# Disc-Shaped Monopole Antenna with Dual Band-Notched Function for UWB Applications

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***Abstract*** **─** In this paper, we present a novel design of dual band-notched printed monopole antenna for UWB applications. By cutting an anchor-shaped slit in the disc-shaped radiating patch a single frequency band-stop performance can be achieved, also in order to create dual band-notched function, we use a T-shaped strip protruded inside a rectangular slot in the ground plane that with this design, a dual band-notched operation has been obtained. Simulated and measured results obtained for this antenna show that the proposed monopole antenna offers two notched bands, covering all the 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX and 4 GHz C bands range. Good antenna gains and radiation behavior within the UWB frequency range have also been obtained. The antenna has a small dimension of $12\times 18$ mm$^2$.

***Index Terms*** **─** Anchor-shaped slit, disc-shaped radiating patch, dual band-notched function, T-shaped protruded strip structure, and ultra wide band (UWB) systems.

## I. INTRODUCTION

In UWB communication systems, one of the key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Consequently, a number of printed monopole antennas with different geometries have been experimentally characterized and automatic design methods have been developed to achieve the optimum planar shape. Moreover, other strategies to improve the impedance bandwidth have been investigated [1-4]. The frequency range for UWB systems between 3.1 GHz to 10.6 GHz will cause interference to the existing wireless communication systems, such as, the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15 GHz – 5.35 GHz and 5.725 GHz – 5.825 GHz bands, WiMAX (3.3 GHz – 3.6 GHz) and C-band (3.7 GHz – 4.2 GHz), so the UWB antenna with a single and dual band-stop performance is required. Lately to generate the frequency band-notch function, modified planar monopoles several antennas with band-notch characteristic have been reported [5-7]. In [5], and [6], different shapes of the slots (i.e., SIR and folded trapezoid) are used to obtain the desired band notched characteristics. Half wavelength U-shaped slots are embedded in the radiating patch to generate the single and multiple band-notched functions [7].

In this paper, a novel and compact microstrip-fed monopole antenna with dual band-notched characteristic for UWB applications has been designed and manufactured. In the proposed structure, single frequency band-notched characteristics is obtained by applying the anchor-shaped slit in the disc-shaped radiating patch and also by creating the T-shaped strip protruded inside the rectangular slot in the ground plane, dual band-notched function can be provided. The dual notch bands, covering 5.02 GHz – 5.97 GHz WLAN band, 3.3 GHz – 3.8 GHz WiMAX, and

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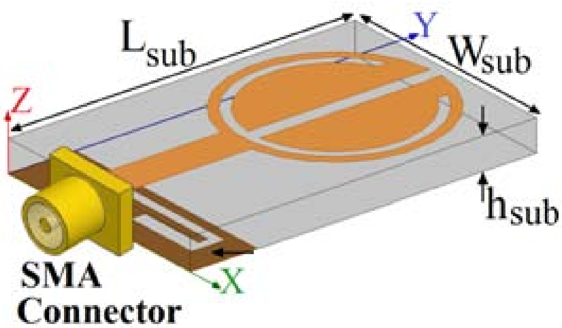
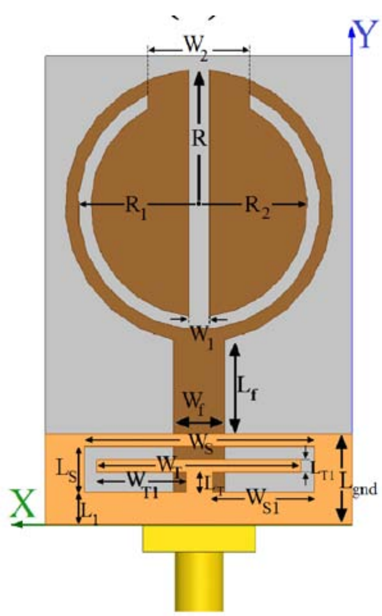
3.7 GHz – 4.2 GHz C- Band. Details of the proposed design and experimental results are also presented and discussed. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest.

