Fractal array antennas with NP generator model

Chatree Mahatthanajatuphat¹ and Prayoot Akkaraekthalin²
Department of Electrical Engineering, King Mongkut’s Institute of Technology North Bangkok
1518 Pibulsongkram Rd., Bangsue, Bangkok 10800 Thailand
¹cmp@kmitnb.ac.th and ²prayoot@kmitnb.ac.th

Abstract

This paper presents array antennas using a technique of fractal geometry. The antennas are designed to operate at frequency 2.45 GHz, which is used in application of wireless LAN. A single fractal antenna is created by iterating a Narrow Pulse (NP) generator model at each side of normal square patch antenna. The advantage of fractal technique is that the antenna size can be reduced comparing with a normal square patch antenna. The array antennas have equal space between edges of each element, which is 0.5λo. It has been found that dimension and side lobes of the fractal array antennas are reduced comparing with the array of normal square patch antenna. However, the radiation patterns of the proposed antennas are still identical to the normal square patch antenna array. The properties of the antennas such as return losses, radiation patterns and gain have been carried out via numerical simulation and measurement.

1. Introduction

Nowadays, wireless communication systems are becoming increasingly popular. There have been ever growing demands for antenna designs that possess the following highly desirable attributes: compact size, low profile, multi-band, and etc. There are varieties of approaches that have been developed over the years, which can be utilized to achieve one or more of these design objectives. Recently, the possibility of developing antenna design objective has been improved due to use of fractal concept. The term of the fractal geometries was originally coined by Mandelbrot [1] to describe a family of complex shapes that have self-similarity or self-affinity in their geometrical structure.

In literature review, we have found advantages of the fractal geometries, which support the attributes of compact size, and multi-band frequency operations. Recently, the antenna design, which has the characteristic of compact size by using the fractal technique, is known as Koch monopole antenna [2]. This fractal antenna is created by iterating the initial triangle pulse through a monopole antenna. Next, a miniaturization of loop antenna using fractal was known as Minkowski square loop antenna [3]. The fractal antenna was created by using the initial square pulse (SP) to iterate at each side of loop. The extended version of miniaturization square loop antenna was found in [4], which created by using the generator for 3/2 curve fractal to increase the electrical lengths in a fit small area.

Also, the fractal geometries still have the attribution of multi-band. The Sierpinski gasket monopole antenna in [5] was introduced by Puente. This popular antenna used the self-similarity properties of the fractal shape to translate into its electromagnetic behavior. The classic Sierpinski gasket can be generated by the Pascal triangle that was introduced in [6]. However, other antennas, which have the characteristic of multi-band created by fractal geometries, are following: slot spiral antenna [7], multiple ring monopole antennas [8], coplanar waveguide (CPW) fed circular fractal slot antenna [9] etc.

In this paper, we use the attribute of compact size in fractal properties to design fractal array antennas. The proposed antennas are created by using the technique of parallel feeding to fractal antennas. The antennas are designed by using the initial NP generator model [10]. The characteristics of the fractal array antennas will be investigated by simulation using the full wave method of moments (MoM) software package from IE3D at operating frequency of 2.45 GHz. Especially, the radiation pattern of the proposed antennas will be investigated to observe the magnitude of side lobe.
The organization of this paper is as follows. In sections 2 and 3, a brief explanation on the antenna design will be given. Simulation and measured properties of the antennas will be discussed in section 4. Results are discussed in section 5.

