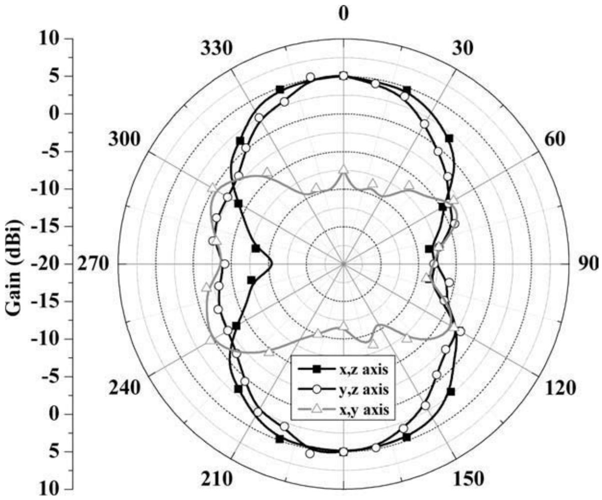


**Figure 5** UWB tag antenna's radiation pattern at 7.25 GHz

have a common propagation axis on $X$, $Y$ axis, consequently, it is possible to communicate with a tag on twice band is this axis.

## 3. CONCLUSIONS

This study shows the feasibility to associate UHF RFID and UWB system on a same substrate for tag. Thanks to that it is possible to exploit the advantages and minimize drawbacks to each technology. Different antenna's topologies for UHF and UWB RFID applications are presented. Tag is a multichip device and the main difficulties consist to minimize coupling effects between UHF and UWB antenna. UHF antenna has typical impedance, and it is possible to reconfigure it easily to every kind of UHF RFID chip impedance. UWB tag antenna has a reflection coefficient lower than −10 dB on European UWB frequency band. Perspectives are to design a reader and tag antenna matched on all UHF RFID and FCC UWB frequency band. One of the perspectives is to design a RFID tag antenna singly fed and matched on twice bands.

## REFERENCES


1. K.M. Sik, K.H. Wook, and C.N. Young, Automated robot docking using direction sensing RFID, in 2007 IEEE International Conference on Robotics and Automation, 2007, pp. 4588–4593.
2. L. Hui, H. Darabi, P. Banerjee, and L. Jing, Survey of wireless indoor positioning techniques and systems, IEEE Trans Syst Man Cybern C Appl Rev 37 (2007), 1067–1080.
3. M.D. Ben Allen, E. Okon, W. Malik, A. Brown, and D. Edwards, Ultra wideband antennas and propagation for communications, Radar and Imaging, Wiley, Hoboken, NJ, 2006.
4. K.V.S. Rao, P.V. Nikitin, and S.F. Lam, Antenna design for UHF RFID tags: A review and a practical application, IEEE Trans Antennas Propag 53 (2005), 3870–3876.
5. T. Deleruyelle, P. Pannier, and S. Bourdel, Multi-standard slot antenna in 860–960 MHz and 2.45GHz RFID band, in 2008 IEEE Antennas and Propagation Society International Symposium, San Diego, CA (AP-S 2008), 2008, pp. 1–4.
6. C.C. Ho and R.D. Murch, Antenna modifications for enhancing RFID tag reading range, in 2007 IEEE Antennas and Propagation Society International Symposium, 2007, pp. 1084–1087.
7. G. Marrocco, The art of UHF RFID antenna design: Impedance-matching and size-reduction techniques, IEEE Antennas Propag Magazine 50 (2008), 66–79.
8. W.X. Hui and C.Z. Ning, Comparison of planar dipoles in UWB applications, IEEE Trans Antennas Propag 53 (2005), 1973–1983.
9. C.Z. Ning, M.J. Ammann, Q. Xianming, W.X. Hui, T.S.P. See, and A. Cat, Planar antennas, IEEE Microwave Magazine 7 (2006), 63–73.
10. Y. Tikhov, K. Yongjin, and M. Young-Hoon, A novel small antenna for passive RFID transponder, in 2005 European Microwave Conference, Paris, France, 2005, p. 4.




