Progress In Electromagnetics Research Letters, Vol. 15, 19–26, 2010

A NOVEL RECTANGULAR SLOT ANTENNA WITH EMBEDDED SELF-SIMILAR T-SHAPED STRIPS FOR WLAN APPLICATIONS

L. Kang, Y.-Z. Yin, S.-T. Fan, and S.-J. Wei

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

Abstract—A novel rectangular slot antenna with embedded self-similar strips is proposed for wireless local area network (WLAN) applications. The proposed antenna comprises a T-shaped monopole and inverted self-similar strips embedded in the rectangular slot etched on the ground plane. The measured results of the fabricated antenna show that the impedance bandwidths (VSWR < 2) are 180 MHz from 2.36 to 2.54 GHz and 920 MHz from 5.05 to 5.97 GHz, which cover all the 2.4/5.2/5.8 GHz WLAN operating bands. And the radiation patterns are almost omni-directional in the azimuthal plane within the lower operating bands.

1. INTRODUCTION

With the development of modern wireless communication technology, multi-band antenna design has become very important for wireless local area network. In practice, IEEE 802.11 WLAN standards consist of 2.4 GHz (2.4–2.484 GHz), 5.2 GHz (5.15–5.35 GHz) and 5.8 GHz (5.725–5.825 GHz) frequency bands. In order to cover WLAN operating bands, related printed patch antennas [1–3] have been proposed recently. The antennas in [1] and [2] comprise six half-wavelength dipoles and a double-layer structure, respectively, which make the antenna structure complex. And a relatively large ground is applied in [3]. Slot antennas have advantages of small size and wide operating bandwidth. Therefore, many different sorts of slot antennas have been proposed, such as M-slot folded patch antenna [4], square slot antenna [5], square slot antenna with embedded crossed strips [6],

Corresponding author: L. Kang (klcolor63@163.com).

triangular slot antenna with inset F-shaped strips [7], T-shaped slot antenna [8], E-shaped slot antenna [9], two ring slots antenna [10], rectangular slot antenna with U-shaped strips [11], square ring antenna with tuning stub [12], rectangular slot antenna with fork-like tuning stub [13], triangular slot antenna with fork-like tuningstub [14], etc. Among the antenna designs mentioned above, the antenna in [4] can only excite one resonant frequency band, which cannot cover 2.4–2.484 GHz lower operating band. In [5–8], the antennas can generate two resonant frequency bands but cannot completely cover all the 2.4/5.2/5.8 GHz WLAN operating bands. The double-layers structure applied in [9] and the relative large size of the antenna in [10] and [11] make them hard to fabricate and integrate.

In this paper, a novel rectangular slot antenna with embedded self-similar strips is demonstrated for 2.4/5.2/5.8 GHz WLAN operations. Two resonant modes are excited with the use of a T-shaped monopole and inverted self-similar T-shaped strips embedded in the rectangular slot etched on the ground plane. The size of the antenna can be miniaturized by adopting the bottom self-similar strips, because the strips can extend the path of the current distributed on the ground plane, thus effectively lower the first resonant band of the antenna. By adjusting the parameters on the top monopole and bottom strips, good impedance match and radiation characteristics can be obtained. Details of the antenna design, and both the simulated and the measured results are presented and discussed.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure 1. The antenna is designed and fabricated on a substrate with dielectric constant of 2.65, thickness of 1 mm and area of $45 \times 40\,\text{mm}^2$ ($L_0 \times W_0$). There is a T-shaped monopole located on the top side of the substrate which mainly contributes to the higher resonant frequency. The monopole consists of a horizontal strip with width W_2 and length L_2, and a vertical strip with width W_3 and length $L_3 + L_a$. The dimension of the rectangular slot etched below is $25.2 \times 21.5\,\text{mm}^2$ ($L_1 \times W_1$). Embedded in the slot are inverted T-shaped strips similar to the monopole above, which generate current flow path for the lower resonant frequency. The dimensions of the top monopole and bottom self-similar strips are nearly the same except the length of the vertical strips. Two parameters are defined, R for the length ratio of the vertical strips of top T-shaped monopole and bottom self-similar strips protruded into the slot, L_a to L_b and D for the distance between the two horizontal strips along x axis. By fixing the optimum parameters of the proposed antenna, appropriate impedance bandwidths for the WLAN applications at 2.4, 5.2 and 5.8 GHz can be achieved. Through a parametric study with the aid of Ansoft's High Frequency Structure Simulator (HFSS), the optimum design parameters of the proposed antenna are set as presented in Table 1. A prototype of the demonstrated antenna is fabricated according to the aforementioned design result, as shown in Figure 2.

