UWB Microstrip Antenna with Tuneable Band-Notched characteristics for Wireless Applications

Kalyan Rayavaram[1], K.T.V. Reddy[2] and Padma Priya Kesari[3]

[1]*Department of Electronics and Communication Engineering, JNT University Anantapur, Anantapuramu, Andhra Pradesh, India*

[2]*IETE HQ, New Delhi, India*

[3]*Department of Electronics and Communication Engineering, JNT University Kakinada, Kakinada, Andhra Pradesh, India*

Abstract - This paper presents the design and simulation of an ultra-wideband (UWB) microstrip antenna with tuneable band-notched characteristics for wireless applications. The antenna is designed on FR4 substrate with dielectric constant 4.4, loss tangent 0.02, thickness of 0.8mm and the size of the proposed antenna is 29×14 mm^2. The rectangular monopole antenna endures a rectangular radiating patch with chamfered bevel slots on the top side, and a defective ground plane on the bottom side of the substrate. To realize band notch characteristics, slot is created on the patch to achieve notch at 4.6 GHz (4.1 GHz to 5.4 GHz) which eliminates INSAT signal. The proposed antenna is well miniaturized and can be easily integrated with any compact devices. The simulated result shows that proposed antenna gain a good range of UWB from (3.1 GHz to 12.9 GHz).

Keywords: UWB, Rectangular monopole antenna.

I. INTRODUCTION

In wireless communication system Ultra-Wideband (UWB) is a widely admired and attractive technique used for short range communication applications. From the past few years UWB have becomes the highlight of wireless communication due to advantages of low spectral power density, high speed data rate and many others. In February 2002 the Federal Communication Commission (FCC) allocated a bandwidth of 7.5 GHz i.e., from 3.1 to 10.6 GHz to be used for communication purposes, by far the demand for UWB increasing rapidly [1].

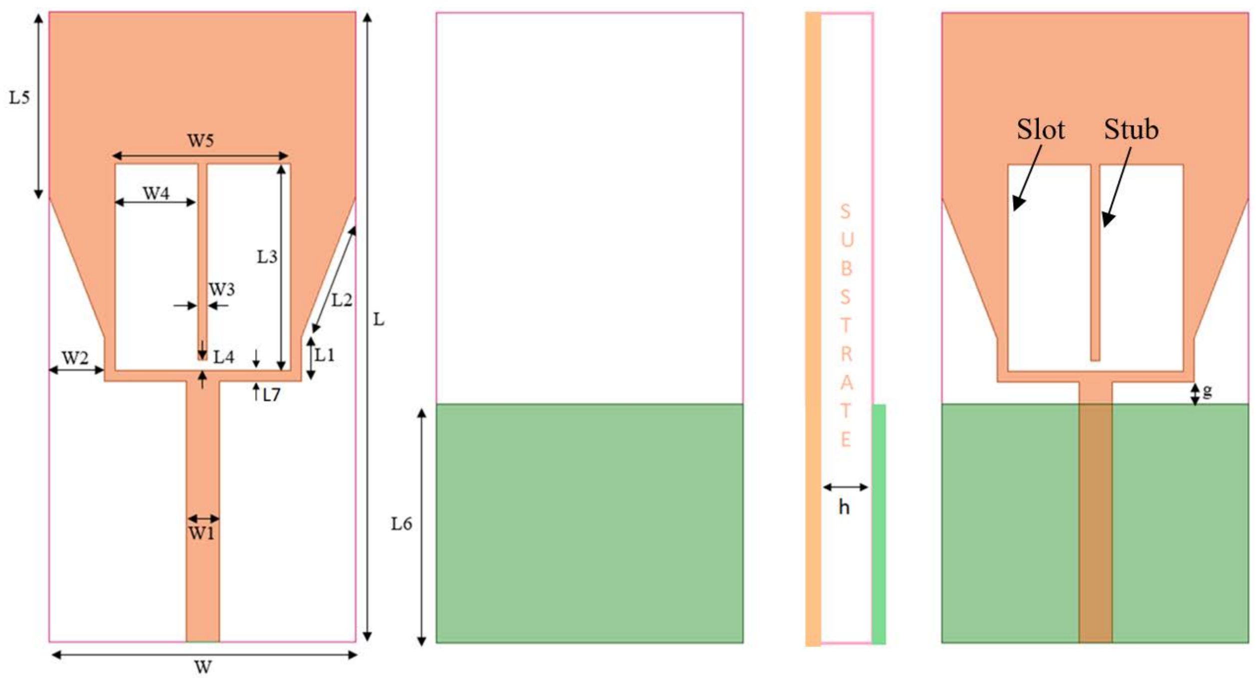
A lot of research on UWB system brought some challenges including their impedance matching, compact size, low manufacturing cost etc. which are introduced while designing antenna for UWB applications. The operating frequency of UWB allocated by FCC includes several narrowband wireless standards that have been allocated to share some part of this spectrum. These include INSAT 4.6GHz, wireless local area network (WLAN) services 5.5GHz etc. which interfere with the UWB system. So somewhere its needed an antenna with band notched property that can diminish the unwanted interferences from these coexisting wireless system rather than by using an additional band stop filter. There are various methods which are helpful for introducing a notch in UWB antenna. The most commonly used technique is by adding different slots on the radiating material or in the ground plane or also on the feed line. Different shapes are used like V shaped slot is used on the patch to create band notch characteristics [2], As reported, a T-shaped slot in the radiating patch provides strong notch band rejections up to VSWR = 26 which is tuneable over a wide frequency range from 3.55 GHz to 6.80 GHz [3], In order to achieve band rejection characteristic, the H-shaped slot is utilized in to the elliptical open ended microstrip feed line. By changing the H-shaped slot parameters the band notched characteristics can be controlled [4], U shaped filter is used on a UWB planer monopole antenna to eliminate WLAN frequency [5], By inserting a C-shaped slot on the elliptic radiating patch, a notched frequency band is created. The slot length contributes to both the notch center frequency and notch bandwidth, while the slot width contributes mainly to the notch bandwidth [6].

