A Compact Printed Wide-Slot UWB Antenna With Band-Notched Characteristics

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***Abstract*—In this paper, we present an offset microstrip-fed ultrawideband antenna with band notched characteristics.The antenna structure consists of rectangular radiating patch and ground plane with rectangular shaped slot,which increases impedance bandwidth upto 123.52%(2.6-11GHz).A new modified U slot is etched in the radiating patch to create band-notched properties in the WiMAX (3.3-3.7GHz) and C-band satellite communication (3.7-4.15GHz).Furthermore, parametric studies have been conducted using EM simulation software CADFEKO suite(7.0).A prototype of antenna is fabricated on 1.6mm thick FR-4 substrate with dielectric constant of 4.4 and loss tangent of 0.02.The proposed antenna exhibits directional and omnidirectional radiation patterns along E and H-plane with stable efficiency over the frequency band from 2.6GHz to 11GHz with VSWR less than 2,except 3.3-4.15GHz notched frequency band.The proposed antenna shows good time domain analysis.**

Keywords—ultrawideband(UWB); L-shaped ground plane; modified U-slot; slot antenna; band notch.

I. INTRODUCTION

According to FCC UWB is a very promising technology that have a large unlicenced bandwidth of 7.5GHz ranging from 3.1GHz to 10.6GHz [1].Since then UWB communication system has been favourable due to various advantages such as high data transmission rate,low cost and ease of integration.Now-a-days,recent communication systems required single antenna having large impedance bandwidth.In order to enhance wide impedance bandwidth of UWB antenna in that case slot antenna is the important part which satisfy demand of UWB.To improve impedance bandwidth different shapes of slot such as rectangle,circle,elliptical,hexagonal,pentagonal,tapered has been used.

The ultrawideband communication system is entitled to operate within 3.1-10.6GHz band.There are some narrow band wireless communication systems are exist within the UWB system.These narrowband systems are Wi-MAX (IEEE802.16) operating in the frequency band of 3.3-3.7GHz, C-band satellite communication operating in the frequency band of 3.7-4.15GHz, WLAN(IEEE 802.11a and HIPERLAN/2) operating in the frequency band of 5.15-5.825GHz, X-band satellite communication operating at 7.25-7.75GHz band. These narrow band systems can cause interference to the UWB system. Hence, it is essential to design UWB antenna with band notched characteristics in the frequency band of 3.3-3.7GHz, 3.7-4.15GHz, 5.15-5.825GHz,7.25-7.75GHz respectively,to reduce interference between WiMAX, C-band, WLAN, X-band and UWB system.

To reduce this interference,many significant band-notched techniques have been used in UWB antennas,including etching an angle-shaped parasitic slits[2],C-shaped slot and L-shaped stub[3], a pair of S-shaped slits and elliptical ring slot[4], inverted U and fork-shaped parasitic structures[5].Band rejection characteristics are obtained by embedding different shapes of the slots such as a square ring[6] and folded trapezoid[7].In [8]-[9] dual band antenna operating in bluetooth and UWB proposed but without band-notched characteristics.In [10] the UWB antenna with integrated Bluetooth and band-notched characteristics are investigated ,so as to reduce interference between narrowband and UWB systems .In reference[11] U- slot is used to realize single band notched function and in reference[12] dual band notching with integrated Bluetooth have been proposed.

In this paper,a compact band-notch UWB antenna is presented.By inserting modified U slot in the radiating patch band notch function from 3.3-4.15GHz is obtained.The designed antenna is simulated using CADFEKO suite(7.0).By cutting wide rectangular slot from ground plane much wider impedance bandwidth from 2.6GHz to 11GHz can be obtained.

II. ANTENNA DESIGN

Fig.1 describes the evolution of rectangular slot UWB antenna.The basic antenna comprises a rectangular patch and ground plane with rectangular slot.The basic rectangular monopole UWB antenna is simulated using FR-4 substrate having compact substrate dimension of $33 \times 35.5 \times 1.6\text{mm}^3$. Rectangular tunning stub is fed by an offset microstrip line

To achieve 50Ω characteristics impedance feedwidth of microstrip line can be calculated using formula (1).

$$z = \frac{377}{\sqrt{\varepsilon r}[(Wf/t)+2]} \quad (1)$$

Here,εr is the dielectric constant of 4.4, *Wf* is width of feedline, *t* is thickness of 1.6mm and *z* is characteristic impedance of 50Ω.From all this given data feedwidth of offset microstrip line can be calculated[13][14].

