COMPACT RECTANGULAR SLOT MICROSTRIP ANTENNA WITH BAND-NOTCHED CHARACTERISTICS FOR ULTRAWIDEBAND APPLICATIONS

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ABSTRACT

In this paper, we present an offset microstrip-fed ultrawideband antenna with band notch characteristics.The antenna structure consists of rectangular radiating patch and ground plane with rectangular shaped slot, which increases impedance bandwidth upto 117.73%(2.9-11.2GHz).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) and optimized with stable radiation pattern which satisfied UWB requirement for VSWR<2.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 designed antenna exhibits bidirectional and omni directional radiation patterns along E and H-plane with stable gain and efficiency over entire operating band except notch frequency band. Simulated results are in good agreement with the measured results of the proposed antenna which makes it a good candidate for UWB application.

KEYWORDS

Band Notch,L-Shaped Ground Plane, Modified U-Slot,Ultrawideband(UWB),Slot Antenna.

1.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 WiMAX(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 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 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 2.9 to 11.2GHz can be obtained.

2.ANTENNA GEOMETRY AND DESIGN

Fig.1 describes the evolution of rectangular slot UWB antenna.The basic antenna comprises 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 $33X35.5X1.6mm^3$. 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).

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

Here,εr is the dielectric constant of 4.4,*w* 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[11][12].

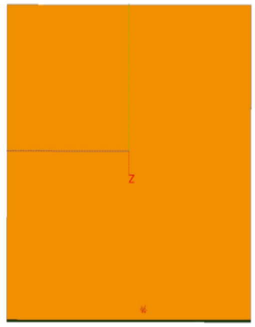
2.1Evolution of Rectangular Slot UWB Antenna

Fig.1(a) shows evolution of UWB antenna for different shape of ground plane and effect of ground plane in terms of bandwidth are discussed using CADFEKO(7.0) EM simulation software[13].Initially for full ground plane less BW(1.98%) is achieved. For U-shaped ground plane 100.67% bandwidth is achieved. For partial ground plane 107.30% bandwidth is achieved. In order to achieve wide impedance bandwidth large rectangular slot is cut from ground to form L-shaped ground which has large impedance bandwidth of 117.73%.This L-shaped ground satisfied demand of UWB. Following formulae are used to calculate percentage of bandwidth.

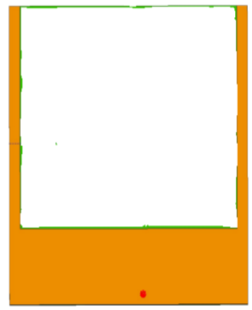
$$\%\,Bandwidth = \frac{(Fh - Fl)}{Fc} \qquad (2)$$

$$Fc = \frac{(Fl + Fh)}{2} \qquad (3)$$

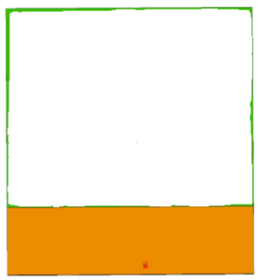
Where, *Fh* is higher frequency in GHz ,*Fl* is lower frequency in GHz and *Fc* is centre frequency in GHz.



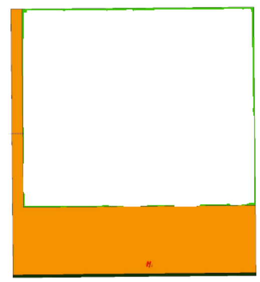
Step 1.(Full ground)



Step 2.(U-shape ground)

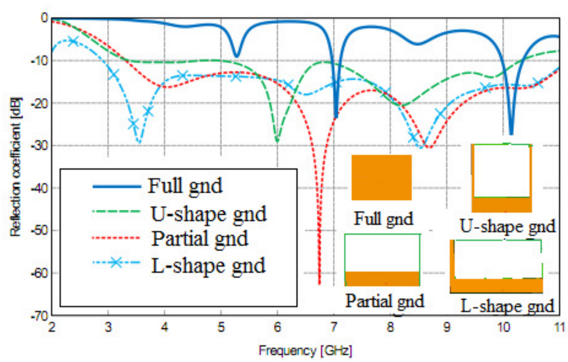


Step 3.(Partial ground)



Step 4.(L-shape ground)

(a)



(b)

Figure 1.(a)Evolution of rectangular slot UWB antenna (b)Simulated reflection coefficient for different ground plane

Fig.1(b) shows the simulated results in terms of reflection coefficient(S_{11}) for different ground plane.Only for L-shaped ground desired impedance bandwidth is obtained.

