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INTERNAL SHORTED PATCH ANTENNA INTEGRATED WITH A SHIELDING METAL CASE FOR UMTS OPERATION IN A PDA PHONE

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Abstract—An internal shorted patch antenna integrated with a RF/battery shielding metal case for application in a UMTS mobile phone is presented. The shorted patch antenna is mounted at the dented portion of the shielding metal case, with the top patch flushed with the top surface of the shielding metal case. This configuration shows no protruded portions, which makes the antenna very suitable to be integrated in a UMTS mobile phone as an internal antenna. With the integrated design, which provides a coupling-free region for the nearby electronic components or conducting elements in the mobile phone, possible coupling between the antenna and associated components can be avoided. Details of the proposed design showing a wide bandwidth for UMTS (Universal Mobile Telecommunication System, $1920 \sim 2170$ MHz) operation are demonstrated, and effects of the dimensions of the RF/battery shielding metal case are presented and discussed.

1. INTRODUCTION

Shorted patch antennas, such as planar inverted-F antennas (PIFAs) for application as internal mobile phone antennas, have been recently demonstrated and reported in literature [1–6]. However, among these antenna designs, the system ground plane is usually treated as the antenna's ground plane. These kinds of internal mobile phone antennas merely use a simplified framework to study and develop antennas. That is, no additional associated components such as the RF/battery shielding metal case are placed nearby. However, for

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practical application, the shielding metal case or battery is in fact considered in the antenna design [7–9]. Due to coupling effects of the shielding metal case on the antenna performance degradation, the isolation distance between the internal antenna and the metal case is required (usually at least 5 mm or even larger than 7 mm). This isolation distance will further lead to the constrained usage of the internal board space available in a mobile phone. Recently, the concept of integrating the internal antenna and RF shielding metal case has been considered to be a promising antenna solution [10–15]. For these designs, the isolation distance is no more needed, and more compact structure of the internal antenna and associated components can be also obtained. However, among these integration designs, the internal antenna is usually integrated to the side surface of the shielding metal case and occupies a system ground-plane space of the mobile phone.

In this paper, we propose an internal shorted patch antenna integrated with a RF/battery shielding metal case for UMTS mobile phone application. The antenna is suitable to be stacked over and flushed to the dented portion of the shielding metal case (see Fig. 1). In this case, the shorted patch antenna and shielding metal case are integrated into a single package. Furthermore, almost no board space on the system circuit board is required for employing antenna. The integrated design, which provides a coupling-free space for the RF components, battery and other conducting elements in the mobile phone, is capable of eliminating the isolation distance between the antenna and the shielding metal case. The shielding metal case not only accommodates the associated components and modules but also serves as the antenna's ground plane. With the proposed design, the antenna performance will not be affected by the nearby components. This can lead to a simpler design process for the internal antenna for mobile phone. On the other hand, the shorted patch antenna is placed at the corner of the system circuit board, the possible fringing electromagnetic (EM) fields of the antenna inside the mobile phone are expected to be greatly suppressed. In this study, an integration design of the shorted patch antenna and the RF/battery shielding metal case for operation in the UMTS band is conducted. Details of the proposed antenna and the experimental results are presented and discussed. Effects of the dimensions of the shielding metal case on the antenna performance are also studied.

2. ANTENNA DESIGN

Figure 1 shows the configuration of the proposed antenna integrated with a RF/battery shielding metal case, which is soldered onto the top portion and flushed to the edge of the system ground plane of a UMTS mobile phone. This design shows no protruded portions and allows the antenna and the shielding metal case to be easily concealed within the casing as an internal element. In this study, a 0.2 mm thick copper plate of dimensions of $L \times W$ is used as the system ground plane.

The RF/battery shielding metal case (made of a 0.2 mm thick copper plate) is designed to be of a dented shape at the corner of the top edge. The dented portion has an area of $16 \times 33\,\text{mm}^2$ and a depth of 5 mm for accommodating the proposed antenna. Note that the shielding metal case has a total length of S_1, a height of 8 mm, and a smaller height of 3 mm at the corner of the top edge. In addition, S_2 is the length from the bottom of the shielding metal case to the corner

