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An Ultra Wide Band Antenna Design for Indoor Geolocation Applications

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Abstract: In this paper, we present a miniaturized, Ultra Wide Band (UWB) elliptical slot antenna with a circular stub as a tuning element printed on a FR4 substrate with a dielectric constant of 4.4 operating in the frequency range from 2 GHz up to 14 GHz over which the return loss below -10 dB. The antenna is intended to operate in a system designed to assist the visually impaired in indoor navigation utilizing UWB technology. The concentric circular tuning stub is introduced in order to tune and hence improves coupling of the higher-order modes when the electrical path of the slots and tuning stub becomes an integer number of the guide wavelengths surface current distributions are provided at these higher-order modes to demonstrate the working principle, the frequency response of S_{11} as well as the radiation patterns in two principal planes at 3.1 GHz, 6.4 GHz, 10.6 GHz and 11 GHz. A graded feed design has been developed to improve the matching of the input impedance of the source over the operating bandwidth of interest. The performance of the proposed feed in terms of bandwidth achieved is shown to outperform the conventional rectangular and tapered feed designs reported in the literature. A parametric study has been conducted to identify the critical parameters that affect the performance of the antenna design in terms of tuning, gain and bandwidth. It has been found that for a properly designed graded feed, the most significant geometrical parameter which affects the bandwidth is the slot dimension especially in the higher frequency regime. On the other hand, we have found that the gap between the tuning stub and the slot has no significant effect on the input impedance.

Key words: Printed antenna · Ultrawideband technology · Slotted ground plane · Wireless communication

INRODUCTION

Ultra-wide-band (UWB) technology is receiving considerable research interest in numerous wireless communication applications because it allows for extremely high data throughput with low power consumption for short range of about 10 m [1]. UWB systems are most suitable for digital domestic applications due to the low power consumption and hence prolonged battery life, high speed data transfer for multimedia content and short range connectivity for data transfer to other devices. An emerging research demand pertains to the design of UWB wearable antennas of low complexity and cost as alternative to replace wired connectivity option [1].

Accurate indoor geolocation is an important and novel emerging technology for commercial and public safety. In commercial applications for residential and nursing homes, there is an increasing need for indoor geolocation systems to track people with special needs, the elderly and children who are away from visual supervision, to navigate the blind, to locate in-demand portable equipment in hospitals and to find specific items in warehouses with accuracy better than one meter [2]. It is well known that the key to solving this problem is the combination of different positioning techniques [3].

A wide variety of UWB antenna designs have been reported in the literature. The majority of the previous designs attempts focused on how to achieve a wider impedance matching bandwidth to prevent and distortion in both radiation pattern and pulse shape. Results reported in [4] revealed that the planar UWB monopoles are favorable due to their matching impedance bandwidth which may be greater than 10:1.

An UWB antenna design has been introduced in [5] which enhanced the impedance bandwidth to a ratio of 10:1 and increased the gain from 5 dBi to 8 dBi over the operating bandwidth. Two different planar inverted cone antennas were proposed in [5].

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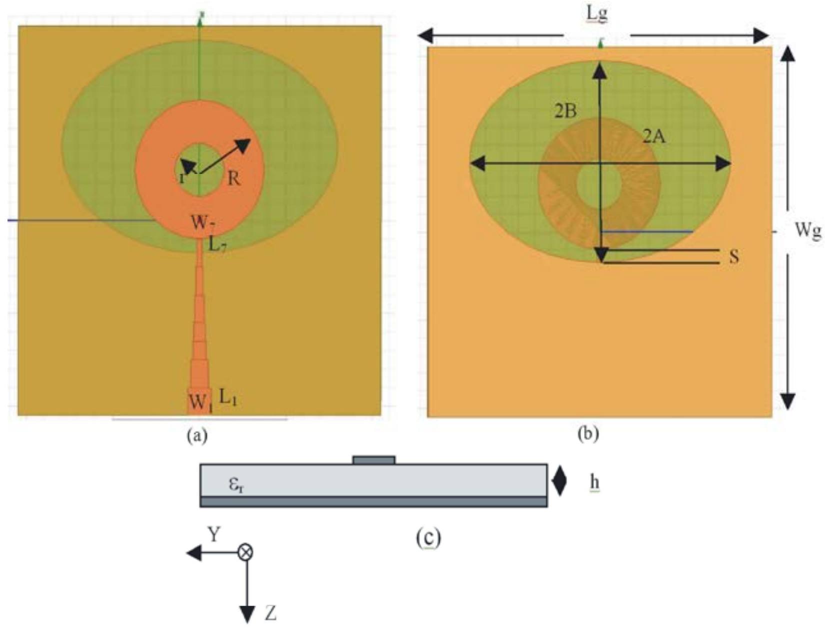

