Jordan Journal of Electrical Engineering
ISSN (Print): 2409-9600, ISSN (Online): 2409-9619

UWB Antenna for WLAN Band Rejection

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Received: March 14, 2018 *Accepted: May 20, 2018*

Abstract—An ultra-wide band (UWB) planar antenna is designed with a filtering property to reject the interference between the UWB and wireless local area network (WLAN) applications. In this paper, a simple rectangular patch with one rectangular cut in each of its corners is designed on FR4-substrate with 50 Ω microstrip feed line and partial ground plane. A band rejection for the WLAN application at 5 GHz is created by etching two circular slots connected by a rectangular strip in the patch. The design is investigated using two electromagnetic simulators; high frequency structure simulator (HFSS) and computer simulator technology (CST). The simulation results show good impedance matching over 3.8-14.5 GHz for return loss (RL)≥10 dB with a band rejection range from 4.7 to 5.9 GHz. Higher gain and efficiency at the pass bands during sharp drop at the rejected band are achieved. Dipole shape radiation pattern in the E-plane and good omni-directional pattern in the H-plane are achieved over the frequency range of interest.

Keywords— Gain and bandwidth, reflection coefficient, rejection band, slots, ultra-wide band.

I. INTRODUCTION

The UWB is a wireless technology that offers a wide frequency range with very low power consumption. In 2002, federal communication commission (FCC) authorized unlicensed use of UWB band ranging from 3.1 to 10.6 GHz with maximum radiated power of -41.3 dBm/MHz [1]. These UWB patch antennas are designed with different geometries; triangular [2], circular disc [3], square [4] or combination between rectangular and circular patches [5]. Several methods are used to enhance the antenna bandwidth by using different arrangements. A square patch antenna with an inverted T-shaped slot and inverted T-shaped conductor at the patch back side to achieve a percentage bandwidth (PBW) of 131.57% over the frequency range 2.91-14.1 GHz are proposed in [6]. An egg shape patch and symmetrical ground plane with a triangular notch and semi-elliptical fractal complementary slot are introduced in [7] to achieve a PBW of 171.54% over the frequency range 1.44-18.8 GHz. Three round ground grooves are etched in the partial ground plane to get PBW of 175% over the frequency range of 3.25-50 GHz as given in [8]. One round cut in each corner of the patch antenna with one ground groove to get a bandwidth of 3.42-11.7 GHz with PBW 109.52% is suggested in [9]. Three ground modifications consisting of two sleeves, two rectangular slots and one rectangular groove are introduced in [10] to achieve a bandwidth of 3.4-22.4 GHz (or PBW of 147.29%).

Several narrow band communication systems share the UWB frequency band 3.1-10.6 GHz such as wireless local area network (WLAN) for IEEE 802.11a operating in the range 5.15-5.825 GHz, satellite services operating in the range 4.5-5 GHz, IEEE 802.16, worldwide interoperability for microwave access (WiMAX) system operating at in the range 3.3-3.7 GHz and international telecommunication union (ITU 8 GHz) band operating at 7.725-8.275 GHz. These systems transmit their signals within the UWB frequency band which can be

