Compact dual-band antenna using inverted-L loop and inner rectangular loop for WLAN applications

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A small loop antenna for WLAN applications is proposed, which is comprised of an inverted-L loop and an inner rectangular loop achieving dual-band resonances within a compact size of 4.5 mm × 6.5 mm. A series capacitor in the feeding loop is employed for impedance matching of both bands and a shunt capacitor for high band, respectively. The proposed compact antenna is able to achieve −10 dB impedance bandwidth of 120 and 1260 MHz and average radiation efficiency of 69 and 61% in the 2.4 GHz band and the 5 GHz band, respectively.

Introduction: The WLAN 2.4 GHz band (IEEE 802.11b) suffers from interference and slow internet connection because of the rapid expansion of user demands, while the additional 5 GHz band (IEEE 802.11a) has more bandwidth and less interference. Therefore, the large communication capability makes a dual-band WLAN antenna more attractive compared to a single band antenna. There have already been some designs using modified planar inverted-F antenna (PIFA) [1] or monopole [2] to realise dual-band resonances, and a dual-band ground radiation antenna was also described in [3]; however, most of them occupy large spaces.

In this Letter, we propose a compact dual-band WLAN antenna with much smaller dimensions of 4.5 mm × 6.5 mm. The proposed antenna comprised of an inverted-L loop and an inner rectangular loop can respectively generate 2.4 and 5 GHz loop current modes which excite the ground plane as dipole-type radiators [4–7]. To realise simultaneous impedance matching in both bands, a series capacitor and a shunt capacitor which form a matching circuit are employed. The simulated and measured results certify good performances in both bands.

Antenna configuration: As shown in Fig. 1, the proposed dual-band loop antenna is placed in the short side of a 100 mm × 50 mm ground plane, printed on a 1 mm-thick FR4 substrate ($\varepsilon_r = 4.4$). The antenna structure is located 10 mm away from the left edge of the ground plane to effectively generate coupling with the ground plane in both bands. The entire antenna structure only occupies a small ground clearance of 4.5 mm × 6.5 mm ($\sim 0.04\lambda \times 0.05\lambda$ and $0.08\lambda \times 0.12\lambda$ at 2.4 and 5 GHz, respectively), and the width of all the conductor lines is 0.5 mm.

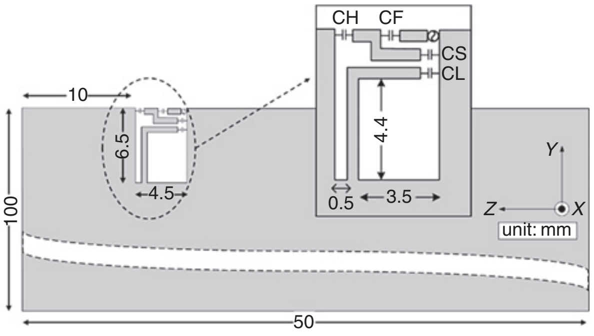

Fig. 1 *Configuration of proposed dual-band antenna*

In the structure of the proposed antenna, the impedance matching circuit is comprised of a series capacitor CF and a 3 mm shunt line with a capacitor CS, the gap between is 0.2 mm. The inner conductor line divides the entire rectangular loop into two parts: the outer inverted-L loop and the inner rectangular loop. The outer inverted-L loop is comprised of the outer conductor line with a capacitor CH and the inner conductor line with a capacitor CL, constituting the high band resonant loop; and the inner rectangular loop is comprised of the inner conductor line with a capacitor CL, forming the low band resonant loop. In simulation, the values of CF, CS, CH and CL are 1.9, 0.2, 0.13 and 0.3 pF, respectively.

Controlling mechanisms: The simulated surface current distributions formed at 2.45 and 5.5 GHz are shown in Fig. 2, respectively. It is clearly seen that the 2.45 GHz current mode is the inner rectangular loop, where CL is used for resonant frequency adjustment. The 5.5 GHz current mode is the outer inverted-L loop, comprised of the outer conductor line with CH and the inner conductor line with CL, where CH is the dominant factor responsible for resonant frequency adjustment.

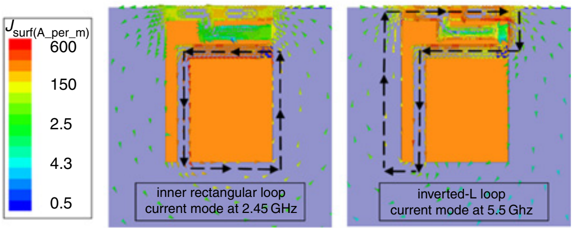

Fig. 2 *Current distributions on proposed dual-band antenna*

a 2.45 GHz
b 5.5 GHz.

As shown in Fig. 3*a*, increasing CL from 0.25 to 0.35 pF leads to a lowered resonant frequency from 2.6 to 2.3 GHz in the low band with little shift in the high band. Fig. 3*b* shows that as CH increases from 0.08 to 0.18 pF, the resonant frequency in high band shifts from 6 to 5 GHz with a slight change in the low band.

