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Design of defected ground structure antenna for UWB applications

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Abstract- In this paper, an ultra-wideband antenna is designed with Y-shaped patch and a defected ground plane in which two symmetrical U-shaped slots is made. The proposed antenna fulfils the criteria of ultra-wideband from frequency range of 2.87 GHz to 12 GHz. The simulated value of VSWR is less than two for the proposed design .The gain of the antenna is attained more than 5 dB. By using defected ground structure gain, bandwidth and reflection co-efficient parameter are improved. The proposed antenna is capable for various applications such as WIMAX, WLAN, Spacecraft, satellite and X-band etc. In this paper different result of antenna such as reflection co-efficient, gain, VSWR, radiation pattern are discussed using ANSOFT HFSS**.**

Keywords— *U-shaped slot, UWB antenna, WIMAX, WLAN, Satellite application.*

1. INTRODUCTION

Now-a-days ultra wide band antenna is preferred due to its various attributes like simple in design, impedance bandwidth and Omni-directional radiation pattern. The easiest method to construct all these antennas is by using microstrip feeding technique. Microstrip patch antenna is comprised of a radiating patch at one X-Y plane of a dielectric substrate and a ground plane is on the inverted X-Y plane of substrate. A defect in the ground structure is the most widely used techniques for the purpose of implementation of the patch antenna [1]-[4]. DGS structure is obtained by adding defects in the ground plane which will affect the distribution of current which depends on the size and shape of defect. The distribution of current will also affects the input impedance and the direction of passage of current of the antenna. DGS structure can also restrain the propagation of electrical and magnetic waves and the excitation which is passed through the dielectric substrate of the antenna [5]. The frequency band of WIMAX (Worldwide interoperability for microwave Access) band lies between 2.87 GHz to 4.38 GHz. There are two types of bands for the requirement of WIMAX. First one is the medium band which starts from 3.2 GHz to 3.8 GHz and other band is called the high band which starts from 5.2 to 5.8 and WLAN (Wireless local area network) serves the purpose from 4.79 GHz to 6 GHz [6]-[13]. These two standards have various characteristics like high-speed, cost effective, simple structure, easy to fabricate than other designs. They are used in hand-held computers and intelligent networks. The installation of optical fibre cable at remote places is a cumbersome method so WIMAX overcome these challenges by exchanging the cable and helps in fitting the requirement of wireless broadband connection. The coverage of 30 m is provided by the WIMAX band which is more than as compared to MAN (Metropolitan area network) with a length of 50 km [14]-[18]. The various services are provided by WIMAX band such as data and telecommunication services etc. As wideband antenna uses the frequency spectrum of WIMAX band for its operation so patch antennas are preferred over other types of antennas. They are more commonly used in the design of an antenna because of its simple design, minimum cost, easy to fabricate and compatibility factor as compared with other antennas [19]. They are preferred for those applications which have high frequency as the parameters of an antenna changes with the variation in wavelength and resonant frequency [20]. The IEEE 802.11a which starts from

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5.20 GHz to 5.775 GHz, Satellite application for X-band covers from 8 GHz to 12 GHz respectively are described in [21]-[24].

In this paper, two symmetrical U-shaped defects are etched from the ground plane and Y-shaped patch with a feed-line is embedded into the patch element. The length, width and height of the antenna are 64×60×1.57 mm^3 respectively. The proposed antenna satisfies the criteria of an ultra frequency band of 2.87 GHz to 12 GHz. The antenna parameters like gain, reflection co-efficient and radiation pattern can be analyzed and simulated with the help of ANSOFT HFSS software.

II MATHEMATICAL APPROACH FOR DEFECTED GROUND STRUCTURE

Design equations for defected ground structure patch antenna are described in [25]

A To calculate the patch width

$$w = \frac{c}{2fr\sqrt{\frac{\varepsilon r+1}{2}}} \quad (1)$$

Where w = Width of the patch
fr = resonant frequency
c= Velocity of light

B To calculate the patch antenna length

$$L = Leff - 2\Delta L \quad (2)$$

$$Leff = \frac{c}{2f0\sqrt{\epsilon eff}} \quad (3)$$

Where ϵ eff can be calculated by

$$\in eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}(1+12h/w)^{1/2} \quad (4)$$

