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A Novel Bi-Elliptical Planar Antenna for Ultra Wideband Communications

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ABSTRACT

A novel planar bi-elliptical antenna has been proposed for Ultra Wideband (UWB)applications. The microstrip fed antenna covers complete unlicensed UWB band from 3.1 to 10.6 GHz. The proposed antenna has been analyzed for its impedance bandwidth and its radiation characteristics. The optimization and evolution of antenna has been discussed in detail. The antenna has been realized on the low cost FR4 substrate and it measures 40 × 48 mm^2. The measured group delay of the antenna is less than 2 ns. The antenna gain varies between -3 and 4 dBi.
KEYWORDS: Microstrip antennas, planar antennas, UWB antennas.

I. INTRODUCTION

Short range wireless communication standards especially Wireless Local Area Network (WLAN) and Wireless Personal Area Network (WPAN) shall require data rate of more than a Gigabit per second in near future [1]. The WPANs involve networking of various wireless devices including home entertainment systems which require very high data rate to communicate with one another. Since, Shannon capacity theorem defines the limits of achievable data rate [1], which is approachable either by high signal power or by large bandwidth. The unlicensed Ultra Wideband (UWB) from 3.1 to 10.6 GHz offers a significant large frequency band for high date rate systems but it imposes upper power limitations of -41dBm/MHz which is acceptable for short range communications therefore, UWB is a potential candidate for short range wireless networks. Compact wireless devices require miniaturized antenna systems since bulky and non planar antenna operating in UWB frequency range are not feasible for such applications [2 - 4].

This work proposes a novel bi-elliptical UWB antenna which is suitable for various UWB applications by offering quasi omni-directional radiation pattern. The antenna cover the complete unlicensed UWB band unlike various UWB antennas [5, 6] and it can be used for any narrow band or broadband applications in the operating frequency range.

II. MATERIALS AND METHODS

1. Antenna design and optimization

The antenna was designed by using a commercially available software HFSS by analyzing a single elliptical radiating element with partial grounding. This radiating element however offered a small bandwidth around 2.8 and 7.5 GHz as shown in Figure 1.

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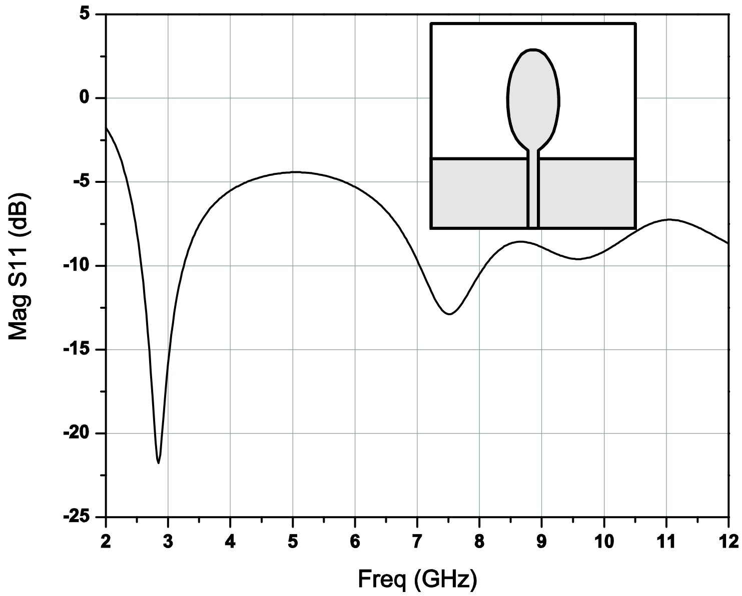

Figure 1. Microstrip fed elliptical radiator with partial grounding

Another elliptical radiating element has been added and placed with a certain angle to the first elliptical radiator to enhance the radiation. The design parameters were optimized and significant improvement has been observed especially towards the upper band of UWB frequency range as shown in Figure 2.

