Design of Fractal Antenna for RFID Applications

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ABSTRACT: *In this paper, sierpinski carpet fractal shape antenna for RFID applications is proposed. The proposed antenna has been designed with scaling factor of one-fourth with the aim of reducing antenna size and improved performance parameters. Fractal shaped has been developed to improve the characteristics and to miniaturize the size of proposed antenna. Usually, an antenna works at one or two frequencies, whereas with fractal antenna, it can be performed to have multiple resonance frequencies. Several properties for multi-band operation of the proposed antenna have been studied which include the return loss, radiation pattern, input impedance and gain by using IE3D, full wave electromagnetic simulation package by Zeland Software Inc..*

Keywords *- Fractal, Microstrip Antenna, Radio frequency identification (RFID), Transmission*

I. INTRODUCTION

The rectangular microstrip antenna consists of a microstrip transmission line made of conducting material on one side of a thin dielectric substrate which has a ground plane on the other side (Fig.1). The continuous shrinking size of electronic equipment demands similar size antenna elements in order to fit properly in wireless devices without compromising the other radiation properties of the antenna [2]. In this respect microstrip patch antennas (known also as patch antenna) are quite an evident choice because of its other benefits like low profile, light weight, low cost and easy fabrication. But as far as size of these patches is concerned, the patch length should be around half-a-wavelength for the structure to act as a good radiator. A microstrip antenna is characterized by its Length, Width, Input impedance, gain and radiation patterns. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. Microstrip antenna falls into the category of printed antennas, of all the printed antennas, including dipole, slots, and tapered slots; microstrip antenna is most popular and adaptable. This is because of all its salient features like ease of fabrication, good radiation control, and low cost of production.

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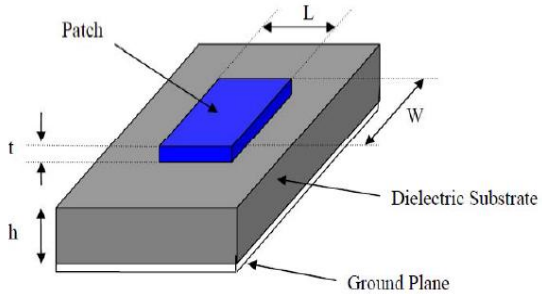


Fig 1. Rectangular microstrip patch antenna[7]

Due to the advancement in wireless communication systems and increase in their application, small size and multiband antennas are in great demand. The effects of electromagnetic waves on fractal bodies have been intensively studied in latest years [5]. Fractal geometries have two properties, space filling and self- similarity. Fractal geometries due to their self-similarity properties have proved to be very promising tool for designing miniaturized multi frequency antennas. The use of fractals provides us with a larger set of parameters to control the antenna characteristics. In addition some applications of the patch antenna in communication systems required smaller antenna size in order to meet the miniaturization requirements [8].Some examples of fractals are given in (Fig 2). The multiband properties of fractal shapes, such as sierpinski carpet have their application in Radio Frequency identification [5].

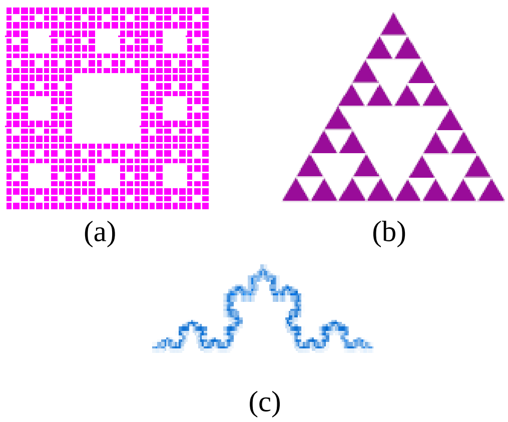


Fig 2. Fractal structures (a) Sierpinski Carpet (b) Sierpinski Gasket (c) Koch Curve[14]

Radio Frequency Identification (RFID) is a wireless rapidly advancing identification technology. RFID is an automatic identification technology on storing and retrieving data using devices called RFID tags and RFID readers. An RFID tag is a small object that can be attached to a thing, animal or a person. Tags are classified as active tags, passive tags and semi-passive tags.

