Chapter 1

Introduction

1.1 Background

The experimental verification of Maxwell’s theory of electromagnetic waves by Herz during the period 1886 to 1888 opened up new directions in applied electromagnetic research. Inspired by such experiments Sir Jagadish Chandra Bose demonstrated the experiments in the mm wave range in 1897 and later in 1901 Guglielmo Marconi demonstrated commercial wireless telegraphy [1]. The field of wireless communications has been undergoing a revolutionary growth in the last decade. This is attributed to the invention of portable mobile phones some 15 years ago. The success of the second-generation (2G) cellular communication services motivates the development of wideband third-generation (3G) cellular phones and other wireless products and services, including wireless local area networks, home RF, Bluetooth, wireless local loops, local multi-point distributed networks (LMDS), to name a few. The crucial component of a wireless network or device is the antenna. It would be appropriate to include here an excerpt from the article by John D Kraus [2].

"With mankind’s activities expanding into space, the need for antennas will grow to an unprecedented degree. Antenna will provide vital links to and from everything out there. The future of antennas reaches to the stars. One hundred year from now, in 2084, will our present technology seem as primitive as this transmitter of Hertz now appears to us?"

Wireless technology has undergone different phases of development ever since its inception. Over the years there have been different standards of this technology that evolved out of the demands [3]. On the other hand, for safety and portability reasons, low power, multi-functional and multi-band wireless devices are highly preferable. All these stringent requirements demand the development of highly efficient, low-profile and small-size antennas that can be made imbedded into wireless products. In the last 2 decades, two classes of novel antennas have been investigated and extensively reported on. They are the microstrip patch antenna and the dielectric resonator antenna. Both are highly suitable for the development of modern wireless communications. Recently, investigations on dielectric resonator antenna have received increasing attention due to their attractive features like low
cost, small size, low weight, low losses, high radiation efficiency, wide bandwidth and higher gain compared to more traditional microstrip antennas. Dielectric resonators are important components for several communication systems operating at microwave and millimetre wave bands [4]. The use of a dielectric resonator as a resonant antenna was first proposed by Professor S. A. Long in the early nineteen eighties [5]. Characteristic of such DRAs depend on its size, shape and material permittivity [6]. Since the dielectric resonator antenna has negligible metallic loss, it is highly efficient when operated at millimetre wave frequencies. Conversely, a high-permittivity or partially metallised dielectric resonator can be used as a small and low-profile antenna operated at lower microwave frequencies. Low loss dielectric materials are now easily available commercially at very low cost. This would attract more system engineers to choose dielectric resonator antennas when designing their wireless products. Since dielectric resonator antennas are so promising in practical applications, hundreds of articles on the design and analysis of dielectric resonator antennas can be found in reputable international journals or in major international conference proceedings.

Over the period new design concepts on dielectric resonator antenna have been introduced. The present study is based on one such new concept known as “Fractal”. B.B. Mendelbrot introduced the fractal geometry to mathematics for the first time in the year 1975 [7]. The word fractal means an object, which is indefinitely divided. Its Latin name is “fractus” that descends from the verb “frangere”, which means to break. This branch of geometry saw intensive study in 1970s. Since then this branch of geometric interpretations have found numerous applications in different fields of science and engineering and of late has been incorporated in the design of antenna. The fractal antennas and arrays result from the amalgamation of two apparently disjoint fields: electromagnetic theory and geometry. A fractal is a recursively-generated structure that has a fractional dimension. Fractals also describe many real-world objects, such as clouds, mountains, Brownian motion, and coastlines and trees that do not correspond to simple geometric shapes.

Dielectric Resonator Antenna based on various geometries has been discussed along with different feeding mechanisms in several texts [4, 8]. So far Euclidian designs of DRAs are considered, there are extensive analytical results on antenna characteristics but in fractal paradigm there is none. However there are some empirical relations, obtained from simulation or experimental data, put forward by researchers on resonant frequency expressions for specific designs of such antenna.
1.2 Motivation of the Thesis

Fractal dielectric resonator antenna design paradigm is still in its infancy. New geometrical design and modifications of conventional DRA incorporated fractal geometry are still open to researchers. There are no closed form formulae related with fractal area, volume or order of iteration except few empirical formulae for resonant frequency, for design and analysis of conventional dielectric resonator antennas. Thus for any antenna engineer it is challenging to take up fractal dielectric resonator antenna design problem.

