DOI: 10.30888/2415-7538.2018-09-1-049

УДК 621.396

EVALUATION OF THE POSSIBILITY OF USING APPROXIMATE MODELS IN THE EVALUATION OF THE AVERAGE CHARACTERISTICS OF SCATTERING OF ELECTROMAGNETIC WAVES

ОЦЕНКА ВОЗМОЖНОСТИ ИСПОЛЬЗОВАНИЯ ПРИБЛИЖЕННЫХ МОДЕЛЕЙ ПРИ ОЦЕНКЕ СРЕДНИХ ХАРАКТЕРИСТИК РАССЕЯНИЯ ЭЛЕКТРОМАГНИТНЫХ ВОЛН

Stepanchuk A.P. / Степанчук А.П.
SPIN: 6863-3305
Tcepkovskaya T.A. / Цепковская Т.А.
SPIN: 2567-8407
Voronezh Institute of High Technologies, Voronezh, Lenina73a, 394043
Воронежский институт высоких технологий, Воронеж, ул.Ленина 73а, 394043

Abstract. *The paper considers the problem of scattering of electromagnetic waves on a hollow structure. The hollow structure of simple form and complex with the final loading are considered. To characterize these structures the integral equation method is used, the integral equation is solved on the base the method of moments. The dependence of the difference average RCS of hollow structures with complex load and its model from the tilt angle of back side for various apertures is shown.*

Keywords: *hollow structure, integral equation, scattering characteristics.*

Introduction.

Modern scatterers of electromagnetic waves are characterized by the fact that they are in a very large number of cases have a complex structure. The analysis and design of such facilities must undertake to implement with the use of such models and methods, which provide a possible smaller mistakes [1, 2].

In the research and development of electrodynamic objects now more intensively computer aided design (CAD) are used. This gives you the opportunity to formulate and to solve various problems of the theory of diffraction of electromagnetic waves (EMW) in various structures with complex shapes.

When analyzing the possibilities of solving problems of diffraction of radio waves, as well as the design of facilities in some cases knowledge of the constraints on the average characteristics of the scattering is required.

In this paper, we analyze the two-dimensional model of scattering of electromagnetic waves. This is due to the fact that in large number of cases, the three-dimensional problem can be reduced to two-dimensional [3, 4].

The aim of this work to study the possibility of using approximate models to estimate the average characteristics of the scattering objects on the example of hollow organs and the development of proposals for the approximation of characteristics.

The results can be used to construct subsystems of CAD design objects with the required average characteristics of the scattering.

The technique. In currently available software systems and systems design solution is usually to split the space into cells in the numerical solution of differential or integral equations, for example, by the method of moments. But such a division does not account for the specific behavior of the currents on the surfaces (contours) of objects. The problem is solved without taking into account the possibility of dimension reduction of the resulting systems of linear equations, for example, by data to two-dimensional task, or the use of analytical solutions, a combination of several methods. All this, ultimately, significantly increases the calculation time of the characteristics of objects, as one of the main stages of design of complex diffractive structures and antennas.

When using a diffraction approach, the hollow structure is considered as a body of complex shape, in which the scattering of EMW occurs. The method of integral equations when considering hollow structures (and other objects), is a rather cumbersome method, often requiring large resources, like other numerical methods. However, if we consider structures that are bodies of revolution, the most successful is a combination of methods of integral equations and eigenfunctions. The main role is played by the angular or azimuthal coordinate of the φ. For this coordinate the required fields, as when using the method of eigenfunctions, decomposed in Fourier series, and the field of individual harmonics because of the orthogonality be independent. This allows for each azimuthal harmonic to build a relatively simple integral equation which is solved numerically. This reduces the dimensionality of the electrodynamic problem is solved and reduced requirements for the amount of machine memory and computation time of the computer.

Integral equations for one body can be generalized for a system of bodies [6, 7]. Under the integration domain and the domain of variation of the observation point in this case should be understood the surface of not one, but together bodies.

Let's consider the scattering of electromagnetic effects for two-dimensional perfectly conducting hollow structure (Fig. 1).

This structure can have complex loading (Fig. 2). To estimate the average characteristics of this structure, you can use the model shown in Fig. 1.

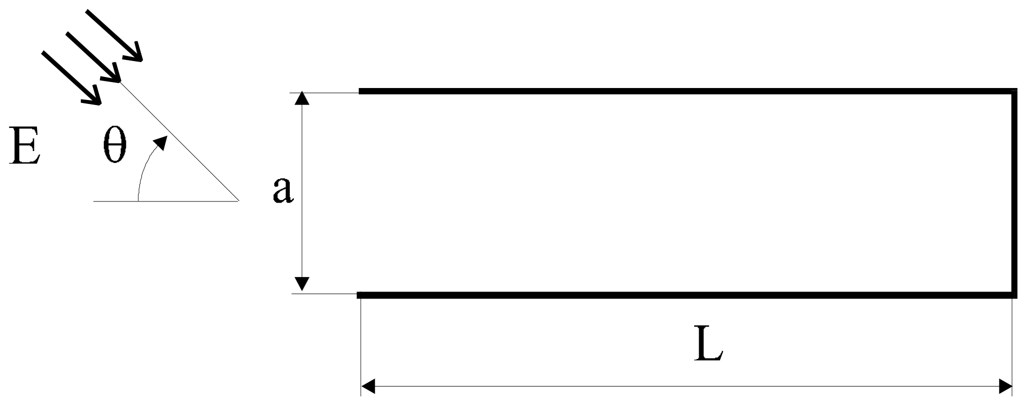

Fig. 1. – The geometry of two-dimensional hollow structure of a simple form, a is the aperture; L is the length of the structure; E is vector of the incident electromagnetic waves; θ is the angle flat EMW.

