GSM850/900/1800/1900/UMTS Printed Monopole Antenna for Mobile Phone Application

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1. Introduction

Owing to the rapid growth in mobile communications, the internal antenna for the mobile phone is generally required to be capable of multiband operation, especially penta-band operation covering GSM850/900/1800/1900/UMTS. However, owing to the limited space available inside the mobile phone, it is usually a big challenge for antenna engineers to achieve penta-bend operation for the internal mobile phone antenna with a small size.

In this paper, we present a promising design of using a printed monopole antenna to achieve penta-band operation for the mobile phone. The proposed printed monopole antenna is to be printed directly on the system circuit board of the mobile phone, hence making it easy to fabricate at low cost. In addition, the printed monopole antenna is of low profile in appearance and thus especially suitable for application in a thin mobile phone [1, 2]. The proposed antenna also provides a promising solution for the printed monopole for internal mobile phone antenna applications to easily generate two wide operating bands for covering GSM850/900 and GSM1800/1900/UMTS operations. The proposed printed monopole shows a simple radiating metal pattern of a driven strip and a coupled strip. The enhanced bandwidth in the lower band at about 900 MHz is obtained by incorporating a high-pass matching network [3, 4] to the printed monopole, which results in a dual-resonance excitation for the excited resonant mode in the lower band; this leads to a wide lower band for the antenna to cover GSM850/900 operation. On the other hand, the coupled strip can contribute an additional resonant mode for the antenna's upper band to achieve a much widened bandwidth to cover GSM1800/1900/UMTS operation. In addition, since the coupled strip is excited through a small coupling gap by the driven strip [5], not through direct excitation as the traditional two-branch monopole antenna [6], its effects on the existing resonant modes contributed by the driven strip are found to be very small. This behavior makes the lower and upper bands of the proposed monopole antenna easy to be adjusted separately. This makes the antenna easy to design for practical applications. Details of the proposed printed monopole antenna for penta-band operation are presented.

2. Design of Proposed Printed Monopole Antenna

Fig. 1(a) shows the geometry of the proposed printed monopole antenna, and the equivalent circuit of the high-pass matching network incorporated to the antenna is shown in Fig. 1(b). The printed monopole consists of a driven strip and a coupled strip; both strips are in a folded configuration to achieve a compact size. The driven and coupled strips are printed on the small top no-ground region (size 10×60 mm^2) of the system circuit board of the mobile phone, which uses a 0.8-mm thick FR4 substrate of dimensions 100×60 mm^2 in this study. On the back surface of the system circuit board the system ground plane of width 60 mm and length 100 mm is printed. The dimensions of the system circuit board and ground plane studied here are reasonable for general smartphones or PDA (Personal Digital Assistant) phones [7, 8]. Also note that the coupled strip is capacitively excited through a narrow coupling gap of width 0.5 mm by the driven strip. With this coupling structure, the inclusion of the coupled strip to the proposed antenna can have very small effects on the existing resonant modes generated by the driven strip. This feature can make it relatively easy for the design of the multiband internal mobile phone antenna to achieve wide operating bandwidths for its lower and upper bands, and is advantageous for practical applications.

In the first step of the design, the driven strip is selected to have a length of about 80 mm, which makes it capable of generating a quarter-wavelength resonant modes at about 900 MHz and a half-wavelength resonant mode at about 2000 MHz. The two resonant modes, however, usually cannot provide wide operating bandwidths for the desired lower and upper bands to cover GSM850/900 and GSM1800/1900/ UMTS operation.

In the second step, the bandwidth of the lower band is effectively enhanced by incorporating a high-pass matching network to the driven strip. The matching network consists of two high-pass circuits in series, whose equivalent circuit is shown in Fig. 1(b). Each circuit is formed by a chip inductor (L_1 or L_2) and a chip capacitor (C_1 or C_2) as shown in Fig. 1(a). With the proper matching network incorporated, the excited quarter-wavelength mode of the driven strip can be tuned to have a dual-resonance behavior [9], thus resulting in a much widened lower-band bandwidth to easily cover GSM850/900 operation. In addition, the incorporated matching network in this study shows no degraded effects on the obtained bandwidth of the antenna's upper band, an advantage over the matching circuit applied in the antenna design in [3].