It had been observed that the dielectric resonator is fabricated from a dielectric material having low-loss (loss tangent $\approx 10^{-4}$, or less) and high dielectric constant ($\varepsilon_r \approx 10$ to 100). Improving impedance bandwidth by optimizing the DRA dimensions, mode merging techniques, lowering the radiation Q-factor by using various shapes, modification of ground plane has been reported [9-19] and introduction of fractals in dielectric resonator antenna [20]. The author has been motivated by the above facts and incorporated various fractal shapes in DRA which result in improved impedance bandwidth. In addition, an attempt to reduce the antenna cost has been made by realizing fractal DRA using low dielectric permittivity material.

1.3 Organization of the Thesis

A historical perspective on the development of dielectric resonator antennas since the concept was laid down in 1939 is provided in Chapter 2. This chapter reviews, in more detail, different bandwidth enhancement techniques, including the reduction of Q-factor by loading effect, the employment of matching networks, and the use of multiple resonators. In this era of wireless communications, low-profile and small-size antennas are highly preferable for mobile devices, such as cellular phones, notebook computers, personal digital assistant (PDA), etc. Applications of fractal geometry are becoming increasingly widespread in the fields of science and engineering. Many more fractal-shaped antennas exist already on the market and are used in cars, mobile phones and data-transfer devices. A number of designs of dielectric resonator antenna and a comprehensive overview of fractal antenna engineering reported by various researchers in this field are summarized as a ready reference.

In Chapter 3, a new broadband dielectric resonator antenna introducing fractal geometry in Sierpinski Gasket form has been presented. This is realized by drilling off Sierpinski gasket fractal shaped holes in original equilateral triangular dielectric resonator. First and second iteration Sierpinski gasket shaped fractal triangular dielectric resonator antenna with coaxial
probe has been investigated. Operating principle of this antenna is addressed based upon the investigation of parametric studies, resonance and radiation characteristics.

In Chapter 4, two variants of Sierpinski carpet fractal shaped dielectric resonator antenna (SCFDRA) are studied. The first one is a Sierpinski carpet patterned cylindrical Dielectric Resonator Antenna (DRA) operating in the X-Band. This DRA is realized from low cost Teflon. Antenna design methodology is discussed along with some parametric studies, its resonance and radiation characteristics.

This chapter concluded with a second type of variation in SCFDRA, which is a Sierpinski Carpet Fractal shaped Rectangular DRA. The proposition was mainly aimed at emphasizing the overall performance of such design modifications rather than simply correlate experimental and simulated results. For completeness the radiation pattern is also presented.

In Chapter 5 two consequences by using boundary fractal in DRA which is tuned to the body area network frequencies as well as the IEEE 802.11a WLAN frequencies is reported. In first configuration boundary fractal is used to achieve wide bandwidth and the second investigation involves miniaturization of rectangular DRA by using fractal rectangular curve along the cross-sectional boundary. Antenna design methodology is discussed along with some simulated parametric studies, its resonance and radiation characteristics.

Chapter 6 introduces the fractal DRA. Fractal antennas are in use for multiband operation. As is the usual practice they are fabricated from conducting materials. The procedure of designing the fractal DRA is vividly outlined. To form the fractal DRA, of rectangular cross section and triangular cross section with coaxial probe feeding, the drilled out regions in the form of Sierpinski carpet in rectangular DRA and Sierpinski gasket in triangular DRA are filled with silver paste material. Fractal antenna design methodology is discussed along with some simulated parametric studies, its resonance and radiation characteristics. For validation of simulated results, a prototype of fractal rectangular DRA has been fabricated.

The last chapter, i.e. Chapter 7 concludes the research that has been done and proposes new research areas on fractal dielectric resonator antenna. Contributions of this thesis are the Sierpinski Gasket fractal shaped DRA, Sierpinski Carpet Fractal structure on Cylindrical and Rectangular DRA, boundary fractal in modified rectangular curve shaped DRA, fractal DRA of rectangular, triangular cross section, and monopole type Sierpinski carpet fractal patterned rectangular DRA. Scope for further research and development is also summarised in this chapter.
A view graph of the organization of the thesis is presented in Fig. 1.1.

Figure 1.1 Organisation of the Thesis.
References


