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COMPACT CPW-FED SQUARE SLOT ANTENNA FOR DUAL-BAND OPERATION

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Abstract—A novel compact square slot antenna design with coplanar waveguide (CPW)-fed for dual-band operation is presented. The proposed antenna is simply composed of a square slot resonator and a monopole radiator. By employing the special square slot structure, the antenna can achieve a new resonance while maintaining a small size. Based on this concept, a prototype of dual-band antenna is designed, fabricated and tested. The experimental results show the antenna has the impedance bandwidths of 400 MHz (2.33–2.73 GHz) and 1020 MHz (3.27–4.29 GHz), covering both WiMAX in the 2.5/3.5 GHz bands and WLAN in the 2.4 GHz band.

1. INTRODUCTION

With the explosive growth of worldwide interoperability for microwave access (WiMAX) and wireless local area network (WLAN), the demand for dual- or multi-band antenna is apparent as modern portable wireless communication devices need to integrate several communication standards into a single system. Many antenna designs for these applications have been reported [1–7]. Most of these antennas can satisfy either the WLAN standard [1–5] or the WiMAX standard [6, 7]. Various types of antennas have been proposed in the recent literatures [8–17] to achieve dual- or multi-band operation. The modified multi-branched monopoles, which have different configurations-Y shape [8], S shape [9], T shape [10] and G shape [11], are often adopted to realize dual-band operation because of their easy implementation. These antennas have the advantages of simple structure, wide bandwidth and regular omnidirectional radiation patterns. However, their sizes are too large for the limited

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space of portable wireless device. In recent years, many slot antenna structures [12–17] are proposed for dual- or multi-band applications, such as elliptic slot [12], annular slot [13], cross slot [14], triangular slot [15] and meander slot [16, 17]. Among these, the special slot designs in [15–17] can reduce antenna size effectively. In [14], a triangular slot loaded patch antenna is excited by the strip monopole. And the different kinds of slot are applied to generate two resonance modes in the designs of multiple meandering slots antenna [15, 16]. They are much smaller than the modified multi-branched monopoles. However, the structures are much more complex.

In this paper, a novel square slot antenna with CPW-fed is presented, which has not only good dual-band operation performance, but also simple structure and compact size. The proposed antenna consists of a special square slot resonator and a monopole radiator. The square slot etched on the ground, embedded with a tuning stub, can yield a new resonance mode. By adjusting the lengths of the square slot and tuning stub, the resonant frequency can be tuned independently and good impedance match can be obtained. All of these show that the antenna is suitable for both WiMAX and WLAN applications. The measured results are in good agreement with the simulated results. Details of the antenna design and experimental results analysis are demonstrated in the paper.

2. ANTENNA DESIGN

Figure 1 depicts the geometry of the proposed dual-band antenna. It is composed of a square slot resonator with a tuning stub and a monopole

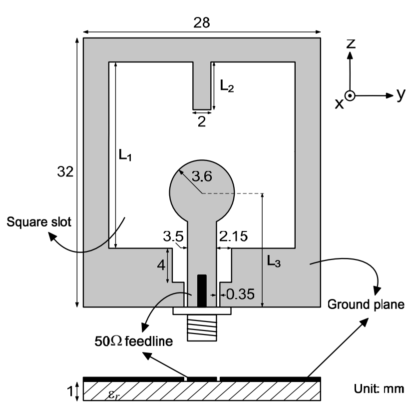


Figure 1. Geometry of the proposed antenna.

radiator, which are etched on an FR4 substrate with a thickness of 1 mm and a relative permittivity of 4.4. This antenna has a small overall size of $28 \times 32\,\text{mm}^2$. A square slot resonator is formed by extending a ring form the ground. The inner length of the square slot is L_1. In the slot is embedded a tuning stub with 2 mm width and length L_2. They can independently yield a resonance mode, covering both WLAN in the 2.4 GHz band and WiMAX in 2.5 GHz band. A monopole radiator is fed by a 50 Ω CPW line, the end of which is joined to a circular patch with radius 3.6 mm. The step shape gap of the CPW line plays an important role in improving the antenna's impedance match. This simple design can obtain a wide frequency band ranging from 3.27–4.29 GHz, which covers the 3.5 GHz WiMAX standard applications.

3. PARAMETRIC STUDY

In our design, the lower band (2.33–2.73 GHz) and upper band (3.27–4.29 GHz) are obtained by applied of the square slot resonator and the monopole radiator, respectively. Through adjusting the lengths of these structures, a parametric study is made to illustrate the functions of the different parts of the proposed antenna. During the design process, an electromagnetic (EM) solver Ansoft HFSS based on the finite element method (FEM) is employed to perform the analysis. The final optimized parameters of the proposed antenna are listed in Table 1.

