4. CONCLUSIONS

By using dual-bandpass diplexers and aperture coupling technology, our proposed dual-polarized dual-bands antenna can provide a pair of orthogonal polarization states at dual operating frequencies. Numerical and experimental results validate our design.

ACKNOWLEDGMENT

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INTEGRATED INTERNAL PATCH ANTENNA FOR UMTS MOBILE PHONE APPLICATION

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ABSTRACT: *A novel design of the internal patch antenna mounted above and integrated with the shielding metal case for mobile phone application is presented. The antenna mainly comprises a simple rectangular patch as the antenna's top radiating patch and a shielding metal case as part of the antenna's ground plane. The antenna is integrated to the shielding metal case through short-circuiting and occupies almost no board space on the system circuit board. In addition, possible electronic components or conducting elements in the mobile phone can be assembled in close proximity to the integration design at no expense of the antenna performance. Detailed results of the design example for universal mobile telecommunication system (1920–2170 MHz) operation in a mobile phone are presented and discussed.*

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Key words: *antennas; mobile phone antennas; internal mobile antennas; shorted patch antennas; integrated antennas; UMTS antennas*

1. INTRODUCTION

Conventional internal patch antennas for mobile phone application usually use the system ground plane as the antenna's main ground plane [1]. The side surfaces of this kind of antenna are mainly open to exterior, thus allowing the antenna's fringing electromagnetic fields to be penetrated into the interior of the system circuit board. This phenomenon leads to an isolation distance required between the internal antenna and nearby conducting elements to lessen the antenna performance degradation or further fine tuning in the antenna structure because of some coupling effect. Very recently, the concept of integrating the internal antenna and the RF shielding metal case/wall has been considered to be a promising antenna solution [2–5]. For these designs, the shielding metal case/wall not only performs as part of the antenna's ground plane but also provides a coupling-free region for assembling the RF modules and other components. As a result, the isolation distance is no more needed, and more compact arrangement of the internal antenna and associated components can be also achieved. It is also noted that, among these integration designs, the internal antenna is usually integrated to the side surface of the shielding metal case/wall and occupies a certain board space on the system circuit board of the mobile phone.

In this article, we present a new integration design of the internal patch antenna and the shielding metal case for mobile phone application. The antenna is suitable to be stacked over and short-circuited to the shielding metal case without increasing the antenna's height above the system ground plane as compared with that of the conventional patch antenna [1]. With the proposed design, the internal patch antenna occupies almost no board space on the system circuit board. In addition, the coupling between the antenna and associated nearby components inside the mobile phone can be also mitigated, thereby leaving the antenna performance not affected. A design example applied to a mobile phone for UMTS (universal mobile telecommunication system, 1920–2170 MHz) operation is demonstrated, and experimental results of the constructed prototype are presented and discussed. A study for analyzing the air-layer thickness of the antenna (i.e., the distance between the antenna's radiating patch and the shielding metal case) on the achievable impedance bandwidth is also conducted. Moreover, effects of the presence of a nearby conducting element on the antenna performance are studied.

2. ANTENNA DESIGN

Figure 1(a) shows the configuration of the proposed internal patch antenna mounted above the RF shielding metal case for a UMTS mobile phone. The antenna is a flat rectangular metal plate and shows a low profile of $h = 3$ mm to the shielding metal case. In this case, the patch antenna and the shielding metal case together

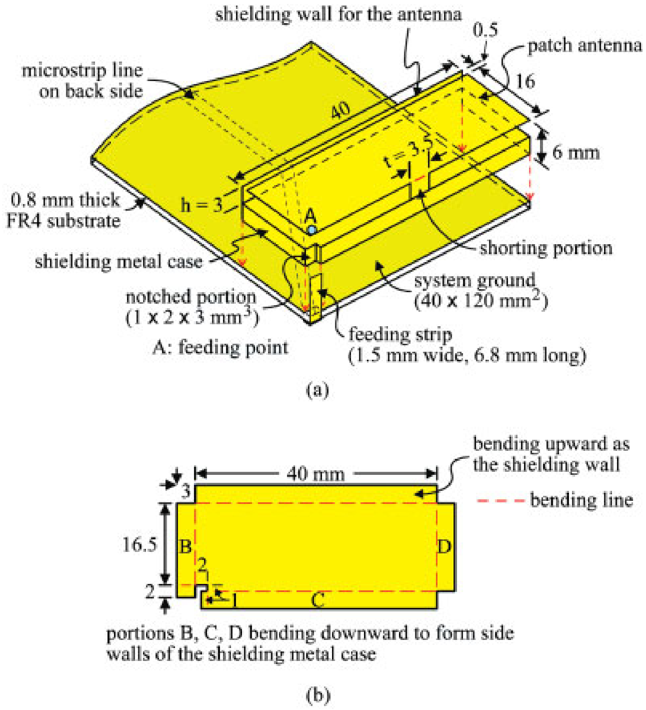

Figure 1 (a) Configuration of the integrated internal patch antenna mounted above the shielding case for a UMTS mobile phone. (b) Detailed dimensions of the flat metal plate for fabricating the shielding metal case. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

maintain the same height above the system ground plane as the conventional patch antenna [1] and yet provide more compact arrangement of the antenna and associated components. In addition, with $h = 3$ mm only, the antenna is capable of generating a wide operating bandwidth to cover the UMTS band. When a larger value of h is selected, a wider achievable impedance bandwidth can be further obtained. Effects of the parameter h on the impedance bandwidth will be analyzed more with the aid of Figure 5 in Section 3. As for the system ground plane, it is chosen to have reasonable dimensions of length 120 mm and width 40 mm for a practical mobile phone.