## II. ANTENNA DESIGN

The presented small monopole antenna fed by a microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 1.6 mm, permittivity 4.4, and loss tangent 0.018. The basic monopole antenna structure consists of a disc-shaped radiating patch, a feed line, and a ground plane. The proposed antenna is connected to a 50-Ω SMA connector for signal transmission.




(a)




(b)

Fig. 1. Geometry of the proposed monopole antenna; (a) side view and (b) bottom view.

In this study, the anchor-shaped slit in the radiating patch perturbs the resonant response and also acts as a half-wave resonant structure [8-9]. At the notch frequency, the current concentrated on the edges of the interior and exterior of this slit [8]. Additionally, based on Defected Ground Structure (DGS), the rectangular slot with a T-shaped protruded strip inside the slot act as a filtering element to create a new band notch function of the proposed antenna, because it can create additional surface current path in the ground plane. At the notch frequency, the current flows are more dominant around the modified slot, and they are oppositely directed between the protruded strip and the ground plane [10]. As a result, the desired high attenuation near the notch frequency can be produced, in addition to the modified inverted T-shaped coupled strip.

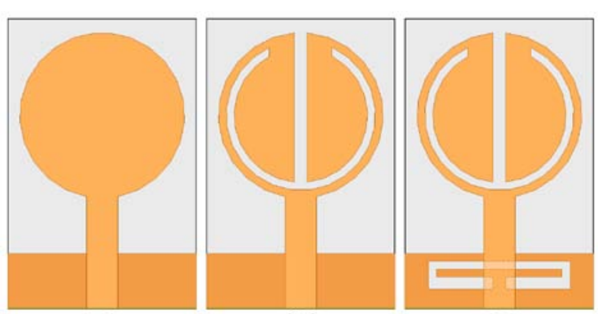
In this work, we start by choosing the dimensions of the designed antenna. These parameters, including the substrate, are $W_{Sub} \times L_{sub} = 12\ mm \times 18\ mm$ or about $0.15\lambda \times 0.25\lambda$ at 4.2 GHz (the first resonance frequency). Next step, we have to determine the radius of the radiating patch $R$. This parameter is approximately $\lambda_{lower} / 4$, where $\lambda_{lower}$ is the lower bandwidth frequency wavelength. $\lambda_{lower}$ depends on a number of parameters, such as the radiating patch length as well as the thickness and dielectric constant of the substrate on which the antenna is fabricated [11]. The important step in the design is to choose $L_{notch}$ (the length of the filter). $L_{notch}$ is set to band-stop resonate at $0.5\lambda_g$, where $L_{notch1}=R+0.5\prod \times(R_1+R_2)$, and $L_{notch2}=0.5W_S+W_{S1}+L_S+L_T+W_T$, $\lambda_{g1}$ and $\lambda_{g2}$ correspond to the notched band frequencies wavelength (3.8 GHz is the first notched frequency and 5.5 GHz is the second notched frequency). The optimized values of the proposed antenna design parameters are as follows:

$W_{sub} = 12\ mm$, $L_{sub} = 18\ mm$, $h_{sub} = 1.6\ mm$, $W_f = 2\ mm$, $L_f = 3.5\ mm$, $R = 10\ mm$, $R_1 = 4.75\ mm$, $R_2 = 4.5\ mm$, $W_1 = 0.5\ mm$, $L_1 = 1.5\ mm$, $W_2 = 4\ mm$, $W_S = 10\ mm$, $L_S = 1.75\ mm$, $W_{S1} = 4.5\ mm$, $W_T = 9.5\ mm$, $L_T = 0.75\ mm$, $W_{T1} = 4.25\ mm$, $L_{T1} = 0.5\ mm$, and $L_{gnd} = 3.5\ mm$.