Table 1. Optimal parameters of proposed antenna.

Parameters	L_1	L_2	L_3
Physical size (mm)	22.5	4.2	14.6

3.1. The Length of One Side of the Square Slot

The return loss characteristics of this antenna for various L_1 are demonstrated in Figure 2. As the length of one side of the square slot (L_1) increases from 22 mm to 23 mm, the lower band of the antenna shifts down obviously while the resonance frequency of the upper band changes slightly. From the results shown in Figure 2, it is observed that the perimeter of the square slot has a strong effect on the lower frequency characteristics of the antenna. Therefore, it is shown that the 2.5 GHz resonance mode is achieved by the square slot and tuned by the length of its sides.

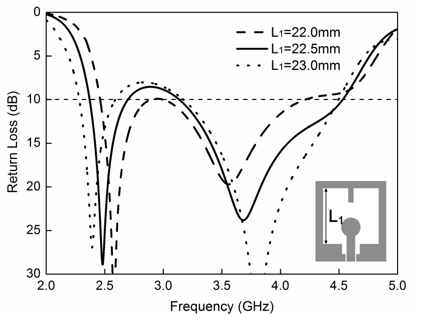


Figure 2. Simulated return losses of the proposed antenna for various L_1.

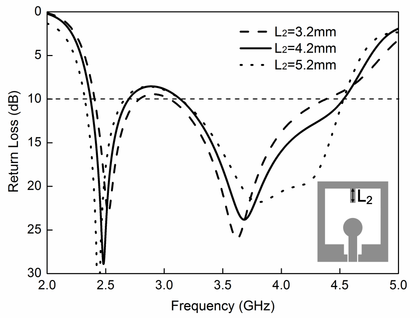


Figure 3. Simulated return losses of the proposed antenna for various L_2.

3.2. The Length of the Tuning Stub

As shown in Figure 3, when the length of the tuning stub (L_2) is 3.2 mm, 4.2 mm and 5.2 mm, the return loss of the antenna at 2.5 GHz is 22.5 dB, 28 dB and more than 30 dB, respectively. Thus, the stub plays a crucial role in improving the antenna's impedance match at 2.5 GHz band. However, the return loss of the upper band also moves up slightly while the length L_2 changes from 3.2 mm to 5.2 mm. Therefore, when L_2 is fixed at the optimized value 4.2 mm, the antenna achieves a good return loss at both the 2.5 GHz and 3.5 GHz band. As mentioned above, by properly adjusting the length of the stub embedded in the square slot (L_2), the proposed antenna can obtain a good impedance match at the 2.5 GHz band.

3.3. The Length of the Monopole Radiator

From the discussion in Section 3.1 and 3.2, it is found that the special square slot, embedded with a tuning stub, can yield a lower resonance as well as a good impedance match. Figure 4 shows the effect of the length of the monopole radiator on the resonant frequency of the proposed antenna at the 3.5 GHz band. Therefore, by tuning the monopole length L_3, it is found that the upper resonance can be adjusted flexibly with little effect on the response in lower bands.

4. EXPERIMENTAL RESULTS

The dual-band square slot antenna proposed in the paper is fabricated with the optimized parameters given previously. The measured and

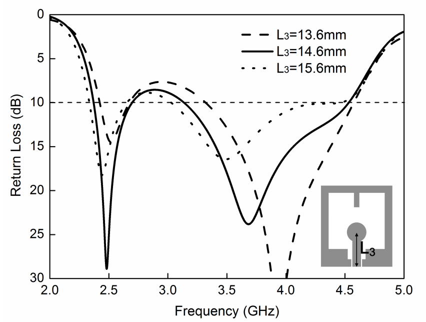


Figure 4. Simulated return losses of the proposed antenna for various L_3.

