# ANTENNA SYNTHESIS BASED ON THE ANT COLONY OPTIMIZATION ALGORITHM

**[1] Slyusar V. I. and [2] Ermolaev S. Y.**

[1] Central Research Institute of Armaments and Military Equipment of Ukraine's Armed Forces, Kiev, Ukraine
E-mail: swadim@inbox.ru
[2] The Povolzhskiy state university of telecommunications and informatics
Samara, Russia
e-mail: aspcreator@mail.ru

## Abstract

This report are described the versions and the synthesis results of new designs of electrically small antenna based on ant colony optimization algorithms. To study the parameters of the frame and non-loopback vibrators MMANA package was used. Geometric forms that were obtained might be used as contour lines of printed, slot antenna or as forming surface of the crystal dielectric resonator antenna. A constructive meta-heuristic search algorithm for optimization of the antennas forms using solutions of travelling salesman problem (TSP).

***Keywords:*** Ant colony system (ACS), travelling salesman problem (TSP), MMANA

## 1. INTRODUCTION

One of the important directions in the antenna theory development is to find their optimal design solutions. To optimize the form of an antenna ant colony algorithm can be used. One similar example was described in work [1, 2], which proposed the optimal design of antennas RFID-tags based on ant colony optimization algorithms (ACO). It should be noted that there might be several possible options of using ACO in the synthesis of antennas. For example, one of them is that the ACO procedure serves only as the generator of multiple optimal solutions, among which you have to select the best ones in terms of achievable parameters, simulating the form of antenna in the NEC, MMANA package etc. Another option involves an iterative search for optimal solutions with step-by-step test of the antenna dynamic properties in the indicated packages and the adjustment of the antenna shape synthesis similar to how it was done in the synthesis of genetic antennas discussed in [3].

In this report, the authors have used ACO as an instrument of multiple optimal solution generation by using travelling salesman problems [4] as a prototype of antenna structure generator. This problem is solved in a classical manner, i.e. the salesman needs to visit each city only once (to avoid loops and unnecessary connections) and return to the starting city. Moreover, the length of the route should be minimal.

## 2. RESULTS

Reviewed lattice structure of the problem was a matrix of 100 cities in the format 10 × 10.

In the first case one «ant» was located in each city. With the ant assistance, in accordance with the logic of ant algorithm implemented in software, the optimal closed route was found, allowing to bypass all cities by the shortest way (Hamiltonian cycle of minimum length [4]). The results of the program were displayed as a sequence of the city coordinates which the optimum line passes through. The outcome was saved as a file with the extension ". maa" in a format that allows you to open it in MMANA. It helped to automate the antenna design parameter calculations to the maximum.

Coordinate transformation matrix of cities in a coordinate system of MMANA carried out in a such way that the reference point in the construction of the antenna coordinates (0,0) is located in one of the 4 vertices of the city matrix, coinciding, for example, with its 100th site. The optimization results were saved in a coordinate table in the MMANA file as a sequence of coordinates of the beginning and end of each straight-line segments of an elementary length equal to the distance between the nodes in the lattice. In all problems, it was equal to 10. Therefore, it turned out that the table describing the location of antenna sites consisted of more lines than in the case if only the initial and final coordinates of straight line segments were taken into consideration. This solution decreases the accuracy of some calculations because of the large number of fragments, but the deterioration is negligible.

As a result of consistent selection of optimal routes, a few closed winding lines were formed. They were passing through all points of the coordinate matrix, which can be used as forming lines in the synthesis of new conduct frame antenna designs (Fig. 1, 3 - 6). Moreover, for the antenna inscribed in the square with side of 0.1 m, bandwidth reached 9% at frequencies around 800 MHz (fig. 3, 4). Geometric forms that were obtained might be used as contour lines of printed, slot antenna or as forming surface of the crystal dielectric resonator antenna.

Another version of the ACO implementation was avoiding the requirement to return to the initial point of the road. In this case the program was looking for the shortest Hamiltonian path that passes through all cities. In this version at the beginning of the algorithm all the "ants" are housed in the same city (as opposed to a travelling salesman problem). The final search result depends on what node to start with a movement. For this purpose the program can vary the "Beginning of the Route" coordinates.

Search of the non-closed route, as opposed to travelling salesman problem, provided the best form of non-loopback wire vibrators (Fig. 2, 7 - 10). In fact, in this case there is another option of antenna synthesis based on the ACO. Essentially, under this approach, the actual antenna appearance was obtained when the local evaporation rate trace was increased to 0.75. And it was fully identical to meander-line winding trajectory shown in the article of RFID [1, 2]. For this antenna, there is an analytical formula of resonance frequencies calculation, allowing to verify the accuracy of the MMANA functioning and to eliminate the questions about the reliability of results.

