A Planar Microstrip Patch Antenna Design for UWB Applications with Band Notched Characteristics using Rectangular and T-shaped Slots

[1]Vikas Sisodiya, [2]Piyush Vyas
[1]M.Tech. Student, [2]Associate Professor
[1]Department of Electronics & Communication Engineering,
[1]Jodhpur Institute of Engineering & Technology, Jodhpur, India

Abstract*— A rectangular planar Ultra-wide band antenna with dual band notched characteristics is proposed using two rectangular slots and one T-shaped slot on radiating patch. The proposed structure uses one T-shaped slot between two identical rectangular slots with stepped corners on the radiating microstrip patch antenna. Microstrip fed line is utilized along with partial ground plane in this design. This antenna operates in frequency ranging from 2.99 to 11.76 GHz with dual band notching ranging from 3.33 to 3.84 GHz and 5.21 to 7.28 GHz respectively. The VSWR is below 2 for entire said frequency range except for the two band rejections. The bandwidth of the proposed structure is nearly 6.187 GHz. This antenna may be utilized for applications in upper S band, C band, X band, ITU uplink satellite communication band (8.1-8.4 GHz) while rejecting 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX, RFID (6.6 to 7.1 GHz) and whole U-NII (Unlicensed National Information Infrastructure) (5.15 to 5.825 GHz) band.

***IndexTerms*— Rectangular ultra-wide band antenna, partial ground plane, stepped corners, dual band notch characteristic, T-shaped and rectangular slots.**

I. Introduction

The last two decades have witnessed the usage of Ultra-Wide Band (UWB) antennas in various applications like radar, sensors, military, RFID, Imaging, etc. But, there usage in the ultra-wide band applications has increased drastically after the approval of license free usage of ultra-wide band by FCC (Federal Communications Commission) [2-8]. It was on 14th February, 2002 when US-FCC has approved the license free usage of ultra-wide band raging from 3.1 GHz to 10.6 GHz for low power and short range applications [1]. This was the eye-catching approval for researchers and academicians. Then after many ultra-wide band antenna designs were proposed using various band enhancement techniques like partial ground plane, defected ground structure (DGS), shorting pin, shorting wall, stacking, slotting, stubs, stepping, beveling, etc [2-19]. Many of the proposed designs do not fulfill the basic requirements of an ultra-wide band antenna. An UWB antenna must operate over entire ultra-wide band from 3.1 GHz to 10.6 GHz as per the FCC. Secondly, it should have either unidirectional or bidirectional radiation pattern as per the requirement of applications [5, 12, 15-18]. Many researchers want that an UWB antenna must have a constant gain over entire operating bandwidth, which is the ideal condition.

Some researchers found that if an UWB antenna is used for numerous applications then there would be interference from the overlapping or nearby band(s) [8, 11, 13-14]. So the researchers have decided to reject those interfering bands by the help of creating destructive interference at those selective frequencies which was termed as band-notched characteristics. Some researchers focused on one band notching where as some designed UWB antenna with multiple band-notched characteristics.

The top and bottom side of the antenna is shown in figure 1 and 2 given above. In this paper, an UWB antenna design with dual band notched characteristic is presented using one T-shaped and two identical rectangular slots on radiating patch. The proposed structure uses one T-shaped slot between two identical rectangular slots with two level stepped corners on the radiating microstrip patch antenna. In addition to above, a microstrip fed also utilized along with partial ground plane for better results. Computer Simulation Technology Microwave Studio (CST-MWS) is used to design this antenna. Bandwidth of the antenna increases as the ground plane is removed partially along with the stepped corners [3, 8-12].

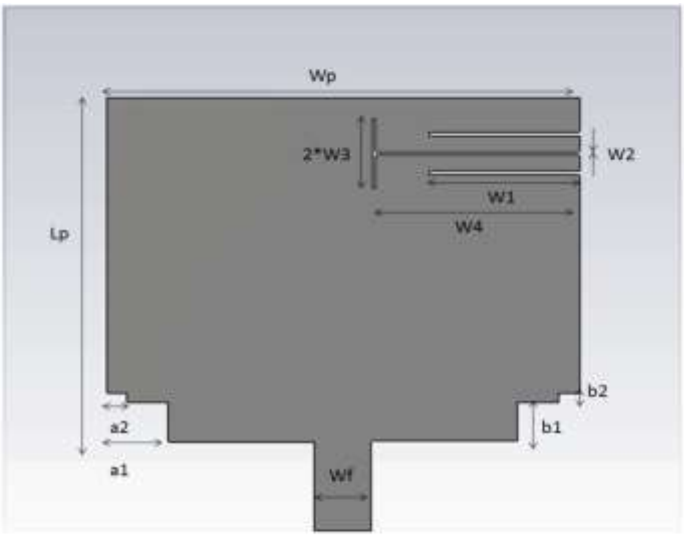

Figure 1. Top View of the proposed antenna.