To realize dual notched bands characteristics, a T-shaped stub embedded in the square slot of the radiation patch and a pair of U-shaped parasitic strips beside the feed line is used [7], two short circuit folded stepped impedance resonators are used two achieve dual band notched characteristics. the folded SIRs are employed effectively for notching unwanted frequency bands [8], a microstrip open-loop resonator is used on the ground plane to generate frequency band notch [9], a novel modified complementary split-ring resonator (CSRR) is etched inside the inner patch to obtain a band-notched function [10], a pair of bended dual- L-shape branches are attached to the slotted ground to achieve dual band notched characteristics [11], By etching four u-shaped slots with different dimension in the radiating patch, the dual stopbands can be obtained. And the stopband bandwidth can be controlled by adjusting the three u-slots dimension [12], With a pair of C-shaped slots and a U-shaped slot introduced on the radiating patch, two frequency-notched responses are obtained. And, good radiation patterns and gains within the operating band have been observed [13], By inserting a meandering slot between the feed-line and the radiation patch and, with adding a pair of symmetrical C-shape strips to the feed-line dual band notched characteristics are achieved [14].

However, the above design has larger size of the antenna or limited band notch performance. This paper presents an ultra-wideband (UWB) microstrip antenna with tuneable band-notched characteristics for wireless applications. The proposed antenna covers the full range of UWB and also its capable of rejecting frequencies like INSAT signal. this approach has acceptable band notch performance without increasing size and complexity of antenna and how it is achieved is discuss in the following section.

II. ANTENNA DESIGN

This section describes the basic antenna covering the entire band width of UWB frequency range with band notched characteristics. The effects of geometric parameters of the patch and the ground plane are shown. This antenna is printed on a FR4 substrate with dielectric constant 4.4, loss tangent 0.02, size of 29x14 mm^2 and thickness of 0.8mm. The feed line and the radiating patch is printed on the top side of the substrate and ground plane is printed on the bottom side. Width of microstrip feed line is fixed as 1.5mm to achieve 50-ohm characteristic impedance.



a) Top view (b) Bottom view (c) Side view (d) Combined view

Fig. 2.1 Proposed UWB Antenna with band notch characteristics

TABLE 1. OPTIMIZED DIMENSIONS OF THE PROPOSED ANTENNA

Parameter	Length in mm	Parameter	Length in mm	Parameter	Length in mm	Parameter	Length in mm
L	29	L4	0.5	W	14	W4	4
L1	2	L5	8.5	W1	1.5	W5	8
L2	6	L6	11	W2	2.5	h	0.8
L3	9.5	L7	0.5	W3	0.4	g	1

The geometry of antenna with band notched characteristics for UWB applications is shown in fig. 1.1 In the presented design a slot on the patch is introduced with a stub in between, to achieve notch at 4.6GHz (INSAT signal). The simulation of proposed antenna has been done on HFSS 13 software. Table 1 shows the optimized dimensions of the antenna.

III. SIMULATION/EXPERIMENTAL RESULTS

Full-wave electromagnetic simulations using Ansoft's high frequency structure simulator (HFSS) were carried out to characterize the performance of the antenna with different slots. In order to reduce the EMI with the INSAT band, a band-notched function covering 4.6 GHz is desired. The desired band notch is achieved by a slot on the patch with a stub in between. notice that the length of the slot has an augmented design to enhance its capacitance. By placing the slot close to the feed line, it creates a single band-notched frequency filter. Note that with this design, there is no need to change the dimensions of the original UWB antenna. Rather, one simply needs to tune the resonance of the slot by adjusting its length L3 and W5 (W4+W4) to achieve the desired band-notched function.

