A Planar Double Inverted-L Antenna Using Short Stub in Slot Line for WLAN Applications

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1. Introduction

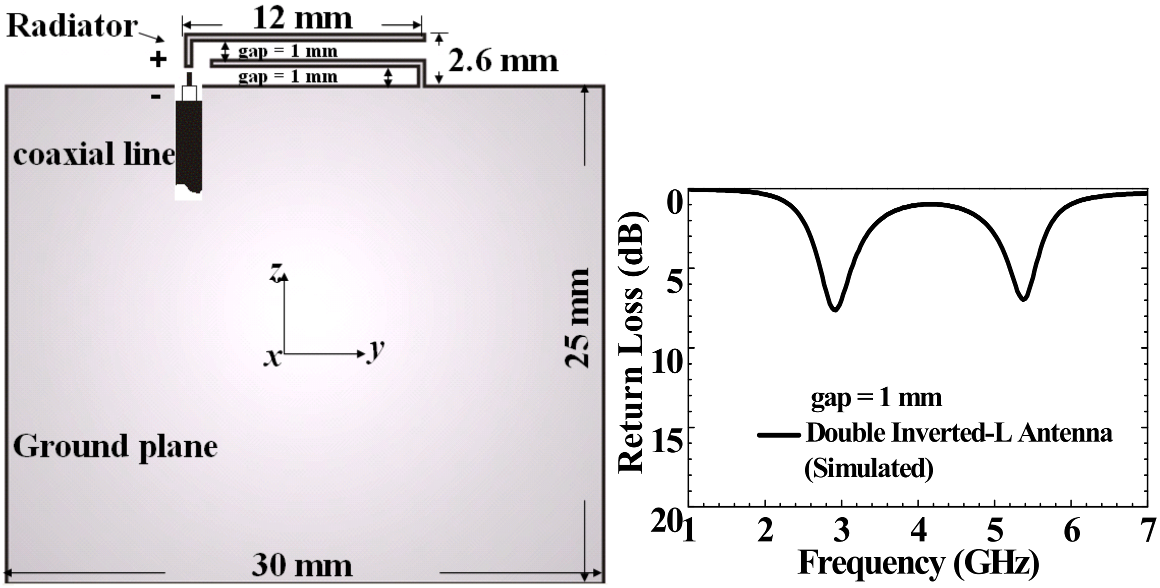
A planar double inverted-L antenna using short stub in slot line for WLAN applications is presented. A mechanism utilizing short stub is designed on the slot line of the 17 mm length (= 0.17 λ_g at 2.44 GHz = 0.41 λ_g at 5.5 GHz) to satisfy single band IEEE 802.11a, or b/g, or achieving dual band (a/b/g), it can provide three kinds of RF module applications. The radiator and ground plane with slot line of the overall antenna architecture fed with 50 Ω coaxial line are coplanar on the FR4 epoxy substrate. The Radiator of the antenna is planar dual resonators with the size of 2.6 mm × 12 mm ($0.04\lambda_0 \times 0.1\lambda_0$ at 2.44 GHz).

Many WLAN antennas have been proposed in the literatures. In order to reduce antenna profile, the PIFA topology is often used, such as two strips separated with an L-shaped slit [1], double short stub [2], short meandering stub [3], ground plane with an open slit [4]. Also, there are two miniaturized design, one for spiral-shaped radiator of inductive coupling and another for radiator of capacitive coupling [5]. However, in there printed antenna designs, for example, the line width of the antenna transition is inconsistent with the line width of the front-end circuit, this discontinuity effect will cause frequency shifting. In addition, via-hole design will result in manufacturing complexity and unexpected radiation. According to the above discussions, here an antenna design with a coaxial-line feed, coplanar structure, no transmission-line transition, no via hole, and a larger ground plane design for avoiding other resonant path is proposed in this paper. Furthermore, the double inverted-L radiator design can generate dual-band resonance. This proposed antenna contains a slot line with short stub design which can manipulate the impedance matching of the dual band.

