Progress In Electromagnetics Research Letters, Vol. 22, 139–146, 2011

TRIPLE-BAND OPEN L-SLOT ANTENNA WITH A SLIT AND A STRIP FOR WLAN/WIMAX APPLICATIONS

K. Song, Y.-Z. Yin, and B. Chen

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

Abstract—An open L-slot antenna with triple-band operation for WLAN and WiMAX applications has been designed and implemented with a slit and a strip, which can be used to generate two band-rejected characteristics. Both the strip and the slit play a very important role in suppressing the dispensable bands. By adjusting the dimensions of the slit and strip, the proposed antenna shows three separated operating frequencies with a bandwidth of 14% from 2.24 to 2.58 GHz, a bandwidth of 19% from 3.02 to 3.66 GHz, and a bandwidth of 10% from 5.62 to 6.21 GHz, respectively. Detailed designs and experimental results are reported in this paper.

1. INTRODUCTION

Wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) have been widely applied in mobile devices such as handheld computers and intelligent phones. Hence, the need for multi-band circuit elements capable to operate in the WLAN and WiMAX bands becomes a new tendency, and the multi-band antenna has attracted much public attention [1–10]. In [1–3], printed double-T [1], meander [2], and G-shaped [3] monopoles were used to generate two resonances for dual-band applications. And, some tri-band and quad-band operation antennas also have been reported with triangle-shaped monopole [4], composite meta-material resonators [5], flower-like CPW-FED monopole [6] and asymmetrical radiator patch with a trapezoidal ground plane [7]. Furthermore, some other novel

Received 14 January 2011, Accepted 25 March 2011, Scheduled 30 March 2011
Corresponding author: Kun Song (songkun@mail.xidian.edu.cn).

multi-band antenna structures with several arms and partial ground plane [8], 3D fractal monopole [9], with a parasitic M-strip [10] and a pair of symmetrical L-strips [11] have been provided and investigated, respectively. Although these antennas in [8–11] can achieve good multi-band characteristics, they are somewhat large in size.

Recently, some wide open slot antenna designs for wideband and ultra-wideband applications have been proposed in the literatures [12–14]. In [12, 13], wide open L- and T-shaped slots etched on the finite ground plate edge are reported for wideband applications. To cover the UWB frequency range, a bandwidth enhancement scheme was also presented in [14] to improve the limited operation band greatly. Unfortunately, this novel broadband antenna should be used with a filter to suppress the dispensable bands that lead to increase in cost. How to investigate these open slot antennas for multi-band applications are rarely reported.

In this paper, a triple-band open L-slot antenna just like [13] with a slit and a strip is designed for WLAN and WiMAX applications. For good suppression in the dispensable bands, the slit and the strip are used to generate two band-rejected characteristics. From the simulated and measured results, the proposed antenna shows three separated operating frequencies with a bandwidth of 14% from 2.24 to 2.58 GHz, a bandwidth of 19% from 3.02 to 3.66 GHz, and a bandwidth of 10% from 5.62 to 6.21 GHz, respectively. Both the strip and the slit play a very important role in suppressing two undesired bands. The effects of major parameters on the band-rejected performance are also analyzed and discussed as follows.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure 1. The antenna is designed and fabricated on a substrate with a dielectric constant of 4.4, a thickness of 0.8 mm, and a total area of $35 \times 30\,\text{mm}^2$. A rectangular radiation patch with a size of $8 \times 6.5\,\text{mm}^2$ is fed by a 50-Ω micro-strip line on the top side of the substrate. A strip is added on the patch and the length of the strip is L-strip. On the opposite side, an open L-slot and a slit are etched on the ground plane. The length of the etched slit is L-slit. With the strip and the slit, two band-rejected features have been generated to reject the interferences in the dispensable bands. For a good research here, both the strip and the slit are set with the same width of 0.25 mm to produce stronger resonance for better band-rejected performance. Their lengths are set as about $0.25\lambda_g$ at each notched frequency (λ_g is the wavelength in the medium) when they work alone. For good band-notched characteristics, their

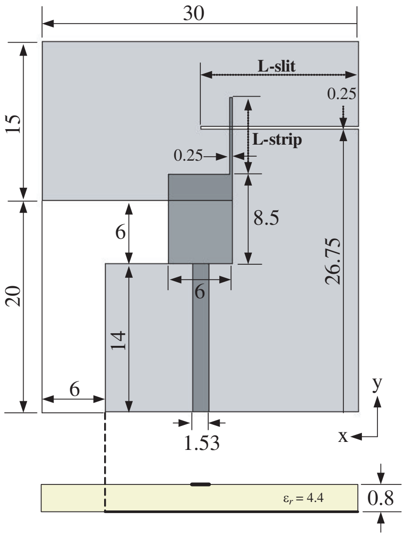


Figure 1. Geometry of the proposed triple-band antenna (Units: mm).

