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UWB Band-notch Antenna with a Semicircular Annular Strip

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ABSTRACT

A microstrip line fed compact planar monopole antenna with band-notch characteristics is proposed for Ultrawideband (UWB) communication applications. The proposed compact antenna is consists of an annular ring patch and a partial ground plane with a rectangular slot. A semicircular annular strip is etched above the radiating patch to achieve notch frequency band. The proposed antenna has a stop-band of 5.1 to 5.8 GHz while maintaining the wideband performance from 2.99 to more than 12 GHz with VSWR≤2. A symmetric radiation pattern and stable gain except in the notched band makes the proposed antenna suitable for being used in UWB applications.

Key words: Notch-frequency band, WLAN, UWB, printed antenna

INTRODUCTION

In the recent years Ultra-Wideband (UWB) technology become more and more important owing to many potential applications such as multimedia communications, sensor networks, ground-penetrating radar, medical imaging and precision localization systems (Bialkowski *et al*., 2006; Turk and Nazli, 2008; Viani *et al*., 2008; Azim *et al*., 2010; Islam *et al*., 2009a; Mei and Yu, 2010; Islam *et al*., 2010b). Due to the characteristics like as high data transmission rates, high precision ranging, low complexity and easy connections UWB technology has been used in a large number of devices such as laptops, high definition TVs, digital cameras and wearable bio-medical sensors. In all these applications, antenna- the key component of UWB system needs to be of low cost and small enough to be embedded into the wireless devices or integrated with other RF circuits and have broad impedance bandwidth with stable radiation characteristics.

In February 2002, the US the Federal Communications Commission (FCC) released a frequency spectrum of 3.1 to 10.6 GHz as an unlicensed band for UWB radio communication (FCC, 2002). In UWB frequency band there are some other existing narrowband services that already occupy frequencies in the UWB band, such as WLAN radio signals. Most WLAN systems are designed to operate in the 5.15-5.825 GHz ranges. These existing bands may cause interference with UWB systems. One possible way to suppress the interfering signals is to use a spatial filter such as a frequency selective surface above the antenna (Yeo and Mittra, 2002). However, this approach will increase the cost and system complexity and requires more space when integrated with other microwave circuitry. Another technique is to design antennas that are capable of filtering the frequency band from 5.15 to 5.825 GHz in UWB systems to avoid possible interference between UWB and existing WLAN systems i.e., antennas with band-notched characteristics.

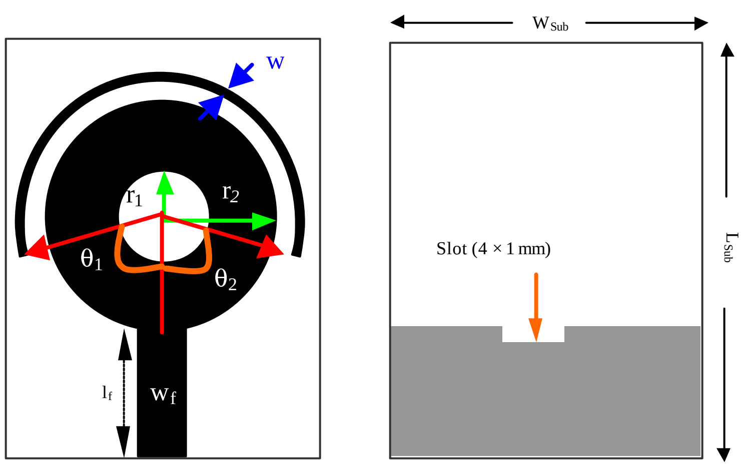
Recently, many UWB antennas have been attempted to overcome interference problem using frequency band rejected function design. Many techniques have already been proposed to design band-notched slot antennas, for example, an isolated slit inside a patch, two open-end slits at the top edge of a T-stub, two parasitic strips (Lin and Hung, 2006) and a square ring resonator embedded in a tuning stub (Lui *et al*., 2007). The antenna structure proposed by Lin and Hung (2006) is simple and the aperture size is compact. Although a broad impedance bandwidth and stable radiation patterns are obtained, the ground plane is a bit too large.