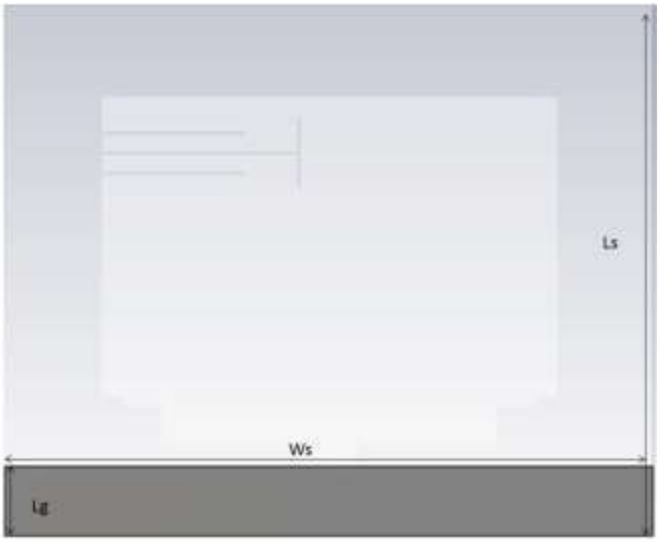

Figure 2. Bottom View of the proposed antenna.

II. DESIGN

The proposed antenna is designed and simulated using FR-4 (Flame Retardant material) substrate of 1.6 mm height with a permittivity of 4.3 and loss tangent (tan δ) of 0.025. In the proposed design one T- shaped slot is used between two identical rectangular slots along with partial ground plane. Partial ground plane and two level stepped corners are utilized for bandwidth enhancement. In the design process it was observed that the two level stepped corners and partial ground plane adds to the bandwidth where as the said band notching structures helps in rejecting some frequency bands, which is discussed in the result section. The dimensions of all the slots are optimized for its best values using parameter variation method. The optimized parameters of the proposed antenna are as follows: W_s = 32.42 mm, L_s = 27.0 mm, W_p = 22.80 mm, L_p = 17.8 mm, W_f = 2.75 mm, W_g = 32.42 mm, L_g = 3.55 mm, a_1 = 3.0 mm, a_2 = 1.0 mm, b_1 = 2.0 mm, b_2 = 0.5 mm, W_1 = 7.2 mm, W_2 = 0.8 mm, W_3 = 1.8 mm, W_4 = 10.0 mm, h = 1.6 mm and m_t = 0.035 mm.

III. RESULTS AND DISCUSSIONS

The proposed antenna is designed and simulated using a software tool CST-MWS in three stages. In the first stage, the microstrip patch antenna is designed using standard equations and then in order to increase the bandwidth (to meet the UWB requirements) ground plane is truncated partially along with two level stepped corners on the radiating patch antenna. After this stage the structure is operating as an ultra-wide band antenna. In the second stage, two identical rectangular slots are inserted on the top right side of the patch to reject upper frequency band (5.21 to 7.28 GHz). The band rejection was needed to reduce the interference from the nearby frequency bands as an UWB antenna can operate on any frequency between 3.1 GHz to 10.6 GHz. In the last stage, one T-shaped slot is inserted between the two rectangular slots and one additional band rejection is observed by virtue on destructive interference from the two types of slots.

The parametric study of the selected parameters is discussed in this section. The dimensions of stepped corners are sensitive to bandwidth of the proposed design. It can be easily seen from figure 3 given below that the bandwidth of the design is sensitive to the height of the first level stepped corners. It increases with the decrease in 'b_1' parameter and vice-versa.

