Progress In Electromagnetics Research C, Vol. 18, 47–57, 2011

ENHANCED BANDWIDTH DOUBLE-FED MICROSTRIP SLOT ANTENNA WITH A PAIR OF L-SHAPED SLOTS

L. Hadizafar and M. N. Azarmanesh

Microelectronics Research Laboratory
Urmia University, Urmia, Iran

M. Ojaroudi

Electrical Engineering Department
Islamic Azad University, Ardabil Branch, Ardabil, Iran

Abstract—In this paper, a modified square slot antenna with modified radiating patch, for UWB applications is proposed. The proposed antenna consists of a square radiating patch with a double fed structure and a ground plane with a pair of L-shaped slots which provides a wide usable fractional bandwidth of more than 140% (3–18 GHz). By optimizing the L-shaped slots dimensions and rectangular slot width, the total bandwidth of the antenna is greatly improved. The designed antenna has a small size of $35 \times 35\,\mathrm{mm}^2$.

1. INTRODUCTION

Commercial UWB systems require small low-cost antennas with omnidirectional radiation patterns and large bandwidth [1]. It is a well-known fact that printed slot antennas present really appealing physical features, such as simple structure, small size and low cost. Due to all these interesting characteristics, microstrip slot antennas 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 key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Consequently, a number of microstrip slot antenna with different geometries have been experimentally characterized [2–5]. In this paper, we propose a novel modified

Received 28 September 2010, Accepted 21 October 2010, Scheduled 24 November 2010
Corresponding author: Leila Hadizafar (st_l.hadizafar@urmia.ac.ir).

microstrip slot antenna with increased impedance bandwidth, for UWB applications. At first, by inserting a pair of L-shaped slots in the ground plane, the total bandwidth of the antenna is greatly improved. Moreover, by cutting a rectangular slot in the radiating patch, a double fed structure is generated and also much wider impedance bandwidth can be produced. In this design, the proposed antenna can operate from 3 to 18 GHz and the proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and experimental results are presented to demonstrate the performance of a suggested antenna.

2. ANTENNA DESIGN

The proposed slot antenna fed by a 50-Ohm microstrip line is shown in Fig. 1, which is printed on a FR4 substrate of thickness 0.8 mm, and permittivity 4.4. The width W_f of the microstrip feedline is fixed at 1.5 mm. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission. The L-shaped slots embedded in the ground plane are important parameter in determining the sensitivity of impedance matching. The modified truncated ground plane acts as

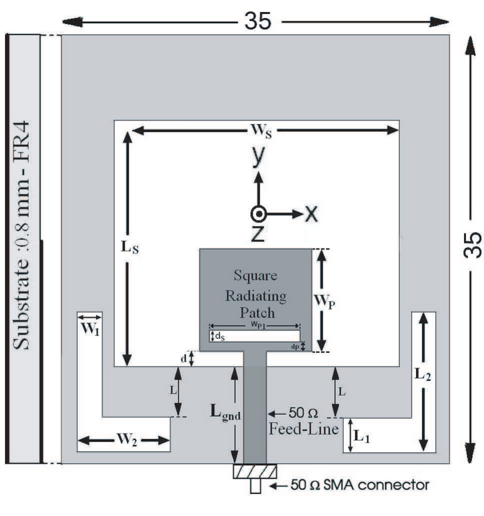


Figure 1. Geometry of proposed antenna with a double fed structure and a pair of L-shaped slots.

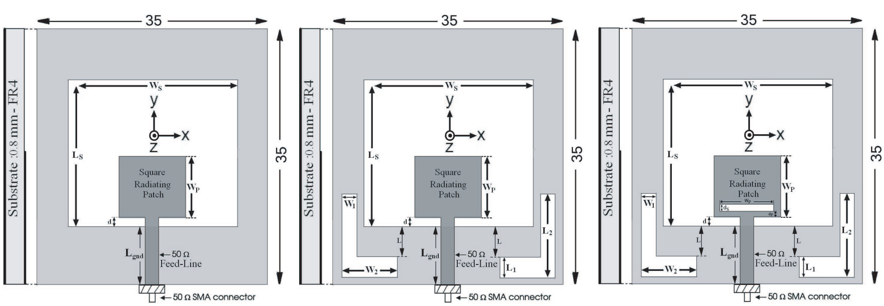
an impedance matching element to control the impedance bandwidth of the proposed antenna. This is because the truncation creates a capacitive load that neutralizes the inductive nature of the patch to produce nearly-pure resistive input impedance [6].

