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Analysis and Simulation of Fractal Antenna for Mobile Wimax

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Abstract

The growing demand of wireless services requires the definition of new standards able to provide an increased degree of mobility for the end user and a higher speed of data transmission. Among emerging standards, one of the most promising is the IEEE 802.16 Wireless Metropolitan Area network Air Interface (generally called Wimax).In last few decade the miniaturization led antenna to be conformal, low profile, multi –band, hence Fractal antennas came into existence which due to its self-similar geometry takes less area and thus its low profile. This paper presents the design of Sierpinski carpet fractal antenna for three iterations. This antenna is designed using HFSS software on FR4 substrate having dielectric constant 4.4 and having fed 50 ohms micro-strip line and optimized to operate in multiple bands between 2 – 6 GHz.

Keywords:*Fractal, Wimax,Sierpinski Carpet Fractal Antenna(SCFA), Microstrip Antenna*

1. Introduction

Antennas enable wireless communications between two or more stations by directing signals toward the stations. An antenna is defined by Webster's Dictionary as - “a usually metallic device (as a rod or wire) for radiating or receiving radio waves”. The IEEE Standard Definitions of Terms for Antennas (IEEE Std. 145–1983) defines the “antenna or aerial as a means for radiating or receiving radio waves” [2]. For wireless communication system, antenna is one of the most critical components. A good design of the antenna can thus improve overall system performance. Microstrip patch antennas are widely implemented in many applications due to their attractive features such as low profile, light weight, conformal shaping, low cost, high efficiency, simplicity of manufacture and easy integration to circuits. However the major disadvantage of the micro-strip patch antenna is its inherently narrow impedance bandwidth. Further the tremendous increase in wireless communication in the last few decades has led to the need of larger bandwidth and low profile antennas for both commercial and military applications. One technique to construct a multiband antenna is by applying fractal shape into antenna geometry.

2. Fractal Antennas

Mandelbrot offered the following definition “A fractal is by definition a set for which the hausdorff dimension strictly exceeds the topological dimension”, which the later retracted and replaced with: - “A fractal is a shape made of parts similar to the whole in some way”. So, possibly the simplest way to define a fractal is as an object that appears self-similar under varying degrees of magnification, and in effect, possessing symmetry acrossscale, with each small part of the object replicating the structure of the whole [3].A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the

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length, or increase the perimeter of material that can receive or transmit electromagnetic radiation within a given total surface area or volume [3]. Fractals are complex geometric designs that repeat themselves, or their statistical properties on many scales, and are thus “self-similar.” Fractals, through their self-similar property, are natural systems where this complexity provides the sought-after antenna properties. Some key benefits of fractal antennas area:

- Fractal Antennas radically alter the traditional relationships between bandwidth, gain and size, permitting antennas that are more powerful, versatile and compact.
- Fractal Antennas produces fractal versions of all existing antenna types, including dipole, monopole, patch, conformal, bi-conical, spiral, helical and others, as well as compact variants of each only possible through fractal technology [6].
- Fractal Antenna’s technology affords unique improvements to antenna arrays, increasing their bandwidth, allowing multiband capabilities, decreasing size load and enabling optimum smart antenna technology.
- Increased bandwidth, multi-band and gain in addition to smaller size.
- The inherent qualities of fractals enable the production of high performance antennas that are typically 50 to 75 % smaller than traditional ones [4].
- Additionally, fractal antennas are more reliable and lower cost than traditional antennas because antenna performance is attained through the geometry of the conductor, rather than with the accumulation of separate components or separate elements that inevitably increase complexity and potential points of failure and cost. The result is one antenna able to replace many at a high value offering to our customer.

