USING GLOBAL OPTIMIZATION TO RECONSTRUCT PHASE DISTRIBUTION ON ANTENNA'S APERTURE FROM ONLY AMPLITUDE MEASUREMENTS

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ABSTRACT

The paper deals with the reconstruction method of a phase distribution on the antenna's aperture. The method is based on the only amplitude near-field measurement over two surfaces surrounding the antenna under test. Firstly, an initial estimation is found by using a global optimization and subsequent a common Fourier iterative algorithm is used to find the final solution. The genetic algorithm was chosen to determine the initial estimation. Reconstruction of the phase distribution was carried out on the GSM-900 antenna.

1. INTRODUCTION

The standard measurement methods in the near field of the antenna require the knowledge of both amplitudes and phases. In order to reach a sufficient accuracy of the reconstruction of the radiation patterns, the high-precision phase distribution has to be known. This breeds a lot of defects which can be eliminated by using the only amplitude near-field measurements, and subsequent iterative numerical methods to reconstruct the phase.

During eighties and nineties, two methods were developed for the reconstruction of the phase: the method exploits the functional minimization [1] and the simple Fourier iterative algorithm [2]. In the paper, a method combining both the functional minimization and Fourier iterative algorithm is described. As a global optimizer, a genetic algorithm is applied.

2. PHASE RECONSTRUCTION METHODS

The goal of these methods is to find out the complex intensity of the electric field distribution on the aperture of the measured antenna. If the phase distribution on the aperture is known, we are able to determine both the phase distribution on two scanning surfaces (plane surfaces in our case) and the antenna radiation pattern.

The functional minimization method is based on the minimization difference between the calculated amplitudes and the measured ones on two surfaces in the near-field region. Known minimization algorithms can be divided into local and global methods.

The Fourier iterative algorithm minimizes the functional also. The initial estimation is refined in every step. A success of the Fourier iterative algorithm as well as other local methods depends on the choice of the initial estimation.

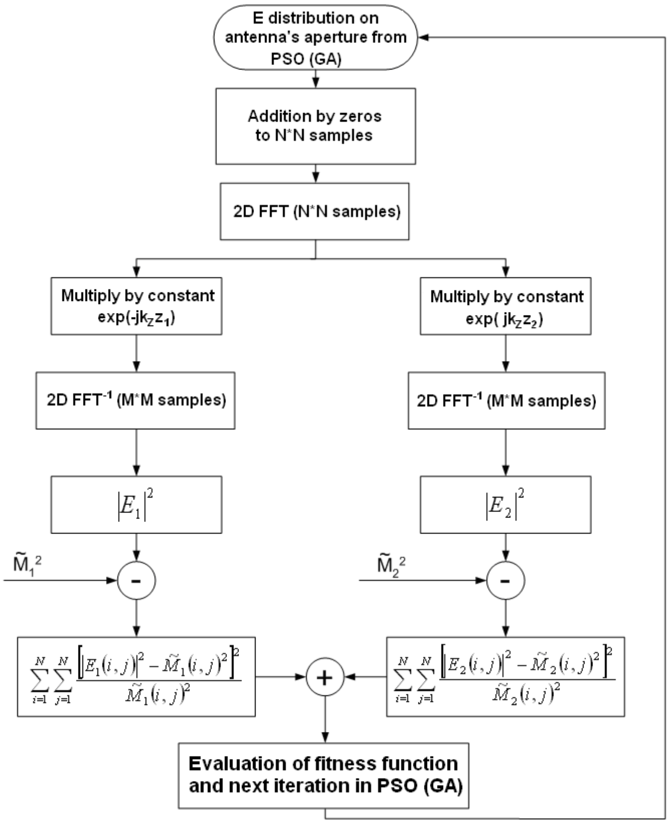

Figure 1: The flow chart of the evaluating initial estimation by the global optimization.

The presented method combines the global optimization and the Fourier iterative algorithm [3]. First, the global optimization algorithm is used to find the initial estimation lying in the area of the global minimum. The flow chart for finding out the estimation is shown in Fig. 1. The second part, the common Fourier iterative algorithm is used to improving the initial estimation. The genetic algorithm (GA) was chosen for the functional minimization.