Using a rectangular slot in the radiating patch increases the upper-edge frequency, and it is possible to control this frequency by adjusting the slot width [7]. By cutting a modified slot of suitable dimensions at the radiating patch a new fed configuration can be constructed. The truncated radiating patch is playing an important role in the broadband characteristics of this antenna, because it can creates additional surface current paths in the antenna, also due to double fed structure the proposed antenna displays a good omni-directional radiation pattern even at higher frequencies.

3. RESULTS AND DISCUSSIONS

In this Section, the microstrip slot 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 parameters of this proposed antenna are studied by changing one parameter at a time and fixing the others. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [8].

The optimal dimensions of the designed antenna are as follows: $W_{sub} = 35\,\text{mm}$, $L_{sub} = 35\,\text{mm}$, $W_P = 8\,\text{mm}$, $W_S = 26\,\text{mm}$, $L_S = 20\,\text{mm}$, $W_f = 1.5\,\text{mm}$, $L_{gnd} = 8\,\text{mm}$, $d = 1\,\text{mm}$, $d_P = 1\,\text{mm}$, $d_S = 1\,\text{mm}$, $W_{P1} = 7\,\text{mm}$, $L = 4\,\text{mm}$, $W_1 = 2\,\text{mm}$, $L_1 = 3\,\text{mm}$, $W_2 = 9\,\text{mm}$, and $L_2 = 11\,\text{mm}$.



(a) (b) (c)

Figure 2. (a) The ordinary Square Slot Antenna. (b) The Square Slot Antenna with a pair of L-shaped slots. (c) The proposed antenna.

Figure 2 shows the structure of the various square slot antennas. As shown in Fig. 3, in the proposed antenna configuration, the ordinary square slot can provide the fundamental and next higher resonant radiation band at 3.15 and 6 GHz, respectively, in the absence of the L-shaped slots and the rectangular slot. The upper frequency bandwidth is significantly affected by using L-shaped slots in the ground plane. In addition, by inserting rectangular slot on the radiating patch the impedance bandwidth is effectively improved at the upper frequency [9].

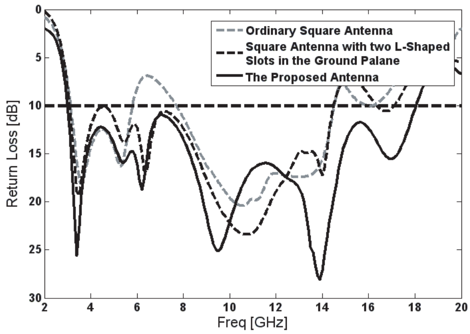


Figure 3. Simulated return loss characteristics for antennas shown in Fig. 2.

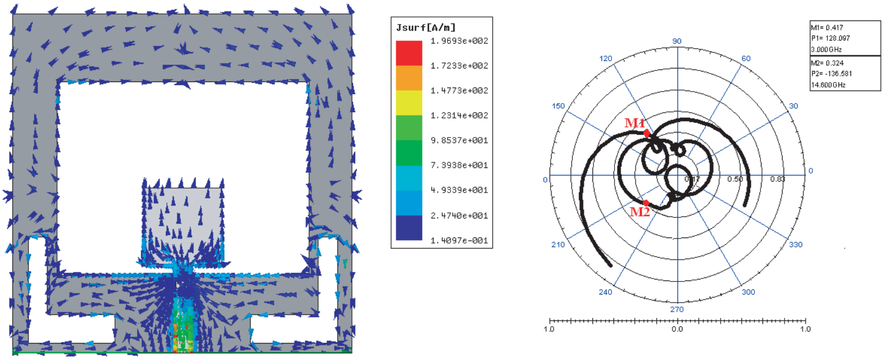
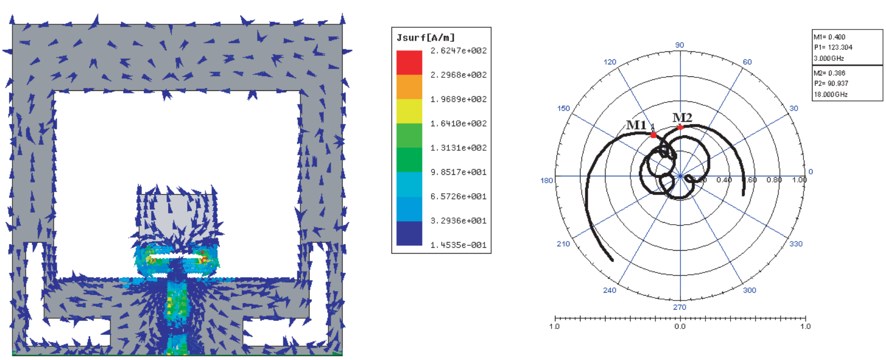


