The development of CAD of information systems and software for diffractive structures

Igor Lvovich, Andrew Preobrazhensky, Oleg Choporov

Abstract:

The CAD development of diffraction devices is one of the promising directions for development of computer-aided design, and antenna equipment. In this paper the basic features of CAD development of electronic devices are introduced. For optimal choice of basic elements for radar antennas in the analysis of radar characteristics, it's recommended to use the principle of maximal correlation coefficient of selected basic elements parameters and the required characteristics of electromagnetic waves scattering, as well as cost characteristics of the antenna along with the desired characteristics and technical specifications of the automated design. The structural scheme of CAD diffractive structure is examined in detail. The operation of the CAD program head and the structure of information support for CAD and its relations with the software are described.

Keywords:

Simulation modeling, CAD, scattering of electromagnetic waves, radar antenna.

ACM Computing Classification System:

Equation and inequality solving algorithms, Parallel programming languages, Optimization algorithms.

Introduction

The lenses of radar signals (radar target) space, air, land, water and energy converters of electromagnetic waves (banners, a means of reducing the visibility in the radio waves, the antenna of the microwave and EHF ranges) as a rule, are characterized by their large electrical size, complex geometry, presence of absorbing and non-linear elements. Analysis and synthesis of the above-mentioned electrodynamic objects based on rough ideas about proceeding in which physical processes carry the risk of significant and barely controllable errors in the evaluation of their main characteristics, which, as a rule, quickly change with frequency, polarization and angle of incidence of electromagnetic waves. Measurement of basic characteristics of radar targets (polarization matrix, effective surface scattering in monostatic and bi-static modes scattering) in a wide frequency range and broad angular sector requires a certified or specially equipped antenna of a polygon, or a certified anechoic chamber (the cost of which can provide several million dollars), and large expenditures of time and resources.

For the optimal choice of the basic elements of radar antennas in the analysis of radar characteristics [1-3], you may use the principle of maximal correlation coefficient of selected parameters of basic elements and the required characteristics of scattering of electromagnetic waves, as well as cost characteristics of the antenna with the desired characteristics and technical specifications for automated design. The use of the system of weights of importance of basic parameters and characteristics of user-defined CAD, severely limits the number of possible design options.

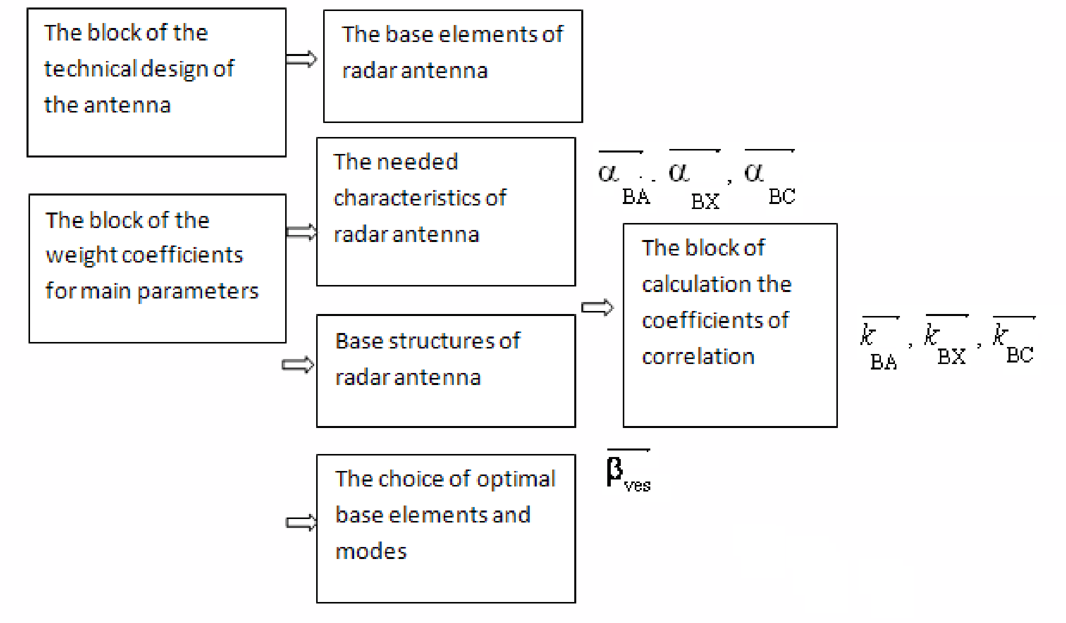

Figure 1. Flowchart of making design decisions using the principle of maximum correlation coefficient

