ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 10(44), DOI: 10.17485/ijst/2017/v10i44/120582, November 2017 ISSN (Online) : 0974-5645

Ultra-Wide Band Antenna Design using Stairs for Personal Area Network Wireless Application

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Abstract

Objectives: This paper explains about the staircase antenna with characteristics of ultra-wide band (UWB). The design of proposed work describes stairs along the radiating patch with micro strip feed. **Method/Statistical Analysis:** The projected ultra-wide band antenna is designed and simulated using High Frequency Simulation Software (HFSS). **Findings:** The simulation and Measured result of the antenna prove that it has a good impedance matching over the UWB frequency range from 3.5 - 10.4GHz. The VSWR is less than 2 for entire operating frequency range. This antenna finds its uses in WiMax and Wi-Fi without interference. Stair Case patch design is chosen to get ultra wide bandwidth and strips are introduced to get band notch characteristics. **Applications:** The proposed antenna is suitable for its use in WPAN applications and for short range communication.

Keywords: Rectangular Planar Ultra-Wide Band Antenna, Stepped Micro Strip Feed, Stepped Partial

1. Introduction

In commercial use purpose tremendous growth has been observed in UWB technology since FCC release the frequency range of 3.1-10.6 GHz[1-4]. Recently, ultra-wide band (UWB) components become popular and attractive for short range high data rate wireless communication due to development in high rate data network[5]. Wireless technology rapidly expanded over all areas. Now wireless technology is not only used for commercial but it is also used for military purposes due to low cost and flexible way of communication.

UWB wireless communications is speedily advancing as a high data rate wireless communication technology[5,6]. However the designing of UWB antenna is more difficult than a narrow band antenna[6]. As mentioned by FCC, the UWB antenna operation should be in the ultra wide range i.e. 3.1 GHz to 10.6 GHz. An Over the desired range of frequencies the designed UWB antenna should exhibit excellent VSWR, coverage, gain and bandwidth. Another important aspect of designing UWB antenna these days is miniaturization[7-10].

This paper proposes the design of a new printed monopole antenna for UWB applications. The shape of rectangular radiator is cut into stairs like structure to form a printed monopole antenna that radiate in UWB frequency range.

2. Antenna Design

A plane rectangular patch is designed to derive the proposed antenna. For designing conventional rectangular patch antenna the equations available in literature are utilized. Length and breadth of rectangular patch antenna is calculated by equations 1 to 5. FR4 substrate material is used for designing the proposed antenna which have epsilon = 4.4 and thickness = 1.6 mm. The frequency range of UWB communication is from 3.1-10.6 GHz, so the resonant frequency of antenna (f_c) selected is 3.4 GHz. Width of rectangular microstrip patch is given by:

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$$w = \sqrt{\frac{2}{\epsilon_{rel} + 1}} \quad .. \qquad (1)$$

Where v_o is the velocity of the light
ϵ_{rel}= 4.4 the dielectric constant of the dielectric material
Where fc = 3.4 GHz

So w = 26.8 mm

3. Effective Refractive Index

There is fringing effect observed in patch antennas which is passing of electromagnetic radiations from patch to ground plane through substrate and air. As dielectric constant of both substrate and air is different. So following equation is used to calculate the effective dielectric constant

$$\epsilon_{rel(eff)} = \frac{\epsilon_{rel} + 1}{2} + \frac{\epsilon_{rel} - 1}{2}[1+12\frac{h}{w}]^{-1/2} \qquad (2)$$

Where w = 26.8 mm
h=1.6 mm (height of the substrate.)

$\epsilon_{rel(eff)}$=3.25

Due to fringing effects the length gets varied by ΔL. Following equation is used to calculate this variation in length

$(\Delta l)/h = 0.412$

$$\frac{(\epsilon_{rel(eff)}+0.3)\{\frac{w}{h}+0.264\}}{(\epsilon_{rel(eff)}+0.258)\{\frac{w}{h}+0.8\}} \quad .. \qquad (3)$$

Δl = 0.757 mm

So, the effective length l_{eff} of rectangular microstrip patch is given by

$$l_{eff} = \frac{v_0}{2f_c\sqrt{\epsilon_{rel(eff)}}} \quad ... \qquad (4)$$

Where $\epsilon_{rel(eff)}$=3.25

Hence actual length of antenna is given by

$l = l_{eff} - 2\Delta l$
$l = 24.1 - 1.5 = 22.6$ mm

The rectangular patch antenna with length 2.6 mm and width 26.8 mm is designed in HFSS as given in Figure 1.

Figure 2 presents the return loss plot obtained after simulating basic patch antenna. Initially antenna is designed to work on lower UWB frequency. With the help of standard equations the basic antenna operating at 3.4 GHz is designed. To achieve middle UWB frequencies the dimensions of patch is reduced. Further, in order to achieve higher UWB frequency band as well as overall UWB, steps are introduced in patch in iterative manners. The parametric study is also performed to achieve desired UWB bands (3.2 to 10.6 GHz).

In this step the dimensions of patch is reduced to achieve wide bandwidth. As shown in Figure 3, the optimized length is 26 mm and width is 20 mm for the designed antenna. As presented in Figure 4, modified patch antenna covers the range from 6.4 to 7.8 GHz.

The patch antenna results were improved by cutting steps along the width as shown in Figure 5 to get the wide band. On the upper and lower side of patch a step was cut[6,7]. It has been observed from the return loss graph shown in Figure 6 that the antenna with single stair is now resonant at dual frequency bands from 5.9 to 6.4 GHz and 9.2 to 9.6 GHz.

In next step the antenna was further modified by cutting one more step[8] as shown in Figure 7. This modification improves the bandwidth and antenna now covers the frequency range between 3.4 to 9 GHz and 10.2 to 10.6 GHz as shown in Figure 8 thereby making it a ultra wideband structure.