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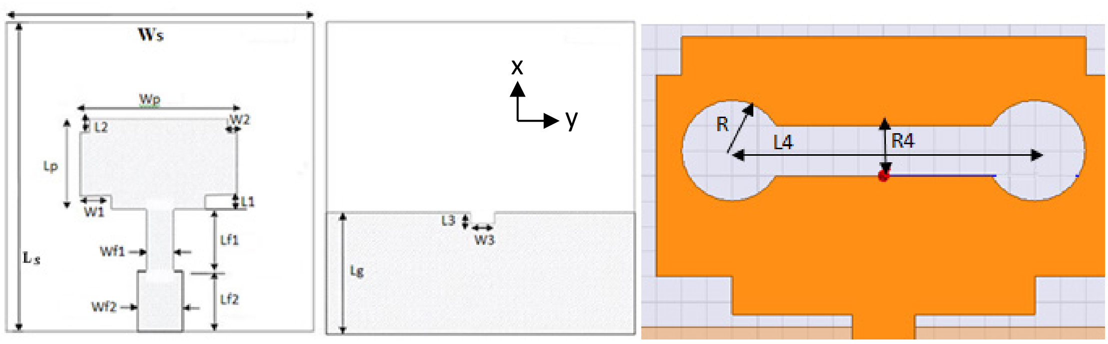
considered as an interfering noise to the UWB receiver which affects the overall UWB system performance. The traditional method to suppress these unwanted interferences is by adding external filters at the antenna end which increases the device complexity and cost. UWB antennas are designed with filtering characteristics using different methods by etching various slots in the patch, ground plane or feed line. Adding H-shape and U-shape slots at the patch and the feed line respectively are used to reject the WLAN, 5.15-5.825 GHz, and X-band, 7.25-8.4 GHz, applications [9]. H-shape and two U-shape slots are etched in the coplanar waveguide (CPW) ground and the square patch respectively to introduce two band rejections 5-6 GHz for WLAN and 7.7-8.5 GHz for X-band applications [11]. Two C-shape slots are introduced to the radiation patch to achieve two band rejections 3.38-3.82 GHz for WiMAX and 5.3-5.8 GHz for WLAN signals [12]. Two C-shape and one U-shape slots are introduced in the patch to create two band rejections 3.24-3.78 GHz and 5.13-6.32 GHz [13]. A circular slot in the rectangular patch with a defected ground structure (DGS) is designed for dual band notch 5.08-6.14 GHz and 9.58-10.69 GHz in the WLAN applications [14]. Two E-shape slots in the patch are used to create one band rejection 5-6 GHz with center frequency at 5.2 GHz [15]. C-shape slot is etched on the truncated corners square patch antenna to provide a frequency notched in the range 4.91-5.96 GHz [16].

In this paper, a new UWB antenna design with a band rejection property is proposed and investigated. The antenna design, shape and geometry dimensions are outlined in Section II. The proposed antenna consists of two steps microstrip feed line, rectangular radiation patch with one rectangular cut in each corner (upper and lower), and partial ground plane with rectangular groove. In order to reject the WLAN frequency band, two circular slots connected by a rectangular strip in the patch are used. The parametric analysis, simulation results and discussions are presented in section III. The experimental verifications are outlined in section IV and finally, the conclusion is given in section V.

II. Antenna Design

The proposed antenna geometric parameters are shown in Fig. 1, where all dimensions are obtained through parametric analysis. The antenna dimensions (in mm) are as follows: the substrate is FR4-epoxy with thickness h=1.6, tanδ=0.02, ε_r=4.4, width Ws=36 and length Ls=34. The patch length Lp=11 and width Wp=18. The partial ground plane length Lg=11 and width Ws. Ground rectangular groove width W3=2.5 and length L3=1. The microstrip feed line is designed for 50 Ω impedance with two steps; first step width Wf1=2.5 and length Lf1=5.5 while the second step width Wf2=3 and Lf2=6. One rectangular cut in the two upper patch corners with width W1=3.5 and L1=1.5, while the cuts in the lower patch corners have width W2=1 and length L2=1.5. Band rejection slots consist of two circular slots with radius R=1.25 connected by rectangular strip length L4=10 and width R4=2.



(a) (b) (c)

Fig. 1. The proposed antenna structure: a) UWB patch antenna, b) ground plane, c) UWB with band rejection

III. RESULTS AND DISCUSSION

The design started with a simple rectangular patch antenna fed by microstrip feed line with a full ground plane. The bandwidth enhancement process is started by varying the ground plane length Lg and designing the microstrip feed line with two steps. The simulation results using HFSS for this antenna show low covered bandwidth 4.3-10.4 GHz with PBW of 82.99%. Bandwidth enhancement process is continued by cutting the patch lower and upper corners and adding groove to the ground plane. The patch lower cuts are used to tune the capacitive coupling between the patch and the ground plane, while the patch upper cuts improve the antenna impedance matching. The ground groove is added in the middle of the partial ground plane to adjust the input impedance imaginary part. The simulated scattering parameter S11 versus frequency using two software tools, HFSS and CST, is shown in Fig. 2. Results of S11 show that the bandwidth with RL(-S11)≥10 dB starts at 3.5 GHz using HFSS and at 3.8 GHz using CST, while it ends beyond 15.5 GHz using both simulators. This indicates a large useful bandwidth with PBW over 126% compared to the simple patch antenna.

