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INTERNAL PLANAR WWAN LAPTOP COMPUTER ANTENNA USING MONOPOLE SLOT ELEMENTS

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ABSTRACT: *A planar WWAN (wireless wide area network) antenna comprising two monopole slots operated at their quarter-wavelength modes for GSM850/900/1800/1900/UMTS operation in the laptop computer is presented. With the use of monopole slot elements, the antenna can be easily printed on an inexpensive FR4 substrate and show a planar structure for promising applications in the thin-profile laptop computer. The antenna can provide two wide operating bands at about 900 and 1900 MHz to cover all the five operating bands for WWAN operation and yet occupies a small area of 10 × 75 mm² in the narrow spacing between the display and the laptop computer casing. The user's hand effects on the antenna performances when the touch panel or touch screen is used for the laptop computer are also studied.* © 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 1274–1279, 2009; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.24336

Key words: *internal laptop computer antennas; monopole slots; quarter-wavelength slots; WWAN antennas; printed antennas*

1. INTRODUCTION

Planar antennas that can be printed on a thin dielectric substrate are promising candidates for applications in the thin-profile mobile devices including the mobile handsets, laptop computers, and so on. For such applications in covering WWAN operation in the five operating bands of GSM850/900/1800/1900/UMTS, it is especially a challenging task for the promising planar printed antennas to be embedded inside the thin-profile laptop computer. This is owing to the relatively much larger ground plane connected to the embedded internal antenna for the laptop computers, when compared with the mobile handsets. In this case, especially for operating in the 900-MHz band, the large connected ground plane will mainly function as a reflector than as a part of radiator, thus, resulting in an increased size of the embedded internal antenna to achieve the required resonant length for the desired resonant mode excitation. Moreover, since the available space along the narrow spacing at the top edge of the laptop display [1-10] to accommodate the internal WWAN antenna is also limited as other mobile devices, the study on the promising WWAN antennas with compact size and thin profile to cover the desired penta-band operation including GSM850 (824–894 MHz), GSM900 (890–960 MHz), GSM1800 (1710–1880 MHz), GSM1900 (1850–1990 MHz), and UMTS (1920–2170 MHz) is hence interesting and important for practical applications. Also note that although there are some reported internal WWAN antennas for laptop computer applica-

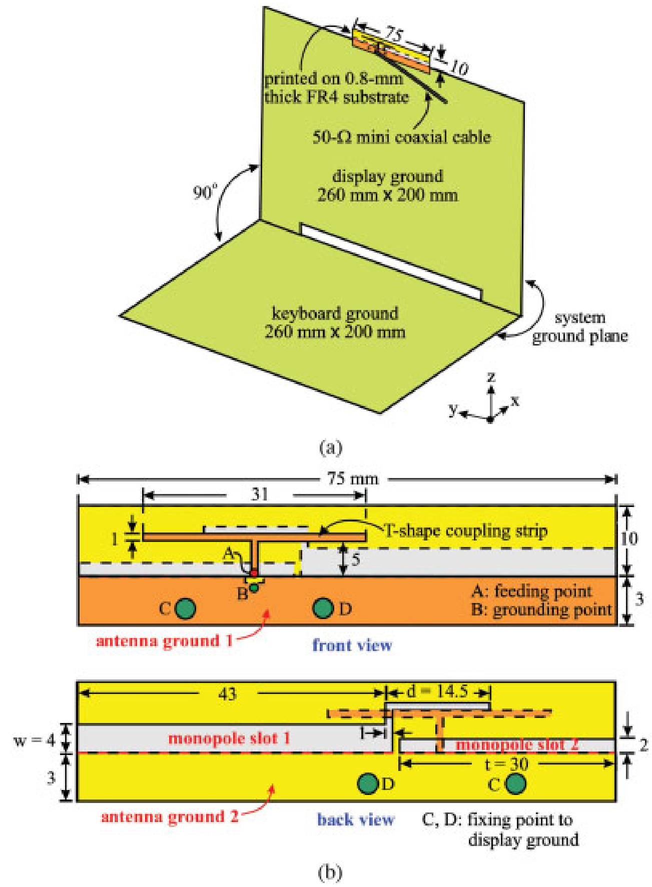

Figure 1 (a) Geometry of the proposed internal planar WWAN laptop computer antenna using monopole slot elements. (b) Detailed dimensions of the antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

