Small-size LTE/WWAN coupled-fed loop antenna with distributed parallel resonant circuit

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***Abstract* – A small-size LTE/WWAN coupled-fed loop antenna with a rotated U-shaped strip for laptop-computer applications is presented. The coupled-fed loop antenna formed by a feeding strip and a coupled shorting strip can support two operating bands, both of which cannot cover the desired frequency bands. By embedding a rotated U-shaped strip into the coupled-fed loop to maintain the compactness of the antenna, a distributed parallel resonant circuit (PRC) is formed to expand the bandwidths of the lower band and the higher band. The proposed antenna has a uniplanar structure and is easy to be fabricated on a thin FR4 substrate with an area of only 10 × 50 mm^2.**

***Index Terms* —LTE/WWAN antennas, multi-wideband antennas, distributed parallel resonant circuit.**

I. Introduction

In recent years, laptop-computer antennas have been required to cover the GSM850/900/1800/1900/UMTS and LTE700/2300/2500 operating bands to support the WWAN and LTE operations for 2G/3G/4G communications. To provide two wide operating bands for the LTE/WWAN operation, some internal antennas reported in [1-2] were designed to employ lumped elements to reduce the antenna's size. However, lumped elements will decrease the radiation efficiency and increase the fabricated cost. To implement the internal LTE/WWAN antenna in a smaller size remains a challenging task, owing to the very limited available space demanded in the laptop computer.

In this article, we present a promising design of internal laptop-computer antennas having a reduced antenna size by using an integration technique with a coupling feed and a distributed PRC that can provide two wide operating bands (698–960 and 1710–2690 MHz) to cover the eight-band LTE/WWAN operation. On the basis of the proposed technique, the antenna's metal pattern can be printed on only one side of a small-size planar FR4 substrate with an area of 10 × 50 mm^2.

II. Proposed Antenna

Figure 1(a) shows the geometry of the proposed antenna. The antenna is mounted along the top edge of the display ground. The dimensions of the display and keyboard grounds are selected to be 260 mm × 200 mm, which are reasonable dimensions for the laptop computer with a 13-inch display panel. The proposed antenna is formed by a coupled-fed loop antenna and a rotated U-shaped strip, all printed on a 0.4-mm-thick FR4 substrate of size 10 × 50 mm^2. The rotated U-shaped strip is connected to the place near the input port of the coupled-fed loop antenna. The coupled-fed loop antenna composed of a feeding strip and a meander shorting strip can generate one and two resonant modes in the lower and upper band, respectively. However, the bandwidths of the lower and upper bands are too narrow to cover the desired frequency bands for the LTE/WWAN operation. The rotated U-shaped strip is encircled by a portion of the meander shorting strip with a gap to form a distributed PRC. We call this portion the coupling portion. The gap and the length of the coupling portion provide a distributed capacitance and a distributed inductance, respectively. The distributed PRC leads to a parallel resonance generated at about 1300 MHz, which results in a new resonance (zero reactance) occurring

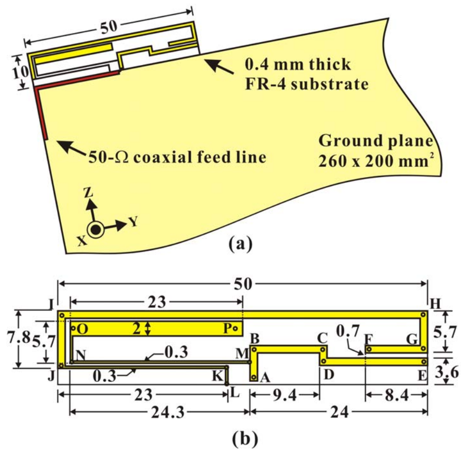

Fig. 1. Geometry of proposed antenna for laptop-computer application.

nearby and leads to a new resonant mode excited at about 950 MHz. This new resonant mode can combine with the quarter-wavelength mode of the coupled-fed loop antenna to cover the desired LTE700/GSM850/900 operation (698–960 MHz), which greatly enhances the bandwidth of the antenna's lower band. In addition, the rotated U-shaped strip can generate a higher-order monopole mode at about 2610 MHz. This mode can also combine with those contributed by the feeding strip and the coupled shorting strip to cover the GSM1800/1900/UMTS/LTE2300/2500 operation. To feed the antenna, a 50-Ω mini coaxial line is used, whose central conductor and outer grounding sheath is connected to point

A in the feeding strip and point L in the antenna ground, respectively. The antenna is also fabricated and tested.

