A Novel Fractal Monopole Antenna with Wide Bandwidth Enhancement 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 are generated. By only increasing the fractal iterations, larger bandwidth is attained. The designed antenna has a compact size of 25×25×1 mm^3 and operates over the frequency band between 2.2 and 17 GHz for VSWR<2. The process of improving the impedance bandwidth and measured results are presented and discussed.

Index Terms **─** Fractal, monopole antenna, Ultra-Wideband (UWB).

I. INTRODUCTION

With the development of wireless technology, satellite navigation systems, wireless LANs, Ultra-Wideband systems (UWB) and some combinations of them are introduced. Therefore, a single antenna with stable radiation properties and wide impedance Bandwidth (BW) enough to cover the multiple wireless communication systems is respectable [1-4].

During the recent years, various types of monopole antennas using modified patch and ground plane or feeding structure have been discussed in order to achieve more improvement of the BW [1-6] and radiation characteristics [6-8]. In addition, reducing the antenna size with keeping the previous features such as wide BW, good matching and stable radiation characteristics is more beneficial.

In this letter, a wideband fractal monopole antenna is presented. Fractal geometry has been useful to design small, multiband, and high-directive elements [9-13]. Effects of the fractal iterations and a semi-elliptical ground plane will be shown. Here, we show that by increasing of the fractal iterations, impedance bandwidth is between 2.2 to 17 GHz and can support most of the communication standards such as IEEE802.11a 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.

II. ANTENNA DESIGN

The geometry of the proposed antenna which consist of fractal patch with a semi-ellipse shaped ground plane is illustrated in Fig. 1. The scale factor for converting the first iteration to second iteration is 0.5 and etc. The construction procedure of the antenna is illustrated in Fig. 3. The final fractal shape of radiating patch is achieved by inscribing the first itration of koch fractal within the circular radiating patch, and repeating this three times. More itrations aren't implemented because of negligible effect on impedance bandwidth of proposed antenna.

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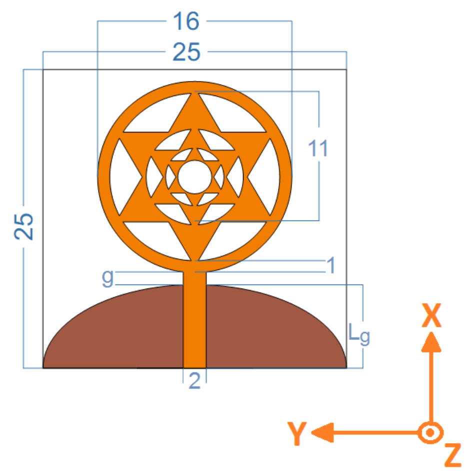

Fig. 1. Configuration and parameters of the proposed antenna (unit: millimeters).

The proposed fractal antenna with specified dimension of 25×25 is printed on FR4 substrate with relative permittivity of 4.4, loss tangent of 0.02 and thickness of 1 mm. To achieve a better impedance matching that results in bandwidth enhancement, the technique of loading a rectangular notch with dimension of 2×2 mm^2 at the feeding position in the ground plane is used [1]. The proposed shape of the truncation in the ground-plane acts as an effective impedance matching network to realize an antenna with a wide impedance bandwidth. This is because the truncation creates capacitive loading that neutralizes the inductive nature of the patch to produce nearly pure resistive impedance present at the antenna's input [14-16]. The width W_f and length L_f of the microstrip feed line to achieve 50 Ω characteristic impedance are fixed at 2 and 8 mm, respectively.

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 is printed on the top surface of the substrate, has the distance of g=0.5 mm to the ground plane.

The dimension of the ground plane is L_g=7.5 mm and the width of W_g=25 mm. The final optimal values of the parameters of the antenna are shown in Fig. 1. Moreover, the structure of the antenna is symmetrical with respect to the longitudinal direction. The height of the feed gap between the main patch and the ground (g) is also an important parameter to control the impedance bandwidth. Since g is the gap between the ground plane and the patch, in a broad sense, the ground plane serves as an impedance matching circuit and it also turns the resonant frequency [1]. By adjusting g, the electromagnetic coupling between the lower edge of the patch and ground plane can be properly controlled [3].

III. SIMULATED AND MEASURED RESULTS

The parameters of the proposed antenna are studied by changing one parameter at a time while 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 iterations of the proposed antenna, and different values of L_g and g based on the third iteration of the proposed fractal antenna. Eventually, the simulation and measured of proposed fractal antenna are presented.

The simple semi-ellipse Ground (GND) plane acts as an impedance matching circuit [5]. The parameters L_g and g, is the two prominent factors of the third iteration of the proposed fractal antenna, which are optimized to attain the most impedance bandwidth and better impedance matching. The simulated S_{11} curves for the third iteration of fractal antenna with different values of L_g and g are plotted in Fig. 2.

