Dual Band-Notch Small Square Monopole Antenna with Enhanced Bandwidth Characterestics for UWB Applications

M. Ojaroudi [1], N. Ojaroudi [2] , and Y. Ebazadeh [3]

[1] Young Research Group
Ardabil Branch, Islamic Azad University, Ardabil, Iran
m.ojaroudi@iauardabil.ac.ir

[2] Department of Electrical Engineering
Ardabil Branch, Islamic Azad University, Ardabil, Iran
n.ojaroudi@yahoo.com

[3] Department of Computer Engineering
Germi Branch, Islamic Azad University, Germi, Iran
y.ebazadeh@iaugermi.ac.ir

Abstract **─** This article proposes a novel printed monopole antenna for ultra wideband applications with dual band-notch function. The antenna consists of a square radiating patch with four rectangular slits and a ground plane with a pair of T-shaped parasitic structures, which provides a wide usable fractional bandwidth of more than 165% (2.79-14.83 GHz). In order to generate single band-notch characteristics, we use two rectangular slits in the corners of square radiating patch. By adding two rectangular slits in the center of the modified radiating patch, a dual band notch function is achieved and also by inserting a pair of T-shaped parasitic structures in the ground plane, additional resonances are excited and hence much wider impedance bandwidth can be produced, especially at the higher band. The measured results reveal that the presented dual band-notch monopole antenna offers a very wide bandwidth with two notched bands, covering all the 5.2/5.8GHz WLAN, 3.5/5.5 GHz WiMAX and 4-GHz C bands. The designed antenna has a small size of 12×18 mm^2.

Index Terms **─** Dual band notch function, square monopole antenna, ultra-wideband (UWB) applications.

I. INTRODUCTION

In UWB communication systems, one of the key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Consequently, a number of microstrip antennas with different geometries have been experimentally characterized. Moreover, other strategies to improve the impedance bandwidth which do not involve a modification of the geometry of the planar antenna have been investigated [1-4].

The frequency range for UWB systems between 3.1 to 10.6 GHz will cause interference to the existing wireless communication systems, such as, the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15–5.35 GHz and 5.725–5.825 GHz bands, WiMAX (3.3–3.6 GHz and C-band (3.7–4.2 GHz), so the UWB antenna with a single and dual band-stop performance is required. Recently to generate the frequency band-notch function, modified planar monopoles have been recently proposed [5-10]. In [5] and [6], different shapes of the slits (i.e., W-shaped and folded trapezoid) are used to obtain the desired band notched characteristics. Multiple [7] half-wavelength U-shaped slits are embedded in the radiation patch to generate the single and multiple

Submitted On: Jan. 2, 2012
Accepted On: April 25, 2012

band-notched functions, respectively. In [8], band-notch function is achieved by using a T-shaped coupled-parasitic element in the ground plane.

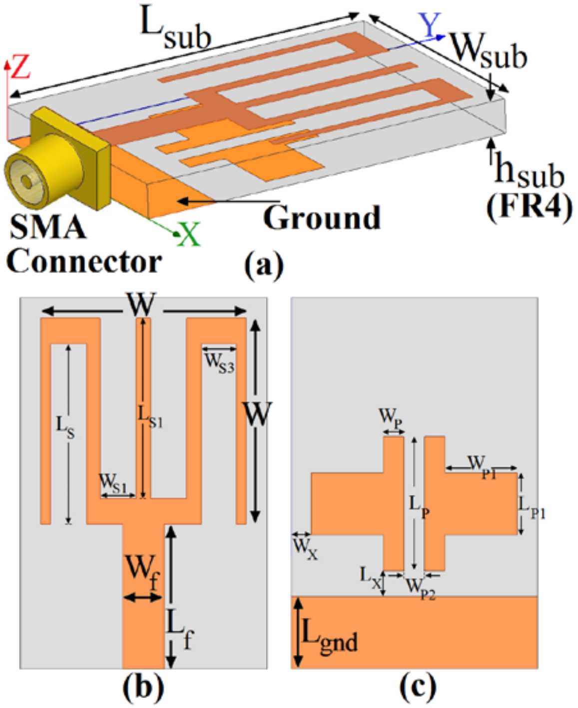
In this paper, a new dual band-notched printed monopole antenna with multi resonance performance is presented. In the proposed structure, single band-notch function is provided by cutting two rectangular slits in the corners of the square radiating patch and dual band-notch characteristic is obtained by cutting four rectangular slits in the radiating patch. Finally by inserting a pair of T-shaped parasitic structures on the ground plane, additional resonances are excited and the bandwidth is improved that achieves a fractional bandwidth with multi resonance performance of more than 165%.