Another simple way to design band-notch antenna is to etch thin slots on the antenna surface, such as L-shaped slot (Zaker *et al*., 2009), U-shaped slot (Zhou *et al*., 2008; Jang and Hwang, 2009; Dissanayake and Esselle, 2007) and T-shaped slot (Ojaroudi *et al*., 2009). By adding either a Split-Ring Resonator (SRR) (Liu *et al*., 2008; Chang and Wu, 2008) or a multi-resonator load (Ma *et al*., 2008) in the antenna structure, the undesired frequencies can be rejected so that the system performance may be enhanced well. However, all of these designs need a complex structure to generate and control the stop-band property, so that the cost in fabricating antenna will be increased for practical applications.

In this study, a novel compact printed UWB antenna with band-notched characteristic is proposed. By inserting a semicircular annular strip along with the annular ring radiating patch, the stop-band can easily be obtained. The proposed antenna has a simple configuration, is easy to fabricate.

ANTENNA DESIGN

Figure 1 shows the configuration and dimensions of proposed antenna. The antenna is fabricated on an inexpensive FR4 substrate with thickness of 1.6 mm and relative permittivity of 4.6. The proposed antenna has an annular ring patch with an inner radius of r_1 and outer radius of r_2. A microstrip feed-line is printed on the same side of dielectric substrate. The length and width



(a) Top layer (b) Bottom layer

Fig. 1: Geometry of the proposed antenna

of the microstrip feed line are fixed at l_f and w_f respectively to achieve 50Ω characteristics impedance. An SMA is connected to the port of the feeding microstrip line.

The partial ground plane of height of 7.5 mm is printed on the other side of the substrate. A rectangular slot with dimensions 4×1 mm is introduced on the top edge of the partial ground plane to alter the input impedance characteristics. The gap between the radiating patch and ground plane is 0.5 mm. The antenna has an overall size of $W_{Sub} \times L_{Sub}$.

To achieve band-notch characteristic, a semicircular annular strip of width w has been etched above the annular ring patch which leads to high impedance at the notch frequency. The length and position of the parasitic element is bound by the angles θ_1 and θ_2. The effective length of the semicircular annular strip is nearly equivalent to half a wavelength for the frequency around 5.45 GHz. This means that the notched band can be generated around 5.45 GHz. However, the actual notch frequency of the microstrip-fed slot antenna can be above or below this approximate frequency depending on the location of the strip.

RESULTS AND DISCUSSION

The performance of the proposed antenna was analyzed and optimized by method of moments based full-wave electromagnetic simulator Zeland IE3D (Zeland, 2006). The effects on return loss obtained after changing the values of w is depicted in Fig. 2. It is observed that, as the values of w increases from 1 to 3 mm, the centre frequency of the notched band is almost constant at 5.5 GHz. However, the band notch frequencies with the increase of the circular parasitic element width. From these results, it can be concluded that the width of band notched frequencies can be controlled by changing width of w. It is also observed that the increase of the width of circular element also decreases the return loss value which an important factor for the band notch characteristic of ultra wide band antennas.

The return loss curves of the proposed antenna, with different values of θ_1 are plotted with θ_2 = 90°, in Fig. 3. As the value of θ_1 increases from 60 to 110°, the centre frequency of notched band is varied from 4.6 to 6.4 GHz. At the same time, the return loss values of the centre frequencies also vary and it becomes lowest when θ_1 = 80°. Due to the increase of θ_1, the length of the parasitic element also decreases and consequently the centre frequency of the band antenna