2.2Parametric Study of Rectangular Slot UWB Antenna

Fig.2 represents the simulated results for different values of width of ground such as Wg=1,1.5,2mm.For all these values of Wg antenna resonates for entire ultrawideband,but for Wg=1.5mm return loss is maximum for lower and higher frequency of operation.Hence optimum desired results are obtained for Wg=1.5mm.

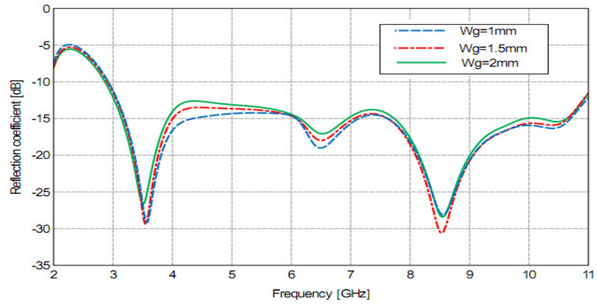


Figure 2.Return loss vs.frequency graph for different width of ground plane

The effect of ground length(Lg) is presented in fig.3.It shows simulated results for different values of length of ground(Lg) such as 8,9 and 10mm.When Lg=8mm S_{11} gets disturbed at higher frequency range.For Lg=10mm return loss is very poor at 4.3GHz frequency.Only for Lg=9mm we achieved satisfied UWB.

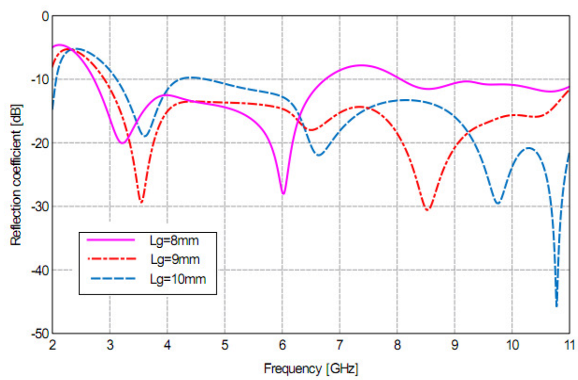


Figure 3.Return loss vs.frequency graph for different length of ground plane

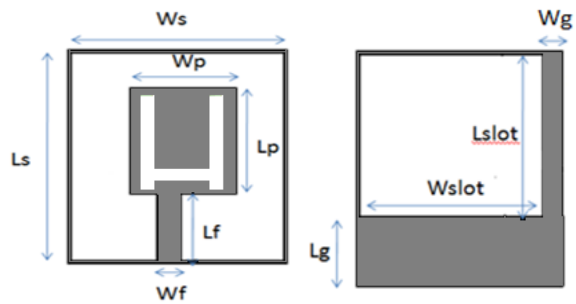
2.3 Bandnotch Rectangular Slot UWB Antenna

Fig.4 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.8.The current is mainly concentrated on the radiating patch.In order to obtain band-notch characteristics a new modified U-slot is cut from the radiating patch.After cutting modified U-slot band notch is generated between 3.3 to 4.15GHz. The length of modified U-slot is calculated using equation (4)

$$Lnotch = \frac{c}{2f\sqrt{\varepsilon reff}} \qquad (4)$$

To design the basic geometry of band notch rectangular slot UWB antenna following compact dimensions are used.

Ws=33mm,Ls=35.5mm,Wp=12mm,Lp=16mm,Wf=2.8mm,Lf=10.25mm,Wg=1.5mm,Lg=9mm, Wslot=31.5mm,Lslot=26.5mm.



(a)Top View (b)Bottom View

Figure 4.Geometry of band notch rectangular slot UWB antenna

2.4 Effect of Modified U-Slot Width Variation

Parametric study of band notch antenna is carried out 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.It is observed that increase in the slot width results in shifting of resonance frequency.Here only for 1mm width of slot highest notching is obtained.

