Compact Printed Monopole Antenna with Dual Band-Notched Characteristics for UWB Applications

Su Sandar Thwin

Abstract—**A compact microstrip-fed planar ultra-wideband (UWB) monopole antenna with dual band-notched characteristics is proposed. The proposed design consists of a rectangular radiating patch and partial ground plane. Wideband matching is obtained by using the stair cased rectangular radiating element and slotted partial ground plane. A U-shaped slot resonator and an inverted U-shaped slot resonator are embedded in the feed line and radiating patch respectively for rejecting 3 GHz WiMAX band and 5 GHz WLAN band. The proposed antenna is printed on the FR4 substrate and is optimized by ANSOFT High Frequency Structure Simulator (HFSS). A prototype is fabricated according to the optimized parameters values, and the antenna characteristics are measured. The results show that the proposed antenna is of UWB characteristic and exhibits band rejection of 3 GHz and 5 GHz WiMAX and WLAN bands.**

Index Terms—**Dual band-notched antenna, staircase rectangular patch, slotted ground plane, UWB notched antenna**

I. Introduction

The commercial use of huge band from 3.1 GHz to 10.6 GHz has completely revolutionized by Federal Communication Commission's (FCC)'s in February 2002 [1]. After the FCC's ruling in February 2002, the researchers all over the world designed and proposed many UWB antennas, which are compact, low cost, light weight and easily integrated with RF/microwave circuits in the UWB systems. Along with the UWB spectrum (3.1 - 10.6 GHz), some narrowband systems operate. Notable among them is IEEE 802.11a and HPERLAN/2 WLAN system. Hence, to mitigate the interference from the above narrowband system, band-notch function is desirable in the UWB system. Many designs of the UWB band-notched antennas are proposed [2]-[9] to alleviate the disturbance caused by the WLAN and WiMAX with the UWB system. There are several types of UWB antenna [2]-[9]. A bell shaped patch with stair case structure is proposed in [2] with the two parasitic patched are printed on the substrate to provide the band-notch characteristics. An arc shaped slot is cut in the elliptical shaped patch [3], with a rectangular slot is cut in the ground plane. A rectangular tuning stub [4] is embedded in the circular annular ring, which generates the band-notched characteristics in the UWB spectrum. An L-shaped slot [5] is cut in the edges of main radiator with a C-shaped in the main radiator. Two L-shaped slots are cut from the ground plane with an arc is cut from the circular radiating patch [6]. An E-shaped slot is cut from the rectangular radiating patch with a notched ground plane [7], and a C-shaped parasitic strip combined with the circular slot antenna [8]. Two C-shaped slots cutting in the radiating patch for a dual band-notched UWB antenna was presented in [9].

In this paper, a simple and compact microstrip line-fed planar UWB antenna with dual band-notched characteristics in 3 GHz and 5 GHz is proposed. The dual band-notched characteristic can be achieved by embedding the inverted U-shaped and U-shaped slots in the radiating patch and transmission line. The notch frequencies can be done by adjusting the total length of the inverted U-shaped and U-shaped slots to be approximately half the guided wavelength of the required notch frequency. The appropriate gain and stable radiation patterns are obtained. Moreover, the simulated results have a good agreement with the measured ones.

II. Antenna Design

The configuration of the proposed microstrip transmission line-fed monopole antenna with partial ground plane is illustrated in Fig. 1. The antenna 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. The shape of the radiating element is rectangular and there is a stair cased structure symmetrically at the two bottom corners of the radiating element. The radiating element is fed by 50Ω microstrip transmission line has a center width W_f = 3mm, which is terminated with a sub miniature A (SMA) connector for the measurement purpose. On the back of the substrate, multiple rectangular slots are embedded on the top side of the partial ground plane. The dimension of partial ground plane which is printed in the back side of the substrate is chosen to be W × L_g and each slot is 2 mm × 1 mm. The gap between the radiating patch and ground plane is G. 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 = 30mm, L = 30mm, W_p = 15mm, W_1 = 14mm, W_2 = 0.6mm, W_3 = 0.5mm, W_f = 3mm, L_1 = 9.5mm, L_2 = 7.4mm, L_3 = 7.5mm, L_g = 11.5mm, G = 1mm, S_1 = 1.5mm, S_2 = 1.5mm, S_3 = 2mm, D_1 = 1.5mm, D_2 = 1mm, D_3 = 1mm, G_1 = 1mm.