II. ANTENNA DESIGN

As shown in Fig. 1, the proposed monopole antenna is fed by a microstrip line and it is printed on a FR4 substrate of thickness 1.6 mm. As shown in Fig. 1, the proposed antenna consists of a square radiating patch with four rectangular slits and a ground plane which is partially modified with two T-shaped parasitic structures. The basic antenna structure consists of a square patch, a feedline, and a ground plane. The square patch has a width W. As can be seen in Fig. 1, the width and length of the feed line, which is connected to the patch are W_f and L_f, respectively. On the other side of the substrate, a conducting ground plane of width W_{sub} and length L_{gnd} is placed. The width W_f of the microstrip feedline is fixed at 2 mm. The proposed antenna is connected to a 50Ω SMA connector for signal transmission.

In this study, four modified rectangular slits with variable dimensions are used in order to generate the dual frequency band-stop performance, as displayed in Fig. 1. These slits can create additional surface current paths in the antenna therefore perturb the resonant response [7]. At the notch frequencies, the current flows are more dominant around these slits, and they are oppositely directed between the slits edges [10]. Also T-shaped parasitic structures play an important role in the broadband characteristics of this antenna because they can achieve additional resonances and improve the bandwidth [10]. In other words, the impedance bandwidth is effectively improved at the upper frequency that can be regarded as a parasitic resonator electrically to the square monopole.

The optimal dimensions of the designed antenna are as follows: $W_{sub}=12mm$, $L_{sub}=18mm$, $h_{sub}=1.6mm$, $W=10mm$, $W_f=2mm$, $L_f=7mm$, $W_{S3}=0.5mm$, $L_S=8.75mm$, $W_{S1}=2mm$, $L_{S1}=9mm$, $L_X=0.5mm$, $W_X=1mm$, $W_P=1.2mm$, $L_P=8mm$, $W_{P1}=2.75mm$, $L_{P1}=3.5mm$, $W_{P2}=0.5mm$ and $L_{gnd}=3.5mm$.



(a) (b) (c)

Fig. 1. Geometry of proposed antenna with four rectangular slits and a pair of T-shaped parasitic structures, (a) side view, (b) top view, (c) bottom view.

III. RESULTS AND DISCUSSIONS

The microstrip-fed monopole antenna was constructed and studied to demonstrate the effect of the proposed dual band-notch function and bandwidth enhancement technique. The numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The parameters of this proposed antenna are studied by changing one or two parameters at a time and while others are fixed.

The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [12].

Figure 2 shows the structures of various antennas used for simulation studies. Return loss characteristics for ordinary square patch antennas (Fig. 2(a)), with a pair of rectangular slits (Fig. 2(b)), and with four rectangular slits (Fig. 2(c)) are compared in Fig 3. As shown in Fig. 3, in the proposed antenna configuration, the ordinary square monopole can provide the fundamental and next higher resonant radiation band at 4.3 and 8.2 GHz, respectively. In order to generate single band-notch characteristics, two rectangular slits are used at the corners of square radiating patch. By adding two rectangular slits in the center of modified radiating patch a dual band–notch function is achieved that covering all the 5.2/5.8GHz WLAN, 3.5/5.5 GHz WiMAX and 4-GHz C bands. Also the input impedance of the proposed antenna structure and the various monopole antenna structures that are shown in Fig. 2, are shown in Fig. 4.

To understand the phenomenon behind this dual band-notch performance, the simulated current distribution on the modified radiating patch for the proposed antenna without T-shaped parasitic structures at the notch frequencies of 3.8 GHz and 5.5 GHz is presented in Fig. 5(a) and 5(b), respectively. As it can be observed in Fig. 5(a), 5(b), the current is concentrated on the edges of the interior and exterior of the rectangular slits at 3.8 GHz and 5.5 GHz. Therefore, the antenna impedance changes at these frequencies due to the band-notch properties of the rectangular slits.

