Metaheuristics with Local Search Scheme for Design of Metal-Only Reflectarray Antenna

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1. Introduction

To design an antenna in millimeter-wave, we use a metal-only reflectarray (MOR) antenna. The antenna gain of a MOR antenna can be improved by adjusting the depths of grooves. However, it should consider that the depths of grooves are dependent each other. This characteristic makes the design of a MOR antenna more complicated. In this paper, to find the optimal depths of all grooves, three kinds of metaheuristics which are genetic algorithms (GA) [1], particle swarm optimization (PSO) [2], and differential evolution (DE) [3] are use. A detailed description of a MOR antenna can be found in [5]. In order to improve the performance of metaheuristics, we introduce a local search scheme.

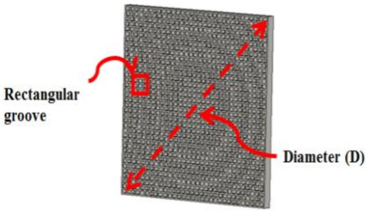

Figure 2. A metal-only reflectarray (MOR) antenna composed of rectangular grooves.

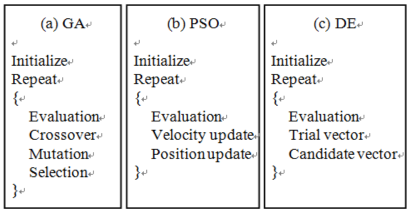

Figure 1. Pseudo codes of the three kind of algorithm

2. Optimization

In order to obtain the optimal antenna gain of a MOR antenna in Fig. 1, the depths of rectangular grooves should be adjusted by utilizing the phase matching condition proposed in [4], [6]. When the depth of a certain groove is controlled to increase the antenna gain, the reflected fields of its neighboring grooves are also changed. Due to this behavior of a MOR antenna, optimizing the depths of all grooves is very difficult. To solve this problem we use three kinds of metaheuristic techniques: GA, PSO, and DE.

Fig. 2 shows the pseudo codes of GA, PSO, and DE algorithms. In metaheuristics, the solution representations should be deliberately designed according to the problem characteristics. In the MOR antenna, the solution vectors are represented by the depths of grooves. In the initial solution vector group, one solution is generated by a mode matching and Green's function method [4] and the other solutions are generated randomly by using kiss random function. The generated solution vectors are evaluated, evolved, and updated based on specific metaheuristic operations. These operations are repeated until the terminal condition is satisfied. In the GA, the operation consists of crossover, mutation, and selection. We used arithmetic crossover, random initial mutation, and tournament selection. In the PSO, the operation consists of velocity and position update. We used a standard PSO [2]. In the DE, the operation consists of making trial and candidate vector. We used a standard DE [3]. A fitness function of GA, PSO, and DE is given by.

$$\text{Fitness} = \eta = \frac{G}{G_{ideal}} \times 100\ [\%] \qquad (1)$$

where η is aperture efficiency, G and G_{ideal} are antenna gains for current setup and ideal case, respectively. To improve an original meta-heuristic algorithm, we introduce a local search scheme. In the local search, we restrict search space of the depths of grooves. We also guess that the optimal depths of grooves exist around the depths of grooves calculated by a geometrical optics (GO) [5]. In [5], we used a GO to obtain the phase distributions in grooves equivalent to a parabolic reflector antenna. In this regard, we reduce search space for the depth of the *n*th groove ($d^{(n)}$) to the search space between the depth of previous groove($d^{(n+1)}$) and the depth of a next groove ($d^{(n-1)}$) as

$$d^{(n-1)} \le d^{(n)} \le d^{(n+1)} \qquad (2)$$

Fig. 3 represents the restricted search space of the depth of groove. Solid lines in Fig. 3 indicate the depths of grooves from the surface of a MOR.

3. Simulation environment and results

In this simulation experiment, we initialize the parameters of a MOR antenna and rectangular grooves as follows: the diameter of a MOR antenna is 3.6cm, A feed for the MOR antenna is a point. The population size is 20 and maximum iteration is 1000 for three kinds of metaheuristics, respectively. For GA, a crossover rate is 0.7 and a mutation rate is 0.015. For PSO, c_1 and c_2 for velocity (V_{id}) is 1.42694. For DE, crossover rate is 0.8 and F for generating trial vector is 0.8. Initial calculation was conducted by using a mode matching and Green's function method [5] where the ratio of focus to diameter (*f/D*) is 0.75.

Fig. 4 shows the simulation results of GA, PSO, and DE. Irrespective of meta-heuristic algorithms in Fig. 2, a local search scheme in Fig. 3 dramatically improves the convergence rate of algorithms. This indicates that the local search scheme is a simple but efficient accelerator of a given algorithm.

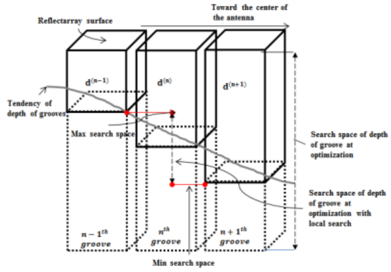

Figure 3. Limited search space by depth of neighboring grooves

(a) GA vs. GA (local search) **(b) DE vs. DE (local search)** **(c) PSO vs. PSO (local search)**

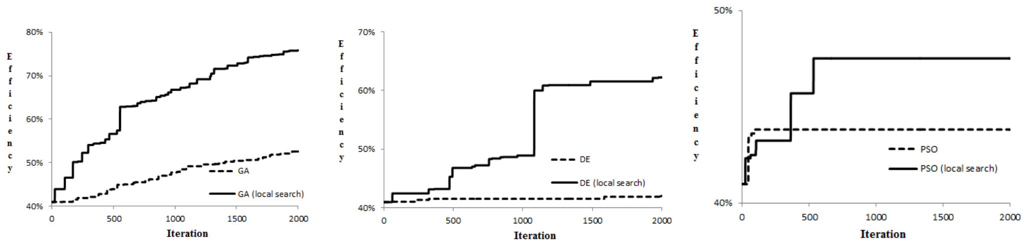

Figure 4. Experimental results of GA, DE, PSO

4. Conclusion

In this paper, three kinds of metaheuristic algorithms and a local search have been applied to obtain the optimal design of a MOR antenna. Experimental results show that the gains obtained by three kinds of metaheuristics are superior to the gains computed by a mode-matching and Green's function method. Moreover, the metaheuristic algorithms with a local search outperform the simple meta-heuristic algorithms.

5. References

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