A. STUDY OF SLOT WIDTH

Fig. 3.1 and Fig. 3.2 shows the simulated S11 and VSWR characteristics of the proposed antenna for different values of W4. As shown increasing the width of the slot will increase the notch height. One can represent that at notch frequency the perfect coupling is done by increasing the width of the slot. By increasing the width from 1mm to 4 mm the return loss is varied from -9dB to -2.5dB. Whereas VSWR is increased from 2.5 to 7.5 at notched band.

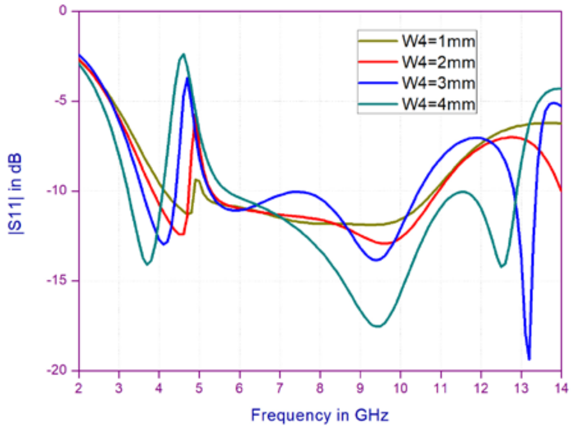


Fig. 3.1 Simulated S11 characteristics of proposed antenna with different values of W4

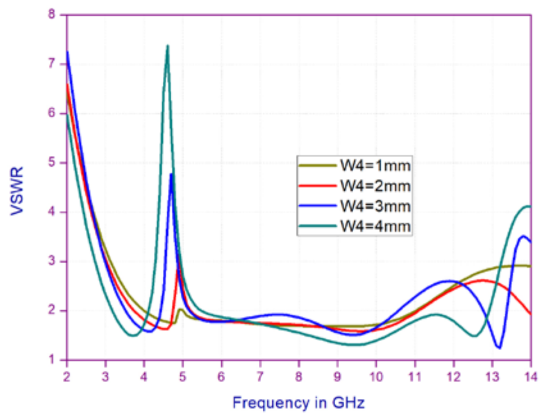


Fig. 3.2 Simulated VSWR characteristics of proposed antenna with different values of W4

B. STUDY OF SLOT LENGTH

Fig. 3.3 and Fig. 3.4 shows the simulated S11 and VSWR characteristics of the proposed antenna for different values of L3. One can represent increasing the slot length reduces the notch frequency. As shown the notch frequency is reduced from 5.8GHz to 3.5GHz by increasing the slot length from 7mm to 13mm. For 7mm the notch frequency is at 5.8GHz (upper ISM band), for 8mm the notch frequency is at 5.2GHz (lower ISM band), for 9.5mm the notch frequency is at 4.6GHz (INSAT Signal), for 13mm the notch frequency is at 3.5GHz (WIMAX) frequencies. So we can represent that this antenna is tuneable for different notch frequencies. VSWR values says that the Higher notch frequency (upper ISM band) is having 8.5 whereas lower notch (WIMAX) is having 6.5. for the proposed antenna the VSWR value is 7.5. for lower ISM band notched frequency the VSWR value is 8. Hence the antenna is good candidature for ultra wide band applications

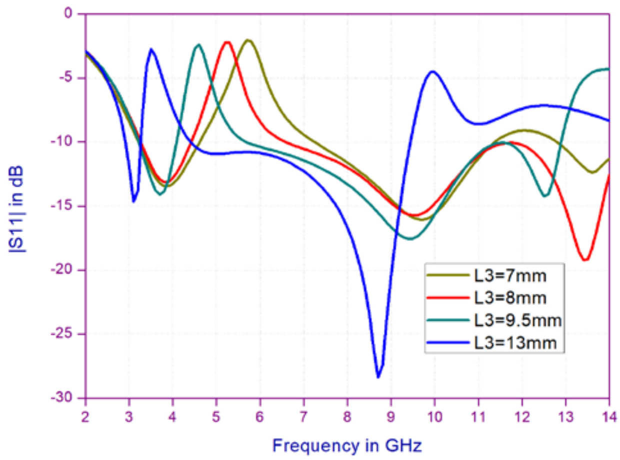


Fig. 3.3 Simulated S11 characteristics of proposed antenna with different values of L3

