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A Modified Fractal Microstrip Patch Antenna for Wireless Applications

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Abstract: *This article presents rectangular microstrip antennas in modified fractal geometries. The modified fractal antennas are designed using the HFSS, which is based on the finite element method of computational electromagnetics. Three forms of the designed antennas is discussed and the various electrical parameters such as reflection coefficient, 2 D radiation pattern and 3 D radiation pattern are investigated. The designed antennas have various wireless applications such as 1.8 GHz GSM and 2.4 GHz WLAN and IEEE 802.11(a, b ,g and n).The designed antennas also have wideband behavior with the multiband applications.*
Key Words: *Micro strip patch antenna, Fractal, WLAN*

I. Introduction

In high performance spacecraft, aircraft , missile and satellite applications there is a requirement of antennas that have less size ,low in weight , easy in installation and have good performance. Now days there are many other government and commercial applications such as mobile radio and wireless communication that have similar applications. To meet all these applications micro strip antennas can be used. These antennas are low in profile and conformable to planar and non-planar surfaces. These are also compatible to MMIC's. Microstrip patch antenna, shape is very versatile in terms of resonant frequency, polarization and radiation pattern and polarization. In wireless communication one of the objectives is the design of wide band and multiband antennas.

The fractal antenna is prominent antenna for all such applications. Several antenna configurations based on fractal geometries have been reported in recent years. These are low profile antennas with moderate gain and can be made operative at multiple frequency bands and hence are multi-functional. In this work the multi-band (multifunctional) aspect of antenna designs are explored further with special emphasis on identifying fractal properties that impact antenna multi-band characteristics. Antennas with reduced size have been obtained using Hilbert curve fractal geometry. Furthermore, design equations for these antennas are obtained in terms of its geometrical parameters such as fractal dimension. Antenna properties have also been linked to fractal dimension of the geometry. The primary motivation of fractal antenna engineering is to extend antenna design and synthesis concepts beyond Euclidean geometry. In this context, the use of fractals in antenna array synthesis and fractal shaped antenna elements have been studied. Obtaining special antenna characteristics by using a fractal distribution of elements is the main objective of the study on fractal antenna arrays. It is widely known that properties of antenna arrays are determined by their distribution rather than the properties of individual elements. Since the array spacing (distance between elements) depends on the frequency of operation, most of the conventional antenna array designs are band-limited. Self-similar arrays have frequency independent multi-band characteristics. Fractal and random fractal arrays have been found to have several novel features. Variation in fractal dimension of the array distribution has been found to have effects on radiation characteristics of such antenna arrays. The uses of Random fractals reduce the fractal dimension and size, which leads to a better control of side lobes. Synthesizing fractal radiation patterns has also been explored. It has been found that the current distribution on the array affects the fractal dimension of the radiation pattern. It may be concluded that fractal properties such as self-similarity and dimension play a key role in the design of such antenna arrays.

II. Modified Fractal Microstrip Patch Antenna Design.

The designed fractal microstrip patch antennas are discussed in the three configurations that is base form, first iterative form and second iterative forms. The base antenna is simple rectangular patch antenna. The base form of the antenna is designed for the 2.4 GHz frequency. The substrate material is FR4/glass epoxy of relative dielectric constant of 4.4, height is 1.6mm and the loss tangent is 0.02. The dimensions of the rectangular patch in microstrip patch are taken according to the following formulas.

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1+\frac{12h}{w}\right)^{-(1/2)} \quad (2)$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

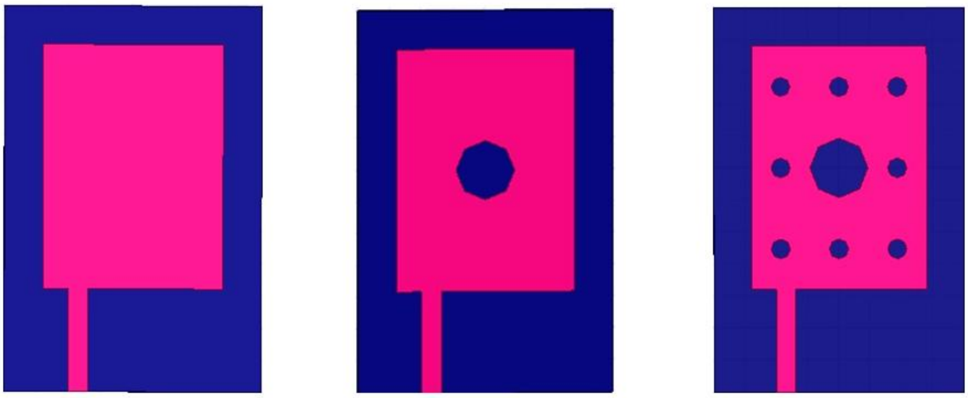
$$L = L_{eff} - 2\Delta L \quad (5)$$

Where, c = Velocity of light in free space
f_0=Operating resonant frequency
ε_r = Relative dielectric constant
ε_{reff} =Effective dielectric constant of the substrate
h= Height of the substrate
W = Width of the dielectric substrate