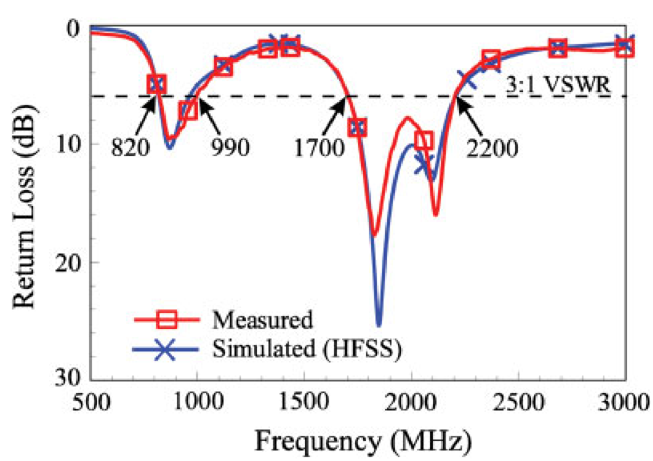

Figure 2 Measured and simulated return loss for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

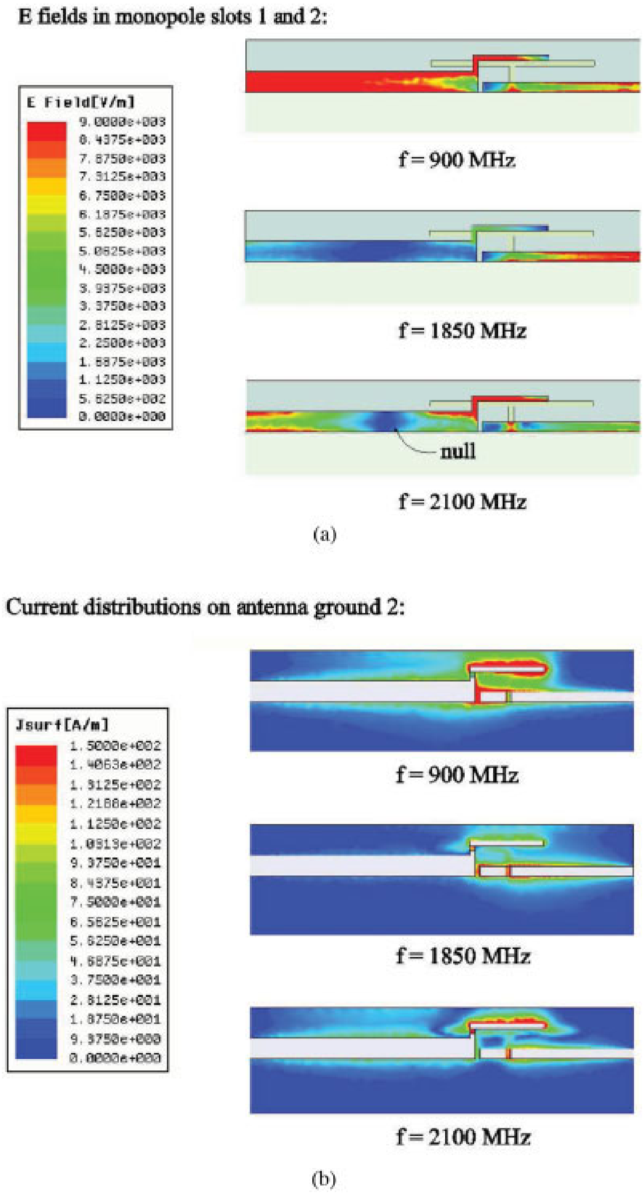

Figure 3 (a) Simulated electric field distributions in slots 1 and 2 and (b) simulated surface current distributions at 900, 1850, and 2100 MHz for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

tions [7-10], the promising antennas having a thin profile and capable of penta-band operation are still very scant in the open literature.

