A.S. Borisov, S.A. Borisov

ABOUT LEVELS OF SIGNALS REFLECTED BY A TRANSITIONAL LAYER AT VERTICAL SOUNDING BY A PARAMETRICAL SOURCE

Taganrog State University of Radioengineering (TSURE)
Russia, 347928 Taganrog, Nekrasovsky, 44
Tel.: (86-34)-310-635
E-mail: fep@tsure.ru

Ocean is the vertically stratified medium, in which everywhere it is possible to select a thin structure of temperature distribution, and consequently of sound velocity. Frequently thin structure has a step-like character. The boundary between marine water and bottom sediments also can be indistinctly expressed, have a transitional layer, in which the sound velocity has an increased gradient. One of the models circumscribing similar transitional layers, is the Epstein transitional layer. The acoustic sounding of a thin structure allows to evaluate the characteristics of layers of sound velocity jump, to study its physical nature and character of hydrophysical fields interaction in ocean.

In the paper the frequency properties of a transitional Epstein layer for normal incidence of a sound wave are considered, the levels of reflected signals of parametrical sources are evaluated.

The acoustic sounding of ocean microstructure allows to evaluate characteristics of thin layers of sound velocity, to study its physical nature and character of hydrophysical fields interaction in ocean. The sound velocity in layers with a step-like character [1] of its physical properties, can be approximated, so-called, Epstein transitional layer.

The reflection coefficient of transitional layer for normal incidence of sound wave is equal [2]

$$V(iw)=\frac{\tilde{A}(iS)}{\tilde{A}(-iS)}\cdot\frac{\tilde{A}\left[i\frac{S}{2}(1+n_{\infty})\right]\cdot\tilde{A}\left[1-i\frac{S}{2}(1+n_{\infty})\right]}{\tilde{A}\left[i\frac{S}{2}(1-n_{\infty})\right]\cdot\tilde{A}\left[1+i\frac{S}{2}(1-n_{\infty})\right]}, \qquad (1)$$

where $\tilde{A}(\bullet)$ - gamma function;

$S = 2k/m = l/(0.28 \cdot \ddot{e})$ - relative thickness of a layer; m - scaling coefficient;

n - refraction coefficient; l, k - wavelength and wave number (outside of layer);

l - effective thickness of layer (at 0.5 level from maximum value of sound velocity saltation in layer).

$n_{\infty} = c_0 / (c_0 + \Delta c_{\max})$;

$\Delta c_{\max}$ - difference of sound velocities in mediums after and before transitional layer.

The analysis of expression (1) shows, that the reflection coefficient of transitional layer, in difference from a reflection coefficient of Epstein's symmetrical layer, has a unresonance character [3]. The module of reflection coefficient frequency characteristic of a transitional layer represents under the form a transmission factor of a low-pass filter. On Figures 1 and 2 the typical dependences of reflection coefficient module and phase are indicated. As it is visible from fig.1, the sound reflection coefficient of the transitional layer has constant significance in some frequency band. The blockage of a frequency characteristic up to a level 0.707 and less happens at wave-thickness of layer, satisfying to an inequality $l / l \geq 0.13$. Magnitude of a reflection coefficient, for want of holding the condition $l / l \leq 0.13$, depends only on a saltation of sound velocity on a layer. The maximum significance of a reflection coefficient does not depend on a thickness of a layer. The thickness of a layer influences on shear frequency - shear frequency increases with a diminution of thickness.

Maximal values of a reflection coefficient V, for example at jump of a sound velocity 5, 20 è 50 m/s, are equal $1.6 \cdot 10^{-3}$, $6.6 \cdot 10^{-3}$ *è* $1.6 \cdot 10^{-2}$, accordingly.

The phase of transitional layer reflection coefficient varies from zero significance in the field of the lower frequencies, accepting negative significances with a minimum in the field of shear frequency and further smoothly increase up to significance $+p$, i.e., in difference from a symmetrical layer the transitional layer can distort the form of broadband signals more essentially.

As the thin structure of ocean has a rather broad band of the vertical sizes modifications, for deriving the full information about it physical performances it is necessary to use broadband sounding systems. Possibility of complicated broadband signals radiation or operative reorganization of radiation frequency in broad frequency band has the parametrical acoustic emitters, therefore they are the perspective tool in solving problem of remote sounding of a thin ocean structure.

Jump layer wave-size influence on the module of reflection coefficient

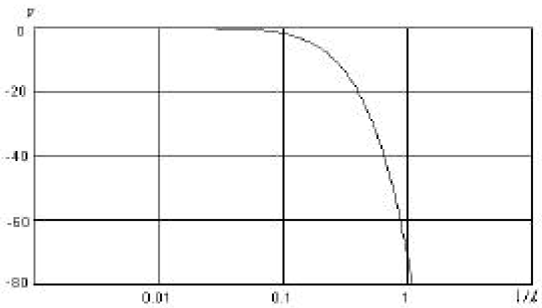

Fig.1.