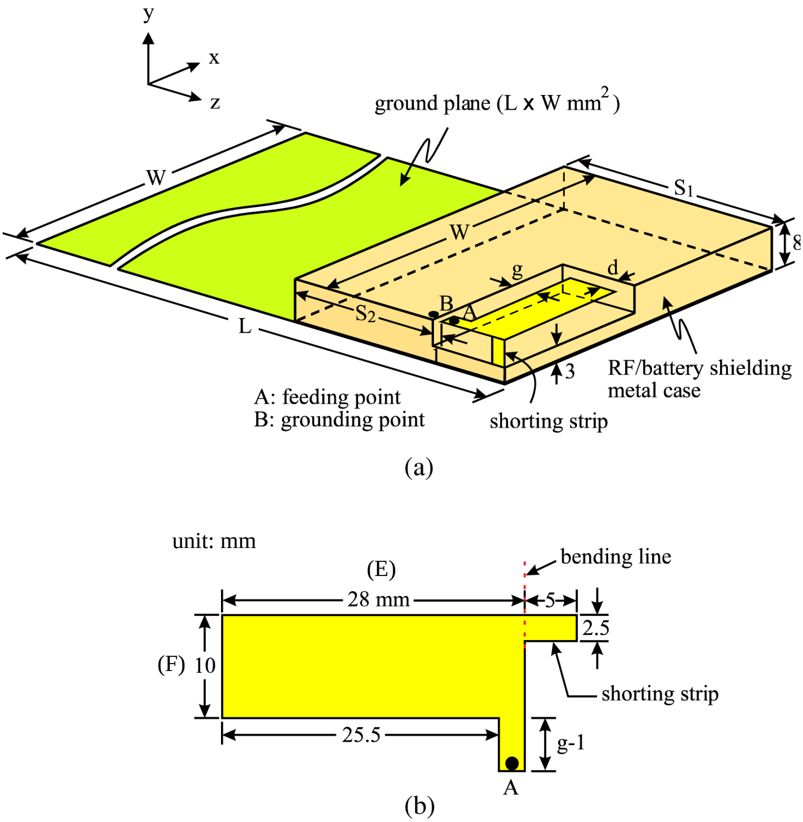

Figure 1. (a) Configuration of the internal shorted patch antenna integrated with a shielding metal case for UMTS mobile phone application. (b) Dimensions of the UMTS antenna.

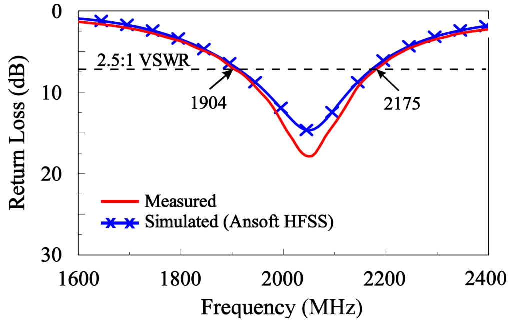

Figure 2. Measured and simulated return loss of the proposed antenna with $d = 5\,\mathrm{mm}$, $g = 6\,\mathrm{mm}$, $S_2 = 30\,\mathrm{mm}$, $S_1 = 46\,\mathrm{mm}$, $L = 100\,\mathrm{mm}$, $W = 70\,\mathrm{mm}$; other parameters are given in Fig. 1.