In the third step, the obtained bandwidth of the upper band is greatly increased by adding the coupled strip, which is to be capacitively excited through a narrow coupling gap of 0.5 mm by the driven strip. With a length of about 45 mm, the coupled strip can contribute a quarter-wavelength resonant mode at about 1800 MHz, which incorporates the half-wavelength resonant mode of the driven strip at about 2000 MHz to form a much widened upper-band bandwidth to easily cover GSM1800/1900/UMTS operation. Note that with comparison to the use of an additional resonant strip directly connected to the driven strip, the use of the coupled strip in this study can have very small degrading effects on the obtained bandwidth of the existing resonant modes of the driven strip. This behavior makes it easy to tune the antenna's lower band and upper band separately. By following the three design steps described above, it becomes an easy task to achieve GSM850/900/1800/ 1900/UMTS penta-band operation for an internal printed monopole antenna for mobile phone applications.

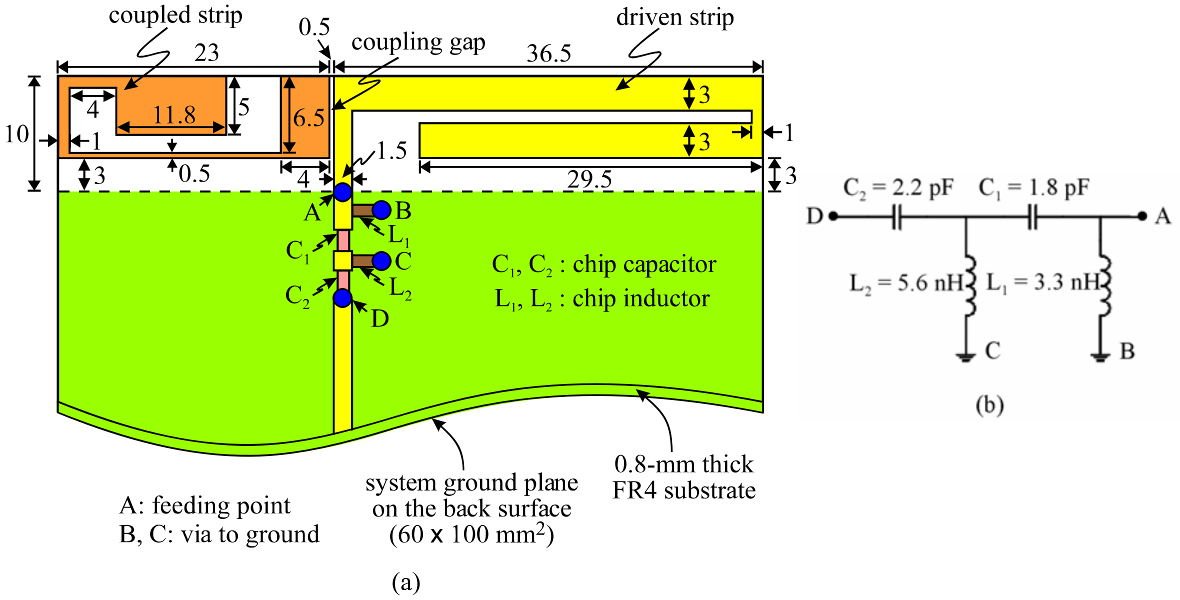


Figure 1: (a) Geometry of the proposed printed monopole antenna. (b) The equivalent circuit of the high-pass matching network incorporated to the antenna.

