Bandwidth Enhancement of Small Internal WWAN Tablet Computer Antenna Using Distributed Parallel Resonant Circuit

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Abstract

An internal WWAN tablet computer antenna with a size of 12×35 mm^2, about the smallest among the related antennas that have been reported, is presented. Bandwidth enhancement of the antenna is achieved by embedding a distributed parallel resonant circuit which widens the operating bandwidth without increasing the antenna size.

Keywords : Tablet computer antennas, WWAN antennas, printed antennas

1. Introduction

The reported internal WWAN antennas for the tablet computers or notebook computers are generally required to have a length of about 50 mm or larger to be mounted along the top edge of the display ground to achieve a wide lower band at about 900 MHz to cover the GSM850/900 operation [1-2]. The antenna length of about 50 mm or larger is generally required in order to achieve a large bandwidth for the antenna's lower band for the GSM850/900 operation. For the present, the large lower-band bandwidth requirement for the GSM850/900 operation is a major design challenge for achieving a small internal WWAN antenna with a length of about or less than 40 mm for tablet computer applications. When a planar structure for the internal WWAN antenna is demanded for application in slim tablet computers with very thin thickness, the design challenge on achieving decreased size of the antenna is even bigger.

In this paper, we present a new antenna structure especially suitable for the internal WWAN antenna to achieve decreased size for slim tablet computer applications. The antenna structure is to be disposed on a thin FR4 substrate and comprises an antenna ground and a radiating portion. For achieving penta-band WWAN operation in the GSM850/900/1800/1900/UMTS bands, the proposed antenna requires a small printed area of 12 × 35 mm^2 on a 0.8-mm thick FR4 substrate. The antenna size is about the smallest among the internal WWAN antennas that have been reported for the tablet or notebook computer applications [1-2].

2. Proposed Antenna

Fig. 1 shows the geometry of the proposed planar internal WWAN tablet computer antenna. As shown in the figure, the antenna is printed on a 0.8-mm thick FR4 substrate of relative permittivity 4.4, loss tangent 0.02, and size 12 × 35 mm^2. The antenna is mounted along the edge of the shielding metal wall (size 5 × 150 mm^2) at the top edge of the display ground of size 150 × 200 mm^2. The display ground is for accommodating a 9.7-inch display for the tablet computer, which is commercially available on the market. Note that the antenna is not placed at the center of the shielding wall, but with a distance of 20 mm to one corner of the shielding wall. In this case, other internal antennas (not studied here) can also be possible to be mounted along the shielding wall, leading to more efficient integration of the internal antennas along the edges of the tablet computer.

As shown in the figure, in addition to the radiating portion of the antenna, there is an antenna ground of size 6 × 6 mm^2 disposed at one corner of the back side of the FR4 substrate. On the antenna ground region of the FR4 substrate, a series LC matching circuit of a chip capacitor 6.8 pF and a chip inductor 3.9 nH is disposed. This matching circuit makes it convenient to adjust the impedance matching of the antenna, especially the impedance matching for frequencies in the upper band of the antenna.

The radiating portion of the antenna comprises a feeding strip, a parasitic shorted strip, and a distributed parallel resonant (DPR) circuit. The feeding strip (section DE in the figure) has a length of 30 mm, which is connected to the series LC matching circuit and then to be fed by a 50-Ω mini coaxial line. The central conductor and outer grounding sheath of the coaxial line are respectively connected to point A and B on the antenna ground region of the FR4 substrate. Note that point B is at a grounding pad which is electrically connected to the antenna ground through a via-hole at point C. For practical tablet computer applications, the coaxial line is further connected to a transceiver module disposed on the back side of the display ground (not shown here). The feeding strip is used to generate a 0.25-wavelength resonant mode at about 1800 MHz.

