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A Modified Crown Square Fractal Patch Antenna for Dual and Multiband Operation

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Abstract : *A simple and efficient method of achieving multiband operation on a microstrip patch antenna is presented on this paper. The patch is designed by simply modifying the crown square geometry, which is fractal geometry. Multiband characteristic is obtained by the self similar property of the designed patch. Method to vary the operational frequencies for one antenna is also suggested. The physical dimensional parameters of the designed antenna can be adjusted so as to obtain the frequencies to some useful frequency ranges. The proposed antennas are giving broadside radiation on the working frequencies. The antennas are designed using finite element method based HFSS and its performance is demonstrated in terms of return loss, radiation pattern and VSWR.*

Keywords: *Broadside radiation , Crown square geometry, Fractals, Microstrip patch antenna , Multiband operation.*

I. Introduction

Antenna development plays an important role for the advancements in wireless communication area. It is the device that helps to transmit and receive the signals and because of that it cannot be avoided in a wireless communication system. There is a huge demand of low profile, miniaturized antennas in this area. Microstrip patch antennas have several advantages like easy integration to the printed circuit, light weight etc. Because of the incorporation of different technologies on the same circuit board there is a necessity of designing antennas which can operate on these different frequency ranges which is nothing but the multiband operation. Multiband operation can be achieved by modifying the geometry of the patch. One of the most suggested method to achieve this is by using fractal geometries in patch. Fractal geometry is basically having the self similar property, and that particular property is used on the presented work.

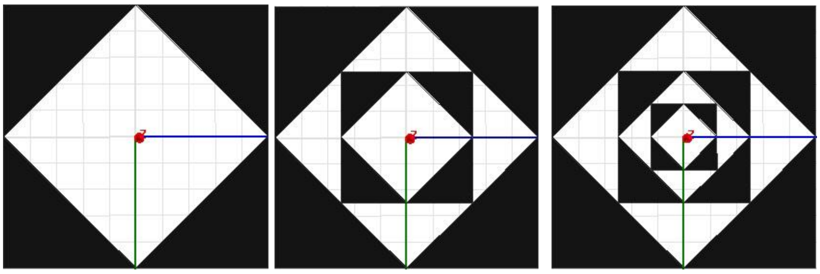
Fractal geometries are different from Euclidian geometry, which is widely used various complex shapes found in nature. Fractal electrodynamics deals with the incorporation of fractal geometries into the field of electromagnetic theory to attain better radiation properties rather than the classical Euclidian geometries. A lot of research works has been done in this area and some of them are given in [1-4]. Fractal antennas with different shapes like Sierpinski carpet[5], Sierpinski gasket[6], Koch island[7] etc are already developed. The main advantages of fractal antennas like compact size, wide band, multiband etc were discussed on these studies.

Crown square geometry[8] is a particular type of fractal geometry in which one square is inscribed in another square in such a way that the corners of the inscribed square bisect the sides of the bigger square. If the process is repeated further, it can be developed to a fractal. For the development of patch with a normal crown square geometry, the inscribed square inside the basic square is subtracted from the same. The consecutive iterations for the crown square geometry are shown in the Fig 1. This basic geometry structure can be modified slightly to vary the operating frequencies. In the proposed antenna a solid square patch is always kept at the centre.

The design of patch, geometrical dimensions and feeding are explained under antenna design. Then the simulation and result of the designed antenna is explained.

II. Antenna Design

The dielectric material substrate chosen is Rogers TMM 4 (tm), which is having a relative permittivity of 4.5. The thickness of the substrate is 1.6 mm. Corner feeding to the basic square shape using a microstrip line is used.



(a) (b) (c)

Figure 1: Crown square geometry iterations: (a) Generator, (b) Iteration 1, (c) Iteration 2

2.1. Modified Crown Square Geometry

In normal crown square geometry it can be observed that the second inscribed square has the same orientation as that of the initial square. If the first inscribed square is made blank space on the patch antenna then the second square will be a solid patch region. Only the first inscribed square defines the blank space. As the resonant frequency depends on the size of the solid patch region, we can vary the operation frequency by varying the size of the inscribed solid square. By observing the figure we can understand that, the blank region defined by the first inscribed square is formed by four triangles along the sides of the inscribed solid square. By simply varying the altitude of those four squares, we can vary the size of the inscribed square.

