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Diffraction of Impulse Sound Signals on Spheroidal Body, Put in Plane Waveguide

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Abstract With the help of the Fourier transform and characteristics of the stationary (continuos) sound signal are calculated the impulses, scattered by the ideal spheroid, placed in the waveguide. In the first part of the paper is presented the method of the imaginary sources and imaginary scatterers from the solution of the problem of the sound diffraction on the spheroidal body, put in the plane waveguide. In the second part of the paper are calculated the impulse signals with different filling, scattered by the the ideal soft spheroid, placed in the plane waveguide.

Keywords Diffraction, Waveguide, Impuls, Spheroidal Body, Source, Scatterer, Imaginary

1. Introduction

At the basis of the method of the imaginary sources and imaginary scatterers is calculated the pulse sequence, got from the spheroidal scatterer, accommodated in the plane waveguide with the ideal boundary conditions. The impulse signals put the energy, therefore they are propagating with the group velocity (as and the energy), which lie in the principles of the method of the imaginary sources and imaginary scatterers.

2. The Method of the Imaginary Sources and Imaginary Scatterers for the Spheroidal Body, Put in the Plane Waveguide

The scattering of sound by the bodies, placed in the waveguide, are investigated in the papers[1] –[9]. In thepaper[1] were calculated the spectral characteristics of the idial spheroid, placed in the sound channel, by the impulse irradiation; in the papers[8] and[9] with the help of the method of the imaginary sources and scatterers are found the vertical distributions of the scattered sound field of the ideal soft spheroid, placed in the plane waveguide, at the irradiation his by the harmonic signal. In the present paper are investigated and calculated the impulse signals with the different filling.

Let's put the ideal soft spheroid into the liquid layer with the thickness H and the constant sound velocity. At the upper boundary of the waveguide is fulfilled Dirichlet condition, at the lower boundary – Neimann condition. The axis of the rotation of the prolate spheroid will be orientated parallel to the boundaries of the waveguide and perpendicular to the plane of the figure 1.

The dimensions of the scatterer, distance from it to the boundaries and the thickness of the waveguide H are supposed to be such that we can do without taking into consideration the scattering of the second order of the waves reflected from the boundaries of waveguide are not taken into account in the further process of the diffraction.

The centre of the scatterer is fixed on axis X at the distance 200 m. from the bottom, at the horizontal distance L from it and on the axis X (Figure 1) is placed the point-source 01 of the impulse sound signal. Using the method of the imaginary sources and scatterers[8. 9], are found the scattered impulse signal in the point 0. The sound impulse signals were the two appearance: with the harmonic and frequency-modulated filling. In the point 0 arrive the signals from everybody scatterers and everybody sources.

The spectrum $S_0(2\pi\nu)$ of the sound impulse of the source $\Psi_i(t)$ with the harmonic filling has the appearance[10] :

$$S_0(2\pi\nu)=\frac{i\nu_0}{\pi(\nu_0^2-\nu^2)}(-1)^n\sin(\pi n\frac{\nu}{\nu_0}), \quad (1)$$

where: ν_0 – the frequency of the filling of the impulse; n – the number of the oscillation periods of the harmonic signal in the impulse; ν – the circular frequency.

The normalized impulse $\Psi_i(t)$ and the modulus of his spectrum $|S_0(\nu)|$ are presented at Figure 2.