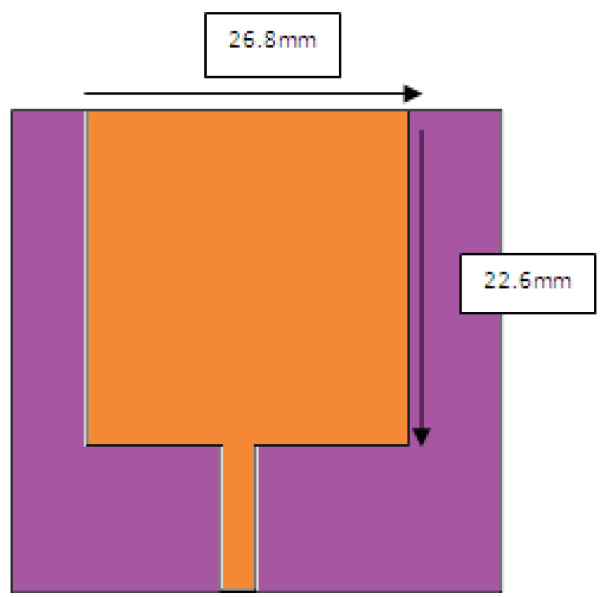

Figure 1. Rectangular Patch Antenna.

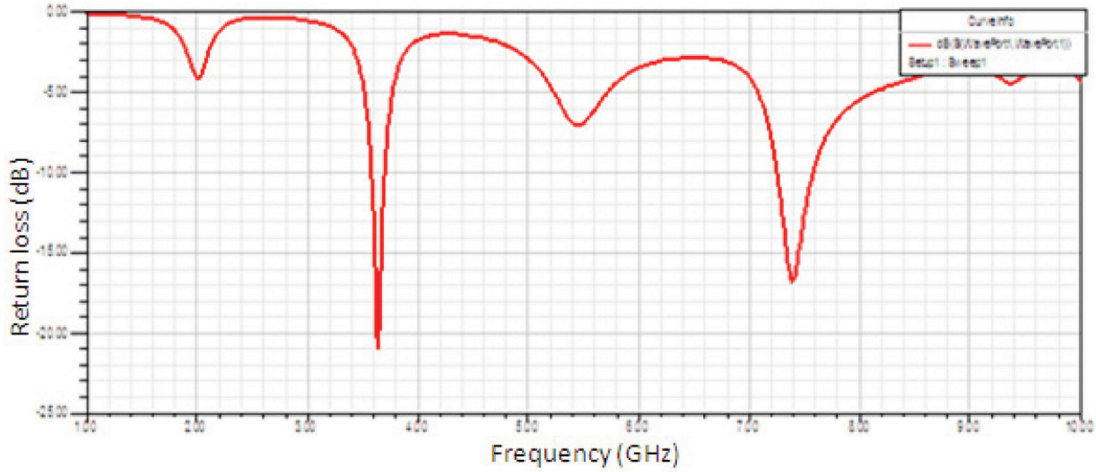

Figure 1. Rectangular Patch Antenna.

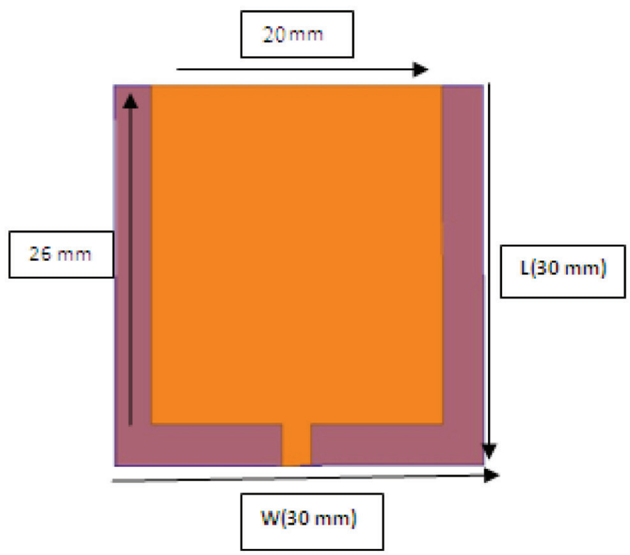

Figure 3. Rectangular patch Antenna with modified dimension.

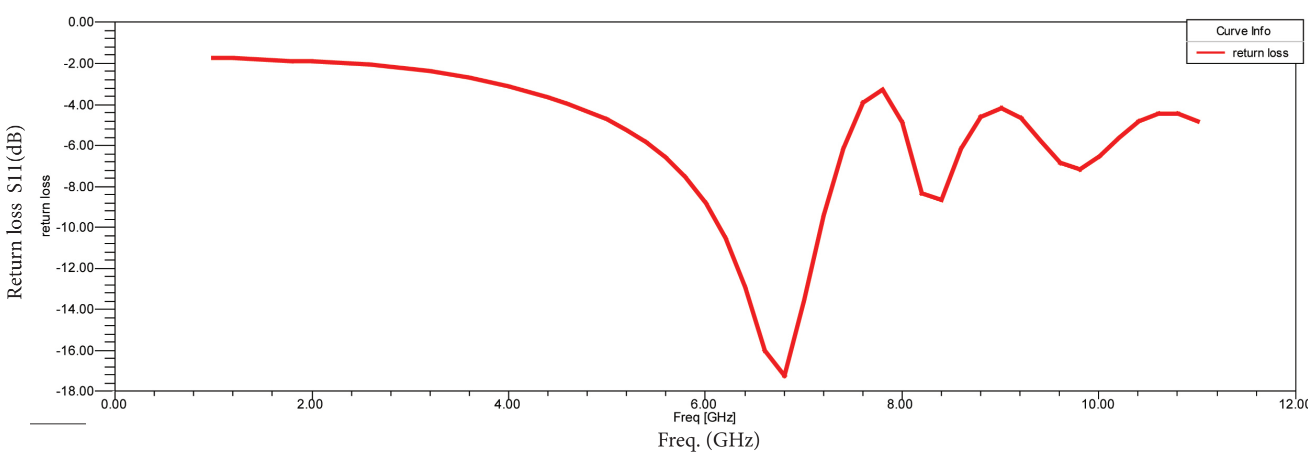

Figure 4. Simulated S11 Plot of modified Patch Antenna.

