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Design and Simulation of Miniaturized Minkowski Fractal Antennas for microwave applications

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Abstract: In Modern era of technology lots of research is going on in the Wireless Technology. Fractal is a recursively generated structure having self-similar shape, which means that some of the parts have the same shape as the whole object but at different scale. The self-similarity property of fractals if a small part of a fractal is magnified, more features that are reminiscent of the whole can be seen. Achievement of fractal owns property of increasing electrical length of antenna largely and 65% size reduction achieved compared to an ordinary Microstrip antenna at same resonance frequency. Tag and reader are the main two components which involves in the implementation of RFID. A tag consists of an antenna and a programmable chip. Basically a rectangular patch antenna has designed to resonate at 1.03 GHz. Introduction of a floral shaped fractal into basic rectangular patch antenna in the first iteration which resonates at 0.72 GHz and further in second iteration it resonates at 0.636 GHz. result shows the increment in electrical length of microstrip antenna and shifting of resonant frequency.

Index Terms: Fractal, Minkowski island, Koch snowflake, Floral, Microstrip, RFID, patch

I. INTRODUCTION

Microstrip antennas has property of low profile, low cost, conformability and ease of integration with active devices[1].conformal makes it so they can adapt to a curved surface; for example, that of an airplane or other motor vehicle. These make them very popular and attractive for the designers since the early days they appear the size of antenna desired that the reduced size antenna have equivalent operation in comparison with ordinary developed antennas. Small antenna has limits in terms of gain and bandwidth but there are so many communication systems which do not require large bandwidth. Use of dielectric substrates with high permittivity ,applying resistive or reactive loading, increasing the electrical length of antenna by optimizing its shape, Utilization of strategically positioned notches on the patch antenna these are the techniques which are helpful in the reduction of size of antennas. Several methods have been considered to reduce the Microstrip antenna size such as the use of shorting posts, material loading and geometry optimization. Use of slots with different shapes in microstrip patch antennas had proved to be satisfactory in producing miniaturized elements Fractal is a recursively generated structure having self-similar shape, which shows that some of the parts have the same shape as the whole object but at different scale. Fractal has self similarity and another space filling properties.

II. BASIC THEORY OF FRACTAL

Mandelbrot has coined the term fractal and he has investigated the relationship between fractals and nature using discoveries made by Gaston Julia, Pierre Fatou, and Felix Hausdorff [1]. He was able to show that many fractals exist in nature and can be used to accurately model certain phenomena. In addition, he was able to introduce new fractals to model more complex structures, including trees and mountains that possess an inherent self-similarity and self-affinity in their geometrical shape. Fractal concepts have been applied to many branches of science and engineering, including fractal electrodynamics for radiation, propagation, and scattering. Fractals can be classified in two categories: deterministic and random. Deterministic such as the von Koch snowflake and the Sierpinski gaskets, are those that are generated of several scaled-down and rotated copies of themselves. Such fractals can be generated using computer graphics requiring particular mapping that is repeated over and over using a recursive algorithm. Random fractals also contain elements of randomness that allow simulation of natural phenomena.

Procedures and algorithms for generating fractals, both deterministic and random, can be found. Fractal geometries can best be described and generated using an iterative process that leads to self-similar and self-affinity structures as Minkoski island and Koch loop Another classic fractal is the Sierpinski gasket and this fractal can be generated with the Pascal triangle [1]. The trend of the fractal antenna geometry can be concluding by observing several iterations of the process. The final fractal geometry is a curve with an infinitely intricate underlying structure such that, no matter how closely the structure is viewed, the fundamental building blocks cannot be differentiated

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because they are scaled versions of the initiator. Fractal geometries are used to represent structures in nature, such as trees, flowers, birds ,plants, mountain ranges, clouds, waves, and so on[2].

III. MINKOWSKI ISLAND FRACTAL GEOMETRY

In order for an antenna to work equally well at all frequencies, it must satisfy two criteria: it must be symmetrical about a point, and it must be self-similar, having the same basic appearance at every scale that makes it has to be fractal. The fractal geometry defines a structure with long lengths that fit in a compact area. This feature of fractals can be used to design miniaturized resonant antennas due to their reduced physical lengths.The shape of the fractal is formed by an iterative mathematical process. This process can be described by an iterative function system (IFS) algorithm, which is based upon a series of affine transformations [Werner and Ganguly (2003)]. An affine transformation in the plane ω can be written as:

$$w\begin{pmatrix}x_1\\x_2\end{pmatrix} = Ax + t = \begin{pmatrix}r_1 cos\theta_1 & -r_2 sin\theta_2\\ r_1 sin\theta_1 & r_2 cos\theta_2\end{pmatrix}\begin{pmatrix}x_1\\x_2\end{pmatrix} + \begin{pmatrix}t_1\\t_2\end{pmatrix} \quad (1)$$

where x_1 and x_2 are the coordinates of point x. If $r_1=r_2=r$ with $0<r<1$, and $\theta_1=\theta_2=\theta$, the IFS transformation is a contractive similarity (angles are preserved) where r is scale factor and θ is rotation angle [5]. The column matrix t is just a translation on the plane.