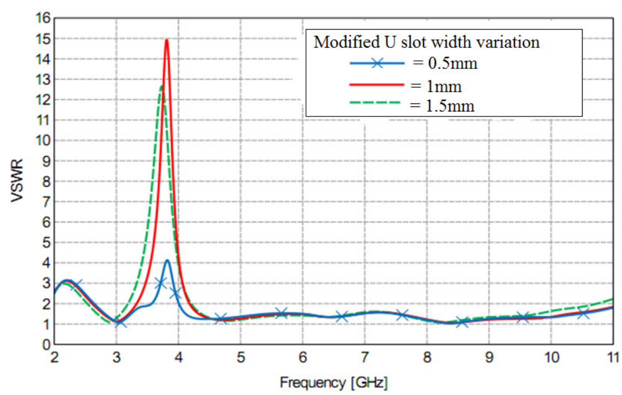


Figure 5.VSWR vs.frequency graph of band notch rectangular slot UWB antenna for different width of modified U slot

2.5 Efficiency of Bandnotch Antenna

It is observed that efficiency decreases to 20% at notch frequency band while above 70% at other frequencies.Hence from fig.6 it is clearly observed that antenna filter frequency band from 3.3 to 4.15GHz.

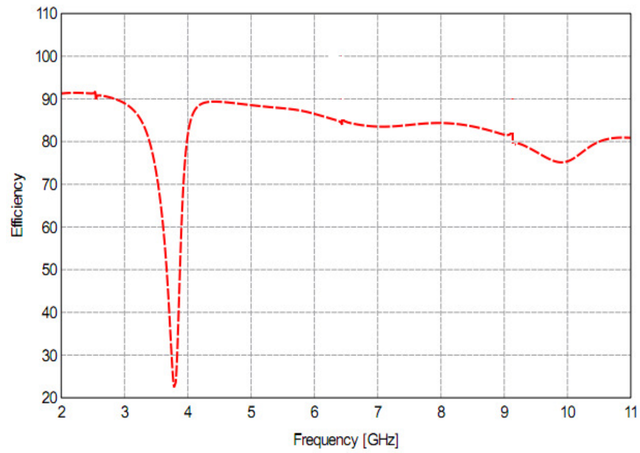


Figure 6.Efficiency vs.frequency graph of band notch rectangular slot UWB antenna

2.6 Gain of Bandnotch Antenna

Fig.7 shows gain vs.frequency graph of the designed antenna.It is observed that gain is suddenly dropped at notch frequency band so as to reduce interferences between UWB system and narrowband systems.

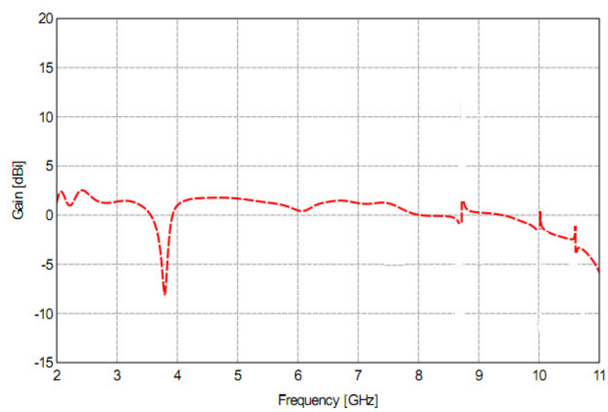
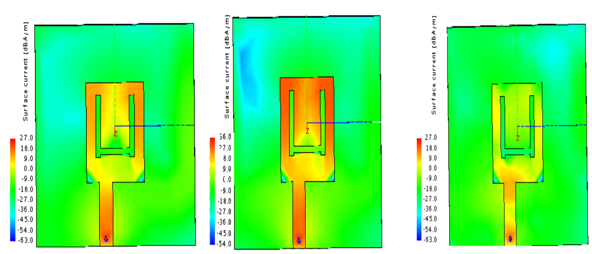


Figure 7.Gain vs.frequency graph of band notch rectangular slot UWB antenna

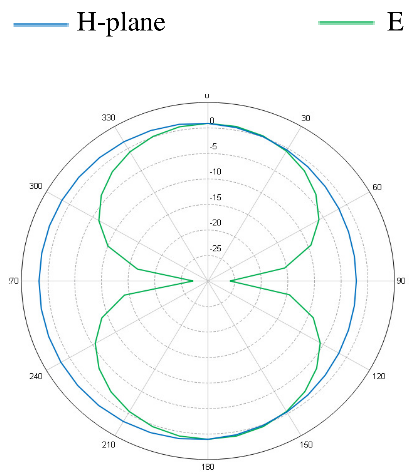
Fig.8 shows the surface current distribution at different frequency.It is observed that maximum current flows in modified U slot at 3.5GHz notch frequency band as compared to others.



