Zaslavsky Yu.M., Kerzhakov B.V., Kulinich V.V.

WAVE HODOGRAPH SIMULATION BY THE VERTICAL SEISMIC PROFILING OF THE SHALLOW-WATER SEAFLOOR

Institute of Applied Physics Russian Academy of Sciences
ul.Ul'janova, 46, Nizhni Novgorod, 603950, Russia
Tel.: (8312)164764 Fax: (8312)365976; zaslav@hydro.appl.sci-nnov.ru

The report is devoted to the numerical simulation of the seismic-acoustic wave field produced by the pulse source on the shallow-water seafloor. The set of wave hodograph by the vertical seismic profiling of the typical layer bottom structure is built at low sound frequencies. It allows to perform the identification of the seismic-acoustic waves excited as in a water as well in a rigid bottom medium and to investigate the influence on them of bottom layer acoustic parameter exchange. The results demonstrate the possibilities of significant acoustic parameter estimation which are interest for the prediction of the presence of oil-saturated layers in the seafloor.

Borisov A.S.

TO A QUESTION OF A NOISE STABILITY OF GEOACOUSTIC SYSTEMS OF VERTICAL SOUNDING WITH DYNAMIC ADAPTIVE ECHOSIGNALS FILTRATION

Taganrog state university of radio engineering
Russia, 347928, Taganrog, Rostov region, Nekrasovskii, 44
Tel.: (8634) 371-795; E-mail: sabor@list.ru

At acoustic sounding of sea ground the echosignals form undergoes the distortions caused by influence of physical characteristics of a ground. It turn in results to losses in the signal/noise ratio, and, hence, in decrease of accuracy characteristics of geoacoustic systems. In work results of calculations of hydrolocation systems of vertical sounding of the sea deposits noise stability using in reception dynamic adaptive echosignals filtration in view of sea ground characteristics are submitted. The comparative estimation of a noise stability of such systems and systems without application of adaptive filtration is made.

Being propagated in sea deposits, the acoustic probing signal undergoes the distortions, the appreciable contribution in which brings frequency-dependent absorption of a sound [1, 2]. Such distortions of echosignals form, coming with various depths, result in losses in the signal/noise ratio, and, hence, and in resolution and accuracy of geoacoustic location systems [3, 4]. In the present work the question of a noise stability of the systems using in reception math filtration, king into account the current frequency echosignals distortions is considered.

It is known [5], that the signal/noise ratio (on capacity) on an output of the matched filter at the moment of the ending of a signal T, in case of reception of the undistorted signal on a background of white noise is

$$Q_0 = \frac{\left[\int\limits_{-\infty}^{\infty} S_0(\omega)\cdot K(\omega)d\omega\right]^2}{\int\limits_{-\infty}^{\infty} N(\omega)\cdot K^2(\omega)d\omega}, \tag{1}$$

where $S_0(\omega)$, $N(\omega)$ – modules of spectral density of echosignal and noise, accordingly, $K(\omega)$ – the module of the filter transfer coefficient.

If received deformed echosignal with spectral density $S_1(j\omega)$ the signal/noise ratio on an output of the filter coordinated with the probing signal, will be equal

$$Q_1 = \frac{\left[\int\limits_{-\infty}^{\infty} S_1(j\omega)\cdot K(j\omega)d\omega\right]^2}{\int\limits_{-\infty}^{\infty} N(\omega)\cdot K^2(\omega)d\omega}. \tag{2}$$

Spectral function $S_1(j\omega)$ can be defined as product of multiplication of a probing signal spectral density and transfer coefficient of probing layer of a ground $H(j\omega)$:

$$S_1(j\omega) = S_0(j\omega) \cdot H(j\omega). \tag{3}$$

The module of ground layer transfer coefficient $H(j\omega)$ can be defined as follows:

$$H(\omega) = \exp\left[-2lk\left(\frac{\omega}{2\pi}\right)^n\right], \tag{4}$$

where l – thickness of a layer, k and n – coefficients, dependent on type of a sea ground [6, 7].

Apparently from expression (4) ground transfer coefficient depends on the distance $r = 2l$ gone by a sound wave in a ground, hence, the relation Q_1 will be function of sounding depth and decrease with increase l. Then, making the assumption of linearity of phase-frequency characteristic of the channel of propagating (there is no dispersion of sound velocity), we shall write down expression (2) for the relation signal/noise Q_1 as functions of probing layer thickness

$$Q_1(l) = \frac{\left[\int_{-\infty}^{\infty} S_0(\omega) \cdot H(\omega,l) \cdot K(\omega) d\omega\right]^2}{\int_{-\infty}^{\infty} N(\omega) \cdot K^2(\omega) d\omega}. \tag{5}$$

Adaptive echosignals filtration allows to reduce losses in the signal/noise ratio. In case of application of the filter coordinated with deformed echosignal, expression for the relation signal/noise on its output we shall define as

$$Q_2(l) = \frac{\left[\int_{-\infty}^{\infty} S_0(\omega) \cdot H(\omega,l) \cdot K_1(\omega,l) d\omega\right]^2}{\int_{-\infty}^{\infty} N(\omega) \cdot K_1^2(\omega,l) d\omega} = \frac{\left[\int_{-\infty}^{\infty} S_0(\omega) \cdot H^2(\omega,l) \cdot K(\omega) d\omega\right]^2}{\int_{-\infty}^{\infty} N(\omega) \cdot \left[K(\omega) \cdot H(\omega,l)\right]^2 d\omega}, \tag{6}$$

where $K_1(\omega) = K(\omega)H(\omega,l)$ – the module of frequency transfer coefficient of the watching filter.

