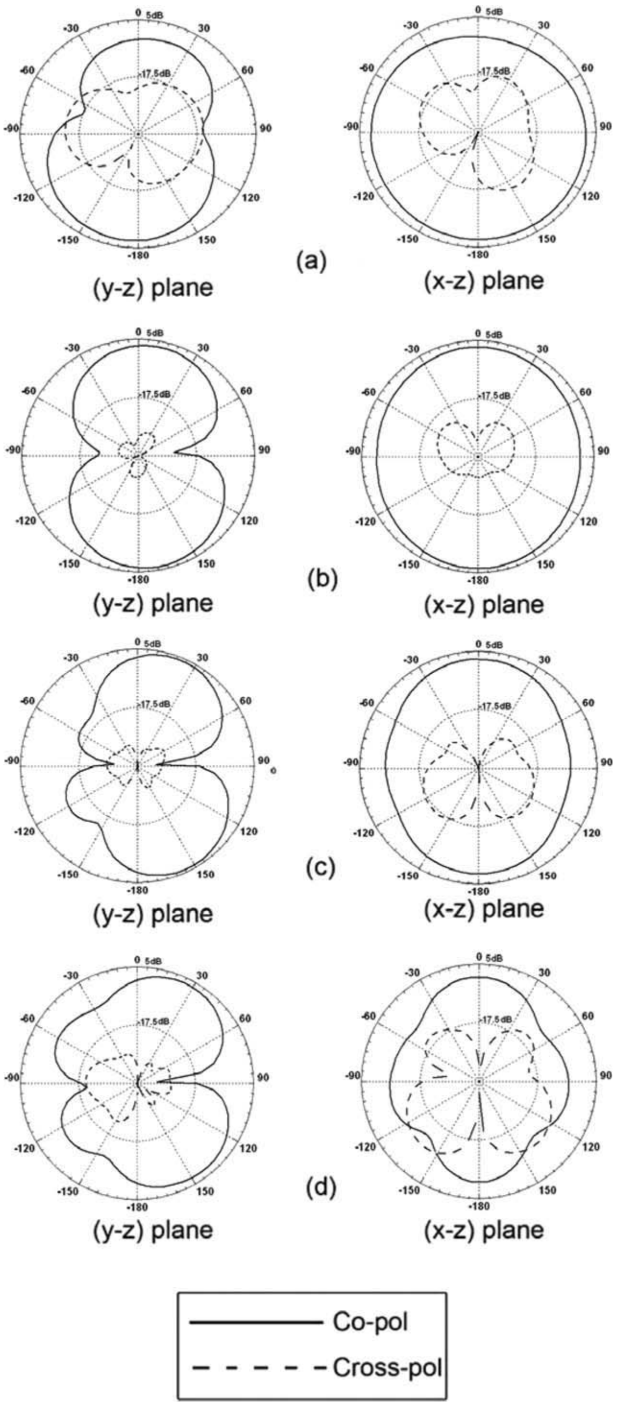


**Figure 8** Measured radiation pattern of the proposed antenna. (a) 4, (b) 6, (c) 7, and (d) 9 GHz

design at the patch and improving it, currents are regularly concentrated around this slot. Figure 6 shows characteristics of measured and simulated return loss to the proposed antenna. From this figure, it's obvious that a slight difference occurred between simulated and measured results in the position of resonance about 10 and 11 GHz, which caused by SMA port effects in laboratory. Figure 7 shows measured antenna gain from 3 to 11 GHz for the proposed antenna. Measured radiation pattern at frequencies of 4, 6, 7, and 9 GHz in H-plane($x$–$z$ plane) and E-plane($y$–$z$ plane) plotted in Figure 8. From the results of these patterns measurement, it can be found that presented antenna totally acts similarly with printed monopole antennas in middle and lower frequency bands. This figure is approximately indicative of omnidirectional radiation pattern in $x$–$z$ plane.

