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RESEARCH ARTICLE

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Genetic algorithm optimization of broadband microstrip antenna

Abstract Genetic algorithm (GA) is utilized to design microstrip patch antenna shapes for broad bandwidth. A new project based on GA and high frequency simulation software (HFSS) is proposed to perform optimization. Reasonable agreement between simulated results and measured results of the GA-optimized design is obtained. The optimized patch design exhibits a three-fold enhancement in bandwidth when contrasted with a standard square microstrip antenna, showing the validity of this project.

Keywords genetic algorithm (GA), optimization, broadband, high frequency simulation software (HFSS), microstrip patch antenna

1 Introduction

Microstrip antennas are expected to find many promising applications in wireless communications because of their attractive merits of low profile, light weight, ease of fabrication, and good conformability with integrated circuits. However, it is well known that standard microstrip patch antennas exhibit very narrow operating bandwidth. Many efforts have been devoted to solve this problem to some extent [1–3].

With the rapid development of microstrip antenna design techniques, genetic algorithms (GAs) are introduced into the design process in order to design and optimize microstrip antenna shapes for broadband operation [4,5]. Shape optimization based on GA is a promising technique because the bandwidth enhancement can be realized without increasing the antenna size and manufacturing cost.

In this paper, we will discuss the use of GA for broadband applications. A new project based on GA and high frequency simulation software (HFSS) is proposed and realized with an optimization program compiled by Matlab and Visual Basic (VB) script of HFSS. A novel broadband microstrip antenna is investigated. Finally, a three-fold bandwidth enhancement from GA optimized microstrip antenna compared to that of a standard square microstrip antenna is reported.

2 GA optimization

GA is used here to optimize the shape of microstrip antenna for broad bandwidth.

A standard square microstrip patch antenna is considered to be composed of 6×6 subpatches, as shown in Fig. 1 (left). In our GA optimization, some of these subpatches are subtracted to achieve broad bandwidth, while others are remained. For instance, subpatches with "×" are subtracted. The GA-optimized patch is illustrated in Fig. 1 (right).

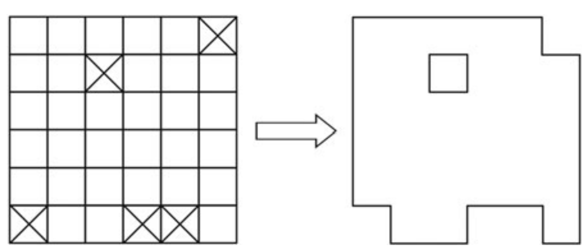

Fig. 1 Illustration of optimization

A project suitable for the optimization of microstrip antenna shapes is proposed by combining the merits of GA with HFSS. In our GA optimization, we use a two-dimensional chromosome to encode each patch shape into

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a binary map [6]. The subpatches remained are represented by ones, and those subtracted are represented by zeros. Thus, we translate the patch shape into the 6×6 binary gene matrix. Connecting rows of the matrix, a chromosome is formed.

An optimization program has been compiled to realize the project. The program includes two modules: genetic algorithm module and fitness module, as shown in Fig. 2. The genetic algorithm module is compiled by Matlab. The fitness module is compiled by Matlab and VB script of HFSS.

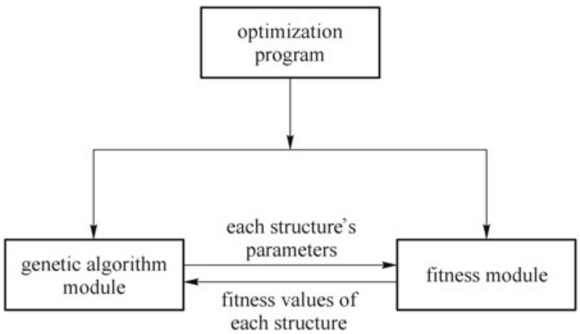

Fig. 2 Framework of optimization project

The genetic algorithm module shown in Fig. 3 is used for optimizing operations. It performs three tasks as follows:

1) It generates the parameters of each structure and sends them to the fitness module.

2) It receives each structure's fitness value from the fitness module.

3) Based on the fitness values, the next generation is created by a reproduction process that involves roulette-wheel selection, crossover, mutation, and elitist strategy. The reproduction process is iterated until the fitness function converges to a maximum value, or the termination criterion is met.

The fitness module shown in Fig. 4 executes the calculation of fitness values. It performs three tasks as follows:

1) It receives parameters of each structure from the genetic algorithm module and calls HFSS to calculate the electrical characteristic parameters of each structure.

2) The calculated electrical characteristic parameters, such as return loss (S_{11}), are then substituted into the fitness function to evaluate each structure's fitness value.

3) The calculated fitness values are then returned to the genetic algorithm module for GA operations.

