Loop-type ground antenna using resonated loop feeding, intended for mobile devices

Y. Liu, X. Lu, H. Jang, H. Choi, K. Jung and H. Kim

A loop-type ground antenna, designed as a rectangular ground clearance connected by a capacitor, is proposed for mobile devices. The electromagnetic mechanism underlying the antenna operation is based on a new feeding method; a capacitor is used to cause a current loop to resonate at the operating frequency band. The proposed antenna is 5 × 3 mm and is easily implemented within mobile devices. The −10 dB bandwidth of the antenna is 400 MHz, from 2.3 to 2.7 GHz. The radiation pattern it produces shows omnidirectional performance on the horizontal plane.

Introduction: Various personal mobile devices supporting wireless internet access technologies, such as Wi-Fi (IEEE 802.11a/b/g) and WiMax (IEEE 802.16e), have enabled new market segments and therefore rapidly increased in importance. These wireless communication systems place stringent constraints on receiver design in order to obtain high data rates. The antennas in mobile transceivers must meet challenging requirements in the receiving mode, such as high sensitivity to data signals, while maintaining good radiation performance in the transmitting mode, as well as small physical size. Electrically small loop antennas, the circumference of which is less than about one-tenth of a wavelength, are less sensitive to near-field electric noise [1], making them naturally favourable for improving the sensitivity of the receiver in mobile communications.

However, it is difficult to achieve acceptable input impedance to be matched to standard feed lines using small loop antennas. Several reports have focused on overcoming this issue in megahertz communication bands. In [2], a matching network composed of a tuned capacitor (to bring the loop close to a resonant frequency) and an additional shunt element (to adjust the input impedance) was utilised. In [3], a two loop configuration was studied, in which the transformer coupling between the two loops was employed as a new feeding mechanism. A loop-type ground antenna was presented at the 2.4 GHz frequency band in [4], in which the radiating elements are essentially highly excited loops using loop feeding; it achieved an acceptable impedance bandwidth (9.6%) coupled with electrically small size.

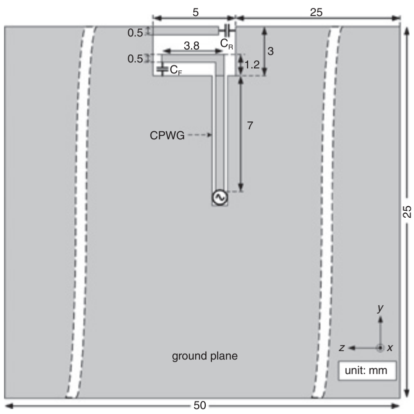

Fig. 1 *Geometry of proposed antenna*

In this Letter, we present a modified ground antenna and develop a new type of feed structure to further enhance impedance bandwidth. Our antenna is designed to operate at the 2.5 GHz frequency band. Two different loops are employed for radiating and feeding purposes. First, the radiating loop is a rectangular ground clearance located near the edge of a printed circuit board; this loop is formed by a chip capacitor, C_R, as shown in Fig. 1. Next, a feeding loop, which is an even smaller rectangular loop, is constructed via a conductor line terminated with a chip capacitor, C_F, as shown in Fig. 1. This creates a current loop that resonates at the operating frequency band. Owing to resonance, a large current is generated along the feeding loop, which produces magnetic flux to drive the radiating loop. As described in [4], the radiating loop establishes the spread of loop-type current distributions on the ground plane and the unusual surface current distributions imply that the major radiator acts as the ground plane. Thus, the proposed antenna can be referred to as a ground antenna [5]. The Ansoft HFSS EM simulator is utilised for antenna design simulation.

Antenna design: As shown in Fig. 1, the radiating loop of the proposed antenna is rectangular in shape and measures 5 × 3 mm. The perimeter of this loop measures 16 mm, approximately 0.13λ. The capacitor, C_R, is connected in series with the radiating loop; this is a 0.2 pF tuned capacitor which controls the resonant frequency. The feeding loop is fed via a coplanar waveguide with ground (CPWG) and its specific placement introduces a tight magnetic coupling into the radiating loop. The width and the length of the feeding loop are 1.2 mm and 3.8 mm, respectively; the perimeter of the feeding loop is 10 mm, approximately 0.08λ. The 50 × 25 mm ground plane is printed on a 1 mm-thick FR4 substrate, where $\varepsilon_r = 4.4$.