For thin-profile laptop computer applications in this study, we present a promising planar printed antenna using monopole slot elements [11-22]. The monopole slot element has an open end at the edge of the ground plane and can resonate at the quarter-wavelength (0.25 λ) mode, which is different from the traditional slot element having two closed ends and mainly resonated at the half-wavelength (0.5 λ) modes [23, 24]. Since the resonant slot mode usually shows a wide operating bandwidth [25], the 0.25 λ−mode excitation makes the monopole slot element attractive for internal mobile device antenna applications. Several promising monopole slot antennas have also been reported for applications in the mobile handset [11-15]. For laptop computer applications, however, there are still no related designs reported in the open literature.

The proposed antenna comprises two monopole slots and is suitable to be printed on a thin, small-size FR4 substrate to have a planar and compact structure. The antenna hence shows a very thin profile, making it very suitable to be placed at the top edge of the laptop display at which it is usually the thinnest part in the thin-profile laptop computer. Details of the proposed antenna are described in the article. Effects of the user's hand on the performances of the proposed antenna are also studied. The obtained results will be useful for the laptop computer equipped with the touch panel or touch screen [26]. In this case, the user's hand can be very close to the embedded antenna mounted along the top edge of the touch panel (see the study model in Fig. 8), and hence, the user's hand effects are expected to be large and should be considered. The radiation efficiency and radiation patterns of the proposed antenna with the user's hand in its near proximity are presented and discussed.

2. PROPOSED MONOPOLE SLOT ANTENNA

Figure 1(a) shows the geometry of the proposed monopole slot antenna for WWAN operation in the laptop computer. Detailed dimensions of the metal pattern of the antenna are given in Figure 1(b). The antenna is mounted at the center of the top edge of the system ground plane which is formed by the display ground and the keyboard ground, both of the same size 260 × 200 mm^2.

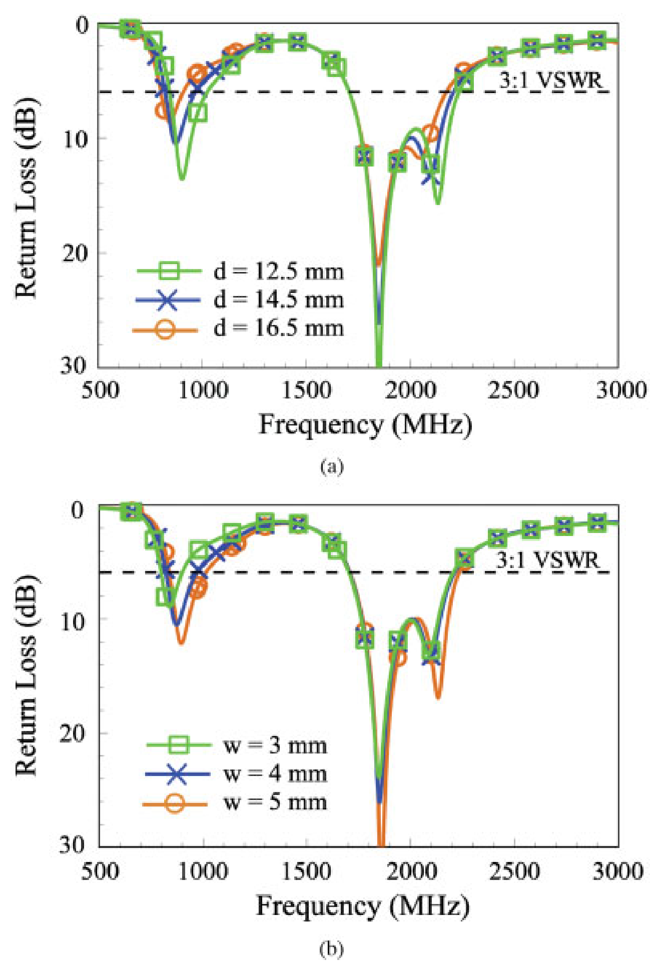

Figure 4 Simulated return loss as a function of (a) the end-section length *d* and (b) the width *w* of monopole slot 1; other dimensions are the same as in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

