Distance Optical Method for Monitoring the Parameters of Hydroacoustic Vibrations

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This paper presents remote optical method for measuring the parameters of acoustic signals, propagating in the marine waters, from the air environment without mechanical contact with water. It is based on the principle of recording on CCD the parameters of laser radiation, scattered by optical inhomogeneities of the seawater surface.

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1. Introduction

Asia-Pacific region is situated in the most seismically active area of the Earth, where over the last decade have occurred the grate seismic events. This activity is often expressed in the fractures of tectonic plates, which in the most cases are under the water. Therefore, the seismic activity of the fractures is the source of a wide range of sonar signals, the low-frequency component of which is weakly damped in sea water and may extend to tens of kilometers with minimal losses. Registration parameter of these oscillations is actual not only to solve the fundamental problems of geodynamics, but it is important for the life of the Asia-Pacific region.

The continuous growth of national and international requirements to ensure the proper level of maritime safety, protection of transport routes and transport infrastructure against acts of unlawful interference, also requires the development of effective methods for monitoring of acoustic fields in the marine waters based on the detection of low frequency acoustic waves generated by the propellers and machinery underwater vehicles, seismic crust movement, volcanic activity.

2. Content

Increasingly important role in solving the problems of monitoring sonar signals become non-contact optical methods for measure the parameters of such signals from the air environment, without mechanical contact with water. The most of these methods are based on the principle of registration by photo detector intensity of laser radiation scattered by vibrating water surface.

Since the size of the light-scattering inhomogeneities located at the ocean-atmosphere line, created by the acoustic wave should be comparable to the size of the aperture of the laser beam, the study of low frequency acoustic waves by such methods is very difficult. In this connection it is advisable not to register the parameters of radiation, scattered by optical inhomogeneities of the water-air border, created by acoustic waves, but the parameters of radiation, scattered by diffuse objects outside water environment and reflected back surface of the liquid.

It is assumed that the relief of the water surface will be modified by acoustic signal, which in turn will lead to modulation of the spatial distribution of the intensity of the reflected waves. The principles of processing of such speckle-modulated signals are well known now.

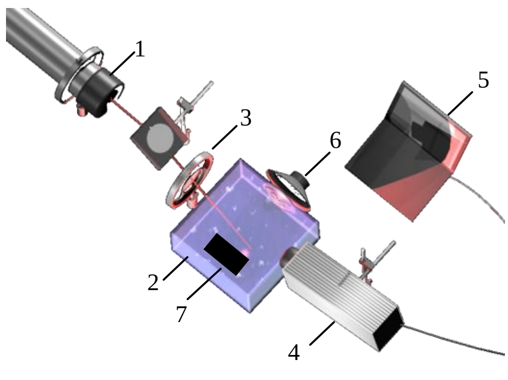

Fig.1. Experimental setup. 1 – He-Ne laser (wavelength 630 nm), 2 – saltwater pool, 3 – diffuse object, 4 – CCD high speed camera (shooting speed 500 fps, resolution 640*480 ps), 5 – PC, 6 - audio source, 7 – hydrophone

Therefore, the aim of this work is to develop the method of registration the parameters of hydroacoustic vibrations on such basis.

Fig.1. explains the scheme of the corresponding experiment. Coherent laser beam is scattered by diffuse object, reflected the surface layer of sea water and is directed to high-speed CCD camera.

