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Wide Band CPW-fed Circular Patch Antenna with Tapered Ground Plane

Maryam MAJIDZADEH* Changiz GHOBADI
Electrical Engineering Department, Urmia University, Urmia, IRAN

***Corresponding Author**
e-mail: maryam_majidzadeh37@yahoo.com

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Abstract

A novel Co-Planar Waveguide (CPW)_ fed antenna is presented for Ultrawide Band (UWB) applications. The main body of the antenna comprises of a simple circular patch and a ground plane with tapered stepped structure. The bandwidth enhancement is realized by the addition of the tapered steps to the antenna ground plane. The antenna is printed on a compact area of $20 \times 20 \times 1.6mm^3$ FR4 substrate and operates over the very wide band of 3-29.5GHz for S11<-10dB, that is as high as 163%. Good agreement is obtained between the simulated and measured results. Antenna design process and bandwidth enhancement technique will be discussed in detail.

Keywords: UWB antenna, CPW feed line, Circular radiating patch.

INTRODUCTION

Due to the continuous progress of UWB technology, there has been a growing demand for novel and modified communication devices. Antennas, as an important part of the communication systems, are not an exception and has subjected to great changes. Nowadays, the proposed UWB antennas are required to offer some characteristics such as compact size, wide bandwidth, easy fabrication and good radiation properties. Many difficulties are met in the design of antennas with the mentioned merits, but the main considered problem, is the problem of narrow bandwidth. In the literature, a vast variety of antennas are presented to operate over the frequency band of 3.1-10.6GHz which is assigned by FCC as UWB frequency range. Different techniques and various combinations of radiating patch shapes and feeding structures are adopted by the authors to widen the impedance bandwidth. For instance in [1], a monopole like slot and a fork shaped feeding structure is employed to design an UWB antenna. In [2], in order to enhance the impedance bandwidth, a parasitically loaded circular hat patch is introduced. An elliptical monopole patch combined with a trapeziform ground plane is presented in [3]. Authors in [4] offer a slot antenna with an arc shaped tuning stub which provides an impedance bandwidth of 135%. The antenna proposed in [5], uses stair case radiating element and an inverted stair-style ground to reach the UWB frequency range. In this paper, a novel CPW-fed antenna is presented for UWB applications. What makes the antenna distinctive, is the very simple structure, by which a very wide band along with proper radiation properties are obtained. The antenna is printed on FR4 substrate with permittivity of 4.4, loss tangent of 0.002 and thickness of 1.6mm. A simple circular patch is fed by a CPW feed line. The ground plane structure consists of tapered steps that are added to create a new path for the current and enhance the bandwidth. The antenna in this work has smaller size respect to the most of the previously designed antennas and operates over larger bandwidth. The widest impedance bandwidth is obtained with the circular patch. The simulation results are carried out using Ansoft High Frequency Structure Simulator (HFSS). The rest of the paper is organized as follows: Section 2 describes the antenna geometry and design process. The simulated and measured results are presented in Section 3, and finally section 4 concludes the paper.

MATERIALS AND METHODS

The schematic geometry of the proposed antenna is shown in Fig.1.a. The fabricated antenna with the SMA connector connected to its extremity is also shown in Fig.1.b. The antenna is printed on a FR4 substrate with permittivity of 4.4, loss tangent of 0.002 and thickness of 1.6mm. Both the circular radiating patch and the ground plane are printed on one side of the substrate, so the fabrication is very easy and low cost. As it is seen from Fig.1, a simple circular patch with radius of 4mm is fed by a 50Ω CPW feed line. The length and width of the feed line are 4.65mm and 2mm respectively. The feed line width and the separation between the feed and ground plane (s=0.5mm) are selected to reach the 50Ω input impedance. The ground plane of the proposed antenna has a very simple structure. Three steps are added to the ground plane to enhance the antenna bandwidth. The addition of these steps creates a new path for the current. The flow of current through this newly created path, leads to impedance matching improvement and consequently bandwidth enhancement.

