# A Compact Dual Band –Notched UWB Antenna using Inverted T-shaped Slots

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Abstract: *This paper proposes a compact printed monopole antenna with dual band-notched characteristics for ultrawideband application. The proposed antenna consist two inverted T-shaped slots in radiating patch, which provides dual band-notched characteristics and partial ground plane with a slit, which provides large usable fractional bandwidth 129% (2.8-13.1 GHz).The upper inverted T-shaped slot provides notch band for 3.5/5.5-GHz WIMAX between 3.3-4 GHz and lower inverted T-shaped slot provides notch band for 5.2/5.8-GHz WLAN between 4.6-5.9 GHz. By properly adjusting the dimension of these slots band-notched characteristics such as notch frequency and notch bandwidth can be control. The proposed antenna has size of 24×28 mm$^2$ and provides 10 dB return loss bandwidth from 2.8 GHz to 13.1 GHz with two notched bands, covering 5.2/5.8-GHz WLAN, 3.5/5.5-GHz WIMAX. The simulated VSWR and radiation pattern of proposed antenna are presented, which prove that the proposed antenna is a good candidate for various UWB applications*.

**Keywords:** Compact printed monopole antenna, inverted T-shaped slot, ultrawideband (UWB) application**.**

## 1. Introduction

In the last few years, the ultrawideband (UWB) technology has been developed widely and rapidly. Commercial ultra-wideband (UWB) systems require small low-cost antennas with omnidirectional radiation patterns and large bandwidth. Among the newly proposed ultrawideband (UWB) antenna designs, the printed monopole antennas should be the most promising candidate because of their simple structure, small size, and low cost. Due to all these interesting characteristics, planar monopoles are extremely attractive to be used in emerging UWB applications, and growing research activity is being focused on them. Consequently, a number of planar monopoles with different geometries have been experiment-ally characterized [1], [2].

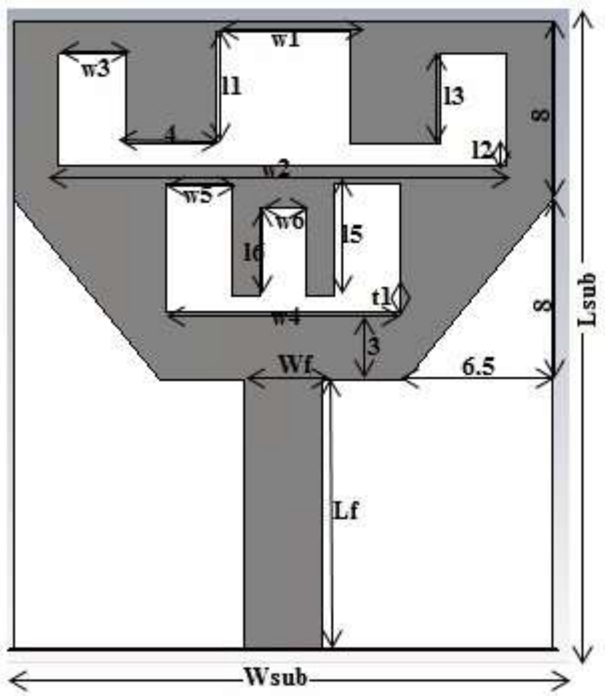
UWB printed antenna designers often face challenges such as meeting space constraints, achieving a wide impedance bandwidth and wide radiation patterns. In addition, the antenna may need to reject effectively potential interference from the existing narrowband systems operating at higher power levels. This particular requirement becomes more stringent as many wireless systems including 3.6 GHz IEEE 802.11y Wireless Local Area Networks (WLAN) (3.6575-3.69 GHz), 4.9 GHz public safety WLAN (4.94–4.99 GHz) and 5 GHz IEEE 802.11a/h/j/n WLAN (5.15–5.35 GHz, 5.25–5.35 GHz, 5.47–5.725 GHz, 5.725–5.825 GHz) are operating within the FCC UWB band of 3.1–10.6 GHz. So that UWB antennas are also necessary for the rejection of the electromagnetic interfaces with these existing communication systems.

