

Design of Star-Shaped Microstrip Patch Antenna for Ultra Wideband (UWB) Applications

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ABSTRACT

The design and analysis of a new ultra wideband microstrip antenna for optimum performance that satisfied a large bandwidth starting from 3.9GHz to 22.5GHz is introduced . The UWB antenna is capable of operating over an UWB as allocated by the Federal Communications Commission (FCC) with good radiation properties over the entire frequency range. The techniques of enhancing the bandwidth of microstrip UWB antenna were utilized to enhance the performance of the designed antenna. The effect of shifting feed line from the center of patch to the edges was studied in addition to the effect of changing the length of the ground plane. The antenna was designed and simulated using High Frequency Structure Simulator HFSS software packages..

KEYWORDS

UWB, Microstrip line feed, Patch antenna, offset feed.

1. INTRODUCTION

The Federal Communication Commission (FCC) specified some rules for Ultra Wideband (UWB) antenna implementations. It specified the antenna impedance bandwidth form 3.1GHz to 10.6 GHz and any signal that occupies at least 500MHz spectrum can be used in UWB systems[1]. UWB technology can be considered as the most promising wireless technologies that guarantee to provide high data rate transmissions, low complexity, very low interference and easy connection in many different devices such a laptop, digital camera, and high definition TV. Furthermore, it allows the industry to provide a greater quality of services to the end users. High-performance printed circuit board antennas are essential in portable systems [2].The microstrip antennas are considered to be a key component for these applications due to its advantages such as, low profile, low cost, ease of integration with microwave integrated circuits (MIC) and light weight. It consists of a perfect conducting patch over a thin dielectric material called the substrate that is placed above a ground plane. There are many different patch shapes such as the rectangular, circular, elliptic, circular ring, triangular and hexagonal. There are various techniques for feeding the antenna such as microstrip line feed, coaxial probed feed, aperture-coupled and electromagnetically coupled [3]. The major disadvantages of a microstrip antennas are low power handling capability and narrow bandwidth[4]. There are continuous works for increasing the bandwidth using different techniques. One of them a technique with less complexity in structure depends on small cut on the outskirts at the upper and lower edge of patch [5]. The used of two steps at the lower edge of patch, a single horizontal rectangular slot on the patch also give good

results [6]. Recently other techniques have been examined to enhance the UWB antenna using of modified shape of short ground plan. Also making multiple rectangular slots at top side of the ground plane enhances the bandwidth of antenna [7]. A larger patch with an etched slot at the lower edge of antenna with vertical slot on patch and small cut on ground plane so modified the impedance bandwidth of antenna [8]. All these techniques and others are based on the modification of the surface current destruction to enhance the antenna bandwidth.

In this paper, a microstrip star-shape antenna was studied using Ansoft's HFSS software package. HFSS is a full-wave electromagnetic simulator based on the finite element method that is considered to be the industry standard for electromagnetic and antenna simulations [9]. The antenna consists of a star-shape radiating element with a partial ground plane and a microstrip line feed from the edge of the patch. The parameters structure of the antenna was optimized to achieve the widest antenna bandwidth and impedance matching.

2. STAR-SHAPED MICROSTRIP PATCH ANTENNA

2.1 Antenna Structure

The structure and dimensions of the proposed antenna are given in Figure 1. A 50 Ω microstrip feed line is printed on the top of "Arlon DiClad 880 (tm)" substrate. The substrate has a thickness of $h=1.9\text{mm}$ and a relative permittivity $\epsilon_r = 2.2$, $l_s=25\text{mm}$ and $w_s=15\text{mm}$ denoting the length and the width of the substrate, respectively. The width of the microstrip feed line is fixed at $w_f=4.7\text{mm}$ to achieve 50 Ω impedance. On the other side of the substrate, the conducting ground plane has a length of $l_g=7.1\text{mm}$ and width w_g the same of substrate width.

