Air-noise reduction on geophone data using microphone records

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ABSTRACT

This paper proposes using microphone recordings of air waves, recorded close to a geophone, to suppress air-wave noise on the geophone. The types of air-wave noise on the geophone may include air-coupled ground roll, air blast, ground-coupled air blast, and wind noise. Microphone recordings of air waves are related to ground measurements and geophone disturbances. We can thus attempt to use the air wave to filter the geophone data. Tests on recordings from the Calgary General Hospital implosion on October 4, 1998 indicate success in reducing noise on the geophone data. I propose designing a geophone with an attached microphone to reduce noise on the geophone data.

INTRODUCTION

Air blasts, ground-coupled air waves, and air-coupled ground are all potential problems in recording seismic signals. These noises can certainly overwhelm subsurface reflection signals, especially when the noise source is near the receivers. While there are many ways to filter this noise, it still can be a problem, due to aliasing, for example. In addition, winds above a certain speed can create unacceptably high noise levels and shut down seismic acquisition operations.

Some ambient noise can be attenuated, in the marine case, by recording pressure (hydrophone) data along with geophone measurements. The hydrophone information is used to suppress fluid-reverberations in the geophone data. Similarly, we might consider suppressing air-associated noise, recorded on a geophone, by use of output from a nearby microphone.

AIR BLAST

Air waves travel at the speed of sound in air (about 332 m/s). An example noise spread from Sheriff and Geldart (1982) is shown in Figure 1. If a surface source is used, such as a Poulter charge or land air gun, the air wave may be significant and problematic (Yilmaz, 1987). Vibrators can also generate considerable air disturbances. Ewing et al. (1957) note that air waves can couple into the ground's surface and generate Rayleigh waves. These occur when the Rayleigh wave phase velocity (for some frequency) is close to the speed of sound in air (Figure 2). In addition, ground roll can also generate an air wave when its velocity is close to that of sound in air. This may be the source of some reports of a low-frequency rumble, associated with surface wave propagation, after an earthquake occurs (Ewing et al., 1957). Air waves are a problem on near-offset seismic data. In shallow surveys, the ground roll and air waves can overwhelm otherwise usable data. It would be very helpful to attenuate the various air-wave events registered on seismic recordings.

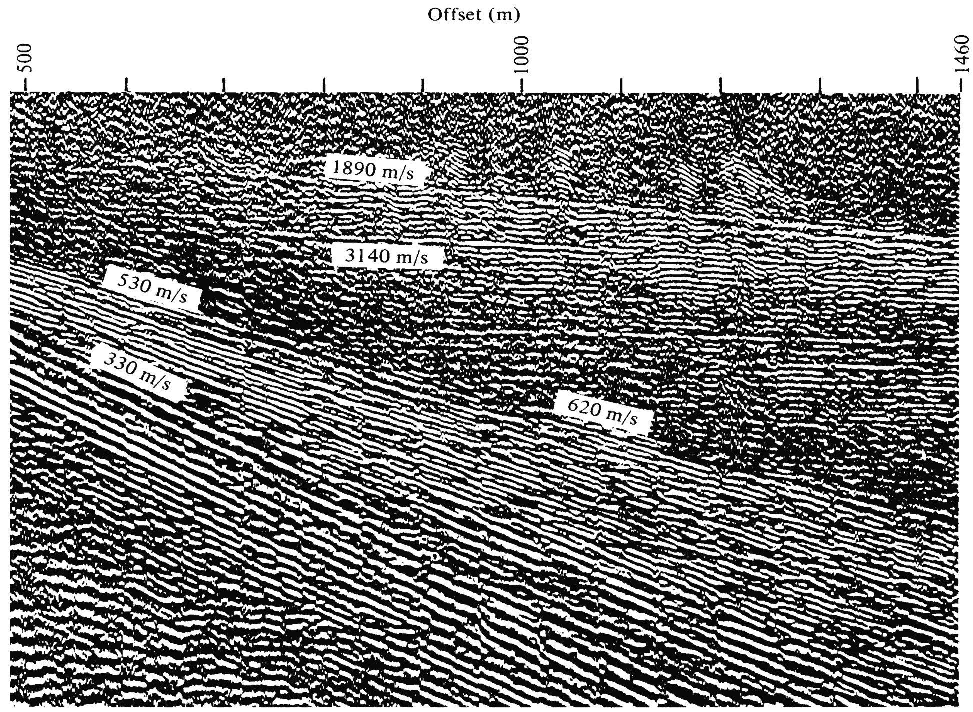

Figure 1. Noise spread showing various noise trains. Note the air blast at 330 m/s (from Sheriff and Geldart, 1982).

