# A Modified Elliptical Slot Ultra Wide Band Antenna

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## ABSTRACT

In this paper we present a Modified Elliptical Slot Ultra Wide Band (UWB) antenna. The antenna covers a very large band from 2.27 to more than 15 GHz. The solution of this antenna consists in varying the ellipse dimensions and the length of the tuning stub of the antenna. The antenna can be used for many modern communication systems. A comparison between simulated and measured results is also presented. The proposed antenna designs and performances are analyzed using Ansoft High Frequency Structure Simulator (HFSS).

**Keywords:** Elliptical Slot Antenna, microstrip feed line, Ultra-wideband (UWB), Wireless Communications.

## 1. INTRODUCTION

Recently, due to the miniaturization of the personal communication devices, the need of compact antennas has become a necessity. Moreover, the growth of wireless systems operating in multiple independent bands or wide bands leads to the use of multi-functional antennas such as UWB.

In general, The FCC in the USA has allocated a frequency band from 3.1 GHz to 10.6 GHz for UWB transmission [1]. Due to their capabilities for high data rate information transmission, Ultra-Wideband communication systems are highly promising. In addition, these systems have low power consumption and low interference and an immunity to multipath fading [2].

Conventional UWB antennas having spiral or log periodic geometries cause distortion to the radiated signal, since they radiate each frequency component form different part of the antenna; these antennas are said to be dispersive [3].

Due to their small size, light weight, low profile, low cost, and ease of integration with other microwave components, microstrip patch antennas are an obvious choice [4]. These antennas have simple feeding techniques, especially microstrip line and coplanar waveguide (CPW) feeds. So they are compatible with wireless communication integrated circuitry and they are being used in a large variety of applications such as radar, missiles, aircraft, satellite communications, mobile communication base stations and handsets, as well as in biomedical telemetry services. Most of these applications require a wide bandwidth, where this is not the case in a conventional microstrip antenna [5]. Different Techniques were discussed in reference in [6] to overcome the problem of narrow bandwidth and reduce the size of microstrip antennas.

Lately, UWB antennas having adequate radiation characteristics, simple structure and fabrication have been proposed [7, 8, 9]. Such antennas are broadband dipoles with circular, square, elliptical, pentagonal and hexagonal configurations [10, 11] or UWB reconfigurable antennas [12] .

In this paper, a modified elliptical slot antenna, based on previous studies [13], is proposed and investigated. In addition, a result comparison with the initial design is done. The geometric antenna dimensions are controlled such that an ultra wide band response is obtained with a bandwidth of more than 10 GHz and acceptable radiation pattern properties. Furthermore, the antenna can cover more applications such as the existing WLAN, and DMB bands, 2.45/5.2/5.8-GHz-ISM UWB (3.1 - 10.6 GHz) etc.

The paper is organized as follows: Section 2 describes the antenna geometry and its frequency response. Section 3 analyzes the characteristics of the antenna taking into account the effect of each parameter. In Section 4, some practical results are presented. Finally a conclusion summarizes the main characteristics of the proposed antenna.

## 2. ANTENNA GEOMETRY

The geometry of the proposed modified elliptical slot antenna is illustrated in figure-1.

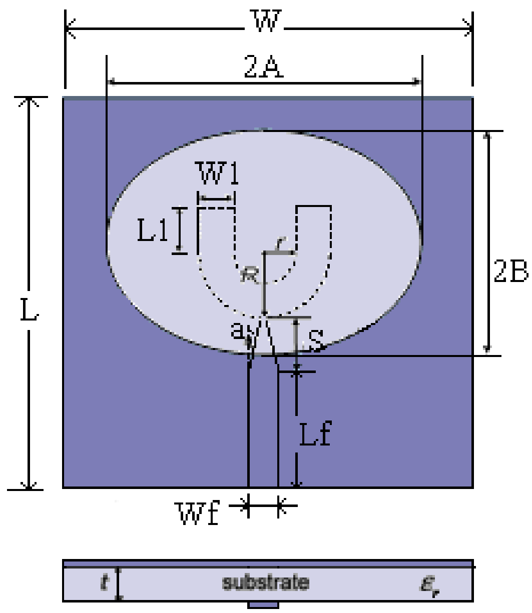


**Figure 1: Geometry of the proposed elliptical slot antenna**

This antenna has a modified elliptical slot antenna fed by a microstrip line, it has a U-shaped tuning stub that enhances the coupling between the slot and the feed line. Tapering the feed line permits the broadening of the operating frequency.