Fig. 1: Antenna Geometry (a) Top view (b) Bottom view (c) Side view.

Tuning the UWB antenna bandwidth is achieved by introducing tuning stubs of different geometries such as triangular [6], circular/elliptical ring [7, 8], U-shaped [9-11], C-shaped [12], oblate spheroid [13] and rectangular [14]. All these techniques are aimed at enhancing the impedance band width and radiation pattern performance at selected frequencies within the operating band.

Four multiresonant split-ring loops have been presented in [15] and achieved a band width from 2 GHz to 20 GHz with impedance bandwidth of 160%. Many prototypes were simulated and fabricated to study the effects of the ground plane geometry, split-ring numbers and split-ring diameters on the impedance and radiation pattern performances.

To accomplish a wide impedance matching over the operating frequency band, one of the most common methods is to introduce via holes. This method provides a good performance for impedance matching with 117% impedance of less than -10 dB. The antenna proposed in [16] consisted of slot etched on the ground plane in a trapezoidal shape and the rectangular patch in the center of the slot.

In this paper, we present a miniaturized, UWB elliptical slot antenna with a circular stub as a tuning element printed on an FR4 substrate of with a dielectric constant of 4.4 operating in the frequency range from 2 GHz to 14 GHz with the return loss being below -10 dB. The antenna is intended to operate in a system designed to assist the visually impaired in indoor navigation utilizing UWB technology. The system design specifications require an antenna with a size of 42 mm × 42 mm × 2 mm, 2 GHz-14 GHz bandwidth over which the return loss should be below -10 dB and gain above -6 dB. The High Frequency Structure Simulator (HFSS) commercial software package by Ansys, which is based on the Finite Element Method FEM, has been used to design, analyze and optimize the antennas reported in this paper.

Table 1: Antenna dimensions

Symbol	Value	Symbol	Value
A	16 mm	R	7.5 mm
B	11.5 mm	r	2.9 mm
ϵ_r	4.4	S	1.5 mm
H	1.575 mm	W_2	2 mm
L_g	42 mm	W_3	1.5 mm
L_1, L_2, L_4, L_5	3 mm	W_4	1.1 mm
L_3	4 mm	W_5	0.8 mm
L_6	3.05 mm	W_6	0.55 mm
W_1	2.74 mm	W_g	42 Mm

Antenna Geometry: Figure 1 shows the proposed antenna, while the detailed dimensions are reported in Table 1. The square ground plane has dimensions of 42 mm × 42 mm. The antenna is printed on an FR4 with a dielectric constant, ϵ_r = 4.4. An elliptical slot is etched on the ground of major axis, 2A=32 mm and minor axis 2B=23 mm. On the other side the concentric circular tuning stub is printed with the graded feed, the inner and outer radii of the stub are 2.9 mm and 7.5 mm respectively.

The length of the graded feed is equal to 16.92 mm, which is equal to half the guided wavelength at the center operating frequency with six equal segments lengths and widths, denoted by L_n and W_n respectively and are reported in Table 1.