The calculated width is 38 mm and the length is 28 mm. The microstrip feed line technique is used for the feeding of all the antennas. The width of the microsrrip feed line is calculated for the 50 ohm is 3.05 mm.

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{reff}\left[\frac{W}{H}+1.393+\frac{2}{3}ln\left(\frac{W}{H}+1.444\right)\right]}} \quad \text{for } W/h \gg 1 \quad (6)$$

The Feeding is done near to the edge so that higher order mode is excited along with the TM_{01} mode at the 2.4 GHz. The three iterations are made in length and three iterations are made in the width 38 mm in rectangular patch. So the entire rectangular patch consists of the 9 rectangular segments of dimensions 9.33 mm and 12.66 mm. In the first iterations an octagonal slot is made in the rectangular patch. In the first iterations the octagon is removed from the central rectangular portions. In the second iterative form additional eight octagons slot are made in rectangular patch. The addition eight octagon slot is made from the nine additional rectangles of the dimensions 3.11 mm1 and 4.22 mm. The structure is named modified because the slot is made in the shape of octagon from the rectangle. The designed modified fractal microstrip patch antenna is shown in figure 1.



(a) (b) (c)

Fig. 1 Modified Fractal Microstrip (a) Base Antenna (b) First Iterative Antenna (c) Second Iterative Antenna

III. Results and Discussions

The return loss of all the three designed antennas are simulated and discussed. The S_{11}(dB) Vs frequency curve of the base form of rectangular patch antenna is shown in fig 2.

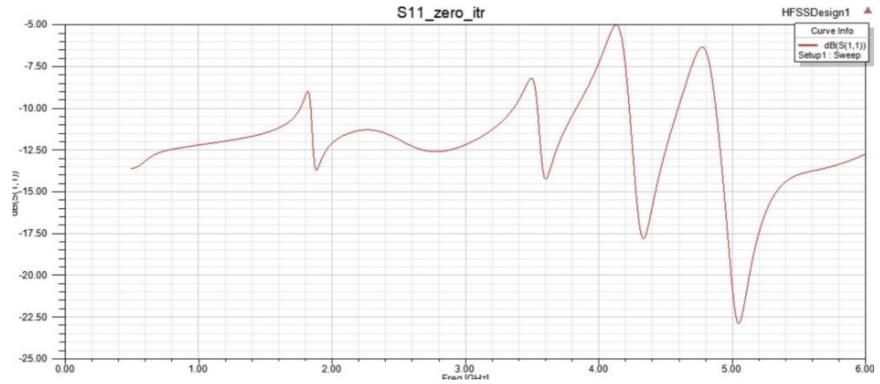


Figure . 2 S_{11} Vs frequency curve for base form of the modified fractal antenna

The above curve shows that the antenna is resonating at the multiband frequency and also shows the wideband behavior at the different frequency such as 1.8, 2.4, 3.6,4.3 and 5.1 GHz with return loss -13 dB,-12.5 dB,-14.5 dB, 18 dB and -23 dB. The S_{11}(dB) Vs frequency curve of the base form of rectangular patch antenna is shown in fig 3.