The most commonly used method is inserting various shapes of slots in the radiating elements or in the ground plane [3]–[9]. Parasitic elements, electromagnetic- band gap (EBG) structures [10], integrated stop band filters [11], defected ground structures (DGS) [12], [13] and frequency selective surfaces (FSS) positioned above the antennas [14] have also been used to achieve band rejection. Another popular method is to use a resonator on the other side of the substrate, such as a split ring resonator (SRR), square ring resonator [15], CPW resonator [7], composite right/left-handed (CRLH) resonator [16], capacitive loaded loop (CLL) resonator, open-loop resonator [17], [18] or a dual-gap open-loop resonator.

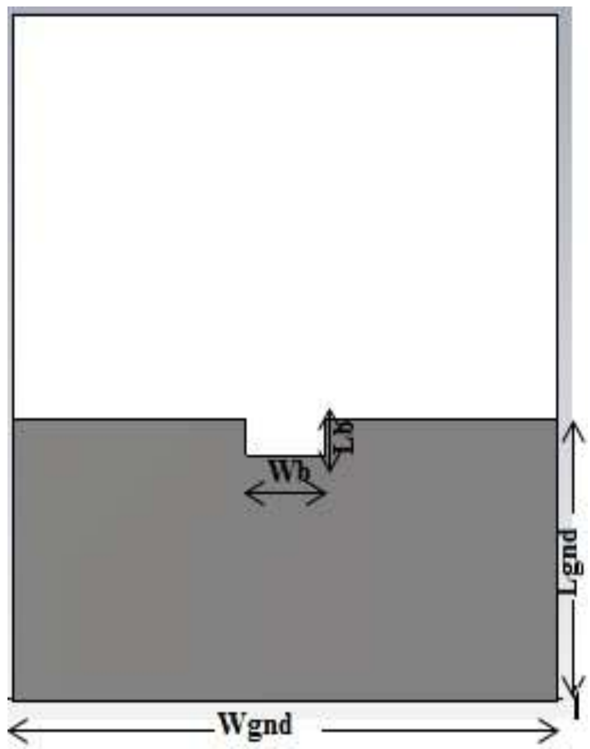
In this paper a simple and more compact dual band-notched monopole antenna is proposed. First, by inserting a slit at ground plane, fractional bandwidth increased up to more than 140% (2.4-13.6 GHz). Then dual band-notch function is provided by cutting two inverted T-shaped slots in radiating patch, in which upper slot provides a notch band between 3.2-3.8 GHz and lower slot provides notch band between 4.9-6.5 GHz. Hence proposed antenna provides wide impedance bandwidth between 2.4-13.6 GHz with dual band-notch covering 5.2/5.8-GHz WLAN, 3.5/5.5-GHz WIMAX.

## 2. Antenna Design and Configurations

Fig. 1 shows the geometry of the proposed printed UWB antenna, which is printed on 28×24 mm$^2$ RO4003TM substrate with dielectric constant of 3.38 and thickness of 1.524 mm. The basic antenna structure consist a 16×24 mm$^2$ rectangular patch which is chamfered at the bottom edge, 50Ω microstrip line which is 3.5 mm wide and 12 mm long and a ground plane with a slit of dimension 1.5×3.5 mm$^2$. The proposed antenna is connected to a 50Ω SMA connector for signal transmission.




(a) Front view




(b) Rear view

**Figure 1**: Geometry of proposed antenna

In this structure, by creating a rectangular slit in ground plane impedance matching of antenna is changed. The optimized dimension of slit 1.5 × 3.5 $mm^2$ provides better impedance matching and leads the antenna to operate between 2.8 – 13.1 GHz. To realize dual band-notched characteristics two inverted T-shaped slots are embedded in radiating patch. The upper slot provides notch band between 3.3 – 4 GHz covering 3.5/5.5-GHz WIMAX and lower slot provides notch band between 4.6 – 5.9 GHz covering 5.2/5.8-GHz WLAN.