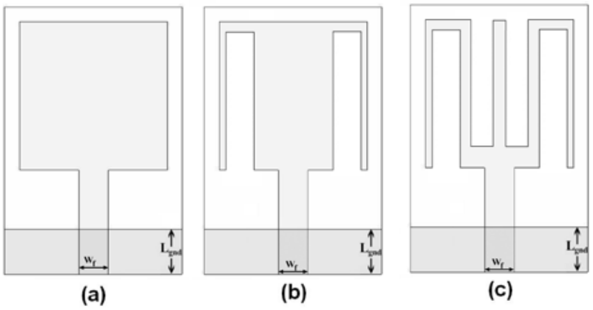


Fig. 2. (a) The ordinary square antenna, (b) the square antenna with two rectangular slit in corners, (c) the square antenna with four rectangular slits.

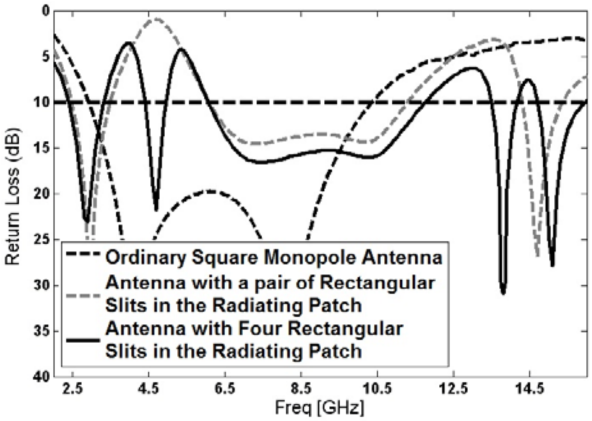


Fig. 3. Simulated return loss characteristics for antennas shown in Figure 2.

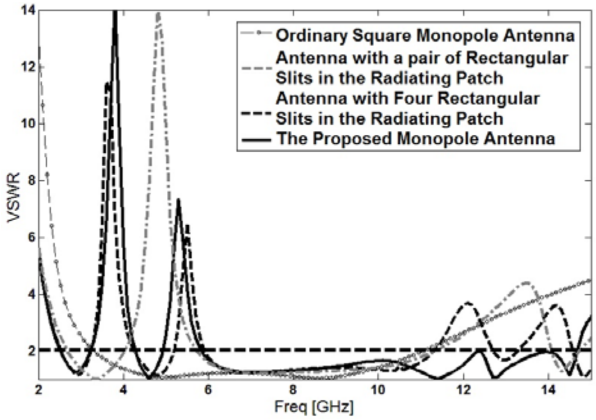


Fig. 4. Simulated VSWR characteristics for the proposed antenna structure and antennas shown in Figure 2.

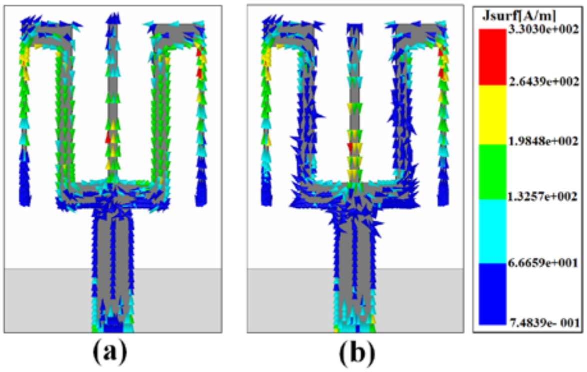
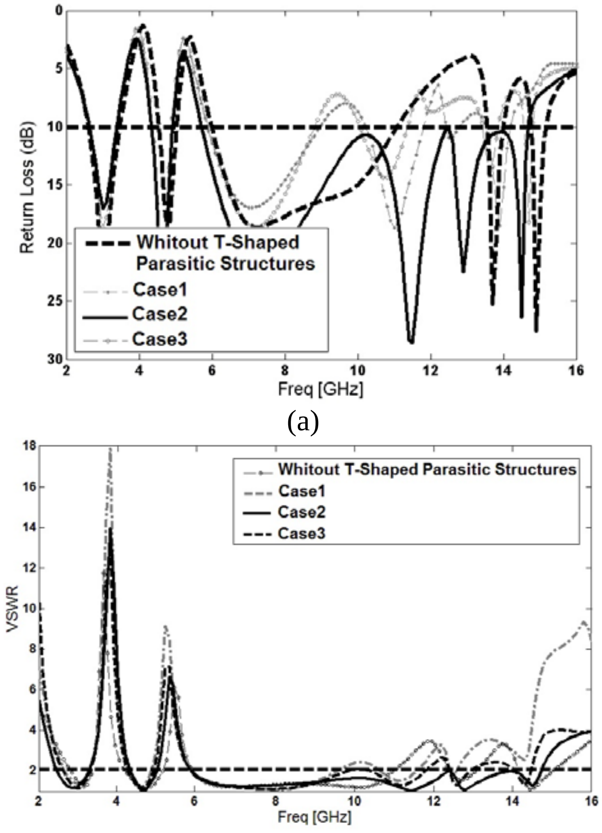