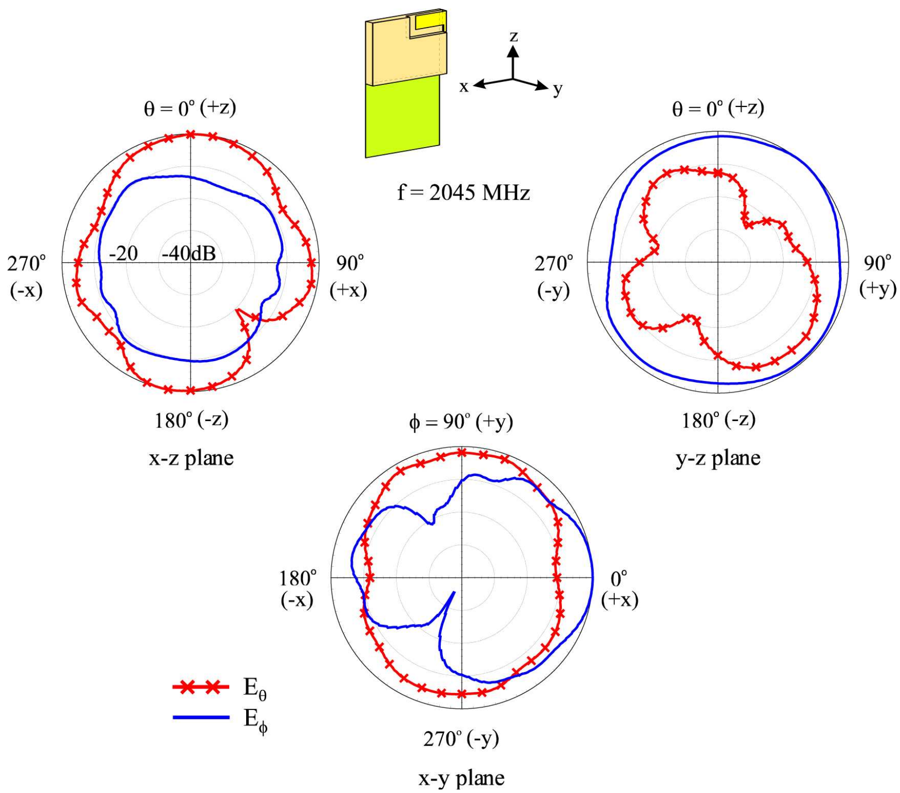

Figure 3. Measured radiation patterns at 2045 MHz for the antenna studied in Fig. 2.

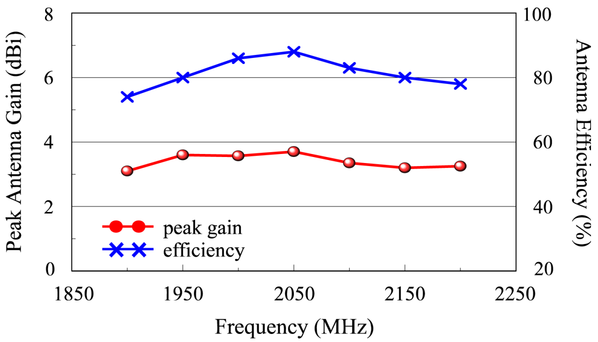

Figure 4. Measured antenna gain and simulated antenna efficiency over the UMTS band for the antenna studied in Fig. 2.

of the dented portion. The antenna is easily constructed from cutting a single metal plate, and detailed dimensions are given in Fig. 1(b). The top patch is made of a 0.2 mm thick copper plate, and the dimensions of the rectangular patch are selected to be 28 mm × 10 mm ($E \times F$). Note that the shielding metal case also functions as the antenna's ground plane and has an air-layer thickness of 5 mm. In this case, the antenna occupies no space on the bottom ground or system ground plane of the mobile phone.

For testing the antenna, a 50-Ω mini coaxial line is used. The central conductor is connected to point A, and its outer grounding sheath is soldered to point B at the shielding metal case. The shorting strip (of constant width 2.5 mm) is connected to the shielding metal case such that the antenna is integrated to the shielding metal case. The short-circuiting provides an additional inductance to compensate for the large capacitance contributed to the distance between the antenna and the shielding metal case, thereby leading to improved impedance matching.

As for the center frequency of the proposed antenna, it is mainly controlled by the dimensions of top patch and can be approximately determined from

$$f \approx \frac{c}{4(E+F)} \tag{1}$$

where c is the speed of light in free space; f is the desired resonant frequency (in this case, $f = 2045\,\text{MHz}$); $E\,(\text{mm})$ and $F\,(\text{mm})$ are the length and width of the top patch, respectively. Therefore, the dimensions of the top patch can be fine-adjusted in the experiment for obtaining the desired center resonant frequency.

The gap distances (d and g) between the antenna and the

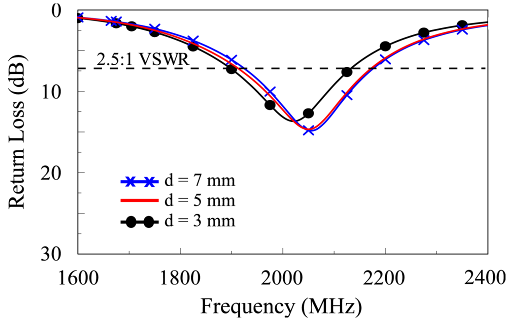

Figure 5. Simulated return loss of the proposed antenna with $d = 7, 5, 3\,\mathrm{mm}$, respectively; $g = 6\,\mathrm{mm}$, $S_2 = 30\,\mathrm{mm}$, $S_1 = 46\,\mathrm{mm}$, $L = 100\,\mathrm{mm}$, $W = 70\,\mathrm{mm}$.