The block diagram of this stage is shown in Fig. 1 using the following notation: $\overrightarrow{\alpha_{T3}}$ is a vector, each element of which is a function of a certain number of variables (e.g., frequency, azimuthal and elevation coordinates, etc.) corresponding to the technical task;

$\overrightarrow{\alpha_{B\grave{A}}}$, $\overrightarrow{\alpha_{B\tilde{O}}}$, $\overrightarrow{\alpha_{B\tilde{N}}}$ – vectors containing the appropriate dependencies for the basic elements of antennas, the required values of radar characteristics and basic structures of antennas respectively;

$\overrightarrow{\beta_{ves}}$ – the vector of weights of importance of basic parameters and characteristics of antennas;

$\overrightarrow{k_{BÀ}}$, $\overrightarrow{k_{BÕ}}$, $\overrightarrow{k_{BÑ}}$ – vectors containing the appropriate correlation coefficients.

The need for prior analysis of the basic elements caused by a significant amount and complexity of the processes occurring in real antennas. In addition, this approach is due to the impossibility of constructing a simple equivalent model of arbitrary diffractive structures.

Developed in the present work, CAD diffractive structures have the following features [4-7]:

– usage along with rigorous methods of mathematical modeling of heuristic methods have a narrow scope;

– diversity and object oriented physical-mathematical models, which are based on implemented algorithms in the framework of CAD and programs to improve performance of solving the problems of modeling;

– lack of a unified mathematical apparatus developed in the CAD system, limiting the scope of its tasks;

– support for expansion of the variety of designed objects due to the modular organization of CAD.

The structure of the developed CAD system is depicted in figure 2.

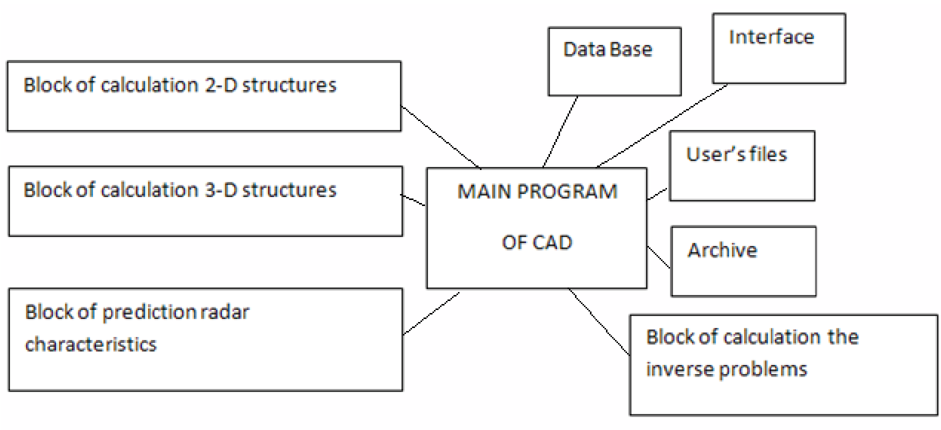

Figure 2. The structural scheme of CAD diffractive structures

Database management system (DBMS) database is characterized by the use of a relational data model. In the database (DB) stored key parameters and dependencies that characterize standard elements included in the composition of technical objects (cylinders, wedges, hollow structure (cavity), etc.) and materials (metals, dielectrics, magneto-dielectric). Each type of basic elements and materials may be characterized by its set of numerical parameters. The sets of components for the same type are presented in tables in first normal form.

The archive is used to store user files, designed for specific tasks-aided design and modeling. Classification of tasks for the archive of information is compiled by the user. They must be continuously updated and expanded when working with CAD.