3. Wimax

Wimax is a standard for fixed broadband wireless access system, which employ a point-to-multipoint an architecture and operate between 10 and 66 GHz providing only line of sight (LOS) applications. In order to extend the 802.16 air interface standard guaranteeing Non-Line-Of-Sight (NLOS) features, a successive release called IEEE 802.16a has been proposed to deliver services over a scalable, long range, high capacity wireless communications for carriers and service providers around the world. It covers the frequency range between 2 and 11 GHz and it is suitable for last-mile applications [5]. In such a frame-work, the available band between 2.5- 5.0 GHz turns out to be particular interest since it doesn’t require a Line-Of-Sight propagation and can be usefully exploited for end-user wireless portable devices. As far as wireless portable devices are concerned, it is mandatory to develop miniaturized radiators able to guarantee a good efficiency and reliability. In such a field, fractal antennas seem to be good candidates for achieving reduced dimensions keeping suitable radiation properties. As a matter of fact the use of fractal geometries (or more precisely, pre fractal that are built with a finite number of fractal iterations) for antenna synthesis has been proven to be very useful in order to achieve miniaturization and enhanced bandwidth.

Table 1. Wimax Standards

S. No.	Standard	*Frequency*	*Speed*	*Range*
1	Fixed Wimax (802.16-2004)	2-11 GHz (3.5 GHz in Europe)	75 Mbps	10 km
2	Mobile Wimax (802.16e)	2-6 GHz	30 Mbps	3.5 km

The first mobile Wimax products are scheduled to be roll out late this year 2013 or very early in 2007.

- Mobile Wimax offers low latency and high Quality of Service (QOS).
- It has no difficulty accessing IP multimedia data or implement technologies such as VOIP.
- Cellular, Wi-Fi and even Bluetooth through its relationship with Ultra wideband (UWB) also have designs on the multimedia services market.

Mobile Wimax can be embedded on any number of personal devices such as PDAs, notebook PCs, game consoles, iPods, MP3 players, and cellular phones. As such, its potential to compete with cellular technology is obvious, particularly for broadband, data-centric applications.

4. Design of an Antenna

The same antenna used for different bands requires the antenna to be a multiband antenna and could be operated at different frequencies. The mathematician Waclaw Sierpinski (1882-1969) presented the Sierpinski Carpet [5]. The carpet is a generalization of the cantor set to two dimensions. In this paper we have taken Sierpinski carpet geometry for designing Fractal antenna which is developed using software Ansoft HFSS on a low cost FR4 substrate due to ease of its availability for which thickness we considered h=1.6mm and permittivity=4.4 the dimensions of the patch are calculated using the formulas [2] as shown in table (II).The construction of our design begins with designing a patch (W =37mm, L=28mm, $L_{1=}$10mm, W_1=3mm) and in 1st iteration square patch is segmented by removing the middle square from it. For the 2nd iteration the square is cut into 9 congruent sub squares by 3-by-3 grade, and the central sub square is removed [7]. The same procedure is then applied recursively to the remaining eight sun squares and for 3rd iteration again we take one third of second sub squares. Figure (1) shows the design of first iteration of Sierpinski carpet fractal antenna.

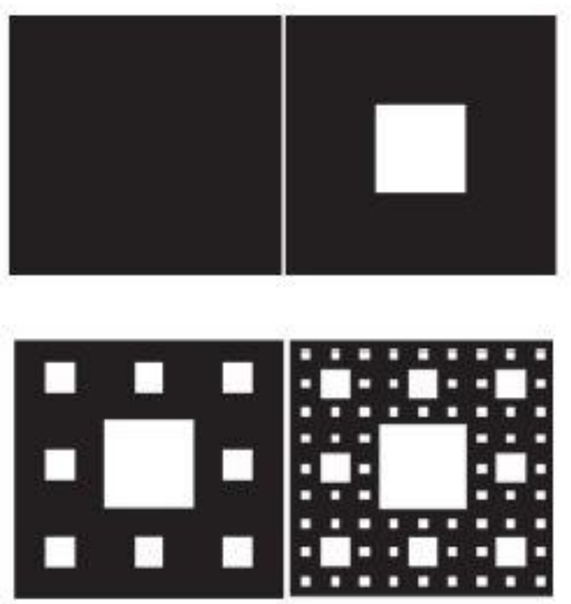

Figure 1. Sierpinski Carpet Antennas upto 3 Iterations

Table 2. Design Calculation

S.No.	Dielectric substrate(FR4)	$\varepsilon_r = 4.4$, tanδ=0.09
1	Substrate height	1.6mm
2	$w = \frac{c}{2 f_0}\sqrt{\frac{2}{\varepsilon_r + 1}}$	37mm
3	$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-1/2}$	4.08
4	$\Delta L = 0.412\, h \frac{(\varepsilon_{reff} + 0.3)\left[\frac{w}{h} + 0.264\right]}{(\varepsilon_{reff} + 0.258)\left[\frac{w}{h} + 0.8\right]}$	0.732mm
5	$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}}$	29.46mm
6	$L = L_{eff} - 2\Delta L$	28mm