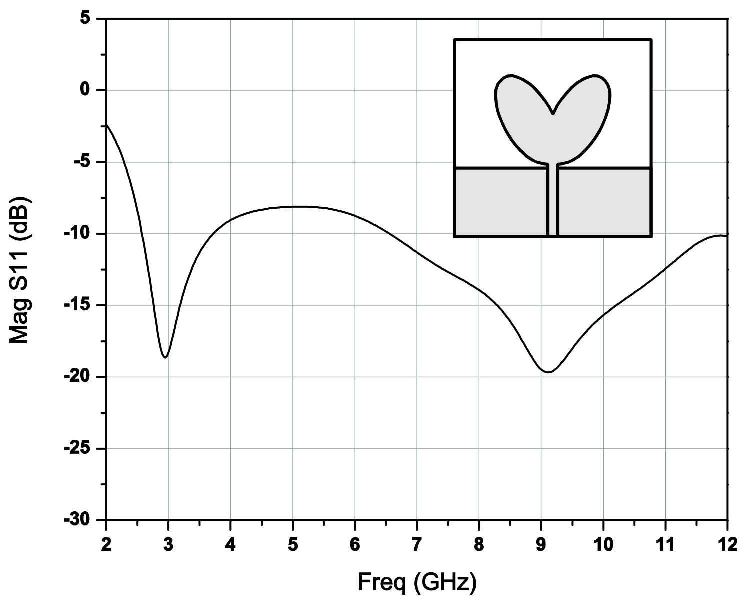

Figure 2. Introduction of second elliptical radiating element

The middle frequency band around 5 GHz still required improved impendence matching therefore, to achieve this mid-band matching; a circular slot has been added to the base of two ellipses. This circular slot creates degenerated modes and antenna starts radiating at the middle frequencies around 5 GHz. Along with the circular slot the vertices of the ground plane were truncated by an exponential taper to avoid sharp discontinuity. These modifications are shown in Figure 3.

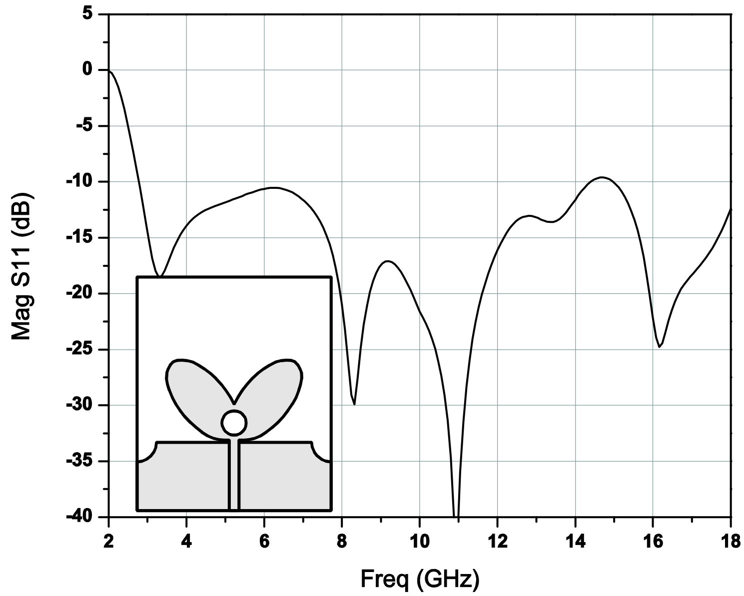

Figure 3. A set of elliptical radiator with circular slot

The antenna covers the complete UWB band at this stage. Additionally two stubs were extended from the top of both ellipses and they were optimized at a certain angle, this perturbs the current distribution and enhances the radiation by improving the impedance matching. The final bi-elliptical antenna layout is given in Figure 4 and its optimized dimensions are listed in table I.