The unit of calculation for scattering characteristics of two-dimensional structures allows anyone to calculate the scattering parameters. The unit of calculation of scattering characteristics of three-dimensional structures allows to calculate the scattering parameters. Functions for the block of prediction of radar characteristics include the prediction of scattering characteristics for diffractive structures. Forecasting is based on data from a data block.

The block for solving inverse problems of scattering of electromagnetic waves allows to predict the shape of the object in the restored premises of the reflectors, the prediction of the characteristics of radar absorbing materials and coatings applied to the surface of the object.

The unit for calculation of scattering characteristics of antennas, using blocks calculating the scattering characteristics of two-dimensional and three-dimensional structures allows calculation of characteristics of two-dimensional periodic gratings and metal-dielectric antennas, the calculation of the characteristics of horn-gap excitation of the diffraction element antenna arrays for microwave range of wavelengths, and the scattering characteristics of dipole antennas.

The main program controls all CAD blocks and coordinates the sharing of information between interconnected functional blocks. Its operation is illustrated in figure 3.

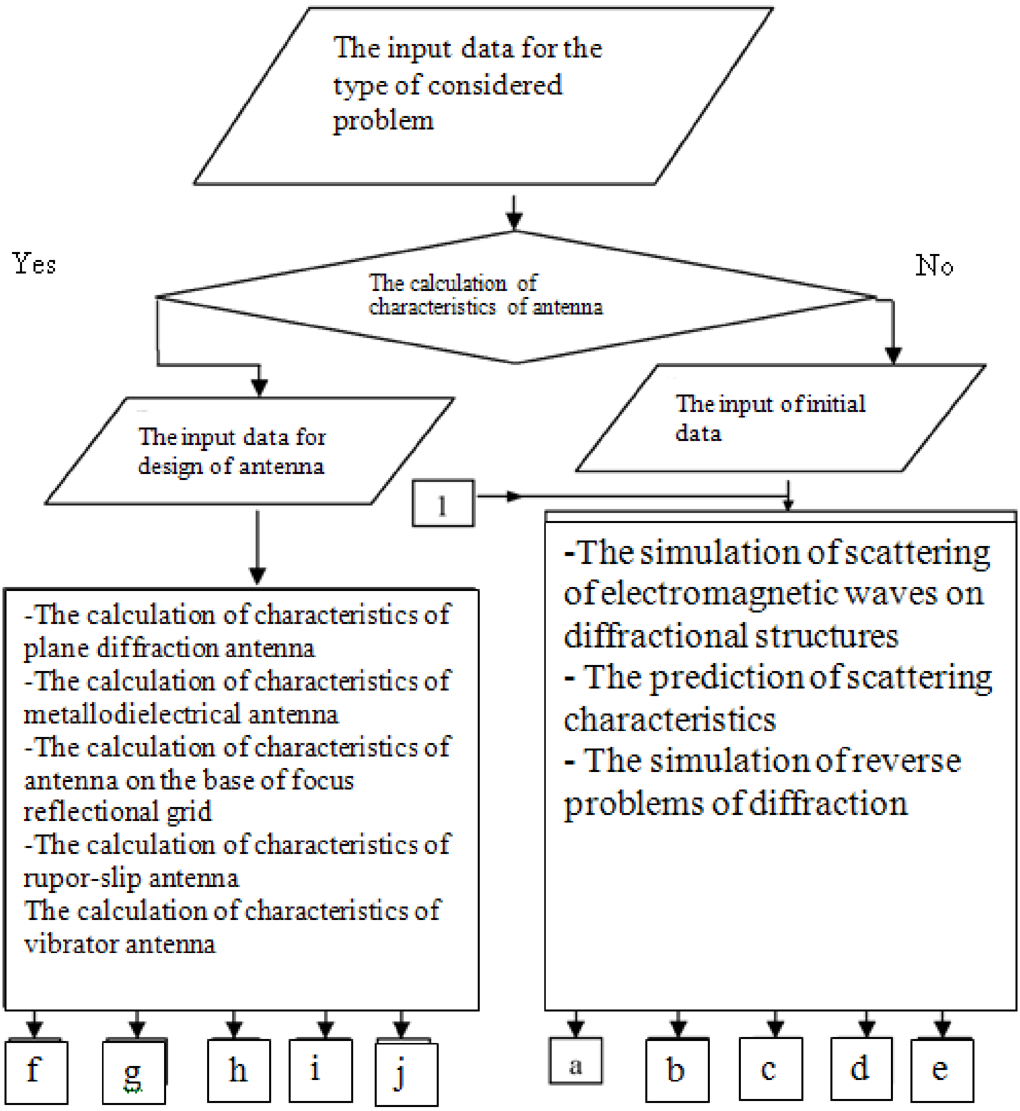

Figure 3. The operation of the head of a CAD program (sheet 1)

