achieved over the entire band of operation. The cross polarization level is better than −15 dB on-axis. The radiation pattern shows a squint as the frequency is shifted from the designed frequency. The feed provides the wideband impedance match and the dimensions of the slot are optimized at the centre frequency and so, as the frequency is off from the resonance, the beam shows a tendency to squint from the bore sight axis. Figure 4 shows the radiation patterns in H-plane at 1.75, 2.5, and 3.5 GHz. The front-to-back ratio is better in this plane and it is around 25 dB over the band. The on-axis cross polarization is low and maintained at less than −22 dB over most of the antenna operation band and at higher frequencies, the cross polarization lobes peak up off the boresight. This is common in wide slot antennas with wideband feeding mechanism. This can be attributed to the two-dimensional field existence in the wide slot antennas.

4. CONCLUSIONS

A coplanar waveguide slot antenna with wideband feeding mechanism in the form of a printed radial stub is presented. The antenna exhibits an impedance bandwidth of an octave band (1.75–3.7 GHz). Unidirectional patterns are obtained with a back plate kept at $\lambda/4$ distance for frequencies of operation. The CPW to coaxial transition is provided by a simple perpendicular feeding mechanism, which simplifies the feeding and reduces the size of the overall antenna. The antenna is compact and finds its applications in wideband mobile communication systems where it can be directly integrated with microwave circuits.

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INTERNAL GSM/DCS/PCS ANTENNA FOR USB DONGLE APPLICATION

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ABSTRACT: *A GSM/DCS/PCS internal antenna suitable to be embedded at the widened end portion of a promising USB dongle for wireless network access in a laptop computer is presented. The proposed internal antenna uses two separate resonant strips folded into a compact structure to generate two wide operating bands at about 900 and 1800 MHz to cover the GSM and DCS/PCS operations. In addition, although in a compact structure, the antenna's two resonant strips are designed to be less coupled, thus allowing the antenna's lower and upper bands to be adjusted separately, without affecting each other. Details of the USB dongle embedded with the proposed internal antenna are described, and experimental results are presented and discussed.* © 2006 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 2408–2412, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21974

Key words: *antennas; mobile antennas; internal antennas; USB dongles; GSM/DCS/PCS antennas*

1. INTRODUCTION

USB (Universal Serial Bus) dongles [1] are frequently used in laptop computers for providing additional functions such as the plug-and-play function. Recently, it is becoming very attractive that this kind of USB dongles be embedded with antennas for achieving wireless network access. For this perspective application, we demonstrate in this paper a promising internal antenna for GSM (global system for mobile communication, 890–960 MHz), DCS (digital communication system, 1710–1880 MHz), and PCS (personal communication system, 1850–1990 MHz) operations in the USB dongle. With the proposed antenna embedded in the USB dongle and the traditional 2.4/5 GHz internal antenna embedded in most of the laptop computers for WLAN (wireless local area network) operation [2–5], seamless or ubiquitous wireless network access can be provided for wireless users with their laptop computers. Detailed configuration of the proposed internal GSM/DCS/PCS antenna embedded in the USB dongle is described, and experimental results of a constructed prototype are presented and discussed.

2. PROPOSED ANTENNA FOR THE USB DONGLE

Figure 1(a) shows the geometry of the proposed internal antenna for GSM/DCS/PCS operation in the USB dongle. Detailed dimensions of the antenna unfolded into a planar structure are shown in Figure 1(b). In this study, the antenna in the planar structure is obtained by line-cutting a 0.2 mm thick copper plate. Then, by following the bending lines shown in the figure, the planar structure is folded into the proposed configuration shown in Figure 1(a). Notice that the main portion of the USB dongle has a size of 90×15 mm^2, on which the associated components such as the SIM card, baseband module, and RF module are accommodated (see the promising USB dongle shown in Fig. 2). Also note that the width of the dongle is selected to be 15 mm, which is a reasonable width for general USB dongles. A widened end portion of dimensions 15×28.5 mm^2 is then extended from the main portion to accommodate the proposed antenna. In this case, the main and

