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EXCITATION OF LATERAL WAVES BY PARAMETRIC ACOUSTIC ARRAY IN SHALLOW WATER

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In this work the results of a laboratory experiments for nonlinear excitation of seismic waves in hydroacoustic waveguides are described. Under model conditions the influence of lateral waves of various types on the interference structure of near acoustics fields of a waveguide was investigated. The use of highly directed radiation produced by a parametric antenna allows us to selectively excite not only propagating modes of the waveguide, but also lateral modes produced by seismic (longitudinal and transverse) waves, propagating in an underlying ground.

The frequencies, which are used in underwater acoustics, dispose in the range from 1 Hz to kHz and the distance in the range from 10 to several thousand kilometers. Under these conditions the influence of the ocean bottom on propagation of the signals is not limited by the absorption of the acoustic energy. The bottom is often a medium, where longitudinal, transverse and surface waves propagate. That's why the bottom directly influences on the formation of the acoustic in water layer [1]. Under real conditions the speed of seismic waves, as a rule, is more the speed of sound waves in water layer, and it changes from 1540 m/s in the upper sediment layers to 5700 m/s in rock grounds [2]. That's why the propagation of elastic oscillations in the ground and their secondary radiation into the water layer lead to arising of the lateral waves. Which greatly influence on the formation of near acoustic field in waveguides.

The influence of lateral waves on the formation of the spatial interference structure of the acoustic field in shallow water is investigated in detail by analytical and numerical methods [3-5]. In works [6, 7] shows that the experimental space – frequency interference structure of broadband sound at low frequencies (below critical frequency of the first mode) is a result of an interference of zero mode and the shear wave. However, in this works the bottom of shallow sea modeled by the liquid space. Under real conditions [8, 9] not only longitudinal waves, but shear waves influences for the interference structure of an acoustic field in waveguide. Investigation of the contribution of lateral waves to the interference structure of a sound field in shallow water makes it possible to determine the geoacoustic parameters of the ocean bottom. In work [10] the sound speeds in sediment layers are experimentally determined.

At the first the opportunity of using the parametric acoustic array for profilation of bottom and bottom layers was taken into the consideration in 1968 [11]. The parametric acoustic array possesses all the qualities that are necessary for this task, to be more exact: high directivity on the law frequency and the small sizes what allows using it on the small oceanography ships. Also in this work mentioned the possibility of using the parametric acoustic array in archeology research.

Let us note, however, that until now investigation of the characteristics of seismic waves and their influence on interference structure of acoustic fields in waveguides was carried out with the use of either explosives [3, 10] or linear point sources [6]. This makes it impossible to independently take into account the influence of lateral waves of various kinds on the resulting acoustic field in the point of reception because such sources excite the full spectrum of the propagating and lateral waves. It is expedient to use highly directed sound sources to carry out correct experimental studies of the influence of lateral waves on the acoustic field in few-mode waveguides.

In this work for the first time highly directed radiation from an acoustic parametric array in a waveguide with an elastic bottom was used to generate seismic waves in the bottom. The use of this type of radiators allowed us to selectively excite bottom waves of various kinds. Due to this fact the partial contribution of lateral waves to the resulting acoustic field was accounted for.

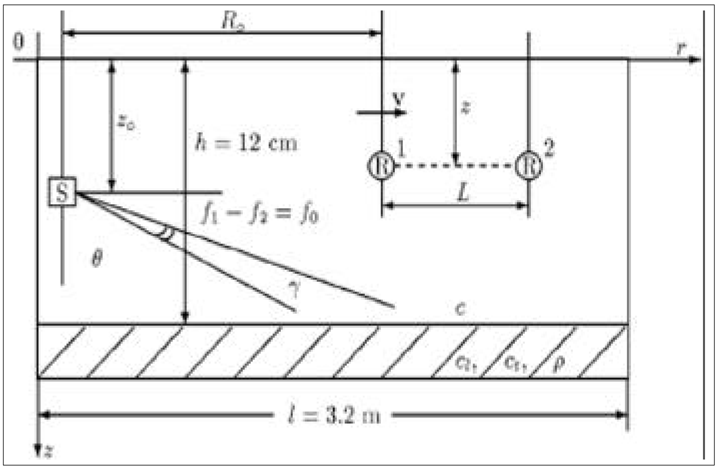

Fig. 1.

The experimental studies of the acoustic fields in homogeneous waveguides were carried out in a water tank where the bottom was hanging on rods with variable height. In figure 1 shows the geometry of the experimental setup. The length of the waveguide was 3.2 m. The thickness of the water layer as the same in all experiments and was equal to 12 cm. The sound speed in water was c_0=1475 m/s. The bottom was modeled by a sheet of steel 10 mm thick. The acoustic parameters of the steel were the following: the speed of longitudinal waves c_l = 5680 – 6100 m/s, the same speed in a thin steel rod c_l^* = 4900 – 5200 m/s, the speed of transverse waves c_t = 2300 – 3100 m/s, the density ρ = 7.76 ã/ñì^3. The main parameters of the radiated pulsed signal were the frequencies of the pumping waves f_1 = 3 MHz and f_2 = 3.2 MHz. To optimize excitation of seismic waves, the radiation axis of the parametric array was oriented in the vertical plane at the angle of full internal reflection caused by existence of seismic waves of different kinds in the bottom layers studied. These angles were defined by the speed of longitudinal and transverse waves in the bottom. They were equal to θ_1 = 14° for longitudinal waves in the steel and of the order of θ_2 = 30° for the transverse waves.