Layer wave-size influence on the phase of reflection coefficient

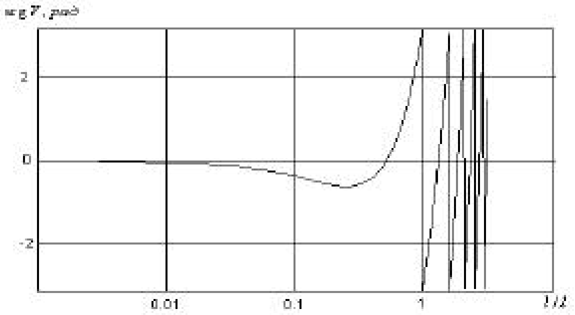

Fig.2.

For want of parametrical sound radiation the coherent component of a signal reflected by a transitional layer, can be found from expression [3]

$$P_-(z)=\frac{P_{01}P_{02}\text{âÙ}}{2\text{ñ}_0c_0^3}V_-\frac{\exp(-2\text{â}_-z_h)}{1+z_h^2/L_d^2}I_1(z)\,, \qquad (2)$$

where $I_1(z)=\int\limits_0^{z_h}\frac{exp(-\hat{a}\cdot y)dy}{1-j(z_h-y)/L_d+y(2jL_d+z_h)/L}$;

$b=b_1+b_2-b_-$; b_-,b_1,b_2 - attenuation factors of waves with frequencies Ω, w_1, w_2, accordingly; $L=l_{d1}l_{d2}$; $L_d=\frac{\grave{U}\cdot R^2}{4\cdot c_0}$; $l_{d\,1,2}=R^2\grave{u}_{1,2}/2c_o$;

$\tilde{n}_o, c_o$ - density of a medium and velocity of a sound in it at absence of perturbations;

P_{01}, P_{02} - amplitudes of primary waves sound pressure on a surface of pump antenna;

ε - parameter of nonlinearity; R – pump antenna radius;

V_- - coefficient of reflection from a sound velocity saltation layer for difference wave;

$k_-=\grave{U}/c_o$; $l'_{d1}=\grave{u}_1a_1^2/2c_o$; $l'_{d2}=\grave{u}_2a_2^2/2c_o$; $a_{1,2}^2=R^2(1\mp jz'_n/l_{d1,2})$; $\hat{a}'=\hat{a}_1+\hat{a}_2+\hat{a}_-$.

In the formula (2) the nonlinear interaction of pump waves inside a layer were not taken into account. Using expressions (1) and (2), it is possible to evaluate levels of signals, reflected by a transitional layer of sound velocity jump. For example, at following performances of sound velocity jump layer and parametrical emitter: effective thickness - $\ell=0.1\,m$; overfall of sound velocity on a layer – 2m/s; reflection coefficient – $V=3\cdot10^{-4}$ (on frequency 20 kHz); frequencies and levels of pump - $f_{01}=60\,kHz$, $f_{02}=80\,kHz$, $P_{01,02}=3.5\cdot10^5\ Pa$, accordingly; diameter of the pump antenna aperture - $R=1.5\ m$, we will receive the graph of sound pressure level in a reflected wave dependence on a distance from the jump layer (fig.3).

It is visible from the graph, that the levels of reflected signals make magnitudes from shares up to several tens Pascals, that allows to realize sounding of transitional hydrological layers by parametrical sources. However, for deriving levels of reflected signals exceeding levels of sea noise on lower frequencies, we will need pump antennas with more large sizes than indicated in the example.

Dependence of sound pressure
in a reflected wave levels from a distance to a sound

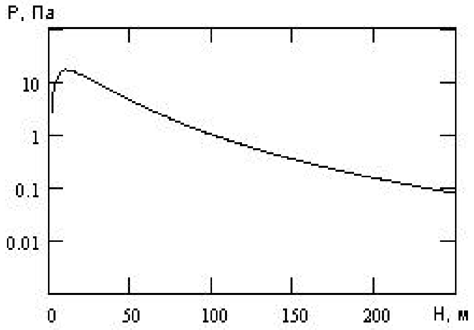

Fig. 3.

Therefore the use of parametrical antennas in sounding of hydrological heterogeneities in the field of 5-10 kHz and lower by simple signals can appear impossible because of low levels of sound pressure on difference frequencies. In this case it is necessary to use a complicated signals of rather large duration with a consequent match filtration of reflected signals, because the coherent component in reflected by hydrological layers signals can essentially exceeds scattered component.

REFERENCES

1. Brekhovskikh L. Ì., Lysanov U.P. Theoretical bases of ocean acoustics, Leningrad, 1982, p.264. (In Russin).
2. Brekhovskikh L. Ì. Waves in stratified mediums. Ì., 1957. (In Russin).
3. Borisov S.À. Levels evaluation of signals, reflected by a saltus layer of sound velocity at vertical sounding by a parametrical source // The Materials of All-Russia Scientific Conference "Ecology 2000 - Sea and Man", IASES, Taganrog 2000, p.123-127. (In Russin).