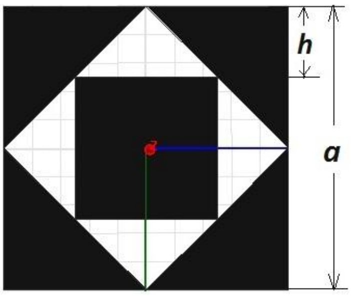
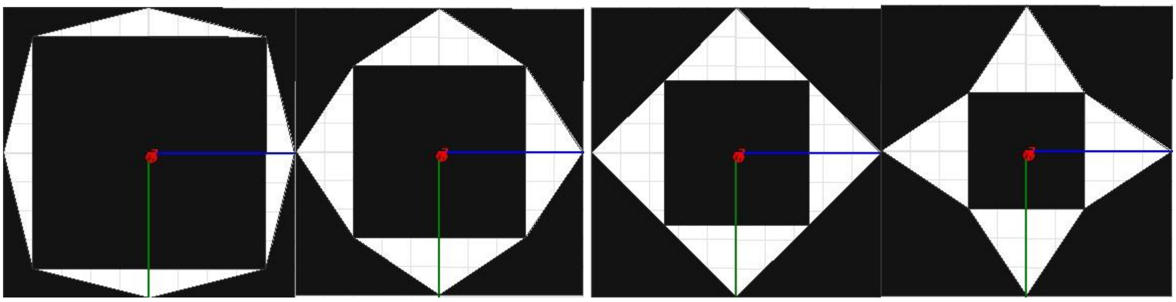


Figure 2. Parameters ‘h’ and ‘a’

The ratio mentioned in this paper is defined as: rt=h/a (1)

The parameters ‘h’ and ‘a’ are shown in Fig 2. The side length of the basic square is defined as ‘a’ and the altitude of each cut out triangle is given as ‘h’. The variations in the geometry for different values of ‘rt’ is shown in the Fig 3. It can be observed that the size of the inner solid square is varying with the value of ‘rt’.



(a) (b) (c) (d)

Figure 3. Geometry variations for different values of ‘rt’: (a) rt=0.1 (b) rt=0.2 (c) rt=0.25 (d) rt=0.3

The lower operating frequency is defined by the first outer square and the higher operating frequency is defined by the inscribed solid square. After defining the value of rt, one can have the basic figure as shown. This process can be repeated with the same ratio to the inner solid square to get the fractal iterations for the same. One such next iteration patch has also been simulated in this study and the results obtained are also presented.

III. Simulation And Result

The designed antenna was simulated in finite element method based Ansoft HFSS 13. It is a high performance full-wave electromagnetic field simulator for 3D passive device. It is having Microsoft windows graphical user interface.

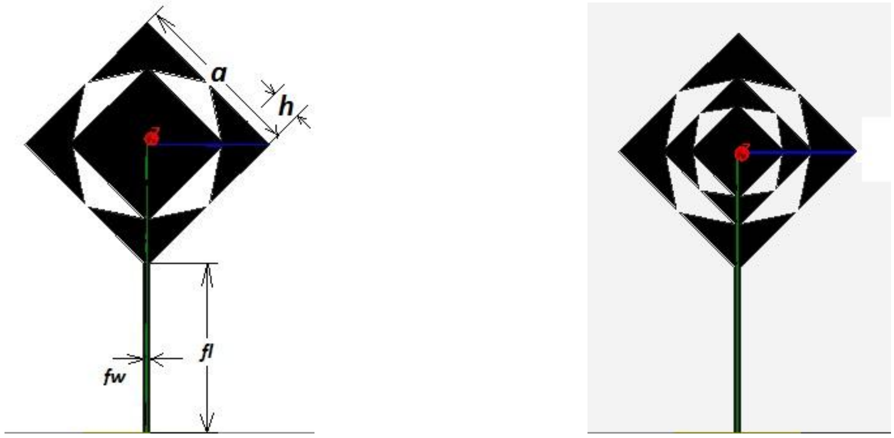


Figure 4. Simulated patch shape for basic antenna and next iteration fractal.