# DESIGN OF A NOVEL BAND-NOTCHED SLOT PATCH ANTENNA FOR UWB COMMUNICATION SYSTEMS


**M. Naser-Moghadasi,[1] G. R. DadashZadeh,[2] A.-A. Kalteh,[1] and Bal S. Virdee[3]**

[1] Faculty of Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran; Corresponding author: mn.moghaddasi@srbiau.ac.ir
[2] Department of Electrical Engineering, Faculty of Engineering, Shahed University, Tehran, Iran
[3] Faculty of Computing, London Metropolitan University, 166-220 Holloway Road, London N7 8DB, United Kingdom


*Received 13 September 2009*


**ABSTRACT:** *A novel band-notched elliptical slot antenna is presented for ultra-wideband (UWB) applications. The proposed antenna is fed via a microstrip-line that is connected to an elliptical shaped patch which incorporates an inverted-U slot. The inverted-U slot behaves like a band reject network designed to eliminate 5.15–5.825 GHz band-limited by IEEE 802.11a and HIPERLAN/2. Effects of varying the inverted-U shaped slot parameters on the antenna's performance show that notch band can be finely tuned. The antenna with optimal parameters was realized and its performance measured. The antenna was fabricated on a RT/duroid 6006 that has a thickness of 1.27 mm and a relative permittivity of 6.15. The size of the actual antenna is 50 × 50 mm$^2$. The radiation characteristics of the proposed antenna satisfy UWB system requirements.* © 2010 Wiley Periodicals, Inc. Microwave Opt Technol Lett 52: 1599–1603, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.25237


**Key words:** microstrip slot antennas; ultra-wideband antennas; band notched antennas

## 1. INTRODUCTION

The need of high data rate transmission from wireless communication systems is becoming more and more urgent and various solutions have been proposed to date. To realize this requirement, most of the attention has been focused on Ultra-Wideband (UWB) techniques as it offers numerous advantages, such as: higher data rates, immunity to multi-path cancellation, higher communication capacity, operational security, and low interference with legacy systems [1]. Antennas are the particularly challenging aspect of UWB technology. To satisfy such a requirement, various wideband antennas have been studied [2–7]. The UWB communication systems use the 3.1–10.6 GHz frequency band, which unfortunately includes the IEEE 802.11a frequency band (5.15–5.825 GHz). Therefore, IEEE 802.11a may cause unwanted interference with the UWB communication system. To overcome this electromagnetic interference, various UWB antennas with a notch function have been developed [8–16].

In this article, a novel elliptical slot antenna with band-notched characteristics is described for UWB applications. The band-notched function is achieved by utilizing an inverted-U shaped slot embedded within the elliptical patch, which is fed via a microstrip line. The bandwidth and frequency of the notch