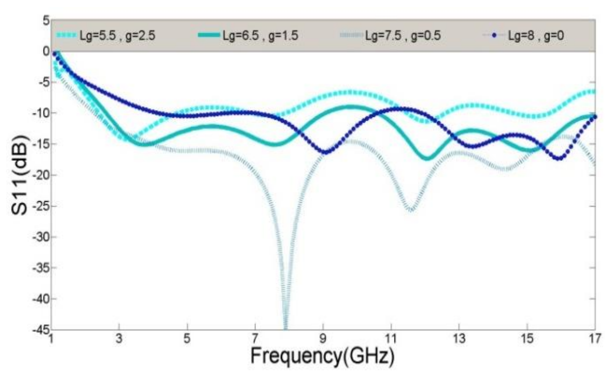

Fig. 2. Simulated S_{11} curves for the third iteration of the fractal antenna with different L_g and g.

When the ground length L_g enlarges, the impedance bandwidth increases up. As shown in Fig. 2, the small changes in the width of the gap between the fractal patch and the ground plane, g, has an impressive effect on the impedance matching of the third iteration of the fractal antenna. By decreasing *g* up to 0.5 mm, the ellipticity of the ground plane improves the impedance matching of the proposed antenna. Also, with increasing L_g to 8 mm and decreasing g to 0 mm simultaneously, unprincipled results will be obtained. Consequently, the optimum value for L_g and g are 7.5 and 0.5 mm, respectively. Simulated S_{11} for the first three iterations of the fractal is framed in Fig. 3. From the simulation results in Fig. 3, it is observed that by increasing fractal iteration on the fractal patch impedance bandwidth will be increased and new resonances attained.

The measured results of S_{11} parameter of the designed antenna is presented in Fig. 4. The 10-dB bandwidth of the proposed antenna is 2.2~17 GHz. From the simulation and measured results, it is observed that the impedance bandwidth increases in the measurement.

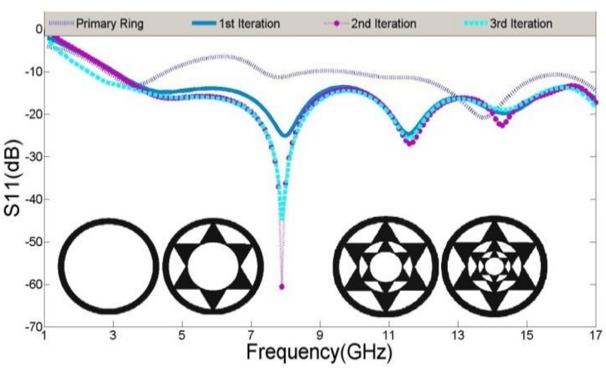

Fig. 3. The simulated S_{11} curves for the first three iterations of the fractal antenna and primary ring.

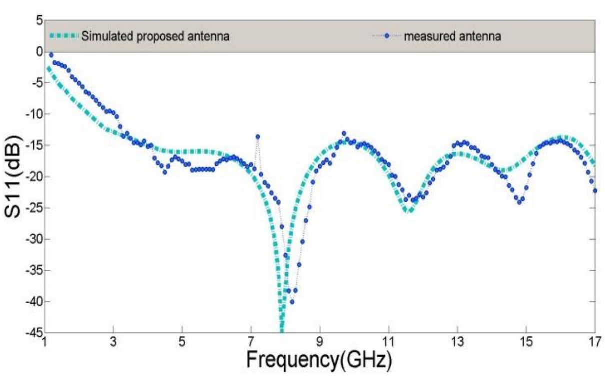

Fig. 4. The S_{11} curves of the simulated proposed fractal antenna and measured antenna.

The proposed fractal antenna have not only been simulated, but additionally fabricated as printed monopoles using common Printed Circuit Board (PCB) methods (Fig. 5). The impedance bandwidth of the antenna is measured using the Agilent 8722ES Network Analyser. In this part of the paper, we have presented the measured results for a fabricated model of the proposed fractal antenna using optimum simulated design parameters. Measured results of the radiation patterns of the corresponding proposed antenna at 4.5, 6, 9, and 13 GHz are depicted in Fig. 6. It is seen that the fractal antenna provides omni-directional radiation patterns in the H-plane (y-z plane) and stable patterns in the form of figure-eight in the E-plane (x-z plane).

The Simulated and measured results of radiation efficiency and peak gain variation of proposed fractal antenna are displayed in Fig. 7. Here, a raising gain from 2.2 to 17 GHz is manifest with small fluctuation in simulation. As shown in Fig. 7, the simulated peak gain is stable along 2.2-17 GHz of the antenna operating band. Also, the measured peak gain has an increasing procedure from 2.2 to 12 GHz with small frequency variation. Also, radiation efficiency in Fig. 7 is presented. We see that good adjustment is available between simulated and measured results. The real and imaginary parts of the antenna input impedance for the proposed fractal antenna are simulated and presented in Fig. 8.