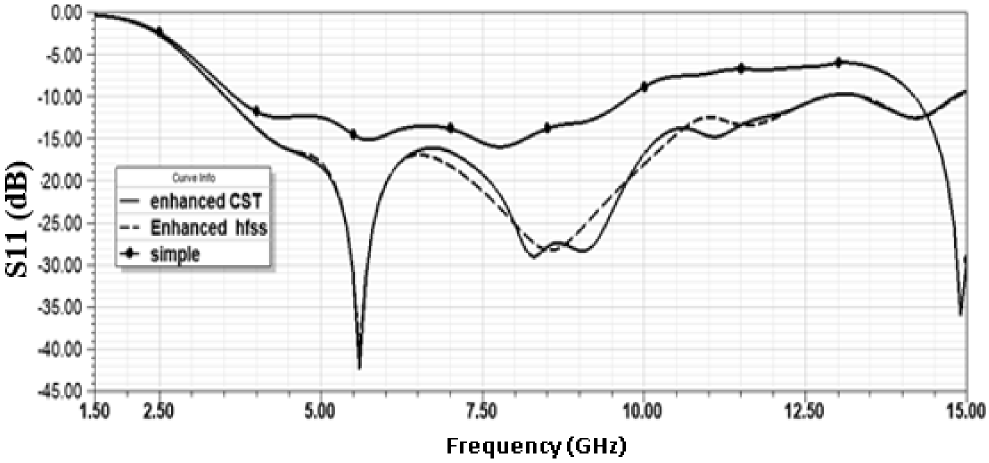


Fig. 2. The scattering parameter S11 after bandwidth enhancements

WLAN band rejection is achieved by etching two circular slots connected with one rectangular strip in the patch. A parametric study is conducted on the slot parameters, (R, L4 and R4). Only one parameter was varied while others were kept constant. These parameters can be changed as follows: R between 1.25 to 2 mm, L4 between 7 to 10 mm and R4 between 1 to 3 mm. Increasing the values of the parameters shifts the rejection band center frequency to lower values with a wider rejection band as shown in Figs. 3, 4 and 5. The best result is at R=1.25 mm, L4=10 mm and R4=2 mm, where the center frequency is at 5.2 GHz and the rejection band is between 4.7 to 5.9 GHz.

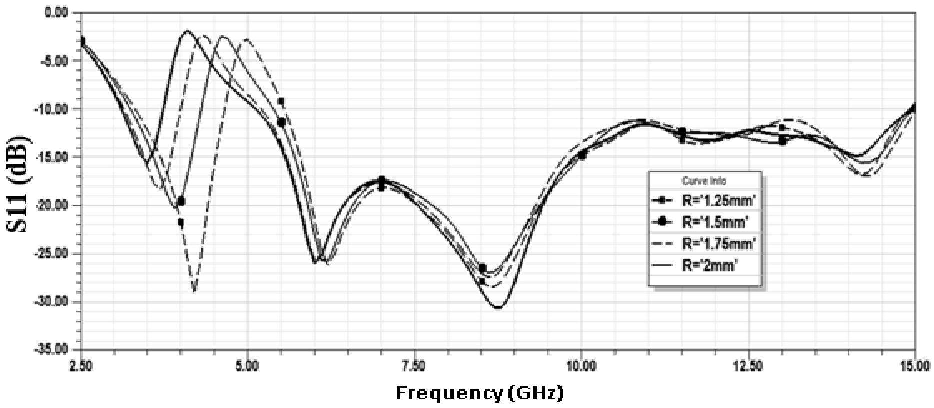


Fig. 3. The scattering parameter S11 when varying the circular slot radius (R)