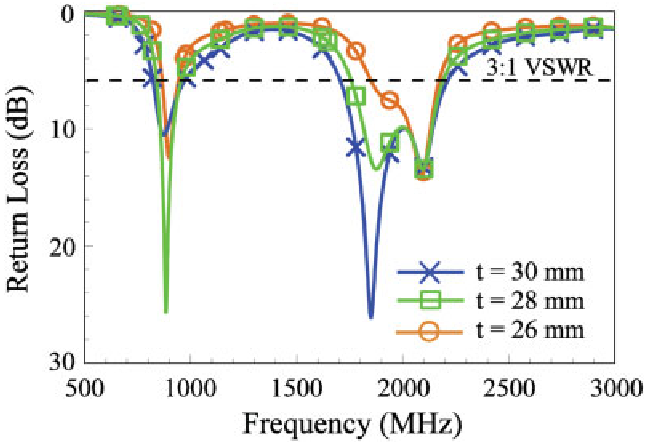

Figure 5 Simulated return loss as a function of the length *t* of monopole slot 2; other dimensions are the same as in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

The keyboard ground is oriented in the azimuthal plane (*x*-*y* plane), whereas the display ground is in the vertical plane (*y*-*z* plane).

The proposed antenna is printed on a 0.8-mm thick FR4 substrate and will occupy a small area of 10×75 mm^2 above the top edge of the display ground, which is promising [7-10] for its practical application in the thin-profile laptop computer. As shown in Figure 1(b), the antenna comprises two monopole slots of different sizes. The longer slot (monopole slot 1) has a length of about 60 mm and is bent to be of a step shape for reducing the antenna size. The longer slot can support a quarter-wavelength mode at about 900 MHz for GSM850/900 operation and a half-wavelength mode at about 2100 MHz for UMTS operation. By adjusting the end-section length *d* (14.5 mm in this study), the two modes supported by the longer slot can be controlled. Also, by adjusting the width *w* (4 mm here) of the open-end section of the longer slot, the achievable bandwidth of the two excited modes can be increased. For the shorter slot (monopole slot 2), it has a length *t* of about 30 mm and can support a quarter-wavelength mode at about 1850 MHz for GSM1800/1900 operation; by varying the length *t*, this quarter-wavelength mode can be adjusted. Hence, with the two slots, the five operating bands of GSM850/900/1800/1900/UMTS can be covered. Detailed effects of the parameters *d*, *w*, and *t* will be analyzed in "Results and Discussion."

The two slots are arranged to be extended in opposite directions and placed as close as possible to each other to achieve a compact size. With the proposed compact configuration, the two slots can also be successfully excited using a simple T-shape coupling strip formed by a vertical strip of length 5 mm and a horizontal strip of length 31 mm. The vertical strip is mainly for exciting the shorter slot, and its one end (point A) is the antenna's feeding point. The horizontal strip is for exciting the longer strip and is centered with respect to the vertical strip. For testing the antenna in the experiment, a 50-Ω mini coaxial line is used with its central conductor connected to point A and outer grounding sheath connected to antenna ground 1 at point B, the grounding point. Also note that antenna ground 1 is connected to antenna ground 2 on the back side of the FR4 substrate through two fixing points C and D, which are further connected to the display ground; in this case, the antenna is firmly mounted at the top edge of the display ground.

