Supersensitive Detector of Hydrosphere Pressure variations in Hydroacoustic Research

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***Abstract*—This paper describes the possibility of using a laser interference device as a hydroacoustic signal receiver. A supersensitive detector of hydrosphere pressure variations, created based on the equal-arm Michelson interferometer, was used in hydroacoustic studies. These experimental studies were conducted using hydroacoustic and seismoacoustic radiators as a signal source. A hypersensitive sensor of hydrosphere pressure variations was used as a signal radiator. The device received a signal from both hydroacoustic and seismoacoustic radiators.**

Keywords—supersensitive detector of hydrosphere pressure variations, hydroacoustic radiator, seismoacoustic radiator

I. Introduction

A supersensitive detector of hydrosphere pressure variations has been developed in the laboratory of the Pacific Oceanological Institute [1]. This device is based on modern laser interference methods according to the scheme of the equal-arm Michelson interferometer. A Mellis Griot frequency-stabilized laser with a long-term stability of 10^{-9} is used as a light source. This makes it possible to register variations in the hydrosphere pressure in the frequency range from 0 (conditionally) to 1000 Hz with an accuracy of 0.24 MPa at a depth of up to 50 m. A round stainless steel membrane fixed at the edges is used as a sensing element. On the one hand, the membrane is part of the interferometer; on the other hand, it is in contact with water. When the pressure changes, the membrane bends in one direction or the other, changing the length of the measuring arm. Because of this change, the device registers with high accuracy. Fig. 1 shows the schematic diagram of the measuring part of the device. The device for operation is prepared as follows:

1. Air is pumped into the chamber (1).

2. When the device is submerged to the bottom, the valve (9) opens, and air from the chamber flows through the tubes (2, 3) into the chamber between the membrane (4) and the dividing plate (8). The external and internal pressures are aligned. The membrane becomes neutral.

3. After installing the device to the desired depth, the valve closes, and the device is ready for operation.

4. Under the influence of variations in external pressure, the membrane bends this displacement and is measured by an interferometer.

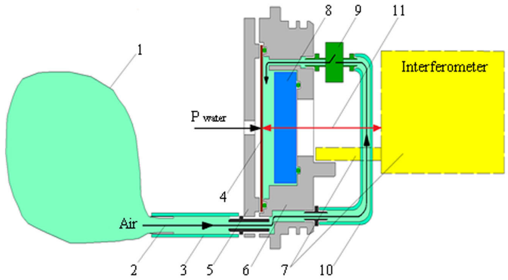

Fig. 1. Schematic diagram of the measuring part of the device. Air chamber (1), branch pipe (2), tube (3, 10), membrane (4), protective plate (5), corpus (6), interferometer (7), dividing plate (8), valve (9), and laser beam (11).

A supersensitive detector of hydrosphere pressure variations was tested at the marine experimental station of the POI FEB RAS. They recorded various wave processes from wind waves to tides. Experimental studies conducted using an ultrasensitive sensor of hydrosphere pressure variations have made it possible to study wave processes and their interaction. The natural fluctuations of the bays of the Poset Bay of the Sea of Japan [2], the mechanisms of occurrence and development of hydrophysical disturbances of gravitational and infragravity sea waves [3], the interaction of sea waves and atmospheric depressions [4], and other natural phenomena were studied.

A number of experimental studies were conducted using low-frequency hydroacoustic and seismoacoustic radiators to study the operation of a supersensitive detector of hydrosphere pressure variations [5,6]. The data obtained during these works allowed the evaluation of the device operation in the frequency range of hydroacoustic and seismoacoustic radiators.

II. Experimental Studies

Experimental studies were conducted at the marine experimental station of the POI FEB RAS. Hydroacoustic and seismoacoustic radiators were used as a signal sources. A supersensitive detector of hydrosphere pressure variations was used as a signal receiver. The work was conducted using hydroacoustic and seismoacoustic radiators separately.

In the first experiment, a sonar radiator operating at frequencies from 30 to 40 Hz was used. The radiation was carried out at two points, with the distance from the receiver being 1800 m and 1600 m. So, at the time of operation of the sonar radiator at station 1, the distance from the receiver was 1, 800 m, and the depth of the tone signal emission took place at depths of 5 and 15 m with the same power. At the time of operation at station 2, the distance from the radiator to the receiver was 1, 600 m, at the same radiation power and

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at the same depths as that for station 1. Fig. 2 shows the schematic map of the experiment.

