Band-Rejected UWB Monopole Antenna with Bandwidth Enhancement

S. Ojaroudi [1], Y. Ojaroudi [1], N. Ojaroudi [2], and N. Ghadimi [2]

[1] Young Researchers and Elite Club
Islamic Azad University, Germi Branch, Germi, Iran

[2] Young Researchers and Elite Club
Islamic Azad University, Ardabil Branch, Ardabil, Iran
noradin.ghadimi@gmail.com

Abstract **─** In this study, we present an Ultra-Wideband (UWB) monopole antenna with band-notched function. The proposed antenna is fed by a microstrip line. By using two modified fork-shaped slots in the ground plane, bandwidth is increased that provides a wide usable fractional bandwidth of more than 135% (2.82-15.63). In order to achieve band-rejected performance, a cross-ring slot was inserted at the square radiating patch and a frequency band-notched of 5.11-5.97 GHz has been received. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range. The designed antenna has a small size.

Index Terms **─** Band-notched function, cross-ring slot, fork-shaped slot and UWB monopole antenna.

I. INTRODUCTION

In UWB communication systems, one of key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band [1]. 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 [2-5].

The Federal Communication Commission (FCC)'s allocation of the frequency range 3.1-10.6 GHz for UWB systems and it will cause interference to the existing wireless communication systems, such as the Wireless Local Area Network (WLAN) for operating in 5.15-5.35 GHz and 5.725-5.825 GHz bands; so the UWB antenna with a single band-stop performance is required [6-9]. Lately, to generate the frequency band-notch function, modified planar monopoles several antennas with band-notch characteristic have been reported [10-13]. In [14], [15] and [16], different shapes of the parasitic structures (i.e., SRR, L-shaped and protruded strips) are used to obtain the desired band notched characteristics. H-ring conductor-backed plane structure is embedded in the antenna backside to generate the single and dual band-notched functions in [17].

In this paper, a new multi-resonance small monopole antenna with band-notched function is presented. In the proposed structure, by inserting a pair of fork-shaped slots in the ground plane, multi-resonance characteristic can be achieved. In order to generate a single band-notched function, we insert a modified cross-ring slot in the radiating patch. The designed antenna has a small size of 12×18 mm^2. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest.

II. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed planar monopole antenna that is fed by microstrip line, which is printed on an FR4 substrate of thickness 1.6 mm, permittivity 4.4 and loss tangent 0.018. As shown in Fig. 1, the presented antenna

Submitted On: January 21, 2013
Accepted On: July 23, 2014

consists of a square radiating patch with a cross-ring slot and modified ground plane with two fork-shaped slots. The basic antenna structure consists of a square patch, a feed line and a ground plane. The square patch has a width of *W*. The square patch has a width of *W*. The patch is connected to a feed line with the width of W_f and the length of L_f. On the other side of the substrate, a conducting ground plane with the width of W_{Sub} and the length of L_{gnd} is placed. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission.

