Parametric Optimization of Protective Meander Line Turn in Air Filling by Genetic Algorithm

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***Abstract* — One-criterion parametric optimization by genetic algorithm (GA) of air protective meander line turn cross-section is executed. For this task the quality function which provides geometric mean of wave impedances for even and odd modes of the line (*Z*) to be equal to the 50 Ω is formulated. All of 4 cross-section parameters of the investigated structure are simultaneously optimized. The results of 5 GA runs with 10 and 100 generations of 30 individuals are described. Well reproducibility of *Z* value around the value of 50 Ω with deviation less than 0.1% is demonstrated. The optimization time costs were estimated. The source code of the program (in TALGAT software) is presented in Appendix.**

Keywords* — *protective device, meander delay line, even and odd modes, optimization, genetic algorithm.

I. Introduction

Recently, the basis for designing the any systems and studying the processes occurring inside them is the mathematical simulation, which is carried out by means of computation tools. The main advantage of this approach is the possibility of a process investigation without the physical prototype designing (which is often impossible) and the possibility of the error identification in early steps of a design process. A special necessity for the mathematical simulation arises for solving the tasks of the applied electrodynamics. It is necessary for the design of electronic equipment, which is based on the computer simulation and the optimization, in particular.

The problem of a complex system optimization, to which many tasks are reduced, is one of the main problems in the artificial intellect world [1]. Often, a task is presented as an objective function, which is needed to minimize or maximize, and some initial data set and restrictions of the solution. For the main part of these tasks, the deterministic solution methods are unacceptable or do not provide the required accuracy [2]. Therefore, the alternative approach is needed – using the evolution optimization methods [3].The most popular optimization methods are stochastic and thermodynamics approaches (for example, Monte Carlo, simulated annealing), a deterministic approach (for example, branch and bound and tabu search), and heuristic and meta-heuristic approaches (for example, evolution programming, evolution strategies and genetic algorithms (GA)). The most notable are the GA because they are part of heuristic methods group and combine the elements of the deterministic and stochastic approaches. The basis of GA is the natural selection principle (the survival of the strongest or fittest). The GA uses the following terminology: the genome is a class of possible solutions, giving an idea of what kind of solution there can be at all; objective function is a one-to-one motion that takes the space of variables to the solution space and returns the objective function value to the variable; gene is one of the task parameters; individual (chromosome, individuum) is the set of genes; population is the set of individuals; generation is life cycle of the population (from a birth up to a formation of a new one); evolution is the sequence of generations before the GA cessation condition is reached. The sphere of GA application is wide: from the computer-aided design [4, 5], the combinatorial tasks solving and the neural networks designing to the expert and learning systems application [6, 7].

The urgent task is to protect electronics against dangerous electromagnetic influences. Intentional electromagnetic interference (IEMI) is especially dangererous, in particular, ultrashort pulses [8]. Meanwhile, for the protection from this threat, new devices based on simple printed structures are actively developed [9]. These structures promise to be effective, cheap, light and reliable. However, to obtain a set of the best characteristics an optimization of these devices is desirable.

One of the tasks, where the optimization is needed, is the choice of the protective meander line turn parameters [10, 11]. The turn allows providing the decomposition of the pulse into a sequence of the pulses with lower amplitude, thus, its influence on the low-frequency circuits of the electronic equipment is minimized. The first studies of this approach were performed on the example of analysis of the signal propagation in a turn of asymmetrical meander line in the air [12, 13]. The result of these works is a set of selected cross-section parameters and line length, which provides the maximum ultrashort pulse amplitude attenuation. But this selection was made by heuristic search of parameters without accounting the load parameters influence on a signal distortions and attenuations of the signal amplitude at the end of the line. Meanwhile, the increasing of optimized parameters number makes urgent to utilize the methodology of optimization by GA as a tool for

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optimization of any parameters number of the various structures by different criteria. In this paper, the achievement of this aim is demonstrated on the example of optimization by GA of all cross-section parameters of a turn of meander line in air for the matching with 50 Ω tract.