A. Evolution of Rectangular Slot UWB Antenna

Initially basic rectangular patch antenna with full ground plane provides less impedance bandwidth from 6.971-7.149GHz(2.52%).In order to achieve the wide impedance bandwidth over entire UWB range,a wide rectangular slot is cut from ground to form U shaped ground plane.After forming U shaped ground,the impedance bandwidth increased from 3.4-10.31GHz(100%).So still entire UWB is not achieved.Further a wide rectangular slot is cut from ground to form partial ground plane which has less impedance bandwidth from 3.3-11GHz(107%).Finally a wide rectangular slot is cut from ground to form L-shaped ground which has large impedance bandwidth from 2.9-11.2GHz(117%).This L-shaped ground satisfy demand of UWB.

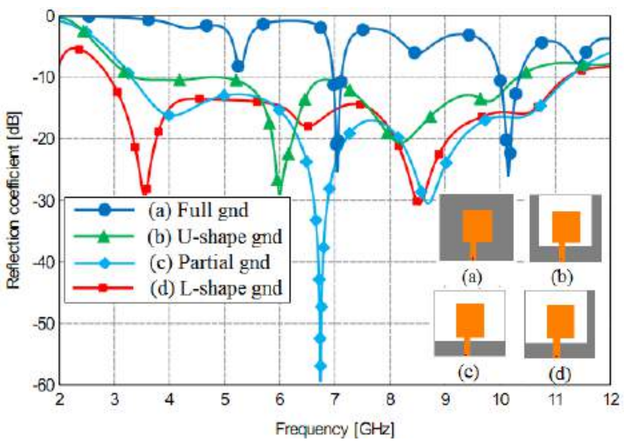


Fig. 1. Simulated reflection coefficient at different stages of evolution of ground plane

Fig.1 shows the evolution of UWB in terms of reflection coefficient(S_{11}) for different ground plane.Here, only for L-shaped ground plane a wide impedance bandwidth is obtained.

B. Bandnotch Rectangular Slot UWB Antenna

Fig.2 shows geometry of proposed antenna with band notch characteristics.The design of this antenna is mainly depends on the current distribution as shown in Fig.9.The current is mainly concentrated along the radiating patch.In order to obtain band-notch characteristics a new modified U-slot is cut from the rectangular radiating patch.After cutting modified U-slot band notch is generated between 3.3 to 4.15GHz and also impedance bandwidth of UWB antenna is effectively improved at the initial frequency band (2.6-11GHz).The length of the modified U-slot with 3.5GHz center frequency can be calculated using equation (2)

$$Lnotch = \frac{c}{2f\sqrt{\varepsilon reff}} \quad (2)$$

To design the basic geometry of band notch rectangular slot UWB antenna following compact dimensions are used. Wsub=33mm, Lsub=35.5mm, Wp=12mm, Lp=16mm, Wf=2.8mm, Lf=10.25mm, Wg=1.5mm, Lg=9mm, Wslot=31.5mm, Lslot=26.5mm, Ws1=1mm, Ls1=10mm, Ws2=8mm, hslot=0.5mm.

