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A COMPACT CPW-FED OMNI-DIRECTIONAL MONOPOLE ANTENNA FOR WLAN AND RFID APPLICATIONS

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Abstract—A compact dual-band CPW-fed triangle-shaped antenna is proposed for applications in 2.4/5 GHz WLAN and RFID. The designed antenna, including ground plane, is only 28 mm in height and 26 mm in width. By introducing a Π-shaped slot and a T-shaped strip, the proposed antenna can generate two separate impedance bandwidths. Prototypes of the proposed antenna have been constructed and tested. The measured impedance bandwidths, ranging from 2.36 GHz to 2.50 GHz and from 5.01 GHz to 6.33 GHz separately, are obtained with return loss less than −10.00 dB, which meet the required bandwidths specification of WLAN and RFID. Good omni-directional radiation and appropriate gain characteristics in the desired frequency bands have been achieved.

1. INTRODUCTION

In recent years, the technologies of wireless communication systems have been rapidly growing demands for greater capacities broadband service to support wireless devices. Antennas as one of the crucial components of these communication systems have been paid great attention to. In order to respond to the rapidly growing demands, an antenna should be operational in many frequency bands [1–5]. For wireless local-area network (WLAN) systems, the frequency bands of a WLAN antenna may cover 2.400–2.484 GHz (specified by IEEE 802.11b/g) and 5.150–5.350/5.725–5.825 GHz (specified by IEEE 802.11a). In addition, the center frequencies of radio frequency identification (RFID) are at 2.45 GHz and 5.8 GHz in the microwave

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frequency band. Therefore, the antennas with multi-frequency operation capabilities, compact size, low cost, and high efficiency have become a hot research point in recent years [6–8]. As a good candidate, Microstrip antennas have the attractive features of compactness, lightweight, low profile and conformability to any structure [9]. For the specific application, there are some methods used in microstrip antennas in order to achieve multiband operation. In [10, 11], the designs of multiple branches can provide a dual-band operation. In [7], the antenna can generate dual-band to cover WLAN by folding the arms. Some monopole antennas with slot loading, such as square ring slot [5], circular ring slot [5], square slot [8], annular-ring slot [12] and rectangular slot [13], are reported, providing multi-resonant modes.

In this paper, a novel coplanar waveguide (CPW)-fed monopole antenna with simple structure and compact size is presented. The proposed antenna consists of a modified inverted trapezoid strip and a matching CPW feed structure. The CPW-fed slot antenna has the advantages of uniplanar structure, wide bandwidth, and easy integration with RF front-end circuitry [13]. By properly introducing a Π-shaped slot and a T-shaped strip to the antenna, small size, dual-band operation, and good radiation performance suitable for the WLAN and RFID systems can be achieved. Compared with the antennas in [14–16], the proposed antenna doesn't require large grounds, so it has a much smaller size, which is practical for small communication terminals. The proposed antenna was simulated using Ansoft High Frequency Structure Simulator 12 (HFSS 12), and the prototype of the antenna was constructed and tested. Details of the antenna design are described, and both the simulated and measured results are presented and discussed.

2. ANTENNA DESIGN

The configuration of the proposed planar dual-band antenna is illustrated in Fig. 1. This antenna is printed on FR4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.6 mm, and fed by a CPW transmission line with a fixed metal strip thickness of 3.6 mm and a gap distance of 0.4 mm between the strip and the ground. Two finite ground planes with the same size of $10.3 \times 6.5\,\mathrm{mm}^2$ are situated symmetrically on each side of the CPW line. The dimensions of the designed antenna, including the substrate, is $28 \times 26\,\mathrm{mm}^2$, or about $0.22\lambda \times 0.21\lambda$ with respect to 2.4 GHz. The antenna is symmetrical with respect to the longitudinal direction, its main structure is an inverted trapezoid patch loaded with a T-shaped patch and a Π-shaped slot. The bottom of the trapezoid patch is connected to the