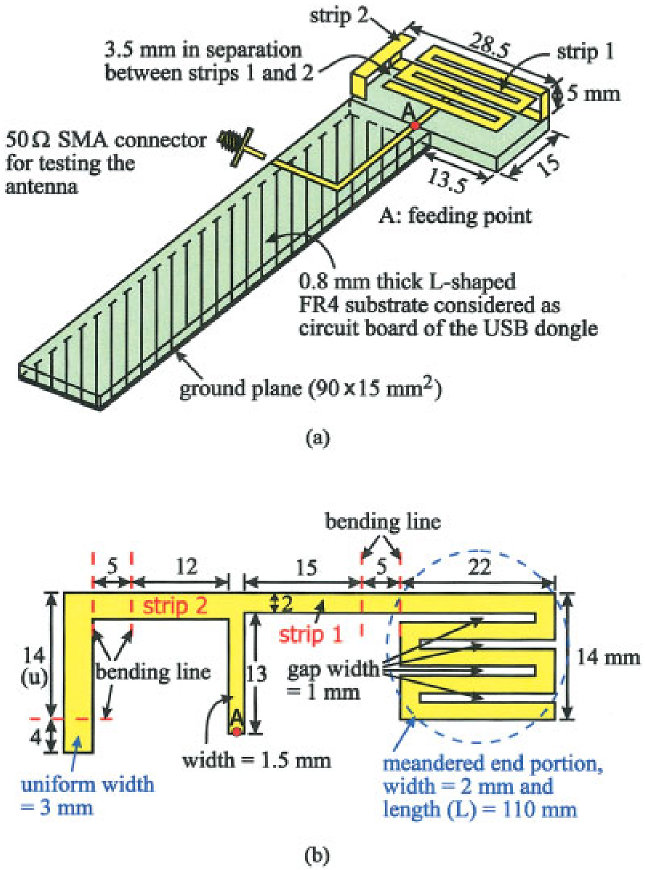

Figure 1 (a) Geometry of the proposed internal antenna for GSM/DCS/PCS operations in the USB dongle. (b) Detailed dimensions of the antenna unfolded into a planar structure. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

widened end portions of the studied USB dongle is formed into an L shape. In this study, a 0.8 mm thick L-shaped FR4 substrate is used and considered as the system circuit board of the USB dongle.

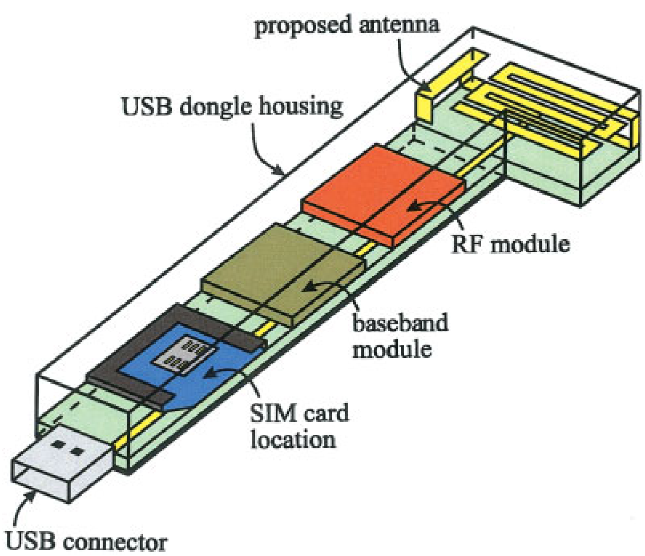

Figure 2 Example of a promising USB dongle with the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

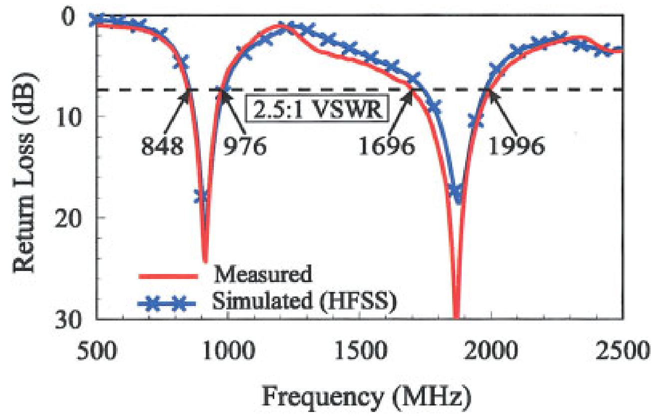

Figure 3 Measured and simulated return loss of the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

In addition, a ground plane of dimensions 90 × 15 mm^2 is printed on the main portion of the USB dongle, leaving the widened end portion ungrounded.

