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Design And Performance Analysis of Minkowski Square Loop Fractal Antenna

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ABSTRACT

With the rapid evolution in wireless communication systems and increasing importance next generation wireless applications, wideband and low profile antennas are in great demand for both commercial and military applications. There are also many applications like personal communication systems, small satellite communication terminals, WLAN and Radar applications, which use Multi-band and wideband antennas. Fractal antennas have useful applications in cellular telephone and microwave communications. Video conferencing, streaming video are main applications that are included in next generation networks and requirements for these applications are high data rates require to have high bandwidth. But as size of antenna reduces bandwidth support also reduces. So it is required to have small size with high bandwidth. Recent progress in the study of fractal antennas suggests some attractive solutions for using a single small antenna operating in several frequency bands. The term fractal, which means broken or irregular fragments, was originally given by Mandelbrot to describe a family of complex shapes that possess an inherent self-similarity in their geometrical structure. Applying fractals to antenna elements allows for smaller, resonant antennas that are multiband/broadband and may be optimized for gain. In this paper minkowski fractal antenna is proposed and compared according to their specification and iteration factor. The performance of both fractal antennas is simulated in HFSS and results obtained are compared. It is found from the analysis that the gain, directivity, Bandwidth and input impedance of the antenna has improved.

Keywords: fractal antenna, minkowski, iteration factor, compact size, microstrip antenna

1. INTRODUCTION

In today's era rapid increase in the need and demand for next generation wireless network applications motivated the antenna designers to design new antennas that simultaneously appear miniaturized and at the same time useful for many wireless standards [1]. The most important requirements for such kind of antenna are that the antenna should work for many applications simultaneously and must have small size [2-3]. For performing multi-application operations at a single time, multiband characteristic is required. These multiband characteristics can be achieved by using the concept of fractal antenna. Fractals are broken or irregular fragments, generally shaped composed of multiple copies of themselves at different scales [4]. In other words we can define fractal as a rough or fragmented geometric shape that can be subdivided in parts, each of which is a reduced-size of the whole structure. . This repeating operation can be algebraic, symbolic, or geometric, proceeding on the path to perfect self-similarity. This fractal geometry, which has been used to model complex objects found in nature such as clouds and coastlines, has space filling properties. This space filling properties is useful to minimize the size of antenna. The space-filling property of fractals tends to fill the area occupied by the antenna as order of iteration is increased. In other words it can be explained as a curve that is large in term of physical length but small in term of area in which the curve can be included. While studying the literature of fractal antenna it is found that there is still a space of improvement in performance characteristics of fractal antenna.

In recent years, a lot of studies have done in the area of fractal techniques and fractal antenna structures like dipole [6], monopole [7], patch [8], slot antenna [9] and antenna array structures [10],[11]. Some of these techniques are useful in reducing the size of the antenna, while other used to design antenna having multiband characteristics. These are low profile antennas with moderate gain and can be made operative at multiple frequency bands and hence are multi-functional.

Some of the common fractal geometries that have been found to be useful in developing new multiband antennas are Sierpinski gasket, Minkowski square loop and hexagonal [15]. Sierpinski gasket is one of the earliest structures of fractal geometry. A miniaturization of loop antenna using the fractal technique is known as Minkowski square loop antenna. A hexagonal antenna is suitable for design an antenna of superior characteristic of compact size with microstrip transmission line.

2. MINKOWSKI SQUARE LOOP

A miniaturization of loop antenna using the fractal technique is known as Minkowski square loop antenna[19] . The starting geometry of the fractal, called the initiator, is a square: Each of the four straight segments of the starting structure is replaced with the generator. The starting structure is a rhombus here which is iterated with a square. This iterative generating procedure continues for an infinite number of times.. The Example of Minkowski square loop is shown in figure 1 with two iterations.

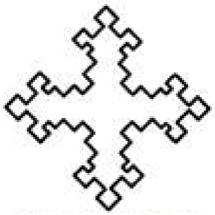


Figure1: Example of Minkowski Square Loop fractal antenna[19]

3. DESIGN OF MICROSTRIP TRANSMISSION LINE

A microstrip line may be viewed as a derivative of a two-wire transmission line and is perhaps the most widely used form of planar transmission line. In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching.. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

One side of the structure is freely accessible for the mounting of packaged devices and the geometry lends itself extremely well to PCB patterning techniques to define the circuit. It has been used extensively in microwave and millimeter circuits and system.

Due to the complexity of the structure, the analytical expression of the per unit length parameters are difficult to obtain. The effective relative permittivity is approximated as

$$\mathcal{E}_{re} \approx \frac{\mathcal{E}_r+1}{2} + \frac{\mathcal{E}_r-1}{2\sqrt{1+12\frac{w}{d}}}$$

This is an empirical expression and is a function of the material property and the ration W/d. W is the width of the strip and d is the thickness of the substrate, which has a relative permittivity$\mathcal{E}_r$.