At the initial moment of measurement, CCD camera records the image of the initial speckle pattern [1]. Changing the liquid surface under the influence of acoustic signals causes speckles rebuilding in the recorded pattern. That modification is found in comparison between the current distribution of the speckle pattern intensity with initial pattern. To compare these distributions you can use correlation function. Calculation of the experimental values of the correlation function is performed according to the expression:

$$B(t)= N^{-1}\Sigma\Sigma I_{ij}(0)\, I_{ij}(t)$$

Where $I_{ij}(0)$ and $I_{ij}(t)$ - value of the light intensity, incident on the (i,j) the pixel CCD at the initial time and at the time t; N - the number of pixels within the interference pattern. [2] Fig. 2. curves *1*, *2* and *3* show experimental curves of the normalized values $\mathbf{B}(t)$ according to the expression:

$$\mathbf{B}(t) = (B(t) - B(\infty))/(B(0) - B(\infty)).$$

Curve 1 in this figure was obtained in the case with fixed surface layer, which is achieved by placing a glass plate on the water surface. Despite the fact that the surface water remains fixed at the initial time,

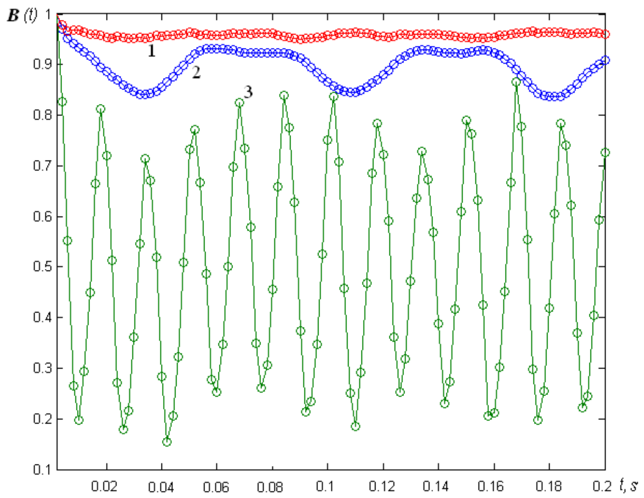

Fig.2. Dependencies of correlation function on time

there is a reorganization of speckles, due to the Brownian motion of particles in the water. This leads to the irreversible rearrangement of the speckle pattern by the characteristic correlation time t_{cor}, defined by particle size, the dynamic fluid viscosity and temperature. At the same time, when the changing of water surface relief is absent, the position of the speckles from the external diffuse scatterer remains constant, so the normalized correlation function becomes zero in $t > t_{cor}$.

Curve 2 was obtained in the case of a free water surface, moving as a result of non-normalized influences on the pool. It is seen that the random vibrations cause displacement of the speckles, formed by a matte diffuser, due to random changes in surface liquid. Curve 3 was obtained when the aqueous medium are excited acoustic oscillations at 60 Hz (curve 3). Fluctuations of the surface leads to a change in the correlation function in the sinusoidal law, and the oscillation frequency of the function equals the frequency of the acoustic signal with an amplitude of $\Delta\rho$. Lower frequency of the acoustic signal is limited by the size of this pool and the upper - the frequency of shooting high-speed camera (500 fps).

Fig.3. shows the dependence of acoustic pressure from the input voltage. It is seen that it is linear.

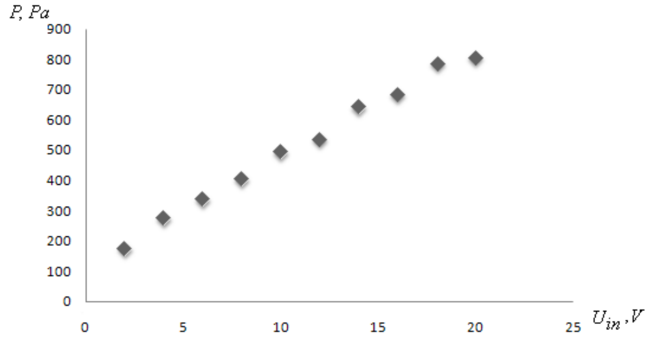

Fig.3. Dependence of the acoustic pressure on the input voltage

3. Conclusions

Thus, the proposed speckle correlation method makes it possible to study acoustic signals of low frequency (from several to 500 Hz) propagating in the liquid, these out contact; to determine the dependence acoustic pressure in the study medium from input voltage.

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