Compact Band-Notched UWB Printed Planar Inverted Cone Antennas

Su Sandar Thwin

Abstract—**A tapered microstrip-fed printed inverted cone antenna with band-notched characteristics suitable for Ultra-Wideband (UWB) wireless systems is proposed. The antenna design consists of a semicircular slot embedded in a planar inverted cone as the radiating patch and a partial tapered ground plane. The proposed antennas are printed on a substrate of permittivity 4.4 and operate over a wide impedance bandwidth from 2.71 GHz to 16 GHz for VSWR 2:1. A semicircular slot is embedded in a planar inverted cone for rejecting the 5 - 6 GHz WLAN band. Prototypes are fabricated according to the optimized parameter values, and the antenna characteristics are measured. The results show that the proposed antennas are of the UWB characteristics and exhibit band rejection of 5 - 6GHz. The radiation patterns are stable and omnidirectional.**

Index Terms—**Band-rejection characteristics, compact printed microstrip antenna, planar inverted cone antenna, ultra-wideband antenna.**

I. Introduction

In the U.S., the Federal Communications Commission (FCC) allocated the frequency band 3.1 - 10.6 GHz for UWB applications in 2002[1]. An antenna plays a very crucial role in conventional communication systems and UWB communication systems**.** Nevertheless, there are more challenges in designing an UWB antenna than a narrow band antenna [2]. Planar monopole antennas have long been reported for its wide band operations, simple structure and nearly omnidirectioanl radiation patterns [3]. In addition the printed version of the monopole antenna has the convenience of compact size and easy integration with microwave circuits [4]. There are various types of UWB antennas which have been designed to achieve the requirement for different applications [5], [6]. A rectangular tuning stub [5] is embedded in the circular annular ring and an L-shaped slot [6] is cut in the edges of the main radiator with a C-shaped in the main radiator for generating the band-notched characteristics in UWB spectrum. The planar inverted cone antenna (PICA) is proposed by Suh [7] and variants of the PICA concept has been investigated by other[8]. A typical PICA is composed of single flat element vertically mounted above a large ground plane and likes a wide monopole antenna.

In this paper, tapered microstrip-fed PICAs with band-notched characteristics suitable for UWB wireless systems is proposed. The 5GHz band-notched characteristics can be achieved by embedding the semicircular slot in the radiating patches. The notch frequency can be done by adjusting the total length and width of the semicircular slots.

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II. Antenna Design

The geometrical parameters of the proposed microstrip-fed monopole antenna with partial ground plane are illustrated in Fig. 1 (a). The antenna, having compact dimensions of 23.6mm × 40mm, is fed with a 50 Ω microstrip line and fabricated on the FR4 substrate with thickness 1.6 mm and relative permittivity of 4.4. On the back of the substrate, the finite ground plane has the dimensions of 23.6 mm × 24 mm. On the front surface of the substrate, the radiating element of 14 mm × 14 mm is printed. It is based on the conventional planar monopole circular disc antenna. The shape of the radiating element is like a planar inverted cone. The total height of the radiating element is about $\lambda_L/4$, where λ_L denotes a wavelength at the lowest operating frequency. As shown in Fig.1 (a), in order to match the radiation patch's resistance with the microstrip-fed, a linear tapered section has been used to connect the two parts. And the top parts of the partial ground plane are also tapered for impedance matching. The antenna was simulated and optimized by the Ansoft High-Frequency Structure Simulator (HFSS) simulation software. The optimal dimensions of the designed antenna are as follows: W = 23.6 mm, L = 40 mm, R = 7 mm, S = 8.8 mm, D = 1mm, W_S = 1 mm, W_f = 3mm, L_f = 7mm, L_{g1} = 21mm, L_{g2} = 3mm. Fig.2 shows the simulated and measured *VSWRs* of the primitive antenna. The $VSWR \leq 2$ for the primitive antenna is from 2.71 to 16 GHz. This shows that there is a good impedance matching between radiating patch, tapered feed line and tapered partial ground plane.

