UWB Monopole Antenna with Dual Band-Stop Performance Using G-Shaped SRR and SIR Structures at Feed Line

Sajjad Ojaroudi [1], Yasser Ojaroudi [1], Noradin Ghadimi [2], and Nasser Ojaroudi [2]

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

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

Abstract ─ This article presents a new design of ultra-wideband monopole antenna with the characteristics of dual band rejection .The antenna consists of a circular radiating patch, a feed-line with G-shaped Step-Impedance Resonator (SIR) slot and Split-Ring Resonator (SRR) structure, and a ground plane which provides a wide usable fractional bandwidth of more than 120% with two notch bands around 5.15-5.35 GHz and 7.25-7.75 GHz, to avoid interferences from High Performance Radio Local Area Networks (HIPERLAN) and downlink frequency of X-band satellite systems. The simulated and measured results show that the antenna design exhibits an operating bandwidth (VSWR<2) from 2.86 to 12.92 GHz, excluding the rejected bands. The proposed antenna configuration is simple, easy to fabricate and can be integrated into any UWB system. The antenna has an ordinary circular-disc radiating patch, therefore displays good omni-directional radiation patterns, even at higher frequencies.

Index Terms ─ Dual band-notched function, G-shaped structure, hiperlan, satellite communications, UWB.

I. INTRODUCTION

After allocation of the frequency band from 3.1 to 10.6 GHz for the commercial use of Ultra-Wideband (UWB) systems by the Federal Communication Commission (FCC) [1], ultra-wideband systems have received phenomenal gravitation in wireless communication. Designing an antenna to operate in the UWB band is quite a challenge, because it has to satisfy the requirements such as ultra wide impedance bandwidth, omni-directional radiation pattern, constant gain, high radiation efficiency, constant group delay, low profile, easy manufacturing, etc. [2]. 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 antennas with different geometries have been experimentally characterized [3-7].

There are many narrowband communication systems which severely interfere with the UWB communication system, such as the High Performance Radio Local Area Networks (HIPERLAN) operating at 5.15-5.35 GHz, or downlink of X-band satellite communication (7.25-7.75 GHz). Therefore, UWB antennas with band-notched characteristics to filter the potential interference are desirable. Nowadays, to mitigate this effect, many UWB antennas with various band-notched properties have developed [8-11]. Many techniques are also used to introduce notch band for rejecting the interference in the UWB antennas. It is done either by inserting switchable structures in the ground plane [12], applying a shunt open-circuited stub [13], using Step-Impedance Resonators (SIR) [14], inserting fractal structures [15], or using T-ring slot at the square radiating patch [16].

All of the above methods are used for rejecting a single band of frequencies. However, to effectively utilize the UWB spectrum and to

Submitted On: December 1, 2013
Accepted On: September 6, 2014

improve the performance of the UWB system, it is desirable to design the antenna with dual band rejection. It will help to minimize the interference between the narrow band systems with the UWB system. Some methods are used to obtain the dual band rejection in the literature [17-20].

In this paper, a different method is proposed to obtain the dual band rejection of frequency bands for HiperLAN and downlink frequency of X-band satellite communication systems. The HiperLAN frequency band is rejected by inserting a G-shaped SRR in the feed-line at center frequency of 5.2 GHz, and a G-shaped SIR is inserted to reject the desired downlink band of satellite systems at a center frequency of 7.5 GHz. The proposed antenna with the dual band-notched function is successfully implemented and the simulation results show reasonable agreement with the measurement results. The designed antenna has a small size. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest.

II. ANTENNA DESIGN

The structure of proposed monopole antenna fed by a microstrip line is shown in Fig. 1. The dielectric substance (FR4) with thickness of 1.6 mm with relative permittivity of 4.4 and loss tangent 0.018 is chosen as substrate to facilitate printed circuit board integration. The basic monopole antenna structure consists of a circular radiating patch, a feed line, and a ground plane. The proposed antenna is connected to a 50-Ω SMA connector for signal transmission. The radiating patch is connected to a feed line of width W_f and length L_{gnd} .The width of the microstrip feed line is fixed at 2 mm, as shown in Fig. 1. On the other side of the substrate, a conducting ground plane of width W_{sub} and L_{gnd} length is placed. Final parameter values of the presented antenna design are specified in Table 1.

