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A Novel Flower-Shaped Fractal Monopole Antenna with Enhancement of Bandwidth for UWB Applications

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Abstract

A novel wideband fractal monopole antenna with a semi-elliptical ground plane is presented. In this letter, by inserting a fractal shape in the conventional circular ring, much wider impedance bandwidth and new resonances will be generated. By only increasing the fractal iteration, new bandwidth is attained. The designed antenna has a compact size of $15\times20\times1$ mm^3 and operates over the frequency band between 2 and 21 GHz for VSWR<2. The process of improving the impedance bandwidth and measured results has been presented and discussed.

Keywords: Fractal monopole antenna, ultra wideband (UWB), flower-shaped fractal.

INTRODUCTION

With the improvement of wireless communicati-on, radar, location tracking, ultra-wideband (UWB) systems and some other, UWB antennas have recieved enormous concentration from researchers. For that reason, a monopole antenna with stable radiation properties that has an impe-dance bandwidth (BW) that is wide enough to cover the multiple wireless communication systems is appreciable [1-4].

In the current years, some kind of monopole antennas using modified patch and ground plane or feeding structure have been considered due to more improvement of the BW [1-6] and radiation characteristics [6-8]. additively, minimizing the antenna size with keeping the previous features such as wide BW, good matching and stable radiation characteristics is more profitable.

In this letter, an wideband fractal monopole antenna is presented. Fractal geometry has been useful to design small, multiband, and high-directive elements [9-13]. Effect of the fractal iterations and a semi-elliptical ground plane will be showed. Here, we show that by increasing of the fractal iterations, impedance bandwidth is between 2 to 21 GHz and can support most of the communication standards such as IEEE 802.11a in the US(5.15-5.35 GHz, 5.725-5.825 GHz), HIPERLAN/2 in Europe (5.15-5.35 GHz, 5.47-5.725 GHz) and UWB (3.1-10.6 GHz). The proposed antenna design, simulation and measured results are shown and discussed.

Antenna Design And Configuration

Figure 1 shows an illustration of the unmodified fractal with and without primary ring with the modified design of the third iteration of the fractal. By changing the triangular-shaped to petal-shaped acceptable results attained from the folwer-shaped fractal antenna. The iteration scale for the fractal is 0.5. Figure 2 shows the geometry of the proposed antenna which consist of flower-shaped and a semiellipse-shaped ground plane. The proposed fractal antenna printed on FR4 substrate (permittivity 4.4 and loss tangent 0.024) with compact dimension of $15\times20\times1$ mm^3 . To achieve impedance matching that results in bandwidth enhancement, the technique of loading a rectangular notch (2×2 mm at the fee-ding position in the ground plane introduced [4]. The width and length of the microstrip feed line are fixed at 2 and 5 mm respectively, to achieve 50 Ω characteristic impedance [1].

Due to the increasing fractal iteration on the fractal patch, it is expected that the bandwidth of antenna will be increased [1]. The fractal patch has a distance of g=0.3 mm to the ground plane having length of 5 mm and width of 15 mm printed on the back surface of the substrate.

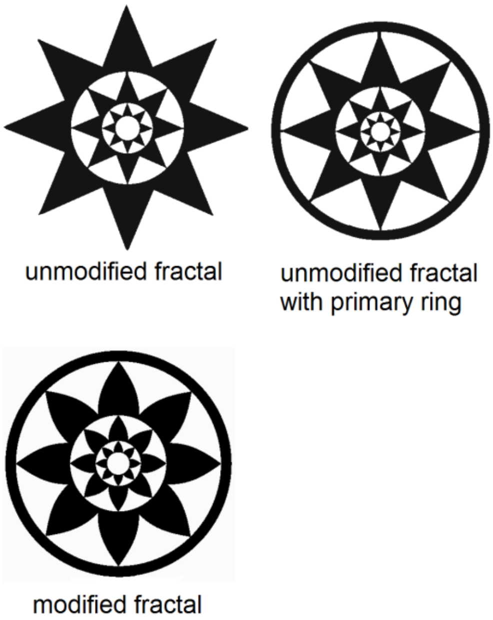

Fig. 1. Illustration of the unmodified fractal with and without primary ring with the modified fractal scheme for the 3rd iteration.

