# Miniaturization of Dual-Band PIFA for Wireless LAN Communication

Yang Liu, Jaeseok Lee, Sinhyung Jeon, Kyung-Young Jung, Hyunghoon Kim, and Hyeongdong Kim

*In this letter, a simple method for reducing the size of a dual-band planar inverted-F antenna (PIFA) is described. This method is based on a coupling capacitor connected in parallel to the PIFA feed conductor. The proposed antenna occupies a small ground clearance of 10 mm×5 mm and is able to provide –10-dB impedance bandwidths of 120 MHz and 760 MHz for 2.45-GHz and 5.5-GHz wireless local area network applications, respectively. The measured antenna efficiencies are 71.8% and 73.6%, averaged over the 2.45-GHz and 5.5-GHz frequency bands, respectively.*

*Keywords: PIFA, dual-band, resonated loop feed structure, WLAN.*

## I. Introduction

Wireless local area networks (WLANs) remain one of the fastest growing areas of data communications of the decade. Recently, dual-band WLAN antennas were used to resolve congestion in the 2.4-GHz bandwidth to meet the rapidly rising market demand for faster data rates. Despite abundant research on mobile antennas, which has focused on providing sufficient bandwidth to simultaneously cover the 2.45-GHz and 5.5-GHz frequency bands [1]-[3], all existing approaches require large ground clearance, which is a critical limitation of modern mobile handsets.

A simple design for a dual-band planar inverted-F antenna (PIFA) is found in [4]. According to this design, a capacitor is inserted into the feed conductor, causing the conventional shorting pin loop to resonate. In the research [4], this resonated loop feeding method achieved wide impedance bandwidths at the dual frequency bands of WLAN, but, unfortunately, it also required a large ground clearance (15 mm×5 mm) to maintain antenna performance. The problem is that the input impedance at the higher band presents a large impedance mismatch as the size of the ground clearance is reduced. In this letter, we modify the resonated loop feed structure to further reduce the antenna size. A shunt capacitor, $C_S$, is added in parallel to the feed conductor, as shown in Fig. 1. The shunt capacitor plays a dual role in realizing the size reduction of the PIFA, changing the resonant frequency of the lower band and controlling the input impedance at the higher band. Details of the antenna design and experiment results are discussed as follows.

## II. Antenna Design and Operating Mechanism

As shown in Fig. 1, the proposed antenna structure with dimensions 9 mm×5 mm is placed in a ground clearance that measures 10 mm×5 mm. The 100 mm×50 mm ground plane, which is the size used in modern mobile handsets, is printed on a 1-mm-thick FR4 substrate, where $\varepsilon_r$=4.4. The shorting conductor is 1 mm in width and is separated from the feed conductor by 0.7 mm. The resonated loop feed structure is formed by the feed and shorting conductors with a capacitor $C_F$ (0.2 pF). As the ground clearance becomes small, the capacitance of a parasitic capacitor, $C_P$, between the PIFA top conductor and the ground plane increases, and the resonated loop feed structure can decompose the PIFA into two different loop-type radiators. The first, operated at the lower band, is formed by the top conductor and ground plane connected by

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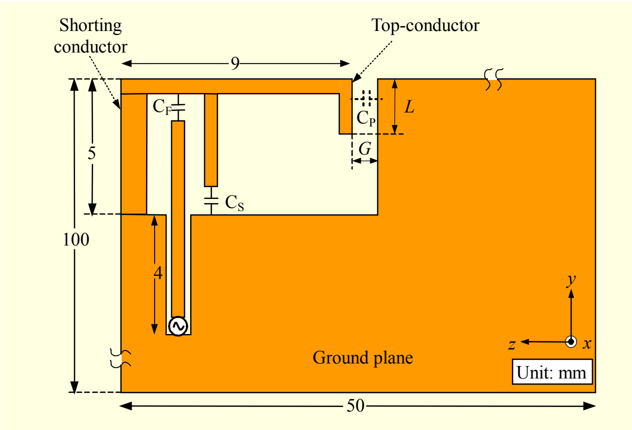


Fig. 1. Geometry of proposed dual-band PIFA: parameters $L$ and $G$ are chosen to be 1.8 mm and 1 mm, respectively, in this work.

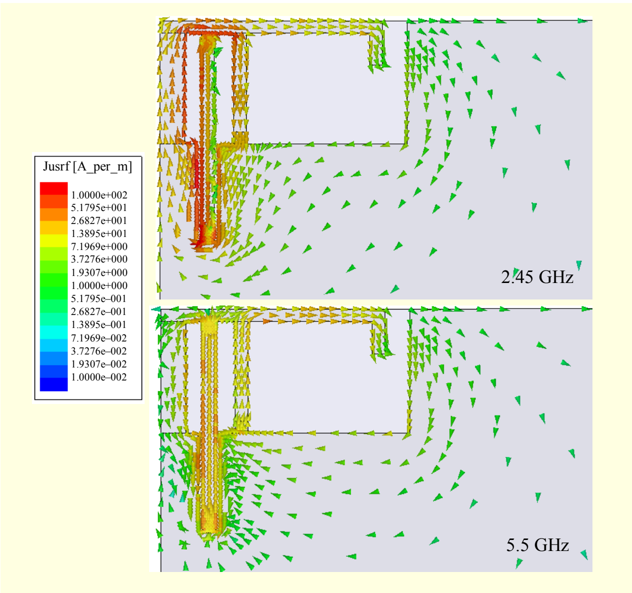


Fig. 2. Computed normalized surface current density at 2.45 GHz and 5.5 GHz.

