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WAVE DIFFRACTION BY AXIALLY SYMMETRICAL SYSTEM OF FINITE SOFT CYLINDERS

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ABSTRACT

A new strong mathematically rigorous and numerically efficient method for solving the boundary value problem of scalar wave diffraction by a system of infinitely thin circular cylindrical screens is proposed. The method is based on a combination of Orthogonal Polynomials Method [1-2] and Analytical Regularization Method as used in [3,4,5]. The solution is generalization of the investigation done for one cylinder [6] and the method has been demonstrated on flat soft circular ring [6,7,8]. As a result of the suggested regularization procedure, the initial boundary value problem was equivalently reduced to the infinite system of the linear algebraic equations of the second kind, i.e. to an equation of the type $(I+H)x=b$, $x,\ b\in l_2$ - in the space l_2 of square summable sequences. This equation can be solved numerically by means of truncation method with, in principle, any required accuracy. Pilot experiments show good perspective of such cylindrical reflector for development of individual antenna tag for rescue radar or broadcast systems in mm waveband.

Let surface S have the following property,

$$S=\bigcup_{j=1}^{N} S_j\ ,\ S_j \cap S_{j+1}=\varnothing \qquad (1)$$

S is a system of finite circular cylinders located on z-axis defining, (Figure 1)

$$S_j=\{(z,\rho,\varphi): z\in[\zeta_j-L_j,\zeta_j+L_j],\ \rho=a_j, \varphi\in[-\pi,\pi]\},\ j=1,2,\dots,N. \qquad (2)$$

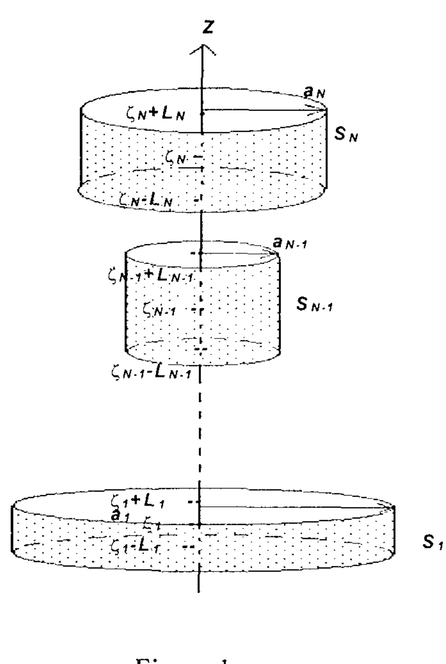

Figure 1

The following integral equation of the first kind is equivalent to the diffraction problem posed,

$$\int_S J_D(p).G(q,p)ds_p=-u^i(q);q\in S \qquad (3)$$

where, $u^i(q)$ is known incident wave, $J_D(p)$ is unknown function i.e. current density like, $J_D(p)=[d(p)]^{1/2}\ H(p)$, $p\in S$, where $H(p)$ is a smooth function on surface S , $d(p)$ is the distance to the nearest edge of a ring, $G(q,p)$ is the Green's function of free space.

The axially symmetricy of the system of obstacles leads to an infinite system of one dimensional, non-interacting integral equations of the first kind below,

$$2\pi\sum_{j=1}^{N} a_j \int_{\zeta_j-L_j}^{\zeta_j+L_j} Z_m^j(z_p) G_m^{j,l}(|z_p - z_q|) dz_p = g_m^l(z_q), \quad z_q \in [L_l, L_l], \; l = 1,2,\dots,N, \tag{4}$$

in terms of Fourier coefficients.