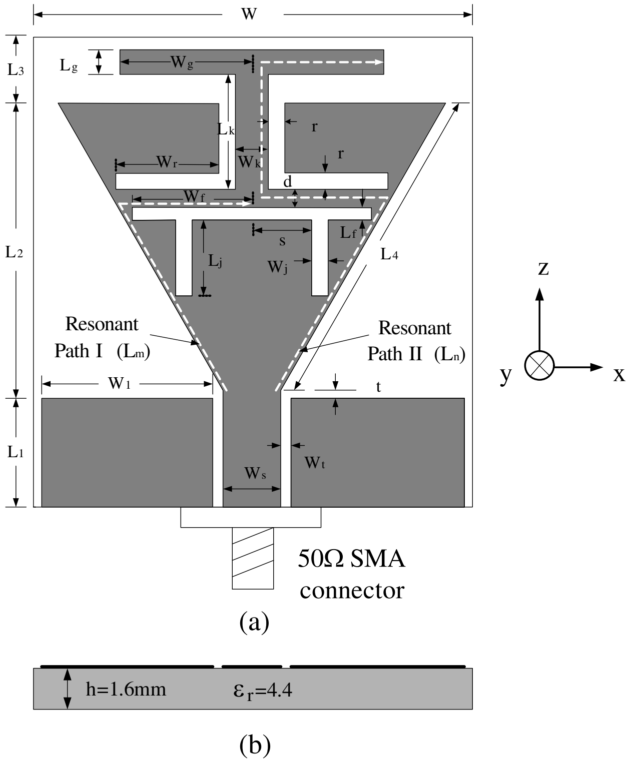


Figure 1. Configuration of the proposed antenna (in mm): (a) top view. (b) Side view.

end of the CPW line with a spacing of 0.5 mm from the edge of the ground plane. The resonant mode at 5 GHz band occurs as a result of the Π-shaped slot, which provides a resonant path (the resonant path I) has a length of about 19.2 mm (L_m) or about 0.33 wavelength relative to the frequency of 5.2 GHz. The T-shaped strip increases the current path of the resonant mode and reduces the required size of the proposed antenna for a fix operating frequency. The length of the second resonant path is $L_n = 36.9$ mm, which is 0.30 wavelength at the resonant frequency of 2.4 GHz. The flipped L-shaped slits on each side of the T-shaped patch can increase the current path of the resonant mode of the proposed antenna, which reduces the required size of the proposed antenna. The geometrical parameters of the proposed antennas are described in Table 1. The resonant frequency and the bandwidth of the operating frequency can be controlled by the length of W_f and W_g, the influence will be discussed in the following section.

Table 1. The design parameters of the proposed patch antenna.

Parameter	Value [mm]	Parameter	Value [mm]
W	26	L_g	1.5
W_1	10.3	W_j	1
L_1	6.5	L_j	4.5
L_2	17.5	W_k	2
L_3	4	L_k	7
L_4	19.5	W_r	6
W_s	3.6	r	1
W_t	0.4	d	1
W_f	7	s	3.5
L_f	0.8	t	0.5
W_g	7.9		

3. RESULTS AND DISCUSSION

Effects of some important structure parameters on impedance matching of the proposed antenna are investigated. Fig. 2 shows the return loss for successive value of the length W_f of the crossmember of the Π-shaped slot when the other parameters such as W_g (= 7.9,mm) remain constant. From the graph, it can be seen that when W_f increases from 6 mm to 7.5 mm, the upper resonant frequency moves towards left, which means that the upper resonant frequency decreases with the increase of the length W_f, while the bandwidths of the lower band change slightly. Hence the first resonant frequency (at 2.4 GHz) is almost independent of the variation of the parameter W_f, the upper band can be adjusted to achieve good impedance matching for the proposed antenna while the impact for the bandwidths of the lower band is little. Fig. 3 shows the return loss curves for different values for the length W_g of arm of T-shaped strip when the other parameters such as W_f (= 7 mm) are kept constant. It can be observed that the first resonant frequency moves towards left when W_g increases from 7 mm to 9 mm, which means the first resonant frequency decreases with the increase of the length W_g. This can be explained that the resonant path increases with the increase of the length W_g. On the other hand, the bandwidths of the 5 GHz band shift slightly. After properly optimizing the parameters, the length $W_f = 7$ mm and $W_g = 7.9$ mm are selected.

The fabricated prototype of the antenna with optimal geometrical parameters is shown in Fig. 4. The measured versus the simulated

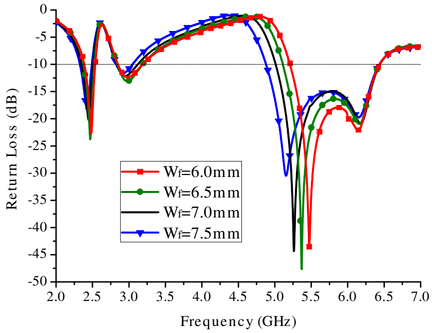


Figure 2. Simulated return loss varying with length W_f, W_g = 7.9 mm.

