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Using Inverted T-Shaped Slot for Current Modification in Printed Ultrawideband Antenna

Mahdi MOOSAZADEH[1*] Zahra ESMATI[2]

[1] Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran 1477893855, IRAN

[2] Department of Electrical Engineering, Urmia Branch, Islamic Azad University, Urmia, IRAN

***Corresponding Author**
e-mail: mahdimoosazadeh59@yahoo.com

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Abstract

A printed monopole antenna with novel design is proposed. The antenna is designed to achieve an ultrawideband an omnidirectional performance. The antenna is constructed using a rectangular shaped radiator with an embedded inverted T-shaped slot located near the feed point. The ground plane is formed from half an ellipse with an embedded truncated circular slot located near the lower edge of the radiator. For an improved impedance matching, the radiator includes two notches at its lower corners. The effect of the design parameters of the antenna on its impedance bandwidth is explained. The simulated and measured performance of the antenna shows a band from 2.5 to 11.2 GHz with an omnidirectional radiation pattern.

Keywords: Monopole antenna, ultrawideband antenna, planar antenna.

INTRODUCTION

There has been a huge interest in the design of ultrawideband (UWB) antennas since the adoption of the UWB (3.1 GHz to 10.6 GHz) in 2002 [1-11]. One of the major challenges in the design of ultrawideband antennas is how to achieve a compact size with low cost, low weight, and desired radiation pattern characteristics and electrical properties across the band of interest.

Planar monopole antennas have attracted much interest for ultrawideband (UWB) applications due to their low profile, simple geometry and good impedance properties. In the design of UWB planar monopole antenna, the shape of the radiator, ground plane, and geometry of slots in the ground plane if used are of vital importance. The utilized shapes for the slots in the ground include rectangular, triangular, circular, and elliptical ones [1-11]. Different methods such as the truncated slot in the radiator or in the ground plane have been proposed for increasing the frequency range and radiation pattern [3-8].

In this letter, a novel printed rectangular monopole antenna is proposed for UWB applications. The construction of the designed antenna is aimed at achieving the required UWB performance while using small size and low cost structure. In the proposed antenna, an inverted T-shaped slot is utilized in the radiator to improve the bandwidth. If appropriate dimensions are chosen for the inverted T-shaped slot located near the feedline connection with the radiator, it will prevent the excitation of horizontal currents in the radiator, force the current to take vertical positions with uniform distribution. The end result is an enhancement in the impedance bandwidth. A slotted and curved ground is used in the antenna for a further improvement in the performance.

MATERIALS AND METHODS

Configuration of the proposed antenna is shown in Fig. 1(a). The antenna is constructed using the substrate FR4 with the thickness 1 mm and relative dielectric constant 4.4. The radiator of the antenna consists of a rectangular patch with length L and width W. There is an embedded inverted T-shaped slot at the lower end of the radiator to enforce a certain path and direction on the excitation current. The inverted T-shaped slot has a significant impact on the performance at the upper frequency band. It also produces an additional resonance and increases bandwidth.

For an improved matching with the 50Ω microstrip feeder, a rectangular step having a length L_2 length and width W_3 is used to connect the radiator to the microstrip line. The ground plane at the back of the substrate is in the form of a half-ellipse with an embedded circular-shaped notch located at the upper part of the ground and truncated towards the radiator. The distance between the rectangular step and ground plane is determined by the gap parameter (gap=L_f-r_1), where L_f is length of the feeder, and r_1 is the vertical radius of the half ellipse representing the ground.

In most of the small antennas, the modified ground plane acts as an impedance matching circuit. In the proposed antenna, there is a direct relation between the gap distance separating the radiator and the ground and the ellipticity ratio. In other words, a carefully selected value for the gap means an improved impedance matching, and thus an improved performance, especially at the upper frequency band. The truncated circular notch in the half-ellipse shaped ground plane is designed for a further improvement in the impedance matching. Two rectangular notches at the corners of the rectangular radiator are used to enhance impedance bandwidth as well [11].