In the limited space of the widened end portion the proposed antenna is located, with the antenna height limited to be 5 mm

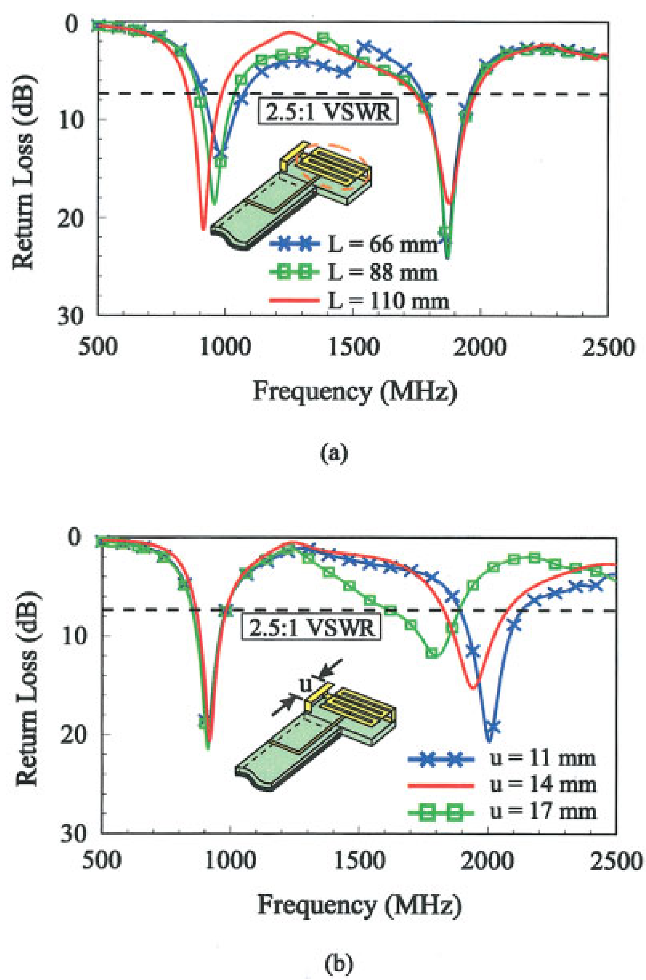

Figure 4 Simulated return loss (a) as a function of *L* and (b) as a function of *u*. Other parameters are the same as shown in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