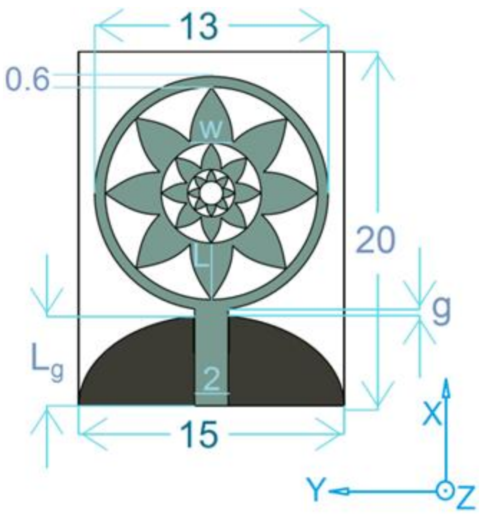

Fig. 2. Geometry of the proposed fractal antenna (unit:millimeters).

SIMULATED AND MEASURED RESULTS

The parameters of the proposed antenna are studied by changing one parameter at a time and fixing the others. To fully understand the behavior of the antenna's structure and to determine the optimum parameters, the antenna was analyzed using Ansoft HFSS (ver. 13). In this section, we have presented the simulated results for the first three iteration of the proposed antenna, and different values of g based on the third iteration of the proposed fractal antenna. Also the effect of different width and length of the petals has been investigated. Eventually the simulation and measured of proposed fractal antenna is presented.

The simulated S_{11} curves for the first three iterations of the modified fractal and third iteration of unmodified fractal with and without the primary ring are framed in Fig. 3. From the simulation results in Fig. 3, it is observed that increasing fractal iteration on the fractal patch will increase impedance bandwidth. Fig. 3 demonstrates that in the first iteration, we can not access the antenna with the properties of UWB antenna, thus the impedance matching becomes poor. In step 2 also we have less impedance matching and there is a shift in the resonant frequency towards higher frequencies. Besides, unmodified fractal straitened impedance bandwidth and has an unanticipated result for the two status of having ring and without ring. The simple semiellipse ground (GND) plane acts as an impedance matc-hing circuit [5]. The parameter g, is the prominent factor of the third iteration of the proposed fractal antenna, which is optimized to attain the most impedance bandwidth and better impedance matching [1]. The simulated S_{11} curves for the third iteration of fractal antenna with different values of g are plotted in Fig. 4.

Fig. 5 shows the effect of different width and length of the petals for the third iteration of the modified fractal. From the simulation results in Fig. 5, it is observed that for the length L=3 mm and width W=2.4 mm we have more better impedance bandwidth for the third iteration of fractal. The measured results of S_{11} parameter of the designed antenna is presented in Fig. 4. The measured 10-dB bandwidth of the proposed antenna is 1.8~21 GHz. From the simulation and measured results, it is observed that the impedance bandwidth enhances in the measurement.

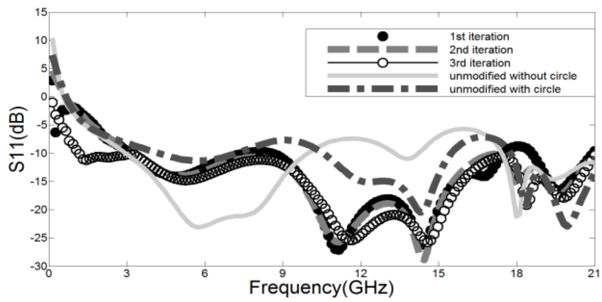

Fig. 3. The simulated S_{11} curves for the first three iterations of the modified fractal and third iteration of unmodified fractal with and without the primary ring.

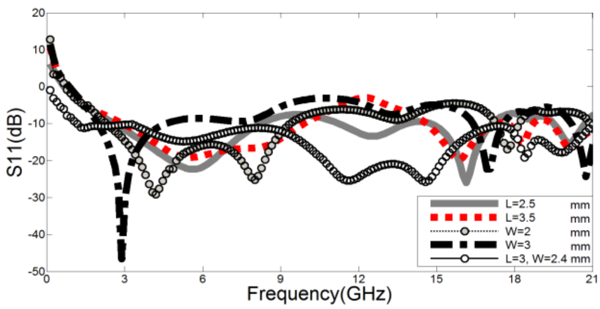

Fig. 4. The simulated S_{11} curves for the third iteration of fractal antenna with different values of g.

