HEXA-BAND INTERNAL PRINTED SLOT ANTENNA FOR MOBILE PHONE APPLICATION

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ABSTRACT: *A promising internal printed slot antenna for hexa-band operation in the mobile phone is presented. The antenna comprises a C-shaped slot and an open-ended monopole slot, and both are integrated into a compact configuration to occupy a small area of 21 × 45 mm² in the top portion of the system circuit board. The integrated C-shaped slot and monopole slot are fed in series using a 50-Ω microstrip feedline. The antenna can provide two wide operating bands centered at about 900 and 2200 MHz to cover the GSM850/900/DCS/PCS/UMTS mobile communication and the 2.4-GHz WLAN operation. Good radiation performances of the proposed antenna over the operating bands are also obtained.* Microwave Opt Technol Lett 50: 35–38, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22981

Key words: *internal mobile phone antennas; printed slot antennas; monopole slot; antennas; multiband operation; hexa-band operation*

1. INTRODUCTION

Printed slot antennas including the open-ended monopole slot antenna have been shown to be promising for application in the mobile devices [1–9]. They are easy to fabricate at low cost on the system circuit board of the mobile device. Although the general printed slot antennas are mainly operated as a half-wavelength resonant structure [1–5], not like the planar inverted-F antenna or the shorted patch antenna as a quarter-wavelength resonant structure [10, 11], they are still very promising to occupy a compact size in the mobile phone for 900/1800 MHz operation. Recently, a folded slot antenna occupying a small area of 21 × 45 mm² in the system circuit board of the mobile phone for quad-band operation covering GSM900 (Global System for Mobile Communication, 880~960 MHz), Digital Communication System (DCS, 1710~1880 MHz), Personal Communication System (PCS, 1850~1990 MHz), and Universal Mobile Telecommunication System (UMTS, 1920~2170 MHz) have been demonstrated [5]. This attractive design suggests that the printed slot antennas are also a promising candidate for internal multiband mobile phone antennas.

Recently, it has also been shown that by cutting the printed slot at the edge of the ground plane, an open-ended monopole slot antenna can be obtained [6–9], which can be operated as a quarter-wavelength resonant structure. This property is attractive for achieving a reduced size at a fixed operating frequency. In this article, we apply such a monopole slot antenna to integrate with the reported folded slot antenna in [5] to achieve enhanced operating bandwidths in both the antenna's lower and upper bands to obtain a hexa-band operation, without increasing the size of the antenna. In this case, the proposed antenna can cover GSM850/900 (824~894/880~960 MHz) operation in its lower band and DCS/PCS/UMTS/Wireless Local Area Network (WLAN, 2400~2484 MHz) operation in its upper band. Detailed design considerations of the antenna are described, and results of the fabricated prototypes are presented and discussed.

2. DESIGN CONSIDERATIONS OF THE PROPOSED ANTENNA

Figure 1(a) shows the proposed slot antenna printed on the top portion of the ground plane of the system circuit board, and the antenna is also enclosed by a 1-mm thick plastic housing [see Fig. 1(b)], which can be treated as the mobile phone housing. The plastic housing has a relative permittivity of 3.5 and a width of 10 mm, which is about the size of the popular thin mobile phones. The system circuit board in this study is a 0.8-mm thick FR4 substrate, and the ground plane printed on the FR4 substrate with length (L) 100 mm and width 45 mm is treated as the system ground plane of the mobile phone.

The antenna comprises a C-shaped slot and an open-ended monopole slot. The C-shaped slot has a configuration similar to that studied in [5], in which its lower band and upper band can cover GSM900 and DCS/PCS/UMTS operation, respectively. The C-shaped slot with a uniform width of 2.5 mm is centered at the top portion of the system circuit board and occupies a small area of 21 × 45 mm², the same as that in [5]. The length of the C-shaped slot has a length of 108 mm in this study and can generate a fundamental (0.5-wavelength) resonant mode and a second (1-wavelength) resonant mode at about 900 and 1800 MHz for quad-band operation. The detailed design considerations for the C-shaped slot to achieve quad-band operation have been described in [5].

