Cpw-fed slot antenna for mimo system applications

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Abstract

A compact CPW-fed slot antenna is proposed for wireless local area networks (WLAN) applications in IEEE 802.11b/g/a systems. The measured results of the fabricated antenna show that the impedance bandwidths are 600 MHz from 2.1 to 2.7 GHz and 1500 MHz from 4.8 to 6.3 GHz, which cover all the desired operating bands. A multi-feed 4-element planar array was designed and simulated. It shows that the features of small size, uniplanar structure, good radiation characteristics, and small mutual coupling are promising for multi-input multi-output (MIMO) applications.

Keywords: slot antenna; dual-band operation; CPW-fed; WLAN; MIMO

1. Introduction

Wireless communications, especially the wireless local area network (WLAN) communication, have evolved at astonishing rate during the last decade. Among these standards, IEEE 802.11 b/g requires a band of 2.4 -2.484 GHz; IEEE 802.11a, a band of 5.15-5.35 GHz and an additional band of 5.725-5.825 GHz. Therefore, design of broad dual and multi-band antennas with low-profile, lightweight, flush mounted and single-feed to fit the limited equipment space of the WLAN device has gained increasing demands. Compared to most stripline-fed or probe-fed WLAN antennas such as the planar inverted-F antennas , the chip antennas , and the planar slot monopole antennas , the coplanar waveguide (CPW)-fed antennas are popular for many communication applications because of being compatible with the monolithic microwave integrated circuits (MMIC) and they own relatively much wider bandwidth than the conventional microstrip ones . A CPW-fed antenna not only performs better with respect to bandwidth and radiation pattern, but is also easily manufactured, which has made its importance increased.

Dual-band operations have become very important in wireless local-area network (WLAN) applications. In order to respond to the rapidly growing demands, an antenna should be operational in many frequency bands (Zhang et al., 2009; Lin and Chi ,2005; Ren, 2008). Therefore, the antennas with multi-frequency operation capabilities, compact size, low cost, and high efficiency have become a significant point in recent years (Zhu et al., 2010; Guo et al., 2011; Hu et al., 2011). As a good candidate, microstrip antennas have the attractive features of compactness, lightweight, low profile and conformability to any structure. For the specific application, there are some methods used in microstrip antennas in order to achieve multiband operation. In (Guo et al., 2011), the antenna can generate dual-band to cover WLAN by folding the arms. In (Deepu et al., 2007), the designs of multiple branches can provide a dual-band operation. Some monopole antennas with slot loading, such as circular ring slot (Ren, 2008), square slot (Hu et al., 2011), annular-ring slot (Chen, 2005) and rectangular slot (Chen et al., 2008), are reported, providing multi-resonant modes. However, most of these presented dual-band antenna designs have drawbacks of complex structure and large size for practical applications.

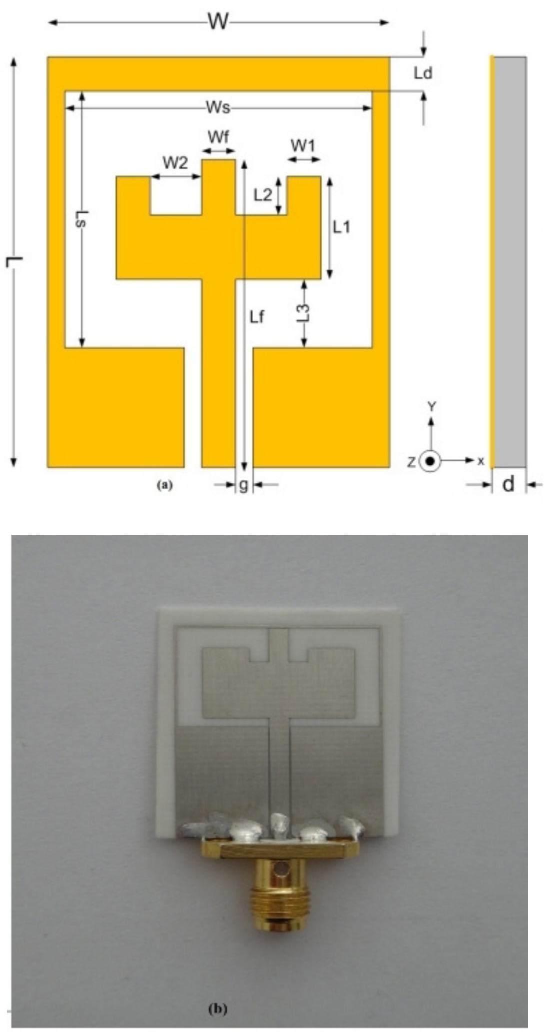
A multi-input multi-output (MIMO) communication system has been one of the most promising technologies, well suited for high data rate communication. A MIMO system utilizing several antenna components is more advantageous than single-input single-output (SISO) in an aspect of increasing channel capacity and reducing transmitting power. However, these approached utilize spatial diversity of spaced out antenna elements, and the volume of antennas occupy is usually large because of the complexity of physical structure as well as the diversity requirement. Consequently, the issue of a size reduction has become a more crucial factor in communications systems. Printed antennas feed by coplanar waveguide have attracted attention for many years. When compared with other printed radiating elements, CPW-fed antennas take advantages for not only a broad bandwidth, but also a smaller mutual coupling between adjacent lines and easier integration capability with solid-state active devices (Naser-Moghadasi et al.,2010; Yoon , 2006) .Therefore CPW-fed antennas are good options as elements for MIMO applications.

