CPW-Fed Slot-Like Sleeve-Monopole Antenna with Bandwidth Enhancement for UWB Wireless Communications

S. Bashiri [1], Ch. Ghobadi [1], J. Nourinia [1], and M. Ojaroudi [2]

[1] Department of Electrical Engineering
Urmia University, Urmia, Iran
st_s.bashiri@urmia.ac.ir, ch.ghobadi@urmia.ac.ir, and j.nourinia@urmia.ac.ir

[2] Young Researchers Club
Ardabil Branch, Islamic Azad University, Ardabil, Iran
m.ojaroudi@iauardabil.ac.ir

Abstract **─** This paper proposes a novel slot-like sleeve-monopole antenna for ultra wideband applications with multi-resonances performance. The antenna consists of a CPW-fed sleeve monopole antenna with a coupled inverted U-shaped strip, surrounded by a pair of folded strips, which provides a wide usable fractional bandwidth of more than 120 % (3.09 GHz - 12.86 GHz). By adding a coupled inverted U-shaped strip with variable dimensions on the radiating patch and also by inserting two folded strips, additional resonances are excited and hence much wider impedance bandwidth can be produced, especially at the higher band. The designed antenna has a small size of 30 × 30 mm^2. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range.

Index Terms **─** Coupled inverted U-shaped strip, slot-Like sleeve-monopole antenna, and ultra wideband communications.

I. INTRODUCTION

Commercial UWB systems require small low-cost antennas with omnidirectional radiation patterns and large bandwidth [1]. It is a well-known fact that planar monopole and slot antennas present really appealing physical features, such as simple structure, small size, and low cost. Due to all these interesting characteristics, planar monopoles and slots are extremely attractive to be used in emerging UWB applications, and growing research activity is being focused on them.

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, number of printed microstrip slot and monopole antennas with different geometries have been experimentally characterized [2, 3] and automatic design methods have been developed to achieve the optimum planar shape [4, 5]. Moreover, other strategies to improve the impedance bandwidth have been investigated [6-9].

A simple method for designing a novel and compact CPW-fed slot-like sleeve-monopole antenna with multi resonance performance for UWB applications has been presented. In the proposed structure, based on electromagnetic coupling theory (ECT), by inserting a coupled inverted U-shaped strip, surrounded by a pair of folded strips, on the sleeve monopole antenna, additional resonances are excited and the bandwidth is improved that achieves a fractional bandwidth with multi resonance performance of more than 120 %. Good return loss and radiation patterns characteristics are obtained in the frequency band of interest. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications.

Submitted On: July 27, 2012
Accepted On: Aug. 29, 2013

II. ANTENNA DESIGN

The proposed slot-like sleeve-monopole antenna fed by a 50 Ω coplanar waveguide (CPW) line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 1.6 mm and permittivity 4.4. The basic antenna structure consists of a CPW-fed monopole antenna with a pair of sleeves and a coupled inverted U-shaped strip, surrounded by a pair of folded strips. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission.

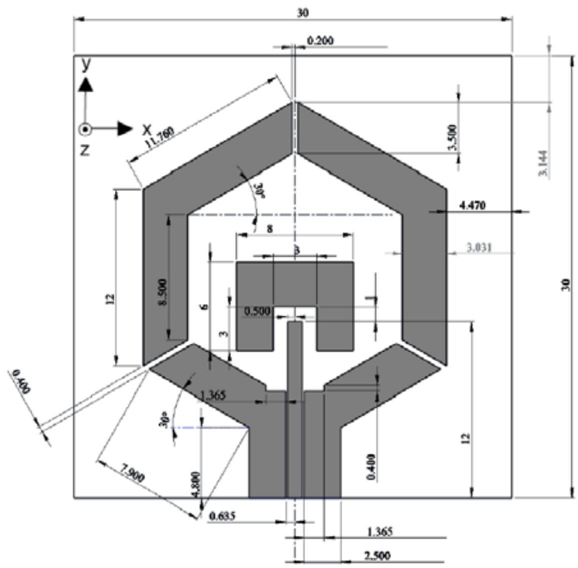

Fig. 1. Geometry of the proposed antenna (unit: mm).