Figure 4. (a) Simulated current distributions for the square slot antenna with a pair of L-shaped slots at 6.3 GHz. (b) Input impedance of the square slot antenna with a pair of L-shaped slots on a Smith Chart.

The simulated current distributions for the square slot antenna with a pair of L-shaped slots in the ground plane at 6.3 GHz are presented in Fig. 4(a). It can be observed in Fig. 4(a) that the current concentrated on the edges of the interior and exterior of the L-shaped slots at 6.3 GHz. Therefore, the antenna impedance changes at this frequency due to the resonant properties of the slot. It is found that by using these slots, the third resonance occurs at 6.3 GHz in the simulation. The input impedance of the square slot antenna with a pair of L-shaped slots on a Smith Chart is shown in Fig. 4(b). Fig. 4(b) shows that the impedance bandwidth of the square slot antenna with a pair of L-shaped slots in the ground plane is as large as 11.8 GHz (from 3 to 14.8 GHz).

The simulated current distributions for the proposed antenna at 17.2 GHz are presented in Fig. 5. It can be observed in Fig. 5(a) that the current concentrated on the edges of the interior and exterior of the rectangular slot at 17.2 GHz. Therefore, the antenna impedance changes at this frequency due to the resonant properties of the rectangular slot It is found that by using this notch, the sixth resonance occurs at 17.2 GHz in the simulation. To understand the phenomenon behind this wide impedance performance, the input impedance of the proposed antenna on a Smith Chart is shown in Fig. 5(b). Fig. 5(b) shows that the impedance bandwidth of the proposed antenna is as large as 15 GHz (from 3 to 18 GHz).

Another main effect of the rectangular slot occurs on the radiating pattern. Fig. 6 shows the effects of rectangular slot on the radiation patterns in comparison with the same antenna without slot. As shown



(a) (b)

Figure 5. (a) Simulated current distributions for the square proposed antenna at 17.2 GHz. (b) Input impedance of the proposed antenna on a Smith Chart.