It is then found that by adding a monopole slot in the region encircled by the C-shaped slot as shown in the figure, which does not increase the size of the antenna, both the bandwidths of the antenna's lower and upper bands can be greatly improved. The monopole slot has a uniform width of 3 mm and a length of about 42 mm, with its end portion widened (size 7 × 8 mm²) to achieve enhanced bandwidths. Similar to the strip monopole [12], a wider width generally can lead to a wider achievable bandwidth. In this case, the monopole slot can provide a fundamental resonant mode (0.25-wavelength mode) at about 800 MHz, which incorporates the fundamental mode of the C-shaped slot to achieve a wide

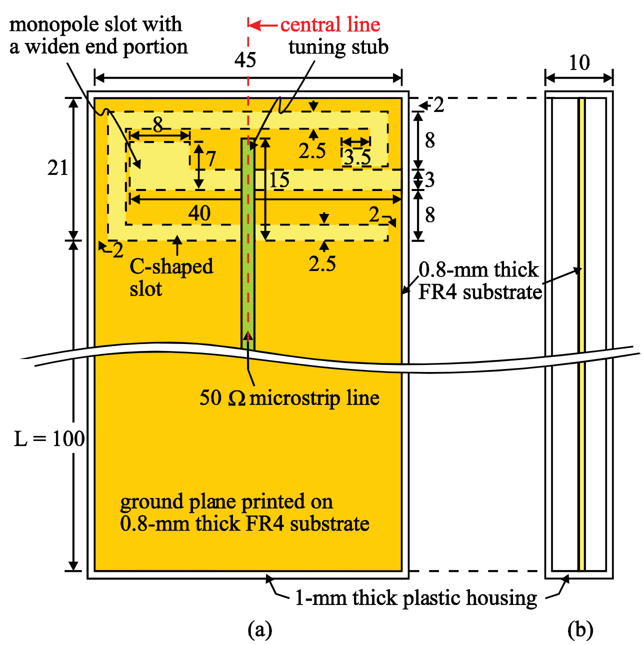

Figure 1 (a) Configuration of the proposed hexa-band printed slot antenna on the system circuit board enclosed by a 1-mm thick plastic housing. (b) Side view of the configuration in (a). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

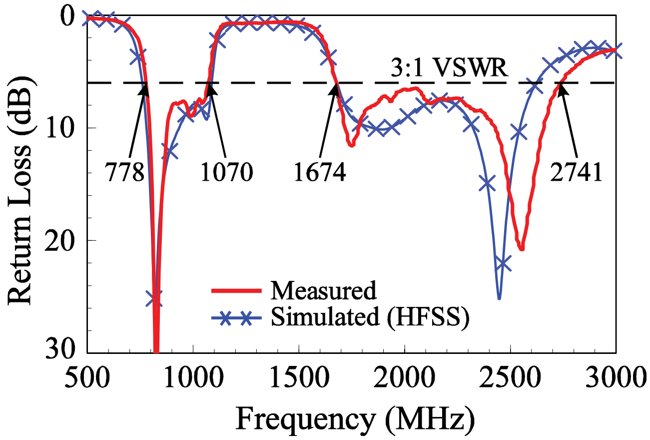

Figure 2 Measured and simulated return loss for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

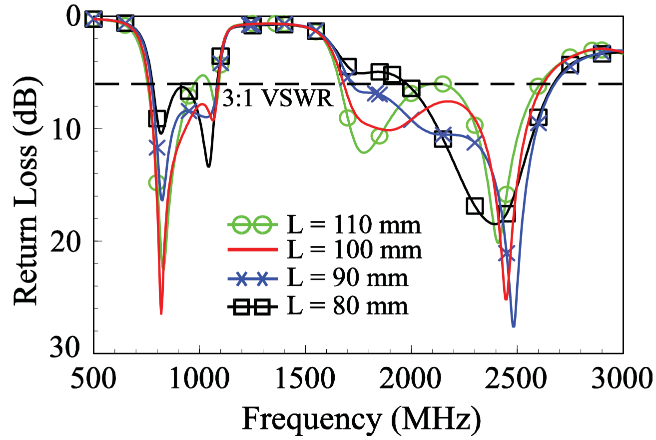

Figure 4 Simulated return loss for the proposed antenna as a function of the groundplane length *L.* [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

operating band covering GSM850/900 (824∼894/880∼960 MHz) operation. In addition, the monopole slot can also generate a second resonant mode at about 2500 MHz to incorporate the second mode of the C-shaped slot to achieve a wide upper band covering DCS/PCS/UMTS/WLAN operation. With the wide lower and upper bands obtained, hexa-band operation is achieved for the proposed antenna.