II. Initial Data for the Optimization

The cross-section of the one turn of the meander line with edge coupling in the air filling is given in Fig. 1. The cross-section constitutes two parallel signal conductors over a ground plane. The geometrical dimensions of the cross-section: *w* and *t* are the width and thickness of the signal conductors; *s* is the separation of signal conductors; *h* is the height of signal conductors over the ground plane.

The aim of the optimization using GA is to search for the set of *w*, *t*, *h* and *s* parameter values providing the geometric mean of even and odd mode impedances equal to 50 Ω. Thus, from the methodological considerations for the most general formulation of the task, all 4 cross-section parameters were optimized simultaneously. As for the objective function, in this example, it includes only one criterion. The optimization task is formulated as $Z=f(w, t, h, s)\to 50$ Ω with 10 µm≤w≤500 µm, 10 µm ≤t≤500 µm, 10 µm ≤h≤500 µm, 1 µm ≤s≤100 µm.

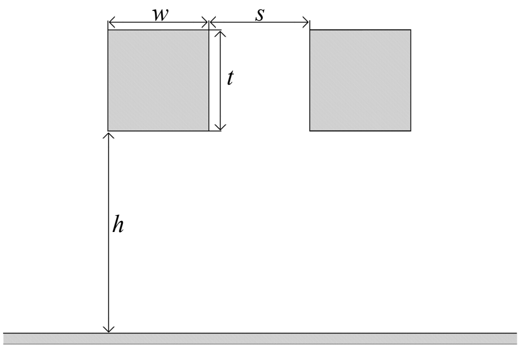

Fig. 1. Cross section of a meander line turn with edge coupling in air filling

III. The Optimization Results

For the line optimization, the TALGAT software is used [14]. GA was launched 5 times with 10 and 100 generations of 30 individuals. The results are summarized in Table I, II and diagrammatically represented in Fig. 2–7.

TABLE I. GA results for 30 individuals and 10 genereations

Run	*Z*, Ω	*T*, s	*w*, µm	*t*, µm	*h*, µm	*s*, µm
1	49.9947	128.32	297.555	417.373	183.45	93.048
2	49.9835	134.372	368.085	238.128	265.995	39.7858
3	49.9683	130.508	112.045	282.661	79.8718	61.0722
4	49.9918	143.256	91.9321	397.708	95.7379	68.8536
5	49.9948	161.143	282.332	301.555	427.982	29.4076

TABLE II. GA results for 30 individuals and 100 genereations

Run	*Z*, Ω	*T*, s	*w*, µm	*t*, µm	*h*, µm	*s*, µm
1	49.9915	1840.6	449.007	379.532	297.136	71.751
2	50.0008	2149.04	316.681	332.794	244.514	55.3152
3	50.0041	1718.06	429.523	480.433	300.359	89.2336
4	50.0102	1960.23	382.052	471.939	341.497	70.2992
5	49.997	2677.52	135.052	403.241	196.602	48.5067

From Table I, II the well reproducibility of *Z* value around the value of 50 Ω. Detailed values of *Z* for 10 and 100 generations are shown in Fig. 2. For 10 generations, the values of *Z* vary from 49.9683 to 49.9948 Ω and for 100 generations – from 49.9915 to 50.0102 Ω. Thus, the optimization criterion is performed with the high accuracy (deviation is less than 0.1%) even for 10 generations.

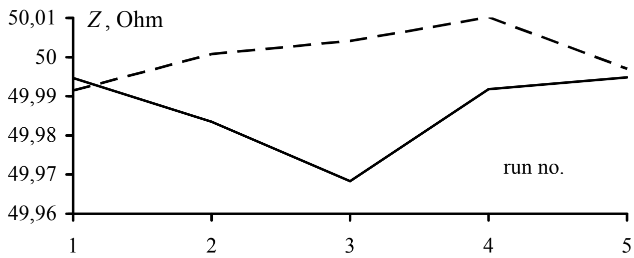

Fig. 2. Obtained values of *Z* 10 (——) and 100 (– –) generations

The optimization time is estimated. The total calculation time for runs 1–5 with 10 and 100 generations is presented in Fig. 3. The maximum calculation time for 10 generations was 2.7 min, while for 100 – 44.6 min.

