Analysis of the effect of synchronization of a group of non-explosive sources on the results of field work

O A Maykov

Siberian Federal University, 79, Svobodny pr., Krasnoyarsk, 660041, Russia

E-mail: maykov_oleg@bk.ru

Abstract. The article deals with the issues of synchronization of a group of sources for exploration of minerals. A group of 3 impulse sources with different delay times (500,1000,2000 μs) for a two-phase medium is modeled, the upper layer is a water layer 20 meters deep, the lower layer is a layer of sedimentary rocks 350 meters deep. Impulse action is one period of harmonic oscillation with a period of 0.1 s. Time diagrams were recorded at depths of 50 and 100 meters. It is shown that the use of a delay of 2000 μs leads to a halving of the signal amplitude at a depth of 100 meters. The data obtained show that improving the synchronization of a group of sources for the needs of seismic exploration will allow focusing and creating the maximum signal amplitude at a given point.

1. Introduction

Conducting marine seismic surveys in shallow and transit conditions is one of the most difficult tasks in the production of geological exploration work. At the same time, the main problem is the lack of technical and technological means that would allow such work to be carried out with the required performance and would make it possible to obtain high quality data. The most problematic area during seismic exploration in water areas is the land transition areas, i.e. a strip of extreme shallow water with depths from 0 to 1.5 meters. While ensuring high quality and manufacturability of seismic 3D-survey, it must be stated that today there are no sources of vibration excitation for work on the land-sea border [1]. Recently, for work in the zone of extreme shallow water, the method of pneumatic sources screwed into the ground has become widespread [1, 2]. Obviously, this method, firstly, does not provide the required productivity of work, and secondly, it has a negative impact on the environmental situation in the work area. A comparative analysis of the harmful acoustic impact of all known types of seismic sources on the marine fauna is given in [3].

In an ordinary explosion, a shock pressure wave arises, a similar effect is caused by a pneumatic emitter (air gun): the air bubble it creates practically repeats the explosive effect of the instantaneous expansion of the area of influence, which leads to the same results that are fatal for aquatic biocenoses. Less powerful sources such as "Boomer" and "Sparker" lead to the same negative consequences, since the spark effect of the "Sparker" creates an explosive effect associated with the instantaneous evaporation of water in the zone of passage of the electric discharge, and the action of the "Boomer" is based on the instantaneous shear of the impact surface under by the influence of electrodynamic induction [3].

Most often, electrodynamic sources (boomers) are used in the water area for detailed dismemberment of the uppermost part of the section (UPS), since they operate in a fairly high frequency range of 500
Hz to 5 kHz, which makes them effective for studying UPS [4]. It is shown in [3] that the most acceptable option for seismic exploration, from the point of view of a significant reduction in the negative environmental impact on marine biocenoses, is the use of pulsed non-explosive sources with an electromagnetic drive "Yenisei" as sources of seismic vibrations, as well as the closest analogue of this technology, described in the works of Yakovlev DA, where a prototype of a pulsed water seismic source "Aqua" with an electromagnetic drive was investigated [5]. The disadvantage of this particular work is that this installation was studied exclusively from an electromechanical point of view, that is, the processes taking place in the system until the moment of energy discharge into the aqueous medium were considered, without evaluating the most important parameters of the added mass and the hydrodynamic resistance of the medium.

Seismic exploration based on coherent sounding signals is an alternative approach to airguns in the aquatic environment and pulsed sources on land, which can significantly reduce the harmful acoustic impact on the environment. It is the provision of high identity that will make it possible to increase the resolution of seismic exploration by means of coherent accumulation [6]. Among similar technologies, one can single out, for example, broadband hydroacoustic emitters of the electrodynamic type (developed at the Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod) [7]; piezoceramic emitters of a new generation [8]. It should be noted that none of the above technologies has received widespread use in water seismic exploration, but they are used to a greater extent in the tasks of hydroacoustic illumination of the underwater environment, as well as as scientific equipment for the study of deep and superdeep wells. The main disadvantages are: extremely high unit cost, reliability issues have not been resolved.