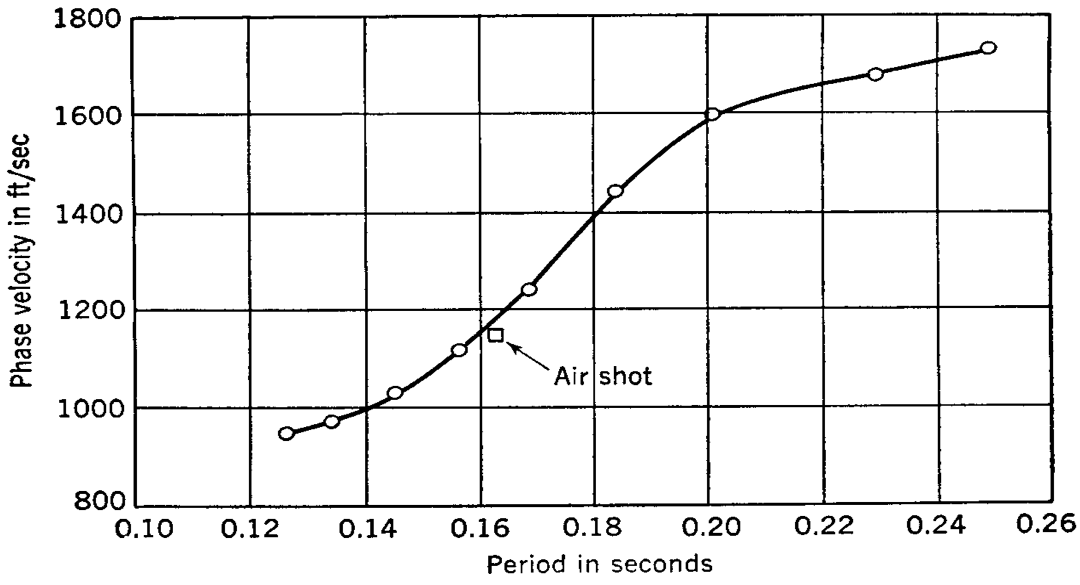

Figure 2. Ground roll dispersion plot showing velocity versus period. Indicated is the velocity and frequency of an air wave from the same area (from Ewing et al., 1957).

WIND NOISE

Winds arise from pressure differences in the atmosphere. They can be a significant problem in seismic surveying as the wind forces can be translated into geophone motion. This is either directly via wind pressure on the geophone case or through intervening materials that vibrate (e.g., trees, roots, grass, etc). After winds reach a certain velocity, there is too much noise recorded on the geophone to continue effective operation and recording. If we could actively filter some of this noise then perhaps seismic operations could be extended into more windy conditions

FIELD EXAMPLE

The example used here is from the Calgary General Hospital implosion on Sunday, Oct. 4, 1998. Seven sites around the hospital, each consisting of a 3-C geophone and microphone plus seismograph, were used by Explotech Engineering Ltd. with Stanley Buildings to monitor the blast. The microphone (pressure) measurements were made to ensure compliance with explosion-related regulations. These stations varied from 37m to 165m from the blast. The recordings and their analysis are further discussed in a document prepared by Explotech (1998). The data analysed here are from station #5 at 803 1st Ave. NE on the 3rd floor, some 165 m from the blast. The triaxial geophone and microphone both had bandpass responses from 2Hz to 250Hz. Although not analysed here, the Department of Geology and Geophysics at the University of Calgary and the CREWES Project also recorded the blast with two orthogonal lines of 3-C geophones.