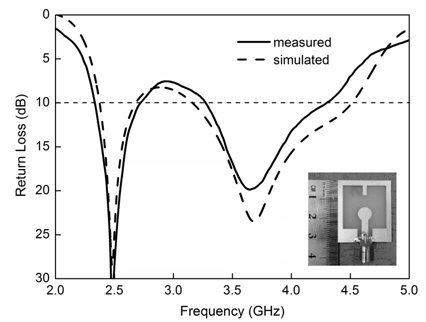
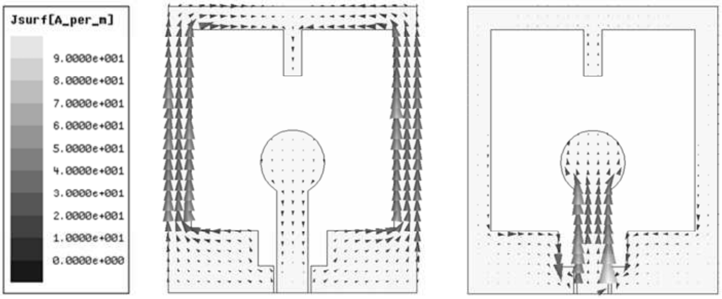


Figure 5. Measured and simulated return losses of the proposed antenna.

simulated return losses against frequency for this antenna are presented in Figure 5. As can be seen, the measured and simulated results show reasonable agreement in two desired bands. The square slot resonator provides a lower resonance and the impedance bandwidth with the criterion of return loss less than 10 dB reaches about 400 MHz from 2.33 to 2.73 GHz, which is sufficient for the standards of WiMAX and WLAN in the lower frequency band. Besides, the simple monopole radiator can achieve a wide upper band from 4.29 to 3.27 GHz with the return loss below 10 dB, covering WiMAX in the 3.5 GHz band.

In order to further study the electromagnetic mechanism of the proposed antenna for dual-band operation, surface current distributions of the whole antenna at the frequencies of 2.5 GHz and 3.5 GHz are given in Figure 6. It can be clearly seen from the figure that the current distributions are different in the two bands. When the antenna operates at 2.5 GHz, most of the surface currents are concentrated along the square slot as shown in Figure 6(a). This indicates that the square slot acts as a resonator to generate the lower resonance mode. Figure 6(b) shows the simulated current distributions at 3.5 GHz. As expected, the strong resonant currents flow along the monopole to yield the upper resonance mode. Due to resonance characteristic of the monopole, this simple design can obtain a wide frequency band, covering the 3.5 GHz WiMAX applications.

The measured radiation patterns in x-z plane (E-plane) and x-y plane (H-plane) at 2.5 GHz and 3.5 GHz are shown in Figure 7. The proposed antenna features a stable omnidirectional H-plane pattern and a bidirectional E-plane pattern over the desired operating bands. Figure 8 shows the peak gains in the 2.5/3.5 GHz bands. The obtained average gains are about 2.4 dBi for the lower band and 2.7 dBi for the



(a) (b)

Figure 6. Surface current distributions of proposed antenna at (a) 2.5 GHz, (b) 3.5 GHz.

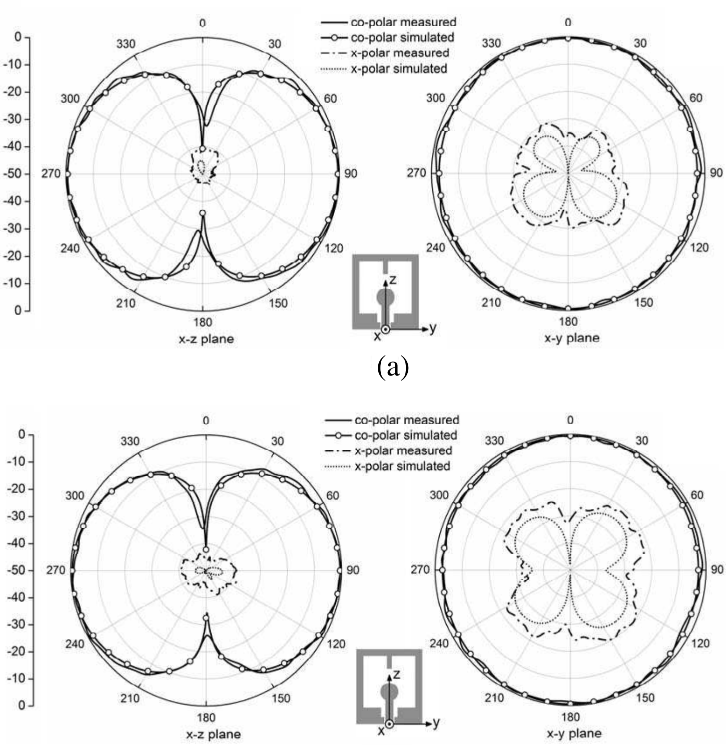


Figure 7. Measured and simulated radiation patterns of the proposed antenna at (a) 2.5 GHz, (b) 3.5 GHz.