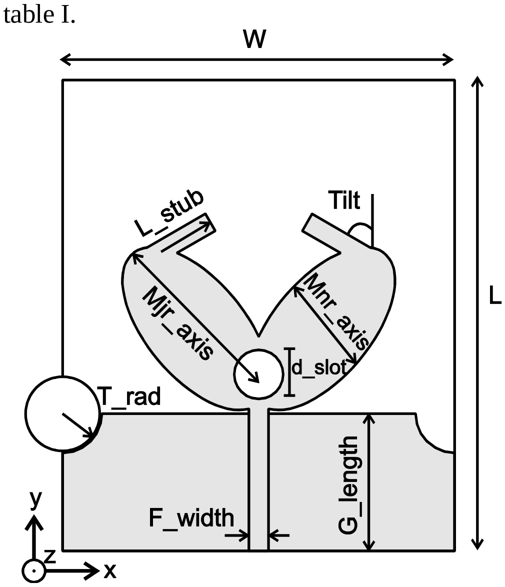

Figure 4. Final antenna design layout

Table I. Optimized antenna dimensions

Parameters	Description	Values (mm)
W	Width of substrate	40
L	Length of substrate	48
Mjr_axis	Major axis of ellipse	5
Mnr_axis	Minor axis of ellipse	2.5
Tilt	Tilt angle of stub	60 deg
L_stub	Length of stub	6
d_slot	Circular slot diameter	5
F_width	Width of central feed line	2
G_length	Length of ground plane	14
T_rad	Truncation circle radius	4

III. Results and Discussion

1. Design Realization

The antenna was fabricated on low cost FR4 substrate with permittivity of 4.4 and thickness of 1 mm shown in Figure 5. The realized set of antennas was tested using Agilent PNA-X N5242A network analyzer for their performance. The return loss comparison of the simulated and measured prototype is shown in Figure 6. It can be observed that the return loss is less than -10 dB in complete band. The simulated and measured results show slight variations especially at the upper UWB band but since the measured return loss is below -10 dB so it can be considered that the antenna is working efficiently in the UWB band.

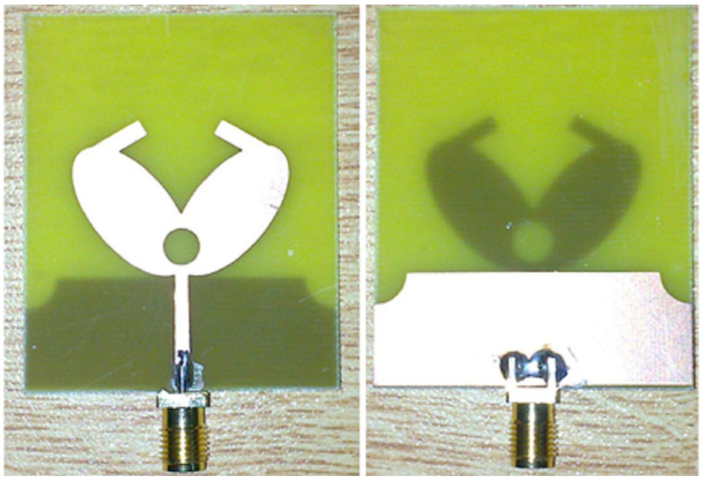

Figure 5. Fabricated bi-elliptical UWB band antenna (a) top view (b) bottom view

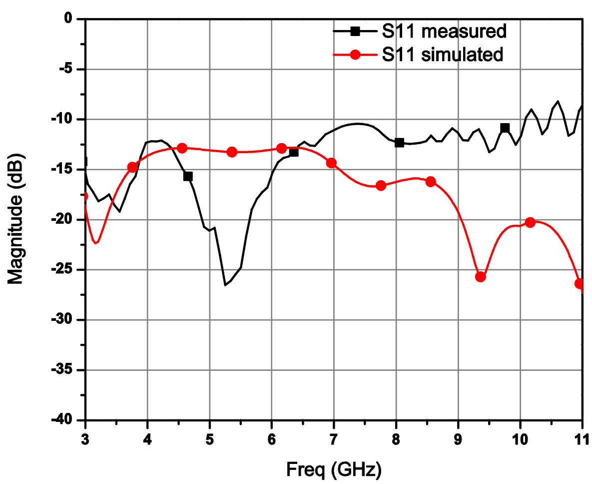

Figure 6. Comparison of simulated and measured return loss

The phase variation is very important since a large bandwidth is covered so the group delay has been measured. Two bi-elliptical antennas were separated by a distance of 12 cm and the group delay was measured. The measured delay is shown in Figure 7. The delay is less than 2 ns in the complete band.