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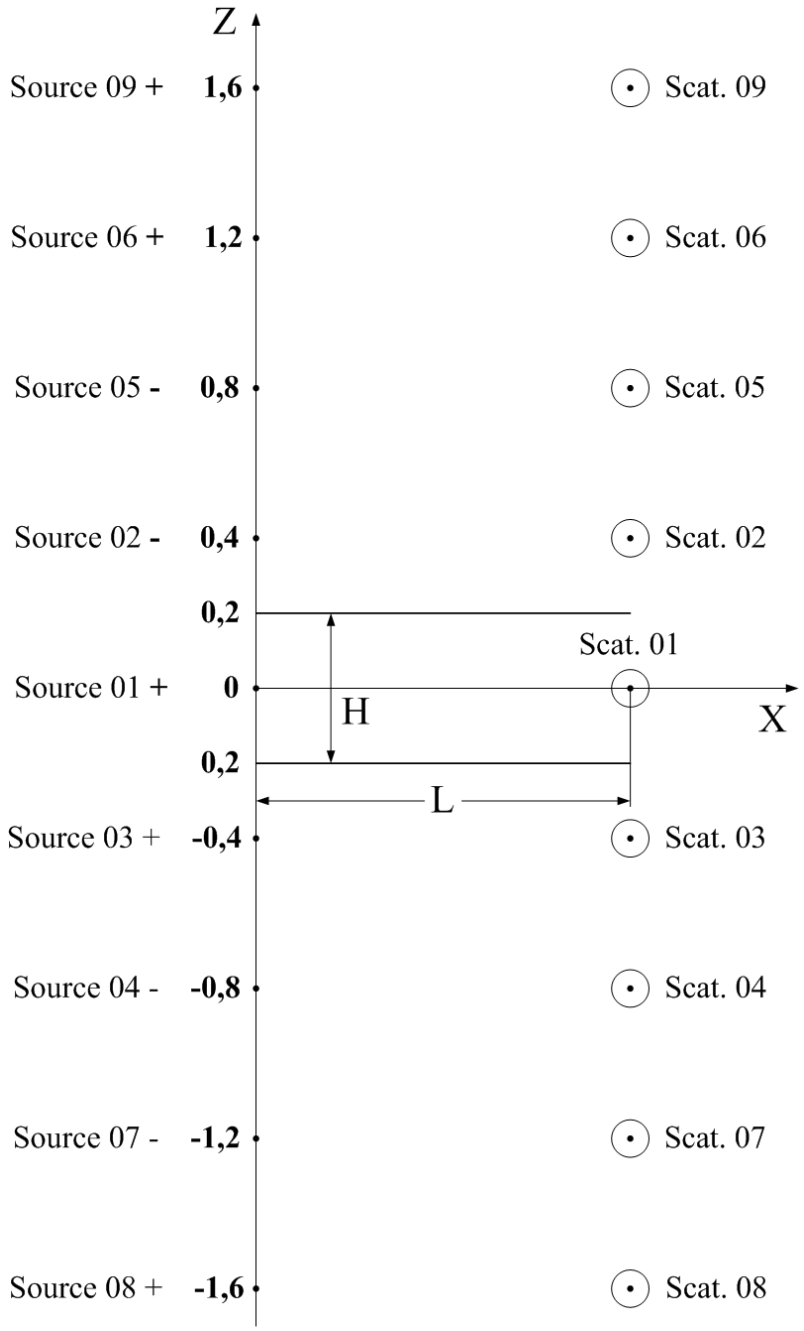

Figure 1. The mutual disposition of the impulse point-soirces and scatterers in the plane waveguide

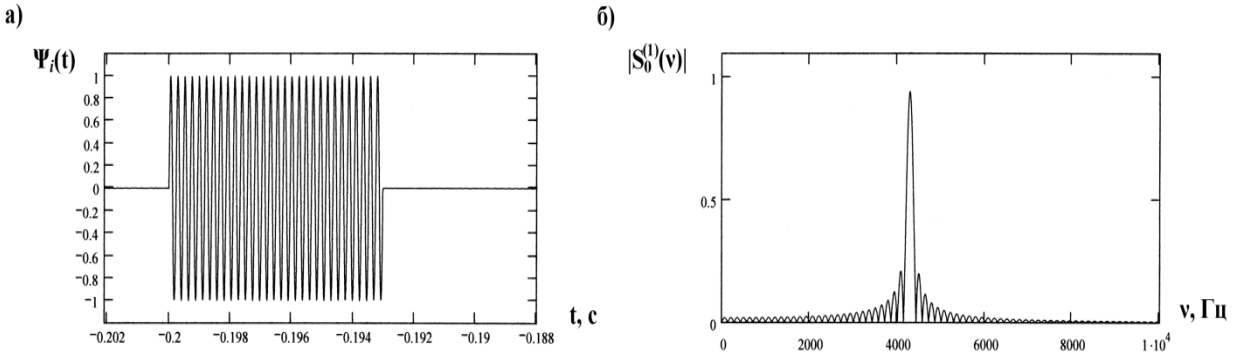

Figure 2. a) the falling impulse $\Psi_i(t)$ with the harmonic filling; b) the modulus of the spectrum $|S_0(\nu)|$ of the impulse $\Psi_i(t)$