In this paper, we propose a CPW-fed slot antenna with simple structure and compact size. These antennas can be tuned to cover the 2.4/5 GHz WLAN bands. A multi feed 4-element planar antenna array with the same size is placed on a 73mm × 77mm substrate whose thickness is 0.5 mm and dielectric constant is 3.38. The simulated mutual coupling between adjacent elements is small and the return loss of each element in array is in good agreement with that of the single antenna element. The numerical simulations for this class of antennas are performed using Ansoft HFSS (high frequency structure simulator) software package, which is based on the finite element method. Section 2 brings out the antenna geometry useful for designing an optimized antenna. Simulation and measurement results are given in Section 3, and Section 4 concludes this paper work.

2. Antenna geometry and parametric study

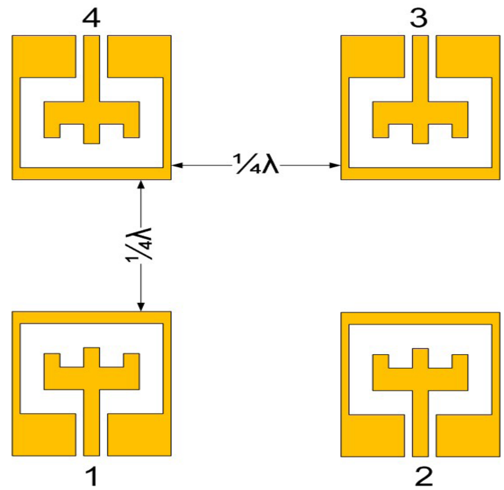
The geometry and parameters of proposed antenna are illustrated in Fig.1 (a). The antenna is etched on Rogers RO4003 substrate with a thickness of d=20 mil (0.5 mm) and dielectric constant of 3.38. The size of the ground plane is W=21 mm × L=23 mm. The slot has a width, Ws=20.5 mm and length, Ls=10.8 mm. The antenna is excited by a 50 Ω microstrip line with fork-shaped tuning stub. The width of the 50 Ω microstrip line is Wf=2 mm, and the gap of the CPW line is g=0.12 mm.The fork-shaped tuning stub is located at the center of the slot. Detail dimensions and location of the fork-shaped tuning stubs are Lf=22.7 mm, Ld=0.2 mm, L1=7.5 mm, L2=1.5 mm, L3=1 mm, W1=4.7 mm and W2=2 mm.The photograph of the fabricated antenna is shown in Fig.1 (b).

Fig.1. *(a) Geometry and (b) photograph of proposed antenna*



The geometry of multi-feed 4-element planar antenna array is shown in Fig.2, the size of array is 73 mm × 77 mm, is placed on a substrate whose thickness is 20 mil (0.5 mm) and dielectric constant is 3.38, the distances between the adjacent elements are 31mm, is smaller than quarter wavelength. These antenna elements are arrayed with quarter wavelength interval in both horizontal and vertical directions, respectively. The 4-element array designed for MIMO communication system with a compact size and low mutual coupling.

Fig.2. *Geometry of multi-feed 4-element planar antenna array.*



These dimensions are obtained after performing and optimization. In order to provide design criteria for this antenna, the effects of each geometrical parameter are analyzed. The antenna dimensions W1 and L2 are initially set at 4.7 and 1.5 mm, respectively, and then one parameter is changed at a time while the others are kept constant. Fig. 3 and Fig. 4 show the effect of changing W1 and L2, respectively. As W1 and L2 are increased, second resonant frequency moves towards lower frequencies and cannot cover 5.8 GHz. By reducing W1, on the other hand, second resonant frequency moves towards upper frequencies and could not cover 5.2 GHz.

