

# Vector-phase methods in acoustics: Problems and aspects of use

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There is an approach, named the vector-phase methods, based on enhanced amount of the acoustic field information extracted from each point of the field at the present samples volume. They are realized by setting both receivers of sound pressure and gradient pressure or oscillatory velocity ones simultaneously in the limited number of medium points. Usually there we obtain the oscillatory velocity projections on vertical  $V_z$  and two horizontal ( $V_x, V_y$ ) directions in the space. In spite of the fact, that vector receivers are used in hydroacoustics more than 30 years, until now exists much undecided problems, concerned with possibilities their practical using.

The experimental and theoretical researches made for a long time at acoustics department of Physics Faculty of Moscow M.V.Lomonosov State University have allowed formulating a number of approaches to the decision of some important problems of acoustics. The application of these methods for the solving of practical acoustics tasks is being discussed in this paper.

We will select two reference direction of the vector receivers' using: for study of the acoustic noise fields' structure in the ocean and for decision of the hydroacoustics practical applied problems.

The first direction is concluded the next components.

## 1. POSSIBILITY OF THE NOISES LEVELS MEASUREMENT WITH BOARD OF SHIP, NOT HAVING MODE OF SILENCE

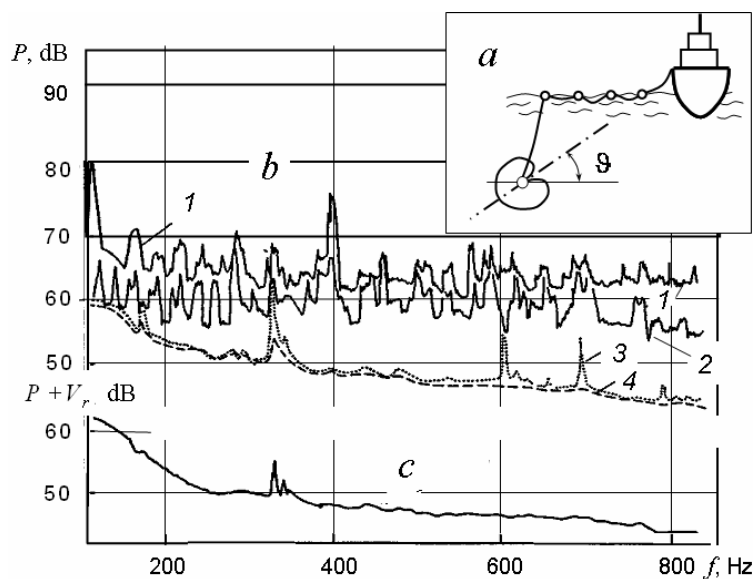


Fig.1. The example of registration of the noises levels in the field of ship noises: *a* – geometry of experiment; *b* – spectrum of noises, registered omnidirection hydrophone (1) and horizontal channel VR (2) under working ship mechanisms, registered omnidirection hydrophone under working special diesel-generator (3) and in mode of silence i.e. under completely out-of-work ship mechanisms (4); *c* – spectrum, received under working ship mechanisms by selectivity of receiving module from ship by means of using cardioids ( $P + V_r$ ), with minimum of the directivity characteristic, orientated on ship.

**2. SEPARATION OF THE CONTRIBUTIONS TO THE OCEAN NOISES OF THE DIFFERENT TYPE SOURCES**, based on measurements vector-phase structure of field. In particular, if through  $P_N$  signify the levels of sound pressure, generated by choppy surface, but through  $P_H$  – similar levels of noises, coming from far-field, then their relative contribution possible to state the value from measured magnitude of  $P/V_z$ :  $P_H / P_N = [P/(\rho c V_z)] \cdot n / (n + 1) - 1$ , where  $n$  is not far to unit for many regions of ocean.

**3. THE ESTIMATION OF THE NOISES ANISOTROPY, COMING FROM FAR-FIELD AND HAVING COMPARATIVELY STABLE DIRECTIONS IN SPACE** (fig.2). That value in the horizontal direction  $\mathbf{r}$  possible to be get from the averaged value

of the acoustic power flux  $W_{Rr} = (1/\tau) \int_0^\tau P(t) V_r(t) dt$ . The relative contribution of such noises, is defined the

coefficient  $\alpha = \langle W_{Rr} \rangle / \langle P^2 \rangle$ . We will note that  $\alpha \approx P_H / P_N$ , if noises predominantly anisotropic. Otherwise usually  $\alpha < P_H / P_N$ .

