Dual-Band Planar Monopole Antenna for Multiband Mobile Systems

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***Abstract*—In this letter, a simple planar monopole antenna with two operating bands for multiband mobile systems application is proposed. The proposed antenna is composed of two inverted-L branches and an open stub for impedance tuning. Both branches are resonating as quarter-wavelength monopole structures. The antenna covers the 890–970-MHz and 1670–2350-MHz bands. A modified design for 824–895-MHz and 1440–2180-MHz bands can be easily achieved by narrowing the widths of the lower resonant branch and the open stub. Both simulation and experimental results for the antenna characteristics are presented and discussed.**

***Index Terms*—Mobile antennas, monopole antennas, printed antennas.**

I. Introduction

FOR mobile handset applications, broadband or dual-band planar monopole antennas with low profiles are very attractive. In contrast to the planar inverted-F antenna (PIFA), the planar monopole antenna does not require 3-D feeding structures such as feeding probe and shorting pin, which inevitably have certain heights and occupy certain volumes. Thus, the planar monopole antenna has become a better choice especially when the thickness of the antenna structure is strictly limited. Many planar monopole antennas have been reported recently [1]–[12]. Among them, wrapped and folded planar monopole antennas with wide bandwidth and omnidirectional patterns are proposed to achieve the compact size for mobile applications [1]–[7]. Although these antennas use planar feeding structures, they still occupy a space as large as that of the PIFA. When side-feed [8] and trapezoidal feeding structures [9] are used, the cost and the complexity of the planar monopole antennas are increased. To alleviate these problems, the printed circuit board (PCB) process is adopted [10]–[12]. The designs include using modified T-shaped strip to meet the multiband operations [10], fabricating two resonant paths with an additional impedance tuning strip inside [11], and introducing a loop antenna for internal compact dual-band mobile phone application [12]. However, the global system for mobile communication (GSM 900, 890–960 MHz) band is not included and fully covered in [10] and [11], respectively, and the personal communication system (PCS, 1850–1990 MHz) and the universal mobile telecommunication system (UMTS, 1920–2170 MHz) bands are not included in [12].

Manuscript received September 05, 2008; revised October 07, 2008. First published October 31, 2008; current version published January 16, 2009. This work was supported by the National Science Council, Taiwan, under Contract NSC 96-2752-E-002-002-PAE.

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Digital Object Identifier 10.1109/LAWP.2008.2008110

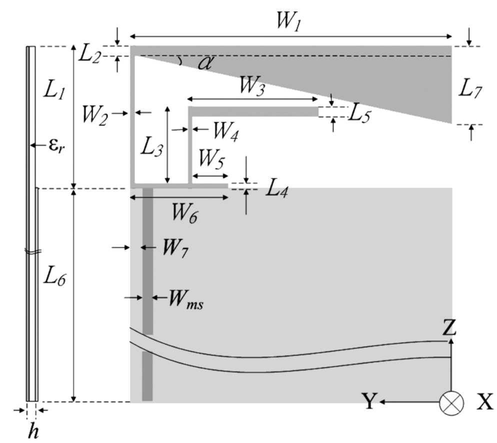


Fig. 1. Geometry of the proposed dual-band planar monopole antenna.

In this letter, by introducing a triangular strip monopole to replace the loop used in [12], the proposed antenna can cover more application frequency bands, which include the spectrums of GSM 900, digital communication system (DCS, 1710–1880 MHz), PCS, and UMTS bands. Also, as shown in Fig. 1, since there is an empty area at the lower right corner of the proposed antenna, the actual occupied antenna area is less than $L_1 \times W_1$ and is similar to and smaller than that used in [11] and [12], respectively. Besides, the lower operating band of the proposed antenna can be easily modified from GSM 900 to GSM 850 (824–894 MHz) by narrowing the strip widths without occupying additional area or largely altering the antenna structure. The operating mechanism and details of the design are discussed. Simulated and experimental results of the antenna characteristics are both presented and discussed.