FILTERING PROCEDURE

Air pressure on the microphone is related to ground motion described on the geophone in a number of ways: Air pressure can vibrate the geophone directly or via ground coupling. Similarly, ground motion can vibrate the air and geophone case and thus the microphone. The microphone and vertical geophone data used here are from station #5 and are scaled to the same maximum value. We can see from the raw data that the two traces are similar (Figure 3). In fact, by cross-correlating the data, we find that the traces are about 180° out of phase (Figure 4). Thus, the most basic procedure to reduce noise is to just add the microphone trace to the geophone trace. In fact, this simple procedure leads to a reduction in what we interpret is the air noise. The summed trace is also shown in Figure 3. We can also shift the traces relative to each other and sum to try to achieve better cancellation. Figure 5 shows a panel of incremental shifts and sums. Shifts around 0 ms appear to provide (marginally) the greatest noise reduction in the first few seconds. Future work will develop more sophisticated ways to filter the geophone data.

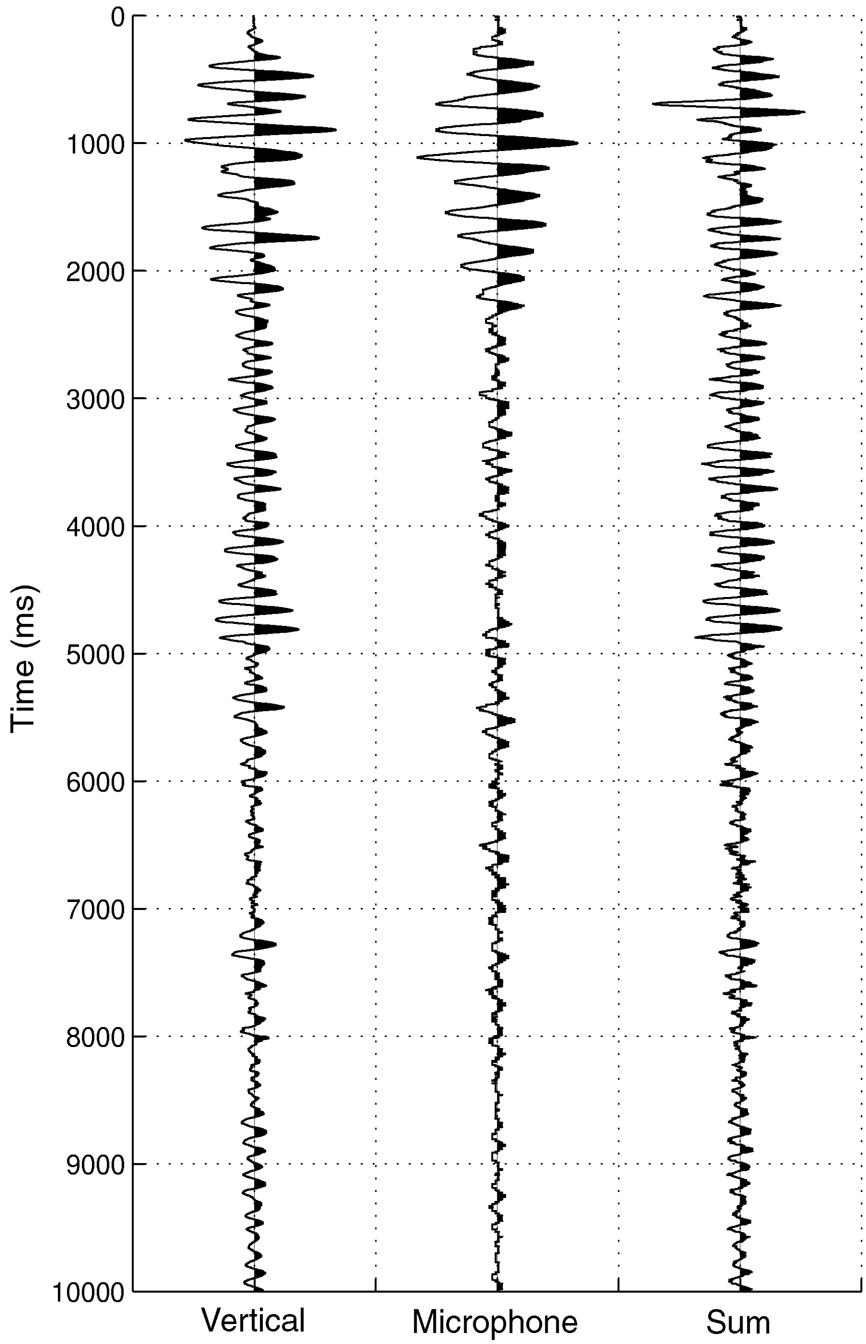

Figure 3. Raw vertical geophone and microphone traces from site #5 and their sum.