5. Feeding Technique

In this paper micro-strip line feeding has been used. In this type of feed technique, a conducting strip is connected directly to the edge of the micro-strip patch as shown in Figure 2 .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 [4]. The location of micro-strip feed to the patch is adjusted to match with its input impedance (usually 50 ohm).

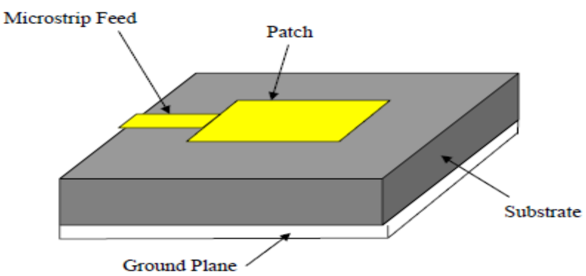

Figure 2. Micro Strip Line Feed

6. Simulation Results

The Sierpinski carpet antenna design, has been simulated by varying two parameters, (i) position of the feeding line from the edge of the substrate. (ii) Width of the micro-strip feed. By selecting these parameters, the proposed antenna can be tuned to operate within the frequency range 2GHz –6GHz. Figure 3(a) shows the design of 1st iteration of Sierpinski carpet micro-strip antenna (SCFA). Same analysis has been carried out by varying the feed location and the width of the micro-strip feed for the first iteration SCFA. Figure- 3(b) &(c) shows S11 (reflection coefficient) VSWR graph respectively.

