Microstrip Patch Antenna Combining Crown and Sierpinski Fractal-Shapes

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ABSTRACT

This paper presents a design of Microstrip Patch Antenna Combining Crown and Sierpinski Fractal-Shapes and experimentally studied on IE3D software [10]. This design is achieved by cutting multi shapes in square pattern combined with crown & sierpinski fractal shapes and placing a single coaxial feed. The Sierpinski pre-fractal can be defined by an iterated function system (IFS). As a consequence, the geometry has a multilevel structure with many equal sub domains. It is experimentally found that the resonant frequency of the patch can be greatly lowered, and the higher the iteration order of the fractal shapes, the lower the resonant frequency becomes. And this property can be utilized to reduce the size of the microstrip patch antennas. It is also found that, the radiation patterns of the proposed fractal-shaped antennas maintained because of the self-similarity and Centro- symmetry of the fractal shapes. Crown & sierpinski fractal shapes patch antenna is designed on a FR4 substrate of thickness 1.524 mm and relative permittivity of 4.4 and mounted above the ground plane at a height of 6 mm. Bandwidth as high as 31.14% are achieved with stable pattern characteristics, such as gain and cross polarization, within its bandwidth. Impedance bandwidth, antenna gain and return loss are observed for the proposed antenna. Details of the measured and simulated results are presented and discussed.

Categories and Subject Descriptors

B.2.2 [**arithmetic and logic structures]:** Performance Analysis and Design Aids – *Simulation, Verification.*

General Terms

Design, Measurement, Theory

Keywords

Crown square, Sierpinski gasket, Multi-band frequency, Radiation pattern.

1. INTRODUCTION

Antennas are considered to be the largest components of integrated low-profile wireless communication systems, therefore antenna miniaturization is a necessary task in achieving an optimal design for integrated wireless communication systems. In high performance aircraft, spacecraft, satellite, and missile applications where size, weight, cost, performance, ease of installation, low profile, easy integration to circuits, high efficiency antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communication [1]-[20].

The interaction of electromagnetic waves with fractal bodies has been recently studied . Most fractal objects have self-similar shapes, which means that some of their parts have the same shape as the whole object but at a different scale [11]–[14]. The construction of many ideal fractal shapes is usually carried out by applying an infinite number of times an iterative algorithm such as the multiple reduction copy machine (MRCM) algorithm [11]. In such iterative procedure, an initial structure called generator is replicated many times at different scales, positions and directions, to grow the final fractal structure. Because of the space-filling and self-similarity properties of the fractal shapes, fractal theory have been applied to the microwave engineering widely to reduce the size of microwave components, such as electromagnetic band gap (EBG) low-pass filters, branch-line couplers, and etc. By combining the conventional crown square structure and the Sierpinski fractal-shape, the antennas achieved a maximum size reduction. However, the patches derived from this technique are uncentrosymmetrical, thus the radiation patterns changed greatly, and furthermore, this technique decreases the operating bandwidth almost by a factor of 2/3. Fractal shapes have also been applied to the edges of the patch to reduce the size of the microstrip patch antennas in. Although the essence of this technique falls into the inductive loading, the radiation patterns of the antennas derived from this technique maintained because of the self-similarities of the fractals. Fractal antennas have been used as miniature multi-band antennas in which the self-similarity property is used to cause the antenna to resonate in a number of frequency bands. Over the years, various fractal

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structures have been considered for antennas applications. However the greatest inconvenience with this category of multi-band antenna is that all the resonating frequencies of the antenna in its classical from are not the user-defined frequencies. Modifications are therefore required to the structure of the antenna for it to work at the user-defined frequencies. However, a Systematic procedure is used to obtain a final structure.

2. ANTENNA DESIGN

In a fractal antenna the multiple frequencies of operation depend on the overall dimensions of the structure and the scale factor. Controlling the multiple bands of fractal antennas has been demonstrated by proper adjustment of the scale factor in some fractal structure [16, 17].However, from antenna designer's point of view, one need to know the design parameters of the antenna, given the working frequencies.

This crown square antenna is constructed by removing a square shape from an original square as shown in figure 1. After this a same shape with a scale of is added after $(n-1)^{th}$ iteration. The monopole antenna based on the Sierpinski gasket has been extensively studied as an- excellent candidate for multi-band applications. The classical structure of this category is the Sierpinski gasket, which consists of a series of scaled triangles having a scaling of $r = 0.5$(a scale-factor ratio of $\delta = 2$).The electrical properties of this antenna translate into a log-periodic allocation of frequency bands, where these multiple bands each have a common behavior. Manifestations of this behavior have also been observed in the radiation patterns. It has also been demonstrated that the position of the multiple bands can be controlled by proper adjustment of the scale factor used to generate the Sierpinski antenna [16]. Changing the scale factor from 0.5 produces a so-called perturbed Sierpinski gasket, which can be used to control the band spacing. The multi-band behaviors of the antennas, and their patterns for scale factors other than 0.5, have also been observed. However, in all these reported results it could be clearly seen that the log-periodic property was compromised for first couple of frequencies, and for the rest of the frequencies, the frequency ratios did not exactly match the scale factor. This deviation was observed for classical as well as perturbed Sierpinski gaskets. Approximate formulas were reported for classical and perturbed Sierpinski gaskets, for locating the operational frequencies.The design idea was taken from broadband antennas to make the antenna work in a large band of frequencies of the many broadband antennas. Hence the chosen shape of the Microstrip Patch Antenna Combining Crown and Sierpinski Fractal-Shapes, with an aim to achieve smaller size antenna [5]. The geometry of this fractal type microstrip patch antenna is presented in fig.1 with front (top) view.