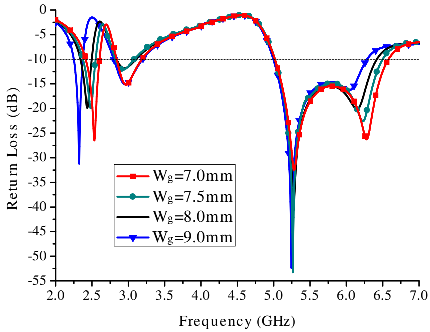


Figure 3. Simulated return loss varying with length W_g, W_f = 7 mm.

magnitude of reflection coefficient (S_{11}) (dB) from HFSS are shown in Fig. 5. The reflection coefficient measurement was performed by using Agilent N5230A Network Analyzer. From the graph, it is quite clear that there is a reasonably good agreement between the measured and simulated reflection coefficients. The discrepancy between them may be caused by the SMA connector or cable connector, which was not accounted for in the simulation but was used in the experiment. With the measurement, the first resonance occurs at 2.45 GHz having the reflection value of −22.68 dB with the −10 dB bandwidth is from 2.36 GHz to 2.50 GHz, which meets the bandwidth requirement for IEEE 802.11b/g. In the higher frequency, the resonant modes are excited at 5.26 GHz and 6.10 GHz. The −10 dB bandwidth is 1320 MHz from 5.01 GHz to 6.33 GHz or about 25.38% for the frequency 5.2 GHz, which meets the bandwidth requirement for WLAN and RFID applications.

To gain a better understanding of the excitation behavior of the proposed antenna, the current distributions at 2.45 GHz and 5.2 GHz are illustrated in Fig. 6. As can be seen, the strongest electric current exists around the Π-slot and along the T-strip at 2.45 GHz. The current path is similar to the resonant path II which was previously pointed out in Fig. 1. For the upper band at 5.2 GHz in Fig. 6(b), it can be observed that the current distributes mainly around the Π-shaped slot. The current path is similar to the resonant path I as shown in Fig. 1. Hence, by adding appropriate T-shaped strip and Π-shaped slot, the suitable resonant path can be created to radiate electromagnetic energy efficiently at the different resonant frequencies. The ground plane of the proposed antenna is also a part of the radiation elements at both sample frequencies. The dimension of the ground plane can be adjusted

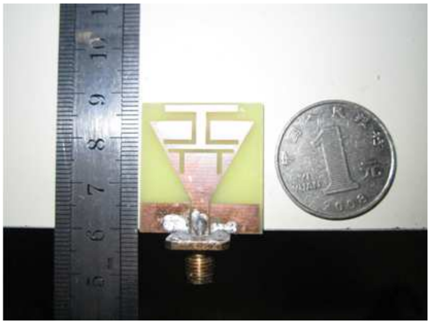


Figure 4. The photograph of the proposed antenna.

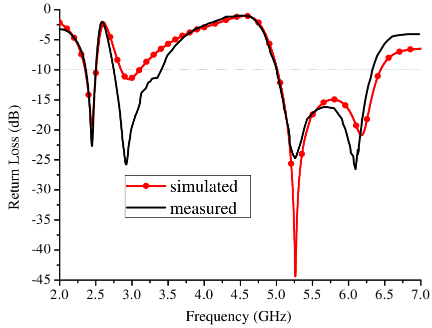
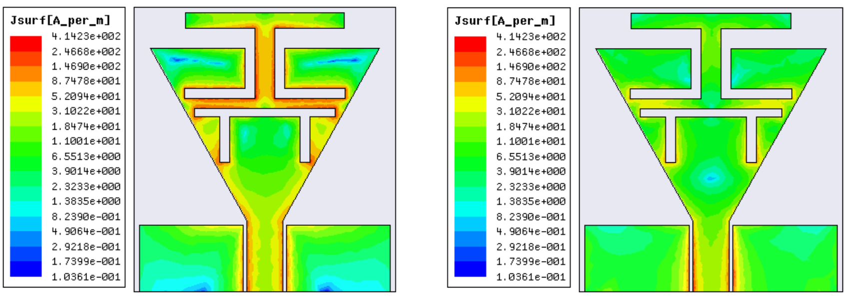


Figure 5. Measured and simulated return loss against frequency for the proposed antenna.