The optimal dimensions of the designed antenna are as follows: Wsub = 24 mm, Lsub = 28 mm, Wf = 3.5 mm, Lf = 12 mm, Wgnd = 24 mm, Lgnd = 11.5 mm, l1 = 5 mm, l2 = 1 mm, l3 = 4 mm, l5 = 5 mm, l6 = 4 mm, w1 = 6 mm, w2 = 20 mm, w3 = 3 mm, w4 = 10.5 mm, w5 = 3 mm, w6 = 2 mm, t1 = .7 mm Moreover, the structure of the antenna is symmetrical with respect to the longitudinal direction.

## 3. Results and Discussions

In this Section, the printed monopole antenna with various design parameters was constructed, and simulated return loss, and radiation characteristics are presented and discussed.

The parameters of this proposed antenna are studied by changing one parameter at a time and fixing the other. The designed antenna is simulated using CST Microwave Studio [19].

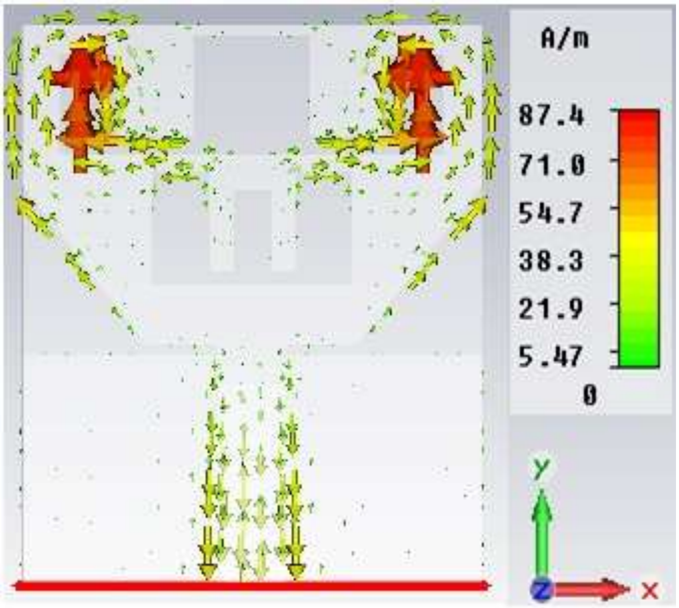
### 3.1 Full Band UWB Monopole Antenna

To increase impedance bandwidth of simple printed monopole antenna a rectangular slit created in ground plane as shown in Fig. 1. Fig. 2 shows the effect of slit on the impedance matching in comparison to the same antenna without them. It is observed that by inserting rectangular slit in ground plane, the impedance matching of antenna can be improved. Hence impedance bandwidth is effectively increased up to 13.1 GHz.

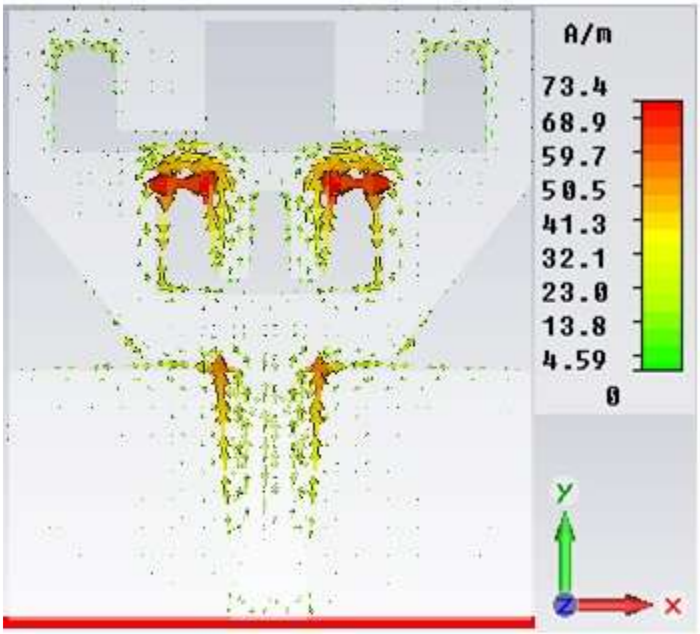

**Figure 2:** Simulated VSWR characteristics for simple monopole antenna and monopole antenna with rectangular slit in ground plane