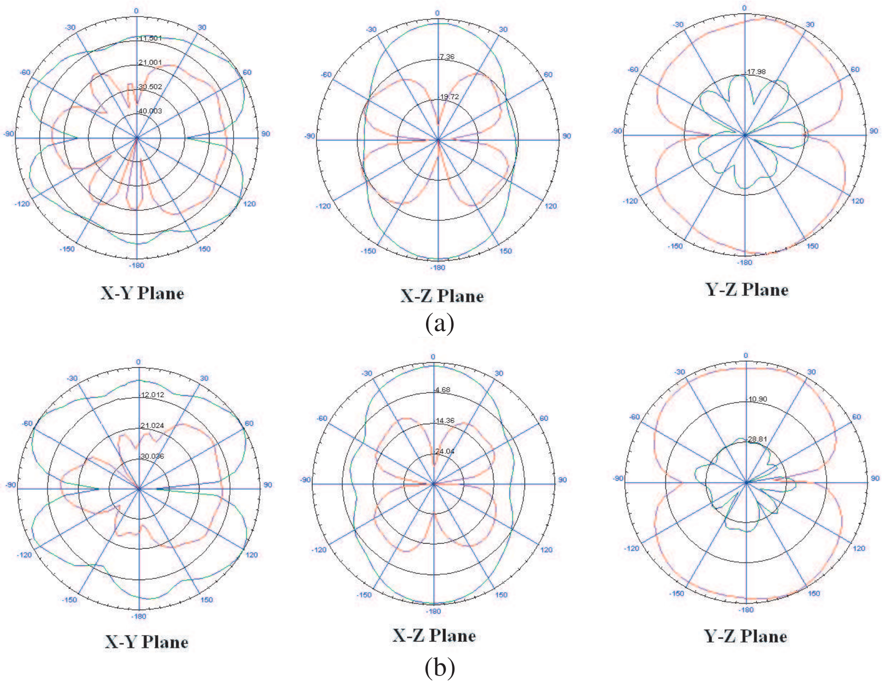


Figure 6. Simulated radiation patterns of the proposed antenna at 9.2 GHz. (a) Without slot. (b) With slot.

in Fig. 6, it can be seen that the cross-polarization in with slot case is smaller than cross-polarization in without slot case. On the other hand, the inserting of the modified rectangular slot decreases the cross-polarization in the radiation pattern, and also it can be seen that the radiation patterns in with slot case in x-z plane are nearly omnidirectional for the mentioned frequency. In this structure, by cutting a rectangular slot of suitable dimensions at the radiating patch a double-fed structure can be constructed. This structure has a novel feeding configuration that consists of a splitting network connected to two symmetrical ports on its base. As shown in Fig. 5, it has been demonstrated that the insertion of two symmetric feed ports prevents the excitation of horizontal currents and assures that only the dominant vertical current mode is present in the structure [7].

Figure 7 shows the return loss characteristics simulated for different values of d_S. By properly tuning d_S, the antenna can create the sixth resonant frequency in individual resonant radiation band based on double fed structure. As illustrated in Fig. 7, the distance d_S

is an important parameter in determining the sensitivity of impedance matching. It is seen that the upper-edge frequency of the impedance bandwidth is increased with increasing d_S, but the matching became poor for larger values.

Using a pair of L-shaped slots increase the upper-edge frequency, and it is possible to control this frequency by adjusting the slot length and width [9]. By optimizing these parameters, a ultra-wide band antenna is produced. The simulated return loss characteristics with different values of L_2 and W_1 are plotted in Fig. 8 As shown in Fig. 8(a), it is found that when L_2 is larger than 11 mm, the proposed antenna does not satisfy the return loss requirements for UWB in low frequencies. From the result in Fig. 8(b), it is also observed that when W_1 is larger than 2 mm, the impedance matching of the proposed

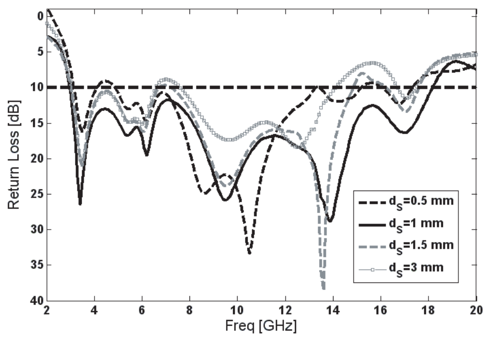
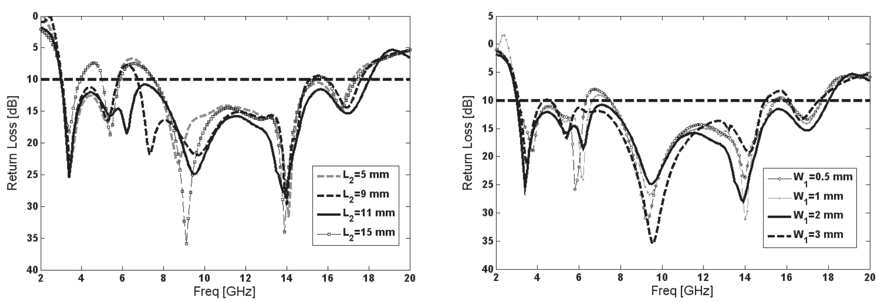


Figure 7. Simulated return loss characteristic for various values of d_S.