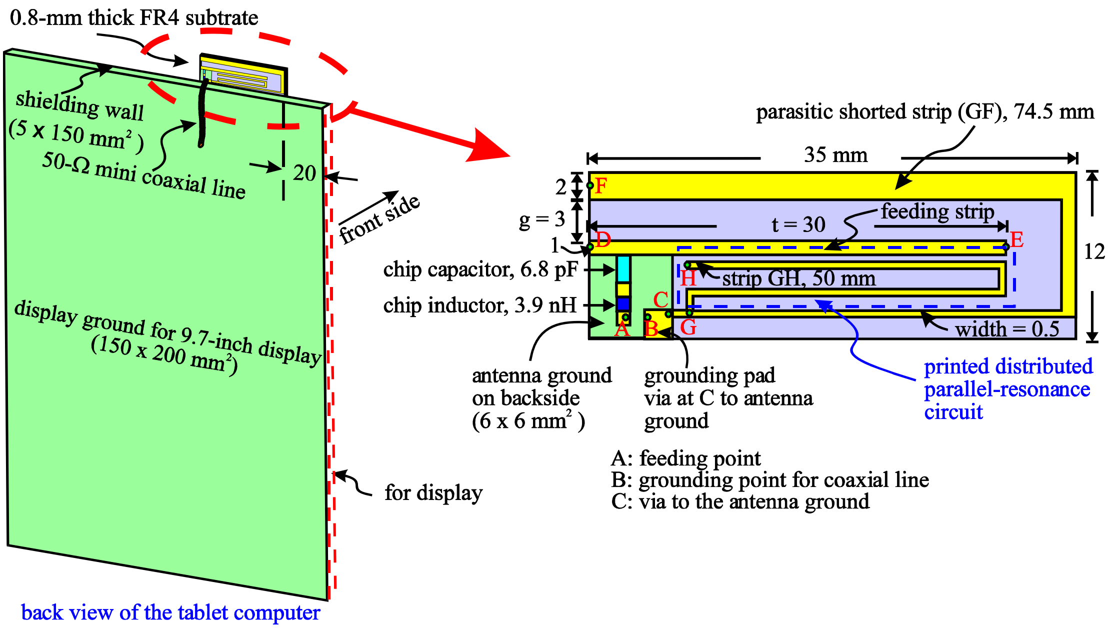


Figure 1: Geometry of the proposed planar WWAN tablet computer antenna.

The parasitic shorted strip (section CF) has a length of 74.5 mm and is short-circuited to the antenna ground through the grounding pad. The shorted strip is parasitically excited by the feeding strip and encircles the feeding strip to achieve a compact size for the antenna. The shorted strip can generate a 0.25-wavelength resonant mode at about 850 MHz and a higher-order resonant mode at about 2200 MHz. The latter can be combined with the resonant mode at about 1800 MHz contributed by the feeding strip to form the desired antenna's upper band to cover the GSM1800/1900/UMTS operation. As for the 0.25-wavelength resonant mode contributed by the shorted strip, it is generally of narrow bandwidth and cannot cover the desired antenna's lower band for the GSM850/900 operation, when the distributed parallel resonant circuit is not present.

To effectively enhance the antenna's lower-band bandwidth, the distributed parallel resonant circuit is printed in-between the feeding strip and the shorted strip. The parallel resonant circuit is formed by adding the strip GH of 50 mm, with its one end connected to the shorted strip at point G close to the grounding pad and its end section capacitively coupled through a 0.5-mm gap to the feeding strip. The capacitive coupling at the end section of the strip GH contributes a capacitance, while the strip GH itself contributes an inductance [3]. The contributed capacitance and inductance can be adjusted to result in a parallel resonance at a frequency slightly higher than the resonant frequency of the 0.25-wavelength mode of the shorted strip. In this study, the parallel resonance occurs at about 1200 MHz, and an additional resonance (zero reactance) is occurred at about 1000 MHz. This results in a dual-resonance excitation of the 0.25-wavelength mode of the shorted strip and greatly enhances the antenna's lower-band bandwidth for the GSM850/900 operation.

3. Results and Discussion

Fig. 2 shows the photo of the fabricated antenna and the measured and simulated return loss of the fabricated antenna. Note that in the experimental study, the grounding pad of the antenna is connected to the shielding metal wall, and the antenna is tested along with the display ground shown in Fig. 1. Good agreement between the measured data and the simulated results obtained using simulation software HFSS version 12 is observed. Based on 3:1 VSWR (6-dB return loss), which is widely used as the design specification of the internal WWAN antenna [4], two wide operating bands are obtained. The lower and upper bands respectively cover the desired 824 ~ 960 and 1710 ~ 2170 MHz bands for the penta-band WWAN operation.

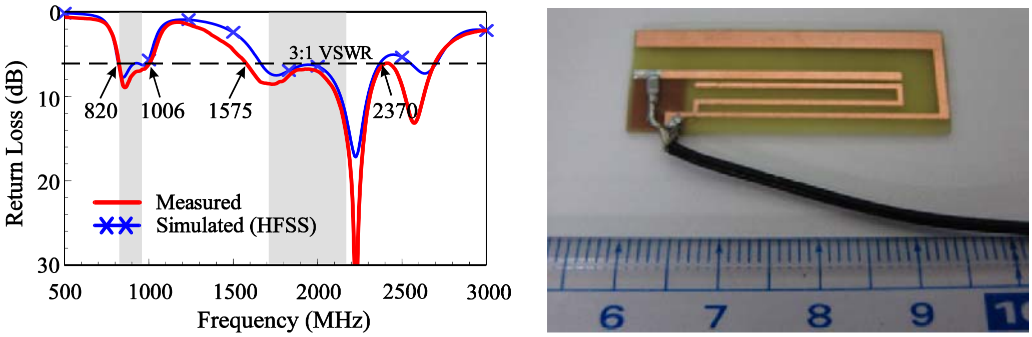
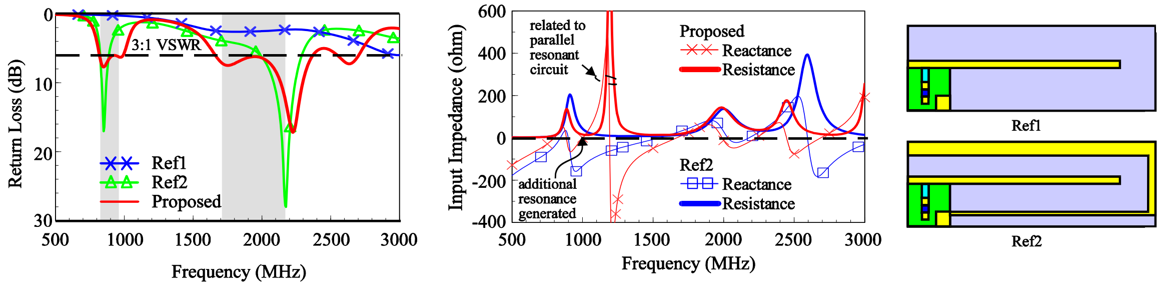