a) Active tags carry their own power supply like a battery for processing and communicating. The battery gives the possibility of building up more reliable communication but it increases the cost and product size [8].

b) Passive tags absorb energy from electromagnetic field that is provided by RFID reader with a distance of several meters away. Passive RFID tags are the most commonly used type nowadays because there is no battery inside the tag which makes them low cost and small. Load modulation is used for communication and channel separation is done by TDMA. Problem faced is that the tags are using same frequency for power harvesting and communication. When a tag is too close to other tags, they will interfere with each other and the performance will be degraded.

c) Semi-passive tags are a combine of active tags and passive tags. They use load modulation for communication and contain a battery for supplying energy. This provides stable power source and eliminates the needs of power harvesting, hence the communication distance is increased. Again, the battery increases the cost and product size. All these three types of RFID tags are using narrowband technology which is difficult to provide and precise [9].

RFID readers are of two types. One is fixed reader and other is mobile reader. The number of readers required to cover an area depends on factors like the properties of the reader, tag and the shape of an area to be covered [5]. RFID technology plays an important role for controlling, detecting and tracking items along its lifespan. RFID systems are commonly used to track and record the movement of ordinary items such as library books, clothes, factory pallets, electrical goods and numerous items.In this project our purpose is to design a multiband sierpinski carpet fractal antenna to improve the behavior of conformal patch antenna and to make it suitable for RFID applications. The proposed antenna has an omnidirectional radiation pattern or hemispherical coverage and good gain.

II. DESIGN OF FRACTAL ANTENNA.

The purpose of this work is to design fractal antenna using simulation software like IE3D [11]. The IE3D software by Zeland Software Inc. has been considered as the benchmark for electromagnetic simulation package. It is full wave, method of moment (MOM) simulator that solves distribution on 3D structures [10]. IE3D is a very fast and accurate simulator. Moment method simulator such as the IE3D needs to solve matrices. The time for solving matrices is the most important part in an IE3D simulation.

2.1 Design Considerations

The following design considerations are worth mentioning:

Geometry of the patch antenna consists of a dielectric substrate separating the patch and the ground plane. Suitable dielectric material of height *h*, having a relative permittivity, ε_r

and a specified loss tangent (tanδ) needs to be selected.

$$f_r = \frac{c}{2L\sqrt{\varepsilon_r}} \quad \text{equation(2.1)}$$

Dimension of the rectangular patch of width *W* and length *L* has effect on performance of the antenna. Resonant frequency f_r of the rectangular patch antenna is dependent on the length *L* and relative permittivity ε_r. For TM10 mode, f_r is given by equation (2.1).

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + \frac{12h}{W}}} \quad (2.2)$$

Since the fringing field that results in increase of effective length of the patch, it can be accounted for by considering effective dielectric constant ε_{re} given by the equation (2.2).

$$\Delta L = 0.412h \frac{(\varepsilon_{re} + 0.3)\left[\frac{w}{h} + 0.264\right]}{(\varepsilon_{re} - 0.258)\left[\frac{w}{h} - 0.813\right]} \quad (2.3)$$

The increase in length of the patch ΔL due to fringing field is given by equation (2.3).

$$L = L_{eff} - 2\Delta L = \frac{c}{2 f_r \sqrt{\varepsilon_{re}}} - 2\Delta L \quad (2.4)$$

The actual length of the patch is given by equation (2.4), where 'L' is the effective length of the patch. It is important to note that width *W* has insignificant effect on the resonant frequency f_r and the radiation pattern of the antenna. Input impedance and hence the bandwidth is affected by the width of the patch [4].

2.2 Antenna Configuration

The rectangular patch antenna is approximately a one-half wavelength long section of rectangular microstrip transmission line. When air is the antenna substrate, the length of the rectangular microstrip antenna is approximately one-half of a free-space wavelength. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases.

In this project, conventional sierpinski carpet structure is modified by varying scaling factor from one-third to one-fourth. By varying the scaling factor of a conventional antenna not only improves its performance but also make the structure of antenna smaller in size.

Fig.3 shows the geometry of proposed modified sierpinski carpet fractal antenna for zero, first and second iteration. Table 1 shows the dimensions of designed antenna.