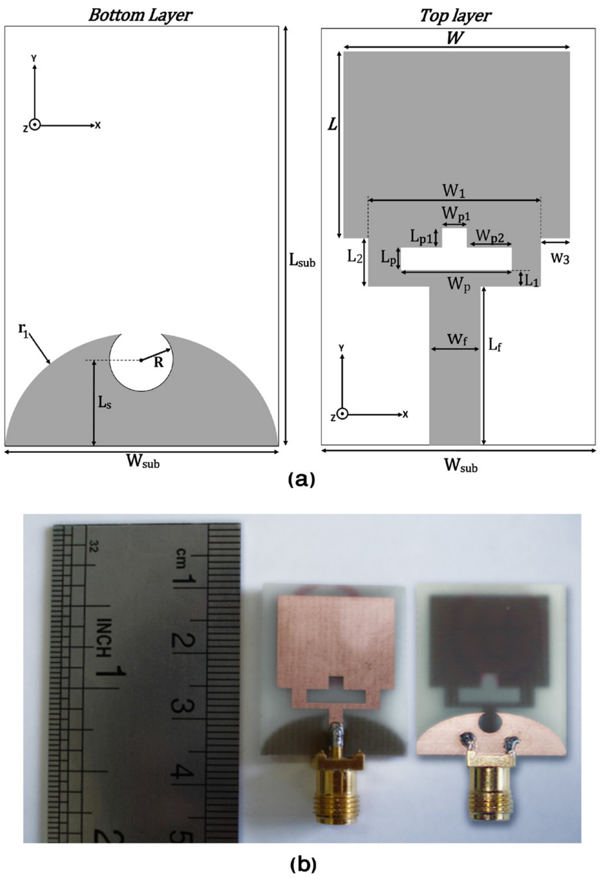

Fig.1. Configuration of the proposed antenna. (a) Dimensions and parameters of the antenna; (b) photograph of the developed antenna (front and back).

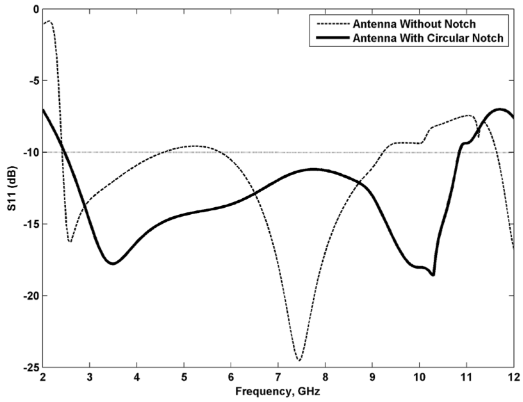

Fig.2. Effect of the ground slot on S_{11}.

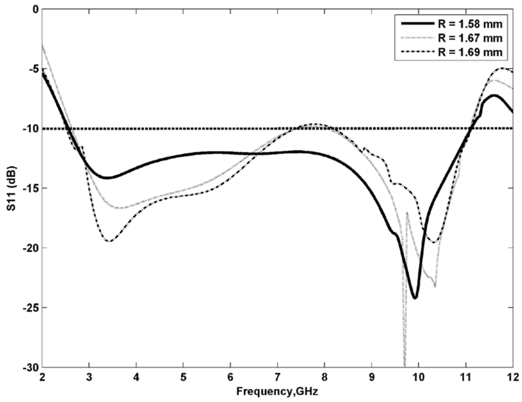

Fig.3. Effect of the radius (R) of the ground slot on S_{11}. The slot is located at L_s =4.8 mm.

The optimal parameters of the constructed antenna are as follows: W_{sub} = 20 mm, L_{Sub} = 26 mm, W =16 mm, L = 14 mm, L_p = 2 mm, W_p = 8 mm, W_1 = 12 mm, W_f = 1.875 mm, L_f = 7 mm, , L_s = 4.8 mm, gap = 0.7 mm, r_1 = 0.63, R = 1.58mm, L_{p1} = 2 mm, L_1 = 0.9 mm, L_2 = 3 mm, W_{p1} = 2 mm, W_{p2} = 3 mm, W_3 = 2 mm. This size of the constructed antenna is 20 mm × 26 mm as shown in Fig. 1(b).