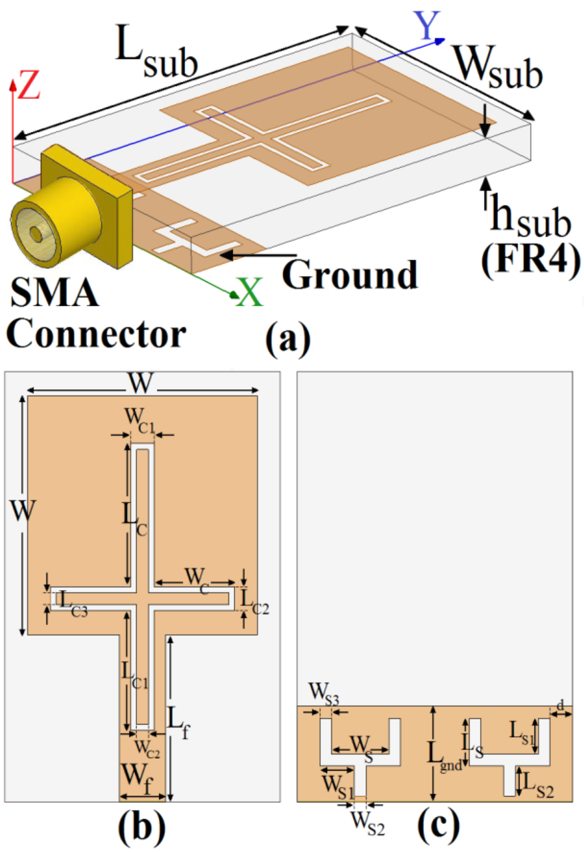

Fig. 1. Geometry of the proposed monopole antenna: (a) side view, (b) top layer and (c) bottom layer.

In this design, to achieve a multi-resonance function and give a bandwidth enhancement performance, two fork-shaped slots inserted in ground plane. By applying a cross-ring slot at radiating patch, a frequency band notch function (5.11-5.97 GHz WLAN) is generated. Regarding Defected Ground Structures (DGS), the creating slots in the ground plane provide an additional current path. Moreover, this structure changes the inductance and capacitance of the input impedance, which in turn leads to change the bandwidth. The DGS applied to a microstrip line causes a resonant character of the structure transmission with a resonant frequency controllable by changing the shape and size of the slot [18]. Therefore, by cutting two fork-shaped slots at the ground plane and carefully adjusting their parameters, much enhanced impedance bandwidth may be achieved. As illustrated in Fig. 1, to achieve a band-notched characteristic, the cross-ring slot is placed on the radiating patch. At the notched frequency, the current flows are more dominant around the cross-ring slot and they are oppositely directed between the slot and the radiation patch. As a result, the desired high attenuation near the notch frequency can be produced [19-20]. Final values of the presented antenna design parameters are specified in Table 1.

Table 1: The final dimensions of the antenna

Param.	W_{sub}	W	W_S	L_{S1}	W_{S3}	W_{C1}	L_{C2}
(mm)	12	10	2.5	2	0.5	1.5	1
Param.	L_{sub}	W_f	L_S	W_{S2}	W_C	L_{C1}	L_{C3}
(mm)	18	2	2	0.5	3.5	6	0.5
Param.	L_{gnd}	L_f	W_{S1}	L_{S2}	L_C	W_{C2}	d
(mm)	3.5	7	1.5	0.5	6	0.5	1

III. RESULTS AND DISCUSSIONS

In this section, the microstrip monopole 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 proposed microstrip-fed monopole antenna was fabricated and tested to demonstrate the effect of the presented. Ansoft HFSS simulations are used to optimize the design and agreement between the simulation and measurement is obtained [21].

The configuration of the various antenna structures were shown in Fig. 2. VSWR characteristics for ordinary square monopole antenna, square monopole antenna with two fork-shaped slots in the ground plane and the proposed antenna structure are compared in Fig. 3. As shown in Fig. 3, it is observed that the upper frequency bandwidth is affected by using the fork-shaped slots in the ground plane and the notch frequency bandwidth is sensitive to the cross-ring slot at radiating patch.

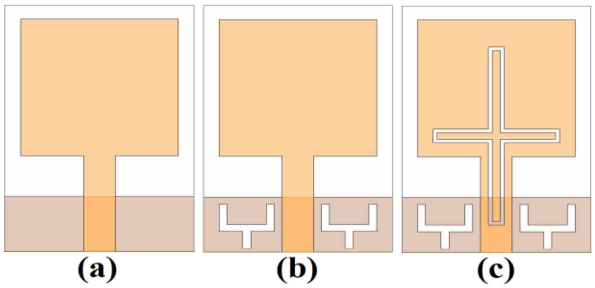

Fig. 2. (a) Basic structure (ordinary square monopole antenna), (b) antenna with a pair of fork-shaped slots in the ground plane and (c) the proposed antenna.

