Progress In Electromagnetics Research Letters, Vol. 21, 109–117, 2011

AN ULTRA-COMPACT DUAL-BAND ANTENNA WITH TUNING ARMS FOR WLAN APPLICATIONS

H. S. Ding

Department of Communication and Information Systems
Chongqing University of Posts and Telecommunications, China

Z. Q. Li and P. Gao †

Research Institute of Electronic Science and Technology
University of Electronic Science and Technology of China, China

Abstract—An ultra-compact dual-band printed antenna is proposed. Connective and concentric double split rings (CCDSR) are used to generate two resonant frequencies in wireless local area network (WLAN) frequency bands. Tuning arms are added to the microstrip fed line, which can be used to tune the upper frequency band. The dimension of this antenna is only $9 \times 24 \times 1\,\text{mm}^3$, much smaller than those reported antennas. The measured -10 dB bandwidth in the 2.44 GHz band is 140 MHz (2.37–2.51 GHz) and in 5.34 GHz is 1.23 GHz (4.86–6.09 GHz), covering the 2.4/5.2/5.8 GHz WLAN operating bands. Good radiations at these bands are also observed.

1. INTRODUCTION

Wireless local area network (WLAN), which facilitates wire-free communication between Personal Digital Assistants (PDAs), notebooks, laptops and other equipment in a local area, has made tremendous advancements in recent years [1]. The 2.4 GHz WLAN system occupies frequency band from 2.4 GHz to 2.484 GHz for IEEE 802.11b/g, and 5 GHz WLAN system occupies those from 5.15 GHz to 5.35 GHz and from 5.725 GHz to 5.825 GHz for IEEE 802.11a simultaneously. In addition, planar monopole antennas have found

Received 18 January 2011, Accepted 3 March 2011, Scheduled 6 March 2011
Corresponding author: Zhi-Qiang Li (lzq001@uestc.edu.cn).
† Z. Q. Li is also with School of Physical Electronics, University of Electronic Science and Technology of China, China.

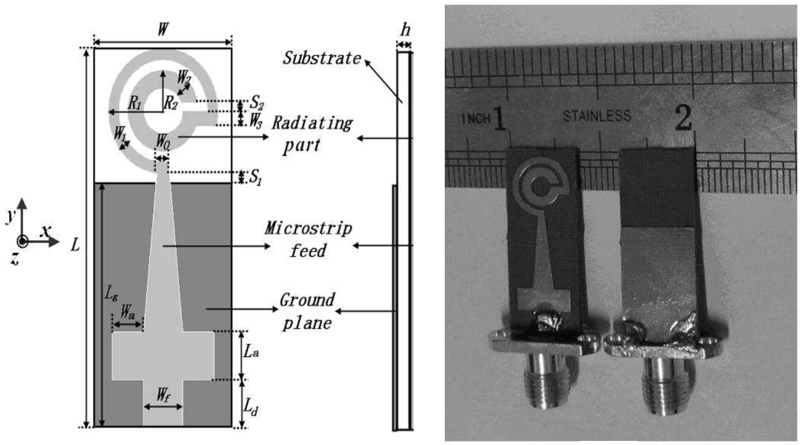
wide spread application in wireless communication industry due to their attractive features as ease of fabrication, low cost, and nearly omnidirectional radiation characteristics.

Microstrip-fed and coplanar waveguide (CPW)-fed monopole antennas have been reported [1–19]. Some special techniques have been used to generate dual-band characteristic, such as tapered bent folded patch [2], fork-like monopole [3], patch with shaped slots [4, 5], double-T antenna [6], parasitic strips antenna [7], varactor diodes [8], cutting slots on the patch [9], tuning stub [10], PIFA antenna [11], cross-slot antenna [12], and some antennas which use two or three radiant patches to satisfy 2.4 GHz band, 5.2/5.8 GHz band [13, 14]. Miniaturization of antenna is especially attractive in integrate circuit. However, many antennas have relatively large dimension, which limits their applications in practical work.