As we can see from figure 3-4, CAD diffractive structures and antennas consists of two main parts – analysis of diffraction patterns and diffraction analysis of antennas.

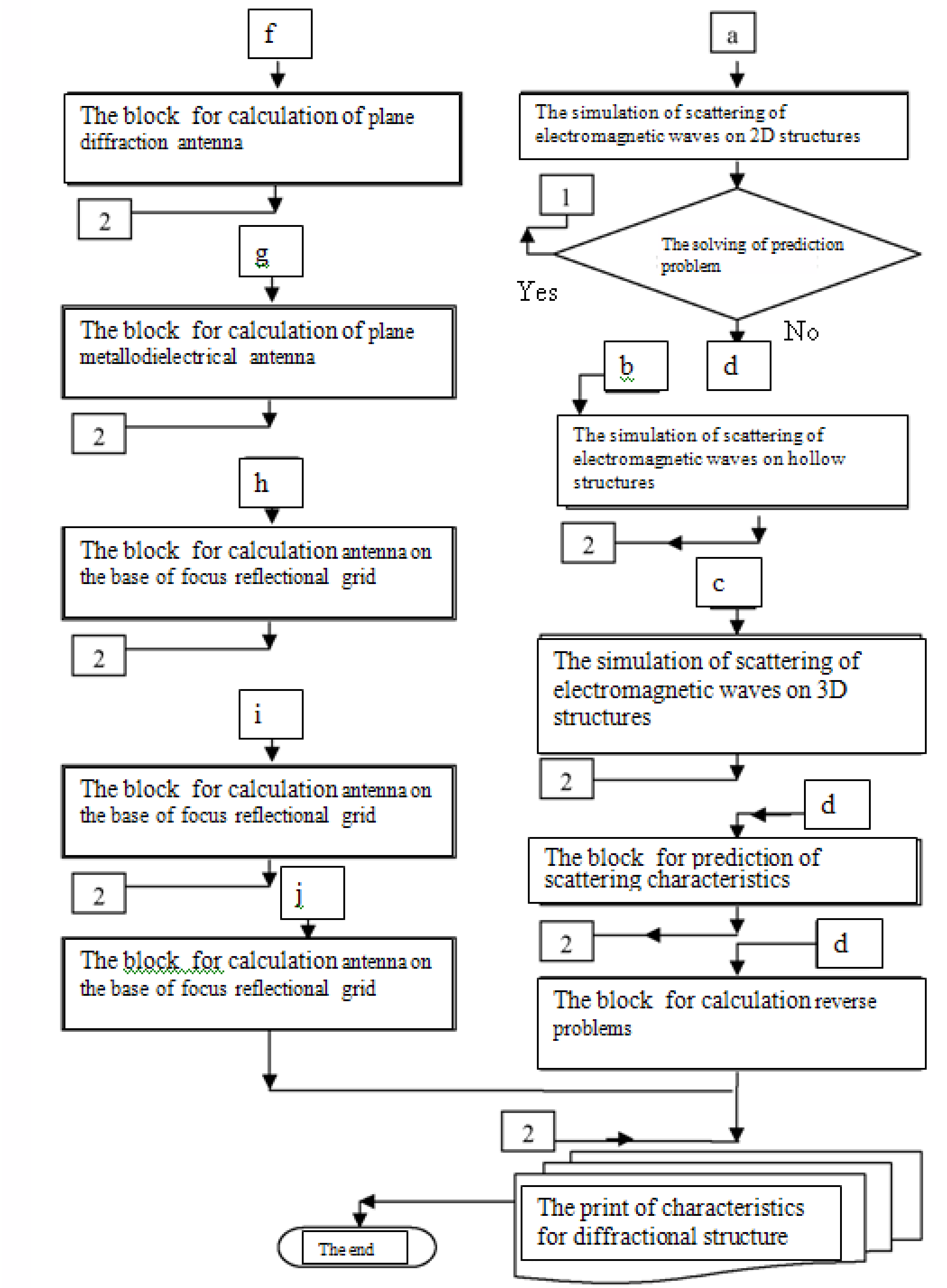

Figure. 4. The operation of the head of a CAD program (sheet 2)