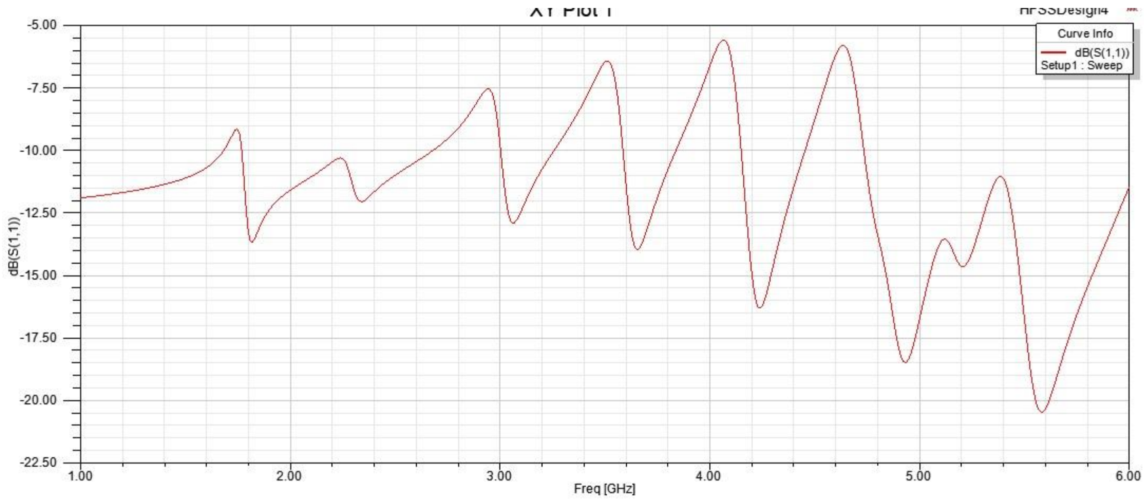


Figure 3 S_{11} Vs frequency curve for first iterative modified fractal microstrip patch antenna

It is shown from the above curve that the no. of resonating frequency band increases in the first iterative antenna as compared to base antenna. As the frequency increases the wide band behavior also increases in the first iterative antenna as compared to base antenna. The second iterative form of the modified fractal antenna is shown in fig. 4.

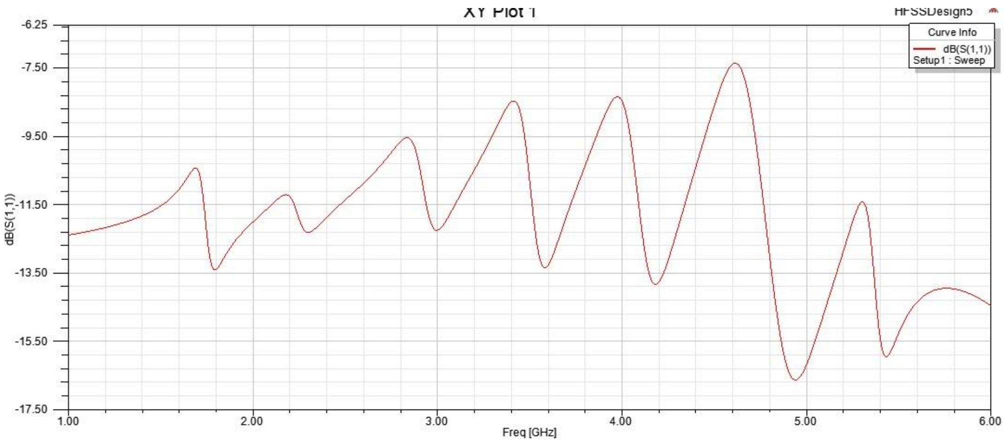
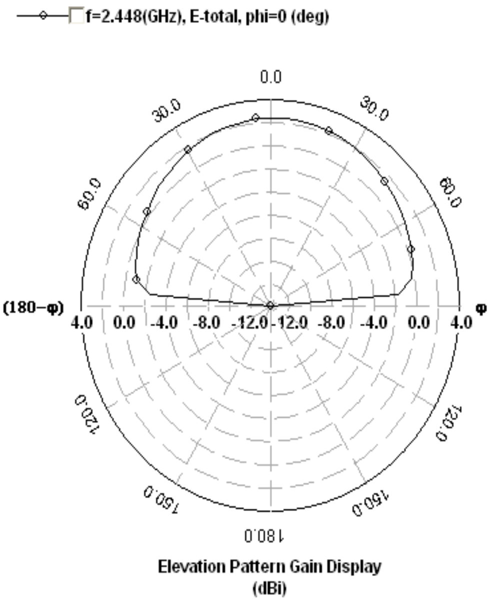
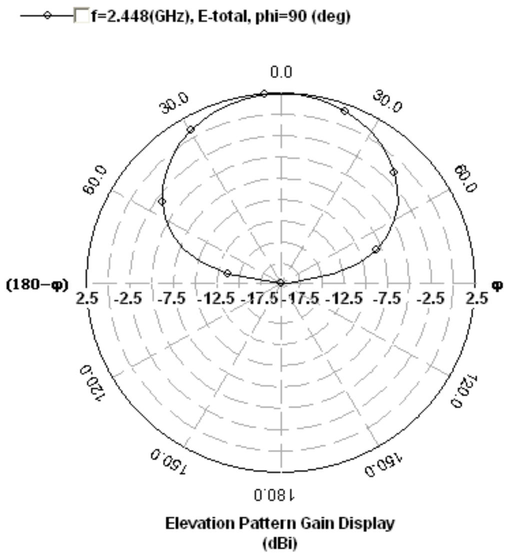