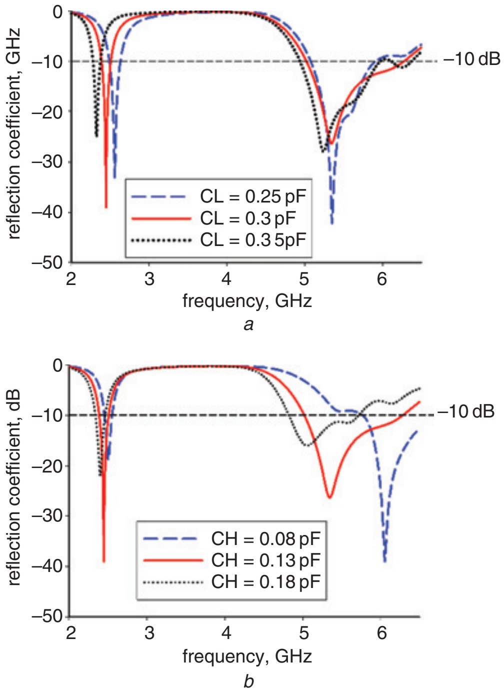

Fig. 3 *Simulated reflection coefficients with different CL and CH*

a Different CL
b Different CH

The proposed antenna is controlled by CF for impedance matching of both bands and by a shunt CS for impedance matching of the high band. As shown in Figs. 4*a* and *b*, the impedance loci on Smith chart for both bands get larger simultaneously as CF increases from 0.5 to 1.9 pF. Moreover, the high band impedance loci turn smaller as CS increases, while the low band impedance loci barely change. In this way, simultaneous impedance matching for both bands can be achieved. The simulated impedance loci on Smith chart with different CH are also investigated in Fig. 4*c*. With the increase of CH from 0.05 to 0.2 pF, the impedance loci of the low band on Smith chart get lager; however, the resonant frequency of the high band also greatly changes. This is because CH is not only responsible for the resonant frequency of the high band, but also for the impedance matching of the low band.

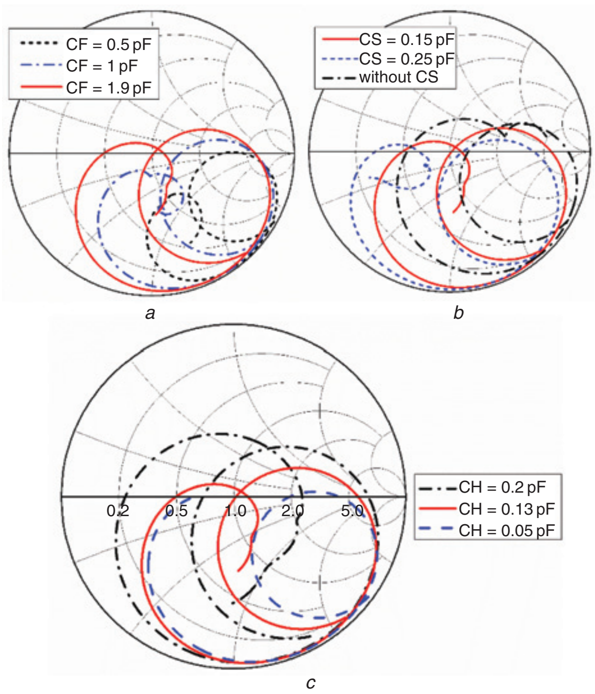

Fig. 4 *Simulated impedance loci in Smith chart with different CF, CS and CH*

a Different CF
b Different CS
c Different CH

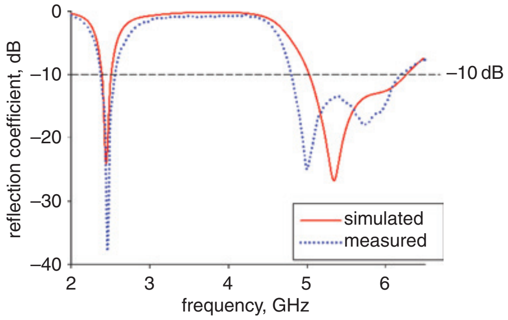

Fig. 5 *Simulated and measured reflection coefficients of proposed dual-band antenna*

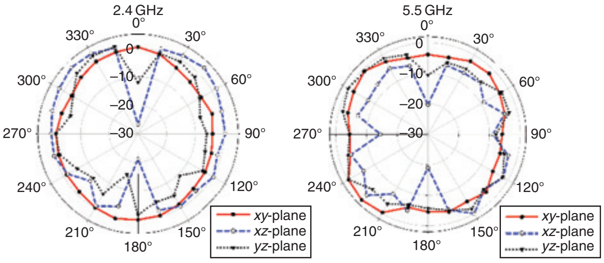

Fig. 6 *Measured radiation patterns at 2.45 and 5.5 GHz*

Simulated and measured results: Fig. 5 shows the simulated and measured reflection coefficients of the proposed antenna. In simulation, the −10 dB impedance bandwidths are 120 MHz (from 2.39 to 2.51 GHz) in the low band and 1260 MHz (from 5.04 to 6.30 GHz) in the high band. The measured results matches well with the simulation ones. The measured radiation efficiencies in the dual bands are shown in Table 1, and the average efficiencies are obtained as 69 and 61% in the low and high band, respectively, indicating good radiation efficiencies. In Fig. 6, the proposed antenna generates omnidirectional radiation patterns on the *xy*-plane at both 2.45 and 5.5 GHz, indicating that the dual-band antenna works by coupling with the short side of the ground plane as a dipole radiator.

Table 1: Measured radiation efficiencies

Frequency (GHz)	2.40	2.45	2.50	5.20	5.40	5.60	5.80
Efficiency (%)	67.7	71.4	68.3	58.5	64.6	65.0	57.7

Conclusion: In this Letter, a compact loop-type antenna is proposed for dual-band WLAN operations. The frequency controlling mechanisms and impedance matching mechanisms are discussed by simulation. The −10 dB impedance bandwidths cover all the operating frequencies in both bands, and the measured results coincide well with the simulation ones. Good radiation patterns and sufficient radiation efficiencies are also obtained in both 2.4 and 5 GHz WLAN bands.

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One or more of the Figures in this Letter are available in colour online.

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