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STUDY OF THE BAND-NOTCH FUNCTION FOR SWALLOW-TAILED PLANAR MONOPOLE ANTENNAS

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Abstract—In this paper, we propose two swallow-tailed ultra-wideband planar monopole antennas that exhibit notch characteristics in the IEEE802.11a frequency band (5.15–5.825 GHz) by inserting various slots into the antennas. The effects of the lengths of the slots on the notched frequency band are analyzed. The radiation patterns of the proposed antennas are also measured and the gains are shown to be flat, except in the notched frequency band.

1. INTRODUCTION

The increasing demand for wireless communication services stimulates the need for antennas capable of operating at a wide frequency range. Since the Federal Communications Commission (FCC) released the commercial use of UWB radio system [1], many researchers have been paying much attention to high-speed indoor data-communication application. Antennas are the particularly challenging aspect of UWB technology. To satisfy such a requirement, various wideband antennas have been studied [2–8]. Among the many possible alternatives, planar monopole antennas are good candidates owing to their simple structures, low cost and ease of construction while featuring wide impedance bandwidth, pure vertical polarization and horizontal omnidirectional radiation pattern.

However, the UWB communication systems use the 3.1–10.6 GHz frequency band, which includes the IEEE802.11a frequency band (5.15–5.825 GHz). Therefore, UWB communication systems may generate interference with IEEE802.11a. The UWB antenna must have the band-notched characteristic at 5.15–5.825 GHz in order to prevent the signal of the IEEE802.11a frequency band. Recently, various band-notched UWB antennas have been developed for UWB communications [9–11]. Such as the circular disc monopole antenna inserted by an arched slot [12], the square metal-plate monopole antenna with bevels embedded by an inverted U-shaped slot [13], and so on.

In this paper, swallow-tailed UWB antennas with a notch function are proposed and optimized. This study is a continuation of [14], in which a novel swallow-tailed UWB planar monopole antenna with semi-elliptical base was designed. The swallow-tailed UWB antenna without slot can cover the entire UWB frequency band and has a notch for the 5.15–5.825 GHz frequency band by inserting optimized inverted U or inverted V-shape slot into the antenna. The effects of the length of the slot on the notched frequency band are discussed. Besides, the gains of the two antennas are measured and shown to be flat, except in the notched frequency band. The antenna construction and design are described in Section 2, and the experimental results of the proposed antennas are presented in Section 3. Section 4 gives the conclusion.

2. ANTENNA DESIGN

The configuration of the proposed swallow-tailed planar monopole antenna without slots depicted in Fig. 1(a) is vertically mounted on a ground plane of dimensions $100\times100\,\text{mm}^2$. The antenna is excited through a feeding post connected to the lower edge of the semi-elliptical

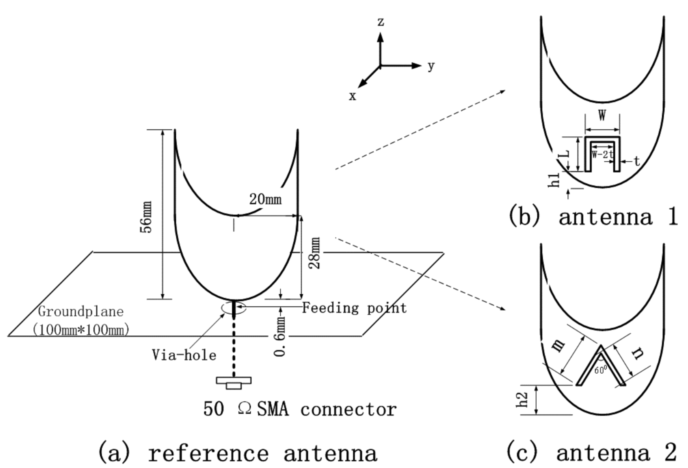


Figure 1. Geometry of the proposed antennas and a coordinate system. (a) without slot (reference antenna); (b) with inverted U-shape slot (antenna 1); (c) with inverted V-shape slot (antenna 2).

