A Study on Hybrid of Genetic Algorithm and Evolution Strategy for Antenna Design

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This paper proposes a hybrid algorithm based on Genetic Algorithm (GA) and Evolution Strategy (ES). The GA is not successful in searching an optimal solution in the view point of convergence speed and solution quality. The ES has the risk of being trapped in a local minimum. The hybrid algorithm is composed of GA and ES in order to make up for these defects of GA and ES. The procedure of searching an optimal solution in hybrid algorithm is as follows. Firstly, the vicinity of optimal solution is reached by using the GA. And then the ES is used to find an accurate optimal solution. In terms of the convergence rate, the proposed hybrid algorithm is compared with the GA using the optimal design of 2.45 GHz CPW-fed circularly polarized antenna. The results of the antenna optimized using GA and hybrid algorithm satisfy the objective value. The convergence rate graph shows that convergence rate of GA decreases and ES rapidly searches optimal solution in the vicinity of optimal solution after 380 iterations.

***Index Terms*—Genetic Algorithm, Evolution Strategy, Hybrid Algorithm, CPW-fed circularly polarized Antenna**

I. Introduction

THE typical evolutionary algorithm of optimization technique is known as Genetic Algorithm and Evolution Strategy. The GA is much better at processing solution having discontinuities, constrained parameters, and/or large numbers of dimensions with many potential local minima. But this is not very successful in confirming the global minima in terms of convergence speed and solution quality [1-2]. Also, the fundamental merit of the ES is a comparatively small number of simulation calls required before convergence is achieved in the vicinity of optimal solution, whereas the main weakness is the risk of being trapped in a local minimum. This may be in some cases avoided by running several independent evolutions in parallel with different initial conditions, on the other hands, this may lead to an unacceptable increase in the number of simulation [3].

We propose hybrid algorithm that make up the defects of GA using the advantage of ES. In terms of the convergence rate, the proposed hybrid algorithm is compared with the GA using 2.45 GHz CPW-fed circularly polarized antenna optimal design.

II. Genetic Algorithm

The GA is invented to mimic some of the processes observed in natural evolution and is stochastic search techniques based on the mechanism of natural selection and natural genetics. The GA start with an initial set of random solutions called population. Each individual in the population is decoded a chromosome, representing a solution to problem at hand. The decoding formula is defined as (1).

$$X = X_{\min} + \frac{X_{\max} - X_{\min}}{2^{N^X} - 1} \sum_{n=0}^{N^X - 1} b_n^X 2^n \quad (1)$$

For every parameter X we assign its lower and higher limits, X_{min} and X_{max}. The number of bits is N^X. Where $b_0^X, \cdots, b_{N^X-1}^X$ is the binary representation of X. The chromosomes evolve through successive iterations, called generations. During each generation, the chromosomes are evaluated, using some measures of fitness. To create the offspring that are form by either merging two chromosomes form current generation using a crossover operator or modifying a chromosome using a mutation operator. A new generation is form by selecting, according to the fitness values, some of the parents and offspring; and rejecting others in order to keep the population size constant. Fitter chromosomes have higher probabilities of being selected. After several generations, the algorithms converge to the best chromosome, which represents the optimum solution [4-5].

III. Evolution Strategy

The ES is a heuristic search technique within the broad category of evolutionary computation. In evolutionary computation, heuristic search is performed by simulating the effects of Darwinian evolution on a population of solutions. Each of these solutions has a fitness value. Using this fitness value, natural selection allows the better solutions to survive and reproduce, whereas the worse solutions will be removed from the population. The ES will have a population of one and use only mutation operators to create new solutions. When the total number of new solutions which can be generated is small, it is important to use a small population which will allow a larger number of generations [6].

IV. Proposed Hybrid Algorithm

The disadvantage of GA is that it becomes very slow and inaccuracy when it goes close to the final global minimum in terms of the convergence rate and the solution quality. The ES algorithm can complement the problem. Hybrid algorithm is composed of GA and ES. Firstly, GA is used to search the vicinity of optimal solution and then the ES is applied to rapidly investigate an accurate optimal solution. Fig. 1 shows the flow chart of the hybrid algorithm.

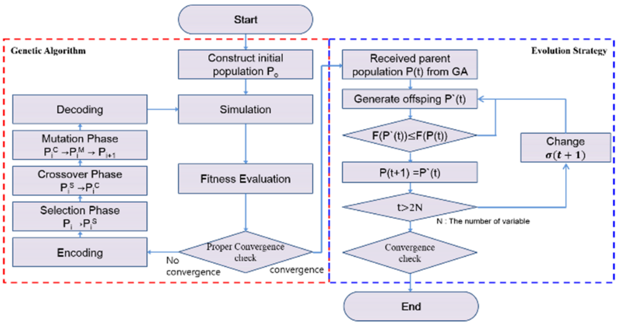

Fig. 1. Flow chart of the hybrid algorithm

V. COMPARE ALGORITHMS WITH TEST FUNCTION

A. Antenna Design

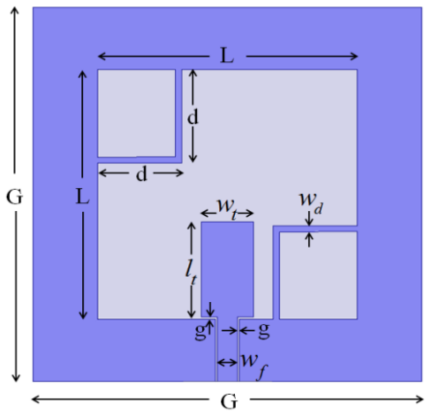

Fig. 2. Antenna design parameters

This circularly polarized antenna with a coplanar waveguide feed has received increasing attention in circular polarization applications. Fig. 2 shows the geometry of the reference antenna, which is implemented on a FR4 substrate with a length of G and a height of h = 0.74 mm. Since the parameters l_t and w_t may greatly influence the impedance matching of the antenna, we refer to the protruded metal strip as a tuning stub. Each of the w_d-wide metallic strips has a length of d, respectively, in the directions perpendicular and parallel to CPW [7].

B. Objective Function

The performance of GA and hybrid algorithm for the optimal design of CPW-fed circular polarized antenna using equivalent objective function is compared. Objective function is defined as (2).

$$F = F_S + F_A$$

$$F_S = \frac{1}{N}\sum_{f=f_1}^{f_2}\left|\max(0, S_{11}(f) - S_{obj})\right|^2 \qquad (2)$$

$$F_A = \left|\max(0, A(f_0) - A_{obj})\right|^2$$

N is the number of sampling points. We fix resonant band from $f_1 = 2.3\ GHz$ to $f_2 = 2.6\ GHz$ and set resonant frequency $f_0 = 2.45\ GHz$. $S_{11}(f)$ means the return loss at a sampling frequency f, and the target return loss value is $S_{obj} = -10\ dB$ and $A(f_0)$ means the axial ratio at a resonant frequency f_0, and the target axial ratio value is $A_{obj} = 3\ dB$.

VI. COMPARE GA AND HYBRID ALGORITHM

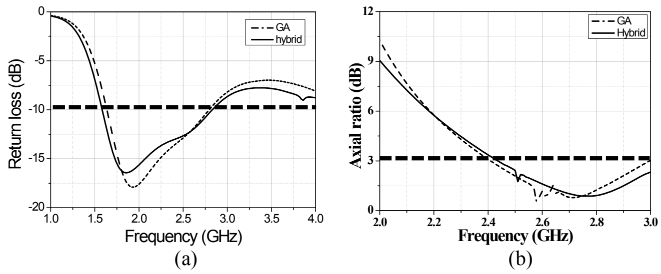

Fig. 3. Simulated result of antenna that optimized GA and hybrid algorithm (a) Return loss, (b) Axial ratio

The return losses of the antennas optimized using GA and hybrid algorithm satisfy the objective value below -10 dB in resonant band. According to the Fig. 3, the axial ratios of GA and hybrid algorithm are 2.57 dB, and 2.86 dB at 2.45 GHz, respectively.

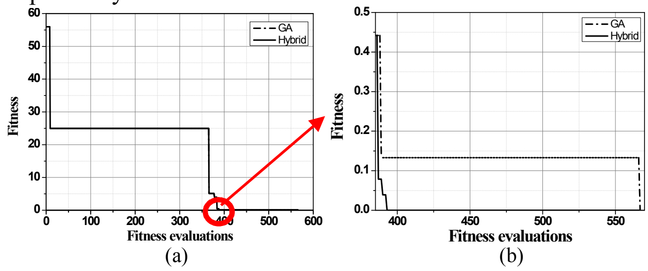

Fig. 4. Convergence rate

Overall convergence rate is shown in Fig. 4(a). Fig. 4 (b) presents the enlargement of Fig. 4 (a) after 380 iterations and shows that convergence rate of GA decreases and ES rapidly searches optimal solution in the vicinity of optimal solution. The result shows that the hybrid algorithm has faster convergence rate than GA.

The extended paper will explain hybrid algorithm in detail and show the merit of hybrid algorithm in terms of convergence rate and solution quality by using various test function.

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