Electrical field intensity in the given distance from the antenna can be computed similarly as in case of planar antennas radiation or radiated plane, using the Huygens principle [4]. Resulting electrical field intensity is defined as [4]:

$$\mathbf{E}(\theta,\phi,r) = j\frac{e^{-jkr}}{r}k_z\mathbf{A}(k_x,k_y), \tag{1}$$

where r is a point of view distance (θ, ϕ) and $\mathbf{A}(k_x, k_y)$ is called planar waves spectrum, which is defined by two-dimensional Fourier transformation

$$\mathbf{A}(k_x, k_y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \mathbf{E}(x, y, 0) e^{-jk_x x} e^{-jk_y y} dxdy \,. \tag{2}$$

Where $\mathbf{E}(x, y, 0)$ is continuous electrical field distribution on plane in the near field and k_x, k_y, k_z are wave number in the direction of x, y, z axes. Using formulation (1), electrical field intensity is transformed into spectral domain (into angular spectrum) at the same location and using (2) angular spectrum is moved to another distance.

2.1. GENETIC ALGORITHM

By analogy with a natural selection and an evolution, the set of parameters to be optimized (genes) defines an individual (chromosome). The set of the individuals forms the population, which is evolved by means of the selection, the crossover, and the mutation genetic operators [4]. To assess the individual, the objective function F was defined and had the following form:

$$F = \sum_{i=1}^{N}\sum_{j=1}^{N} \frac{\left[\left|E_1(i,j)\right|^2 - \tilde{M}_1(i,j)^2\right]^2}{\tilde{M}_1(i,j)^2} + \sum_{i=1}^{N}\sum_{j=1}^{N} \frac{\left[\left|E_2(i,j)\right|^2 - \tilde{M}_2(i,j)^2\right]^2}{\tilde{M}_2(i,j)^2} \,. \tag{3}$$

In (1), $E_1(i, j)$ is the computed complex intensity in the point i, j on the first scanning plane, and $E_2(i, j)$ is the computed complex intensity in the point i, j on the second scanning plane. Next, $\tilde{M}_1(i, j)$ is the measured amplitude in the point i, j on the first scanning plane, and $\tilde{M}_2(i, j)$ is the measured amplitude in the point i, j on the second scanning plane.

The population decimation and the tournament were used for selecting parents (the selection) [4]. The optimizations were repeated 30 times and were stopped in the 3000^{th} iteration. The average realizations and the best realizations are shown in Fig. 2. Since the population decimation had the best individual, we used it in the following computations.

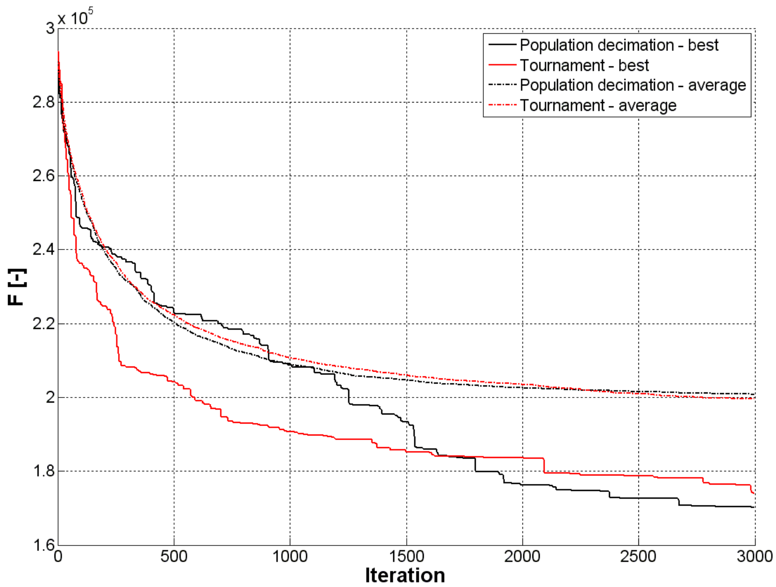

Figure 2: Convergence of GA: the population decimation and the tournament selection.