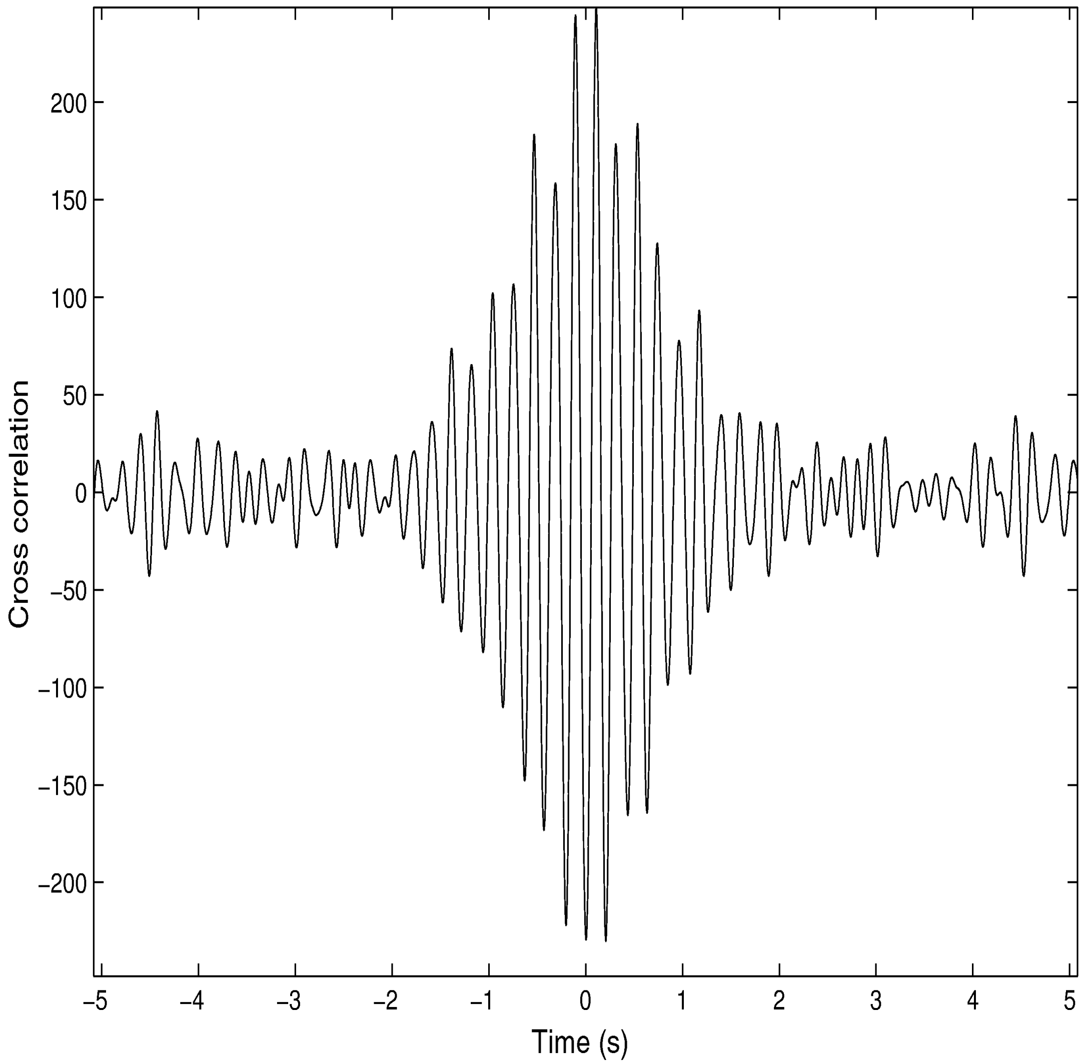

Figure 4. Cross-correlation of the microphone trace with the geophone trace from site #5. The traces are approximately negatively correlated or opposite polarity.