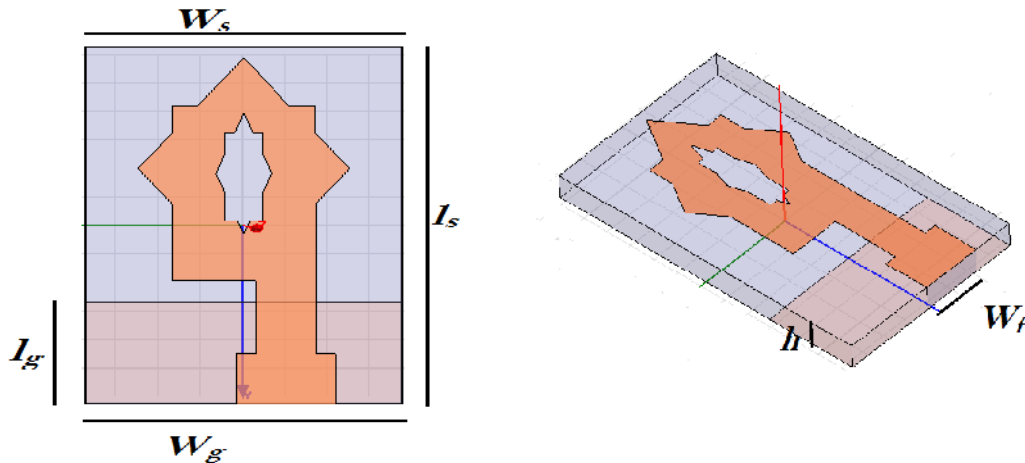


Figure 1. star shape antenna

2.2 Result and Discussion

2.2.1 Antenna Bandwidth

Frequency bandwidth (BW) is the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. The frequency bandwidth of an antenna can be expressed as either absolute bandwidth (ABW) or fractional bandwidth (FBW) as shown in equation 1 and 2

$$ABW=f_H-f_L \tag{1}$$

$$FBW=2\left(\frac{f_H-f_L}{f_H+f_L}\right) \tag{2}$$

Where f_H , f_L and f_c denote the upper edge ,lower edge and center frequency respectively. For broadband antennas, the bandwidth can also be expressed as the ratio of the upper to the lower frequencies, where the antenna performance is acceptable, as shown in equation 3[1].

$$BW=\left(\frac{f_H}{f_L}\right) \tag{3}$$

The bandwidth of antenna can be considered as the range of frequencies bounded by the S_{11} that is lower than -10dB and it can be calculated from the S_{11} (dB) plot [1]. Figure 2 shows that the bandwidth covering an extremely wide frequency range from 3.9GHz to 22.5GHz with a operating frequency of 10.29 GHz.

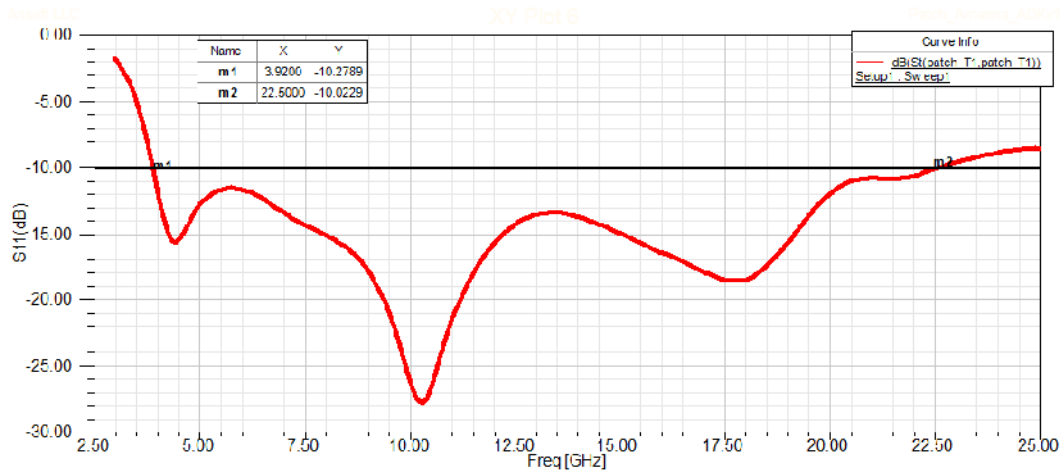


Figure 2. S_{11} (dB) of antenna

2.2.2. Antenna Impedances

The microstrip transmission line feed was selected as feeding techniques for desired antenna. In this method a conducting strip connects directly to the edge of microstrip patch. The advantage of this technique comes from that layout, where the feed can be etched to same substrate to provide a planar structure [10]. The most challenge in design microstrip line is to calculate the width of line that provides good impedance matching. There is a relatively straight forward equation to calculate the characteristic impedance Z_0 given, feed line width w_f , substrate height h , and effective dielectric constant ϵ_{eff} [3].

