Capacitively Coupled-fed Electrically Small Loop Antenna with High Efficiency for WiFi Application

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Abstract— An efficient electrically small planar loop antenna with capacitive feed is proposed for WiFi applications. The feeding element of our antenna is a printed T-shaped monopole, which is capacitively coupled to the radiating capacitively-loaded loop and good impedance matching is achieved through the capacitive coupling mechanism. Thus the capacitive feed leads to high radiation efficiency, gain and broad impedance bandwidth. The radiating element of the proposed antenna is comprised of a planar printed loop with an interdigital capacitor inserted on one side and a copper wall with height of 3 mm and thickness of 0.3 mm attached to the printed loop. The attached wall enables the antenna occupies more volume, which lowers its Q value and contributes to larger bandwidth. The proposed antenna exhibits a simulated -10 dB impedance bandwidth of 190 MHz from 2.39 GHz to 2.58 GHz, which is suitable for WiFi application.

1. INTRODUCTION

With the rapid development of mobile communication technology, the demand for electrically small antennas (ESAs) with miniaturized size, high radiation efficiency and broad bandwidth keeps increasing. Especially for modern mobile terminals, such as cell phones, laptops, and PDAs, the space available for the antenna is extremely limited. As is known to all, due to the intrinsic small radiation resistance and large reactance, electrically small antennas without external matching networks are poorly matched to 50-ohm feed lines, leading to low radiation efficiency and small bandwidth. Many methods have been taken to design ESAs with high performance, including reactive loading [1], shape meandering of wire antennas [2, 3], using dielectric substrate of high permittivity [4], etc.. In this paper, the problem of impedance matching is solved by coupled-fed technique, which have been widely used in monopoles [5], PIFAs [6], loop antennas [7], etc..

However, the other challenge in designing ESAs is to increase the bandwidth. According to the well-known relation between bandwidth and Q [8, 9], the intrinsic bandwidth of ESAs is limited due to their physical dimensions. In this paper, a copper wall (red part in Figure 1) attached to the printed loop is introduced. The attached wall enables the antenna occupies more volume, thus lowers its Q value and contributes to larger bandwidth. The proposed antenna exhibits a simulated -10 dB impedance bandwidth of 190 MHz from 2.39 GHz to 2.58 GHz, which is suitable for WiFi application.

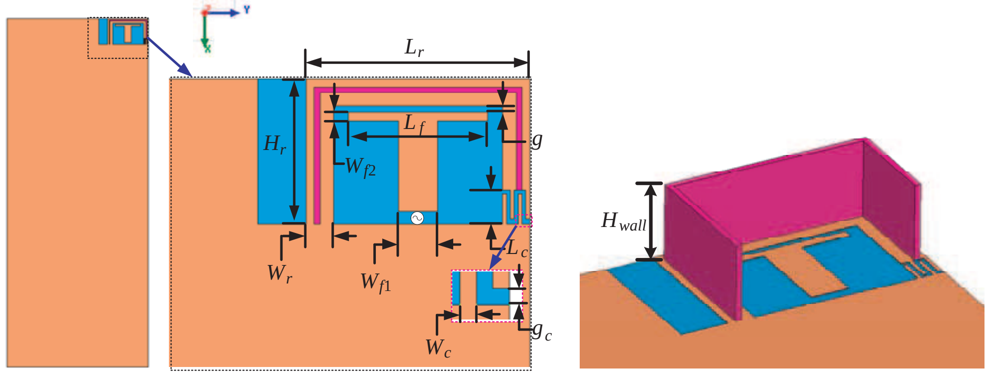
2. ANTENNA DESIGN

The prototype and configuration of the proposed antenna is depicted in Figure 1 and detailed dimensions are given in Table 1. A substrate with size of 100 mm $\times$ 40 mm $\times$ 1 mm, relative permittivity of 2.6 and loss tangent of 0.002 is used as the system circuit board in this paper. A system ground plane is printed on the top side of the circuit board, with a no-ground portion of 14 mm $\times$ 7.5 mm at one corner. The antenna is mounted on the no-ground portion.

Table 1: Detailed dimensions of the proposed antenna.

Parameter	Length (mm)	Parameter	Length (mm)
L_r	11.5	H_r	7.5
W_r	1.4	L_f	7.2
W_{f1}	2.0	W_{f2}	0.5
g	0.3	L_c	1.7
W_c	0.3	g_c	0.2

Figures 1 (a) and (b) give top and 3D view of the antenna, respectively. The radiating element of the proposed antenna is a modified capacitively-loaded loop (CLL). It is comprised with a printed



(a) (b)

Figure 1: Geometry of the proposed planar loop antenna. (a) Top view. (b) 3D view.

half rectangular loop with an interdigital capacitor inserted on one side and a copper wall with height of 3 mm and thickness of 0.3 mm attached to the printed loop. The attached wall (red part in Figure 1) enables the antenna occupies more volume, thus lowers its Q value and contributes to larger bandwidth. The interdigital capacitor provides loaded capacitance, which allows the loop with total length of about 24 mm (about 1/5 wavelength at 2.47 GHz) to self-resonates at 2.47 GHz. The feeding element of our antenna is a printed T-shaped monopole, which is capacitively coupled to the radiating CLL and good impedance matching is achieved through the capacitive coupling mechanism. The advantage of using this feeding technique is that the inductive impedance of the feeding line is effectively canceled by the capacitance introduced by the feed and radiating element.