Figure 4 S_{11} Vs frequency curve for second iterative modified fractal microstrip patch antenna

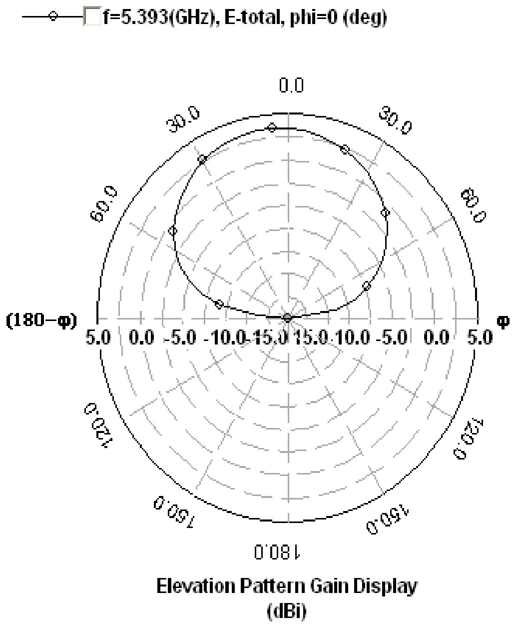
The return loss curve for the second iterative form of the modified fractal microstrip patch antenna shows that the wide band behavior and multi band behavior is increased and the return loss is also decreased as compared to the base antenna and the first iterative antenna. Figure 4 shows the 2 D radiation pattern at selective frequencies of all the three antennas.



(a)



(b)



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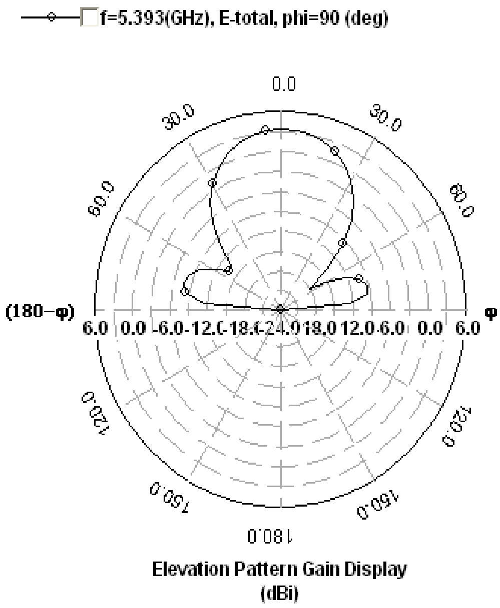
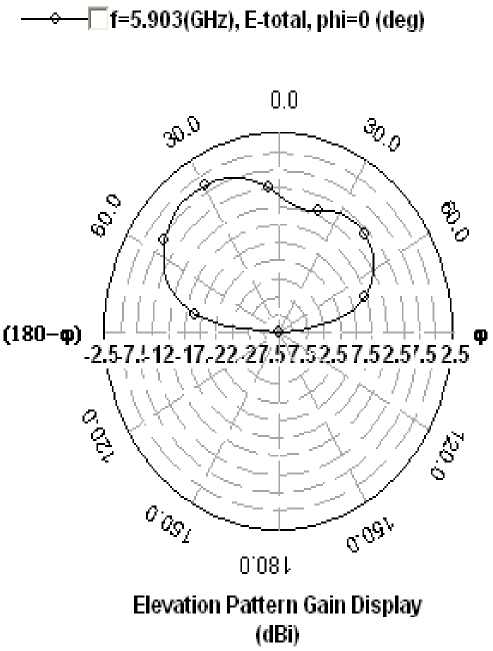
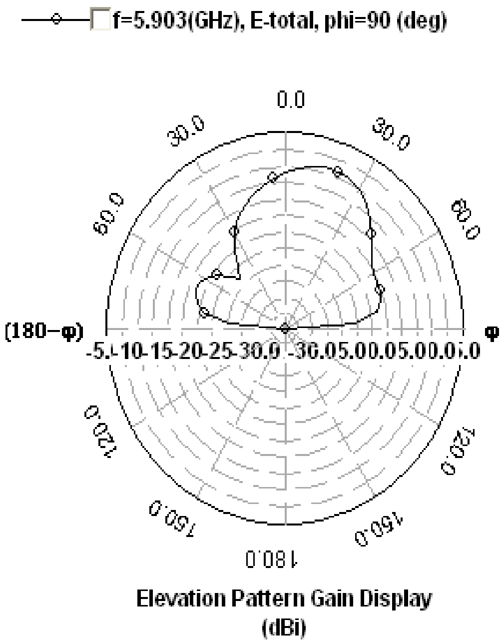