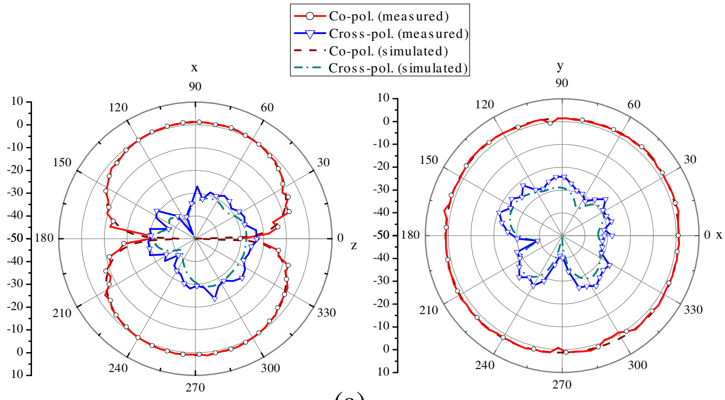


(a) 2.45 GHz (b) 5.2 GHz

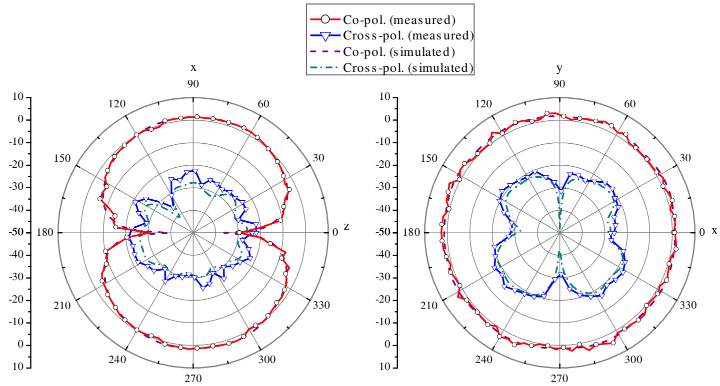
Figure 6. Simulated surface current distribution at different frequencies for the proposed antenna.

to achieve better impedance matching.

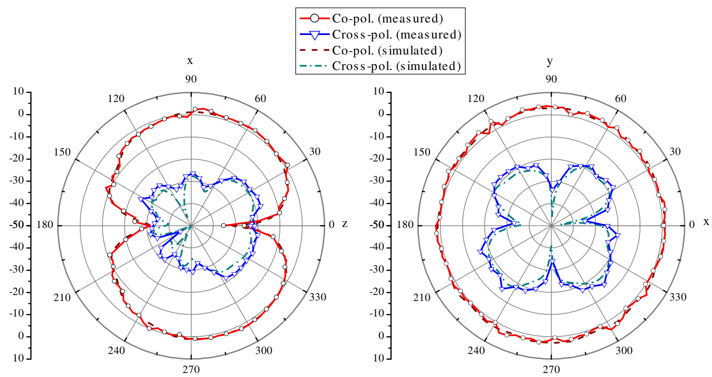
The radiation characteristics of the proposed antenna have also been investigated. Fig. 7 shows the simulated and measured radiation patterns at resonant frequencies of 2.45 GHz, 5.2 GHz, and 5.8 GHz, which depicted the E-plane radiation patterns and the H-plane radiation patterns. The measured results show that the very good omni-directional patterns in the H planes and the nearly bidirectional patterns in the E planes are obtained for all frequency bands. The peak gain of the proposed antenna for the frequencies throughout the matching bands is shown in Fig. 8. Over the band 2.36–2.50 GHz, the antenna gain varies from 1.3 to 2.6 dB. In the 5 GHz operating bands, the antenna gain varies from 1.8 to 4.0 dB.



(a)



(b)



(c)

Figure 7. Measured and simulated radiation patterns at: (a) 2.45 GHz, (b) 5.2 GHz, (c) 5.8 GHz.

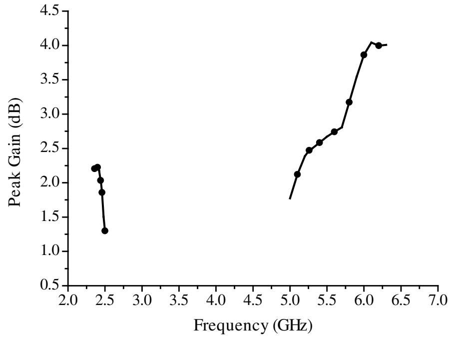


Figure 8. Variations of the peak gains against frequency for the proposed antenna.

4. CONCLUSION

A novel compact CPW-fed antenna showing dual-band operation has been presented. By employing two different types of resonant structure — a Π-shaped slot and a T-shaped strip, it can obtain good dual-band operation performance while maintaining small size and simple structure. The fabricated prototype with a size of $0.22\lambda \times 0.21\lambda \times 0.013\lambda$ (λ is the wavelength relative to the frequency 2.4 GHz) provides a bandwidth from 2.36 GHz to 2.50 GHz for the IEEE 802.11b/g/n standard and a broad band from 5.01 GHz to 6.33 GHz for the IEEE 802.11a/n standard. Omni-directional radiation performance and sufficient gain through the operating frequencies can also be obtained. In addition to the simple and uniplanar structure, the flexible and nearly independent allocation of the two operating frequencies makes the proposed antenna applicable for WLAN and RFID applications.

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