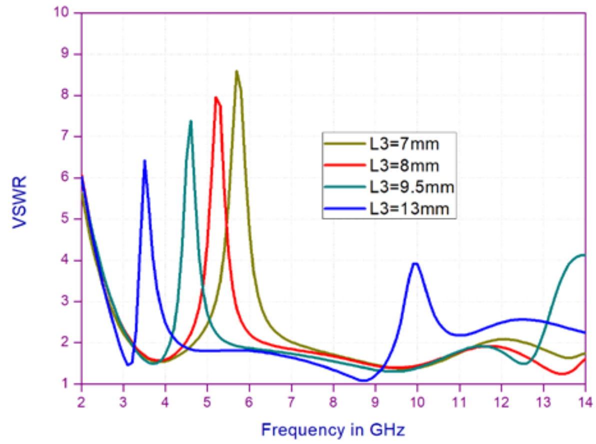


Fig. 3.4 Simulated VSWR characteristics of proposed antenna with different values of L3

Fig. 3.5 and Fig. 3.6 shows the simulated S11 and VSWR characteristics of proposed antenna for different values of L3.

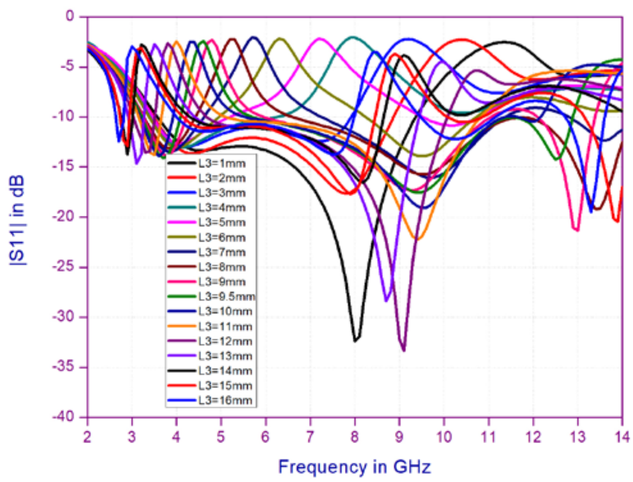


Fig. 3.5 Simulated S11 characteristics of proposed antenna with different values of L3

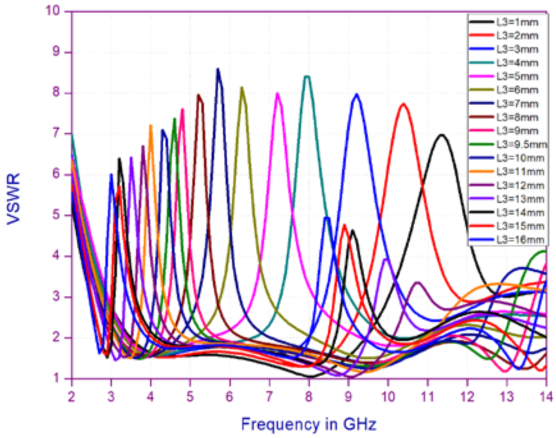


Fig. 3.6 Simulated VSWR characteristics of proposed antenna with different values of L3

If L3 is increased from 1mm to 16mm the notch frequency is reduced from 12GHz to 3GHz. As shown in fig. 3.7 and fig. 3.8 for L3 values 14mm to 16mm two notched bands are achieved without increasing size of the antenna and without increasing the number of slots.

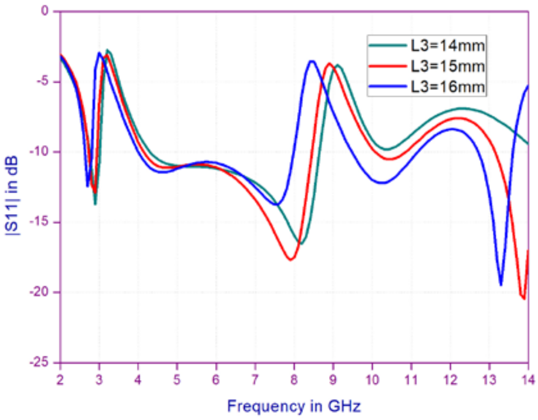


Fig. 3.7 Simulated S11 characteristics of proposed antenna with different values of L3

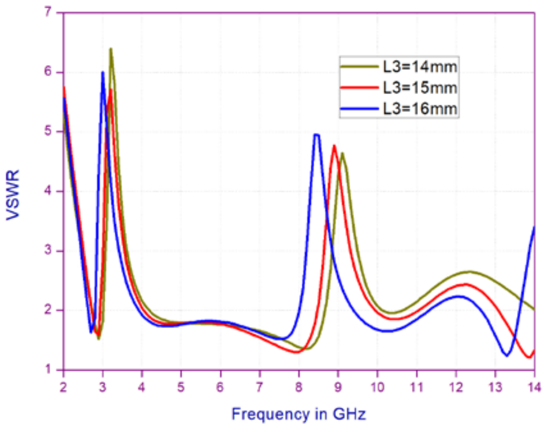


Fig. 3.8 Simulated VSWR characteristics of proposed antenna with different values of L3