With this antenna configuration, the input impedance of the antenna can be controlled by the area of the feeding loop. It also can be adjusted via the capacitor, C_F, without changing the area of the feeding loop. Most importantly, when C_F is tuned to make the feeding loop resonate at the operating frequency band, the current along the feeding loop will be much greater than that of the shorted feeding loop. Note that this resonated current loop acts as a source which excites the radiating loop such that it radiates efficiently over a wide range of frequencies. The value of C_F is 0.7 pF. When C_F is removed by shorting the feeding loop, the area loop needs to be about two times larger than the present size for impedance matching, causing the bandwidth to be reduced by approximately half. The size of the chip capacitors is 1 × 0.5 × 0.5 mm for length, width, and height, respectively.

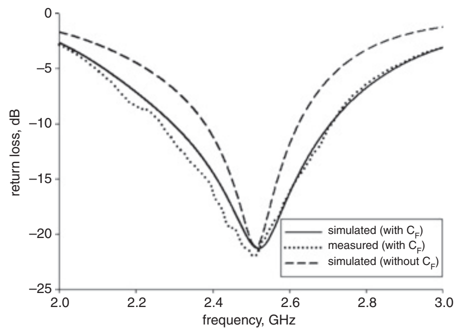

Fig. 2 *Simulated and measured return loss*

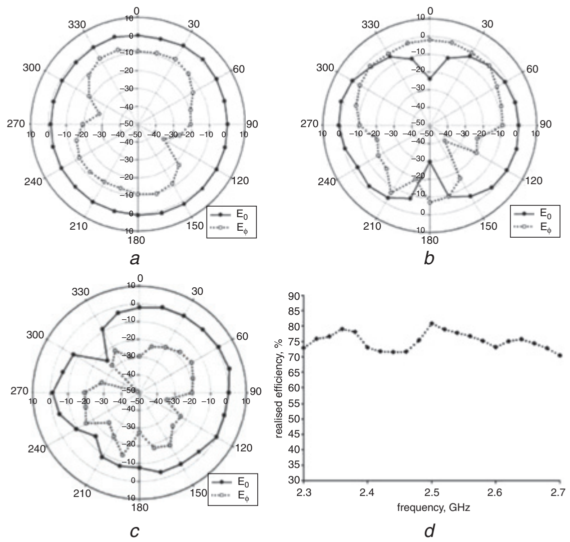

Fig. 3 *Measured radiation patterns and realised efficiency*

a xy-plane
b xz-plane
c yz-plane
d Realised efficiency

Experimental results: Simulations were conducted to demonstrate the bandwidth variation that occurs when loop feeding is accomplished, both with and without the capacitor, C_F. As shown in Fig. 2, the −10 dB bandwidth is 240 MHz (9.6%) at 2.5 GHz, for a shorted feeding loop without C_F; it is 400 MHz (16%) from 2.3 to 2.7 GHz with the proposed feeding method with C_F. The experimental data agrees well with the simulation result. Fig. 3 shows the radiation patterns measured at 2.5 GHz. Good omnidirectional performance is obtained for the E_θ component on the horizontal plane (*xy*-plane); the average gain is 0.26 dBi and the gain variations are less than 3 dBi. On the *xz*-plane, the radiation pattern of the E_θ component is symmetric, and the average gain is −2.36 dBi. For the E_θ component on the *yz*-plane, it is observed that there are two nulls which appear at $\theta = 225^\circ$ and $\theta = 315^\circ$, yielding an average gain of −2.41 dBi. The maximum gain of the antenna is 2.67 dBi at 2.5 GHz. Fig. 3*d* shows that the measured realised efficiency is 75.8%, averaged over the operating frequency band.

Conclusion: A loop-type ground antenna with an innovative feeding method is proposed for mobile applications. The proposed feeding method resulted in successful enhancement of the impedance bandwidth (16%) of the antenna at the 2.5 GHz frequency band while maintaining good antenna efficiency. The measured return loss agrees with the simulated result. An omnidirectional radiation pattern is observed on the horizontal plane and good radiation performance is achieved at the operating frequency band.

12 January 2011
doi: 10.1049/el.2011.0094

Y. Liu, X. Lu, H. Jang, H. Choi, K. Jung and H. Kim (*Department of Electronics and Computer Engineering, Hanyang University, Seoul, Republic of Korea*)

E-mail: hdkim@hanyang.ac.kr

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