A.S. Borisov

ABOUT RESOLUTION OF MARINE SEDIMENTS ACOUSTIC PROFILING

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

The influence of frequency dependence of sound attenuation in marine sediments on a sounding signals resolution is analyzed in this work. The passing of acoustic videopulse and linearly frequency modulated radio pulse with rectangular envelop through a silty sediments layer is considered. The resolution dependencies on sounding depth are calculated.

The information about a thin stratified marine ground structure is of interest at a solution of many problems of marine geology, hydrotechnical buildings engineering, prediction of sound fields in the sea. The resolution is the important profilers engineering parameter, permitting to estimate its ability to divide echo signals from two closely located adjacent boundaries of a marine ground layer.

The profilers resolution can be estimated on duration of received signals after a processing device. Herewith a minimum distance on a time axis that describes the range resolution, is selected equal to a signal's envelop width at a 0,5 level from a maximum. It is accepted to evaluate the resolution Δr basing on effective power spectrum width of a signal Δf_{ef} [1]:

$$\Delta r = c \cdot \frac{1}{2 \cdot \Delta f_{ef}}, \qquad (1)$$

where

$$\Delta f_{ef} = \frac{1}{2 \cdot p \cdot \left|G_{\max}(jw)\right|^2} \int_0^\infty \left|G(jw)\right|^2 dw, \qquad (2)$$

$G(jw)$ –spectrum density of signal; c – sound velocity. It is necessary to mark, that at such approach to the problem of an resolution evaluation, the resolution of two signals is determined only by form of these signals, i.e. it is considered, that the a signal-to parasite ratio is sufficiently great. The situation, when a the signal-to parasite ratio is sufficiently great, can take place at use a narrow-beam parametric acoustic profiler, towed on rather small distance from a ground surface. Herewith the "sound spots" on a ground surface and layers are small, therefore reverberation from them has a small level and quickly attenuate in time, i.e. it is possible to consider such sound spots as a dot or small dimensioned objects.

It is known, that the acoustic impulses propagation in mediums with frequency - dependent attenuation, such are the marine soils also, the signals spectrum is undergone the distortions – maximum frequency of a spectral density displaces in low frequencies site, the spectrum width is decreases [2]. Therefore, the signals resolution is decrease also.

Let's consider the influence of marine ground sound attenuation frequency dependence on a profilers resolution modification. Let's take deterministic model of a marine ground, supposing, that: the ground structure is homogeneous, the sound velocity is constant, no sound velocity dispersion, the propagating wave is longitudinal and has a plane phase front, the law of a frequency sound attenuation dependence in a ground is constant, no nonlinear effects.

Such statement of the problem allows to estimate influence of a sound absorption on effective spectrum width of echo signals and, therefore, on a profiler resolution.

At made assumptions, it is possible to present a sound wave propagation in a medium as passing of a signal through a low-pass filter [3] with frequency transmission coefficient:

$$K(f,r) = \exp\left(-r \cdot k \cdot f^n\right), \qquad (3)$$

Here r is the distance, passed by a sound wave [m], k – specific attenuation coefficient [Np/m·kHz], f – frequency [kHz], exponent n, in dependence on marine ground type, varies from 0,5 up to 2 [4].

Spectrum of the passed a distance r in a ground signal, can be presented as a multiplication of emitted signal's spectral density $G_0(jf)$ by ground layer transmission coefficient $K(f,r)$:

$$G(jf,r) = G_0(jf) \cdot K(f,r). \qquad (4)$$

Effective power spectrum width of propagating in marine soil signal is possible to find with the help of expression:

$$\Delta f_{ef}(r) = \frac{1}{2 \cdot p \cdot \left|G_{\max}(jw, r)\right|^2} \int_0^\infty \left|G_0(jw) \cdot K(w, r)\right|^2 dw \cdot \qquad (5)$$

Then, the resolution of propagating in soil layer signals, – $\Delta r(r)$ can be determine, by substituting a value of $\Delta f_{ef}(r)$ into expression (1).

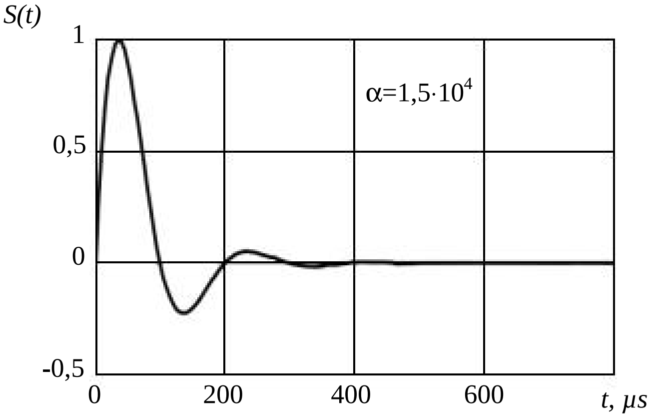

Fig.1. Acoustic videopulse, normalized to amplitude maximum.

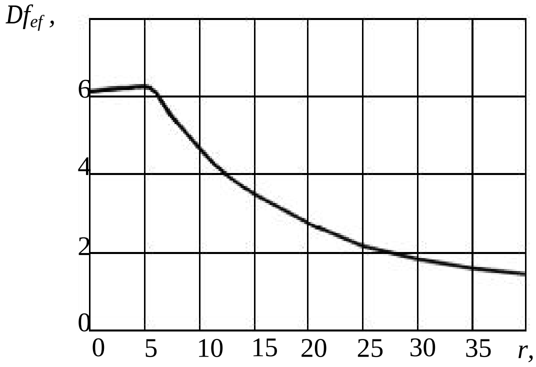

Fig.2. Modification of videopulse’s effective spectrum width.

