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Band-Notched UWB Monopole Antenna Design with Novel Feed for Taper Rectangular Radiating Patch

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Abstract—In this paper, a novel dual notch bands Ultra Wide-Band (UWB) antenna for WLAN and WiMAX applications is presented. The antenna contains a taper rectangular monopole antenna with new feed line which is designed and modified for 2–12 GHz. To achieve notch band at WLAN frequencies, different methods are compared such as L-shape slots for one notch or dual rings in notch designing. On the other hand, the novel F-shape feed line is designed to achieve dual notch band characteristic. The effects of stubs parameters at notch frequencies are presented. The benefit of this novel feed line is designing multi-band and reconfigurable antenna by changing stub line parameters. The simulated results of prototype antenna are obtained with HFSS and CST. Total size of the antenna is 60 mm × 60 mm × 1.6 mm. It is fabricated on FR-4 low cost substrate and fed by 50 Ω microstrip line.

1. INTRODUCTION

During the last decade, wireless communication systems have progressed too fast and become the most important part in notebooks and cellular phones because of mobility and low cost [1, 2]. A WLAN links two or more devices and provides a high speed connection through a wide-band internet access. Recently, broadband systems are designed for faster communication and more data transfer [3, 4]. In 2002, the Federal Communication Commission (FCC) confirmed the frequency band from 3.1 to 10.6 GHz for low-power UWB applications [5].

To prevent interference with existing wireless networks WLAN (5.15–5.825 GHz) and WiMAX (5.25–5.85 GHz) according to IEEE 802.11 standard the UWB antenna with a rejected band is desirable [6]. DCS (1.71–1.88 GHz), PCS (1.75–1.87 GHz), UMTS (1.92–2.17 GHz) and 2.4 GHz WLAN are some frequencies used for wireless and personal communication, which are not in UWB frequency ranges. Thus UWB antenna which covers these frequency bands is required. One way to access such structures is to design multi-band antenna that operates at specific frequencies. However, it is very difficult to achieve such structures which support all these frequencies [2, 7]. IEEE 802.11a standard considers 5.15–5.35 GHz and 5.725–5.825 GHz as send and receive bands, respectively. IEEE 802.11bg applies 2.4 GHz (2.4–2.484 GHz) to WLAN applications [8–10].

Monopole antennas with microstrip feed line are widely used in designing UWB antenna because of low profile, low cost, light weight, easy fabrication, designing in desirable shape and integration with printed circuit boards. They also have UWB impedance matching (more than 100%) [11]. Various types of microstrip circular and elliptical patches have been considered. CPW circular patches and truncated ground plane are used for increasing the antenna impedance bandwidth [12–14]. Nowadays

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slot antennas are a typical kind of UWB antenna [15, 16]. Various methods have been proposed for the design of multi-band antennas. The slots are the basic and conventional way for designing of notch band in UWB antennas. So for this purpose, many slot shapes have been presented such as C, H, U and L [17, 18]. In some researches, UWB monopole antenna with coplanar-waveguide (CPW) feed line is presented, and notch frequencies are obtained by slots. For having notch structure, slot is inserted in patch, and the truncated ground plane is used for the improvement of impedance bandwidth [19, 20]. Other methods, such as parasitic strips and fractal structures, are conventional methods for designing multiple band notch antennas on CPW or other UWB structures [21, 22]. Also many researches on applying metamaterial and CRLH structures to design notch band in antenna have been reported [22–24].

In this paper, a novel taper rectangular patch for UWB application is presented. The effect of slots making a notch band at WLAN and WiMAX frequencies is also shown. At last, the novel F-shape feed line for obtaining dual notch band is presented. The feed line can be combined with conventional slots and stub line for notch and reconfigurable multi-band application without using slot on antenna radiator.

2. ANTENNA DESIGN

2.1. Antenna Structure

Figure 1 shows the proposed UWB antenna configuration. The antenna consists of a rectangular ground plane and a taper rectangular patch which is implemented on the same side of the substrate. The antenna is excited by a microstrip line connected to patch through via with 1 mm radius. The microstrip line has 3 mm width which provides 50 Ω input impedance. A compact patch, with size 24 × 25 mm, is achieved.