Figure 2: Measured and simulated return loss of the proposed antenna and the photo of the fabricated antenna.

To analyze the operating principle of the antenna, Fig. 3(a) shows a comparison of the simulated return loss for the proposed antenna, the case with the feeding strip only (Ref1), and the case with the feeding strip and parasitic shorted strip only (Ref2). From the results, it can be concluded that the resonant mode at about 1800 MHz is mainly contributed by the feeding strip, while the resonant modes at about 850 and 2200 MHz are mainly contributed by the parasitic shorted strip. Further, by adding the strip GH to Ref2 to form the proposed antenna, an additional resonance at about 1000 MHz is seen, which greatly enhances the lower-band bandwidth of the antenna.

To see more clearly the effects of adding the strip GH to form a distributed parallel resonant circuit, Fig. 3(b) shows a comparison of the simulated input impedance for the proposed antenna and the case with the feeding strip and parasitic shorted strip only (Ref2). Results clearly show that a parallel resonance is excited at about 1200 MHz, which greatly modifies the impedance matching of the frequencies of the high-frequency tail of the 0.25-wavelength resonant mode contributed by the shorted strip. An additional resonance is then generated at about 1000 MHz, which leads to a dual-resonance excitation for the 0.25-wavelength resonant mode contributed by the shorted strip to achieve a wide lower band for the antenna.



(a) (b)

Figure 3: Comparison of (a) the simulated return loss for the proposed antenna, the case with the feeding strip only (Ref1), and the case with the feeding strip and parasitic shorted strip only (Ref2), and (b) the simulated input impedance for the proposed antenna and Ref2.

To analyze the effects of the matching circuit disposed on the antenna ground region of the FR4 substrate, Fig. 4 shows a comparison of simulated return loss for the proposed antenna and the case without the matching circuit (Ref3). Small effects on the lower band are seen. On the other hand, the matching circuit can effectively tune the impedance matching for frequencies in the upper band and result in good impedance of at least 6-dB return loss for frequencies in the desired upper band. Furthermore, the measured results show that the radiation efficiency is all larger than 50% over the penta-band WWAN operating bands. Detailed measured results and discussions on parametric studies of the proposed antenna will be given in the presentation.

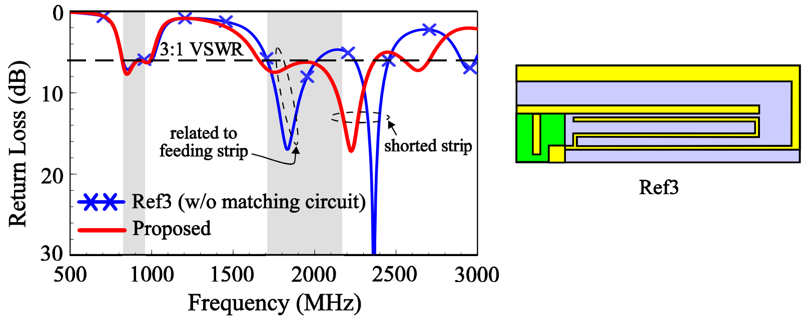


Figure 4: Comparison of simulated return loss for the proposed antenna and the case without the matching circuit (Ref3).

4. Conclusion

A small planar internal WWAN antenna with a size of 12 × 35 mm^2 for tablet computer applications has been presented. The antenna has a planar structure and can be printed on a thin FR4 substrate at low cost. The proposed antenna successfully applies the bandwidth-enhancement technique of using a printed distributed parallel resonant circuit, which leads to the excitation of a dual-resonance mode for the antenna's lower band. A wide lower band is hence obtained for the GSM850/900 operation. A matching circuit disposed on the antenna ground of the proposed antenna has also been shown to be very helpful for tuning the impedance matching of the resonant modes in the antenna's upper band. With the distributed parallel resonant circuit and the matching circuit disposed on the dielectric substrate on which the antenna is printed, small size of the proposed WWAN antenna is obtained. It is expected that the bandwidth-enhancement techniques introduced in this study can be applied to the related internal tablet computer antennas to achieve small size yet wideband operation.

References

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