NUMERICAL IMPLEMENTATION OF TRANSFORM OPERATORS METHOD FOR COMPOSITE WAVEGUIDES IN TIME-DOMAIN

L. G. Velychko[1] and Y. K. Sirenko[1,2]

[1]*Institute of Radiophysics and Electronics, Kharkov, Ukraine*
[2] *Gebze Institute of Technology, Gebze/Kocaeli, Turkey*

We present here a numerical implementation of the method of transform operators of signal evolutionary basis, developed originally in [1], for complex waveguide structures. By way of example we consider the propagation of nonstationary signal in a plane-parallel waveguide with multiple perfectly conducting slit diaphragms.

In [1] the evolutionary basis of propagating signals uniform for all waveguide structures has been selected. This has determined a space in the framework of which one can be possible to describe the scattering features of any compact inhomogeneity in regular waveguides in terms of boundary and transport transform operators. Such operators, being a space-time analogues of generalized scattering matrix widely used in a frequency domain, allow one to study separate details of the general picture of transient processes. They simplify substantially the algorithmization of problems of growing complexity through the selection of more simple (base unit) and solved ones. By this means, in the final computational scheme, we can realize the successive progress through the time layers, which does not require inversion of any operator.

In the present communication we give the examples of numerical implementation of the method of transform operators of signal evolutionary basis for time-domain analysis of a composite plane-parallel structure with inhomogeneities in the form of perfectly conducting slit diaphragms. One possible version of a structure geometry is shown in Figure 1. The structure is excited from the left by a nonstationary signal

$$U(y,z,t) = \sum_n v_n(z,t)\mu_n(y).$$

Secondary fields in the regular regions **A**, **B**, **C**, and **D** can be represented in the form

$$U(\mathbf{A},\mathbf{B},\mathbf{C},\mathbf{D}) = \sum_n w_n^{\mathbf{A},\mathbf{B},\mathbf{C},\mathbf{D}}(z,t)\mu_n(y),$$

where $\mu_n = \left(1/\sqrt{a}\right)\sin\left(\lambda_n(y+a)\right)$ and $\lambda_n = \pi n/2a$ are eigen cross functions and eigenvalues of the regular waveguide; $\left\{w_n(z,t)\right\}_n$ is a so-called 'evolutionary

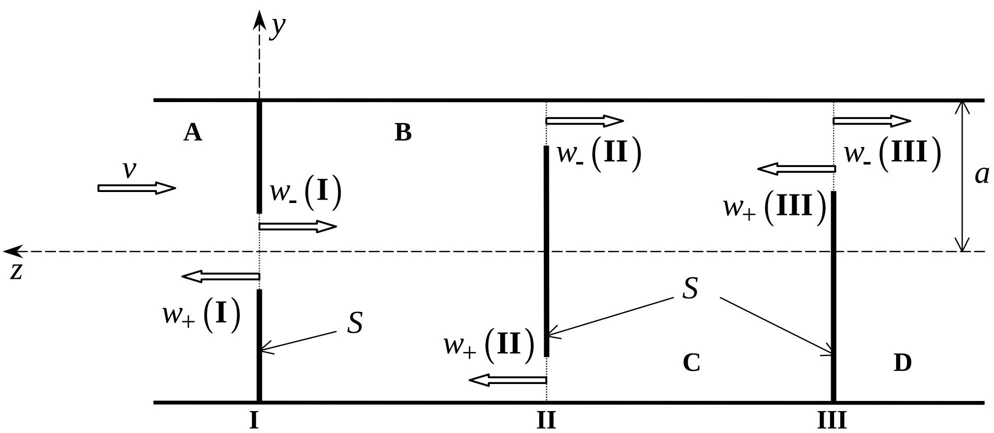

Figure 1

basis' of a nonstationary wave on finite regular sections of the guiding structure.

Following the technique developed in [1] let us introduce the evolutionary basis transform operators R^i and T^i ($i = \mathbf{I}, \mathbf{II}, \mathbf{III}$), which are space-time analogs of the reflection and transmission operators for the elementary inhomogeneities **I**, **II**, and **III**. If we regard the sets of such operators are known for simple inhomogeneities (base units), the algorithm for analyzing a composite structure composed from base units in our case is reduced to the solution of the following system of operator equations

$$\begin{cases} w'_+(\mathbf{I}) = R^{\mathbf{I}}[v] + T^{\mathbf{I}} Z^{\mathbf{B}}\left[w'_+(\mathbf{II})\right] \\ w'_-(\mathbf{I}) = T^{\mathbf{I}}[v] + R^{\mathbf{I}} Z^{\mathbf{B}}\left[w'_+(\mathbf{II})\right] \\ w'_+(\mathbf{II}) = R^{\mathbf{II}} Z^{\mathbf{B}}\left[w'_-(\mathbf{I})\right] + T^{\mathbf{II}} Z^{\mathbf{C}}\left[w'_+(\mathbf{III})\right] \\ w'_-(\mathbf{II}) = T^{\mathbf{II}} Z^{\mathbf{B}}\left[w'_-(\mathbf{I})\right] + R^{\mathbf{II}} Z^{\mathbf{C}}\left[w'_+(\mathbf{III})\right] \\ w'_+(\mathbf{III}) = R^{\mathbf{III}} Z^{\mathbf{C}}\left[w'_-(\mathbf{II})\right] \\ w'_-(\mathbf{III}) = T^{\mathbf{III}} Z^{\mathbf{C}}\left[w'_-(\mathbf{II})\right] \end{cases},$$