### 3.2 UWB Monopole Antenna with Dual Band-Notched Characteristics

To realize band-notched characteristics two inverted T-shaped slots embedded in radiating patch as shown in Fig. 1. The upper T-shaped slot provides notched band ranging 3.3 – 4 GHz which cover 3.5/5.5-GHz WIMAX (3.3 – 3.6 GHz) and lower inverted T-shaped slots provides notched band ranging 4.6 –5.9 GHz which cover 5.2/5.8-GHz WLAN (5.15 – 5.825 GHz).




(a)




(b)

**Figure 3:** Simulated surface current distributions on the radiating patch for the proposed antenna at (a) 3.5 GHz (first notch frequency) and (b) 5.5 GHz (second notch frequency).

In order to understand the phenomenon behind this dual band-notch performance, the simulated current distribution on the radiating patch for the proposed antenna at the notch frequencies of 3.5 GHz and 5.5 GHz is presented in Fig. 3(a) and 3(b), respectively. It can be observed in Fig. 3(a) and 3(b) that the current concentrated on the edges of the interior and exterior of the upper inverted T-shaped slot at 3.5 GHz and on the edges of the interior and exterior of the lower inverted T-shaped slot at 5.5 GHz. It can be observed from Fig. 3 (a) and 3 (b) that currents are oppositely directed between the interior and exterior edges. Therefore, the resultant radiation fields becomes canceled out, and high attenuation near the resonant frequency is achieved, therefore the proposed antenna at these notch frequencies does not radiate efficiently which results in notched band.

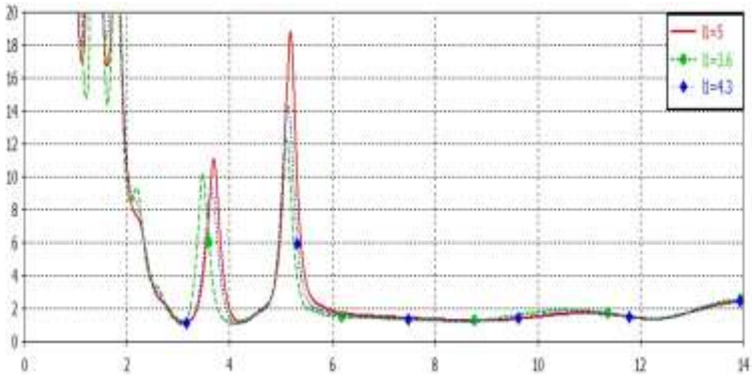
The center frequency of the notch band, along with peak VSWR, is controlled by the length, width and position of the inverted T-shaped slots, as described below.

**1) Effect of l1 Variation:** By varying length l1 of upper inverted T-shaped slot notch frequency for WiMAX notch band can be controlled. The effects of l1 variation on notch frequency are shown in Fig. 4(a). It can be observed from Fig. 4 (a), as the l1 increases from 3.6 mm to 5 mm, the notch frequency decreases from 3.6 GHz to 3.4 GHz.

