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DESIGN OF NOVEL WIDEBAND MONOPOLE ANTENNA WITH A TUNABLE NOTCHED-BAND FOR 2.4 GHZ WLAN AND UWB APPLICATIONS

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Abstract—In this article, a novel wideband planar monopole antenna for applications in 2.4 GHz WLAN and UWB bands is presented and investigated. The proposed antenna is composed of a gourd-like radiation element fed by a 50 Ohm microstrip line and a step-shaped ground plane. A pair of slot lines is etched symmetrically on the ground plane to obtain the 5 GHz band-notched characteristic, and the notched band can be tuned. The proposed antenna is successfully simulated, designed, and measured. The measured results agree reasonably with the simulated ones. According to the measured results, the proposed antenna yields a wide bandwidth ranging from 2.2 to 11 GHz for VSWR less than 2, except the notched band of 5.1–6.2 GHz for 5 GHz WLAN. Moreover, it exhibits nearly omnidirectional radiation patterns, stable gain, and small group delay variation across the operation band, which meets the requirements of 2.4 GHz WLAN and UWB applications.

1. INTRODUCTION

In recent years, the increasing demand for wireless communication services stimulates the need for antennas capable of operating at a wide frequency range. Among several types of antennas suitable for wideband applications, planar monopole antennas are promising due to their attractive merits such as low cost, wideband operation, omnidirectional radiation, easy fabrication, etc. Thus, various planar monopole antennas with wideband characteristic have been reported [1–4]. The conventional methods for broadening impendence bandwidth are to modify the shapes of the radiation element [1],

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ground plane [2, 3] as well as feeding structure [4]. In particular, it is desired to design a wideband antenna that can operate in multifunctional wireless communication systems without performance distortion, such as UWB and 2.4/5 GHz WLAN systems. However, the frequency range for UWB systems approved by the FCC is from 3.1 to 10.6 GHz, where the 5.15–5.825 GHz frequency band has been allocated to 5 GHz WLAN systems. To avoid potential interference between them, the wideband antenna with 5 GHz notched band is highly demanded. Based on this requirement, many wideband antennas with band-notched characteristic have been reported [5–9]. Various approaches to achieve band-notched function have also been introduced. One of the most widely used methods is to etch slots on the patch [5, 6] or on the ground plane [7, 8]. Nevertheless, most of them possess the lowest operating frequency at about 3 GHz, which makes them not suitable for applications in 2.4 GHz WLAN (2.4–2.484 GHz) systems. A wideband antenna with small size designed for 2.4 GHz WLAN and UWB bands with 5 GHz notched band is still rarely studied in the open literature.

In this article, a wideband planar monopole antenna for applications in 2.4 GHz WLAN and UWB systems is proposed. By adopting the gourd-like patch and the step-shaped ground plane, broadband impedance bandwidth can be easily obtained. To produce a band-notched operation covering the 5 GHz WLAN band, a pair of slot lines is etched symmetrically on the ground plane. Furthermore, the band-notched characteristic can be easily tuned by means of adjusting the length and the width of the presented slot line. Details of the antenna design are described. Both simulated and experimental results are presented and discussed as follows, such as band-notched characteristic, radiation pattern, antenna gain, and group delay.

2. ANTENNA DESIGN

Figure 1 shows the geometry and configuration of the proposed wideband planar monopole antenna. As shown, the proposed antenna is composed of a gourd-like radiation element fed by a microstrip feed line, and a step-shaped ground plane. The radiation element is printed on the low-cost FR4 substrate with thickness of 1 mm, relative dielectric constant of 4.4, and total size of 36 mm × 40 mm. The width of the feed line denoted as W_f is fixed at 2 mm to implement 50 Ohm characteristic impedance. A SMA connector is connected to the feed line to facilitate its connection with other communication devices. In this design, the gourd-like radiation element is based on the geometry combination of a circular patch with a radius of R_1, and a great circular patch with a radius of R_2. As depicted, the distance of centers between them is denoted as D_2. The tapered symmetrical structure of the radiation element enables the radiator to support multiple resonant modes, and thus ensures wideband operation [10]. On the backside of the substrate, the modified ground plane with step-shaped structure is placed. The step-shaped structure plays an important role in the impendence matching over a wide operation band [3, 10].