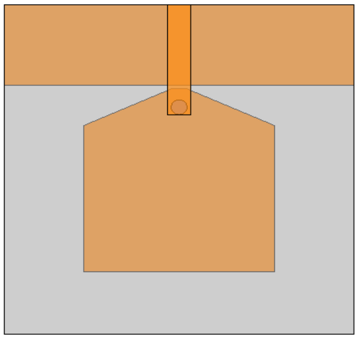


Figure 1. The proposed antenna configuration.

The simulated and measured results are shown in Fig. 2. The antenna has good VSWR in 2.2–11 GHz. The antenna is fabricated on a FR-4 low-cost substrate with relative permittivity of 4.4 and height of 1.6 mm. Total size of the antenna is 45 mm × 44 mm × 1.6 mm. The distance of gap between patch and ground is 0.5 mm.

Figure 3 shows the efficiency of prototype UWB antenna, which lies between 60% and 92%, and in this frequency range the antenna gain is 2–6.5 dBi.

3. BAND NOTCHED DESIGNS

The goal of this paper is to design UWB antenna with dual-band rejection. In order to generate dual band-notched characteristic, three different antennas are considered, and the effect of deformation is examined. For the first and second antennas by inserting slot on the patch, a notch band has been created. For the third one by putting an F-shape stub next to the feed line, two notch bands are obtained. Fig. 4 shows the geometry and parameters of these antennas. In the first antenna, radiating

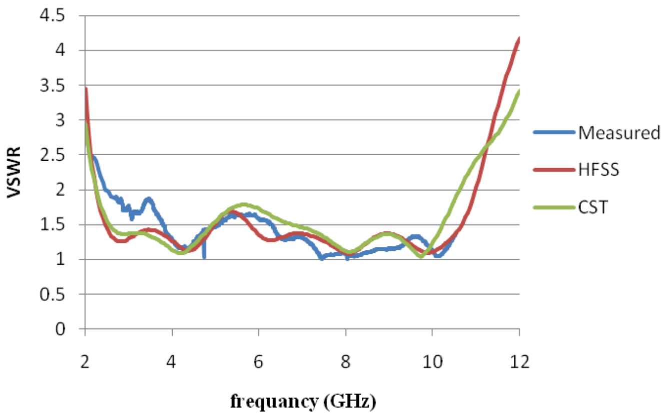


Figure 2. Comparisons of VSWR among CST, HFSS and experimental result.

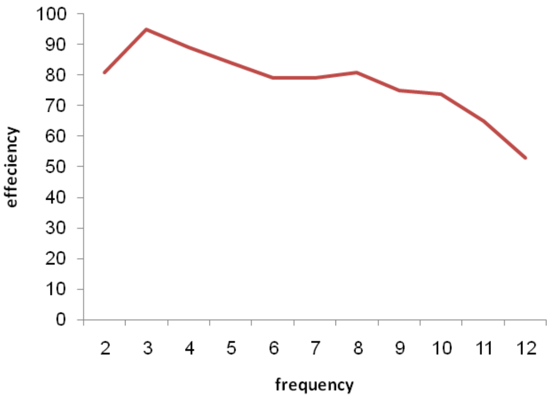
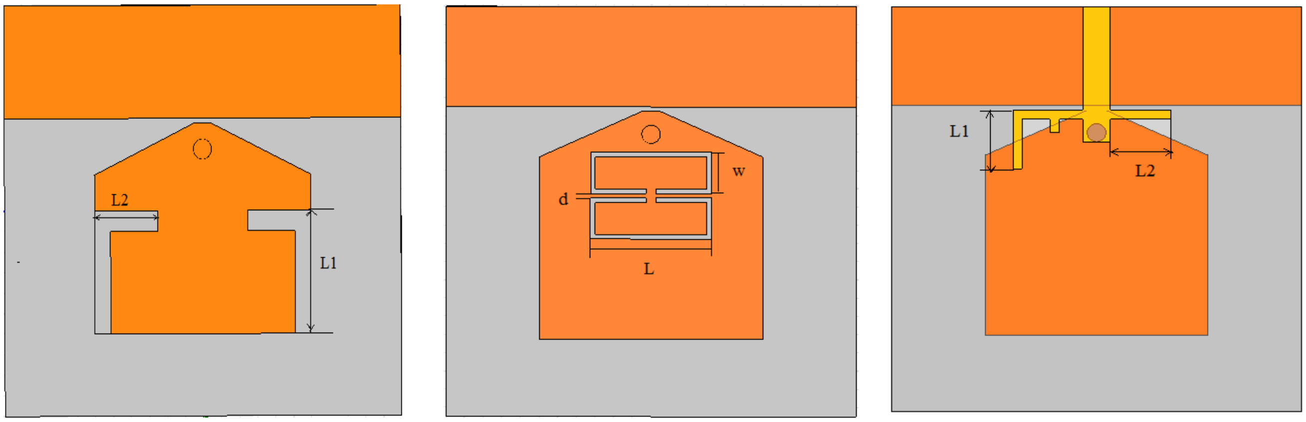


Figure 3. The simulated efficiency of UWB antenna in CST.