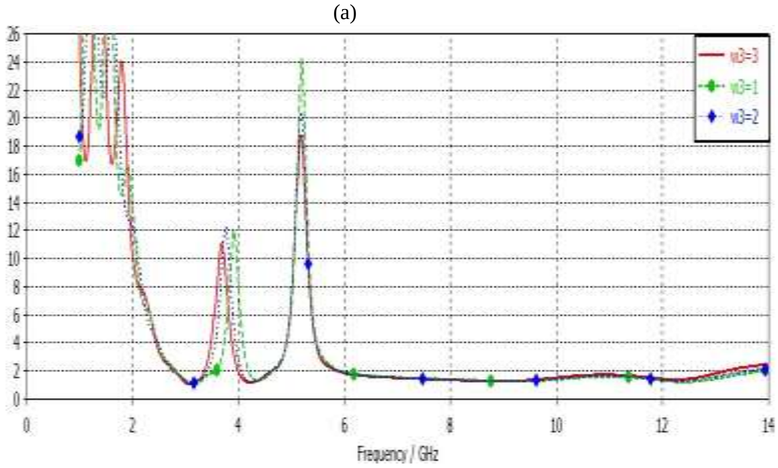
**2) Effect of w3 Variation:** The effect of gap w3 variation on notch frequency is shown in Fig. 4(b). It can be observed from Fig. 4(b) as the gap w1 increases from 1 mm to 3 mm, the notch frequency for WiMAX notch band decreases from 3.9 GHz to 3.6 GHz.

**3) Effect of w5 Variation:** By varying length w5 of lower inverted T-shaped slot notch frequency for WLAN notch band can be controlled. The effects of w5 variation on notch frequency are shown in Fig. 4(c). It can be observed from Fig. 4 (c), as the w5 increases from 1 mm to 2 mm, the notch frequency decreases from 5.2 GHz to 5 GHz and increases from 2 mm to 3 mm notch frequency increases to 5.17 GHz.

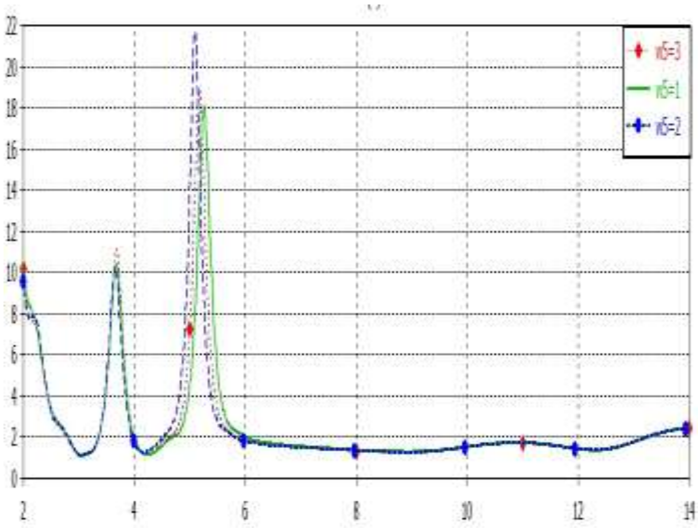
**4) Effect of l5 Variation:** By varying length l5 of lower inverted T-shaped slot notch frequency for WLAN notch band can be controlled. The effects of l5 variation on notch frequency are shown in Fig. 4(d). It can be observed from Fig. 4 (d), as the l5 increases from 2 mm to 5 mm, the notch frequency decreases from 7.2 GHz to 5.17 GHz.



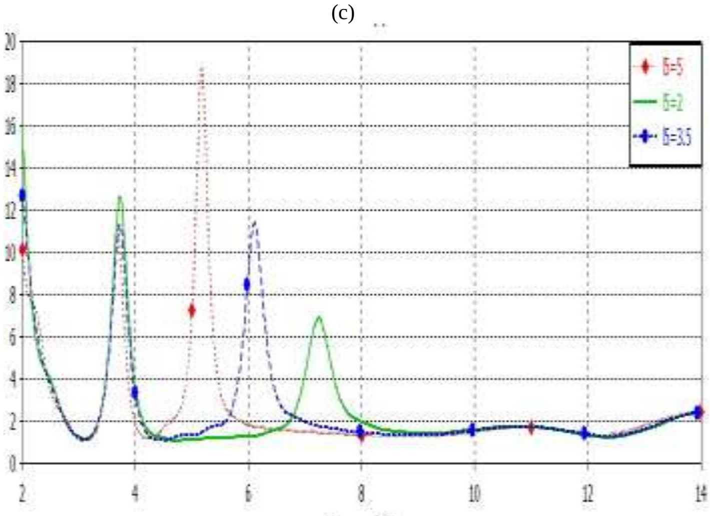
(a)




