Progress In Electromagnetics Research C, Vol. 9, 109–117, 2009

COMPACT TOP-LOADED MONOPOLE ANTENNA WITH A PAIR OF SLEEVES ON THE GROUND PLANE FOR MULTI-BAND WLAN APPLICATIONS

J. Chen and G. Fu

Key National Laboratory of Antennas and Microwave Technology
Xidian University
Xi'an, Shaanxi 710071, China

G.-D. Wu

Research and Development Center of ZTE
Xi'an, Shaanxi 710071, China

S.-X. Gong

Key National Laboratory of Antennas and Microwave Technology
Xidian University
Xi'an, Shaanxi 710071, China

Abstract—A novel printed top-loaded monopole antenna with a pair of sleeves on the ground plane for multiband wireless local area network (WLAN) applications is presented. This antenna is composed of a top-loaded monopole and two sleeves on a ground plane. Both the antenna and the ground plane are printed on the same side of an inexpensive FR4 substrate. This antenna has light weight and compact size of only $29 \times 45 \times 0.5\,\text{mm}^3$. The operation bandwidth of this proposed antenna covers 2.4 GHz/5.2 GHz/5.8 GHz WLAN bands and 7.4 GHz∼8.8 GHz for UWB application, which perfectly meet the requirement of multiband working. The measured and simulated results agree well with each other.

Corresponding author: J. Chen (jinchen@mail.xidian.edu.cn).

1. INTRODUCTION

More and more attention is paid to printed antennas for WLAN applications since they have many advantages such as low cost, simple structure, compact size and so on, which enable them to be fit into many kinds of wireless electronics devices. Dual-band and multi-band antennas for WLAN applications are especially attractive since they not only take the task of multi-band working, but also eliminate the need of two or more separate antennas, thus avoiding the isolation problem existing between several antennas. Many antennas for this use have been proposed [1–15], while most of them are designed to cover two frequency bands of WLAN [1–11]. Some of them are presented for multi-band operations, while they have relatively larger dimension [12–15], which limits their applications in practical work. In this paper, a compact multiband printed antenna with top-loaded monopole and a pair of sleeves on the ground plane supporting WLAN in IEEE 802.11 b/a/g at 2.4 GHz, 5.2 GHz, 5.8 GHz and 7.4 GHz∼8.8 GHz for UWB application is presented. The dimension of this proposed antenna can be greatly reduced by top-loaded technology. Meanwhile, the top-load and sleeves on the ground plane of this proposed antenna can excite discontinuous resonant bands in order to realize multiband working. Details of the antenna design and experimental results are presented and discussed.

2. ANTENNA DESIGN

The geometry and photo of this open sleeve antenna are shown in Figure 1. The top-loaded radiator and the ground plane with a pair of sleeves are printed on the same side of a FR4 substrate which has a size of $L \times W = 29 \times 45\,\text{mm}^2$ and a relative permittivity of 4.4, while the other side of this substrate is without any metallization. The thickness of the substrate is 0.5 mm.

In this design, top-load is added to the end of the monopole to privide wider bandwidth and reduce the dimension of this proposed antenna. Meanwhile, two symmetrical strips are placed on the top of the ground plane to form a multi-resonant structure in order to realize multi-band characteristic. Top-load and sleeves on the ground plane have excited three resonant modes having different electric current distributions in the metal region so as to form three discontinuous resonant bands thus endow the proposed antenna with multiband characteristic. The parameters denoted as L_1, H_d and L_t will take very important role in exciting resonant modes of the proposed antenna, the influence will also be discussed in the following section. The monopole