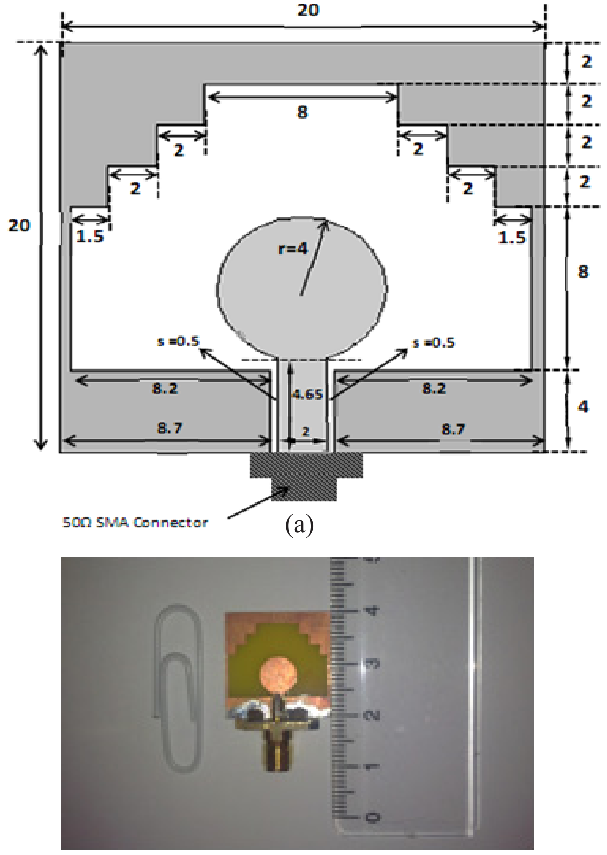

Fig.1. The geometry of the proposed antenna (a) The schematic structure, (b) The fabricated antenna.(unit:mm)

RESULTS AND DISCUSSIONS

Radiating Patch Shape

As it was mentioned earlier, a circular patch is used in the antenna structure. To show the effect of patch shape on the antenna performance, five antennas with different patch shapes are presented in Fig.2. Triangular, square, hexagonal, elliptical and circular patches are the configurations selected to be investigated. The return loss curves of the antennas with mentioned patches are plotted in Fig.3.

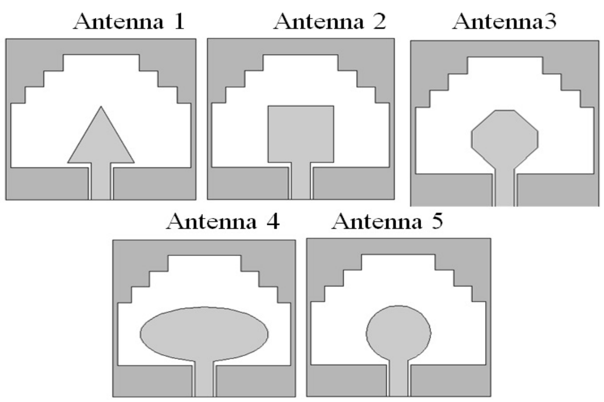

Fig.2. The geometry of the proposed antennas with different patch shapes

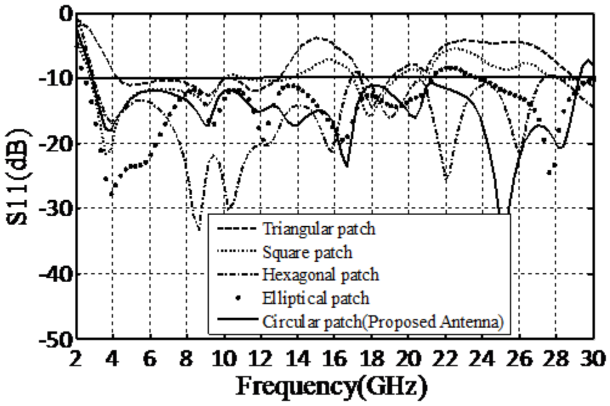

Fig.3. Simulated return loss curves for the proposed antennas with different patch shapes.

From Fig.3, it is seen that both lower and upper frequencies are sensitive to the variation of antenna radiating patch shape. Simulation results show that with triangular and square patch, the antenna does not satisfy the UWB frequency range. With hexagonal, elliptical and circular patches, the impedance matching has improved significantly specially at the frequency band of 13-30GHz. Fig.3 confirms that the circular patch has the widest impedance bandwidth among the other patch shapes

Antenna Design Steps

To better understand the antenna design, the design process is divided to four steps. The development process is shown in Fig.4. In step.1, the antenna consists of a circular radiating patch and a simple ground plane. In step.2 to step.4, the tapered steps are added to the antenna structure repeatedly. The antenna in step.4, shows the final geometry presented in this paper. The return loss curves for the antennas are also shown in Fig.5.