When there is cardioids used, it is possible enough simplified and rough estimation of spatial anisotropy of noises on areas of water, using estimations of the levels differences, registered by cardioids "onward-back" toward, characterized by angle  $\alpha$  in planes, including  $r$ :

$$K_a = 10 \log \left\{ \frac{[P + \rho c V(\alpha)]}{[P - \rho c V(\alpha)]} \right\}.$$

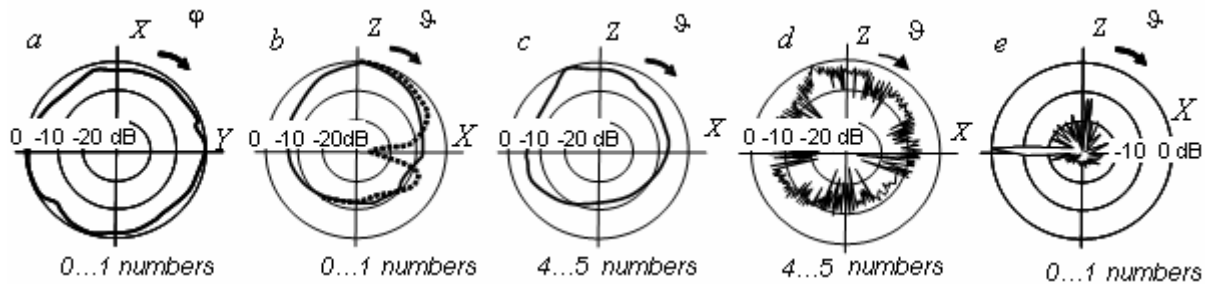


Fig.2. The examples of experimental registration of spatial distribution of the noises in the one deep region of Pacific ocean in horizontal  $XY$  and vertical  $XZ$  planes finding by means of cardioids ( $a-c$ ) and on acoustic power flux for the time, corresponding to dependencies  $c$  ( $d$ ) and dotted line  $b$  ( $e$ ).

#### 4. ESTIMATION OF THE NOISES SPATIAL SPECTRUM OF AREA OF WATER ON RESULTS OF MEASUREMENT OF PROJECTIONS OF ACOUSTIC POWER FLUX ON THE THREE MUTUALLY ORTHOGONAL DIRECTIONS IN THE SPACE AREA OF SMALL WAVE SIZES.

Besides it is necessary to consider the classification of the acoustic sources, based on the analysis of differed-phase relation between pressure and oscillatory velocity, which permit to classify the acoustic field, at least once, on three types: diffuse field, field of standing waves, anisotropic (coherent) field, but on measurements of phases  $\Delta\varphi_{pv}$ , or relations imaginary  $W_I$  and real  $W_R$  components of acoustic power flux  $W_I/W_R$  and  $P/\rho c V$ , in the near oscillator field to realize the most simplest classification of sources – monopole, dipole, quadrupole etc.

Amongst applied problems, we will select

– **Definition of directional characteristic of source** by simultaneous measurements of pressure and the normal component of gradient pressure on closed surface in near zone, using integral theorem Helmholtz

$$P(M) = \int_S \left\{ P(N) \frac{dG(N)}{dn} - G(N) \frac{dP(N)}{dn} \right\},$$

– **The detection of the characteristic sizes of small-scale inhomogeneity in ocean.** The method is based on radiation of tonal acoustics signal with frequency  $f$ , its receiving at such a distance  $r$ , that  $k \gg 2\pi a/\lambda$ , where  $a$  is characteristic size of inhomogeneity and on simultaneous measurement of amplitude and phase of sound pressure and two orthogonal components of oscillatory velocity on horizontal plane. Further, bearing angle  $\varphi$  of sound signal source and a dispersion of bearing for the same time are determined, and the characteristic size of small-scale inhomogeneity is calculated by the formula:  $a = 2\sqrt{\pi} \langle \mu^2 \rangle \cdot r / \sigma_\varphi^2$ , where  $\langle \mu^2 \rangle$  is dispersion of relative fluctuation of sound speed,  $\sigma_\varphi$  is dispersion of bearing angle  $\varphi$  in the direction of sound signal source.

The vector-phase methods are effective for **studying of reflecting properties of multilayered bottom at extremely low frequencies** too, defining particularities of spreading the sound on lengthy shallow tracks.

Moreover, this is far from all potentialities of using vector-phase methods.