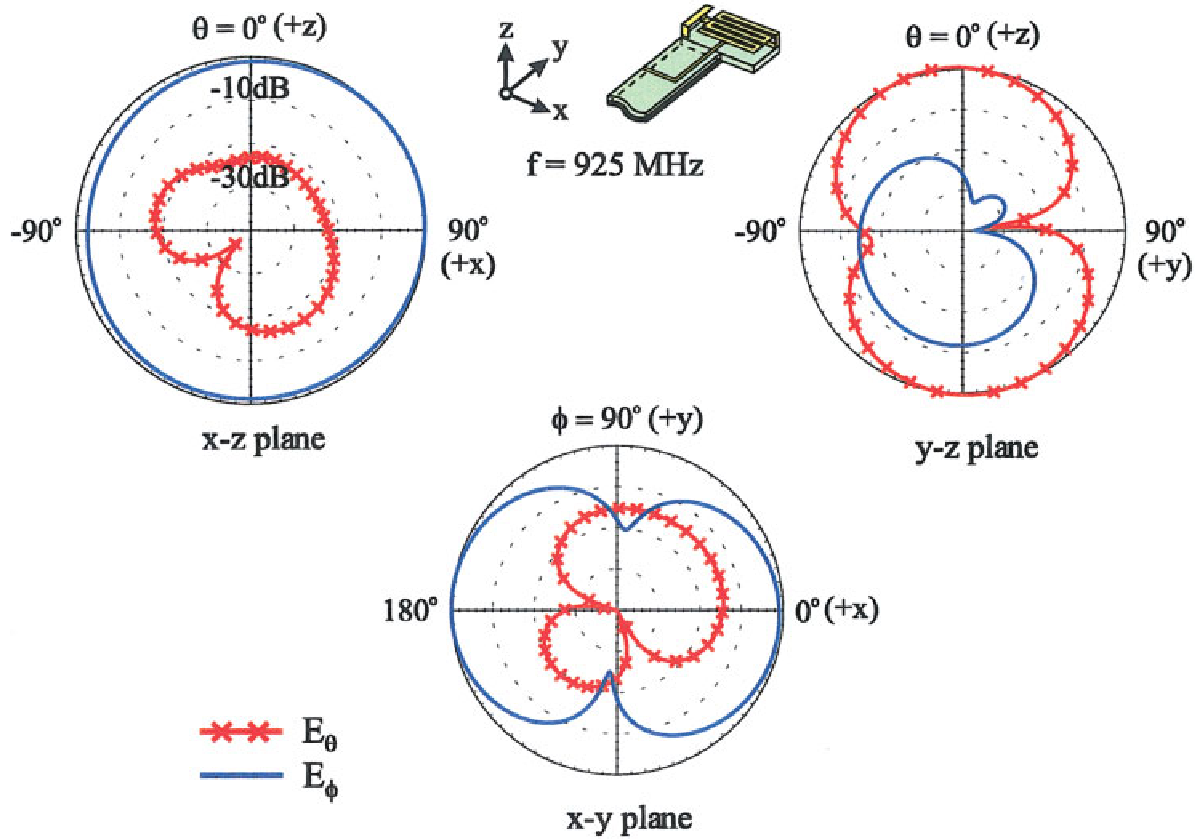

Figure 5 Measured radiation patterns at 925 MHz for the antenna shown in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