RESULTS AND DISCUSSION

In this section, we investigate using a parametric study the effect of the different design parameters R, L_1, and Wp on the performance. In the parametric study, the best range of values for each parameter is estimated. The optimum values are then found for the whole structure of the antenna. The simulated results are obtained using the Ansoft HFSS.

The first investigated parameter is the effect of the truncated circular slot in the ground plane. Fig. 2 shows the simulated reflection coefficient (S_{11}) with and without using the truncated slot in the ground. From Fig. 2, the effect of the circular truncated slot is clear on improving the impedance matching between the radiator and the feeder. The band is extended from (2.5 GHz to 9 GHz) to (2.5 GHz to 11 GHz). Fig. 3 shows the effect of the size of the circular slot in the ground without changing its position. In this Figure, it is clear that choosing a suitable size for the slot improves the performance significantly, especially at around 8 GHz. According to the simulated results, the optimized value of 1.58 mm for the radius of the slot is found.

The effect of the inverted T-shaped slot in the radiator on the current distribution is also investigated. Fig. 4(a) shows the distribution of the current in absence of the slot at the frequency 8 GHz. It is clear the random direction of the currents at the lower part of the radiator. That random distribution for the current limits the band of operation for the antenna. Inserting an inverted T-shaped slot in the radiator force the current to follow an almost vertical patch towards the upper edge of the radiator as depicted in Fig. 4(b).

The position of the inverted T-shaped slot is also investigated. The simulated results shown in Fig. 5 show the significant impact of the position of the slot on the performance, especially at the upper and lower edge of the band. Concerning the dimensions of the slot, Fig. 6 shows the simulated S_{11} for different values of the slot's width W_p. It is clearly observed from Fig. 6 that the parameter W_p is a critical parameter to control the performance at the upper frequency.

At the lower corners of the radiator, a pair of rectangular notches with $L_2 \times W_3$ is used. The reason of using these notches is minimize the electromagnetic coupling between the radiator and the ground plane. This effect eventually helps in improving the impedance bandwidth of the antenna. The dimensions of those notches are chosen via the optimization capability of the utilized software.

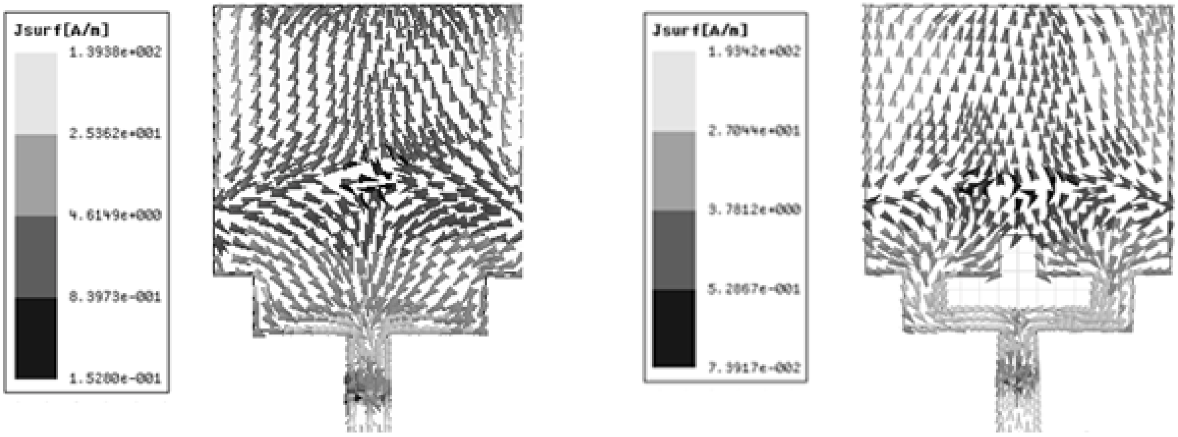

Fig.4. Effect of the inverted T-shaped slot in the radiator on the current distribution. (a) Current distribution in the radiator at 8 GHz without slot, and (b) current distribution with slot.