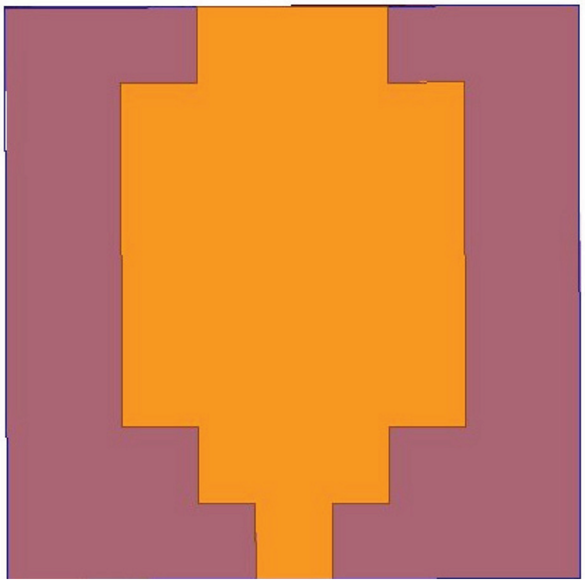

Figure 5. Single step introduce in Patch Antenna.

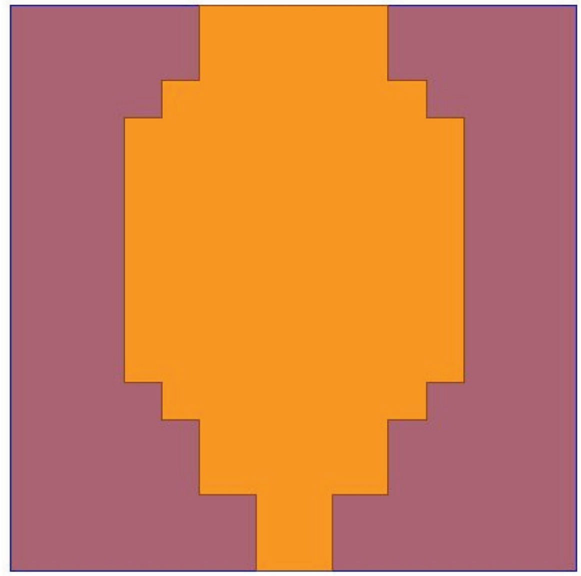

Figure 7. Two steps introduced in Patch Antenna.

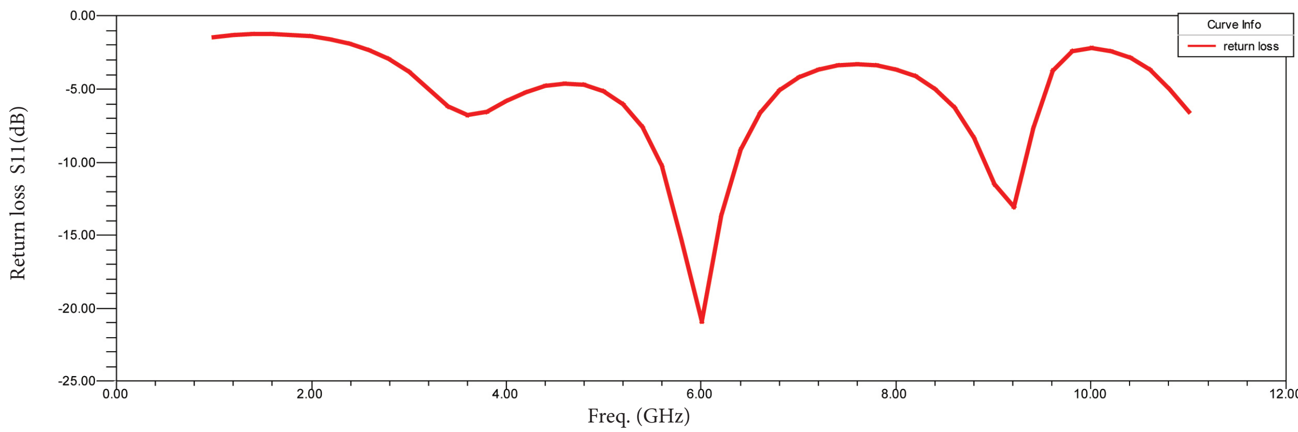

Figure 6. Simulated S11 Plot for Single Step Patch Antenna.

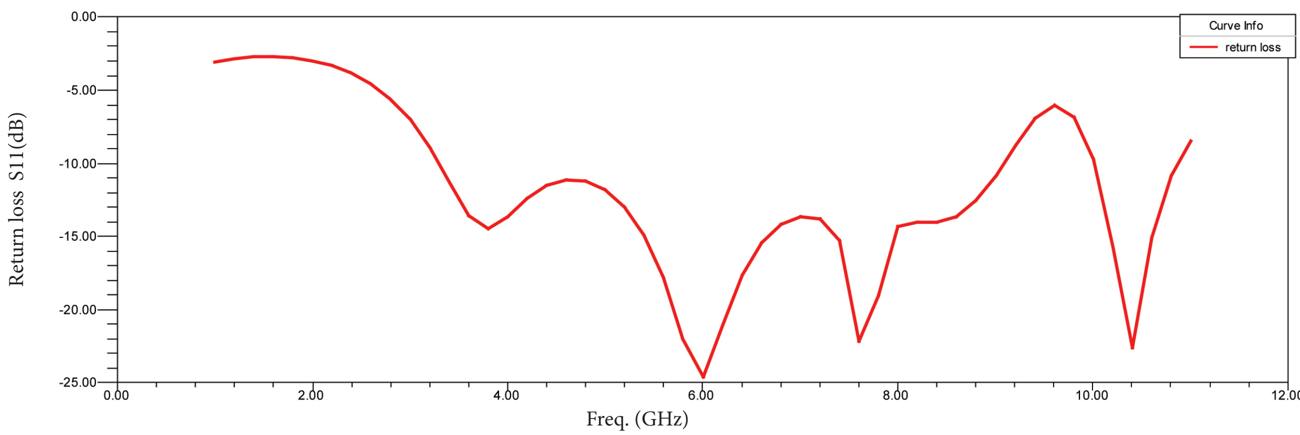

Figure 8. Simulated S11 plot ofdouble steps Patch Antenna.