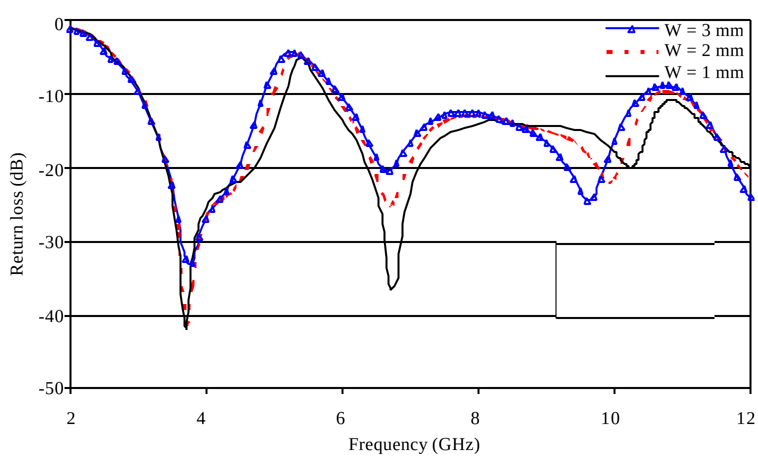


Fig. 2: Return losses for different values of w

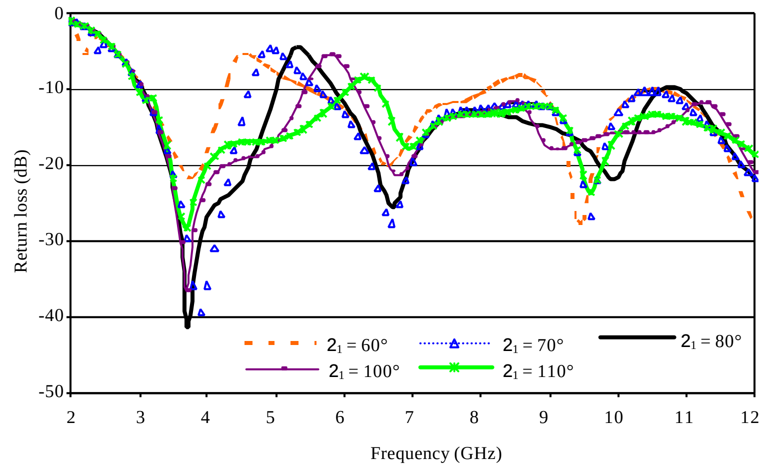


Fig. 3: Return losses for different values of θ_1

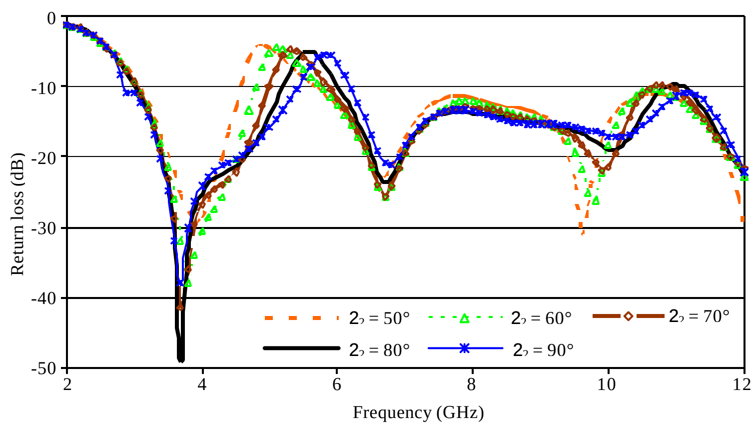


Fig. 4: Return losses for different values of θ_2

also decreases. Thus centre of the notch frequency is controllable by changing the value of θ_1. Figure 4 illustrates the return loss curves with the optimal value of θ_1 (80°) for different values θ_2. As the values of θ_2 are varied from 50 to 90°, the centre frequency of notched bandwidth varies from 4.9 to 5.8 GHz. The effects of θ_2 have the same type effect of θ_1, because both of them are related to the length of the parasitic element. However, the results clearly indicate that the notch band can be adjusted by changing the values of θ_2. The optimal parameters of the semicircular annular strip as well the antenna parameters are as follows: w = 1 mm, θ_1 = 80° and θ_2 = 70°, r_1 = 3 mm, r_2 = 8 mm, l_f = 7.5, w_f = 3 mm, W_{Sub} = 28 mm and L_{Sub} = 27 mm.