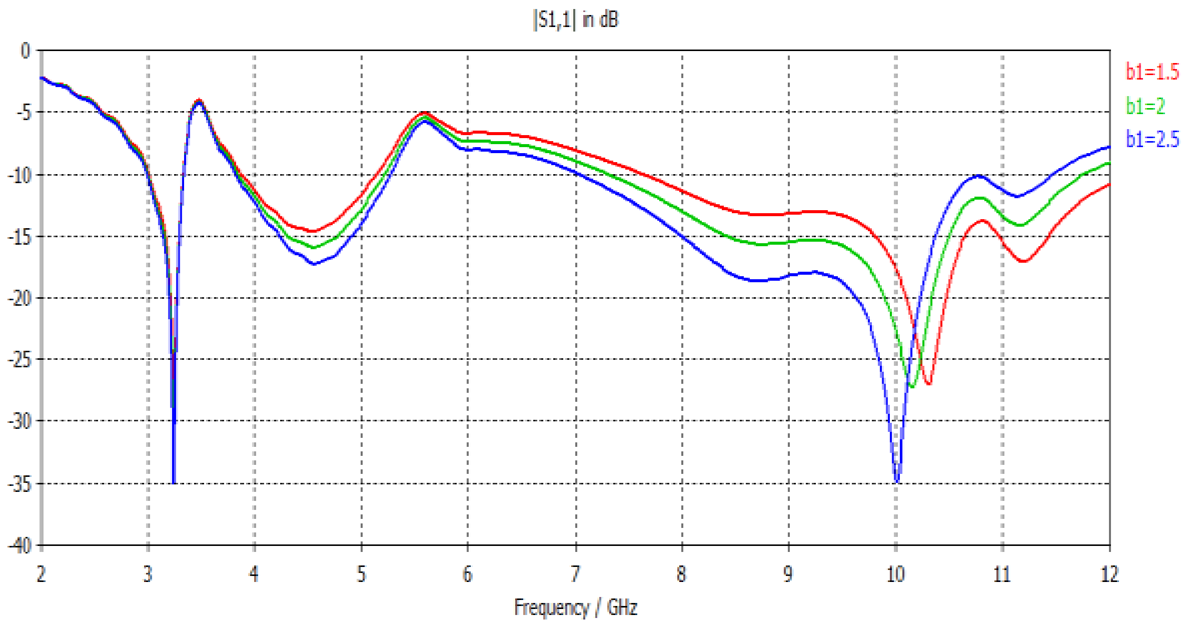

Figure 3. Parameter variation of height of first stepped corner b_1.

The variation in the length of the two identical rectangular slots is given below in figure 4. As the dimensions of the parameter 'W_1' is increased, the second band rejection shifts to the lower side with narrowing in the bandwidth in band rejection. So the second band rejection can be controlled by adjusting the dimensions of the two identical rectangular slots.

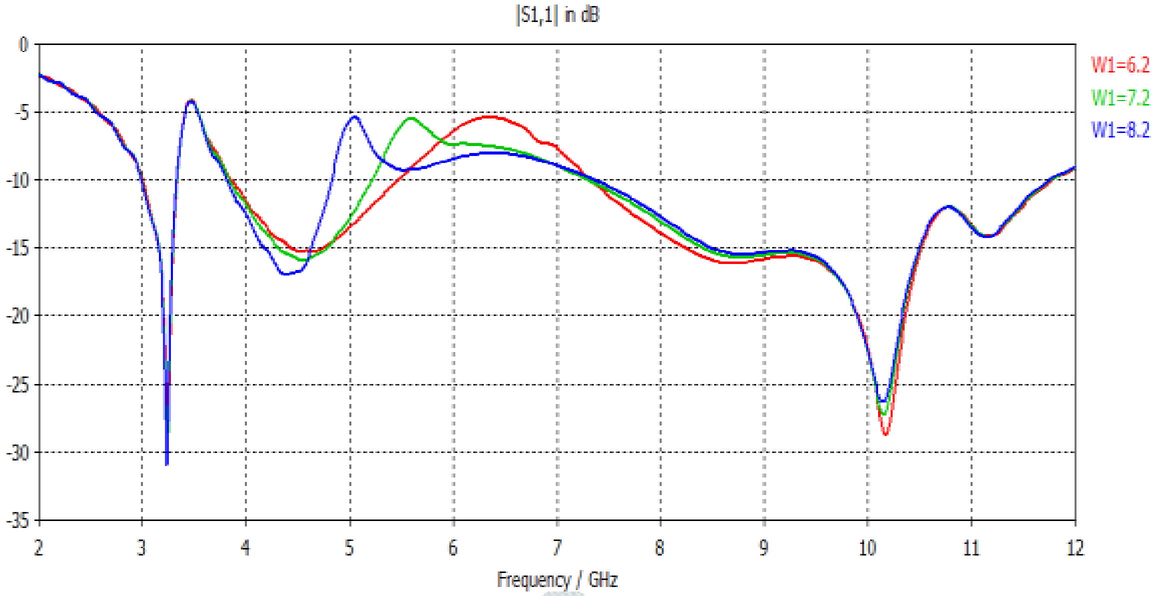

Figure 4. Parameter variation of rectangular slots length W_1.

The variation in the width of the slots is given below in figure 5. As the dimensions of the parameter 'W_2' is increased, the first band rejection shifts to the upper frequencies in band rejection. So the first band rejection can be controlled by adjusting the dimensions of the slots.