And ϵ eff is the effective dielectric constant of the substrate

III. ANTENNA STRUCTURE AND ITS DESIGN

The proposed antenna comprises of a ground plane as in rectangular shape with dimensions of 40×23 mm2 on the X-Y plane of the substrate. The rectangular ground plane is having two symmetrical U-shaped slots. On the inverted X-Y planes, a Y-shaped patch with microstrip-fed is designed. For the purpose of better impedance matching by the patch antenna microstrip feed line with a length of 24.26 mm and a width of 3 mm is used. The proposed antenna is designed with RT-DUROID 5870 dielectric substrate having a dimension of 46×40 mm2, loss tangent of 0.0012 and thickness of 1.57 mm respectively.

The design of proposed antenna, front side of proposed antenna and back side of proposed antenna are shown in fig. 1, fig.2 and fig.3 respectively.

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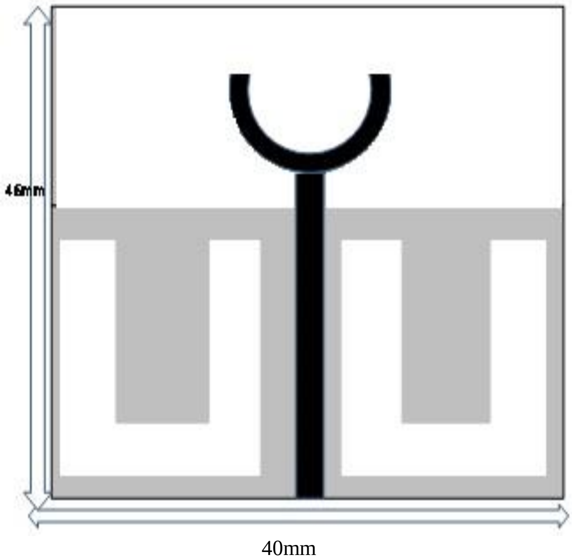

Fig.1. Design of proposed antenna

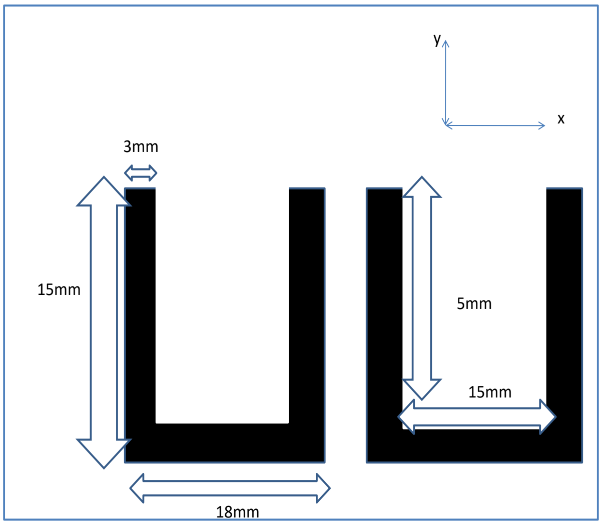

Fig.2. Front side of proposed antenna

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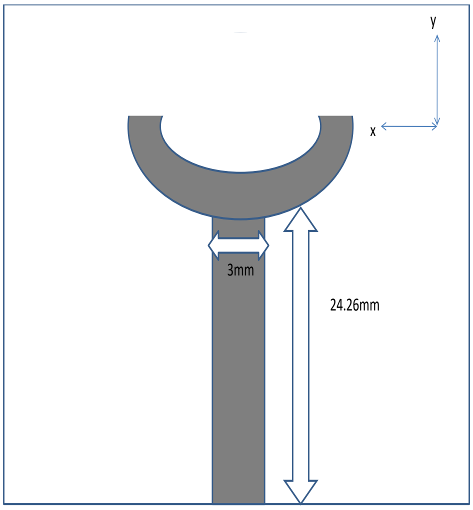

Fig.3. Back side of proposed antenna

Table 1 showing different parameters and their respective length (in mm)

Parameter	**Length (in mm)**
Ground structure width	23
Ground structure length	40
Thickness of substrate	1.57
Radius of inner circle R1	9
Radius of outer circle R2	13
Length of substrate	46
Width of substrate	40

IV RESULTS

The proposed antenna and its parameters have been analyzed by ANSOFT HFSS software. Fig 4 shows the reflection co-efficient characteristics of the proposed antenna. It is observed from fig. 4 the minimum value of reflection co-efficient is -36 dB at 3.3 GHz. The bandwidth of proposed antenna is 9.31 GHz which is from 2.87 GHz to 12 GHz.

