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EXPERIMENTAL RESEARCH OF THE BROADBAND PULSE SIGNALS DISPERSIONIN OCEAN WAVEGUIDES

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The results of the measurements of mode composition and dispersion characteristics of the shallow and deep water ocean waveguides at the distances up to 100 kms and up to 600 kms respectively are given. The frequency - temporary distributions of the received signals energy with wideband pulse sounding of the waveguides are obtained. The Wigner - Ville distribution for the time - frequency signal processing was used for achievement high time - frequency resolving power. The dynamics of dispersion patterns transformation and changes of waveguides mode spectrum depending on length of propagation path with various seafloor structure are shown. The comparison of the experimental data for a case of the shallow sea with results of accounts was carried out and it shown to be in good agreement.

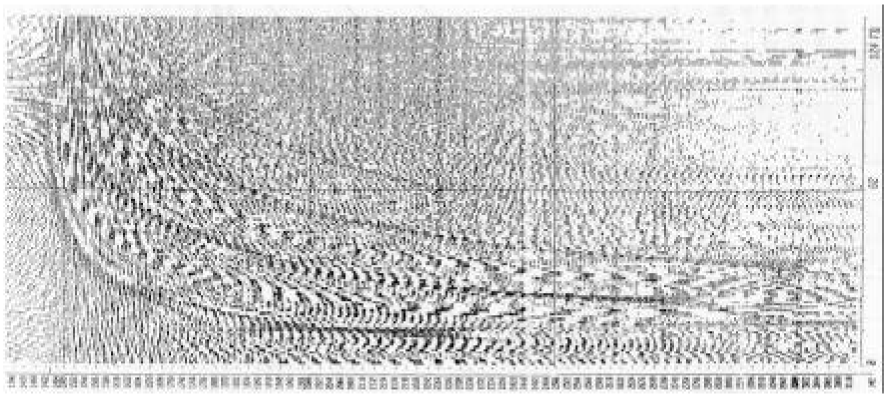
It is known that acoustic field in ocean waveguide is defined a lot of the factors, such, as physical parameters of the water mass, structure and properties seafloor, heavy sea surface, presence of internal waves, fluid flows and other inhomogeneities on the sound propagation path. The existence of the connection between measured acoustic field parameters in some area of space and media properties along sound propagation path allows in principle to solve a task of the diagnostics of such complex objects as the ocean waveguide. The reconstruction of the internal structure image of researched object using some characteristics of sounding signal that is interacted with the object composes the problem of the ocean ingomogeneities acoustic tomography. Depending on a physical nature of reconstructed inhomogeneities the integral spatial - temporary characteristics of the registered received sounding signal (complex amplitude and intensity of an acoustical field, time of propagation or relative delay of the pulse signal etc.) and the inhomogeneities parameters reconstruction algorithms connected to model of processes of the sound waves propagation and their interaction with media inhomogeneities are defined.

The spatial - temporary characteristics of the acoustic field in propagation broadband sound essentially depend on the frequency. The model of the processes description can change also in dependence on wave length and inhomogeneity dimension ratio. The dispersion characteristics of the sound propagation channels represent very sensitive in relation to hydrologic - acoustic properties of waveguides including spatial-localized ingomogeneities.

The theoretical study of the dispersion waveguide properties is usually based on a formalizm of the modes and the rays [1,2] and theirusing allows to compute wave arrival times as a function of the frequency for some model. At the same time the information importance of the frequency dependence of the propagation time of the various modes initiated experimental researches of the time - frequency structure of wideband pulse acoustic signals in ocean [3-6] with use dynamic spectral analysis and processing method based on Wigner - Ville distribution [7] that permits to raise time - frequency resolving power [4-7]. In this study the results of the experimental researches of the ocean waveguides dispersion characteristics t(w) with using broadband pulse waveform sounding technique from pneumatic and explosive sources are given. The theoretical dispersion curves were also calculated for simple model and compared to the data of the measurements in case of shallow sea.