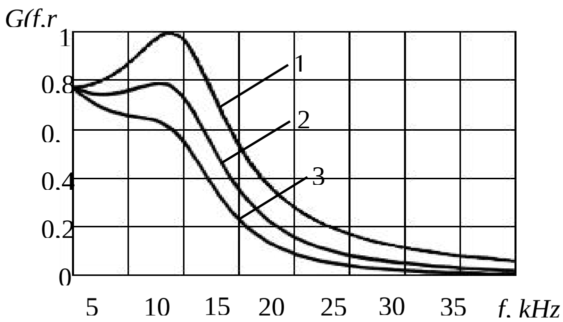

Fig.3. Normalized spectral densities of videopulse: 1 - initial; 2 - passed 5m in layer; 3 - passed 10m.

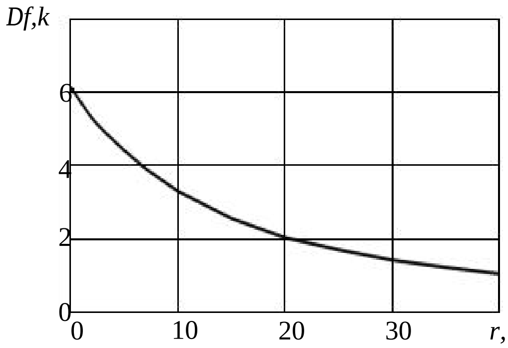

Fig.4. Modification of the LFM pulse’s effective power spectrum width.

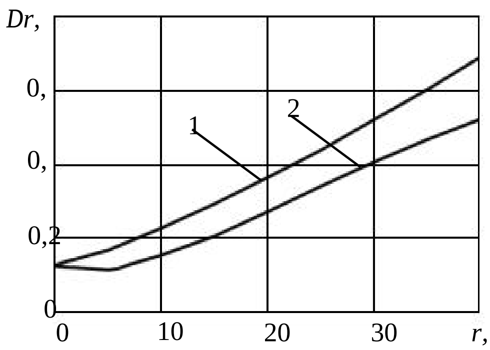

Fig.5. Modification of signals resolution: 1 – LFM pulse; 2 – videopulse.

As an example we shall consider models of widely used in practice of profiling acoustic signals: acoustic videopulse and rectangular radio pulse with linearly frequency modulated (LFM) filling. Such signals are radiated by “boomers” and “chirp-sonars” accordingly. Let's accept, that the signals are propagating in a silty marine sediments layer ($c \approx 1500\ m/s$) with frequency-dependence sound attenuation coefficient: $b = 0.049 \cdot f^{1}$ [4].

The approximating function of acoustic videopulse (Fig.1) can be a function:

$$S(t) = A \cdot \exp(-a\ t) \cdot \sin(w_0\ t)\ . \qquad (6)$$

Spectral density of signal (6), found by means of direct Fourier transform is defined by expression:

$$G_0(jw) = \frac{w}{(a + j \cdot w_0)^2 + w^2}\ . \qquad (7)$$

Effective power spectrum width of such signal (Fig.1), calculated on the formula (2), is 6120 Hz. The results of signal’s effective power spectrum width dependence on passed in a ground distance evaluation (expression (5)), are represented as the graph in Fig.2. As it is visible from the graph, the effective spectrum width of videopulse, is linearly increases on a site from 0 up to 5m and on a 5m distance it is equal: $\Delta f(5) = 6246\ Hz$. This result is explained by coming the form of videopulse’s spectral density envelope nearer to rectangular at sounding depth up to 5m (see Fig.3.). As it expected, from the 5m distance the effective spectrum width is decreasing. For a comparison with a signal (6) we shall consider now frequency distortions of rectangular LFM impulse:

$$S(t) = \begin{cases} A \cdot \cos(w_0 t + \dfrac{m t^2}{2}), & |t| < \dfrac{t}{2}\ , \\ 0, & |t| > \dfrac{t}{2} \end{cases} \qquad (8)$$

with parameters: central frequency $f_0 = 5000\ Hz$, initial effective power spectrum width $\Delta f_{ef} = 6120\ Hz$, duration $t = 10\ ms$. The dependence graph of LFM pulse spectrum width on sounding depth is shown in Fig.4.

The graphs of signals (6) and (8) resolution dependencies on distance r are plotted by calculated values Δf_{ef} in Fig.5. From obtained results of considered impulse signals resolution calculation it is possible to make a conclusions that with increasing of a layer thickness the profiling resolution is decreasing for both signals types, however for small distances (*r<5…7ì*) the acoustic videopulse more preferable then LFM - radio pulse, as it the resolution does not vary almost, or even can be increased (see. Fig.5). Since some distances (in dependence on soil type) the LFM signals can be used more effective then videopulses as at identical with them resolution can have essentially greater energy because of possibility to increase its duration.

R E F E R E N C E S

1. Sloka V.K. Questions of Processing the Radar Signals. Moscow, “Soviet radio”, 1970. 256p. (In Russian).
2. Bulatova G.M., Gorshkov V.N., Dubrov E.F., Pestrinsky A.I., Tupaev K.K. Measurement of elastic oscillations velocity and attenuation in bottom sediments of water areas shelf zone. The IX all-Union Acoustic Conference Reports. Section Å. Moscow, AS USSR, 1977. pp. 49-52. (In Russian).
3. Golubkov A.G. Specialized Hydroacoustic Systems. Leningrad, “Sudostroenie”, 1987.–136p. (In Russian).
4. Barnick V.R., Vendt G., Kablov G.P., Jakovlev A.N. Sonar Systems of Vertical Ground Probing. Novosibirsk, Novosib. University, 1992.–218p. (In Russian).