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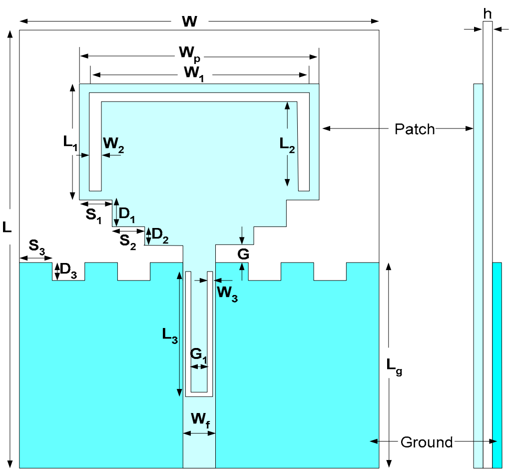


Fig. 1. Geometry of the designed antenna

Fig. 2 shows the simulated *VSWR* of the primitive UWB antenna (antenna without slots). The $VSWR \leq 2$ for the primitive antenna is from 3.1 to 11.8 GHz. This depicts that there is a good impedance matching between the microstrip transmission line and the stair cased rectangular radiating element. The staircase structure and partial ground plane with multiple rectangular slots improve the impedance matching and the bandwidth of the primitive antenna.

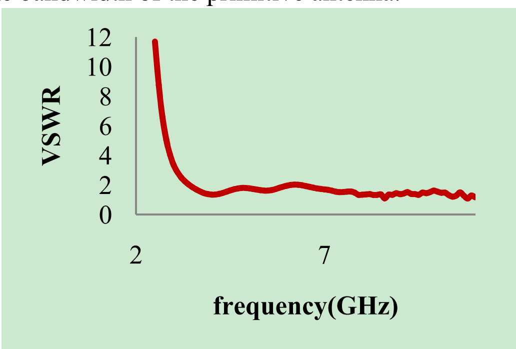


Fig. 2. Simulated VSWR of the primitive antenna

Some narrowband systems like IEEE 802.11*a* and HIPERLAN/2 WLAN system operate along with the UWB spectrum (3.1 – 10.6 GHz). The band-notch function is desirable in the UWB system to mitigate the interference from the above narrowband system. By removing the inverted U-shaped slot from the stair cased rectangular radiating patch and a U-shaped slot from the microstrip transmission line, the dual band-notch function is created. The rejected frequency can be assumed as (1)

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

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

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 slots. However, the widths of the slot also affect the notched bandwidth. At the desired notch frequency, the current distribution is around the U-shaped slots.

Fig. 3 depicts the simulated *VSWR* of the proposed antenna for different values of L_2. As observed, the adjustment of the band-notched frequency can be done by varying the length (L_2) of the inverted U-shaped slot. By decreasing L_2 from 7.4 mm to 5.4 mm, the tip of the notched band shifted from 3.2 GHz to 3.7 GHz and VSWR drops from 8.64 to 4.85. The total length of the inverted U-shaped slot for the proposed antenna is ($2L_2 + W_1$). The simulated VSWR of the proposed antenna for different values of L_3 is also illustrated in Fig.4. As mentioned in Fig.4, the 5 GHz band-notched frequency can be done by adjusting the length (L_3) of the U-shaped slot. By decreasing L_3 from 8.5 mm to 6.5 mm, the tip of the notched band also shifted from 5.1 GHz to 6.7 GHz. The total length of the U-shaped slot at the microstrip transmission line is ($2L_3 + G_1$).

