

GA Design of Small Wire Antennas

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INTRODUCCION

As it is well known electrically small antennas are inherently very reactive and inefficient radiators and they present a very narrow bandwidth when they are tuned to resonance [1]-[2]. Hence, to the design of this kind of antennas it is necessary to seek a compromise between several parameters like resonance frequency, bandwidth and efficiency. In a previous work [3] a multi-objective Genetic Algorithm (GA) in conjunction with the numerical electromagnetic code (NEC) was applied to the optimization of electrically small wire antennas looking for such a compromise. As a result it was shown that, for a given overall wire length and antenna size, the performance of genetically optimized antennas with zigzag-like and meander-like geometries was always better than that of the ones obtained using genetically optimized prefractal geometries like generalized Koch-like antennas [3].

Other prefractal wire antennas were subsequently considered in [4] such as those with Peano or Hilbert geometries (see Figure 1a) and a GA was applied with the aim of finding zig-zag and meander designs that surpass the performance of the above mentioned prefractal antennas. The results obtained confirmed that genetically optimized zigzag-like and meander-like antennas present better characteristics than those of all the members of the prefractal families considered. However, when other prefractal groups of wire antennas such as Delta, Y or Koch Sierpinski [5] (Figure 1b) were considered, it was not always possible to find GA-designed zig-zag or meander type antennas better than such prefractal monopoles. We believed this could be related to the fact that these Sierpinski antennas include closed loop shapes in their geometries, i.e., elementary magnetic dipoles, while our GA designs do not, since we have restricted ourselves to zig-zag and meander type curves. In order to give more freedom to the GA code, the possibility of including closed loops was subsequently allowed in the search for the best possible structure. Thus the new set of genetically optimized antennas presented a better performance than all the prefractal antennas including loops illustrated in Figure 1b. In this communication we present and discuss these latter results.

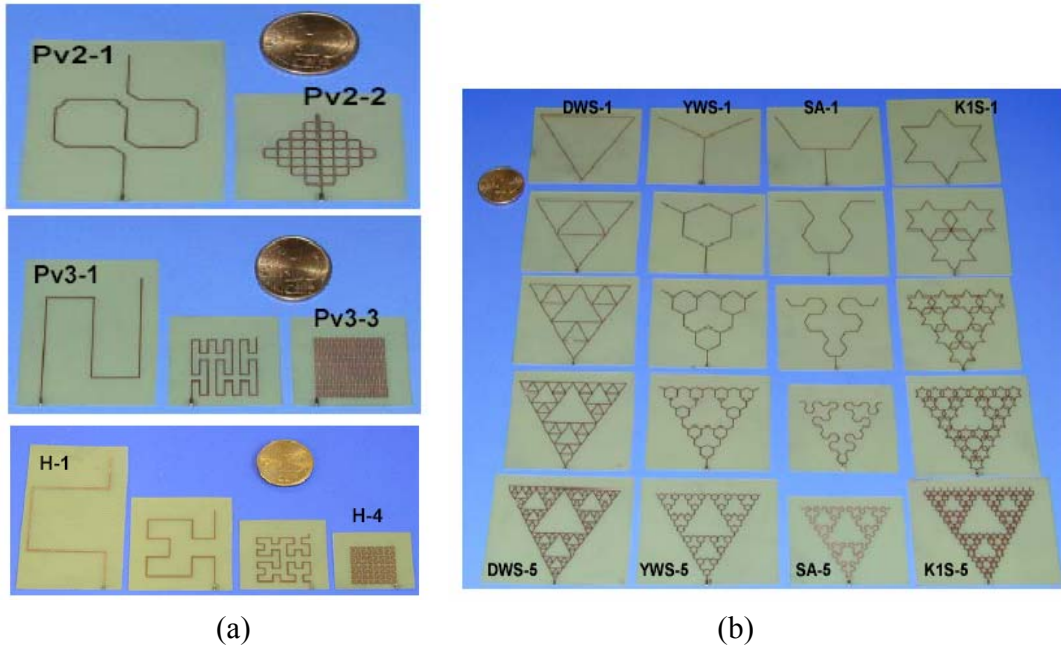


Figure 1. a) From top to bottom: Iterations 1 and 2 of a Peano curve version 1, Iterations 1 to 3 of a Peano curve version 2, Iterations 1 to 4 of a Hilbert curve. b) From left to right, four iterations of: Delta wire Sierpinski, Y Wire Sierpinski, Sierpinski arrow head, Koch Sierpinski.

RESULTS

Following a similar procedure to that described in [3], a multi-objective (Pareto) GA code [6] has been used to find small monopole antenna designs, with a better performance than that of the prefractal antennas shown in Figure 1b. To allow the GA code to look for structures including closed loops in their geometries and to consider sizes similar to those of the Sierpinski structures, the GA optimized antennas were built by filling an equilateral triangle. This equilateral triangle is assumed to be the same height, $a=6.22$ cm, as that of the Sierpinski antennas using the basic shapes plotted on the right side of Figure 2. To this end the main triangle is divided into 16 equilateral subtriangles that are randomly replaced by one of these basic shapes.