RUSULTS AND DISCUSSION

We have conducted a parametric study to optimize the antenna performance in terms of bandwidth, gain and radiation pattern. First we considered the major and minor axes of the elliptical slot and examined their effects on the input impedance in the frequency band from 2 GHz to 14 GHz. It can be seen from Fig. 2 that at the optimal values (*A*=16 mm and *B*=11.5 mm), a return loss below -10 dB is over the frequency band of interest. Next we examined the gap between the concentric circular stub and the elliptical slot edge denoted by *S*. It should be noted that in [17], the S_{11} parameter is noted to be largely dependent of this parameter, hence on the tuning of the higher order modes. However, it is clearly shown in Fig. 3 that this parameter has no significant effect on the input impedance. It should be emphasized that this conclusion has been achieved due to the proposed feed shape which has been found to provide the desired reflection characteristics with excellent tuning performance in the frequency range of interest. Therefore, we chose *S*=1.5 mm for all subsequent results.

The main difference between the proposed antenna and that reported in [17] is the introduction of graded feed which enhanced the proposed antenna performance and reduces the dependence of tuning on the parameter *S*. To validate our proposed antenna, we compared its performance against the same antenna but with tapered and strip line feed as shown in Fig. 4. It evident that the new design provides better results with coupling coefficient below -10 dB within the operating bandwidth.