3. RESULTS AND DISCUSSION

The proposed antenna was fabricated and tested. Figure 2 shows the measured and simulated return loss for the fabricated proto-

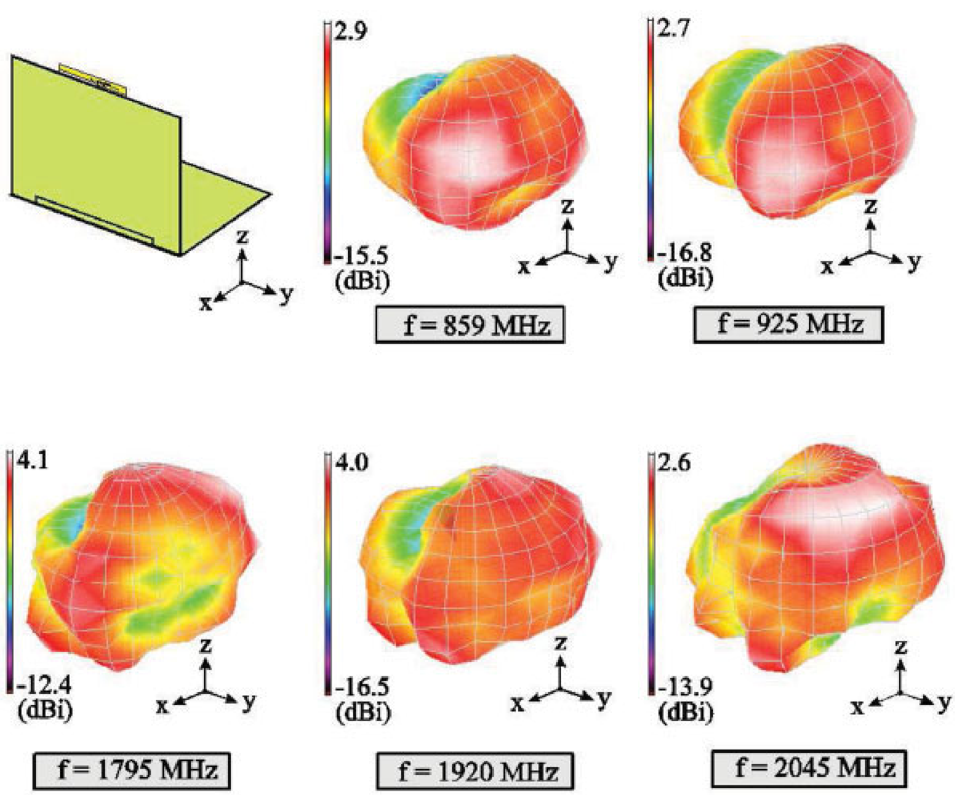

Figure 6 Measured 3-D radiation patterns at 859, 925, 1795, 1920, and 2045 MHz for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

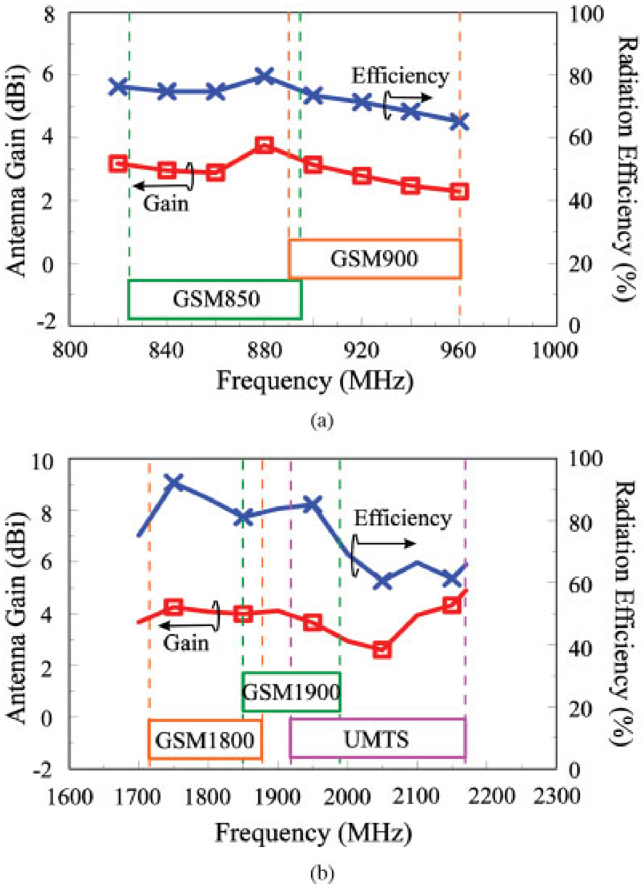

Figure 7 Measured antenna gain and radiation efficiency for the proposed antenna. (a) GSM850/900 bands. (b) GSM1800/1900/UMTS bands. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

