Simulation of Radiation Characteristics of Sierpinski Fractal Geometry for Multiband Applications

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Abstract—**The choice of adopting the periodical geometries like fractals for wireless applications has been a usual practice considering their geometrical ease in supporting multiband. Among the traditional fractal geometries Sierpinski, Koch are some to name with paramount applications in multiband fractal antennas. In this work we simulated Sierpinski structures for frequencies close to wireless LAN applications which would allow for further modifications to reproduce exact resonant frequencies required for this application. The efficient CAD tool of High Frequency Structure Simulation software package is used to design the required geometry of the proposed fractal antennas. The Finite Element Method based solver of electromagnetic models in HFSS is employed to solve the modeled geometry. Various reports like radiation pattern, reflection coefficient curves, VSWR and field distribution are generated to study the characteristics of the geometries.**

Index Terms—**Sierpinski, fractal antenna, multiband antenna.**

I. Introduction

A man often come across many shapes in the mother nature which are left undescribed by tradition Euclidean geometry. This has become a challenge for many years. The sea coast, the shape of a leaf, the shape of a sub-continent and many more shapes needs a different approach in describing them. This drawback has been overcome by fractal geometry which has the capability to describe shapes with fractal dimensions including 1D, 2D and 3D.

Fractals are no more a new word to the galaxy of researchers in electromagnetics. These geometries have proved themselves as one of the best radiating elements supporting for multiband applications. Designing multiband antennas is a challenge since the antenna needs to behave similar at several frequency bands. Radiating elements which are frequency independent have proved themselves that they are capable as multiband elements provided they have similar behavior at all the resonant frequencies. The behavior in the sense actually refers to various antenna properties like its radiation pattern, impedance properties, directivity and side lobe levels. It should be understood that being frequency independent alone will not be the stake mark to be multiband since it can be multiband without being frequency independent. It has already been investigated that self complimentary and self scalable geometries are capable of serving as frequency independent radiating elements. The principle of self complimentarity and constant impedance property which is called as Mushaike’s relationship is presented in the series of studies on self-complementary antennas summarized in [1] which is considered as the origination of such antennas. A fractal is a result of a repetitive generation of objects having fractal dimension [2]. They come interlaced one within another following iterative phenomenon. Unlike Euclidian geometry (plane or solid geometry) most natural objects have dimensions other than whole numbers where as, fractals form the best representation of those. Fractals come into two major varieties [3] referred as Deterministic and Random. The deterministic category constitutes of those geometries that are composed of several scaled copies of it. Several popular geometries like Sierpinski and Koch fall under this category. Some random fractals exhibit the property of self similarity. Since its evolution, fractals have stolen a major role, satisfying the immense need of dual frequency antennas in WLANS since the release of a complete ISM band. The term fractal is derived from latin word fractus which means broken, was first coined by Benoit Mandelbrot, the pioneer of classifying this geometry. Soon the field found an extensive application in statistical analysis, nature modeling, compression, computer graphics and of course antennas [4], [5]. The unique geometrical properties of advanced antennas based on fractal geometry have been investigated in [6]-[9] and the performance in terms of various properties like size, gain and multifrequency behavior is also reported. A variety of fractal design antennas were first published in 1995 by N. Cohen in [10], [11].

II. Sierpinski Geometry

Sierpinski takes the position of widely studied and employed fractal geometry for EM applications. The description of Sierpinski consists of equilateral triangles with defined dimension in different scales. Generation of the geometry refers to the number of triangles inserted one with in itself. It can be achieved either by attaching triangles progressive scales to itself or by decomposition large triangle into small. In either the cases number of self similar copies refer to the iteration of the generation. Fig.1 shows the formation of a Sierpinski triangle geometry using Iterative process.

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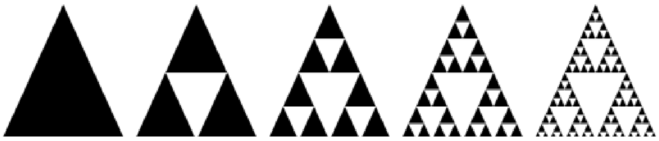
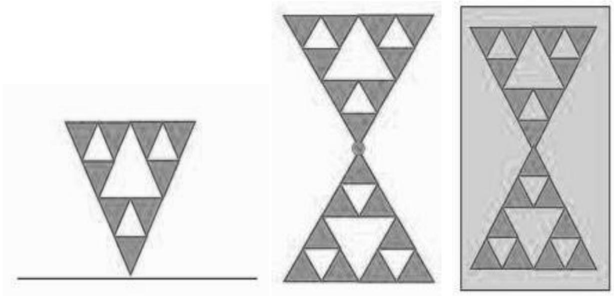


Fig. 1. Sierpinski triangle generated using iterated function system.

Monopole and dipole are the two forms in which a Sierpinski is extensively investigated [12] and are as shown in the Fig. 2.



(a) (b) (c)

Fig. 2. Sierpinski as (a) monopole (b) dipole (c) patch.