4. Effect of Varying Steps Length and Width on Return Loss

The best values of different parameters which are mentioned in Figure 9 is considered and parameterized to proposed UWB antenna. In this parametric study the optimal value of each parameter was selected and remaining parameters were optimized by fixing it. In this parametric study the simulation results were obtained using ANSYS SOFT HFSS simulator to simulate the antenna parameters. The proposed antenna is investigated for step width (a, band c) and step length (s1,s2,s4 and s5) of this structure for best results[9,10].

4.1 Variation of Parameter 'a'

At first the value of 'a' is varied from 17mm to 19mm with a step of 1mm with fixed values of parameters b and c. Great impact was observed on bandwidth as well as on return loss due to variation in the parameters of proposed antenna. As the bandwidth improved by increase the value of 'a' and further increase in 'a' results in decrease in bandwidth. Peak of the return loss curve is sensitive to the variation of this parameter. The optimal value of 'a' is 17mm as shown in Figure 10.

4.2 Variation of Parameter 'b'

In next step value of 'b' is varied from 13 to 15 mm with a step of 1mm with fixed values of parameters a and c. The bandwidth obtained at 14mm and 15mm is very proximate to each other as shown in Figure 11. Peak of the return loss curve is also sensitive to the variation of this parameter so, 15mm is considered as optimum value for parameter 'b'.

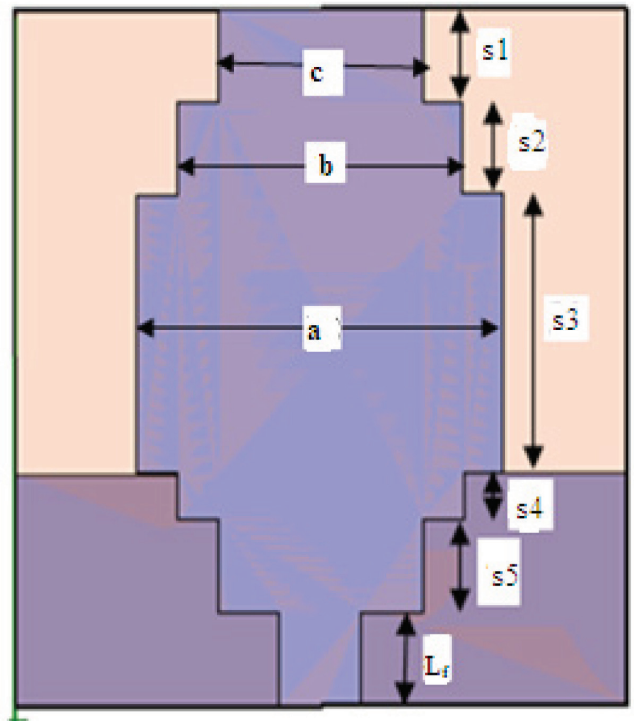

Figure 9. Geometry of proposed antenna.s

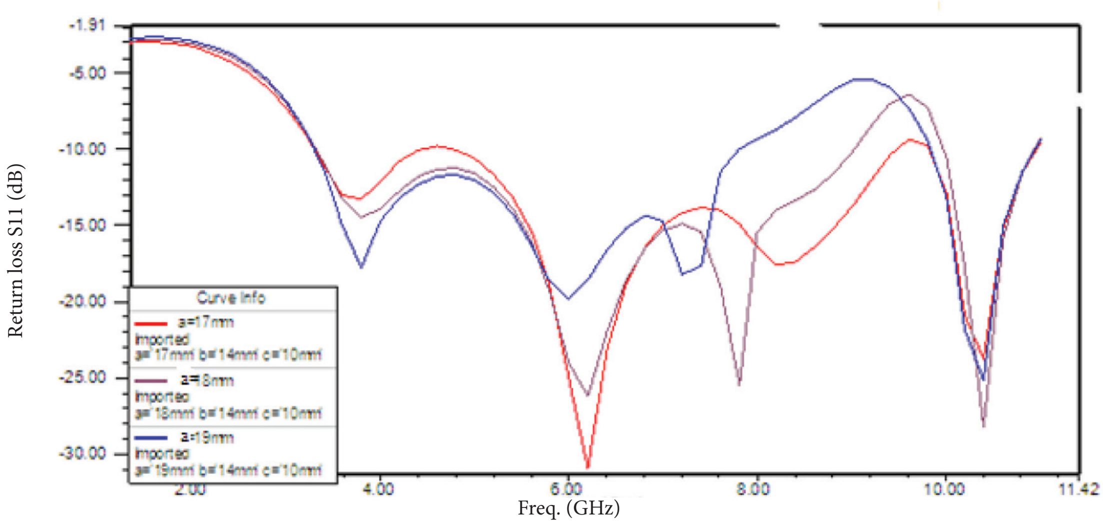

Figure 10. Parametric Study of 'a'.

4.3 Variation of Parameter 'c'

Further, the value of 'c' is parameterized by varying it from 9 to 11 mm with fixed values of parameters a and b. At c=9 mm bandwidth achieved in lower UWB band is better than the upper UWB band. As the value of 'c' is increased the bandwidth gets improved however on further increase the bandwidth is decreased. Finally the optimum value of c is 10mm as shown in Figure 12.

