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**THE SIMULATION OF METAL-DIELECTRIC ANTENNA ON
THE BASE OF COMBINED APPROACH**

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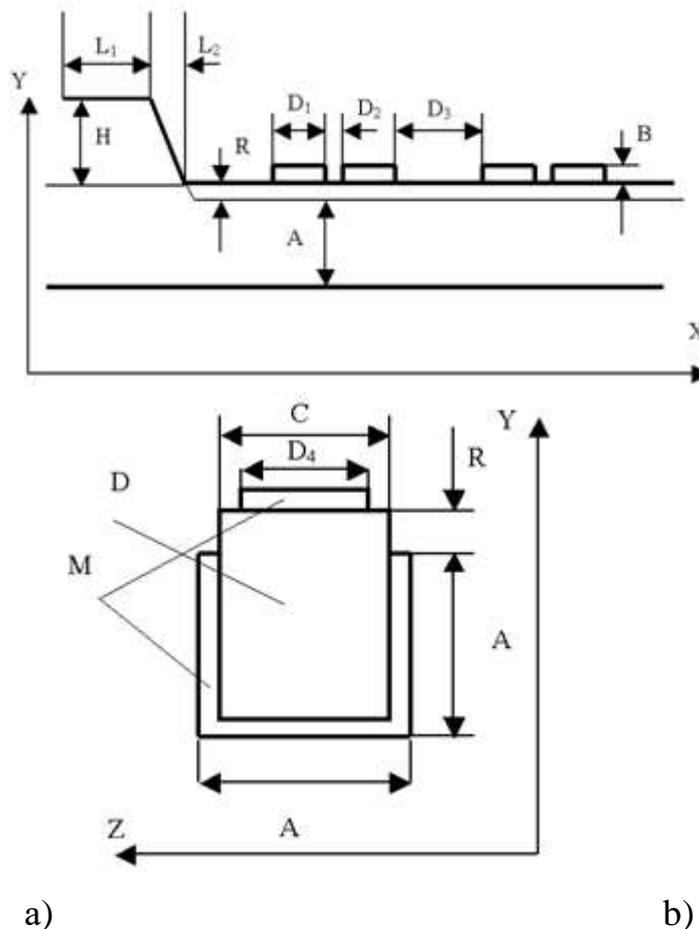
The structure of modern radio transmitting devices may include antennas formed of both metal and dielectric components-metal-dielectric antennas. They are compact enough and can be placed on various objects of equipment. The paper presents a simulation of a metal-dielectric antenna based on a combined approach. The scheme of antenna construction in different planes is given. The process of scattering of a plane electromagnetic wave on an antenna is considered. The combined algorithm including the method of the integral equation, parallel approach and genetic algorithm is developed. In this paper, the integral equation is used to determine the unknown surface electric currents on the antenna surface, it is solved on the basis of the method of moments. A parallel algorithm was used to speed up the calculations. The impedance matrix is represented as a block matrix. Each block has its own parallel stream. Taking into account the influence of a plane dielectric waveguide on the scattered field, a method associated with a generalized scattering matrix is used. To solve the problem of multi-alternative optimization associated with determining the linear dimensions of the antenna device at a given operating frequency of the antenna, a genetic algorithm is used. As a result, the dimensions of the designed antenna for the specified dimensions of its components are obtained.

Keywords: antenna, integral equation, parallel approach, optimization, genetic algorithm.

Introfuction. The process of simulations scattering of radiowaves on technical objects with different shapes has great importance because it is necessary to solve problems of radar recognition, electromagnetic compatibility and so on [1-3]. The aim of this paper is the development algorithm, that based on the method of integral equation, parallel approach and genetic algorithm, for optimization scattering characteristics. The method of integral equations can be considered as a universal method. We can use it if we know the object surface and the electrical characteristics (impedance) of the surface. But, if the object dimensions are large enough, we need to accelerate computing. We used the parallel approach. To obtain the required level of scattered electromagnetic fields we use a genetic algorithm. Using a combination of the above-mentioned methods, we can synthesized of the desired antenna structures.