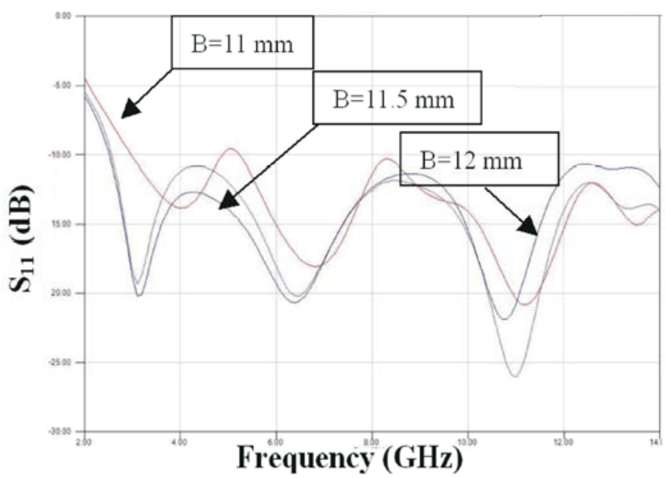

Fig. 2: Return losses versus slot axes

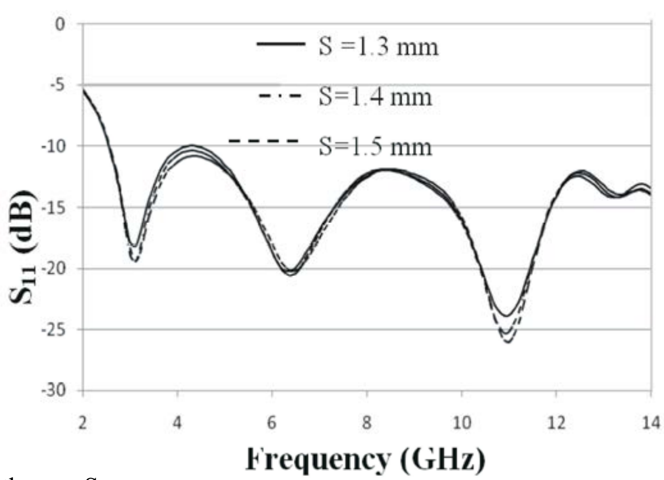

Fig. 3: Return losses versus the gap S

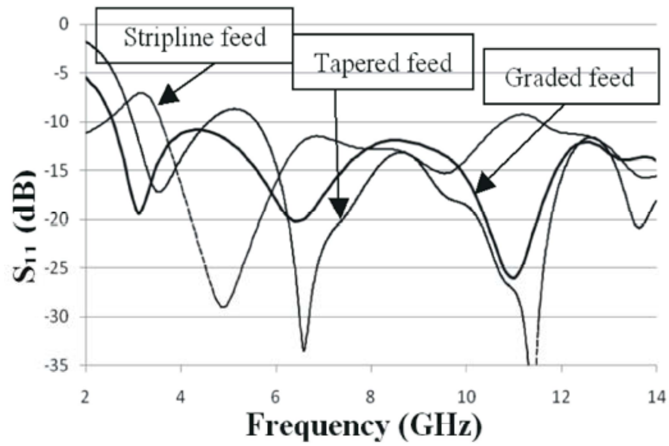

Fig. 4: Return losses for the three feed geometries

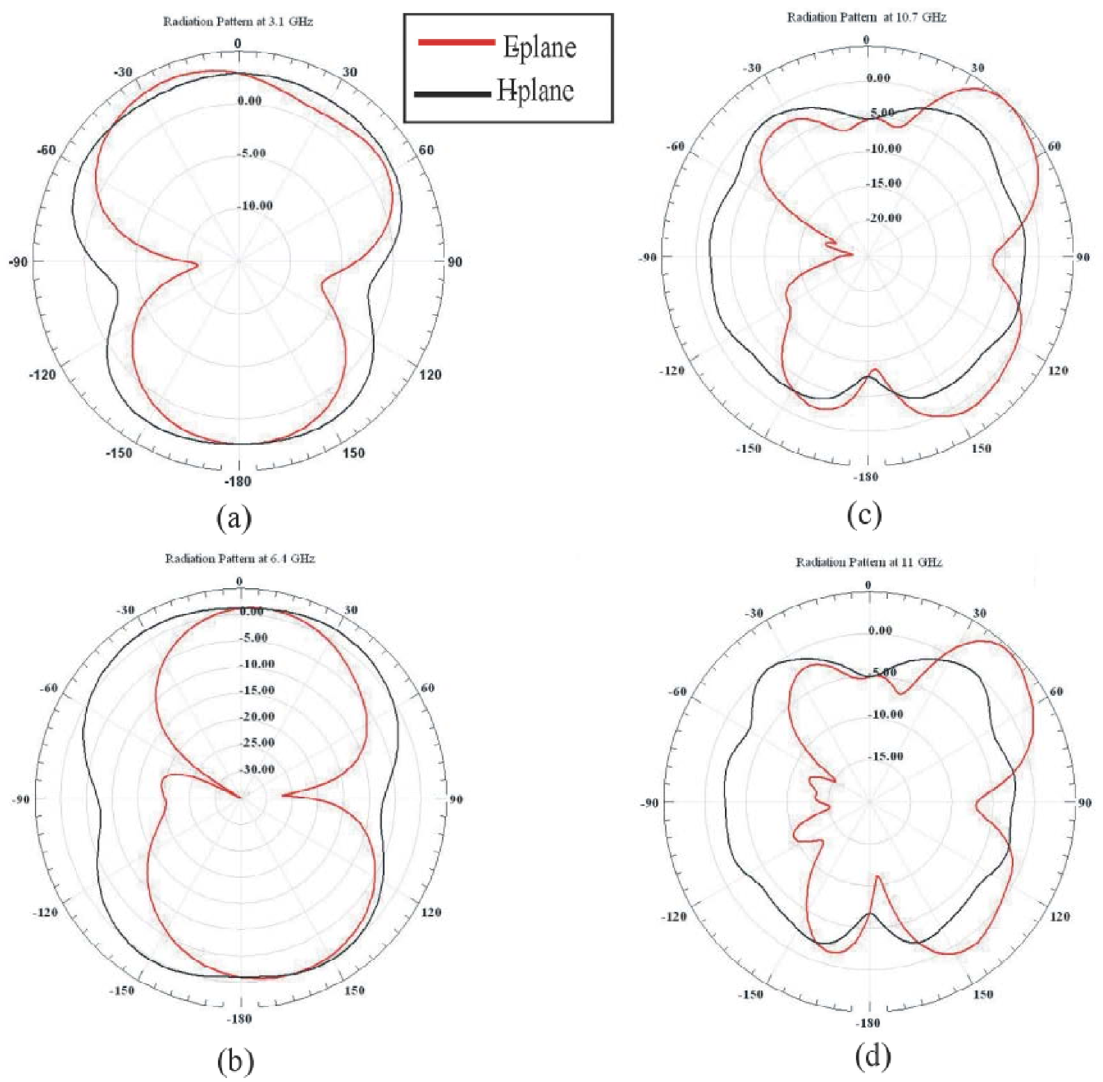

Fig. 5: Radiation pattern in the E-plane and H-plane for (a) 3.1 GHz, (b) 6.4 GHz, (c) 10.7 GHz and (d) 11GHz

