Design of Compact Dual-band High-gain Planar Antenna for WLAN

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Abstract. A compact dual-band planar antenna with high gain for WLAN application is presented. The antenna fed by CPW is composed of T-type feed and double C-type meander line, which generate the higher and lower operation bands respectively. DGS structure in CPW ground broadens the bandwidths of high frequency. Through electromagnetic simulator software simulation and analysis, the overall size is 30×15.25×1.6mm. The simulation results show that the proposed antenna can operate in 2.35~2.52GHz and 3.85~6.14GHz, which cover the WLAN operating bands of IEEE 802.11n and 802.11a/b/g. The gain is 1.42dBi at 2.45GHz, and 4.42dBi at 5.2GHz, and 5.38dBi at 5.8GHz, respectively. The radiation pattern of the antenna is omnidirectional and has higher gain.

1. Introduction
With the development of the mobile Internet era, WIFI smart applications for mobile terminals are widely used, and there is an increasing demand for dual-band broadband and miniaturized local area network WLAN antennas. IEEE’s WLAN protocol suite includes 802.11b/g (2.4~2.4835GHz), 802.11a (5.15~5.35GHz, 5.475~5.725GHz, 5.725~5.85GHz), and 802.11n (2.4G/5G), which requires WLAN. The antenna meets the characteristics of dual-band and broadband, miniaturization, and omnidirectional radiation.

Reference [1-2] adopts the zigzag double-segment meandering technology to easily realize the dual-band miniaturized antenna, but the asymmetrical branches and meandering design lead to high out-of-roundness of the pattern. The broadband antenna proposed in the reference [3-4] can only meet 5.2/5.8GHz, and cannot cover low frequency 2.4GHz. Reference [5-6] realizes dual-band through parasitic branches, which is small in size but low in gain. Reference [7] proposes that the monopole and the rectangular patch are coupled to form a dual-band, which has good broadband characteristics and acceptable gain, but the size is slightly larger.

This paper designs a CPW feed, T-type feed and double-C zigzag line structure to achieve dual-band WLAN antenna, combined with defective technology to achieve broadband, combined with meandering design to achieve miniaturization. The antenna can cover the WLAN 2.45/5.2/5.8GHz working frequency band, and obtains good omnidirectional characteristics and high gain due to the symmetrical structure. This article gives the detailed design and simulation analysis of the antenna.

2. Antenna structure and design principle
The structure of the compact dual-band WLAN antenna proposed in this paper is shown in figure 1. The three-dimensional structure of the antenna shown in figure 1 (a) adopts a planar structure of T-type feed and double C radiating stubs. The dielectric substrate is made of domestic F4BM-2, the dielectric
constant is 2.65, the loss tangent is 0.001, the length of the dielectric substrate is a, the width is b, and
the thickness is h. The CPW (co-planar wave-guide) feed and the antenna are co-planar on the top layer
of the medium. Figure 1(b) shows that the surface layer of the medium is the co-planar part of the CPW
and radiation branches. Feed bandwidth of CPW is $W_f$, the width is $L_f$, the spacing with the floor is
g. There is a triangular notch in CPW floor, which is designed to widen the working bandwidth of the
high frequency band. Floor width is $W_g$, the length is $L_g$, the gap width is $W_g$. A symmetrical
distribution of two C branches is shown in figure length $L_1$, $L_2$, $L_3$, and the width is $W$. The double
C branch current path is long and the resonance produces 2.45 GHz frequency band. The common part
width of T type feed and double C branch is $T$, and the length is a. Because of the short current path,
the resonance at high frequency 5.2/5.8 GHz is mainly realized.

![Figure 1. Structure of the WLAN dual-band antenna](image1)

As a resonant monopole antenna, the resonant frequency can be obtained by calculating the length
of branches. Because the low-frequency monopole uses twists and turns for miniaturization, its length
is greater than 1/4 wavelength. The twists and turns of the double C structure are designed for
miniaturization and form a symmetrical radiating monopole, which helps to increase the gain in the low
frequency range. Symmetrical structures such as the positive middle feeding and symmetrical radiating
stubs are all conducive to forming a regular omnidirectional pattern to meet the pattern requirements of
the WLAN antenna.

Through the simulation of full-wave simulation software, the current distribution of the antenna is
shown in figure 2. From the current distribution, at low frequency 2.45GHz, the current is mainly
concentrated on the double C stub. It can be seen that the double-C zigzag line forms a symmetrical
radiating mono-pole, which mainly produces low-frequency resonance. When the high frequency is
5.4GHz, the current distribution is mainly concentrated in the T-type feed, which shows that the T-type
feed is the main contributor to the high-frequency resonance. The simulation result of the current
distribution also confirms the design principle of the above-mentioned dual-frequency antenna.