To obtain the stopband of 5 to 6 GHz, the semicircular slots are etched in the radiating patches. The rejected frequency can be assumed as (1)

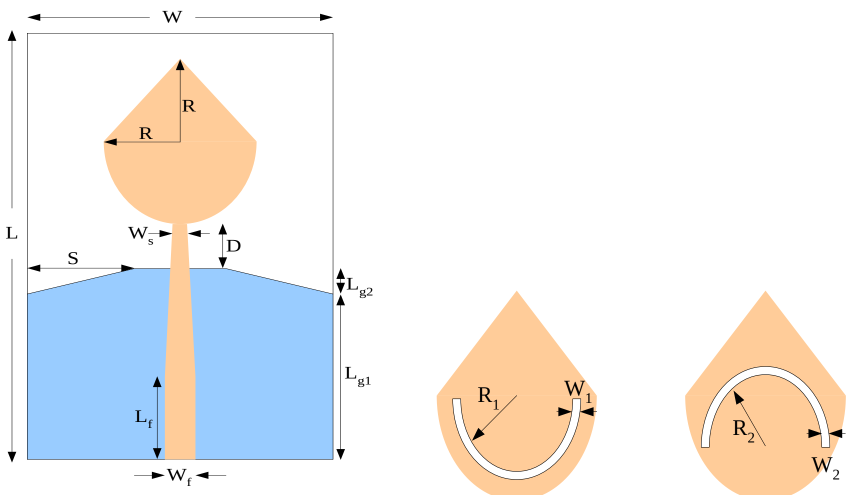
$$f_{notch} = \frac{c}{2L_{slot}\sqrt{\varepsilon_{eff}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_{\gamma}+1}{2} \quad (2)$$

where L_{slot} is the length of the slot; ε_{eff} is the effective dielectric constant; c is the speed of light.

We can use (1) and (2) to predict the length of the slot resonator, then, optimize the parameter L_{slot} with full wave simulation. The half wavelength of the slot resonators is short at both ends. The adjustment of the band-notched frequency can be done by varying the lengths of the semicircular slots. However, the widths of the semicircular slot also affect the notched bandwidth.

Fig.1(b) and (c) show the main parts of the proposed monopole antennas with semicircular U-shaped slot resonator in the radiating patch (antenna 1) and semicircular inverted U-shaped slot resonator in the radiating patch (antenna 2), respectively. The slots in antenna 1 and antenna 2 have uniform widths, $W_1 = 0.5$ mm , $W_2 = 0.8$ mm and $R_1 = 5.5$ mm , $R_2 = 4.6$mm.



(a) Primitive antenna (b) antenna1 (c) antenna 2

Fig. 1. Geometry of the designed antenna (a) UWB antenna (primitive antenna); (b) with U-shaped slot (antenna 1); (c) with inverted U-shaped slot (antenna 2)

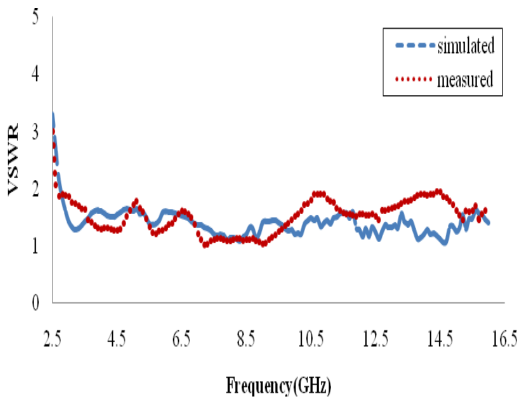


Fig. 2. Simulated and measured VSWRs of primitive antenna

As demonstrated in Fig.3, the width W_1 of the semicircular U-shaped slot determines the frequency range of the notched band. When W_1 is approximate to 0.5mm, the desired notched band of about 5 - 6.2 GHz is obtained. Fig.4 shows the simulated *VSWR* of the antenna 2 for various values of the width W_2 of the semicircular inverted U-shaped slot with other dimensions unchanged. It is seen that the width W_2 of the semicircular inverted U-shaped slot is a critical parameter to determine the stop band for 5 – 6 GHz. The simulated current distributions of the proposed antenna 1 and antenna 2 at typical frequencies (4, 5.6 and 8 GHz) are illustrated in Fig. 5(a) and (b). We find that the currents are concentrated at the edges of the semicircular slots for 5.6 GHz notched frequency for antenna 1 and antenna 2, respectively.