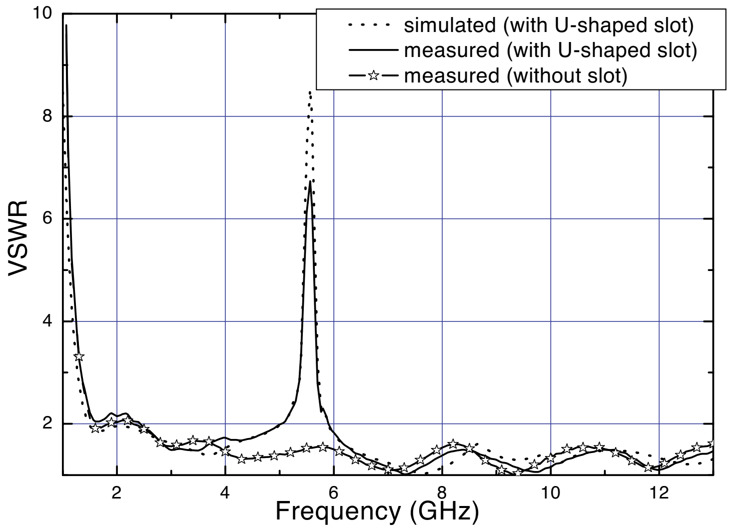
base along the major axis, which has a distance of 0.6 mm to the ground plane. The feeding post in this study is the central conductor (diameter 1.2 mm) of a 50 Ω SMA connector, which is located below a via-hole in the center of the ground plane. The planar monopole consists of a semi-elliptical base and a rectangle plane with a semi-ellipse incised. Note that, the semi-ellipse incised is just the same dimensions as the semi-elliptical base, whose major axis and minor axis are 28 mm and 20 mm, respectively. All metal plate used in this study is a 0.2 mm thick brass sheet.

Figures 1(b) and (c) show the main parts of the proposed swallow-tailed monopole antennas with an inverted U-shape slot (antenna 1) and an inverted V-shape slot (antenna 2), respectively. Both of the slots are placed symmetrically with respect to the centerline of the planar monopole, with their opening facing the feeding point at a distance of h_1 and h_2. The inverted U-shape slot has a uniform width t, an outer vertical length L, and an outer horizontal width W. Therefore the slot length in this case is given by $2L + W - 2t$. The inverted V-shape slot is composed of two equilateral triangles, which share the same hemline. The side-length of the out triangle is m while the inner is n. Thus the slot length here is $m + n$.

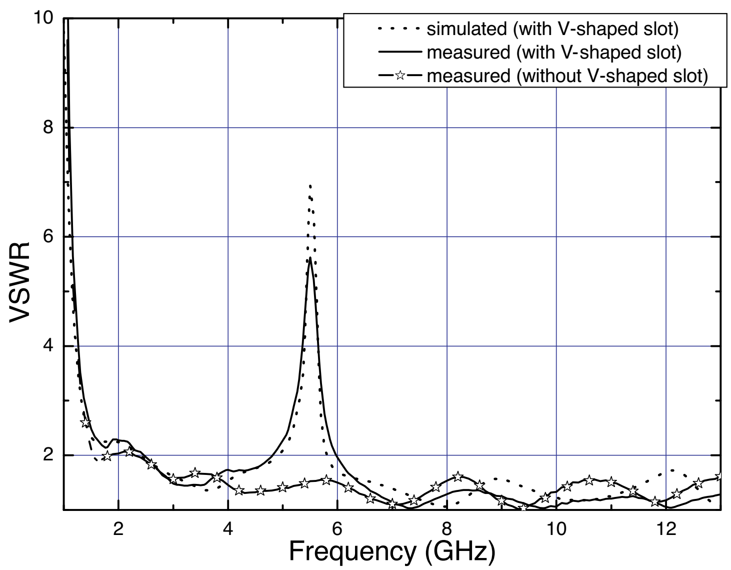
By adjusting the lengths of the slots to be about a half-wavelength at the center frequency of the desired notched-frequency band (about 5.5 GHz for IEEE802.11a frequency band in this study), the proposed UWB planar monopole antennas will become non-responsive at that frequency band.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the measured and simulated VSWR for the proposed antennas. Results of the swallow-tailed monopole without slot are also shown for comparison. For the constructed prototypes, the inserted inverted U-shape slot is with $L = 11.5$ mm, $W = 6.5$ mm, $h_1 = 2$ mm, $t = 1$ mm, while the embedded inverted V-shape slot is with $m = 14.5$ mm, $n = 13.5$ mm, $h_2 = 5$ mm. In this case, the lengths of the slots are 27.5 mm ($= 2L + W - 2t$) and 28 mm ($= m + n$), respectively, which are approximately one half-wavelength at 5.5-GHz (27.27 mm). From the results, it is clearly seen that the band-notched characteristics are obtained for the proposed antennas in the IEEE802.11a frequency band, and small effects on the other frequencies in the UWB bandwidth are brought. It is also noted the good agreement between the measured data and the simulated results, which are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS), is achieved. Figure 3 shows the