From the transmission line theory, the relation between the velocity and per unit length inductance and capacitance is

$$V=\frac{1}{\sqrt{LC}} = \frac{c}{\sqrt{\mathcal{E}_{re}}}$$

The characteristic impedance can be expressed as

$$Z_o = \sqrt{\frac{L}{C}} = \frac{1}{vC} = \frac{\sqrt{\mathcal{E}_{re}}}{cC}$$

Thus, to compute the characteristics impedance, we just need to obtain the per unit length capacitance C once the effective permittivity is known. The first higher mode in a micro stripline is TE10 mode, its cut-off wavelength is twice the strip width, expressed as:

$$\lambda_c \approx \sqrt{\mathcal{E}_r}(2W+0.8d)$$

The lowest transverse mode electric mode is TE1, with cut-off frequency:

$$(f_c)_{TE_1} = \frac{3c\sqrt{2}}{8d\sqrt{\mathcal{E}_r-1}}$$

The lowest transverse magnetic mode is TM0, with cut-off frequency:

$$(f_c)_{TM_0} = \frac{c\sqrt{2}}{4d\sqrt{\mathcal{E}_r-1}}$$

And, for most Microstrip lines, conductor loss is much more than dielectric loss. The attenuation constant can be calculated by:

$$\propto_c = \frac{R_s}{Z_o W}$$

where $R_s = \sqrt{\frac{\omega\mu}{2\sigma}}$ is the surface resistivity of the conductor.

4. RESULT ANALYSIS OF MINKOWSKI FRACTAL ANTENNA

The minkowski patch fractal antenna with 2nd iteration is shown in figure2. The antenna is designed and simulated using simulation tool Ansoft HFSS.

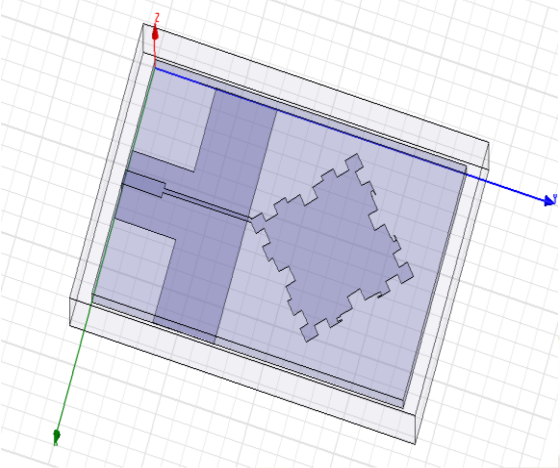
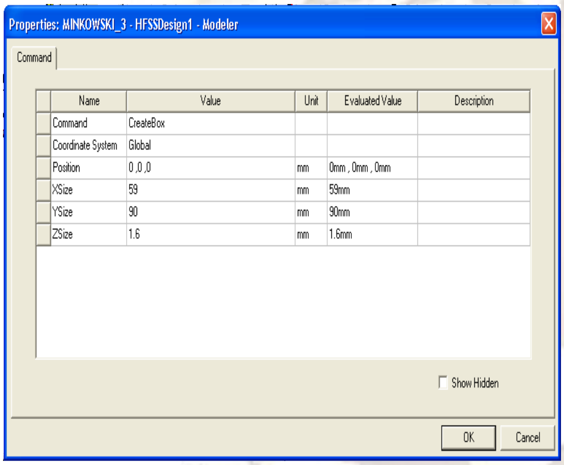


Figure 2: Minkowski Fractal Antenna with second iteration



Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate System	Global			
Position	0 ,0 ,0	mm	0mm , 0mm , 0mm	
XSize	59	mm	59mm	
YSize	90	mm	90mm	
ZSize	1.6	mm	1.6mm	

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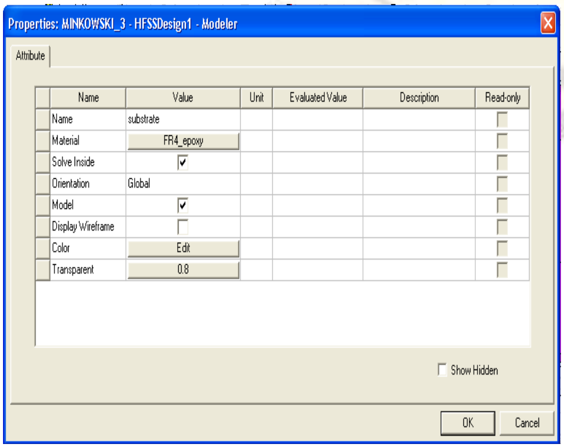
Figure 3: Dimensions used for designing minkowski square loop Antenna



Name	Value	Unit	Evaluated Value	Description	Read-only
Name	substrate				☐
Material	FR4_epoxy				☐
Solve Inside	☑				☐
Orientation	Global				☐
Model	☑				☐
Display Wireframe	☐				☐
Color	Edit				☐
Transparent	0.8				☐

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Figure 4: Material properties for antenna design

Figure 5 shows the return loss as a function of frequency which shows the multiband behavior of the antenna having return loss less than -10dB.