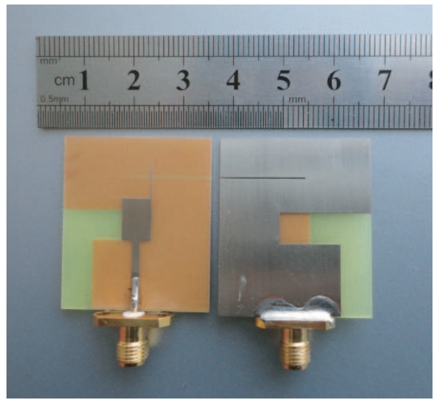


Figure 2. Prototype of the proposed triple-band antenna.

positions and widths should be adjusted carefully. By varying the values of L-strip and L-slit, two appropriate band-rejected features can be achieved. The required numerical analysis and proper geometrical parameters of the proposed antenna are investigated with the aid of Ansoft's High Frequency Structure Simulator (HFSS) software. The optimal design parameters of the strip and the slit are set as follows: L-strip = 7.2 mm, and L-slit = 17 mm. A prototype of the proposed triple-band antenna has been fabricated and shown in Figure 2.

3. RESULTS AND DISCUSSION

With the aid of Ansoft's HFSS and WILTRON37269A vector network analyzer, the proposed triple-band antenna with optimal geometrical parameters was fabricated and tested. The simulated and measured return losses of the proposed triple-band antenna are shown in Figure 3. Using both the strip and the slit, three distinct operating frequencies with a bandwidth of 14% from 2.24 to 2.58 GHz, a bandwidth of 19% from 3.02 to 3.66 GHz, and a bandwidth of 10% from 5.62 to 6.21 GHz, respectively, can be achieved. Obviously, both the strip and the slit have a strong mutual effect on generating two rejected bands.

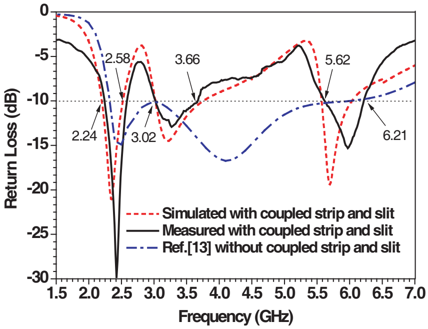


Figure 3. Measured and simulated return losses versus frequency.

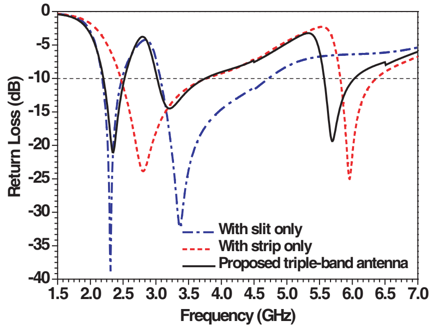


Figure 4. Simulated return losses with the different structures.

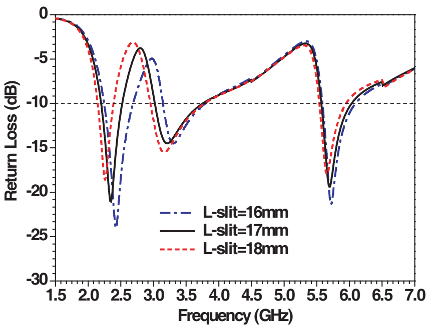


Figure 5. Simulated return losses with different vales of L-slit (L-strip = 7.2 mm).

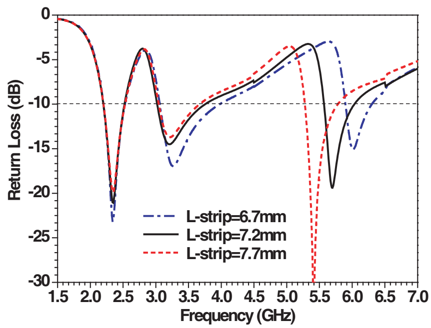
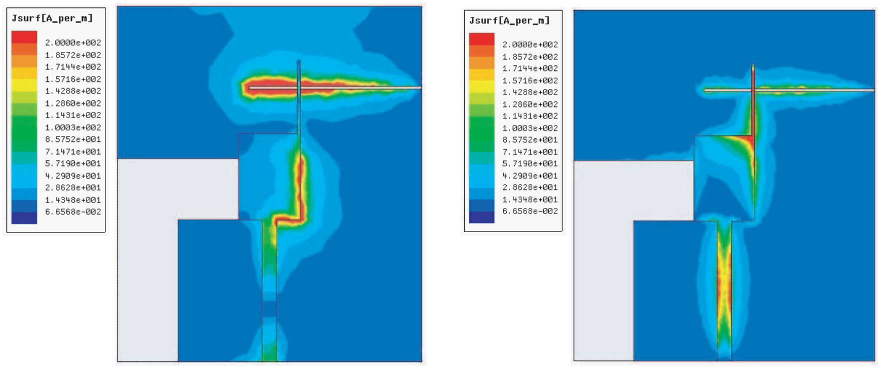


Figure 6. Simulated return losses with different vales of L-strip (L-slit = 17 mm).