type. The measured data are in good agreement with the simulated results obtained using Ansoft HFSS [27]. Two wide operating bands centered at about 900 and 1950 MHz are obtained. The lower band shows a wide bandwidth of 170 MHz (820–990 MHz) and easily covers GSM850/900 operation. For the upper band, it is formed by two resonant modes as described in "Proposed Monopole Slot Antenna" and has a wide bandwidth of 500 MHz (1700–2200 MHz), also easily covering GSM1800/1900/UMTS operation.

Figure 3(a) shows the simulated electric field distributions at 900, 1850, and 2100 MHz in slots 1 and 2, and their corresponding simulated surface current distributions on antenna ground 2 are given in Figure 3(b). The electric field distributions clearly show that the maximum field occurs at the open ends of the two slots and gradually decreases to be null at their closed ends at 900 and 1850 MHz. For the surface currents along the boundaries of slots 1 and 2, about symmetric distributions along the two opposite long edges are seen. Since the electric field and surface current distributions are similar to those in each half section (from the slot center to each closed end) of the traditional slot antenna excited at the half-wavelength mode, the resonant modes at about 900 and 1850 MHz can be identified as the quarter-wavelength mode of slots 1 and 2 in this study. Further, at 2100 MHz, strong electric field excitation in slot 1 is seen and the electric field shows a null at about the center of slot 1. About symmetric surface currents along the two opposite long edges of slot 1 are also seen. This indicates that the excited resonant mode at about 2100 MHz can be identified as the half-wavelength mode of slot 1.

Figure 4 shows the simulated return loss as a function of the end-section length d and the width w of slot 1. Other dimensions are the same as in Figure 1. Results for the length d varied from 12.5 to 16.5 mm are shown in Figure 4(a), whereas those for the width w varied from 3 to 5 mm are presented in Figure 4(b). It is seen that when either the length d or the width w is varied, the resonant mode at about 1850 MHz is almost not varied. On the other hand, the resonant modes at about 900 and 2100 MHz are affected. This behavior suggests that the two resonant modes at about 900 and 2100 MHz are mainly generated and controlled by slot 1, which agrees with the discussion in Figure 3. Further, from the simulated return loss as a function of the length t of slot 2 varied from 26 to 30 mm shown in Figure 5, large effects on the resonant mode at about 1850 MHz are seen, and the effects on the two other resonant modes are very slight. This indicates that slot 2 mainly controls the excitation of the resonant mode at 1850 MHz, which also agrees with the discussion in Figure 3.

Radiation characteristics of the proposed antenna are also studied. Figure 6 shows the measured three-dimensional (3-D) total-power radiation patterns at 859, 925, 1795, 1920, and 2045 MHz (central frequencies of the respective operating band). Owing to the relatively large ground plane connected to the antenna, the radiation patterns are different from those of the internal WWAN antennas for the mobile handsets [28]. However, the radiation efficiency over the five operating bands is all better than 60% (see the measured results shown in Fig. 7), making the proposed antenna promising for practical applications. For the measured antenna gain, small variations (less than 2 dB) in the GSM850/900 and GSM1800/1900/UMTS bands are also seen. Over the GSM850/900 band, the antenna gain varied in the range of about 2.2–3.7 dBi; whereas over the GSM1800/1900/UMTS band, the antenna gain is varied from about 2.8 to 4.8 dBi.