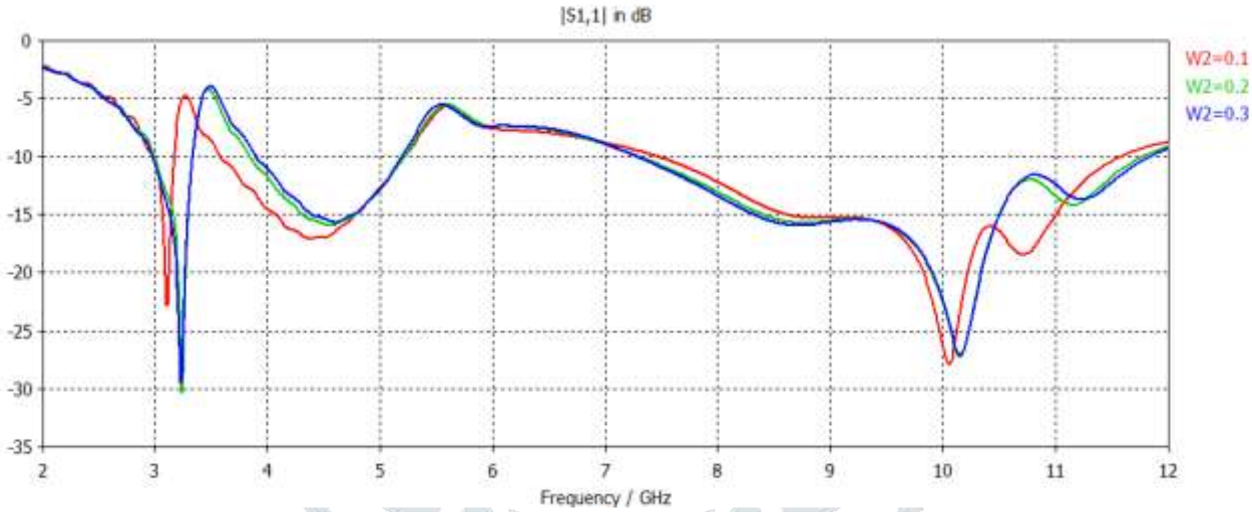

Figure 5. Parameter variation of slot widths W_2.

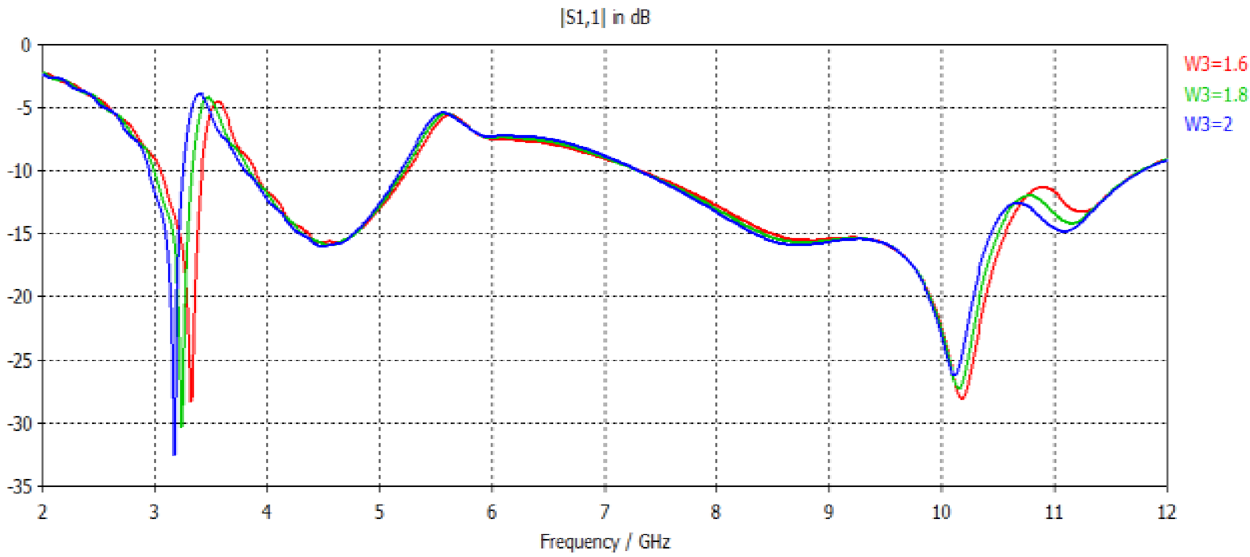

Figure 6. Parameter variation of width of T-shaped slot W_3.

The variation in the width of the T-shaped slot is shown in the figure 6 given above. The selectivity of the first band rejection can be controlled by varying the width of the T-shaped slot. As the value of parameter 'W_3' is increased then the first band rejection shifts to the lower frequencies and vice-versa.

The variation in the length of the T-shaped slot is shown in the figure 7 given below. The selectivity of the first band rejection can be controlled by varying the width and length of the T-shaped slot; but majorly it more sensitive to the length of the T-Shaped slot. As the value of parameter ‘W_4’ is increased then the first band rejection shifts to the lower frequencies with slight reduction in the value of peak return loss (S_{11}) and vice-versa.

