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Development of a non-explosive water source of seismic acoustic waves with an electromagnetic drive to automate the work in transit zones and in shallow water

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Abstract. The paper examines the theoretical aspects of the excitation of seismic waves in the aquatic environment, addresses the problems of instrumental implementation of a fundamentally new source of seismic vibrations that can work in the waters, in tidal and coastal zones, i.e. produce continuous seismic profiling from the water area to the land. The scientific substantiation of the developed SI design is given. The effectiveness of two polar excitation of the aquatic environment is evaluated in comparison with the water electromagnetic pulse sources of the Yenisei series. The comparative analysis results of SR experimental model effectiveness with VEM-50 production model of the "Yenisei" model range is given on the basis of experimental data obtained at the geophysical well of the testing and testing ground of the Siberian Federal University.

1. Introduction

The ecological consequences of traditional methods of exciting seismic vibrations in water areas using explosions and pneumatic guns have been studied sufficiently in the works of ichthyologists and hydrobiologists. A number of studies have shown that the blast wave has a sharply negative effect on hydrobionts [1-3].

The generation nature of an elastic wave produced by a pneumatic impulse is fundamentally different from the excitation of seismic-acoustic (SA) waves generated by a short-stroke impulse effect caused by the movement of a flat float bottom due to electromagnetic forces. In particular, when a seismic source is operating with a single short pulse is generated with a duration of (1 ÷ 10) ms. At the same time the air bubble is not formed, as during the work of pneumatic radiators. The air bubble has the effect of instantly expanding the area of impact, which, firstly, leads to results that are fatal to aquatic biocenoses, and secondly, it causes "parasitic" vibrations, which are interferences. In addition, the pulses emitted by the airguns are uncontrollable, i.e. temporal and frequency characteristics have poor repeatability from exposure to exposure. The use of VINS will allow coherent accumulation, i.e. to ensure the operation of the source, without resorting to the mode of maximum instantaneous power of impact on the environment, which is detrimental to aquatic biocenoses.

Accordingly, the use of a pulsed electromagnetic seismic source in seismic prospecting will reduce the degree of negative acoustic impact on the ecosystem of the reservoir, as well as provide an opportunity to work in extreme shallow water. Attempts to create such systems have already been described in [4–7], as well as their use to create coded sequences [8].

“Yenisei” seismic sources have a number of significant drawbacks. In this connection, we define the basic required initial parameters of the studied water source, and also take a number of assumptions necessary for the physical and mathematical substantiation of the design features of the seismic source (SS), which will ensure its advantages over the source of the “Yenisei” series.

1. The impact on the medium is a bipolar impulse, which allows to increase the coefficient of performance (Efficiency) of the investigated SS by eliminating the process of "departure" of the reactive mass beyond the working fence between the anchor and the inductor. This is the main difference from the "Yenisei" SS, which is able to work only in the unipolar pulse mode, which is formed due to the attraction and "departure" of the reactive mass. Water is considered as an isotropic and incompressible medium.

2. The emitter plate area should be sufficient to ensure the specific impact on the medium is not more than 1 kg/cm^2, in order to prevent the occurrence of cavitation processes in the emitter zone.

3. The contact of the flat bottom of the radiator with the water surface allows the formation of a bipolar shock.

4. Estimation of the parameter of the attached mass of water will make it possible to optimize the parameters of the seismic pulse duration and the associated values and shapes of the supply currents and voltages for better matching of the transmission of seismic acoustic energy to the medium.

2. Methods and materials

The monitoring and control system (MCS) of a group of emitting modules must ensure synchronism of the emitters' operation and control of the operating parameters of the emitters, including: starting and tripping in accordance with the set parameters on command; transfer of control data to external devices; quality control of actuation in accordance with the requirements for the parameters of identity: phase (synchronism), not more than ± 250 µs; amplitude, not more than 15%.

MCS was created both from existing software and hardware on the market with a slight revision in order to interface them, and with the use of its own software and hardware solutions and know-how. MCS consists of three main elements:

1. Synchronization system and management consisting of:
1.1 Controller - 1 pc.;
1.2 SGD-SP console - 1 pc.;
1.3 Switch-stabilizer - 1 pc.
2. HydroPro software and hardware complex consisting of:
2.1 Receiver coordinate-time support - 1 pc;
2.2 Interface module for work in the slave/master mode to provide galvanic isolation of the actuator - 1pc.
3. Optocoupler unit for interfacing the synchronization system and HydroPro complex.