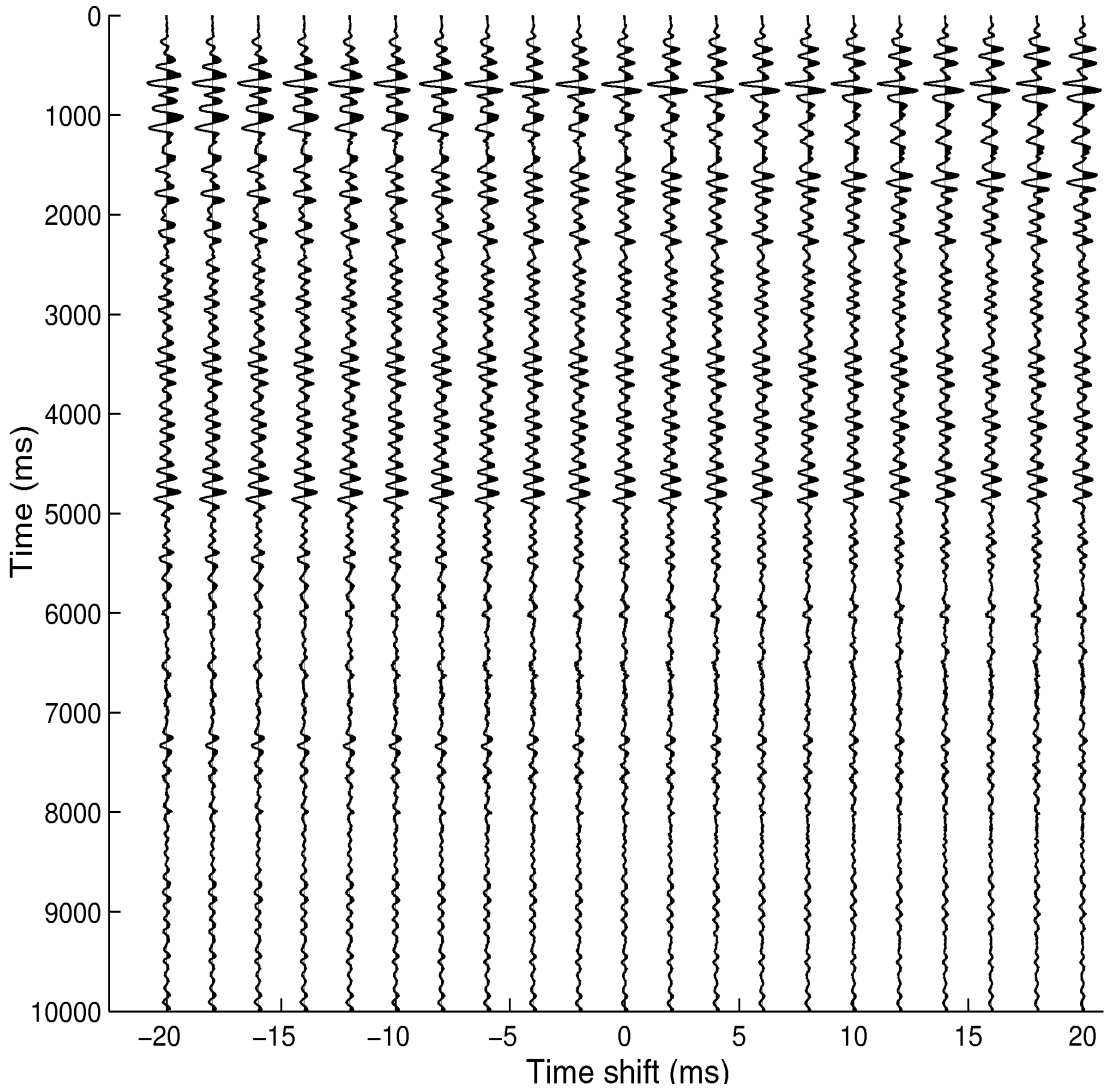

Figure 5. Summed geophone and microphone traces as a function of relative shift.