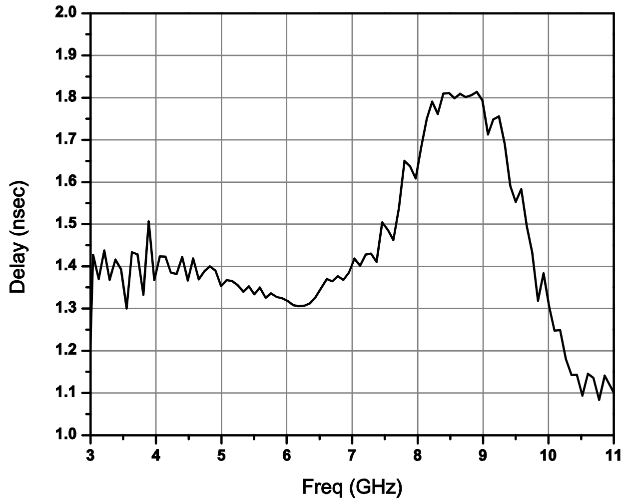

Figure 7. Group delay of antenna

The antenna exhibits quasi-omni directional radiation pattern. The radiation patterns at 4, 7 and 10 GHz has been given for elevation and azimuth plane (Figure 8).

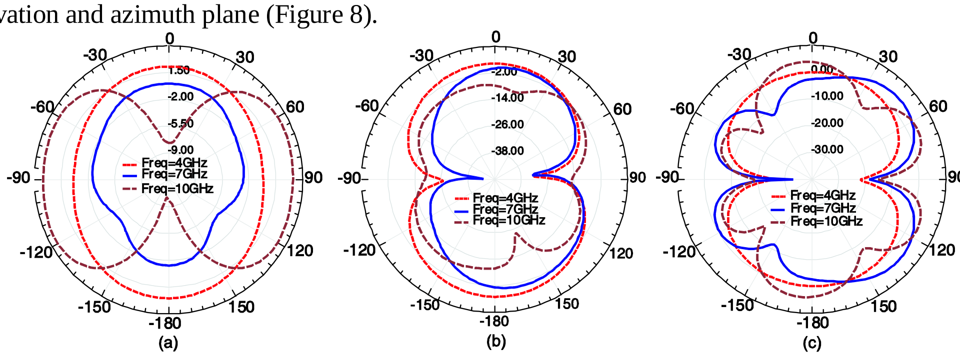

Figure 8. Gain radiation pattern of bi-elliptical antenna at 4, 7 and 10 GHz for (a) elevation plane phi=0^o, (b) elevation plane phi=90^o, (c) azimuth plane.

The antenna gain varies between -3 to 4 dBi the gain variation is plotted in Figure 9.

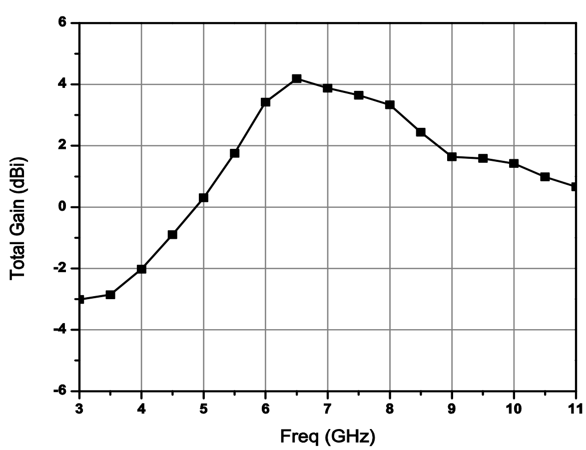

Figure 9. Gain variation vs frequency of the bi-elliptical antenna

IV. Conclusion

A novel planar UWB antenna has been presented. The antenna was evolved from a single elliptical radiator and various modifications have been made to the basic elliptical radiator design to achieve the desired performance. The antenna performs well for complete unlicensed ultra wideband frequency range. The antenna exhibits quasi-omni directional radiation characteristics with total gain variation between -3 and 4 dBi. The antenna is suitable for short range wireless networks especially WPANs and WLANs. The antenna footprint is 40×48 mm^2.

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