

A.N. Rutenko

**INTERNAL WAVES EFFECT ON THE INTERFERENCE AND MODE
STRUCTURES OF THE LOW-FREQUENCY ACOUSTICS FIELD
IN SHALLOW SEA**

V.I.II'ichev Pacific Oceanology institute,
Far Eastern Branch, Russian Academy of Sciences.
ul. Baltiyskaya 43, Vladivostok, 690041, Russia
Ph: (4232) 312120; Fax: (4232) 312573
E-mail: pacific@online.marine.su

Abstract - The results of *in situ* observations for the internal waves influence on the frequency-spatial parameters of the acoustic field in shallow sea, are presented. Measurements have been carried out in the shelf zone of the Sea of Japan at fixed path, equipped of the sound sources and two vertical acoustic-hydrophysical measuring systems [1]. Considerable transformations of the interference and mode structure of the acoustic field are explained by its resonance interaction with the spatial non-homogeneities of the sound velocity field, which are generated by the internal waves.

It is known, that during the propagation of the acoustic waves generated by a point source, in the sea wave-guide it is formed a complicated spatial-frequency distribution of the acoustic energy, called a fine interference structure. This structure is stable if in superposition there are coherent waves, but in real media the coherency may be violated due to the influence of the refraction index fluctuations to the amplitude and phase of the interfering waves. Experimental and analytical studies have shown that the internal waves (IW) possess strong effect on sound propagation in the non-regular shallow-water wave-guide typical for the shelf zones of the tidal seas with density stratification [1,2]. Refraction and scattering of the acoustic waves on the non-homogeneities of the sound velocity field which are created by the IW, lead to the interaction of the propagating normal acoustic modes, note that this process can turn to be of resonance type [2].

Let's consider the effects in the acoustic field produced by one non-linear IW. Fig.1 presents the IW profile (h_{iw}) and the plots of variations of the intensity (I) and phase (j) of the acoustic fields with the frequencies of 307, 317, and 327 Hz, measured at 260 m off the emitter at different horizons, and they correspond to the solitary internal wave (BB.1) propagation along the route. The figure shows that the BB.1 effects in the acoustic field possess frequency and vertical selectivity. Variations h_{bb} are maximal in the interferential minimums in distribution $I(z, \mathbf{w})$ (see plot $I(t)$ for signal with frequency of 317 Hz, measured by hydrophone P.2). Dependence of j variations of the acoustic field on the signal frequency is less expressed than for I , and it is possible to note a relative phase coincidence of j variations at different horizons corresponding to the results of vertical probing $j(z)$ (see Fig.3ã). Acoustic route is oriented along the typical direction of the short IW distribution. Fig.1 shows, that BB.1 peak came out to the route at 3h32min and correspondingly to the plots $j(t)$ (at the IW thermocline rise the signal phase values decrease) and passed over the emitter at 3h52min. Thus, the plots presented in Fig.1 characterize qualitatively and quantitatively the effects in the acoustic field which are produced by the solitary IW propagating along the acoustic route. Basing on profile h_{BB} of the BB.1 let's estimate the spatial scale of the sound velocity field non-homogeneity propagating along the acoustic route with the phase velocity of the IW making : $\Delta x \approx 140$ m, $\Delta z \approx 4$ m. Strong influence of the BB.1 on the propagation of the acoustic waves can be explained by their resonance interaction with the «acoustic non homogeneity», created by the IW. Using the MOATL program for the acoustic route with hydrological conditions and geometry similar to the *in situ* experiment in approximation of 8 normal modes of the acoustic field with the frequency of 315 Hz, the numerical experiments have been performed. In case, when at the route near the reception system it was generated the disturbance in distribution $C(x, z)$ with spatial parameters of the BB.1 the calculations have shown, that $h_{iw} \approx l$, $k_{iw} \cong k_1 - k_3 \cong k_2 - k_5$. Here h_{iw} - the height of the BB.1, l - length of the acoustic wave, k_{iw} - wave number of the BB.1, k_n - wave number of the acoustic