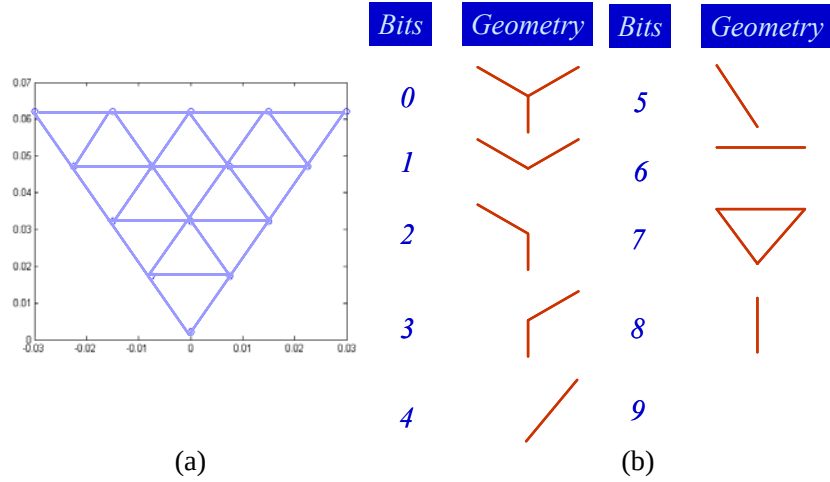


Figure 2. a) Area to be filled b) Building blocks to replace the subtriangles in a).

A set of monopole antennas that constitute the initial generation were randomly formed and encoded into chromosomes using fixed point decimal coding [6]. The antennas were assumed to be made of copper, with a finite conductivity of $\sigma = 5.8 \cdot 10^7$ S/m, and fed at their base. Their efficiency, η , input impedance and resonance frequency were calculated applying the frequency-domain method-of-moments-based NEC code. Three fitness functions were defined in terms of the resonance frequency, the Q factor and the efficiency, so that GA would evolve towards smaller individuals with a lower Q factor and higher efficiency.

After applying the GA operators [6] of tournament method, one point crossover and a Gaussian-probability-distribution mutation, the multi-objective GA procedure renders a front or surface of optimal solutions (Pareto front) from which the designer can select the individual that best fits the requirements of the problem at hand. The procedure is applied by means of domination schemes using triangular sharing functions to guarantee diversity in the final set of optimal solutions [6]. The specific GA adopted in this work employs both a crossover operator and a mutation operator with probabilities 80% and 5%, respectively. The population is formed with 20 chromosomes, comprising a set of $N=16$ genes which represent coded versions of the individual characteristics.

As the GA progresses, a 3D graph of k_0 , a , η and Q is generated corresponding to each individual after each generation (where k_0 represents the wave number corresponding to the resonance frequency). The envelope of this graph evolves to an optimal set of solutions, called the Pareto front [6] from which the designer can choose the individual that best fits the design requirements. Figure 3 plots two projections of the Pareto surface corresponding to the results obtained after 6800 generations. In order to compare the characteristics of the same set of specific individuals, we first project the Pareto surface onto the efficiency- Q plane, then select the individuals with lower Q and plot both their efficiency and their Q factor versus their electrical size (see lines with triangles in Figure 3). Note that, under these circumstances, there is always a

GA design which presents a better performance than that of any prefractal Sierpinski antenna of the same length showing a higher efficiency and lower Q. As an example, the genetically generated antenna of $k_0 a = 0.98$, is depicted in Figure 4 having an efficiency of 98.57 and $Q=6.36$ (obtained using NEC). Measurements of Q and η are being conducted for the antenna shown in Figure 4 following the methods described in [7]. They will be shown at the presentation.

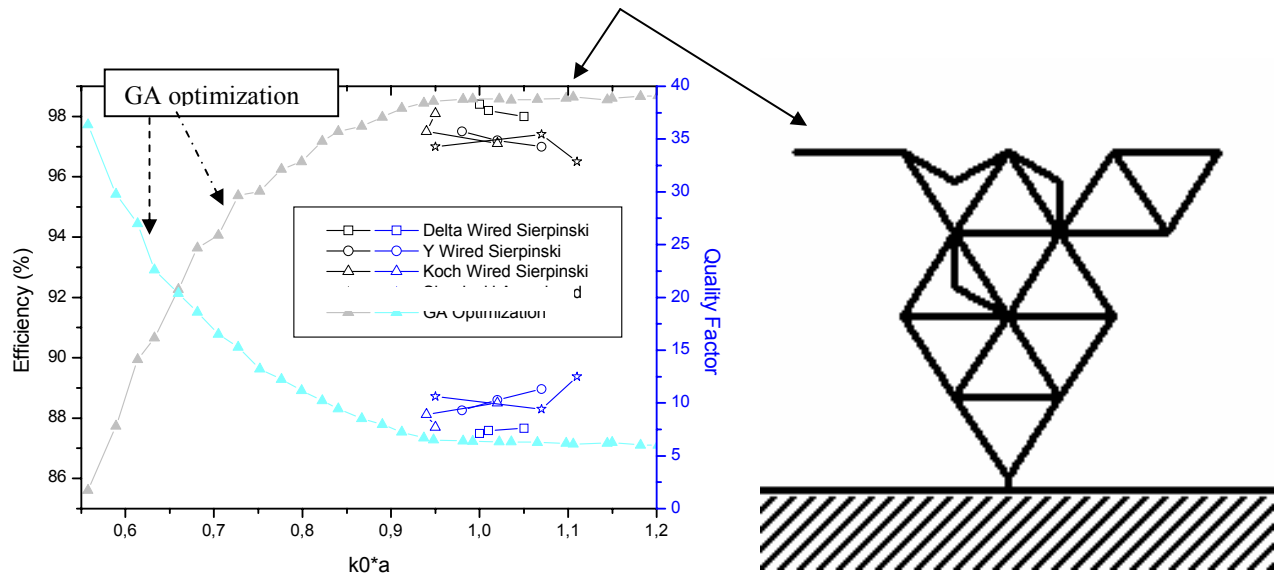


Figure 3: Efficiency and Q factor of the individuals obtained with GA and of the prefractal antennas

Figure 4: Geometry of the individual marked with an arrow in Figure 3

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