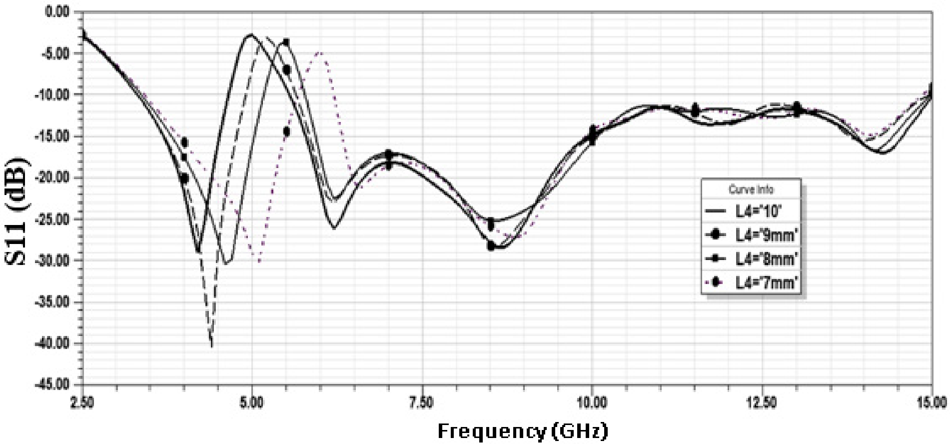


Fig. 4. The scattering parameter S11 when varying the distance between slots (L4)

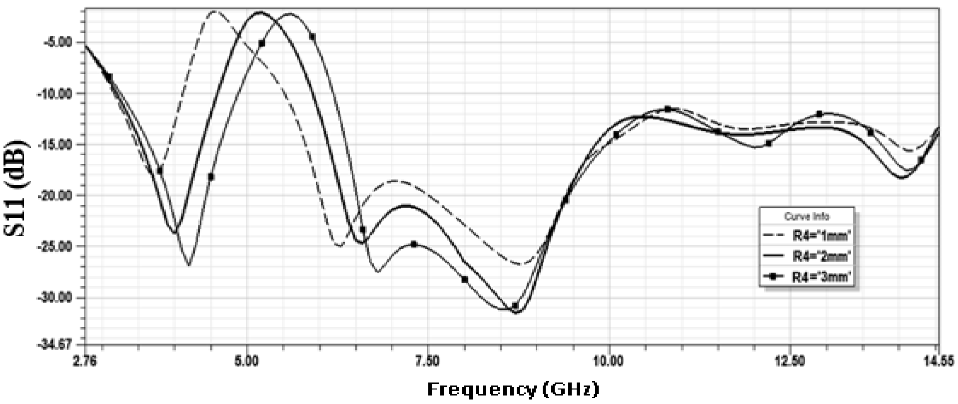


Fig. 5: The scattering parameter S11 when varying the rectangular strip width (R4)

The proposed antenna scattering parameter S11 versus frequency using HFSS and CST software tools is shown in Fig. 6. The rejection band at RL≥10 dB starts at 4.7 GHz and ends at 5.9 GHz in both simulators, which reject the interference of the WLAN (from 5.15 to 5.825 GHz).

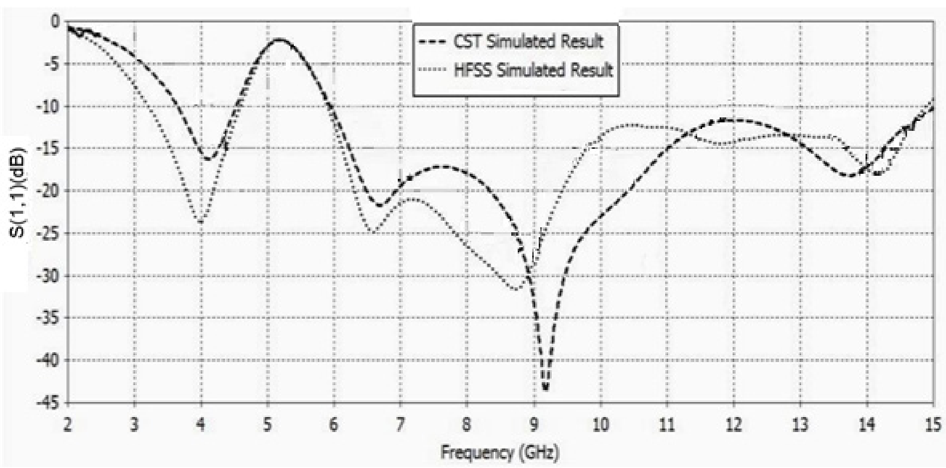


Fig. 6 The simulated scattering parameter S11 versus frequency using HFSS and CST software tools