C. STUDY ON POSITION OF SLOT

Fig. 3.9 and Fig. 3.10 shows the simulated S11 and VSWR characteristics of proposed antenna for different values of L7. Here the position of slot near from feed line is increased from 0.5 mm to 3.5mm one can observe that if the slot is near to the feed line the antenna is perfectly coupled whereas if it is away from the feed line the results are not accurate. It is also clearly shown that the VSWR values decreases by increasing the position from feed line. If the values are increased from 0.5mm to 3.5mm the VSWR values are decreased from 7.5 to 5.5. For 0.5mm the VSWR value is 7.5. For higher VSWR values the better notching so the position of the slot is fixed at 0.5mm on the patch.

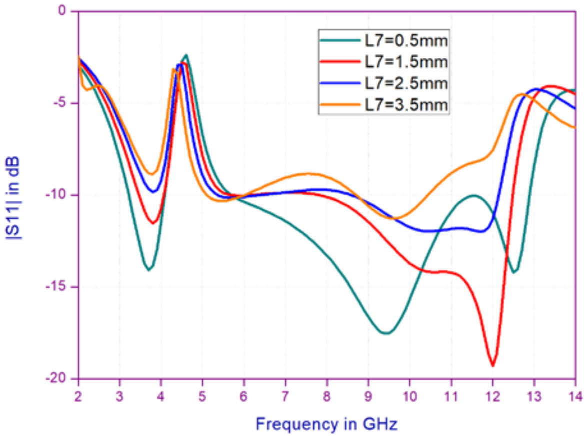


Fig. 3.9 Simulated S11 characteristics of proposed antenna with different values of L7

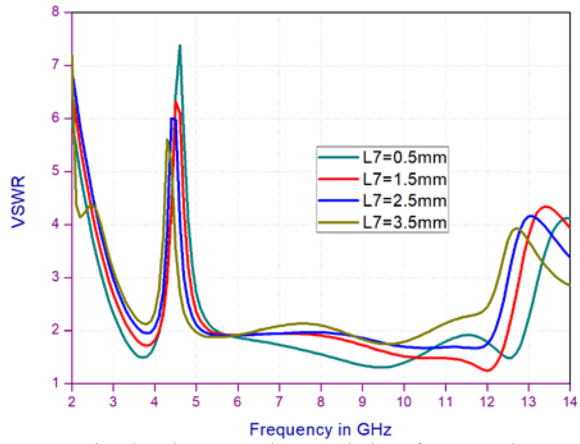


Fig. 3.10 Simulated VSWR characteristics of proposed antenna with different values of L7

D. STUDY OF STUB LENGTH

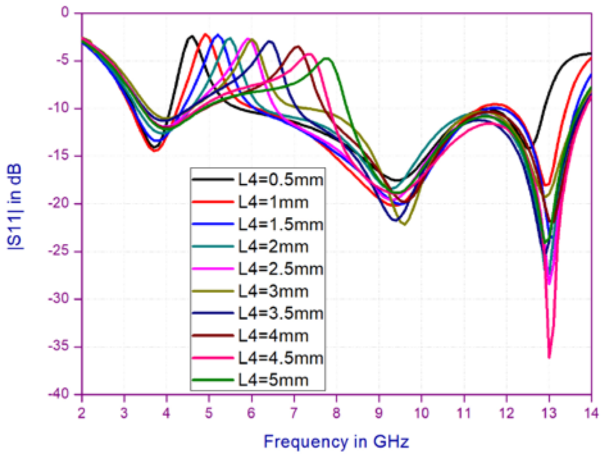


Fig. 3.11 Simulated S11 characteristics of proposed antenna with different values of L4

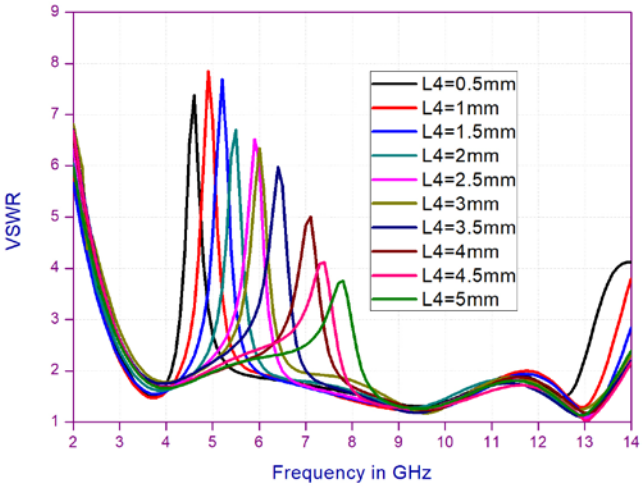


Fig. 3.12 Simulated VSWR characteristics of proposed antenna with different values of L4

Fig. 3.11 and Fig. 3.12 shows the simulated S11 and VSWR characteristics of proposed antenna for different values of L4. As shown if the length L4 is increased from 0.5mm to 5mm the frequency of notch is increased from 4.6GHz to 8GHz. VSWR values are also reduced by increasing L4. The VSWR values are increased from 3.5 to 7.9 if the L4 values are increased.

