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A New Fractal Based Printed Slot Antenna for Dual Band Wireless Communication Applications

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Abstract — Different fractal based structures have been widely used in numerous antenna designs for various applications. In this paper, a printed slot antenna has been introduced as a candidate for use in the dual band wireless communication applications. The antenna slot structure is in the form of a Sierpinski gasket of the first iteration. The antenna has been fed with 50 Ohm microstrip transmission line, and the slot structure is to be etched on the reverse side of the substrate. Performance evaluation of the proposed antenna design has been carried out using a method of moments based EM simulator, IE3D. Simulation results show that the resulting antenna exhibits an interesting dual frequency resonant behavior making it suitable for dual band communication systems including the dual band WLAN applications. Parametric study has been carried out to explore the effects of antenna parameters on its performance.

1. INTRODUCTION

The pioneer work of Mandelbrot [1] in fractal geometry had stimulated microwave circuits and antenna designers, in their attempts to realize miniaturized circuits and components, to seek out for solutions by investigating different fractal geometries. However, the recent developments in modern wireless communication systems have imposed additional challenges on microwave antenna and circuit designers to produce new designs that are miniaturized and multiband. Fractal curves are characterized by a unique property that, after an infinite number of iterations, their length becomes infinite although the entire curve fits into the finite area. This property can be exploited for the miniaturization of microstrip antennas, resonators, and filters. Due to the technology limitations, fractal curves are not physically realizable. Pre-fractals, fractal curves with finite order, are used instead [2, 3].

Slot antennas based on fractal curves such as Koch, Sierpinski and others have attracted the researchers to achieve antenna miniaturization with multiple resonances [4–11]. Sierpinski gasket fractal has been reported in [4] to model a dual band microstrip line fed slot antenna for GSM and 2.4 GHz WLAN bands. In [5], a Koch fractal slot antenna has been proposed to construct a CPW fed slot antenna for the two bands WLAN and WiMAX applications. Fractals generated from many Euclidean geometries such as the circle, triangle and others, have been employed to produce dual band antennas for a variety of communication applications [6–10]. Circular and half circular fractal shaped dual band antennas have been reported in [6] and [7] respectively for use in dual bands WLAN. Triangular based fractal based antenna has been proposed in [8] for GSM and DSC applications. Elliptical fractal patch antenna has been investigated a candidate for use in dual band communications [9]. Moreover, a quasi-fractal based slot geometries have been successfully used in different ways to form parts (or the whole) of the ground plane of dual band antenna [10].

In this paper, a new electromagnetically coupled microstrip-fed printed slot antenna design based on the first iteration of Sierpinski gasket fractal geometry has been presented as a dual band printed antenna for the 2.4/5.2 GHz bands WLAN applications.

2. THE PROPOSED ANTENNA STRUCTURE

The Sierpinski triangle or gasket is obtained by repeatedly removing (inverted) equilateral triangles from an initial triangle of a unit side length. For many purposes it is better to think of this procedure as repeatedly replacing an equilateral triangle by three triangles of half the height [11]. Figure 1 demonstrates the fractal generation process of the Sierpinski gasket up to the second iteration.

The geometry of the proposed Sierpinski gasket based slot antenna is shown in Figure 2. The first iteration Sierpinski gasket based slot structure has been constructed on, on the ground plane side of a dielectric substrate. The dielectric substrate is supposed to be the FR4 with a relative dielectric constant of 4.4 and thickness of 1.6 mm. The slot antenna is fed by a 50 Ω microstrip line printed on the reverse side of the substrate. A microstrip line, with a width of about 3.0 mm is placed on the centreline of the slot structure (x-axis). This type of feeding have been found to be more reliable for fractal slot antenna application [12, 13].
3. THE ANTENNA DESIGN

A printed slot antenna, based on the first iteration Sierpinski gasket, has been designed to resonate at 2.4 GHz. After suitable dimension scaling, the resulting antenna slot side length has to be determined. Observing the influence of the various parameters on the antenna performance, it has been found that the dominant factor in the antenna is the slot side length in terms of the guided wavelength $\lambda_g$.