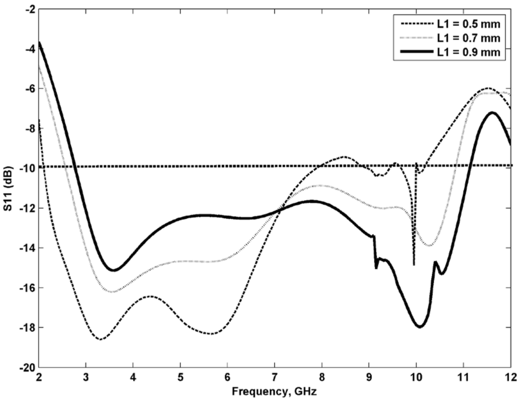

Fig.5. Effect of the position of the T-shaped slot on S_{11}. (L_{p1}= W_{p1}=2 mm, L_2=3mm, W_3=2mm).

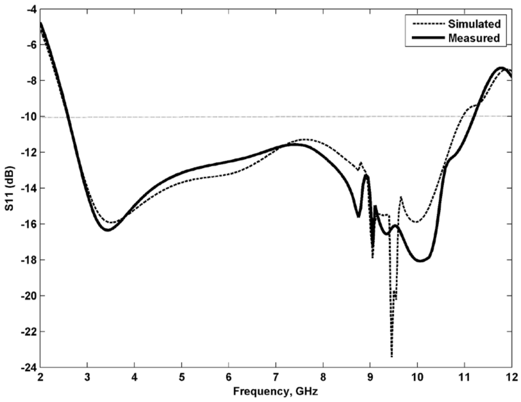

Fig.7. The simulated and measured S_{11}.

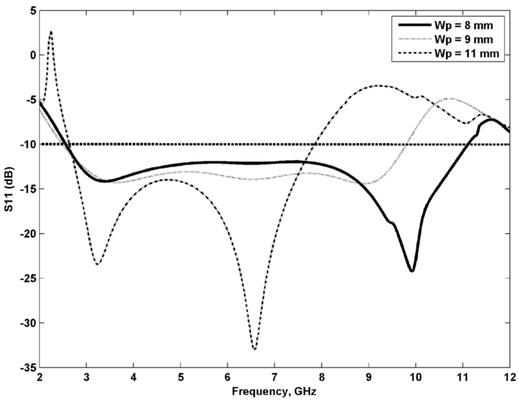

Fig.6. Effect of the dimensions of the T-shaped slot on S_{11} (L_1 is fixed at 0.9 mm).

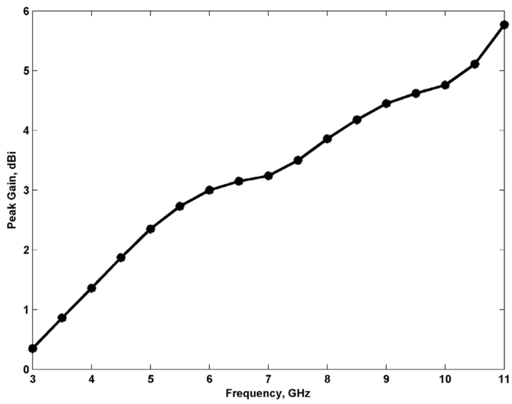

Fig.8. The measured gain of the proposed antenna.

The simulated and measured reflection coefficients (S_{11}) are shown in Fig. 7. The designed antenna provides an ultrawideband performance across the band from 2.5 to 11.2 GHz assuming the -10 dB reflection coefficient as the reference.

Fig. 7 shows that the simulated and measured performance agrees very well across the whole investigated band.

Fig. 8 shows the measured gain from 3 GHz to 11 GHz for the fabricated antenna. From this figure, it is possible to see that the gain varies from 0.3 dBi at 3 GHz to 5.8 dBi at 11 GHz. This variation in the gain is expected for the designed antenna. It has a compact size and thus a small gain at the lower end of the investigated band. However, the effective size of the antenna appears larger significantly due to the lower wavelength at the upper end of the band, and thus the gain increases consequently.