In this paper, an ultra-compact dual-band printed monopole antenna for WLAN application is presented. The dimension of the proposed antenna is only $9\times24\,\text{mm}^2$, much smaller than those reported antennas (The least size in [1–19] is $30\times25\,\text{mm}^2$). Connective and concentric double split rings (CCDSR) are used as radiating element to generate two WLAN frequency bands and prolong current path for compactness. Moreover, tuning arms are added to the microstrip fed line, then, the upper resonant frequency can be adjusted.

2. ANTENNA DESIGN

Geometry sketch and actual dimensions of the proposed antenna are illustrated in Figure 1. The antenna is comprised by three parts, a radiating element, a feeding part and a ground plane. It is printed on a dielectric substrate of PTET with thickness $h = 1\,\text{mm}$ and relative permittivity $\varepsilon_r = 2.4$. The overall dimension of the antenna is $9(W)\times24(L)\,\text{mm}^2$. In order to match the radiation element's resistance with the microstrip-fed line, a linear tapered section has been used to connect the two parts. The size of the radiating element is $8\times8\,\text{mm}^2$. The CCDSR is used to generate two resonant frequency bands, and the finite ground plane has dimension of $14\times9\,\text{mm}^2$. Therefore, the characteristics of omni-directional radiation patterns and dual operating bands are obtained. For impedance matching at 5 GHz-band, two symmetrical arms are added. The optimal dimensions of the designed antenna are as follows: $L = 24\,\text{mm}$, $W = 9\,\text{mm}$, $W_a = 2\,\text{mm}$, $W_f = 2.85\,\text{mm}$, $W_0 = 0.8\,\text{mm}$, $W_1 = 0.8\,\text{mm}$, $W_2 = 1.2\,\text{mm}$, $W_3 = 1\,\text{mm}$, $L_a = 3\,\text{mm}$, $L_g = 15\,\text{mm}$, $L_d = 3\,\text{mm}$, $R_1 = 4.2\,\text{mm}$, $R_2 = 2.6\,\text{mm}$, $S_1 = 1\,\text{mm}$, $S_2 = 0.5\,\text{mm}$, $h = 1\,\text{mm}$.



(a) (b)

Figure 1. (a) Geometry sketch of the proposed antenna. (b) Actual dimensions of the proposed antenna.

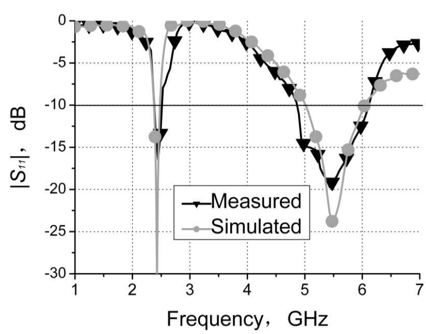


Figure 2. $|S_{11}|$ of the proposed antenna.

3. RESULTS

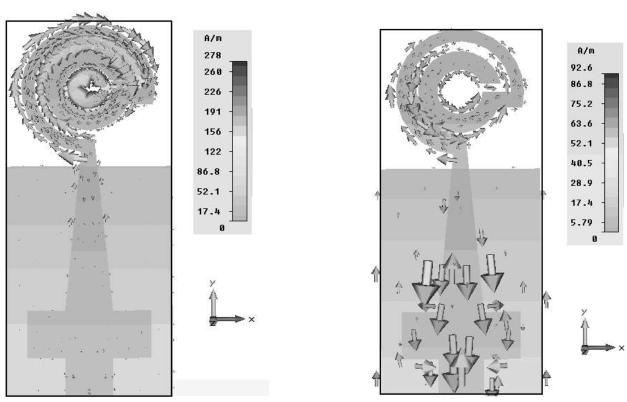
The antenna was investigated using HFSS and measured by an Agilent E5071C ENA series network analyzer with highest frequency at 8.5 GHz. Figure 2 shows the simulated and measured $|S_{11}|$ of the proposed antenna. The lower resonant frequency is 2.44 GHz, and the upper resonant frequency is 5.46 GHz. In 2.4 GHz band, the -10 dB bandwidth ($|S_{11}| < -10$ dB) is about 140 MHz (2.37–2.51 GHz), which meets the bandwidth requirement for IEEE 802.11b/g. In 5 GHz band, the -10 dB bandwidth ($|S_{11}| < -10$ dB) is about 1.23 GHz (4.86–

6.09 GHz), which also meets the bandwidth requirement for IEEE 802.11a. In conclusion, the measured results are in agreement with the simulated ones.