The object of research. Metal-dielectric antenna used in technical devices [4-6]. To bring the analysis of their scattering properties, require rigorous electrodynamic approaches in which taking into account the fact that

antennas are characterized by a complex structure can be taken into account subtle diffraction effects [7-9]. In Fig. 1, you can see a cross section of the antenna being considered.



a) b)
 Fig. 1. Cross section of the analyzed antenna
 a) for plane X0Y, b) for plane Y0Z

Its components - dielectric waveguide placed in a metal housing, there are metal strips placed on a dielectric layer. The processes of excitation in the dielectric waveguide is observed from the front side, this used flat wave. When calculating the currents on the comb, you must use the method of integral equations [10-12].

The method of integral equation. On one period we can use the integral equation [7]

$$J_s(r) = 2n \times H^i(r) + \frac{1}{2\pi} n \times \int_s J_s(r) \times \text{grad}' G ds', \quad (1)$$

where $G = \exp(-jkr)/r$ is 3D Greens' function, according to free space, we can consider it as solution of Helmholtz equation for δ -source; s is the surface of diffraction object; n shows the direction of external normal to the surface of structure;

$J_s = [n \times H]$ describes the surface density of the equivalent electric current;

$H^i(r) = \mathbf{\tilde{o}}H_x^i + \mathbf{y}H_y^i + \mathbf{z}H_z^i$ is the vector of spreading plane electromagnetic wave.

As a result of using the method of moments we have the set of equations [13-15]:

$$\begin{bmatrix} U_{xx} & U_{xy} & U_{xz} \\ U_{yx} & U_{yy} & U_{yz} \\ U_{zx} & U_{zy} & U_{zz} \end{bmatrix} \begin{bmatrix} J_x \\ J_y \\ J_z \end{bmatrix} = \begin{bmatrix} R_x \\ R_y \\ R_z \end{bmatrix}, \quad (2)$$

here J_x, J_y, J_z are projection density to the surface electric currents. In this set of equations we denote:

$$\begin{aligned} (U_{xx})_{mn} &= \frac{1}{2\pi} \int_S ((n_y)_m (grad'_y)_{mn} + (n_z)_m (grad'_z)_{mn}) ds'_n - \delta_{mn}; \\ (U_{xy})_{mn} &= -\frac{1}{2\pi} \int_S (n_y)_m (grad'_x)_{mn} ds'_n; \\ (U_{xz})_{mn} &= -\frac{1}{2\pi} \int_S (n_z)_m (grad'_x)_{mn} ds'_n; \\ (U_{yx})_{mn} &= -\frac{1}{2\pi} \int_S (n_x)_m (grad'_y)_{mn} ds'_n; \\ (U_{yz})_{mn} &= -\frac{1}{2\pi} \int_S (n_z)_m (grad'_y)_{mn} ds'_n; \\ (U_{yy})_{mn} &= \frac{1}{2\pi} \int_S ((n_x)_m (grad'_x)_{mn} + (n_z)_m (grad'_z)_{mn}) ds'_n - \delta_{mn}; \\ (U_{zx})_{mn} &= -\frac{1}{2\pi} \int_S (n_x)_m (grad'_z)_{mn} ds'_n; \end{aligned} \quad (3)$$

$$(U_{zy})_{mn} = -\frac{1}{2\pi S} \int (n_y)_m (grad'_z)_{mn} ds'_n;$$

$$(U_{zz})_{mn} = \frac{1}{2\pi S} \int ((n_x)_m (grad'_x)_{mn} + (n_y)_m (grad'_y)_{mn}) ds'_n - \delta_{mn},$$

where $m, n = 1, \dots, N$, and N is the total number of dividing points of the surface. In these expressions δ_{mn} – the symbol of Kronecker [16,],

$$grad G_{mn} = -\hat{r}_{mn} \frac{1 + jkr}{r_{mn}} \exp(-jkr_{mn}) =$$

$$\mathbf{i}(grad_x)_{mn} + \mathbf{j}(grad_y)_{mn} + k(grad'_z)_{mn}, \quad (4)$$

$\hat{r}_{mn} = \frac{r_{mn}}{|r_{mn}|}$ can be calculated as a unit vector that is directed from the source to the observer [17, 18].