II. Antenna Configuration and Operation

The geometry of the proposed dual-band planar monopole antenna is shown in Fig. 1. This antenna has a simple structure with two resonant branches for dual-band operation and an open stub W_5 for impedance tuning. The lower and upper resonant frequencies are mainly controlled by the inverted-L strips of lengths $(L_1 + W_1)$ and $(L_3 + W_3)$, respectively, which correspond to quarter wavelengths at their respective resonant frequencies. If we keep only the lower resonant branch and remove the other, the resonant frequency would be located at about 1000 MHz. On the contrary, the resonant frequency would be located at about 2000 MHz. When both branches are combined

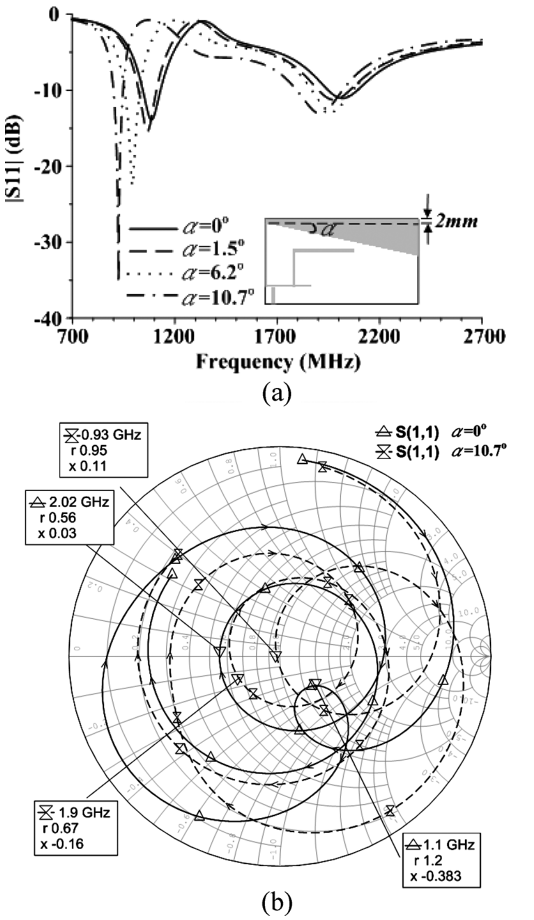


Fig. 2. Simulated (a) return loss responses and (b) Smith chart with various flare angle α of the proposed antenna. All the other parameters are kept unchanged.

TABLE I
DESIGN PARAMETERS (UNIT: MILLIMETERS)

L_1	L_2	L_3	L_4	L_5	L_6	L_7
20	2	11	1	2	76	9
W_1	W_2	W_3	W_4	W_5	W_6	W_7
38	1	18.6	1	4	15	1

$\alpha = 13.32°$.
Antenna size: 38 × 20 mm^2; Ground plane size: 38 × 76 mm^2.

together, due to the mutual coupling between them, both resonant frequencies would be shifted lower and the impedance bandwidth could cover the specified mobile applications. If we replace the triangular strip with radial stubs but keep the other branch unchanged, the lower resonant frequency would be determined by the longer radial stub rather than have an additional resonant frequency in the lower band. Also, when we compare the simulated return loss responses between the original design and the design with triangular strip replaced by radial stubs, though the input match is better in the new design with radial stubs, its bandwidth is narrower than that of the original design. Since bandwidth is more important in our design, we choose to use triangular strip instead of radial stubs.

At the lower resonant branch, the flare angle α of the triangular strip is used to extend the resonant length and make the lower resonant bandwidth shift lower to cover the GSM band. When the flare angle increases from 0° to 10.7°, the lower resonant frequency is decreased, while the upper resonant frequency and bandwidth are slightly decreased and increased, respectively. These characteristics could be observed from the simulated return loss responses and Smith chart with various α plotted in Fig. 2. As shown in Fig. 2(b), the lower and upper resonant frequencies are changed from 1100 and 2020 MHz to 930 and 1900 MHz, respectively. The width W_2 of the vertical strip is used for impedance matching at the lower resonant frequency. For the upper resonant branch, since W_3 is directly related to the gap between the two resonant branches, slight variation of W_3 would affect both lower and upper resonant frequencies. Thus, W_3 should be fixed rather than used as a parameter for impedance tuning. In addition, when the gap between the lower and upper resonant branches is fixed, both resonant bands are almost unaffected with the variations of L_5 and W_4. Unlike W_3, which is sensitive in both resonant bands, L_3 is used in tuning the upper band with little effect on the lower band. The other parameters such as L_4, W_6, and W_7 are used for fine tuning of the input impedance. By narrowing the widths of the lower resonant branch W_2 and the open stub L_4, the lower resonant frequency can be shifted even lower to make the lower resonant bandwidth shift from the GSM 900 band to the GSM 850 band. Note that the radiating elements and the 50-Ω microstrip feed line are designed on the same layer of the substrate to reduce the complexity of manufacturing.