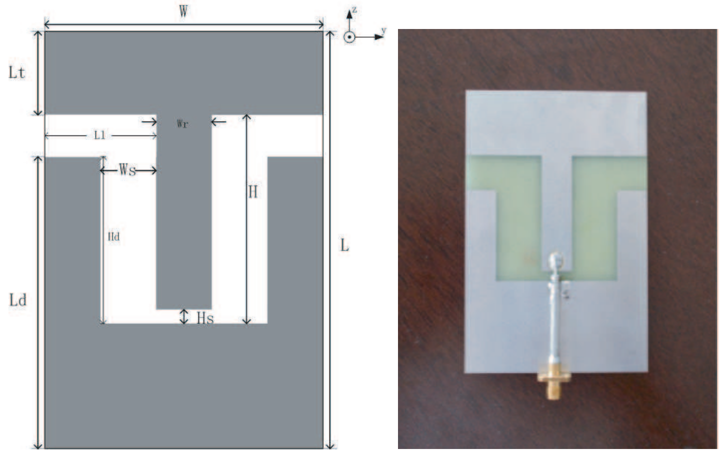

Figure 1. Geometry and photo of this proposed antenna.

is fed by the ground plane via a rigid cable, which can be seen in the photograph in Figure 1. Through lots of simulations, the antenna parameters are set as follows: $W = 29\,\text{mm}$, $L = 45\,\text{mm}$, $L_t = 10.4\,\text{mm}$, $L_d = 29\,\text{mm}$, $W_r = 4.8\,\text{mm}$, $W_s = 7.2\,\text{mm}$, $H = 20\,\text{mm}$, $H_s = 2\,\text{mm}$. The antenna area ($29 \times 45\,\text{mm}^2$) is much smaller than the multi-band antenna present in [12–15], which are $150 \times 50\,\text{mm}^2$, $150 \times 150\,\text{mm}^2$, $56 \times 34\,\text{mm}^2$ and $30 \times 54\,\text{mm}^2$ respectively.

3. RESULTS AND DISCUSSION

In order to examine the radiation characteristics of this proposed antenna, the prototype based on the design was fabricated and measured to compare with the simulation results. Measured and simulated return loss obtained from HFSS v11 and WILTRON37269A vector network analyzer are presented and compared in Figure 2. It can be seen in Figure 2 that the lower frequency band is about 310 MHz from 2.36 GHz to 2.72 GHz (14%) for return loss less than −10 dB, which meets the bandwidth requirement for 2.4 GHz WLAN operation. As for the middle frequency band, the bandwidth is 280 MHz (3.92–6.2 GHz), or 45% with respect to the center frequency of 5.06 GHz, which covers the whole 5 GHz WLAN band. The higher frequency band is 1400 MHz or about 17% for UWB operation.

Varying the key parameters L_1, H_d and L_t in Figure 1 will arouse the shift of resonant frequency. The tuning effects of varying the length of the protrudent part of the top-load as $L_1 = 8.1$, 10.1 and 12.1 mm with other parameters fixed is presented in Figure 3. As can be observed from this figure, the first resonance frequency shifts toward the lower frequency as the length L_1 increased while other resonant frequency bands are almost not affected. As for varying the sleeve length H_d to be 6.9, 10.9 and 14.9 mm ($L_1 = 12.1$ mm and $L_t = 10.4$ mm), it can be seen from Figure 4 that with the

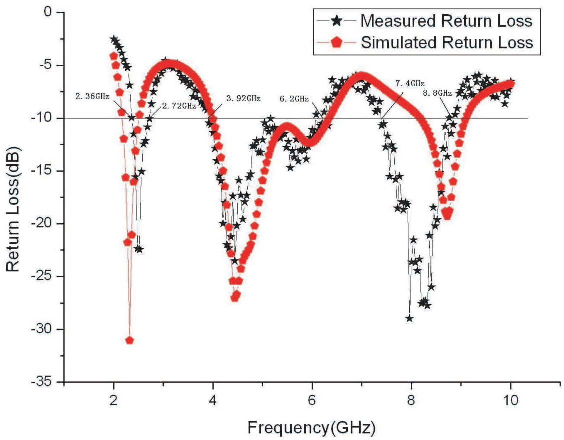

Figure 2. Simulated and measured return loss of the proposed antenna.