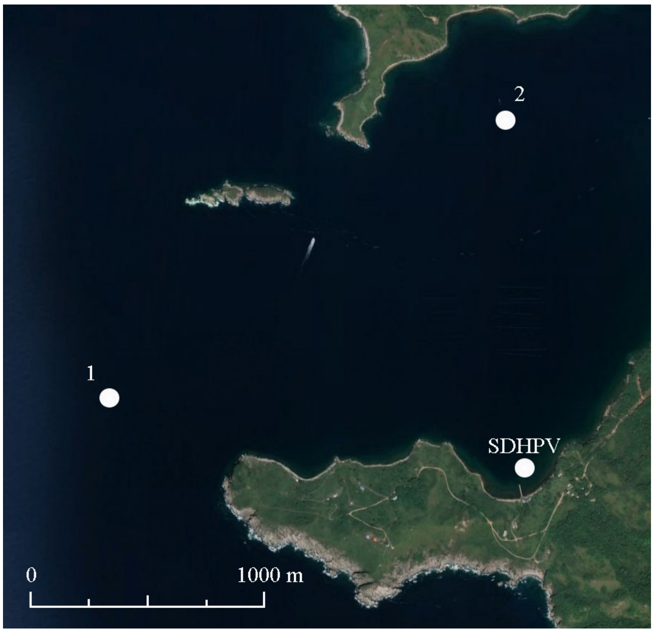

Fig. 2. Schematic map of the first experiment.

At different depths, the sonar radiator operated with the same power. At station 1, the emission of a tone signal at a frequency of 33 Hz at a depth of 5 m began at 11:45:30 and ended at 11:59:30. Moreover, the emission of the same signal at a depth of 15 m began at 12:10:40 and ended at 12:23:40. Fig. 3 shows a dynamic spectrogram recording of a supersensitive detector of hydrosphere pressure variations. Fig. 3(a) and 3(b) corresponds to the radiation at station 1 and that at station 2, respectively. Two horizontal red lines are the tone signals of the radiator. At station 2, the emission of a tone signal at a frequency of 33 Hz at a depth of 5 m began at 13:28:00 and ended at 13:42:00. Moreover, the emission of the tone signal at a frequency of 33 Hz at a depth of 15 m was began at 13:52:20 and ended at 14:06:20. The received tonal signals are clearly expressed on the dynamic spectrogram of the recording of the hypersensitive sensor of hydrosphere pressure variations. The device received both radiated signals at the stations.

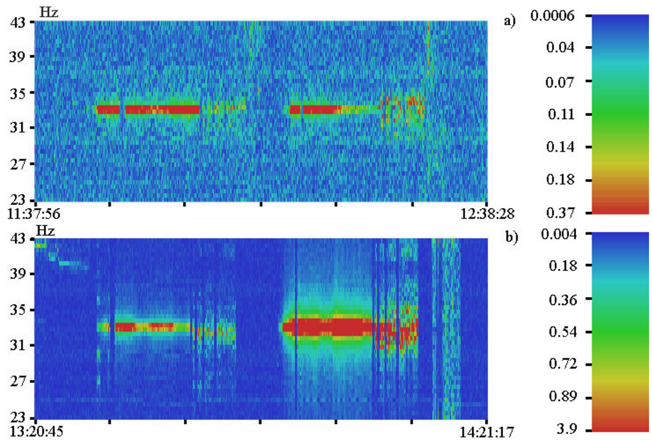

Fig. 3. Dynamic spectrograms of recordings of the supersensitive detector of hydrosphere pressure variations at the time of operation of the sonar radiator.

The spectra will be used to isolate the signal of a low-frequency sonar radiator. Fig. 4 shows the spectra of recordings of a supersensitive detector of hydrosphere pressure variations at the time of operation of a low-frequency sonar radiator. The four spectra shown in the figure correspond to the four radiation moments at the stations. Fig. 4(a) and 4(b) corresponds to radiation at station 1 at depths of 5 m and 15 m, respectively. Fig. 4(c) and 4(d) corresponds to radiation at station 2 at depths of 5 m and 15 m, respectively.

As shown in Fig. 4, at the time of operation of the sonar radiator at station 1 at depths of 5 m and 15 m, the signal amplitudes were 0.18 Pa and 0.17 Pa, respectively. Meanwhile, at the time of operation of the sonar radiator at station 2 at depths of 5 m and 15 m, the signal amplitudes were 0.63 Pa and 2.42 Pa, respectively. The amplitude of the signal at the second station is greater than at the first, although the distance from the radiator to the receiver is the same in both cases. This is due to the location of the radiator. On the signal propagation path from station 1 to the receiver, a part of the land blocks the direct propagation of the signal. When the sonar emitter at station 2 was operating, the signal propagated in a straight line without obstacles.

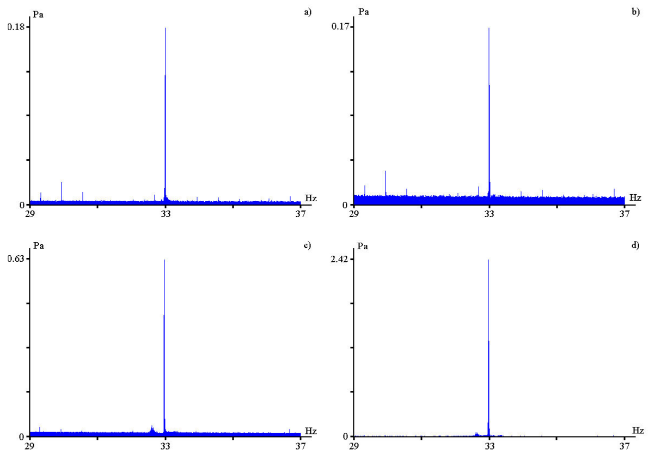

Fig. 4. Spectra of recordings of the supersensitive detector of hydrosphere pressure variations at the time of operation of the sonar radiator.

