TRAINS, PLANES, & FISHING BOATS: A GEOPHONE SENSOR FOR UNDERWATER ACOUSTICS

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1. Introduction

Usually, ocean acousticians use hydrophones (i.e. pressure sensors) for very-low-frequency measurements, either placed on the seabed or suspended in the water. Occasionally, we use transducers that sense the particle velocity associated with the acoustic wave in the water. In recent years, some investigators[1] have been using geophones (i.e. velocity sensors) coupled to the seabed itself. Geophones measure the motion at the seabed, which can be different from that in the adjacent water mass. In particular, geophones—unlike hydrophones—can sense the propagation of shear waves in the seabed. Seismologists have been using geophones in their Ocean Bottom Seismometer (OBS) packages for years. This paper describes the configuration, testing, and calibration of an OBS for underwater acoustic experiments.

2. Description of the OBS package

The geophones are shown in Fig. 1, installed in a gimbal mount. The gimbals are suspended in a frame attached to one end-cap of the cylindrical pressure vessel that houses the OBS. The gimbals are necessary to ensure that the vertical geophone is aligned with the direction of gravity and that the horizontal geophone is aligned in a perpendicular direction, as the two sensors are constructed differently. Also shown are the slip-rings that carry the geophone signals to the geophone preamps and the printed circuit board containing the preamps. The principal component of these is the LT1028 operational amplifier chip, which has an extremely low noise level.

Figure 1 *The geophones mounted in gimbals on the OBS endcap. Note the slip rings and the preamps.*

A typical geophone consists of an electric coil and mass suspended by a spring in a magnetic field that is fixed to the body reference frame. Relative velocity between the case and the mass/coil creates an EMF that drives a current through the output load. The mass/spring system has a resonance frequency, above which the response is flat and below which the response decreases rapidly. There is little natural damping in the system; the system Q is controlled by a shunt resistor in parallel with the input resistance of whatever amplifier is used.

3. Calibration and Testing

When simply measuring the time-of-arrival of an impulsive signal—a typical OBS task—the sensitivity and self-noise level are not major considerations. However, for underwater acoustic measurements of ambient noise and propagation loss, we must ensure that the sensor self-noise level is well below the ambient noise level and that we accurately calibrate the sensor sensitivity over the frequency band of interest.

During a previous OBS deployment, we used preamps that were too noisy and we could not measure ambient noise. Fig. 2 shows the noise level at the input of the new preamps for three cases: the amplifier input shorted; the geophone attached electronically but with the motion clamped; and the geophone sitting on land in a quiet state. We are satisfied that we can measure ambient noise with this new arrangement.

We calibrated the vertical geophone using a shaker table, an accurate voltmeter, and a reference B&K accelerometer. We kept the geophone in the gimbal and frame as shown in Fig. 1 in order to account for the transfer function of the mounting method. With a 1.8 kΩ shunt resistor across the coil outputs, the geophone sensitivity above the resonance frequency of 4.5 Hz is 31 dBV re 1 m/s. At resonance this rises slightly to 34 dBV. Below resonance the response falls off at 40 dB/decade.

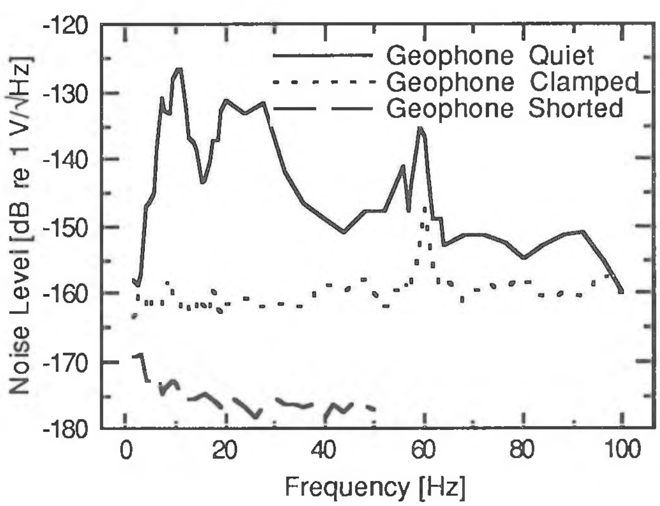

Figure 2 *Noise levels at preamp input.*

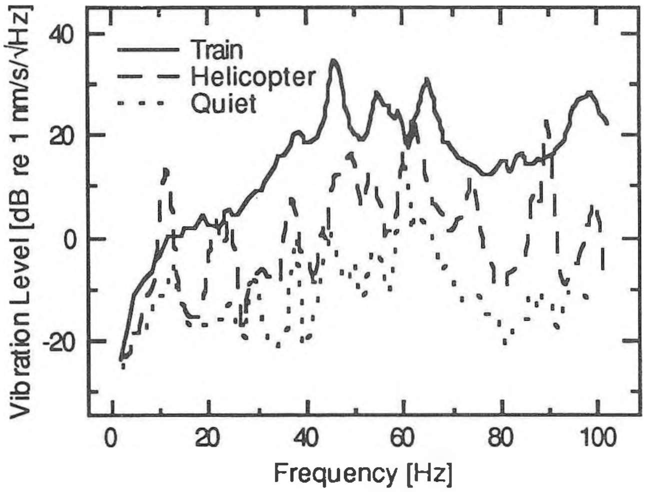

Figure 3 *Noise spectra received at the vertical geophone from two sources of opportunity.*

4. Detection of Sources of Opportunity

While testing the OBS at a quiet location on land (the basement of a DREA building at 0600 one Sunday morning), we had the opportunity to observe signals from two sources of opportunity. The first was a train passing the sensor location at a distance of about 50 metres; the second was a low-flying helicopter at a range of several hundred metres. Fig. 3 shows noise spectra from the two sources, compared with a "quiet" noise spectrum. Note that the reference velocity is 1 nanometre per second and we have used a constant calibration factor of 31 dBV re 1 m/s.