## 4. CONCLUSIONS

A monopole antenna with circular-shaped patch and a wrench-shaped design at the center was proposed for modifying the blind spot at the performance of antenna. Proposed antenna with modified patch and with truncated ground plane has desirable return loss level and radiation pattern characteristics with two square and circular-shape linked notches. Constructed antenna properly covers the UWB spectrum and operates from 3.1 to 11.91 GHz. Proposed antenna with proper dimensions and aforementioned characteristics are suitable for UWB systems.

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# A TUNABLE DUAL BAND NOTCH ON A UWB PRINTED SLOT MONOPOLE ANTENNA BY USING OPEN CIRCUIT STUBS

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**ABSTRACT:** *A new printed wide slot antenna with single- and dual-band notch behavior is presented. The base of antenna is a simple fork-shaped radiating patch, which covers the ultra-wideband (UWB) frequency range. By using additional protrudent open circuit stubs on the base patch, multiband notch behavior is obtained. Effects of varying the added stubs parameters on the antenna performance show that the center frequency of band rejections can be finely tuned. The proposed dual-band notch antenna covers 2.4–10 GHz with two bands rejection*

*for WiMAX (3.3–3.9 GHz) and WLAN (5.7–6 GHz) bands.* © 2011 Wiley Periodicals, Inc. Microwave Opt Technol Lett 53:1931–1935, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.26095

**Key words:** *slot antenna; ultrawideband antenna; dual-band notch*

## 1. INTRODUCTION

Design of a small-size antenna that covers the UWB frequency range and also is suitable for use with portable communication systems is highly desirable. Several articles have been published [1–5], which have used different shapes of printed microstrip-fed wide slot antennas to obtain wide band performance. Such antennas have great features such as being completely uniplanar, low profile, light weight, easy integration with active devices or monolithic microwave integrated circuits (MMICs), low cost, easy fabrication, and stable radiation patterns across the operating band.

Because of overlap between different frequency bands form commercial and industrial applications, using band rejection networks have been highly increased. Thus, to avoid interfering between communication frequency bands, different works have been reported of which most of them have tried to avoid interfering between the UWB and other commercial bands, which include WLAN and WiMAX frequency bands. To do this, various techniques were used to design a microstrip-fed printed wide slot antenna with band-notch characteristics. By using slits on ground plane, a band-notch behavior for WLAN frequency band is obtained for a UWB antenna [6]. Also, it is shown that by using open-circuit stubs on ground plane, a band-notch antenna can be attained [7]. By introducing a narrow slot on radiating patch at appropriate position, a UWB antenna with notch characteristic on WLAN band is presented [8]. Furthermore, the elimination of both WiMAX and WLAN bands together to reduce the interference between UWB and other practical bands were desired in [9, 10].

In this letter, a novel method to achieve a single- and dual-band-notch behavior on a base UWB antenna is presented. To obtain single- and dual-band notch characteristics, single and dual open circuit stubs are used, respectively. The length of stubs fixed at value of quarter-wavelength for each band stop. The added stubs are responsible for band rejection and can be easily tuned to eliminate both WiMAX (3.3–3.9 GHz) and WLAN (5.7–6 GHz) bands. The simulations are carried out using the commercially available software package HFSS. The simulation and measured results of dual-band notch antenna are agreed and show good bands rejection at both desired bands. Also, an omnidirectional and stable radiation pattern and consistent group delay over the UWB band are obtained.

## 2. ANTENNA DESIGN

The configuration of base antenna with a simple structure is shown in Figure 1(a). The base antenna has small size of 28 × 32 × 1 $mm^3$, which is fabricated on a FR4 substrate with $\varepsilon_r = 4.4$ and loss tangent 0.02. To design a wideband antenna with multiband notch characteristic, a fork-shaped radiating patch can be a good candidate. The dimensions of base fork-shaped radiating patch are considered so that the antenna operates over UWB range. A microstrip line of width $W_f$ and length $L_f$ is considered to feed the base patch. To achieve 50-Ω characteristic impedance, $W_f$ is fixed at 1.86 mm. A simple rectangular slot with dimension of 24 × 20 $mm^2$ is used at the bottom side of antenna to realize both wider impedance bandwidth and omnidirectional radiation characteristics. As shown in Figure 1(a), the distance between the lower side of radiating patch and ground plane is fixed at g.

