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MODELING OF LOCATION SENSING CONSIDERING DIFFRACTION EFFECT

We propose a method of acoustic wave propagation modeling in monostatic sounding systems, with taking into account the effect of diffraction. Location sounding images of farther objects are distorted by diffraction on near objects. The diffraction effects are considered in Kirchhoff's approximation.

Ключевые слова: *acoustic tomography, diffraction, Helmholtz equation, locating sensing.*

Introduction

The problem of acoustic sensing is often the problem of calculating the diffraction field on objects of arbitrary shape [1-2]. It is necessary to find methods of rapid numerical modeling of large volumes of heterogeneous acoustic media. The method of finite difference time-domain solutions for the wave equation is rather universal. [3], but demanding to computing requirements. The method of final elements [4] applied to modeling of monochromatic fields has similar disadvantages. In modeling of the location multiposition sounding systems it is necessary a complete simulation of wave propagation for each of the provisions of the transmitter and receiver, that increases the computation time per several thousand times.

Let us consider the case of monostatic multiposition sensing. In this case for modeling acceleration the theorem of reciprocity is proposed . The theorem allows to calculate a field only in the direction of the disseminating object, taking into consideration that the backscattered field passes on a similar trajectory. It is proposed to solve a diffraction problem in frequency area on the basis of a field presentation in a range of flat waves and Kirchhoff's approximation.

Statement of the problem and the mathematical model.

Let us consider the location-sensing circuit of inhomogeneous medium (Fig. 1). In the environment there are many scattering objects of arbitrary shape, impermeable acoustic waves.

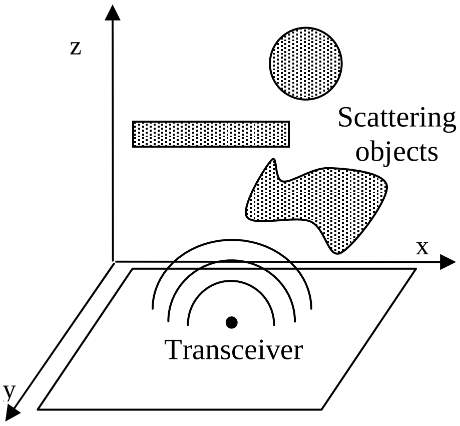

Fig.1. Scheme of measurements

We consider that the radiator is a dot isotropic source and moves together with the receiver on the XOY plane. As sounding is monostatic (the radiator and the receiver are combined), then according to the theorem of reciprocity, the phase ways passed by a wave from a radiator to the lens and from the lens to the receiver coincide. Therefore, for modeling of a phase of a wave it is enough to calculate a field from the lens to the receiver at the doubled frequency. The exact value of the waves amplitude can be neglected, as for radar sensing in the far zone of greatest interest is the phase of the wave. Therefore when modeling monostatic locational sounding we will replace all lenses of the environment on equivalent inphase isotropic radiators working at the doubled frequency. At the same time objects don't pass acoustic waves, and a diffraction of waves appears on these objects. We define the distribution of objects in the form of a function which $M(x,y,z)$ equals 1 where the object is, and equals zero where the medium is homogeneous. We will divide medium into thin horizontal layers much less than a wavelength thick. Field of each layer we will describe passing through a range of flat waves, and we will consider influence of barriers in Kirchhoff's approximation. The field of equivalent sources will be calculated iteratively from layer to layer from the farthest object in the direction of the plane of the measurement:

$$U(x,y,z-\Delta z)=(1-M(x,y,z-\Delta z))\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\tilde{U}(k_x,k_y,z)\exp(ixk_x+iyk_y+i\Delta z k_z)dk_x dk_y\,, \qquad (1)$$

where $\widetilde{U}(k_x,k_y,z)=\frac{1}{4\pi^2}\int\limits_{-\infty}^{+\infty}\int\limits_{-\infty}^{+\infty}(U(x,y,z)+M(x,y,z))\exp(-ixk_x-iyk_y)dxdy$ – spectrum of plane waves field equivalent source at a distance z; $k_z=\sqrt{(2k)^2-k_x{}^2-k_y{}^2}$ – the vertical component of wave vector at the doubled frequency; Δz – the thickness of the layers.

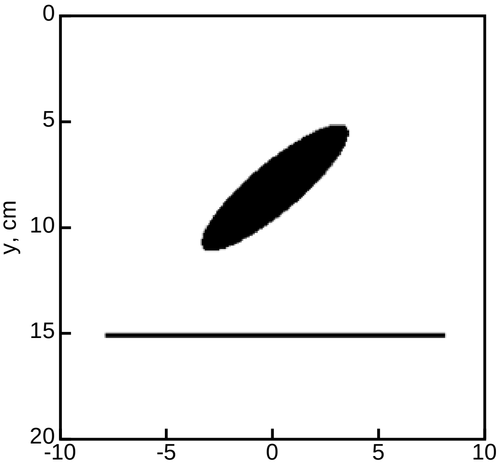

Fig.2. Modeling object

According to the offered mathematical model the numerical modeling locational sounding of objects presented in fig. 2 at frequency from 20 – 40kgts was carried out.