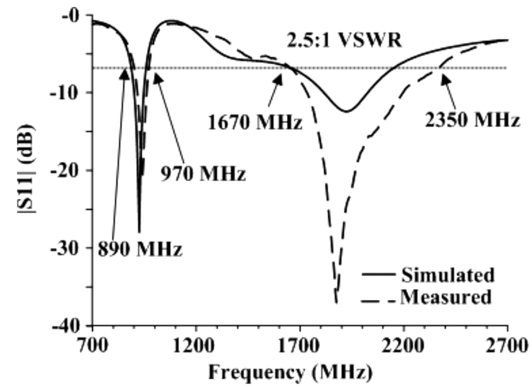
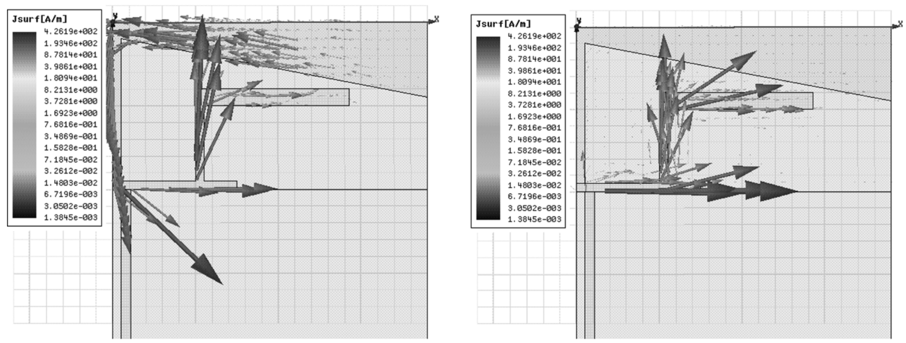


Fig. 3. Measured and simulated return losses of the proposed antenna.

III. ANTENNA DESIGN AND EXPERIMENTAL RESULTS

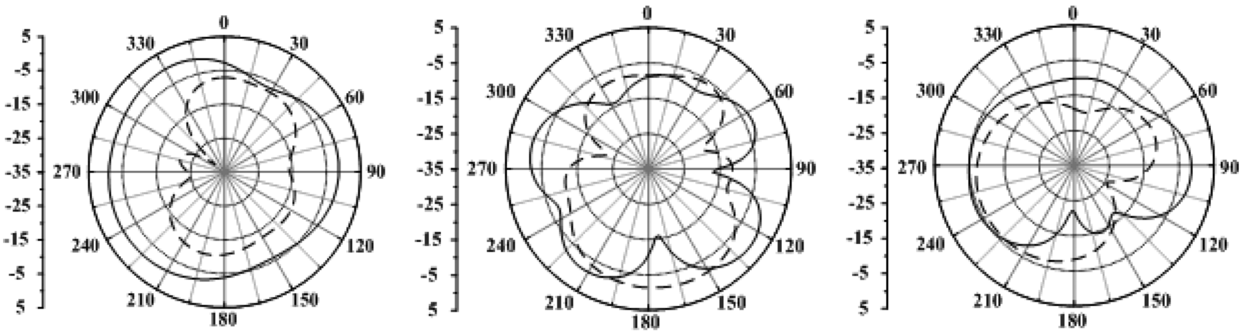
A test piece of the proposed antenna of dimension $L_1 \times W_1 = 20 \times 38$ mm^2 is fabricated on an FR4 substrate with dielectric constant $\varepsilon_r = 4.4$, thickness $h = 0.6$ mm, and loss tangent $\tan\delta = 0.02$. The width of the 50-Ω microstrip feed line $W_{\rm ms}$ is fixed to be 1.2 mm and the size of the ground plane $(L_6 \times W_1)$ is 76 × 38 mm^2. The detailed antenna design parameters are listed in Table I. Note that there is an empty area at the lower right corner of the antenna, hence the actual antenna size is smaller than 20 × 38 mm^2.