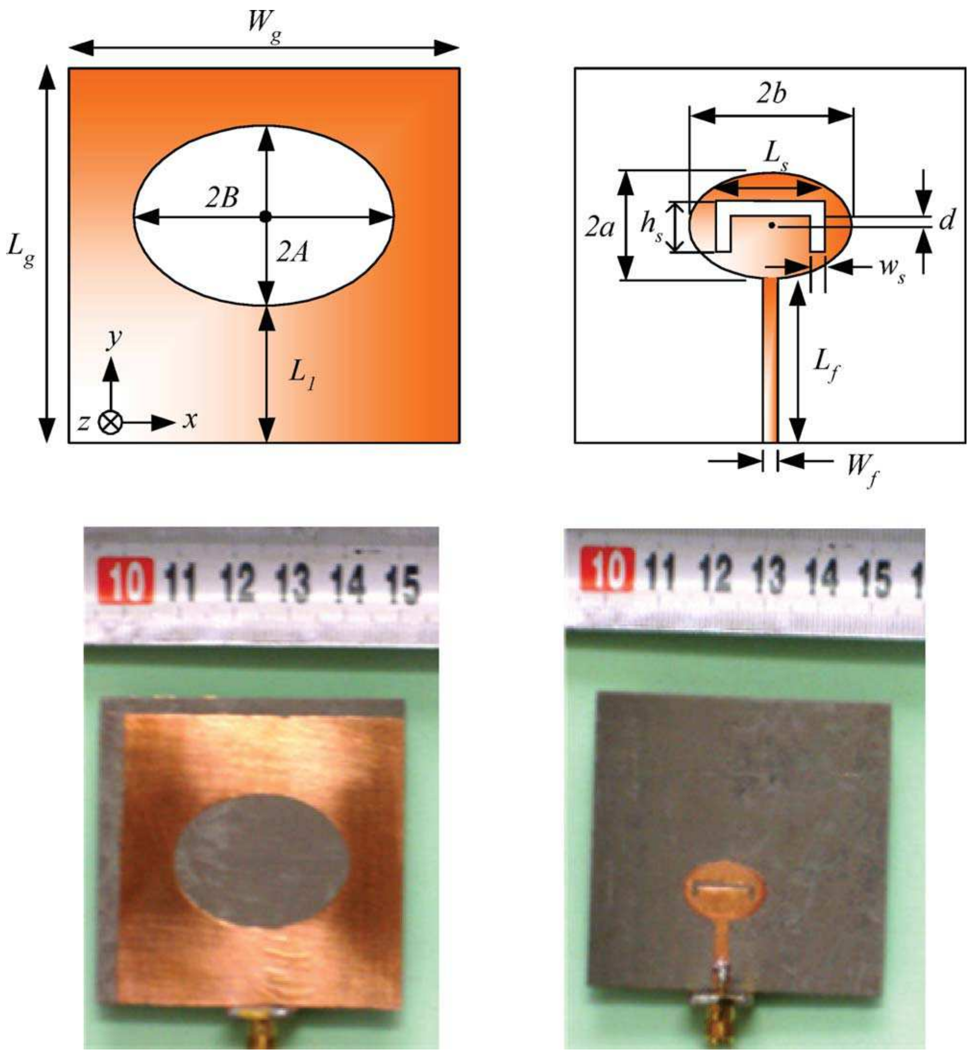


**Figure 1** Geometry of proposed UWB antenna: (a) top layer and (b) bottom layer showing the feed network. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

is controllable by varying the dimensions of the inverted-U slot and its relative position. This antenna can operate over the commercial UWB frequency range (3.1–10.6 GHz) and effectively suppresses any interference with the existing 5.15–5.825 GHz band occupied by wireless local area network (WLAN) and HIPERLAN/2 systems. Effects of varying the parameters of

