Comparative Study on Printed Dual-band Antennas for WLAN Terminal

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1. Introduction

The wireless local area network (WLAN) technology, as a valuable and cost-effective solution of high-speed data communication, it expects a physically compacted dual-band antenna with good impedance matching and radiation properties, for integrating more systems into one module. This antenna should be printed on a planar structure with light weight, and easy to be embedded; also its feeding circuit should be simplified for avoiding the transmission loss [1].

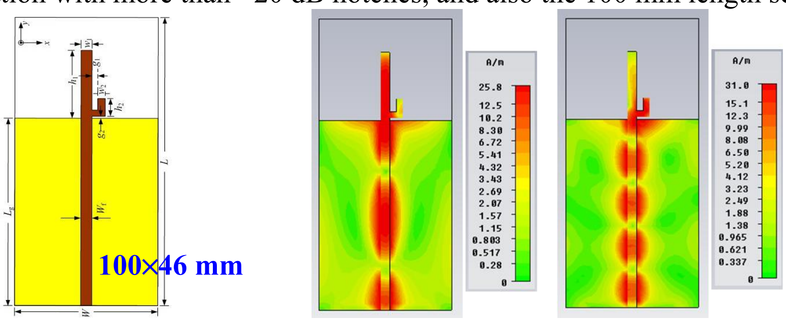
A number of kinds of dual-band antennas had been developed as reported, some possess simple structure but large sizes as in [1]-[3]; and some involve complicated Balun structure as in [4]-[6].

In this paper, three types of compact printed dual-band antennas with the structures of branched-monopole, inversed-F, and folded-dipole are proposed; their prototypes are designed and tested in sequence. Both the simulated and measured results show all they satisfy the basic requirement of bandwidth by IEEE 802.11b/g (2.40~2.48 GHz) and IEEE 802.11a (5.15~5.35 GHz indoor band) standards; however, the last one is prior in radiation patterns and structural compactivity.

2. Branched-Monopole Type with Direct Feeding

The structure of a printed monopole antenna fed by microstrip-line (MSL) is very simple, it lets the strip be protruded from its truncated ground-plate, its resonate frequency and bandwidth are determined by the length and width of the protruded strip.

An initial idea to perform dual-band operation is attaching single branched strip with different length as shown in Figure 1*a*, where the sizes and position of branch are sensitive to the properties of antenna. Due to the strong coupling between the trunk and branch, a full-wave analysis with optimized selection is necessary by using both computer simulators CST and HFSS for mutual checkout. The designed sample performs isolated current distribution for different bands as shown in Figure 1*b*. It critically satisfies the impedance matching of VSWR≤ 2:1 in both WLAN bands of (2.412~2.483), (5.15~5.35) & (5.725~5.825) GHz, However, its patterns are poor in omni-directional radiation with more than −20 dB notches, and also the 100 mm length seems too longer.



(*a*) Structure (*b*) Current distribution for 2.45 GHz & 5.24 GHz

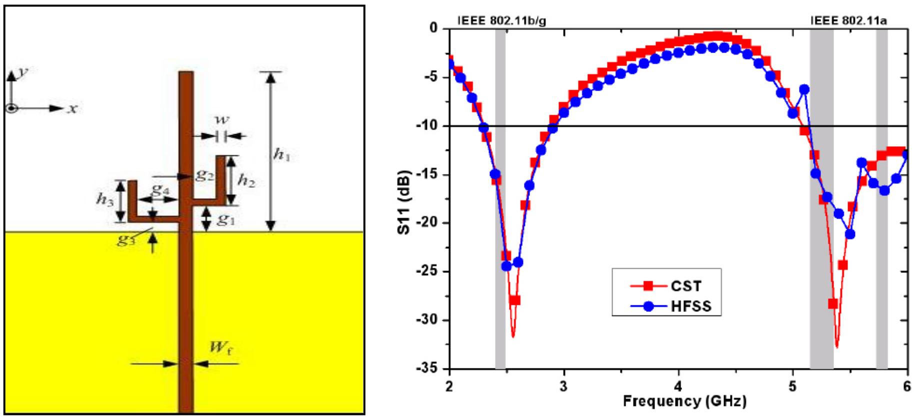
Fig. 2 Monopole antenna with single branch

An improved structure with double (but different) branches to form more resonate mechanism is shown in Figure 2*a*, its optimized structural data are listed in Table 1, its frequency response of $|S_{11}|$ is displayed in Figure2*b*. With comparing to the initial one, the bands for VSWR≤ 2:1 cover (2.30~2.89) GHz [22.7 %]and also continuous (5.68~6.00$^+$) GHz [16.6$^+$ %]; Its structural length is reduced to 60 %; and the notches in pattern is lighten to about −15 dB.