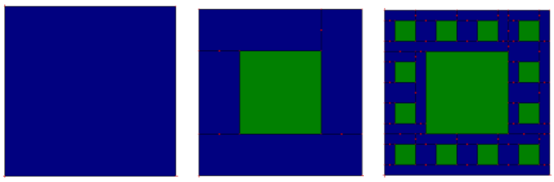


Fig 3. Modified sierpinski carpet (a) zero iteration (b) first iteration (c) second iteration

Table 1

DIMENSIONS OF PROPOSED FRACTAL ANTENNA

S. No	**Parameters**	**Dimensions**
1	Length of proposed Antenna, L	40mm
2	Width of proposed Antenna, W	40mm
3	Height of the substrate, h	1.6mm
4	Dielectric constant, ϵ_r	4.4
5	Length of ground plane, Lp	40mm
6	Width of ground plane, Wp	40mm

III. SIMULATION & MEASUREMENT RESULTS

3.1 Return Loss - Figure 4 shows the reflection coefficients for all the three iterations of proposed fractal antenna that is first, second and third iteration. As expected, it was demonstrated that with increase in the iterations, resonant frequency shifts towards lower side which satisfy the spacing filling property of fractals. The simulated resonant performance characteristics of the proposed antenna are reported in Table 4.1 reveals that the proposed structure possess multiband characteristics and produces more number of bands than its conventional counterpart. This multiband nature of the proposed modified fractal antenna satisfies the self-similar property of the fractal antennas. It can also be noticed that there is an increase in the impedance bandwidth of the proposed structure when the iterations of the fractal antenna increases, with considerable improvement in the impedance matching of the antenna. The proposed antenna resonates on 2.4 GHz and 5.75 GHz frequency bands that make it suitable for RFID applications.

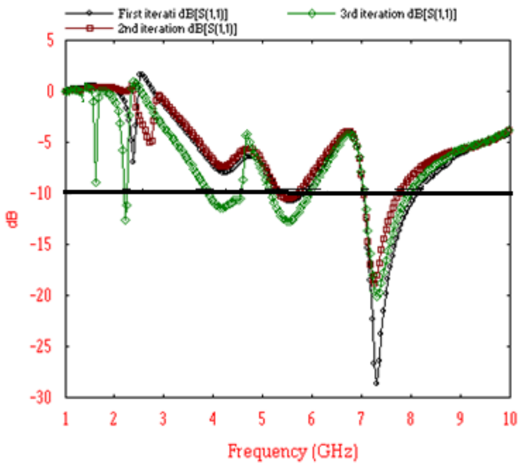


Fig 4. Resonating properties of all the three iterations of proposed modified sierpinski carpet fractal antenna.

3.2 Input Impedance of the proposed antenna is shown in figure 5.

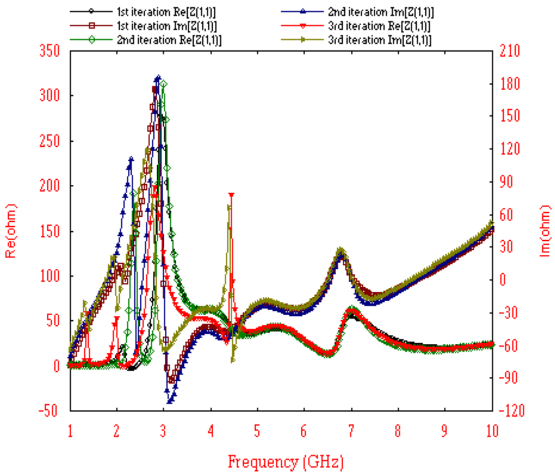


Fig 5. Simulated input impedance of all the three iterations of proposed modified sierpinski carpet fractal antenna.