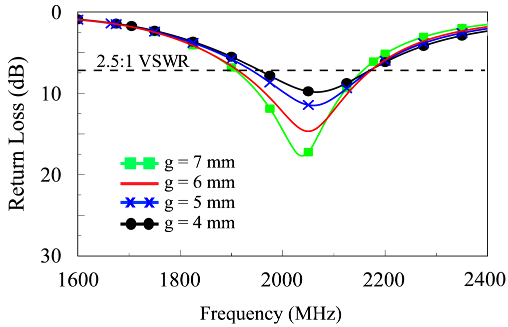

Figure 6. Simulated return loss of the proposed antenna with $g = 7, 6, 5, 4\,\mathrm{mm}$, respectively; $d = 5\,\mathrm{mm}$, $S_1 = 46\,\mathrm{mm}$, $L = 100\,\mathrm{mm}$, $W = 70\,\mathrm{mm}$.

shielding metal case are important parameters affecting the impedance matching. Effects of the variation in the feed gap on the antenna impedance matching will be studied in Section 3 with the aid of Figs. 5 and 6. In addition, since the RF/battery shielding metal case can function as the antenna's ground plane, the variation in the dimensions of the shielding metal case is very likely to have some effects on the antenna performance. The dimensions of the system ground plane are also important parameters for the proposed design. Effects of the system ground-plane dimensions on the antenna impedance matching will be also analyzed with the aid of Figs. 7–9 in the next section.

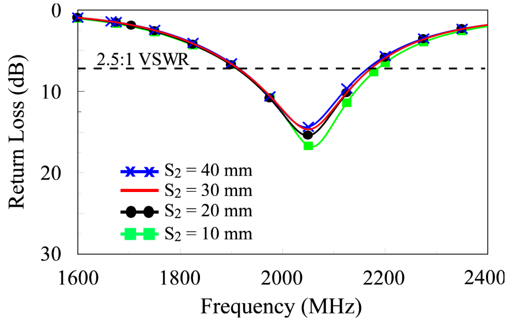

Figure 7. Simulated return loss of the proposed antenna with $S_2 = 40, 30, 20, 10$ mm, respectively; $d = 5$ mm, $g = 6$ mm, $L = 100$ mm, $W = 70$ mm.

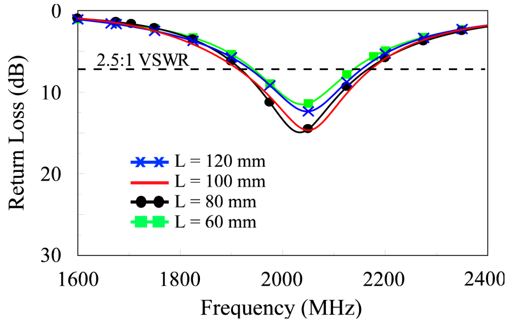

Figure 8. Simulated return loss of the proposed antenna with $L = 120, 100, 80, 60$ mm, respectively; $d = 5$ mm, $g = 6$ mm, $S_2 = 30$ mm, $S_1 = 46$ mm, $W = 70$ mm.

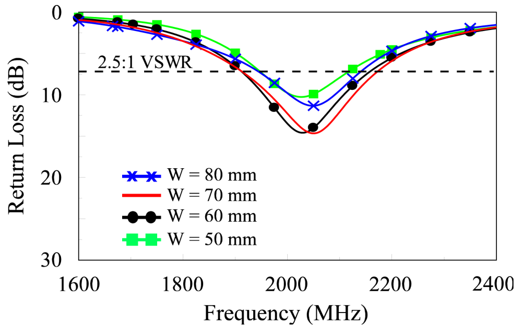

Figure 9. Simulated return loss of the proposed antenna with $W = 80, 70, 60, 50$ mm, respectively; $d = 5$ mm, $g = 6$ mm, $S_2 = 30$ mm, $S_1 = 46$ mm, $L = 100$ mm.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Based on the design dimensions shown in Fig. 1, the proposed antenna was constructed and tested. The ground plane is first selected to have dimensions of 100 mm × 70 mm ($L \times W$), which are reasonable for a practical PDA (Personal Digital Assistant) mobile phone. The lengths S_1 and S_2 of the shielding metal case are first selected to be 46 and 30 mm, respectively. The gap distances d and g are chosen to be 5 and 6 mm. Other parameters are given in Fig. 1. Fig. 2 shows the measured and simulated return loss. The simulated results are obtained using Ansoft HFSS (High Frequency Structure Simulator) [16] and match well with the measurement. The measured impedance bandwidth, defined by 2.5 : 1 VSWR, which is quite good for practical PDA or mobile phone application, reaches about 271 MHz (1904 $\sim$ 2175 MHz) and covers the required UMTS band. Fig. 3 shows the measured radiation patterns at 2045 MHz. Note that the radiation patterns obtained show high cross-polarization levels. This characteristic is similar to that of the conventional mobile phone PIFA [1]. The results of other frequencies across the bandwidth were also measured, and radiation patterns similar to those plotted here are observed. The measured antenna gain and simulated antenna efficiency are presented in Fig. 4. The measured antenna gain is about 3.1–3.7 dBi for frequencies across the UMTS band. Good radiation efficiency is also obtained, and it is found to be in the range about 74–88% from the simulated results.