Sierpinski has some typical properties like dimension of approximately 1.585, which means that it is a union of three copies of itself, scaled by a factor of ½ [13] and the area being zero[14]. The remnant area after each iteration is clearly 75% of the area from the previous iteration, and an infinite number of iterations lead to zero. The Sierpinski has the ease of modifiable geometry to achieve high directivity. The generation of Sierpinski on the BowTie is proposed as a miniature antenna with high directivity in [6]. High Directivity microstrip patch array inspired by the Sierpinski fractal is simulated with fewer radiating elements in [15]. A modified Sierpinski is designed as a dual frequency microstrip multistacked antenna and metallised foam in [16]-[18].

III. SIMULATION RESULTS

A four iteration fifth generation Sierpinski gasket geometry has been modeled using the effective CAD tool in the HFSS and the same has been represented in the Fig. 3. This geometry has been designed with the steps as discussed in Fig. 1. A rectangular air box is laid around the geometry to facilitate the free space conditions and carry out the solution because of the default the HFSS environment is Perfectly Electric Conducting and in order to isolate the antenna from this environment we have to create our own environment. While simulating such triangular geometries we find a constraint with the meshing phenomenon in HFSS tool. The rectangular gridding cannot incorporate the entire triangular geometries which makes the simulated results deviate slightly from that of practical but with an acceptable deviation. In addition to this constraint a general drawback is with its fabrication of printed planar and complexed geometries of antennas. Hence a modification to the geometry is in demand, subject to the case where the resonant frequencies are not altered.

A study of reflection coefficient characteristics from Fig.4. reveals various resonant frequencies at which the computed value takes minima. It can be inferred from the reflection coefficient characteristics that at five different frequencies (ie; 2.54GHz, 3.56GHz, 5.17GHz, 6.49GHz, 8.84GHz) there is considerable S11 magnitude of less than -10dB and a minimum of -30.14dB at 8.84GHz. Other dips which are above the reference level are ignored. These reports are generated using the terminal solution data after successive solving using interpolation and then fast solution type available in the tool.

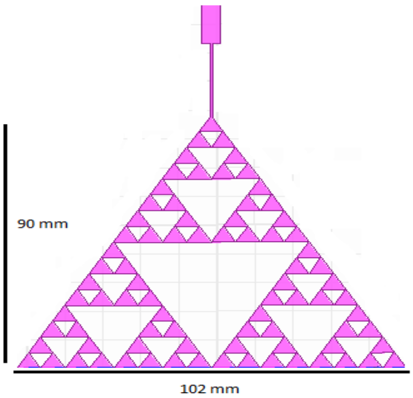


Fig. 3. Simulated sierpinski triangle.

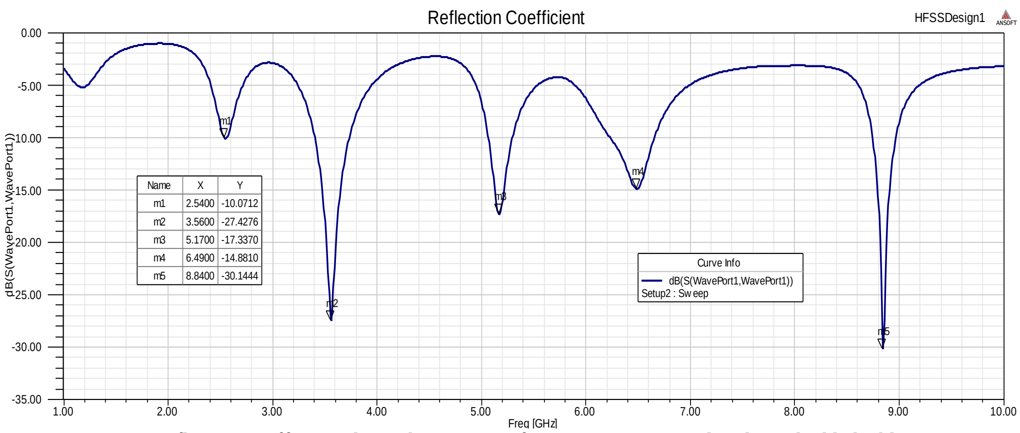


Fig. 4. Reflection coefficient plot with resonating frequencies mentioned in the embedded table.

To understand the multifrequency characteristics of an antenna a study of the reflection coefficient curves alone is not sufficient it may show a very low reflection coefficient in some modes with exhibiting the desired radiation pattern. To support the same, radiation pattern reports are generated at the resonant frequencies as shown in the Fig 5(a) through

Fig 5(h). Fig 5(a)-(d) represent the distribution of the field for all θ and Ø=0^0 and Fig 5(e)-(h) represent the distribution of the field for all θ and Ø=90^0. Directivity characteristics of the antenna can be studied from the Frequency versus Directivity plot as shown in the Fig 6. The directivity takes respectable value at regions of some frequencies which are treated as resonating frequencies with the knowledge from the radiation characteristics. Similarly VSWR values at the resonating frequencies are considerably good in analogous to reflection coefficient curve as shown in Fig. 7.