The corner fed patch was designed as shown in the Fig 4. The size of the bigger square can be determined by the simplest formulations given in [9]. The optimum dimensions to resonate at the particular frequencies along with the impedance matching for these antennas were obtained through the parametric analysis in HFSS. The 'rt' value has also been determined using parametric analysis, so that the antenna should work on the useful frequency ranges. By varying the ratio we can vary the spacing between the frequencies.

After simulation the optimum values for the basic antenna variables are obtained as follows:

a=26.87 mm
h=4.886 mm
fl=26.5 mm
fw=1 mm
rt=0.1818

The results obtained are shown in the Fig 5-10 for the basic antenna along with the next iteration antenna. It can be observed that, because of the presence of two solid basic squares, two fundamental frequencies are obtained with broadside radiation for the basic antenna. This makes the antenna a simple dual band antenna. Subsequently for the next iteration three solid square patch are present and that is why we are getting three operating frequencies with broadside radiation. This makes the antenna a multiband antenna.

The radiating frequencies showing in between the obtained frequencies does not have broadside radiation since they are obtained by the higher modes of the bigger patches. The basic antenna is working on 1.77 GHz and 5.8 GHz. The corresponding far field radiation patterns are shown in the figure for phi=0 degree and phi=90 degree (red and violet respectively) with theta is varying from 180 degree to -180 degree. The next iteration antenna result shows that it is operating in 1.57 GHz, 3.7 GHz and 9.26 GHz. Radiation patterns are also shown. The VSWR plots are also shown for both the simulated antennas. It can be observed that the antennas have broadside radiation on the corresponding working frequencies.

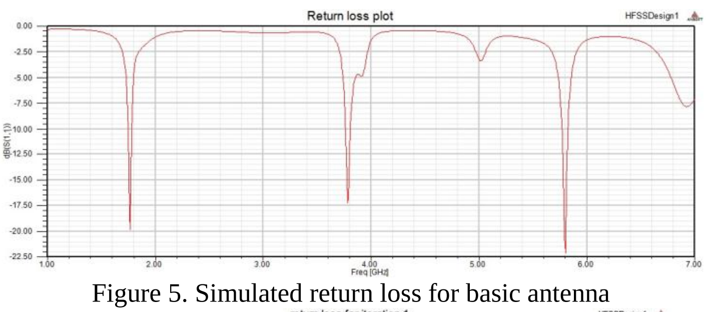


Figure 5. Simulated return loss for basic antenna

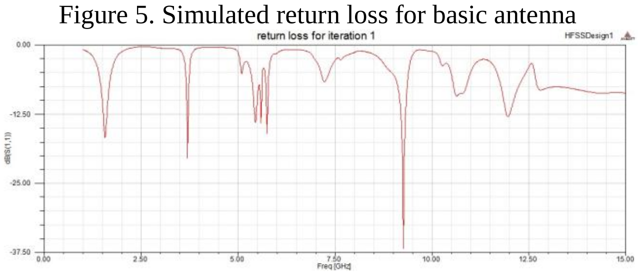


Figure 6. Simulated return loss for next iteration antenna.

