A Compact Tri-band Monopole Antenna with Multiple Meander Lines for WLAN and WiMAX Communication Applications

Xinbo Liu, Yingsong Li, and Wenhua Yu
College of Information and Communications Engineering
Harbin Engineering University, Harbin, China

Abstract— In this paper, a compact tri-band monopole antenna with three meander lines is proposed and investigated for wireless local area networks (WLANs) and worldwide interoperability for microwave access (WiMAX) applications. The designed tri-band antenna is realized by using three meander line structures that are connected to the 50-Ohm microstrip feed signal line to generate the desired triple resonance frequencies. By adjusting the dimensions of the proposed three meander lines, the expected resonant frequencies can be tuned for WLAN and WiMAX communication applications. The simulation results demonstrate that the optimized tri-band monopole antenna can give three impedance bandwidth for $S_{11} \leqslant -10$ dB of 156 MHz (2.39–2.55 GHz), 450 MHz (3.30–3.75 GHz) and 730 MHz (5.14–5.87 GHz), which can be applied to cover both 2.4/5.2/5.8-GHz WLAN bands and 3.5/5.5-GHz WiMAX bands. Furthermore, omnidirectional radiation patterns can be achieved, which make the designed tri-band monopole antenna promising for integrating into modern portable devices.

1. INTRODUCTION

With the rapid progress of wireless communication, WLAN and WiMAX have been extensively studied, which result in a great demand for multiband antennas. Recently, many researchers are focused on the antenna designs with simple structure, low cost, small size and multi-bands. To achieve these performances, a great number of multiband antennas have been presented for WLAN and WiMAX applications [1–5]. However, most of these antennas are large in size. To further reduce the size of the antenna, a multi-band antenna has been developed by using parasitic elements, which can just provide dual-band [6]. In sequence, several asymmetric coplanar strip (ACS)-fed antennas with small sized have been proposed and well designed by numerical and experimental methods [7–9]. However, these proposed antennas can only operate for single or dual band applications. In [10–14], several triple band antenna have been presented for WLAN and WiMAX applications. Although these antennas can provide multiband characteristics, some of them are complex in structure or large in size.

In this paper, a simple tri-band antenna is proposed and investigated by using high-frequency structure simulator (HFSS) for WLAN and WiMAX communication applications. The designed tri-band antenna is realized by using three meander line structures that are connected to the 50-Ohm microstrip feed signal line to generate the desired triple resonance frequencies. By adjusting the dimensions of the proposed three meander lines, the expected resonant frequencies can be tuned for WLAN and WiMAX communication applications. The experimental results demonstrate that the optimized tri-band monopole antenna can give three impedance bands for $S_{11} \leqslant -10$ dB. The proposed antenna is optimized and the results show that the antenna not only has good tri-band characteristic, but also has omnidirectional radiation patterns, which makes it suitable for both WLAN and WiMAX communication applications.

2. ANTENNA DESIGN

The configuration of the proposed tri-band WLAN and WiMAX antenna is shown in Figure 1. The proposed antenna is designed on a FR4 substrate with a relative permittivity of 4.4, loss tangent of 0.02, thickness of 0.8 mm and its total size is 30 mm × 20 mm. The proposed antenna consists of three meander lines that are connected to the feed signal line, a partial ground plane and a 50-Ohm microstrip feed signal line with a width of 1.4 mm. In this design, the meander lines are used to generate the three resonance frequency bands. All the meander lines are quarter-wavelength resonance at the desired frequencies. The desired center frequencies are tunable by adjusting the dimensions of these meander lines, which make the proposed antenna easy to fabricate. The proposed antenna is optimized and the optimal parameters are listed as follows: $W = 20$, $W_1 = 0.9$, $W_2 = 1$, $W_4 = 2$, $W_5 = 1$, $W_6 = 1.2$, $W_7 = 6$, $W_8 = 1.4$, $L = 30$, $L_1 = 2.4$, $L_2 = 5$, $L_3 = 7$, $L_4 = 20$, $L_5 = 9.5$, $L_6 = 9.5$, $L_7 = 2.5$, $L_8 = 4$, $L_9 = 7$, $L_{10} = 1$, $L_{11} = 7$ (unit: mm).