Figure 5 shows the performance of the proposed monopole antenna with and without semicircular annular strip. It is observed that the sharp frequency band-notch characteristic is obtained at the desired centre frequency of 5.45 GHz when a semicircular annular strip is introduced along with the annular ring patch. Taking Voltage Standing Wave Ratio (VSWR) 2 equivalent line as reference, the antenna is notches the bandwidth of 0.7 GHz, from 5.1 GHz to

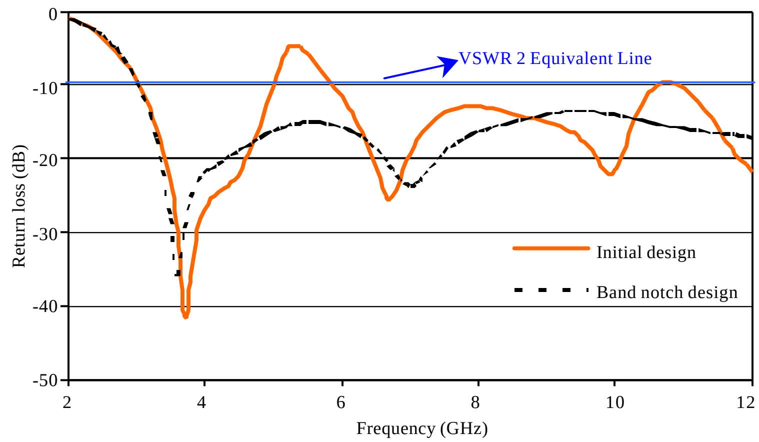


Fig. 5: Comparison of the return losses between initial design and band-notch design

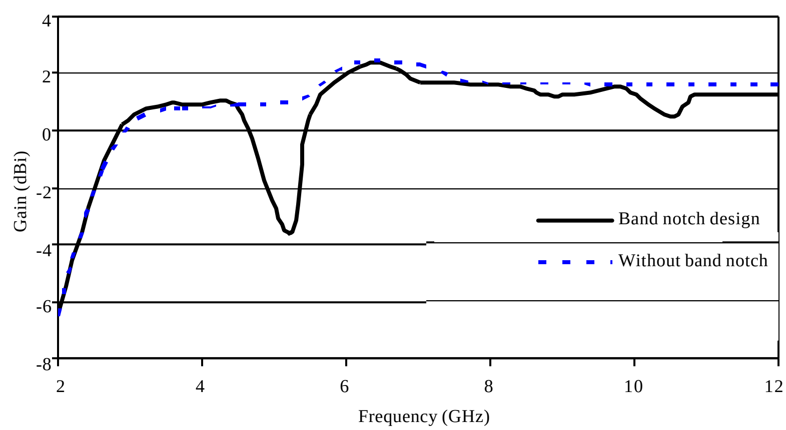


Fig. 6: Gain vs. frequency response of the proposed antenna

5.8 GHz which covers the WLAN bands that make interference with the UWB band. Figure 6 presents the gain of the proposed antenna. As depicted in the graphs, the gain decreases significantly at the notched frequency band which reaches up to -3.8 dBi at the centre frequency. However, at the frequency of 10.6 GHz the antenna gain slightly decreases because of the low matching of that antenna in that frequency. Even though the gain shows value larger than zero at that frequency. Other than the notched frequency band, for other frequencies the antenna gain is about the same for the proposed antenna without semicircular annular strip. The radiation patterns of the band notched antenna at 3.5, 5.5, 7 and 10.5 GHz are pictured in Fig. 7. A stable radiation pattern is observed over the wide frequency band of the antenna. The similar radiation pattern of centre notch frequency, 5.5 GHz claims that the antenna is unable to interfere with the WLAN band with it low gain. Over all the operating frequencies, the antenna exhibits symmetric radiation characteristics. However, there are some nulls observed in the radiation pattern of the antenna which are due to the higher harmonics of the high frequencies.