The design objective is to find a solution satisfying return loss requirement over the entire target frequency band. Since GA optimization involves various random operations, the solution is not always unique. Elitist strategy ensures the convergence of GA, which is validated through computer simulation. In other words, the program

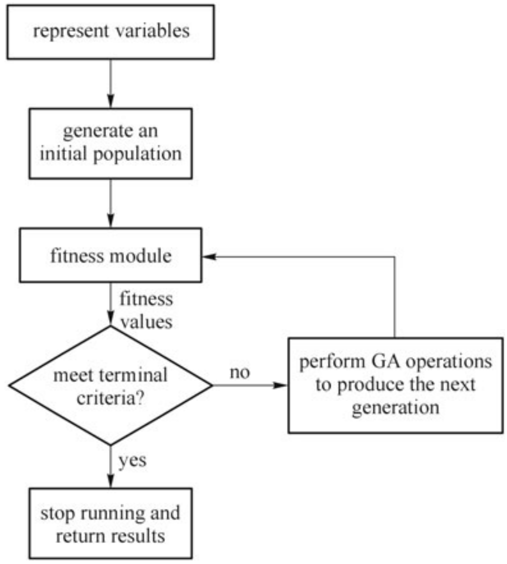

Fig. 3 Block diagram of GA module

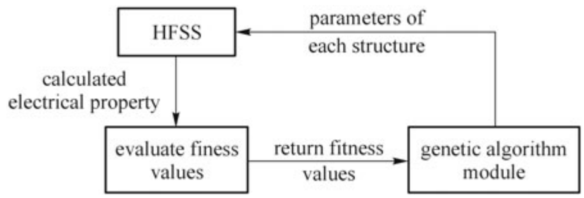

Fig. 4 Block diagram of fitness module

is stable, and it can always find a satisfying solution. Further discussion about the uniqueness and stability of GA can be found in Ref. [7].

The design goal is to broaden the bandwidth of a microstrip patch antenna by optimizing the patch shape. The target frequency band ranges from 2.3 GHz to 2.6 GHz, determined from 10 dB return loss. To achieve this goal, the fitness function is defined as the average of those S_{11} values that exceed -10 dB over the frequency band of interest:

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

$$Q(f_i) = \begin{cases} 10, & S_{11}(f_i) < -10, \\ |S_{11}(f_i)|, & S_{11}(f_i) \geqslant -10, \end{cases} \tag{2}$$

where f_i is the sampling frequency. If the average of those S_{11} values on the sampling frequencies exceeds -10 dB, we consider that the design goal is achieved.

In this design, the sampling frequency ranges from 2.3 GHz to 2.6 GHz, separated by 50 MHz.

3 Results

Figure 5 shows the shape of the GA-optimized microstrip antenna.

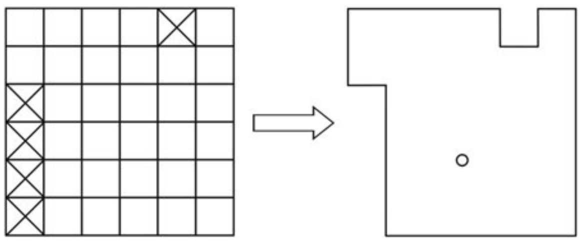

Fig. 5 Shape of GA-optimized microstrip antenna

The dot represents the position of the probe feed. The size of the antenna in Fig. 5 is 30 mm × 30 mm. We employ Rogers RO4003 as the substrate material. The thickness of the substrate is 5 mm. The prototype is constructed to experimentally verify the GA design. Figure 6 shows the comparison of return loss between the measurement and simulation results. Reasonable agreement is obtained. The optimized microstrip patch antenna exhibits a bandwidth of 17.7% by measurement and 17.3% by simulation. This is about three times that of a square microstrip patch antenna (30 mm × 30 mm), which has a bandwidth of 6%.

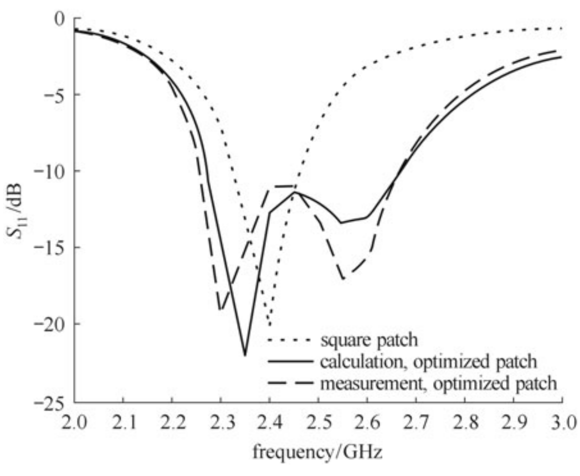

Fig. 6 Return loss of optimized patch (measurement and simulation) compared with unoptimized square patch

The operating principle of the GA-optimized patch antenna is discussed. It can be seen in Fig. 6 that the GA-optimized patch antenna has two resonant frequencies. The bandwidth enhancement is achieved because one operating mode in the vicinity of the fundamental mode is excited.

4 Conclusion

Genetic algorithm is used to optimize shapes of microstrip antenna for broad bandwidth. A new project based on GA and high frequency simulation software (HFSS) is proposed to perform the optimization. The optimized patch antenna exhibits a three-fold enhancement in bandwidth when contrasted with a standard square microstrip patch antenna, indicating that the proposed project and its application to broadband antenna design are effective. The operating principle of the optimized antenna can be interpreted in terms of dual-mode operation. In future work, new genetic techniques will be introduced into the program continuously to enhance the convergence rate and search ability.

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