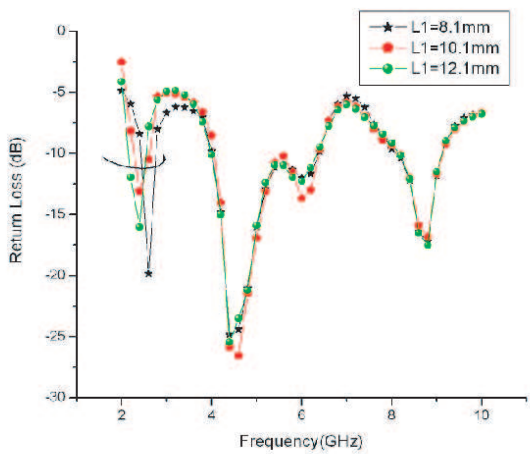

Figure 3. Measured return loss against frequency for proposed antenna with various length L_1, $H_d = 14.9$ mm and $L_t = 10.4$ mm (other parameters are the same as in Fig. 1).

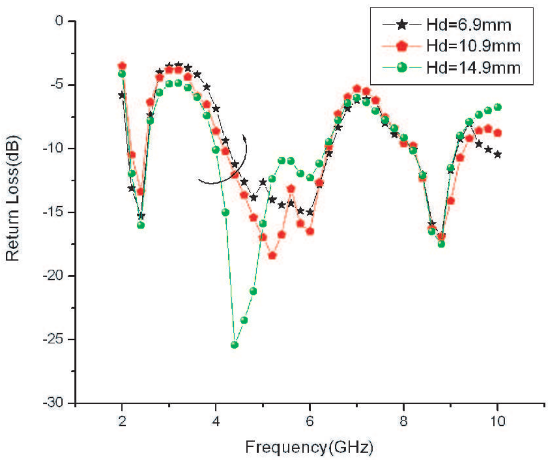

Figure 4. Measured return loss against frequency for proposed antenna with various length H_d, $L_1 = 12.1\,\text{mm}$ and $L_t = 10.4\,\text{mm}$ (other parameters are the same as in Fig. 1).

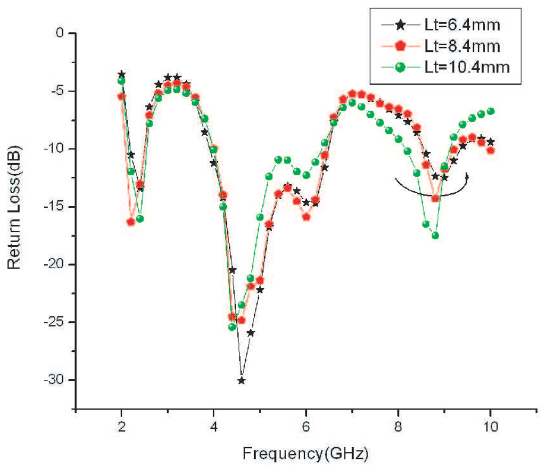

Figure 5. Measured return loss against frequency for proposed antenna with various length L_t, $H_d = 14.9\,\text{mm}$ and $L_1 = 12.1\,\text{mm}$ (other parameters are the same as in Fig. 1).

increasing of length H_d, the middle frequency band shifts towards the lower frequency with the bandwidth increases slightly. While other resonant frequency bands have not been changed. Changing of the