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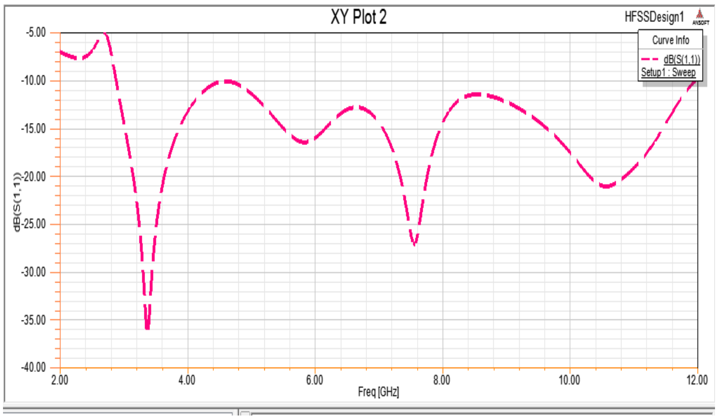

Fig.4. Reflection co-efficient parameter of proposed antenna

Fig 5 shows VSWR characteristics for the proposed antenna. From the fig.5 it has been observed that for the entire ultra band of 2.87 GHz to 12 GHz, the value of VSWR is less than 2. It means the antenna is properly matched.

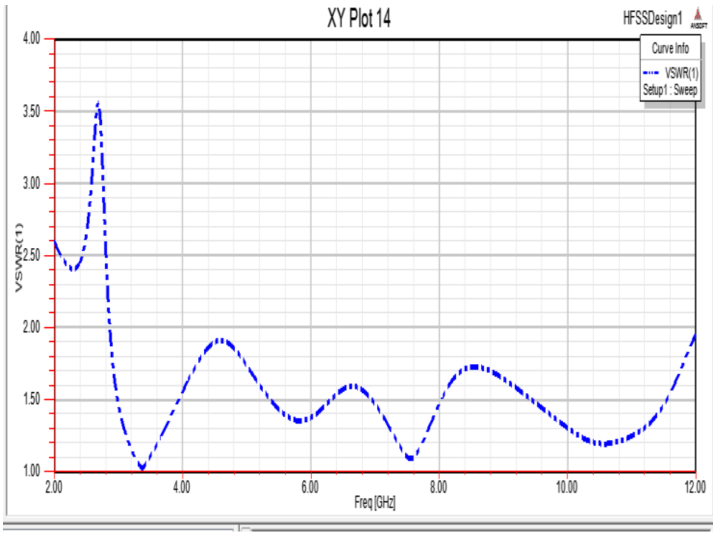

Fig.5. Plot showing simulated voltage standing wave ratio (VSWR)

Fig 6 shows variation in reflection co-efficient at different dimensions of feed line. Earlier the length and width of feed-line are set at the values of 24.26 mm and 3 mm and it is observed that on extending the length by 0.7mm and width by 0.4mm is shows good results so the final length and width of feed-line is 24.96mm and 3.4mm respectively.

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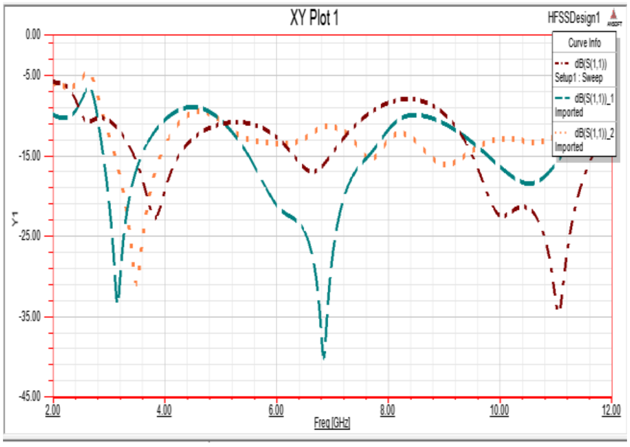