The slot and the feeding are printed on different sides of the substrate. The slot has a long axis radius A and a short radius B. It is etched on a rectangular (LxW) FR4 substrate with thickness t=1.6 mm and a relative dielectric constant $\varepsilon_r$=4.4. The feed line is tapered with a slant angle a = 15˚ for a height S. The U-shaped tuning stub has the following dimensions: R and r are the outer and inner radii of the circular ring respectively, $L_1$ and $W_1$ are the height and width of the two symmetrical identical branches.

## 3. ANTENNA PARAMETER EFFECTS

### 3.1 Return loss

The proposed design in reference [13] with initial dimensions of A=16mm, B = 11.5mm, t = 1.5mm and L=6mm, had frequency range from 2.6 to 10.6 GHz as shown in figure-2.

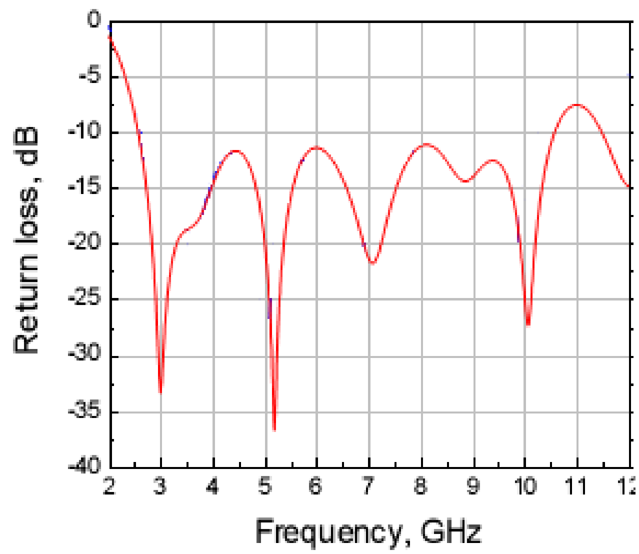


**Figure 2: Return Loss of the Elliptical Slot Antenna (initial design)**

The most important design parameters that affect the performance of the modified elliptical slot antenna are the dimensions of the elliptical slot A & B and the height of the branches of the U-shaped tuning stub. Thus those parameters

must be investigated to reach the optimum design.
Before reaching the optimum design, we passed through many steps of simulation. We started with the initial design and the thickness of the substrate (t) is 1.6 mm instead of 1.5 mm.

**Effect of Elliptical Slot Dimensions:** For the elliptical disc monopoles [13], an empirical formula for estimating the lower frequency of the -10 dB bandwidth $F_1$ is derived. This is based on the equivalence of a planar configuration to a cylindrical wire, as shown:

$$F_l = \frac{30*0.32}{2A+0.25B} \qquad (1)$$

Where $F_1$ in GHz, A and B are in cm.

From this formula Eq.(1) it is clear that as the values of A and B increases $F_1$ becomes lower.
Figure-3 shows the simulated return loss of the antenna upon varying the elliptical slot dimensions A and B.

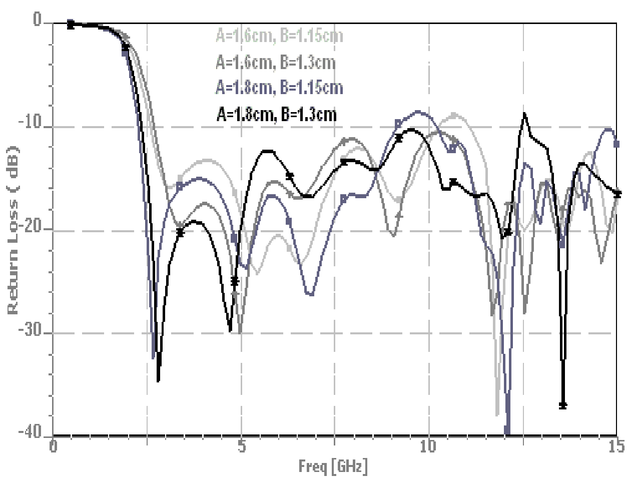


**Figure 3: Return Loss due to the variation of ellipse dimensions**

It is verified that $F_1$ is lower at high values of A and B, and the optimum values are A=1.8 cm and B=1.3 cm.

**Effect of the U-shaped Tuning Stub Height:** In this step we varied the height of the U-shaped tuning stub to enhance the bandwidth. The different values of the height ($L_1$) are: 5, 6.5, 7.5 and 9 mm.