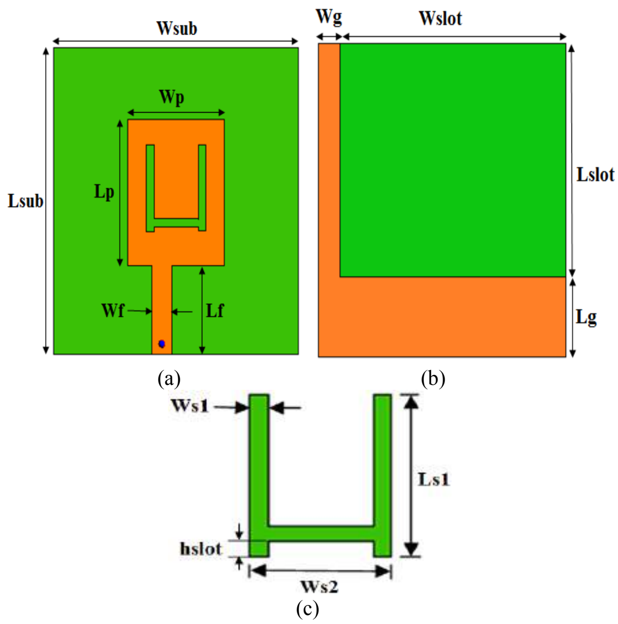


Fig. 2. Geometry of band notch rectangular slot UWB antenna.(a)Top view (b)Bottom view (c)Modified U slot in the radiating patch

C. Effect of Modified U-Slot Width Variation(Ws1)

Parametric study of band notch antenna is carried by changing one parameter at a time and other parameters are remain unchanged.In this study width of modified U-slot is changed.Simulated results are observed for different width of modified U slot such as 0.5mm,1mm and 1.5mm.As shown in Fig.3 ,it can be observed that increase in the slot width results in shifting of resonance frequency.Here only for 1mm width of slot desired notching is obtained from 3.3 to 4.15GHz.

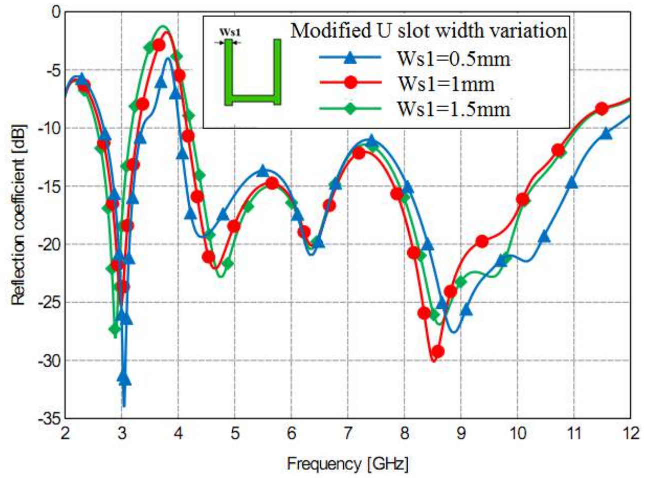


Fig. 3. Simulated Reflection coefficient vs. frequency graph for different width of modified U slot(Ws1)

D. Effect of Modified U-Slot Length Variation(Ls1)

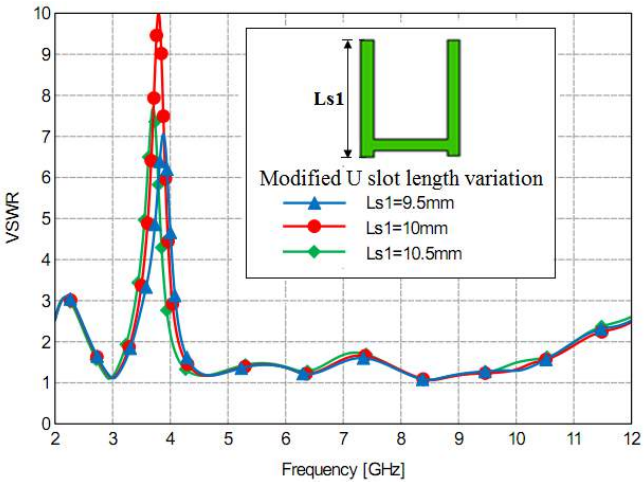


Fig. 4. VSWR vs. frequency graph for different length of modified U slot(Ls1)

Fig.4 shows that with increase in the length of slot, resonant frequency shifts to the lower side.This is due to the fact that as slot length increases the resonant frequency decreases, governed by equations (4).