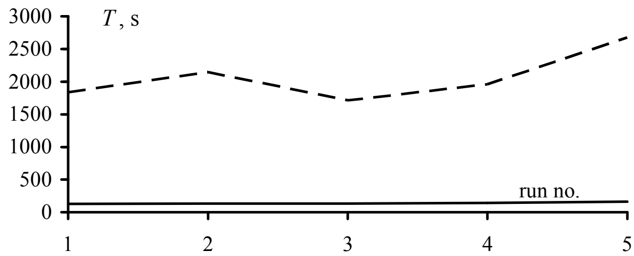

Fig. 3. Calculation time for 10 (——) and 100 (– –) generations

As for values of *w*, *t*, *h* and *s*, as the Table I, II show they are rather strong differ both for 10 and 100 generations, so for runs 1–5. The obtained values are shown in Fig. 4–7. One can see that the values do not converge to a single value. Meanwhile, they should not converge from physical considerations, because per-unit-length capacitance of a structure does not change with the proportional changing of all parameters of the structure. Therefore, when all 4 cross-section parameters optimizing, the equality of geometric mean of even and odd mode impedances to resistance 50 Ω are provided no by one set of parameter values, but by many other sets. Essentially, in this task the objective function has a set of maximums, but does not have global one.

Meanwhile, when one or more parameters of the considered structure are fixed, the optimization task becomes physically established and appropriated. The same is correct with the increasing of a number of optimization criteria. Therefore, the performed work is important from the point of view of methodology. The source code of the program (in TALAGAT system), allowing for a parametric optimization of air meander line turn is presented in Appendix.