The measured and simulated return losses of the test piece are shown in Fig. 3. The $|S_{11}|$ is measured by using the network analyzer E8364B from Agilent Technologies. All the simulations are carried out using the package software HFSS 10.0 from *Ansoft*. The lower and upper resonant frequencies which locate at about 930 and 1880 MHz are mainly determined by $(L_1 + W_1)$



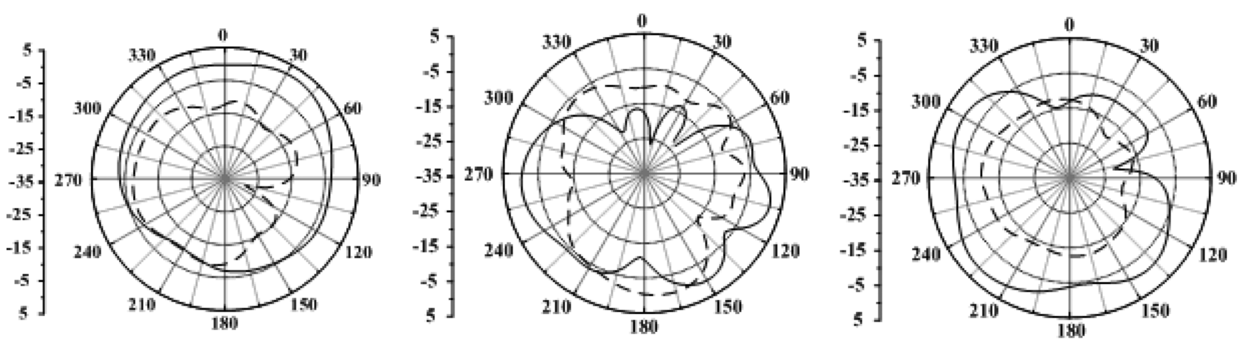
(a) (b)

Fig. 4. Simulated surface current distributions at (a) 930 MHz and (b) 1900 MHz.



(a) (b) (c)

Fig. 5. Measured 2-D gain patterns at 930 MHz. (a) XY plane, (b) XZ plane, and (c) YZ plane. Vertical axis: gain in decibels; solid line: E_θ; dashed line: E_ϕ.



(a) (b) (c)

Fig. 6. Measured 2-D gain patterns at 1880 MHz. (a) XY plane, (b) XZ plane, and (c) YZ plane. Vertical axis: gain in decibels; solid line: E_θ; dashed line: E_ϕ.

and $(L_3 + W_3)$, respectively. The measured return loss bandwidth, defined by VSWR ≤ 2.5, for the lower band is 80 MHz (890–970 MHz), which covers the GSM 900 band. The bandwidth of the upper band is 680 MHz (1670–2350 MHz), which is sufficient to cover the DCS, PCS, and UMTS bands. The simulated surface current distributions at both resonant frequencies are shown in Fig. 4. At the lower resonant frequency, since the simulated surface current distributions on the triangular strip of the lower resonant branch and the horizontal strip of the upper resonant branch are out of phase, the far-field radiation is mainly due to the vertical strip of the lower resonant branch, and hence, an almost omnidirectional pattern in XY plane is expected. While at the upper resonant frequency, since the surface current distributions are mainly concentrated in the upper resonant branch without any opposite phase current existing, a larger realized gain response can be obtained. The gain patterns are measured in the anechoic chamber. To clearly present the magnitude of the radiation, here we choose the gain patterns rather than the normalized radiation patterns commonly used in the antenna measurement. Figs. 5 and 6 are measured 2-D gain patterns at 930 and 1880 MHz, respectively. The almost omnidirectional gain pattern in the azimuthal plane (XY plane) can be seen at 930 MHz, while most radiated power points to the lower half of the antenna plane (YZ plane) at 1880 MHz. The measured and simulated realized gain data are presented in Fig. 7(a) and (b). The realized peak gains are about 0.3–3 dBi in the lower band and 1.5–3.5 dBi in the upper band. Note that, in Fig. 7(b), there is a gain drop at near 1900 MHz. It is not a measurement error. It may be that it is because of the FR4 substrate and it may be that it is because of the nature of this type of antenna. However, the measured gain drop from maximum is smaller than 1.5 dB, which is acceptable for mobile handset applications.