2. Antenna Design

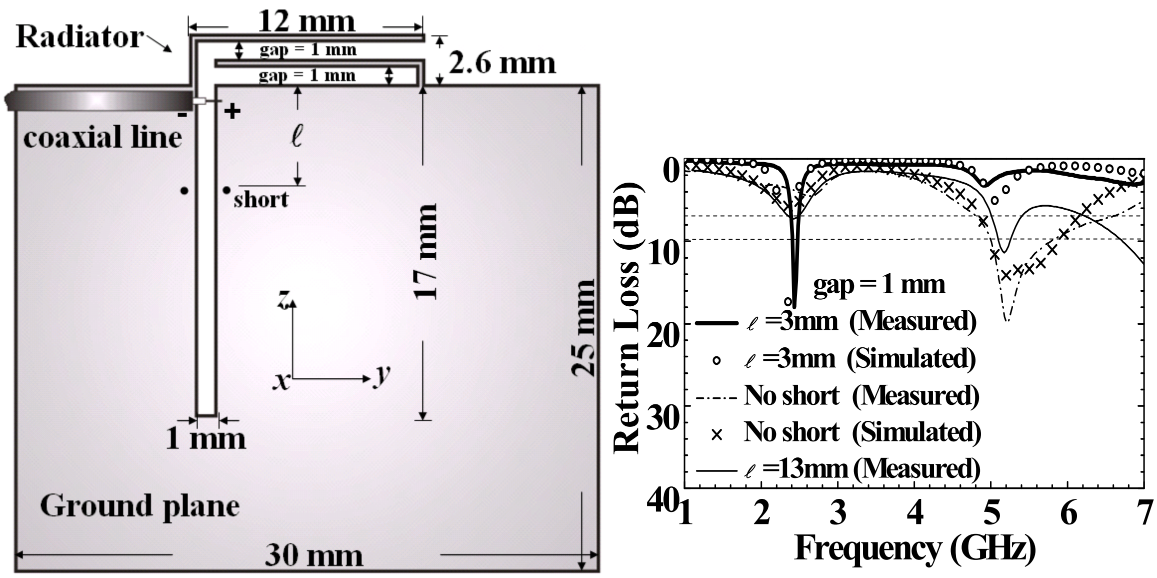
The antenna was fabricated on a FR4 epoxy substrate 0.8 mm thick, with a relative dielectric constant of 4.4, loss tangent of 0.02, and 50 Ω coaxial line of a diameter 1.13 mm. As shown in Fig. 1(a), the radiator of the overall antenna is composed of two inverted L-shaped radiators. The size of the radiator is 12 mm × 2.6 mm. Strips are all in the width of 0.3 mm, the gap of 1 mm, the antenna profile is 2.6 mm, and the ground plane is 30 mm × 25 mm. The total size is 30 mm × 30 mm. The larger ground plane can avoid other resonant path. The double inverted L-shaped strips are dual resonators so that the dual band can be generated by means of the dual resonators coupling. In Fig. 1(b), the simulated return loss shows the dual-band property. In order to enhance the bandwidth of the resonant frequency, a matching network between antenna and RF modules is often used to adjust input impedance. An appropriately circuit-matching technique can reduce the complexity of the antenna design. We attempt to achieve bandwidth by means of adjusting short-stub location in a 17 mm length slot line without any chip inductors or chip capacitors as shown in Fig. 2(a). Due to the low profile, small antenna has a problem of cancelling the capacitive input impedance. As shown in Fig. 2(b), the structural-parameter ℓ (i.e. the short-stub location) can be chosen in different length in order to generate different shunt inductive reactance for band selection. When there is no short stub in the slot, it can achieve 802.11a (indoor 5150-5350 MHz as well as outdoor 5727-5828 MHz) bandwidth of VSWR $\leqq$ 2. If ℓ = 3 mm, we can achieve

802.11b/g bandwidth of VSWR ≦ 2. Furthermore, if ℓ = 13 mm, then 802.11a (indoor 5150-5350 MHz)/b/g bandwidth of VSWR ≦ 2.5 can be obtained.



(a) (b)

Figure 1: Double inverted-L antenna. (a) Structure. (b) Simulated return loss.

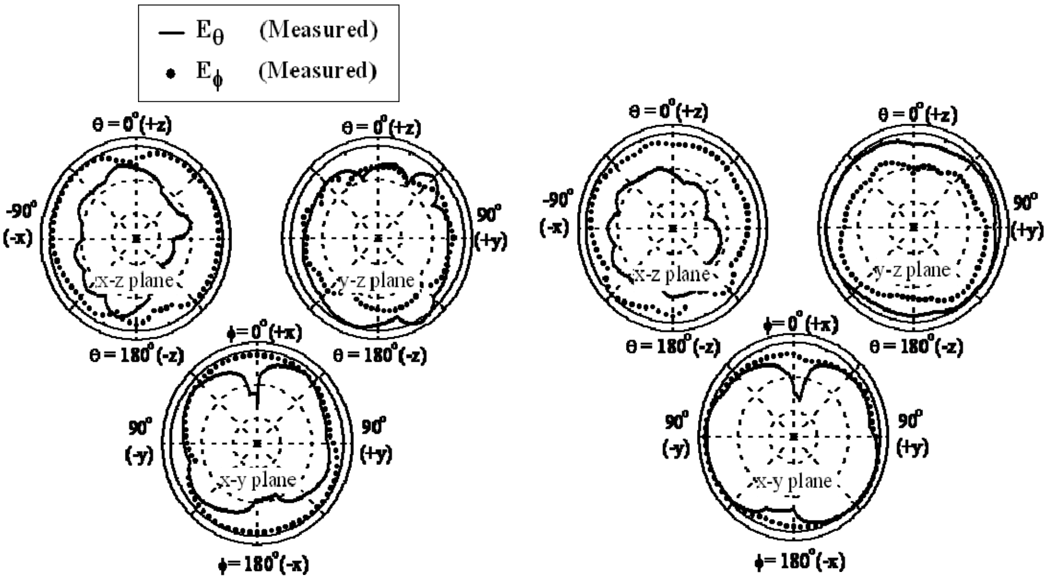


(a) (b)