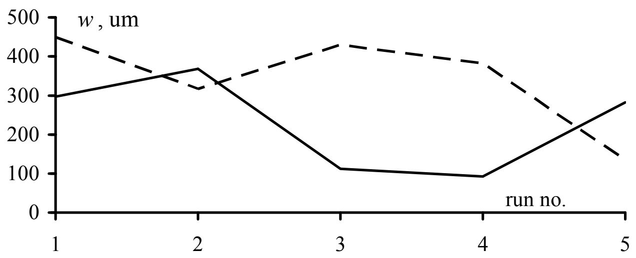

Fig. 4. Obtained values of *w* for 10 (——) and 100 (– –) generations

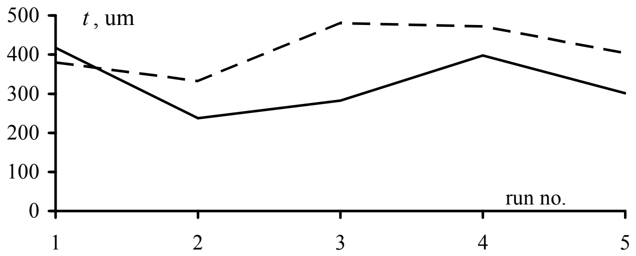

Fig. 5. Obtained values of *t* for 10 (——) and 100 (– –) generations

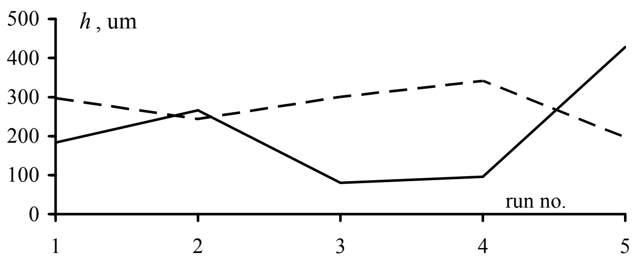

Fig. 6. Obtained values of *h* for 10 (——) and 100 (– –) generations

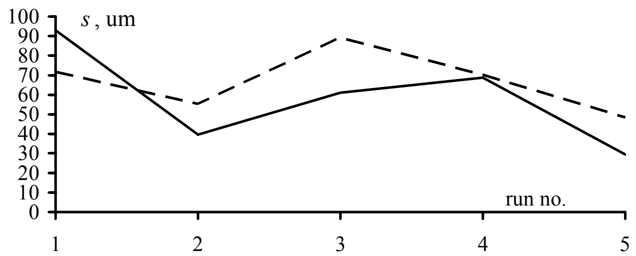

Fig. 7. Obtained values of *s* for 10 (——) and 100 (– –) generations

IV. Conclusion

One-criterion parametric optimization by GA of air protective meander line turn cross-section is executed. For this task the quality function which provides geometric mean of wave impedances for even and odd modes of the line to be equal to the 50 Ω is formulated. As a result of the analysis, it was revealed that the cross-section parameters do not converge to a single value, which agrees with analytical estimates: per-unit-length capacitance of a structure does not change with the proportional changing of all parameters of the structure. Thus, in this task the GA objective function has a set of maximums, but does not have global one. Meanwhile, when one or more parameters of the considered structure are fixed, the optimization task becomes physically established and appropriated. The same is correct with the increasing of a number of optimization criteria. Therefore, the performed work is important from the point of view of methodology. In despite of poor converging of the protective turn cross-section parameters the well reproducibility of Z value around the value of 50 Ω is obtained. For 10 generations, the values of Z vary from 49.9683 to 49.9948 Ω and for 100 generations – from 49.9915 to 50.0102 Ω. Thus, the optimization criterion is performed with the high accuracy (deviation is less than 0.1%) even for 10 generations. Additionally, the optimization time costs were estimated. It was shown, that the maximum calculation time for 10 generations was 2.7 min, while for 100 – 44.6 min. The source code of the program (in TALGAT software), is presented in Appendix.

Appendix

Programm of searching the optimum parameters of an air meander line turn with edge coupling

```
INCLUDE "UTIL"
INCLUDE "MOM2D"
INCLUDE "MATRIX"
INCLUDE "GA"

CREATE_KEYWORD "quality_function"
SET "w" GA_PARAM_1
SET "t" GA_PARAM_2
SET "d" MUL 3.
SET "hC" GA_PARAM_3
SET "ErAir" 1.0
SET "s" GA_PARAM_4
SET "segm" 1.e-5
SET_AUTO_SEGMENT_LENGTH segm
SET_INFINITE_GROUND 1

CONDUCTOR
SET_ER_PLUS ErAir
LINE d hC PLUS d w hC
LINETO PLUS d w PLUS hC t
LINETO d PLUS hC t
LINETO d hC

CONDUCTOR
SET_ER_PLUS ErAir
LINE PLUS PLUS d w s hC PLUS PLUS PLUS
d w s w hC
LINETO PLUS PLUS PLUS d w s w PLUS hC t
LINETO PLUS PLUS d w s PLUS hC t
LINETO PLUS PLUS d w s hC
SET "conf_ig" GET_CONFIGURATION_2D
```

```
SET "mC" CALCULATE_C SMN_C conf_ig conf_ig
SET "mL" CALCULATE_L SMN_L conf_ig conf_ig
CALCULATE_EIGENVALUES_r CALCULATE_ZC mL mC
SET "mZe" REAL GET_EIGENVALUES
SET_VARIABLE "Rval" SQRT MUL GET_MATRIX_VALUE mZe 0 0 GET_MATRIX_VALUE mZe 1 1
SET "my_temp_var" MINUS 50. Rvalue
ECHO my_temp_var
SET "qf_result" my_temp_var
END_CREATE_KEYWORD ABS qf_result
REPORT_TIMER GA_MIN 30 1000 0.1 0.5 4. 10.0e-6 500.0e-6 10.0e-6 500.0e-6 10.0e-6 500.0e-6 1.0e-6 100.0e-6 "quality_function"
ECHO GET_BEST_GA_PARAMETER 0 //w
ECHO GET_BEST_GA_PARAMETER 1 //t
ECHO GET_BEST_GA_PARAMETER 2 //hC
ECHO GET_BEST_GA_PARAMETER 3 //s
```

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