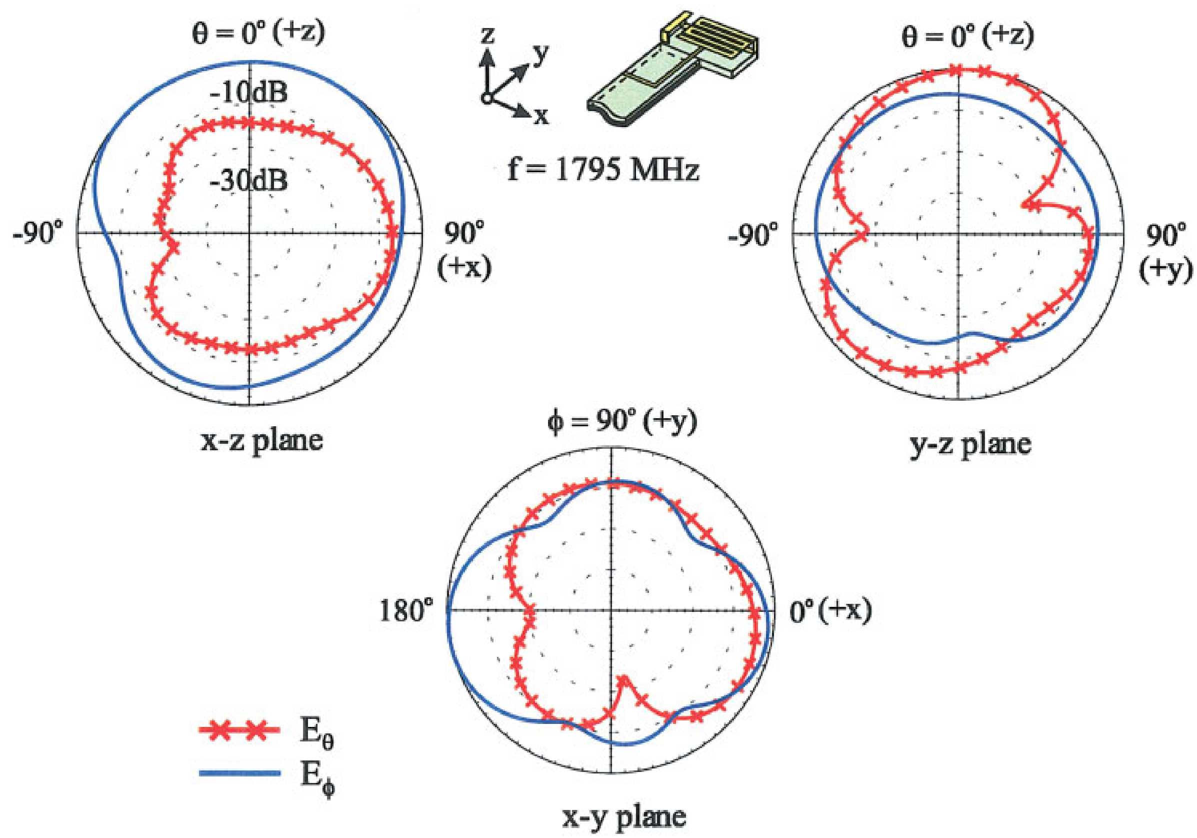

Figure 6 Measured radiation patterns at 1795 MHz for the antenna shown in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

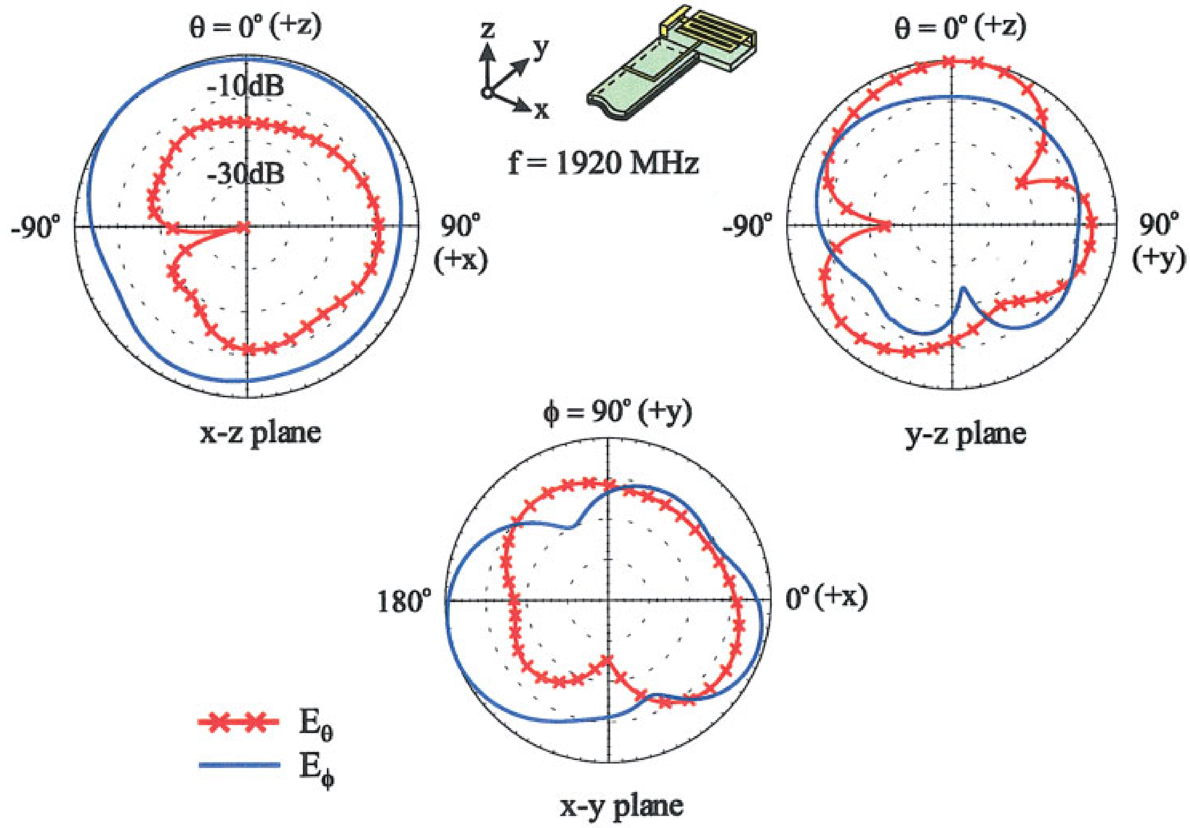

Figure 7 Measured radiation patterns at 1920 MHz for the antenna shown in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