Fig. 5. Simulated surface current distributions on the radiating patch for (a) the proposed antenna without T-shaped parasitic structures at first band-notch central frequency (3.8 GHz), (b) the proposed antenna without T-shaped parasitic structures at second band-notch central frequency (5.5 GHz).

In order to increase the upper frequency bandwidth, two T-shaped parasitic structures are inserted in the ground plane of the proposed antenna, as displayed in Fig. 1. Three such T-shaped parasitic structures with different sizes are specified in Table I as cases 1, 2 and 3.

Table 1: Three cases of proposed antenna with different values of T-shaped parasitic structures

Case	L_{P1}(mm)	L_P (mm)	W_{P1}(mm)	W_P (mm)
1	3	9	3.5	1
2	3.5	8	2.75	1.2
3	5	7	1	1.5



(a)

(b)

Fig. 6. Simulated return loss and VSWR characteristics for the proposed antenna without T-shaped parasitic structures and three cases 1, 2 and 3 with it as shown in Table 1.

Figure 6 shows the effects of T-shaped parasitic structures with different values on the impedance matching in comparison with the same antenna without them. It is found that by inserting the T-shaped parasitic structures with suitable dimensions in the ground plane additional resonances are excited and hence much wider impedance bandwidth with multi-resonance characteristics can be produced, especially at the higher frequencies.

The simulated VSWR curves with different values of L_S are plotted in Fig. 7. As shown in Fig. 6, when the height of the slits increases from 5.25 to 9.25 mm, the center of lower notch frequency is decreased from 4.8 to 3.45 GHz and also the center of higher notch frequency is decreased from 6.5 to 4.9 GHz. From these results, we can conclude that the notch frequency is controllable by changing the interior height of the corner slit.

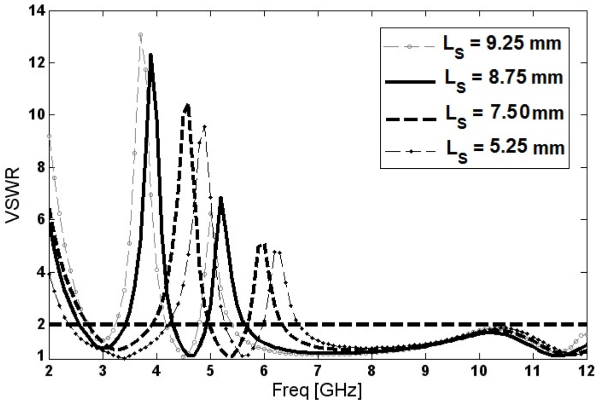


Fig. 7. Simulated VSWR characteristics for various values of L_S .

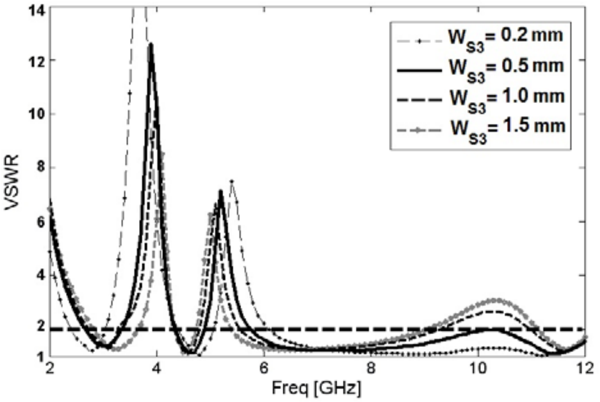


Fig. 8. Simulated VSWR characteristics for various values of W_{S3}.