Table 1: Final parameter values of the antenna

Parameter	W_{sub}	W_{sub}	W	L	W_f
(mm)	12	18	0.25	3.8	2
Parameter	L_f	W_1	L_1	W_2	L_2
(mm)	7	0.25	3.3	0.75	4.25
Parameter	W_3	L_3	W_4	L_4	W_5
(mm)	0.25	4.75	1.3	0.25	0.75
Parameter	L_5	W_6	L_6	d	R
(mm)	0.25	1.25	1.65	0.25	5

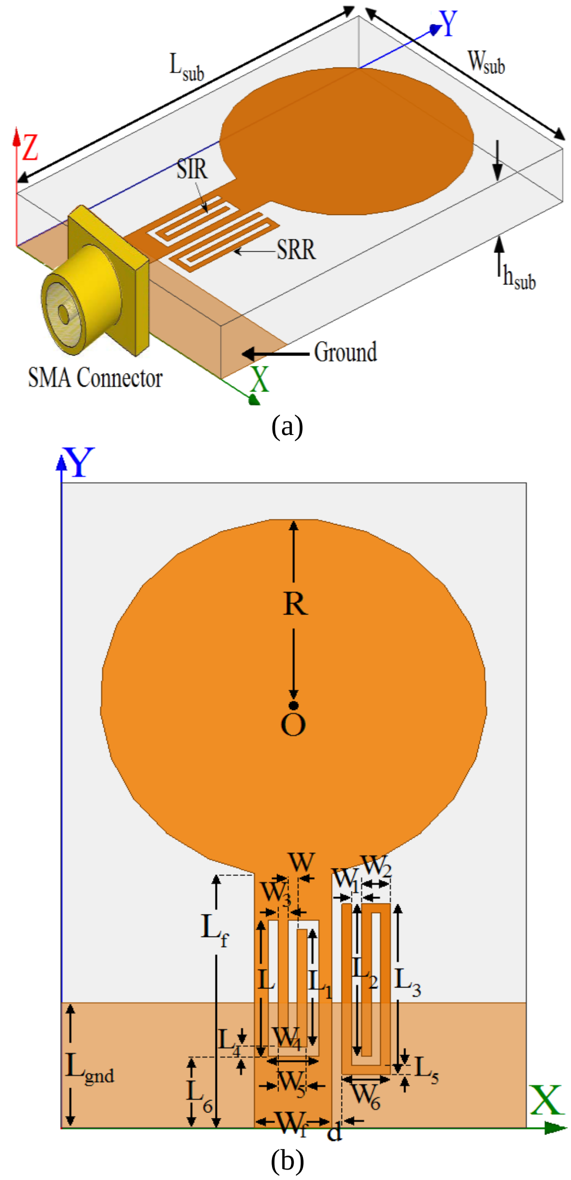

Fig. 1. Structure of the proposed antenna: (a) side view, and (b) top view.

At the first notched frequency, the current concentrated on the edges of the interior and exterior of G-shaped SRR. Additionally, the G-shaped SIR acts as a filtering element to generate another notched frequency, because it can create additional surface current path around of feed-line. At this notched frequency (7.5 GHz), the current flows are more dominant around the modified SIR, and they are oppositely directed between the inserted slits and the radiating patch [8-12]. As a result, the desired high attenuation near the notched frequencies can be produced.

III. RESULTS AND DISCUSSIONS

In this section, the microstrip monopole antenna with various design parameters was constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The analysis and performance of the proposed antenna is explored by using Ansoft simulation software High-Frequency Structure Simulator (HFSS) [21], for better impedance matching.

The structure of the various antennas used for simulation studies were shown in Fig. 2. VSWR characteristics for the ordinary circular monopole antenna (Fig. 2 (a)), antenna with a G-shaped SRR at feed-line (Fig. 2 (b)), and the proposed antenna structure (Fig. 2 (c)) are compared in Fig. 3.

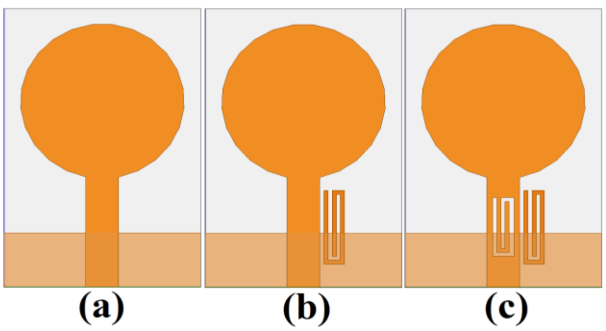

Fig. 2. (a) Ordinary square antenna, (b) antenna with a G-shaped SRR at feed line, and (c) the proposed antenna.