Analyzing expression (6), it is possible to make a conclusion, that the Q_2 will depend also on distance as the numerator in expression (6) is proportional to a square of echosignal energy, and a denominator - echosignal energy which decreases with distance. Hence, adaptive filtration will also give losses in the signal/noise ratio.

Let's compare a noise stability of the systems using in reception dynamic adaptive filtration and systems, using the filters coordinated with the probing signal. Losses in the signal/noise ratio at sounding a sea ground which arise because of a mismatch of the receiver at reception of the deformed signal, we shall define as the relation

$$\eta_1 = \frac{Q_1}{Q_0}. \tag{7}$$

And losses at application of an adaptive filtration as

$$\eta_2 = \frac{Q_2}{Q_0}. \tag{8}$$

Let's analyze the received expressions (7) and (8) on model of linearly frequency-modulated (LFM) probing pulse, the module of which spectral function is equal to constant value within the limits of a signal band ΔF (LFM signal with the big base).

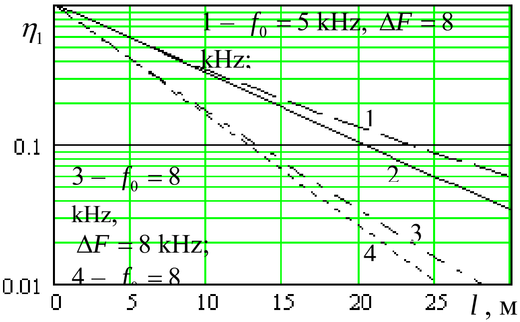

Fig. 1. Losses of the coordinated filtration at oozy deposits sounding

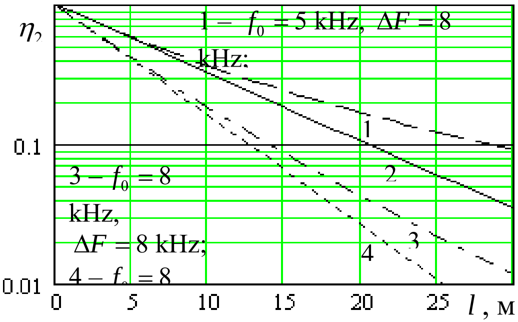

Fig. 2. Losses of an adaptive filtration at oozy deposits sounding

On fig. 1 and 2 results of the numerical analysis relations (7) and (8), accordingly are submitted. As a sounding ground the model of oozy deposits ($k = 0{,}05$ dB / (kHz^n·m), $n = 1$) [7] is taken. Results of calculations show, that with increase of sounding depth loss grow, thus, the above the central frequency f_0 of a probing signal and already its spectrum, the sizes η_1 and η_2 with distance faster decrease. From the received schedules it is visible, that losses η_1 increase with depth a little bit faster, than η_2. For example, for a signal with f_0 =5 kHz and ΔF =8 kHz at depths of sounding l =25 m and 30 m loss because of a mismatch of the receiver η_1 will make accordingly 10,5 dB and 12 dB (curve 1 on fig. 1). And losses of an adaptive filtration η_2 will make approximately 9 dB and 10 dB (curve 1 on fig. 2). Also, it is necessary to note, that the more deviation of frequency of the radiating signal, the greater prize gives an adaptive filtration. So, for example, at sounding deposits by a LFM pulse with the same central frequency f_0 =5 kHz and deviation ΔF =2 kHz (curves 2 on fig. 1 and 2), the prize Q_2 in comparison with Q_1 will not exceed 0,2 dB in all a range of sounding depths.

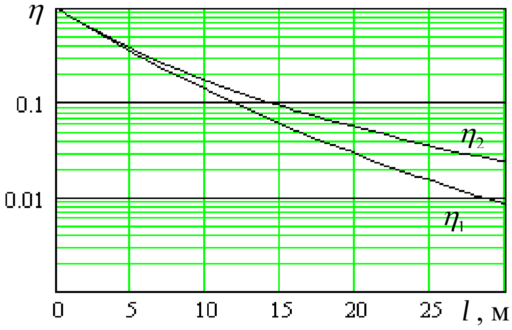

Fig. 3. Losses in the signal/noise ratio at sandy deposits sounding

At increase of specific attenuation coefficient value k a prize in the signal/noise ratio at an adaptive filtration increases. For example, on fig. 3 schedules of dependence η_1 and η_2 on depth of sounding of a sandy ground ($k = 0{,}1$ dB / (kHz^n·m), $n = 1$ [7]) by LFM signal with f_0 =5 kHz and ΔF =8 kHz are submitted. Here at $l = 30$ m η_2 exceeds η_1 approximately on 4,8 dB.