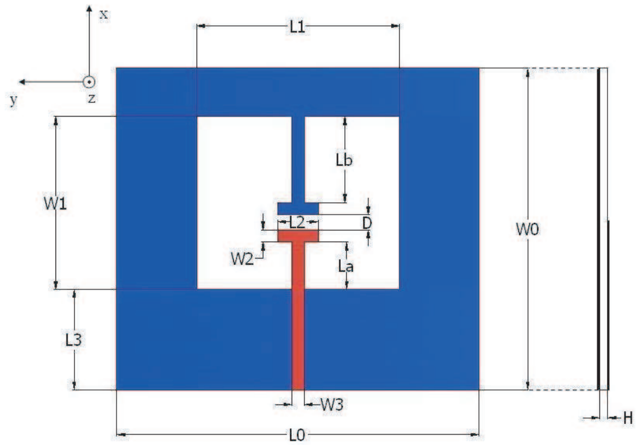


Figure 1. Geometry of the proposed antenna.

Table 1. Optimum parameters of the proposed antenna.

Antenna parameters	Value/mm	Antenna parameters	Value/mm
L_0	45	W_0	40
L_1	25.2	W_1	21.5
L_2	5	W_2	1.5
L_3	12.5	W_3	1.5
L_a	5.9	D	1.9
L_b	10.7	R	0.55
H	1		

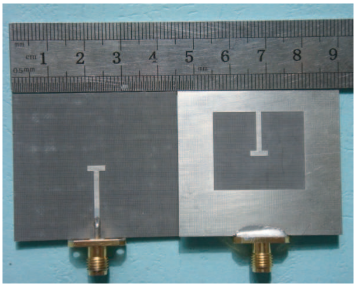


Figure 2. Prototype of the proposed antenna.

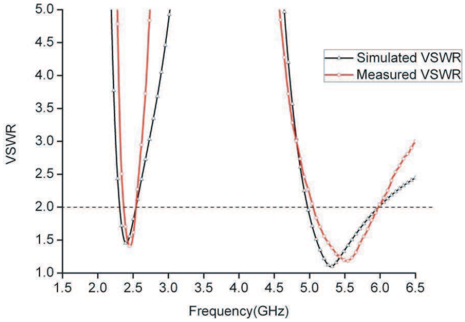


Figure 3. Simulated and measured VSWR of the proposed antenna with parameters $R = 0.55$ and $D = 1.9$ mm.

3. RESULTS AND DISCUSSION

The prototype of the demonstrated antenna has been constructed and experimentally studied. With the help of the HFSS and WILTRON37269A vector network analyzer, the simulated and measured Voltage Standing Wave Ratio (VSWR) curves are shown in Figure 3. From the measured curve, it can be observed that the lower frequency band for VSWR < 2 ranges from 2.36 to 2.54 GHz with the center frequency at 2.46 GHz, which meets the bandwidth requirement for 2.4 GHz WLAN operation. And the higher frequency band extends from 5.05 to 5.97 GHz with the center frequency at 5.53 GHz, which covers both 5.2 and 5.8 GHz WLAN operating bands. It is obvious that the measured VSWR curve matches with the simulated one.

Figures 4 and 5 show the VSWR curves for the proposed antenna with various parameters on the top T-shaped monopole and bottom embedded self-similar strips. As indicated in Figure 4, for $D = 1.9$ mm, with the increase of R, the two resonant frequency bands move closer, the lower frequency band increases while the higher one decreases. In order to cover both lower 2.4 GHz and higher 5.2/5.8 GHz operating bands, the optimized value for R is fixed at 0.55. Clearly in Figure 5, D also has a great effect on the impedance match of the lower resonant band and the mutual coupling of the top and bottom strips. For R is fixed at 0.55, the lower frequency band increases while the higher one is less affected when D is increased. And when D becomes larger or smaller, the mutual coupling of the top and bottom strips will be correspondingly weaker or stronger. It can be found for $D = 1.9$ mm, good impedance match can be obtained for both lower and higher frequency bands.