Structural synthesis of antennas is based on the optimal choice of combinations of basic structures of radar antennas, basic antenna elements, the required values of radar characteristics. The optimality chosen criterion is the maximum of the correlation coefficient between the given and design specifications of antennas, depending on the specific base elements of the structural scheme and mode.

Specification for the design of radar antennas could be represented as a vector $\overrightarrow{\alpha_{T3}}$, each element of which is a function of a certain number of variables (e.g., frequency, asimuthal and elevation coordinates $(\eta_1,\eta_2,...,\eta_L)$, etc.). The elements of this vector may be, for example, the functional dependence of the gain of the radar antenna, its efficiency, VSWR, cross-polarized radiation, slope, angle-frequency characteristics of the antenna, etc. Denote by $\overrightarrow{\alpha_{\text{VÀ}}}$, $\overrightarrow{\alpha_{BV}}$, $\overrightarrow{\alpha_{BC}}$, the vector-function containing the appropriate dependencies to the underlying antenna elements, the required values of the characteristics, the basic structures of antennas, and using the vector of weights $\overrightarrow{\beta_{ves}}$ of importance of basic parameters and characteristics of antennas, determined based on customer requirements to design the antenna. All the above vectors have the same dimension K.

The set of vectors for each stage of making design decisions (selection of the basic elements, values of the characteristics, the basic structures of the antenna) forms a rectangular matrix, the number of rows corresponds to the number of source options for each stage: $\Delta_{\text{VÀ}}=\left(\overrightarrow{\alpha_{\text{VÀ}1}}\ \ ...\ \ \overrightarrow{\alpha_{\text{VÀN}}}\right)$, $\Delta_{BV}=\left(\overrightarrow{\alpha_{BV1}}\ \ ...\ \ \overrightarrow{\alpha_{BVM}}\right)$, $\Delta_{BC}=\left(\overrightarrow{\alpha_{BC1}}\ \ ...\ \ \overrightarrow{\alpha_{BCQ}}\right)$ [8].

The process of structural synthesis of antenna is reduced to the following series of procedures to find maximums of the respective correlation coefficients

$$\overrightarrow{k_{\text{VÀ}\,j}}=\sum_{i=1}^{K}\frac{\beta_{ves\,i}\cdot\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{VÀ}\,ij}}(\eta_1,\eta_2...\eta_L)\cdot\overrightarrow{\alpha_{\text{ÒÇ}\,i}}(\eta_1,\eta_2...\eta_L)\,d\eta_1d\eta_2...d\eta_L}{\sqrt{\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{VÀ}\,ij}}(\eta_1,\eta_2...\eta_L)^2\,d\eta_1d\eta_2...d\eta_L\times\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{ÒÇ}\,i}}(\eta_1,\eta_2...\eta_L)^2\,d\eta_1d\eta_2...d\eta_L}},$$

$$j=1,...,N$$

$$\overrightarrow{k_{BV\,j}}=\sum_{i=1}^{K}\frac{\beta_{ves\,i}\cdot\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{BV\,ij}}(\eta_1,\eta_2...\eta_L)\cdot\overrightarrow{\alpha_{\text{ÒÇ}\,i}}(\eta_1,\eta_2...\eta_L)\,d\eta_1d\eta_2...d\eta_L}{\sqrt{\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{BV\,ij}}(\eta_1,\eta_2...\eta_L)^2\,d\eta_1d\eta_2...d\eta_L\times\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{ÒÇ}\,i}}(\eta_1,\eta_2...\eta_L)^2\,d\eta_1d\eta_2...d\eta_L}},$$