Fig.6. Variation in reflection co-efficient at different feed-line dimension

Fig 7 shows variation in reflection co-efficient at different values of the radius of the radiating patch. Initially the dimension of inner and outer radius of semicircle is 9 mm and 13 mm taken respectively. Firstly the size of the inner and outer radius of semicircle is increased by 0.4 mm and the red colour line is obtained as shown in fig.7. After that the size of the inner and outer radius of semicircle is increased by 0.7mm and the blue colour line is obtained. So finally we choose the dimension of inner and outer radius of semicircle is 9.7 mm and 13.7 mm respectively and the reflection co-efficient is shown by blue colour line.

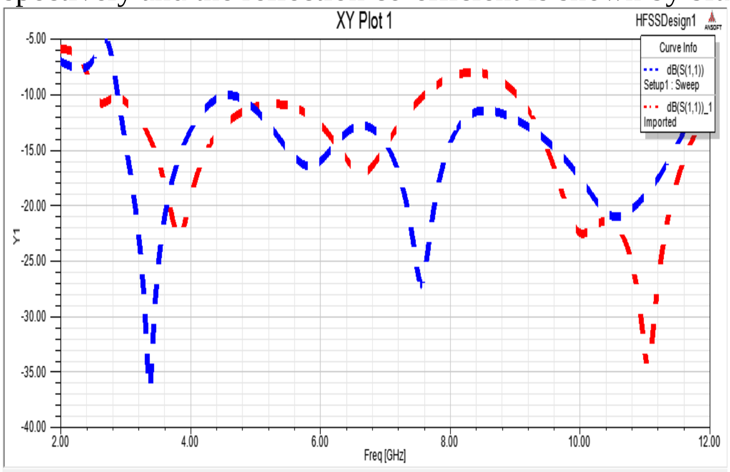

Fig.7. Variation of reflection coefficient as the radius of circle changes

Fig 8 shows the variation in reflection co-efficient as the shape of patch changes. It has been observed from the fig 8 that the pink line as better than the blue line in terms of values of reflection co-efficient so that dimension of patch is selected as per pink line.

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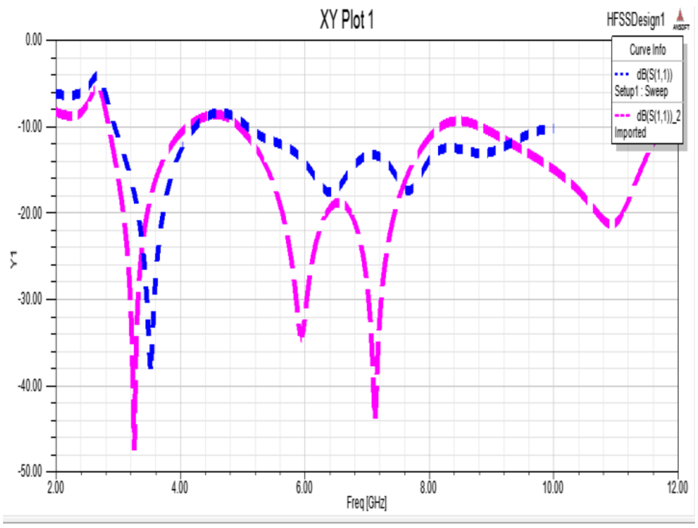

Fig.8. Variation in reflection co-efficient as the shape of patch changes

Fig. 9 and fig.10 shows current field distribution at resonant frequency of 3.3 GHz and 7.5 GHz. Current distributions describe that which part of the antenna should be responsible for resonant frequency because of resonant frequency is inversely proportional to path length of current distribution.