The radiation characteristics of the proposed antenna are also investigated. The measured radiation far-field patterns for the antenna at 2.4, 5.2 and 5.8 GHz are shown in Figure 6. The measured results indicate that within the lower operating band the radiation patterns

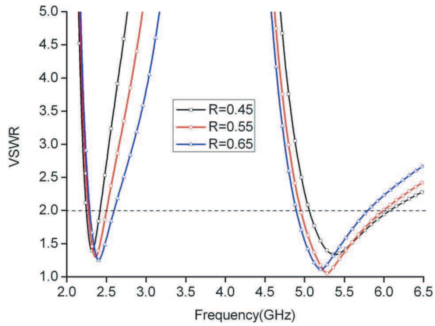


Figure 4. Simulated VSWR for different values of R ($D = 1.9$ mm).

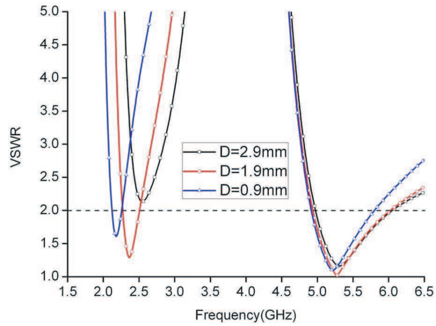
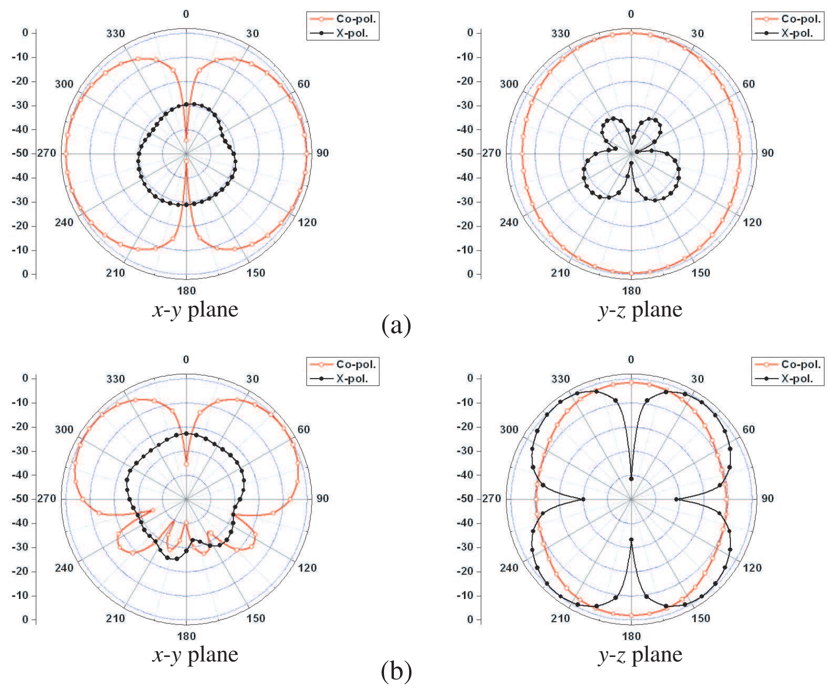
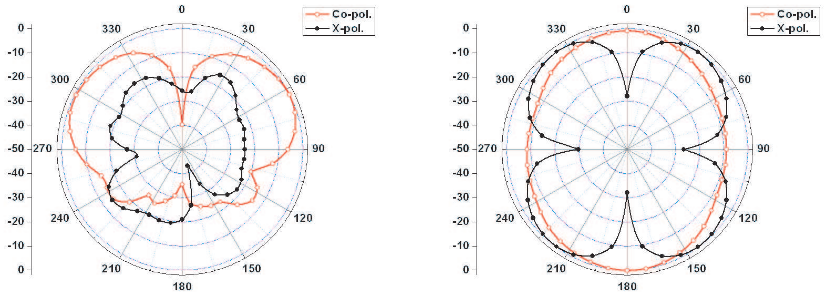


Figure 5. Simulated VSWR for different values of D ($R = 0.55$).





x-y plane (c) *y-z* plane

Figure 6. Measured radiation far-field patterns for the proposed antenna operating at (a) 2.4 GHz, (b) 5.2 GHz and (c) 5.8 GHz.

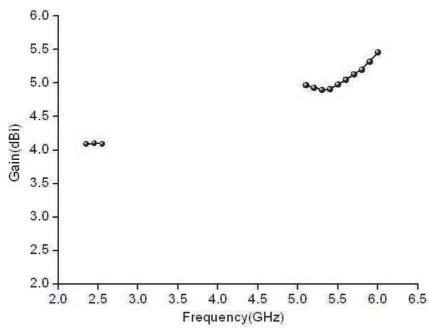


Figure 7. Measured peak gains of the proposed antenna.

are almost omni-directional in the azimuthal plane. And because of the nonnegligible y-directed current components on the ground plane at 5.2 and 5.8 GHz, cross-polarization components in the y-z plane may be almost equal to or a bit higher than the copolarization components. The measured peak gains of the proposed antenna are about 4.1 dBi at 2.35–2.55 GHz with less than 0.5 dBi gain variation and range from 4.9 to 5.5 dBi at 5.1–5.9 GHz with less than 1 dBi gain variation.