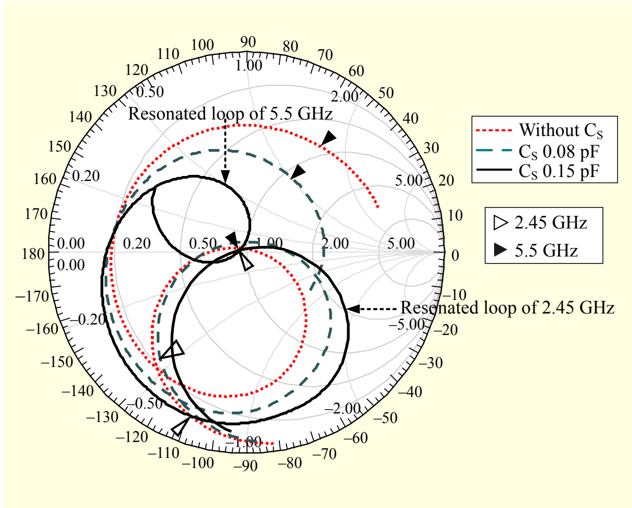


Fig. 3. Impedance variation with different capacitances of $C_S$.

the shorting conductor and is excited via the resonated loop, as shown in Fig. 2(a). The second, operated at the higher band, is formed by the top conductor and ground plane connected by the feed conductor and is coupled by $C_F$, as shown in Fig. 2(b).

The input impedance of the first radiator can be controlled by the area of the resonated loop feed structure or by $C_F$ [4], and the input impedance of the second radiator can also be influenced by varying the capacitance of $C_F$, resulting in a difficulty in achieving simultaneous impedance matching at the dual frequency bands. To solve this problem, a shunt capacitor, $C_S$, is used. It is placed 0.8 mm away from the feed conductor. For the second loop-type radiator electrically coupled by $C_F$, the amount of charge on the top conductor is compactly accumulated close to $C_F$. These charges can be dispersed by the added path of $C_S$, resulting in a weak electric coupling such that the input impedance at the higher band can be conveniently controlled by varying the capacitance of $C_S$. The resonant frequencies of the two radiating loops are determined by $C_P$ [5]-[7], which can be controlled via parameter $L$ or parameter $G$. The resonant frequencies can also be controlled by $C_S$ since it is connected in parallel to $C_P$.

Figure 3 shows the responses of the PIFA with various capacitances of $C_S$. The frequencies range from 2.2 GHz to 6.2 GHz. When the feed structure is without $C_S$, the loop-type radiation mode of 5.5 GHz presents a large impedance mismatch. As the capacitance of $C_S$ increases to 0.15 pF, it results in a well-matched impedance radiation mode that is able to provide sufficient bandwidth at the 5.5-GHz frequency band. Note that the input impedance of the loop-type radiation mode of 2.45 GHz is almost unchanged when the capacitance of $C_S$ varies; this would be easy for antenna impedance tuning, as described in [8]. Moreover, increasing the capacitance of $C_S$ lowers the resonant frequencies of both radiating loops.

What is also worth mentioning here is that because the radiator is formed by the large current loops in the ground plane, the resonant frequency and the input impedance could be dependent upon the size or the shape of the ground plane and can also be affected by various components installed within mobile terminals, such as cameras, speakers, and the battery, among other things. Fortunately, our antenna allows for the resonant frequency to be conveniently controlled by the capacitance of $C_P$, and the input impedance can be conveniently adjusted by the reactive elements included in the feed structure, which changes the mutual impedance between the feed and the radiator. However, in a special case, the radiation performance may be significantly affected. If a liquid crystal display or other conducting plane, which is usually

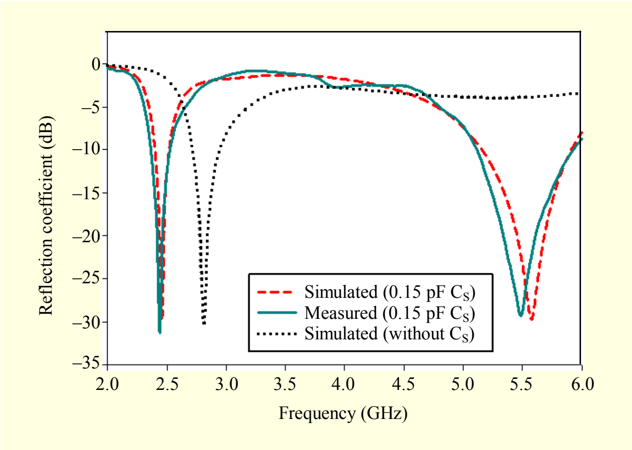


Fig. 4. Simulated and measured reflection coefficient.