The time - frequency characteristics of the acoustic pulse signal over band 5 - 124 Hz of the pneumatic sound source (volume 3 litres, depth Zs=10 m) received by the autonomous bottom station hydrophone at distance r = 20 kms, the receiver depth Zr = 120 m, in shallow water region of the Barents Sea with depths Zo=100-120 m is shown in Fig.1. It is uneasy to see that the signal contained the four lowest order waveguide modes with duration about 1,5seconds. The time - frequency energy distribution of the accepted signal was obtained using a time - frequency analysis method based Wigner – Ville distribution that securities more better resolving both on the frequency and on the time. The comparison of the experimental data with account corresponding two - layers model of the shallow water waveguide (with seafloor parameters: the

124 Hz



0 ***2,7sec***

Fig.1 The frequency-temporary distribution of the received pulse signal energy. Barents Sea (r = 20 km, Zs = 10m, Zr =120 m, Zo = 100-120m).

marine sediment density r_b=2 g/cm^3, bottom half-space sound speed C=1800 m/s, speed profile as function of depth in water layer C(z) – the experiment data) is shown in Fig.2. The calculated arrival time curves for different modes are imposed as continuous lines on

124 Hz

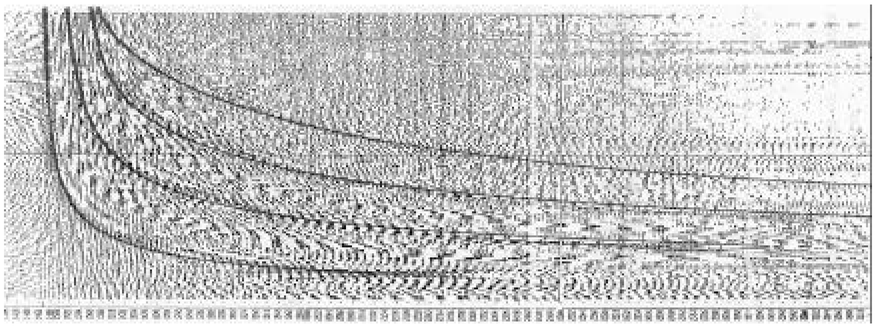


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Fig.2 The camparison of the experimental data and the computed dispersion curves for two-layers model (bottom density r_b=2 g/cm^3, bottom half-space sound speed Cb=1800 m/s, C(z) – the date of the experiment).

the experimental data. The comparison shows good agreement for the four modes. In the frequency range 5-124 Hz about ten modes can be excited in this model of the waveguide at the same time only

256 Hz

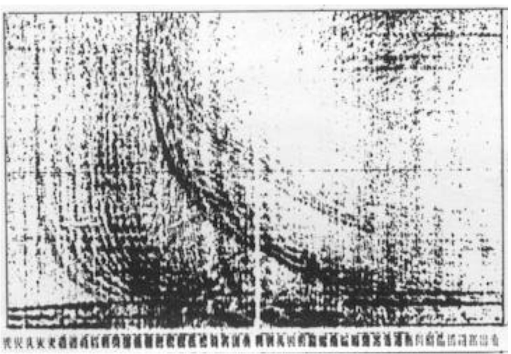


Fig.3 The frequency-temporary distribution of the received pulse signal energy. South-Chinese Sea. (r = 45 km, Zs = 10m, Zr = 45m, Zo = 40–50 m).

2,0 sec

the first four modes are observed. The frequency dependences of their group velocity concide with accounted that confirms a correct choice of the model.

The result of the received pulse signal processing during the similar a shallow water experiment conducted in South-Chinese sea region with depths Zo=40-50 m at the distance r=45 km is shown in Fig.3. The source and receiver depths are 10 and 45 m, respectively. It is nesessary to emphasize the essential difference of the mode composition in this case as the result of the presence of the two mode group that are defined by the water layer and sea floor structures. The mode ground group is observed in the form of the forerunner and has other kind of the dispersion curves $t(\omega)$ in arrival time - frequency plane. It is obvious that the account of the dispersion patterns $t(\omega)$ should be executed in this situation in view of the layered structure and elastic properties of seafloor model.