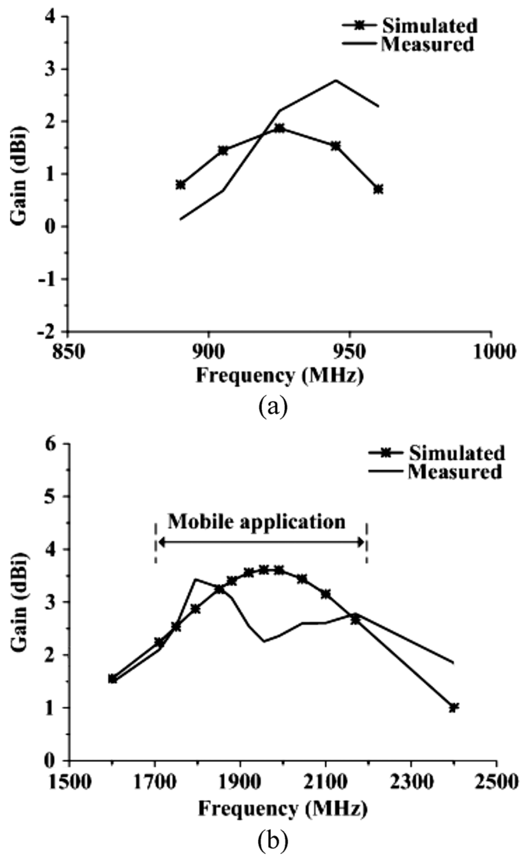


Fig. 7. Measured and simulated realized gain in (a) lower band and (b) upper band.

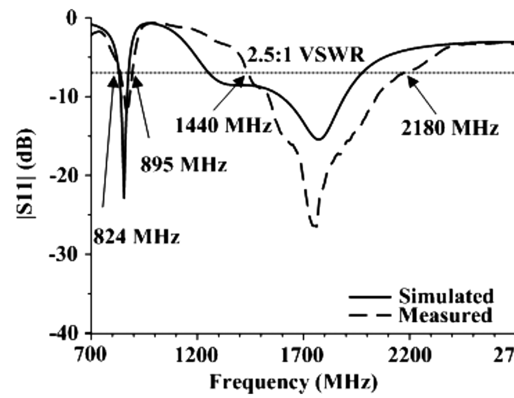


Fig. 8. Measured and simulated input return losses of the modified design.

In addition, based on the previous discussions, a modified design for the GSM 850 band could also be obtained by simply decreasing W_2 and L_4 from 1 to 0.3 mm. The measured and simulated return losses of the modified design are shown in Fig. 8. The return loss bandwidths of this design are from 824 to 895 MHz and from 1440 to 2180 MHz. Besides the required GSM 850 band, the bandwidth of this modified design could also cover the DCS, PCS, and UMTS bands. Without adding another element or largely altering the antenna structure, different specifications and requirements could be easily achieved.

IV. Conclusion

A dual-band planar monopole antenna consisting of two inverted-L branches, one with a triangular strip and the other with a bent strip and a tuning stub, for multiband mobile systems application, has been proposed. A prototype design for GSM900/DCS/PCS/UMTS operation has been implemented and tested. Good antenna gains and radiation patterns have been obtained. Moreover, by just narrowing the widths of the lower resonant branch and the tuning stub of the original design, a modified design for GSM850/DCS/PCS/UMTS operation could easily be achieved. In addition, the antenna occupies only a small area ($<20 \times 38$ mm^2) and is easy to design and fabricate. These properties make the antenna suitable for use in the mobile handset systems.

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