Figure 8 illustrates the simulated VSWR characteristics with various values of W_{S3}. As the width W_{S3} increases from 0.2 to 1.5 mm, the filter bandwidth is varied from 0.6 to 1.3 GHz for lower notch frequency and also varied from 0.8 to 1.2 GHz for higher notch frequency.

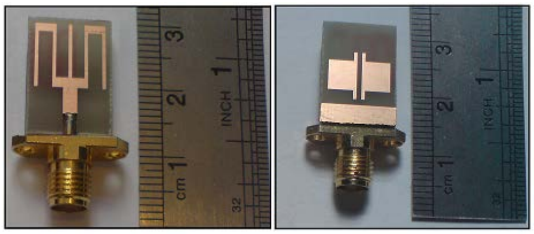

(a) (b)

Fig. 9. Photograph of the realized antenna, (a) top view, (b) bottom view.

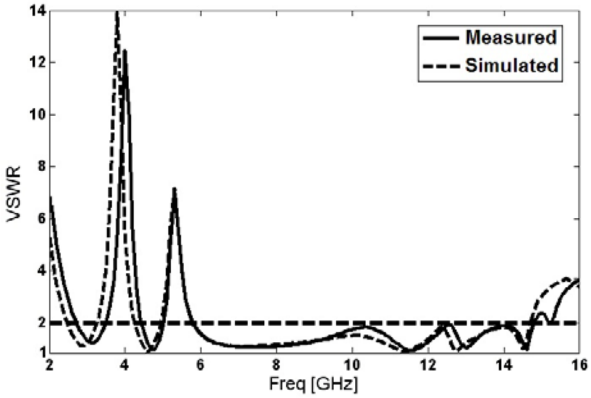


Fig. 10. Measured and simulated VSWR for the proposed antenna.

A prototype of the proposed monopole antenna, as shown in Fig. 9, was fabricated and tested in the Antenna Laboratory at Microwave Technology Company (MWT), and the VSWR were measured using a HP 8720ES network analyzer in an anechoic chamber. Figure 10 shows the measured and simulated VSWR characteristics of the proposed antenna. The fabricated antenna has the frequency band of 2.79 to over 14.83 GHz with two rejection bands around 3.45-4.23 and 5.07–5.89 GHz. As shown in Fig. 10, there exists a discrepancy between measured data and the simulated results which could be due to the effect of the SMA port. In order to confirm the accurate return loss characteristics for the designed antenna, it is recommended that the manufacturing and measurement processes need to be performed carefully.

The difference in the measured and simulated results in Fig. 10 can also be due to the use of FR4. The designed and fabricated FR4 substrate might not have the same dielectric constant value. As in reality the dielectric constant of an FR4 substrate usually can be anything from 4.1 - 4.9 GHz.