Table 1 Optimized data of monopole antenna with double branches [mm]

L	W	L_g	h_1	W_s	w	h_2	h_3	g_1	g_2	g_3	g_4
58	50	25	22	1.5	1.0	7.0	5.5	3.50	2.25	1.50	3.75

* printed on a FR-4 substrate with thickness t = 0.8 mm and ε_r = 4.4

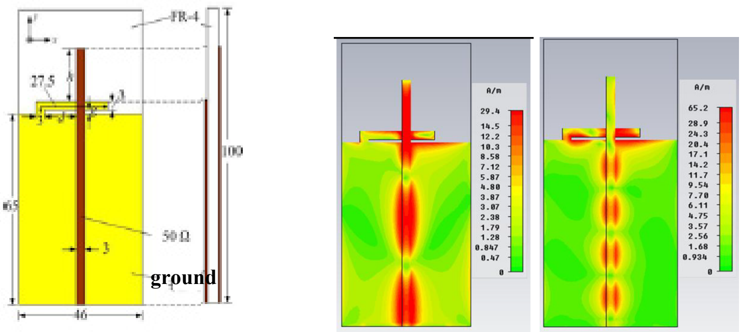


(a) Structure (**58×50 mm**) (b) frequency response of $|S_{11}|$

Fig. 2 Monopole antenna with double branches

3. Inverted-F Type with Coupled Feeding

If a protruded monopole is coupled by a inverted-L stub at the edge of ground-plate, it becomes a full-printed structure of initial inverted-F antenna as shown in Figure 3*a*, on which the current distribution for different bands are also isolated on monopole or stub parts respectively in Figure 3*b*. However, the orthogonal structure with less coupling is helpless to improve the property of separated dipole or stub, which results in failure at higher band.



(a) Structure (b) Current distribution for 2.45 GHz & 5.24 GHz

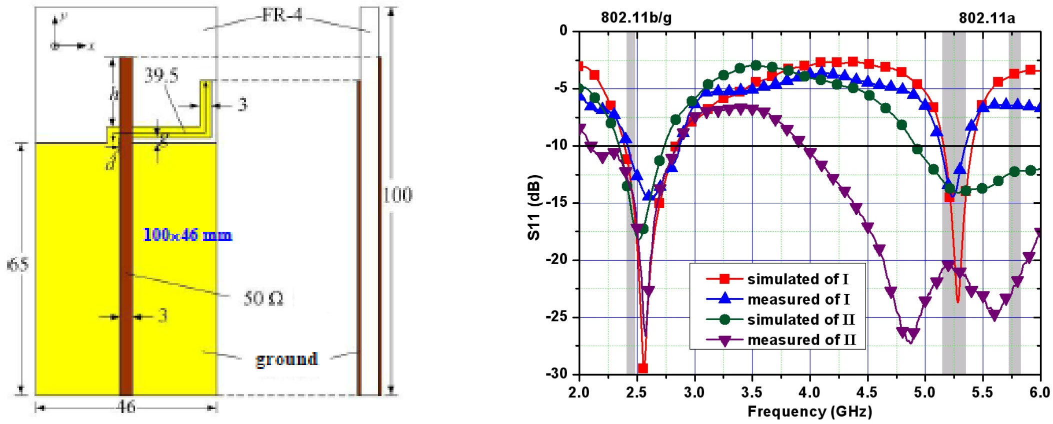
Fig. 3 Inverted-F antenna with inverted-L stub

An improved structure with inverted-Z stub as Figure 4*a* may produce stronger coupling to the monopole by its parallel segment, then adjust the antenna properties. By means of simulation, an optimized set of structural data {h=22, g=1.0, d=0.5, t=1.6 (mm), and that labeled in Fig 4*a*} provides good performances as follows: both the simulated and measured curves of $|S_{11}(f)|$ are displayed and compared with that of inverted-L stub together, the improved structure can cover all the 2.45/ 5.25/ 5.75 WLAN bands too; However, the patterns still not satisfied; the total length of antenna is most longer..