For $\frac{w}{h} \geq 1$

$$\epsilon_{eff} = \frac{(\epsilon_r + 1)}{2} + \frac{(\epsilon_r - 1)}{2} \left[1 + 12 \frac{h}{w_f} \right]^{-1/2} \tag{4}$$

$$Z_0 = \frac{120\pi}{\sqrt{\epsilon_{eff} \left[\frac{w_f}{h} + 1.393 + 0.667 \ln \left(\frac{w_f}{h} + 1.444 \right) \right]}} \tag{5}$$

From equation 4 and 5 we found that to achieve 50 Ω characteristic impedance the w_f is equal to 5.8mm, but the optimized value using HFSS software we found that $w_f=4.7$ mm.

Figure 3 shows the resistance and reactance behavior of the antenna as a function of frequency. It shows that the low S_{11} (<-10dB) always occurs over the frequency range when the input impedance is matched to 50 Ω, i.e. the input resistance R is close to 50 Ω while the input reactance X is not far from zero. At operating frequency, the resistance is closed to 50 Ω and the reactance closed to 0, thus resulting in an impedance matching at the antenna and hence increasing of the operating bandwidth.

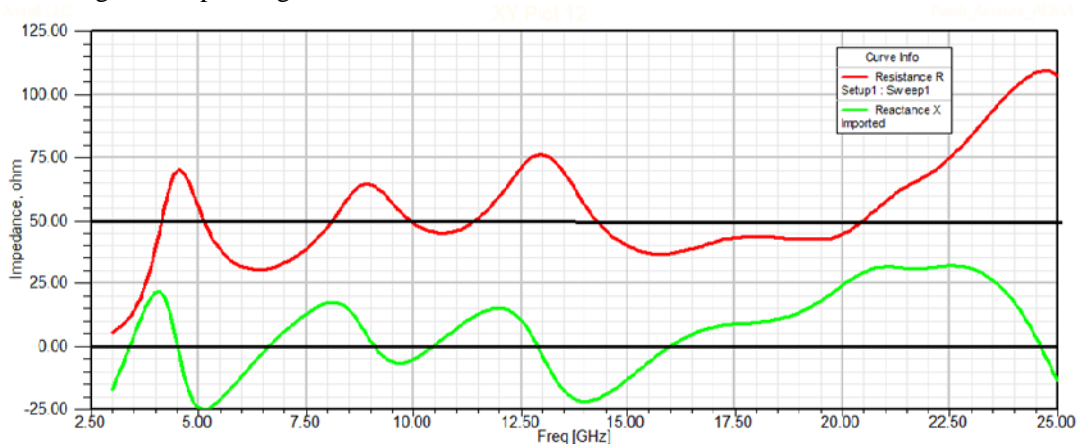


Figure 3. Resistance R and Reactance X

2.2.3 Antenna Gain

The simulated of maximum gain of the optimized antenna at $\phi = 0^\circ, 90^\circ$ and $\theta = 0^\circ - 180^\circ$ as a function of frequency is illustrated in Figure(4). It shows that at 10.29 GHz and 17.8GHz frequency the gain is 4.48dB and 4.4dB respectively at $\phi = 90^\circ$, but at $\phi = 0^\circ$ the gain is 1.95dB and 5dB for both 10.29 GHz and 17.8GHz frequency respectively.

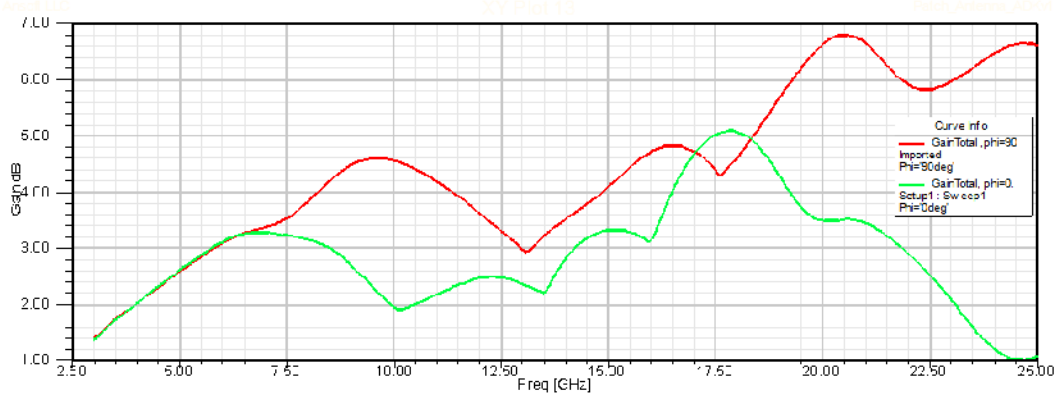


Figure 4. The simulated Gain of the antenna at $\phi = 0^\circ, 90^\circ$ and $\theta = 0^\circ - 180^\circ$ over frequency band