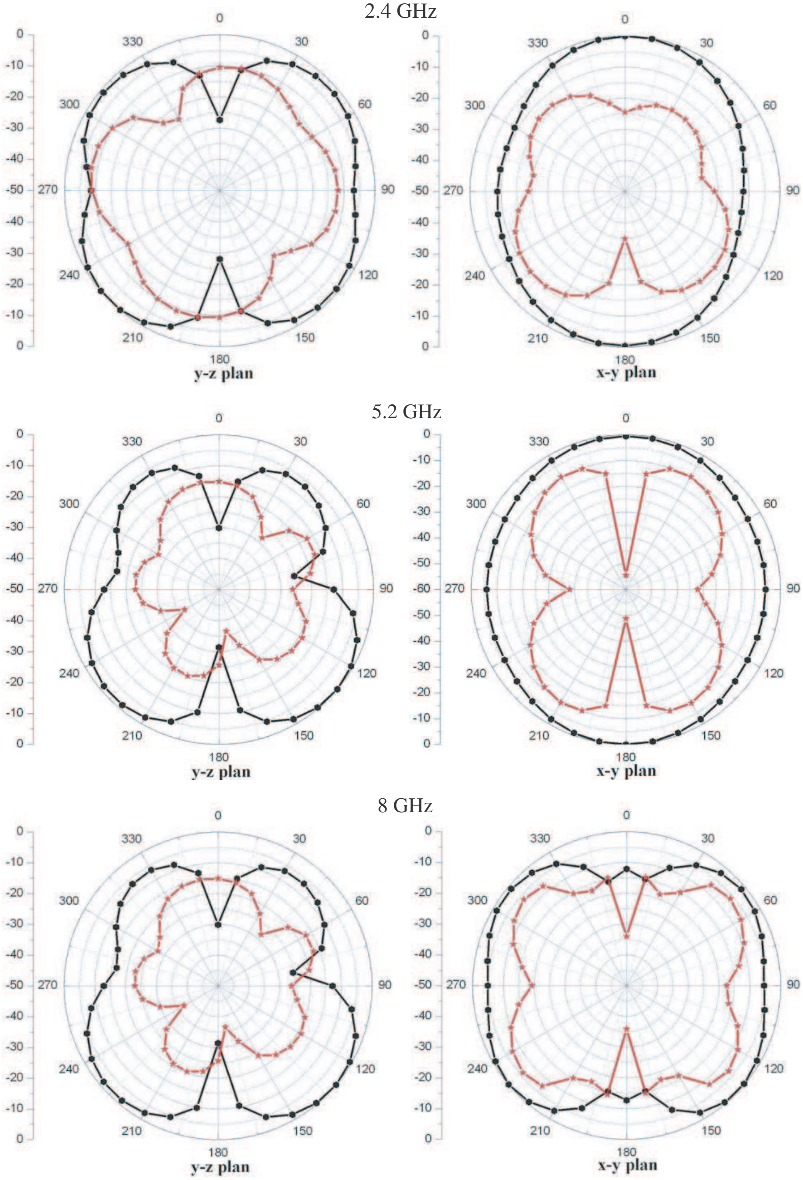

Figure 6. The co- (-•- E_θ) and cross- (-⋆- E_φ) polarized radiation patterns in the azimuth plane (x-y plane) and elevation plane (y-z plane).

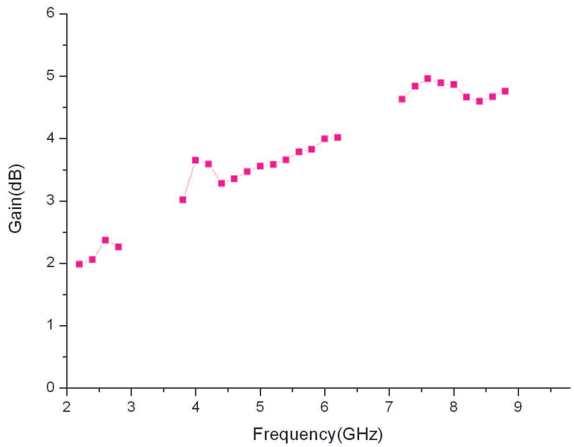

Figure 7. Peak gain of the proposed open sleeve antenna.

width of the top-load L_t can arouse the movement of higher resonant frequency band without strong influence on other frequency bands. The effect of varying L_t to be 6.4, 8.4 and 10.4 mm ($L_1 = 12.1$ mm, and $H_d = 14.9$ mm) on resonant frequency band is shown in Figure 5.

The measured radiation patterns in azimuth plane (x-y plane) and elevation plane (y-z plane) at 2.4 GHz, 5.2 GHz and 8 GHz are plotted in Figure 6. Good dipole-like omni-directivity in azimuth plane has been shown. Figure 7 presents the measured peak gain of the antenna in these three operating frequency bands. The maximum antenna gains in these three impedance bands are around 2 dB, 3.5 dB and 5 dB respectively.