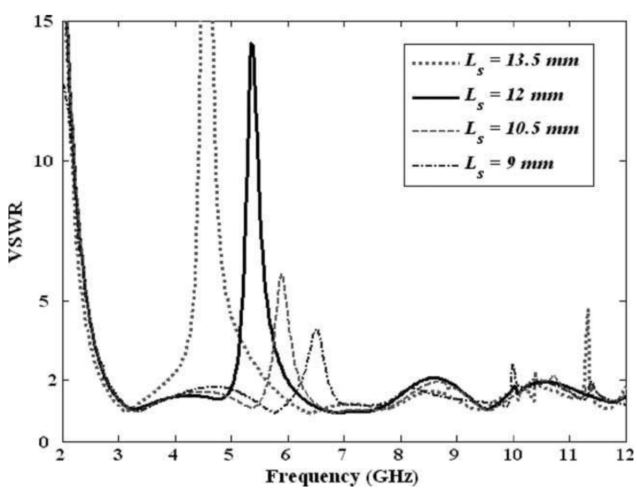


**Figure 2** Effect of $L_s$ on the antenna's band-notching characteristic

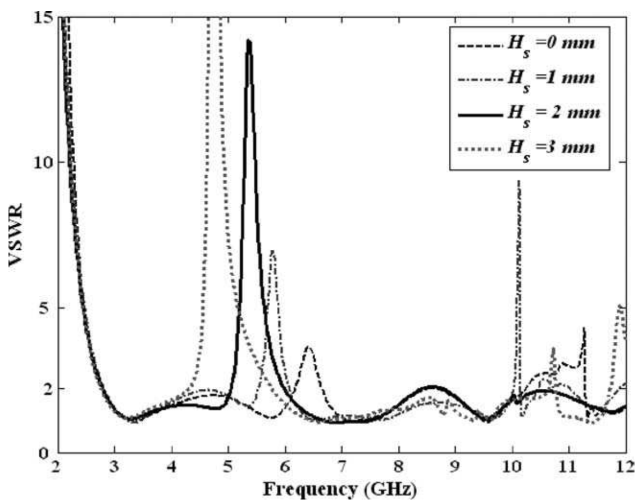


**Figure 3** Effect of parameter $H_s$ of inverted-U slot on the antenna's band-notching characteristic

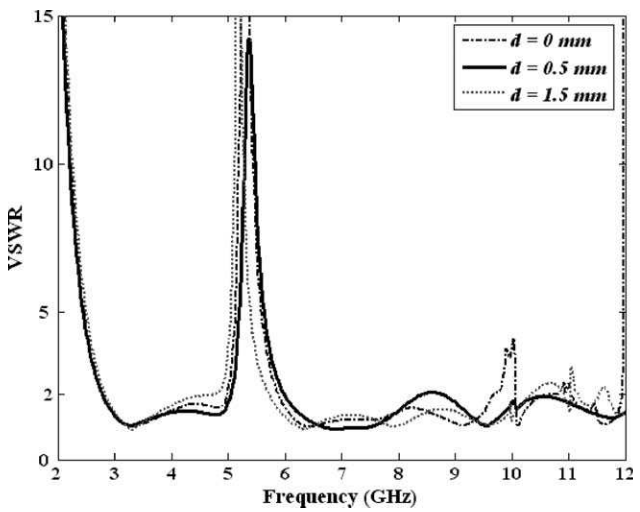


**Figure 4** Affect of inverted-U slot position on the band-notched characteristics

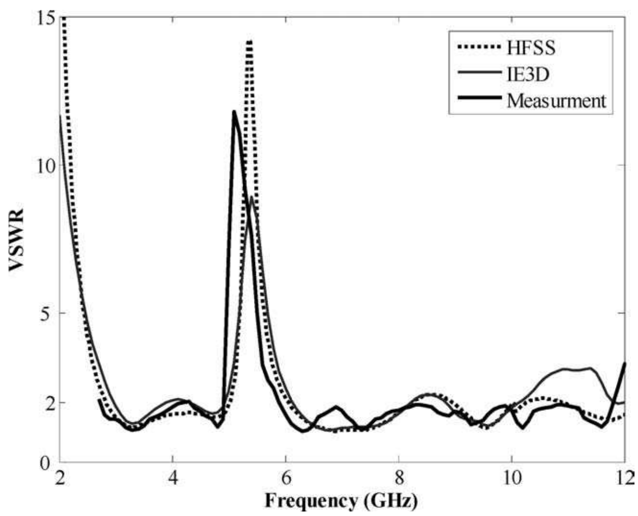


**Figure 5** The VSWR response of the proposed UWB antenna with dimensions defined in Table 1

inverted-U shaped slot on the performance of antenna have also been investigated. The antenna structure was analyzed using Ansoft HFSS software [17]. The numerical study of the proposed antenna was also investigated by using IE3D software based on the method of moments [18]. The proposed antenna prototype design with optimal parameters was fabricated and measured. The agreement between the simulation and experimental results was very good.