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{\text{eff}}}}$$  \hspace{1cm} (1)

where $\varepsilon_{\text{eff}}$ is the effective dielectric constant.

Then the lowest resonant frequency, $f_{0L}$, relative to the slot side length is formulated by

$$f_{0L} = \frac{2C_o}{3a\sqrt{\varepsilon_{\text{eff}}}}$$  \hspace{1cm} (2)

where $C_o$ is the speed of light in free space, and $a$ is the slot side length. Higher order resonances are attributed to the smaller self-similar structures, as will be seen later.

The Sierpinski fractal slot antenna with the layout depicted in Figure 3, has been modeled and analyzed using the method of moments (MoM) based electromagnetic (EM) simulator IE3D [14].

4. PARAMETRIC STUDY AND PERFORMANCE EVALUATION

According to (2), the modeled antenna slot side length, $a$, that matches the specified frequency, has been found to be of about 47.23 mm, with a microstrip feed line length of about 9.2 mm, measured from the origin. The antenna exhibits a dual band response, centered on 2.4 and 5.2 GHz. The lower resonant band, which is mainly attributed by the slot side length, has good match. However, it has been found that the position of the upper resonant band is sensitive to the feed line length. This band is with relatively low match as compared with the lower one. Figure 4 shows the return loss responses corresponding to different values of feed line length increments, of 0.5, 1.0, 1.25, and

![Figure 1: The generation of the Sierpinski gasket. (a) The zero iteration, $n = 0$, (b) the 1st iteration, $n = 1$, and (c) the 2nd iteration, $n = 2$.](image)

![Figure 2: The geometry of the proposed 1st iteration Sierpinski gasket printed slot antenna.](image)

![Figure 3: The layout of the modeled antenna with respect to the coordinate system.](image)
2.0 mm, along the x-axis. It is clear that, how the feed length affects the position and the matching of the upper band, while it has a very slight effect on the lower band.

In order to enhance the matching and tuning the position of the upper band, a small vertical stub has been attached to the feed line. The position of this stub has a considerable effect on the matching of the upper resonant band, while, again, it has almost a slight effect on the lower band. Figure 5 demonstrates the return loss responses corresponding to different values of the vertical stub positions, in steps of 0.2 mm, along the x-axis and keeping the feed line length unchanged.

The optimal microstrip feed line length and stub position achieving a good impedance match of the 2.4 and 5.2 GHz WLAN bands have been found to be of 11.43 mm and 0.52 mm respectively, away from the origin. The resulting resonant frequencies are $f_{0L} = 2.408 \text{ GHz}$, and $f_{0U} = 5.247 \text{ GHz}$, with corresponding bandwidths (for $S_{11} \leq -10 \text{ dB}$) of about 8.47%, and 8.80% respectively. Figure 6 shows the simulated 3D electric field patterns, $E_{\theta}$ at 2.4 and 5.2 GHz. With regard to the resulting gain, it is 2.11 dB and 3.72 dB in the lower and upper bands respectively.
5. CONCLUSIONS

A microstrip line fed printed slot antenna, with slot structure based on the first iteration Sierpinski gasket, has been presented in this paper. The antenna has been analyzed using a method of moments based EM simulator, IE3D. Simulation results showed that the antenna possesses a dual band resonant behavior meeting the requirements of the 2.4/5.2 GHz WLAN. A parametric study has been conducted to explore the effects of the most effective antenna parameters on its overall performance. The lower resonance has been found to be dominantly attributed by the side length of the slot structure, while the length of the feed affects, to certain extents, the position and the matching of the upper resonant frequency. It has been found that adding a vertical stub, at a proper position on the feed, will facilitate better matching and precise allocation of the second resonant frequency. Making use of this feature, the proposed antenna offers, it might be useful for many dual band communication applications.

REFERENCES