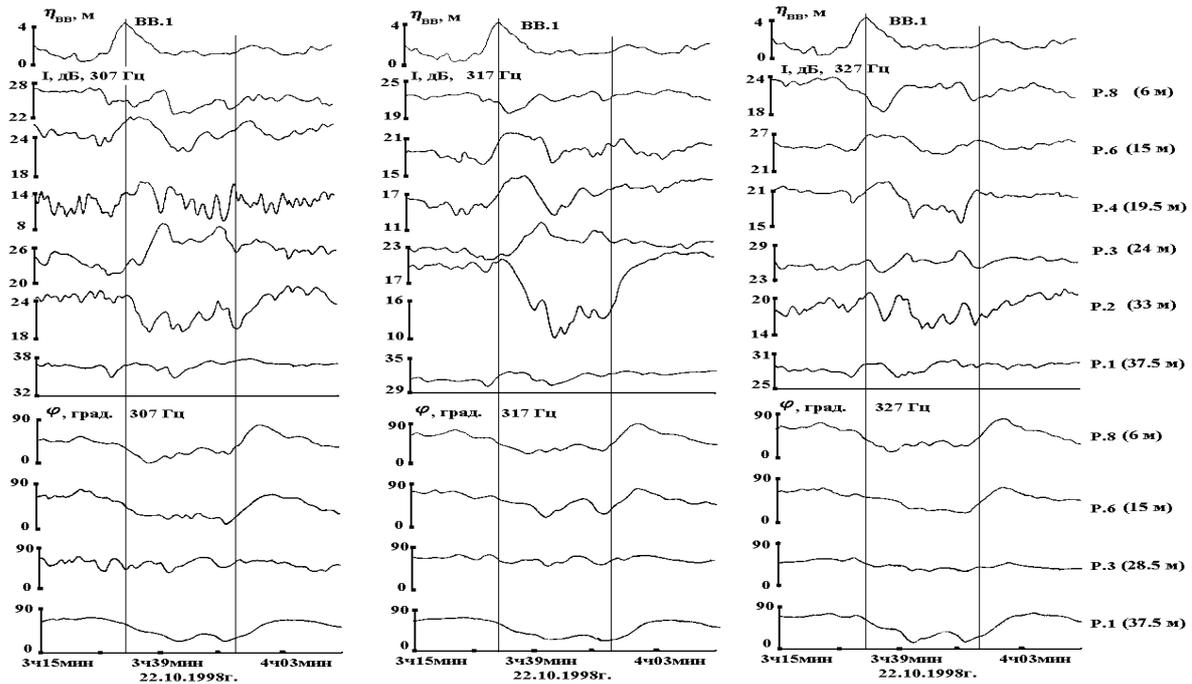


Fig. 1.

mode n . Consequently, BB.1 could lead to the resonance interaction of the first mode with the third one, being accompanied by the correspondent flows of the acoustic energy and by changes in frequency-spatial interference structure of the acoustic field in the reception point. Plots of variations I , given in Fig.1, confirm the frequency selectivity (resonance) in the interaction of the acoustic waves and the BB.1. According to plots P.2 in Fig.1 the level of the signal with the frequency of 317 Hz during the BB.1 propagation along the route, in average, decreased up to 12 dB, that of the signal with the frequency of 307 Hz - up to 4 dB, and with the frequency of 327 Hz - practically didn't change. BB.1 propagation along the acoustic route generated variations j corresponding to more rapid propagation of the acoustic energy, though in average, at the route the volume of cold water increased (see profile of BB.1). Results of the numerical experiment match the *in situ* measurements as far as V_{gr} increased for the most part of normal acoustic modes propagating along the route with the BB.1. Note also, that while it was the second