(a) Measured and simulated VSWR for antenna 1 and reference antenna



(b) Measured and simulated VSWR for antenna 2 and reference antenna.

Figure 2. Measured and simulated VSWR for proposed antennas.

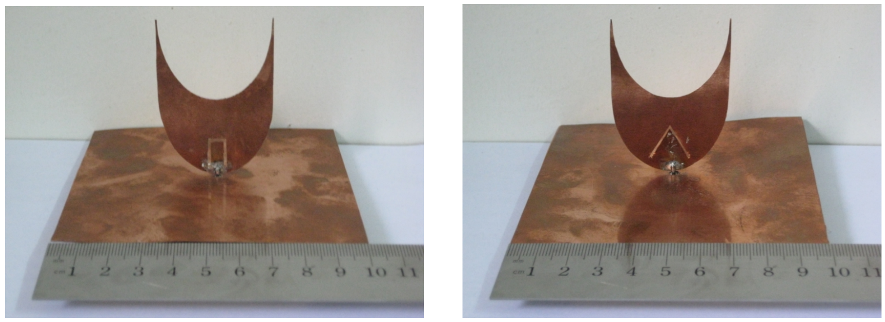
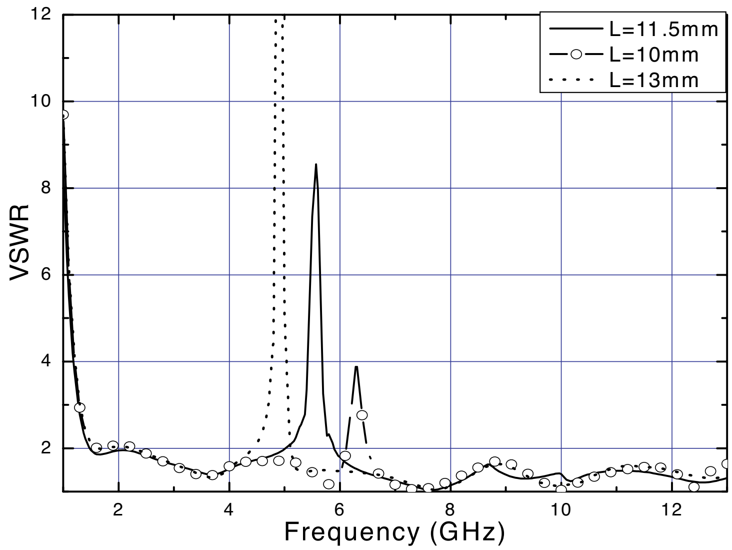


Figure 3. The prototypes of the proposed antennas.

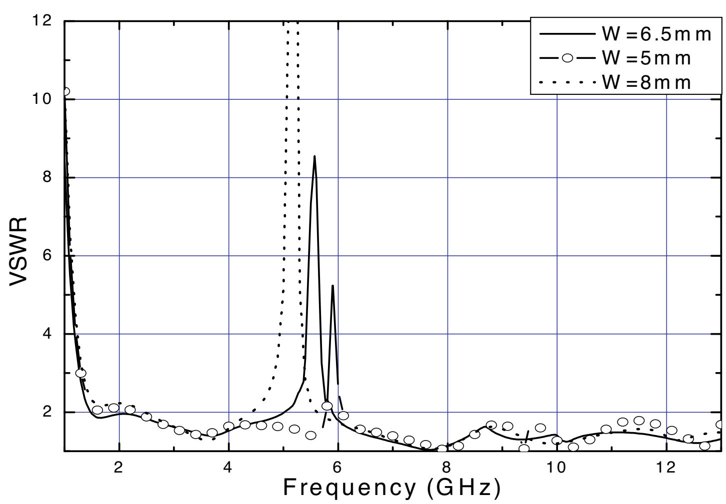
prototypes of the proposed antennas.