(a) (b) (c)

Figure 4. Geometry of the notched-band antenna using (a) L-shape slots, (b) C-shape slots, (c) an F-shape stub connected to feed line.

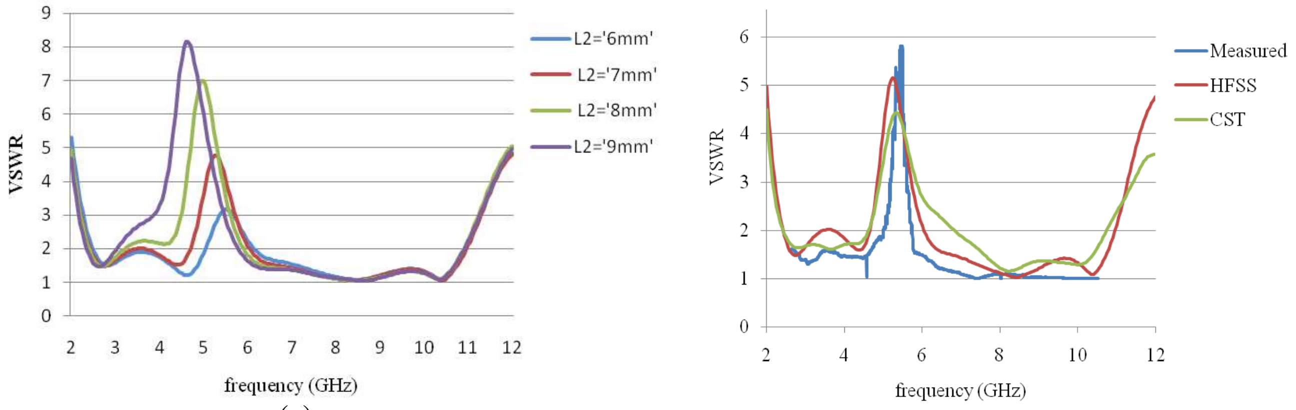
patch contains two L-shape slots with $L_1 = L_2 = 10\,\text{mm}$ as shown in Fig. 4(a). It causes a rejection band between 5–6 GHz which covers WLAN (5.15–5.35 GHz and 5.725–5.825). In the second design, two parallel C-shape slots have been utilized for notch band at 4 GHz, shown in Fig. 4(b). The third antenna contains an F-shape stub which is added to microstrip feed line as shows in Fig. 4(c). It causes two rejection bands, at 2.5–3.2 GHz and 5–6 GHz for WLAN rejection.

3.1. One Notch Antenna

By adding two L-shape slots to UWB antenna, one notch band at 5–6 GHz for eliminating interference with WLAN frequencies is obtained. The effect of different lengths of L_2 on VSWR with constant L_1 is investigated. L_2 affects the notch frequency of the antenna evidently. As L_2 increases, the frequency of notched-band decreases and notch bandwidth increases (see Fig. 5). The notch band is placed at 5–6 GHz with $L_2 = 7\,\text{mm}$, and the antenna covers 2.3–4.9 GHz for WLAN, Bluetooth, WiMAX and also 6–10.6 GHz for hyper LAN.

Figure 5(b) shows simulated and measured results of the L-shape slot antenna. The L-shape slot dimensions are $L_1 = 10\,\text{mm}$, $L_2 = 8\,\text{mm}$, and slot width is 2 mm.

Figure 6 shows simulated efficiency of the prototype UWB antenna with L-shape slots, which lies



(a)

(b)

Figure 5. (a) Change of L_2 in L shape slot antenna with $L_1 = 10\,\text{mm}$, (b) comparisons of VSWR among CST, HFSS and experimental result in L shape slot antenna.