A column vector of free members is as follows:

$$(R_x)_m = 2((n_y)_m (H_z^i)_m - (n_z)_m (H_y^i)_m);$$

$$(R_y)_m = -2((n_x)_m (H_z^i)_m - (n_z)_m (H_x^i)_m); \quad (5)$$

$$(R_z)_m = 2((n_x)_m (H_y^i)_m - (n_y)_m (H_x^i)_m).$$

The features of the parallel approach. To solve the system of equations (5) you can use several methods, which in turn can parallelize computations on the computer [19-21]. The best method in this case is the decomposition: for an arbitrary matrix U there exists a decomposition

$$U = T \cdot S, \quad (6)$$

where T and S – the lower and upper triangular matrices, respectively. The equation (6) takes the form

$$T \cdot S \cdot B = V. \quad (7)$$

If we denote $Y = S \cdot B$, the solution of equation (7) is from a sequential solution of two systems with triangular matrices, that leads to reducing the memory required to store these matrices in memory.

The fact that the storage in memory of a computer a triangular matrix is about two times less memory ($\frac{m \cdot (m + 1)}{2}$ memory cells, where m – the length of the array), than storage square matrix. First we solve the system

$$L \cdot Y = V, \quad (8)$$

then solve the system of linear equations with upper triangular matrix

$$S \cdot B = Y. \quad (9)$$

After obtaining the decomposition (9) for the matrix U , you can use it to solve systems of equations with this matrix and different values for the right part B .

This is done iterative manner, by successive changes in the right part of equation (2), the results of the decision system at each iteration.

And in the case of using the method of Gauss, another method to solve the system of equations required at each iteration to re-perform direct and reverse this method.

When using the decomposition required only at each iteration to solve equation (7).

You can perform these two methods of solving the system of equations in terms of estimates of the number of arithmetic operations to understand that the more effectively you can parallelize.

The number of arithmetic operations when solving the system of equations by Gauss method is estimated as $O(n^3)$, where n is the number of variables.

For band matrix with half-width tape rating accepts a value $O(n \cdot k^2)$.

As it follows from the estimates above, the computational complexity of the method and the Gaussian method, decomposition of matrix is almost identical.

However, if you want to solve several systems with the same matrix of coefficients but with different vectors free members, the method of matrix-decomposition will be more optimal, as in this case there is no need to perform decomposition of the matrix of coefficients repeatedly.

It is enough to save the resulting triangular matrix in memory (and they take up so much space, as mentioned above) and, by substituting different vector of free members, to the solution methods of the forward and reverse lookup.

Take the algorithm for the parallel solution of matrix equation method matrix-decomposition, the algorithm assumes that the system of linear equations is solved without pivoting.

To solve the system of linear equations (7), the matrix U is distributed to p processors (threads) as follows

$$\begin{pmatrix} \alpha_1 & \beta_1^S & \dots & \dots & \dots & \dots \\ \beta_1^T & \gamma_1 & \Omega_2^S & \dots & \dots & \dots \\ \dots & \Omega_2^T & \alpha_2 & \beta_2^S & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \beta_{p-1}^T & \gamma_{p-1} & \Omega_p^S \\ \dots & \dots & \dots & \dots & \Omega_p^T & \alpha_p \end{pmatrix} \cdot \begin{pmatrix} x_1 \\ \xi_1 \\ x_2 \\ \dots \\ \dots \\ \xi_{p-1} \\ x_p \end{pmatrix} = \begin{pmatrix} t_1 \\ w_1 \\ t_2 \\ \dots \\ \dots \\ w_{p-1} \\ t_p \end{pmatrix}, \quad (10)$$

where α_i – matrix of dimension $n_i \times n_i$, $i = 1, \dots, p$;

γ_i – matrix of dimension $k \times k$; x_i, b_i – vectors with dimension n_i ;

ξ_i, w_i – vectors with dimension k ;

$\sum_{i=1}^p n_i + (p - 1) \cdot k = n, k$ – the half-width of the ribbon matrix.

This block tridiagonal partition is only possible if $\forall i n_i > k$.

This condition restricts the maximum possible level of concurrency: the maximum number of processors (threads) p that can be used for parallel execution must satisfy the condition $p < (n + k) / (2 \cdot k)$.

Then that matrix is the first step of the block-cyclic reduction, which rearranges columns and rows so that they were all odd rows and columns, and then all the even.