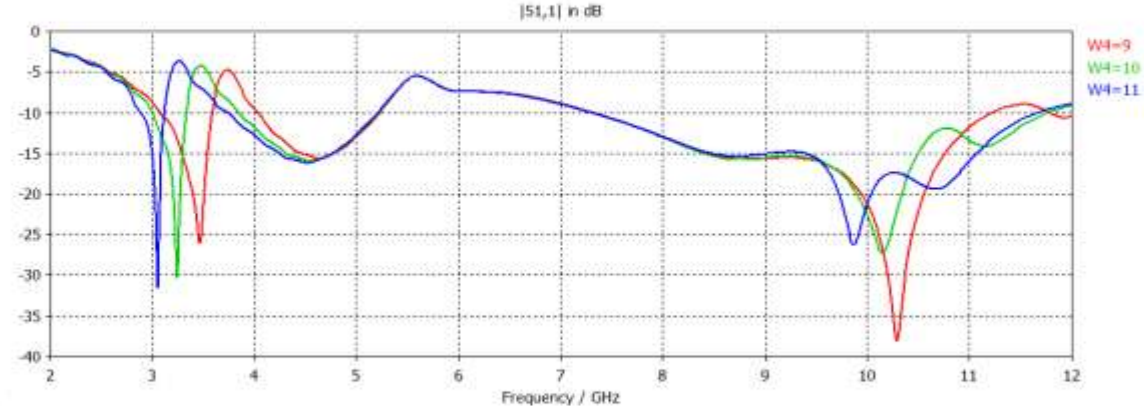

Figure 7. Parameter variation of length of T-shaped slot W_4.

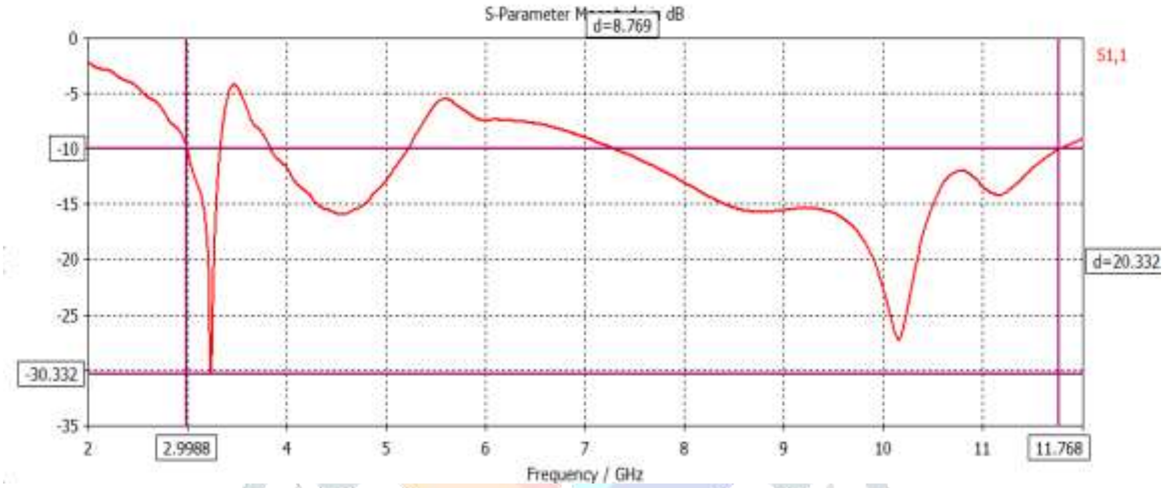

Figure 8. Return loss (S_{11}) curve of the proposed antenna.

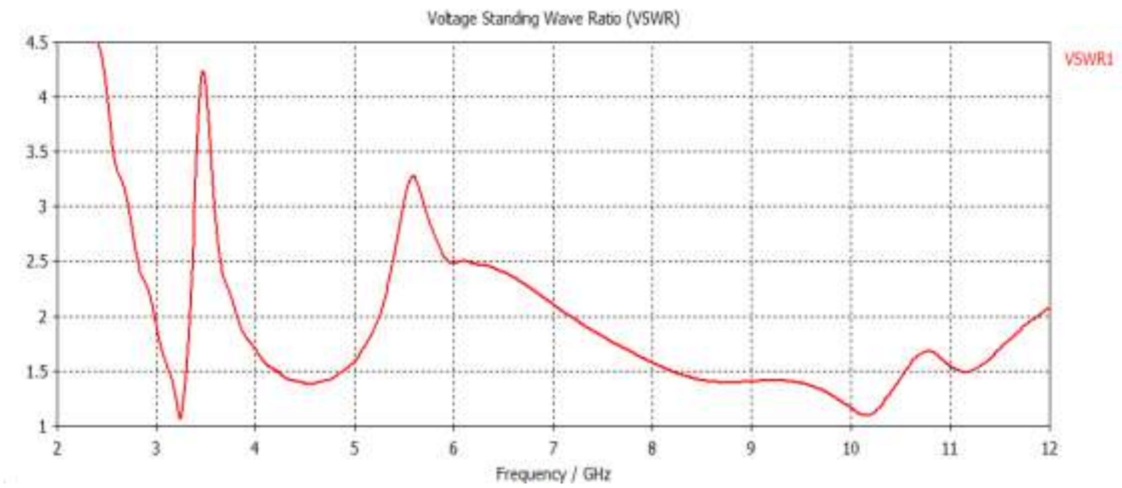

Figure 9. VSWR curve of the proposed antenna.

