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 up to 117.73% (2.9-11.2GHz). A new modified U slot is etched in the radiating patch to create band-notchted 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 tuning stub is fed by an offset microstrip line.

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

$$z = \frac{377}{\sqrt{\varepsilon_r \left( \frac{W}{t} \right) + 2}}$$

Here, $\varepsilon_r$ is the dielectric constant of 4.4, $w$ is width of feedline, $t$ is thickness of 1.6mm and $z$ is characteristic impedance of 50$\Omega$. From all this given data feedwidth of offset microstrip line can be calculated[11][12].

2.1 Evolution 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.

$$\%\ Bandwidth = \frac{(F_h - F_l)}{F_c}$$

Where, $F_h$ is higher frequency in GHz, $F_l$ is lower frequency in GHz and $F_c$ is centre frequency in GHz.
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.

### 2.2 Parametric Study of Rectangular Slot UWB Antenna

Fig.2 represents the simulated results for different values of width of ground such as $W_g=1, 1.5, 2$ mm. For all these values of $W_g$ antenna resonates for entire ultrawideband, but for $W_g=1.5$ mm return loss is maximum for lower and higher frequency of operation. Hence optimum desired results are obtained for $W_g=1.5$ mm.
The effect of ground length ($L_g$) is presented in Fig. 3. It shows simulated results for different values of length of ground ($L_g$) such as 8, 9, and 10 mm. When $L_g=8$ mm, $S_{11}$ gets disturbed at higher frequency range. For $L_g=10$ mm, return loss is very poor at 4.3 GHz frequency. Only for $L_g=9$ mm, we achieved satisfied UWB.

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 4.15 GHz. The length of modified U-slot is calculated using equation (4).

$$L_{notch} = \frac{c}{2f \sqrt{\varepsilon_{eff}}}$$ (4)

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

$W_s=33$ mm, $L_s=35.5$ mm, $W_p=12$ mm, $L_p=16$ mm, $W_f=2.8$ mm, $L_f=10.25$ mm, $W_g=1.5$ mm, $L_g=9$ mm, $W_{slot}=31.5$ mm, $L_{slot}=26.5$ mm.
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.

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.
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.

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.
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 ($\Phi=0^\circ$) and elevation plane ($\Phi=90^\circ$) 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 ($\Phi=0^\circ$). It is observed that as frequency increases radiation patterns are distorted due to reduction in efficiency at higher frequency range.

![Radiation Patterns at different frequency of band notch rectangular slot UWB antenna](image)

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.

![Prototype of fabricated bandnotch rectangular slot UWB antenna](image1)

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.

![Simulated and measured VSWR of bandnotch rectangular slot UWB antenna](image2)

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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Short Biography

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