The simulated radiation patterns for the E and H planes at different frequencies 4, 6.5, 9.2 and 13.6 GHz are shown in Fig. 7, where the E and H planes are the xz-plane (φ=0˚ and 0˚<θ<180˚) and the yz-plane (φ=90˚ and 0˚<θ<180˚) respectively. The antenna exhibits a dipole-like shape in the E-plane at a low frequency range while the number of lobes rises with the increase of frequency because of the existence of higher order modes. The H-plane shows a good omni-directional pattern at a low frequency range; and it becomes less omni-directional with an increase in the frequency. The simulated peak gain is shown in Fig. 8, where the gain is low in the rejection frequency range. It reaches 0.2 dBi at 5.6 GHz and rises when increasing the frequency to reach a maximum value of 6.6 dBi at 14 GHz. The radiation efficiency for the proposed antenna is shown in Fig. 9, where it has a low value in the rejection band (it reaches 40% at 5.2 GHz) and high values at the pass band (it reaches 97.1% at 7.8 GHz). The vector current distributions at different frequencies 5 and 9 GHz are shown in Fig. 10. It can be noticed that the high and strong current concentration around the patch slots at 5 GHz compared to any other patch area causes band rejection, while at 9 GHz the current distribution is uniformly and weak around the slots.

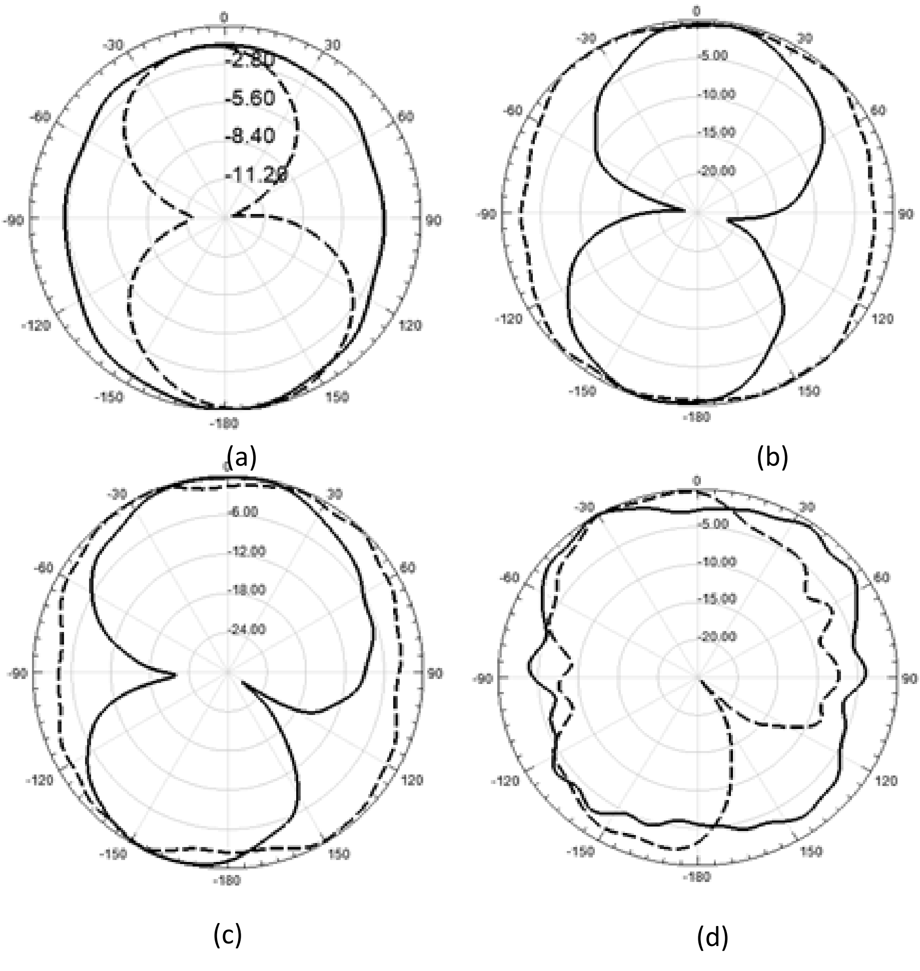


Fig. 7. The radiation patterns at: a) 4 GHz, b) 6.5 GHz, c) 9.2 GHz, d) 13.6 GHz (E- - - & H ___)