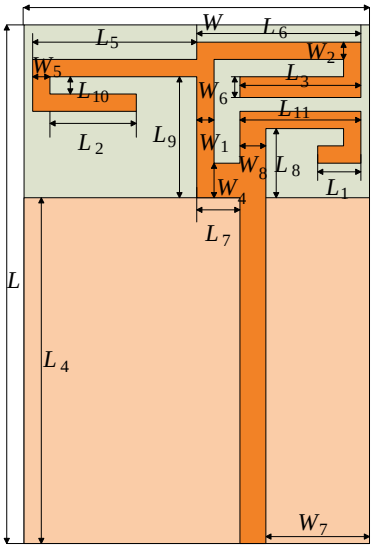

Figure 1: Geometry structure of the proposed antenna.

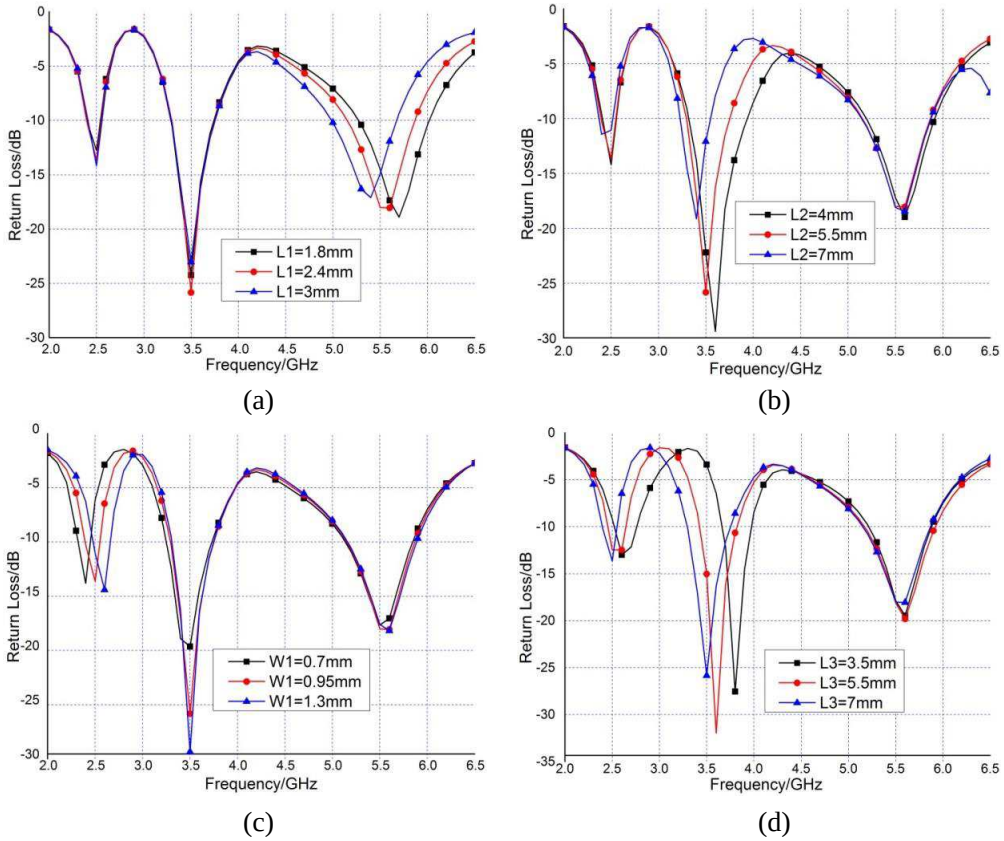

Figure 2: Parameter effects on the resonance characteristic of the antenna. (a) L_1. (b) L_2. (c) W_1. (d) L_3.