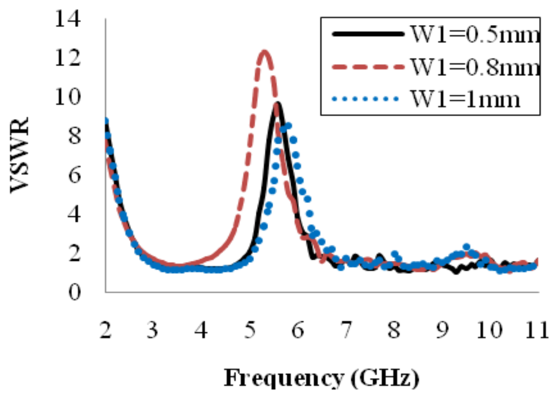


Fig. 3. Simulated VSWR for various semicircular U-shaped slot width W_1 for antenna 1

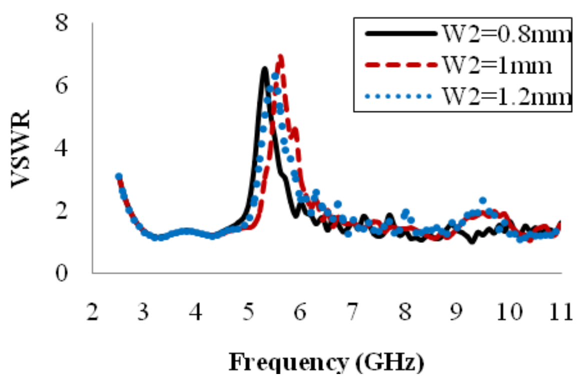


Fig. 4. Simulated VSWR for various semicircular inverted U-shaped slot width W_2 for antenna 2

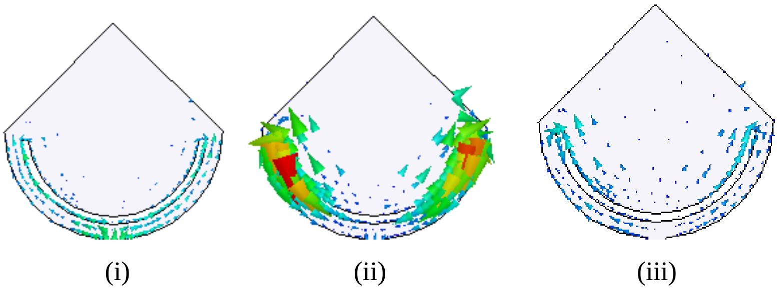


Fig. 5. (a) Current distributions of antenna 1(i) 4 GHz, (ii) 5.6GHz, (iii) 8 GHz

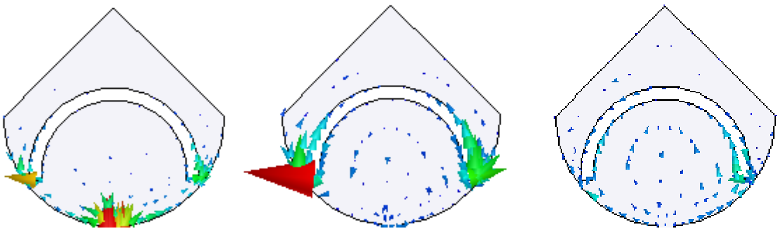


Fig. 5. (b) Current distributions of antenna 2(i) 4 GHz, (ii) 5.6GHz, (iii) 8 GHz

III. Results and Discussions

The proposed antennas were fabricated and the prototypes of the proposed antennas are shown in Fig. 6. The *VSWR* was measured using the Agilent Vector Network Analyzer 8722ES. Fig.7 and 8 show the simulated and measured VSWR against frequency for antenna 1 and antenna 2, respectively. It is observed that the designed antennas exhibit the stop band of 5 - 6.2 GHz for antenna 1 and 5 – 6 GHz for antenna 2, which maintaining wideband performance from 2.71 – 16 GHz for $VSWR \leq 2$, covering the entire UWB frequency band.