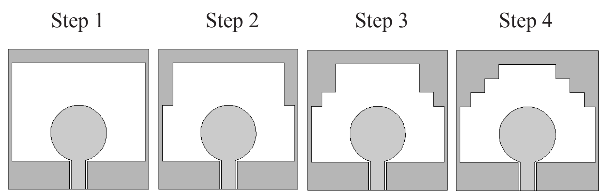

Fig.4. Configuration of the antennas in four steps

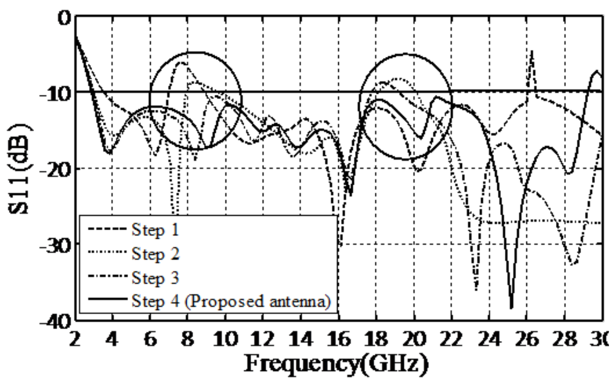

Fig.5. Simulated return loss curves for the antennas in Fig.4.

From Fig.5, it is clear that both edge frequencies are changed by the changes made in the ground plane structure of the proposed antenna. The antenna in step.4 which shows the final design presented in this paper, operates over wider bandwidth. In the final design, the impedance matching has obviously improved at the frequency ranges of 16-18GHz and 22-24GHz, that are shown in Fig.5 by two circles. To have a deeper insight of the effect of the tapered steps, the surface current distribution at the sample frequency of 7.5GHz, is also shown in Fig.6. It is seen that the addition of the tapered steps has smoothed the sudden sharp point of the current path. When the current flows through the new path, formed by the tapered steps, it does not encounter sharp points and consequenctly the bandwidth is enhanced.

The Circular Patch Radius(r)

It was mentioned that the circular patch, has wider bandwidth respect to the other patch shapes. To investigate the effect of the circular patch dimensions on the antenna performance, return loss curves for different values of r are plotted in Fig.7. It is seen that by increasing r from the initial value of 3.5mm, by a step of 0.5mm, the lower and upper edge frequencies, has shifted toward lower and higher frequencies, which leads to the bandwidth enhancement.

Fig.8 shows the measured and simulated resturn loss curves. As it is seen nearly good agreement is obtained between the measured and simulated resuts. The difference may be due to the SMA connector and soldering effects. Measured results show that the proposed antenna operates over the frequency range of 3-29.5GHz.

The measured gain of the antenna is also plotted in Fig.9. Acceptable gain is obtained for the antenna over the UWB frequency range.

The antenna patterns at the sample frequencies of 5GHz, 10GHz and 17GHz at H-plane and E-plane are measured and plotted in Fig.10. Nearly constant and stable pattern is observed for the fabricated antenna.

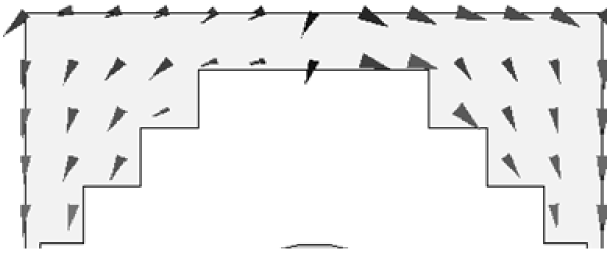

Fig.6. The current distribution at the frequency of 7.5GHz.