3. RESULTS AND DISCUSSION

A full-wave simulation of the proposed antenna is conducted with Ansoft High Frequency Structural Simulator (HFSS). In Figure 2, the simulated reflection coefficients of the antenna are provided. The proposed antenna with wall height H_{wall} of 3 mm exhibits a simulated -10 dB impedance bandwidth of 190 MHz from 2.39 GHz to 2.58 GHz, covering the bandwidth from 2.4 GHz to 2.48 GHz for WiFi application. The simulated resonant frequency of this antenna is 2.47 GHz, where the reflection coefficient is -30.4 dB and radiation efficiency is 98.6%. The far-field properties of the proposed antenna are also simulated with HFSS and the radiation patterns on three orthogonal planes are shown in Figure 3. One sees that the maximum radiation of such an antenna is toward its opposite direction with a tilt angle, and the radiation pattern is symmetrical with respect to the plane of the planar loop, implying its potential use as electrically small radiators for pattern diversity based MIMO terminals with very small inter-element space.

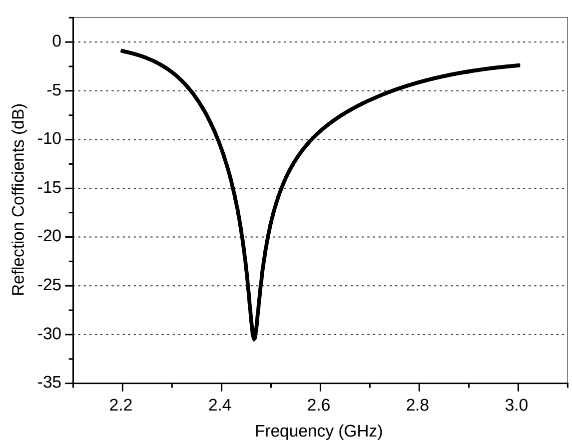
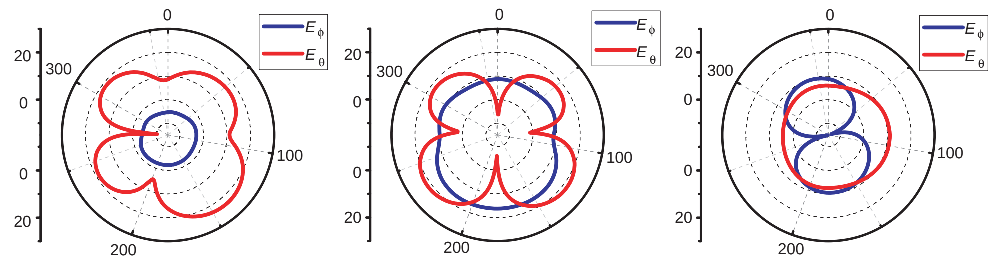


Figure 2: Simulated reflection coefficients of the proposed antenna.

Figure 4 shows the effects of the height H_{wall} of attached wall of the modified CLL. The simulated -10 dB impedance bandwidth and resonant frequency of the proposed antenna with different H_{wall}



(a) (b) (c)

Figure 3: Radiation pattern at 2.47 GHz. (a) *yoz*-plane. (b) *xoz*-plane. (c) *xoy*-plane.

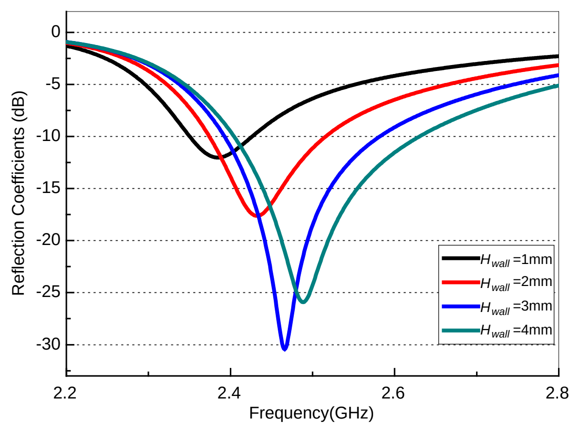


Figure 4: Simulated reflection coefficients of the proposed antenna with different values of H_{wall}.

Table 2: Simulated bandwidth and resonant frequency with respect to the height of wall H_{wall}.

H_{wall} (mm)	1	2	3	4
Bandwidth (MHz)	76 2350–2426	142 2374–2516	190 2392—2582	226 2404–2630
Resonant Frequency (GHz)	2.385	2.432	2.466	2.488

are given in Table 2. We can see that as H_{wall} increases from 1 mm to 4 mm, the bandwidth gets broader from 76 MHz to 226 MHz, and resonant frequency gets higher from 2.385 GHz to 2.488 GHz. As the antenna with larger H_{wall} occupies larger volume, it has smaller Q value and broader bandwidth. And larger H_{wall} leads to smaller current destiny on the radiating CLL, which lowers the loss resistance, so higher radiation efficiency is obtained. For the good of the balance between bandwidth and low-profile of the antenna, we choose $H_{wall} = 3$ mm as the optimal value of the parameter.

4. CONCLUSIONS

In this paper, we have proposed an electrically small planar loop antenna. A copper wall is attached to the CLL, which enables the antenna occupies more volume, thus lowers its Q value and contributes to larger bandwidth. The interdigital capacitor provides loaded capacitance, which allows the loop with total length of about 24 mm (about 1/5 wavelength at 2.47 GHz) to self-resonates at 2.47 GHz. With the capacitive coupled feeding, the electrically small loop can be directly connected with a 50-Ohm feed line, and good radiation efficiency and gain have been obtained. The proposed antenna can be applied in mobile terminals for WiFi application.

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