3. Results and Discussion

The proposed penta-band printed monopole antenna was constructed and tested. Results of the measured and simulated return loss of the constructed prototype are shown in Fig. 2. Good agreement between the measured data and simulated results obtained using Ansoft HFSS [10] is obtained. Two wide operating bands for the antenna's lower and upper bands are obtained. For the lower band at about 900 MHz, the impedance bandwidth defined by 3:1 VSWR or 6-dB return loss (general standard for practical mobile phone applications) reaches 175 MHz (815~990 MHz), allowing the antenna to cover GSM850/900 operation. For the upper band, a much wider bandwidth as large as 715 MHz (1700~2415

MHz) is obtained, which easily covers GSM1800/1900/UMTS operation. From the results, penta-band operation for the proposed printed monopole antenna has been obtained.

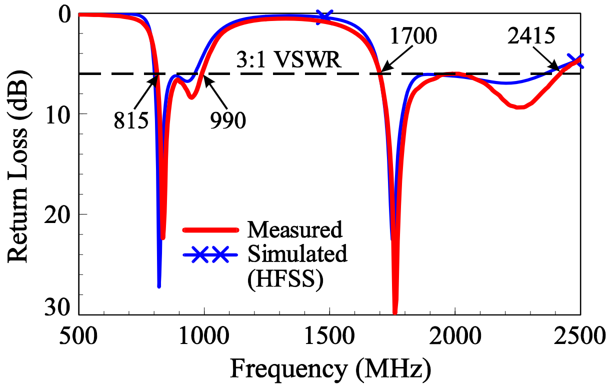
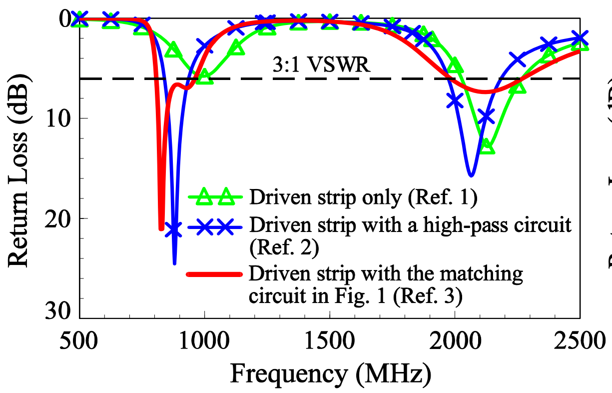


Figure 2: Measured and simulated return loss for the proposed antenna.

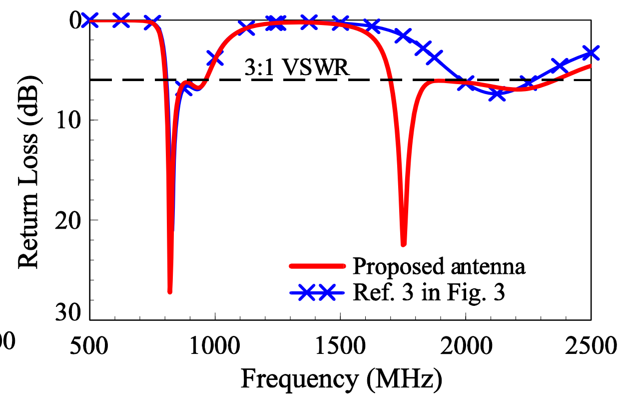
To study the effects of the high-pass matching network, a comparison of the simulated return loss for the driven strip only (Ref. 1), the driven strip with a high-pass circuit only (Ref. 2), and the driven strip with the matching network shown in Fig. 1 (Ref. 3) is presented in Fig. 3(a). In this study, the three cases are without the coupled strip. From the results, it is seen that the driven strip alone (Ref. 1) can generate two resonant modes at about 1000 and 2000 MHz; however, the obtained bandwidths are far from those required for penta-band operation. By adding a simple high-pass circuit as shown in the figure, improved impedance matching over the two resonant modes, especially the lower resonant mode, is obtained (see Ref. 2 in the figure). The obtained bandwidth of the lower band, however, is still not enough for the desired GSM850/900 operation. With the use of two high-pass circuit in series (the matching network shown in Fig. 1), a dual-resonance excitation for the lower resonant mode of the driven strip alone is obtained (see Ref. 3 in the figure), which greatly increases the lower-band bandwidth for covering GSM850/900 operation. Note that for Ref. 3, the upper-band bandwidth is also increased with the presence of the matching network shown in Fig. 1, although the bandwidth is still far from that required for GSM1800/1900/UMTS operation.