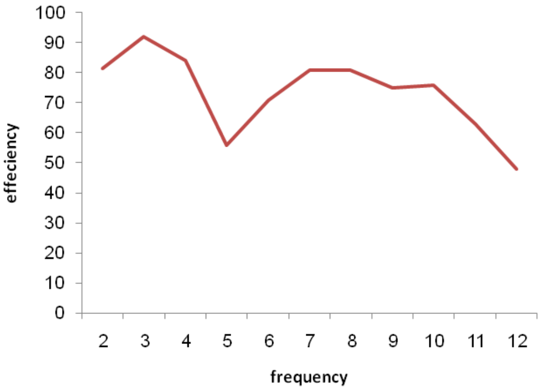


Figure 6. The efficiency of a L shape notch antenna.

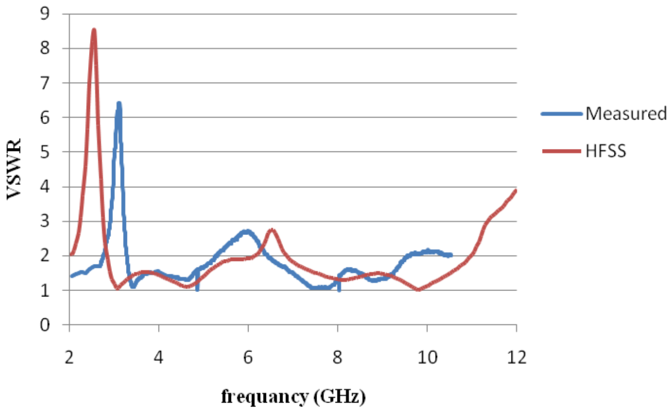


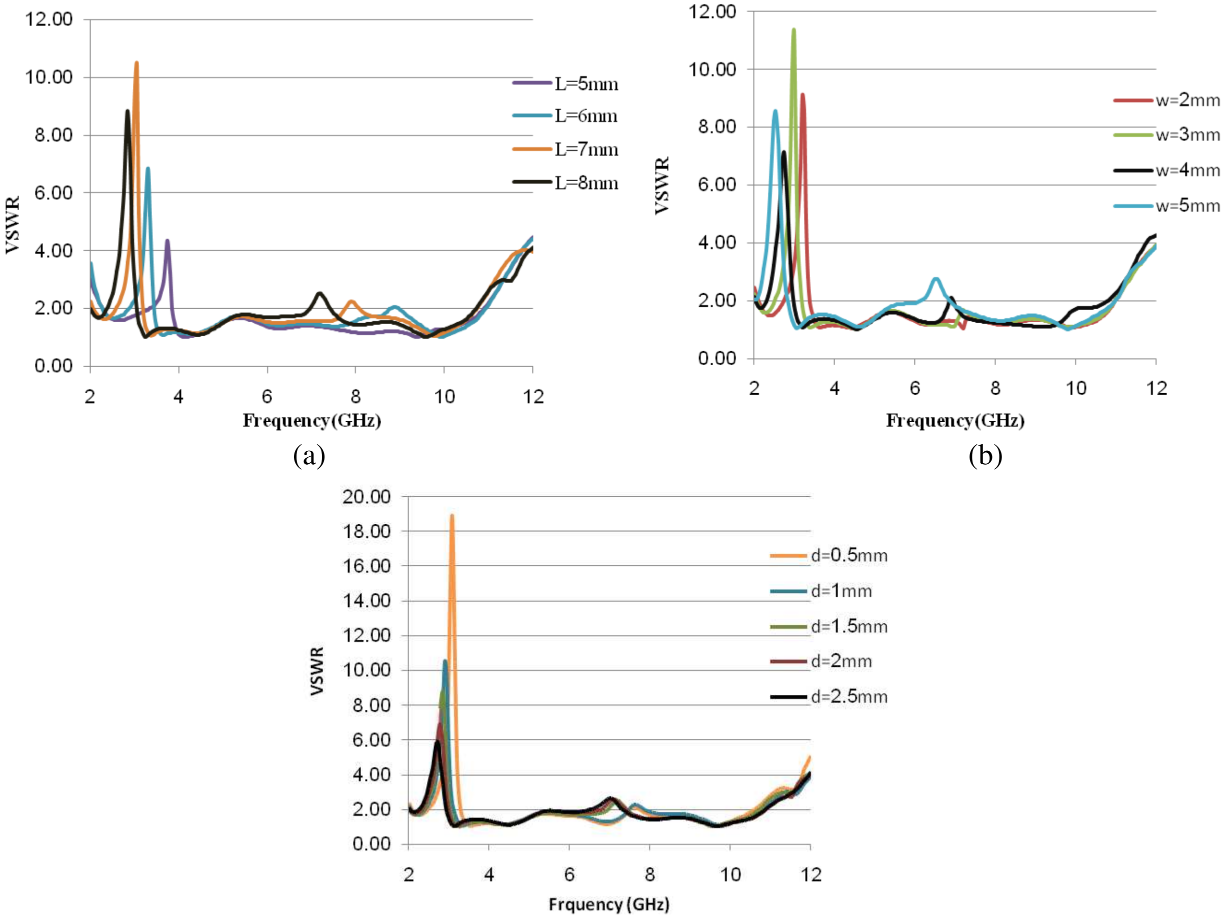
Figure 7. Comparisons of the simulated and measured VSWR in C shape slot.