E. Effect of Modified U-Slot Width Variation(Ws2)

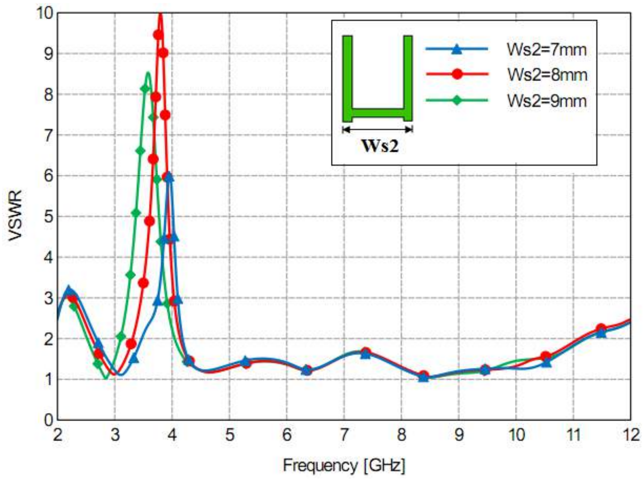


Fig. 5. VSWR vs. frequency graph for different width of modified U slot(Ws2)

Fig.5 shows the effect of Ws2.Here Ws2 is varies from 7mm to 9mm. As shown in Fig.5 ,it can be observed that increase in the slot width(Ws2) results in shifting of resonance frequency towards left side while for decrease in the slot width(Ws2) results in shifting of resonance frequency towards right side.Here only for 8mm width of slot desired notching is obtained from 3.3 to 4.15GHz.

F. Effect of Feed Position

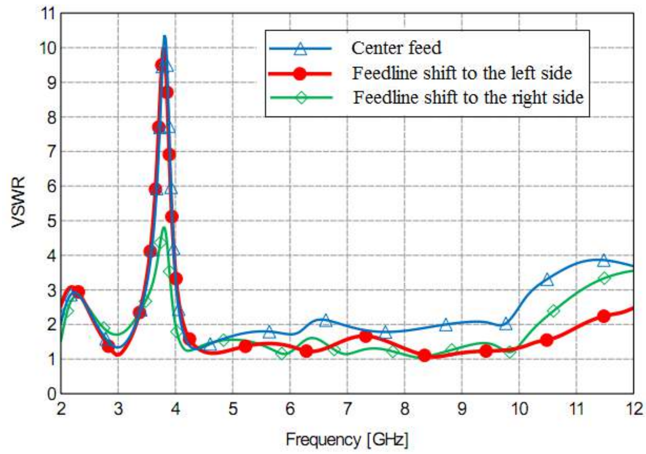


Fig. 6. VSWR vs. frequency graph for different feed position

Fig.6 shows the effect of feed position. Here only for feed shift to left side we achieved large impedance bandwidth from 2.6-11GHz and desired notching within aforementioned frequency band.

G. Effect of Height of Modified U Slot (hslot)

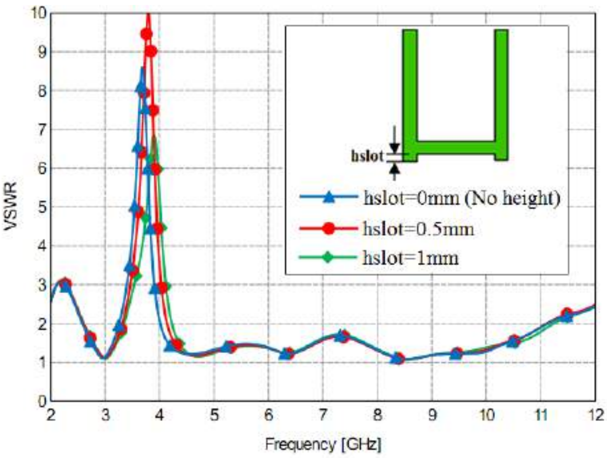


Fig. 7. VSWR vs. frequency graph for different height of modified U slot

Simulated results are observed for different height of modified U slot(hslot).As shown in Fig.7 ,it can be observed that increase in the height of modified U slot(hslot) results in shifting of resonance frequency towards right side.Here only for 0.5mm height of modified U slot desired notching is obtained from 3.3 to 4.15GHz.

H. Efficiency of Bandnotch Antenna

It can be observed in Fig.8 that efficiency decreases to 20% at notch frequency band while above 70% at other frequencies.Hence from figure it is clearly observed that antenna filter frequency band from 3.3 to 4.15GHz.