4. Folded-dipole Type with Direct Feeding

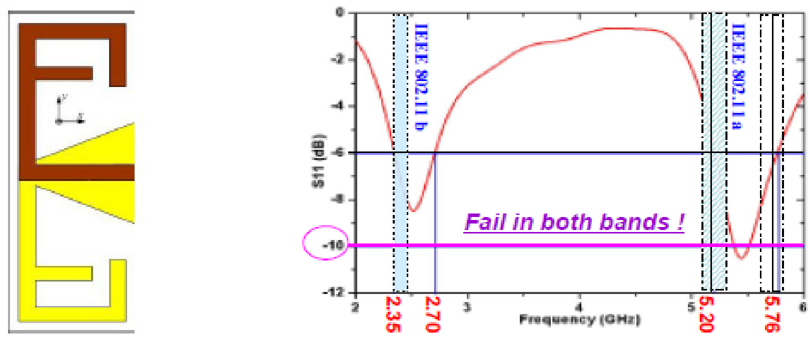
In order to shorten the length of radiator and to fit the width of ground-plate, the protruded monopole may be replaced by laid dipole. Thus, an initial antipodal folded-dipole antenna is proposed in Figure 5*a*, where the folded-arms with a pair of short branches perform the resonance at lower and higher bands respectively; a tapered ground-plate provides a Balun for connecting to MSL. However, even if run the simulation with optimization, the VSWR in both bands are unqualified always as in Figure 5*b*, due to inductive mismatching appeared in a Smith-Chart.

An improved scheme to supplement the inductive input impedance is loading a capacitance at the input-port, hence a pair of shorter open-stubs as strip-bar is employed as shown in Figure 6*a*, in which the optimized structural data are labelled. Two arms with different colours mean that printed on different sides of a FR-4 substrate (thickness t =0.8 mm). The current distribution on the upper arm for both bands are displayed in Figure 6*b*, obviously, they are almost same.



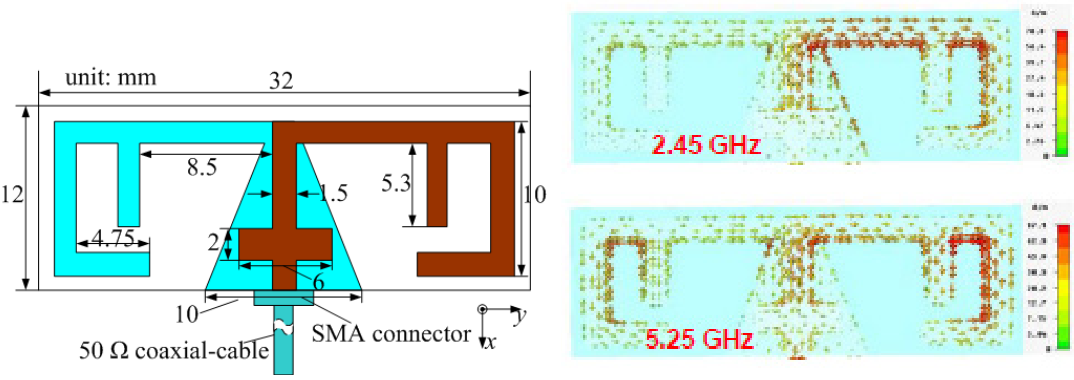
(a) Structure (**100×46 mm**) (b) frequency response of $|S_{11}|$

Fig. 4 Inverted-F antenna with inverted-Z stub



(a) Structure (b) Frequency response of $|S_{11}|$

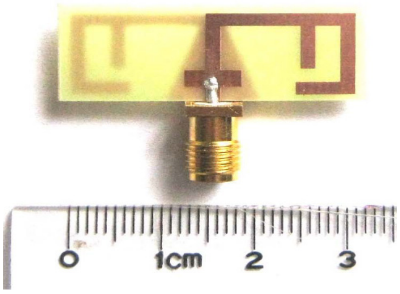
Fig. 5 Folded-dipole antenna with direct feeding