This article is organized as follow: section II presents the configuration of proposed antenna, parametric study of antenna is investigated in section III, the simulated and measured results are discussed in section IV, and finally the conclusion is provided in section V.

## 2. ANTENNA CONFIGURATION

The geometry of the proposed elliptical slot antenna possessing band-notched function is depicted in Figure 1 along with its characterizing parameters. The antenna is located in *x*-*y* plane and the normal direction is parallel to *z*-axis. The antenna consists of an elliptical slot with axial dimensions of $A$ and $B$ directly over an elliptical radiating patch with axial dimensions of $a$ and $b$, which is feed via a 50 Ω microstrip-line of width $W_f$ = 2 mm. The band-notching characteristic of antenna is achieved by creating an inverted-U slot within the elliptical patch. The proposed antenna is constructed on a dielectric substrate RT/duroid 6006 with relative permittivity ($\varepsilon_r$) of 6.15 and thickness of 1.27 mm. The antenna has a ground-plane size of $L_g \times W_g = 50 \times 50$ mm$^2$.

## 3. PARAMETRIC STUDY OF ANTENNA

To achieve the desired band-notched characteristic, the effect of the inverted-U slot parameters on the antenna's performance was studied.

The simulated VSWR of the antenna for different values of $L_s$ is plotted in Figure 2. This figure shows that by increasing the length of $L_s$ the notching frequency shifts towards lower frequencies and its bandwidth corresponding increases too.

**TABLE 1 Dimensions of the Proposed UWB Antenna**

| Parameter | $W_g$ | $L_g$ | $A$ | $B$ | $L_1$ | $a$ | $b$ | $W_f$ | $L_f$ | $W_s$ | $L_s$ | $H_s$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Value (mm) | 50 | 50 | 12 | 16 | 13 | 5.25 | 7.5 | 2 | 13.3 | 1 | 12 | 2 | 0.5 |

Figure 3 shows the simulated VSWR response of antenna for different values of $H_s$. It can be observed in that in this case the notch's center frequency decreases with the increase of the length of $H_s$. The effect of the slot's position relative to the center of the elliptical patch, defined by parameter $d$, on the antenna's performance is depicted in Figure 4. As shown, the position of the slot has negligible effect on the band-notch characteristic.

These results clearly indicate the principal slot parameters that significantly affect the antenna performance are its horizontal and vertical lengths.

## 4. RESULTS AND DISCUSSIONS

The simulated and measured results of VSWR, radiation patterns, and gain of the proposed antenna are presented in this section. The simulations were performed using Ansoft HFSS and IE3D, which utilize numerical methods for electromagnetic computations. The VSWR of antenna was measured by the Agilent 8722ES network analyzer.

### *4.1. VSWR*

The simulated and measured VSWR of the proposed UWB antenna, whose dimensions are defined in Table 1 is depicted in