Effects of the user's hand [29-31] pointing on the touch panel of the laptop computer are also studied. Figure 8 shows the studied simulation model using SPEAG SEMCAD [32]. The user's hand is pointing on the touch panel at its top edge. In the figure, the touch panel (not shown) is assumed to have a thickness of 8 mm and supported by the display ground; on the top edge of the display, a metal frame of width 5 mm is also assumed. Along the top edge of the touch panel, three different conditions of the user's hand pointing at left edge, center and right edge of the touch panel are studied. For the center condition, the user's hand is just pointing below the antenna. The simulated results of the 3-D radiation patterns, radiation efficiency, and return loss at 925 and 1920 MHz for the three different conditions are presented in Figure 9. Results for the case without the user's hand are also

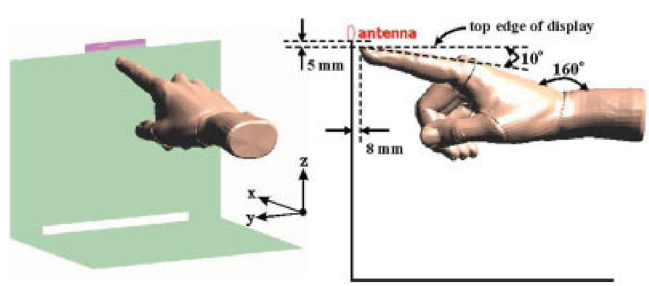

Figure 8 Simulation model (SPEAG SEMCAD [29]) for the proposed antenna with the user's hand pointing on the touch panel of the laptop computer. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

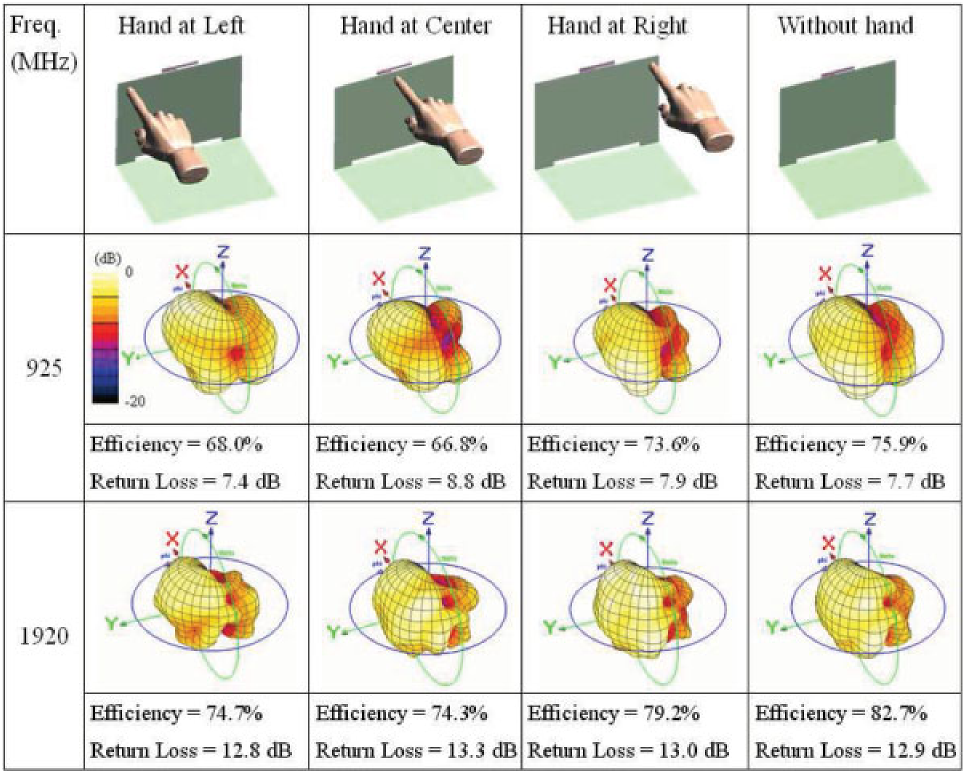

Figure 9 Simulated 3-D radiation patterns, radiation efficiency and return loss at 925 and 1920 MHz for different positions of the user's hand pointing on the touch panel. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

shown for comparison. Small variations in the radiation patterns and return loss for the presence of the user's hand are noted. However, since the user's hand is considered as a very lossy material [29-31], an efficiency decrease of about 9% is seen when the user's hand is pointing at the left edge and center of the touch panel at both frequencies. This is largely because the radiation patterns are relatively strong at the left edge ($+y$ direction) compared with the case at the right edge ($-y$ direction), hence causing larger effects when the user's hand is pointing at the left edge. The asymmetric radiation patterns (also see Fig. 6) are owing to the asymmetric monopole slot configuration in the proposed antenna. As for the center condition, the user's hand is very close to the antenna, thus resulting in large radiation power absorption by the user's hand. This behavior leads to the radiation efficiency decrease.