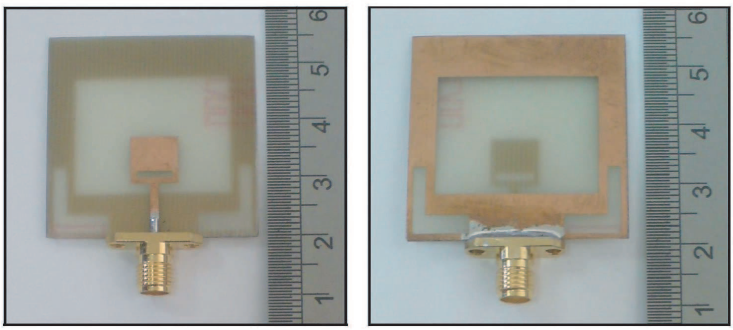


(a) (b)

Figure 8. (a) Simulated return loss characteristics of the proposed antenna with different values of L_2. (b) Simulated return loss characteristics of the proposed antenna with different values of W_1.

antenna is changed at both lower and higher frequencies. Therefore the horizontal width of the L-shaped slots can be used to extend the lower edge frequency or the upper edge frequency of the impedance bandwidth, and also by using two L-shaped slots variable dimensions on the ground plane, the return loss amplitudes in third and fifth resonances are changed.

The proposed antenna has a slightly higher efficiency rather than ordinary square antenna throughout the entire radiating band, which is mainly owing to the new resonant properties. Results of the calculations using the software HFSS indicated that the proposed antenna features a good efficiency, being greater than 83% across the entire radiating band.



(a) (b)

Figure 9. Photograph of the realized antenna.

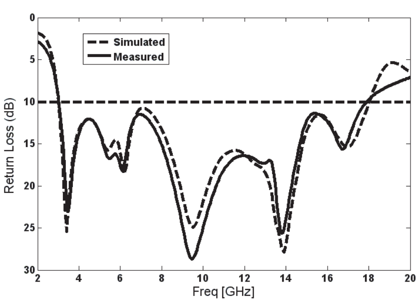


Figure 10. Measured and simulated return loss characteristics for the proposed antenna.

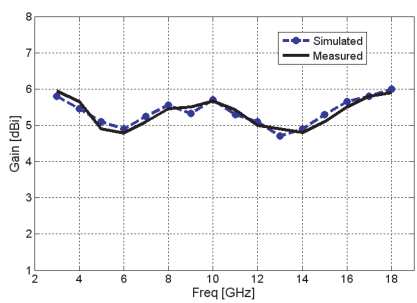


Figure 11. Measured and simulated antenna gain of the proposed antenna.