where $w'_\pm = \left(\partial/\partial(\pm)z\right) w(z,t)\Big|_{z\in \text{diaphragm plane}}$; $Z^{\mathbf{B}}$ and $Z^{\mathbf{C}}$ are diagonal operators describing the wave transformation when passing the finite regular sections between the diaphragms.

The elements of the transform operators for base inhomogeneities (cross diaphragms) can be calculated from the following formulas [1]:

$$R_{np}(t-\eta) = \sum_m \lambda_m I_{mn} \int_0^t J_1\left(\lambda_m (t-\tau)\right) R_{mp}(\tau-\eta)\, d\tau + \\ + I_{pn}\delta^{(1)}(t-\eta),$$

$$T_{np}(t-\eta) = R_{np}(t-\eta) - \delta_n^p v'_p(0,t),$$

$$I_{mn} = \int_{y\in S} \mu_m(y)\mu_n(y)\,dy,$$

$$v'_p(0,t) = \left(\lambda_p^2 + \partial^2/\partial t^2\right)\left[J_0\left(\lambda_p(t-\eta)\right)\chi(t-\eta)\right],$$

where J are the Bessel functions, χ is the Heaviside function, $\delta^{(1)}$ is the generalized first order derivative of the delta function, δ_n^p is the Kronecker delta, and $\eta > 0$.

The method is being realized numerically for the first time and hence the most attention is considered on its testing, efficiency, etc. Figure 2 illustrates the state of the process in hand at different instants of time.

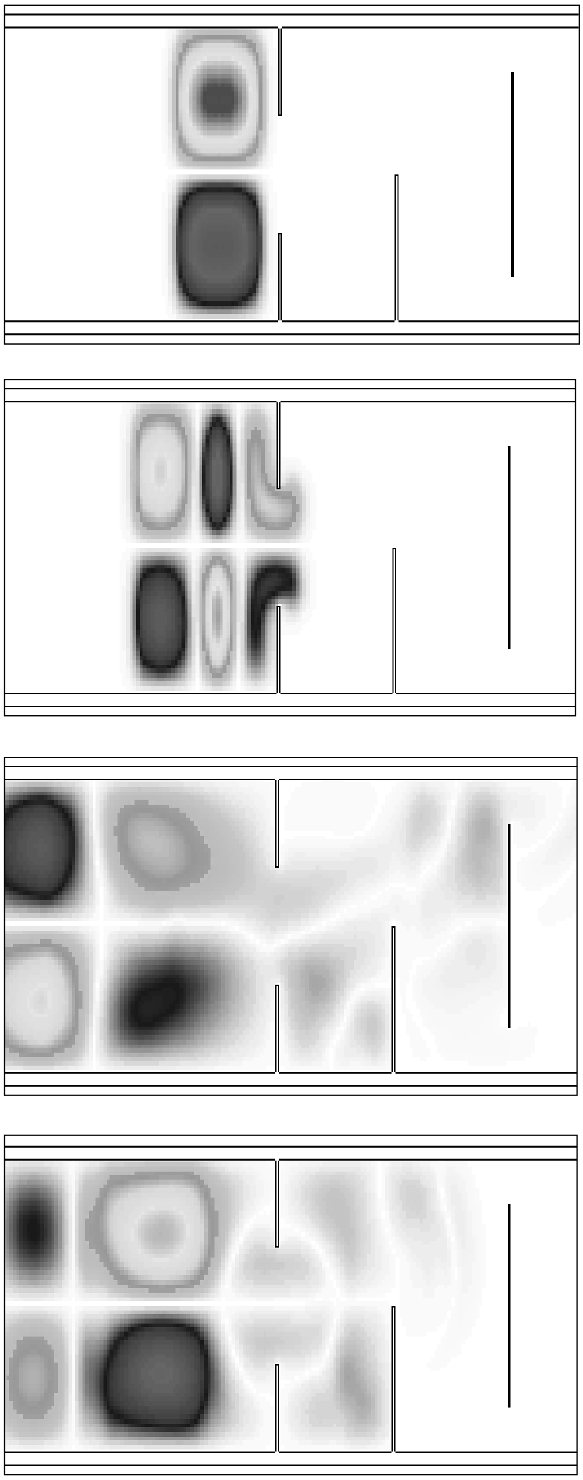

Figure 2

REFERENCES

1. Y. K. Sirenko, I. V. Sukharevsky, et al, 'Fundamental and Applied Problems in the Theory of Electromagnetic Wave Scattering', Ed. by Y. K. Sirenko, Krok, Kharkov, 2000.