$$j=1,...,M$$

$$\overrightarrow{k_{\text{BÑ}\,j}}=\sum_{i=1}^{K}\frac{\beta_{ves\,i}\cdot\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{BÑ}\,ij}}(\eta_1,\eta_2...\eta_L)\cdot\overrightarrow{\alpha_{\text{ÒÇ}\,i}}(\eta_1,\eta_2...\eta_L)\,d\eta_1d\eta_2...d\eta_L}{\sqrt{\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{BÑ}\,ij}}(\eta_1,\eta_2...\eta_L)^2\,d\eta_1d\eta_2...d\eta_L\times\int\limits_{S_1S_2...S_L}\overrightarrow{\alpha_{\text{ÒÇ}\,i}}(\eta_1,\eta_2...\eta_L)^2\,d\eta_1d\eta_2...d\eta_L}},$$

$$j=1,...,Q$$

where $S_1,S_2,...,S_L$ – the range of the parameters $(\eta_1,\eta_2,...,\eta_L)$.

For each of the vectors of correlation coefficients using standard procedures we get the maximum elements, numbers of which correspond to the optimum for a given technical specifications for the design of basic antenna elements, values of the characteristics, and basic structures of antennas.

Software modules have user-friendly interface and may be maximized to fit the window when developing CAD was made by C++ Builder. The response time for one specific module using a PC with a Pentium III-900 can be in the range from several seconds to several tens of minutes. The desirable volume of the computer's RAM – at least 256 MB (the order of matrices solving systems of linear algebraic equations might reach 3000 up to 5000) - free hard disk capacity – 200 MB.

The database has a file structure and carries out the input, storing, searching and providing information about the characteristics and parameters:

- standard elements and diffractive structures;
- basic elements of diffraction antennas and metal-dielectric antennas;
- tabulation according to functions for calculation of which is required considerable machine time (for example functions involving integrals used to determine the scattering characteristics of diffractive structures);

– source data of all ongoing projects;

intermediate data arrays organized in the form of temporary files;

– electrodynamic models of diffraction structures, and antennas formed as a result of design.

For communication with the user the user interaction program is divided into the graphical interface program and processing program along with object-oriented messages [62, 198-199].

The program processing object-oriented messages allows you to enter source data and to modify the database using the special text forms and queries.

The dialog mode is performed by engaging the drop-down system menus that allow you to enter raw data into a user-friendly form to manage the process of formation of electrodynamics, mathematical and optimization models, modifications of the database contents, ability to choose various views for simulation results, optimization and automated design (in the form of the surface, maps of lines of equal level, the family of graphs in cartesian or polar coordinates, tables, etc.), management of communication with the database or other CAD programs.

CAD structure software allows us to develop several simultaneously running projects. The source data for each project is stored as a file in the database. The model is created and updated with a special project file that contains the description of the generated model. In the case of an adequate model, this file is stored in the database. Intermediate results may be stored as external files or in the computer memory or they are removed automatically.

The composition of the structural scheme of data transmission and management is the communication interface with the database and other hardware-software units that allow to carry out data entry and to communicate these findings in an external subsystem or the database. The communication interface also converts the files used by the CAD format for external programs or databases.

The structure of information support of CAD and its relationships with the software is shown in Fig. 4. The database contains files with names MPL (the library of electrodynamic parameters of materials), SEL (a library of standard diffractive structures), SCL (a library of basic structural patterns of diffraction antennas), TFL (library of tabulated functions), and the file extensions .trd (source projects).edm (the project files for the generated electrodynamic models) .rez (files of results of models and computer-aided design), .tmp (intermediate data).

Database management provides the monitor module that is being used as a text editor module database correction database (CDB) program processing object-oriented messages. The MPL, SEL, BAL, BEL, SCL, BVL, SAL, PSL, TFL files have the extension .dbf and are stored in a database format of Builder C++. This fact allows us to minimize the size of files maintaining compatibility with the most common databases. Other files commonly used in CAD systems are used in plain text format view of the data [9].