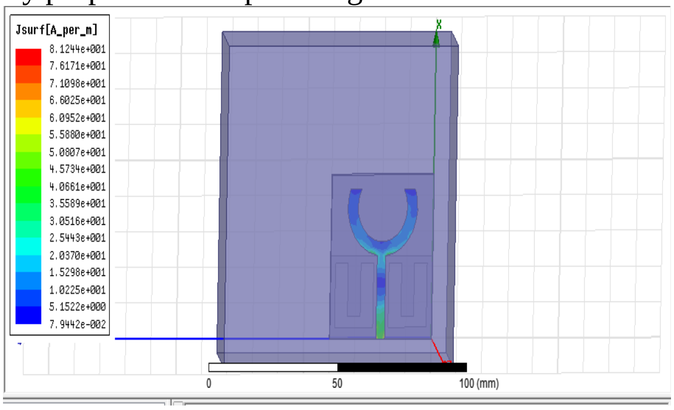

Fig.9.Current distribution at 3.3 GHz

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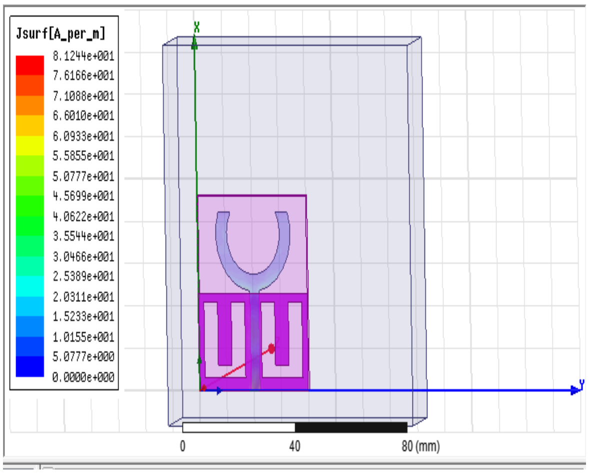

Fig.10. Current distribution at 7.5 GHz

Fig.11 to fig.14 shows radiation pattern of E-plane and H-plane at the two resonant frequencies. E-plane can be determined by taking phi as 0 degree and theta as all values which is shown by figure 11, 12. H-plane can be determined by taking phi as 90 degree and theta as all values which can be shown by figure13, 14. Radiation pattern is the graphical representation of radiation intensity of antenna at different values of phi and theta. It is observed from the fig. 11 to fig. 14 that the E plane and H plane radiation pattern are bi-directional and Omni-directional pattern respectively.

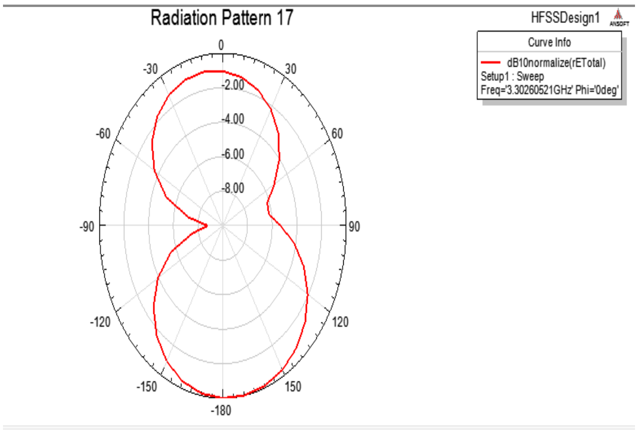

Fig.11. E-plane at 3.3 GHz

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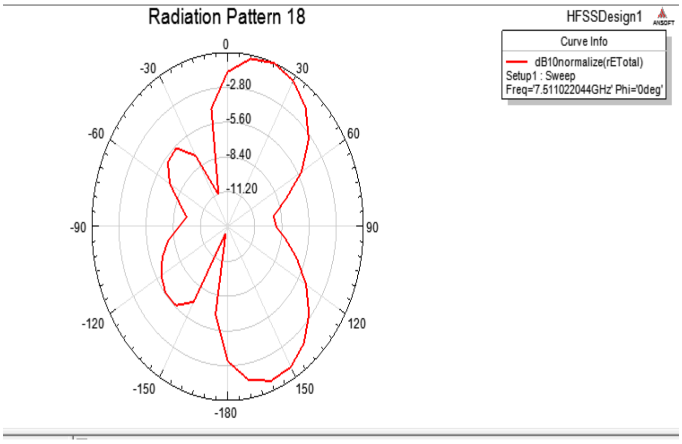