## 2. Coupling Analysis

The NP generator model, as shown in Fig. 1, is introduced to explain the iteration of the proposed antennas. The iteration depth $W$ is smaller than $a/3$ [3]. In the proposed paper, the iteration depth $W$ of the NP generator model is approximately $0.222a$. The details of the designed fractal antenna with NP generator model are described in [10]. Before designing the fractal array antennas, we have to investigate the coupling coefficient in H-plane of the square patch antenna, 1st iteration of fractal antenna, and 2nd iteration of fractal antenna. Also, the substrate of 1.6 mm thickness with dielectric constant of 4.1 was used in the experiment of coupling coefficient. The test of coupling coefficient $S_{21}$ of the two square patch antennas, 1st iteration of fractal antennas, and 2nd iteration of fractal antennas were done with distance $(d)$ between centers of the two antennas, as shown in Fig. 2. The distances $(d)$ are following: $0.3\lambda_0$, $0.4\lambda_0$, $0.5\lambda_0$ until to $\lambda_0$. Fig. 2 shows that the simulation agrees well with the measurement. It can be clearly observed that the coupling coefficient will be reduced with the increment of the distance between centers of the two antennas. The results indicate that the coupling of the fractal antennas with the NP generator model is smaller than that of a square patch antenna at the same distance.

## 3. Array Antenna Configuration

The fractal element mentioned in the previous section is used to create 2x1 array antennas. The matching circuits and the array elements are both on the same layer, as depicted in Figs. 3. The material of the substrate is FR4 with dielectric constant of 4.1, and the thickness of the substrate is 1.6 mm. T-junctions were used as power dividers to provide equal amplitude and in-phase signal for
each radiator. The radiator dimensions of the square patch array antenna, the 1st iteration, and the 2nd iteration of fractal array antennas, as shown in Figs. 3, are 90.7x29.5 mm$^2$, 86.6x25.3 mm$^2$, and 84.4x23.2 mm$^2$, respectively. The distance between centers of two antennas is set to be 61.22 mm, which is approximately 0.5$\lambda_0$. Therefore, the radiator dimensions of the 2nd iteration of the 2x1 fractal array antenna with the NP generator model is 26.81% smaller compared to the 2x1 array antenna of square patch.

4. Results of Simulation and Experiment

The simulated and measured return losses of the 2x1 array antennas are depicted in Fig. 4(a). The measured results show that the operating frequency of the 2x1 array antennas is approximately occurred at 2.45 GHz. Also, the simulation return losses agree well with the measured return losses. Fig. 4(b) depicts the peak gains of simulation and measurement, which they nearly occur at the operating frequency of 2.45 GHz. The peak gains of simulation are similar to that of measurement. In the simulation and measurement, the peaks gain of the 2x1 array antenna with square patch, 1st iteration and 2nd iteration of fractal antenna are approximately 4 dB, 3 dB, and 2 dB, respectively. Figs. 5 show the measured radiation pattern of the 2x1 array antennas. The black lobe in the X-Z plane of the 2x1 fractal array antenna with 2nd iteration NP generator model is smaller than that of the 2x1 array antenna with square patch about 4 dB. In the Y-Z plane, the null, which occurred in 2x1 array antennas with square patch, does not occur in the 2x1 array antenna with 2nd iteration NP generator model. The maximum gains of radiation patterns in the X-Z plane and the Y-Z plane are approximately occurred at 0 degree at the resonance frequency. Observing the results, the 3-dB beam width of the 2x1 fractal array antennas is approximately 60 degree for the measured radiation patterns.

Figure 3: Geometry of the 2x1 array antennas (a) square patch, (b) the first iteration, and (c) the second iteration.

Figure 4: Simulated and measured results of the 2x1 array antennas for (a) return losses, and (b) gain.
5. Conclusion

In this paper, experiments of the 2x1 fractal array antennas with the NP generator model have been investigated. The dimensions of the proposed antenna are approximately 26.81% smaller than the 2x1 array antenna using square patch. The back lobe of the 2x1 array antennas with square patch can be reduced approximately 4 dB, as using 2nd iteration of NP generator model. The radiation pattern of fractal array antennas are still similar to the direction radiation pattern, which have peaks gain about 3 dB, and 2 dB, respectively, for the 1st iteration and 2nd iteration of NP generator model. The 3-dB beam width of the 2x1 fractal array antennas are approximately 60 degree larger than that of the 2x1 array antenna with square patch.

References