Detailed dimensions of the flat copper plate for fabricating the shielding metal case are shown in Figure 1(b). The shielding metal case is set to be of size $3 \times 16.5 \times 40$ mm^3 and has a small notched portion of size $1 \times 2 \times 3$ mm^3 for accommodating the feeding strip at the corner of the system ground plane. The feeding strip has a length of 6.8 mm and a width of 1.5 mm; its one end is connected to the feeding point A and the other end is connected to a 50 Ω microstrip feed line printed on the back side of the system circuit board. The proposed antenna consists of a simple rectangular patch of size 40×16 mm^2 as the antenna's top radiating patch and a shorting portion of length 3 mm and width (t) 3.5 mm. Note that the radiating patch is stacked over and arranged parallel to the shielding metal case, which also serves as part of the antenna's ground plane. Through the shorting portion at the center of the edge of the patch, the antenna and the shielding metal case are firmly integrated together, which allows the proposed design easy to implement for practical applications.

Also note that there is a small shielding metal wall (size $h \times 40$ mm^2) arranged in perpendicular to the shielding metal case with a small distance d of 0.5 mm to the radiating patch. This shielding metal wall can effectively shield the antenna from other electronic

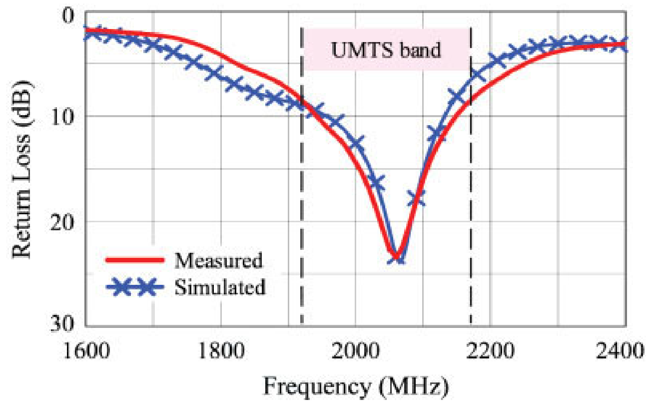

Figure 2 Measured and simulated return loss for the proposed antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

components or conducting elements in close proximity. Detailed results of the integration design with the presence of a nearby conducting element will be discussed in Section 3 with the aid of Figure 6.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the measured and simulated return loss of a constructed prototype. The simulated results are obtained using the Ansoft simulation software HFSS (high frequency structure simulator) [6], and fair agreement between the measured and simulated return loss is obtained. For frequencies across the UMTS band, it is seen that the measured impedance matching is all better than about 7.3 dB (2.5:1 VSWR), which is quite well for practical mobile phone application.

Figure 3 plots the measured radiation patterns at 2045 MHz. Note that the radiation patterns show high cross-polarization levels. This characteristic is similar to that of the conventional internal patch PIFA for mobile phone [1]. Also, the radiation patterns measured at other frequencies across the bandwidth are similar to those shown here, which indicates that stable radiation patterns over the UMTS band are obtained. Figure 4 shows the measured antenna gain and simulated radiation efficiency versus frequency. The antenna gain is varied in a small range of about 3.3–4.1 dBi,

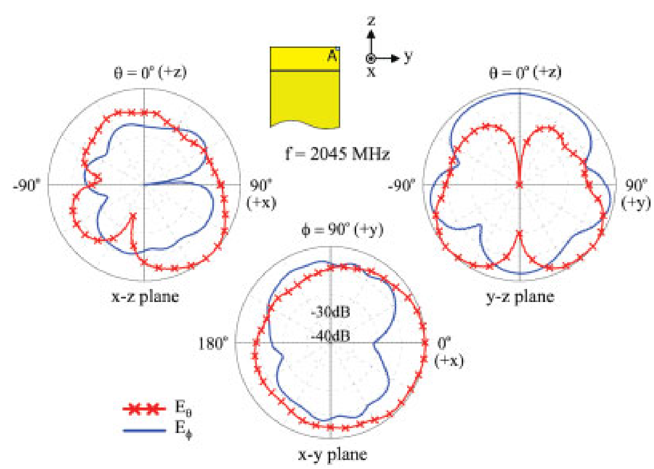

Figure 3 Measured radiation patterns at 2045 MHz for the antenna studied in Figure 2. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