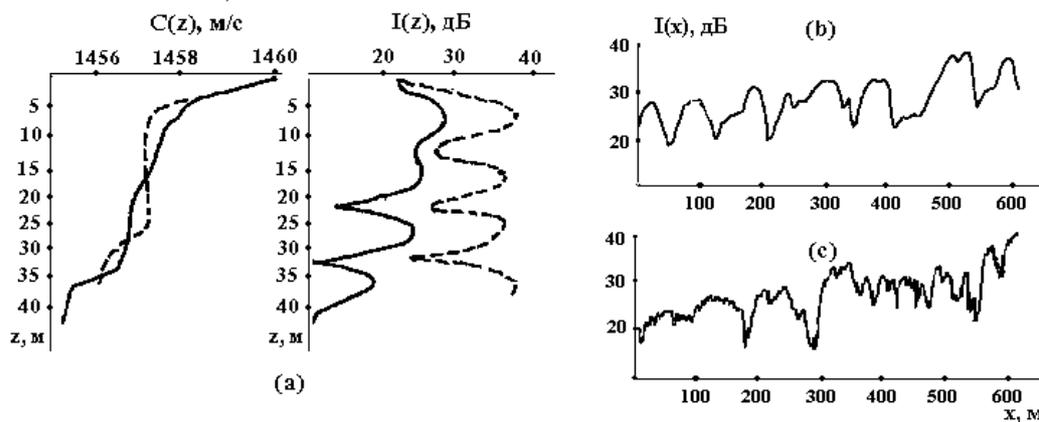


Fig.2.

mode which was propagating with the maximal $V_{gr}^{(2)} = 1486$ m/s along the route without BB.1; it is the third mode which was most rapidly transferring the energy ($V_{gr}^{(3)} = 1485$ m/s) with the BB.1, its amplitude could increase at the expense of the first mode due to their resonance interaction with BB.1.

IW influence on spatial interference structure of the acoustic field with the frequency of 315 Hz is illustrated by Fig.2, which presents the results of the vertical and horizontal (towing) probing performed at the route in winter (b) and autumn (c) hydrological conditions.

Fig.2a shows the plots of $C(z)$ and $I(z)$, corresponding to the probing carried out on March 17, 1997 at a distance of 260 m (dash line) and 1000 m (solid line) off the emitter. Plots $I(z)$ at the same horizons possess four interference maximums. These data testify to the spatial and temporal stability of the vertical interference structure and mode composition of the acoustic field propagating in conditions of almost homogeneous water layer. Fig.2b,c gives the plots $I(x)$, characterizing the horizontal interference structure of the acoustic field, obtained with the help of towing (in direction towards the emitter) «Burun-96» probe carried out on 17.03.97y. (b) and on 13.10.96y. (c). Fig.2b shows, that in conditions of homogeneous water and gentle slope of the bottom - 0.006, in the shallow sea it is formed a stable horizontal interference structure of the acoustic field with the horizontal scale of convergency zones which is stabilized with the distance off the emitter. Scheme of Fig.2c confirms the fact of strong influence of the thermocline non-homogeneities generated by the IW to the spatial interference structure of the acoustic field.