## III. RESULTS AND DISCUSSIONS

The proposed microstrip-fed monopole antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The Ansoft simulation software high-frequency structure simulator (HFSS) [12] version 13, with frequency sweep from 2 GHz to 12 GHz, is used to optimize the design and agreement between the simulation and measurement is obtained. The parameters of this proposed antenna, such as $W_2$ and $W_S$, are studied by changing one parameter at a time and also changing the others. In the HFSS by default, the antenna excited by wave port that is renormalized to a 50-Ohm full port impedance. The proposed antenna is connected to a 50-Ohm SMA connector for signal transmission.

The structure of various antennas used for simulation studies is shown in Fig. 2. Return loss characteristics for the ordinary disc-shaped monopole antenna (Fig. 2 (a)), disc-shaped monopole antenna with anchor-shaped slit (Fig. 2 (b)), and the proposed antenna structure (Fig. 2 (c)) are compared in Fig. 3. As shown in Fig. 3, to generate single frequency band-notched function (3.3/4.2 GHz), we insert anchor-shaped slit in the radiating patch of the ordinary disc-shaped monopole antenna, and also by using a rectangular slot with a T-shaped protruded inside the rectangular slot in the ground plane, the dual band-notch function can be achieved, that covering all the 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX and 4-GHz C band. Also the input impedance of the proposed monopole antenna structure that is shown in Fig. 1, on a Smith chart is shown in Fig. 4.



(a) (b) (c)

Fig. 2. The structure of the (a) ordinary disc-shaped monopole antenna, (b) disc-shaped monopole antenna with anchor-shaped slit, and (c) the proposed antenna structure.

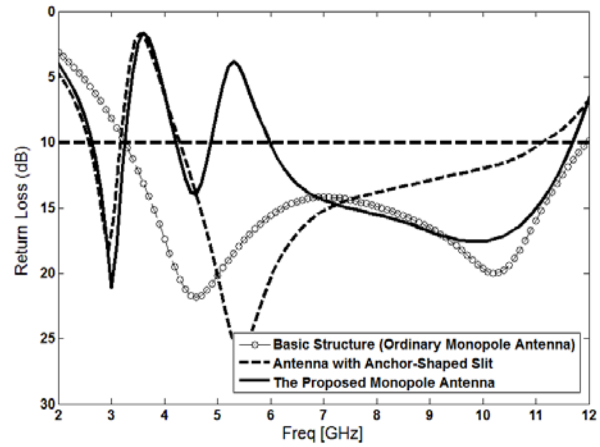



Fig. 3. Simulated return loss characteristics for the various monopole antennas shown in Fig. 2.

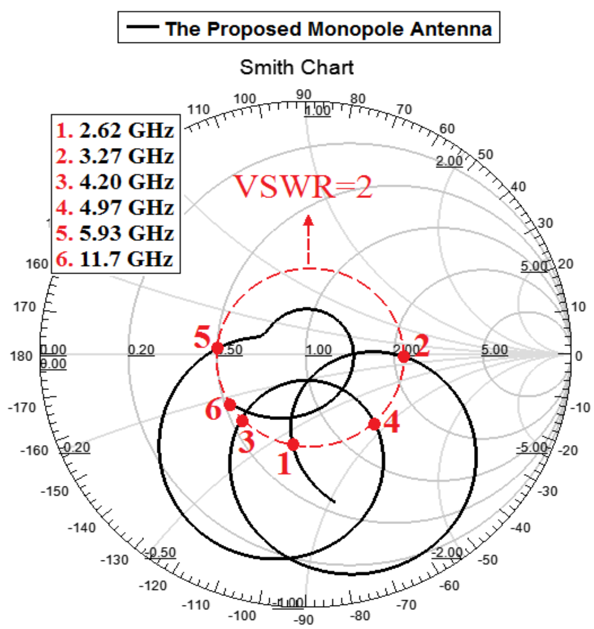



Fig. 4. Smith chart demonstration of the simulated input impedance for the proposed antenna.