between 50% and 94%, and in this frequency range the antenna gain is 2–5 dBi. As seen in Fig. 6, the notch band obviously reduces antenna efficiency to 55%.

Another type of slot for the design of notch frequency at 2–3 GHz is presented in Fig. 5(b). The simulated and measured results of this antenna are shown in Fig. 7. The slight difference between the results is because of imperfect constructed antenna. The C-shape slot dimensions are $L = 8\,\text{mm}$, $w = 4\,\text{mm}$ and $d = 1.5\,\text{mm}$. The width of slot is 0.5 mm.

Figure 8 shows the simulated VSWR of the proposed antenna for various L, w and d of C-shape slots. The notch frequency can be decreased further from 3.75 GHz to 2.85 GHz as the length of the C-shaped slot increases (Fig. 8(a)). As shown in Fig. 8(b), the notch frequency decreases as the width of C-shaped slot w increases. As the slot length is shortened from 2.5 mm to 0.5 mm, the rejection band decreases markedly. It can be concluded that the notch bands for the proposed C-shaped slots antenna are controlled by L, w and d.

Figure 9 shows simulated efficiency of the prototype UWB antenna with C shape slot in CST. Efficiency lies between 55% and 95% and reduces to 30% at notch frequency. Antenna efficiency in the notch bands at 2.7–3.2 GHz sharply decreases. So, C-shape slots show more reduction in efficiency than L-shape slots.



(a) (b)

(c)

Figure 8. Comparison of parameter in C shape slot with (a) $w = 5$ and $d = 1.5\,\text{mm}$, (b) $L = 9\,\text{mm}$ and $d = 1.5\,\text{mm}$, (c) $w = 5\,\text{mm}$ and $L = 8\,\text{mm}$.

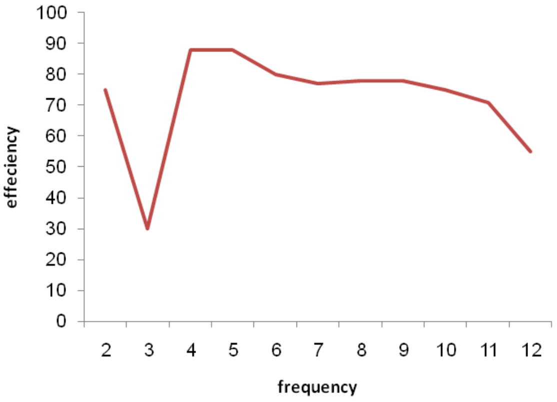


Figure 9. Simulated efficiency of C shape slot notch band antenna in CST.