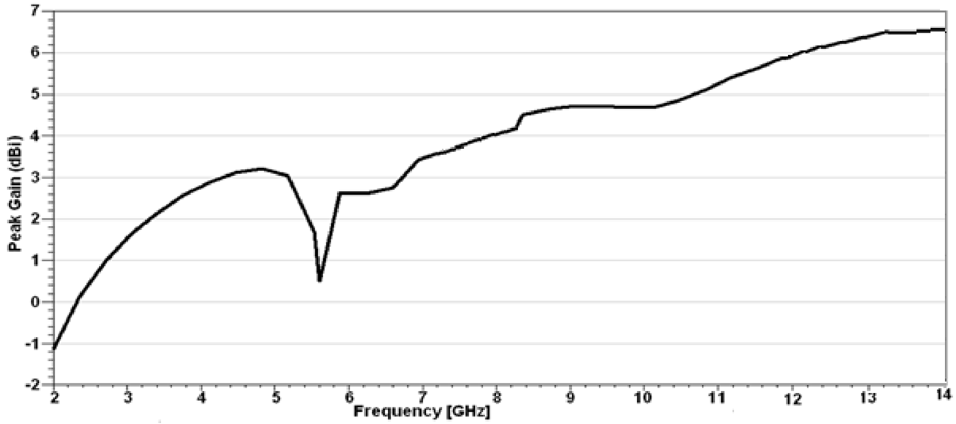


Fig. 8. The proposed antenna peak gain

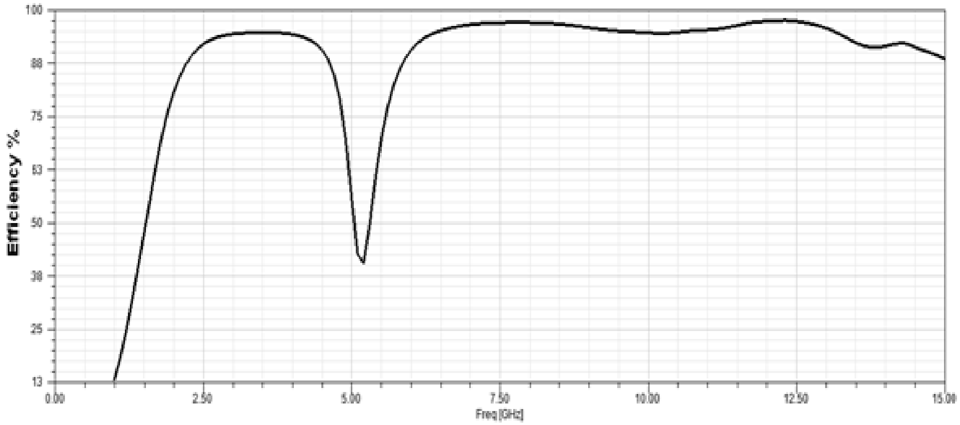
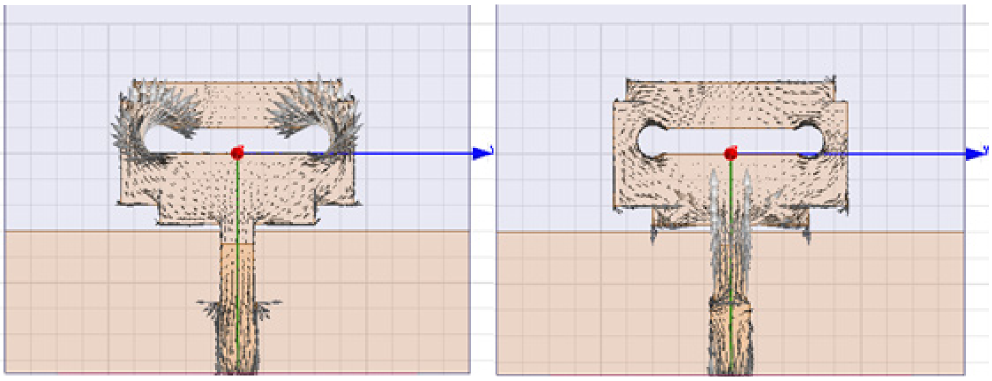