5. Variation in Length of Steps

After fixing the widths of various steps, to attain the ultra-wideband characteristics, the optimization of the proposed antenna is done in terms of length of the staircase (s1,s2,s4,s5). The proposed antenna is investigated for five different step sizes of staircase antenna, in this section. The return loss graph w.r.t. frequency for various

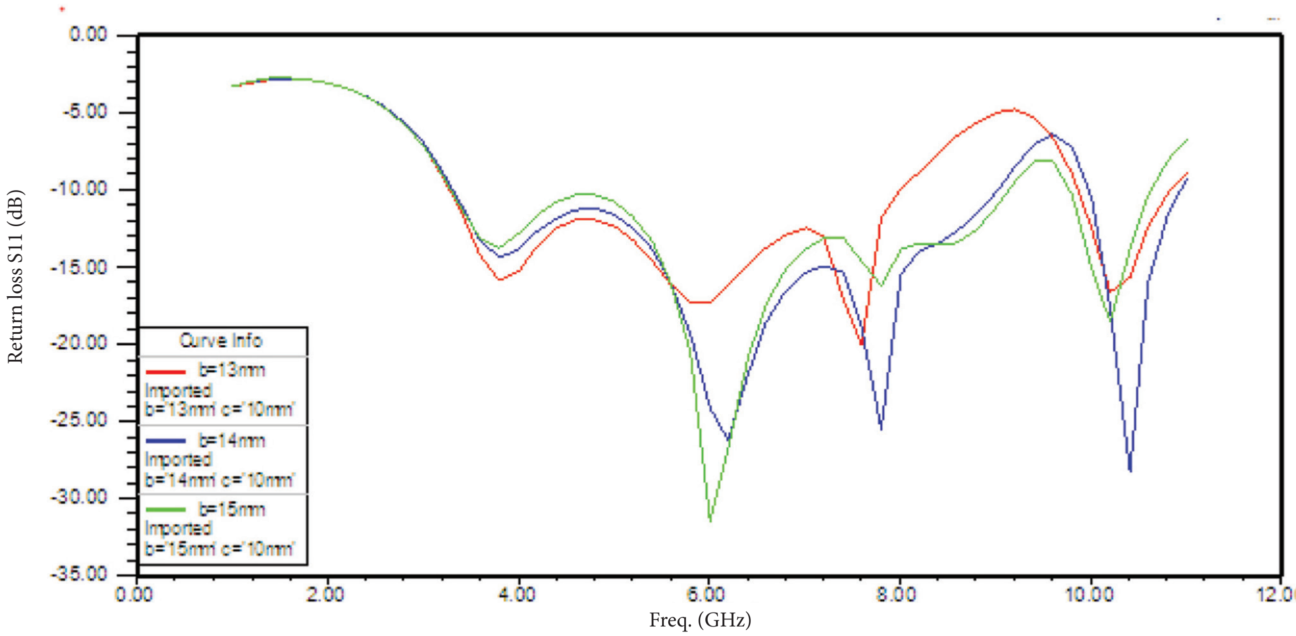

Figure 11. Parametric Study of 'b'.

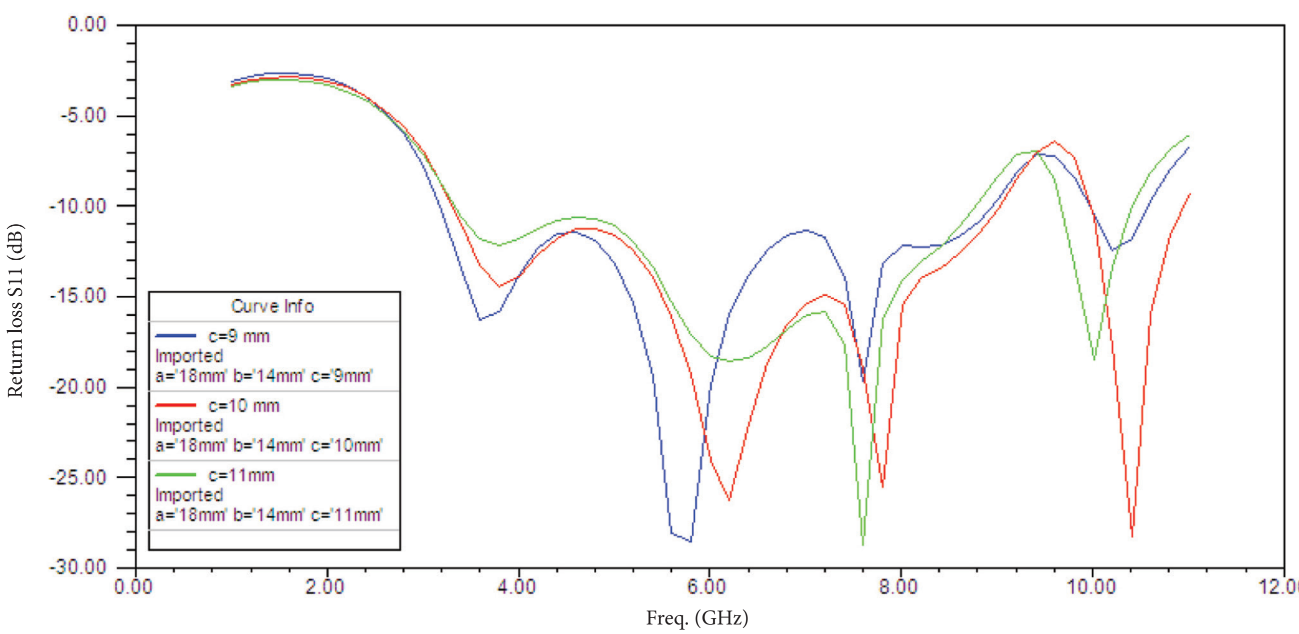

Figure 12. Parametric Study of 'c'.

step sizes has been observed from Figure 13. It is evident that step size 5,5,3,5 (black trace) gives better bandwidth which is necessary for wideband/UWB antennas.