In this study, the modified inverted U-shaped coupled strip act as an impedance matching element to control the impedance bandwidth of the proposed antenna, because it can creates additional surface current paths in the antenna therefore, additional resonance is excited and hence, much wider impedance bandwidth can be produced, especially at the higher band [10]. The electrical current for the exited resonance frequency does change direction along the surface of the coupled strip. Additionally, based on electromagnetic coupling theory, the folded parasitic strips, are placed around the coupled inverted U-shaped strip, and act as parasitic half-wave resonant structure electrically coupled to the sleeve monopole antenna with a coupled inverted U-shaped strip. They perturb the resonant response and also act as a half-wave resonant structure. At the new resonance frequencies, the current flows are more dominant around the parasitic elements [10].

III. RESULTS AND DISCUSSIONS

In this section, the proposed antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [11]. Figure 2 shows the structure of various antennas used for multi-resonance performance simulation studies. Return loss characteristics for ordinary CPW-fed monopole antenna (Fig. 2 (a)), with a pair of rectangular sleeves (Fig. 2 (b)), with a pair of rectangular sleeves and a coupled inverted U-shaped strip (Fig. 2 (c)), and the proposed antenna structure (Fig. 2 (d)) are compared in Fig. 3. As shown in Fig. 3, it is observed that by using these coupled elements including a coupled inverted U-shaped strip, and by inserting a pair of coupled folded strips on the sleeve monopole antenna, additional third and fourth resonances are excited, respectively, and hence the bandwidth is increased.

As shown in Fig. 3, in the proposed antenna configuration, the ordinary sleeve monopole can provide the fundamental and next higher resonant radiation band at 4.5 GHz and 8.48 GHz, respectively, in the absence of the coupled elements. To design a novel antenna, also in order increase the upper frequency bandwidth, a coupled inverted U-shaped strip is inserted in the radiating patch of the sleeve monopole antenna as displayed in Fig. 1. The upper frequency bandwidth is significantly affected by using the coupled inverted U-shaped strip. This behavior is mainly due to the change of the surface current path by the dimensions of the inverted U-shaped strip as shown in Fig. 4 (b). This figure shows that the electrical current for the third resonance frequency (9.8 GHz) does change direction along the coupled inverted U-shaped strip. Therefore, the antenna impedance changes at this frequency, the radiating power and bandwidth will increases. Furthermore, the radiation efficiency will increase. However, the resonant resistance is decreased [6]. In addition, by inserting two coupled folded strips the impedance bandwidth is effectively improved at the upper frequency [10]. The inverted coupled folded strips can be regarded as a parasitic resonator electrically coupled to the sleeve monopole with the coupled inverted U-shaped strip. It is found that by inserting these folded strips of suitable dimensions at the antenna; much wider impedance bandwidth can be produced, especially at the higher band. As shown in Figs. 4 (a) and (c), the current is concentrated on the edges of the interior and exterior of the coupled folded strips at second (6.15 GHz) and fourth (12.2 GHz) resonance frequencies, respectively.