Also note that, with the presence of the FR4 substrate on one side of the slot antennas, the resonant frequency of the antenna is decreased and the resonant length for the monopole slot and the C-shaped slot are also shortened. For this reason, the required length of the monopole slot (about 42 mm) is only about 0.11 wavelength at 800 MHz, and the length of the C-shaped slot (about 108 mm) is only about 0.36 wavelength at 1000 MHz. The proposed integrated C-shaped slot and monopole slot can also be easily fed in series using a 50 Ω microstrip line with a tuning-stub length of 15 mm printed on the system circuit board. The microstrip feedline is centered on the system circuit board, which is helpful to achieve symmetric radiation patterns for the proposed antenna.

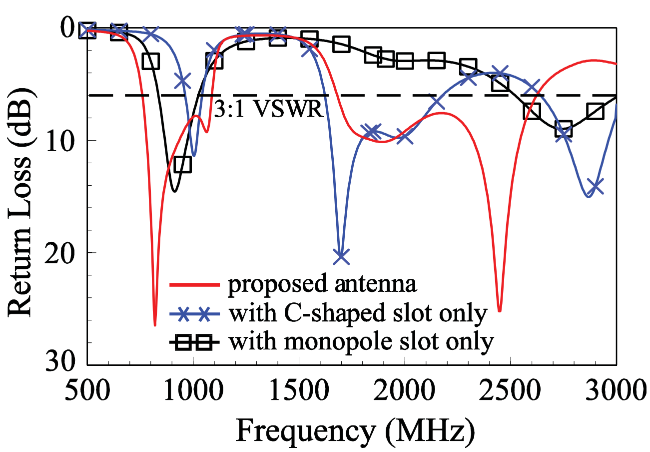

Figure 3 Comparison of the simulated return loss for the proposed antenna, the case with the C-shaped slot only, and the case with the monopole slot only. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

3. RESULTS AND DISCUSSION

The printed slot antenna with dimensions given in Figure 1 was constructed and tested. Figure 2 shows the measured and simulated return loss for the antenna. The simulated results are obtained using Ansoft simulation software high frequency structure simulator (HFSS) (http://www.ansoft.com/products/hf/hfss/, Ansoft