3. RESULTS

The radiation pattern calculating from the reconstructed phase distribution was performed for a directional GSM-900antenna. The analyzed antenna consists of eight vertical half-wavelength dipoles (oriented in *y*) and a reflector (in *xy*). The dipoles are 160 mm long and 7 mm wide. The planar reflector 2 000 × 200 mm is in the distance 28 mm from the dipoles. In phase uniform feeding is assumed. The antenna was analyzed at the resonance frequency 940 MHz.

The values of the *y* electric field intensity component in the discrete points placed in the vertical direction and the horizontal one with a pitch of 150 mm at two scanning planes of the size 22.5 m × 22.5 m were computed by Zeland IE3D. The first plane was placed in the distance of 1580 mm (5λ) from the reflector, and the second one in the distance of 3160 mm (10λ). The aperture of the antenna was 2000 × 200 mm (13 times 3 sampling points). The solution space contains 39 complex parameters, i.e. 78 real parameters which optimal values are going to be found out.

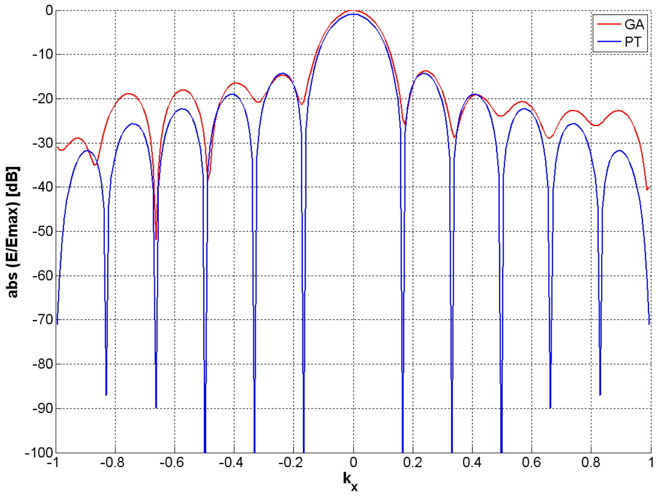

Figure 3: E plane radiation patterns obtained from the initial estimations of GA (red) and the direct transformation (blue)

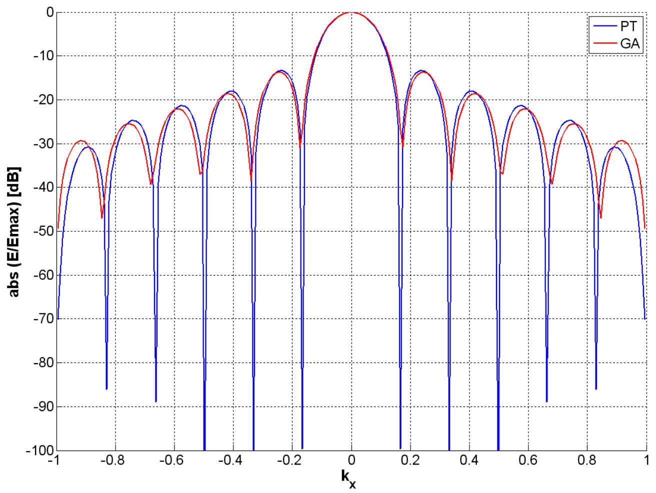

Figure 4: E plane radiation patterns after applying the Fourier iterative algorithm

GA was used for the initial reconstruction of the phases and the amplitudes on the antenna aperture and the scanning planes (the phases only), respectively. The far-field result from the initial estimation obtained with this optimization scheme is shown in Fig. 3 for E plane of the radiation pattern. According to the reconstructed far-field radiation pattern, we can be conclude that result achieving this method hasn't desired accurate, and the Fourier iterative algorithm has to be applied to ensure the precision to the radiation pattern. The radiation pattern after using the Fourier iterative algorithm is shown in Fig. 4.

We can conclude that GA seems to be the suitable tool to solve the problem of the initial estimation. GA is easy to tune and implement and CPU-time demands are acceptable.

4. CONCLUSIONS

GA was demonstrated to be the suitable tool for minimizing the complicated multi-dimensional discontinuous problems. Connecting GA and the Fourier iterative algorithm, an algorithm able to reconstruct radiation patterns from the random initial estimation is obtained.

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