(b)



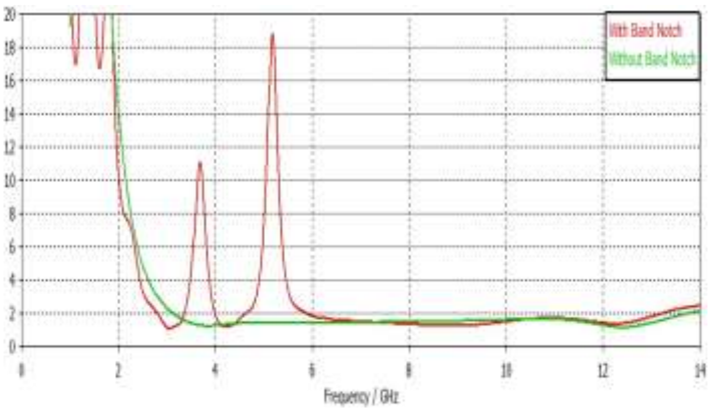

(c)



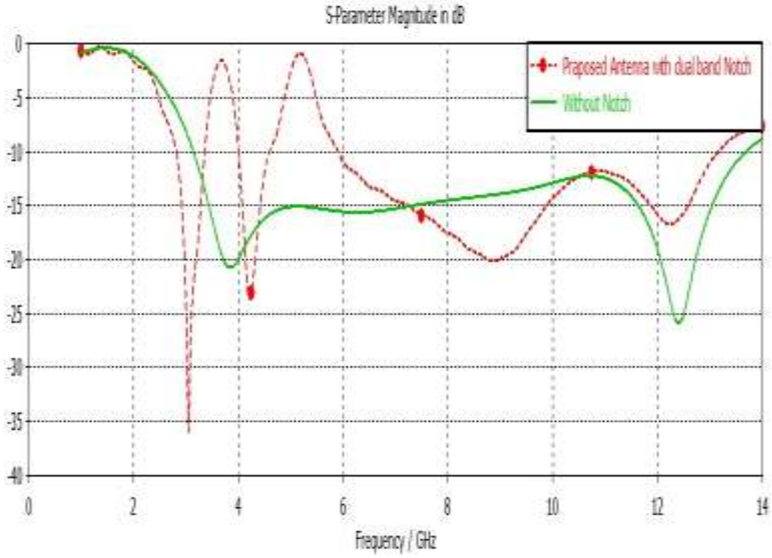

(d)

**Figure 4:** Simulated VSWR curve with different value of (a) l1, (b) w3, (c) w5 and (d) l5 while fixing other parameter

Fig. 5 shows the simulated VSWR characteristics for VSWR ≤ 2 and return loss characteristics for S11 < -10dB of proposed antenna in comparison of same antenna without inverted T-shaped slots at optimal parameter. The simulated antenna covers the frequency range for UWB system between 2.8–13.1 GHz with two notched bands of 3.3–4 GHz and 4.6–5.9 GHz, which cover the 3.5/5.5-GHz (3.4–3.69/5.25–5.85 GHz) WiMAX bands, 5.2/5.8-GHz (5.15–5.35/5.725–5.825 GHz) WLAN bands. It is also clearly seen that by using this filtering structure, the lowest frequency of the antenna is significantly decreased from 3.1 to 2.8 GHz.




(a)




(b)

**Figure 5:** Simulated (a ) VSWR curve and (b) Return loss curve of proposed antenna in comparison of same antenna without inverted T-shaped slots.

Fig. 6 shows the simulated radiation pattern at 4 GHz, 8GHz, and 12 GHz in two principle planes. These planes are referred to as plane y-z (E-plane) and plane x-z (H-plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. The simulated results of these radiation patterns shows that the antenna behaves quite similarly to the typical printed monopoles in E-plane and has nearly omni-direction radiation pattern in H-plane.