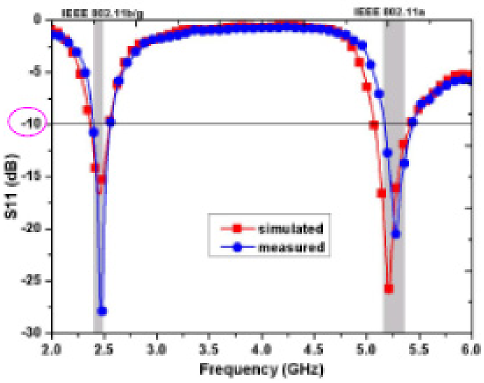


(a) Structure (b) Current distribution for 2.45 GHz & 5.24 GHz

Fig. 6 Folded-dipole antenna with strip-bar

A prototype of this antenna (Figure 7a) has been fabricated and tested. Both simulated and measured $|S_{11}(f)|$ curves are displayed in Figure 7b, in which the frequency band coverage for VSWR≤2:1 are about 6.9% involving the lower WLAN-band; and 5.7% involving the lower part (but not higher part) of higher WLAN-band. The simulated and measured radiation patterns in three coordinate-planes for 2.45 GHz and 5.25 GHz are drawn in Figure 8. Where the patterns in *xoz* plane are almost omni-directional as well as a simple dipole; the radiation along *y*-axis is no longer a null since the contribution from the segment parallel to *x*-axis; the radiation of resultant field in each coordinate planes approach to isotropy.





(*a*) Prototype (*b*) Frequency response of $|S_{11}|$

Fig. 7 Folded-dipole antenna with strip-bar

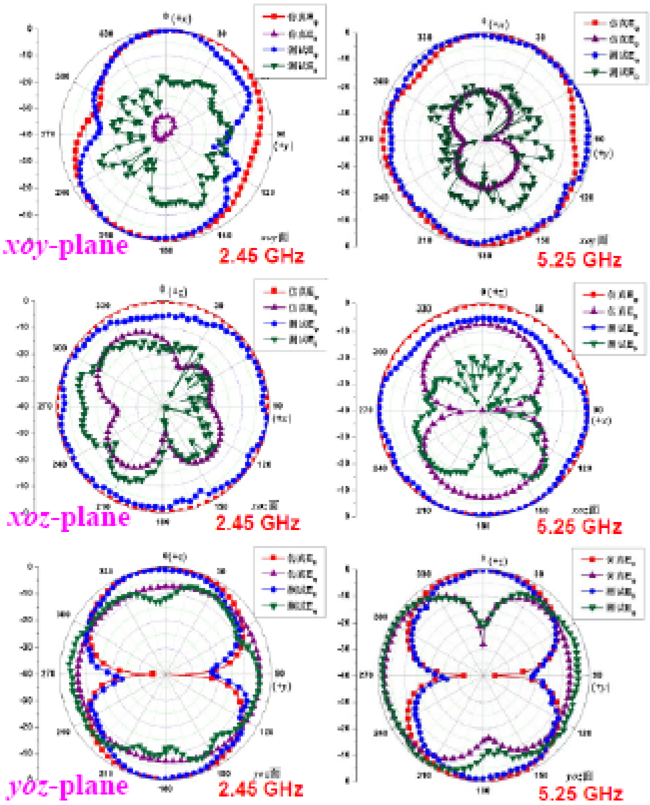


Fig. 8 Radiation pattern of folded dipole with strip-bar

5. Conclusion

This article briefly reports several kinds of printed dual-band antennas with their structural features and performances for WLAN terminal application. In comparison, the folded-dipole with strip-bar is good in omni-directional pattern and most compact, but impedance matching to 50 Ω feed-line is only cover 2.4 GHz band of IEEE 802.11b and 5.2 GHz indoor sub-band of IEEE 802.11a; the inverted-F antenna with inverted-Z stub is matching for all WLAN bands of 2.4/ 5.2/ 5.8 GHz, but its pattern is not satisfied, and the lengthg is most longer; the branched-monopole with double-branches is also matching for all WLAN bands, but its pattern is more unsatisfied with −15 dB notch, and relatively longer in length.

Acknowledgments

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