2.2.4 Antenna Radiation pattern

Figure 5 illustrates the simulated of radiation pattern for both frequency 10.29GHz and 17.8GHz at $\phi = 0^\circ, 90^\circ$ and, $\theta = 0^\circ - 180^\circ$

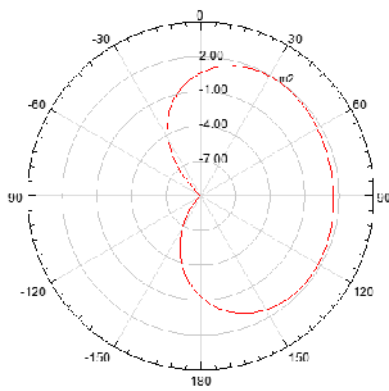


Figure 5.a. radiation pattern at 10.2GHz, $\phi = 0^\circ$

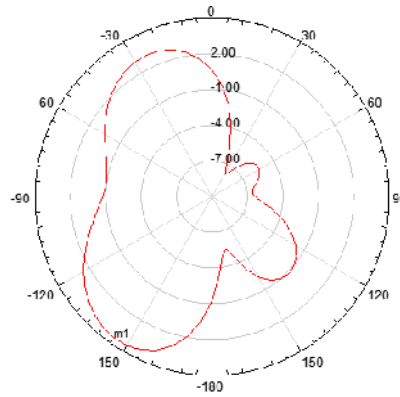


Figure 5.b. radiation pattern at 10.2GHz, $\phi = 90^\circ$

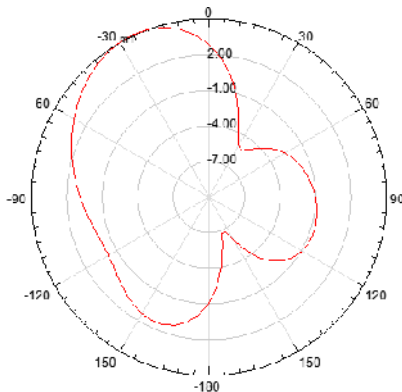


Figure 5.c. radiation pattern at 17.8GHz, $\phi = 0^\circ$

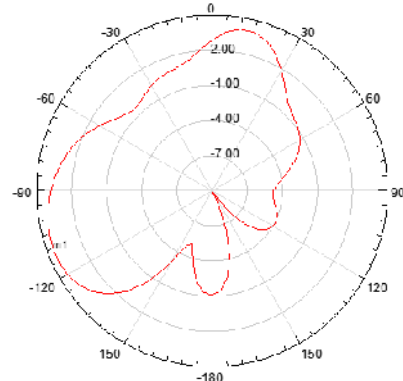


Figure 5.d. radiation pattern at 17.8GHz, $\phi = 90^\circ$

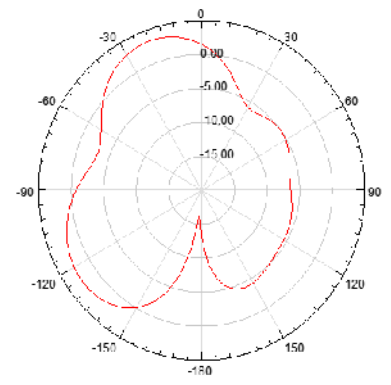
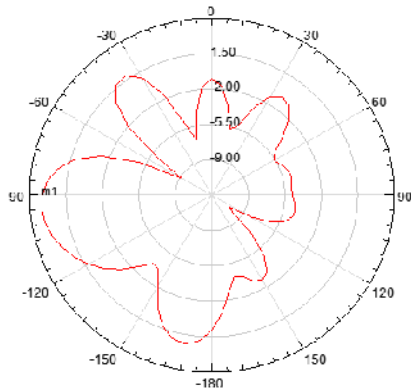


Figure 5.e. radiation pattern at 17.8GHz, $\theta = 0^\circ$

Figure 5.f. radiation pattern at 10.19GHz, $\theta = 90^\circ$

From Figure 5.a-b we can notice that the radiation pattern at 10.9GHz when $\phi = 90^\circ$ is more directional compare to that at $\phi = 0^\circ$. Also from Figure (5.c-d) it is shown that the radiation pattern at 17.8GHz, when $\phi = 0^\circ$ is more directional than that at $\phi = 90^\circ$ Figure 5.e-f show the horizontal plane of radiation pattern at $\theta = 90^\circ$.