Fig. 9(a) shows the far-field radiation patterns of antenna 1in yz-plane and *xy*-plane at 4, 5.5, and 6.5 GHz and also the radiation patterns of antenna 2 at 4, 5.2, and 6.5 GHz are plotted in Fig. 9(b). It can be seen that the antennas has good omnidirectional radiation patterns in *yz*-plane. Furthermore, the measured peak gains of the two antennas are given in Fig. 10, where the significant antenna gain decreases at 5.5 GHz for antenna 1 and 5.2 GHz for antenna 2 indicate the effect of band stop clearly.

Fig. 6. Prototype of the proposed antennas

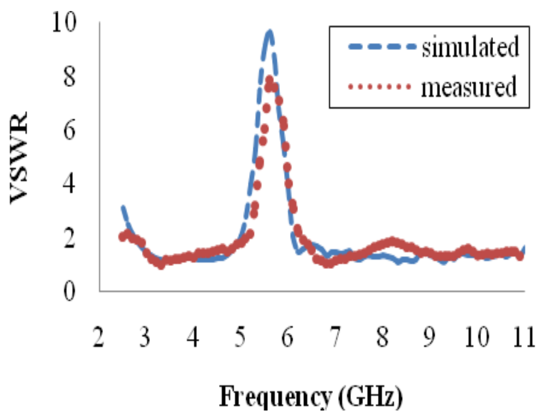


Fig. 7. Simulated and measured *VSWRs* of the antenna 1

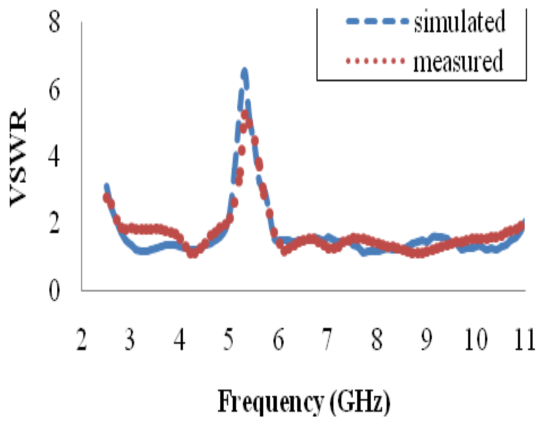
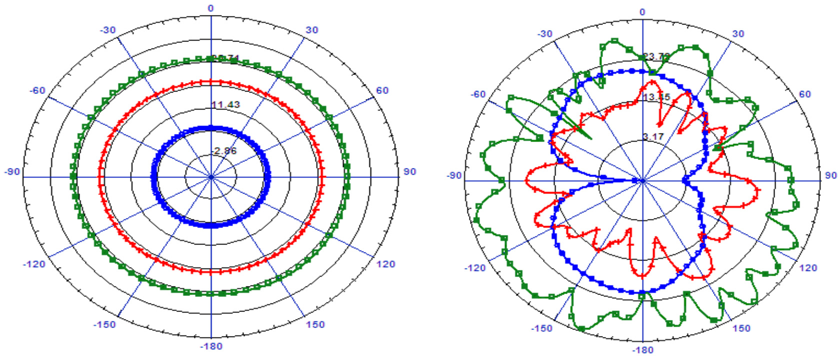
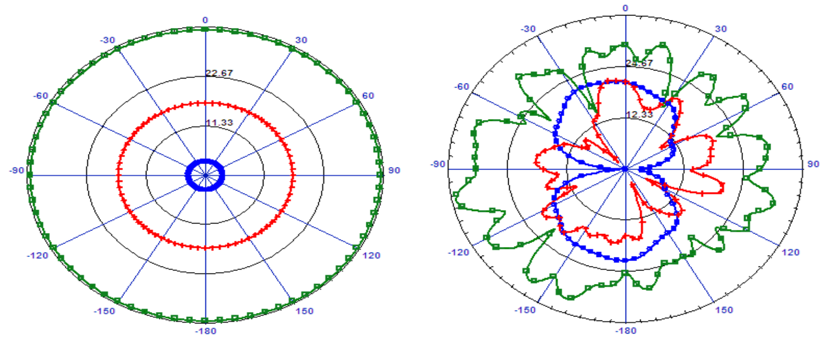