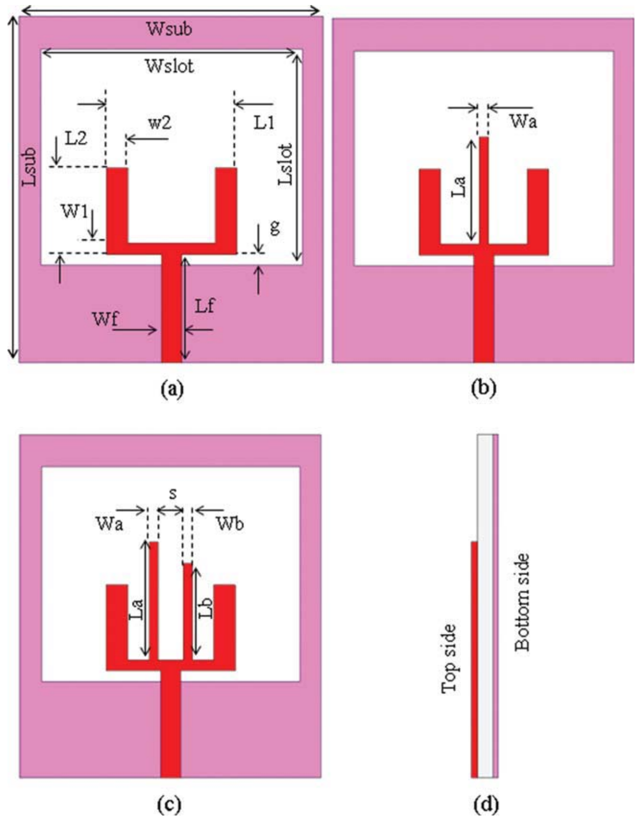


**Figure 1** Multi-band notch antenna configuration (a) Simple fork-shaped antenna (b) Single-band notch antenna (c) Dual-band notch antenna and (d) Side view of antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

To obtain a band-rejection network, a parallel open-circuit stub can be added on the base antenna. As shown in Figure 2, the loaded printed wide slot antenna with an open-circuit stub can be modeled as an open-circuited stub in parallel with the unloaded antenna with radiation resistance *R*. To realize notch characteristic, a protrudent strip, which acting as an open circuit stub, of length $L_a$ and width $W_a$, is added within the base patch. The configuration of single-band notch antenna is shown in Figure 1(b). At the frequency range that the open-circuit stub length is almost $\lambda$ /4, the stub leads to the desired high attenuation and impedance mismatching, resulting in bandstop behavior [11]. As shown, to excite the added stub efficiently, it can be located

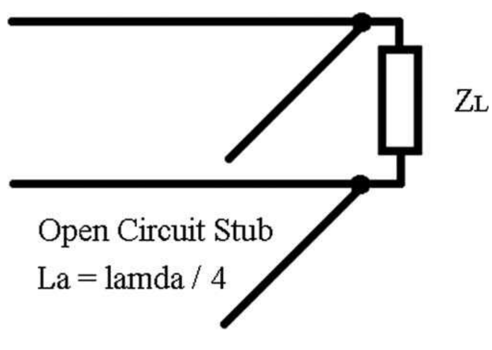


**Figure 2** Equivalent Circuit for single-band notch configuration

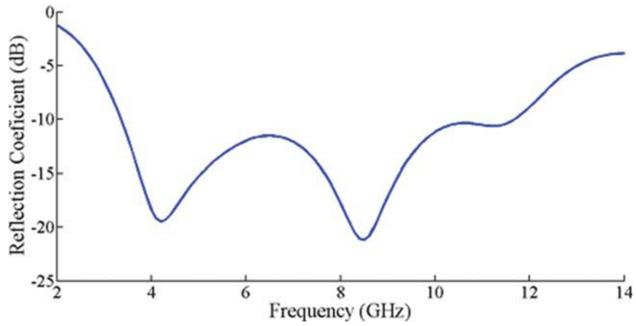


**Figure 3** Reflection Coefficient of the simple fork-shaped antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

along the feed line, which the maximum current is flown around.