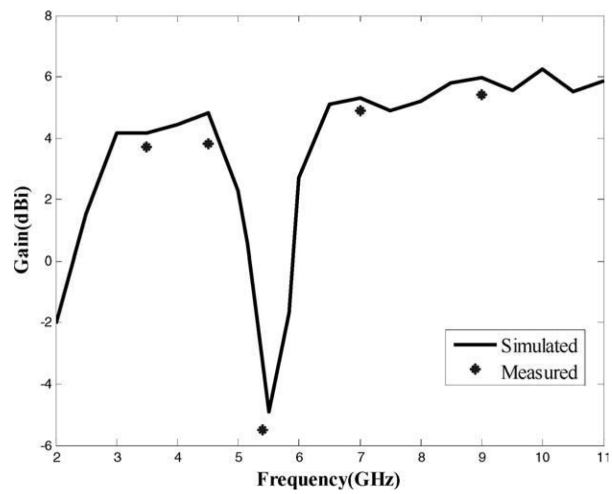


**Figure 6** The calculated and measured gain of the proposed UWB antenna

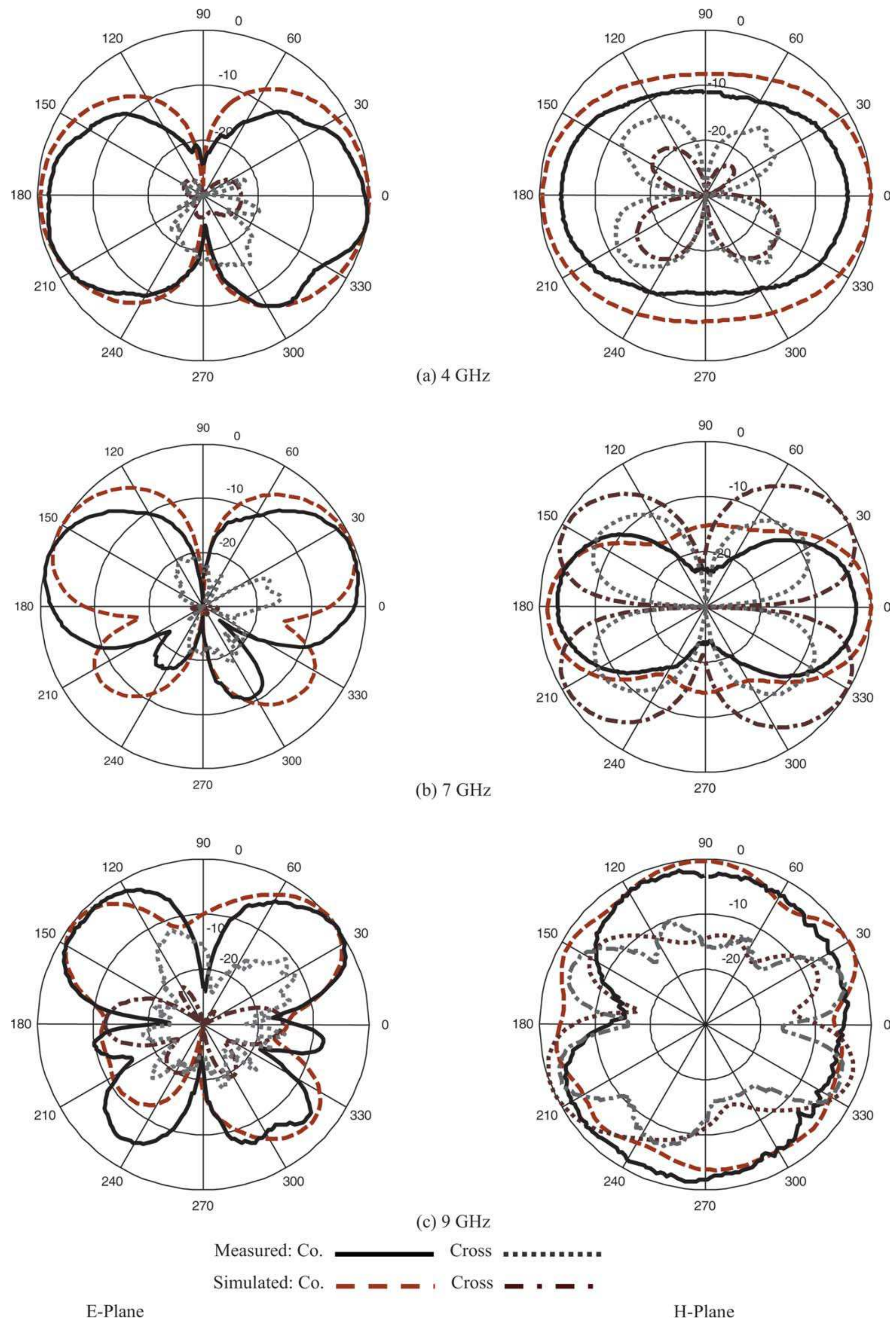


**Figure 7** Measured and simulated *E*-plane and *H*-plane radiation patterns for proposed antenna at: (a) 4 GHz, (b) 7 GHz, and (c) 9 GHz. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 5. From this figure, we can see that the calculated bandwidth of the proposed antenna for which VSWR $\leq$2 is from 2.7 GHz to 10.5 GHz with a notched frequency band of 5.08–5.98 GHz. The measured bandwidth of fabricated antenna is from 2.55 GHz to about 11.7 GHz with VSWR $\leq$2, and the notched bandwidth is over 4.9–5.9 GHz for VSWR $\geq$2. The measured frequency range encompasses the commercial UWB band (3.1–10.6 GHz), and the notch rejects the frequency band of IEEE 802.11a to overcome EMI problems between UWB and WLAN systems. The correlation between the numerical and experimental results is considered to be excellent.

### *4.2. Radiation Patterns and Gain*

The simulated gain of the proposed antenna is shown in Figure 6. It reveals that the antenna gain varies from 4.0 to 6.0 dBi within 2.84–11 GHz frequency band. As anticipated, the gain drops to $-5$ dBi at center frequency of the band notch, which is 5.5 GHz. The measured gain of the antenna, which is indicated by the star symbols closely follows the simulated results. The maximum gain obtained from the measurements in desired UWB frequency bandwidth is around 5.4 dBi, whereas in the notched band it drops down to about $-5.5$ dBi.