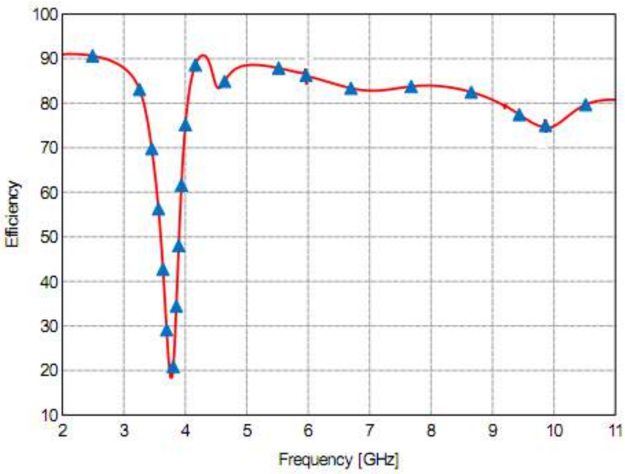
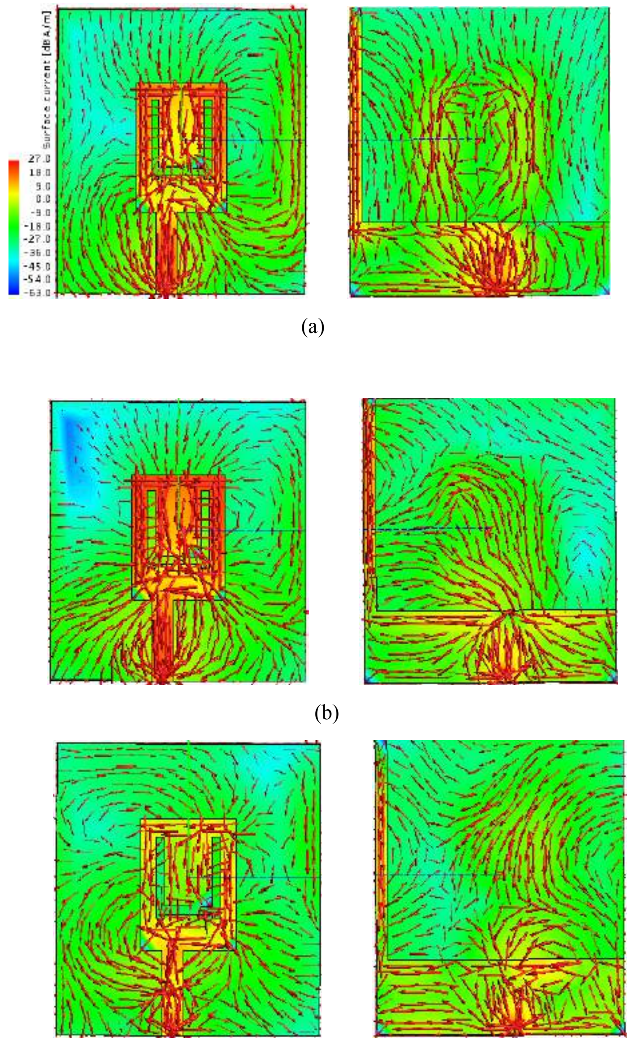


Fig. 8. Efficiency vs.frequency graph of band notch rectangular slot UWB antenna

I. Current Distribution of Bandnotch Antenna

Fig.9 shows the surface current distribution at different frequency.It is observed that maximum current is mainly concentrated on the edges of modified U slot at 3.5GHz notch frequency band as compared to others.



(a)

(b)

(c)

Fig. 9. Surface current distribution of band notch rectangular slot UWB antenna (a) 3.2GHz (b) 3.5GHz and (c)7.7GHz

J. Radiation Characteristics of Bandnotch Antenna

Fig.10 shows the measured and simulated radiation patterns of the proposed antenna including the co-polarization and cross-polarization in the H-plane and E-plane.The measurement is carried by an Agilent network analyser including far-field measurement software and good agreement between simulation and measurement results has been seen. It is observed that antenna radiation characteristics describe the energy directed by the antenna in azimuth plane (Φ=0°) and elevation plane (Φ=90°) at 3.1GHz,5.5GHz and 10.1GHz frequencies.The proposed antenna is radiated as an omnidirectional in H-plane(Φ=0°) and bidirectional in E-plane(Φ=90°).It is observed that as frequency increases radiation patterns are distorted due to reduction in efficiency at higher frequency range.