Applying several of these transformations in a recursive way, the Minkowski island fractals are obtained as depicted in Fig.1. Originally the initiator is a square which can be regarded as a zeroth order of the Minkowski island fractal (F_1).The first iteration of Minkowski island fractal by removing the middle third of each side by some fraction of 1/11 and by applying the same procedure on F_1, the Minkowski island fractal of second iteration (F_2) is obtained.

Fig. 1. Minkowski Islands

IV. IMPLEMENTATION OF MINKOWSKI ISLAND FRACTAL GEOMETRY ON MICROSTRIP ANTENNA

A. Basic Square Initiator

Originally we have taken a square which is initiator for the minkowski island fractal. Microstrip line feeding techniques has used for the basic square Microstrip patch antenna.

This initiator square Microstrip antenna is designed to resonate at the frequency of 1 GHz and having dimensions of $W_1=L_1=71.33$ mm and $L_f=3.0$ mm $W_f= 58$ mm. FR4/ glass epoxy sheet has used as substrate which has length (L_{sub}= 130mm), breadth (W_{sub}= 100mm) ,height (h=1.6 mm) and $\varepsilon_r=4.4$ and tanδ=0.021 of dimension.

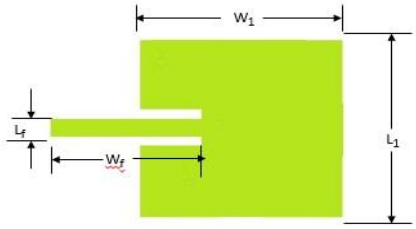

Fig. 2. Initiator Square Microstrip antenna

B. First iteration of Minkowski fractal antenna

With implementation of minkowski island on the square shaped initiator remove the fraction of $\frac{1}{11}$ from the middle third of the each side. And resulted structure is first iteration of minkowski fractal Microstrip antenna (F_1) as shown in Fig.3.L_{1f} = 3.0 mm, W_{1f} = 58.0 mm, L_1 = 71.33 mm, L_{11}= 32.6 mm,L_{12}= 5.9 mm ,L_{13}= 23.5 mm is the dimensions of the below mentioned fig. 3.

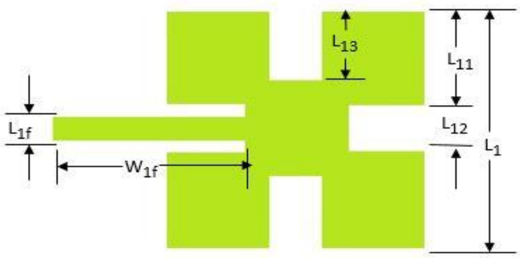

Fig. 3. First iteration of Minkowski fractal Microstrip antenna (F_1)

C. Second iteration of Minkowski fractal antenna

Same procedure is implemented on F_1 as it was implemented on square initiator. remove the fraction of $\frac{1}{11}$ from the middle third remaining of the each side. And resulted structure is second iteration of minkowski fractal Microstrip antenna (F_2) as shown in Fig.4. L_{2f} = 58.0 mm, W_{2f} = 3.0 mm,L_2 = 71.33 mm,L_{21}= 32.6 mm,L_{22}= 5.9 mm,L_{23}= 15.3 mm, L_{24}= 15.3 mm, L_{25}= 2 mm,W_{21}= 23.5 mm is the dimensions of the below mentioned fig. 4.

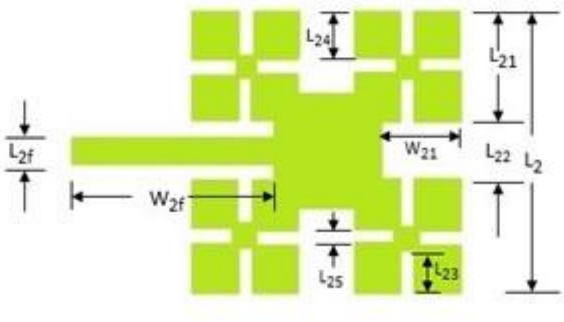

Fig. 4. Second iteration of Minkowski fractal Microstrip antenna(F_2)

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V. SIMULATION AND RESULT COMPARISON

S-parameter narrates the input-output relationship between ports in an electrical system. S_{11}-parameter indicates maximum reflection of power from the antenna hence it is also known as reflection coefficient or return loss (Γ).