In order to know the phenomenon behind this additional resonance performance, the simulated current distributions on the patch for the proposed antenna at 3.8 GHz are presented in Fig. 5 (a). It can be observed in Fig. 5 (a), that the current is concentrated on the edges of the interior and exterior of the anchor-shaped slit at 3.8 GHz. Another important design parameter of this structure is the rectangular slot with a T-shaped protruded strip inside the rectangular slot, used in the ground plane. Figure 5 (b) presents the simulated current distributions on the modified ground plane at the second notch frequency (5.5 GHz). As shown in Fig. 5 (b), at the second notch frequency the current flows are more dominant around the slot with T-shaped protruded strip. As a result, the desired high attenuation near the second notch frequency can be produced [13-14].

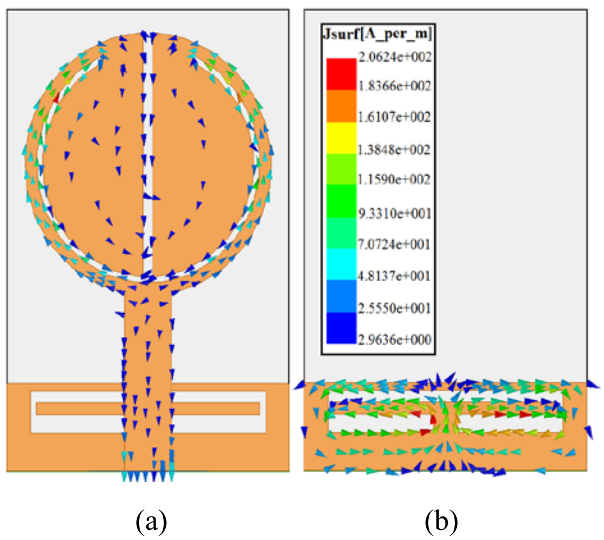



Fig. 5. Simulated surface current distributions for the proposed antenna (a) on the radiating patch at 3.8 GHz and (b) on the ground plane at 5.5 GHz.

Figure 6 shows the conceptual equivalent circuit model for the proposed antenna, which has two RLC band-stop filters. When the current path in the T-shaped strip protruded inside the rectangular slot in the ground plane, which is equal to a half-wavelength at 5.5 GHz as shown in Fig. 6 (b), and in the anchor-shaped slit inside the disc shaped radiating patch, which is equal to a half-wavelength at 3.8 GHz as shown in Fig. 6 (c); the input impedance at the feeding point is equal to zero (short circuit).

Figure 7 shows the simulated VSWR curves with different values of $W_2$ and $W_S$. As shown in Fig. 6, when the width $W_2$ increases from 2 *mm* to 6.5 *mm*, the center of the first notch frequency decreases from 4.17 GHz to 3.26 GHz, also when the exterior width of the rectangular slot $W_S$ increases from 8 *mm* to 11 *mm*, the center of the second notch frequency decreases from 5.93 GHz to 4.79 GHz. From these results, we can conclude that the centers of the notch frequencies are controllable by changing these parameters [15].

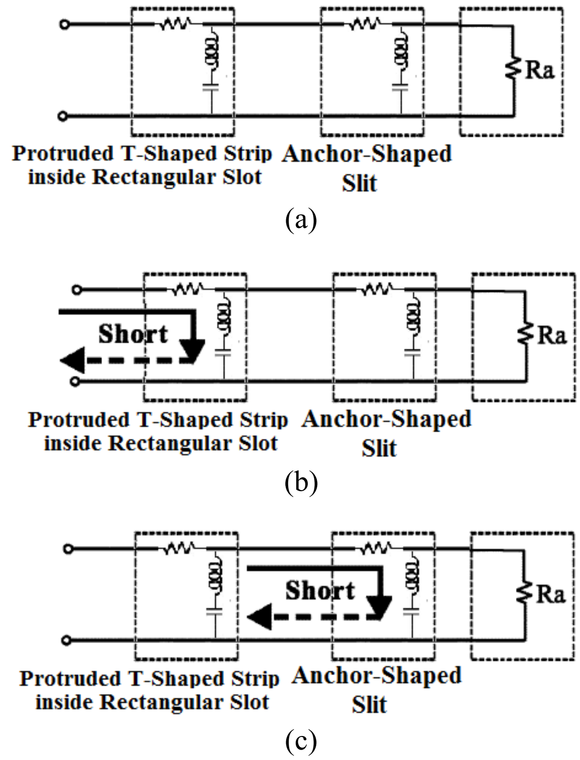



Fig. 6. Conceptual equivalent-circuit model for (a) the proposed antenna, (b) at the second notched frequency, (c) at the first notched frequency.