3. PERFORMANCE OF THE PROPOSED ANTENNA

In this section, the proposed tri-band antenna is investigated by using HFSS which is based on finite element method (FEM). The key parameters L_1, L_2, L_3 and W_1 are selected to evaluate the effects on the impedance bandwidth of the antenna. Figure 2(a) shows the effects on the impedance bandwidth of the proposed tri-band WLAN and WiMAX antenna with respect to the return loss when the parameter L_1 varies from 1.8 mm to 3 mm. With an increment of L_1, the center frequency of the highest band shifts from 5.7 GHz to 5.4 GHz. This is because the increased

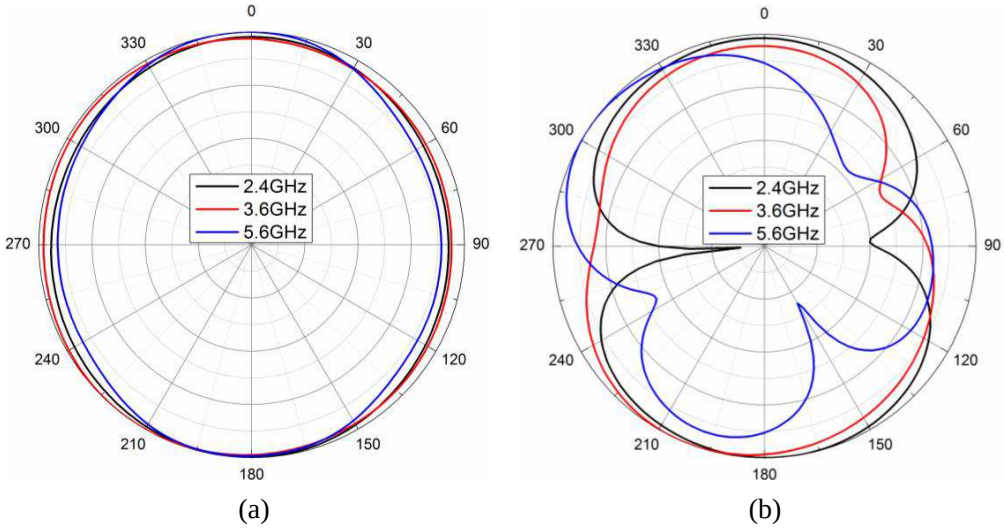

Figure 3: Radiation patterns of the proposed antenna. (a) H-plane. (b) E-plane.

L_1 increases the current path and hence the highest band moves to low frequency. The effects of L_2 are shown in Figure 2(b). When L_2 increases from 4 mm to 7 mm, the center frequency of the middle band at 3.5 GHz WiMAX moves to low frequency. We can see that the center frequency shifts from 3.6 GHz to 3.4 GHz and the bandwidth is also getting narrow because the increased L_2 not only prolong the resonance length but also enhance the coupling of the meander lines. Parameter W_1 has an important effect on the impedance bandwidth of the lowest band and the results are shown in Figure 2(c). It is observed that the center frequency of the lowest band shifts to high frequency with an increase of W_1 and the bandwidth is also slightly enhanced. In order to understand the resonance of the proposed antenna, L_3 is also investigated and the simulated results are demonstrated in Figure 2(d). It can be seen that the center frequencies of the lowest and middle bands move to low frequency. This is because the increased L_3 not only increases the resonance length and makes the lowest frequency move to low frequency, but also affect the current distribution of the left meander line and hence changes the center frequency of the middle band. Thus, we can tune the dimensions of the meander lines to control the resonance frequencies to meet the WLAN and WiMAX applications. The radiation patterns of the proposed antenna are obtained at 2.4 GHz, 3.6 GHz and 5.6 GHz and are shown in Figure 3. It is can be seen from Figure 3 that the proposed tri-band antenna has a nearly omnidirectional radiation patterns in the H-plane and the figure-of-eight-like radiation pattern in E-plane except 5.6 GHz, which indicates that the proposed tri-band WLAN and WiMAX antenna can provide desired radiation characteristics.