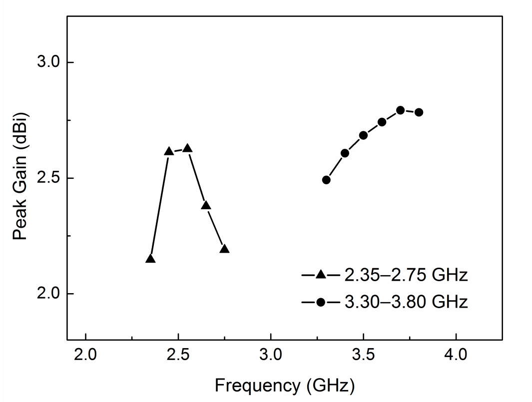


Figure 8. Peak antenna gains for the proposed antenna.

upper band. All of these project the use of the antenna in portable device applications.

5. CONCLUSION

A compact printed slot antenna for dual-band operation is proposed. A simple square slot, embedded with a tuning stub, is presented to achieve a new resonance mode as well as a reduced antenna size. An antenna prototype is then designed, fabricated and measured. The measured results show reasonable agreement with simulated results, validating our design concept. The proposed antenna has the advantages of compact size, simple structure and easy design, showing good dual-band operating bandwidths and stable radiation patterns. Consequently, the proposed antenna is expected to be a good candidate as a modern portable wireless device antenna for WiMAX/WLAN applications.

REFERENCES

1. Zhao, K., S. Zhang, and S.-L. He, "Closely-located MIMO antennas of tri-band for WLAN mobile terminal applications," *Journal of Electromagnetic Waves and Applications*, Vol. 24, No. 2–3, 363–371, 2010.
2. Liu, W.-C., P.-W. Chen, and C.-C. Liu, "Triple-band planar monopole antenna for DMB/WLAN applications," *Journal of Electromagnetic Waves and Applications*, Vol. 24, No. 5–6, 653–661, 2010.

3. Jaw, J.-L., F.-S. Chen, and D.-F. Chen, "Compact dualband CPW-fed slotted patch antenna for 2.4/5 GHz WLAN operation," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 14–15, 1947–1955, 2009.
4. Zhang, T.-L., Z.-H. Yan, L. Chen, and Y. Song, "A compact dual-band CPW-fed planar monopole antenna for WLAN applications," *Journal of Electromagnetic Waves and Applications*, Vol. 22, No. 14–15, 2097–2104, 2008.
5. Shams, K. M. Z., M. Ali, and H. S. Hwang, "A planar inductively coupled bow-tie slot antenna for WLAN application," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 7, 861–871, 2006.
6. Chang, T.-N., G.-Y. Shen, and J.-M. Lin, "CPW-fed antenna covering WiMAX 2.5/3.5/5.7 GHz bands," *Journal of Electromagnetic Waves and Applications*, Vol. 24, No. 2–3, 189–197, 2010.
7. Chen, W.-S. and Y.-H. Yu, "Dual-band printed dipole antenna with parasitic element for WiMAX applications," *Electronics Letters*, Vol. 44, No. 23, 1338–1339, November 2008.
8. 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.
9. Liu, W. C., "Optimal design of dualband CPW-fed G-shaped monopole antenna for WLAN application," *Progress In Electromagnetics Research*, Vol. 74, 21–38, 2007.
10. Liu, W. C., W. R. Chen, and C. M. Wu, "Printed double S-shaped monopole antenna for wideband and multiband operation of wireless communication," *IEE Proceedings — Microwaves, Antennas and Propagation*, Vol. 151, 473–476, 2004.
11. 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.
12. Liu, W.-C. and C.-F. Hsu, "Dual-band CPW-fed Y-shaped monopole antenna for PCS/WLAN application," *Electronics Letters*, Vol. 41, No. 7, 2005.
13. Bao, X. L. and M. J. Ammann, "Microstrip-fed dual-frequency annular-slot antenna loaded by split-ring-slot," *IET Microwaves, Antennas & Propagation*, Vol. 3, 757–764, 2009.
14. Wu, C.-M., "Dual-band CPW-fed cross-slot monopole antenna for

WLAN operation," *IET Microwaves, Antennas & Propagation*, Vol. 1, 542–546, 2007.

15. 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, 2006.
16. Hsieh, C., T. Chiu, and C. Lai, "Compact dual-band slot antenna at the corner of the ground plane," *IEEE Transactions on Antennas and Propagation*, Vol. 57, 3423–3426, 2009.
17. Liu, W.-C., C.-M. Wu, and N.-C. Chu, "A compact CPW-fed slotted patch antenna for dual-band operation," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 110–113, 2010.