4. CONCLUSION

A novel rectangular slot antenna with embedded self-similar strips has been presented and experimentally studied. With the use of self-similar strips, the antenna generates two resonant modes to achieve both 2.4

and 5.2/5.8 GHz WLAN application bands. By tuning the parameters on the top T-shaped monopole and bottom self-similar strips, lower and higher frequency bandwidths can reach about 180 and 920 MHz respectively from measured results. This antenna design is small in size and simple in structure. Therefore, it is in low-cost and easy to fabricate and integrate. Simulated and experimental results indicate that the proposed antenna not only is suitable for 2.4/5.2/5.8 GHz WLAN, but also can be applied to 2.45/5.8 GHz Radio Frequency Identification (RFID) communication systems.

REFERENCES

1. Wu, Y.-J., B.-H. Sun, J.-F. Li, and Q.-Z. Liu, "Triple-band omni-directional antenna for WLAN application," *Progress In Electromagnetics Research*, Vol. 76, 477–484, 2007.
2. Augustin, G., S. V. Shynu, P. Mohanan, C. K. Aanandan, and K. Vasudevan, "Compact dual-band antenna for wireless access point," *Electronics Letters*, Vol. 42, No. 9, April 27, 2006.
3. Sun, S.-Y., S.-Y. Huang, and J.-S. Sun, "A printed multiband antenna for cellphone applications," *Microwave Optical Technology Letters*, Vol. 51, 742–744, 2009.
4. Jolani, F., A. M. Dadgarpour, and H. R. Hassani, "Compact M-slot folded patch antenna for WLAN," *Progress In Electromagnetics Research Letters*, Vol. 3, 35–42, 2008.
5. Eldek, A. A., A. Z. Elsherbeni, and C. E. Smith, "Square slot antenna for dual wideband wireless communication systems," *Journal of Electromagnetic Waves and Applications*, Vol. 19, No. 12, 1571–1581, 2005.
6. Sze, J.-Y. and W.-S. Chang, "Dual-band square slot antenna with embedded crossed strips for wireless local area network applications," *Microwave Optical Technology Letters*, Vol. 51, 435–439, 2009.
7. Wu, J.-W., "2.4/5 GHz Dual band triangular slot antenna with compact operation," *Microwave Optical Technology Letters*, Vol. 45, 81–84, 2005.
8. Liang, X.-L., S.-S. Zhong, and C.-H. Li, "T-shaped slot antenna for 2.4/5.2 GHz WLAN operation," *Microwave Optical Technology Letters*, Vol. 48, 2156–2158, 2006.
9. Archevapanich, T., J. Nakasuwan, N. Songthanapitak, N. Ansntrasirichai, and T. Wakabayashi, "E-shaped slot antenna for WLAN applications," *PIERS Online*, Vol. 3, No. 7, 1119–1123, 2007.

10. Ren, W., "Compact dual-band slot antenna for 2.4/5 GHz WLAN applications," *Progress In Electromagnetics Research B*, Vol. 8, 319–327, 2008.
11. Gai, S., Y.-C. Jiao, Y.-B. Yang, C.-Y. Li, and J.-G. Gong, "Design of a novel microstrip-fed dual-band slot antenna for WLAN applcations," *Progress In Electromagnetics Research Letters*, Vol. 13, 75–81, 2010.
12. Behera, S. and K. J. Vinoy, "Microstrip square ring antenna antenna for dualband operation," *Progress In Electromagnetics Research*, Vol. 93, 41–56, 2009.
13. Wu, J.-W., H.-M. Hsiao, J.-H. Lu, and S.-H. Chang, "Dual broadband design of rectangular slot antenna for 2.4 and 5 GHz wireless communication," *Electronics Letters*, Vol. 40, No. 23, Nov. 11, 2004.
14. Yoon, J. H., G. H. Han, D. H. Kim, J. C. Lee, S. M. Woo, and H. H. Kim, "Design of triangular slot antenna for tri-band (2.4/5.2/5.8 GHz) antenna with fork-like tuning stub," *Microwave Optical Technology Letters*, Vol. 49, 1561–1565, 2007.