Also, to design a dual-band-notch behavior, two open-circuit stubs should be used in the middle part of fork-shaped patch. Figure 1(c) shows the configuration of dual-band notch UWB antenna. At the frequency that the open-circuit stub length is almost $\lambda/4$ leads to the desired high attenuation and impedance mismatching, resulting in dual-band stop behavior. Therefore, the length of each strip is set at the value of quarter-wavelength for each desired band notch. Spacing between the added stubs is $S$. The effects of stubs length and $S$ are studied and discussed.

### 3. RESULTS AND DISCUSSION

A simple structure and appropriate candidate of microstrip-fed printed wide slot antenna to achieve the UWB frequency band is shown in Figure 1(a). The reflection coefficient of fork-shaped radiating patch is presented in Figure 3. It is obvious that the antenna covers the UWB frequency range.

The parametric study of single added stub on the antenna performance is shown in Figure 4. It is clear that by changing the length of stub, $L_a$, the notch frequency can be finely tuned to an appropriate value. As shown, by increase the length of stub the notch frequency decrease. The added stub is quarter-wavelength long for the desired frequency of band notch. A single-band notch UWB antenna is considered to operate over UWB range with a band stop on 5.7–6 GHz (WLAN) band. As shown in Figure 5, current distribution on the added path at the frequency of quarter-wavelength is in the opposite direction of the base radiating patch, resulting in a UWB antenna with single-band notch characteristics.

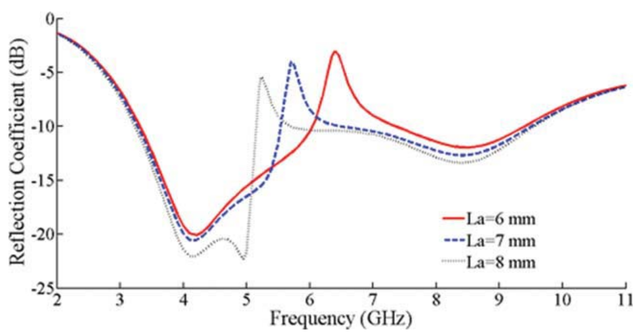


**Figure 4** Parametric study of the single-band notch antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

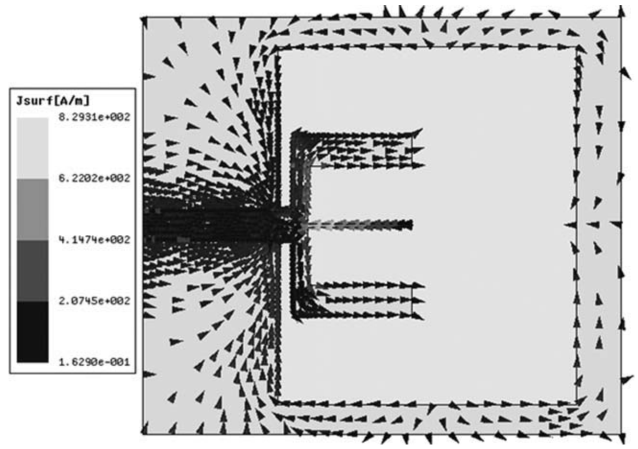


**Figure 5** Current distribution of single-band notch antenna at notch frequency

The dual-band configuration is also studied and the effects of the two added open stubs are presented. Figure 6(a) shows the effects of $L_a$ and $L_b$ on the base UWB antenna. It is obvious that the lengths of added stubs are $\lambda/4$ for each notch frequencies. The effect of spacing between two stubs is presented in Figure 6(b) and shows that $S$ has negligible effects on the center frequencies of band stops. By tuning the length of additional stubs, two band rejection at the frequency bands of 3.3–3.9 GHz (WiMAX) and 5.7–6 GHz (WLAN) can be obtained. Table 1 shows the overall length of $L_a$ and $L_b$ for single- and dual-band notch characteristics. Also, the dimension of designed and fabricated dual-band notch antenna for dual-bands rejection of 3.3–3.9 GHz and 5.7–6 GHz is presented in Table 2. Current

