Nature-Inspired Microstrip Antennas For High-Directivity: Fractals and Genetics

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Abstract

High directivity patch antennas with broadside directivity have practical interest since a narrow beam can be obtained without using an array of antennas. The solution becomes simpler because there is no need of using a feeding network. Two examples of high-directive microstrip antennas synthesized by fractals and genetic algorithm optimization are compared. Both simulated and measured results show the potential of fractals and genetic algorithms to design non-intuitive antennas having broadside and high-directivity performance with a single microstrip element. Said elements are useful for hot-spots.

Index Terms—fractals, genetic algorithm, optimization, high-directivity, microstrip antennas.

Ⅰ. INTRODUCTION

Achieving high-directivity by using a single element microstrip patch antenna is a challenging task, as conventional patches have moderate directivity of about 6-7 dBi [1]. A classical patch, such as a square patch, presents a broadside pattern at its fundamental mode (TM10 or TM01), with a low directivity. A broadside pattern can also be found at a higher order mode (TM30). However, the directivity is again limited, as the radiation pattern presents high secondary lobes. The classic method to increase directivity is to form an array of antennas. However, having as an objective to obtain a simple antenna structure, an array needs a feeding network which on one hand increases the mechanical complexity and on the other hand, the spurious radiation from said network may distort the desired radiation pattern. In order to avoid an array of antennas, various methods to improve the directivity of microstrip antennas have been reported in the literature, such as fractal-inspired antennas [3]-[5] or electromagnetic band gap, superstrates, zero-index metamaterial, modified Peano space-filling curve. In this sense, the present paper compares high-directivity microstrip antennas, where fractal geometry and GA is employed on radiating elements with same size.

The paper is divided as follows: in section II the basics on fractals-geometry the GA algorithm are presented. In section III, a high-directive microstrip antenna using fractal geometry and GA are compared. Finally, in section IV, conclusions are drawn.

Ⅱ. ON FRACTAL AND GENETIC ANTENNAS

Fractal-shapes have been useful to design small, multiband, and high directivity antennas. In particular, thanks to the space-filling properties, examples of small antennas have appeared in the literature. Also, thanks to the self-similarity property, multiband and high-directivity antennas have been designed.

In the present paper, the fractal Sierpinski triangle is used and compare with a GA design (Fig. 1). This element present at a higher order mode with a directivity larger than the directivity of the fundamental mode [3]. Considering a microstrip structure of h=1.52mm, printed on a ε_r=3.38 substrate, a bow-tie patch of 40 mm x 40 mm results in a 6.3dB at the fundamental mode resonating at 1.128GHz. This bow-tie patch is considered the zero iteration of the Sierpinski-patch. In contrast, for the Sierpinski-patch of 3 iterations (Fig. 1), the directivity obtained at a higher-order mode (3.86GHz) increases to 10.9dB (Fig. 2). The reason of this high-directivity is that the current distribution presents a self-similar behavior, i.e, repeated portions of in-phase radiation along the structure. On one hand, this in-phase portions results in a broadside-pattern. On the other hand, since the antenna is operating a high-order mode, the antenna is electrically larger than the antenna size when operating in the fundamental mode. Therefore, a larger directivity is obtained.

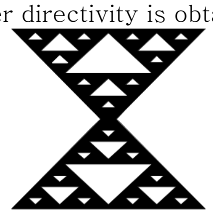

Figure 1 Sierpisnki bowtie of three iterations: it is based on the Sierpinski triangle applied to a bowtie

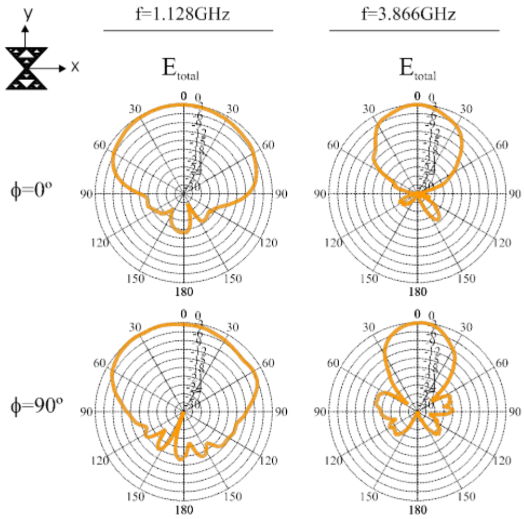

Figure 2 A comparison of the measured radiation pattern for the fundamental mode of the Sierpisnki-shaped antenna and for the higher-order mode

Regarding the genetic-inspired antenna, the proposed design is simulated in the High Frequency Structure Simulator (HFSS) environment in combination with a home-made GA code. The GA operation is written using Visual Basic Script (VBS) Writer and the .VBS file is called into HFSS environment to perform simulations. In order to compare with the fractal-shaped antenna, the same area of 40 mm x 40 mm is used as a reference as well as the same substrate.

The patch area is divided into small cells so as to overlap between adjacent cells. The conducting or non-conducting property of each cell is defined using binary encoding. If a cell is conducting, then the corresponding gene is assigned "1" and if a cell is non-conducting it is assigned "0". The purpose of the overlap between adjacent cells is to avoid having cells contacting by an infinitesimal point which may pose a connection problem when manufacturing the microstrip patch due to the tolerances of the chemical etching (Fig. 3).

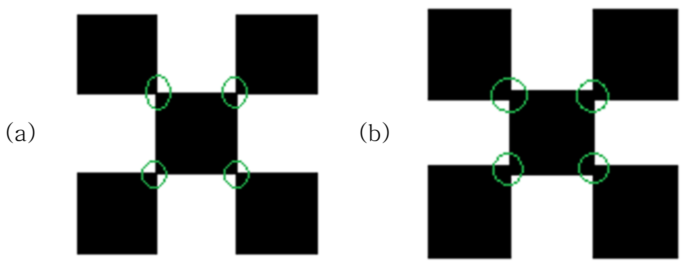

Figure 3 a) Traditional on/off building block with infinitesimal connections. b) Proposed scheme using overlapping based on a shifting of the cell following the vertical axis

The GA scheme is based on the cross-over and mutation operators (Fig. 4). The optimization is finished when the fitness presents convergence.

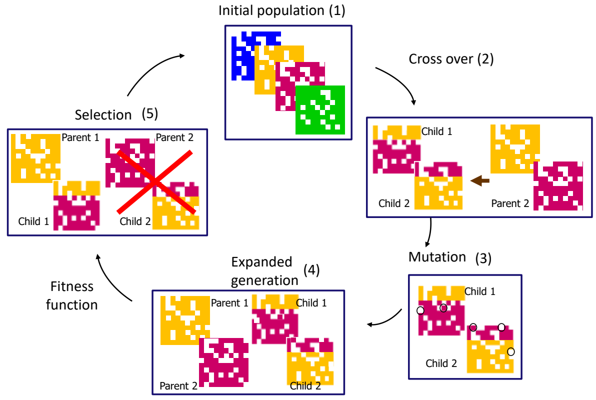

Figure 4Initial population consists on a random population; cross-over operator is used to create new individuals; elitism mutation is applied to ensure a globlal optimization; the fitness function selects the best individual to be on top of the population. Conductor is represented by colours whereas non-conductive portion is represented by white colour

The optimization process is described as above.

Ⅲ. CONCLUSIONS

Microstrip antennas with high-directivity characteristics designed using a single-fed point are interesting since there is no need to include a feeding network as is the case of microstrip arrays. In this sense, the fractal and GA designs presented in this paper, feature high-directivity including patterns with narrow beam at both planes. These designs are of engineering application for hot-spots.

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