The main indicators characterizing the adequacy of the CAD complex objects are used as follows: "fizicheski" results of mathematical modeling, optimization and computer-aided design;

– stability – small changes in input parameters or technical specifications for the design should correspond to small changes of output parameters and characteristics;

– repeatable results – the same input data are entered in different sequences that must correspond to the output unchanged;

– use of different research methods or projects for the same object should result in measurable results;

– correspondence of the results obtained when using different CAD systems, developed by different teams;

– use of correct mathematical methods, models and algorithms;

– fast convergence exploited in CAD algorithms;

– conformity of the research results or the design object data of experimental and field studies.

Of course, the latter criterion of CAD adequacy is crucial. The indicator "physical reality level" may be a subjective assessment of the quality of computer aided design.

Under property we understand effectiveness of the program ensuring the CAD system to perform a required function without excessive misuse of resources. As an assessment of efficiency one often takes characteristics of the program, the value of which is directly proportional to fast-contribution and inversely proportional to the amount of used resources of the computer and external devices [10-15].

Developing CAD systems as a whole it must meet the above criteria. The adequacy of the overwhelming majority of system functions of automated design for diffractive structures under-firmed positive results of experimental and textural studies analyzed (designed) objects.

In conclusion, the main directions of development and modernization designed by CAD should involve:

– improvement of the CAD interface and the extension of possible use of standard databases;

– inclusion of expanding design and engineering capabilities in the computer-aided design system;

– increase of the possible degree of design automation by increasing the number of operations that CAD systems effectively implements without user intervention;

– increase the effectiveness of CAD.