III. RESULTS AND DISCUSSION

Figure 2 shows the simulated return loss and input impedance for the proposed antenna, the case with the feeding strip only (Type 1), and the case with the feeding strip and coupled shorting strip (Type 2). The simulated results using Ansys's full-wave electromagnetic field simulator High-Frequency Structure Simulator (HFSS) [3] are observed.

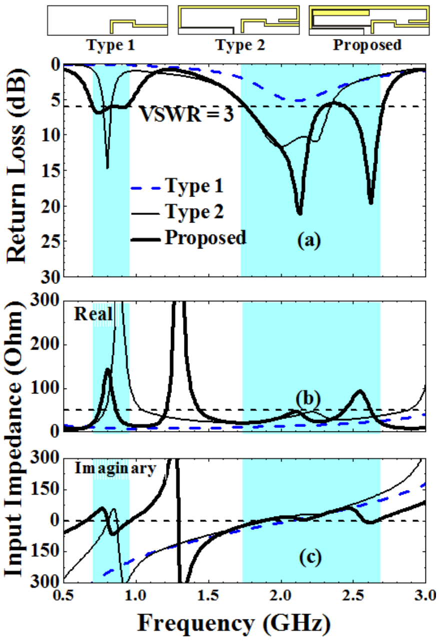

Fig. 2. Simulated return loss and input impedance for the proposed antenna, Type1, and Type2.

With the feeding strip only (denoted by Type 1), a resonant mode at about 2100 MHz is generated (although the impedance matching is not good). When the coupled shorting strip is added to Type 1 (denoted by Type 2), two additional resonant modes are generated, with one mode at about 780 MHz and the other at about 2250 MHz. The mode at about 2250 MHz also combines with the one contributed by the feeding strip to widen the bandwidth of the antenna's upper band. Then, by further adding to Type 2 the rotated U-shaped strip to form the proposed antenna, it is clearly seen that a wideband resonant mode at about 950 MHz is generated, which makes the antenna capable of covering the desired 698–960 MHz band. This behavior can be explained more clearly from the comparison of the simulated input impedance for the proposed antenna and the case without the rotated U-shaped strip (Type 2) in Figures 3(b) and 3(c). In the figure, it is clearly observed that a parallel resonance is generated at about 1300 MHz and a new resonance occurs at about 980 MHz which leads to the wideband resonant mode excited at about 950 MHz as shown in Figure 3(a). In addition, the rotated U-shaped strip can generate a higher-order monopole mode at about 2610 MHz. This mode also combines with the ones contributed by the feeding strip and coupled shorting strip to cover the GSM1800/1900/UMTS/LTE2300/2500 operation. Two wide operating bands covering the desired lower and upper bands for the eight-band LTE/WWAN operation (the shaded regions in Figure 2) are obtained. The impedance matching for frequencies over the desired lower and upper bands is better than 3:1 VSWR or 6-dB return loss.

Figure 3 shows the simulated and measured radiation efficiency and antenna gain of the proposed antenna. Good agreement between the measured and simulated results is obtained. The measured results show that the radiation efficiency is about 51–64% and 62–81% for the lower and upper bands, respectively. The measured antenna gain varies in the range of 0.8–2.2 dBi for the lower band and 1.8–4.2 dBi for the upper band. The measured radiation efficiency and antenna gain are acceptable for practical applications.

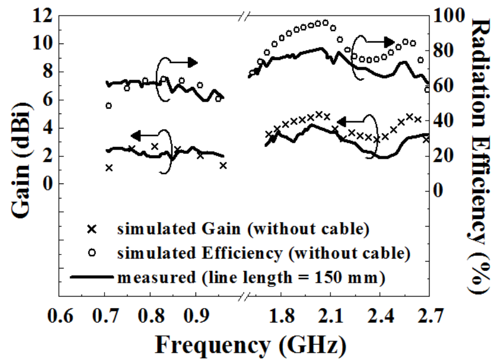

Fig. 3. Simulated and Measured radiation efficiency and antenna gain of the proposed antenna.

IV. CONCLUSION

A promising small-size internal laptop computer antenna with a volume of $10 \times 50 \times 0.4$ mm^3 for the eight-band LTE/WWAN operation has been proposed and studied. With a simple structure formed by a coupled-fed loop antenna and a rotated U-shaped strip, the proposed antenna can be easily implemented at low cost only by printing a metal film on a thin FR4 substrate. The design techniques in achieving small size, yet wideband operation for the proposed antenna have been discussed in detail. The proposed antenna has also been fabricated and tested. Good radiation characteristics for practical applications have been observed. With the obtained results, the proposed antenna should be promising for practical laptop-computer applications.

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