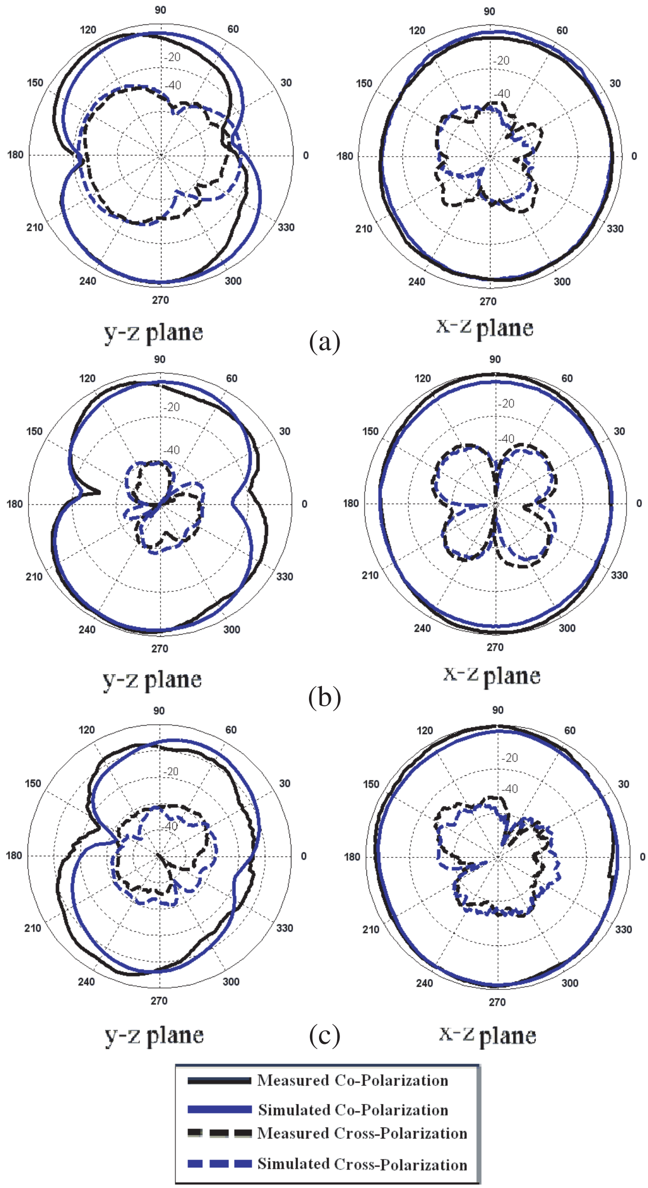


Figure 12. Measured and simulated radiation patterns of the proposed antenna. (a) 4 GHz. (b) 7 GHz. (c) 10 GHz.

The proposed antenna with optimal design, as shown in Fig. 9, was fabricated and tested in the Antenna Measurement Laboratory at Iran Telecommunication Research Center (ITRC). Fig. 10 shows the measured and simulated return loss characteristics of the proposed antenna. The fabricated antenna has the frequency band of 3 to over 18 GHz. As shown in Fig. 10, there exists a discrepancy between measured data and the simulated results this 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 process need to be performed carefully.

Figure 11 shows the measured and simulated maximum gain of the proposed antenna at different frequency up to 18 GHz. It can be seen that the measured peak gains agree very well with the simulated results in the desired frequencies and demonstrates a variation similar to the other wideband antennas.

Figure 12 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). It can be seen that the radiation patterns in x-z plane are nearly omnidirectional for the three frequencies, and also the measured radiation patterns agree very well with the simulated results in the three frequencies.

4. CONCLUSION

In this paper, a novel double-fed slot antenna with wide bandwidth capability for UWB applications is proposed. In this design, the proposed antenna can operate from 3 to 18 GHz with Return Loss < 10 dB and the proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. 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 application.

ACKNOWLEDGMENT

The Author's gratefully acknowledges the IRAN Telecommunication Research Centre, ITRC, for their support and sponsorship.

REFERENCES

1. Schantz, H., *The Art and Science of Ultra Wideband Antennas*, Artech House, 2005.

2. Amini, F., M. N. Azarmanesh, and M. Ojaroudi, "Small semi-circle-like slot antenna for ultra-wideband applications," *Progress In Electromagnetics Research C*, Vol. 13, 149–158, 2010.
3. Rao, P. H., "Feed effects on the dimensions of wide-band slot antennas," *Microwave and Optical Tech. Letters*, Vol. 40, 77–79, 2004.
4. Jang, Y. W., "Broadband cross-shaped microstrip-fed slot antenna," *Electron. Lett.*, Vol. 36, 2056–2057, 2000.
5. Dastranj, A., A. Imani, and M. Naser-Moghaddasi, "Printed wide-slot antenna for wideband applications, *IEEE Transactions on Antennas and Propagation*, Vol. 56, No. 10, 3097–3102, October 2008.
6. Ojaroudi, M., 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, 728–731, 2009.
7. Ojaroudi, M., G. Kohneshahri, and J. Noory, "Small modified monopole antenna for UWB application," *IET Microw, Antennas Propag.*, Vol. 3, No. 5, 863–869, August 2009.
8. Ansoft High Frequency Structure Simulation (HFSS), Ver. 10, Ansoft Corporation, 2005.
9. Rouhi, R., Ch. Ghobadi, J. Nourinia, and M. Ojaroudi, "Ultra-wideband small square monopole antenna with band notched function," *Microwave and Optical Tech. Letters*, Vol. 52, No. 9, 2065–2069, 2010.