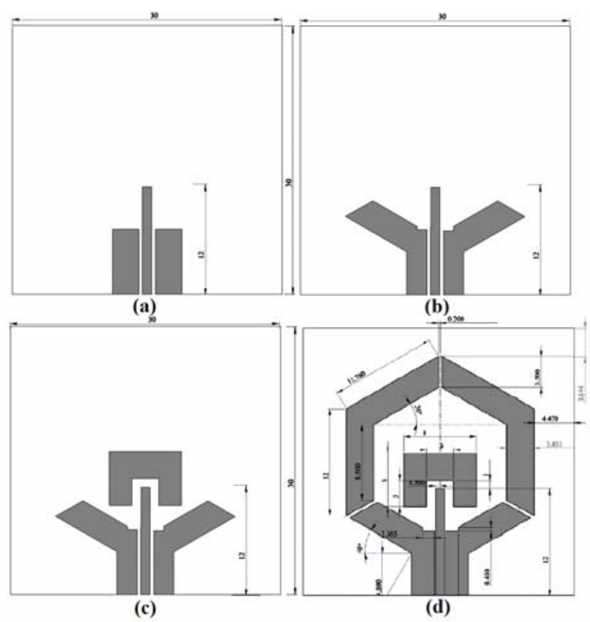

Fig. 2. (a) The basic structure (CPW-fed monopole antenna), (b) the sleeve monopole antenna, (c) sleeve monopole antenna with a coupled inverted U-shaped strip, and (d) the proposed antenna.

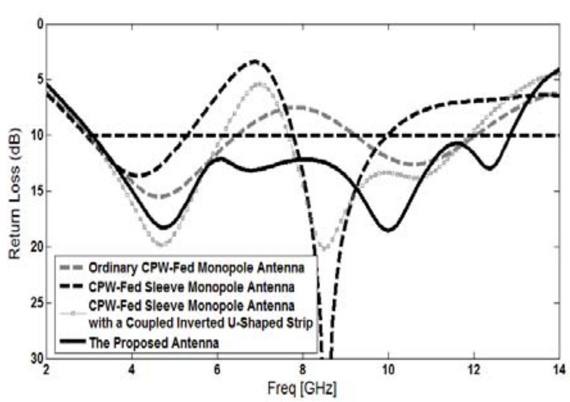

Fig. 3. Simulated return loss characteristics for the antennas shown in Fig. 2.

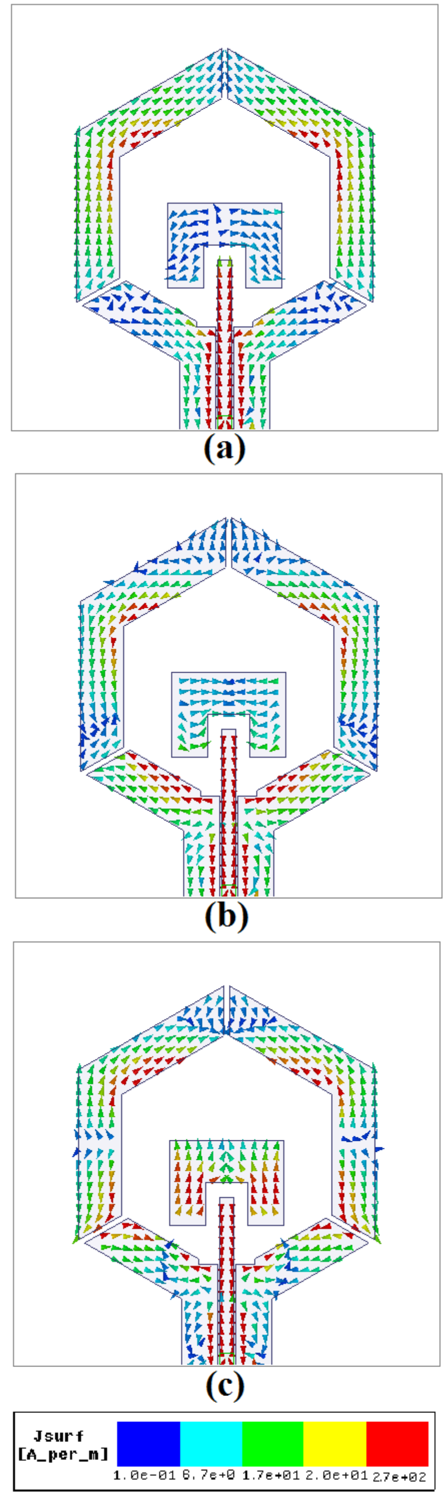

Fig. 4. Simulated surface current distributions for the proposed antenna shown in Fig. 1 at new exited resonance frequencies, (a) 6.15 GHz (second resonance frequency), (b) 9.8 GHz (third resonance frequency), and (c) 12.2 GHz (fourth resonance frequency).