(c)



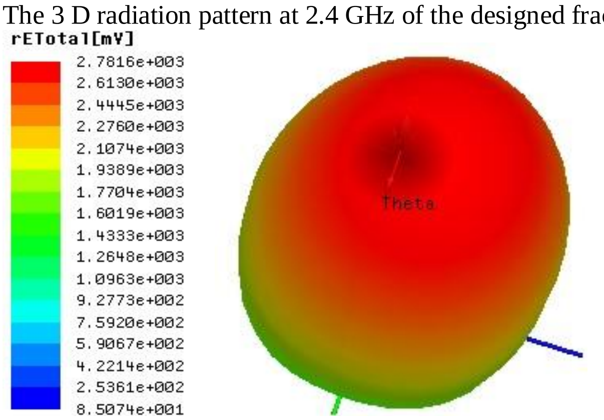
(e)



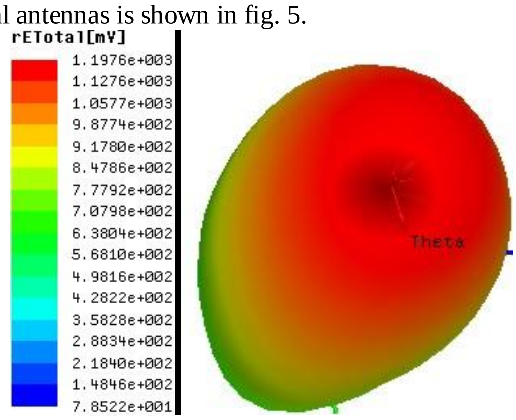
(f)

Figure 4. (a) radiation pattern at 2.4 GHz for base form antenna at two angle phi $=0^0$ and phi 90^0 (b) radiation pattern at 5.3 GHz for first iterative form antenna at two angle phi $=0^0$ and phi 90^0 (c) radiation pattern at 2.4 GHz for base form at two angle phi $=0^0$ and phi 90^0

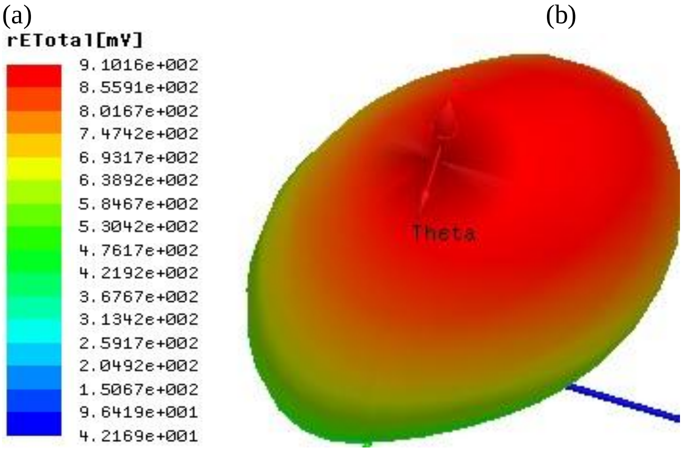
The 3 D radiation pattern at 2.4 GHz of the designed fractal antennas is shown in fig. 5.



(a)



(b)



(c)

Figure 5 (a) for Base Antenna (b) For first Iterative Antenna (c) Second Iterative antenna

All the three radiation pattern shows omnidirectional radiation pattern, This means the designed antenna radiate equally in broad side direction.

IV. Conclusions

The modified fractal antenna designed in this paper shows the multiband as well as the wide band behviours.The designed antennas can be used for various wireless applications such as 1.8 GHz for GSM and 2.4 GHz for various IEEE 802 .11 WLAN applicatios such as Wi-Fi 2.4 GHz, WLAN-IEEE-802.11 a (5GHz) ,WLAN-IEEE-802.11 b (2.4 GHz) WLAN-IEEE-802.11 g (2.4 GHz) ,WLAN-IEEE-802.11 n (2.4 GHz & 5 GHz), WLAN-IEEE-802.11 ac (below 6 GHz). The radiation pattern of the designed antennas at these frequencies is omnidirectional in nature.

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