As a result, so-called even-odd permutation

$$\begin{pmatrix} \alpha & \beta^S \\ \beta^T & \gamma \end{pmatrix} \cdot \begin{pmatrix} x \\ \xi \end{pmatrix} = \begin{pmatrix} t \\ w \end{pmatrix}. \quad (11)$$

The decomposition of a matrix α has the form:

$$\begin{pmatrix} \alpha & \beta^S \\ \beta^T & \gamma \end{pmatrix} = \begin{pmatrix} T & 0 \\ \beta^T \cdot S^{-1} & 1 \end{pmatrix} \cdot \begin{pmatrix} S & T^{-1} \cdot \beta^S \\ 0 & \Psi \end{pmatrix}, \quad (12)$$

where $\Psi = \gamma - \beta^T \cdot \alpha^{-1} \cdot \beta^S$ – the Schur complement [19-21] of the matrix .

To save memory matrix $\beta_i^T \cdot S_i^{-1}$, $T_i^{-1} \cdot \beta_i^S$, $\Omega_i^S \cdot \Xi_i^{-1}$, and $T_i^{-1} \cdot \Omega_i^T$, placed in the same memory cells that are allocated for matrices β_i^T , β_i^S , Ω_i^S , Ω_i^T , respectively.

As in the process of computing the matrices Ω_i^S and Ω_i^T are full, additional space is required in memory for the floating point numbers. In the end, the total memory requirement is about two times larger than for the serial algorithm.

The Schur complement Ψ in the matrix α for α is a block tridiagonal matrix of dimension size $(p-1) \times (p-1)$ of the blocks $k \times k$:

$$\Psi = \begin{pmatrix} \eta_1 & S_2 & & & \\ \varphi_2 & \eta_2 & \dots & & \\ & \dots & \dots & \dots & \\ & & \dots & \dots & S_{p-1} \\ & & & \varphi_{p-1} & \eta_{p-1} \end{pmatrix}, \quad (13)$$

where we have introduced the notation:

$$\begin{aligned} \eta_i &= \gamma_i - \beta_i^T \cdot \alpha_i^{-1} \cdot \beta_i^S - \Omega_i^S \cdot \alpha_{i+1}^{-1} \cdot \Omega_{i+1}^T = \\ &= \gamma_i - (\beta_i^T \cdot \Xi_i^{-1}) \cdot (T_i^{-1} \cdot \beta_i^S) - (\Omega_{i+1}^S \cdot \Xi_{i+1}^{-1}) \times \end{aligned}$$

$$\begin{aligned} & (T_{i+1}^{-1} \cdot \Omega_{i+1}^T), \\ S_i &= -(\Omega_{i+1}^S \cdot \Xi_{i+1}^{-1}) \cdot (T_{i+1}^{-1} \cdot \Omega_{i+1}^T), \\ \varphi_i &= -(\beta_i^T \cdot \Xi_i^{-1}) \cdot (T_i^{-1} \cdot \beta_i^S). \end{aligned}$$

Up to this point interprocessor is not required (or inter-thread if you use multiple threads instead of multiple processors) communication, since each processor (thread) independently computes the decomposition of the block diagonal $\alpha_i = T_i \Xi_i$ computes the blocks $\beta_i^T \cdot S_i^{-1}$, $T_i^{-1} \cdot \beta_i^S$, $\Omega_i^S \cdot \Xi_i^{-1}$, $T_i^{-1} \cdot \Omega_i^T$, and $T_i^{-1} \cdot \beta_i$.

Each processor or thread forms their part of the reduced system $\tau \cdot \xi = \nu$, where

$$\begin{aligned} \tau_i &= \begin{pmatrix} -\beta_i^S \cdot \Xi_i^{-1} \cdot T_i^{-1} \cdot \Omega_i^S & -\Omega_{i+1}^S \cdot \Xi_{i+1}^{-1} \cdot T_i^{-1} \cdot \beta_i^S \\ -\beta_i^T \cdot \Xi_i^{-1} \cdot T_i^{-1} \cdot \Omega_i^S & \nu_i - \beta_i^T \cdot \Xi_i^{-1} \cdot T_i^{-1} \cdot \beta_i^S \end{pmatrix}, \\ \nu_i &= \begin{pmatrix} -\beta_i^S \cdot \Xi_i^{-1} \cdot \nu_i \\ \nu_i - \beta_i^T \cdot \Xi_i^{-1} \cdot \nu_i \end{pmatrix}. \end{aligned} \quad (14)$$

After performing local computations to complete the construction of the matrix η_i processor (thread) with the number i sent by the processor (thread) with the number $i+1$ of the matrix $\gamma_i - \beta_i^T \cdot \Xi_i^{-1} \cdot T_i^{-1} \cdot \Omega_i^S$.