The closest direction for solving problems, to which scientific research is directed, is the approach to research and construction of seismic-emitting equipment based on the electromagnetic principle, which is proposed by Chinese scientists [16] This method is patented, however, publications confirming its characteristics have not yet been presented in the scientific press.

Thus, the development and creation of systems for prospecting for minerals in shallow water is not a trivial task, which is the use of a group of sources to achieve the required impulse force and, accordingly, the depth of research, therefore, the task of synchronizing a group of sources with each other is an urgent task of modern geophysical exploration.

2. Methods and materials

For theoretical modeling and the effect of synchronization of a group of sources, it was proposed to use a two-layer model of the shelf, and to speed up the calculations in a two-dimensional model. The modeling scheme is shown in figure 1, which is a homogeneous layer of seawater 20 m with a density of 1027 kg / m³ and a sound speed of 1521 m / s and a homogeneous layer of sedimentary rocks represented by a sand layer of 300 m with a density of 1500 kg / m³, Young's modulus 130 10^-6 Pa and Poisson's ratio 0.3. The modeled group of sources represents 3 non-explosive sources with an impact force of about 1300 Pa, representing a steel plate with dimensions of 0.1x1 m. To simulate the impulse action, one harmonic oscillation period with a period of T = 0.1 s was used (figure 2), dimensions of 0.1x1 m. To simulate the impulse action, one harmonic oscillation period with a period of T = 0.1 s was used (figure 2).
Modeling was carried out by solving differential equations for a conventional linear elastic material in the formulation of strain-rate:

\[
\rho \frac{\partial \mathbf{u}}{\partial t} - \nabla \cdot \mathbf{S} = F_v
\]

\[
\frac{\partial \mathbf{E}}{\partial t} - \frac{1}{2} \left( \nabla \mathbf{u} - (\nabla \mathbf{u})^T \right) = 0
\]

\[
S = C : E
\]

where \( \mathbf{u} \) is the velocity, \( \rho \) is the density, \( \mathbf{S} \) is the stress tensor, \( \mathbf{E} \) is the strain tensor, \( C \) is the elastic tensor (or the stiffness tensor), \( F_v \) is the possible volume force.

3. Results and discussions
The solution of differential equations is reduced to the calculation of the propagation of a spherical wave through an aqueous medium and sedimentary rocks. The introduction of a delay between the sources leads to a displacement of the maximum of the wave front from the vertical and the higher the delay, the higher the angle of displacement will be. In this case, in the input of the simulation, the dependences of the acceleration amplitude on time were obtained at the measurement points at a depth of 50 and 100 meters, for 4 different delay options shown in figure 3.
Figure 3. time dependence of acceleration at a depth of 50 (green) and 100 (blue) meters, a - full synchronization, b - 500 μs delay between rising sources, c - 1000 μs delay between rising sources, d - 2000 μs between rising sources.

Analysis of the graphs shows that the amplitude of the signals with desynchronization of sources up to 1 ms does not significantly affect the amplitude of the signals for both 50 and 100 meters. A delay of 2 ms between sources leads to a decrease in the amplitude by almost 2 times, which is critical in the author's opinion, and given that real deposits are located at depths of the order of 1-5 km, desynchronization even in 100 μs will have a significant effect on the signal amplitude.

4. Conclusion
The modeling performed shows that the task of synchronizing a group of sources is a very important task for searching for hydrocarbons on the shelf and shallow water. The main advantages of using a group of sources to search for hydrocarbons are reduced to ensuring synchronization between them, as well as ensuring the identity of the exciting pulses. As shown in this article, even a 2 ms resynchronization leads to a 2-fold decrease in the signal amplitude at a depth of 100 meters.

A further prospect of research is reduced to the study of the effect of synchronization of a group of sources for depths of the order of 3-4 km, which requires the use of large computing power, as well as analysis of the effect of real signals from a group of operating sources. According to the author, the
introduction of rigid synchronization up to 1 μs will increase the reliability of the received seismic data not only on the shelf and shallow water, but also on land.

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