A Compact Microstrip-Line-Fed Printed Parabolic Slot Antenna for WLAN Applications

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***Abstract*-This paper presents a compact microstrip-line-fed printed parabolic slot antenna for wireless local area network (WLAN) applications in IEEE 802.11/b/g/a. The proposed antenna consists of a microstrip-fed-line and parabolic slot with a rectangular slot. By introducing rectangular slot with parabolic slot and a loading strip protruded into the rectangular slot, the proposed antenna can achieve two operating bandwidths. The measured impedance bandwidth of proposed antenna covers the operating bands of 2.4-2.84 GHz and 4.13-5.83 GHz, which covers the required bandwidth of WLAN applications. In measured results, good radiation characteristics are obtained.**

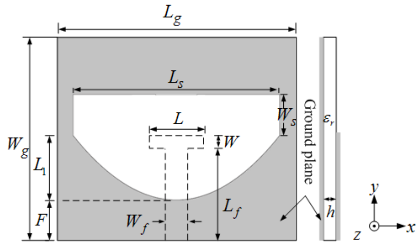
I. INTRODUCTION

Recently, wireless communications have developed rapidly, which leads to great demand for developments in novel wireless products. Antennas are important and indispensable elements of any wireless communication systems. In recent years, printed slot antennas are getting more popular because they usually have a wide impedance bandwidth and can be applied to various wireless communication systems such as WiMAX (Worldwide Interoperability for Microwave Access) and WLAN (Wireless Local Area Network). Furthermore, they also have the advantages of low profile, lightweight, east of fabrication and integration with other devices or RF circuitries. A conventional narrow slot antenna has limited bandwidth, whereas wide slot antennas exhibit wider bandwidth. Many previous studies of the different printed wide slot antennas fed by a microstrip line and coplanar waveguide have been reported [1-2]. By using different tuning techniques or employing different slot shapes such as rectangular, circular, arc-shape, annular-ring, U-shape etc., different slot antennas achieved wideband or ultra-wideband performance [3-4]. In [5], a polygonal slot antenna fed by microstrip line has been proposed. By employing a rectangular slot with a triangular slot on the bottom, the antenna can obtain 104% impedance bandwidth (1.85-5.83 GHz). However, the antenna does not possess a compact profile having a dimension of $100\times80\,\text{mm}^2$. A printed wide-slot antenna fed by a microstrip line has been introduced [6]. This antenna consists of an arc-shape slot and a square-patch feed and can achieve 120% impedance bandwidth (1.82-7.23 GHz). The bandwidth is good enough but the size is very large ($110\times110\,\text{mm}^2$). However, these printed slot antennas mentioned above have larger dimension and may not be suitable for applications that require miniaturized antennas. Moreover, a WLAN antenna should be capable of operating at 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).

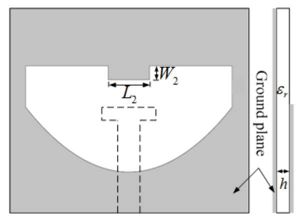
In this paper, a microstrip-line-fed printed parabolic slot antenna that achieves a compact size is proposed. By using parabolic shaped slot with rectangular slot and T-shaped feed, the antenna can obtain dual band operation suitable for WLAN applications. Details of the antenna design and both simulated and measured results are presented and discussed.

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig.1. The antenna is printed on the inexpensive FR4 substrate of thickness h = 1.6 mm, with relative permittivity $\varepsilon_r = 4.4$. The slot and the feeding line are printed on different sides of FR4 substrate. The microstrip fed line has a width W_f = 3.2 mm and a length L_f = 14 mm with a tuning stub width W = 2 mm and L = 8 mm. The slot in the ground plane consists of two sections, the rectangular section with dimensions of $6\times30\,\text{mm}^2$ ($W_s\times L_s$) and the parabolic section with F = 6 mm. Parameter F is used to define the parabolic profile of the slot antenna. By combining rectangular slot and parabolic slot with optimal length F, the proposed antenna can provide the two operating bands. For achieving efficient excitation and good impedance matching, the loading strip is protruded into the rectangular slot, the width and length of the protruded loading strip are denoted as W_2 and L_2, respectively as shown in Fig.1(b). The overall size of the proposed antenna is $30\times35\,\text{mm}^2$ ($W_g\times L_g$).