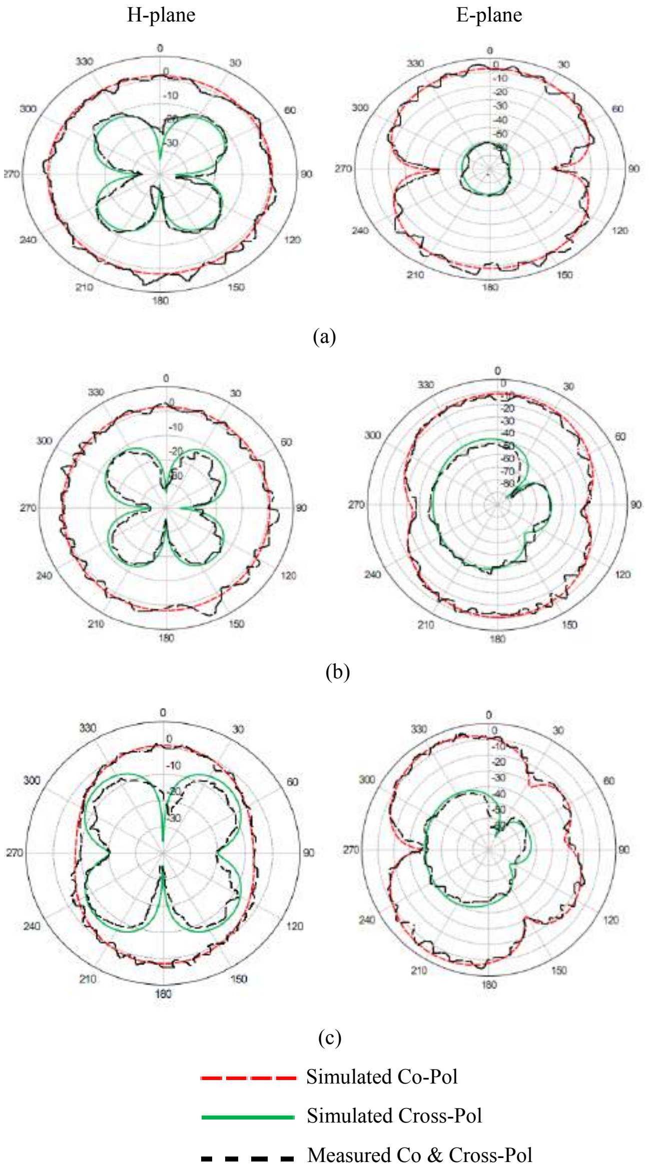


Fig. 10. Measured and simulated radiation patterns of the proposed antenna at (a)3.1GHz, (b)5.5GHz, (c)10.1GHz.

III. RESULTS AND DISCUSSION

Prototype of fabricated bandnotch rectangular slot UWB antenna is shown in Fig.11.This prototype of manufactured antenna is compared with a one rupee coin. Fig 12 shows simulated reflection coefficient of proposed antenna which is below -10dB in UWB range except WiMAX and C- band.