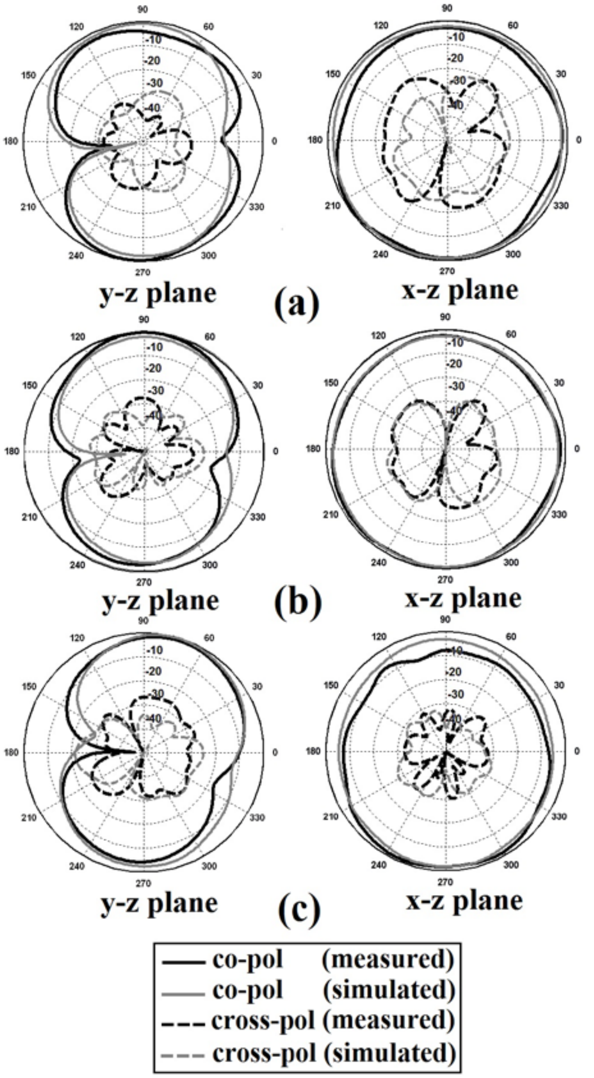


Fig. 11. Measured and simulated radiation patterns of the proposed antenna. (a) 4.8 GHz, (b) 7.5 GHz, and (c) 10 GHz.

The radiation patterns have been measured inside an anechoic chamber. Figure 11 shows the measured and simulated radiation patterns including the co-polarization and cross-polarization in the *H*-plane (*x*-*z* plane) and *E*-plane (*y*-*z* plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. It can be seen that the radiation patterns in *x-z* plane are nearly omnidirectional for the three frequencies. As shown in Fig. 11, the measured radiation patterns agree very well with the simulated results at the three frequencies.

Figure 12 shows the effects of the rectangular slits, and T-shaped parasitic structures on the maximum gain in comparison with the same antenna without them. As shown in Fig. 12, the basic antenna has a gain that is low at 2 GHz and increases with frequency. It is found that the gain of the square antenna is decreased with the use of the rectangular slits, and T-shaped parasitic structures. It can be observed in Fig. 12 that by using a square radiating patch with a four rectangular slits and two T-shaped parasitic structures, two sharp decrease of maximum gain in the notched frequencies band at 3.9 and 5.5 GHz are shown. For other frequencies outside the notched frequencies band, the antenna gain with the filter is similar to those without it. A two-antenna technique is used to measure the radiation gain. It can be seen that for the frequency notch band the gain is negative, which is expected based on the return loss and VSWR measurements.

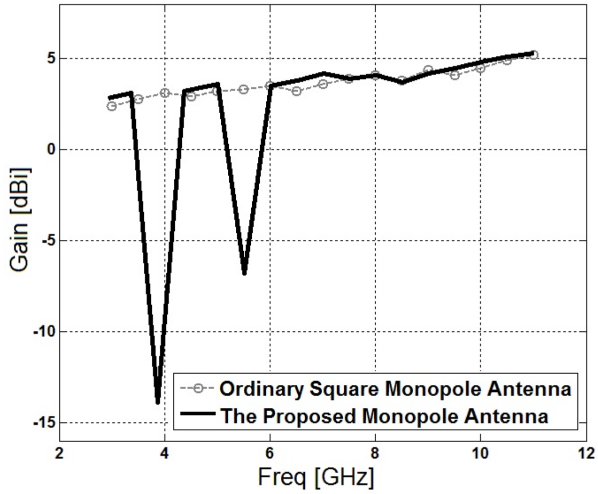


Fig. 12. Measured maximum gain comparisons for the ordinary square antenna and the proposed antenna.

V. CONCLUSION

In this paper, a novel compact wideband planar monopole antenna (PMA) with variable single and dual band-notched characteristics has been proposed for various UWB applications. The fabricated antenna has the frequency band of 2.79 to over 14.83 GHz with two rejection bands around 3.3-4.23 and 5.07–5.89 GHz. By cutting four rectangular slits with variable dimensions on the square radiating patch, dual band-notch characteristics generated and also by inserting two inverted T-shaped conductor-backed plane, additional resonances are excited and hence much wider impedance bandwidth can be produced, especially at the higher band. The proposed antenna has a simple configuration and is easy to fabricate. Experimental results show that the proposed antenna could be a good candidate for UWB applications.

ACKNOWLEDGMENT

The authors are thankful to Microwave Technology (MWT) Company staff for their beneficial and professional help (www.microwave-technology.com).

REFERENCES

[1] M. Ojaroudi, Sh. Yzdanifard, N. Ojaroudi, and M. Nasser-Moghaddasi, "Small Square Monopole Antenna with Enhanced by Using Inverted T-Shaped Slot and Conductor-Backed Plane," *IEEE Transactions on Antenna and Propagation*, vol. 59, no. 2, pp. 670-674, February 2011.