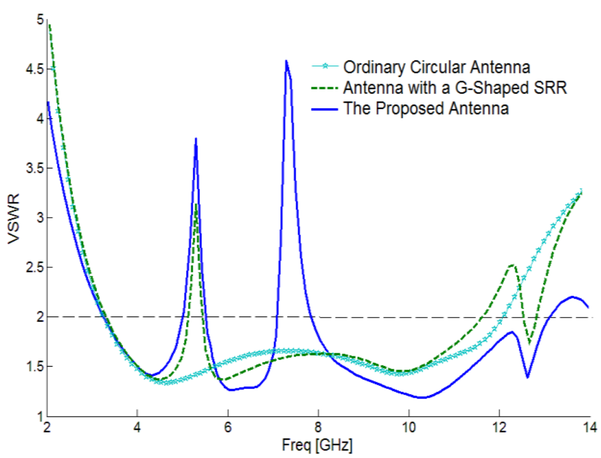

Fig. 3. Simulated VSWR for the various antenna structures shown in Fig. 2.

As shown in Fig. 3, to generate a single frequency band-notched function (5.15-5.35 GHz), we use a G-shaped SRR, and also by adding a G-shaped SIR at feed-line, the dual band-notched function can be achieved that covers all the 5.2 GHz HiperLAN and 7.5 GHz satellite down-link bands.

The simulated current distribution on the radiating patch for the proposed antenna at the notched frequencies of 5.2 and 7.5 GHz is presented in Figs. 4 (a) and 4 (b), respectively. The current direction on the reject structures is opposite to that on the nearby antenna structure, so the far fields produced by the currents on the reject structures and nearby antenna structure cancel out each other in the reject band. In Fig. 4 (b), the current mainly flows around the outer inverted G-shaped SRR, which destructs the radiation of the original antenna at this band and results in the lower stop-band [22-24].

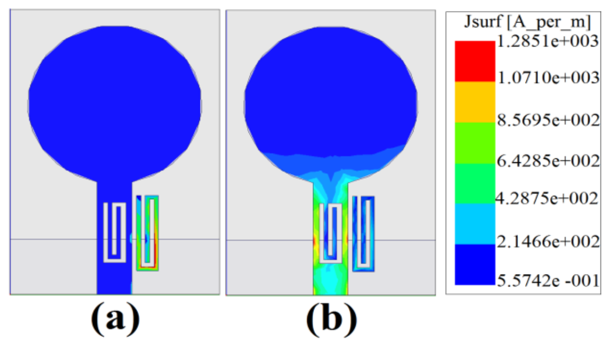

Fig. 4. Simulated surface current distributions for the proposed antenna at the notched frequencies: (a) 5.2 GHz, and (b) 7.5 GHz.

In Fig. 4 (b), the current distribution at 7.5 GHz is even on the outer and inner of G-shaped SIR, but the current direction on the inner slits is opposite to that on the outer ones. It is suggested that two band notches should be mutually interfered with and the notched property does not have any influence on the antenna radiation at 7.5 GHz. Then, a pass-band between two adjacent stop-bands can be obtained because of the mutual interference of the two notched structures [25-27].

Figure 5 shows the measured and simulated VSWR characteristics of the proposed antenna. The fabricated antenna has the frequency band of 3.02 to over 13.32 GHz, with two notch bands around 5.15-5.35 GHz and 7.25-7.75 GHz.

The maximum gain of the proposed antenna was shown in Fig. 6. A sharp decrease of maximum gain in the notched frequency bands at 5.2 and 7.5 GHz are shown in Fig. 6. For other frequencies outside the notched frequency band, the antenna gain with the filters is similar to those without them [28-32].

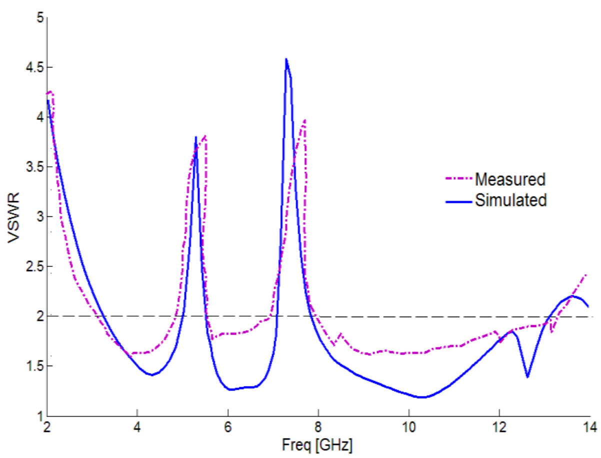

Fig. 5. VSWR comparison of the proposed antenna.