4. CONCLUSION

A top-loaded monopole antenna with a pair of sleeves on the ground plane for multiband wireless local area network (WLAN) applications has been designed and manufactured. By adding a top-load on the end of the monopole and a pair of sleeves on the ground plane, three discontinuous resonant bands in which the return loss is less than -10 dB have been obtained. This proposed antenna has compact size, multiband characteristic and shows very good radiation patterns, which can be the first candidate for wireless communication.

REFERENCES

1. Sun, S.-Y., S.-Y. Huang, and J.-S. Sun, "A printed multiband antenna for cellphone applications," *Microwave and Optical Technology Letters*, Vol. 51, No. 3, 742–744, March 2009.
2. Sze, J.-Y. and W.-S. Chang, "Dual-band square slot antenna with embedded crossed strips for wireless local area network applications," *Microwave and Optical Technology Letters*, Vol. 51, No. 2, 435–439, February 2009.
3. Su, S.-W., J.-H. Chou, and Y.-T. Liu, "Compact paper-clip-shaped wireantenna for 2.4 and 5.2 GHz WLAN operation," *Microwave and Optical Technology Letters*, Vol. 50, No. 10, 2572–2574, October 2008.
4. Ham, C.-K., J.-W. Baik, and Y.-S. Kim, "CPW-fed compact meander and L-shape monopole antenna for dual-band WLAN applications," *Microwave and Optical Technology Letters*, Vol. 50, No. 12, 3147–3149, December 2008.
5. Sim, C.-Y.-D., "Dual band CPW-fed monopole antenna with asymmetrical ground plane for bandwidth enhancement," *Microwave and Optical Technology Letters*, Vol. 50, No. 11, 3001–3004, November 2008.
6. Gu, J.-H., S.-S. Zhong, L.-L. Xue, and Z. Su, "Dual-band monopole antenna with L-shaped strips for 2.4/5 GHz WLAN applications," *Microwave and Optical Technology Letters*, Vol. 50, No. 11, 2830–2833, November 2008.
7. Su, S.-W. and J.-H. Chou, "Printed omnidirectional accesspoint antenna for 2.4/5-GHz WLAN operation," *Microwave and Optical Technology Letters*, Vol. 50, No. 9, 2403–2407, September 2008.
8. 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*, PIER 72, 187–194, 2007.
9. Liu, W.-C., "Optimal design of dualband CPW-fed G-shaped monopole antenna for WLAN application," *Progress In Electromagnetics Research*, PIER 74, 21–38, 2007.
10. Behera, S. and K. J. Vinoy, "Microstrip square ring antenna for dual-band operation," *Progress In Electromagnetics Research*, PIER 93, 41–56, 2009.
11. Lee, Y.-C. and J.-S. Sun, "Compact printed slot antennas for wireless dual- and multi-band operations," *Progress In Electromagnetics Research*, PIER 88, 289–305, 2008
12. Rmili, H., J.-M. Floch, P. Besnier, and M. Drissi, "A dual-

band printed dipole antenna for IMT-2000 and 5-GHz WLAN applications," *Microwave and Optical Technology Letters*, Vol. 50, No. 10, 2585–2587, October 2008.

13. Chun, J.-C., "Wideband cylindrical monopole antenna for multi-band wireless applications," *Microwave and Optical Technology Letters*, Vol. 51, No. 1, 15–17, January 2008.
14. Liu, W.-C., J.-L. Jaw, and B.-C. Chen, "Triple-band CPW-fed monopole antenna with branch strips for wireless applications," *Microwave and Optical Technology Letters*, Vol. 50, No. 11, 2794–2797, November 2008.
15. Wang, C.-J. and S.-W. Chang, "Studies on dual-band multi-slot antennas," *Progress In Electromagnetics Research*, PIER 83, 293–306, 2008.