4. CONCLUSION

A simple tri-band antenna is proposed for WLAN and WiMAX applications by using meander lines. The key parameters of the antenna have been investigated to understand the principle of the antenna. The triple resonance frequencies can be controlled by adjusting the dimensions of the antenna structures. The results showed that the proposed antenna can achieve three operating bandwidth of 156 MHz (2.39–2.55 GHz), 450 MHz (3.30–3.75 GHz) and 730 MHz (5.14–5.87 GHz) to cover WiMAX (3.4–3.69 GHz) and WLAN (2.4–2.483 GHz, 5.15–5.825 GHz) communication systems. The proposed antenna has a small size, three resonance frequencies and omnidirectional radiation patterns, rendering it suitable for WiMAX and WLAN communication applications.

ACKNOWLEDGMENT

This work was partially supported by Fundamental Research Funds for the Central Universities (HEUCFD1433).

REFERENCES

1. Chien, H. Y., C. Sim, and C. H. Lee, "Compact size dual-band antenna printed on flexible substrate for WLAN operation," *IEEE Antennas and Propagation*, 1047–1050, 2012.
2. Chiu, C. H., C. C. Lin, C. Y. Huang, and T. K. Lin, "Compact dual-band dipole antenna with

asymmetric arms for WLAN applications," *International Journal of Antennas and Propagation*, Vol. 2014, Article ID 195749, 2014.

3. Liu, P. G., Y. L. Zou, B. R. Xie, X. L. Liu, and B. H. Sun, "Compact CPW-fed tri-band printed antenna with meandering split-ring slot for WLAN/WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 1242–1244, 2012.
4. Thomas, K. G. and M. Sreenivasan, "A novel triple band printed antenna for WLAN/WiMAX applications," *Microwave and Optical Technology Letters*, Vol. 51, No. 10, 2481–2485, 2009.
5. Zhu, J., M. A. Antoniades, and G. V. Eleftheriades, "A compact tri-band monopole antenna with single-cellmetamaterial loading," *IEEE Transactions on Antennas and Propagation*, Vol. 58, No. 4, 1031–1038, 2010.
6. Li, Y., X. Yang, Y. Bai, and T. Jiang, "Dual-band antenna handles WLAN/WiMAX," *Microwaves & RF*, Vol. 50, No. 6, 80–88, 2011.
7. Li, Y., W. Li, and R. Mittra, "A compact ACS-fed dual-band meandered monopole antenna for WLAN and WiMAX applications," *Microwave and Optical Technology Letters*, Vol. 55, No. 10, 2370–2373, 2013.
8. Deepu, V., R. K. Raj, M. Joseph, M. N. Suma, and P. Mohanan, "Compact asymmetric coplanar strip fed monopole antenna for multiband applications," *IEEE Transactions on Antennas and Propagation*, Vol. 55, 2351–2357, 2007.
9. Li, Y., W. Li, and Q. Ye, "A compact asymmetric coplanar strip-fed dual-band antenna for 2.4/5.8 GHz WLAN applications," *Microwave and Optical Technology Letters*, Vol. 55, No. 9, 2066–2070, 2013.
10. Zhang, X. Q., Y. C. Jiao, and W. H. Wang, "Compact wide tri-band slotantenna for WLAN/WiMAX applications," *Electronics Letters*, Vol. 48, No. 2, 64–65, 2012.
11. Zhao, Q., S.-X. Gong, W. Jiang, B. Yang, and J. Xie, "Compact wide-slot tri-band antenna for WLAN/WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 18, 9–18, 2010.
12. Ren, X. S., Y. Z. Yin, W. Hu, and Y. Q. Wei, "Compact tri-band rectangular ring patch antenna with asymmetrical strips for WLAN/WiMAX applications," *Journal of Electromagnetic Waves and Applications*, Vol.24, No. 13, 1829–1838, 2010.
13. Karimian, R., I. Tehran, H. Oraizi, S. Fakhte, and M. Farahani, "Novel F-shaped quad-band printed slot antenna for WLAN and WiMAX MIMO systems," *IEEE Antennas and Wireless Propagation Letters*, Vol. 12, 405–408, 2013.
14. Wan, Y. T., D. Yu, F. S. Zhang, and F. Zhang, "Miniature multi-band monopole antenna using spiral ring resonators for radiation pattern characteristics improvement," *Electronics Letters*, Vol. 49, No. 6, 382–384, 2013.