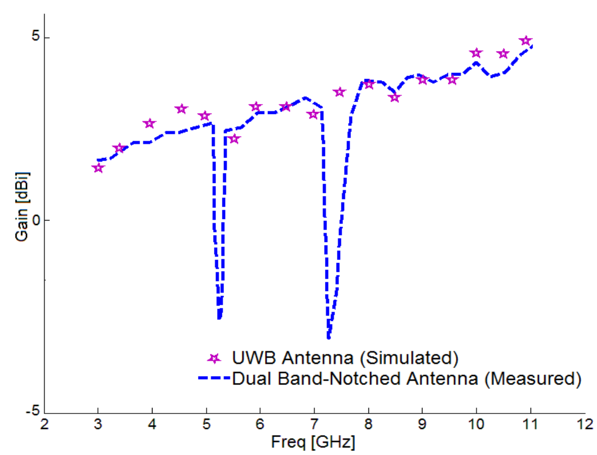

Fig. 6. Measured maximum gain of the proposed antenna.

Figure 7 depicts 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 nearly omni-directional radiation pattern can be observed on x-z plane over the whole UWB frequency range, especially at the low frequencies. The radiation patterns on the y-z plane are like a small electric dipole leading to bidirectional patterns in a very wide frequency band. With the increase of frequency, the radiation patterns become worse because of the increasing effects of the cross-polarization [33-38].

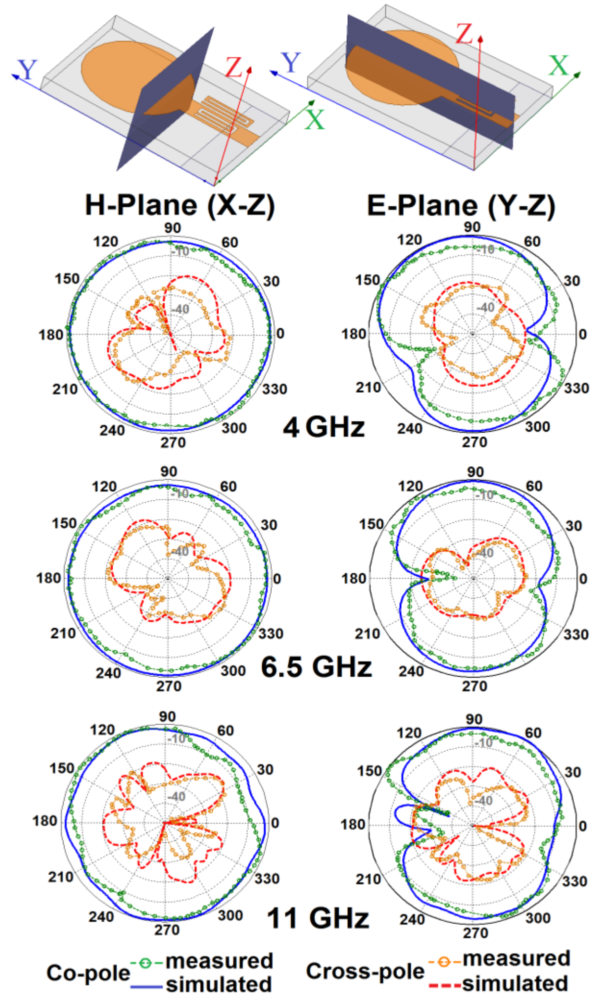

Fig. 7. Measured and simulated radiation patterns.

IV. CONCLUSION

In this paper, a new antenna structure is proposed that provides a double stop-band notch in the 5.2/7.5 GHz for various UWB applications. The fabricated antenna has the frequency band of 2.86 to over 12.92 GHz, with two rejection bands around 5.15-5.35 and 7.25-7.75 GHz. The proposed antenna has a simple configuration and small size. The designed antenna can be used in UWB systems to reduce interference between UWB and other wireless communication systems. The proposed antenna has an ordinary square radiating patch, therefore displays a good omni-directional radiation pattern even at higher frequencies.

ACKNOWLEDGMENT

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

REFERENCES

[1] "FCC news release," *FCC NEWS (FCC 02-48)*, February 14, 2002.

[2] D. Cheng, "Compact ultra-wideband microstrip resonating antenna," *US Patent 7872606*, January 2011.

[3] Z. N. Chen, "Impedance characteristics of planar bow-tie-like monopole antennas," *Electronics Letters*, vol. 36, pp. 1100-1101, June 2000.

[4] 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.