CST microwave has used as simulation tool. Return loss of the square initiator Microstrip antenna is -20 dB at the resonant frequency 1GHz as shown in fig. 5

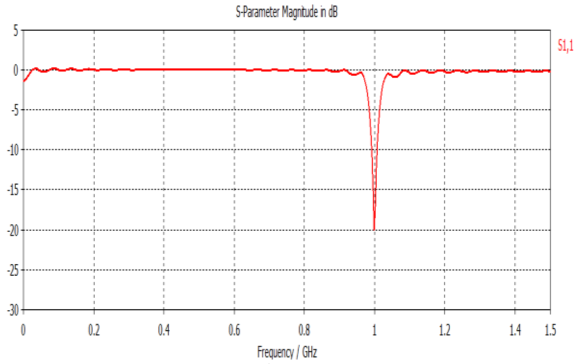

Fig. 5. Simulated return loss of square initiator Microstrip antenna

Simulation from the CST microwave first iteration of minkowski fractal antenna (F_1)results Return loss -31.5 dB at the resonant frequency 0.72GHz as shown in fig. 6

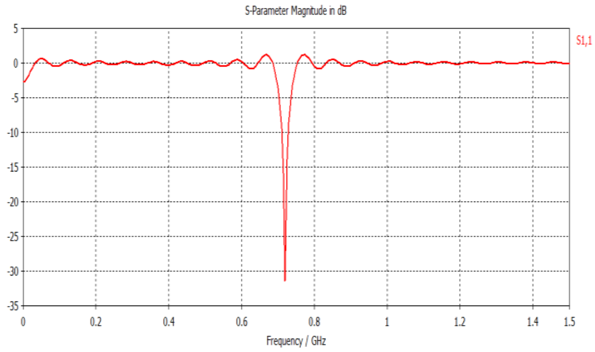

Fig. 6.Simulated return loss of first iteration minkowski fractal antenna (F_1)

Simulation from the CST microwave second iteration of minkowski fractal antenna results Return loss -28.627 dB at the resonant frequency 0.636 GHz as shown in fig. 7

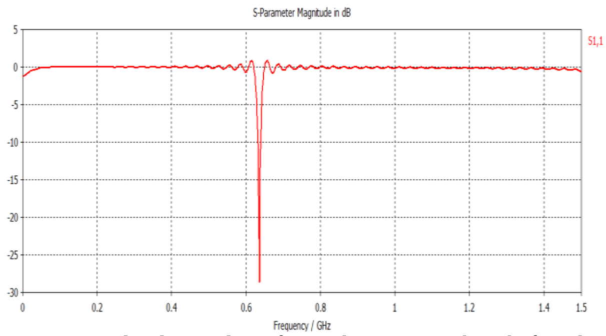

Fig. 7.Simulated return loss of second iteration minkowski fractal antenna (F_2)

Comaparision in the initiator and minkowski fractal microstrip antenna shows the shifting in resonance frequency is due to the increment in the elcrtical length of the microstrip antenna. Fractal pattern minkowski island introduces increase in the electrical length and return loss.

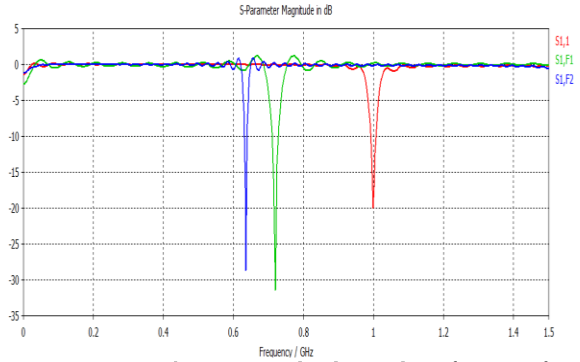

Fig. 8. Comparison between stimulated return loss of initiator, first iteration and second iteration of fractal antenna

Introduction of fractal produces variation in resonant frequency from 1 GHz to 0.636 GHz, and improvement in return loss and also saving in patch area of a fractal microstrip antenna as shown in below mentioned fig. 8. Two compact Minkowski fractal Microstrip antennas have been presented for RFID applications in the 636 MHz and 720 MHz frequency band with adequate gain, and directivity. They offer omnidirectional radiation patterns and good radiation efficiency at the operation frequency. Each of the antenna structures showed high degree of self-similarity and space-filling properties. The antenna designed with the second iteration is more compact than that designed with the first iteration, with a size reduction of about 14%. A further size reduction is expected if a third iteration antenna is designed for the same resonance frequency.

VI. CONCLUSION

A square patch antenna achieved the shifting resonant frequency using minkowski island pattern of fractals . From simulation results, it is found that the improved resonant frequency has shifted from 1 GHz to 636 MHz with same size and dimension of patch antenna in two successive iterations. It shows the return loss of -20 dB at 1 GHz resonant frequency, -31.5 dB return loss at 720 MHz and -28.627 dB return loss at 636 MHz. The proposed antenna can be used in the application of Television, Mobile phones and GPS in Ultra High Frequency range (300 MHz – 1GHz).

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