2.3 Parametric Study

A parameter study was conducted to optimize antenna parameters. It helps to investigate the effect of different parameter on the impedance bandwidth. The effect of feed line shift of microstrip line and the ground plane length are studied. All the antenna parameters were kept constant in the simulation except for the parameter of interest.

2.3.1 Effect of feed shift(Offset feed)

Figure 6 illustrates the simulated of S11(dB) for different feed shift steps for microstrip line feeder from the center of radiating element to its edge when the ground plan width equal to $w_g = 15$ mm and its length is fixed at $l_g = 7.1$ mm. Shift steps of $\Delta = 0, 0.4, 0.8, 1.2, 1.6,$ and 2mm were simulated.

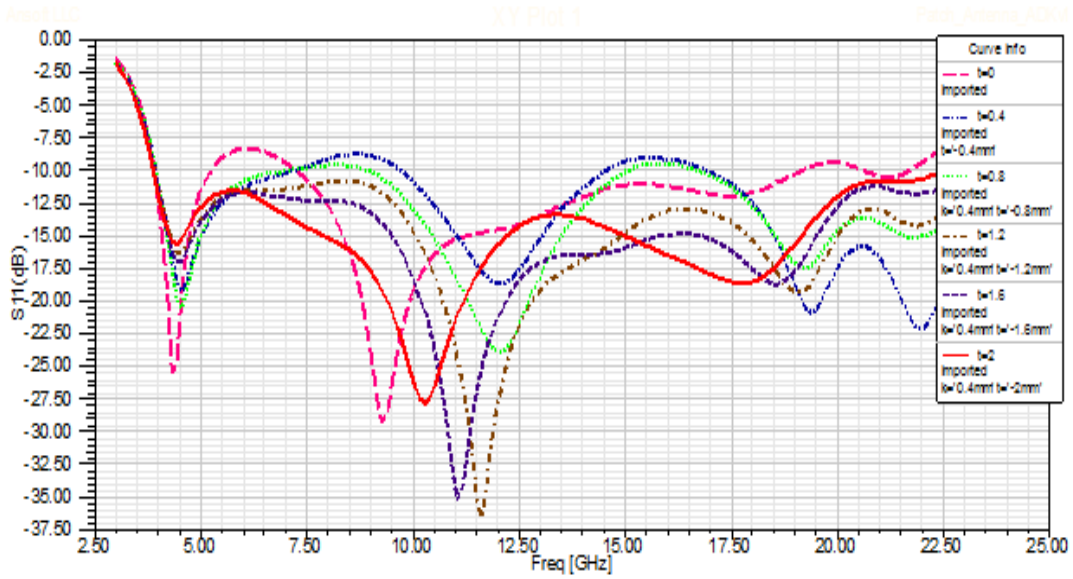


Figure 6. Simulated of S_{11} (dB) curves for different feed shift

It is shown in Figure 6 that the -10dB operating bandwidth of the antenna varies remarkably with the variation of the feed shift t . The optimal feed shift is found to be 2mm with the bandwidth covering an extremely wide frequency range from 3.9GHz to 22.5GHz. The center frequency 10.29 GHz is obtained which is very close to the desired frequency of operation. It was observed from many trials of simulations that as the feed line location is moved away from the center of the patch, the center frequency starts to decrease and the bandwidth increase.

The current distributions on the patch for each feed shift are shown in Figure 7.