The simulated radiation efficiencies of the proposed antenna are shown in Fig. 5. Results of the calculations using the software HFSS indicated that the proposed antenna features a good efficiency, being greater than 82 % across the entire radiating band. The proposed antenna with optimal design, as shown in Fig. 6, was built and tested in the antenna measurement laboratory at Iran Telecommunication Research Center (ITRC). Figure 7 shows the measured and simulated return loss characteristics of the proposed antenna. The fabricated antenna has the frequency band of 3.09 GHz to over 12.86 GHz. As shown in Fig. 7, there exists a discrepancy between measured data and the simulated results. This discrepancy between measured and simulated results is mostly due to a number of parameters such as the fabricated antenna dimensions as well as the thickness and dielectric constant of the substrate on which the antenna is fabricated, the wide range of simulation frequencies and also the effect of SMA soldering. In order to confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully, besides, SMA soldering accuracy and FR4 substrate quality needs to be taken into consideration. In conclusion, as the slot is a short radiator, the SMA connector can modify its impedance matching [4, 5].

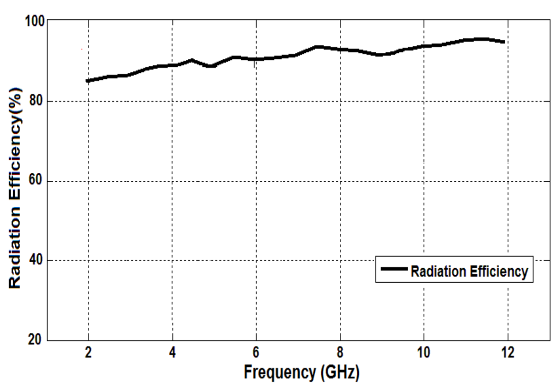

Fig. 5. Simulated radiation efficiency values of the proposed monopole antenna.

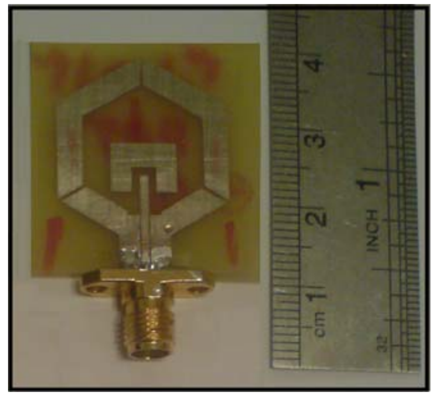

Fig. 6. Photograph of the realized printed slot-like sleeve monopole antenna.

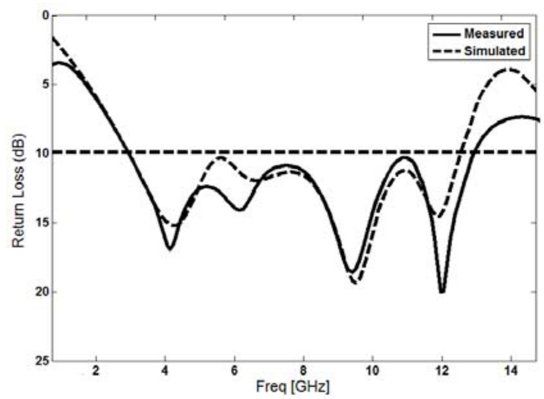

Fig. 7. Measured and simulated return loss characteristics of the proposed antenna.

Figure 8 shows the measured radiation patterns including the co- and cross-polarized in the *H*- (*x*-*z* plane) and *E*-planes (*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 the *x*-*z* plane are nearly omnidirectional even at higher frequencies, and also the cross-polarization level is low for the three frequencies.

Figure 9 shows the simulated and measured maximum gain of the proposed antenna in the *z*-axis direction (*x*-*z* plane). As shown in Fig. 9, the proposed structure has a gain that is low at 2 GHz and increases with frequency [8]. Reasonable agreement between simulations and measurements is demonstrated.