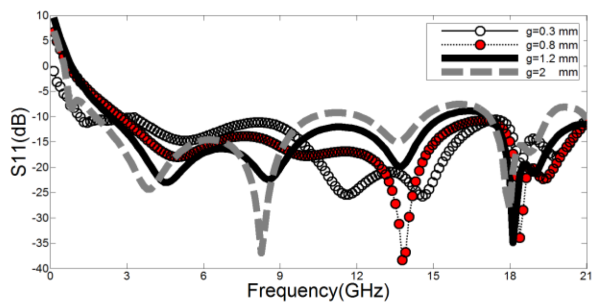

Fig. 5. The simulated result for different types of L and W values.

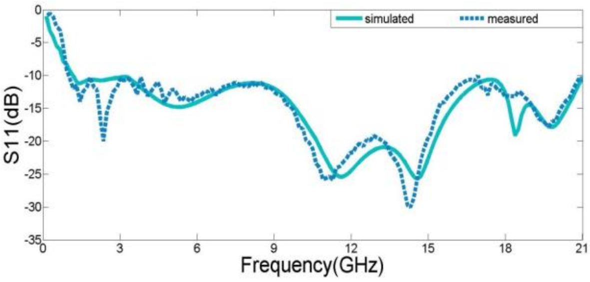

Fig. 6. Comparison between measured and simulated return loss for the proposed antenna.

The 10-dB bandwidth of the proposed antenna is 158% (2-21 GHz) and 160% (1.8-21 GHz) for measured antenna, and a ratio band of 10.5:1 and 11.7:1 respectively calculated. The flower-shaped fractal structure has not only been simulated, but furthermore fabricated as printed monopole using conventional printed circuit board (PCB) techniques (Fig. 7).

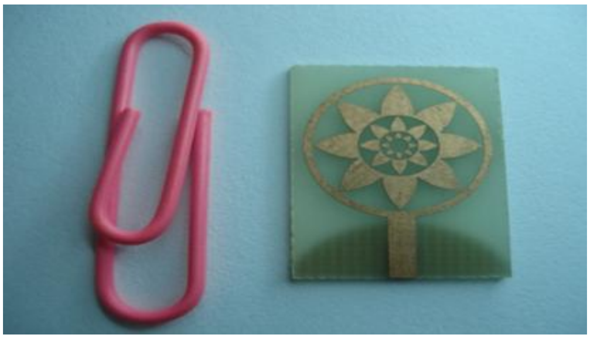

Fig. 7. Photograph of the fabricated fractal antenna.

Measured results of the radiation patterns of the corresponding proposed flower-shaped fractal antenna at 3, 6, 9, and 14 GHz are depicted in Fig. 8. It is obvious that the fractal antenna bring figure-eight shape radiation patterns in the E-plane (x-z plane) and stable patterns in the form of omnidirectional radiation pattern in the H-plane (y-z plane). The simulated and measured peak gain variation of the proposed fractal is displayed in Fig. 9. As shown in Fig. 9, the gain of antenna has an increasing pocedure from 2 to 12 GHz with small undergone. Also it is manifest from Fig 9 that the gain of this antenna is stable along 2-21 GHz approximately. Also radiation efficiency in Fig. 9 is presented. We see that good adjustment is available between simulated and measured results.

In order to verify the capability of the proposed flower-shaped fractal antenna to operate as a UWB antenna, it is necessary to achieve a consis-tent group delay. The group delay needs to be constant over the entire band as well [14, 15]. Measurement of the group delay is performed by exciting two identical prototypes of the antenna kept in the far field for two orientations: side by side and face to face. The separation between the identical fractal monopole antenna pairs was 1 m. Fig. 10 indicates magnitude of group delay for side by side and face to face orientations of the fractal antenna. It is observed that the group delay variation is less than 1 ns for side by side and 0.6 ns for face to face orientations over UWB. It is also interesting to mention that this flower-shaped fractal is invented by authors for the first time. It is observed that in comparison to other fractal and UWB antennas, we have exciti-ng results and very compact dimension having both UWB and fractal properties.