Fig.12. E-plane at 7.5 GHz

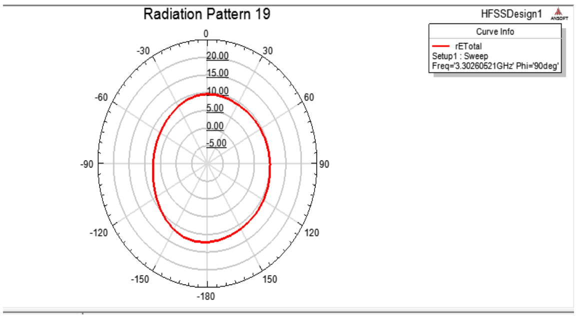

Fig.13. H-plane at 3.3 GHz

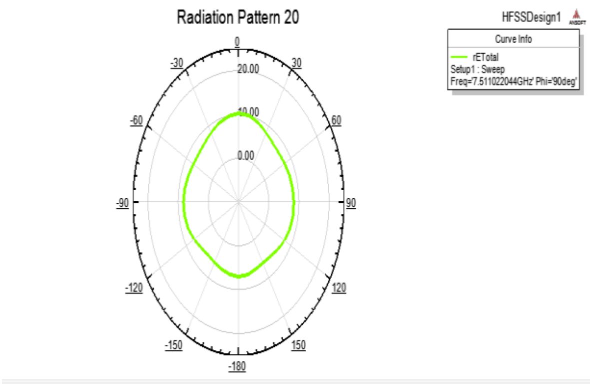

Fig.14. H-plane at 7.5 GHz

Fig 15, 16 shows 3-dimensional polar plot at 3.3GHz and 7.5 GHz frequency band. It can be observed from the diagram that maximum gain for 3.3 GHz frequency range is 7dBi for all values of theta and phi.

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Variation of theta angle lies from 0 to 360 degree with a step size of 10 degree and variation of phi angle lies from 0 to 180 degree with a step size of 10 degree.

And for 7.5 GHz frequency range maximum value of gain is 5 dBi which is shown by red colour in fig.16.

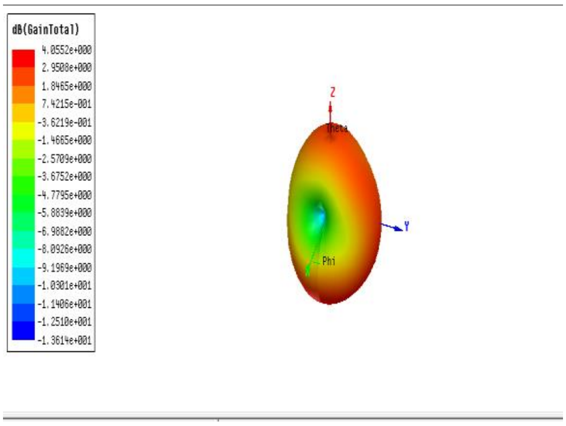

Fig.15. 3D polar plot for 3.3 GHz

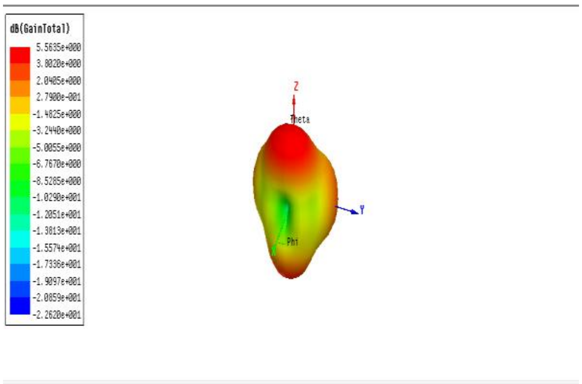

Fig.16. 3D polar plot for 7.5 GHz

V Conclusion

A novel type of antenna is designed with Y shape patch and defected ground plane. Two symmetrical defects of U-shaped have been inserted into the ground structure. The proposed antenna satisfies the criteria of ultra-wideband from frequency range of 2.87 GHz to 12 GHz and UWB covers WLAN, WIMAX, satellite and X-band applications. The proposed antenna has achieved enhanced reflection co-efficient, better impedance matching and good radiation pattern. Moreover H -plane radiation pattern of the antenna is Omni-directional. As it can be analyzed from this work the proposed antenna dimensions are well optimized and used for wideband applications.

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