It should be noted that in the computational experiments ACO values were experimentally selected in the vicinity of those coefficients, which were used by Marco Dorigo (inventor of ant colony optimization algorithms) and his colleagues [4]. In general, the theme of the optimal ACO values selection for antenna synthesis deserves a individual extensive study with the dependency identification of some parameters on the other. This is required to fulfill a very large amount of computing with multiple repetitions of experiments, taking into account that even the number of ants affects the final result, and the best ant range can be found in the artificial colony.

## 3. Conclusion

It has been shown that the use of AOA allows generating the new forms of antenna, among which the best design should be chosen in terms of the parameter values (Fig. 1.a, 2.a). The results comparison with the work of the genetic algorithm in the solution of the travelling salesman problem allows giving preference to the synthesis loopback vibrators ant optimization procedures as being more rapid. A similar application of genetic algorithm is overloaded by synthesis of a large number of lines imperfect by forms with mutual segment intersections.


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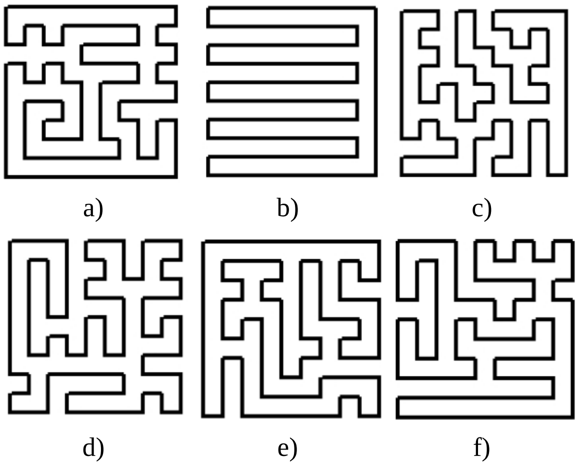


**Fig. 1.** Loopback vibrators 10×10, synthesized by means of ACO algorithm.

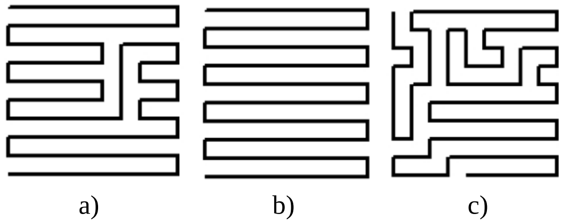


**Fig. 2.** Unloopback vibrators 10×10, synthesized by means of ACO algorithm.

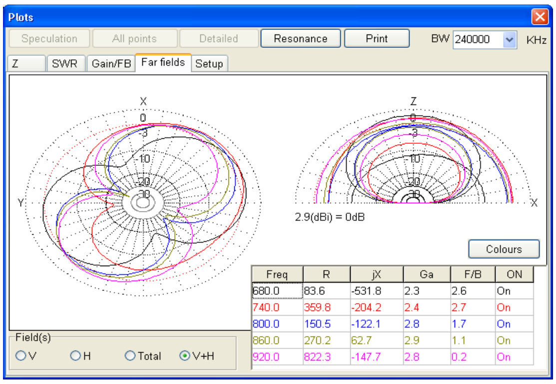


**Fig. 3.** A directivity characteristics (DC) of loopback vibrators 10×10, synthesized by means of ACO algorithm (fig. 1.a).

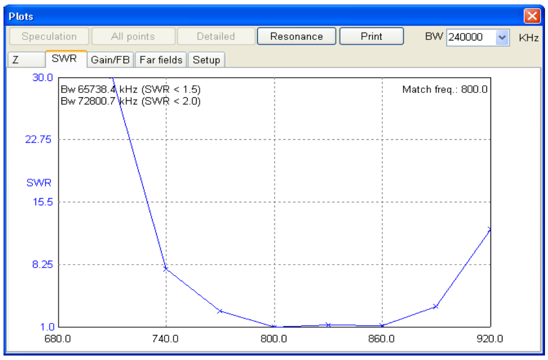


**Fig. 4.** A amplitude-frequency response (AFR) of loopback vibrators 10×10 (bandwidth reached 9%), synthesized by means of ACO algorithm (fig. 1.a).