Proper parametrization of the variable in the equation is required to use the Fourier-Chebyshev expansions defined on the interval [-1,1]. The parametrization to reduce the points on each S_j surface to such an interval is the following:

$$z_p^j = \eta^j(v) = \zeta_j + L_j v, \qquad v \in [-1,1]; \tag{5}$$

$$z_q^l = \eta^l(u) = \zeta_l + L_l u, \qquad u \in [-1,1]. \tag{6}$$

Then we have (4) reduced to:

$$\int_{-1}^{1}\left\{-\frac{1}{\pi} ln|u-v| + K_m^{l,l}(u,v)\right\}\tilde{Z}_m^l(v)dv + \sum_{\substack{j=1\\ j\neq l}}^{N}\int_{-1}^{1}\tilde{G}_m^{j,l}(u,v)\tilde{Z}_m^j(v)dv = \tilde{g}_m^l(u);$$

$$u \in [-1,1], \; l = 1,2,\dots,N \tag{7}$$

Here $K_m^{l,l}$ are sufficiently and $\tilde{G}_m^{j,l}$ are infinitely smooth functions and it is possible to express those functions and the unknown function $\tilde{Z}_m^j(v)$ using Fourier-Chebyshev series.

Therefore the final algebraic system of the first kind that (5) will be reduced to is

$$\gamma_n^{-2} z_n^l + \sum_{s=0}^{\infty}\left[k_{ns}^{l,l} z_s^l + \sum_{\substack{j=1\\ j\neq l}}^{N} k_{ns}^{j,l} z_s^j\right] = b_n^l, \; n=0,1,2\dots \quad l=1,2,3\dots N \tag{8}$$

and will be subject to analytical regularization in the same manner done for single obstacles (as done in [6-7-8]), easily by introducing new variables $\hat{z}_n^l = z_n^l/\gamma_n$ and multiplying each term in (8) by γ_q. Here, $\gamma_0 = (\ln 2)^{-1/2}$; $\gamma_n = |n|^{1/2}$, $n \neq 0$, for every $m=0,\pm 1,\pm 2,\pm 3\dots$ z_n^l and z_n^j are the Fourier - Chebyshev coefficients of the unknown function, b_n^l is Fourier - Chebyshev coefficients of the excitation term, $k_{ns}^{j,l}$ *and* $k_{ns}^{l,l}$ are Fourier - Chebyshev coefficients of the smooth kernels in (7).
Numerical results of the system $ka_1=2$, $ka_2=6$, $ka_3=10$, $kL_1=kL_2=kL_3=4$ in case of a normally incident plane wave, are following. In figure 4 the approximate locations of the surfaces are indicated.

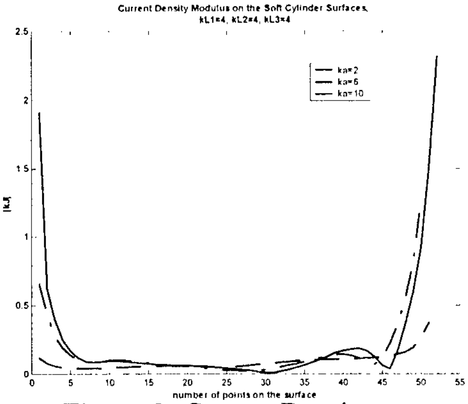

Figure 2: Current Density

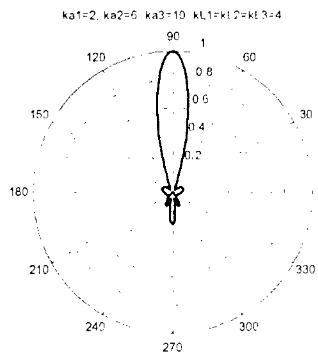

Figure 3: Far Field

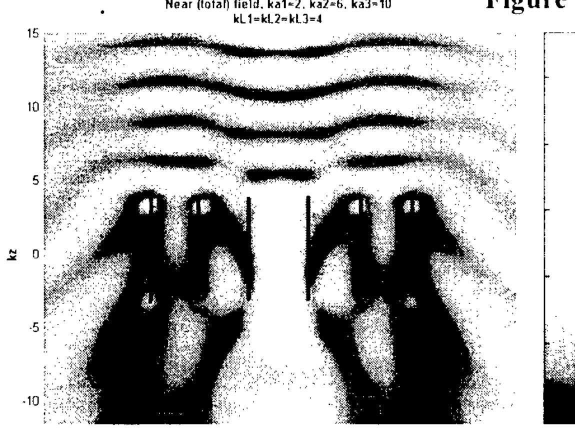

Figure 4: Near Field

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