Figure 2: Double Inverted-L Antenna with short stub in slot line. (a) Structure. (b) Simulated- and measured- return loss for the antenna as a function of the structural parameter (ℓ)

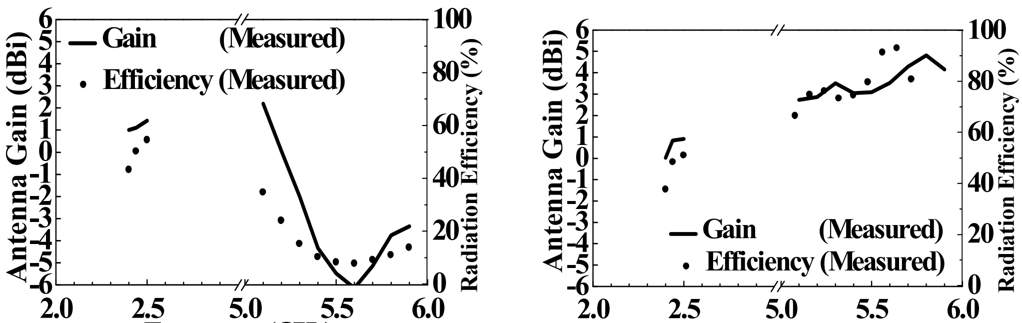
3. Radiation Characteristics

Fig. 3 (a) shows the radiation pattern of antenna with a short stub ℓ = 3 mm at 2440 MHz. Fig. 3 (b) shows another antenna radiation pattern without short stub at 5500 MHz. The principal polarized E_ϕ is generated by x-direction electric current, which is contributed due to the dual resonators, and z-direction magnetic current which is contributed by the slot line. The low profile antenna with all strips in x-direction results both E_θ toward +/- y direction, and E_ϕ toward +/- x direction in the x-y plane. Notably, the major radiation at the x-z plane is E_ϕ toward +/- x direction. As for slot line, which mainly influence is on upper band (5-6 GHz). Especially, the slot line is shorted in the length ℓ = 3 mm which can result in larger E_θ than E_ϕ in +/- y direction in the x-y plane. However, if without short stub, E_ϕ is larger than E_θ in all direction in the x-y plane. Antenna gain and radiation efficiency are shown in Fig. 4(a) and (b) for ℓ = 3 mm operating at lower band (2.4-2.5 GHz) and no short stub operating at upper band (5-6 GHz), respectively. Fig. 4(a) depicts the peak gain of 1dBi and 50% of the radiation efficiency at 2440 MHz. In addition, the return loss at 5500 MHz exceeds 3dB (as in Fig 2(b)), which means that 30% of the energy entered antenna, and the radiation efficiency at 5500 MHz is under 30%. As a result, the total radiation power at 5500 MHz is suppressed under 9% radiation. As shown in Fig 4(b), the slot line without short stub has the peak gain of 3 dBi at 5500 MHz, and 80% of the radiation efficiency. In addition, the return loss at 2440 MHz exceeds 3dB, and the radiation efficiency is under the 49%, therefore, that the total radiation power at 2440 MHz is suppressed under 15% radiation.



(a) (b)

Figure 3: Antenna radiation pattern. (a) The short stub for ℓ = 3 mm in the slot line at 2440 MHz. (b) No short stub in the slot line at 5500MHz.



(a) (b)

Figure 4: Antenna gain and efficiency. (a) Short stub for ℓ = 3 mm in the slot line for lower band (2.4-2.5 GHz). (b) No short stub in the slot line for upper band (5-6 GHz).

4. Conclusion

This paper proposes a coaxial-fed, coplanar antenna with a larger ground plane and double inverted-L (the dual resonators) radiator that can generate dual band. In addition, utilizing shunt slot line and short stub to adjust matching can subject to three kinds of applications (IEEE 802.11a or b/g or a/b/g), it is also suitable for impedance-variation regulation when antenna is integrated with insulator or plastic shell. Antenna gain at 2440 MHz (ℓ = 3 mm) and 5500MHz (no short) are 1 dBi and 3 dBi, that is similar to general low-profile small antenna, and the radiation efficiency at 2440 MHz (ℓ = 3 mm) and 5500 MHz (no short) are 50% and 80%, respectively. It can be used for practical applications.

References

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