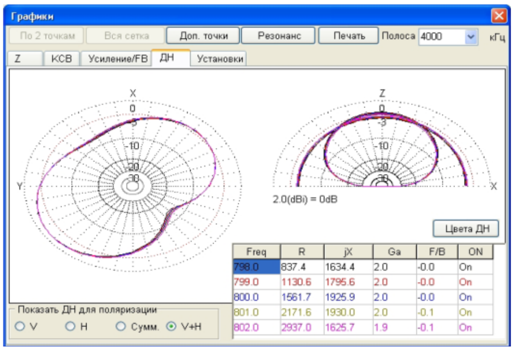

**Fig. 5.** A directivity characteristics (DC) of loopback vibrators 10×10, synthesized by means of ACO algorithm (fig. 1.b).

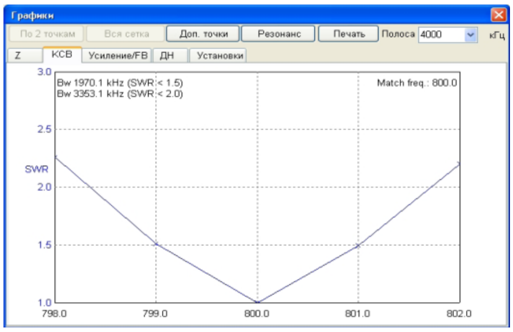


**Fig. 6.** A amplitude-frequency response (AFR) of loopback vibrators 10×10 (bandwidth reached 0,4%), synthesized by means of ACO algorithm (fig. 1.b).

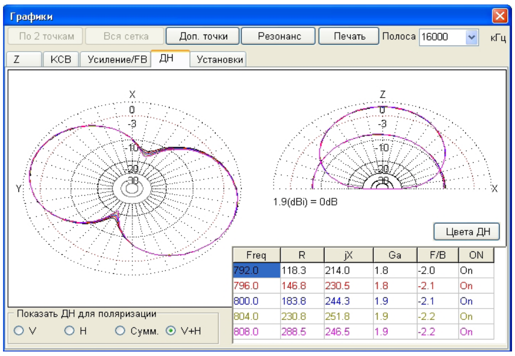

**Fig. 7.** A directivity characteristics (DC) of unloopback vibrators 10×10, synthesized by means of ACO algorithm (fig. 2.a).

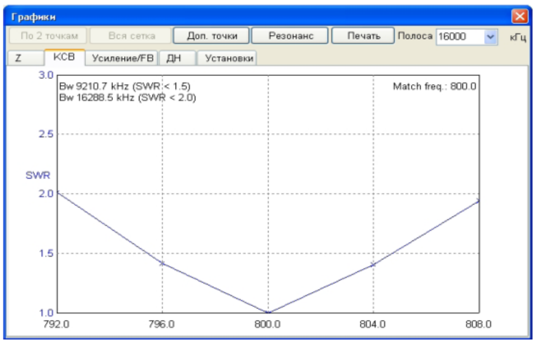


**Fig. 8.** A amplitude-frequency response (AFR) of unloopback vibrators 10×10 (bandwidth reached 2%), synthesized by means of ACO algorithm (fig. 2.a).

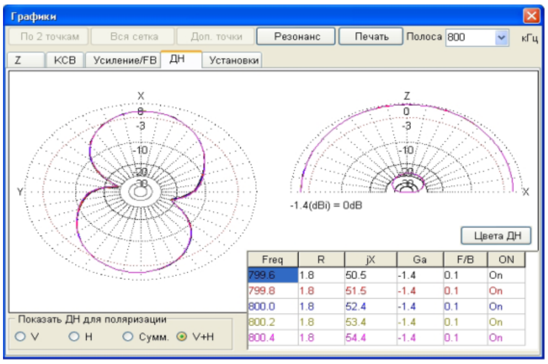

**Fig. 9.** A directivity characteristics (DC) of meander-line vibrators 10×10, synthesized by means of ACO algorithm (fig. 2.b).

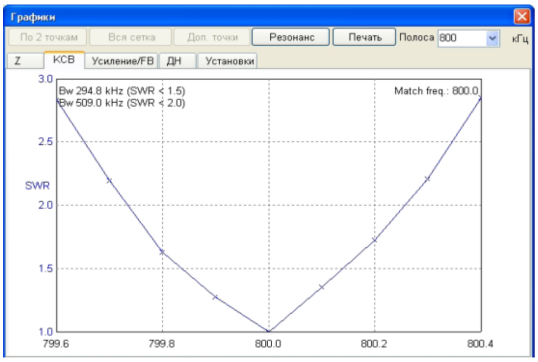


**Fig. 10.** A amplitude-frequency response (AFR) of meander-line vibrators 10×10 (bandwidth reached 0,06 %), synthesized by means of ACO (fig. 2.b).

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