In order to demonstrate the effects of the lengths of the slots on the notched frequency band, Figure 4 shows the simulated results for the swallow-tailed monopole inserted by inverted U-shape slot with various values of L and W, and the plots of the monopole embedded by inverted V-shape slot, which varies with m and n, are depicted in Figure 5. It can be concluded that the notched bands of the proposed antennas are indeed controlled by the lengths of slots, which function as a half-wavelength resonant structure.

The radiation characteristics of the frequencies across UWB band for the proposed antennas are also examined. Figure 6 shows the measured far-field radiation patterns of antenna 1, including the co-polarization and cross-polarization in the elevation direction (x-z and y-z planes) and azimuthal direction (x-y plane) at 4 GHz and 7 GHz. Also, the radiation patterns of antenna 2 are plotted in Figure 7. It is observed that the proposed antennas have monopole-like patterns in elevation and nearly omnidirectional radiation patterns in the azimuth. Figure 8 plots the measured antenna gains for frequencies from 3.5 GHz to 7 GHz of the proposed antennas with different embedded slots. The results show that the two antennas have a good gain flatness except in the IEEE 802.11a frequency band. The slight distortion in the patterns might be attributed to the shape of the planar monopole antenna, reflections from metallic surfaces and edge diffraction. However, these patterns are also acceptable compared to that of some other antennas. Thanks to the low signal level and complex environments for the measurement of the proposed antenna, some measured patterns look rough in spots.



(a) Simulated VSWR for antenna 1 with various values of L ($W = 6.5\text{mm}$, $h_1 = 2\text{mm}$, $t = 1\text{mm}$)



(b) Simulated VSWR for antenna 1 with various values of W ($L = 11.5\text{mm}$, $h_1 = 2\text{mm}$, $t = 1\text{mm}$)

Figure 4. Simulated VSWR for antenna 1 with various of L and W.