only. In this case, the proposed antenna can be concealed inside the housing of the USB dongle to operate as an internal antenna. In order to achieve two wide bandwidths at about 900 and 1800 MHz to cover GSM and DCS/PCS operations, the proposed antenna uses two separate resonant strips of a longer strip with meandered end portion (Strip 1 in this study) and a shorter strip with a simple bent end portion (Strip 2). The two strips support two quarter-wavelength resonant paths at about 900 and 1800 MHz. In addition, although the two strips are folded to be in a compact structure as shown in the figure, there is a wide separation of 3.5 mm between the two strips. This wide separation ensures less coupling between Strips 1 and 2, thus allowing the antenna's two excited resonant modes also to be less coupled. That is, the antenna's excited lower resonant mode can be controlled solely by Strip 1 only; the variations in the length of Strip 2 will have very small or negligible effects on the antenna's lower resonant mode, and vice versa. This characteristic makes the proposed antenna easy to implement for 900/1800 MHz operation. More detailed results will be discussed with the aid of Figure 4 in Section 3.

3. RESULTS AND DISCUSSION

Based on the design dimensions shown in Figure 1, the proposed antenna for USB dongle application was fabricated and tested. Figure 3 shows the measured and simulated return loss of the constructed prototype. The simulated results are obtained using Ansoft simulation software HFSS (High Frequency Structure Simulator) [6], and good agreement between the measurement and simulation is obtained. With the bandwidth definition of 2.5:1 VSWR (about 7.3 dB return loss), the measured bandwidth for the excited lower resonant mode reaches 128 MHz (848–976 MHz), while that of the upper resonant mode is as high as 300 MHz (1696–1996 MHz). That is, two wide operating bands are generated for the proposed antenna, making it easy to cover GSM/DCS/PCS operations. Also note that the bandwidth definition of 2.5:1 VSWR used here is a higher standard for practical mobile device applications, because the internal GSM/DCS or GSM/DCS/PCS antennas of the general mobile phones are usually designed based on the bandwidth definition of 6 dB return loss (3:1 VSWR) only.

To analyze the effects of tuning the lengths of Strips 1 and 2 on controlling the antenna's two excited resonant modes, a simulation study was conducted. Figure 4(a) shows the simulated return loss as a function of L, which is the length of the meandered end portion of Strip 1. Results for three different lengths of $L = 66$, 88, and 110 mm are presented. Note that for the constructed prototype studied in Figure 3, the length L is 110 mm, and there are five parallel sections in the meandered end portion. For $L = 88$ and 66 mm, the parallel sections in the meandered end portion are, respectively, four and three, with the gap width fixed to 1 mm and the strip width fixed to 2 mm. From the obtained results, it is clearly seen that the impedance matching of the excited upper resonant modes is almost unchanged. On the other hand, the excited lower resonant mode is shifted to higher frequencies with a decrease in the length L. This suggests that, by tuning the length L, the antenna's excited lower resonant mode can be effectively adjusted, without affecting the excited upper resonant mode.

For varying the length of Strip 2, the results are shown in Figure 4(b). In this case, the length u of the bent portion of Strip 2 [see the inset in the figure and the antenna's planar structure in Figure 1(b)] is varied from 11 to 17 mm. Note that, for the constructed prototype studied in Figure 3, the length u is 14 mm,

