*Progress In Electromagnetics Research Letters, Vol. 11, 31–38, 2009*

# A PLANAR EYE SHAPE ANTENNA FOR ULTRA-WIDE BAND APPLICATIONS

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**Abstract**—In this paper a new planar monopole antenna is presented. The performance parameters like return loss of the single antenna as well as transmission function, group delay, and the fidelity factor of a two-antenna system are calculated. The radiator is eye-shaped, and it can be used in dipole or monopole configurations. Good ultra wide band performance is achieved. Small size, simple design and suitable electrical performance are among the most advantageous features of this new planar UWB antenna.

## 1. INTRODUCTION

Ultra-wide band technology has attracted much attention these years. In this technology, directly transmitting and receiving of short pulses with wide frequency bandwidth is the main purpose. Federal Communication Commission (FCC) defined UWB regularities for UWB systems in February of 2002. According to this regulation, UWB frequency bandwidth is 7.5 GHz, from 3.1 GHz to 10.6 GHz [1].

Basic analog part of UWB systems is transmitting and receiving antennas. Hence, design and implementation of antennas that meet all specifications of UWB requirements is one of the major challenges for antenna designers and researchers. The most important requirements for UWB antennas are ultra wide operation bandwidth, constant gain, omni-directional pattern, constant group delay, high radiation efficiency, and low profile [2]. In literature, we find many different antennas that are suggested for this application. Two major groups of those are three dimensional monopole antennas and planar antennas. The first group is often made by a radiating element on a ground plane. The radiating element has different shapes such as square [3, 4],

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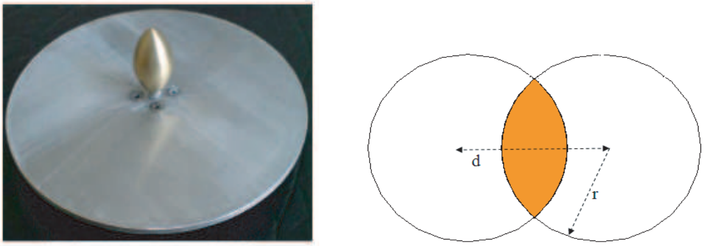
diamond [5], circle [6], trapezoid [7], and Eye shape [8]. Although these antennas are suitable for UWB applications they are not planar structures. Therefore, for applications that need to integrate antennas and digital boards, planar antennas are suitable.

Many different planar antennas for UWB applications with radiating element shapes such as square [9], triangle [10], circle [11], and trapezoid [12] are designed. However, for solving some problems such as good stability of radiation pattern over the whole operating bandwidth and finding the antennas with optimum performance relating to the operation, investigation on new radiators for this application is still going on.

In this paper, an investigation on a useful radiating element for UWB application, named eye antenna, is performed. Also, based on three dimensional eye antenna, a novel planar UWB antenna is presented. UWB performance characteristics of this antenna in terms of input impedance matching condition, radiation patterns, magnitude transfer function, group delay and time domain fidelity factor is presented.

In the rest of the paper, first three dimensional monopole eye antenna and planar eye antenna are presented in Section 2. Section 3 shows the UWB antenna performance characteristics, and Section 4 concludes the paper. Simulation results are obtained using commercial simulator packages such as CST Microwave Studio [13] which utilizes the finite integration technique and HFSS [14] which utilizes the finite element technique for electromagnetic simulations.




(a) (b)

**Figure 1.** A view of (a) basic three dimensional eye antenna was presented in [8] (b) an eye shape radiator.

## 2. ANTENNA DESIGN

Basic three dimensional eye antenna considered here was presented in [8]. Fig. 1(a) illustrates this antenna. Using a coaxial probe through a SMA connector the antenna has been fed. This antenna is screwed to the inner conductor of the coaxial probe, and it is placed over a finite circular ground plane. This antenna has good performance in term of input impedance matching and power radiation pattern stability in wide frequency range. Eye shape radiator of this antenna is shown in Fig. 1(b). A three dimensional eye radiator is made by rotating a planar eye radiator. As it is seen in the figure, eye shape is achieved by intersection of two circles with radius $r$ and center to center space $d$.

Using this radiator, we can make two antenna configurations, the dipole eye antenna and monopole eye antenna. Fig. 2 shows the monopole eye antenna. For dipole configuration, the antenna is fed in center by a lumped port or a balance structure, and in monopole configuration, we used a tapered microstrip feed line. The rectangular shape ground plane, printed on the back side of the substrate, is also shown in the figure by the light gray area.