![Figure 2. Current distribution of WLAN dual-band antenna](image2)
3. Simulation and analysis

According to the antenna structure and design principles described in Part 2, the full-wave simulation software HFSS is used to simulate and analyze the various parameters of the antenna to study the influence of the changes of various parameters on the performance of the antenna.

(a) The effect of W value on S11

(b) The effect of L3 length on S11

Figure 3. Effect of double C twisted line size on the low frequency of antenna

It firstly studies the influence of structural parameters on low-frequency resonance. Figure 3(a) shows that without changing other parameters, as the width W of the double-C zigzag line increases, the antenna’s low-resonant frequency shifts to high-frequency, while there is basically no change in the high resonant frequency. Figure 3(b) shows that other parameters remain unchanged. As the arm L3 of the double C stub increases, the low resonant frequency shifts to the low frequency band. Therefore, it can be seen that the double-C zigzag line mainly affects the low-frequency resonance. Changing the size of the double-C stub can effectively control the impedance characteristics of the low frequency band.

Figure 4. Effect of T feed length \( L_f \) on antenna high frequency

It can study the influence of structural parameters on high-frequency resonance. Figure 4 shows that as the length \( L_f \) of the T-shaped feeder increases, the high-frequency resonant frequency of the antenna shifts to low-frequency, and the high-frequency bandwidth becomes narrower, while the low-resonance frequency hardly changes. It can be seen that changing the size of the T-type feed can effectively control the impedance characteristics of high-frequency resonance.

From the point of view of parameter simulation, there are many parameters affecting the resonant characteristics of the antenna. According to the design principle, it is necessary to optimize the calculation carefully to meet the performance requirements of the antenna. Through simulation optimization, the final size of the antenna structure is shown in table 1.

Table 1. WLAN optimized dimensions of dual-band antennas (unit: mm)

| a  | b  | h  | Lf | Wf | g  | T  |
|----|----|----|----|----|----|----|
| 20 | 30 | 1  | 8  | 2  | 0.2| 4.5|
| L1 | L2 | L3 | W  | Wg | Lg | Wc |
| 16.5| 9  | 13 | 1  | 6.8| 5  | 2  |
Using the final optimized size of the above table, the simulation results of each performance index of the antenna are shown in figure 5~7. The reflection coefficient $S_{11}$ of the antenna is shown in figure 5. The impedance bandwidth of the antenna is $2.35$~$2.52$GHz (RBW: 7%) and $3.85$~$6.14$GHz (RBW: 45.8%), and the results cover the IEEE 802.11 protocol $2.45$/$5.2$/$5.8$GHz working frequency band.

![Figure 5. S11 of WLAN dual-band antenna simulation](image)

The high and low frequency pattern of the antenna is shown in figure 6. Figure 6 (a) ~ (f) are the H plane (x-z plane) and E plane (x-y plane) patterns of the antenna at $2.45$/$5.2$/$5.8$GHz, respectively. The H-plane pattern of high and low frequency points shows that the antenna has good omni-directionality and can radiate and receive signals in all directions. The E-plane pattern is still the classic doughnut of a dipole antenna, which conforms to the radiation principle of the antenna.

![Figure 6. Patterns of WLAN dual-band antenna simulation](image)
Figure 6. Antenna patterns at 2.45/5.2/5.8 GHz

The gain of the antenna is shown in figure 7, and it can be seen that the low frequency band gain is also above 3dBi. Specifically, the antenna has a gain of 3.05dBi at 2.45GHz, a gain of 4.42dBi at 5.2GHz, and a gain of 5.38dBi at 5.8GHz. As a small-sized micro-strip planar antenna, it also obtains a good high gain.

Figure 7. Gain of antenna in operating frequency band

4. Conclusion
This paper proposes a dual-band WLAN antenna design. The antenna adopts CPW feeding, and dual-band operation is formed through T-shaped feeding and symmetrical double-C zigzag lines, combined with defective ground structures to achieve broadband. The antenna can cover the 2.45/5.2/5.8GHz working frequency band of WLAN with a good omnidirectional pattern and high gain. The antenna has a simple structure and compact size, which is convenient for PCB integration. It has engineering application value, and is suitable for the WLAN antenna requirements of miniaturized mobile communication systems.

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