4. ANTENNA CHARACTERISTICS

4.1. Current Distributions

Operational mechanism of the antenna can be investigated from the current of the antenna. Then, we present the simulated current distributions at two frequency bands. Figure 3(a) shows the current distributions at the first resonance frequency (2.45 GHz), and the forward current is distributed on the edge of the entire CCDSR. The length of the forward current path is about $\lambda/4$ of 2.45 GHz. Figure 3(b) illustrates the current distributions at the second resonance frequency (5.5 GHz). The forward current is distributed at the rearward of CCDSR, while the current in front of CCDSR exhibits opposite flowing direction. The length of forward current path is $\lambda/4$ of 5.5 GHz. Therefore, at two radiation modes, the length of radiation current path satisfies monopole antenna's $\lambda/4$ radiation theory. From Figure 3, at the edge of microstrip-fed, more current is distributed at 5.5 GHz frequency than at 2.4 GHz frequency. It denotes that the second resonant mode is also affected by microstrip-fed (tuning arms). Details of the performance of microstrip tuning arms will be discussed in the next section.



(a) at 2.45 GHz (b) at 5.5 GHz

Figure 3. Current distributions on the proposed antenna.

4.2. The Effect of Tuning Arms

Tuning arms play an important role in frequency tuning. Figure 4 shows the simulated $|S_{11}|$ of the proposed antenna with arm length $W_a = 0\,\mathrm{mm}$ (no arms), 1 mm, 2 mm and 3 mm. As can be observed from the figure, the upper (5 GHz) frequency band shifts toward lower frequency as the length W_a increased, while little effect happens to the lower (2.4 GHz) frequency band. The result indicates that the tuning arms are considered to mainly control the upper operating band (5 GHz), and $W_a = 2\,\mathrm{mm}$ is the obtained value for our optimized antenna.

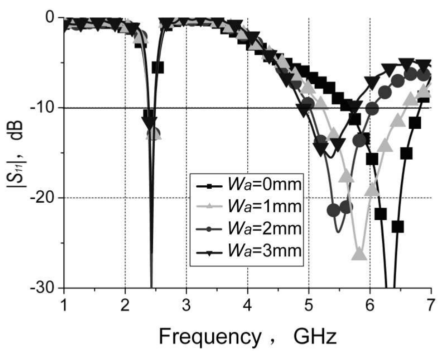


Figure 4. $|S_{11}|$ for different length of arms.

4.3. Radiation Patterns and Peak Gain

Figure 5, Figure 6 and Figure 7 depict the measured results of radiation gain patterns for three different frequencies (2.4, 5.2, and 5.8 GHz) at x-y and x-z planes. Learning from these radiation patterns, we can see that x-z plane patterns are quasi-omnidirectionally and quasi-symmetrically (dipole-like radiation pattern) at three typical frequencies, although distortion is observed at high frequencies. Distortion is probably because the electric length of the antenna is large at high frequencies, then, the distribution of radiation current exhibits non-uniformity at these frequencies. Non-uniform current distributions lead to patterns distortion. Figure 8 shows the antenna's directivity and peak gain (measured and simulated) for frequencies across the lower (2.4 GHz) and upper (5.2/5.8 GHz) bands. Here, only several frequencies have been chosen, based on which a curve is drawn to show the result in whole band. It can be seen from the figure that measured gain is smaller than simulated one, which may be due to measurement environment and fabrication accuracy. The measured gains are about

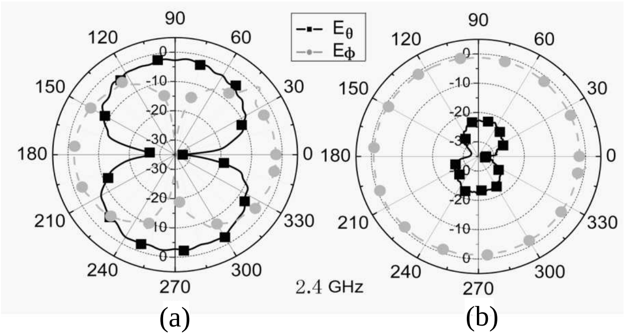


Figure 5. Radiation patterns at 2.4 GHz for the proposed antenna, (a) y-z plane, (b) x-z plane.