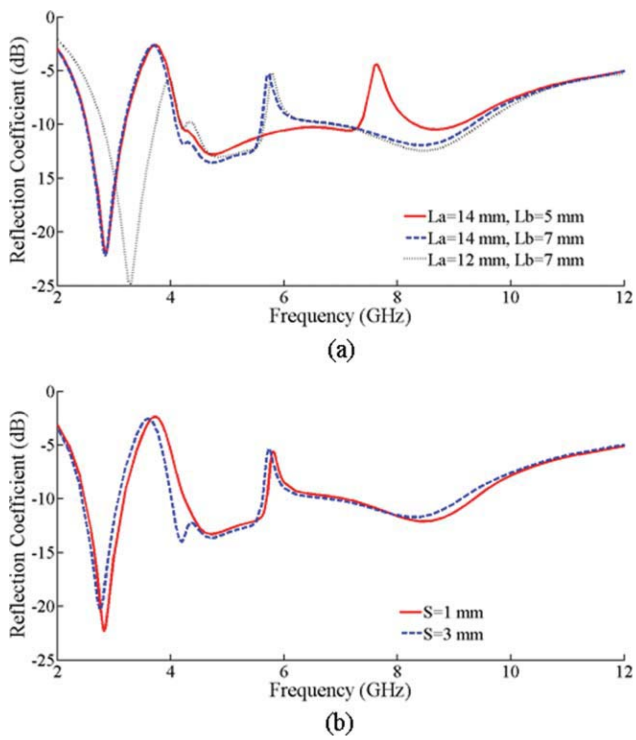


**Figure 6** Parametric study of dual-band notch antenna (a) effect of strips length and (b) effect of separation between strips. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

**TABLE 1** **Open Stub Lengths for Different Bands**

| Notched Bands | Open Stub Length | |
|---|---|---|
| | $L_a$ (mm) | $L_b$ (mm) |
| WiMAX (3.5 GHz) | 14 | Removed |
| WLAN (5.8 GHz) | 7 | Removed |
| WiMAX (3.5 GHz), WLAN (5.8 GHz) | 14 | 7 |

**TABLE 2** **Dimensions of Dual-Band Notch Antenna**

| | |
|---|---|
| $W_1$ | 1 |
| $W_2$ | 2 |
| $L_1$ | 12 |
| $L_2$ | 8 |
| $W_a$ | 0.3 |
| $W_b$ | 0.3 |
| $L_a$ | 7 |
| $L_b$ | 14 |

All dimensions are mm.

distribution of dual-band notch antenna is studied to better understanding of band-rejection network at 3.5 and 5.8 GHz in Figure 7. It is shown that the length of each protrudent strips is about quarter-wavelength long at notch frequencies. The current