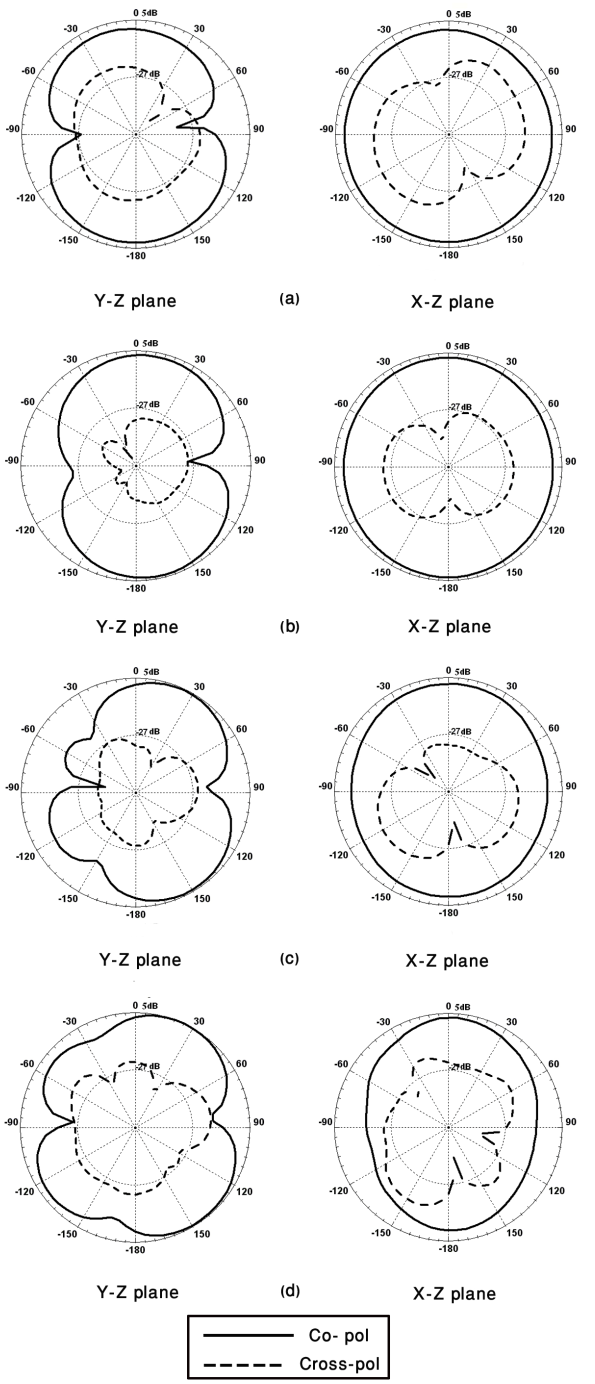

Fig.9. The measured radiation pattern of the proposed antenna. (a) 4 GHz, (b) 6 GHz, (c) 8 GHz, and (d) 10 GHz.

To make sure of the radiation properties of the antenna, the radiation pattern is measured at the frequencies 4, 6, 8 and 10 GHz in H-plane (x-z plane) and E-plane (y-z plane). The results of measurements are shown in Fig. 9. From these results, it is possible to define the antenna as a monopole antenna with an omnidirectional performance in the x-z plane. In the y-z plane, the antenna has the 8-shaped radiation which is an important feature of UWB monopole antennas. Concerning the cross-polarized radiation of the antenna, Fig. 9 shows that the cross-polarized field is less than the co-polarized by an average of 20 dB except at the null radiation directions.

CONCLUSION

A printed monopole antenna with novel design is proposed for ultrawideband (UWB) applications. The antenna is constructed using a rectangular shaped radiator with an embedded inverted T-shaped slot located near the feed point. The ground plane is formed from half an ellipse with an embedded truncated circular slot located near the lower edge of the radiator. For an improved impedance matching, the radiator includes two notches at its lower corners. The simulated and measured performance of the antenna shows a band from 2.5 to 11.2 GHz with an omnidirectional radiation pattern.

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