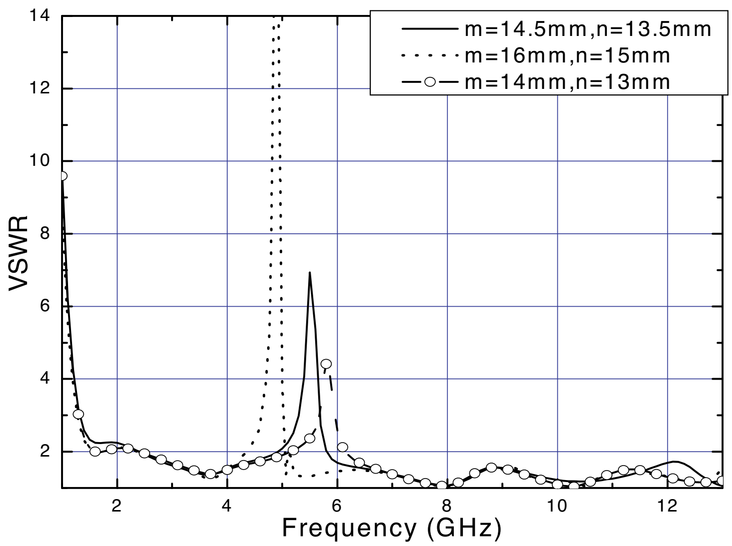
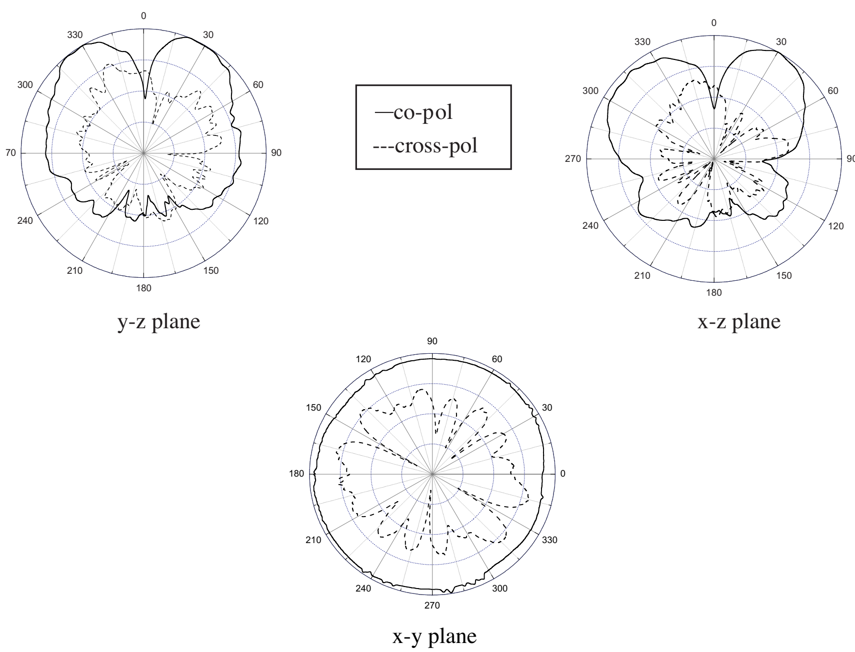
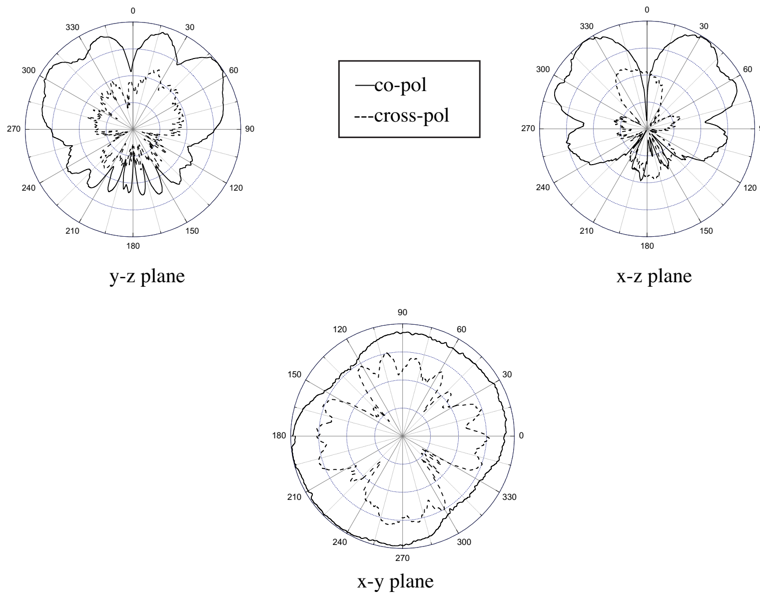


Figure 5. Simulated VSWR for antenna 2 with various of m and n ($h_2 = 5\,\text{mm}$).

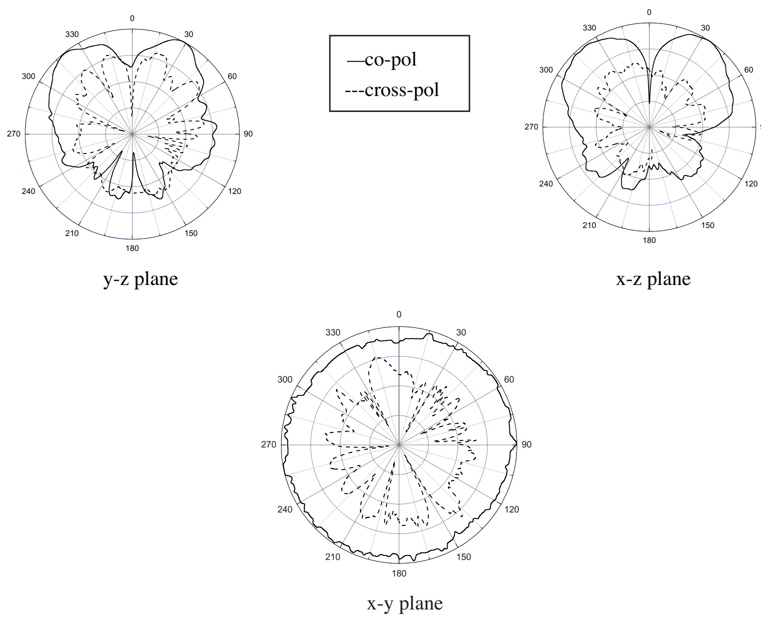


(a)



(b)

Figure 6. Measured far-field radiation patterns of antenna 1. (a) at 4 GHz; (b) at 7 GHz. (10 dB/div).



