Bandwidth enhancement of ground antenna using resonant feeding circuit

R. Zhang, Y. Liu, H.H. Kim and H. Kim

A loop-type ground antenna with wide-band operation is proposed for USB dongle applications. The solution for improving the bandwidth is based on a resonant feeding circuit that includes both an inductor and a capacitor. By choosing an appropriate ratio of the inductance to the capacitance, the impedance bandwidth (VSWR < 2) is 21.8% at 2.2 GHz, sufficient bandwidth to cover both the WCDMA and WiMax frequency bands.

Introduction: Electrically small antennae have recently begun to receive more attention owing to the ever-growing demand for integration and miniaturisation of mobile products. However, designing an electrically small antenna with a wide impedance bandwidth is difficult because the antenna's dimensions have a significant impact on the impedance bandwidth [1]. An innovative loop-type ground antenna [2], formed by a large loop-type current distribution in the ground plane excited by a loop feed structure, has recently been shown to achieve an acceptable impedance bandwidth of 9.6% at 2.4 GHz. A resonant loop-feeding method for exciting the ground antenna, based on the insertion of a capacitor into the loop feed structure, was studied in [3], allowing an improved bandwidth of 16%. In this Letter, we modify the resonant loop feed structure to improve further the impedance bandwidth of the ground antenna. An inductor is added into the feed structure and the capacitance is reduced to maintain the feeding circuit close to the resonant frequency of the ground antenna. The optimal coupling between the feed and the antenna can then be tuned by adjusting the ratio of the inductance to the capacitance to achieve a well-matched impedance over a wide range of frequencies. The validity is demonstrated via both simulation and experimental results. The antenna design goal in this Letter is to cover both the WCDMA and WiMax communication bands in USB dongles, widely used in laptops for mobile broadband access.

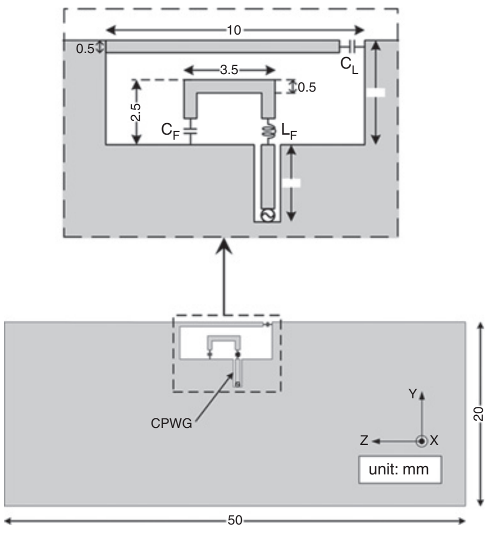

Fig. 1 *Structure of proposed antenna*

Antenna design and simulated results: Fig. 1 shows the geometry of the proposed antenna structure. The dimensions of the PCB (FR4 substrate, $\varepsilon_r = 4.4$, $\tan\,\delta = 0.02$) are $50 \times 20 \times 1$ mm. A 10×4 mm clearance is positioned at the centre of the long edge of the PCB. The resonant frequency of the proposed antenna can be controlled by the capacitor C_L, a phenomenon demonstrated in [2]; its value is chosen to be 0.28 pF. The inductor L_F and capacitor C_F are connected in series in a feeding circuit which is further fed through a coplanar waveguide with ground (CPWG). The input impedance can be controlled by either L_F or C_F, which changes the mutual impedance between the feeding circuit and the resonant loop formed of C_L. Furthermore, wide-band impedance matching can be achieved by choosing an appropriate L_F to C_F ratio. Fig. 2 shows the variation in the normalised input impedance of the ground antenna for three different L_F to C_F ratios. It is shown that as the ratio increases within the limits, the normalised input impedance of the antenna with L_F is obviously closer to the 50 Ω point on the Smith chart and consequently matched over a much wider range of frequencies than an antenna without L_F (when L_F is 0 and C_F is 1 pF). As a result, the optimised L_F and C_F values of the proposed antenna are determined to be 11.5 nH and 0.1 pF, respectively.

