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Novel modified monopole antenna with band-notch characteristic for UWB application

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Abstract: A novel modified printed monopole antenna with variable frequency band-notch characteristic for ultra-wideband (UWB) applications is presented. The proposed antenna consists of a truncated ground plane and a radiating patch with two tapered steps. To generate a notch band at 5–6 GHz with good level of band-notch a new T-shaped parasitic element placed on the back layer of the substrate along with a simple circular slot etched on the patch is implemented. The proposed antenna has a compact size of $14 \times 20\,\text{mm}^2$, a measured impedance bandwidth of 3.05 to 14.7 GHz for $VSWR < 2$ and exhibits an omni-directional H-plane radiation pattern throughout the UWB frequency range.

Keywords: band-notch function, monopole antenna, ultra-wide band

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Ultra-wideband (UWB) technology has undergone many significant developments in recent years. However, there still remain many challenges in making this technology live up to its full potential. Commercial UWB systems require small low-cost antennas with omni-directional radiation patterns [1]. The planar monopole antenna, due to its low-cost, broad bandwidth and attractive profile is a good candidate [2, 3].

UWB antennas are also required to be able to reject interference with existing wireless networking technologies such as wireless local area network (WLAN) for IEEE 802.11a operating in 5.15–5.35 GHz and 5.725–5.825 GHz bands. Recently in literature, a number of antennas with band-notch property have been presented. This includes: using two monopole antennas of same size with a small strip bar in between [4]; slot type split ring resonators (SRRs) etched on the patch [5]; modified planar monopoles with H-shaped conductor-backed plane [6]. Nevertheless, most of these antennas have the common deficiency of large size, which may lead to a challenging task in miniaturizing antenna design.

In this paper, a new band-notched printed monopole antenna with variable frequency band-notch characteristic is presented. The antenna consists of a truncated ground plane and a two-tapered steps radiating patch. The notched band, covering the 5–6 GHz WLAN band with good level of VSWR, is generated by using a modified T-shaped parasitic element placed on the back layer of the substrate along with a narrow circular slot etched on the patch. The designed antenna has a compact size ($14 \times 20\,\text{mm}^2$) and operates over the frequency band between 3.05 to 14.7 GHz for VSWR < 2 with the band rejection over the 5–6 GHz. Experimental and simulated results of the impedance bandwidth behavior, radiation patterns and gain are presented.

2 Modified printed monopole antenna

The structure of the proposed antenna is shown in Fig. 1. The substrate used is FR4 with permittivity 4.4, thickness 1.6 mm, loss tangent 0.0018 and has a size of 14 mm × 20 mm. The width of the microstrip feed line W_f is fixed at 2 mm [2]. The radiating monopole and feeding mechanism are printed on the top side of the substrate, while the ground plane is printed on the bottom side of the substrate. To generate a band-notch characteristic at 5–6 GHz with good level of VSWR a new T-shaped parasitic element is placed on the back side of the substrate and a narrow circular slot is etched on the patch. The T-shaped element can be regarded as a parasitic resonator electrically coupled to the semi-circular monopole. The geometric parameters were adjusted and the following antenna dimensions were obtained (all in mm): $W_{Sub} = 14$, $L_{Sub} = 20$, $L_f = L_d = 6$, $R_1 = 1.5$, $R_2 = 2.5$, $R_3 = 5$,

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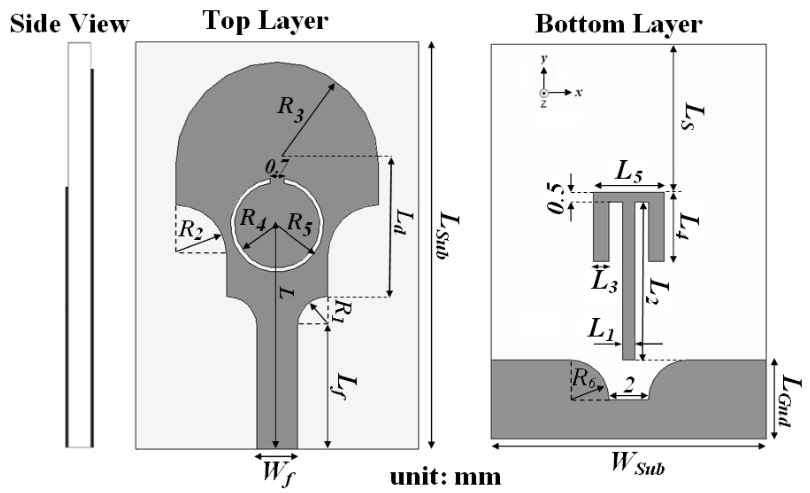

Fig. 1. Configuration and parameters of the proposed monopole antenna.