MCS provides for the operation of sources in two modes - master and slave. The block diagram of the work of the MCS in the master mode is shown in figure 1.

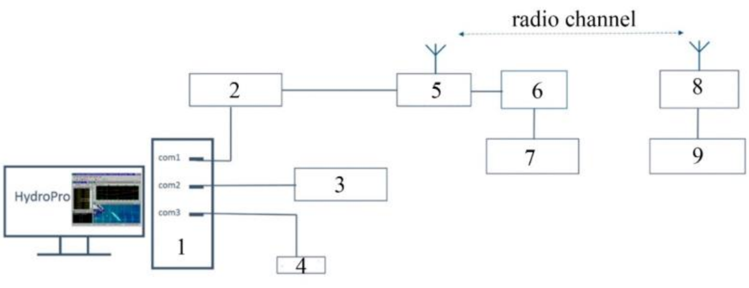

Figure 1. The block diagram of MCS work in the master mode, where 1 - a personal computer, 2 - an interface module, 3 - a coordinate-time receiver, 4 - an echo sounder, 5 - a slave controller, 6 - a SGD-SP console, 7 - VIMS radiator, 8 - host controller, 9 - seismic station.

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Developed within the framework of the project, the generalized algorithm for the operation of the control system in the leading mode is as follows. The coordinates of the points of excitation (PE) are put into in HydroPro software. Real-time HydroPro software receives data at a frequency of 100 Hz about the location of sources and water depth (any type of echo sounder transmits data in NMEA0183 format). The seismic station is in slave mode and is waiting for a command to start from the slave controller. When a ship reaches a given point of excitation, HydroPro sends a command to the actuator, which sends a command to the optocoupler unit (OU), the OU opens the master controller circuit, the controller sends a command to the console, which in turn initiates a strike, and the slave seismic controller that supplies command at the station to start registration. After the strike is made, the ship moves on (without stopping) and when the next PE is reached, the cycle described above is repeated. The location of the vessel and the depth of the water are recorded in the appropriate file and each impact is assigned the coordinates and depth mark.

OU is an optocoupler switch (figure 2). Its use is caused by the following necessity. The controller is started by a seismic station. The launch is as follows. In the controller circuit (contacts “9” and “7” of the “Station” connector (figure 3), a current of 4-6 V constantly flows through. When the operator of the seismic station presses the “Go” button to start the excitation-registration cycle, the station opens contacts “9 "And" 7 "and the current disappears for 5 ms. This is perceived by the controller as a start command. IM does not open the contacts, but sends a command (pulse with adjustable duration and voltage of 5 V) to the external device which makes it impossible to start the controller, therefore SKU was introduced by OB. Using OB at ostizhenii ship desired PV ON HydroPro a command for IM and IM issues a command to ON, which opens the contacts "9" and "7" and the controller realizes this as a command to run.

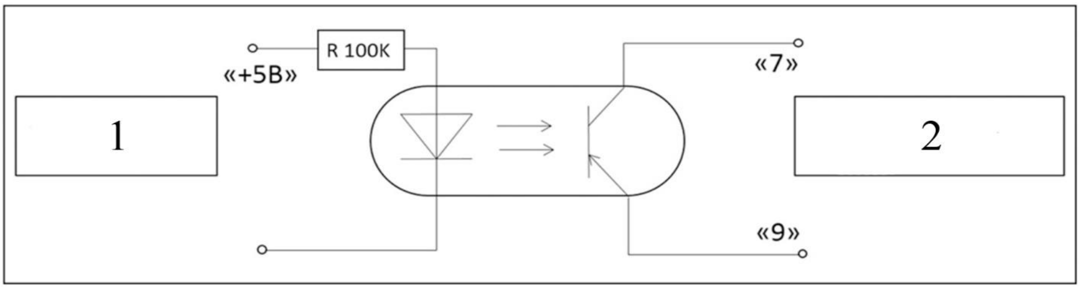

Figure 2. Diagram of the optocoupler unit, where 1 is the connector of the interface module, 2 is the connector of SGD-SP station.

Slave mode is similar to master mode, except that the excitation-registration process is controlled by a seismic station, which after a specified time interval commands the controller (in this case, the slave) located on the vessel and starts the excitation-recording cycle. The controller gives the command to the interface module (IM), and the IM gives the command to the software. HydroPro, in turn, captures the location of the source at the time of the impact. The time interval is set at the rate of PW and the speed of the vessel. OU is not used in this case. The control data is recorded by the monitoring system described in the next section. Autonomous determination of coordinates and time at the base and mobile stations.