(a)



(b)

Figure 1. Geometry of the proposed antenna: (a) without a loading strip, (b) with a loading strip.

The equation of parabolic shape slot antenna is expressed in (1) with $-L_s/2 \leq x \leq L_s/2$.

$$y = \frac{x^2}{4F} + F \qquad (1)$$

where F is parameter to define the width of parabolic slot (L_1) and position of the slot.

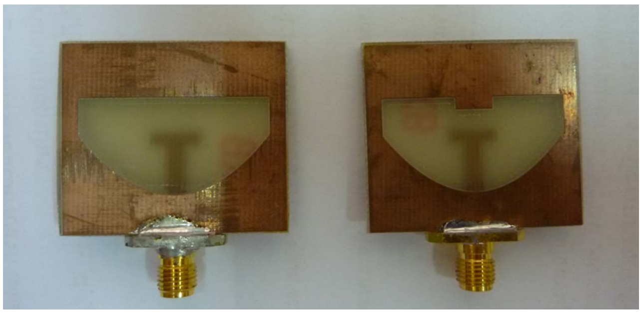


Figure 2. Photograph of fabricated antennas with and without loading strip.

III. Experimental Results and Discussion

Fig.2 shows the prototypes of parabolic shape slot antennas with and without loading strip. The return loss of proposed antenna was simulated by CST microwave studio and measured by vector network analyzer. In this section, some sensitive parameters are studied numerically in order to demonstrate parameters that affect the performance of printed parabolic slot antenna. In the simulation only one parameter is varied each time, whereas the others are kept constant. The case of the proposed antenna without loading strip, the microstrip-line length L_f is an important parameter. By tuning the length of microstrip-line, the lower resonant frequency is shifted and impedance matching of the upper frequency is affected as shown in Fig.3. It is found that the length of L_f = 14 mm can obtain a good impedance bandwidth and cover two operating bands. The length L_s and width W_s of rectangular slot have been also investigated. Fig. 4 shows the return loss of varying the rectangular slot length as L_s = 26, 28, 30 mm with a fixed W_s = 6 mm. It can be observed that with increasing length of L_s, which the surface current path can be extended, the resonant frequency shifts down and impedance bandwidth of the upper band is improved. Fig. 5 shows the return loss for different widths of W_s, where the length of rectangular slot L_s = 30 mm is chosen. It is seen that with decreasing W_s, the impedance matching of the lower band is improved, while the upper resonant frequency shifts down. The parameter F, which is parameter to define the parabolic shape profile, also influences impedance matching of the proposed antenna. Fig. 6 shows the return loss of different lengths of F. When the parameter F = 5 mm, the 10-dB return loss from 2.38 to 5.41 GHz covers 2.4/5.2 GHz, however, it cannot covers at 5.8 GHz band for WLAN operation. When the parameter F = 9 mm, the resonance mode shifts to higher frequency bands and impedance bandwidth is not enough for WLAN application. It is seen that the length of F = 6 mm obtains dual band operation which covers 2.40-2.87 GHz for lower band and covers 3.45-5.87 GHz for upper band.

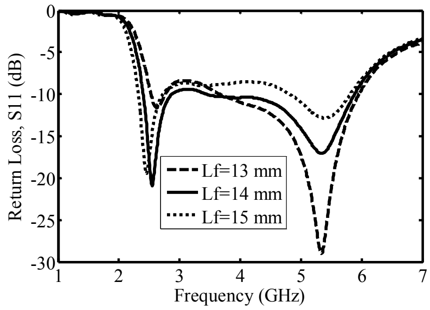


Figure 3. Simulated return loss for various lengths L_f of proposed antenna without loading strip.

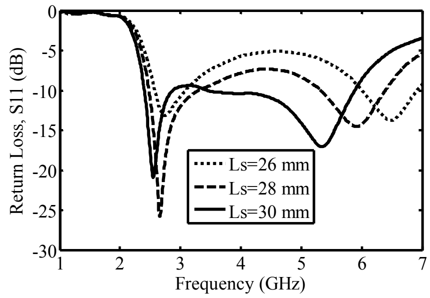


Figure 4. Simulated return loss for various lengths L_s of proposed antenna without loading strip.