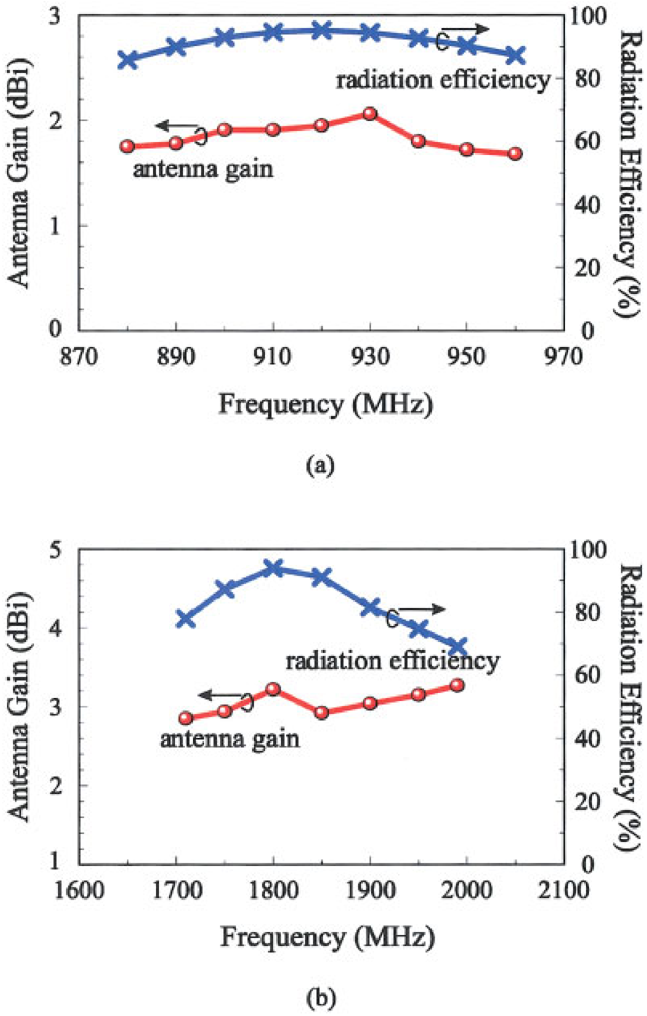

Figure 8 Measured antenna gain and simulated radiation efficiency for the antenna shown in Figure 1. (a) The GSM band. (b) The DCS/PCS bands. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

and the simulated results for three different lengths of $u = 11$, 14, and 17 mm are presented in Figure 4(b). Again, it is observed that the lower resonant mode is almost unaffected. For the upper resonant mode, it is shifted to lower frequencies with an increase in the length u. This also indicates that the antenna's upper resonant mode can be effectively controlled by tuning the length of Strip 2, without affecting the antenna's lower resonant mode. The behavior shown in Figure 4 is mainly owing to the large separation (3.5 mm in this study) selected between Strips 1 and 2 in the proposed antenna, which makes the antenna easy to implement for practical applications.

The radiation characteristics of the constructed prototype were also studied. Figure 5 plots the measured radiation patterns at 925 MHz, the center frequency of the GSM band. Monopole-like radiation patterns are observed, which are similar to those obtained for conventional internal patch antennas for mobile phone applications [2]. In Figures 6 and 7, the measured radiation patterns at 1795 and 1920 MHz, the center frequencies of the DCS and PCS bands, are also plotted. As compared to those at 925 MHz, more variations and nulls in the radiation patterns are seen. This characteristic is also expected and agrees with that of the conventional internal mobile phone antennas [2]. In addition, other frequencies over the GSM, DCS, and PCS bands were also measured, and similar radiation patterns as plotted in Figures 5, 6, and 7 are seen, which indicates that stable radiation patterns for frequencies over the GSM, DCS and PCS bands are obtained for the proposed antenna. Figure 8 presents the measured antenna gain and simulated radiation efficiency for the constructed prototype. In Figure 8(a), the results for frequencies over the GSM band are shown. The antenna gain varied in a small range of about 1.7–2.0 dBi, and good radiation efficiency of about 85–95% is obtained. For the results over the DCS and PCS bands shown in Figure 8(b), the antenna gain also varied in a small range of about 2.8–3.2 dBi, while the radiation efficiency varied from about 65 to 92%.

4. CONCLUSIONS

An internal GSM/DCS/PCS antenna with potential USB dongle applications has been proposed, fabricated, and tested. The proposed antenna is suitable to be mounted at the widened end portion of the USB dongle and can be embedded within the housing of the USB dongle to operate as an internal antenna. Furthermore, the proposed antenna has an advantage that the antenna's lower and upper resonant modes for GSM and DCS/PCS operations can be effectively controlled by tuning the length of the antenna's longer or shorter resonant strip only, which makes the antenna easy to implement for practical applications. In addition, good radiation characteristics for the proposed antenna have also been obtained. It is concluded that, with the proposed antenna embedded in the USB dongle and the traditional 2.4/5 GHz internal antenna embedded in the laptop computers, seamless wireless network access can be provided for wireless users.

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