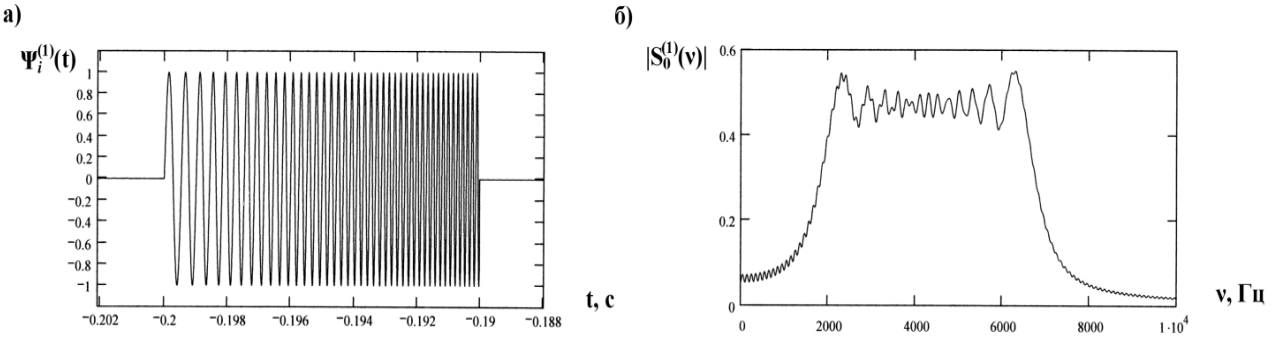

Figure 3. a) the falling frequency-modulated impulse $\Psi_i^{(1)}(t)$; b) the modulus of the spectrum $\left|S_0^{(1)}(\nu)\right|$ of the impulse $\Psi_i^{(1)}(t)$

The spectrum $S_0(2\pi\nu)$ is connected with $\Psi_i(t)$ by the return Fourier transform:

$$\Psi_i(t) = (\pi)^{-1}\,\mathrm{Re}\int_0^{\infty} S_0(2\pi\nu)\exp(+i2\pi\nu)d(2\pi\nu) \tag{2}$$

The spectrum of the reflected signal $S_s(2\pi\nu)$ is by the product of the spectrum $S_0(2\pi\nu)$ at the corresponding meanings of the angular characteristic of the scattering of the soft spheroid $D(\eta,\varphi,\nu)$ (η and φ – the angular coordinates of the point of the observation).

The angular characteristic of soft spheroid $D(\eta,\varphi,\nu)$ had calculated by the formula[8]:

$$D(\eta,\varphi,\nu) = -(2/ik)\sum_{m=0}^{\infty}\sum_{n\geq m}^{\infty}(-1)^n\varepsilon_m\overline{S}_{m,n}(C,\eta_0)\overline{S}_{m,n}(C,\eta)\cos m\varphi\frac{R_{m,n}^{(1)}(C,\xi_0)}{R_{m,n}^{(3)}(C,\xi_0)}, \tag{3}$$

where: $C = kh_0$ – the wave dimension, k – the wave number in liquid, h_0 – the half – focal distance; $\overline{S}_{m,n}(C,\eta)$ – the normalized angular spheroidal function; $R_{m,n}^{(1)}(C,\xi_0)$ and $R_{m,n}^{(3)}(C,\xi_0)$ – the radial spheroidal functions of the first and third forms correspondingly; $\varepsilon_m = 1(m=0), 2(m\neq 0)$; ξ_0 – the radial coordinate of the scatterer; η_0 – the angular coordinate of the source.