Fig. 9. The proposed antenna radiation efficiency



(a) (b)

Fig. 10. The vector current density at: a) 5 GHz, b) 9 GHz

A comparison between the proposed design and different research works is shown in Table 1. The proposed antenna succeeds in achieving a wide impedance bandwidth compared to other works in [13]-[16]. It also achieves a sharp rejection band using a simple design consisting of two circular slots compared to two inverted E-shape slots in [15]. Although the proposed antenna has a larger substrate area than that in [13], [15], the achieved rejection band is sharp enough to cover only the desired frequency range of WLAN (5.15-5.825 GHz) especially at the end frequency of the rejection band. The proposed design has a simple ground plane design for the bandwidth enhancement process compared to that in [16].

TABLE 1
COMPARISON BETWEEN THE PROPOSED DESIGN AND DIFFERENT RESEARCH WORKS

Parameter / Reference	[13]	[14]	[15]	[16]	Proposed Antenna
Antenna substrate size, mm^2	32x28	12x19	35x30	12x18	36x34
Impedance bandwidth, GHz	3.1–10.6	4.6–11.2	3–10.5	4.4–10.8	3.5–15.5
Rejection band, GHz	5.13-6.32	5.08–6.14	4.9-6.2	4.91–5.96	4.7-5.9

IV. EXPERIMENTAL VERIFICATIONS

The proposed antenna is fabricated on FR4 substrate whose dielectric constant ε_r=4.4 and thickness h=1.6 mm are shown in Fig. 11. This antenna is tested at the antenna measurement laboratory at King Abdullah Design and Development Bureau (KADDB). The S11 is measured using Agilent N5242A network analyzer with SAC-26G-0.5 using 50 Ω cables. The measured and simulated S11 curves for the UWB and the proposed antenna are shown in Fig. 12. The measured S11 curve compares favorably with the simulated results obtained from the two simulation software, where the measured rejection band is 4.9-6.2 GHz with a slight shift in the lower and upper edge frequencies. The discrepancy between the measured and the simulated results is mostly due to the tolerance in fabrication and welding of the SMA connector, which are not taken into account through simulation. Besides, the dielectric loss tangent of the FR4 substrate is kept constant during simulation, where it is actually a function of frequency.

Fig. 11. The fabricated proposed antenna

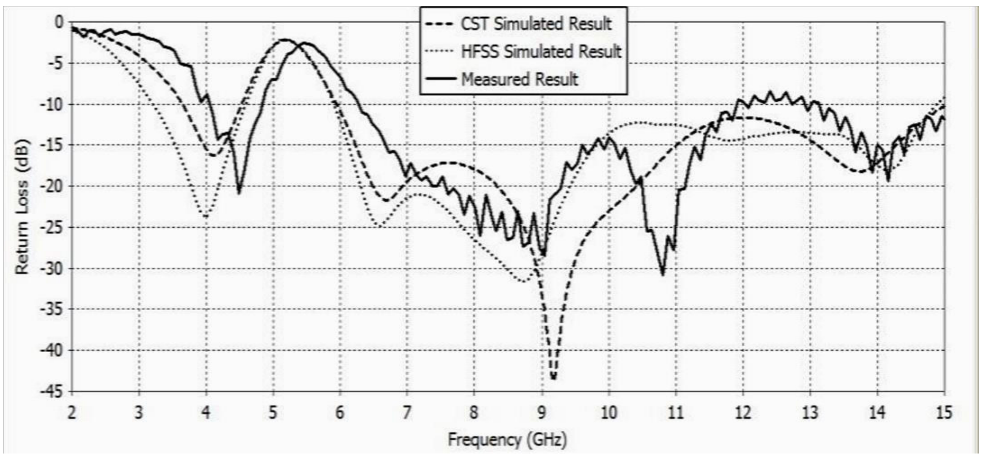


Fig. 12. The simulated and measured S11 curves for the proposed antenna

V. Conclusion

A planar UWB antenna is designed to filter out the interference between the UWB and WLAN applications. In this paper, a simple rectangular patch with one rectangular cut at its four corners is designed on FR4-substrate with 50 Ω microstrip feed line and partial ground plane. WLAN band rejection is achieved by inserting two circular slots connected by a rectangular strip in the patch. The design is investigated using two simulators, HFSS and CST. The simulation results show good impedance matching over 3.8-14.5 GHz for RL≥10 dB with a band rejection range from 4.7-5.9 GHz. The measurement results compare favourably with the results of the simulation. Higher gain and efficiency at the pass bands while sharp drop at the rejected band. The radiation patterns have a dipole shape in the E-plane and an omni-directional shape in the H-plane over the frequency range of interest.