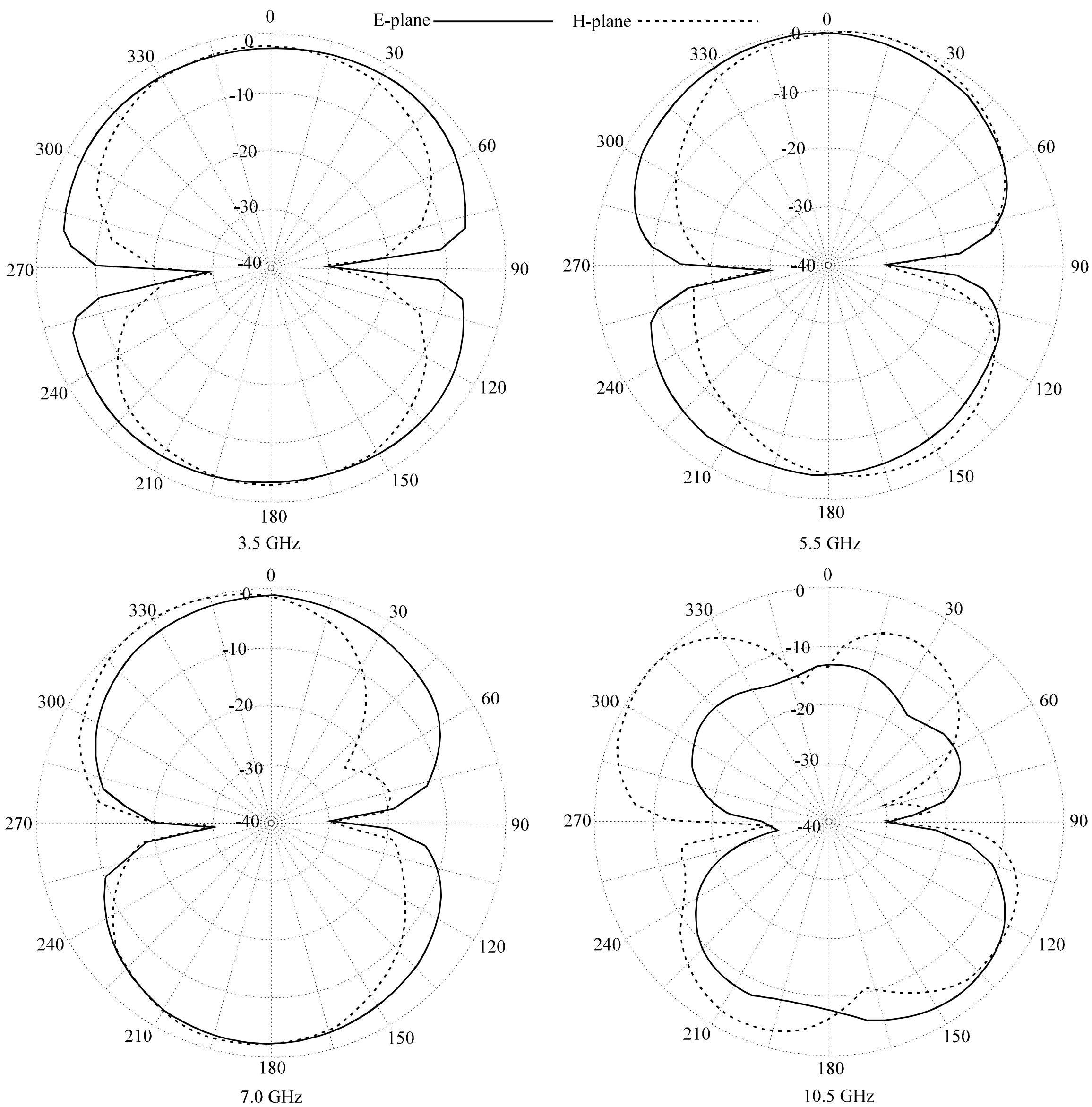


Fig. 7: Radiation pattern of the proposed antenna at different frequencies

CONCLUSION

A band-notched microstrip-fed printed monopole antenna has been proposed. The band-notch function was easily achieved by introducing a semicircular annular strip. The proposed antenna revealed good UWB performance, accompanied with a band-rejection function to avoid interference caused from the existing wireless networking technologies. The characteristics of the low profile and low cost with stable radiation patterns, makes the proposed antenna suitable for being used in UWB applications such as wireless communication and microwave imaging system for medical application.

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