E. STUDY OF STUB WIDTH

Fig. 3.13 and Fig. 3.14 shows the simulated S11 and VSWR characteristics of proposed antenna for different values of W3. As shown if the length W3 is increased from 0.2mm to 0.8mm

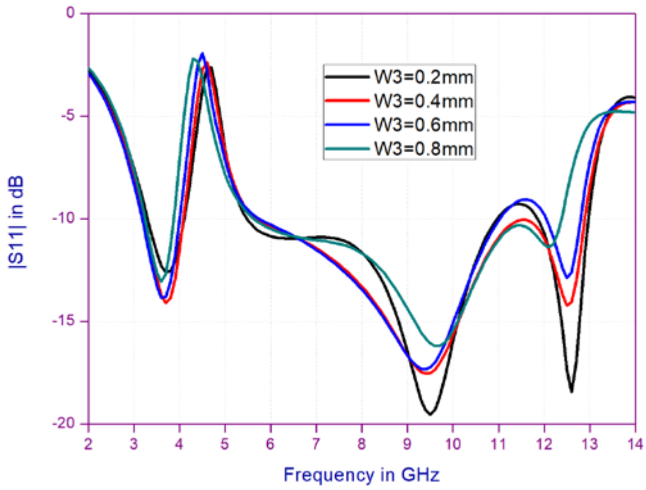


Fig. 3.13 Simulated S11 characteristics of proposed antenna with different values of W3

VSWR is taken as 0.4mm to get the notch at 4.6GHz. A slight variation in Centre frequency of notch is achieved because the length of the slot is slightly increased. This slight variation is considerable. At 0.6mm the better VSWR is achieved as 9.

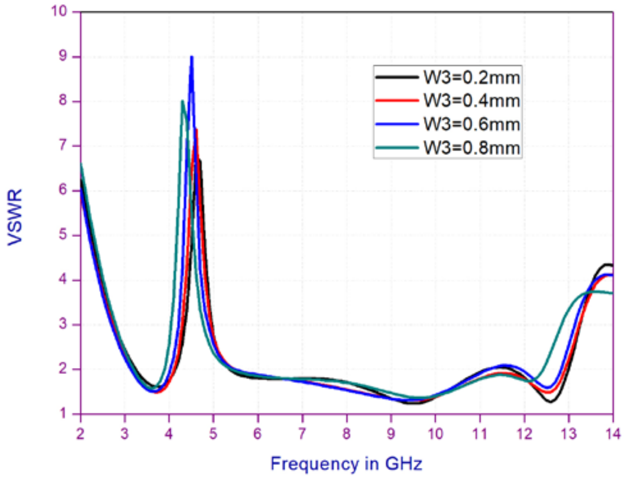


Fig. 3.14 Simulated VSWR characteristics of proposed antenna with different values of W3

Fig. 3.15 shows the simulated S11, Fig. 3.16 shows the simulated VSWR, and Fig. 3.16 shows the simulated gain of proposed antenna.