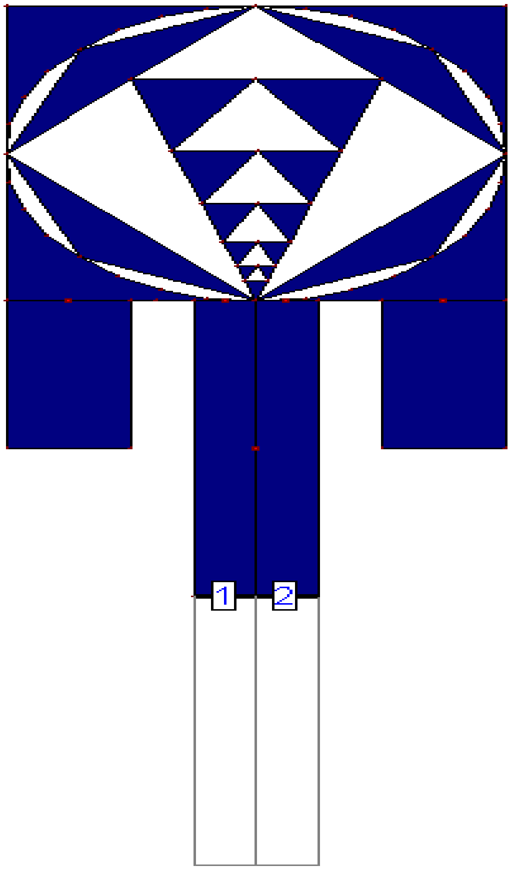

Figure 1. Geometry of proposed fractal type microstrip patch antenna with dimensions h=6mm, t=1.524mm,permittivity=4.4and grid size=.025mm.

This fractal type microstrip patch antenna is fabricated on a FR4 substrate of thickness 1.524 mm and relative permittivity of 4.4. It is mounted above the ground plane at height of 6 mm. In this work, co-axial or probe feed technique is used as its main advantage is that, the feed can be placed at any place in the patch to match with its input impedance (usually 50 ohm). The software used to model and simulate the antenna was IE3D, it can be used to calculate and plot return loss, VSWR, radiation pattern, smith chart and various other parameters.

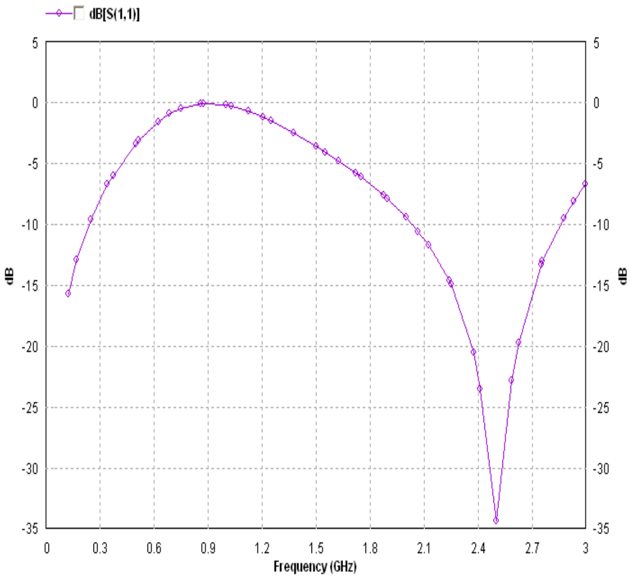

Figure 2. Return loss vs. Frequency curve for proposed antenna

3. RESULTS AND DISCUSSION

The proposed antenna has been simulated using IE3D software [10]. The physical parameters of all antennas are the same, but the resonant frequency decreased as the iteration order increased, thus the electrical length of the ground plane also decreased in their resonant frequency for the proposed fractal patch antennas. The input characteristics of the fabricated small-size fractal patch antennas with different iteration orders are measured through a Vector Network Analyzer. Fig.2 shows the variation of return loss with frequency. Plot result shows resonant frequency 2.53 GHz. And total available impedance band width of 788 MHz that is 31.14% from the proposed antenna. Minimum -34.63 db return loss is available at resonant frequency which is significant. Fig.3 shows the input impedance loci using smith chart. Input impedance curve passing near to the 1 unit impedance circle that shows the perfect matching of input. Fig.4 shows the VSWR of the proposed antenna that is 1:1.20 at the resonant frequency 2.53 GHz.