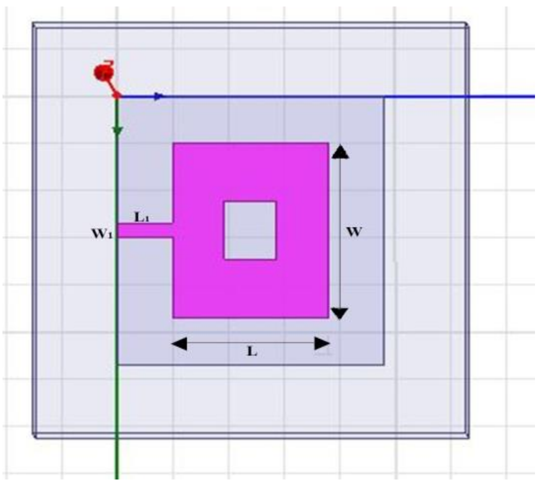

Figure 3 (a). 1st Iteration SCFA Design

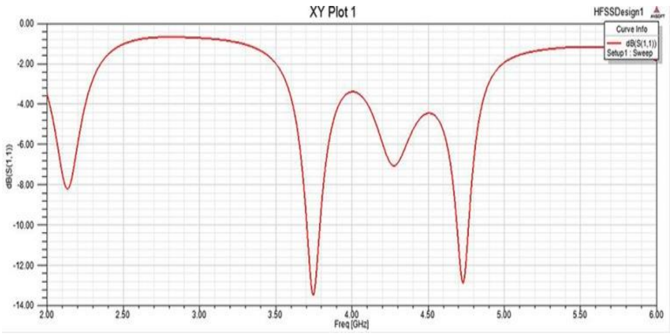

Figure 3(b). S11 Graph 1st Iteration Design

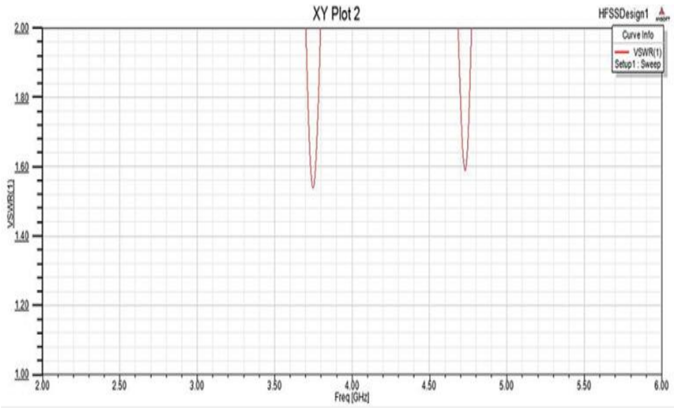

Figure 3(c). VSWR Graph for 1st Iteration Design

Figure 4(a) shows the design of second iteration SCFA which is obtained by further inserting slots one third times that of the centre slot. Same analysis is carried out by varying the feed location and the width of the microstrip feed for the first iteration SCFA. Figure 4(b) shows the reflection coefficient for the best result on variation of feed location and its width W_1. VSWR graph has been shown by Figure 4(c).

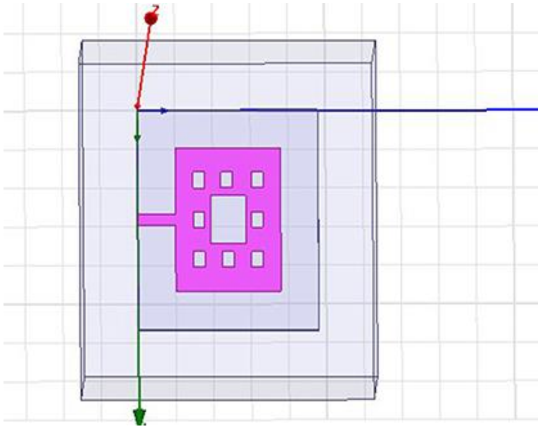

Figure 4(a). 2nd Iteration SCFA Design

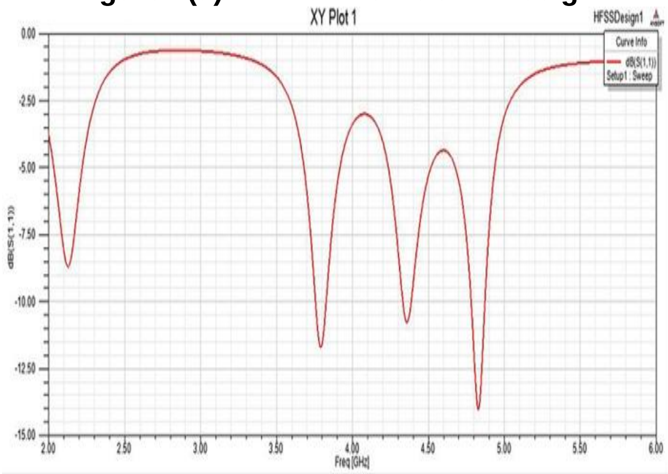

Figure 4(b). S_{11} Graph 2nd Iteration Design

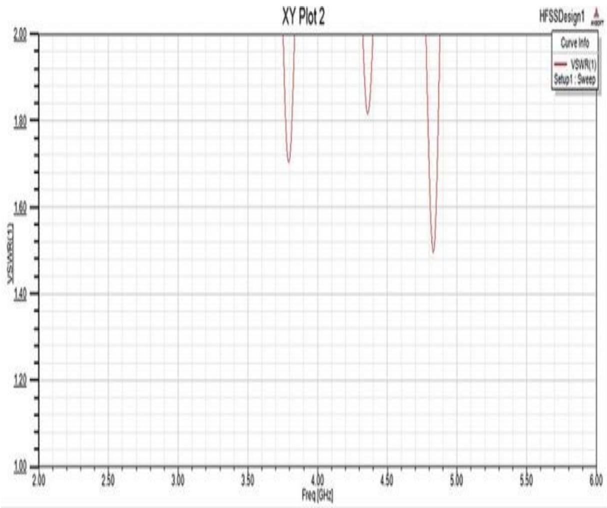

Figure 4(c). VSWR Graph 2nd Iteration Design

Figure 5(a) shows the design of third iteration of SCFA which is obtained by further inserting slots one third times that of the slots in second iteration. Figure 5(b) & (c) shows the reflection coefficient for the best result on variation of feed location its width W_1 and VSWR graph.