[5] 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.

[6] 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, no. 6, pp. 633-639, July 2013.

[7] 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.

[8] T. Dissanayake and K. P. Esselle, "Prediction of the notch frequency of slot loaded printed UWB antennas," *IEEE Trans. Antennas and Propag.*, vol. 55, no. 11, pp. 3320-3325, 2007.

[9] N. Ojaroudi, "Design of small reconfigurable microstrip antenna for UWB-CR applications," *19th International Symposium on Antenna and Propagation, ISAP2014*, Kaohsiung, Taiwan, December 2-5, 2012.

[10] 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.

[11] T. G. Ma and S. J. Wu, "Ultra-wideband band-notched folded strip monopole antenna," *IEEE Trans. Antennas Propag.*, vol. 55, no. 9, pp. 2473-2479, 2007.

[12] N. Ojaroudi and M. Ojaroudi, "A novel design of reconfigurable small monopole antenna with switchable band notch and multi-resonance functions for UWB applications," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 652-656, 2013.

[13] C. Y. Pan, K. Y. Chiu, J. H. Duan, and J. Y. Jan, "Band-notched ultra-wideband planar monopole antenna using shunt open-circuited stub," *Microwave and Optical Technology Letter*, vol. 53, no. 7, pp. 1535-1537, 2011.

[14] N. Ojaroudi, M. Ojaroudi, and S. Amiri, "Compact UWB microstrip antenna with satellite down-link frequency rejection in X-band communications by etching an E-shaped step-impedance resonator slot," *Microw. Opt. Technol. Lett.*, vol. 55, pp. 922-926, 2013.

[15] Y. S. Li, X. D. Yang, C. Y. Liu, and T. Jiang, "Analysis and investigation of a cantor set fractal UWB antenna with a notch-band characteristic," *Progress In Electromagnetics Research B*, vol. 33, pp. 99-114, 2011.

[16] M. T. Partovi, N. Ojaroudi, M. Ojaroudi, and N. Ghadimi, "Enhanced bandwidth of small square monopole antenna by using inverted U-shaped slot and conductor-backed plane," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 12, pp. 1007-1013, 2012.

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

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

[19] Y. Zhang, W. Hong, C. Yu, Z. Q. Kuai, Y. D. Don, and J. Y. Zhou, "Planar ultra-wideband antennas with multiple notched bands based on etched slots on the patch and/or split ring resonators on the feed line," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 9, pp. 3063-3068, 2008.

[20] 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.

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

[22] 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.

[23] N. Ojaroudi, "Design of UWB monopole antenna with dual band-stop characteristic," *In Proceedings of the Loughborough Antennas and Propagation Conference (LAPC '14)*, Loughborough, UK,

November 10-11, 2014.

[24] N. Ojaroudi, "Reconfigurable microstrip-fed monopole antenna for multimode application," *In Proceedings of the Loughborough Antennas and Propagation Conference (LAPC '14)*, Loughborough, UK, November 10-11, 2014.

[25] 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.

[26] 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.

[27] N. Ojaroudi, "An UWB microstrip antenna with dual band-stop performance using a meander-line resonator," *22nd International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, Split, Croatia, September 17-19, 2014.

[28] N. Ojaroudi, "New design of multi-band PIFA for wireless communication systems," *19th International Symposium on Antenna and Propagation, ISAP2014*, Kaohsiung, Taiwan, December 2-5, 2012.

[29] 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.

[30] 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.

[31] N. Ojaroudi, H. Ojaroudi, and N. Ghadimi, "Quad-band planar inverted-F antenna (pifa) for wireless communication systems," *Progress In Electromagnetics Research Letters*, vol. 45, 51-56, 2014.

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

[33] N. Ojaroudi and N. Ghadimi, "UWB small slot antenna with WLAN frequency band-stop function," *Electron. Lett.*, vol. 49, pp. 1317-1318, 2013.

[34] N. Ojaroudi, H. Ojaroudi, and Y. Ojaroudi, "Very low profile ultra-wideband microstrip band-stop filter," *Microw. Opt. Technol. Lett*., vol. 56, pp. 709-711, 2014.

[35] 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, no. 2, pp. 184-189, 2014.

[36] N. Ojaroudi, N. Ghadimi, and Y. Ojaroudi, "Bandwidth improvement of omni-directional monopole antenna with a modified ground plane," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 29, no. 4, pp. 328-334, 2014.

[37] 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, no. 3, pp. 203-207, 2014.

[38] 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, no. 3, pp. 203-207, 2014.