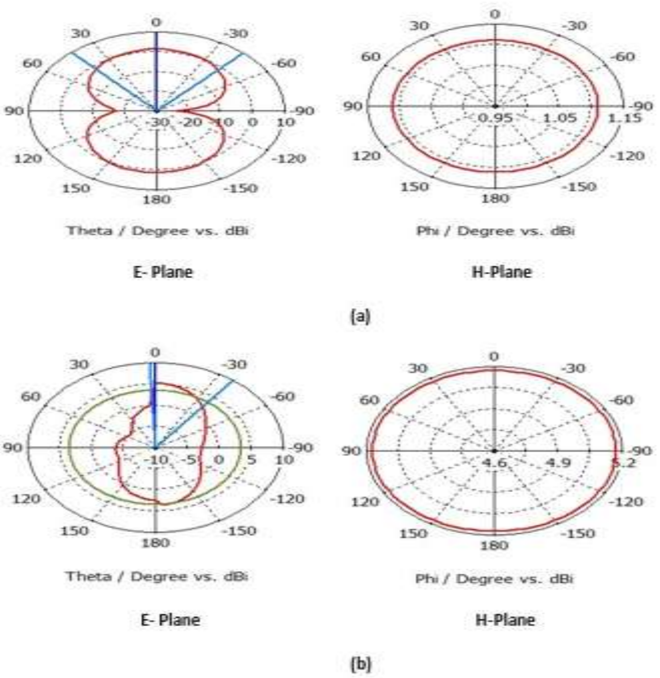



**Figure 6:** Simulated radiation pattern of proposed antenna at (a) 4 GHz, (b) 8 GHz

Fig. 7 shows the measured maximum gain comparison with and without band-notch function. As shown in Fig. 7, gain decreases at the frequency bands of 3.5 GHz and 5.5 GHz. Outside the notched band, proposed antenna gain is approximately similar to simple monopole antenna.Thus, the antenna exhibits stable gain across the operation band.

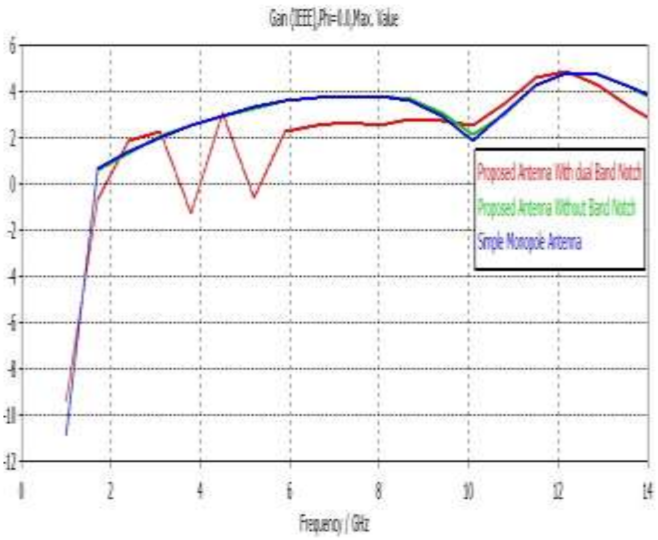



**Figure 7:** Maximum gain comparison of proposed antenna

## 4. Conclusion

A microstrip-fed printed monopole antenna dual band-notched characteristic for UWB applications has been presented and investigated. We showed that by embedding a rectangular slit in ground plane, the proposed antenna offers wide impedance bandwidth from 2.8 to 13.1 GHz and also dual rejection band around 3.3-4 GHz, 4.6- 5.9GHz can be achieved using two inverted T-shaped slot in radiating patch, which exempt interfaces with existing 3.5/5.5-GHz (3.4–3.69/5.25–5.85 GHz) WiMAX bands, 5.2/5.8-GHz (5.15–5.35/5.725–5.825 GHz) WLAN bands. It is also seen that by employing these slots, the lowest frequency of the band can be remarkably decreased up to 0.3 GHz. The proposed antenna shows 10dB impedance bandwidth from 2.8-13.1 GHz.

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