In monopole configuration the ground plane is placed at distance $g$ from the lower edge of radiating eye element. The tapered microstrip line is employed for broadband matching of the antenna to the 50 Ω microstrip line. The width and length of the 50 Ω microstrip line are

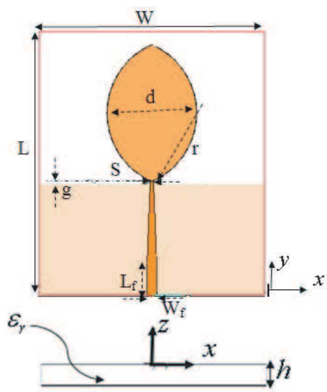



**Figure 2.** Top view of the antenna and its ground plane (the light area).

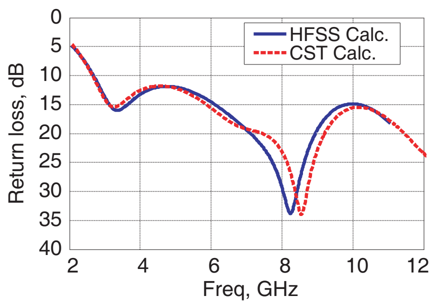



**Figure 3.** Return loss of the planar monopole eye antenna with $r = 10$ mm, $d = 6$ mm, $S = 0.4$ mm, $g = 0.3$ mm.

denoted by $W_f$ and $L_f$ respectively, and the width of the taper at its connecting point to the antenna is given by $S$. The substrate is assumed to be RO4003 ($\varepsilon_r = 3.55$, $\tan\delta = 0.0027$) with the thickness of 20 mil. The antenna design procedure is given below.

Based on numerical experiments for impedance stability over the whole operating band and small size of the antenna, $W = 30$ mm and $L = 35$ mm are selected. Also simulations showe that if we place the first resonance of the antenna at 3.3 GHz, the return loss at the lower edge of the frequency band, i.e., 3.1 GHz will remain lower than 15 dB. For this aim, the value $r$ is optimized to 10 mm, and $d$ is optimized to 6 mm.

While $W_f$ is calculated to be 1.2 mm to match a 50 Ω microstrip line, and $L_f = 5$ mm for fabrication and SMA connector installation reason, $S$ and $g$ are found by optimizing the antenna return loss to remain below 10 dB throughout the frequency band 3.1–10.6 GHz. The optimized values for $S$ and $g$ are found to be 0.4 mm and 0.3 mm, respectively.

## 3. RESULTS AND DISCUSSIONS

The simulated return loss of the monopole eye antenna is shown in Fig. 3. It is clear that both the simulated results by HFSS and CST return losses for the monopole eye antenna have values better than 10 dB throughout the UWB frequency band.

The simulated $H$-plane ($xz$-plane, $\varphi = 0°$, $180°$) antenna gain patterns at 4, 6, 8, 10 GHz for monopole eye antenna are shown in Fig. 4. It can be observed that the $H$-plane patterns are all omnidirectional.

Figure 5 shows the simulated magnitude of the antenna transfer function in a two-antenna configuration. In this case the two antennas are separated by 60 cm in face to face (T-T), face to side (T-S), and side to side (S-S) configurations. In UWB applications, magnitude of the transfer function should be as flat as possible, and its phase must be linear throughout the frequency band. As shown in Fig. 5, the variations of the transfer function for eye shape monopole antenna link are within 10 dB in the whole frequency band.

Figure 6 shows the simulated group delay of the monopole eye antenna. To observe the level of distortions imposed on the transmitted pulses by the monopole eye antenna, the transmitting antenna is fed by the fourth order Rayleigh pulse as the excitation signal. The excitation