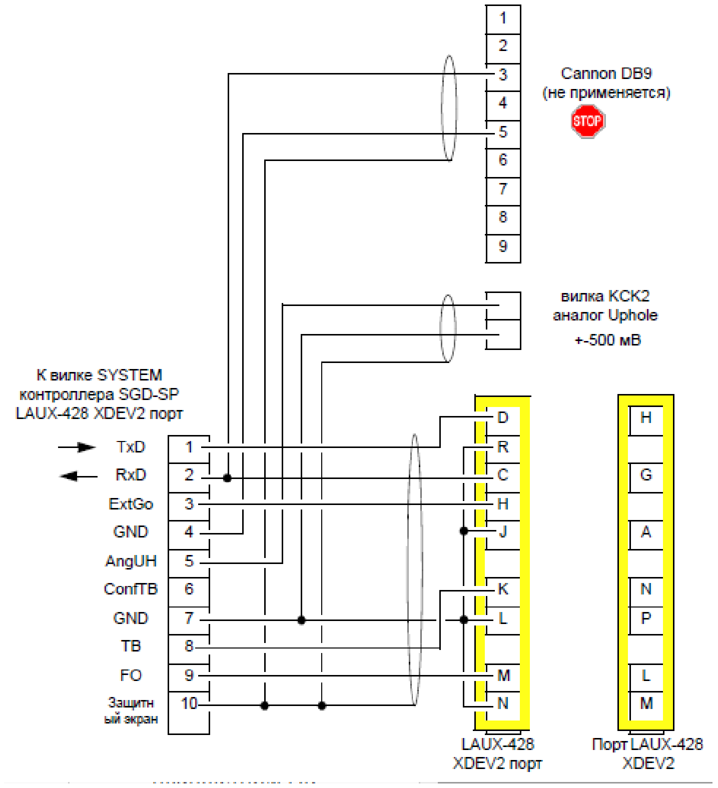

Figure 3. SGD-SP controller cable to Sercel 408, 428 seismic stations.

Adding measurements of navigation parameters, receiving navigation messages using signals from GLONASS, GPS satellite navigation satellites, autonomously determining position and time coordinates, and storing decision results and measurements on the base and mobile station's drives for subsequent precision determination of the relative position of the mobile station in the post-processing; Within the framework of the project, a special complex of coordinate-temporal support for the CCRW adapted to the conditions of water seismic prospecting is being created. Formation and output of the pulses of the reference signal of the time stamp with a period of 1 second for the equipment of the base and mobile stations; Transfer of the digitization of the time scale by UTC, GLONASS or GPS using the interface of the KKVO Project; Transmission of information about the current position, speed and time of the seismic exploration complex to the system controller according to an agreed protocol and to the seismic station via a radio channel using a radio module (range of not more than 10 km).

3. Results and discussions

The tests were carried out in 10.07.2018 and 11.07.2018 in Minusinsk city, 11 Promyshlennaya street, Testing Ground of Evenkyagugeofizika LLC. To measure the field strength, a Gnome seismic station SGD-SLM was used with a measuring probe SGD-SLM / G3, which descended to a depth of 50, 100 meters. With a strike force of 1,700 kg, the amplitude of the received signal was 10 µV. A series of 10 strokes was carried out. Amplitude beat identity was ± 8%. The amplitude identity was too high. The signal level is at the receiver's own noise level. The appearance of the measurement system is shown in figure 4.

Figure 4. Layout of a water source immersed in a pool.

The existing water seismic source VEM-50 with a peak force of 500 kN was used as a reference. A series of 10 strokes was produced, the position of the probe has not changed. The amplitude of the received signal is shown in figure 5.