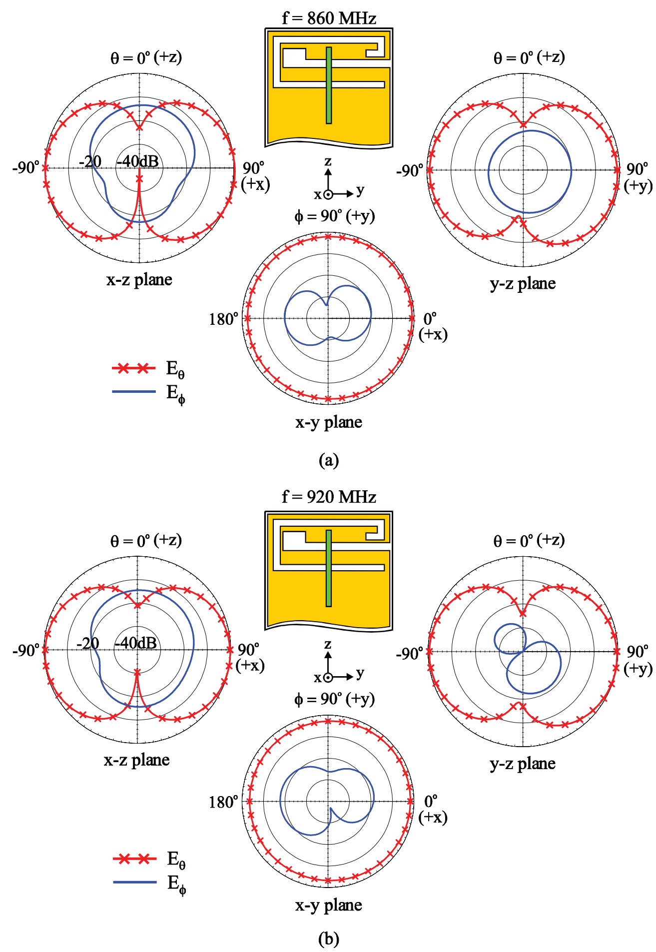

Figure 5 Measured radiation patterns at (a) 860 MHz and (b) 920 MHz for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Corporation HFSS), and agreement between the measurement and simulation is seen. The measured impedance bandwidths, defined by 3:1 VSWR (6 dB return loss), for the lower and upper bands are as large as 292 MHz (778∼1070 MHz) covering GSM850/900 operation and 1067 MHz (1674∼2741 MHz) covering DCS/PCS/UMTS operation. The definition of 3:1 VSWR is generally adopted for the design of internal mobile phone antennas. For frequencies over the 2.4 GHz band (2400∼2484 MHz), the measured return loss is better than about 9 dB in this study, which is also acceptable for WLAN operation for practical applications.

To show the effect of the C-shaped slot and monopole slot on the antenna's lower and upper bands, Figure 3 shows the simulated return loss for the proposed antenna, the case with the C-shaped slot only, and the case with the monopole slot only. From the results, it is clearly seen that each slot can generate a lower resonant mode and an upper resonant mode for contributing to the antenna's lower and upper bands. With the integration of the two slots, the bandwidths of the antenna's lower and upper bands are greatly enhanced, hence the lower band can easily cover GSM850/900 operation and the upper band easily cover DCS/PCS/UMTS/WLAN operation. In this case, hexa-band operation is achieved for the proposed antenna.

Effects of the groundplane length L on the performance of the antenna are also analyzed. Figure 4 shows the simulated return loss for the length L varied from 80 to 110 mm. For the lower band, the impedance matching over the GSM850/900 band is still better than 6 dB return loss. For the upper band, when the length L is decreased, large effect on the impedance matching for frequencies over the first mode (one-wavelength resonant mode contributed by the C-shaped slot) is seen, similar to the behavior seen in [5]. However, the impedance matching is still better than about 5 dB return loss for the length $L = 80$ mm. With some fine tuning of the antenna dimensions, it is still promising to improve the impedance matching to be better than 6 dB for frequencies over the DCS/PCS/UMTS band in the antenna's upper band.

Radiation characteristics of the constructed antenna studied in Figure 2 were also measured. Figures 5(a) and 5(b) plot the measured radiation patterns at 860 and 920 MHz, the center frequencies of GSM850 and GSM900 bands. Monopole-like radiation patterns are seen, which is similar to those of the conventional mobile phone antennas for GSM operation [10]. Stable radiation patterns for frequencies over the antenna's lower band are also observed. For the antenna's upper band, measured radiation patterns at 1795, 1920, 2045, and 2442 MHz, the center frequencies of DCS, PCS, UMTS, and WLAN bands, are plotted in Figures 6(a), 6(b), 6(c), and 6(d), respectively. Stable radiation patterns over the upper band are also observed, which is advantageous for practical application. The obtained radiation patterns are also similar to those of the conventional mobile phone antennas for 1800 MHz operation [10]. Figure 7 presents the measured antenna gain and simulated radiation efficiency over the lower and upper bands. For GSM850/900 operation, the antenna gain is varied in a small range of 1.5∼2.0 dBi, and the radiation efficiency is all better than 90%. For DCS operation, the antenna gain is varied from 3.0 to 4.2 dBi, while the radiation efficiency is about 60∼87%. For PCS/UMTS and WLAN operation, the antenna gain