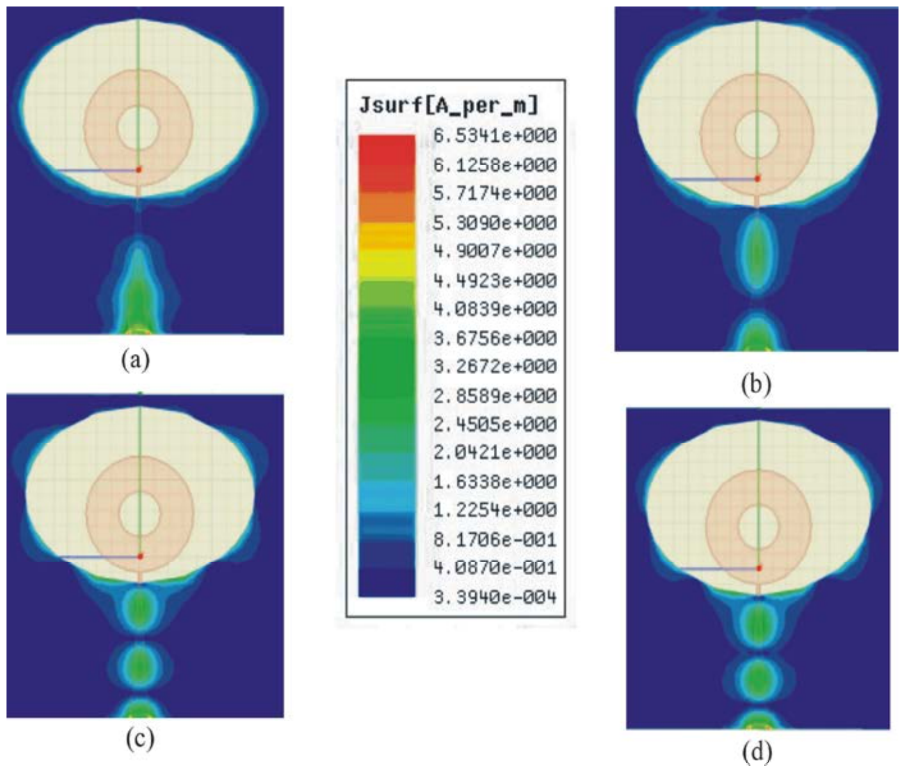

Fig. 6: Surface current distribution for (a) 3.1 GHz, (b) 6.4 GHz, (c) 10.7 GHz and (d) 11 GHz

The radiation patterns in the E-plane and H-plane and the surface current distributions are shown in Fig. 5 and Fig. 6, respectively, at 3.1, 6.4, 10.6 and 11 GHz.

CONCLUSIONS

An elliptical slot antenna combined with a concentric circular tuning stub has been provided that operates over the frequency range from 2 GHz-14 GHz. A graded feed structure has been designed, simulated and optimized to achieve proper matching to the input impedance of the source over the operating bandwidth of interest. The performance of the proposed feed has been compared against the conventional rectangular and tapered feeds reported in the literature. A parametric study has been conducted to identify the critical parameters that affect the performance of the antenna design in terms of tuning, gain and bandwidth. It has been found that for a properly designed graded feed, the most significant geometrical parameter which affects the bandwidth is the slot dimension especially in the high frequency regime. On the other hand, we have found that the gap between the tuning stub and the slot has no significant effect on the input impedance.

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