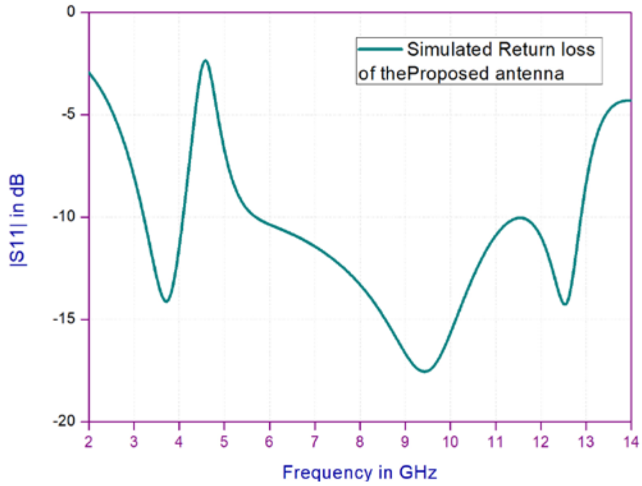


Fig. 3.15 Simulated S11 characteristics of proposed antenna

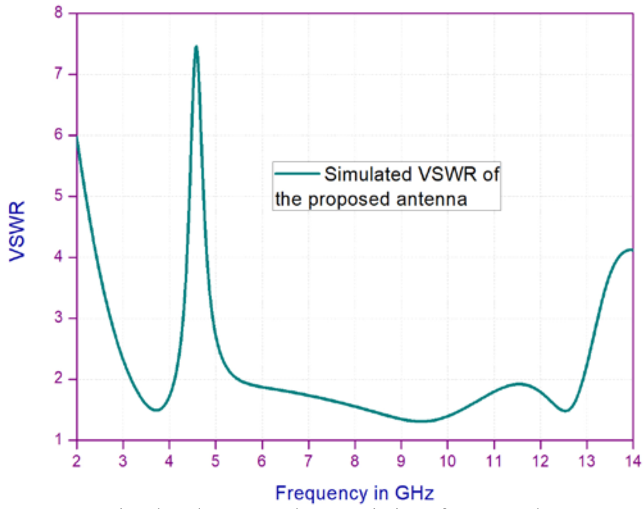


Fig. 3.16 Simulated VSWR characteristics of proposed antenna

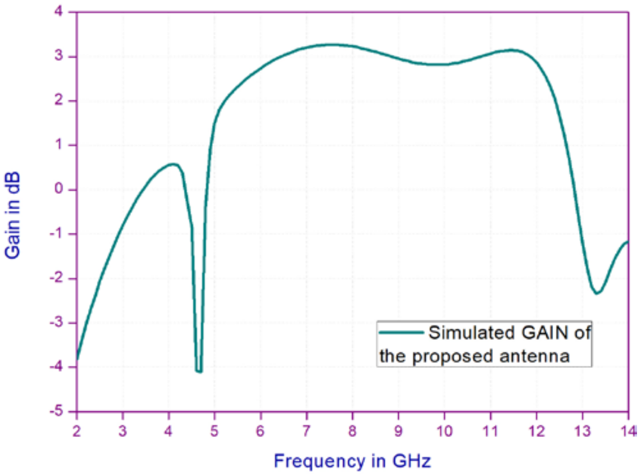


Fig. 3.17 Simulated gain of proposed antenna

As shown in Fig. 3.17 the antenna has a gain that is low at 3.1 GHz and increases with frequency. It is found that the gain of the antenna is decreased with the use of slot in the patch. It can be observed that by using these structures, a sharp decrease of maximum gain in the notch frequencies band at 4.6 is shown. For other frequencies outside the notched frequency band, the antenna gain with the filter is similar to those without it.

To understand the phenomenon of notch performance, the simulated current distributions on the radiating patch for the proposed antenna at the notched frequencies of 4.6GHz are presented in Fig. 3.18. It can be observed that the current is concentrated at the interior and exterior edges

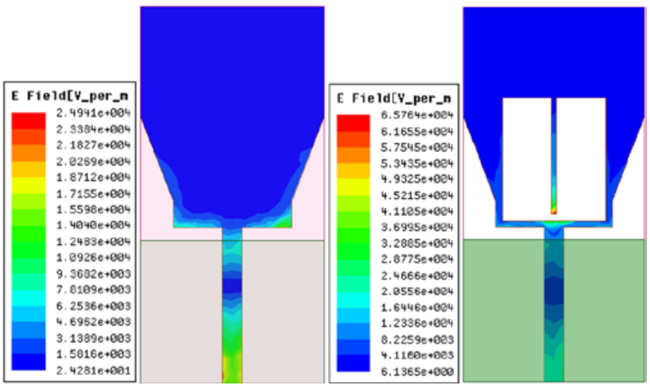


Fig. 3.18 HFSS-Predicted surface current distribution at 4.6GHz notched frequency

Fig. 3.19 Shows the Simulated E-Plane and H-Plane Radiation pattern for proposed UWB antenna at (a) 3GHz (b) 5GHz (c) 7GHz (d) 9GHz. It can be seen that the antenna has a good omnidirectional radiation pattern in the H-plane, and a dipole-like radiation pattern in the E-plane which covers entire UWB (3.1 to 10.6GHz) region and even better band width is achieved for future UWB applications. Also one can represent that for lower frequencies the radiation pattern is dipole like structure whereas for higher frequencies the radiation pattern is scattered.

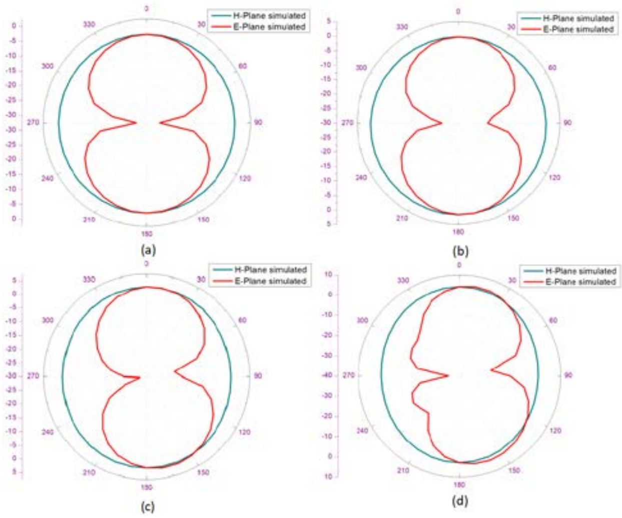


Fig. 3.19 Simulated E-Plane and H-Plane Radiation pattern for proposed UWB antenna at (a) 3GHz (b) 5GHz (c) 7GHz (d) 9GHz.