Fig. 8. Simulated and measured *VSWRs* of the antenna 2



(i) (ii)

(a) antenna 1 : (i) *yz* plane, (ii). *xy* plane [4GHz ; 5.5GHz ; 6.5GHz]



(i) (ii)

(b) antenna 2 : (i) *yz* plane , (ii). *xy* plane [4GHz ; 5.2GHz ; 6.5GHz]

Fig. 9. Radiation patterns of proposed antennas

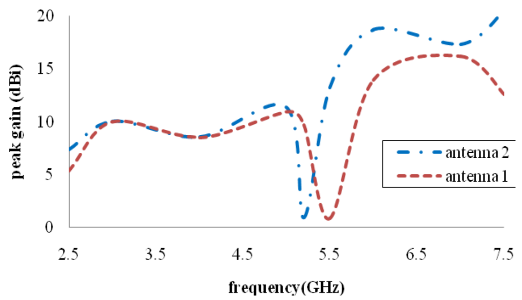


Fig. 10. Peak gain of proposed antennas

IV. Conclusions

In this paper, compact band-notched printed inverted cone monopole antennas are presented. By introducing the tapering of the ground edges and feed line, a wideband impedance matching is achieved. To mitigate the potential interference between the UWB systems and narrowband systems such as WiMAX and WLAN, the semicircular U and inverted U-shaped slot resonators are added for band rejection purpose. Both simulated and measured results show that the antennas not only have notched band over the ultra-wide operation band but also have a good radiation pattern. The size of the proposed PICA is 23.6mm x 40mm and smaller than [7] and [8]. It is easily integrated with RF/microwave circuits for low cost manufacturing and suitable for various UWB applications and high speed pulse communication.

Our future work is to optimize the proposed primitive antenna using other approach. The approach will also be implemented to extend it for multi band-notched against single band-notched UWB printed planar inverted cone antenna.

References

[1] "First report and order," Federal Communications Commission (FCC), April 2002.

[2] K. Y. Yazdandoost and R. Kohno, "Ultra-wideband antenna," *IEEE Communication Magazine*, Vol.42 no. 66, pp. 29-32, 2004.

[3] N. P. Agrawall, G. Kumar, and K. P. Ray, "Wide-band planar monopole antennas," *IEEE Trans. on Antennas and Propag*, Vol. 46, no. 2, pp. 294-295, 1998.

[4] J. Liang, C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disk monopole antenna for uwb systems," *IEEE Trans. on Antennas and Propag.*, Vol. 53, no. 11, pp. 3500-3504, 2005.

[5] Y. Gao, B. L. Ooi, and A. P. Popov, "Band-notched ultra-wideband ring monopole antenna," *Microwave Opt. Technol. Lett.*, Vol.48, no 1, pp. 125-126, 2006.

[6] W. Choi, K. Chaung, J. Chung, and J. Choi, "Compact ultra-wideband printed antenna with band-rejection characteristics," *Electron. Lett.*, Vol. 41, no.18, pp. 990-991, 2005.

[7] S. Y. Suh, W. L. Stutzman, and W. A. Davis, "A new ultrawideband printed monopole antenna: the planar inverted cone antenna (PICA)," *IEEE Trans. on Antennas and Propag*, Vol.52, no. 5, pp. 1361-1365, 2004.

[8] S. Cheng, P. Hallbjorner, and A. Rydberg, "Printed slot planar inverted cone antenna for ultra-wideband applications," *IEEE Antennas Wirel. Propag. Lett*., Vol.7 ,pp. 18-21, 2008.

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