Even-odd permutation, the computation decomposition and the formation of the reduced system is repeated as long as the matrix of the reduced system will not be filled with matrix $k \times k$. In this case, the resulting system can be solved on a single processor or thread.

Since at each iteration of the reduction the dimension of the matrix is reduced in two times, to achieve the result you need to perform $\log_2 p - 1$ steps.

After finding vectors ξ_i processors (threads) compute its vector part x :

$$\begin{aligned} x_1 &= \Xi_1^{-1} \cdot (\gamma_1 - T_1^{-1} \beta_1^S \xi_1), \\ x_i &= \Xi_i^{-1} \cdot (\gamma_i - T_i^{-1} \Omega_i^S \xi_{i-1} - T_i^{-1} \beta_i^S \xi_i), \\ x_p &= \Xi_p^{-1} \cdot (\gamma_p - T_{p-1}^{-1} \Omega_p^T \xi_{p-1}). \end{aligned} \quad (15)$$

Having found a numerical solution, it only remains to find the remaining parameters, the current distribution in the antenna input impedance, radiation pattern, etc., which does not require much time and computational resources.

In order to account for the influence on the scattered field from the planar dielectric waveguide, two-dimensional, located parallel structures that are periodic in a way, a method based on generalized scattering matrix was used in [17] in order to provide a "stitching" of fields that are scattered with a comb and the dielectric plate.

The advantage of such technique in this method is the case of diffraction of the E - and H - polarized waves on a metal comb with a dielectric layer is that the obtained computer time becomes less than if we compare with the solution on the comb (about several tens of percent) (when use the approach of semiinverse the entire structure as a whole).

If we use the Lagrangian, then we go from the optimization problem including the objective function and constraints, the equivalent optimization problem without restrictions

$$F(g, \lambda_1, \lambda_2) = f(g) + \lambda_1 (y^{\max} - |A_1(g) + B_1(g)|) + \\ + \lambda_2 (x^{\max} - |A_1(g) + B_1(g)|), \quad (16)$$

where $\lambda_1 \geq 0$, $\lambda_2 \geq 0$ - uncertain multipliers Lagrange function.

When we construct the algorithm it is necessary to consider the positive and negative characteristics of search engine optimization used optimization function.

At the same time as searching for optimal values of the vector x required to define the variable λ_1 , λ_2 competing option optimization modeling is the transition to multi-criteria problem with the following definition of the weight coefficients of the global objective function.

At the organization of computing experiment it is necessary to provide an opportunity for the researcher to analyze the advantages and disadvantages of search engine optimization used optimization function.

At the same time as searching for optimal values of the vector x required to define the variable λ_1 , λ_2 competing option optimization modeling is the transition to multi-criteria problem with the following definition of the weight coefficients of the global objective function.

The use of genetic algorithm. It was necessary to determine the parameters of the device to the operating frequency of 11.6 GHz.

In this paper we propose to apply the procedure multialternative optimization to obtain a set of interesting from the point of view of practical application of options that most will meet the requirements that are imposed on the function F , subject to optimization [22].

In order to select a particular option among the many dominant you want to use a search algorithm based on genetic approach.

We use the structure of a chromosome, which gives the possibility to encode the order of formation of the components of the antenna structure (Fig.2).

