Chapter 1

Design of New Microstrip Multiband Fractal Antennas:
Sierpinski Triangle and Hexagonal Structures

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ABSTRACT

This chapter presents two new microstrip multiband antennas based on fractal geometry. The purpose is to study the behaviour of structures when applying a fractal aspect. The first antenna is designed and optimized by using Sierpinski triangle technique, it's validated in tne ISM "Industrial Scientific and Medical" band at 2.45 and 5.8 GHz bands which was designed to be suitable for wireless power transmission use, while the second proposed antenna structure is based on the hexagonal geometry, it's validated and tested for DCS (Digital Cellular System) at 1.8 GHz, for 2.45 GHz and for 5.8 GHz, as an example of application wireless mobile system is an application field.

INTRODUCTION

The design of wideband and multiband, low profile and small antennas became the main objective due to the growth of the wireless communication systems. Applications of such antennas cover personal communication systems, small satellite communication terminals, unmanned aerial vehicles, and many more. In order that the antenna be small while respecting the fundamental limits of its electrical length, several limitations are placed in the design.

Among the solutions to these limitations, there is the fractal antennas based on the technique of fractal geometry, which is first used by Mandelbrot (1974) to describe self-similar shapes repeating themselves

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at different scales. Even if some fractal structures were known before Mandelbrot, like Sierpinski carpet or Koch curve (Sierpinski, 1916; Koch, 1906), they were considered just as mathematical shapes without fields of applications. Mandelbrot was able to show that many fractals exist in nature and introduced more complex structures, including trees and mountains based on self-similarity characteristic of fractals. The evolution of computers helped to design a complex fractal structures based on recursive algorithms and then to apply the fractal concept in different branches of science and engineering including fractal electrodynamics for radiation, propagation, and scattering. Since the first application of fractal geometry in antennas theory (Cohen, 1995), many studies and implementations of fractal antennas were validated (Gianvittorio & Rahmat, 2002; Homayoon & Shahram, 2012; Puente & Pous, 1996; Werner & Ganguly, 2003; Wu, Kuai & Zhu, 2009), and some structures became a reference to explain multiband behavior like Sierpinski triangle, or to demonstrate the shrinking possibility like the Koch curve (Puente, Romeu, & Cardama, 1998, 2000). The best way to explain the fractal geometries is by using an iterative process that leads to a self-similar final structure.

In this chapter, two validated examples of fractal antennas will be presented to show the behavior of the antenna when applying fractal geometry. The first one is a design based on Sierpinski triangle and its field of application for Wireless Power Transmission especially rectenna system. The second one is a realized structure with an hexagonal geometry validated for DCS (Digital Communication System) and ISM (Industrial, Scientific and Medical) frequency bands.

This first proposed antenna is based on the second iteration of the Sierpinski triangle. The patch and the ground of the antenna present an identical structure but by applying a mirror effect in the ground. The dimensions of the final structure are 60 x 30 mm^2, the substrate is an FR4 with a relative permittivity equal to 4.4, a loss tangent of 0.025 and a 1.6 mm for the height. The antenna is validated in two ISM bands, [2.4 - 2.89] GHz and [5.59 - 5.94] GHz with a stable radiation pattern. These characteristics make the antenna suitable for Wireless Power Transmission field.

The wireless power transmission system is the possibility to transmit and to feed a system without contact by using microwave energy (Brown, 1984). The key element of such a system is a rectenna which is a rectifier associated to an antenna (McSpadden, Yoo, & Chang, 1992). The antenna convert the electromagnetic waves to an electrical energy and the rectifier convert this energy to a DC current that will be sent to a load. The rectenna system contains also a matching circuit between the antenna and the rectifier. To increase the efficiency of a rectenna system, firstly, the rectifier must be designed with a good input impedance matching with the antenna. Secondly, the antenna should present a significant gain and performances in term of radiation.

The second antenna, is also based on fractal geometry with an hexagonal form. The structure is a microstrip multiband antenna validated for four bands. The antenna dimensions are 57 x 47 mm^2. The realized antenna is validated in the bands [1.71 - 2] GHz, [2.37 -2.66] GHz, [4.15 - 4.5] GHz and [5.8 - 6.06] GHz. The return loss of the four bands is below -15 dB. The radiation pattern measurements is done according to the E-plane and the results present an acceptable gain for the proposed antenna.

The two fractal antennas presented in this chapter present the advantage to be compact, low cost and easy to integrate with wireless communication systems. The studies done to each iteration of this structures help to understand more, the impact and the influence of the fractal geometry on microstrip antennas, especially the multiband behavior.

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