An experiment was conducted using a supersensitive detector of hydrosphere pressure variations as a receiver to test the reception of the seismic acoustic radiator signal. Fig. 5 shows a schematic map of the second experiment. The low-frequency seismic acoustic radiator was located on land at a distance of 50 m from the coastal strip. A supersensitive detector of hydrosphere pressure variations was located at the bottom at a distance of 200 m from the coastal strip.

Fig. 5. Schematic map of the second experiment.

The seismoacoustic radiator operated at a frequency of about 13 Hz intermittently. This signal was recorded on the dynamic spectrogram of the recording of a supersensitive detector of hydrosphere pressure variations. Fig. 6 shows the dynamic spectrogram of recording the emitted signal. It can be seen from the figure that the signal was not tonal but with a changing frequency. The frequency varied smoothly from 12.9 Hz to 13.2 GHz. At different points in time, the frequency varied in different ways.

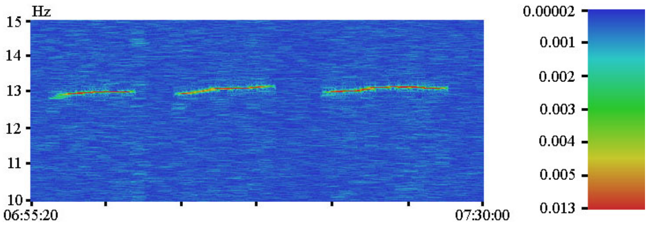

Fig. 6. Dynamic spectrogram of recordings of the supersensitive detector of hydrosphere pressure variations at the time of operation of the seismoacoustic radiator.

Fig. 7 shows the recording spectrum of the supersensitive detector of hydrosphere pressure variations in the third period of operation of the seismoacoustic radiator shown in Fig. 6. This signal has two peaks, i.e., at the beginning and at the end of operation that the emitter worked at frequencies of 13.02 and 13.2 Hz the longest. The maximum amplitude of the received signal was 0.003 Pa.

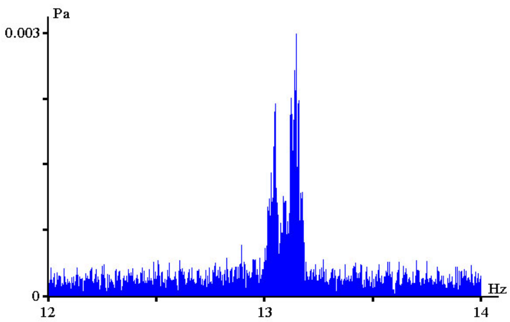

Fig. 7. Spectra of recording of the supersensitive detector of hydrosphere pressure variations at the time of operation of the seismoacoustic radiator.

III. Conclusion

To study the possibility of using a supersensitive detector of hydrosphere pressure variations in hydroacoustic studies, two experiments were conducted using low-frequency hydroacoustic and seismoacoustic emitters as signal sources and a laser interference device as a receiver. The result of the analysis of the data obtained in these experiments revealed that the laser interference device confidently receives both signals. The spectra of the recordings showed that the amplitude of the received signal is several times higher than the background vibrations. Based on the conducted experimental studies, it was found that a supersensitive detector of hydrosphere pressure variations confidently receives signals from both a low-frequency hydroacoustic emitter and a low-frequency seismoacoustic emitter.

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References

[1] G. I. Dolgikh, S. S. Budrin, S. G. Dolgikh, and A. A. Plotnikov, “Supersensitive detector of hydrosphere pressure variations,” Sensors, vol. 20, p. 6998, 2020.

[2] V. A. Chupin, G. I. Dolgikh, S. G. Dolgikh, and S. V. Smirnov, “Study of free oscillations of bays in the northwestern part of Posyet Bay,” J. Mar. Sci. Eng., vol. 10, no. 8, p. 1005, 2022.

[3] G. I. Dolgikh, S. G. Dolgikh, V. A. Chupin, V. V. Ovcharenko, V. A. Shvets, and S. V. Yakovenko, “Registration of nonlinear hydrophysical disturbances—rogue waves in full-scale conditions,” J. Mar. Sci. Eng., vol. 10, no. 12, p. 1997, 2022.

[4] G. I. Dolgikh, S. S. Budrin, S. G. Dolgikh, et al., “Internal marine waves and atmospheric depressions,” Doklady Earth Sci., vol. 462, part 2, pp. 631–633, 2015.

[5] G. I. Dolgikh, S. G. Dolgikh, A. A. Pivovarov, et al., “A hydroacoustic system that radiates at frequencies of 19–26 Hz,” Instrum. Exp. Tech., no. 4, pp. 596–600, 2017.

[6] G. I. Dolgikh, G. N. Batyushin, S. G. Dolgikh, V. P. Dzyuba, and V. A. Chupin, “Transformation of seismoacoustic energy into hydroacoustic,” Doklady Earth Sci., vol. 423, no. 2, pp. 1514–1515, 2008.