Fig.3. *The effect on return loss due to the change of W1*

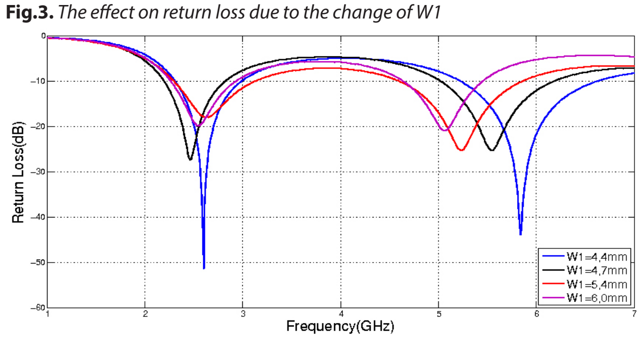
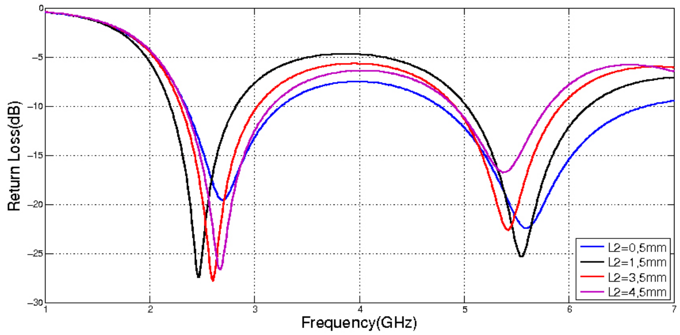


Fig.4. *The effect on return loss due to the change of L2*



3. Simulation and measurement results

The antenna performance was investigated by simulation via High Frequency Structure Simulator Software. Fig.5 shows the measured and simulated return losses of the proposed antenna. The obtained -10 dB return loss are 600 MHz (2.1-2.7GHz) and 1500 MHz (4.8-6.3GHz), corresponding to an impedance bandwidth of 25% and 27% with respect to the appropriate resonant frequencies. Obviously, the achieved bandwidths can cover the WLAN standards in the 2.4 GHz (2.4-2.484 GHz), 5.2 GHz (5.15-5.35 GHz) and 5.8GHz (5.725-5.825 GHz) bands. Fig. 6 to Fig. 8 show the measured and simulated E- and H-plane radiation pattern at 2.45, 5.2, and 5.8 GHZ for E and H plane pattern including both copolarization and crosspolarization.

Fig.5. *Simulated and measured return loss of the proposed antenna*

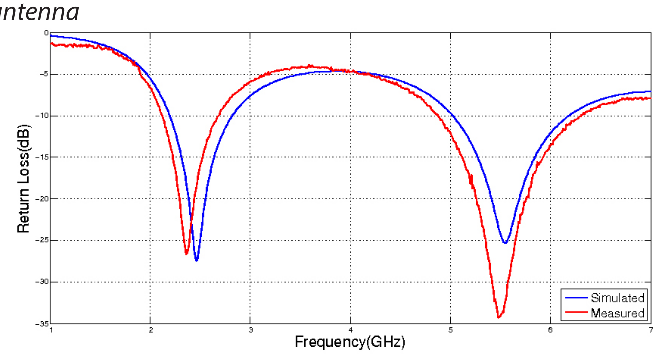


Fig.6. *Simulated and measured radiation patterns of proposed antenna at 2.45 GHz*

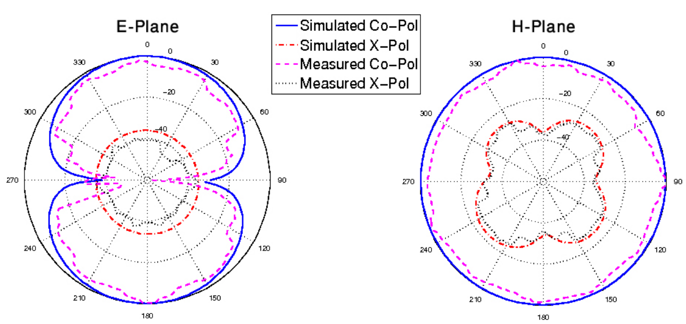


Fig.7. *Simulated and measured radiation patterns of proposed antenna at 5.2 GHz*