The configuration of UWB antenna with dimension is demonstrated in Figure 14 and given in Table 1. The radiating patch has stairs like structure. FR4 epoxy substrate is used to design the antenna with a loss tangent value of 0.02 and dielectric constant of 4.4. The size of substrate is 30 × 30 sq. mm with thickness of 1.2 mm. To excite the antenna a micro strip feed line of 50 ohm is used. The width of feed line is 2.3 mm and ground length is of 10 mm.

Table 1. Parametric Study of Staircase antenna

Parameters	Size in mm
Width of first step(a)	17
Width of second step(b)	15
Width of third step(c)	10
Length of step1(S1)	5
Length of step2(S2)	5
Length of step3(S3)	8
Length of step4(S4)	3
Length of step5(S5)	5
Length of feed line(L_f)	4
Width of feedline(W_f)	2.3

The performance of the proposed antenna is described by the reflection coefficient curve in Figure 15. It has been observed that the proposed staircase antenna achieve the wideband from 3.8 to 9.8 GHz and 10.2 to 10.6 GHz which covers nearly the complete UWB band and suitable for UWB application.

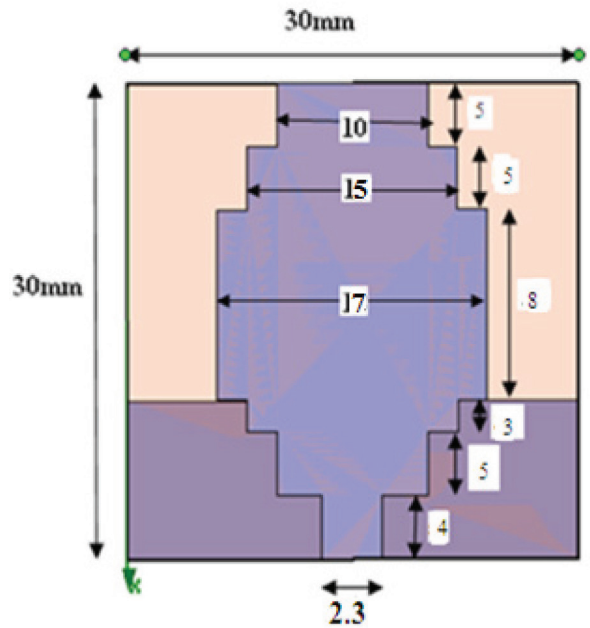

Figure 14. Detailed dimensions of Proposed Antenna.

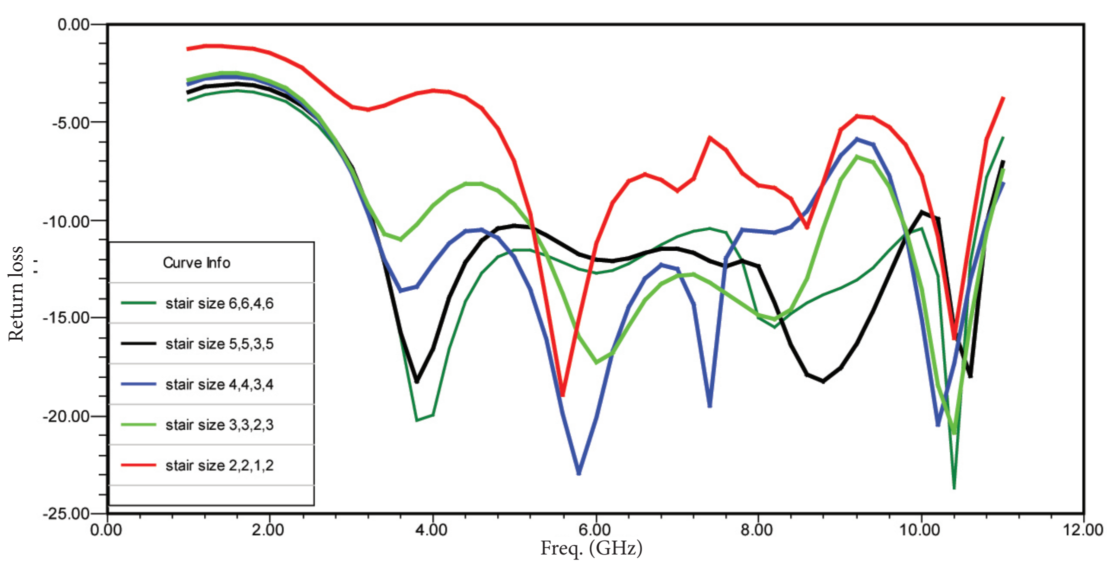

Figure 13. Effect of Variation in Step Length.