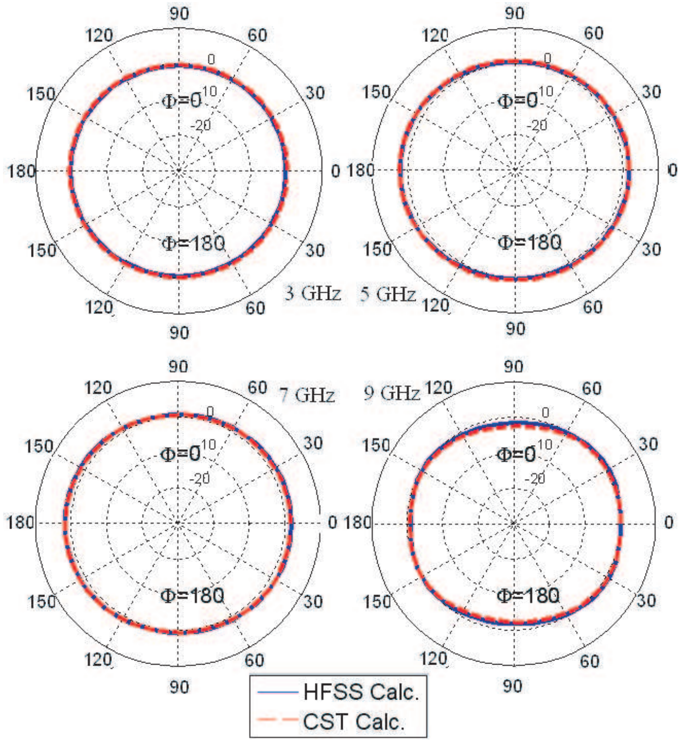



**Figure 4.** *H* plane radiation patterns of the planar monopole eye antenna.

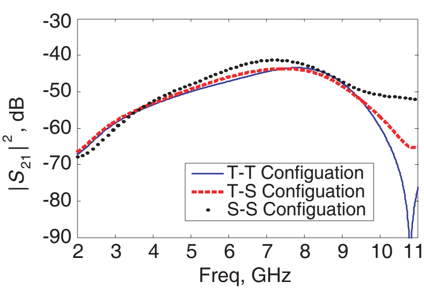



**Figure 5.** Magnitude of transfer functions of the three different configuration of the planar monopole eye antenna.

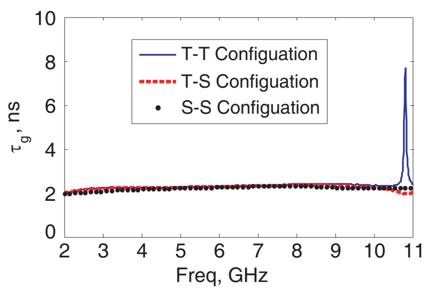



**Figure 6.** Group delays of the three different configuration of the planar monopole eye antenna.

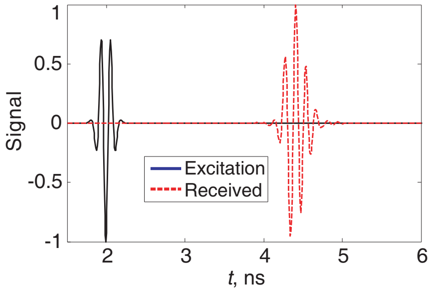



**Figure 7.** Transmitted and received signals in face to face configuration.

signal is given by:

$$s(t) = A\left(\frac{(t-\mu)^4 - 6(t-\mu)^2 + 3\sigma^4}{\sigma^8}\right)e^{-\left(\frac{(t-\mu)^2}{2\sigma^2}\right)} \tag{1}$$

where $A$ is a normalization factor; $\mu$, and $\sigma$ are the center of time axes and the pulse width factor, respectively.

The received signal is shown in Fig. 7. It is seen that the received pulses are distorted and broadened about 1 ns. To measure the similarity of the received and transmitted signals, one may use the fidelity factor $F$ defined in [15–18]. That is

$$F = \max_{\tau} \int_{-\infty}^{+\infty} L(f(t))S_R(t-\tau)dt \tag{2}$$

where $f(t)$, $s_R(t)$ are the transmitted and received signals, respectively, and operator $L$ is

$$L(f(t)) = \frac{d^{n-1}(f(t))}{dt^{n-1}} \tag{3}$$

It is clear that $F$ gives the correlation between the two signals and varies between 0 and 1 with $F = 1$ meaning that the two signals are exactly the same. Using the above-mentioned definition, the fidelity factor between the transmitted and received signals for the monopole eye antenna in the two-antenna configurationis calculated for different values of the pulse width factor.

The fidelity factor between transmitted and received signal (i.e., $n = 1$) is about 0.8747 for pulse width factor $\sigma = 50$ ps, and the fidelity factor between the received signal and first derivative of the transmitted signal i.e., the fifth order Rayleigh pulse ($n = 2$) is about 0.9248 for pulse width factor $\sigma = 60\,\text{ps}$. These values for the fidelity factor show that the antenna imposes negligible effect on the transmitted pulses.

## 4. CONCLUSION

A new printed monopole antenna for UWB applications was proposed. Since the radiating element had an eye shape, the antenna was named eye shape antenna. The antenna has the capability of being exited as a dipole or conversely as a dipole or monopole. Using a monopole configuration, the antenna dimensions were optimized to gain the best return loss response throughout the UWB frequency band. The optimized antenna was simulated, and its performance parameters were calculated in terms of the frequency domain parameters such as return loss, magnitude of $S_{21}$ and the group delay. Calculated results show that the designed antenna satisfies the UWB design goals very well.

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