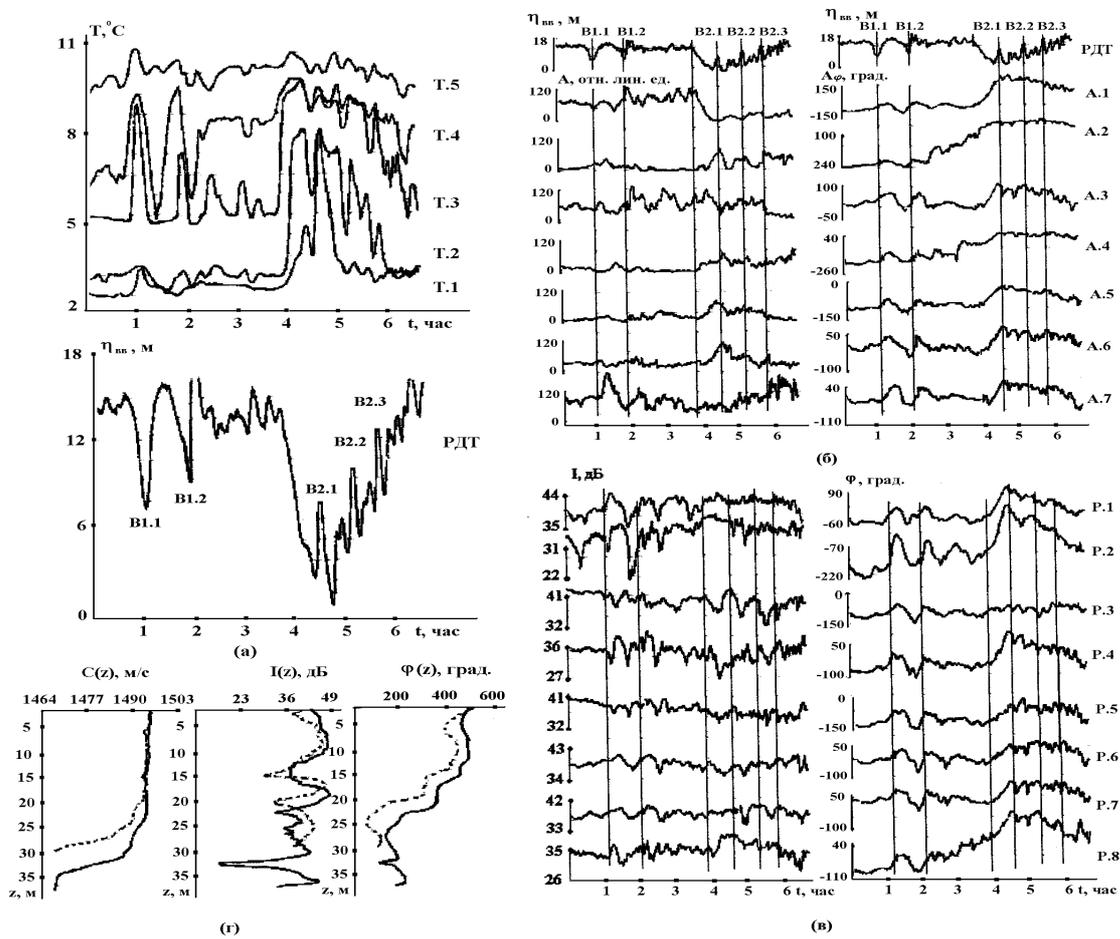


Fig.3.

Fig.3 presents the results of measurements and decomposition of data (according to the modes) obtained during the experiment performed on 17.10.96. According to Fig.3a at the beginning of observations the lower margin of the thermocline occurred at the horizon of 20 m. «Warm solitons» correspond to such position of the thermocline (marked in Fig.3a,á as B1.1 and B1.2). After 3h30min the thermocline sank up to horizon of 32 m and correspondingly it changed the profile of the non-

linear IW - «cold solitons» : B2.1, B2.2 and B2.3. At the rising thermocline the short IW with the periods of 10 minutes are well expressed. Variations I are maximal at horizon of 33 m and reach 15 dB during the advance of B1.1 along the route. Upon the non-linear IW coming out to the route, the fluctuations I and j grew more distinct at all 8 horizons. Fig.3á illustrates the IW influence upon the mode structure of the propagating sound. To analyze the mode structure of the acoustic field we use the value of module A (in linear units) and phase A_j (in degrees) of the corresponding mode coefficient \dot{A} [1]. According to calculations, the IW with $I = 100-250$ m (period of such IW is equal 8-20 min) could lead to the resonance interaction of the registered modes. Fig.3á shows that A_j , especially of the 6-th and the 7-th modes, are similar to the profile of the IW propagating along the route.

The analyses of the experimental data have shown that the increased sensitivity of some modes to the spatial parameters of the thermocline non-homogeneities generated by the IW propagating along it, and the possibility of their resonance interaction account for the most part of the effects observed in a mode structure of the acoustic field.

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