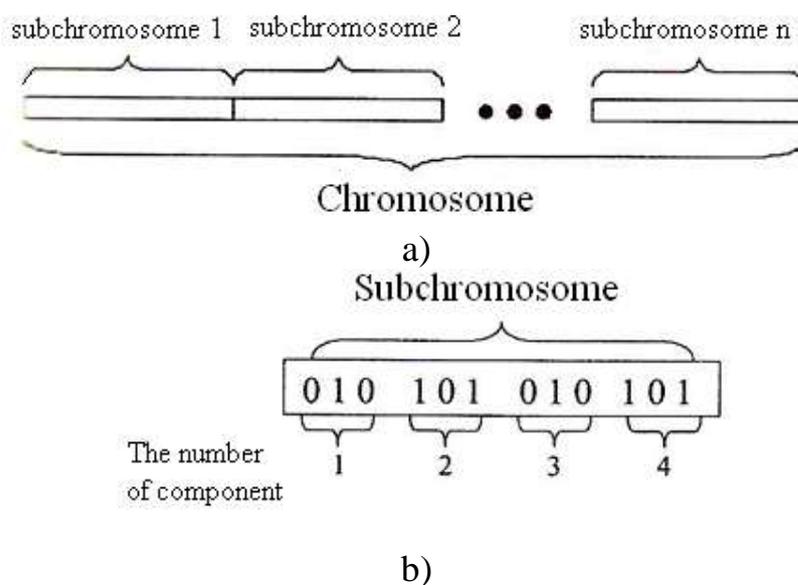


Fig.2. The demonstration of the features of the structure of chromosomes and its parts, which are used in order to conduct automatic synthesis of components of the antenna structure when coding

In order to build the algorithm for the multialternative choice, we consider alternative values for the variables χ_j , $j=1, \dots, J$, which can take the values 1 or 0 codes in the corresponding genes of the chromosome.

A chromosome is a certain set of blocks of chromosomes thus:

1) subchromosome, which is formed from 4 genes and on its basis determines the number N of components of the analyzed antenna;

2) $N-1$ subchromosome has 5 genes, and it allows you to determine the placing of a component (gene 2 – describe the side where there is connection, 3 gene – give the room a connecting surface);

3) N subchromosomes, which consist of 4 genes, and they provide an opportunity to determine the possibility of the shift components (for the generalized coordinates y);

4) N subchromosomes, which consist of 4 genes, and they provide an opportunity to determine the possibility of the shift components (for generalized coordinate z).

First, for each of the components the location of genes χ_j , $j=1, \dots, J$ is carried out, which are responsible for how the component is, and whether their movement. We will hold the designation of chromosomes for this format $\chi_\zeta=(\chi_{j\zeta})$, $\chi=1, \dots, \Lambda$, $j=1, \dots, J$ where Λ is the number of interest dominating variants (Λ in many cases ≤ 7 [23]).

The second step involves the use of basic operations of genetic algorithms for the antenna that includes the following components [24]: crossbreeding and reproduction. During the computational experiment it is possible to use different schemes crossing.

In the first scheme, in order to carry out the operation of the crossing is the division of all chromosomes χ_ζ , $\chi=1, \dots, \Lambda$, that belong to the population X, in local populations of $X_m \neq 0$, $m=1, \dots, M$ ($M \leq J$), for each value Hering distances that apply to any pair of genes $\chi_{j\zeta}$, χ_{jt} , $t, \chi=1, \dots, \Lambda$ are equal to 0.

The choice of the local populations in order to carry out the hybridization is done in a random way.

With this aim is the determination of the number of local populations Λ_m and a random selection is used probability distribution

$$p_m = \Lambda_m / \Lambda, \quad m = \overline{1, M} \quad (17)$$

Basing on (4), we can define implementations of discrete numbers m_1 , m_2 , which are random:

The parent pair $(\chi_\zeta, \chi_t) \in X$ are considered to be chromosomes $\chi_\zeta \in X_{m_1}$ and $t \in X_{m_2}$.

In the second scheme of crossing considering the Hamming distance, which refers to the values of alternative variables $\chi_{j\zeta}$, χ_{jt} , $j=1, \dots, J$ on the two chromosomes χ_ζ , χ_t $\zeta, t=1, \dots, \Lambda$, $h = \|\chi_{j\zeta} - \chi_{jt}\|$. When $h \leq h_0$, where h_0 is a given positive number, there is a study scheme of inbreeding. If $h \geq h_0$, conducted a study of the third scheme of outbreeding. In addition to these schemes the proposed scheme of assortative mating. Then comes the consideration of quantitative assessment of the degree of fit, which is calculated based on the value of optimizable function for each of the chromosomes $\chi_\zeta - F(\chi_{j\zeta})$. For the

first of the schemes, the selection of chromosomes for the process of crossing is based on the following probability distribution

$$p_{\zeta} = F(\chi_{j\zeta}) / \sum_{\zeta=1}^{\Lambda} F(\chi_{j\zeta}), \quad \zeta=1, \dots, \Lambda, \quad (18)$$