The falling impulse with the frequency-modulated filling $\Psi_i^{(1)}(t)$ has the appearance[10]:

$$\Psi_i^{(1)}(t) = \sin[(2\pi\nu_0 + at)t]dt, \tag{4}$$

where: a determines the velocity of the change of the frequency inside the impulse.

The spectrum $S_0^{(1)}(2\pi\nu)$ of the falling impulse with the frequency-modulated filling is found with the help of the Fourier transform for the function $\Psi_i^{(1)}(t)$ [10]:

$$S_0^{(1)}(2\pi\nu) = \int_{\frac{-nT}{2}}^{\frac{+nT}{2}}\exp(-i2\pi\nu)\sin[(2\pi\nu_0 + at)t]dt, \tag{5}$$

Second the frequency ν_0 in the impulse.

The impulse $\Psi_i^{(1)}(t)$ and the modulus of his spectrum $\left|S_0^{(1)}(\nu)\right|$ are presented at Figure 3.

3. Calculation of the Pulse Sequence, Got from Spheroidal Scatterer

By the chosen orientation of the scatterer his angular characteristic $D(\eta,\varphi,\nu)$ is found oneself by "isotropic" in the correlation from the angle φ in the chosen range of the wave dimensions of the spheroid C ($C = 2\pi h_0/\lambda$, where h_0 - the half – focal distance of the spheroid, λ - the length of the sound wave in the liquid)[1, 8]. We map into the source 01 and the scatterer 01 relatively of the boundaries of the waveguide like this, in order that we had 9 the imaginary sources and 9 the imaginary scatterers. The formulas for the calculation of the angular characteristics of the spheroid $D(\eta,\varphi,\nu)$ are given in[11 – 15, 1, 8]. For the chosen system of the sources and scatterers we will calculate the series of the reflected impulses in the point 0. The distance *L* between the source 01 and the scatterer 01 we accept equal 1000 m., H – 400 m., the correlation of the half-axises of the spheroid is equally 10, but his half-focal distance is equally 0,2777 m. At Figure 4 and 5 are presented the normalized series of first three reflected impulses with the harmonic filling $\Psi_s(t)$ (Figure 4) and the frequency-modulated impulses $\Psi_s^{(1)}(t)$ (Figure 5).

Number of the imaginary sources and scatterers are appeared the another impulses, coming in the point 0 noticeable latest.

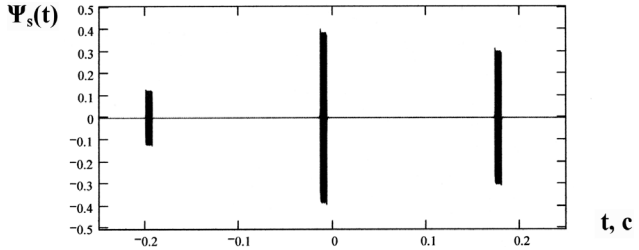

Figure 4. The normalized series of first three reflected impulses with the harmonic filling in the point 0

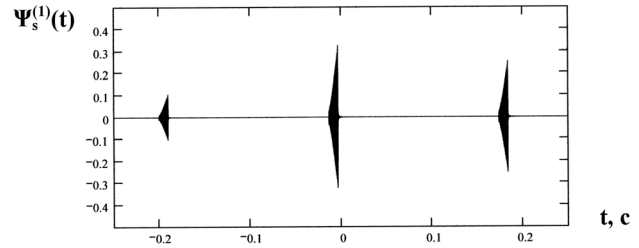

Figure 5. The normalized series of first three reflected frequency-modulated impulses in the point 0

4. Conclusions

In the paper is shown the effectiveness of the method of the imaginary sources and imaginary scatterers for the pulse sequence, got from spheroidal body and based at the use of the group velocity of the sound. The calculations of the scattered impulse signals with the different filling were done with the help of the Fourier transform and the characteristics of the scattering of the stationary (continuos) sound signal.

The applied interest is concluding in the detection of the underwater object in the small sea.

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