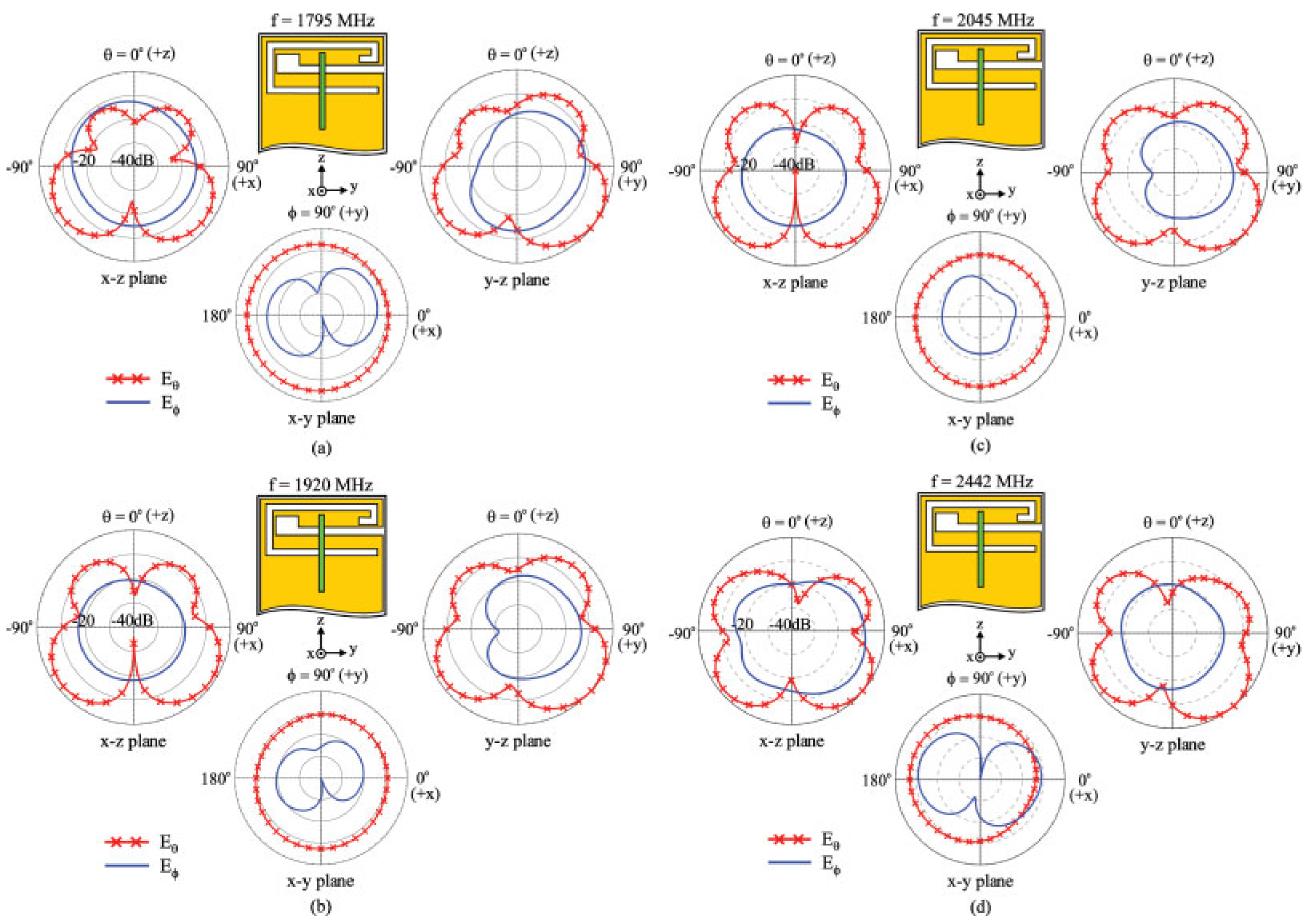

Figure 6 Measured radiation patterns at (a) 1795 MHz, (b) 1920 MHz, (c) 2045 MHz, and (d) 2442 MHz for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