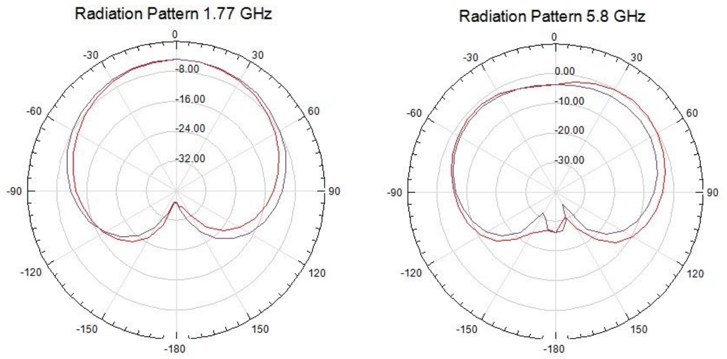


Figure 7. Radiation patterns for the basic antenna

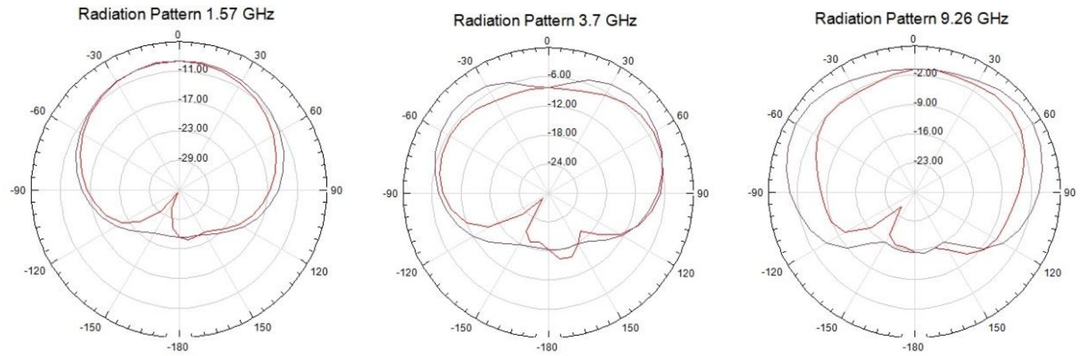


Figure 8. Radiation patterns for the next iteration antenna

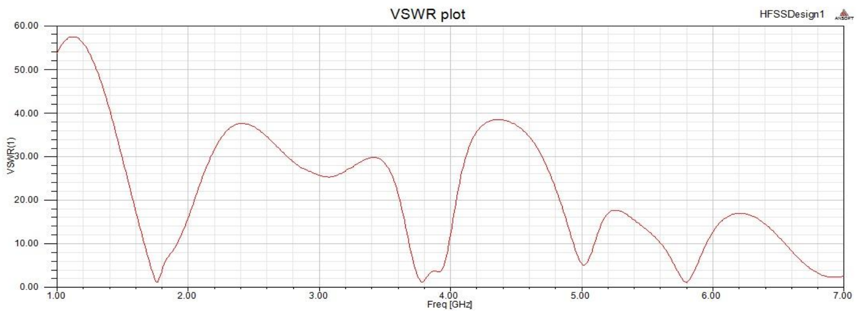


Figure 9. VSWR plot for the basic antenna

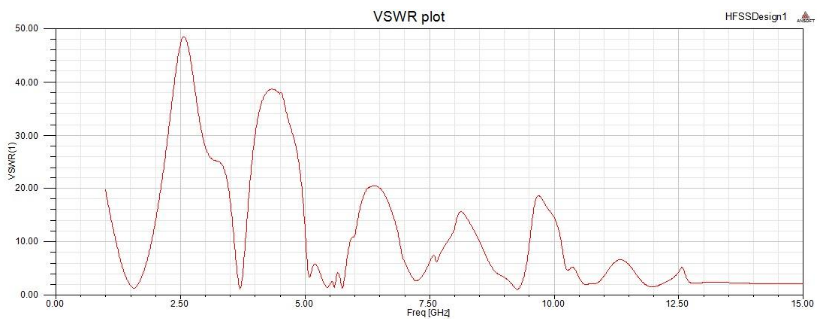


Figure 10. VSWR plot for the next iteration antenna

IV. Conclusion

The design of a modified crown square patch antenna and its next iteration is presented in the paper. It is observed the self similar structure property enables an antenna to work in multiple bands. Also by varying the size of self similar structure one can easily vary the frequencies of operation. This would help to design more sophisticated antennas, which can be used for different applications. Further iterations of the structure can also lead to more higher operating frequencies with broadside radiation, which would be highly desirable factor for the future development of wireless communication.

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