To analyze the effects of the gap distance between the antenna and the shielding metal case on the antenna impedance matching, a simulation study is conducted. Fig. 5 shows the simulated return loss for the cases with $d = 7$, 5, and 3 mm; other parameters are the same as those in Fig. 2. From the results, it is seen that the impedance bandwidth is decreased with a decrease in the gap distance d. It is largely because the coupling between the antenna and the shielding metal case is increased. By the same token, the effects of the variation in the gap distance with $g = 7$, 6, 5, and 4 mm on the impedance matching are observed in Fig. 6. This characteristic is about the same as studied in Fig. 5. Therefore, the values of d and g are chosen to be 5 and 6 mm as the preferred dimensions. Fig. 7 shows the simulated return loss as a function of the shielding metal case length S_2. Note that the size of dented portion is fixed for the parametric studies. That is, for S_2 varied from 40 to 10 mm, the total length S_1 of the shielding metal case is simultaneously decreased. A relatively small variation in the return loss for S_2 varied from 10 to 40 mm is obtained. It is seen that for all conditions, the impedance bandwidths cover the required bandwidth of the UMTS band with various possible shielding metal case length. These results show that the proposed integrated design is suitable for applications in mobile devices.

Finally, effects of the system ground-plane dimensions on the performance of the antenna are studied using Ansoft HFSS. Fig. 8 shows the simulated return loss as a function of ground-plane length L varied from 60 to 120 mm (60, 80, 100, and 120 mm). The simulated impedance bandwidth (BW) and center frequency (f_c) for the length

Table 1. Simulated radiation performances' variation with various ground-plane lengths; $d = 5$ mm, $g = 6$ mm, $S_2 = 30$ mm, $S_1 = 46$ mm, $W = 70$ mm. f_U and f_L are, respectively, the upper and lower edge frequencies of the 2.5 : 1 VSWR return-loss impedance bandwidth (BW), and f_c is the center operating frequency of the impedance bandwidth. Other parameters of the proposed antenna are the same as given in Fig. 2.

L (mm)	BW ($= f_U - f_L$) (MHz)	f_c (MHz)
130	214 (= 2152 − 1938)	2047
120	212 (= 2151 − 1939)	2047
110	221 (= 2158 − 1937)	2052
100	255 (= 2170 − 1915)	2050
90	259 (= 2169 − 1910)	2037
80	243 (= 2163 − 1920)	2032
70	211 (= 2145 − 1934)	2032
60	191 (= 2136 − 1945)	2037
50	178 (= 2130 − 1952)	2040

Table 2. Simulated radiation performances' variation with various ground-plane widths; $d = 5$ mm, $g = 6$ mm, $S_2 = 30$ mm, $S_1 = 46$ mm, $L = 100$ mm. Other parameters of the proposed antenna are the same as given in Fig. 2.

W (mm)	BW($= f_U - f_L$) (MHz)	f_c (MHz)
80	191 (= 2138 − 1947)	2047
70	255 (= 2170 − 1915)	2050
60	240 (= 2155 − 1915)	2030
50	165 (= 2115 − 1950)	2028
40	—	—

L varied from 50 to 130 mm are listed in Table 1 for comparison. The simulated center frequencies are seen to vary in a small range from 2032 to 2052 MHz, about 20 MHz or 1% variation only. As for the impedance bandwidth, it varies from 178 to 259 MHz, about 81 MHz or 37% variation. A relatively large variation in the impedance bandwidth is seen. In this case, the impedance bandwidth can be obtained to cover the UMTS band when $L = 100$ or 90 mm only. The simulated return loss for the ground-plane width W varied from 50 to 80 mm is shown in Fig. 9, and the results are given in Table 2. The variations in the center frequency and impedance bandwidth are seen to be about the same as those for various ground-plane lengths studied in Table 1. The results clearly show that the impedance bandwidth cover the UMTS band when $W = 70$ mm only. Therefore, the dimensions of system ground plane is chosen to be $70 \times 100\,\text{mm}^2$, which is a reasonable size for the system or main ground plane of a practical PDA phone.

4. CONCLUSION

An internal shorted patch antenna integrated with a shielding metal case for UMTS mobile phone application has been constructed and tested, and good radiation characteristic has been also observed. The constructed prototype integrates the antenna and the shielding metal case, which provides a coupling-free space for the RF components, battery and other associated elements in the mobile phone. The integrated antenna shows no protruded portions and is very promising to be concealed within the casing of the mobile phone. Furthermore, the antenna occupies no space on the bottom ground or system ground plane. Experimental results have also indicated that the antenna shows acceptable impedance matching characteristic.

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