The return loss curve of the proposed design is shown in the figure 8 given above. The peak return loss value of -30.332 dB is achieved at 3.24 GHz. The bandwidth of the proposed design is about 6.187 GHz excluding the band rejection frequency bands. Voltage Standing Wave ratio (VSWR) curves of the proposed design is shown in the figure 9 given below. It can be easily observed that the value of the VSWR is less than 2 for entire ultra-wide band range except for the band rejections.

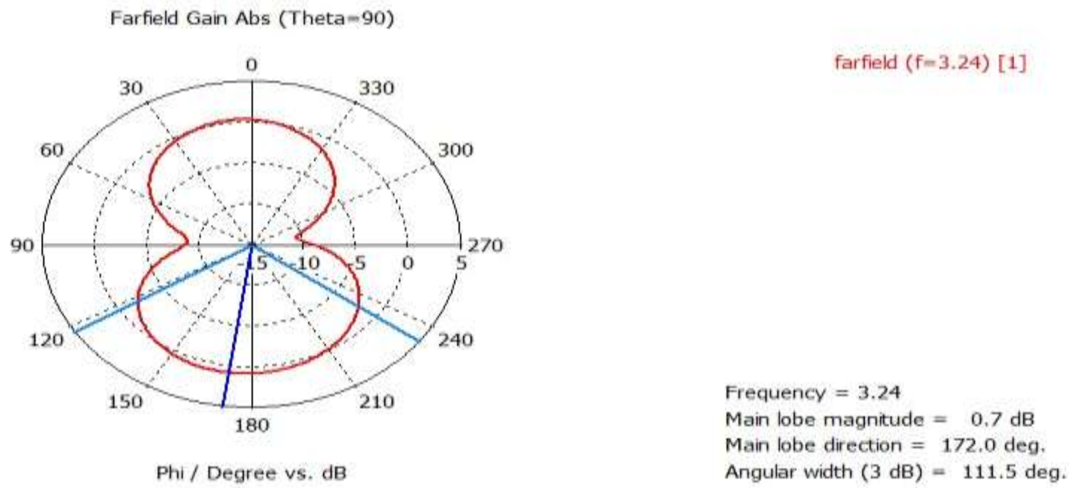

Figure 10. Radiation Plot at 3.24 GHz.

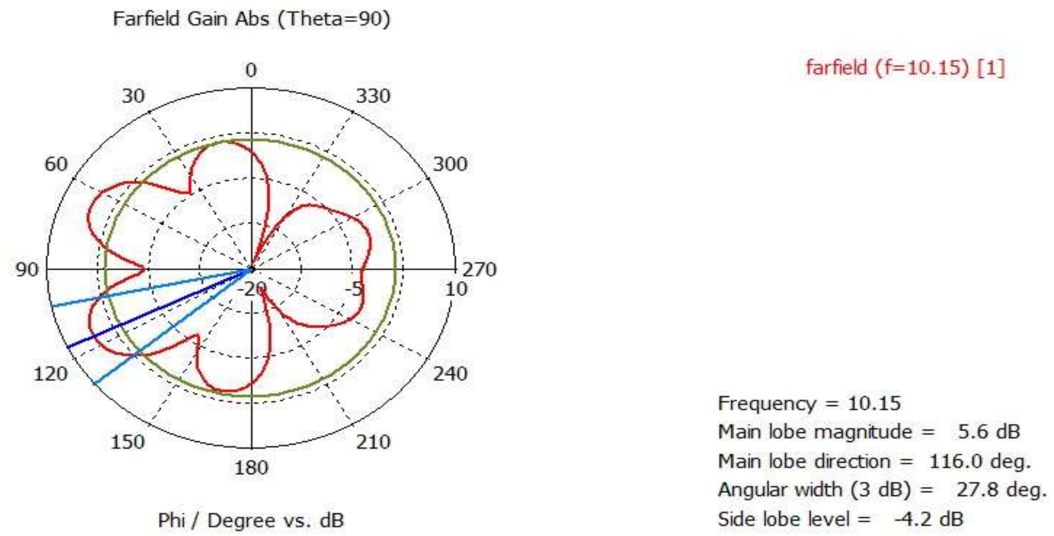

Figure 11. Radiation Plot at 10.15 GHz.

The radiation plots of the proposed design at frequency 3.24 and 10.15 GHz is shown above in the figure 10 and 11 respectively. The gain at 3.24 GHz is 1.63 dB where as it is 5.55 dB at 10.15 GHz. The radiation pattern at 3.24 GHz is bidirectional where as it is radiating nearly in all the directions for the second case.

The surface current at 3.5 GHz and 6 GHz is shown in the figure 12 and 13 given below. It was observed that the T-shaped slot is majorly linked with first band rejection where as the two identical rectangular slots are playing the major role in rejecting the second band i.e. 5.21 GHz to 7.28 GHz.