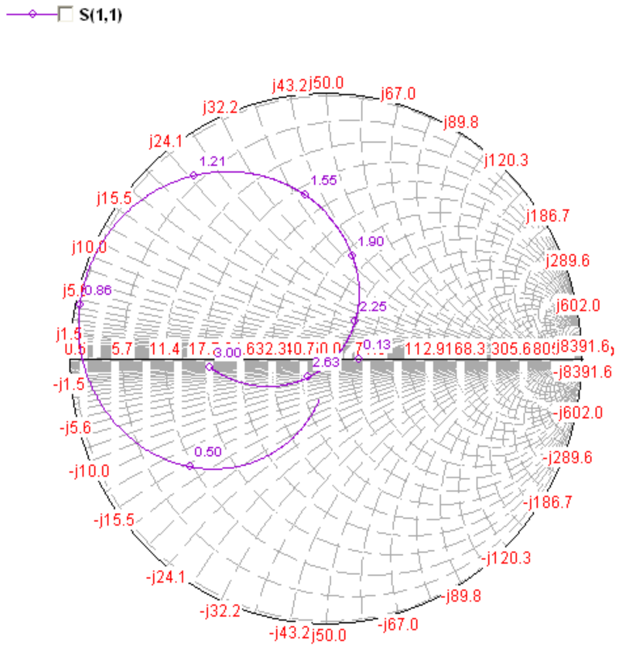

Figure 3. Input impedance loci using smith chart.

Based on the measurement results, we can discuss the size reduction property of the proposed fractal patch antennas. From these results, it is observed that the proposed technique can achieve a maximum size reduction percentage that is greater than the results obtained from other techniques reported so far.

4. CONCLUSIONS

Traditional wideband antennas (spiral and log-periodic) and arrays can be analyzed with fractal geometry to shed new light on their operating principles. More to the point, a number of new configurations can be used as antenna elements with good multiband characteristics.

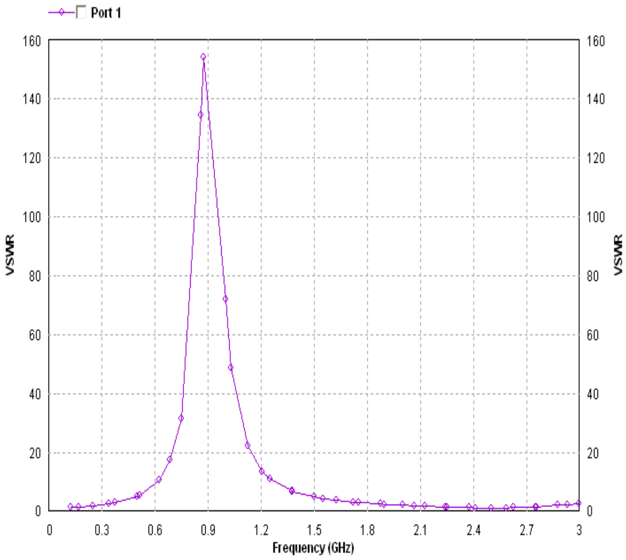

Figure 4. VSWR vs. Frequency curve for proposed antenna

Due to the space filling properties of fractals, antennas designed from certain fractal shapes can have far better electrical to physical size ratios than antennas designed from an understanding of shapes in Euclidean space.

Modern communication systems require antennas with broadband and/or multi-frequency operation modes. These goals have been accomplished employing fractal patch for the radiating element, it is experimentally found that the resonant frequency of the fractal antenna lowered greatly, and this property can be used to reduce the size of the patch antennas. The measurement results show a maximum patch size reduction is achieved by the proposed fractal antennas, without degrading the antenna performances, such as the return loss and radiation patterns. The essence of this size reduction technique is loading the inductive elements (Crown curves) along the patch edges, and loading Self-similar slots (Sierpinski) inside the patch, to increase the length of the current path. The essence of the main- tenance of the antenna radiation patterns is the self-similarities and centrosymmetry of the fractal shapes. The main advantages of the proposed method are: (1) great size reduction achieved (more than 4 times), (2) the radiation patterns maintained, (3) wider operating frequency bandwidth achieved, (4) no vias to the ground, and (5) easiness of the design methodology. To the best of our knowledge, this is the most effective technique pro- posed for the miniaturization of microstrip patch antennas so far. The small-size patches derived from this technique can be used in integrated low-profile wireless communication systems successfully.

With the aim to preserve compactness requirements and to maintain the overall layout as simply as possible and keeping the realization cost very low. In future fractal microstrip antenna reduced patch size and improved bandwidth can be achieved.

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