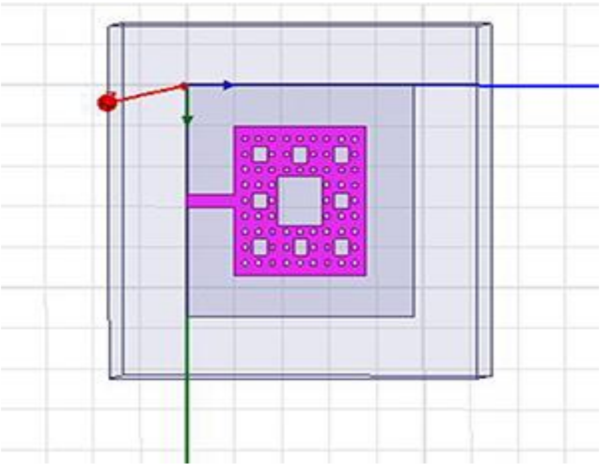

Figure 5(a). 3rd Iteration SCFA Design

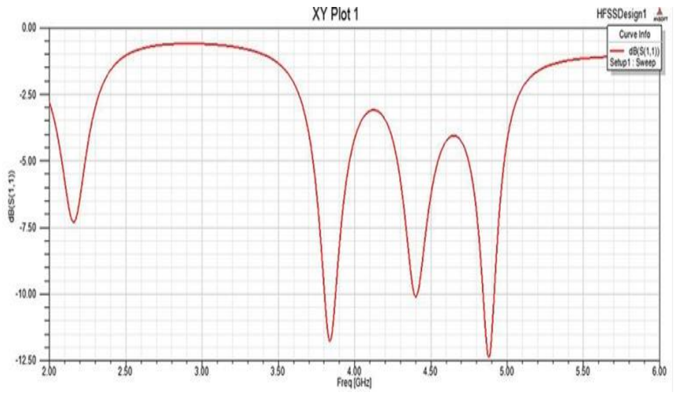

Figure 5(b). S_{11} Graph 3rd Iteration Design

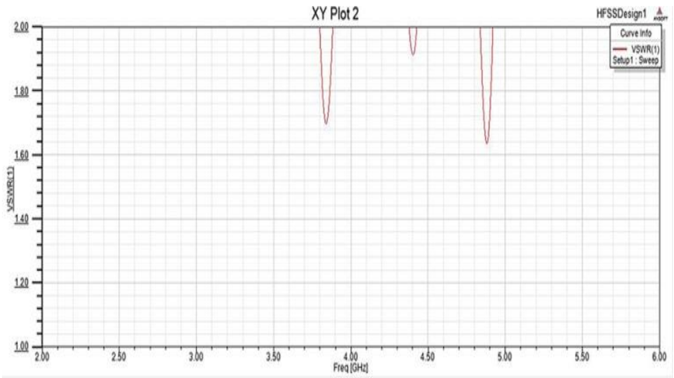

Figure 5(c). VSWR Graph 3rd Iteration Design

Table 2. Comparison of Simulated Results

S. No.	Iteration	Frequency Bands (GHz)	Gain (dB)
1	Resonating Freq.	2.45	1.25
2	1st	3.75,4.73	2.62
3	2nd	3.78,4.36,4.83	3.55
4	3rd	3.84,4.39,4.88	3.68

7. Conclusion

In this paper a micro-strip fed Sierpinski carpet fractal antenna (SCFA) has been designed and implemented up to 3rd iteration. Sierpinski carpet with one third iteration factor, the size of the patch reduces by 33.9% of the conventional micro-strip antenna. As the iterations go on increasing the loading causes multiple resonance and a shift down in frequency. The SCFA has been simulated and the plots of reflection coefficient and VSWR for mobile Wimax operating at 2-6 GHz have been plotted.

Wimax potential uses it to cover the so called “last mile” (or “few kilometre”) area, meaning providing high-speed Internet access to areas which normal wired technologies do not cover (such as DSL, cable, or dedicated T1 lines). Another possibility involves using Wimax as a backhaul between two local wireless networks.

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