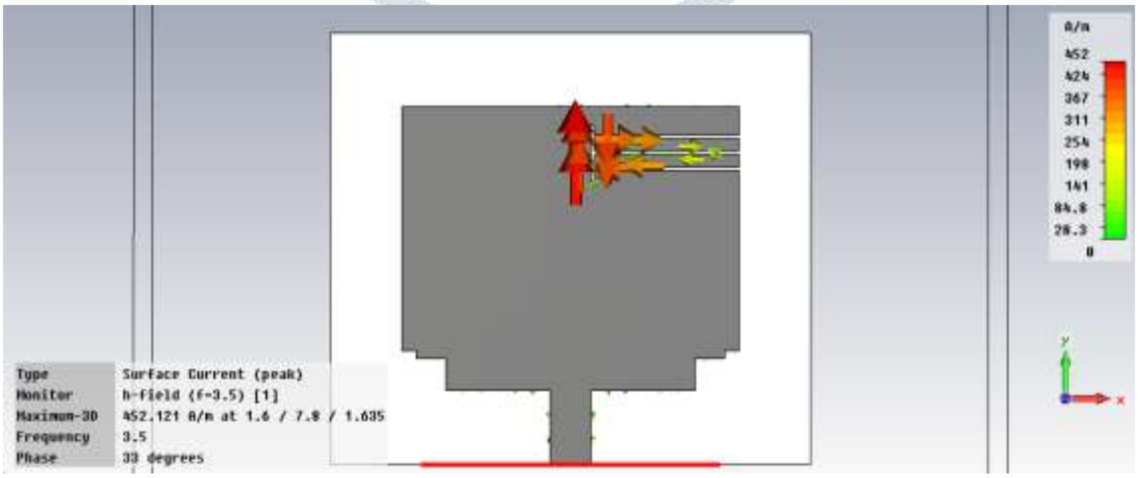

Figure 12. Surface current at 3.5 GHz.

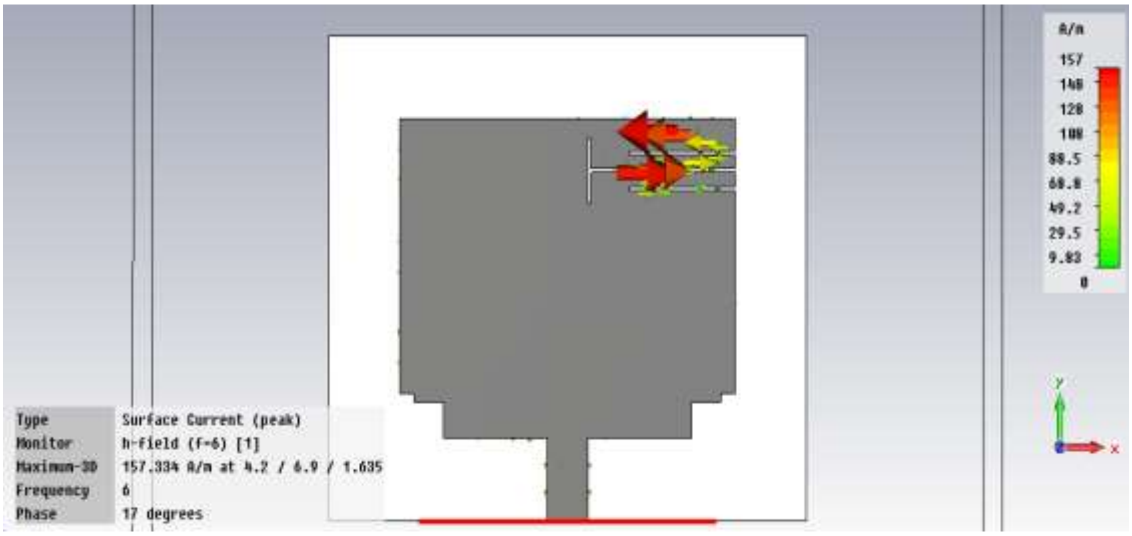

Figure 13. Surface current at 6.0 GHz.

IV. CONCLUSIONS

In this paper a rectangular planar Ultra-wide band antenna with dual band notched characteristics is proposed using two rectangular slots and one T-shaped slot on radiating patch. The proposed structure uses one T-shaped slot between two identical rectangular slots with stepped corners on the radiating microstrip patch antenna. This antenna operates in frequency ranging from 2.99 to 11.76 GHz with dual band notching ranging from 3.33 to 3.84 GHz and 5.21 to 7.28 GHz respectively. The bandwidth of the proposed structure is nearly 6.187 GHz excluding the two band rejections. This antenna may be utilized for applications in upper S band, C band, X band, ITU uplink satellite communication band (8.1-8.4 GHz) while rejecting 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX, RFID (6.6 to 7.1 GHz) and whole U-NII (Unlicensed National Information Infrastructure) (5.15 to 5.825 GHz) band.