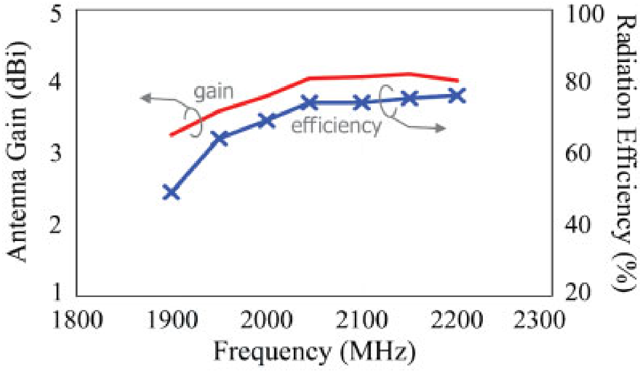

Figure 4 Measured antenna gain and simulated radiation efficiency versus frequency for the antenna studied in Figure 2. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

and the radiation efficiency on average is better than about 70% over the band.

A simulation study on the effects of the parameter *h* on the impedance matching is also conducted. Figure 5 shows the simulated return loss for the cases with $h = 3$, 4, and 5 mm. It should first be noted that with an increase in *h*, the center frequency of the antenna's resonant mode will be lowered. Thus, for easy comparison, a small portion of width *w* is removed from the patch (see inset in Fig. 5) to fine-tune the antenna's center frequency at about 2045 MHz. Moreover, the width *t* of the shorting portion is also adjusted for optimal impedance matching. Various selected values of *w* and *t* for $h = 3$, 4, and 5 mm are given in the caption of Figure 5. As expected, the results show that better impedance matching and wider bandwidth can be obtained for using a larger *h* (that is, a larger thickness of the air-layer substrate) for the antenna.

Finally, for further test, the presence of a nearby conducting element such as a second RF shielding metal case is arranged in close proximity (Figure 6). Other parameters are the same as studied in Figure 2. With or without the presence of the conducting element, small or negligible variations in the impedance matching of the antenna can be observed. The result suggests that the employment of a small metal plate protruded upwards from the edge of the shielding metal case (Fig. 1) can also function as an

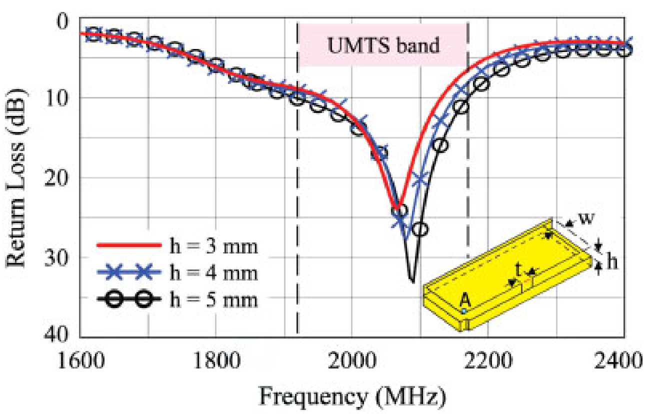

Figure 5 Simulated return loss as a function of *h*; $w = 0$ and $t = 3.5$ mm for $h = 3$ mm (proposed antenna); $w = 3.5$ mm and $t = 4$ mm for $h = 4$ mm; $w = 6.5$ mm and $t = 5$ mm for $h = 5$ mm. Other parameters are the same as given in Figure 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

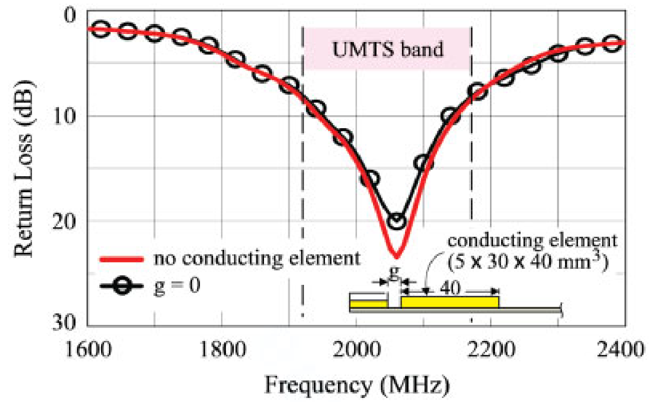

Figure 6 Measured return loss for the proposed antenna with and without a nearby conducting element of size $5 \times 30 \times 40$ mm^3. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

effective shielding metal wall to eliminate the isolation distance between the antenna and other components in the interior of the system circuit board of the mobile phone.

4. CONCLUSION

A shorted patch antenna mounted above and integrated with the shielding metal case for operating as an internal mobile phone antenna has been constructed and tested. The antenna and the shielding metal case together have a height of 6 mm only and are thus suitable to be concealed inside the casing of a mobile phone. In addition, since the antenna is stacked over the shielding metal case, very little board space on the system circuit board is needed for assembling the antenna. This can lead to a flexible arrangement of the antenna and associated components in the mobile phone. Results have also indicated that the antenna can be placed in close proximity to a second RF shielding metal case, with small or negligible effects on the antenna performance.

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