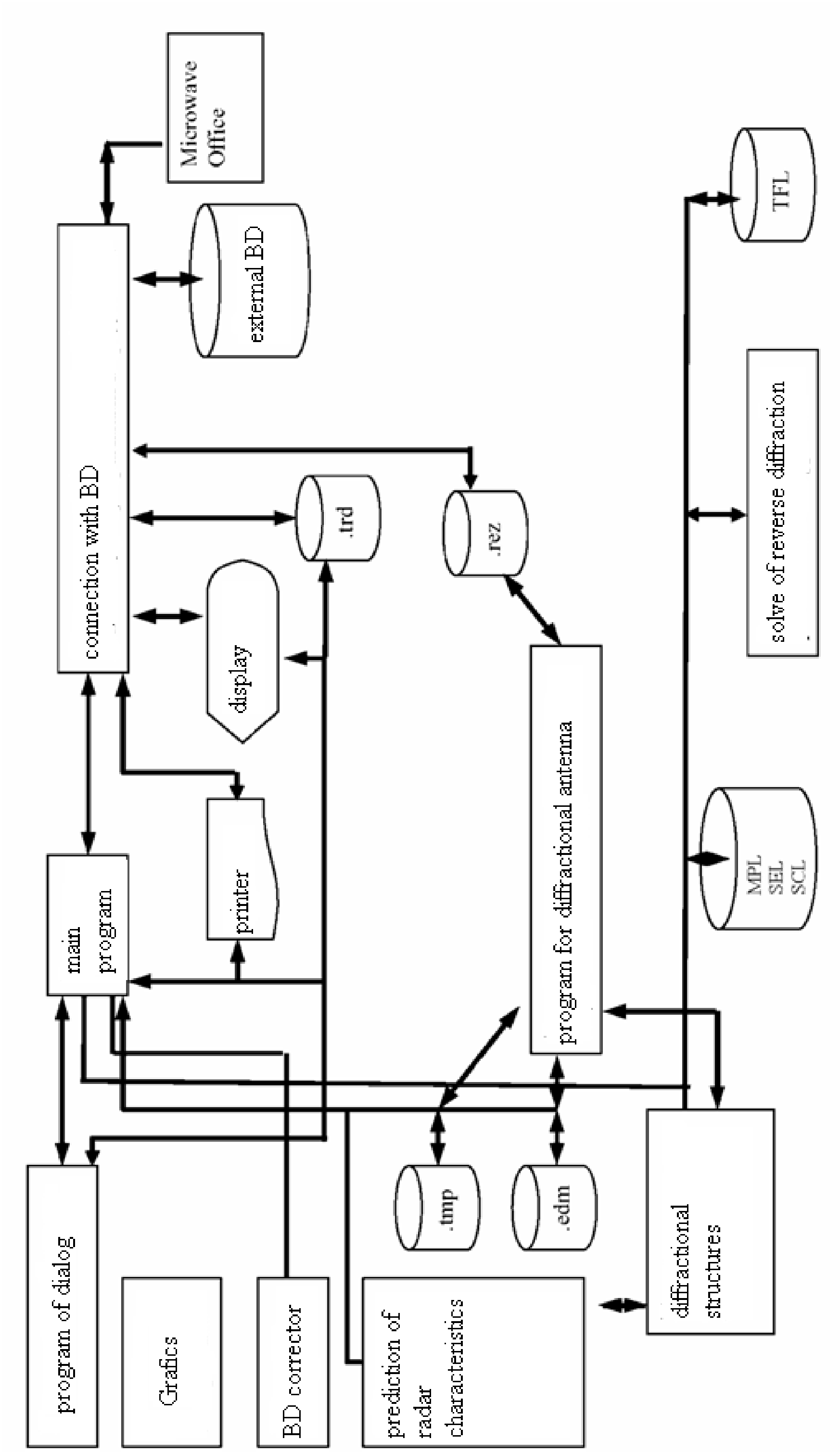

Figure 4. Structure of information support for CAD and its relationships with software

References

[1] ASTANIN, L., KOSTYLEV, A.A. 1989. *Basics ultrawide band radar measurements*. M.: Radio and Communications, 1989, 305 p.

[2] BACHRACH, L.D., et al. 1997. *Reference antenna technology*. M.: *IPRZHR*, 1997, vol. 1, 256 p.

[3] WEINSTEIN, L.A. 1988. *Electromagnetic waves*. M.: Radio and Communications, 1988, 440 p.

[4] NORENKOV, M.: *IP-aided design*. Moscow, 2000.

[5] NORENKOV, M. 2000. IP design automation tools in the electronics. In *Information Technologies*, 2000, no. 10, pp. 31-37.

[6] NORENKOV, M.: IP-aided design systems. In *Principles of construction and structure* IP. M .: Higher School, 1986, vol. 1, 127 p.

[7] KORYACHKO, V.P., KUREICHIK, VM, NORENKOV, IP. 1987. *Theoretical Foundations of CAD*. M .: Energoatomisdat, 1987, 400 p.

[8] KORN, G., KORN, T. 1984. *Mathematical Handbook for Scientists and Engineers*. M .: Nauka, 1984, 831 p.

[9] BATISHCHEV, D.I., LVOVICH, YE, FROLOV, VN. 1997. *Optimization CAD*: Textbook. Voronezh: VSU, 1997, 416 p.

[10] MISHIN, JA. 2013. About the computer-aided design systems in wireless networks. In *Herald of the Voronezh Institute of High Technologies*. 2013, no.10, p. 153-156.

[11] MILOSHENKO, O.V. 2011. Methods for evaluating propagation characteristics in mobile radio communication systems. In *Herald of the Voronezh Institute of High Technologies*. 2011, no. 9, p. 60-62.

[12] GOLOVINOV, S.O., HROMYH, AA. 2012. Management problems of mobile communication systems. In *Herald of the Voronezh Institute of High Technologies*. 2012, no. 9, p. 13-14.

[13] LVOVICH, I.J., VORONOV, A.A. 2011. Application of methodological analysis in the safety study. In *Information and Security*. 2011, vol. 14, no. 3, p. 469-470.

[14] ERASOV, S.V. 2013. Optimising processes in the electrodynamic problems. In *Herald of the Voronezh Institute of High Technologies*. 2013, no. 10, p. 20-26.

[15] BOLUCHEVSKAYA, O.A., GORBENKO, O.N. 2013. The properties of the scattering characteristics of the evaluation methods of electromagnetic waves. In *Simulation, optimization and information technology*. 2013, no. 3, p. 4.

....

Prof. Igor Lvovich, D. Sc.
Pan-European University, Bratislava, Slovakia
office@vivt.ru

Doc. Andrew Preobrazhensky
Voronezh Institute of High Technologies
app@vivt.ru

Prof. Oleg Choporov, D. Sc.
Voronezh Institute of High Technologies
choporov_oleg@mail.ru