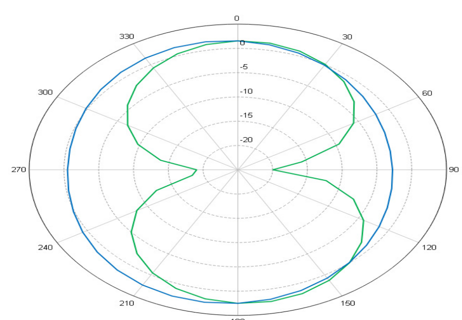
(a)3GHz (b)3.5GHz (c)7.7GHz

Figure 8.Surface current distribution at different frequency of band notch rectangular slot UWB antenna

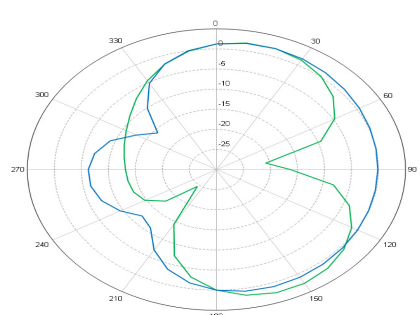
Fig.9 shows radiation patterns of band notch antenna at different frequency obtained by simulation software CADFEKO. It is observed that antenna radiation characteristics describe the energy directed by the antenna in azimuth plane (Φ=0°) and elevation plane (Φ=90°) at 3.1GHz,5.5GHz and 10.1GHz frequencies.It is shown that for all frequencies elevation radiation patterns have almost bidirectional and dipole like radiation patterns because the alternating electric current enters the antenna through feed line and patch junction and leaves the antenna through edges of the radiating patch which results in formation of electric field pattern with maximum field at the radiating edges in the direction of radiation and minimum field at the centre of the patch.The designed antenna is radiated as an omnidirectional in H-plane(Φ=0°).It is observed that as frequency increases radiation patterns are distorted due to reduction in efficiency at higher frequency range.



At 3.1GHz



At 5.5GHz



At 10.1GHz

Figure 9.Radiation Patterns at different frequency of band notch rectangular slot UWB antenna

3.SIMULATION RESULTS AND DISCUSSION

Prototype of fabricated bandnotch rectangular slot UWB antenna is shown in fig.10.This prototype of manufactured antenna is compared with a one rupee coin.

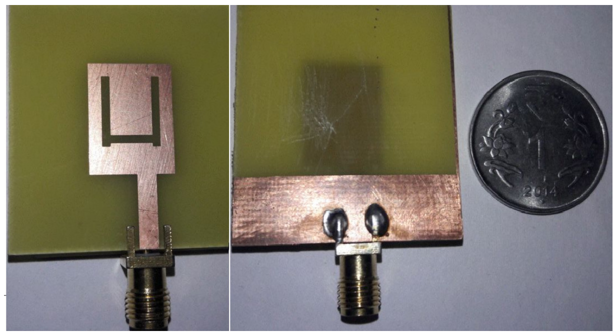


Figure 10.Prototype of fabricated bandnotch rectangular slot UWB antenna

Simulated and measured VSWR of band notch rectangular slot UWB antenna is shown in fig.11.The N9916A vector network analyser is used for measurement.From fig.11 it is clearly observed that measured results are in good agreement with the simulated results.