The simulation and measurement normalized radiation patterns of proposed antenna in *H*-plane (or *x-z*) and *E*-plane (or *y-z*) at frequencies of 4, 7, and 9 GHz are plotted in Figure 7. As shown in the *H*-plane, the antenna design exhibits an omnidirectional profile at low and high frequencies and quasi bidirectional in the mid-range frequencies. However in the *E*-plane, the radiation pattern is bidirectional at low frequencies and quasi bidirectional at mid and high frequencies. The agreement between the measured and simulated radiation patterns is very good.

## 5. CONCLUSIONS

An elliptical slot antenna with an elliptical patch is shown to provide Ultra-Wideband (UWB) performance. It is also shown that band rejection function can be incorporated into the antenna by embedding an inverted-U shaped slot within the elliptical slot. By adjusting parameters of the U-slot, the band notched characteristics can be tuned precisely. The proposed antenna design was fabricated using optimal dimensions to validate its ultra-wideband characteristics. The measurements show that VSWR $\leq$2 is obtained over the band 2.55–12 GHz, and band-notched characteristics is exhibited between 4.9 GHz and 5.9 GHz. Far-field radiation patterns and the gain of the antenna were studied and experimentally verified. These results satisfy the requirement of UWB communication systems.


## ACKNOWLEDGMENT

The authors thank Islamic Azad University's Aliabad Katool branch for supporting this research.