The last example is from a deployment of the OBS on the seabed in 75 m of water. Although we experienced some difficulties on this trial (such as the failure of the horizontal geophone), we were fortunate to record signals from a stern trawler travelling at constant speed on a steady heading that brought it within 2 kilometres of the OBS. Also, there were several noisy whales in the vicinity. Fig. 4 shows a sonogram of the vertical geophone signals: the x-axis is frequency, the y-axis is time, and the grey level represents signal amplitude. One can see broadband noise (the curved swaths of grey) and narrowband signals (vertical lines) from the ship, and the whale sounds (short horizontal lines near 20 Hz).

5. Conclusions

Although the geophone sensors have presented us with some challenging electronic and mechanical problems to solve, these initial results are encouraging. We have been able to receive and record signals from several interesting sources. In future experiments we hope to compare the acoustic performance of geophone sensors with that of hydrophone sensors.

Acknowledgment

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[1] Jens M. Hovem, Michael D. Richardson, and Robert D. Stoll, *Shear Waves in Marine Sediments* (Kluwer Academic Publishers, Dordrecht, 1990).

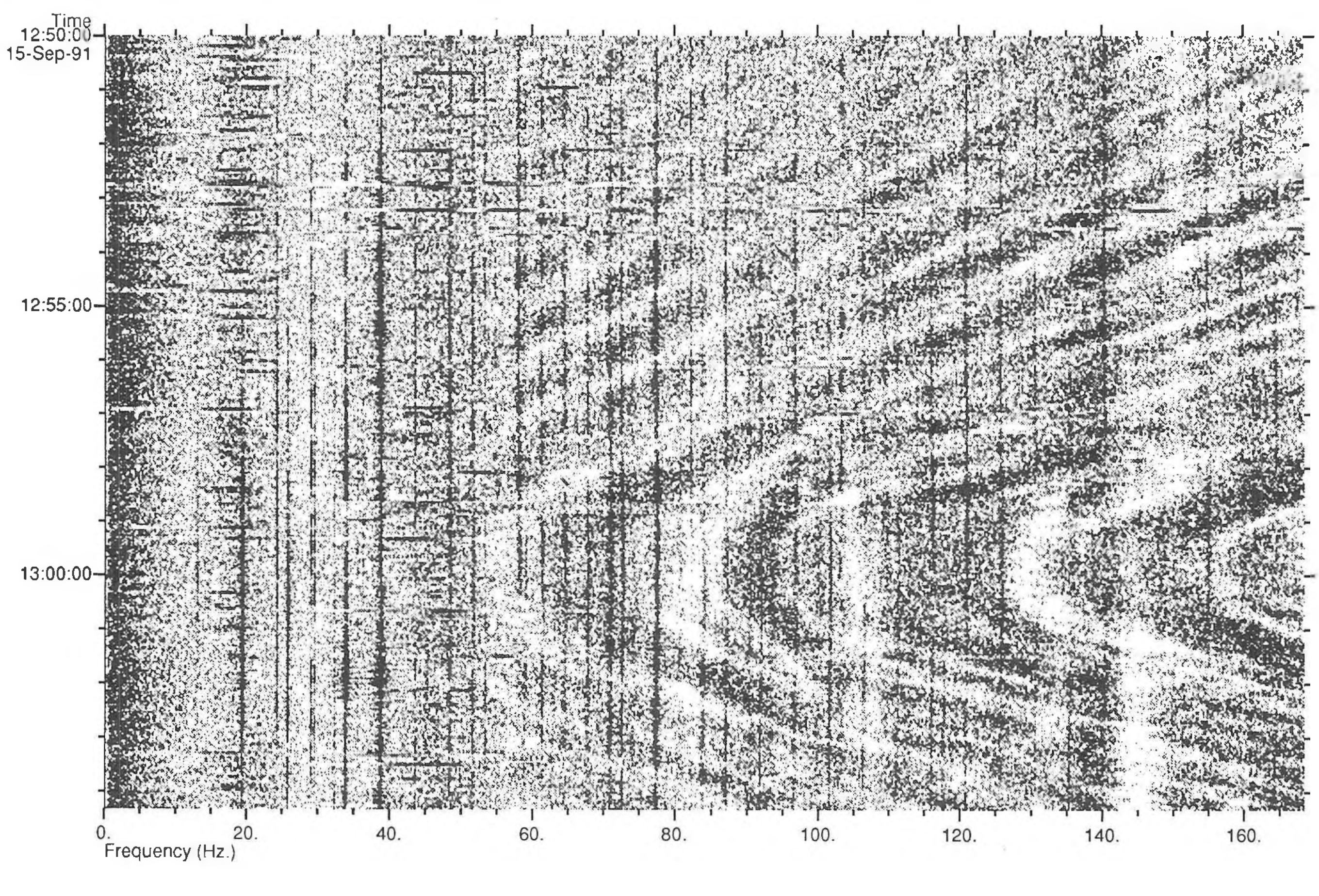

Figure 4 *Sonogram of the signal received from a stern trawler at the vertical geophone on the seabed in shallow water.*