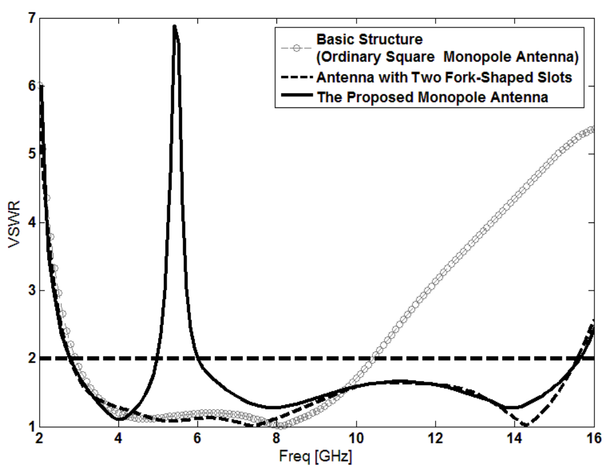

Fig. 3. Simulated VSWR characteristics for the various antennas shown in Fig. 2.

To understand the phenomenon behind this multi resonance performance, the simulated current distributions on the ground plane for the proposed antenna at 14.2 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 two fork-shaped slots at 14.2 GHz. Therefore, the antenna impedance changes at these frequencies due to resonant properties of the fork-shaped slots [22-24]. Another important design parameter of this structure is cross-ring slot used at radiating patch. Figure 4 (b) presents the simulated current distributions in the radiating patch at the notch frequency (5.5 GHz). As shown in Fig. 4 (b), at the notch frequency the current flows are more dominant around of the cross-ring slot. As a result, the desired high attenuation near the notch frequency can be produced.

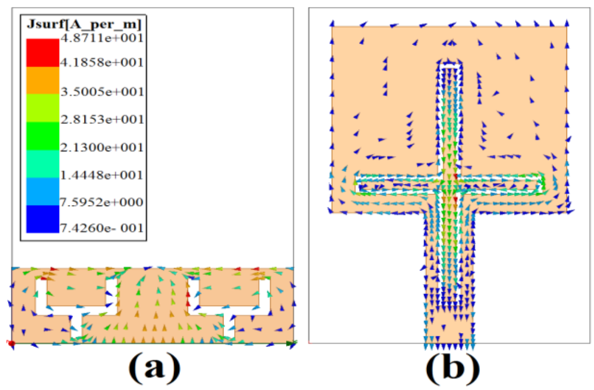

Fig. 4. Simulated surface current distributions for the proposed antenna: (a) on the ground plane at 14.2 GHz and (b) in the radiating patch at 5.5 GHz.

The measured and simulated VSWR characteristics of the proposed antenna were shown in Fig. 5. The fabricated antenna has the frequency band of 2.82 to over 14.63 GHz with notch band function around 5.11-5.97. Figure 6 illustrates the measured 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 omni-directional for the three frequencies [25-28].

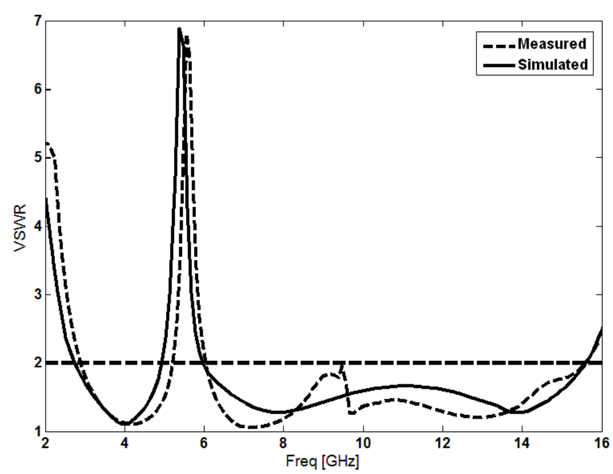

Fig. 5. Measured and simulated VSWR characteristics for the proposed antenna.