REFERENCES

[1] "First report and order in the matter of revision of part 15 of the commission's rules regarding ultra-wide band transmission systems. ET Docket 98 – 153 , "Federal Communications Commission, Washington, DC, FCC 02–48, Apr. 22, 2002.

[2] M. Ojaroudi, S. Yazdanifard, N. Ojaroudi, and R. A. Sadeghzadeh, "Band-Notched Small Square-Ring Antenna With a Pair of T-Shaped Strips Protruded Inside the Square Ring for UWB Applications" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 10, 2011.

[3] M. Mehranpour, J. Nourinia, C. Ghobadi, and M. Ojaroudi, "Dual band-notched square monopole antenna for ultrawideband applications,"IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 172–175, 2012.

[4] N. Ojaroudi and M. Ojaroudi, "Novel Design of Dual Band-Notched Monopole Antenna With Bandwidth Enhancement for UWB Applications" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 12, 2013.

[5] I. Md. Rafiqul, A. A. Zahirul and S. Alkaraki, "Design of Microstrip Patch Antenna Using Slotted Partial Ground and Addition of Stairs and Stubs for UWB Application," Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT), May Edition, 2012.

[6] P. Gao, L. Xiong, J. Dai, Shuang He and Yi Zheng, "Compact Printed Wide-Slot UWB Antenna With 3.5/5.5-GHz Dual Band-Notched Characteristics" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 12, 2013.

[7] R. Azim, Md. T. Islam and A. T. Mobashsher, "Design of a Dual Band-Notch UWB Slot Antenna by Means of Simple Parasitic Slits" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 12, 2013.

[8] Y. Luo, L. Xu, Z. Xin and S. He, "A Compact Cpw-Fed Uwb Antenna With GSM, GPS, Bluetooth And Dual Notch Bands Applications" Progress In Electromagnetics Research C, Vol. 35, 205{219, 2013.

[9] S. R. Emadian, C. Ghobadi, J. Nourinia, M. H. Mirmozafari and J. Pourahmadazar, "Bandwidth Enhancement of CPW-Fed Circle-Like Slot Antenna With Dual Band-Notched Characteristic" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 11, 2012.

[10] Mewara, H. S., Mayank Sharma, M. M. Sharma, and Ajay Dadhich. "A novel ultra-wide band antenna design using notches and stairs", 2014 International Conference on Signal Propagation and Computer Technology (ICSPCT 2014), 2014.

[11] Liu Wen-Chung, Wu Chao-Ming and Dai Yang "Design of Triple Frequency Microstrip Fed Monopole Antenna Using Defected Ground Structure", IEEE Transactions on antenna and propagation , Vol 59, No. 7 July (2011).

[12] Kamma Anil, Reddy G. Shrikanth, Parmar Rajesh Singh and Mukherjee Jyanta, "Reconfigurable Dual- Band Notch UWB Antenna", IEEE (2014).

[13] H.S. Mewara, M.M. Sharma, Mayank Sharma, Mukesh Gupta and Ajay Dadhich, "A Planar Ultra-Wide Band Antenna Design Using Circularly Truncated Corners and Notches" S.C. Satapathy et al. (eds.), Proceedings of the Second International Conference on Computer and Communication Technologies, Advances in Intelligent Systems and Computing 379, DOI 10.1007/978-81-322-2517-1_68 © Springer India 2016.

[14] M. Ojaroudi, Sh. 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 Transaction on Antennas and Propagation, VOL. 59, NO. 2, February 2011.

[15] M. Mehranpour, J. Nourinia, Ch. Ghobadi, and M. Ojaroudi, "Dual Band-Notched Square Monopole Antenna for Ultrawideband Applications" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 11, 2012.

[16] M. Ojaroudi, Sh. Yazdanifard, N. Ojaroudi, and R. A. Sadeghzadeh, "Band-Notched Small Square-Ring Antenna With a Pair of T-Shaped Strips Protruded Inside the Square Ring for UWB Applications" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 10, 2011.

[17] N. Ojaroudi, M. Ojaroudi, Sh. Yazdanifard and R. A. Sadeghzadeh, “Dual Band-Notched Small Monopole Antenna With Novel W-Shaped Conductor Backed-Plane and Novel T-shaped Slot for UWB Applications” IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 11, 2012.
[18] Mohammad Ojaroudi, Nasser Ojaroudi, and Noradin Ghadimi, “Dual Band-Notched Small Monopole Antenna With Novel Coupled Inverted U-Ring Strip and Novel Fork-Shaped Slit for UWB Applications” IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 12, 2013.
[19] A. Sharma and M. M. Sharma, “An UWB antenna design with dual band notched charaterisitic using U-shaped slots”International Conference on Signal Processing and Communication (ICSC), Noida, 2016.