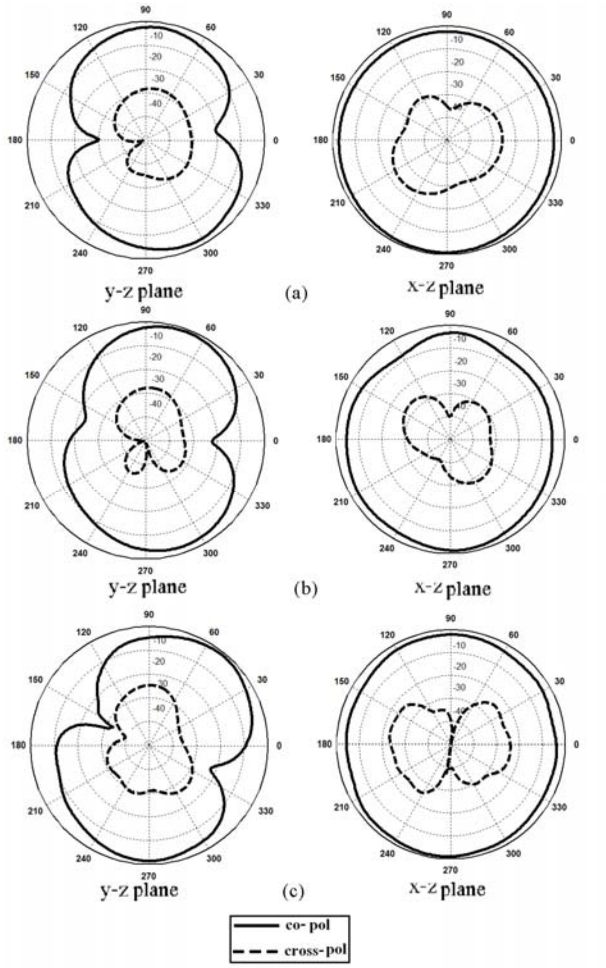

Fig. 8. Measured radiation patterns of the proposed antenna at (a) 6.15 GHz (second resonance frequency), (b) 9.8 GHz (third resonance frequency), and (c) 12.2 GHz (fourth resonance frequency).

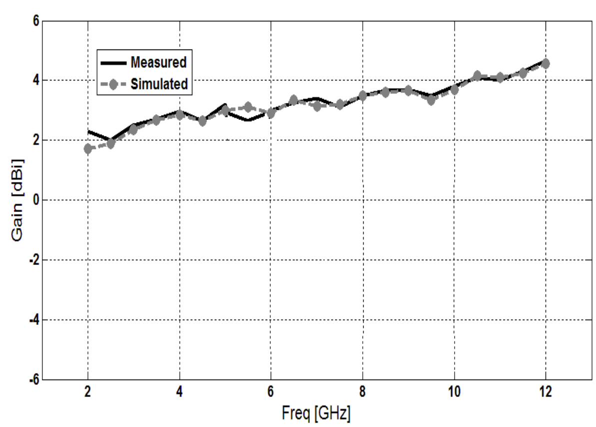

Fig. 9. Measured and simulated maximum gain of the proposed antenna in the *z*-axis direction (*x*-*z* plane).

IV. CONCLUSION

In this paper, a novel slot-like sleeve monopole antenna with multi-resonance characteristics and wide bandwidth capability for UWB applications is proposed. In this design, the proposed antenna can operate from 3.09 GHz to 12.86 GHz. By adding a coupled inverted U-shaped strip and also by inserting a pair of coupled folded strips with variable dimensions on the radiating patch of a CPW-fed sleeve monopole antenna, additional resonances are excited and hence much wider impedance bandwidth can be produced, especially at the higher band. The designed antenna has a small size. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and 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 and A. Faramarzi, "Multi-resonance small square slot antenna for ultra-wideband applications," *Microwave and Optical Tech. Letters*, vol. 53, no. 9, Sep. 2011.

[2] M. Partovi, N. Ojaroudi, and M. Ojaroudi, "Small slot antenna with enhanced bandwidth and band-notched performance for UWB applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 9, pp. 772-778, Sep. 2012.