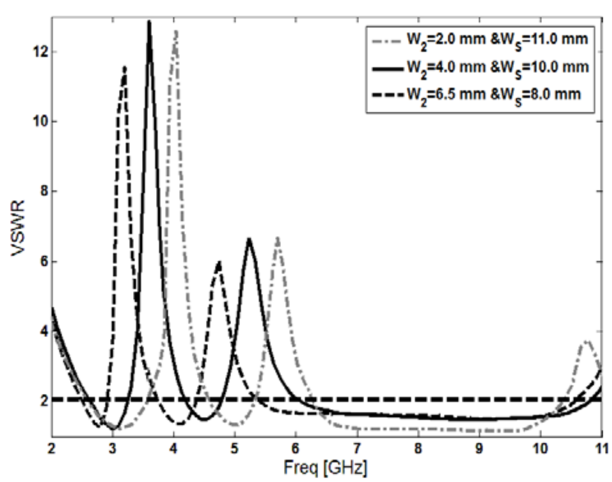



Fig. 7. Simulated VSWR characteristics for the proposed antenna with different values of $W_2$ and $W_S$.

The proposed antenna was built and tested. The measured and simulated VSWR characteristics of the proposed antenna are shown in Fig. 8. The fabricated antenna has the frequency band of 2.77 GHz to over 11.63 GHz with two notched-band function, covering all the 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX and 4 GHz C-Band range. As shown in Fig. 8, there exists a discrepancy between the measured data and the simulated results. Figure 9 illustrates the measured radiation patterns, including the co-polarization and cross-polarization, in the H-plane (xz plane) and E-plane (yz plane). It can be seen that the radiation patterns in the xz plane are nearly omni-directional for the three frequencies.

Figure 10 shows the effects of the anchor-shaped slit and the rectangular slot with a T-shaped protruded strip inside the rectangular slot, on the maximum gain in comparison to the same antenna without them. As shown in Fig. 10, the ordinary disc-shaped monopole antenna has a gain that is low at 3 GHz and increases with frequency. It can be observed in Fig. 10 that by using a disc-shaped radiating patch with an anchor-shaped slit and the rectangular slot with a T-shaped protruded strip inside the rectangular slot in the ground plane, two sharp decreases of maximum gain in the notched frequencies band at 3.8 GHz and 5.5 GHz are shown in Fig. 10. For other frequencies outside the notched frequency band, the antenna gain with the filters is similar to those without it.

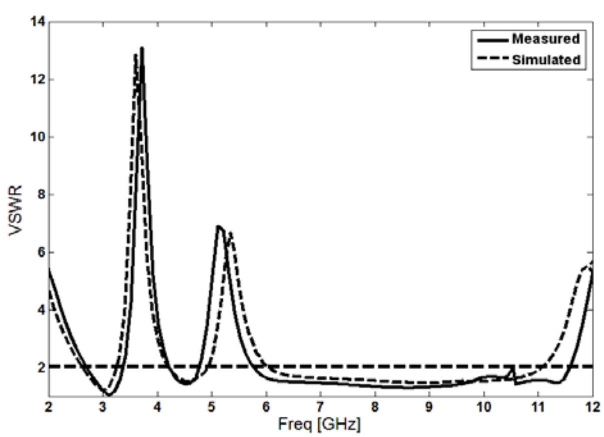



Fig. 8. Measured and simulated VSWR characteristics for the proposed antenna.