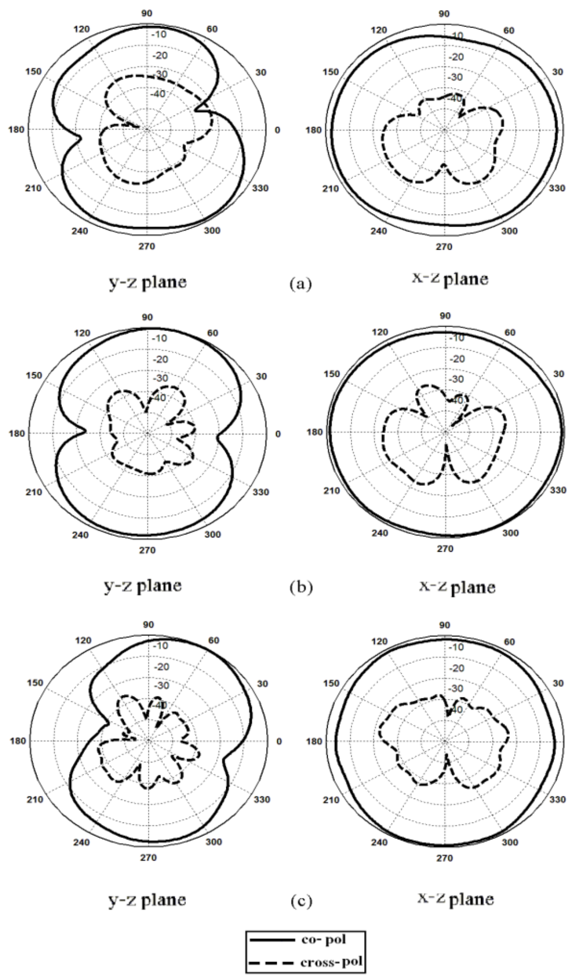

Fig. 6. Measured radiation patterns of the antenna: (a) 4 GHz, (b) 7 GHz and (c) 10 GHz.

IV. CONCLUSION

In this paper, we present a novel multi-resonance monopole antenna for UWB applications with band-notched performance. The proposed antenna can operate from 2.65 to 12.83 GHz with WLAN rejection band around 5.02-5.97 GHz. In order to enhance bandwidth, we insert two fork-shaped slots in the ground plane and also by using cross-ring slot at radiating patch a frequency band-notch function can be achieved. Simulated and experimental results show that the proposed antenna could be a good candidate for UWB applications.

ACKNOWLEDGMENT

The authors are thankful to MWT Company staff (www.microwave-technology.com).

REFERENCES

[1] M. J. Ammann, "Impedance bandwidth of the square planar monopole," *Microw. Opt. Technol. Lett.*, vol. 24, pp. 183-187, 2000.

[2] N. Ojaroudi, "Design of ultra-wideband monopole antenna with enhanced bandwidth," *21st Telecommunications Forum, TELFOR 2013*, Belgrade, Serbia, pp. 1043-1046, November 27-28, 2013.

[3] N. Ojaroudi, "A new design of koch fractal slot antenna for ultra-wideband applications," *21st Telecommunications Forum, TELFOR 2013*, Belgrade, Serbia, pp. 1051-1054, November 27-28, 2013.

[4] N. Ojaroudi, "Compact UWB monopole antenna with enhanced bandwidth using rotated l-shaped slots and parasitic structures," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 175-178, 2014.

[5] N. Ojaroudi, S. Amiri, and F. Geran, "A novel design of reconfigurable monopole antenna for UWB applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 28, pp. 633-639, 2013.

[6] K. Chung, S. Hong, and J. Choi, "Ultra wide-band printed monopole antenna with band-notch filters," *IET Microw. Antennas, Propag.*, vol. 1, pp. 518-522, 2007.

[7] Q. Wu, R. Jin, J. Geng, and J. Lao, "Ultra-wideband rectangular disk monopole antenna with notched ground," *Electron. Lett.*, vol. 43, no. 11, pp. 1100-1101, May 2007.