$R_4 = 2.1$, $R_5 = 2.3$, $R_6 = 2$, $W_f = 2$, $L = 11$, $L_1 = 0.6$, $L_2 = 8$, $L_3 = 0.8$, $L_4 = 3.5$, $L_5 = 3.6$, $L_S = 7.5$ and $L_{Gnd} = 4$. Moreover, the structure of the antenna is symmetrical with respect to the longitudinal direction.

3 Results and Discussion

The parameters of the proposed antenna are studied by changing one parameter at a time while the others are fixed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS).

3.1 Monopole antenna without notch characteristic

The parametric study of the antenna is conducted to obtain the influence of the dimensions on the antenna performance. In the designed antenna, first resonant frequency decreases with the increase of R_1 and R_2, and upper-edge frequency f_u is significantly affected by the variation in R_2, but the lower-edge frequency f_L is only slightly affected by the variation in R_2. Another important parameter of this structure is the feed gap distance ($d = L_f - L_{Gnd}$). By adjusting d, the electromagnetic coupling between the lower edge of the patch and the ground plane can be properly controlled. In the proposed antenna, the lower-edge frequency of the impedance bandwidth is reduced with increasing the feed gap distance.

To minimize the physical size of the UWB antenna and increase the impedance bandwidth, an inward cut can be introduced into the ground plane to alter the input impedance characteristics. This truncated ground plane acts as an impedance matching element to control the impedance bandwidth of the monopole. This phenomenon occurs because the truncation creates a capacitive load that neutralizes the inductive nature of the patch to produce nearly-pure resistive input impedance [2, 3].

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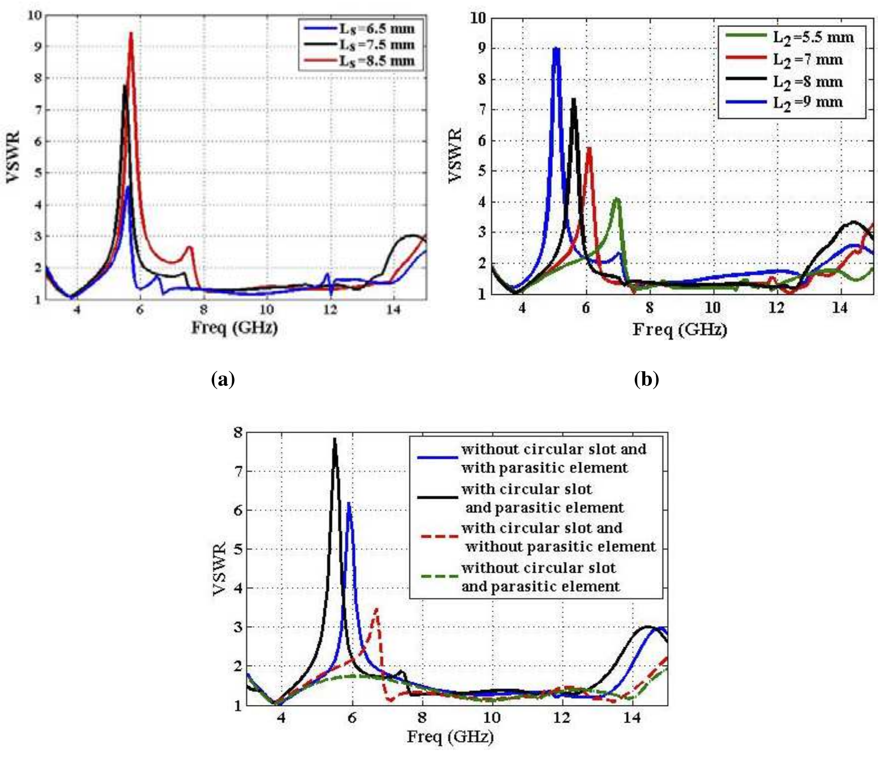
3.2 Monopole antenna with band-notch characteristic