The next experimental dependences of the mode arrival times of the pulse signal on frequency over band 5-124 Hz are shown in Fig.4.This shallow water experiment conducted in the region of Japanese sea with depths Zo=60-70m. The pulse broadband acoustic signal

124 Hz

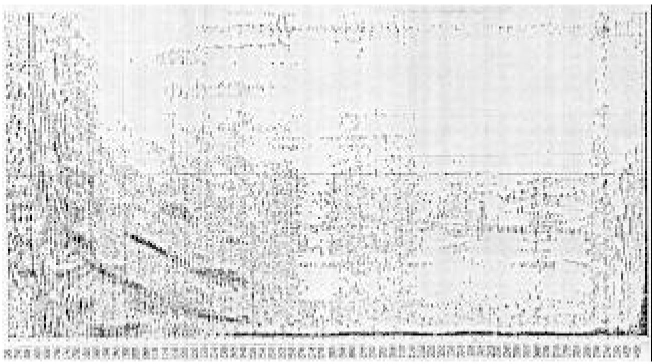


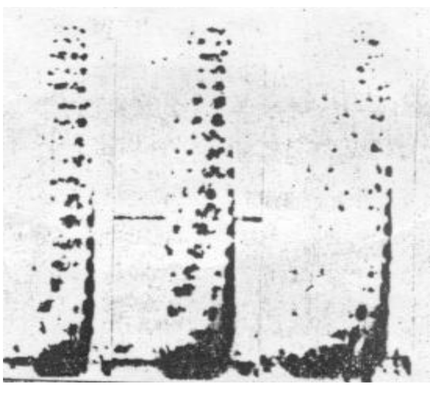
Fig.4 The dispersion dependences of the arrival times of the explosive source signal $t(\omega)$. Japanese Sea. (r = 19km, Zs = 10m, Zr=65m, Zo = 60-70ì).

2,7 sec

transmitted the pneumatic source was received at the distance r=19 km by autonomous bottom station hydrophone. The source and receiver depths are 10 and 65 m respectively. The four modes over the frequency range up to 124 Hz excite and propagate in this waveguide. However the mode dispersion patterns don't create the continuous lines system in this case as it has place in homogeneous waveguide. Here the intensity modulation of the lines at times and displacement of those in time - frequency plane on the frequency axis are observed. This fact testifies to presence of the mode composition transformation of the received signal inconsequence of the researched waveguide inhomogeneity.

The dispersion effects of the water wave that caused by existence of the borders are weakened with the increase of the sea depth, at the same time the influence of the stratification of the sound speed 2 on depth C(z) is displayed more stronger. This factor is well displayed on the spectrograms given in Fig.5.

500Hz



a) **b)** **c)** ***6,0sec***

Fig.5 The frequency-temporary distributions of the received explosive signals in the deep sea at the distances r =300 km (a), 400 km(b) and 600 km(c) (Zs = Zr = 50 m, Zo = 1800 m).

The energy time - frequency distributions of the signals explosive sources (with TNT charge power 0,4 kg) received at the distances 300(a), 400(b) and 600(c) kms in deep water over the band 10-500 Hz are given. The source and receiver depths are 50 m, the sea depth is 1800 m.

In this case when the influence of practically the bottom on the field formation has no effect practically and the waveguide dispersion properties are determined the chanel dispersion, i.e. the sound speed profile on the depth C(z), the arrival time patterns versus the frequency t(w) is observed inverted as those in the shallow sea. It is also excited a set of the modes but the higher order modes arrival the receiver point at the first. There is only the common characteristic property for the dispersion curves - the increase of the response duration with the reduction of the frequency.

This work was financially supported by the Russian Foundation for the Fundamental Research, project no.98-05-64652a.

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