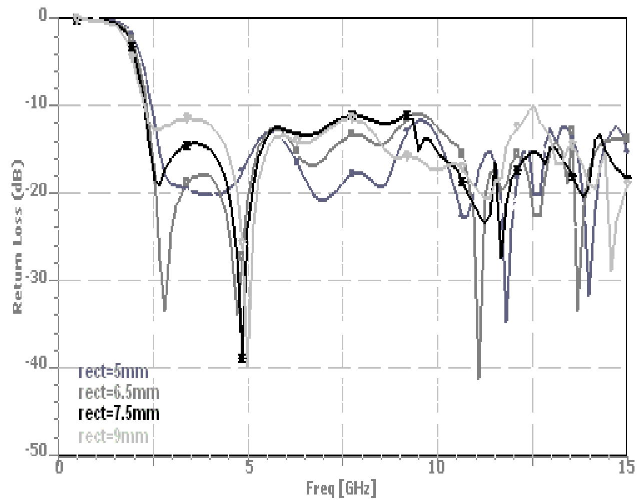


**Figure 4: Return Loss due to variation of U-shaped tuning stub height**

From figure-4 we can see that the optimum height for the tuning stub ($L_1$) is 7.5 mm which gives the highest bandwidth.

Finally the optimum obtained dimensions are summarized in table-1

| Dimensions | (mm) | Dimensions | (mm) |
|---|---|---|---|
| L | 42 | $W_1$ | 3 |
| W | 42 | S | 3.3 |
| A | 18 | R | 5.9 |
| B | 13 | r | 2.9 |
| $L_f$ | 11.3 | a | 15˚ |
| $W_f$ | 2.6 | t | 1.6 |
| $L_1$ | 7.5 | | |

**Table 1: Dimensions of the Modified Elliptical Slot Antenna with optimum design**

These simulations were performed using the Ansoft High Frequency Structure Simulation (HFSS) [14]. Figure-5 shows the simulated return loss curve with the optimal design, i.e. The simulated -10 dB return loss bandwidth is from 2.27 to more than 15 GHz, which conforms to the UWB standards. Moreover a considerable increase in bandwidth is obtained relative to the initial design. This permits to use the antenna in more applications operating near 2.4 GHz.

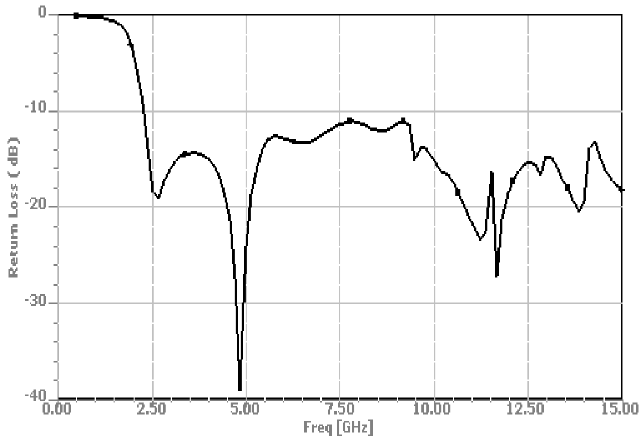


**Figure 5: Return Loss for the Modified Elliptical Slot Antenna with optimum design**

### 3.2 Radiation patterns and Gain

The simulated radiation pattern in the two main planes at 2.4, 3.1, 7.4 and 10.6 GHz are plotted in Figure-6 to figure-9.