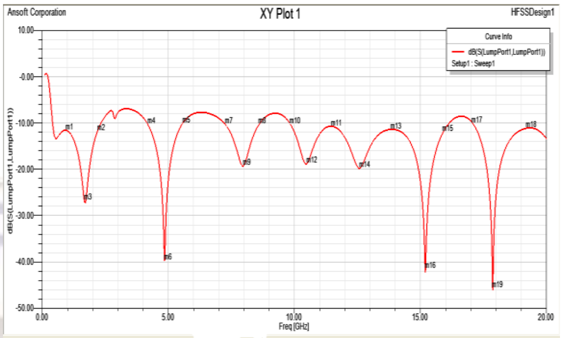

Figure 5: Frequency versus Return loss for Sierpinski Fractal antenna

Table I:.Frequency versus Return loss data table for minkowski square loop Fractal antenna

Name	X	Y
m1	0.9462	-11.5589
m2	2.2005	-11.7526
m3	1.6828	-26.7477
m4	4.1915	-10.2603
m5	5.5752	-10.0641
m6	4.8585	-39.7897
m7	7.2676	10.3022
m8	8.6016	-10.3000
m9	7.9843	-19.2533
m10	9.8459	-10.2574
m11	11.4885	-10.6864
m12	10.5129	-18.7024
m13	13.8379	-11.3609
m14	12.6035	-19.7313
m15	15.9085	-11.8771
m16	15.2017	-41.5189
m17	17.0633	-10.0095
m18	19.2235	-11.0976

m19	**17.8696**	**-45.8040**

VSWR is standing wave ratio that tells about the impedance mismatch. . Increasing in VSWR indicates an increase in mismatch between the antenna and the transmission line. A decrease VSWR means good matching with minimum VSWR is one. It is always desirable for VSWR to be always less than 2. We can see in the figure that all the resonated frequency band have VSWR below 2. Figure 6 shows corresponding VSWR vs. frequency.

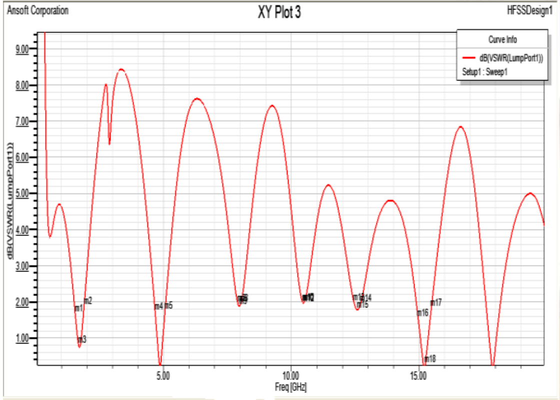

Figure 6: VSWR vs Frequency

The radiation pattern of an antenna provide the information that describes how the antenna directs the energy it radiates. All antennas, if 100% efficient, will radiate the same total energy for equal input power regardless of pattern shape. Radiation pattern for proposed antenna is also depicted in the figure 7 given below. Radiation pattern explains that antenna is radiating in Omni-direction. This is always desirable for the applications like mobile applications and multiband support make it multi-application compatible

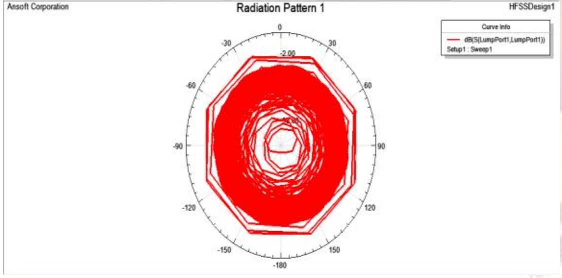

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Figure7: Radiation Pattern.

5. CONCLUSION

Minkowski loop patch antenna shows less than -10dB return loss for frequency bands including 1.6828GHz, 4.8585GHz, 7.9843GHz, 10.5129GHz, 12.6035GHz, 15.2017GHz and 17.8696GHz with -26.7477dB, -39.7897dB, -19.2533dB, -18.7024dB, -19.7313dB, -41.5189dB and –45.8040dB respectively. VSWR in these frequency bands are also in the required region i.e. below 2. These multibands are used by different technologies, so single antenna works for different technologies.This new fractal antenna allows flexibility in matching multi-band operations in which a larger frequency separation is required.

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