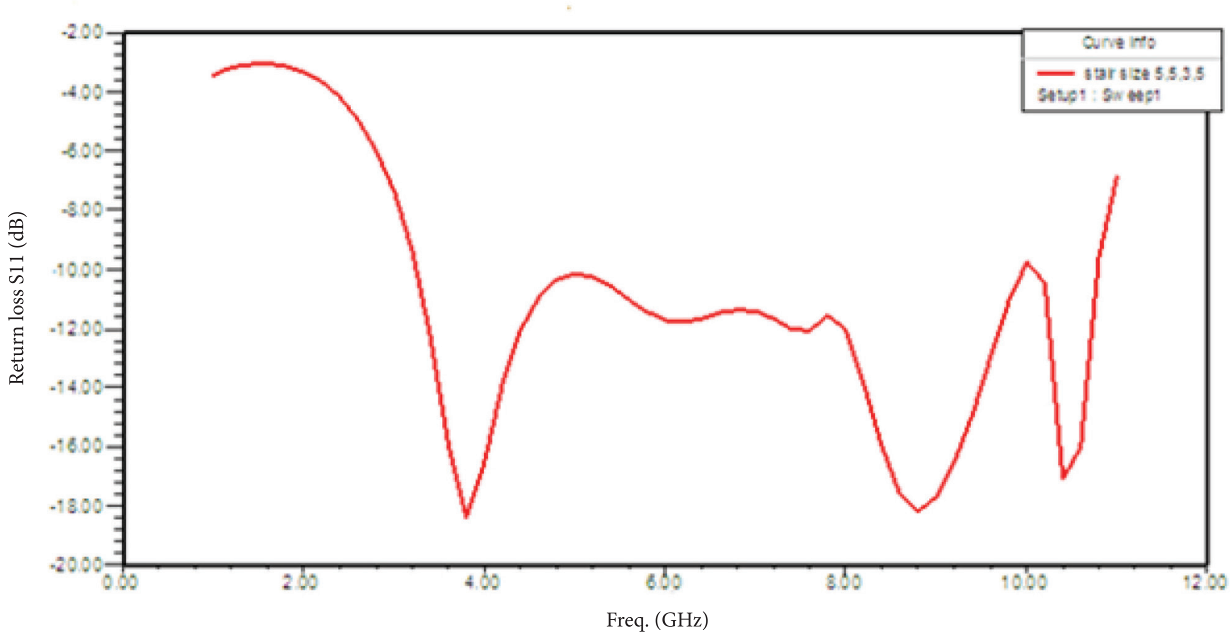

Figure 15. Simulation results of proposed antenna with rectangular ground.

6. Radiation Patterns of the Proposed Antenna

A radiation pattern describes the behavior of antenna's radiation in the surrounding space. The pattern is usually measured at a sufficient distance from the antenna known as far field. The 2D far field radiation patterns of the proposed antenna for simulated and measured normalized power patterns i.e. y-z plane (elevation) and x-y plane (Azimuth) pattern at different frequencies are discussed in this section. In Figure 16 (a) to (h) Co- and cross-polar radiation patterns of proposed antenna are taken at various frequencies i.eat 6.0 GHz, 7.8 GHz, 9.0 GHz and 10.4 GHz respectively in E-plane (Y-Z plane, phi=90, phi=0) and H-plane (X-Y plane, theta=0).

7. Measured Reflection Coefficient

The proposed antenna is fabricated using FR4 substrate by using Wet etching (photolithography) process. The front and back view of fabricated antenna with and without DGS as well as with double strip notch are shown in Figure 17. The reflection coefficient of antenna are measured using Vector Network Analyzer at UIET Kurukshetra. The simulated and measured result of fabricated antennas is shown in Figure 18 found in very good agreement. There is some shift in frequency, which may be due to mismatching between the antenna feeder and the connector, as well as due to dimensional error in fabrication process.

Figure 17. Prototype of proposed antenna.

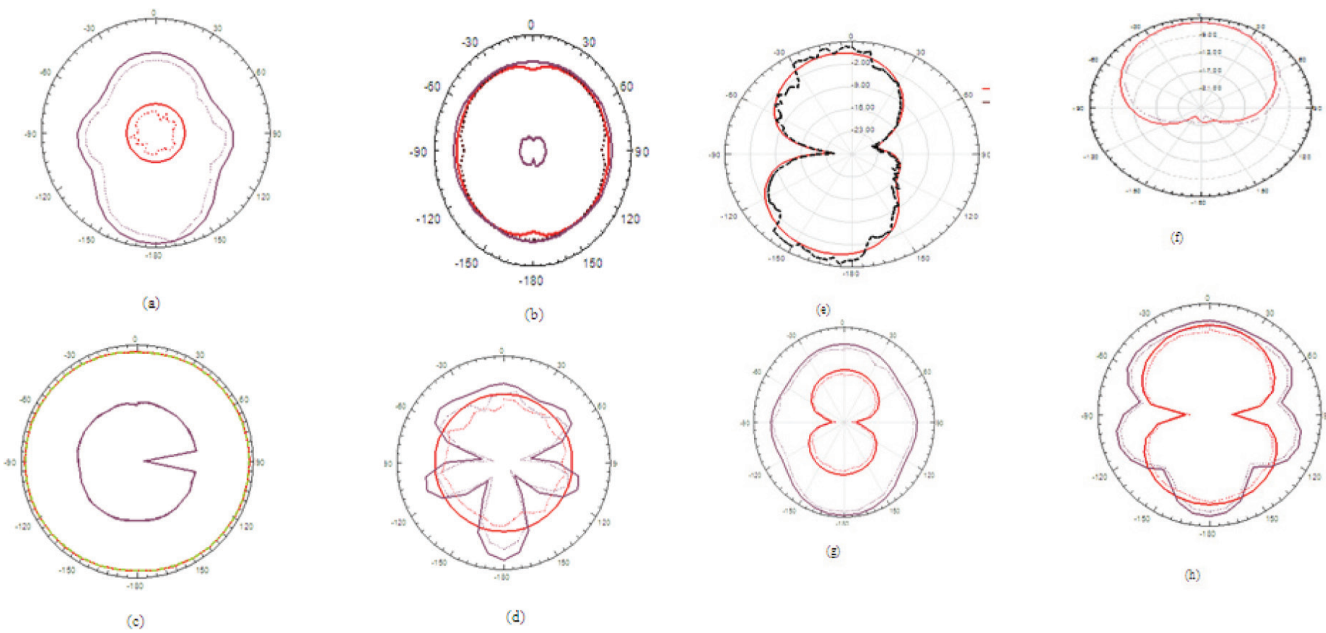

Figure 16. Simulated and measured Co- and cross-polar radiation patterns of proposed antenna (a) to (b) at 6.0 GHz, (c) to (d) at 7.8 GHz, (e) to (f) at 9.0 GHz and (g) to (h) at 10.4 GHz in E-plane (Y-Z plane, phi=90, phi=0) and H-plane (X-Y plane, theta=0).