[8] M. T. 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, pp. 772-778, 2012.

[9] 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, pp. 759-765, 2012.

[10] A. Valizade, C. 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, pp. 816-822, 2012.

[11] A. M. Montaser, K. R. Mahmoud, and H. A. Elmikati, "Integration of an optimized e-shaped patch antenna into laptop structure for bluetooth and notched-UWB standards using optimization techniques," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27,

pp. 786-794, 2012.

[12] M. T. Partovi, N. Ojaroudi, M. Ojaroudi, and N. Ghadimi, "Enhanced bandwidth ultra-wideband small monopole antenna with variable band-stop function," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, pp. 1007-1013, 2012.

[13] N. Ojaroudi and N. Ghadimi, "Band-notched UWB slot antenna," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 1744-1747, 2014.

[14] N. Ojaroudi, "Small microstrip-fed slot antenna with frequency band-stop function," *21st Telecommunications Forum, TELFOR 2013*, Belgrade, Serbia, pp. 1047-1050, November 27-28, 2013.

[15] N. Ojaroudi, "Application of protruded strip resonators to design an UWB slot antenna with WLAN band-notched characteristic," *Progress in Electromagnetics Research C*, vol. 47, pp. 111-117, 2014.

[16] N. Ojaroudi, N. Ghadimi, and Y. Ojaroudi, "UWB microstrip-fed slot antenna with band-rejection performance using an SRR conductor-backed plane," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 29, pp. 203-207, 2014.

[17] M. Ojaroudi, N. Ojaroudi, and S. A. Mirhashemi, "Bandwidth enhancement of small square monopole antenna with dual band-notch characteristics by using an h-ring slot and conductor backed plane for UWB applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 28, no. 1, pp. 64-70, 2013.

[18] N. Ojaroudi, N. Ghadimi and Y. Ojaroudi, "Planar Ultra-Wideband (UWB) Antenna with C-Band Rejection Using Self-Complementary Structures," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 29, pp. 203-207, 2014.

[19] N. Ojaroudi, "Microstrip monopole antenna with dual band-stop function for UWB applications," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 818-822, 2014.

[20] N. Ojaroudi, "Circular microstrip antenna with dual band-stop performance for ultra-wideband systems," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 2095-2098, 2014.

[21] "Ansoft high frequency structure simulation (HFSS)," ver. 13, *Ansoft Corporation*, 2010.

[22] N. Ojaroudi and N. Ghadimi, "Design of CPW-fed slot antenna for MIMO system applications," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 1278-1281, 2014.

[23] N. Ojaroudi and N. Ghadimi, "Dual-band CPW-fed slot antenna for LTE and WiBro applications," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 1013-1015, 2014.

[24] N. Ojaroudi and N. Ghadimi, "UWB multi-resonance antenna with rejection of intelligent transport system band using a cross-shaped conductor-backed plane," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 1641-1644, 2014.

[25] N. Ojaroudi, S. Amiri, and F. Geran, "Reconfigurable monopole antenna with controllable band-notched performance for UWB communications," *20th Telecommunications Forum, TELFOR 2012*, Belgrade, Serbia, pp. 1176-1178, November 20-22, 2012.

[26] N. Ojaroudi, "Design of microstrip antenna for 2.4/5.8 GHz RFID applications," *German Microwave Conference, GeMic 2014*, RWTH, Aachen University, Germany, March 10-12, 2014.

[27] N. Ojaroudi, M. Mehranpour, S. Ojaroudi, and Y. Ojaroudi, "Microstrip-fed monopole antenna with triple band performance for WLAN/WiMAX applications," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 29, pp. 203-207, 2014.

[28] N. Ojaroudi, M. Mehranpour, S. Ojaroudi, and Y. Ojaroudi, "Application of the protruded structures to design an UWB slot antenna with band-notched characteristic," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 29, pp. 184-189, 2014.