[3] B. H. Siahkal-Mahalle, M. Ojaroudi, and N. Ojaroudi, "Enhanced bandwidth small square monopole antenna with band-notched functions for UWB wireless communications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 9, pp. 759-765, Sep. 2012.

[4] M. Ojaroudi, N. Ojaroudi, and Y. Ebazadeh, "Dual band-notch small square monopole antenna with enhanced bandwidth characterestics for UWB applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 5, pp. 420-426, May 2012.

[5] A. Valizade, Ch. Ghobadi, J. Nourinia, N. Ojaroudi, and M. Ojaroudi, "Band-notch slot antenna with enhanced bandwidth by using Ω shaped strips protruded inside rectangular slots for

UWB applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 10, pp. 816-822, Oct. 2012.

[6] G. Zhang, J. S. Hong, B. Z. Wang, and G. Song, "Switched band-notched UWB/WLAN monopole antenna," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 3, pp. 256-260, March 2012.

[7] M. Ojaroudi, Ch. Ghobadi, J. Nourinia, and N. Ojaroudi, "Ultra-wideband small square monopole antenna with dual band notched function," *Microwave and Optical Tech. Letters*, vol. 54, no. 2, pp. 372-374, Feb. 2012.

[8] S. Yzadanifard, R. A. Sadeghzadeh, and M. Ojaroudi, "Ultra-wideband small square monopole antenna with variable frequency band-notch function," *Progress In Electromagnetics Research C*, vol. 15, pp. 133-144, 2010.

[9] X. L. Ma, W. Shao, and G. Q. He, "A novel dual narrow band-notched CPW-fed UWB slot antenna with parasitic strips," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 7, pp. 581-586, July 2012.

[10] Z. L. Zhou, L. Li, and J. S. Hong, "A novel compact monopole antenna with triple high quality rejected bands for UWB applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 8, pp. 654-659, August 2012.

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

Sepideh Bashiri was born on 1986 in Marand, Iran. She received her B.Sc. degree in Electrical Engineering from Tabriz University,and M.Sc. degree in Telecommunication Engineering from Urmia University in 2012 . Her research interests include analysis and design of microstrip antennas, design and modeling of microwave structures, radar systems, and electromagnetic theory. Her 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.

Changiz Ghobadi was born in June, 1960 in Iran. He received his B.Sc. in Electrical Engineering-Electronic and M.Sc. degrees in Electrical Engineering-Telecommunication from Isfahan University of Technology, Isfahan, Iran and Ph.D. degree in Electrical-Telecommunication from University of Bath, Bath, UK in 1998. From 1998 he was an Assistant Professor and now he is an Associated Professor in the Department of Electrical Engineering of Urmia University, Urmia, Iran. His primary research interests are in antenna design, radar and adaptive filters.

Javad Nourinia received his B.Sc. in Electrical and Electronic Engineering from Shiraz University and M.Sc. degree in Electrical and Telecommunication Engineering from Iran University of Science and Technology, and Ph.D. degree in Electrical and Telecommunication from University of Science and Technology, Tehran Iran in 2000. From 2000 he was an Assistant Professor and now he is an Associate Professor in the Department of Electrical Engineering of Urmia University, Urmia, Iran. His primary research interests are in antenna design, numerical methods in electromagnetic, and microwave circuits.

Mohammad Ojaroudi was born in 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. Also from July 2013 he has been working, as a research visitor in Dr. Fathy laboratory in University of Tennessee, Knoxville, USA. From 2007 until now, he is a Teaching Assistant with the Department of Electrical Engineering, Islamic Azad University, Ardabil Branch, Iran.

Since March 2009, he has been the Chief Executive Officer (CEO) in the Microwave Technology (MWT) company, Tehran, Iran. From 2012, Dr. Ojaroudi is a member of the IEEE Transaction on Antennas and Propagation (APS) reviewer group and the Applied Computational Electromagnetic Society. 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 120 journal and international conferences papers. His papers have more than 450 citations with 11 h-index.