By further including the coupled strip to Ref. 3, the upper-band bandwidth of the proposed antenna can be effectively enhanced, allowing the antenna to easily cover GSM1800/1900/UMTS operation. The results are presented in Fig. 3(b) for comparison. It is also seen that the lower-band bandwidth is almost not affected when the coupled strip is added.

The measured patterns for the proposed antenna are similar to those of the traditional internal mobile phone antennas such as the PIFAs [11] and are acceptable for practical applications. Fig. 4 presents the measured antenna gain and simulated radiation efficiency for the proposed antenna. Over the GSM850/900 band, small variations in the antenna gain is seen (about −0.2~−0.5 dBi), and the radiation efficiency is still larger than 50%. While over the GSM1800/1900/UMTS band, the antenna gain is varied from about 0 to 3.2 dBi, and the radiation efficiency is also larger than 50%.



(a)



(b)

Figure 3: (a) Simulated return loss for three reference antennas without the coupled strip.
(b) Simulated return loss for the proposed antenna and Ref. 3.

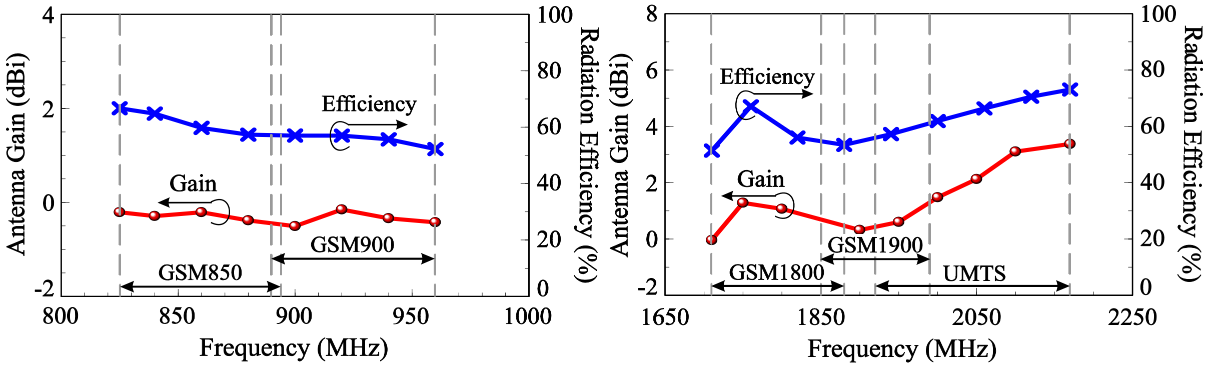


Figure 4: Measured antenna gain and simulated radiation efficiency for the proposed antenna.

4. Conclusion

A penta-band printed monopole antenna easily fabricated on the system circuit board of the mobile phone for covering GSM850/900/1800/1900/UMTS operation has been proposed. The design steps for the printed monopole antenna to achieve two wide operating bands at about 900 and 1900 MHz have been given in the paper. With wide operating bands obtained, the printed monopole antenna also occupies a small area of 10×60 mm^2 only. The design techniques used in the proposed antenna include the use of a high-pass matching network and a coupled strip to be capacitively excited by the driven strip of the antenna. The former effectively enhances the lower-band bandwidth of the antenna by introducing a dual-resonance excitation to the lower band, while the latter contributes an additional resonant mode to the antenna's upper band to enhance the bandwidth. Furthermore, the two design techniques can be applied at the same time, with very small effects on each other. That is, when the lower-band bandwidth is effectively enhanced by the high-pass matching network, the upper-band performances are generally not affected, and vice versa for the added coupled strip for enhancing the upper-band bandwidth. This allows the antenna's lower and upper bands to be adjusted separately, without affecting each other. This feature makes it very convenience and attractive for the proposed penta-band printed monopole antenna for practical applications in the mobile phones.

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