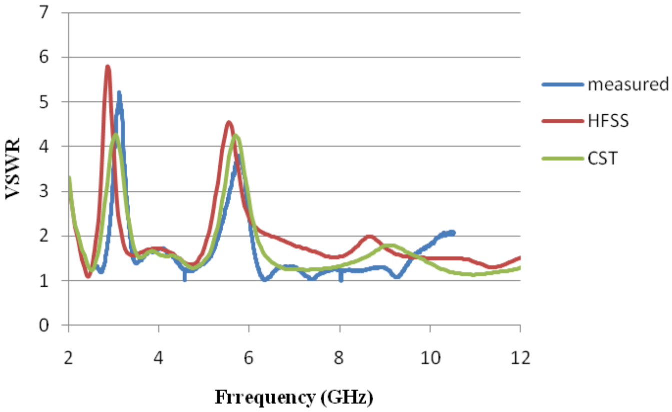
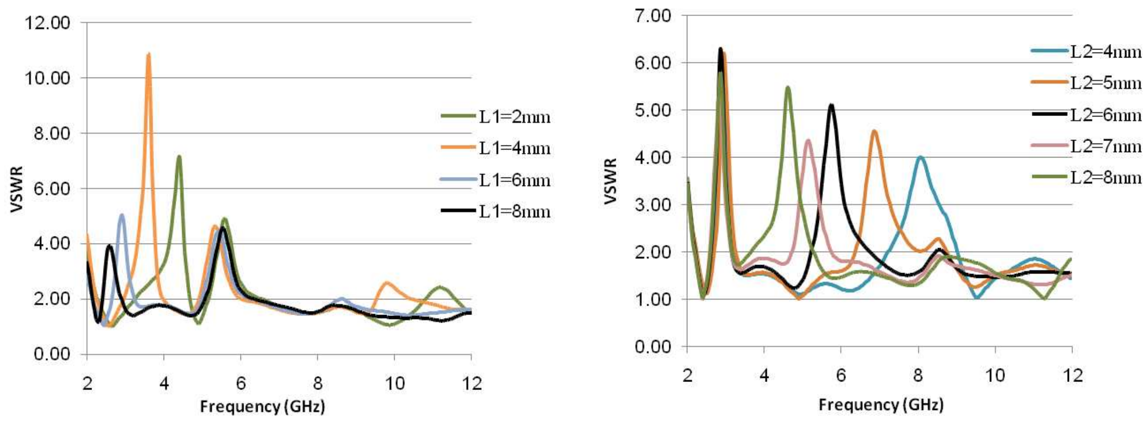


Figure 10. Simulated and measured VSWR of the dual notched-band antennas with an F-shape stub connected to feed line.

3.2. Dual Notch Antenna

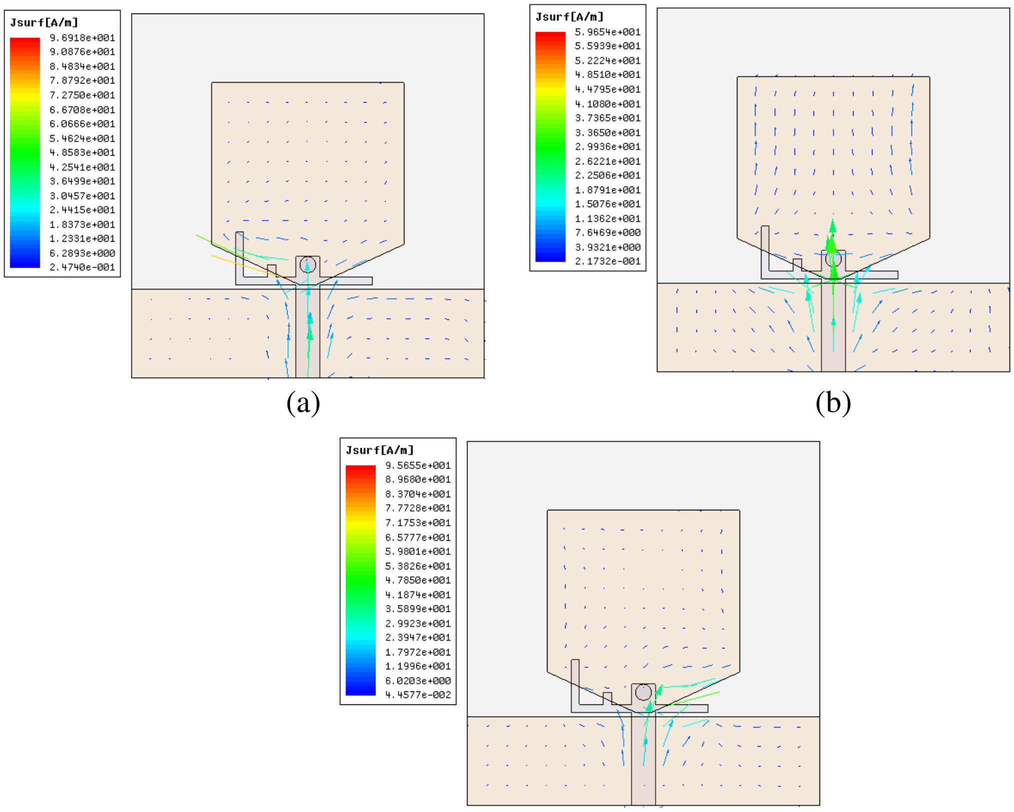
Finally, a novel feed for designing UWB antenna with dual band notch characteristics has been presented. An F-shaped stub is used to implement dual band-notched antennas at 2.5–3 GHz and 5–6 GHz. The simulated and measured VSWRs of the antenna are shown in Fig. 10. The F-shape stub dimensions are $L_1 = 6.5$ mm, $L_2 = 6.5$ mm and width of stub is 1 mm.

