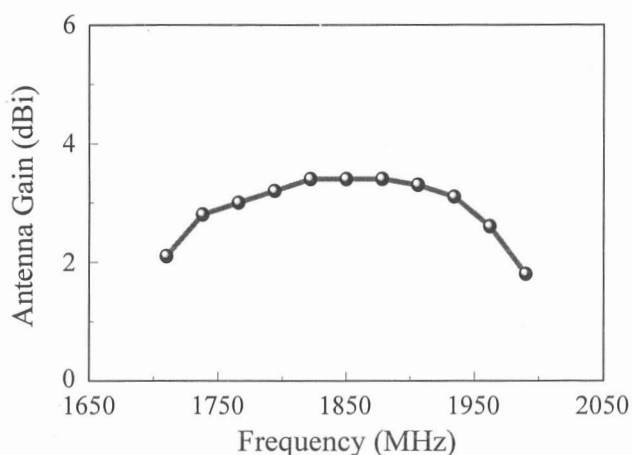


Figure 6 Measured radiation patterns at 1920 MHz



(a)



(b)

Figure 7 Measured antenna gain across the (a) AMPS/GSM (824–894/890–960 MHz) and (b) DCS/PCS (1710–1880/1850–1990 MHz) bands

bands, respectively. Note that the three radiation patterns shown in each figure are all normalized with respect to the measured peak antenna gain of the antenna. Monopolelike radiation patterns for lower frequencies are shown in Figures 3 and 4 and are much smoother than those shown in Figures 5 and 6 for higher frequencies. The radiation characteristics observed are similar to those obtained for other low-profile planar monopole mobile phone antennas in [1–4]. Figure 7 shows the measured antenna gain for frequencies across the AMPS, GSM, DCS, and PCS bands. The peak antenna gain for operating frequencies across the AMPS and GSM bands is about 0.2–1.1 dBi [see Fig. 7(a)], and that for DCS and PCS bands is about 1.8–3.4 dBi [see Fig. 7(b)].

4. CONCLUSION

A novel quad-band internal monopole mobile-phone antenna for AMPS, GSM, DCS, and PCS operations has been proposed, and a prototype has been successfully implemented. The proposed antenna can generate four resonant modes, two for each operating bands at about 900 and 1850 MHz, covering the AMPS/GSM and DCS/PCS bands, respectively. Good radiating characteristics have also been observed across the operating bands.

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NUMERICAL STUDY OF POLARIZATION-DEPENDENT FOCUSING FOR A BILAYER PLANAR FSS REFLECTIVE LENS AT MILLIMETER WAVELENGTHS

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Received 21 August 2003

ABSTRACT: In this paper, we numerically analyze the polarization-dependent focusing properties of a planar reflective lens formed by two parallel layers of nonuniform “gangbuster” surfaces (GSs) above a ground plane. Since these GSs consist of superdense arrays of thin finite-length parallel metallic wires, the desired phase patterns on such a lens surface are achieved by adjusting the lengths of these metallic wires for appropriate polarization components. In our analysis, we use the method of moments (MoM) and the transmission-lines analogy, along with the surface-equivalence theorem, to estimate the field intensity in the focal plane. © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 40: 361–365, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11382