(a)

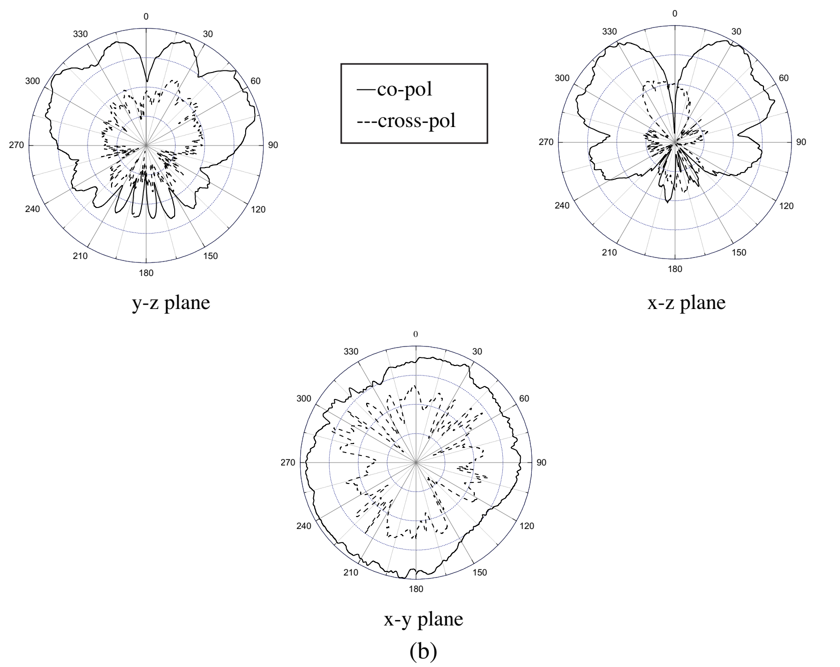


Figure 7. Measured far-field radiation patterns of antenna 2. (a) at 4 GHz; (b) at 7 GHz. (10 dB/div).

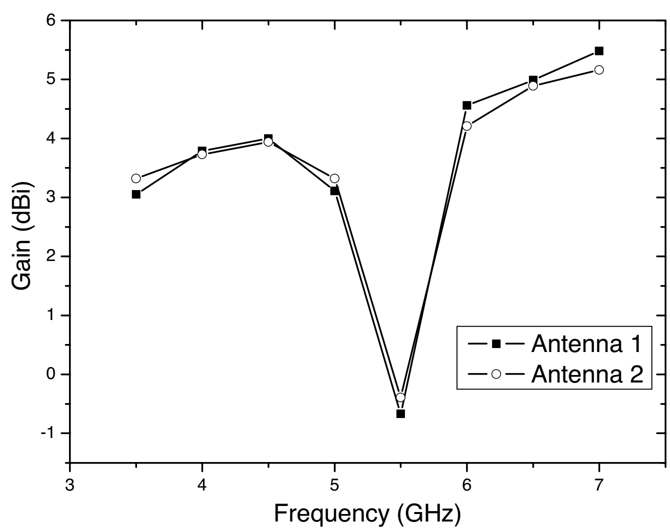


Figure 8. Measured antenna gains vs. frequency for the proposed antennas with different embedded slots.

4. CONCLUSION

Swallow-tailed planar monopole antennas with a frequency-notch function have been proposed in this paper. To obtain a frequency-notched characteristic, we have inserted different shape slots into the swallow-tailed monopole. The notch frequency can be adjusted by changing the slot length, and the proposed antennas show acceptable radiation patterns and good gain flatness, except in the IEEE802.11a frequency band.

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