[2] A. T. Mobashsher, M. T. Islam, N. Misran, "Wideband Compact Antenna with Partially Radiating Coplanar Ground Plane," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 26, no. 1, pp. 73-81, January 2011.

[3] M. Ojaroudi, Ch. Ghobadi, and J. Nourinia, "Small Square Monopole Antenna with Inverted T-Shaped Notch in the Ground Plane for UWB Application," *IEEE Antennas and Wireless Propagation Letters*, vol. 8, no. 1, pp. 728-731, 2009.

[4] J. William, R. Nakkeeran, "A New UWB Slot Antenna with Rejection of WiMax and WLAN Bands," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 25, no. 9, pp. 787-793, September 2010..

[5] Sh. Yazdanifard, R. A. Sadeghzadeh, and M. Ojaroudi, "Ultra-Wideband Small Square Monopole Antenna with Variable Frequency Bond-Notch Function," *Progress In Electromagnetics Research C*, vol. 15, pp. 133-144, 2010.

[6] M. Ojaroudi, Gh. Ghanbari, N. Ojaroudi, and Ch. Ghobadi, "Small Square Monopole Antenna for UWB Applications with Variable Frequency Band-Notch Function," *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 1061-1064, 2009.

[7] K. Chung, S. Hong, and J. Choi, "Ultrawideband Printed Monopole Antenna with Band-Notch Filters," *Microw. Antennas, Prorag.*, vol. 1, no. 2, pp. 518-522, Apr. 2007.

[8] M. Ojaroudi, Sh. Yzdanifard, N. Ojaroudi, and R. A. Sadeghzadeh, "Band-Notched Small Square-Ring Antenna with a Pair of T-Shaped Strips Protruded Inside the Square Ring for UWB Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 227-230, 2011.

[9] Q. Wu, R. Jin, J. Geng, and J. Lao , "Ultra-Wideband Rectangular Disk Monopole Antenna with Notch Ground," *Electron. Lett.*, vol. 43, no. 11, pp. 1100-1101, May 2007.

[10] D. S. Javan, O. H. Ghouchani, "Cross Slot Antenna with U-Shaped Tuning Stub for Ultra Wideband Applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 24, no. 4, pp. 427-432, August 2009.

[11] M. Naghshvarian-Jahromi, N. Komjani-Barchloui, "Analysis of the Behavior of Sierpinski Carpet Monopole Antenna," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 24, no. 1, pp. 32-36, February 2009.

[12] Ansoft High Frequency Structure Simulation (HFSS), Ver. 13, Ansoft Corporation, 2010.

Mohammad Ojaroudi was born on 1984 in Germi, Iran. He received his B.Sc. degree in Power Electrical Engineering from Azad University, Ardabil Branch and M.Sc. degree in Telecommunication Engineering from Urmia University. From 2010, he is working toward the Ph.D. degree at Shahid Beheshti University. From 2007 until now, he is an Teaching Assistant with the Department of Electrical Engineering, Islamic Azad University, Ardabil Branch, Iran. Since March 2008, he has been a Research Fellow (Chief Executive Officer) in the Microwave Technology Company (MWT), Tehran, Iran. His research interests include analysis and design of microstrip antennas, design and modeling of microwave structures, radar systems, and electromagnetic theory. He is author and coauthor of more than 60 journal and international conference papers.

Nasser Ojaroudi was born on 1986 in Germi, Iran. He received his B.Sc. degree in Electrical Engineering from Azad University, Ardabil Branch. From 2011, he is working toward the M.Sc. degree in Telecommunication Engineering at Shahid Rajaee Teacher Training University. Since March 2008, he has been a Research Fellow in the Microwave Technology Company (MWT), Tehran, Iran. His research interests include monopole antenna, slot antennas, microstrip antennas for radar systems, ultra-wideband (UWB) and small antennas for wireless communications, microwave passive devices and circuits, and microwave/millimeter systems.

Yaser Ebazadeh was born on 1981 in Germi, Iran. He received his B.Sc. degree in software Engineering from Tabriz University. From 2011, he is working toward the M.Sc. degree in Computer Engineering at Azarbayjan Shraghi Branch, Science and Research, Islamic Azad University, Tabriz, Iran. He is IT manager of Germi Branch, Islamic Azad University, Germi, Iran. His research interests include Information Security Systems, WiMAX technology simulation in ns-2 simulator and advanced antenna technology in WiMAX.