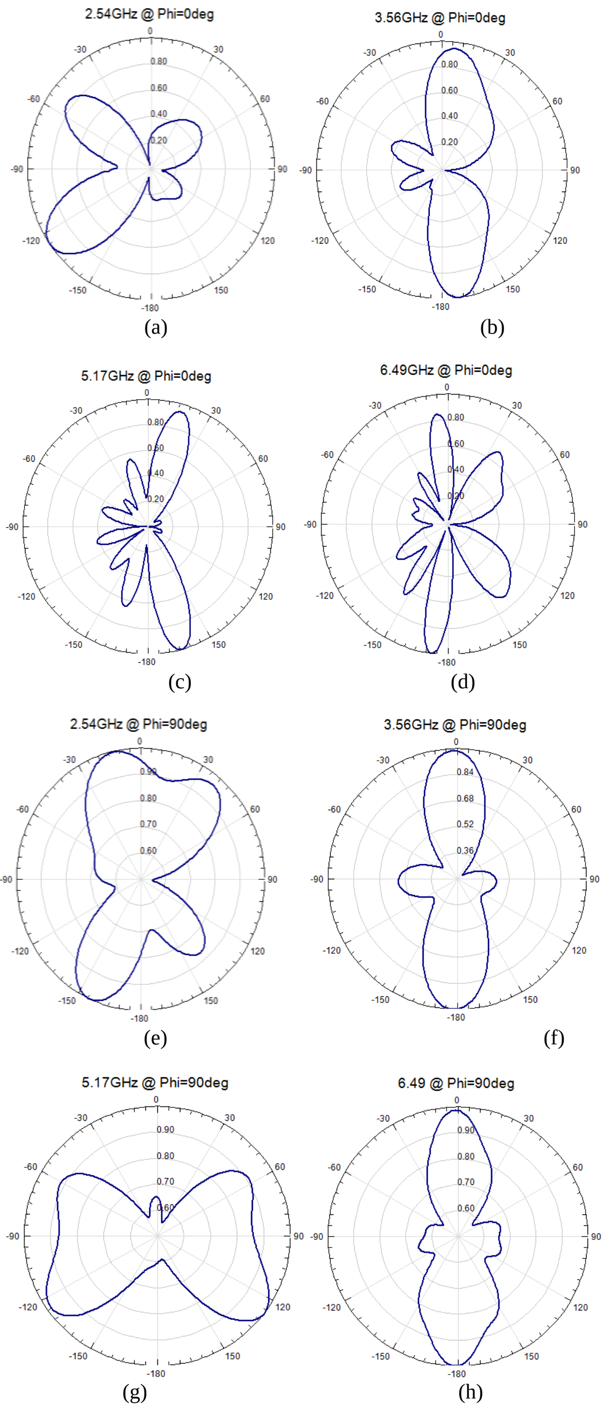


Fig. 5. Radiation patterns of the antenna at .54GHz, 3.56GHz, 5.17GHz, 6.49GHz resonant frequencies for Ø=0^0.

IV. Conclusion

The traditional Sierpinski fractal antenna on patch is considered with five iterations. Consistently the S11 takes minimum value at five different frequencies and their radiation characteristics are generated for further study. Some of them have shown similarity in characteristics in the range of 1GHz to 8GHz. A modified form of the geometry can be employed keeping in view of the problem with fabrication cited above and this work will be the initial point.

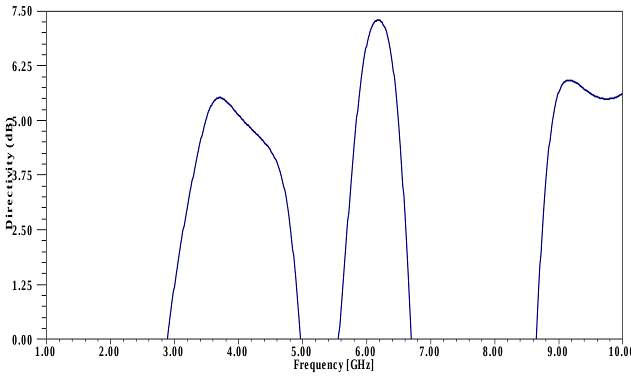


Fig. 6. Frequency *vs* directivity plot.

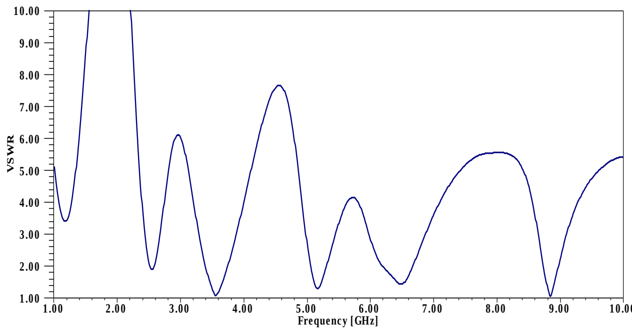


Fig. 7. Frequency *vs* VSWR plot.

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