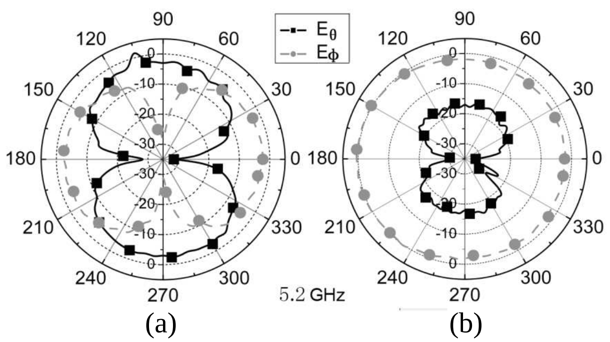


Figure 6. Radiation patterns at 5.2 GHz for the proposed antenna, (a) y-z plane, (b) x-z plane.

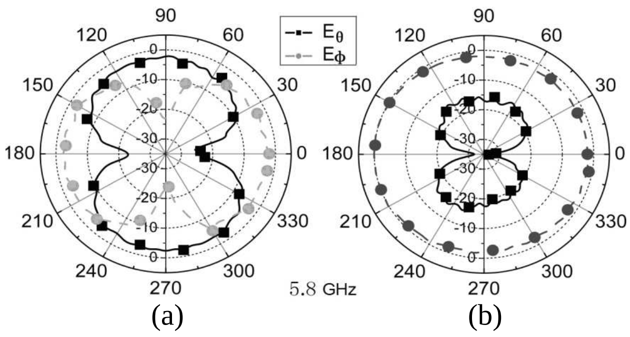
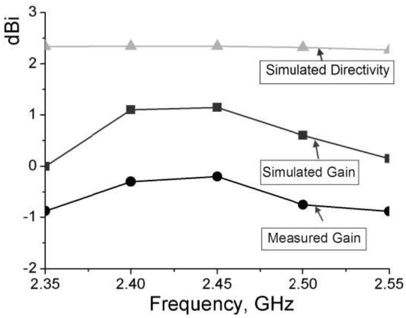
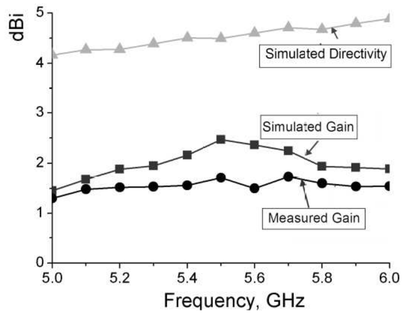


Figure 7. Radiation patterns at 5.8 GHz for the proposed antenna, (a) y-z plane, (b) x-z plane.



(a)



(b)

Figure 8. Peak gain (simulated and measured) and directivity for frequencies across, (a) the 2.4 GHz band (2.4–2.484 GHz), and (b) the 5 GHz band (5.150–5.825 GHz).

0 dBi and 1.7 dBi at the lower and upper bands, respectively. These gain variations are both less than 1.5 dBi.

5. CONCLUSION

A novel printed monopole antenna with ultra-compact size is presented. The dual-band performance is achieved by the specific CCDSR configuration. The simulated and measured results agree well with each other and qualify the capacity of this antenna in WLAN frequency bands (2.4–2.484 GHz, 5.15–5.35 and 5.725–5.825 GHz). The tuning arms are proved to be very helpful for resonant frequency tuning. Moreover, excellent radiation patterns, moderate gain and low cost make this antenna an excellent candidate for WLAN applications.