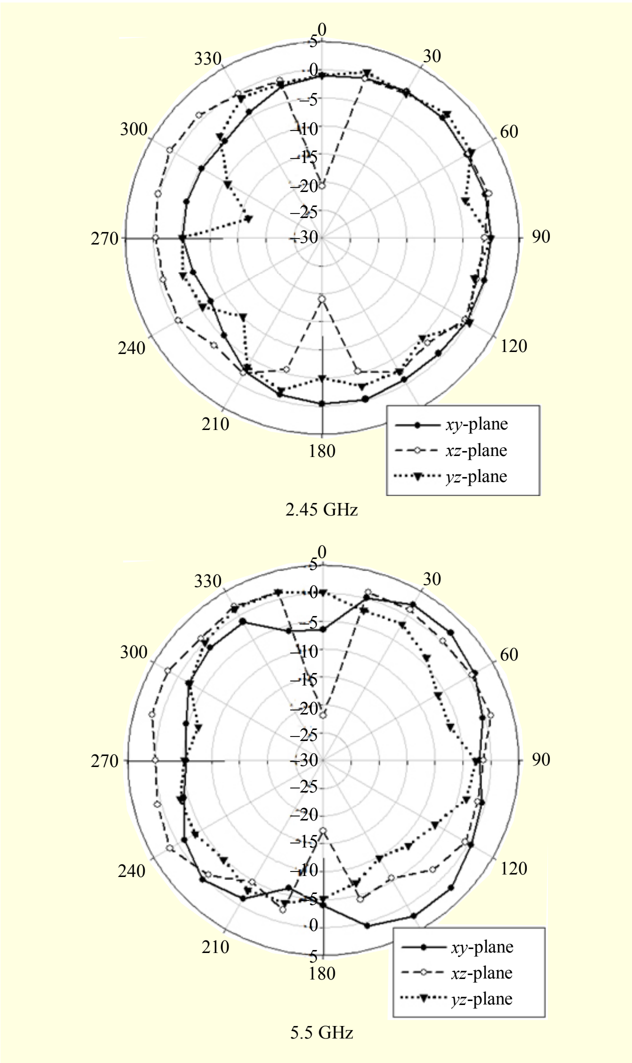


Fig. 5. Measured radiation patterns at 2.45 GHz and 5.5 GHz.

installed beneath the printed circuit board of mobile terminals, fully overlaps the antenna clearance, the magnetic flux

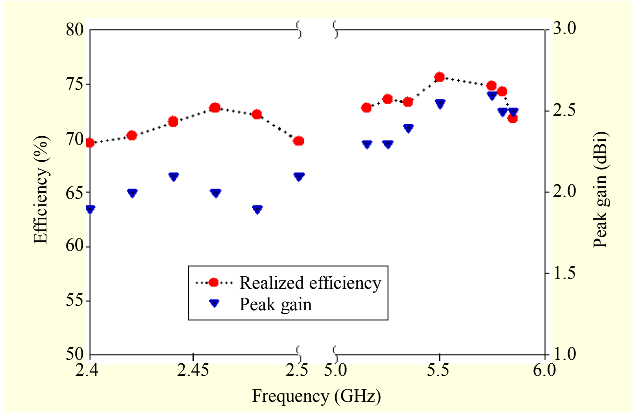


Fig. 6. Measured antenna efficiencies and peak gains.

produced by the radiating current loops in the ground plane can then be decreased due to the anti-phase currents induced in the conducting plane, thus reducing the antenna bandwidth and radiation efficiency. Related research is being carried out to address this issue.

## III. Experiment Results

All antenna simulations are performed using Ansys HFSS. The simulated and measured reflection coefficient of the proposed PIFA is shown in Fig. 4. When the feed structure is without $C_S$, the resonant frequency of the lower band occurs at 2.82 GHz and the antenna cannot efficiently radiate at the higher band due to the impedance mismatch. Owing to the contribution of $C_S$, the –10-dB impedance bandwidths are simulated as 120 MHz (2.40 GHz to 2.52 GHz) and 760 MHz (5.15 GHz to 5.91 GHz) at the dual frequency bands; the measured result agrees with the simulation result. Figure 5 shows the measured radiation patterns at 2.45 GHz and 5.5 GHz. These show the total electric field of the theta and phi components on the *xy*, *xz*, and *yz* planes, which approximate omnidirectional patterns on the *xy* plane. The measured antenna efficiencies are 71.8% and 73.6 %, averaged over the 2.45-GHz and 5.5-GHz frequency bands, respectively, as plotted in Fig. 6.

## IV. Conclusion

A dual-band PIFA modified using a shunt capacitor was successfully miniaturized. The resonant frequency of the lower band and the impedance of the higher band were conveniently controlled by adjusting the shunt capacitor. Consequently, wide impedance bandwidths were obtained at the dual frequency bands even though the ground clearance was small. The measured return loss agreed with the simulated result. Desirable radiation patterns were observed, and the measured antenna efficiencies were sufficient for use in WLAN applications.

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