## REFERENCES


1. R.J. Fontana, Recent system applications of short-pulse ultra-wideband (UWB) technology, IEEE Trans MTT 52 (2004), 2087–2104.
2. N. Behdad and K. Sardbandi, A multi-resonant single-element wideband slot antenna, IEEE Antennas Wireless Propag Lett 3 (2004), 5–8.
3. J. Liang, C.C. Chiau, X.D. Chen, and C.G. Parini, Study of a printed circular disc monopole antenna for UWB systems, IEEE Trans Antennas Propag 53 (2005), 3500–3504.
4. C.-Y. Huang and W.-C. Hsia, Planar elliptical slot antenna for ultra-wideband communications, Electron Lett 41 (2005), 296–297.
5. S. Angelopoulos, A.Z. Anastopoulos, D.I. Kaklamani, A.A. Alexandridis, F. Lazarakis, and K. Dangakis, Circular and elliptical CPW-fed slot and microstrip-fed antennas for ultra wideband applications, IEEE Antennas Wireless Propag Lett 5 (2006), 294–297.
6. K.P. Ray and Y. Rang, Ultra wideband printed elliptical monopole antennas, IEEE Trans Antennas Propag 55 (2007), 1189–1192.
7. J.-R. Verbiest and G.-A.E. Vandenbosch, A novel small-size printed tapered monopole antenna for UWB WBAN, IEEE Antennas Wireless Propag Lett 5 (2006), 377–379.
8. W.J. Lui, C.H. Cheng, Y. Cheng, and H. Zhu, Frequency notched ultra-wideband microstrip slot antenna with fractal tuning stub, IEE Electron Lett 41 (2005), 294–296.
9. K.L. Wong, Y.W. Chi, C.M. Su, and F.S. Chang, Band-notched ultra wideband circular-disk monopole antenna with an arc-shaped slot, Microwave Opt Technol Lett 45 (2005), 188–191.
10. S.W. Su, K.L. Wong, and F.S. Chang, Compact printed ultra-wideband slot antenna with a band-notched operation, Microwave Opt Technol Lett 45 (2005), 128–130.
11. K. Chung, J. Kim, and J. Choi, Wideband microstrip-fed monopole antenna having frequency band-notched function, IEEE Microwave Wireless Compon Lett 15 (2005), 766–768.
12. Y.J. Cho, K.H. Kim, D.H. Choi, S.S. Lee, and S.-O. Park, A miniature UWB planar monopole antenna with 5-GHz band rejection filter and the time domain characteristics, IEEE Trans Antennas Propag 54 (2006), 1453–1460.
13. H.J. Zhou, Q.Z. Liu, Y.Z. Yin, and W.B. Wei, Study of the band-notched function for swallow-tailed planar monopole antennas, PIER 77 (2007), 55–65.
14. W. Ren, Z.G. Shi, and K.S. Chen, Novel planar monopole UWB antenna with 5-GHz band-notched characteristic, J Electromagn Waves Appl 21 (2007), 1645–1652.
15. A.-A. Kalteh, R. Fallahi, and M.G.-Roozbahani, A novel microstrip-fed UWB circular slot antenna with 5-GHz band-notch characteristics, IEEE Int Conf Ultra Wideband Proc 1 (2008), 117–120.
16. R. Fallahi, A.-A. Kalteh, and M.G.-Roozbahani, A novel UWB elliptical slot antenna with band-notched characteristics, PIER 82 (2008), 127–136.
17. Ansoft, High Frequency Structure Simulation (HFSS), Ver. 10, Ansoft Corporation, Pittsburgh, PA, 2005.
18. IE3D, Zeland Software, IE3D User's Manual Release 9, Zeland Software Inc., Fremont, CA [Online]. Available at: http://www.zeland.com.




# DESIGN OF COMPACT MICROSTRIP BAND-PASS FILTER WITH ULTRA-WIDE STOPBAND


**Ko-Wen Hsu and Wen-Hua Tu**

Department of Electrical Engineering, National Central University, Jhongli, Taoyuan, 32001, Taiwan, Republic Of China; Corresponding author: payon12222@gmail.com



*Received 14 September 2009*



**ABSTRACT:** *In this article, a microstrip band-pass filter with compact structure and ultra-wide stopband using quarter-wavelength stepped impedance resonators is proposed. Because of the optimal design for stepped impedance resonators, circuit size is reduced and harmonic response is suppressed. To suppress the higher resonant modes further, two open stubs connected to the input/output ports are used to achieve an ultra-wide stopband. The design procedure and additional lateral-resonated response are discussed in detail. As the presence of the two attenuation poles are around the passband edge, high selectivity and good performance is realized. The proposed filter with a fundamental frequency* $f_0$ *of 0.9 GHz, measured insertion loss of less than 1.5 dB, return loss of better than 16 dB, and wide stopband up to 19* $f_0$ *is demonstrated. The stopband level is lower than 23 dB from 1.1 GHz up to 17.1 GHz.* © 2010 Wiley Periodicals, Inc. Microwave Opt Technol Lett 52: 1603–1606, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.25238