To investigate the effects of an F-shape stub on the proposed antenna, the simulated VSWRs for



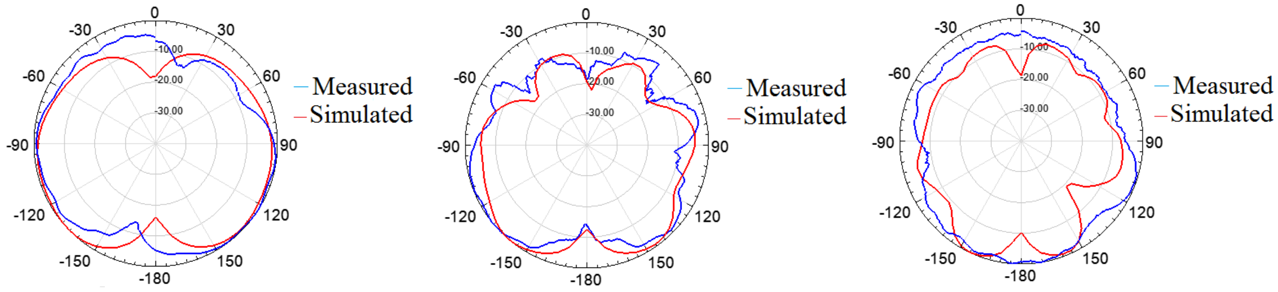
(a) (b)

Figure 11. (a) Change of L_1 in F shape stub, (b) change of L_2 in F shape stub.



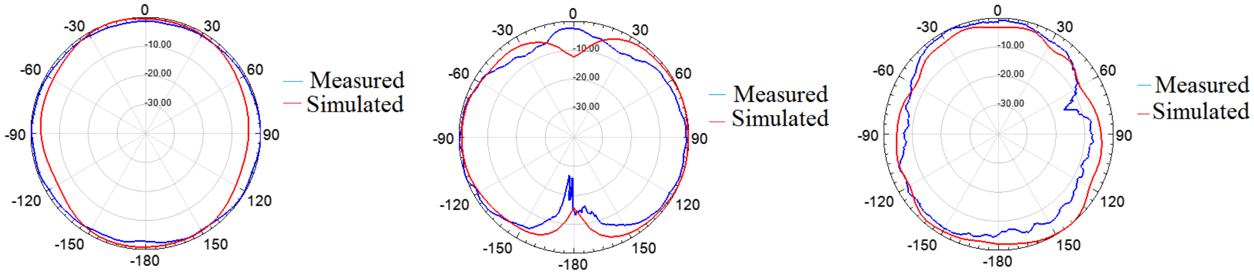
(a) (b) (c)

Figure 12. Simulated current distributions at (a) $f = 2.8$ GHz, (b) $f = 4$ GHz, (c) $f = 5.5$ GHz.



(a) (b) (c)

Figure 13. Measured and simulated E-plane radiation patterns at (a) 4 GHz, (b) 7 GHz, (c) 9 GHz.



(a) (b) (c)

Figure 14. Measured and simulated H-plane radiation patterns at (a) 4 GHz, (b) 7 GHz, (c) 9 GHz.

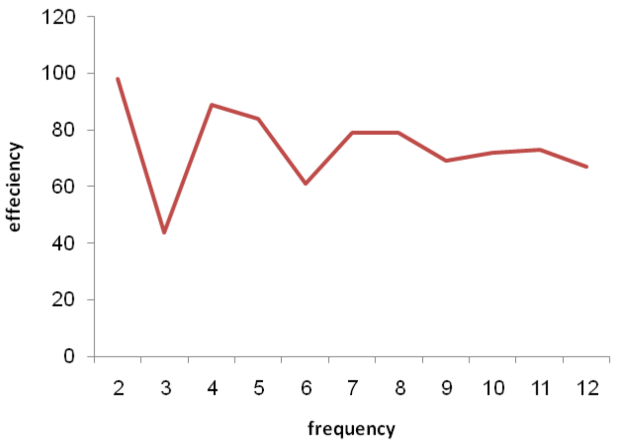


Figure 15. Simulated efficiency of F shape stub antenna in CST.