To demonstrate the effects of the slit and the strip on generating the lower and higher band-rejected features, three different return losses with and without the slit and the strip are shown in Figure 4. Obviously, either of the strip and the slit can generate a rejected band to form dual-band operation. With the strip only, the band-rejected feature at the higher band can be obtained. Similarly, when the slit is individually presented, a band-rejected feature at lower band can be excited. Furthermore, the responses of the proposed antenna with various parameters of L-strip and L-slit are discussed in Figure 5 and Figure 6. As seen from them, it is obvious that two notched bands are adjusted by the lengths of the slit and the strip With suitable dimensions of the coupled strip and slit, three separated bands for WLAN and WiMAX applications can be obtained.



(a) (b)

Figure 7. Simulated current distributions at two notched bands (a) 2.75 GHz, (b) 5.30 GHz, respectively.

In order to study the electromagnetic mechanism of the notched-band operation, the current distributions at the rejected frequencies should be given. Figures 7(a) and (b) show the simulated current distributions at 2.75 GHz and 5.30 GHz, respectively. When the proposed antenna operates at 2.75 GHz, the slit acts a good resonator to generate the lower notched band in Figure 7(a). As expected, Figure 7(b) shows the current distribution along the strip at 5.3 GHz. It also indicates that the strip yields a strong band-rejected characteristic at the higher frequency.

In addition, the far-field radiation patterns of the proposed antenna operating at 2.45 GHz, 3.5 GHz, and 5.8 GHz are presented in Figure 8. It is seen that the proposed triple-band antenna radiates like a monopole antenna does. However, the omni-directional radiation property of H-plane (xoz-plane) at 5.8 GHz has a little deterioration mainly because of the inherent asymmetric structure like Refs. [13, 14].

Finally, the peak gain curve of the proposed antenna is shown in Figure 9. There are about 2.02 dBi at 2.45 GHz, 2.25 dBi at 3.5 GHz, and 3.68 dBi at 5.8 GHz in three operating bands, respectively. Thus, the antenna exhibits stable gain across three operation bands. Due to the band-notched functions, the peak gain decreases in the vicinities of 2.75 GHz and 5.30 GHz. The proposed tripleband antenna is suitable for the WLAN and WiMAX systems.

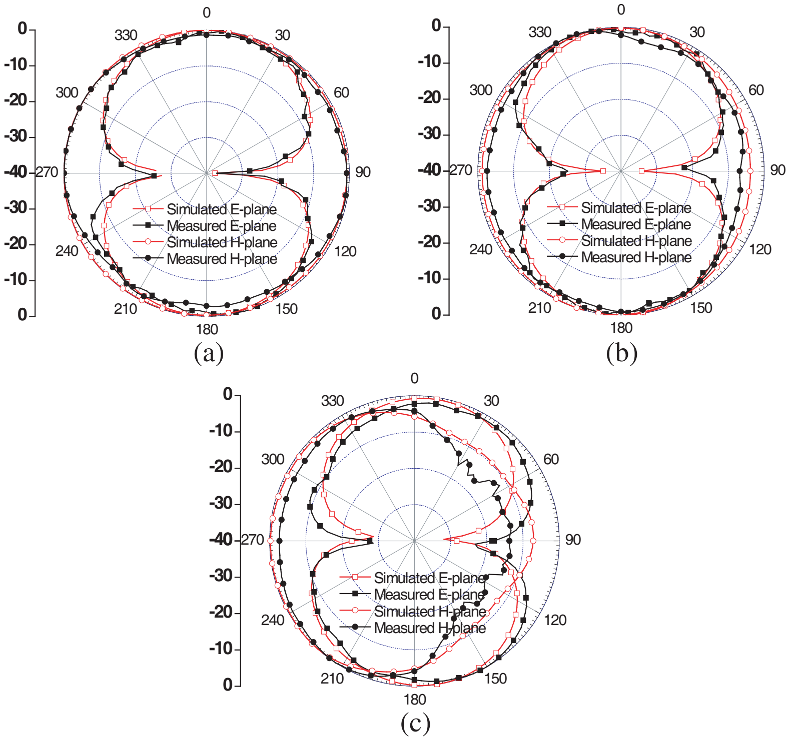


Figure 8. Far-field radiation patterns of the proposed antenna at (a) 2.45 GHz, (b) 3.5 GHz, and (c) 5.8 GHz, respectively.