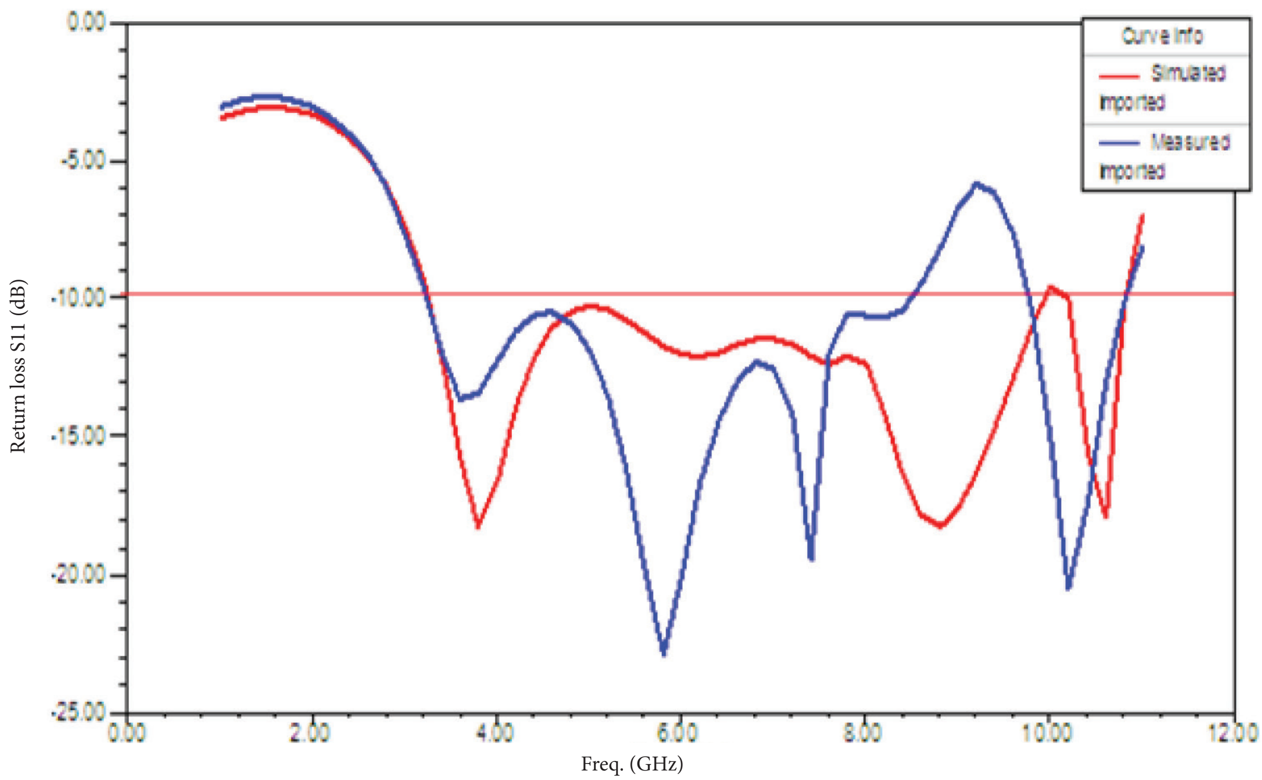

Figure 18. Simulated and measured results of proposed antenna.

8. Conclusion

A printed stair shape monopole antenna for ultra wide-band applications is presented in this paper. The proposed antenna was characterized for reflection coefficient, radiation pattern and current distribution. The effect of different parameters on antenna performance has also been studied. The simulation and measured result of the antenna prove that it has a good impedance matching over the UWB frequency range from 3.5-10.4 GHz. Its fabrication at low cost and the configuration of the proposed antenna is really simple. The proposed antenna is the best candidate for UWB systems as it follows all the characteristics of the UWB systems and can be used in various WPAN applications.

9. References

1. Qiu RC, Liu H, Shen X. Ultra-wideband for multiple access communications. IEEE Communications Magazine. 2005 Feb; 43(2):80-7. Crossref.
2. Liang J. Antenna study and design for ultra wideband communication applications. 2006; p. 1-202.
3. Jogi S. Ultra Wideband Technology Enabling High-Speed Wireless Personal Area Networks. Intel White Paper. 2009.
4. Benedetto MGD, Kaiser T. Federal Communications Commission. In the matter of revision of part 15 of the commission's rules regarding ultra-wide band transmission systems. First Report and Order. 2002; p. 1-118.
5. Allen B, Dohler M, Okon E, Malik W, Brown A, Edwards D. Ultra wideband antennas and propagation for communications radar and imaging. John Wiley & Sons. 2006; p. 1-19.
6. Yoshioka H, Yang L, Tammam E, Yoshitomi K. A highly compact dual-band WLAN/UWB monopole antenna. IEICE Electronics Express. 2012; 9(3):160-4. Crossref.
7. Oudayacoumar S, Karthikeyan T, Hariprasad V. A triple-band microstrip fed monopole antenna using defected ground structure for WLAN and Wi-MAX applications. International Conference on Advances in Electrical Engineering. 2014; p. 1-4. Crossref.
8. Tariq MH, Rashid S, Bhatti FA. Dual Band Microstrip Patch Antenna for WiMAX and WLAN Applications. International Journal of Multidisciplinary and Current Research. 2014 Jan; 2:1-5.
9. Mewara HS, Sharma M, Sharma MM, Dadhich A. A novel ultra-wide band antenna design using notches and stairs. International Conference on Signal Propagation and Computer Technology (ICSPCT). 2014; p. 425-9. Crossref.
10. Padmavathy AP, Madhan MG. An improved UWB Patch Antenna Design using Multiple Notches and Finite Ground Plane. Journal of Microwaves Optoelectronics and Electromagnetic Applications. 2015 Jun; 14(1):73-82. Crossref.