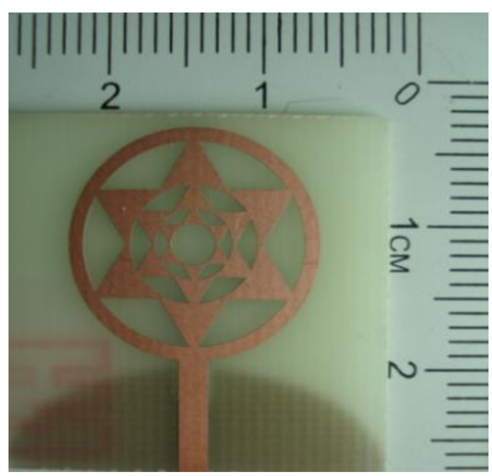

Fig. 5. Photograph of the fabricated prototype fractal antenna.

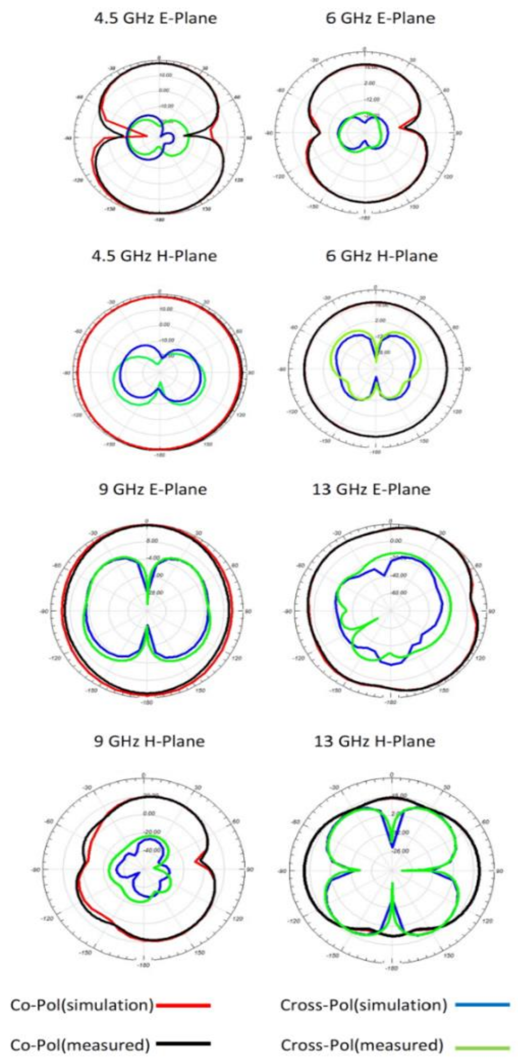

Fig. 6. Simulated & measured E-plane (x-z) and the H-plane (y-z) radiation patterns of proposed fractal antenna at 4.5, 6, 9 and 13 GHz.

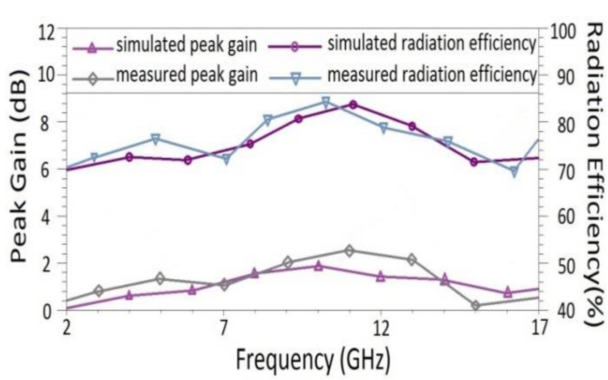

Fig. 7. Simulated and measured results of radiation efficiency and peak gain variation of proposed antenna.

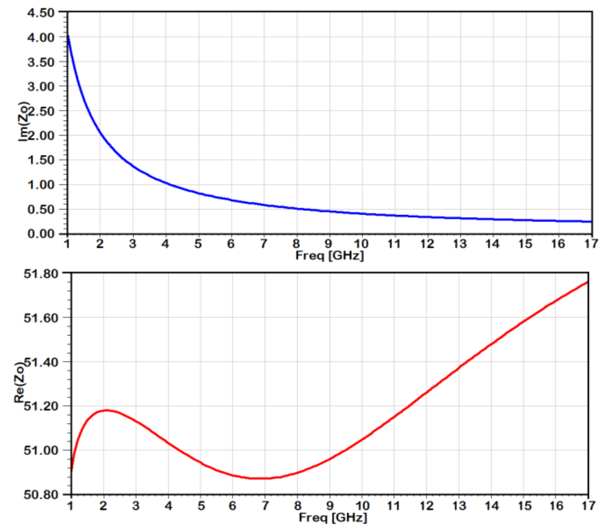

Fig. 8. Simulated antenna input impedance (Ω) curves versus frequency for the proposed antenna.

IV. CONCLUSION

A novel fractal monopole antenna with a 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 obtained. This would be the results of special layout properties. The operating bandwidth of the proposed fractal antenna covers the entire frequency band from 2.2 to 17 GHz. Both measured and simulated results had been suggested that the proposed fractal antenna can be suitable for UWB communication applications.

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