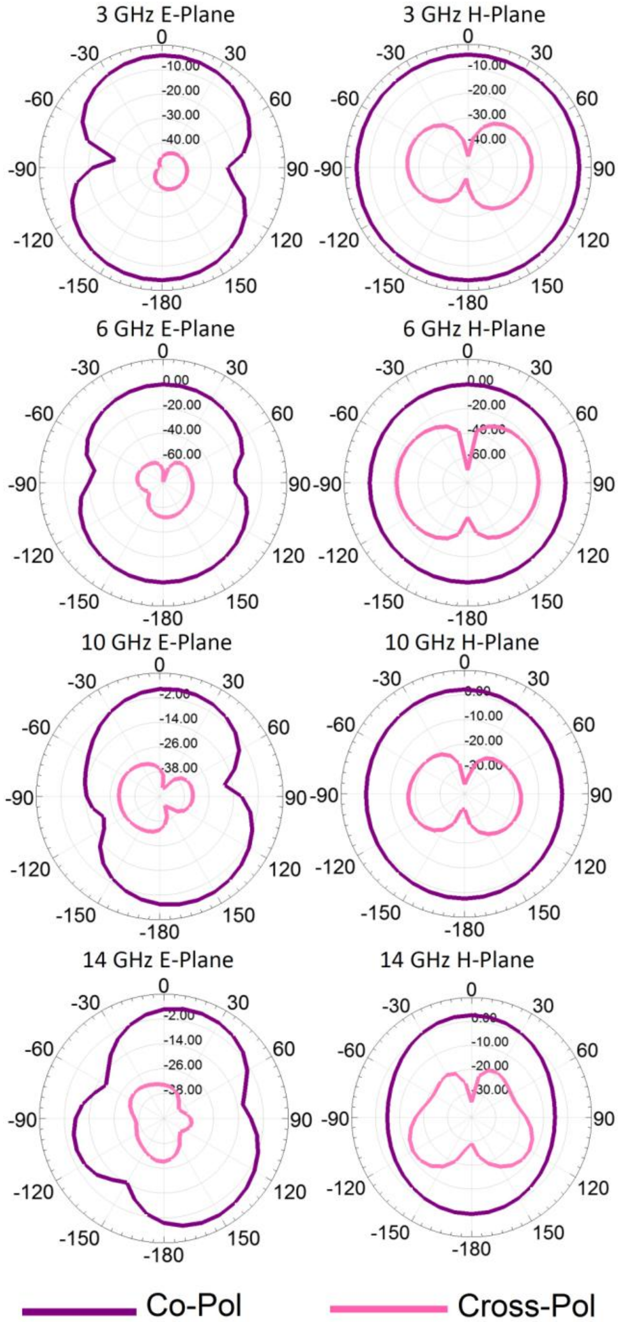

Fig. 8. Measured E (xz)-plane and the H (yz)-plane radiation patterns of proposed fractal antenna at 3, 6, 9 and 14 GHz.

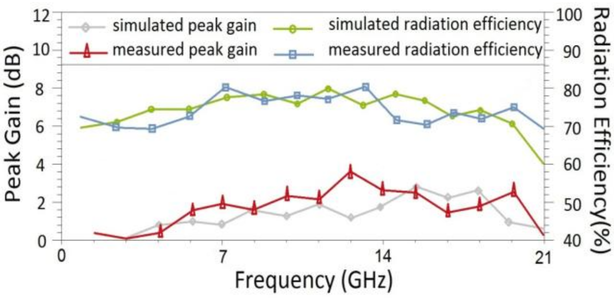

Fig. 9. Simulated and measured results of radiation efficiency and gain variation of proposed antenna.

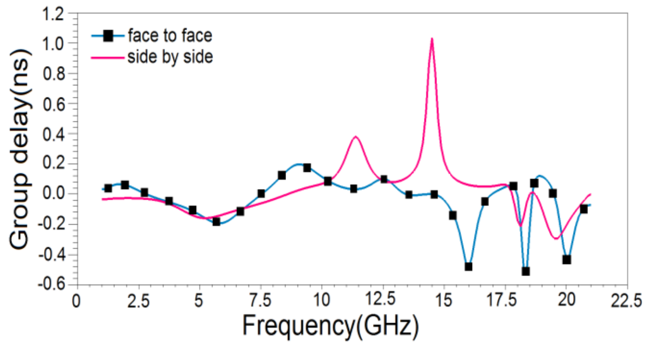

Fig. 10. The group delay of the proposed fractal antenna for side by side and face to face configuration.

CONCLUSION

A novel flower-shaped fractal monopole antenna with a very compact size was presented and investigated. We showed that by increasing the fractal iteration and optimizing antenna parameters with proper values, a very good impedance matching and improvement bandwidth can be attained. This would be the results of the fractal's space-filling and its special layout properties. The operating bandwidth of the proposed fractal antenna covers the entire frequency band from 2 to 21GHz. Both measured and simulated results had been suggested that the proposed fractal antenna can be suitable for UWB communication applications.

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