To implement the band-notched characteristic for 5 GHz WLAN, a pair of slot lines is inserted into and arranged symmetrically with respect to the centerline of the modified ground plane. The geometry of the slot line have also been illustrated in detail. As illustrated in Figure 1, the presented slot line has a total length of $L = Ls_1 + Ls_2 + Ls_3$ and a width of Ws. The design concept of the band-notched function is to adjust the length of the slot line to be about half-wavelength at the desired notched frequency making the input impedance singular [11]. In this study, we take the mentioned concept into account in obtaining the total length of the inserted slot line at the beginning, and then adjust the geometry for the

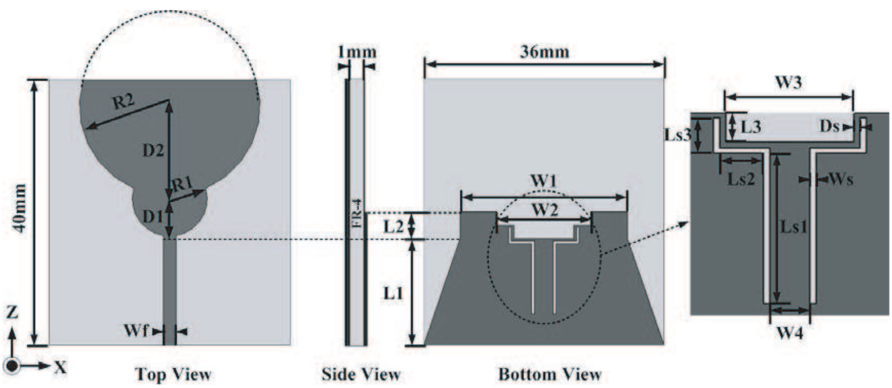


Figure 1. Geometry and configuration of the proposed antenna.

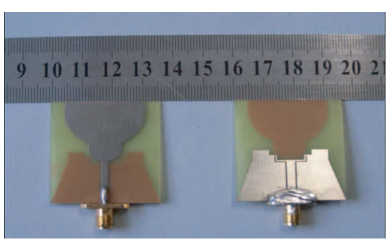


Figure 2. Photograph of the fabricated prototype.

final design. The proposed antenna was simulated and optimized with Ansoft HFSS^{TM} V.11, which utilizes the Finite Element Method (FEM) for electromagnetic computation. Finally, we obtained the optimized antenna dimensions, as listed in Table 1.

3. RESULTS AND DISCUSSION

To verify the proposed design, a prototype of the antenna based on optimized dimensions has been fabricated, as shown in Figure 2. The VSWR and the group delay were measured with the Vector Network Analyzer WILTRON-37269A, while the radiation pattern and antenna gain were measured with the far-field antenna measurement system at Xidian University, Xi'an, China. The measured and simulated VSWR against frequency for the proposed antenna are plotted and compared in Figure 3. As shown in this figure, the proposed antenna yields a wide bandwidth ranging from 2.2 to 11 GHz for VSWR less than 2, which covers the 2.4 GHz WLAN and the UWB bands except

Table 1. The optimized antenna parameters (Unit: mm).

The Relative Permittivity $\varepsilon_r = 4.4$, and $\tan\delta = 0.02$							
D_1	D_2	R_1	R_2	W_1	W_2	W_3	W_4
6	14	5.6	13.5	25	14	9	2.8
L_1	L_2	L_3	Ls_1	Ls_2	Ls_3	Ws	Ds
16	4	2	10.5	3.1	2.5	0.4	0.4

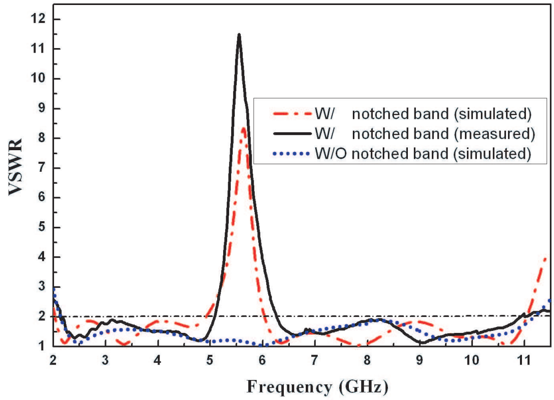


Figure 3. Measured and simulated VSWR of the proposed antenna.