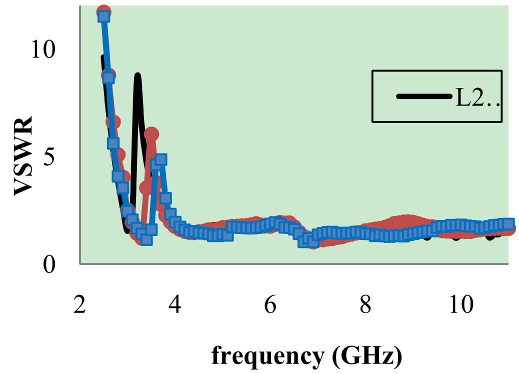


Fig. 3. Simulated VSWR for different values of L_2

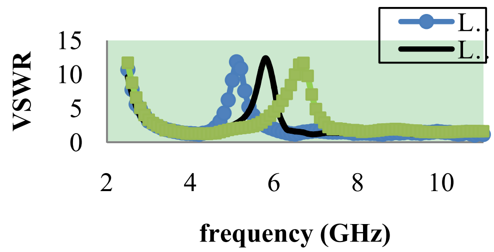


Fig. 4. Simulated VSWR for different values of L_3

III. Results and Discussions

We fabricated the proposed antenna and the prototype of the proposed antenna is illustrated in Fig. 5. We measured the *VSWR* using the Agilent Vector Network Analyzer 8722ES. Fig. 6 shows the simulated and measured *VSWRs* against frequency for the proposed antenna. We can observe that the proposed antenna provides the band-notch in the frequency range of 3 – 4 GHz with a *VSWR* value of about 9 and 5 – 6 GHz with a *VSWR* value of about 11, which maintains wideband performance from 3.1 – 11.8 GHz for $VSWR \leq 2$, covering the entire UWB frequency band. The simulated impedance of the proposed antenna shows that the high VSWR in the WiMAX and WLAN bands result from low input impedances about 9.4 + *j*23.5 at 3.2 GHz and 7.1 + *j*13.3 at 5.8 GHz.

Fig.7 shows the antenna peak gain in the frequency range of 2.5 – 7.5 GHz for the proposed antenna. We can observe that the significant antenna gain decrease at 3.2 GHz and 5.8 GHz indicate the effect of band stop clearly. Furthermore,

Fig.8 depicts the far-field radiation patterns of the proposed antenna at 3.2 GHz, 4.5 GHz and 5.8 GHz. We can observe that the antenna pattern is purely omnidirectional at all simulated frequencies in the *yz*-plane. In *xy*-plane, the radiation pattern is bi-directional and like a dipole antenna. The distortion was observed at high frequency in *xy*-plane. The radiation efficiency of the proposed antenna is more than 90% in the pass band and less than 20% in the stop band.

Fig. 5. Prototype of the proposed antenna

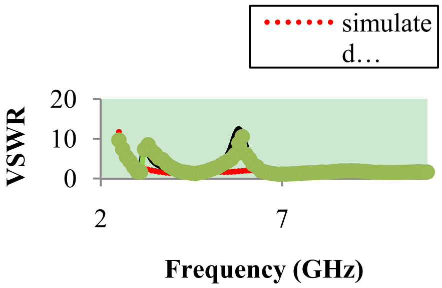


Fig. 6. Simulated and measured VSWRs of the proposed antenna

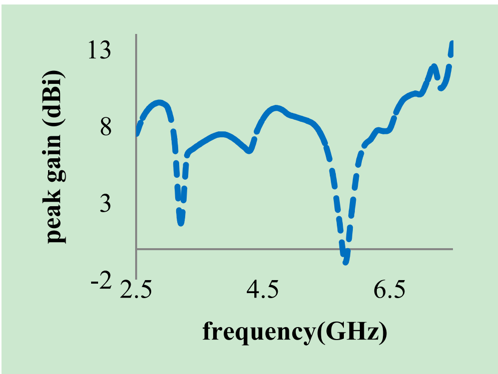
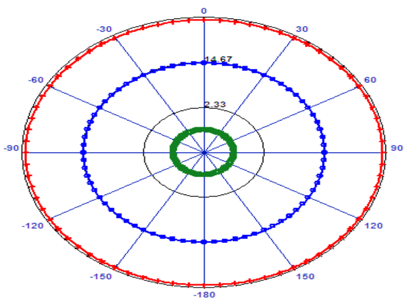
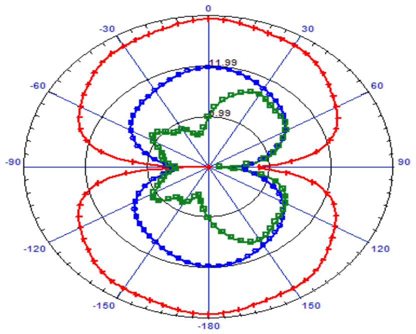


Fig. 7. Peak gain of the proposed antenna



(a)



(b)

a. *yz* plane, b. *xy* plane [3.2*GHz* ; 4.5*GHz* ; 5.8*GHz*]

Fig. 8. Radiation pattern of proposed antenna

IV. CONCLUSIONS

A compact wideband stair cased rectangular-radiating patch monopole antenna is presented. By introducing the stair case structure at rectangular radiating element and multiple rectangular slots at partial ground plane, a wideband impedance matching is achieved. To mitigate the potential interference between the UWB systems and narrowband systems such as WiMAX and WLAN, an inverted U-shaped slot and a U-shaped slot are added for band rejection purpose. Both simulated and measured results show that the antenna not only has dual notched bands over an ultra-wide operation band but also have a good radiation pattern. The proposed planar antenna is easily integrated with RF/microwave circuits for low cost manufacturing and suitable for various UWB applications.

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