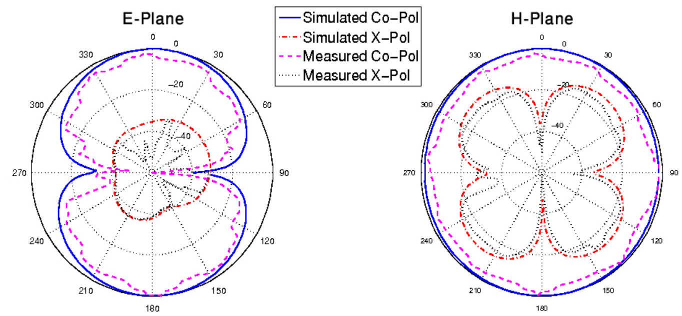


Fig.8. *Simulated and measured radiation patterns of proposed antenna at 5.8 GHz*

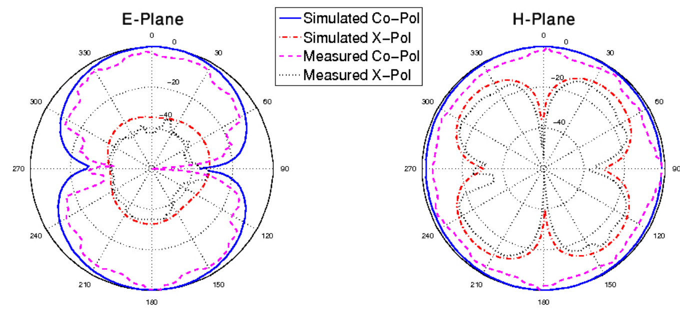
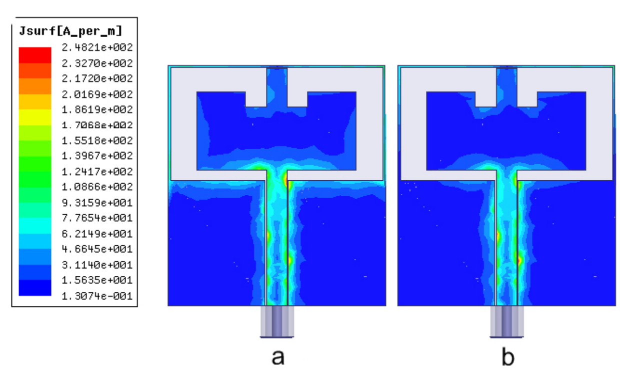


Fig .9 shows the simulated current distributions on the antenna surface at 2.45,5.2,and 5.8GHz.The simulated mutual coupling results of the 4-element planar antenna array system (2 ×2) are shown in Fig. 10. The mutual coupling is relatively weak. The mutual coupling is quite low (Sij<-32dB) in Fig. 10 as expected decreases rapidly with distance. The low coupling between the elements in the array is because of the small size of the antenna elements, which increase the distance between them. In addition, the CPW-fed antenna is inherent in low coupling between adjacent elements. Fig .11 provides antenna gain (Θ=0, Φ=0) for operating frequencies across the two bands. The simulated average gains are 1.33dB (1.08-1.49dB) and 2.36dB (2.02-2.62dB), respectively, within the bandwidths of 2.4 and 5 GHz operating bands.

Fig.9. *Surface current distributions at (a) 2.4 GHz, (b) 5.2 GHz and (c) 5.8 GHz*



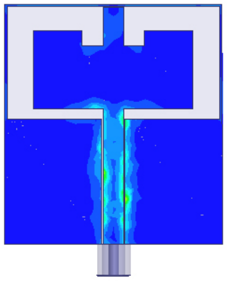


Figure 9 continued..

Fig.10. *Simulated mutual coupling between the adjacent elements in multi-feed 4-element array*