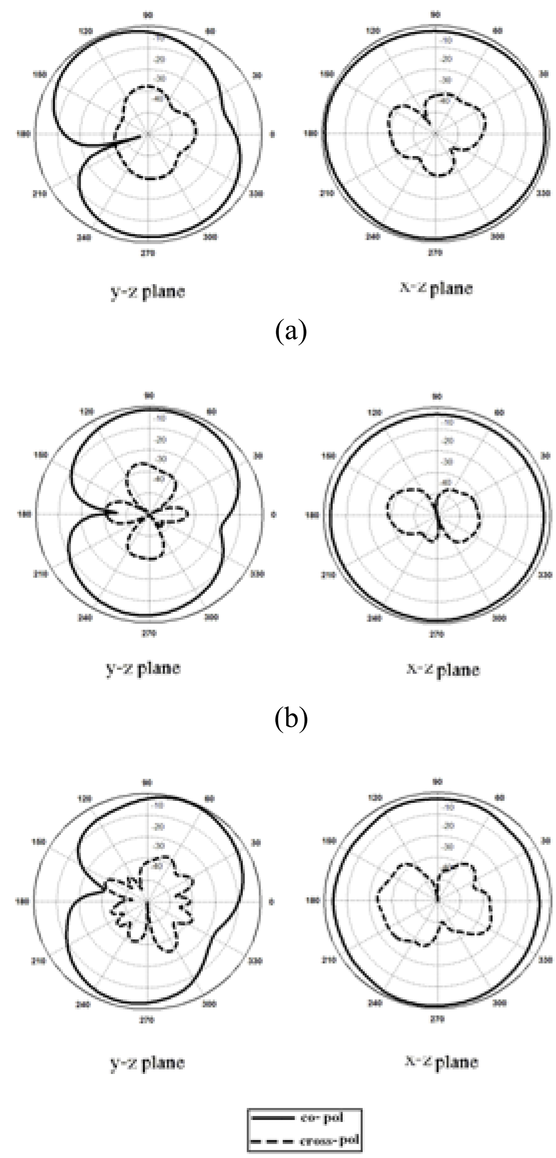



Fig. 9. Measured radiation patterns of the proposed antenna at (a) 4.5 GHz, (b) 7.3 GHz, and (c) 9.5 GHz.

## IV. CONCLUSION

In this paper, we propose a novel design of ultra wide band monopole antenna with dual band-notch function. The presented disc-shaped monopole antenna can operate from 2.77 GHz to 11.63 GHz with two rejection bands around 3.3 GHz – 4.2 GHz and 5.01 GHz – 5.9 GHz. By inserting the anchor-shaped slit structure in the disc-shaped radiating patch a single band-stop performance can be achieved, also in order to generate a dual band-notched function, we use the rectangular slot with a T-shaped protruded strip inside the rectangular slot in the ground plane. The proposed antenna has a simple configuration and is easy to fabricate. Simulated and experimental results show that the proposed antenna could be a good candidate for UWB applications.

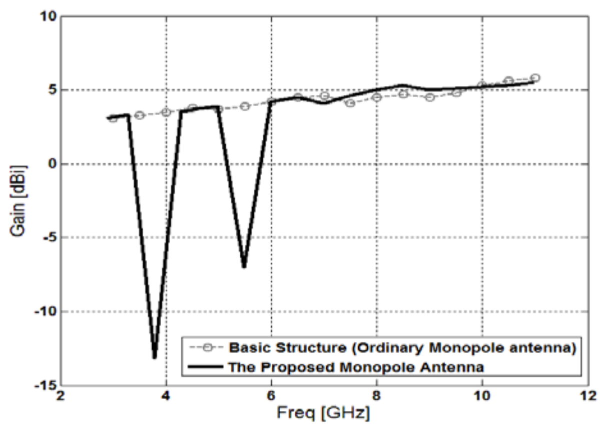



Fig. 10. Maximum gain comparisons for the ordinary disc-shaped monopole antenna (simulated) and the proposed antenna (measured).

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