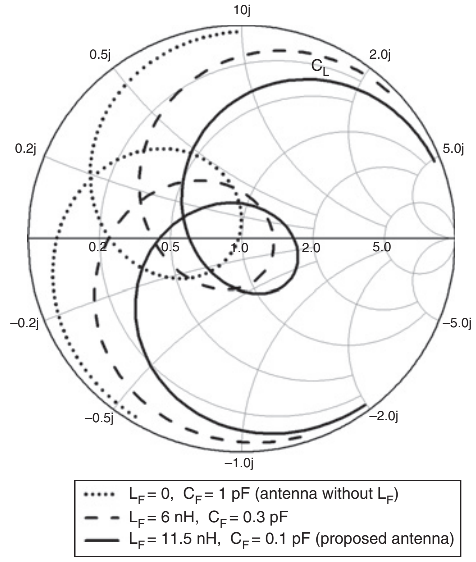

Fig. 2 *Smith chart of ground antenna with different L_F to C_F ratios*

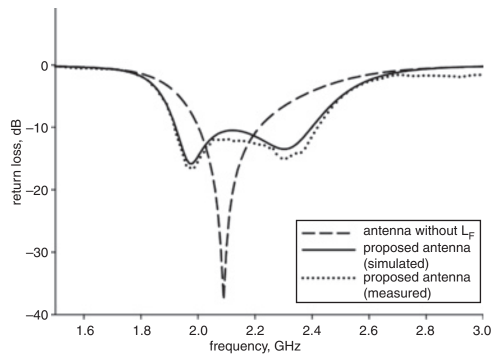

Fig. 3 *Simulated and measured return losses*

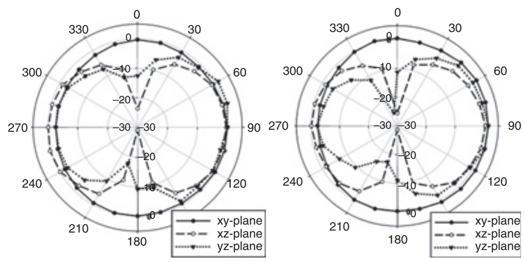

Fig. 4 *Measured radiation patterns of proposed antenna*

a 1.92 GHz
b 2.4 GHz

Experimental results and discussion: The return losses of the proposed antenna and the antenna without L_F are presented in Fig. 3. The simulated and measured results of the proposed antenna are in good agreement. It is noted that two radiation modes occur; one of these is the resonant loop formed of C_L, which is the same as the antenna without L_F. The additional mode is generated when the L_F to C_F ratio is chosen to be an appropriate value. The impedance bandwidth of the proposed antenna with VSWR < 2 is 480 MHz, a substantial improvement (118%) over the 220 MHz that the antenna without L_F is capable of, sufficient to cover both the WCDMA and WiMax bands (1.92–2.4 GHz). Fig. 4 plots the measured radiation patterns of the proposed antenna in the xy, xz and yz planes at both 1.92 and 2.4 GHz. It is apparent that good omnidirectional radiation performance is obtained in the xy plane. The measured radiation efficiency of the proposed antenna from 1.92 to 2.4 GHz is 72% on average, as shown in Fig. 5.

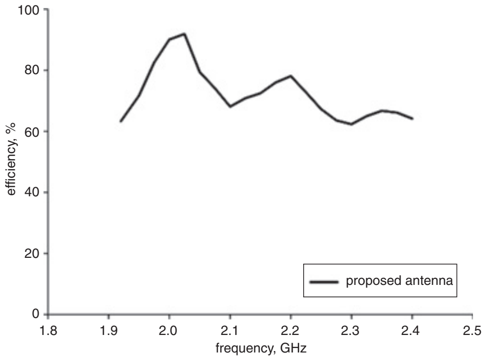

Fig. 5 *Measured efficiency of proposed antenna*

Conclusion: We propose a ground antenna suitable for both WCDMA and WiMax bands (1.92–2.4 GHz) operation in USB dongles. The enhanced impedance bandwidth of the proposed antenna is achieved with a resonant feeding circuit, in which the ratio of the inductance to the capacitance is chosen carefully to match the input impedance of the antenna over a wide frequency range. The radiation performance of the proposed antenna is verified through experimental results.

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