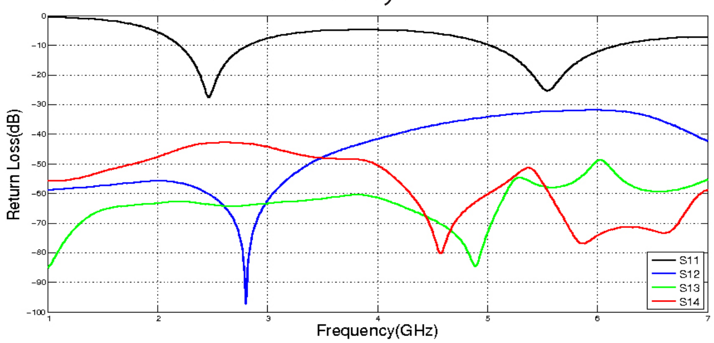
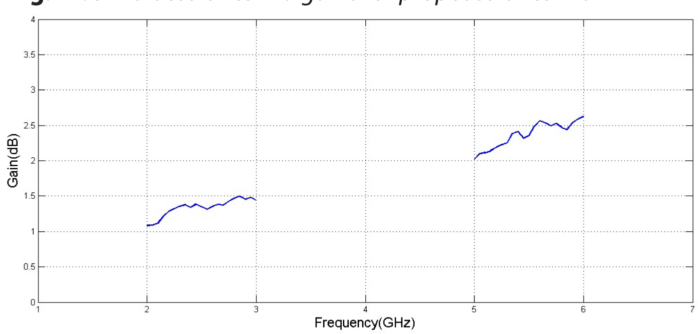


Fig.11. *Simulated antenna gains for proposed antenna*



4. Conclusion

A CPW-fed rectangular slot antenna has been proposed for the 2.4/5 GHz dual-band WLAN operations. The two operating frequencies of the presented antenna have the same polarization planes and similar radiation characteristics. The antenna has characteristics of compact size, a simple structure, good omnidirectionality, and the multi-feed 4-element planar antenna array formed with the compact CPW-fed antennas also has satisfied input return loss bandwidth and good radiation patterns. Therefore, the proposed antenna has provided a new design guideline for the efficient placement of multiple antennas in a small space and the applicability of the dual-band antenna to the MIMO antenna system.

5. References

1. Zhang, J., X.-M. Zhang, J.-S. Liu, Q.-F. Wu, T. Ying, and H. Jin (2009) Dual-band bidirectional high gain antenna for WLAN 2.4/5.8 GHz applications. *Electron Letters*.Vol. 45,pp:6-7.
2. Lin, Y.-D. and P.-L. Chi (2005) Tapered bent folded monopole for dual-band wireless local area network (WLAN) systems. *IEEE Antennas and Wireless Propagation Letters*. Vol. 4, pp: 355-357.
3. Ren, W. (2008) Compact dual-band slot antenna for 2.4/5 GHz WLAN applications. *Progress In Electromagnetics Research B*. Vol. 8,pp: 319-327.
4. Zhu, J., M. A. Antoniades, and G. V. Eleftheriades (2010) A compact triband monopole antenna with single-cell metamaterial loading.*IEEE Transactions on Antennas and Propagation*. Vol. 58, No. 4, pp:1031-1038.
5. Guo, Y. Y., X. M. Zhang, G. L. Ning, D. Zhao, X. W. Dai, and Q. Wu (2011) Miniaturized modified dipoles antenna for WLAN applications. *Progress In Electromagnetics Research Letters*.Vol. 24, pp: 139-147.
6. Hu, W., Y.-Z. Yin, P. Fei, and X. Yang (2011) Compact triband square-slot antenna with symmetrical L-strips for WLAN/WiMAX applications. *IEEE Antennas Wireless Propagation Letters*.Vol. 10, pp: 462-465.
7. Deepu, V., R. K. Raj, M. Joseph, M. N. Suma, and P. Mohanan (2007) Compact asymmetric coplanar strip fed monopole antenna for multiband applications. *IEEE Transactions on Antennas and Propagation*. Vol. 55, No. 8, pp: 2351-2357.
8. Chen, J. S. (2005) Dual-frequency annular-ring slot antennas fed by CPW feed and microstrip line feed. *IEEE Transactions on Antennas and Propagation*.Vol. 53, No. 1, pp: 569-571.
9. Chen, S.-Y., Y.-C. Chen, and P. Hsu (2008) CPW-fed aperture-coupled slot dipole antenna for triband operation. *IEEE Antennas and Wireless Propagation Letters*.Vol. 7, pp: 535-537.
10. M. Naser-Moghadasi, R. Sadeghi Fakhr and A. Danideh (2010) CPW-fed compact slot antenna for WLAN operation in a laptop computer .*Microwave and Optical Technology Letters*.Vol. 52, No. 6, pp: 1280-1282.
11. Yoon, J.H. (2006) Fabrication and measurement of rectangular ring with open ended CPW-fed monopole antenna for 2.4/5.2-GHz WLAN operation. *Microwave and Optical Technology Letters*.Vol.48,pp: 1480-1483.