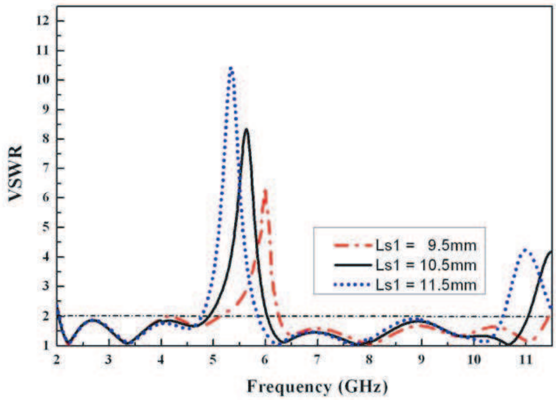


Figure 4. Simulated VSWR of the proposed antenna for various dimensions of Ls_1.

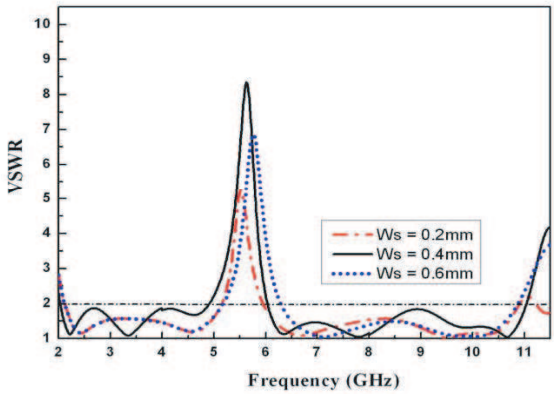
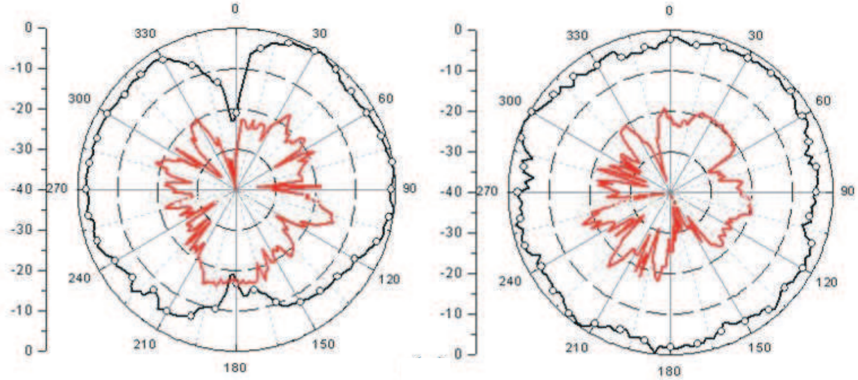


Figure 5. Simulated VSWR of the proposed antenna for various dimensions of Ws.

the notched band from 5.1 to 6.2 GHz. The discrepancy between the simulated and measured results can be mostly attributed to the measured environment effect and the tolerance in manufacturing.