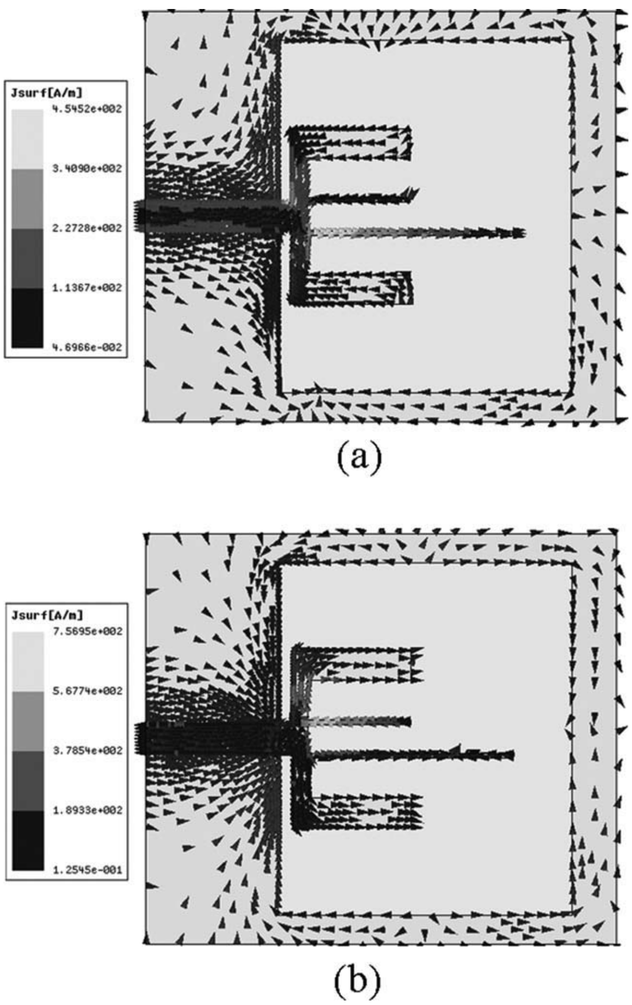


**Figure 7** Current distribution of dual-band notch at frequency of (a) 3.5 GHz and (b) 5.8 GHz

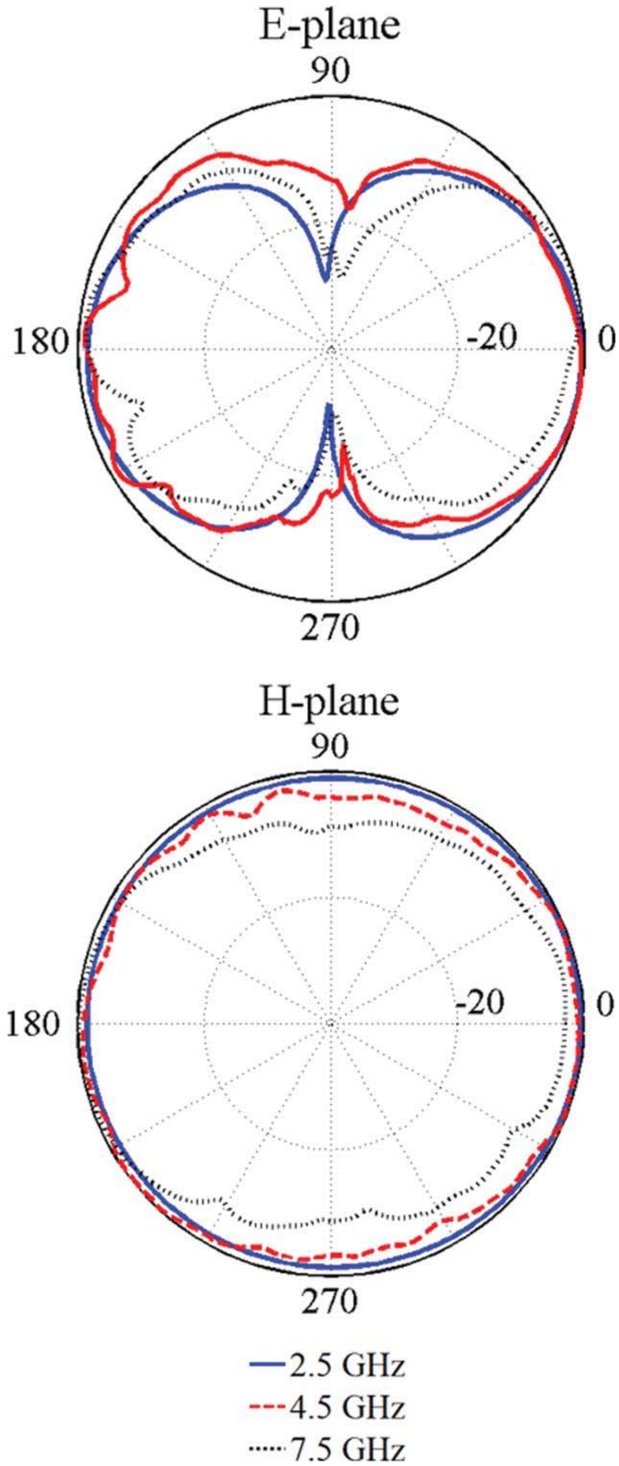


**Figure 8** Measured radiation pattern in both E- and H-plane of dual-band notch antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

distributions on the added stubs at notch frequencies are in opposite direction of base patch resulting in notch behavior. Moreover, it is obvious that whenever the longer stub is activated, the current distribution on the smaller stub is negligible, shows the smaller stub is inactive. Whenever the smaller stub is activated, the current distribution on the longer stub is negligible, shows the longer stub is inactive.