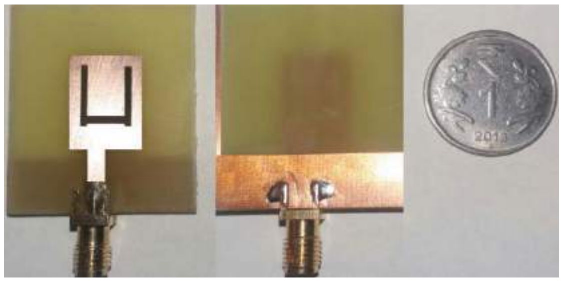


Fig. 11. Prototype of fabricated bandnotch rectangular slot UWB antenna

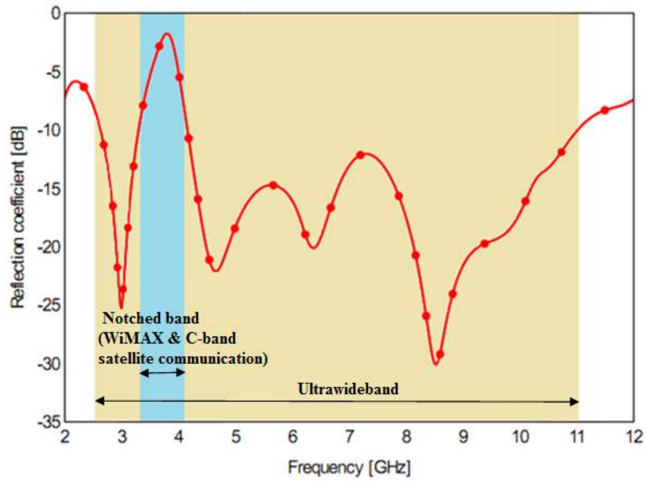


Fig. 12. Simulated band rejection characteristics of proposed rectangular slot UWB antenna

Simulated and measured VSWR characteristics of the proposed antenna are shown in Fig.13.The N9916A vector network analyser is used for measurement. Fig.14 shows Time Domain Analysis of output signal of the received UWB antenna.Basic important requirement of UWB antenna is a good time domain performance.Time domain analysis of CADFEKO[15] is used to obtain pulse spreading behavior of proposed antenna.

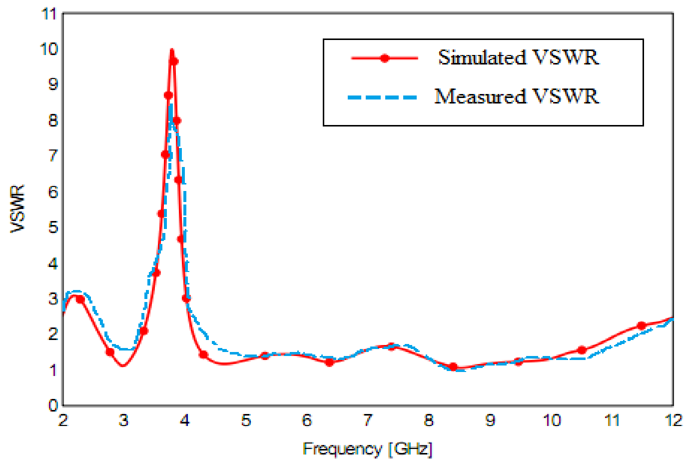


Fig. 13. Measured and simulated VSWR of proposed antenna with notched bands

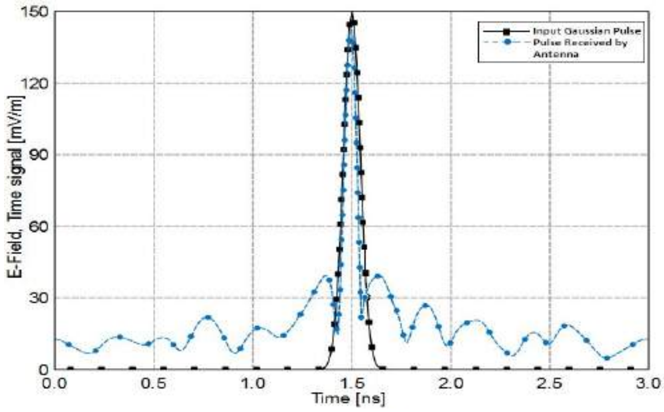


Fig. 14. Time Domain Analysis of output signal of the received UWB antenna.

IV. CONCLUSION

A simple, compact and low cost rectangular slot antenna with band notched characteristics has been designed, simulated, fabricated and measured.The results show that by cutting wide rectangular slot from the ground plane the impedance bandwidth is improved from 2.6GHz to 11GHz.Introducing a modified U slot in the radiating patch and optimizing the width,length of modified U slot, good band rejection characteristics from 3.3-4.15GHz obtained.The proposed antenna shows stable radiation pattern and efficiency over entire UWB band except WiMAX and C-band.This makes proposed antenna a good candidate for personal wireless application.

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