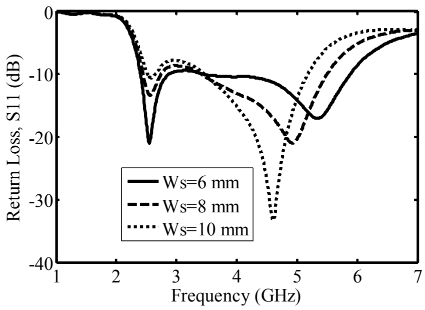


Figure 5. Simulated return loss for various lengths W_s of proposed antenna without loading strip.

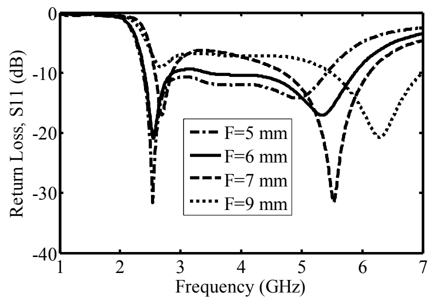
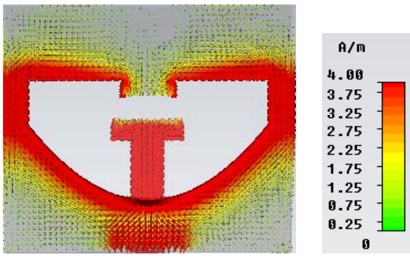


Figure 6. Simulated return loss for various lengths F of proposed antenna without loading strip.

For achieving efficient excitation and good impedance matching, the loading strip is protruded into the rectangular slot. It is found that the length of W_2 has a significant effect on the impedance bandwidth, while L_2 has effect on impedance matching. The optimal length W_2 and L_2 of the loading strip for dual operating bands are found to be 2 mm and 6 mm, respectively. Fig.7 shows the surface current distributions of the proposed antenna at frequencies of 2.4 GHz, 5.2 GHz and 5.8 GHz. The surface current distributions for 2.4 GHz are concentrated on the part of rectangular slot, parabolic slot and microstrip fed line as shown in Fig. 7(a), while that for 5.2 GHz are concentrated on the part of rectangular slot as shown in Fig. 7(b). It can be observed that the surface current distribution at 5.8 GHz is significantly distributed along the part of parabolic slot and microstrip fed line.



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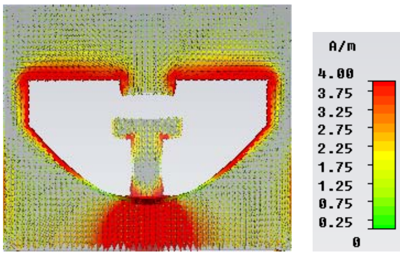

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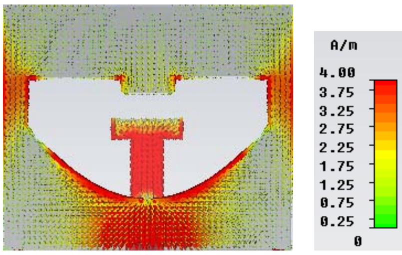


(c)

Figure 7. Simulated surface current distributions of the proposed antenna at (a) 2.4 GHz (b) 5.2 GHz and (c) 5.8 GHz.

