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LINEAR HYDROACOUSTIC ARRAYS IN UNDERWATER CURRENTS: MATHEMATICAL MODELS AND OPTIMIZATION

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Hydromechanical and acoustical characteristics of mooring and drifting linear hydroacoustic arrays in underwater currents are discussed. Linear arrays are considered as nonuniform systems consisted of a flexible cable and a number of hydrophones. Algorythms for the calculation of characteristics of arrays are proposed. It is shown that usual types of arrays with length up to 400 m can be stabilized in currents with velocities up to 0,4-0,5 m/sec by hydromechanical methods. The problem of determination of parameters of water and bottom in a shallow sea is considered. An optimization of geometry and working frequency is necessary to decrease an influence of underwater currents.

In many problems of the ocean acoustics (e.g. in the acoustic tomography, the geoacoustical inversion, or in measurements of the vertical directivity of the ocean noise) a spatial stability of the acoustic array is a usual requrement to the measuring system. Underwater currents are the main reason of the spatial unstability of arrays.

The unstability of arrays in underwater currents occurs due to hydrodynamic forces and gravity of the flexible cable. The most simple way to increase the stability of array is an optimization of its hydromechanical parameters. A hydromechanical optimization gives a possibility to avoid a use of complicated underwater acoustic positioning systems, systems of inclinometers for arrays or special algorythms of signal processing, which require a use of multi-frequency signals. A hydromechanical optimization is the most reliable method to increase the spatial stability of arrays in non-uniform flow field.

Almost all underwater currents in the sea have a three-dimensional (3D) non-uniform flow field. For this reason the 3D-problem is considered in this work (in application to the Ekman models of ocean currents [1]). Main features of 3D-models of Ekman's boundary layers are known to be confirmed by oceanolographic experiments [1].

A linear hydroacoustic array usually consists of a flexible cable with several hydrophones. The lower point of mooring array is fixed on the bottom; the upper point of it is connected to the submerged buoy. The upper point of drifting array is connected to the surface buoy, its lower point is connected to the load (e.g., battery).

Algorythms for the calculation of the equilibrium of the array are based on the finite element method (the array is devided into several rigid finite elements), Newton's method for non-linear equations (the orientation of each finite element can be determined with the help of non-linear equation for the single angular variable quantity), and the 'step-by-step' method, that gives a possibility to take a non-uniformity of the current into account. A scheme of the algoruthm was considered in details in [2]. Algorythms can be used either for mooring or for drifting arrays.

An examples of the equilibrium configuration of the mooring linear array in the bottom Ekman layer are presented on Fig.1 (for different velocities of the current).

All calculated configurations of arrays are 3-dimensional curves, and forms of the array in the current are not plane. When the current velocity increases, the axial symmetry of the directivity pattern is lost. Maximum distortions of the directivity pattern were observed in the vertical plane.

The algorythm mentioned above can be used not only for mooring arrays but for drifting arrays as well. For drifting arrays an aerodynamical force on the surface buoy caused by wind was calculated additionally, and this force was taken into account in the boundary condition for the upper point of the cable. Calculations for Ekman wind currents showed that the direction of the array drift usually does not coincide with directions of the wind and the current.

The spatial stabilization of arrays can be achieved by hydromechanical methods, such as the increasing of a volume of the buoy, decreasing of the cable diameter and density of the cable, and use of faired cables. The problem of optimization is considered to be solved if the dispersion of the acoustical characteristics caused by currents is equal to the dispersion caused by hydroacoustic

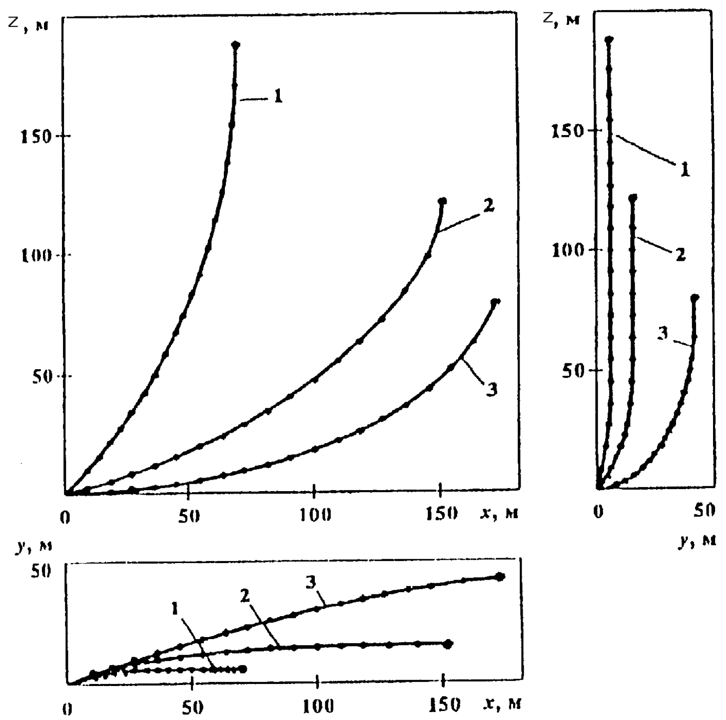

Fig.1. Projections of the linear array in the bottom layer of the Ekman gradient current for velocities v=0,5 m/sec (line 1); 1,0 m/sec (line 2); 1,5 m/sec (line 3)

transducers and electronic equipment. Fig.2 represents optimum diameters of buoy versus current velocity for different diameters of the cable of the array.

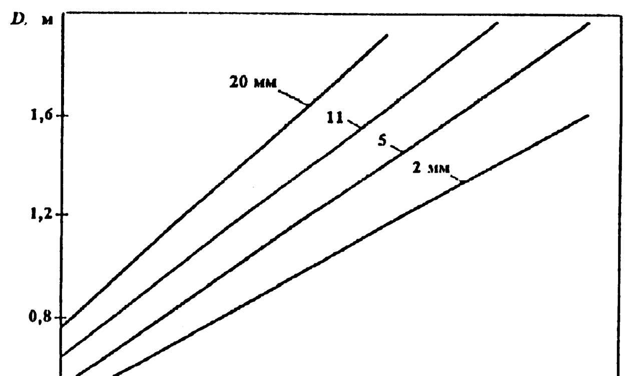

Fig.2. *Optimum diameters of buoy versus current velocity for different diameters of the cable (mooring array, the bottom layer of the Ekman gradient current)*

Vibration of the flexible cable caused by vortexes can be decreased or eliminated by use of faired cables [3]. The hydrodynamic forces on faired cables are much lower compared with bare cables.

Calculations show that usual types of linear arrays having a length up to 400 m can be stabilized by hydromechanical methods for current velocities up to 0,4-0,5 m/sec.

Additional possibilities to decrease an influence of underwater currents in some hydroacoustical problems (such as geoacoustical inversion) consist in the optimization of the geometry and frequency of hydroacoustical system. Calculations show that the optimum depth of the sound source gives a possibility to increase the admitted range of current velocities. The optimum depth of the source is determined by conditions for the generation of normal waves (modes) of higher orders. The optimum frequency is connected with the number of normal waves which can propagate in the waveguide. For instance, if the source is located at the optimum depth, and the optimum frequency is used, the array having length 600 m can determine the sound velocities and densities of water and bottom by means of MFP-method (matched field processing method) in currents with velocities up to 0,45 m/sec.

R E F E R E N C E S

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