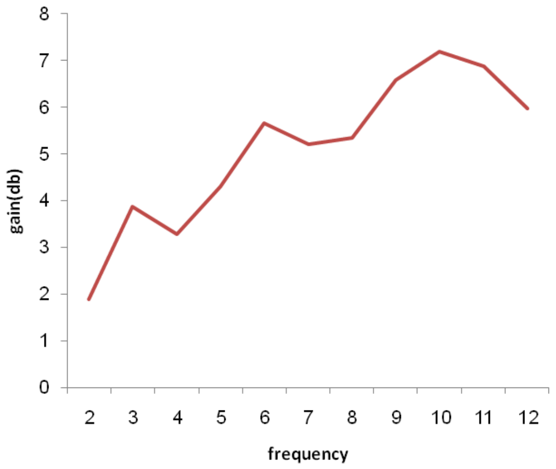


Figure 16. Simulated gain of F shape stub antenna in CST.

various L_1 and L_2 are examined (see Fig. 11). The effect of L_1 and L_2 variation on notch frequency is compared here. Fig. 11 shows that the length L_1 of the F-shaped stub clearly influences the impedance at lower band notch (2.8–3.35 GHz), and the stub length L_2 affects the impedance in top band. In other words, the first notch frequency is controlled by L_1, while L_2 is used for adjusting the second notch band. L_2 does not have effect on the first band notch. The influence of the slot width in the L-shape and C-shape is negligible. As shown in Fig. 11(a), the lower notch band for different frequencies can be achieved. By using $L_1 = 4\,\text{mm}$, the band of 3–4 GHz can be rejected as reported in previous researches [11]. The aim is to design antenna that covers WiMAX band and rejects unnecessary band. Therefore, it shows the flexibility of an F-shape feed line for controlling the frequency bands.

Figure 12 shows the simulated current distributions at 2.8, 4 and 5.5 GHz. Apparently in notch

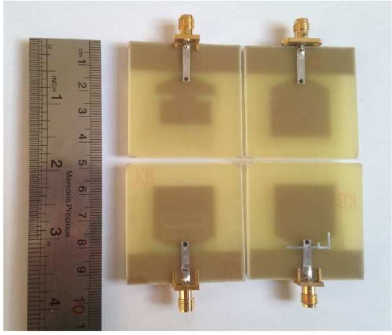


Figure 17. Photograph of the developed UWB antennas.

frequencies at 2.8 GHz and 5.5 GHz the current is concentrated and limited to bottom part of the taper patch. But at 4 GHz the current has been distributed at the edge from via to end of patch.

The measured and simulated radiation patterns in E- and H-planes, for the proposed dual notch antenna at frequencies 4, 7, and 9 GHz, are shown in Figs. 13 and 14. A good agreement between the simulated and measured results is achieved.

Simulated efficiency of prototype UWB antenna with an F-shape stub is shown in Fig. 15, which is between 44% and 98%, and the antenna gain in this frequency range is 1.9–7.2 dBi. Fig. 16 shows the prototype antenna gain. As shown, notch frequencies affect antenna efficiency. A sharp decrease of antenna efficiency is observed in the notched frequency bands. It is reduced to 42% for the first notch and 60% for the second one. Finally, Fig. 17 shows the constructed antennas as illustrated previously.

4. CONCLUSION

The antenna presented in this paper contains a novel taper rectangular monopole antenna with a new feed line, which is designed for 2–12 GHz application. Then notch band has been designed by adding few slots to this antenna for filtering the WLAN frequencies. The final design is a dual-band antenna and supports wireless application WLAN (2.4–2.484 GHz), WiMAX (3.1–4.9 GHz) systems and downlinks of X-band satellite communication (7.25–7.75 GHz) systems. The effect of this filter for some evanescent frequencies is also investigated. The benefit of this novel feed line is designing multi-band and reconfigurable antenna by changing stub line parameters.

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