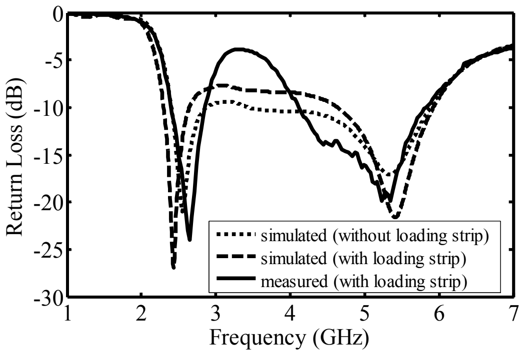
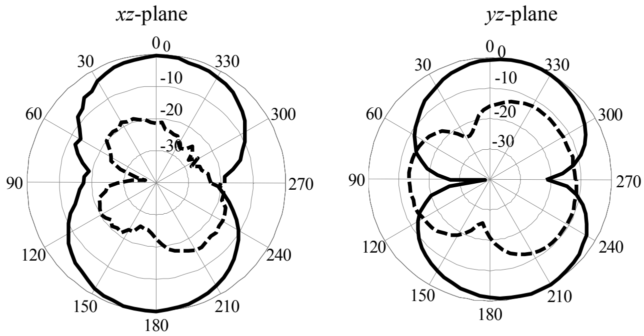
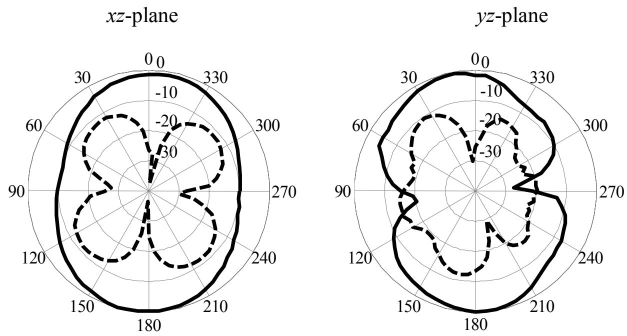


Figure 8. Simulated and measured results of return losses of proposed antenna: W_g =30 mm, L_g = 35 mm, W_s = 6 mm, L_s = 30 mm, F = 6 mm, L_1 = 15.4 mm, W_f = 3.2 mm, L_f = 14 mm, W = 2 mm, L = 8 mm, W_2 = 2 mm, L_2 = 6 mm.

Fig.8 shows the measured and simulated results of return losses of the proposed antenna. It can be seen that the measured return loss of the proposed antenna shifts to the right for the lower operating band and shifts to the left for the upper operating band. The disagreement between simulation and measurement is mainly due to the fabrication tolerance. However, the measured result of proposed antenna still covers the two operating bands of 2.40-2.84 GHz and 4.13-5.83 GHz for 2.4/5.2/5.8 GHz WLAN application.



(a)



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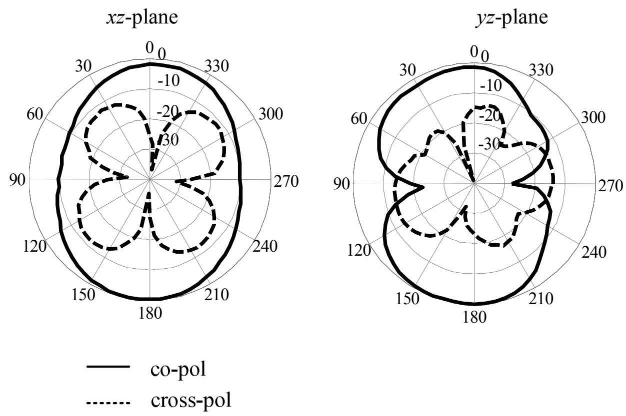

(c)

Figure 9. Measured radiation patterns for the proposed antenna in the *xz*-plane and *yz*-plane at (a) 2.4 GHz (b) 5.2 GHz and (c) 5.8 GHz.

The radiation characteristics of the proposed antenna with loading strip at operating frequencies within the impedance bandwidth are also investigated. Fig. 9 shows the measured radiation patterns in the *xz*-plane and *yz*-plane with both co- and cross polarizations at 2.4 GHz, 5.2 GHz and 5.8 GHz. The measured results show that the radiation patterns of the antenna are still similarly to bidirectional radiation pattern at two operating bands. The measured antenna gains are about 2.48 dBi, 3.15 dBi and 3.23 dBi at 2.4 GHz, 5.2 GHz and 5.8 GHz, respectively.

IV. CONCLUSION

A compact microstrip-line-fed parabolic slot antenna for dual band operations has been presented and implemented. By introducing rectangular slot with parabolic slot and a loading strip protruded into the rectangular slot, the proposed antenna can obtain two separate impedance bandwidths for 2.4 and 5.2/5.8 GHz bands. In the experimental results, bidirectional radiation pattern and sufficient antenna gain of operating frequencies across the two bands can also obtained. In addition, the proposed antenna also has simple structure, compact size and good radiation performances suitable for WLAN applications.

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