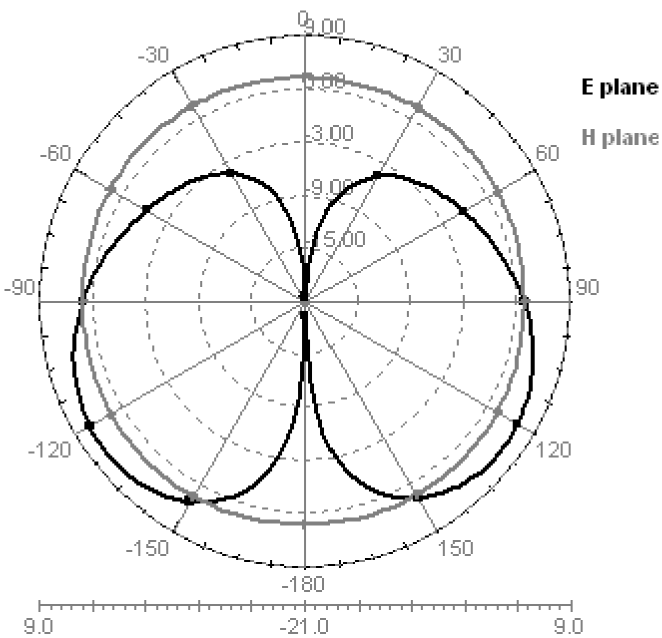


**Figure 6: Gain at 2.4 GHz**

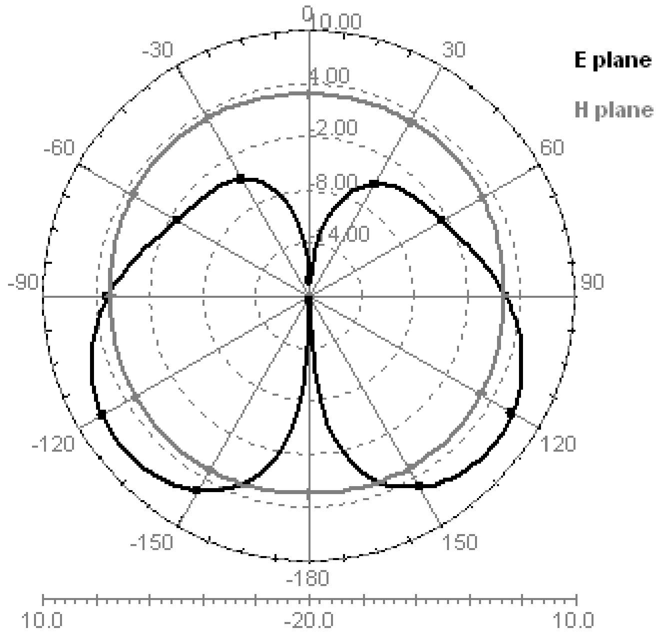


**Figure 7:Gain at 3.1 GHz**

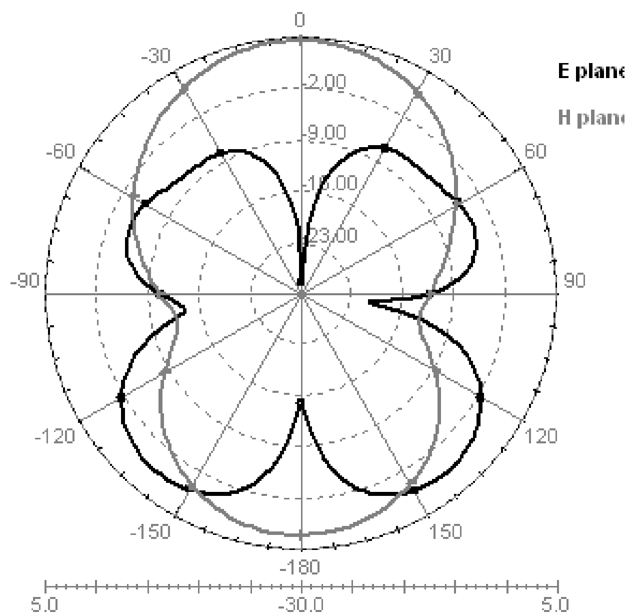


**Figure 8: Gain at 7.4 GHz**

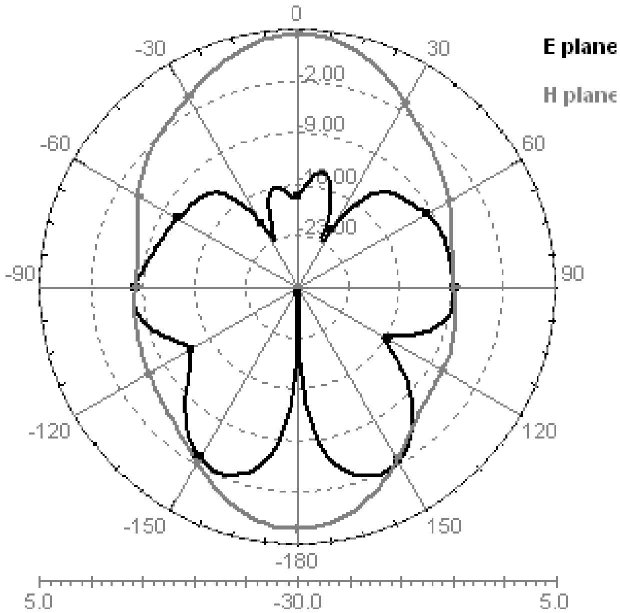

Figure 9: Gain at 10.6 GHz

It is noticed that, the simulated H-plane patterns are omni-directional at lower frequencies (2.4 and 3 GHz) and is near omni-directional at higher frequencies (7.4 and 10.6 GHz) as shown in the figures.

The simulated E-plane patterns show that as the frequency is increased, slight notches start to form and pattern shows more directionality around $130^o$ and $155^o$ at 7.4 GHz and 10.6 GHz respectively.