IV. CONCLUSION

In this paper a compact UWB antenna with band notch characteristics has been presented, which covers the frequency range from 3.1 to 12.9 GHz. By introducing a slot on the patch with stub inserted inside gives notch band centre frequency at 4.6 GHz (Tuneable between 3GHz to 11.5GHz) is obtained which rejects INSAT signal with a band width of 4.1GHz to 5.4GHz. The designed antenna shows maximum gain of 5dB at 10.5GHz. Due to its simple structure, compact size, and excellent performance, the proposed antennas are expected to be good candidates for use in various UWB systems for short distance wireless applications.

REFERENCES

[1] Federal communications commissions, Washington, DC, USA, Federal Communications Commission revision of Part 15 of the commission’s rules regarding ultra-wideband transmission system from 3.1 to10.6 GHz, 2002.

[2] R. Kalyan, K. T. V. Reddy and K. Padma Priya, “compact band notch ultra wide band microstrip antenna for short distance wireless applications”, International Conference on Inventive Communication and Computational Technologies, 10-11 March 2017, Coimbatore, India, DOI: 10.1109/ICICCT.2017.7975161

[3] S.M. Abbas, Y. Ranga, A.K. Verma, K.P. Esselle, A simple ultra wideband monopole antenna with high band rejection and wide radiation patterns, IEEE Trans. Antennas Propag. 62 (9) (2014) 4816–4820

[4] S. R. Branch, Band-notched elliptical slot UWB microstrip antenna with elliptical stub filled by the H-shaped slot, J. Electromagnets. Waves Appl., vol. 22, pp. 1993–2002, 2008.

[5] Y. J. Cho, K. H. Kim, D. H. Choi, S. S. Lee, and S. O. Park, A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics,

IEEE Trans. Antennas Propag., vol. 54, no. 5, pp. 1453–1460, May 2006.

[6] C. Y. Huang, W. C. Hsia, and J. S. Kuo, Planar ultra-wideband antenna with a band-notched characteristic, Microw. Opt. Technol. Lett., vol. 48, no. 1, pp. 99–101, 2005.

[7] Wen Jiang and Wenquan Che, A Novel UWB Antenna with Dual Notched Bands for WiMAX and WLAN Applications, IEEE Antennas and Wireless Propagation Letters, VOL 11, 2012.

[8] Y. Sung, UWB Monopole Antenna with Two Notched Bands Based on the Folded Stepped Impedance Resonator, IEEE Antennas and Wireless Propagation Letters, VOL. 11, 2012.

[9] James R. Kelly, Peter S. Hall, And Peter Gardner, Band-Notched UWB Antenna Incorporating a Microstrip Open-Loop Resonator, IEEE Transactions On Antennas and Propagation, Vol. 59, No. 8, August 2011

[10] Di Jiang, Yuehang Xu, Ruimin Xu and Weigan Lin, Compact dual-band-notched UWB planar monopole antenna with modified CSRR, Electronics Letters 27th September 2012 Vol. 48 No. 20

[11] xianglong liu, yingzeng yin, pingan liu, junhui wang,and bin xu, a cpw-fed dual band notched uwb antenna with a pair of bended dual-l-shape parasitic branches, progress in electromagnetics research, vol. 136, 623.634, 2013

[12] fangfang fan, zehong yan, tianling zhang, and yue song, ultra-wideband planar monopole antenna with dual stopbands, microwave and optical technology letters / vol. 52, no. 1, january 2010.

[13] chen wang, ze-hong yan, bo li, and ping xu, a dual band-notched uwb printed antenna with c-shaped and u-shaped slots, microwave and optical technology letters / vol. 54, no. 6, june 2012.

[14] xianglong-l. liu, yingzeng-z. yin, and junhui-h. wang, a compact dual band-notched uwb antenna with meandering slot and c-shape strips, microwave and optical technology letters / vol. 55, no. 11, November 2013.

[15] sanjeev kumar mishra, rajiv kumar gupta, avinash vaidya, and jayanta Mukherjee, a compact dual-band fork-shaped monopole antenna for bluetooth and uwb applications, ieee antennas and wireless propagation letters, vol. 10, 2011.