For the second diagram, when there is a negative assortative hybridization is the process of selecting randomly one of the chromosomes on the basis of the distribution (5) and the second is determined on the basis of the probability distribution

$$p'_{\zeta} = (1/F(\chi_{j\zeta})) / (1 / \sum_{\zeta=1}^{\Lambda} F(\chi_{j\zeta})), \quad \zeta=1, \dots, \Lambda, \quad (19)$$

In the third scheme using selective crossbreeding. For this purpose, the exclusion from the set of chromosomes $\chi_{\zeta}, \zeta=1, \dots, \Lambda$ those having degree of fitness lower than average degree of fitness many chromosomes $\chi_{\zeta}, \zeta=1, \dots, \Lambda$:

$$F(\chi_{j\zeta}) < \sum_{\zeta=1}^{\Lambda} F(\chi_{j\zeta}) / \Lambda. \quad (20)$$

Then we conduct a random selection for the distribution (17). In order to reduced the many options of interest, you want to create a reproduction of the group through the application of breeding schemes. The two of them are considered. For the first of the schemes are ordered all $\zeta=1, \dots, \Lambda$ in the order of decreasing values of the degrees of fitness. Is the job of the number of reproduction groups Λ_p , on the basis of it is the limitation of many options of interest. For the second scheme is the definition of average degree of fitness $\zeta=1, \dots, \Lambda$ options

$$F^{aver} = \sum_{\zeta=1}^{\Lambda} F(\chi_{\zeta}) / \Lambda. \quad (21)$$

Reproduction group includes only options $\chi_{\zeta p}$, which are characterized by the value of the degree of adaptation is greater than or equal to the average value

$$F(\chi_{\zeta}) \geq F^{aver}, \quad \zeta=1, \dots, \Lambda. \quad (22)$$

The results of simulation. Were determined the following parameters of antenna: $A = 10$ mm, $H = 0.05$ mm, $D_1 = 1$ mm, $D_2 = 4$ mm, $D_3 = 16$ mm, $L_1 = 11$ mm, $L_2 = 5$ mm, $H = 5$ mm, $R = 1.75$ mm, $D_4 = 6.5$ mm, $C = 9.5$ mm.

Conclusion. With use of considered combination of methofs in the paper the possibility is shown of determining the characteristic dimensions of the object that has the necessary frequency of metal-dielectric antenna. On the basis

of obtained results it is possible to design objects with a necessary electrodynamic characteristics.

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**МОДЕЛИРОВАНИЕ МЕТАЛЛО-ДИЭЛЕКТРИЧЕСКОЙ
АНТЕННЫ НА ОСНОВЕ КОМБИНИРОВАННОГО ПОДХОДА**

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В состав современных радиопередающих устройств могут входить антенны, сформированные как из металлических, так и диэлектрических компонентов - металлодиэлектрические антенны. Они являются достаточно компактными и могут размещаться на различных объектах техники. В работе проведено моделирование металлодиэлектрической антенны на основе комбинированного подхода. Приведена схема построения антенны в разных плоскостях. Рассмотрен процесс рассеяния плоской электромагнитной волны на антенне. Разработан комбинированный алгоритм, включающий метод интегрального уравнения, параллельный подход и генетический алгоритм. В работе интегральное уравнение применяется для того, чтобы определить неизвестные поверхностные электрические токи на поверхности антенны, оно решается на основе метода моментов. Для ускорения расчетов использовался параллельный алгоритм. Матрица импедансов представляется как блочная. Для каждого из блоков применяется свой параллельный поток. При учете влияния на рассеянное поле плоского диэлектрического волновода используется метод, связанный с обобщенной матрицей рассеяния. Для решения задачи многоальтернативной оптимизации, связанной с определением линейных размеров антенного устройства при заданной рабочей частоте антенны, используется генетический алгоритм. В результате получены размеры спроектированной антенны для заданных размеров входящих в ее состав компонентов.

Ключевые слова: антенна, интегральное уравнение, параллельные вычисления, оптимизация, генетический алгоритм.