Parametric analysis is made for further study. Figure 4 shows the simulated VSWR of the proposed antenna with different Ls_1. It is seen that the length of the slot line determines the frequency range of the notched band. As Ls_1 increases, the centre frequency of the notched band shifts toward the lower frequency. Figure 5 displays the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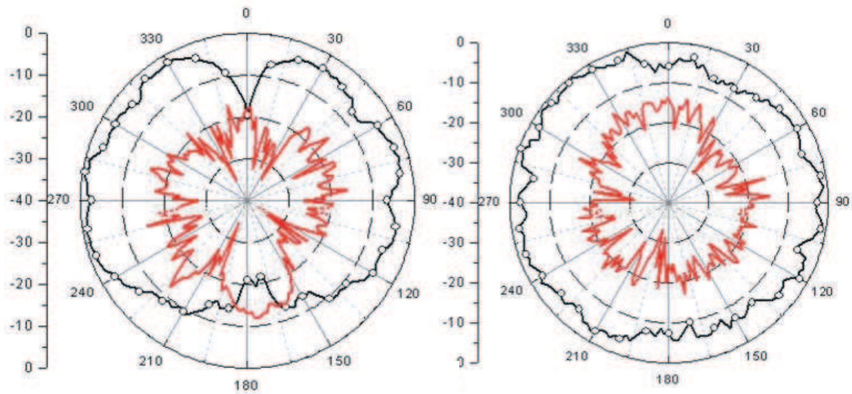
(a)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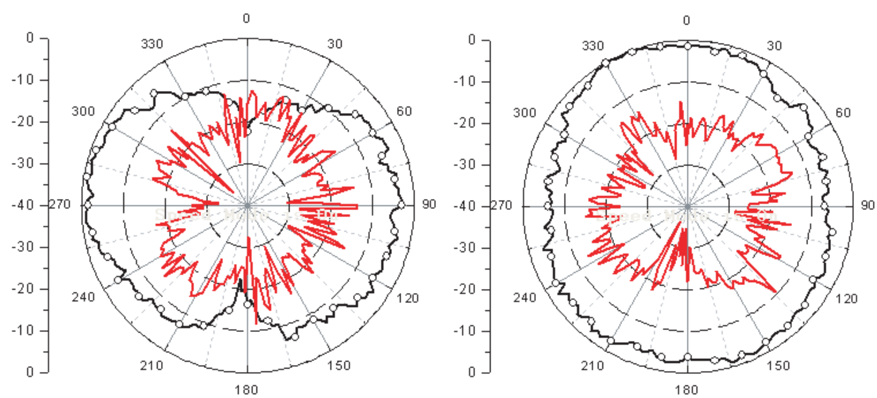
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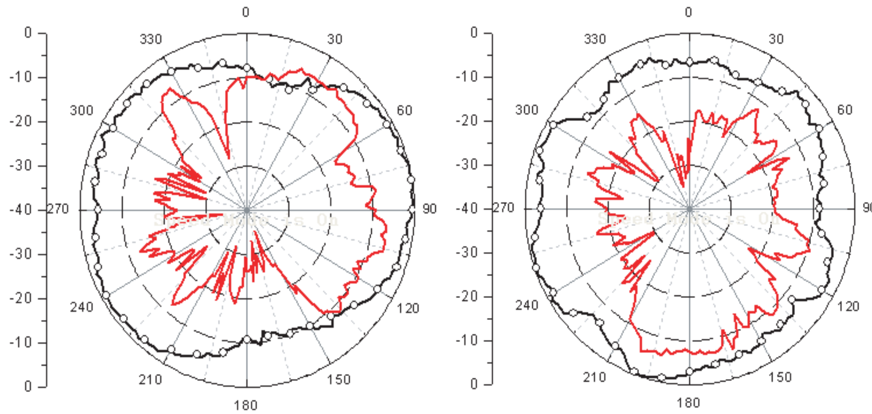


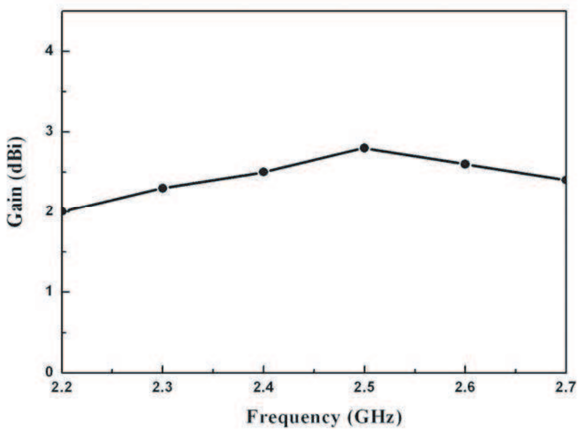
(d)

Figure 6. Measured normalized radiation patterns of the proposed antenna at (a) 2.45 GHz, (b) 4.5 GHz, (c) 7.0 GHz, (d) 9.0 GHz.