References

[1] ET Docket 98-153, Federal Communication Commissions (FCC), "First report and order, revision of part 15 of the commission's rules regarding ultra wideband transmission systems," Washington, DC, *Technical Report*, 2002.

[2] C. Lin, Y. Kan, L. Kuo, and H. Chuang, "A planar triangular monopole antenna for UWB communication," *Microwave and Wireless Components Letters*, vol. 15, no. 10, pp. 624-626, 2005.

[3] J. Xiao, M. Wang, and G. Li, "A ring monopole antenna for UWB application," *Microwave and Optical Technology Letters*, vol. 52, no. 1, pp. 179-182, 2010.

[4] N. Sameena, R. Konda, and S. Mulgi, "A novel slot for enhancing the impedance bandwidth and gain of rectangular microstrip antenna," *Progress in Electromagnetics Research C*, vol. 11, pp. 11-19, 2009.

[5] A. Deshmukh, P. Mohadikar, P. Zaveri, G. Panchal, and S. Mulgi, "Ultrawide-band modified rectangular microstrip antenna," *Proceedings of Online International Conference on Green Engineering and Technologies*, pp. 1-4, 2016.

[6] M. Ojaroudi, S. Yazdanifard, N. Ojaroudi, and M. Naser-Moghaddasi, "Small square monopole antenna with enhanced bandwidth by using inverted T-shaped slot and conductor-backed plane," *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 2, pp. 670-674, 2011.

[7] K. Chen and J. Row, "A compact monopole antenna for super wideband applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 488-491, 2011.

[8] N. Awad and M. Abdelazeez, "UWB antenna with super bandwidth," *Proceedings of APS/URSI International Symposium*, pp. 2129-2130, 2016.

[9] N. Awad and M. Abdelazeez, "Multislot microstrip antenna for ultra-wide band applications," *Journal of King Saud University-Engineering Sciences*, vol. 30, no. 1, pp. 38-45, 2018.

[10] N. Awad, M. Abdelazeez, and A. Al. Sharif, "Enhanced UWB printed monopole antenna based on ground plane modifications," *Jordanian Journal of Computers and Information Technology*, vol. 4, no. 1, pp. 25-33, 2018.

[11] Y. Li, X. Yang, C. Liu, and T. Jiang, "Compact CPW-fed ultra-wideband antenna with dual band-notched characteristics," *Electronics Letters*, vol. 46, no. 14, pp. 967-968, 2010.

[12] J. Xu, D.-Y. Shen, G.-T. Wang, X.-H. Zhang, X.-P. Zhang, and K. Wu, "A small UWB antenna with dual band-notched characteristics," *Antennas and Propagation*, vol. 2012, 2012.

[13] C. Wang, Z.-H. Yan, B. Li, and P. Xu, "A dual band-notched UWB printed antenna with C-shaped and U-shaped slots," *Microwave and Optical Technology Letters*, vol. 54, no. 6, pp. 1450-1452, 2012.

[14] A. Sudhakar, M. Prakash, and M. Satyanarayana, "Compact circular slotted rectangular UWB antenna with WLAN and partial x band rejection," *ARPN Journal of Engineering and Applied Sciences*, vol. 12, no. 13, pp. 4013-4018, 2017.

[15] X.-F. Zhu and D.-L., "Symmetric E-shaped slot for UWB antenna with band-notched characteristic," *Microwave and Optical Technology Letters*, vol. 52, no. 7, pp. 1594-1597 2010.

[16] A. Sudhakar, M. Satyanarayana, M. Prakash, S. Sharma, "Compact UWB planar antenna with WLAN band rejection," *Microwave and Optical Technology*, vol. 54, no. 2, pp. 123-129, 2016.