It is necessary to estimate sector angles counted from the normal to the aperture of a cavity with a complex load, which applies the model to estimate the average characteristics of the scattering. We have sought to ensure that the difference in average radar cross section (RCS) of a hollow structure with a complex load and its model did not exceed 3 dB. Integral Fredholm equation of the first kind for the

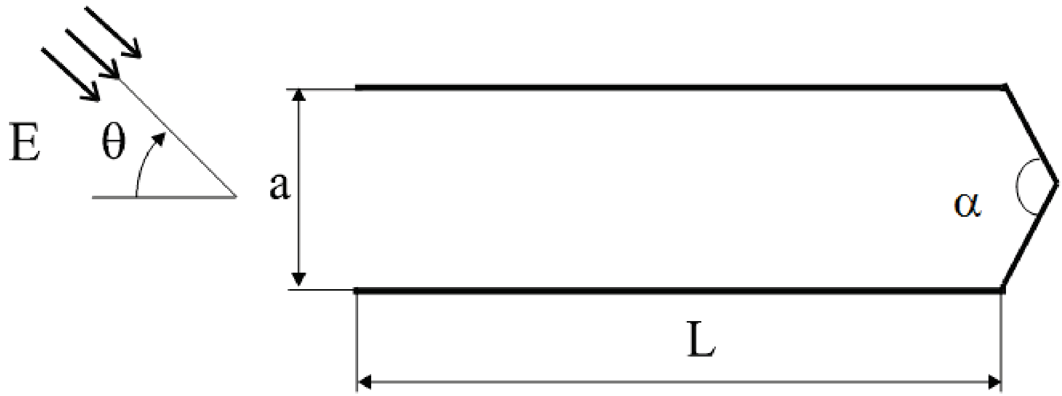

Fig. 2. – The geometry of two-dimensional hollow structure with a complex load, a – aperture; L – the length of the structure; α - the tilt angle; E is the vector of incident electromagnetic wave; θ – angle flat EMW

density of the unknown electric current in the case of E-polarization is of the form [2, 7, 8]:

$$\frac{\omega \cdot \mu}{4} \cdot \int_{\alpha}^{\beta} j(t) \cdot H_0^2 [k \cdot L_0(\tau,t)] \cdot \sqrt{\xi'^2(t) + \eta'^2(t)} dt = E_z^0(\tau),$$

$$\alpha \le \tau \le \beta, \qquad (1)$$

where $L_0(\tau,t) = \sqrt{[\xi(\tau) - \xi(t)]^2 + [\eta(\tau) - \eta(t)]^2}$ – the distance from the observation point to the point of integration, $E_z^0(\tau)$ – the longitudinal component of the tension of the primary electric field at a point on the contour. The outline structure is given in parametric form: $x = \xi(t),\ y = \eta(t),\ \alpha \le t \le \beta$, a $\xi'(t), \eta'(t)$ – the first derivatives of the corresponding functions, $k = 2 \cdot \pi / \lambda$, λ – the length of the incident electromagnetic wave.

The equation (1) was solved using the method of moments. The average RCS is calculated based on the following expression

$$\bar{\sigma} = \sum_{i=0}^{N} \frac{\sigma(\theta_i)}{N+1}, \qquad (2)$$

where $\sigma(\theta_i)$ – is the value of RCS for the viewing angle θ_i.

The results.

In Fig.3 we can see the dependence of the difference Δ medium RCS of hollow structures with complex load and its model from the angle of α. We chose the value of the length L=4λ. This value can be explained by the fact that when falling on the aperture of the cavity and further extending inside the hollow structure of the wave comes to the steady-state regime.

The dependence was approximated in the framework of the method of least squares for different values of the aperture a. The polynomial approximation was the following:

$$y(x) = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3 + ...$$

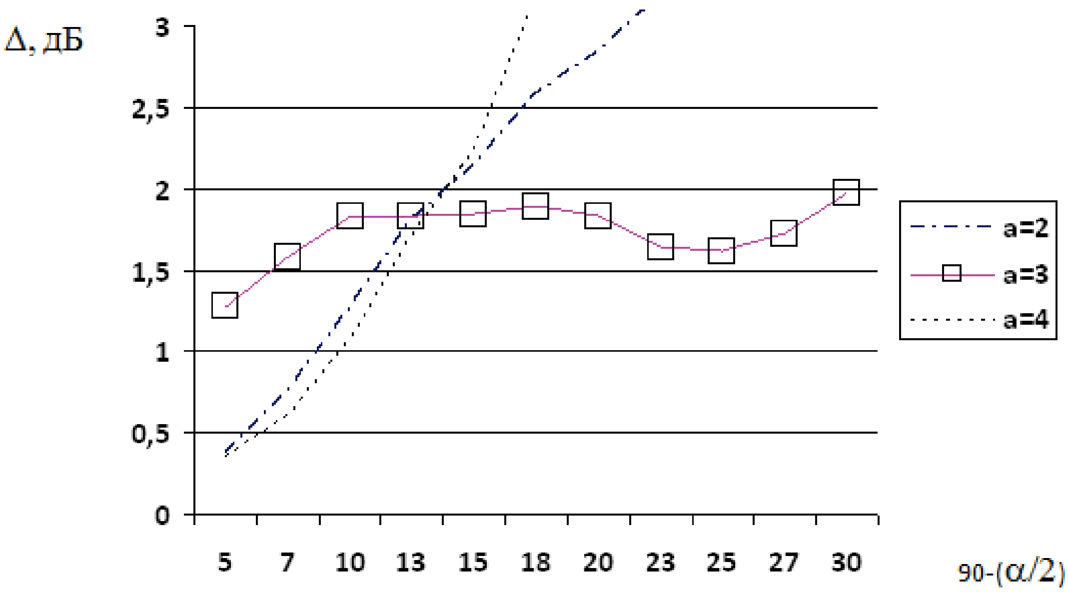

Fig. 3. – The dependence of the difference Δ average RCS of hollow structures with complex load and its model from the angle of α for various apertures a.

The coefficients of the approximation are given in table 1.

The relative approximation error did not exceed 1.5%.

The approximation coefficients can be stored in the CAD database and used in the calculations of scattering characteristics of hollow structures.

Table 1.

The values of the coefficients of the approximating polynomial

	b_0	b_1	b_2
a=2λ	-0.698	0.224	-2.377×10^{-3}
a=3λ	0.668	0.159	-5.067×10^{-3}
a=4λ	0.135	6.786×10^{-4}	9.289×10^{-3}

Conclusion. The most important direction of development of modern CAD antenna feed, microwave devices and systems and diffraction structures is the expansion of the circle of problems solved with their help objectives, as well as an increase in the number of classes and varieties analyzed (projected) electrodynamic objects. Typically, software like CAD is based on the use of universal numerical methods for solving integral equations (finite elements, Galerkin). One of the features of object-oriented CAD systems is used in these analytical methods, which are optimal for solving certain classes of problems.

Thus, the investigated approach and the results obtained can be useful in the design of objects with the specified requirements for average characteristics of the scattering.

References:

1.Preobrazhenskiy A.P. Predicting radar characteristics of objects in the wavelength band using results of measurement of scattering characteristics on discrete frequencies // Telecommunications and Radio Engineering. 2004. V. 62. № 9. pp. 843-850.

2.Preobrazhenskiy A.P. Estimation of possibilities of combined procedure for calculation of scattering cross section of two-dimensional perfectly conductive cavities // Telecommunications and Radio Engineering. 2005. Т. 63. № 3. С. 269-274.

3.Preobrazhenskiy A.P. Prediction of radar characteristics of a perfectly conducting cavity within a wavelength range // Telecommunications and Radio Engineering. 2007. V. 66. № 17. Pp. 1543-1548.

4.Lvovich I.Y., Lvovich Y.E., Preobrazhenskiy A.P., Choporov O.N. Optimization of electromagnetic scattering characteristics on the objects of complex shape based on the "ant" algorithm // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2016. Т. 7. № 5. С. 990-998.

5.Lvovich I., Preobrazhensky A., Choporov O. The development of cad of information systems and software for diffractive structures // Information Technology Applications. 2016. № 1. С. 107-116.

6.Lvovich Ya., Preobrazhensky A., Choporov O. Modeling of scattering of electromagnetic waves on the base of multialternative optimization // Information Technology Applications. 2016. № 1. С. 117-125.

7.Lvovich I., Schindler F., Preobrazhensky A. The simulation of the scattering characteristics for cavities with complex shape. Current Issues of Science and Research in the Global World - Proceedings of the International Conference on Current Issues of Science and Research in the Global World 2015. С. 271-276.

8.Lvovich I.Ya., Lvovich Ya.E., Preobrazhenskiy A.P., Choporov O.N., Sakharov Yu.S. The Use of Genetic Algorithm for Construction Objects with Necessary Average Values Scattering Characteristics // Procedia Computer Science. - Vol. 103. - 2017. - Pp. 378-383. (DOI: 10.1016/j.procs.2017.01.124).

Аннотация. *Рассмотрена задача рассеяния электромагнитных волн на полой структуре. Рассмотрены полые структуры простой формы и сложные с конечной нагрузкой. Для характеристики этих структур используется метод интегральных уравнений, интегральных уравнений на основе метода моментов. Показана зависимость разностной средней ЭПР полых конструкций со сложной нагрузкой и ее модели от угла наклона задней стенки для разных апертур.*

Ключевые слова: *полая структура, интегральное уравнение, характеристики рассеяния.*

Статья отправлена: 11.04.2018 г.