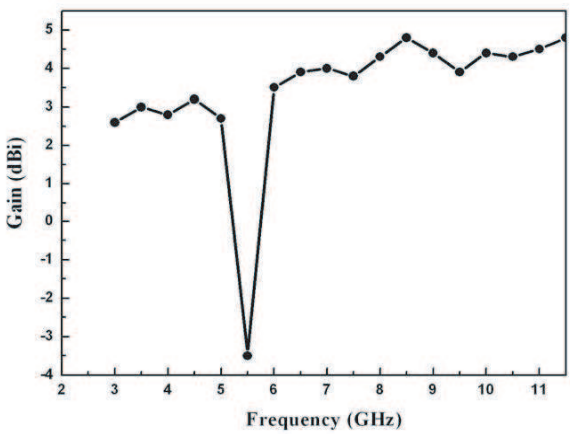
effect of Ws on the notched band. It is observed that the notched bandwidth is increased with increasing Ws. When Ls_1 is equal to 10.5 mm and Ws is optimized at 0.4 mm, the desired notched band centered at 5.5 GHz is obtained. Thus, the specific notched band can been achieve by adjusting the slot length and width.

We have also investigated the radiation characteristic of the proposed antenna in the far-field. The normalized radiation patterns of the proposed antenna, measured at 2.45, 4.5, 7.0, and 9.0 GHz are depicted in Figure 6. From an overall view of these radiation patterns, the proposed antenna exhibits a nearly omnidirectional radiation pattern in the H-plane (x-y plane), and a dipole-like radiation pattern in the E-plane (y-z plane). Figure 7 shows the measured peak gain of the proposed antenna. The maximum peak gain of the 2.4 GHz WLAN band is about 2.8 dBi. For the UWB band, the peak gain decreases drastically in the vicinity of 5.5 GHz due to the frequency notched function. Outside the notched band, antenna gain with a variation of less than 2.5 dBi is achieved. Thus, the antenna exhibits stable gain across the operation band.

Figure 8 shows the measured group delay in the time-domain. If the group delay variation exceeds 1.0 ns, the phases are no longer linear in the far-field region, and pulse distortion is caused. This can be a serious problem in a UWB communication system [9]. In this study, a pair of identical antennas served as the transmitting and receiving antennas, which were connected to the double ports of the analyzer in the face-to-face orientations, with a distance of 30 cm between them. As can be seen from Figure 8, the variation of the group delay is within 1.0 ns both in 2.4 GHz WLAN and UWB bands, and except in the notched band where the maximum group delay is more than 4 ns.



(a)



(b)

Figure 7. Measured peak gain for (a) 2.4 GHz WLAN band, (b) UWB band.

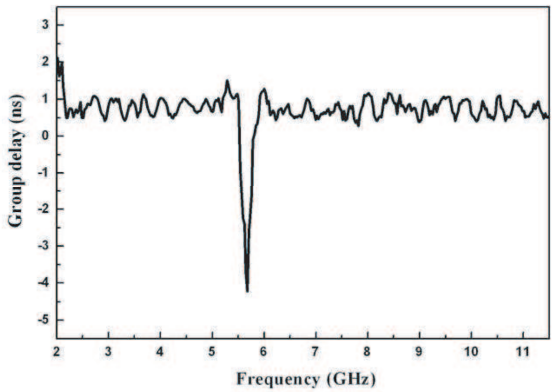


Figure 8. Measured group delay of the transfer system.

4. CONCLUSION

A novel wideband planar monopole antenna with 5 GHz band-notched characteristic for 2.4 GHz WLAN and UWB applications has been presented and investigated with experimental and numerical results. The proposed antenna exhibits wideband characteristic from 2.2 to 11 GHz, while providing band-notched functionality in the frequency band of 5.1–6.2 GHz for 5 GHz WLAN. Near omnidirectional radiation patterns, stable gain, and small group delay variation are obtained throughout the operating frequency band except in the notched band.

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