Calculations for model of sea deposits with square-law dependence of acoustic energy absorption on frequency show, that the prize in the relation signal/noise at use of an adaptive filtration appears more essential and depends both on the central frequency of a probing signal, and from width of its spectrum.

For comparison purposes signal/noise radio at adaptive and not an adaptive echosignal filtration we shall enter the relation

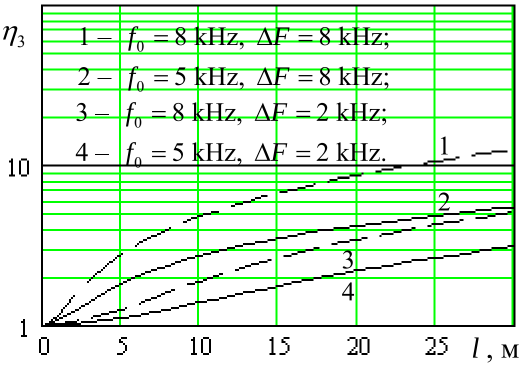

Fig. 4. A comparative estimation of signal/noise ratio dependence at adaptive and not adaptive filtrations

$$\eta_3 = \frac{Q_2}{Q_1}. \qquad (9)$$

On fig. 4 results of the analysis of expression (9) for model of deposits, with values of coefficients $k = 0,05$ and $n = 2$ are submitted. The size η_3 depends as on depth of sounding, that is the prize at an adaptive filtration increases with increase l, and from initial parameters of a probing signal. For example, on depth of sounding $l =$ 20 m value η_3 will make 3,4 dB, and on $l =$ 30 m – 5 dB at use of LFM probing pulse with parameters: $f_0 =$ 5 kHz, $\Delta F =$ 2 kHz (curve 4 on fig. 4). At increase in deviation ΔF up to 8 kHz and preservation $f_0 =$ 5 kHz the size η_3 grows, and will make 6,2 dB at $l =$ 20 m and 7,4 dB at $l =$ 30 m (curve 2 on fig. 4).

Increase of the central frequency in a spectrum of a probing signal also results in increase in the relation η_3. On fig. 4 curves 1 and 3 show behavior of η_3 for probing signal parameters: $f_0 =$ 8 kHz and $\Delta F =$ 8 kHz and 2 kHz. It is visible, that the greatest prize η_3 can be received due to expansion of a strip ΔF. So, at $\Delta F =$ 8 kHz (curve 1) and $l =$ 20 m η_3 will be equal 9,3 dB, and at increase l up to 30 m - 11 dB. For a signal with initial deviation of frequency $\Delta F =$ 2 kHz (curve 3) on the same depths of sounding of value η_3 of 20 and 30 m will be equal 5,3 and 7 dB, accordingly, that a little bit less, than η_3 for a signal submitted on fig. of 4 by curve 2 ($f_0 =$ 5 kHz, $\Delta F =$ 8 kHz) a considered range l.

Thus, the prize η_3 is more, than below frequency f_0 and wider the band ΔF.

The carried out comparative analysis of a noise stability of geoacoustic hydrolocation systems shows, that frequency dependence of absorption of acoustic energy brings losses in the relation signal/noise as systems without application of an adaptive filtration, and with an adaptive filtration of echosignals. And, than distortion of the form echosignals is more essential, the greater prize in the relation signal/noise gives application of an adaptive filtration. Thus optimization of parameters of a probing signal by criterion of a maximum of the signal/noise ratio in conditions of echosignals distortions is possible.

REFERENCES

1. Borisov A.S. Distortions of acoustic pulse form in marine sediments. // Works of XI session of RAO. – M.: «GEOS», 2001. – V. 1. – P. 288 – 291. (In Russian).

2. Borisov A.S., Borisov S.A. Experimental researches of acoustic pulses form distortions in sea sediments // TSURE News. Materials of II All-Russia scientific conference « Ecology 2002 - the sea and the person », MASEB, Taganrog: TSURE, 2002. - P. 42-43. (In Russian).

3. Borisov A.S. To a question on resolution of acoustic marine sediments profiling // Acoustics of Ocean: Reports of VIII school - seminar of acad. L.M.Brehovskih. - M.: "GEOS", 2000. - P. 136 - 139. (In Russian).

4. Borisov A.S. Signal-to-noise stability of the matched filtration of echosignals, past a layer of a ground // Radiation and dispersion of EMW: Materials All-Russia SC. - Taganrog: TSURE, 2001. - P. 268 - 270. (In Russian).

5. Cook Ch., Bernfeld M. Radiolocation signals. - M.: “Soviet radio”, 1971. - 568 p. (In Russian).

6. Hamilton E.L. Geoacoustic models of a sea-bottom // Acoustics of marine sediments. - M.: “World”, 1977. - 533 p. - p. 176 - 210. (In Russian).

7. Barnik V.R., Vendt Г., Kablov G.P., Jakovlev A.N. Hydrolocation sysnems of vertical sea bottom probing. – Novosibirsk: NEI, 1992. – 217 p. (In Russian).