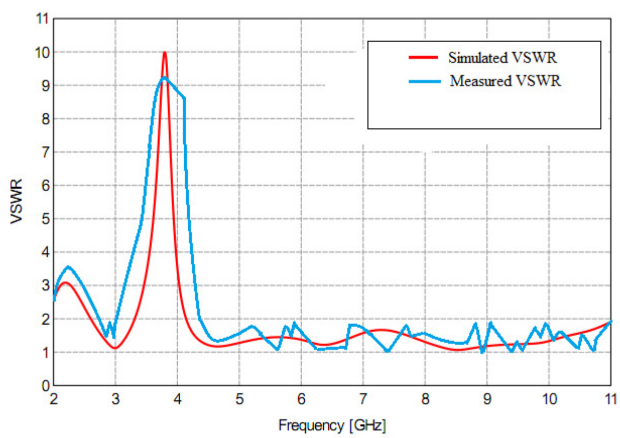


Figure 11.Measured and simulated VSWR of bandnotch rectangular slot UWB antenna

4.CONCLUSIONS

A small and compact rectangular slot antenna with band notched characteristics has been designed, simulated,fabricated and measured.The results show that by cutting wide rectangular slot in ground plane the impedance bandwidth is improved from 2.9 to 11.2GHz.Introducing modified U slot in the radiating patch and optimizing the width of modified U slot,good band rejection characteristics from 3.3-4.15GHz obtained.Good radiation characteristics are obtained along E and H plane.The proposed antenna shows stable efficiency and gain at all desired frequency bands except notched frequency band to minimize the interferences between UWB system and narrowband systems(WiMAX and C-band).This makes proposed antenna a good candidate for personal wireless application.

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REFERENCES

[1] "Federal Communication Commission revision of Part 15 of the commission's rules regarding ultra-wideband transmission systems,"FCC,Washington DC first Report and Order FCC,02.V48,2002.

[2] Rezaul Azim,Mohammad Tariqul Islam,Senior Member,IEEE,&Ahmed Toaha Mobashshsher, "Design of a Dual Band-Notch UWB Slot Antenna by Means of Simple Parasitic Slits",IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS,VOL.12,2013.

[3] Peng Gao,Member,IEEE,Ling Xiong,Jianbo Dai,Shuang He,and Yi Zheng, "Compact Printed Wide-Slot UWB Antenna With 3.5/5.5-GHz Dual Band-Notched Characteristics",IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS,VOL.12,2013.

[4] Seyed Ramin Emadian & Javad Ahmadi-Shokouh, "Very Small Dual Band Notched Rectangular Slot Antenna with Enhanced Impedance Bandwidth",DOI 10.1109/TAP.2015.2456905,IEEE Transaction on Antenna and Propagation.

[5] Reza Zaker,Changiz Ghobadi,and Javad Nourinia, "Bandwidth Enhancement of Novel Compact Single and Dual Band-Notched Printed Monopole Antenna With a pair of L-shaped Slots",IEEE TRANSACTION ON ANTENNAS AND PROPAGATION,VOL.57,NO.12,DECEMBER 2009.

[6] M.Ojaroudi,Sh.Yzdanifard,N.Ojaroudi,and R.A.Sadeghzadeh, "Band-notched small square-ring antenna with a pair of T- shaped strips protruded inside the square ring for UWB applications,"IEEE Antennas Wireless Propag.Lett.,vol.10,pp.227-230,2011.

[7] M.Ojaroudi, "Printed monopole antenna with a novel band-notched folded trapezoid ultra-wideband,"J.Electromagn.Waves Appl.,vol.23,pp.2513-2522,2009.

[8] Rekha.P Labade, Dr.S.B.Deosarkar, Dr.Narayan Pishoroty,Dr.Akshay Malhotra, "A Novel Integrated Bluetooth Dual Band UWB Antenna for Wireless Communication" International Journal of Microwave and Optical Technology,Vol.10,No.3,pp-195-201,May 2015.

[9] Rekha.P Labade, Dr. S.B.Deosarkar,Dr.Narayan Pishoroty,Dr. Akshay Malhotra, "Design and Implementation of an Integrated Bluetooth Ultrawideband Monopole Antenna" Australian Journal of Basic and Applied Sciences,8(15),60-66,2014.

[10] Zhi-Qiang and Cheng-Li Ruan, "A small integrated bluetooth and UWB antenna with WLAN band notched characteristics",Proceedings of International symposium on Signals,System and Electonics,10.1109/ISSSE.2010.5638206,2010, 1971.

[11] G.Kumar and K.P.Ray, "Broadband Microstrip Antennas,"Artech House,1992.

[12] C.A.Balanis, "Antenna Theory Analysis and Design,"3rd Edition, *John Wiley and Sons*,New York,1997.

[13] CAD-FEKO Simulation software,Version 7.0 UserManual.

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Short Biography

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