Genetic Algorithm Optimization for Designing Patch Antennas

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ABSTRACT

Genetic Algorithms have been used for problem-solving and for modeling. As the performance of patch antennas could be optimized via changing antenna parameters, optimization methods became applicable for antenna designing. Patch antennas are simple, inexpensive, light in weight, low in volume and can be easily integrated with microwave integrated circuits. They are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones and pagers. The major disadvantages of the patch antennas are narrow bandwidth and low efficiency. To improve the performance of patch antennas, it is necessary to increase the thickness which reduces their usefulness. In this research, Genetic Algorithm Optimization (GAO) method is used to design the feed position and shape of the patch in order to optimize the bandwidth performance of a thin patch antenna. A patch antenna with thickness of 0.762cm and width of 26 mm and length of 21 mm is divided into 48 cells and performance is improved by selecting the optimized feeding position. The simulations are carried out by using HFSS (High Frequency Structure Simulator) which is a highly accurate commercially used electromagnetic solver. Though the rectangular shape convention patch is narrowband, the optimized patch shows a bandwidth larger than twice of that. The antenna is fabricated and the results are validated using measurements.

KEY WORDS: **Bandwidth, Feed position, Genetic algorithm optimization, Patch antenna**

INTRODUCTION

Genetic Algorithms (GAs) are applied to many scientific, engineering problems, in business problems such as finance, marketing, information systems, and production and entertainment. GAs operate on a group or population of trial solutions in parallel. That is the group of solutions that will compete to reproduce and pass on traits to the next generation. The process begins with the initialization of solution candidates. Successively created populations or GA iterations are called generations. Subsequent generations are made up of children, produced using pairs of parents, who are the members of the current generations.

Each potential solution is referred to as an individual or a chromosome. This string may be stored as a binary bit-string or as an array of integers. A gene is a subsection of a chromosome that usually encodes the values of a single parameter.

In general, a GA optimizer must be able to perform six basic tasks.

1. Encode the solution parameters as genes,
2. Create a string of the genes to form a chromosome,
3. Initialize a starting population,
4. Evaluate and assign fitness values to individuals in the population,
5. Perform reproduction, and
6. Perform crossover and mutation to produce the next generation.

The main phases of GAO are initiation, reproduction and generation replacement. Initiation is filling an initial population with randomly created chromosomes. Reproduction phase produces a new generation from the current generation. A pair of individuals from the population is selected to act as parents through random pairing. Selection is used to fill the new generation and then crossover and mutation were applied to parents to produce children.

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In the generation replacement phase, the new generation replaces the current generation.

Three operations happened during the reproduction phase. They are selection, crossover and mutation. There are two selection methods called tournament selection and proportionate selection. In tournament selection method, a subpopulation is chosen at random from the population individuals compete on the basis of their fitness. The individual in the subpopulation with the highest fitness wins the tournament and becomes the selected individual. Tournament selection has a faster execution time.

During crossover, genes of a pair of individuals are exchanged in order to create the population of the next generation. The two main ways of performing crossover are called single-point and two-point crossover. When a single-point crossover scheme is used, a position of the chromosome is randomly selected as the crossover point. The effect of crossover is to rearrange the genes with the objective of producing better combinations of genes thereby resulting in more fit individuals.

Mutation is another important genetic operator that randomly changes a gene of a chromosome. If we use a binary representation, a mutation changes a 0 t o 1 and vice-versa. This operator allows the introduction of new chromosomes to the population and it assures that the entire search space is connected.

New parents are selected for each child until a new population of adequate size has been created. The new generation will typically have an average fitness level that is above the previous generations. The process is repeated as many times as is necessary to locate the optimal design.

In the most basic form, a patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side (Balanis 1997). There are many configurations that can be used to feed patch antennas. The four most popular are the microstrip line, coaxial probe, aperture coupling and proximity coupling (Sanchez-Hernandez, Robertson, 1996). Coaxial probe feeding method was used for the design as its main advantage is that the feed can be placed at any place in the patch to match with its input impedance, which is 50Ω. The inner conductor of the coax is attached to the radiation patch while the outer conductor is connected to the ground plane (Milligan, 2005). The coaxial probe feed is easy to fabricate and match, and it has low spurious radiation.