REFERENCES

1. Peng, L. and C.-L. Ruan, "A microstrip fed monopole patch antenna with three stubs for dual-band WLAN applications," *Journal of Electromagnetic Waves and Applications*, Vol. 21, No. 15, 2359–2369, 2007.
2. Lin, Y.-D. and P.-L. Chi, "Tapered bent folded monopole for dual-band wireless local area network (WLAN) systems," *IEEE Antennas and Wireless Propagation Letters*, Vol. 4, 355–357, 2005.
3. He, X., S. Hong, H. Xiong, Q. Zhang, and E. M. M. Tentzeris, "Design of a novel high-gain dual-band antenna for WLAN

applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 8, 798–801, 2009.

4. Liu, W.-C., C.-M. Wu, and N.-C. Chu, "A compact CPW-fed slotted patch antenna for dual-band operation," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 110–113, 2010.
5. Liu, H.-W., C.-H. Ku, and C.-F. Yang, "Novel CPW-fed planar monopole antenna for WiMAX/WLAN applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 240–243, 2010.
6. Kuo, Y.-L. and K.-L. Wong, "Printed double-T monopole antenna for 2.4/5.2 GHz dual-band WLAN operations," *IEEE Transactions on Antennas and Propagation*, Vol. 51, 187–2192, 2003.
7. Jan, J.-Y. and L.-C. Tseng, "Small planar monopole antenna with a shorted parasitic inverted-L wire for wireless communications in the 2.4-, 5.2-, and 5.8-GHz bands," *IEEE Transactions on Antennas and Propagation*, Vol. 52, 1903–1905, 2004.
8. Shynu, S. V., G. Augustin, C. K. Aanandan, P. Mohanan, and K. Vasudevan, "Design of compact reconfigurable dual frequency microstrip antennas using varactor diodes," *Progress In Electromagnetics Research*, Vol. 60, 197–205, 2006.
9. Gao. S., L.-W. Li, and A. Sambell, "FDTD analysis of a dual-frequency microstrip patch antenna," *Progress In Electromagnetics Research*, Vol. 54, 155–178, 2005.
10. Eldek, A. A., A. Z. Elsherbeni, and C. E. Smith, "Dual-wideband square slot antenna with a U-shaped printed tuning stub for personal wireless communication systems," *Progress In Electromagnetics Research*, Vol. 53, 319–333, 2005.
11. Zhang, X. and J. Wang, "A novel dual-band planar inverted-F antenna for WLAN applications," *Antennas, Propagation and EM Theory 2008,* 148–151, 2008.
12. Wu, C.-M., "Dual-band CPW-fed cross-slot monopole antenna for WLAN operation," *Microwaves, Antennas* & *Propagation*, Vol. 1, 542–546, 2007.
13. Xin, G. L. and J. P. Xu, "Wideband miniature G-shaped antenna for dual-band WLAN applications," *Electronics Letters*, Vol. 43, 1330–1332, 2007.
14. Li, Z. Q., C. L. Ruan, L. Peng, and X. H. Wu, "Design of a simple multi-band antenna with a parasitic C-shaped strip," *Journal of Electromagnetic Waves and Applications*, Vol. 24, No. 14–15, 1921–1929, 2010.
15. Liu, W. C., "Optimal design of dual band CPW-FED G-

shaped monopole antenna for WLAN application," *Progress In Electromagnetics Research*, Vol. 74, 21–38, 2007.

16. Song, Y., Y. C. Jiao, G. Zhao, and F. S. Zhang, "Multiband CPW-FED triangle-shaped monopole antenna for wireless applications," *Progress In Electromagnetics Research*, Vol. 70, 329–336, 2007.
17. Saed, M. A., "Broadband CPW-few planar slot antennas with various tuning stubs," *Progress In Electromagnetics Research*, Vol. 66, 199–212, 2006.
18. Shams, K. M. Z., M. Ali, and H. S. Hwang, "A planar inductively coupled bow-tie slot antenna for WLAN application," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 7, 861–871, 2006.
19. Zhao. G., F.-S. Zhang, Y. Song, Z.-B. Weng, and Y.-C. Jiao, "Compact ring monopole antenna with double meander lines for 2.4/5 GHz dual-band operation," *Progress In Electromagnetics Research*, Vol. 72, 187–194, 2007.