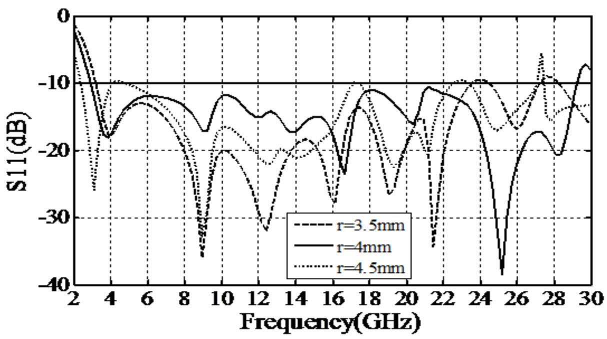

Fig.7. Simulated return loss curves for different values of 'r'

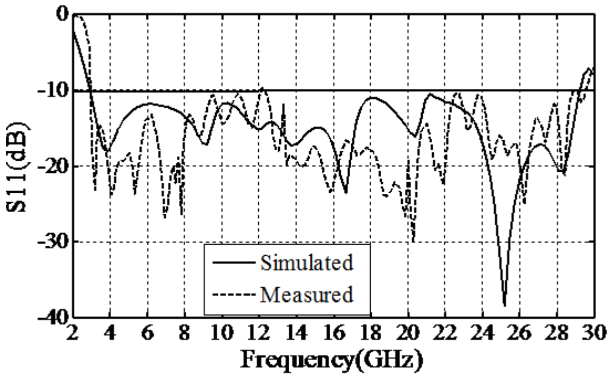

Fig.8. Measured and simulated return loss curves for the proposed antenna.

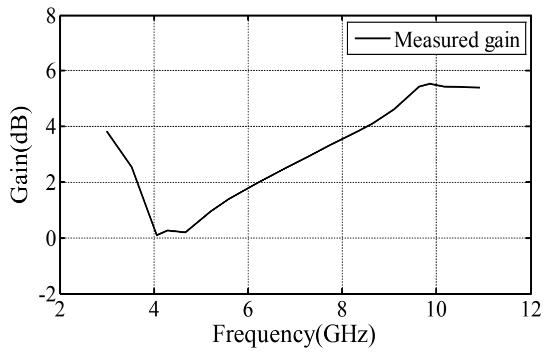

Fig.9. Measured gain of the proposed antenna,

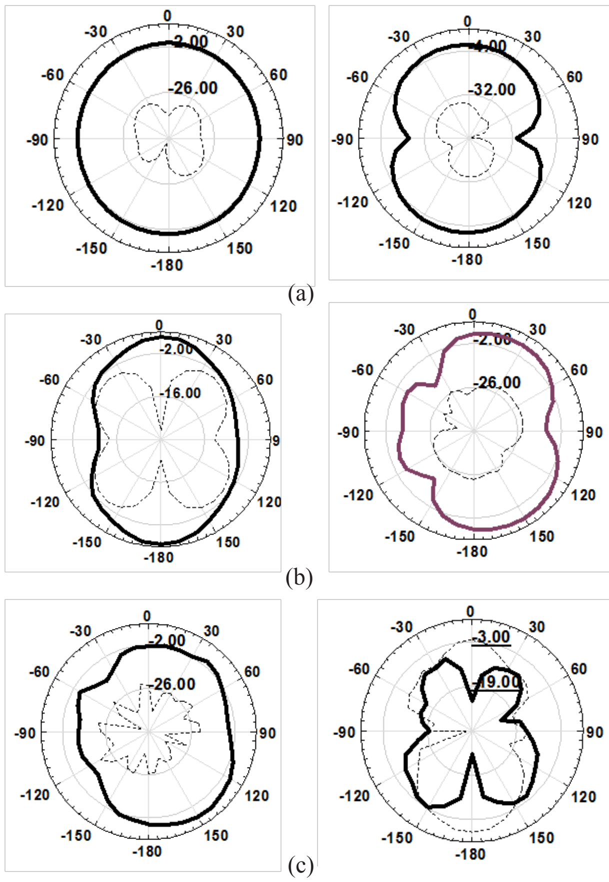

Fig.10. Measured radiation patterns at a: 5GHz, b: 10 GHz, c:17GHz at H-plane and E-plane.

CONCLUSION

A novel CPW-fed antenna is presented for UWB applications. The proposed antenna has a simple structure, consists of a circular patch and a ground plane with tapered steps. The addition of steps on the ground plane of the antenna, leads to the creation of a new path for the antenna current and bandwidth enhancement. The antenna is printed on a compact area of $20 \times 20 \times 1.6 mm^3$ FR4 substrate and operates over the frequency range of 3-29.5GHz that is as high as 163%. Small size, easy and low cost fabrication, very wide operating bandwidth, good radiation properties along with the very simple configuration make this antenna a beneficial choice for UWB applications.

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