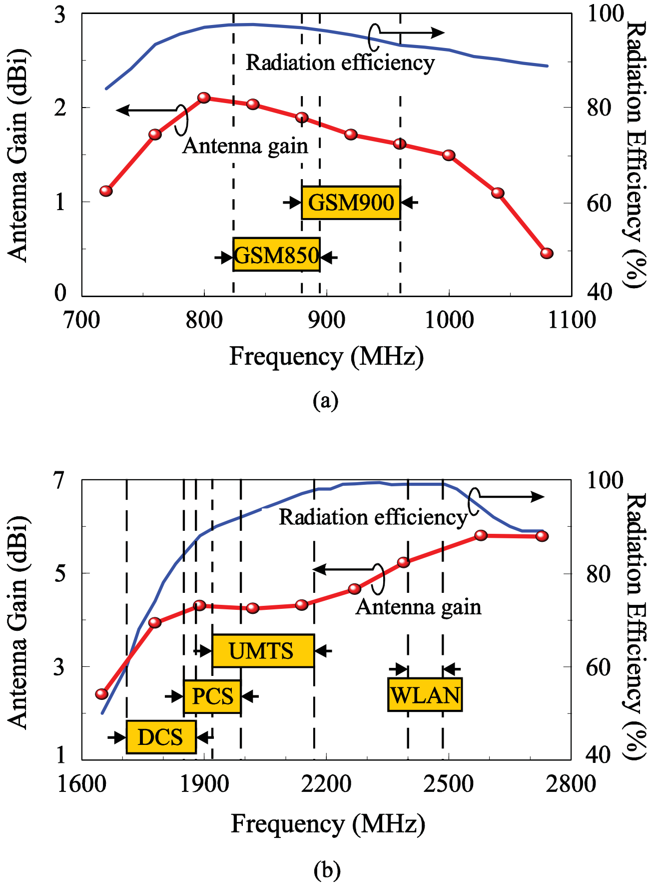

Figure 7 Measured antenna gain and simulated radiation efficiency for the proposed antenna. (a) The GSM850/900 bands. (b) The DCS/PCS/UMTS/WLAN bands. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

is about 4.2 and 5.3 dBi, respectively. For the radiation efficiency, it is all larger than 85% for PCS/UMTS/WLAN operation.

4. CONCLUSION

A novel internal printed slot antenna for hexa-band operation in the mobile phone has been proposed, constructed, and studied. The antenna has a planar structure and is easy to fabricate at low cost on the system circuit board of the mobile phone. With the compact integration of the C-shaped slot and the monopole slot, which are fed in series by using a simple 50-Ω microstrip feedline centered at the system circuit board, two wide operating bands for covering GSM850/900/DCS/PCS/UMTS/WLAN hexa-band operation have been generated. Good radiation characteristics for frequencies over the operating bands have also been obtained.

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INTERNAL HYBRID ANTENNA FOR MULTIBAND OPERATION IN THE MOBILE PHONE

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ABSTRACT: *A new internal hybrid antenna formed by a printed open-ended slot (monopole slot) and a T-shaped metal-strip monopole (monopole T-strip) for multiband operation in the mobile phone is presented. The monopole slot is printed near the top edge of the system circuit board of the mobile phone and can generate a quarter- wavelength resonant mode at about 900 MHz for GSM850/900 operation. The monopole T-strip is bent and mounted above the monopole slot and is used to excite a quarter-wavelength resonant mode at about 1900 MHz to cover DCS/PCS operation. The monopole slot and monopole T-strip are integrated to occupy a compact volume and can be fed using a simple 50 Ω microstrip line printed on the system circuit board. Obtained results indicate that it is promising to integrate two different types of antennas into an internal hybrid antenna for multiband operation in the mobile phone, and good performances of the hybrid antenna over the operating band can be achieved.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 38–42, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22980

Key words: *internal mobile phone antennas; internal hybrid antennas; monopole slot; antennas; quad-band operation*

1. INTRODUCTION

It has recently been shown that by cutting the printed slot at the edge of the ground plane, a quarter-wavelength, or monopole slot antenna can be obtained [1–4]. Such an open-ended monopole slot antenna, different from the traditional half-wavelength slot antenna [5–7], can be operated as a quarter-wavelength resonant structure with a large operating bandwidth. This property makes it very promising to achieve a wide operating band covering GSM850/900 (Global System for Mobile Communication, 824–894 MHz/890–960 MHz) operation with a compact antenna size. It is then found that by integrating a simple T-shaped metal-strip monopole (monopole T-strip) for generating a wide operating band at about 1900 MHz covering DCS/PCS (Digital Communication System,