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Low Frequency Hydrophone for Marine Seismic Exploration Systems

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Summary: The low frequency hydrophone with the frequency range 1-300 Hz for marine seismic exploration systems was developed. The principle of operation of the hydrophone is based on molecular electron transfer [1] that allows you to achieve high sensitivity in the low frequency region. The paper presents the stabilization method of the frequency response in all frequency range with depth up to 30 m. Laboratory and marine tests confirmed the stated characteristics and the possibility of using this sensor in marine seismic systems. An experimental sample of a hydrophone has successfully passed a comparative marine test in Gelendzhik Bay (Black Sea) with technical support from JSC 'Yuzhmorgeologiya'.

Keywords: Hydrophone, Acoustic sensor, Molecular-electronic technology, Negative electrodynamic feedback, Seismic exploration.

1. Introduction

Inertial motion sensors are the main elements of all mineral exploration systems. Currently, in addition to widely used electromechanical geophones, electrochemical geophones operating on the principle of molecular-electronic transfer (MET) [1] have begun to be used in such land systems [2-4].

Hydrophones are one of the main components of marine seismic exploration systems. An experimental sample of the hydrophone was also made and laboratory studies of its main characteristics, such as amplitude-frequency response and self-noise, were carried out.

Most marine operations to search for mineral deposits are held shelf, in coastal and transition zones. Laboratory experiments have shown that in order to stabilize the amplitude-frequency characteristic with the increasing depth, it is necessary to increase the rigidity of the bubble in the upper cover.

2. Stabilization Method of the Frequency Response of the Hydrophone

The detailed scheme and principle of operation of the MET hydrophone (Fig. 1) is described in the paper [5].

If there is air under the cover during assembly, it is at the pressure of 1 atm. In this case, if the constant pressure on the outer membrane increases (for example, when a hydrophone is immersed), the inner membrane will flex until the pressure levels out. Moreover, for the volume V of the bubble under the cover, the following expression will be valid:

$$P_0V_0 = P_1V_1, \tag{1}$$

where P_0 = 1 atm., V_0 is the initial bubble volume at the pressure of P_0, V_1 is the bubble volume at the pressure P_1.

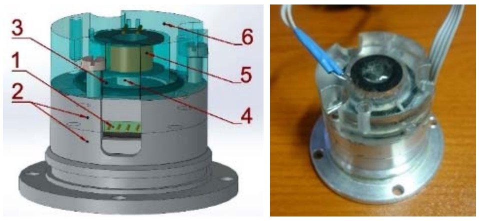

Fig. 1. The scheme and experimental sample hydrophone. 1 - sensing element; 2 - metal flanges; 3 - elastic rubber membranes; 4 – magnet; 5 - electromagnetic coil; 6 - upper cover.

The volume of the internal bubble will decrease inversely to the external pressure. This leads to the fact that the membrane begins to mechanically rest against the coil and thereby distort the output signal. Secondly, the rigidity of the air bubble increases, which leads to a decrease in sensitivity at high frequencies with increasing external pressure. It should also be noted that the feedback option used cannot compensate for the effect of the constant pressure.

Thus, stabilization of the frequency response is reduced in order to increase the rigidity of the isolated volume, which will change slightly with increasing pressure. For this, it was proposed to fill the volume with a compressible liquid, and polymethylsiloxane (PMS) liquid was chosen for that purpose.

3. Laboratory Tests

Two experimental model MET hydrophones were assembled. Their sensitivity was adjusted to 0.8 mV/Pa ±1 dB in the range of 1-300 Hz. The isolated volume of one of them was completely filled with PMS liquid, other second was partially completely filled. Calibration results for different pressure are shown in Fig. 2.

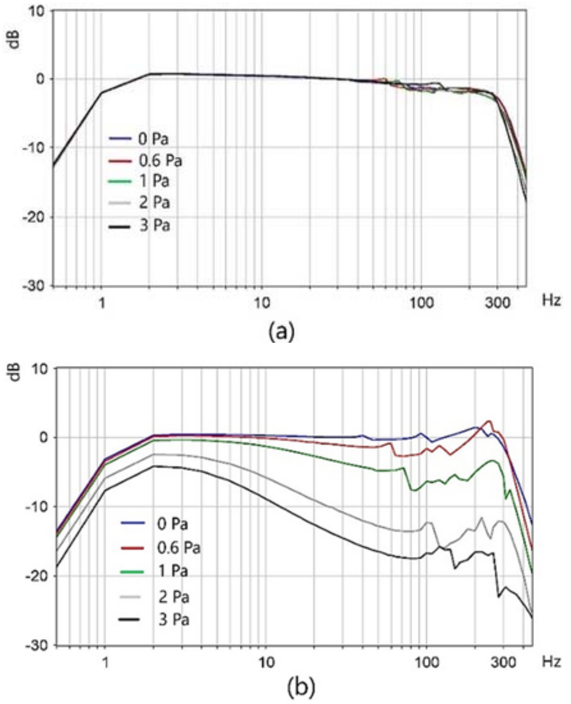

Fig. 2. Frequency response (0.8 mV/Pa) of MET hydrophones with the volume completely filled with liquid under the upper cover (a) and with the volume partially filled under different pressure differences.

Laboratory experiments have shown that the frequency response of MET hydrophone with a completely filled volume under the upper cover varies by -0.1 dB at low frequencies and -0.5 dB at high frequencies with increasing pressure difference on the membranes to 3 atm. While the frequency response of the second changes much more (-22 dB).

Further experiments were carried out with first type of MET hydrophone.

4. Marine Experiments

Marine experiments were held in Gelendzhik Bay (Black Sea) with technical support from JSC «Yuzhmorgeologiya». The experiment was to compare the response of the reference hydrophone (MP-25-250, ARAM ARIES II system) and the MET hydrophone to an external disturbing signal generated by a single pneumatic source of 40 cubic inches. The spectra of one of the elastic signals are shown in Fig. 3.

We see a good match (up to 20 %) of signals in the range from 15 to 100 Hz. The discrepancy at low (1-15 Hz) frequencies is caused by maintaining the flat characteristic of the MET hydrophone in this range and the lower boundary frequency by 10 Hz (-3 dB) at the reference hydrophone. The discrepancy in the range from 100 to 200 Hz can be caused by inaccuracy of placing the hydrophones at one point relative to the signal source. The discrepancy in the spectra at high frequencies (from 200 Hz) is due to the fact that the upper frequency of the working range of the MET hydrophone is 300 Hz, and the frequency response of the hydrophone remains flat.

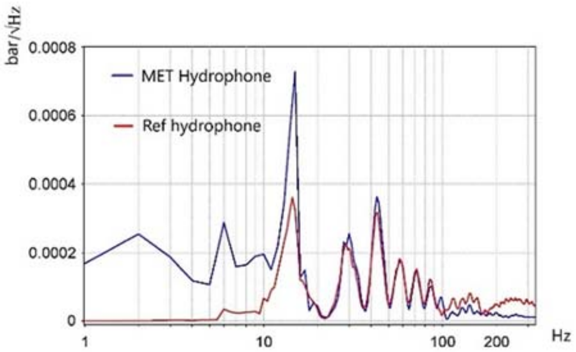

Fig. 3. Spectra of hydrophone signals of the same disturbing action in marine experiments.

5. Conclusions

As a result, the method of stabilizing the frequency response of MET hydrophone in range 1-300 Hz was proposed, tested and confirmed by laboratory and marine tests. Proven working depths are up to 30 m.

Comparative marine tests of the developed model of the MET hydrophone were carried out, which showed the possibility of using this type of hydrophone in marine seismic exploration systems.

Acknowledgements

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