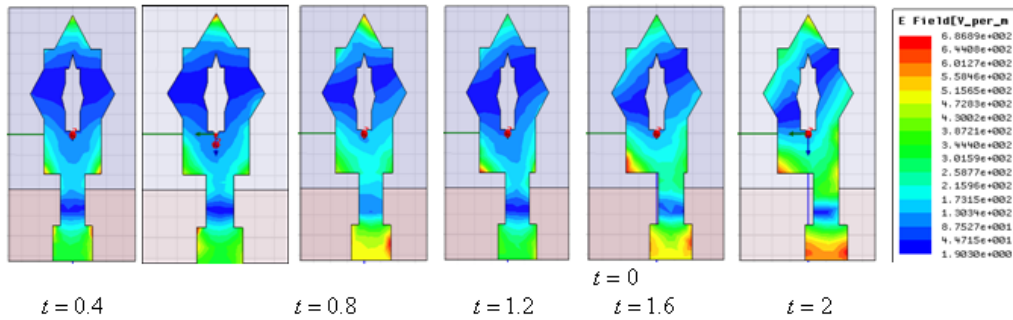
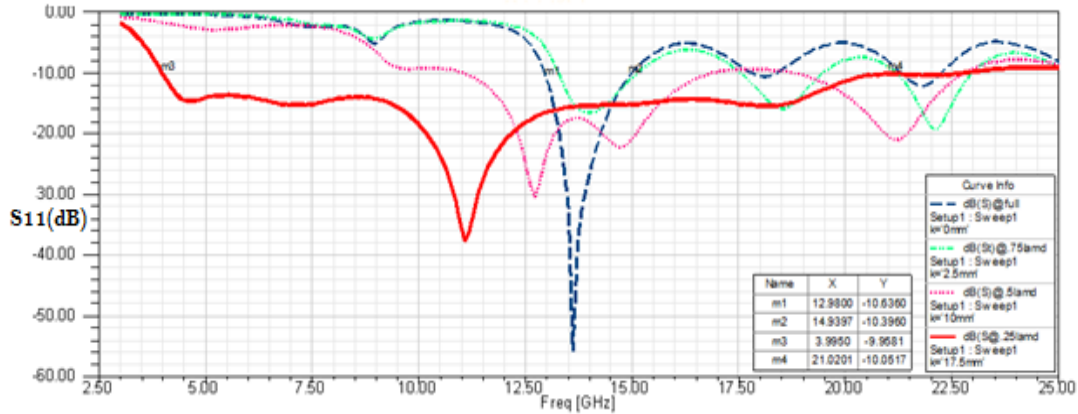


Figure 7. feed shift steps for microstrip-fed line with current distribution on patch

2.3.2 Effect of the Ground Plane

In previous section, it has been demonstrated that the variation of the feed shift t leads to the variations of the frequency bandwidth. In a broad sense, the ground plane serves as an impedance matching circuit and also it tunes the resonant frequencies [1]. To conform this, Figure 8 is given were the simulated S11(dB) curve for the antenna with different ground lengths ($l_g = \lambda, 0.75 \lambda, 0.5 \lambda, 0.25 \lambda$).

Figure 8. Simulated of S₁₁(dB) curve for different ground plan length



($l_g = \lambda, 0.75 \lambda, 0.5 \lambda, 0.25 \lambda, 0.239 \lambda$)

It is noticed in Figure 8 that for full ground plan the first-10dB bandwidth ranges from 12.9GHz to 14.9GHz, which is much narrower than that of a short ground plane. This is due to the impedance mismatch over an extremely frequency range resulting from the full ground plane. When the length of ground plane starts to decrease, $l_g = 0.75, 0.5$ we see that the bandwidth range starts to increase gradually and the S11 under -10dB curve becomes wider at $l_g = 0.25$ bandwidth start from 3.9GHz to 21.GHz. The optimum values was found by optimizing the antenna is $l_g = 0.239 = 7.1\text{mm}$ were the bandwidth ranges from 3.9GHz to 22.5GHz with little frequency shift. Table 1 shows the value of the bandwidth at different length of the ground plane

| l_g | Start frequency GHz | End frequency GHz | Bandwidth GHz |
|-----------------|---------------------|-------------------|---------------|
| λ | 12.9 | 14.9 | 2 |
| 0.75λ | 13.3 | 14.9 | 1.6 |
| 0.5λ | 11 | 17.5 | 6.5 |
| 0.25λ | 3.9 | 21 | 17.1 |
| 0.239λ | 3.9 | 22.5 | 18.6 |

Table 1. The value of bandwidth at different length of ground plane

3.CONCLUSION

In this paper, a design of new microstrip UWB antenna with good performance was proposed. The antenna was designed and simulated using Ansoft's HFSS electromagnetic simulation package. The effects of feeding shift technique and the truncation of the ground plan method were studied. Enhance the antenna performance parameters was achieved. An extreme antenna bandwidth of 18.6GHz was achieved using ground plan 7.1mm.

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