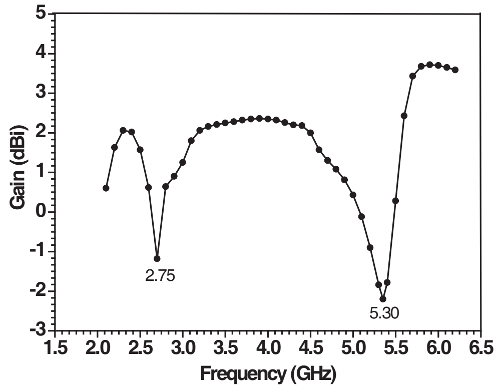


Figure 9. Peak gain of the proposed antenna.

4. CONCLUSION

In this paper, an open L-slot antenna with triple-band operation for WLAN and WiMAX applications has been designed and implemented with a slit and a strip, which can be used to generate two band-rejected characteristics in the dispensable bands. By adjusting the dimensions of the slit and the strip, two good band-rejected characteristics can be achieved. The proposed antenna shows three separated operating frequencies with a bandwidth of 14% from 2.24 to 2.58 GHz, a bandwidth of 19% from 3.02 to 3.66 GHz, and a bandwidth of 10% from 5.62 to 6.21 GHz, respectively. Hence, this triple-band antenna can become a good candidate for WLAN and WiMAX applications.

REFERENCES

1. 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, 2187–2191, 2003.
2. Zhang, L.-N., S.-S. Zhong, X.-L. Liang, and C.-H. Li, "Compact meander monopole antenna for tri-band WLAN application," *Microwave and Optical Technology Letters*, Vol. 49, No. 4, 986–988, April 2007.
3. 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.
4. 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.
5. Si, L.-M. and X. Lv, "CPW-FED multi-band omni-directional planar microstrip antenna using composite metamaterial resonators for wireless communications," *Progress In Electromagnetics Research*, Vol. 83, 133–146, 2008.
6. Lin, D.-B., I.-T. Tang, and Y.-Y. Chang, "Flower-like CPW-FED monopole antenna for quad-band operation of mobile handsets," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 17–18, 2271–2278, 2009.
7. Thomas, K.-G. and M. Sreenivasan, "Compact triple band antenna for WLAN/WiMAX applications," *Electronic Letters*, Vol. 45, No. 16, July 2009.
8. Srifi, M.-N., V.-K. Palukuru, M. Essaaidi, and H. Jantunen,

"Compact planar monopole antenna for 3G and UWB applications," *Microwave and Optical Technology Letters*, Vol. 51, No. 8, 1939–1942, August 2009.

9. Rmili, H., J.-L. Miane, J.-M. Floch, and H. Zangar, "Design of multi and wideband 3D fractal monopole antenna for wireless operations in L- and S-bands," *Microwave and Optical Technology Letters*, Vol. 51, No. 8, 1976–1979, August 2009.
10. Liu, Z.-Y., Y.-Z. Yin, L.-H. Wen, W.-C. Xiao, Y. Wang, and S.-L. Zuo, "A Y-shaped tri-band monopole antenna with a parasitic M-strip for PCS and WLAN applications," *Journal of Electromagnetic Waves and Applications*, Vol. 24, No. 8–9, 1219–1227, 2010.
11. Hu, W., Y.-Z. Yin, X. Yang, K. Song, Z.-Y. Liu, and L.-H. Wen, "A wide open U-slot antenna with a pair of symmetrical L-strips for WLAN application," *Progress In Electromagnetics Research Letters*, Vol. 16, 141–149, 2010.
12. Latif, S.-I., L. Shafai, and S.-K. Sharma, "Bandwidth enhancement and size reduction of microstrip slot antennas," *IEEE Transation on Antennas Propagation*, Vol. 53, No. 3, 994–1003, 2005.
13. Chen, W.-S. and K.-Y. Ku, "Broadband design of non-symmetric ground $\lambda/4$ open slot antenna with small size," *Microwave Journal*, Vol. 50, 110–121, 2007.
14. Song, K., Y.-Z. Yin, S.-T. Fan, Y.-Z. Wang, and L. Zhang, "Open L-slot antenna with rotated rectangular patch for bandwidth enhancement," *Electronics Letters*, Vol. 45, No. 25, 2009.