A new design of band-notched UWB antenna is presented in this study. The proposed antenna has a T-shaped parasitic element designed on the bottom of the substrate, which is electromagnetically coupled to the radiating patch, and a narrow circular slot etched on the patch, as shown in Fig. 1. By introduction of the narrow circular slot etched on the patch a band notch is being created. By adjusting its size, the centre frequency of the notch hardly can be controlled; also the amount of VSWR, with only a narrow circular slot, is low. In the proposed design, to achieve a strong and only variable band-notch characteristic, a T-shaped parasitic element in the ground plane side is added.

The simulated VSWR curves with different values of L_S are plotted in Fig. 2 (a). From the simulation results in Fig. 2 (a), it is observed that the filter bandwidth increases as the length L_S increases. Fig. 2 (b) illustrates the simulated VSWR characteristics with various lengths L_2. As the length L_2 increases from 5.5 to 9 mm, the center frequency of notched band is varied from 7 to 5 GHz. Therefore, a variable band-notched characteristic can be achieved by carefully choosing the parameter L_2 for the T-shaped conductor-backed plane.

For the present antenna design, it can be shown that the parameter L_5 is a



(c)

Fig. 2. (a) Simulated VSWR characteristic of the proposed antenna for various L_S lengths, (b) Simulated VSWR characteristic of the proposed for various L_2 lengths, and (c) Simulated VSWR with and without filter structures.

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critical parameter to control the notch bandwidth and the degree of coupling between the edges of the radiating patch and the vertical arms of the parasitic element. In this case, by increasing L_5, the equivalent capacitance and the quality factor are decreased. Therefore, the notch bandwidth increases. On the other hand, the center frequency of the notch band is almost insensitive to changes in L_5. By increasing L_3 and L_4, the impedance matching of the antenna becomes degraded at higher frequencies.

Fig. 2 (c) shows the effect of T-shaped parasitic element and narrow circular slot in comparison with the same antenna without these elements. It is observed that the sharp frequency band-notch characteristic is obtained when a T-shaped conductor-backed plane is added to the antenna. It is also found that by implementing both the narrow circular slot and the T-shaped parasitic element the optimal band notching can be obtained.

At the notch frequency, the current flows are more dominant around the parasitic element and they are oppositely directed between the parasitic element and the radiating patch. Therefore, the resultant radiation fields cancel out and high attenuation near the notch frequency is produced. Hence, the antenna does not radiate efficiently [6]. All these results certify that the antenna is a promising candidate for UWB communication system to avoid interference with WiMAX (5.25–5.85 GHz) band and WLAN (5.15–5.35/5.725–5.825) bands.

To verify the proposed design, a prototype of the antenna based on optimized dimensions has been fabricated, as shown in Figure 3 (a). The impedance bandwidth was measured by using an Agilent 8722ES Vector Network Analyzer; as shown in Fig. 3 (b), the good agreement between the simulated and measured results is observed. The small difference between the measured and simulated results may be caused by the soldering effect of the SMA connector and its mechanical tolerance, which have been neglected in our simulations. Its measured impedance bandwidth defined by $VSWR < 2$ is from 3.05 to 14.7 GHz while showing the band rejection performance in the frequency band of 5 to 6 GHz.

Two principle planes are selected to present the radiation pattern of the fabricated antenna. These are referred to as y-z plane (E-plane) and x-z plane (H-plane). Fig. 3 (c) illustrates the measured and simulation radiation patterns in the H-plane and E-plane at the frequencies of 4, 8 and 11 GHz of the UWB band. It can be seen that the radiation patterns in x-z plane are nearly omni-directional for the three frequencies. Fig. 3 (d) shows the measured gain of the proposed antenna with and without the notch-band elements. A sharp decrease of antenna gain in the notched frequency band at 5.5 GHz can be observed. For other frequencies outside the rejected band, little change is observed.