Table-2 illustrates the simulated gain of the proposed antenna with different frequencies.

| Frequency (GHz) | 2.4 | 3.1 | 7 | 10.6 | 12 | 14 |
|---|---|---|---|---|---|---|
| Peak Gain (dB) | 7.71 | 6.94 | 5.25 | 6.24 | 7.96 | 8.38 |

**Table 2: Simulated Gain versus Frequency**

## 4. MEASURED RESULTS

The fabricated antenna is shown in figure-10. The antenna was fabricated from a double layer PCB. The U-shaped tuning stub and the microstrip line where etched on one side and the elliptical slot was etched on the other side.

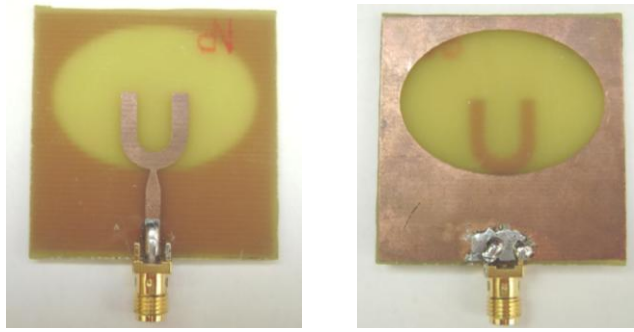
**Figure10: Fabricated antenna**

To measure the return losses, a scalar network analyzer, a hybrid coupler, and a sweep generator (F > 20 GHz) are used.

The simulated and measured return losses are plotted as shown in figure-11.

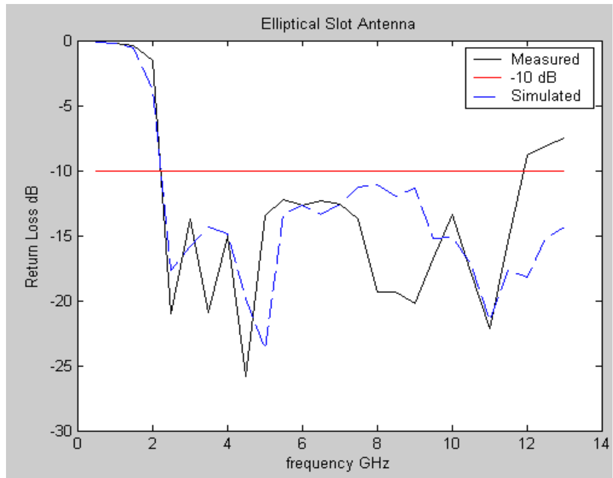

**Figure 11: Measured and Simulated Return Loss of Elliptical Slot Antenna**

This chart shows a satisfactory agreement between both results regarding the *RL* (less than -10 dB).The designed antenna can operate over a wide range of frequencies for modern wireless communications systems.

To determine the maximum gain of the Modified Elliptical Slot antenna, the comparison technique is used. Two identical prototypes are fabricated and placed opposite to each other with a separating distance r. This distance is calculated according to the far field condition refer to Eq. (2):

$$r = \frac{2D^2}{\lambda} \qquad (2)$$

Where D is the largest dimension of the antenna aperture and λ is the operating wavelength

For two identical antennas, operating at the same center frequency, the gain is defined as in Eq. (3):

$$G_o = \frac{1}{2}(W_r - W_t)_{dBm} + 10\log\frac{4\pi r}{\lambda} \quad (3)$$

In this equation, $G_o$ is the antenna gain, $W_t$ is the transmitted power in dBm, $W_r$ is the received power in dBm, $r$ is the distance between the two antennas, and $\lambda_o$ is the operating wavelength.

The equipment used in this system are an antenna test bench including a signal generator and a power meter to measure $W_t$ and $W_r$. The measured gain at 2.4 GHz frequency was around 3 dB. The difference between the measured and the simulated values may be justified by the non ideal measuring conditions, where an anechoic chamber was not available, so interferences had a large effect. Moreover, the antenna substrate has some losses at this frequency.

## 5. CONCLUSION

In this paper, a modified elliptical slot antenna was proposed having a wide bandwidth from 2.22 GHz to more than 15 GHz. The designed antenna has simple configurations and is easy to fabricate. It has been shown that the performance of this antenna in terms of its frequency domain characteristics is mostly dependent on the elliptical slot dimensions and the height of the tuning stub. It is demonstrated by simulation that the proposed antenna can yield an ultra wide bandwidth, and that the radiation patterns are nearly omni-directional over the entire 10 dB return loss bandwidth.

The modified elliptical slot antenna can be used for many applications including 3G, Wi-Fi, WiMAX, as well as UWB applications.

## 6. REFERENCES


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