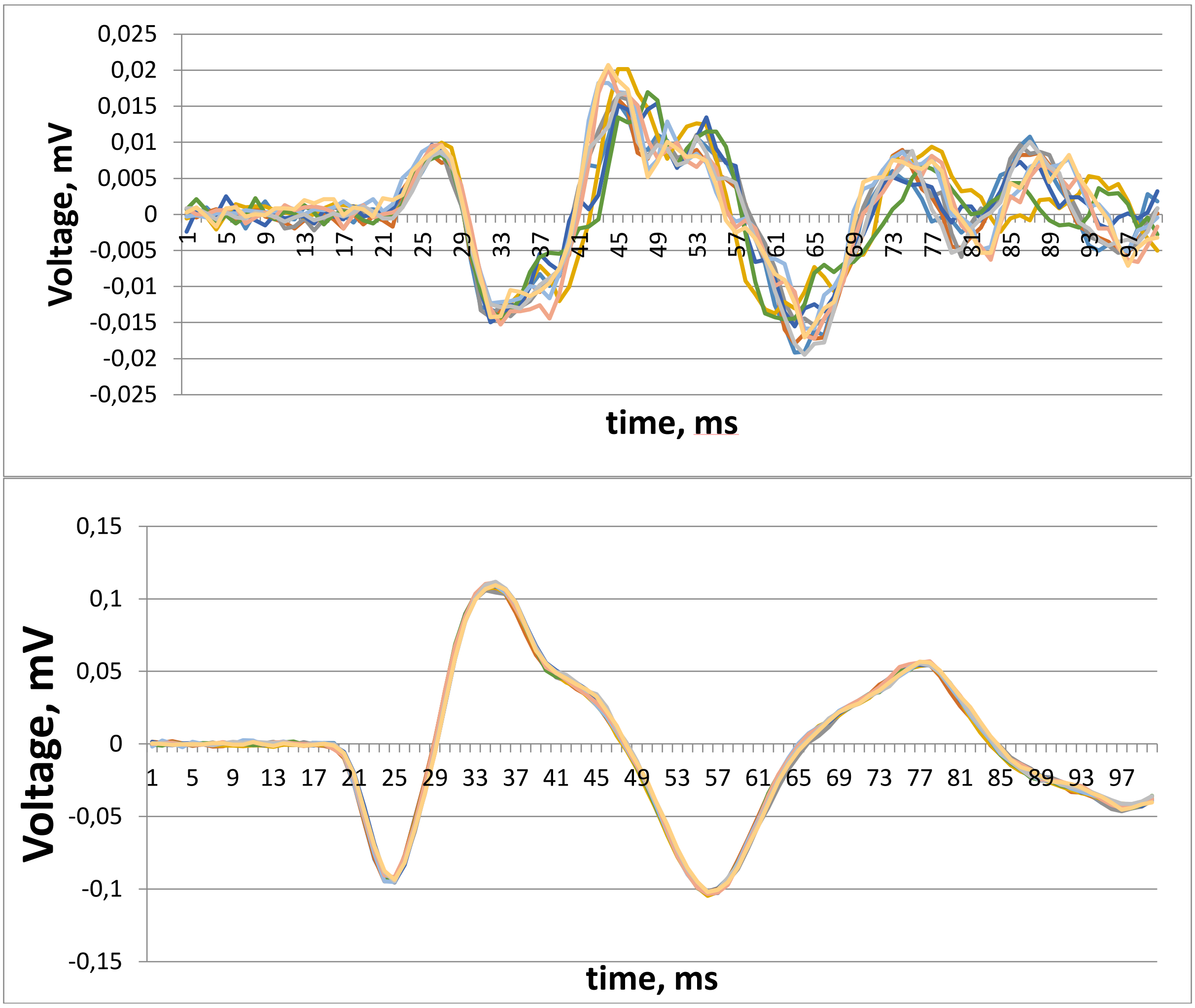

Figure 5. Amplitude of the received signal from the layout and the signal from VEM-50.

As it can be seen from the amplitudes of the received signals, the difference in amplitude is 10 times, in terms of the impact force, the sources differ by 30 times, the masses of the sources differ by 27 times.

4. Conclusion

An important result is the development of a model of the source in the aquatic environment, describing the dependence of the movement of the support plate in a liquid under the action of an external force on its size. When the magnitude of the magnetic gap reaches 0.5 from the maximum excitation current, the movement stops, and the movement of the masses continues upward with deceleration to values of the gap close to zero, while the force is exerted on the radiator with the spring force Fpr. Further, under the action of the same force Fpr, the gap increases, and the force acting on the emitter is maintained equal to Fpr and is directed downwards. When the gap reaches half the maximum value, the current in the magnetic field excitation coil is turned on, and a force Fp is created that acts on the emitter and is directed upwards and brakes the moving masses with a smooth stop when the magnitude of the magnetic gap reaches its maximum value.

The main distinctive features of known water sources, for example, VEM 100, are:

- exclusion of the inductor departure beyond the air gap δ, during the formation of seismic signals;
- elimination of mechanical shock between the anchor and the inductor;
- formation of a bipolar seismic signal, which allows for optimal coordination with the excitation medium;
- the ability to generate vibration signals with a frequency of up to 200 Hz.

These qualities fundamentally expand the operational and informative capabilities of the seismic emitter.

Acknowledgments

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