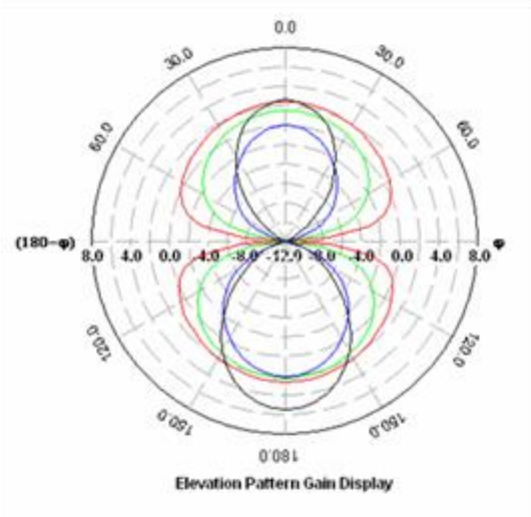
Table 2

Input Impedance Characteristics of proposed antenna

No. of Iterations	Resonant Frequency (GHz)	Reflection Coefficient (dB)	Input Impedance (ohms)
First	5.69 7.25	-11.29 -22.89	42.03-j25.66 61.50-j6.62
Second	5.25 7.23	-11.05 -19.32	62.10-j0.64 41.56-j25.26
Third	2.40 4.43 5.75 7.25	-13.05 -11.89 -13.20 -20.61	44.72+j2.93 51.64-j6.68 43.16-j9.69 59.81-j2.93

3.3 Radiation Pattern

An antenna radiation pattern is a 3-D plot of its radiation far from the source. Antenna radiation patterns usually take two forms, the elevation pattern and the azimuth pattern. The radiation characteristics of proposed modified sierpinski carpet fractal antenna with DGS are shown in (Fig 6) and it has been observed that they are nearly similar in nature for all the frequency bands. The radiation pattern is symmetrical to antenna axis in E-plane and nearly omni directional pattern in H-plane.



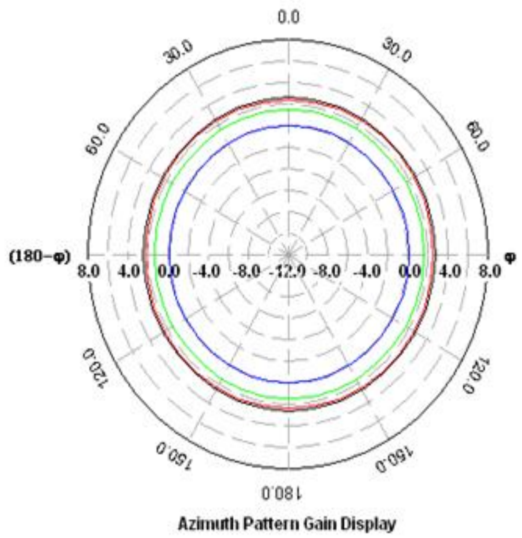


Fig 6. Radiation Patterns of proposed antenna (a) E-plane (b) H-pane

3.4 Gain

Gain for the proposed antennas is shown in (Fig. 7). The gain of the modified sierpinski carpet fractal antenna at 2.40 GHz is 2.91 dBi, at 4.43 GHz is 1.2 dBi, at 5.75 GHz is 2.13 dBi and at 7.25 GHz is 3.72 dBi, as shown in Figure 7. The proposed structure possesses good gain values at all the resonating frequency bands that make the proposed antenna suitable for RFID applications.

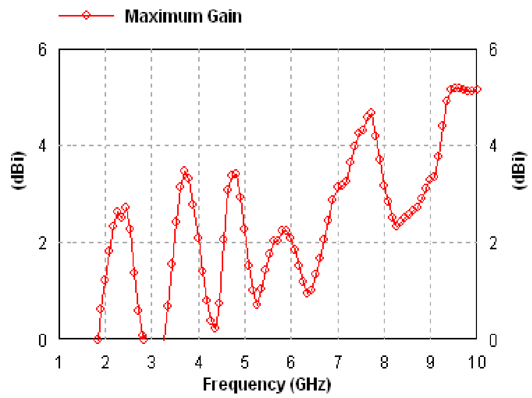


Fig 7. Gain versus frequency of proposed antenna.

IV. Conclusion

The modified sierpinski carpet fractal antenna is designed for RFID applications and presented. The fractal shape has been developed to improve the characteristics of the proposed antenna and also the scale factor variation has been studied. The simulation study is carried out with the full wave EM simulator IE3D. The proposed antenna has good gain and enables connectivity at WLAN standards at 2.4 GHz, and 5.8 GHz. The design is highly compact, low cost and efficiently useful for RFID applications.

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