4 Conclusion

A novel modified printed monopole antenna with band notched characteristic, used for UWB applications has been presented and investigated. The

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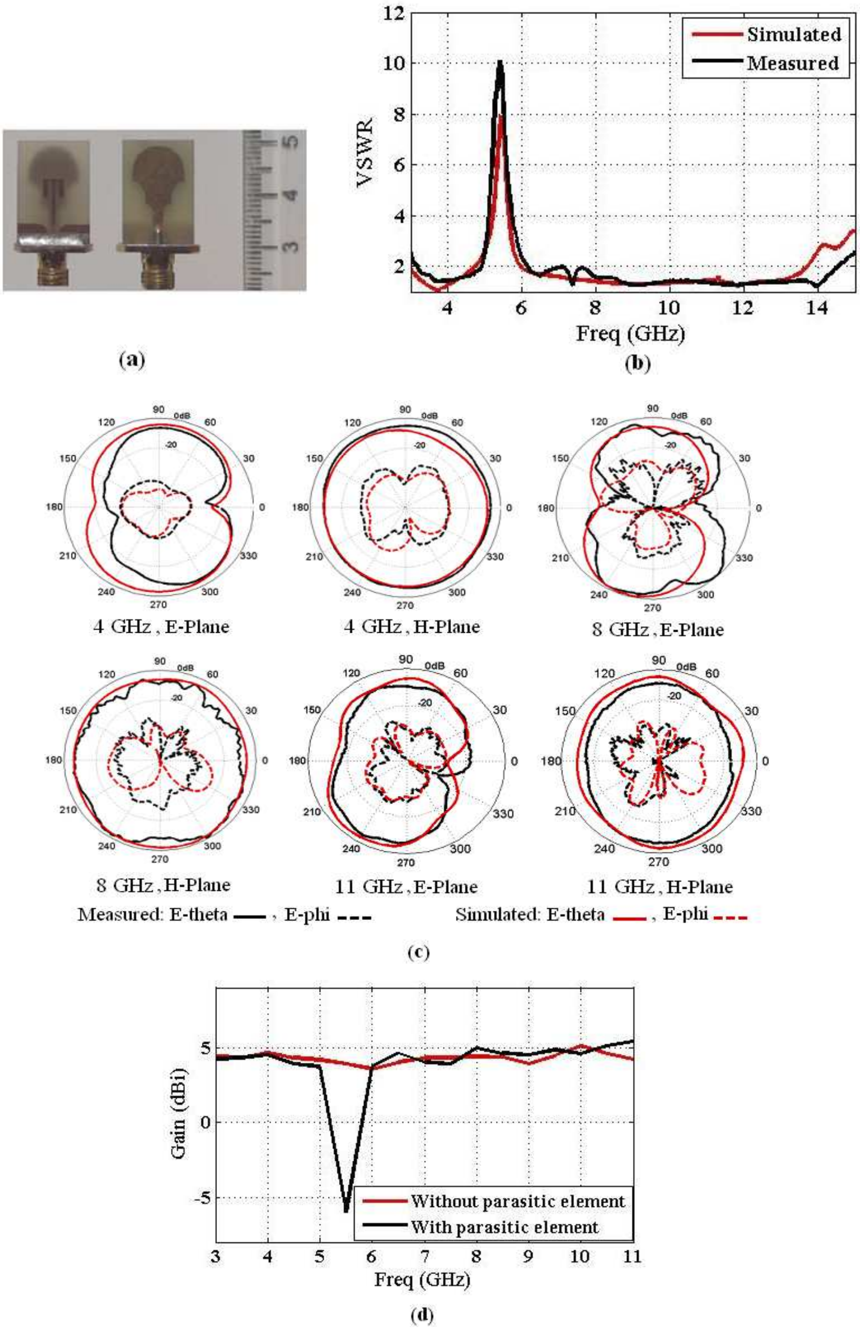

Fig. 3. (a) Photograph of the proposed antenna prototype, (b) Measured and simulated VSWR of the proposed antenna, (c) Measured and simulated radiation patterns of the proposed antenna at frequencies 4, 8, and 11 GHz. (d) Measured antenna gain.

proposed antenna has a T-shaped parasitic element designed on the bottom of the substrate and a narrow circular slot etched on the patch to generate a high value VSWR notch band behavior. It has been observed that such UWB printed monopole antenna has good performance. The simulated results show reasonable agreement with the measured results. The radiation pattern of this antenna shows good omni-directional pattern throughout the

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UWB frequency range.

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