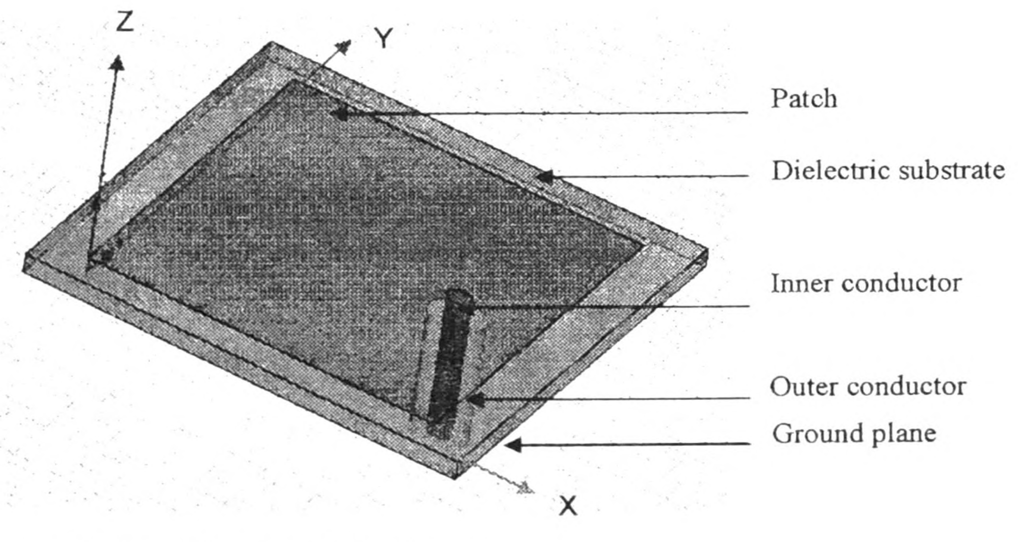

Figure 1: Probe feed patch antenna

RESEARCH OBJECTIVE

The main objective of the research is to use GAO to improve the bandwidth of a thin patch antenna. This paper describes the procedure followed to identify the optimized patch antenna design. Dimensions of the antenna are calculated and in order to achieve the optimized performance, genetic algorithm is used to design the patch shape and feed position. Simulations are carried out using HFSS and the performance is compared with a conventional rectangular shape probe feed patch antenna. The antenna is fabricated and the results are validated using measurements.

LITERATURE REVIEW

GAO has been used successfully in performance optimization of patch antennas. In "E-Shaped Patch Antenna Design Based on Genetic Algorithm Using Decision Fuzzy Rules", dimensions of the slots have been optimized to minimize the maximum return loss at three frequencies. Optimization procedure is used in "Genetic Algorithms and method of moments for the design of PIFAS", in order to detect the optimal patch shape matching the required frequency properties. The optimized goal is to find the minimum of fitness, which is the summation of return loss values at two resonant frequencies. In "Multiband patch antenna with perturbation elements generated by genetic algorithm", the optimization loop operates on a maximization of fitness function that comprises of the impedance matching at two designed frequencies and the maximization of electric field strength in the direction normal to the patch surface.

METHODOLOGY

It was fed off-centered and was assumed to be symmetrical about the centre axis parallel to the length. Therefore, only a half of the patch was coded accordingly as genes in GAO procedure. Patch dimensions were 26×21 mm. The patch area was gridded into 48 cells. First 24 genes of the chromosome were used to define the shape and next four genes were used to define the feed position.

The population size was 20 chromosomes per generation and the used selection method was tournament selection. The probability of crossover was 100% and single point crossover method was used. One bit was mutated in 60% of the individuals within a generation. The percentage of the current generation that was to be replaced was 50%. The temporary population size was 20 and parent population size was also 20. The temporary population was inserted into parent population, producing a temporarily expanded population which was 40 in size. Only 20 individuals were selected from that, based on the fitness value. As replacement of the least-fit individuals was used, the preservation of the fittest individuals was guaranteed.

A rectangular shape conventional patch antenna with same dimensions was also designed and the bandwidth performance was checked for comparison.

RESULTS AND DISCUSSION

A photo of the fabricated optimized patch antenna is shown in Figure2a. It operates in a bandwidth of 230MHz. The printed antenna is tested by using a vector network analyzer in order to validate the simulation results. The resulted plot taken from the vector network analyzer is shown in Figure 2b for comparison. The measurement results agree well with the simulation results.

The rectangular shape conventional patch antenna is narrowband, with a bandwidth of only 9MHz.

(a) (b)

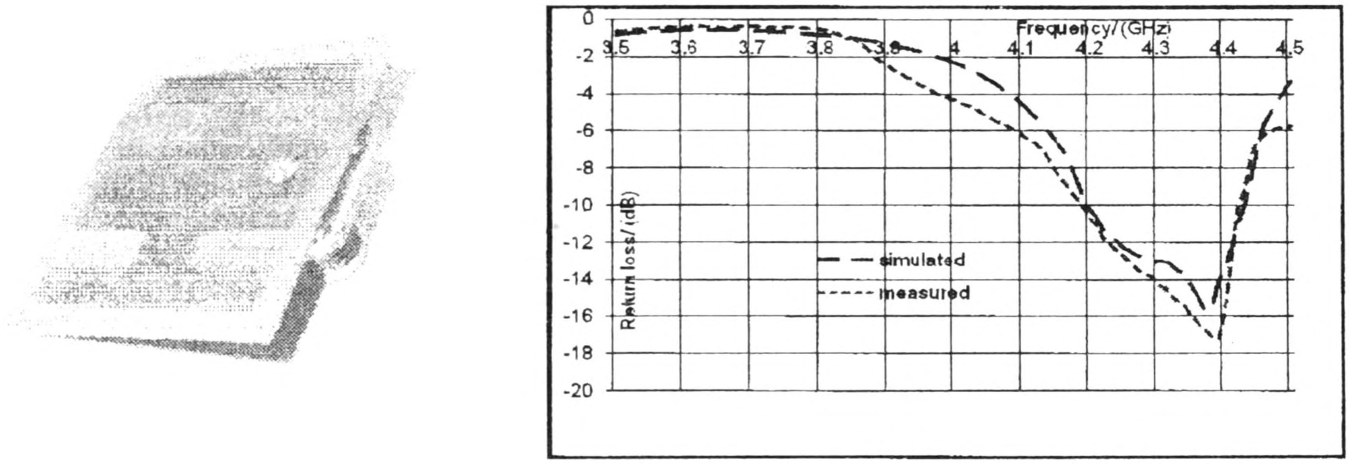

Figure 2: Design Results When Optimize Patch Shape and Feed Position (a) Patch Antenna (b) Return Loss Plot

CONCLUSION

In this paper, GAO has been used to synthesize a thin single probe feed patch antenna with increased bandwidth. The patch geometry and feed position have been optimized to improve bandwidth from 9MHz to 23 MHz. The simulations have been carried out by using HFSS and validated by taking measurements of a fabricated antenna.

Results show that GAO can be used successfully to improve bandwidth of thin narrowband antennas without changing antenna dimensions.

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