In fig. 3 the result of a field modeling of equivalent sources is presented. It is possible to observe effect of diffraction on elliptic object. The field disseminated on a horizontal plate experiences distortions owing to what it is possible to expect incorrect restored images of distant object. At the height $z=0$ of the amplitude and phase of the recorded field in a wide frequency band is registered. Lets restore the three-dimensional scattered image of objects by means of a Stolt migration method [5]:

$$P(x,y,z)=\frac{1}{(2\pi)^3}\int\limits_{-\infty}^{+\infty}\int\limits_{-\infty}^{+\infty}\int\limits_{-\infty}^{+\infty}\widetilde{P}(k_x,k_y,k_z)\exp(ixk_x+iyk_y+izk_z)dk_xdk_ydk_z\ , \qquad (1)$$

where $\widetilde{P}(k_x,k_y,k_z)=\widetilde{U}\left(k_x,k_y,z=0,\omega=\frac{c}{2}\sqrt{k_x{}^2+k_y{}^2+k_z{}^2}\right)$ – three-dimensional spatial range of equivalent sources at the doubled frequency; $\widetilde{U}(k_x,k_y,z=0,\omega)$ –; range of flat waves of equivalent sources in area of measurements at a frequency ω.

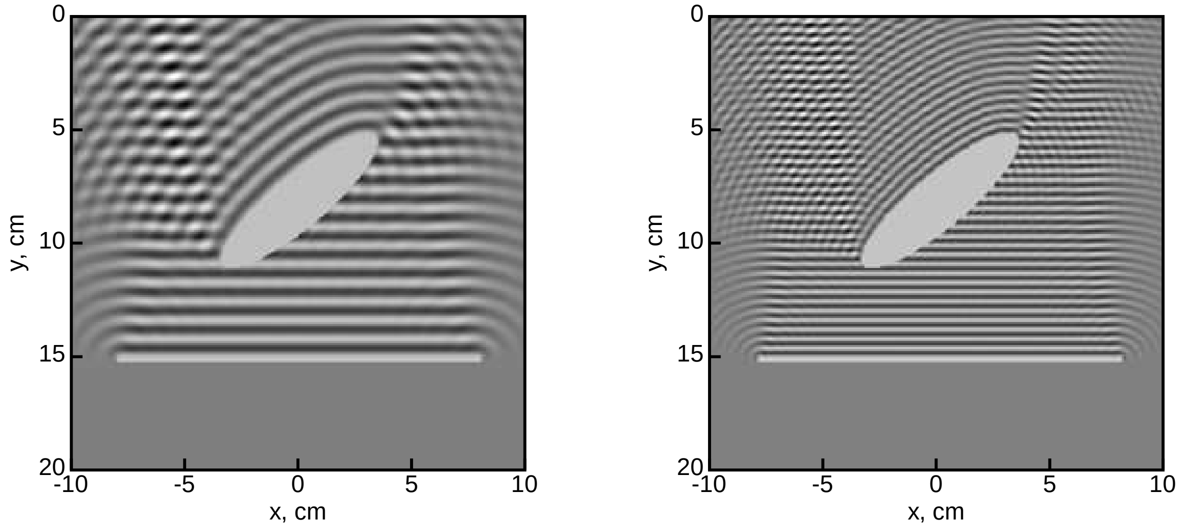

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Fig. 3. Result modeling of a field of equivalent sources at a frequency (and – 20 kHz, – 40 kHz)

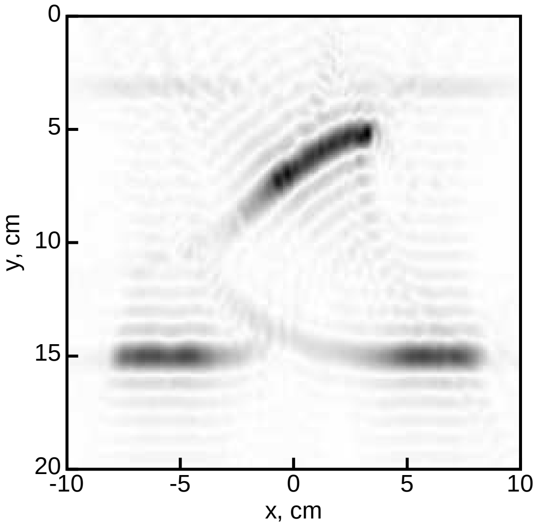

Fig. 4. The reconstructed image of the scattering object.

The restored image of the scattering heterogeneities is submitted in fig. 4. The upper part of the elliptical object restored facing in the direction of the field measurements. Far object has a substantial distortions caused by partial shading and diffraction effects on near objects.

Conclusion

The method of modeling the locational sounding acoustic systems with taking into account the effect of diffraction on objects arbitrary shape is proposed. This method allows us to speed up the process of calculating the results of multiposition monostatic locational sounding.

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МОДЕЛИРОВАНИЕ ЛОКАЦИОННОГО СПОСОБА ЗОНДИРОВАНИЯ С УЧЁТОМ ЭФФЕКТА ДИФРАКЦИИ

Предлагается метод моделирования распространения акустических волн в моностатических локационных зондирующих системах с учётом эффекта дифракции. При локационном зондировании дифракция на ближних объектах возникают искажения изображений объектов расположенных дальше. Эффекты дифракции учитываются в приближении Кирхгофа.

Ключевые слова: *акустическая томография, дифракция, уравнение Гельмгольца, локационное зондирование.*

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