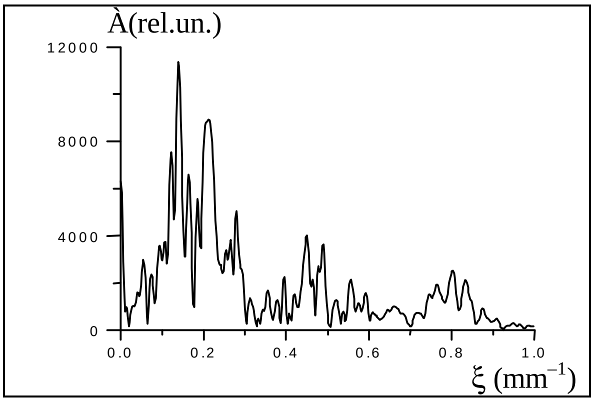

Fig. 2.

In this study a "hybrid" of normal mode selection was used [12]. This method combines the methods of mode selection with respect to the group and phase velocities. The complex amplitude readings were made using a receiver uniformly moving along the waveguide. The obtained information about the interference structure in the region of the "forerunner" allowed us to investigate the spatial spectra of the signal received in waveguide with an elastic bottom.

In fig. 2 the spatial spectrum of the "forerunner" signal in the waveguide with the steel bottom excited by a linear point source of sound is presented. Lateral waves excited by seismic waves of all types – longitudinal waves in the bottom (the range of horizontal wave number is ξ_l = 0.15 – 0.35 mm^{-1}) and transverse waves including surface waves of Rayleigh type (the range of horizontal wave number is ξ_t = 0.45 – 0.53 mm^{-1}) – are presented in the spectrum.

The unique capability of the parametric array to selectively excite different types of seismic waves due to its narrow directivity pattern is demonstrated in fig. 3. In this figure the results of spectral processing of the signal received in the waveguide with the a steel bottom are presented as a function of the angle of inclination of the radiation axis of the parametric array. At the angle of inclination of the radiation axis θ_1 = 14° the best conditions for excitation of longitudinal seismic waves were created (figure 3). Increasing the angle of inclination up to θ_2 = 30° was optimal for excitation of transverse seismic waves, while the lateral waves excited by longitudinal seismic waves were nearly absent in the spectrum of the received signal (figure 4). These results convincingly illustrate the capabilities of the acoustic parametric array to selectively excite different types of lateral waves.

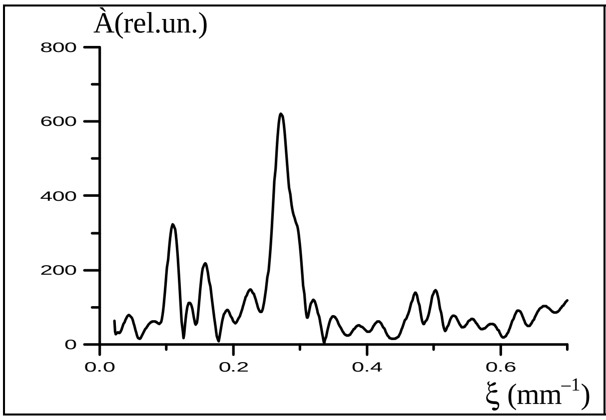

Fig. 3.

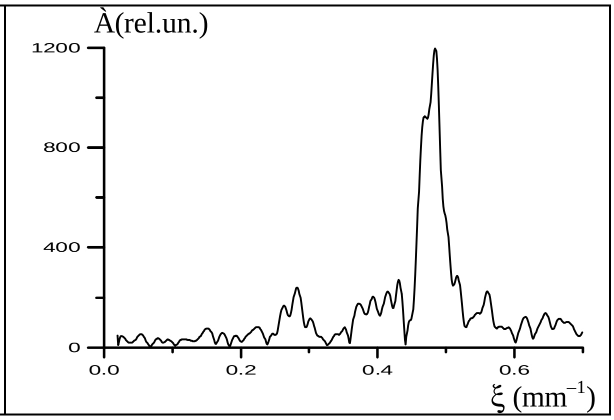

Fig. 4.

In this work the influence of lateral waves on the interference structure of acoustical fields in a waveguide was investigated. To excite bottom waves in underlying materials studied for the first time highly-directed radiation from an acoustic parametric array in a waveguide was used. The use of radiation with narrow angular spectrum allowed us to selectively excite lateral waves of different types and separately account for their contribution into the interference structure of the acoustic field in a waveguide.

This work supported by RFBR grant No. 98–02–16402, CCPE grant No. 97–8.2–78 and INTAS grant No. 97–11134.

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