The normalized radiation patterns of proposed dual-band notch antenna for both E- and H-plane at 2.5, 4.5, and 7 GHz

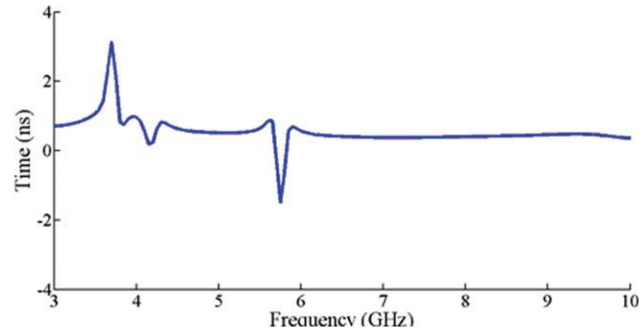


**Figure 9** Group delay of dual-band notch antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

are presented in Figure 8. It is seen that the radiation patterns of designed antenna are omnidirectional in H-plane and directive in E-plane. Measured results of proposed antenna shows that the antenna is suitable for UWB applications. Also, stable radiation characteristics are shown, which is necessary for UWB antennas.

To verify the capability of the proposed antenna to operate as an UWB antenna, the designed antenna should have a consistent group delay. The group delay of the dual-band notch UWB antenna can be obtained from $\tau_g = \delta\beta/\delta\omega$, where $\beta$ is the phase of the transfer function of the antenna. Figure 9 shows the simulation results of the group delay for the face-to-face configuration. It is obvious that the proposed dual-band notch antenna has a consistent group delay, which can be used for UWB applications. A photograph of the fabricated fork-shaped antenna with dual-band notch characteristics is displayed in Figure 10.

## 4. CONCLUSIONS

A printed wide slot antenna is proposed and implemented for UWB applications. The overall size of antenna is $28 \times 32 \times 1$ $mm^3$. The antenna, compact and small, has minimum design parameters, which have been investigated for optimal design. By using protrudent open-circuit stubs at appropriate positions, single- and dual-band notch antenna is also realized with good out of band performance. The operation bandwidth of proposed antenna covers the frequency band from 2.4 to 10 GHz. Both simulated and measured results suggest that the proposed antenna is suitable for UWB communication applications and at the same time operates as a band stop with 5.7–6 GHz (WLAN) and 3.3–3.9 GHz (WiMAX) systems.

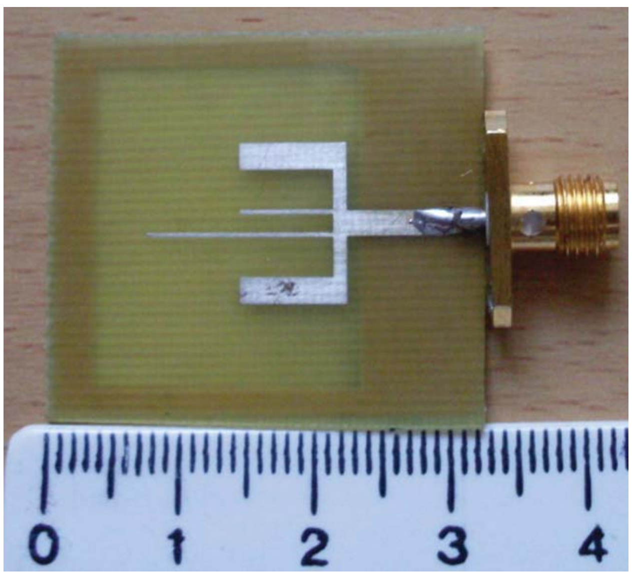


**Figure 10** Photograph of fabricated antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

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# FIBER OPTIC CHEMICAL SENSOR USING FIBER COUPLER PROBE BASED ON INTENSITY MODULATION FOR ALCOHOL DETECTION


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**ABSTRACT:** *A simple intensity modulation based displacement sensor using fiber optic coupler probe is proposed and demonstrated for sensing the concentration of alcohol solution. The intensity of light reduces almost linearly with the displacement and the sensitivity of the*