4. CONCLUSIONS

An internal planar monopole slot antenna printed on a thin FR4 substrate suitable for mounting at the top edge of the laptop display of the thin-profile laptop computer has been proposed and studied. In addition to its thin profile, the antenna occupies a small area of 10×75 mm^2 along the top edge of the laptop display, and yet can generate two wide operating bands at about 900 and 1900 MHz for covering GSM850/900 and GSM1800/1900/UMTS operations, respectively. Good radiation characteristics for frequencies over the two wide bands have also been obtained. When the user's hand is in the near proximity of the antenna, large effects on the radiation efficiency are also seen. The efficiency decrease can be as large as 9%, which needs to be considered for practical applications of the internal WWAN antenna for the laptop computer applications, especially for those equipped with a touch panel or touch screen.

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MEMBRANE-BASED FIBER BRAGG GRATING PRESSURE SENSOR WITH HIGH SENSITIVITY

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ABSTRACT: *A fiber Bragg grating (FBG) pressure sensor packaged by using a hard core in the membrane is presented. By utilizing the unique membrane-based FBG packaging method, its pressure sensitivity has been effectively enhanced. The pressure sensitivity of the FBG reaches 5.75 × 10^{-3}/MPa within the pressure range of 0–0.16 Mpa.* © 2009 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 1279–1281, 2009; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.24335

Key words: *FBG; pressure sensor; sensitivity*

1. INTRODUCTION

Because of its intrinsic advantages, fiber Bragg grating (FBG) has been widely applied as fibre-optic sensors to acquire the information of environmental parameters, including pressure, strain, temperature, voltage, current, etc. For some special applications such as hydrophone and microphone, the bare FBG cannot meet the requirements for high pressure sensitivity because of its low pressure sensitivity [1]. Packaging is a critical technique to improve the pressure sensitivity of the FBG. The sensitivity of the FBG, to a large extent, can be effectively improved with different packaging materials and structures [2–7]. FBG was firstly used as a pressure sensor [1]. In their successive experiments, they packaged the FBG in glass-bubble housing, where the sensitivity of the FBG was increased by -2.02×10^{-5}/MPa [4]. But these are not suitable for the special applications such as FBG hydrophones. In this article, by using a hard core in the membrane, the FBG pressure sensitivity has been effectively enhanced. Compared with the results in our previous report [8], we achieved a packaged FBG with higher sensitivity by a simpler fabrication method. The pressure sensitivity of the FBG reaches 5.75×10^{-3}/MPa within the pressure range of 0–0.16 Mpa.

2. PRINCIPLE

The Bragg wavelength can be described by $\lambda_B = 2n_{\mathrm{eff}}\Lambda$, where n_{eff} is the effective index of the fiber core, and Λ is the grating period. When only pressure is applied onto the FBG, its wavelength shift is given by [1]:

$$\Delta\lambda/\lambda_B = (1 - P_\varepsilon)\varepsilon \qquad (1)$$

where $\Delta\lambda$ is the relative shift of the Bragg wavelength, ε is the axial strain along FBG, and P_ε is the effective photoelastic coefficient of the fiber glass ($P_\varepsilon = 0.22$).

The FBG packaging structure is shown in Figure 1. In the metal tube, there is a plastic plate with a ~0.1 mm hole. The plastic plate is attached to the FBG through the hole. The plastic plate has a hard core and the silicon rubber around the plastic plate is a membrane in the mental tube. The pressure applied onto the FBG can be expressed as: