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Agenetic Algorithm for Optimization of Microstrip Patch Antenna

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ABSTRACT*:* Hybrid Genetic Algorithm is applied to design a single-patch broadband microstrip patch antenna in this paper. The optimization procedure is also included. The broad-band character is realized by taking out some parts of the ordinary patch antenna. The reliability and efficiency of this method are proved by comparing the antenna proposed in this paper to un-optimized patch antenna. It can be seen that the bandwidth expands from 6% of the unoptimized one to 17.8%.

***Keywords*:** Hybrid genetic algorithm, broadband, single-patch, finite element, microstrip patch antenna.

I. INTRODUCTION

Microstrip patch antennas are widely used because of their many advantages, such as low profile, light weight, and economical efficiency. However, the microstrip patch antenna is limited by its main disadvantage: narrow operating bandwidth.

There are many methods to expand the bandwidth of the microstrip patch antenna. In [1], parasitic patches are employed to increase the bandwidth. The two U-shaped parasitic patches are located on the same layer with the main patch. In [2-4], several two-layer microstrip antennas with a parasitic patch stacked on the top of the main patch are proposed. However, these methods enlarge the antenna size at the same time. In [5], by incorporating U-shaped slot, broadband impedance bandwidth is achieved. In [6], an E-shaped broadband microstrip patch antenna is proposed.

With the rapid development of microstrip antenna design technique, genetic algorithm is utilized in the design process [7, 8]. In this paper, a novel wideband microstrip patch antenna is investigated using hybrid genetic algorithm and the results using genetic algorithm and hybrid genetic algorithm are compared. The geometry of the antenna is optimized by genetic algorithm. The electrical property of the antenna is computed utilizing Finite Element software, HFSS, of ANSOFT.

II. ANTENNA DESIGN

A. Optimization Strategy

We have utilized hybrid genetic algorithm to optimize the geometry of the patch antenna. The shape of un-optimized patch is rectangular. Divide it into small rectangular elements, as shown in Fig. 1. By optimizing, some of the elements are taken out, while others are remained. In Fig. 1, the elements with "X" should be taken out. The optimized patch is shown in right side.

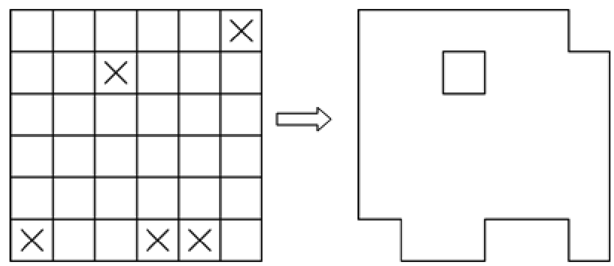

Fig. 1. Microstrip patch to be optimized.

These operations introduce inductance, capacitance and matching components to the equivalent circuit of the patch antenna. Therefore, the antenna changes from a single resonant circuit to a dual resonant circuit. These two resonant circuits couple together and form a wide bandwidth.

Genetic Algorithms are searching and optimization techniques inspired by two biological principles, namely the process of "nature selection" and the mechanics of "natural genetics". There are two phases in a typical genetic-algorithm optimization. These phases are initiation, reproduction and generation replacement. Initiation consists of filling an initial population with a predetermined number of encode, usually randomly created, parameter strings, or chromosomes. Each of these chromosomes represents an individual prototype solution or, an individual. The set of individuals is called the current generation. Each individual in population is assigned a fitness value by evaluating the fitness function for each individual. The reproduction phase produces a new generation from the current generation. Selection with a preference for the individuals with higher fitness is used to fill the new generation, and then crossover and mutation are applied to the individuals in the new generation.

The selection, crossover, and mutation operations are repeated until the optimal or relative optimal solution is found.

Although genetic algorithms can rapidly locate the region in which the global optimum exists, they take a relatively long time to locate the exact local optimum in the region of convergence. A combination of a genetic algorithm and a local search method can speed up the search to locate the exact global optimum. In such a hybrid, applying a local search to the solutions that are guided by a genetic algorithm to the most promising region can accelerate convergence to the global optimum. The time needed to reach the global optimum can be further reduced if local search methods and local knowledge are used to accelerate locating the most promising search region in addition to locating the global optimum starting within its basin of attraction.

```
Hybrid Genetic Algorithm
  {
  Generate initial population Pt
  Evaluate population Pt
  While stopping criteria not satisfied Repeat
  {
  Select elements from Pt to copy into Pt+l
  Crossover elements of Pt and put into Pt+l
  Mutation elements of Pt and put into Pt+1
  Evaluate new population Pt+l
  Apply local search strategy to the result
  Pt = Pt+l
  }
  }
```

B. Optimization Procedure

1) *Step 1:* Translate the geometry parameter into appropriate individual. The first step in using a genetic algorithm on this problem is to choose a coding of the parameters into genes. A binary-string coding is used here. We have divided the patch into small rectangular elements. Each element is corresponding to a gene of an individual. If an element should be taken out, set the corresponding gene to be 0, otherwise, set it to be 1. Thus we translate the geometry parameter of the patch into the m-by-n binary gene matrix. Connect rows of the matrix, forming an individual.

2) *Step 2*: Create the initial population. Having chosen a coding, the genetic algorithm optimization can begin by creating a population of individuals. Randomly generate strings of binary numbers used as individuals of initial population. In each string, number 0 appears with a fixed probability. This initialization probability should be set neither too high nor too low.

3) *Step 3*: Create and solve models in HFSS. Create models according to the genes of individuals in population, set solving conditions and solve models in HFSS. Then return calculated S11 parameters to main function automatically. The returned S11 parameters will be called by fitness function.

4) *Step 4*: Optimization based on GA. The fitness function is the only connection between the physical problem being optimized and the genetic algorithm. The fitness function, which is the measure of goodness of an individual, is used here to assign a fitness value to each of the individuals in the GA population. Successive generations are produced by the application of selection, crossover and mutation, until the optimal or a relatively optimal solution is found or the termination criterion is met.

5) Step 5: The final result is applied to a local search algorithm like simulated annealing for quality improvement.

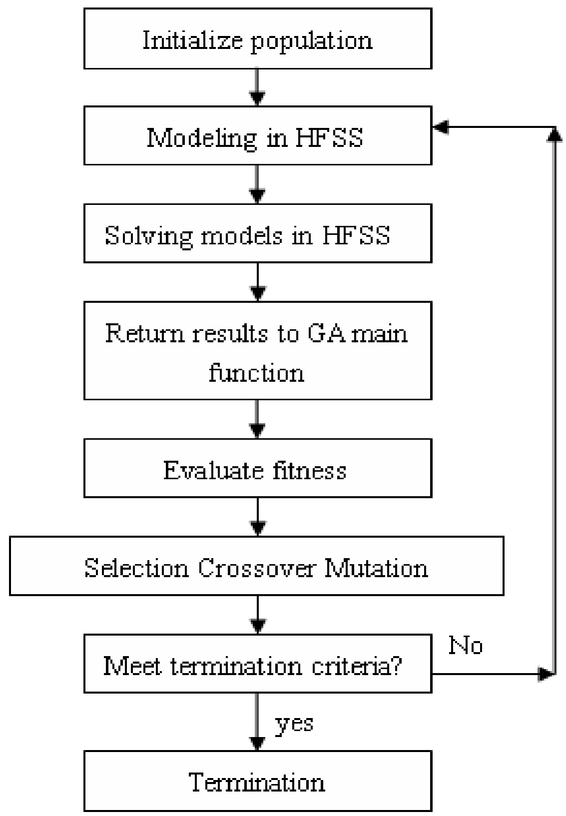

Fig. 2 Flowchart representing HGA apply to micro strip patch.

C. Setting Controls Parameters

The control parameters in the optimization are as follows:
Maximum number of generations: 8
Optimization object: S11 parameter
Population size: 32
Probability of 0 in initial population: 0.15
Probability of crossover: 0.8
Probability of mutation: 0.05

FITNESS

$$P(x) = \frac{1}{N}\sum_{i=1}^{N} Q(fi)$$

$$Q(fi) = \begin{cases} 15 & S11 < -15 \\ |S11(fi)| & S11 \geq -15 \end{cases}$$

Where N is the number of sampling points, fi is sampling frequency:
f_1 = 2.2GHz , f_2 = 2.3GHz, f_3 = 2.4GHz,
f_4 = 2.5GHz , f_5 = 2.6GHz.
Here, m = 6, n = 6.

The geometry parameters of un-optimized patch antenna are as follows:
Patch size: L = 30mm, W = 30mm
Feed location: (0, 0.84)mm
Height of the antenna: h = 5mm
Material relative permittivity: 3.55.

III. RESULTS AND ANALYSIS

Fig. 3. A geometry of optimized antenna.

The S11 parameters of un-optimized and optimized patch antenna are compared as follows:

Table 1. Comparison of Results.

Observation frequencies (MHz)	S11 unoptimized patch	S11 unoptimized patch using GA	S11 unoptimized patch using HGA
2.2	-3	-5	-4
2.3	-7.5	-23.1	-23.8
2.4	-18.5	-11	-14
2.5	-6.5	-12.5	-13
2.6	-3	-16	-17

It can be seen that five elements of un-optimized patch are taken out, namely (5, 13, 19, 25, 31) in the individual. The calculated result shows two neighbouring resonant frequencies (2.3 GHz and 2.55 GHz), and the frequency band ranges from 2.25 GHz to2.68GHz. The two resonant frequencies couple together and form a wide bandwidth. The bandwidth expands from 6% of un-optimized patch to 17.8%.

IV. CONCLUSION

A single-patch broadband microstrip antenna is presented in this paper. By utilizing genetic algorithm to optimize the geometry of traditional rectangular patch antenna, the bandwidth expands from 6% to 17.8%. The method presented here has the attractive features of modularization and intellectualization. The broad-band mechanism is also discussed.

V. FUTURE SCOPE

Due to vast scope of hybrid genetic algorithms, in future we would like to apply it in the geometrical optimization of reconfigurable antennas. Small antennas using RF-MEMS switches can be optimized using genetic algorithms, optimizing beam tilting over a wide range and resonant frequency reconfigurability over 4, 5 and 6GHz.

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