A NOISE-REDUCING MULTI-SENSOR

We can design a two-element, air-wave reducing instrument in a number of ways. Most simply, we could just use a microphone in proximity to the geophone and record it separately. The microphone recordings could be used later to filter the geophone data. Perhaps, even sparsely distributed microphones could be used with a model-based interpolator to filter intervening geophone data. Alternatively, a microphone could be built into the geophone case to give air pressure measurements at the geophone. These microphone recordings could be recorded separately as a two-channel geophone or with a 3-C geophone as a four-channel record. Perhaps more interestingly, we could design a motion sensor that actively reduces noise. In this case, the microphone could be used in series or parallel with the geophone. The air-pressure noise could be subtracted from the geophone output in real time -

simultaneously with the geophone recording. From an active-noise cancelling viewpoint, we might imagine the microphone output resisting the air-correlated noise values from the geophone. Figure 6 shows schematic design of a two-channel sensor and an active noise-suppressing sensor. A small battery could be included, if necessary, to power the microphone and/or the electronic circuitry. An arrangement of microphones might also be required to partially decouple the microphone recordings from the geophone case movement.

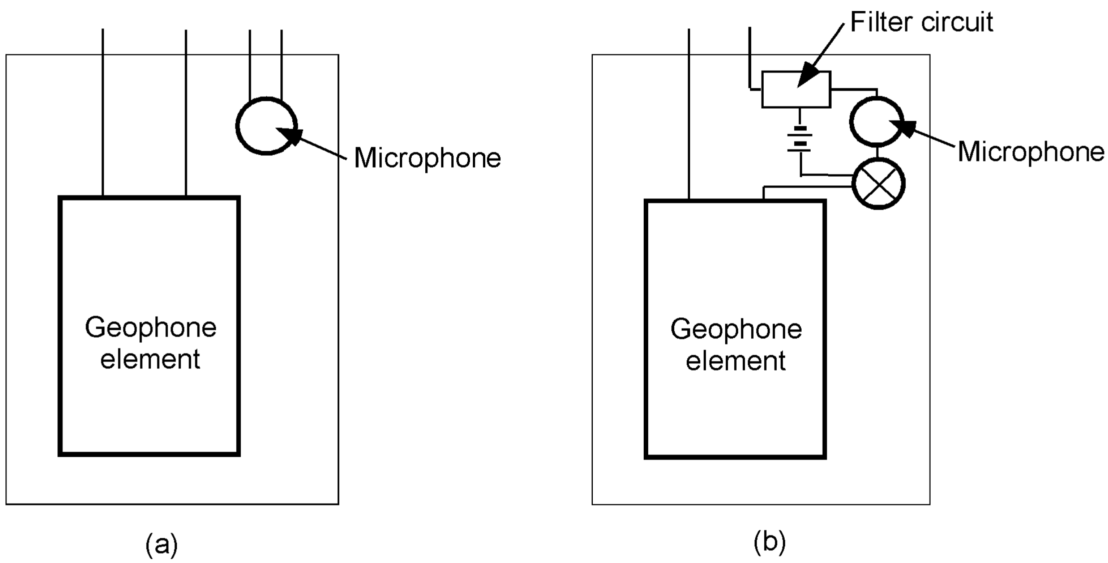

Figure 6. Two-channel (microphone and geophone) motion sensor (a) and single-channel, active noise suppressing geophone (b).

CONCLUSIONS

Air-wave noise is evident on many seismic records. The use of microphone recordings, in addition to the geophone records, provides an opportunity to reduce some of this noise. Preliminary tests on the Calgary General Hospital implosion data, recorded by Explotech Engineering Ltd., suggest that microphone recordings can be used to reduce air blast noise on geophone measurements. In addition, it should be possible to build a motion sensor that could record both microphone and geophone data. The microphone recording could be used to actively filter the geophone data either in the sensor or after recording of both traces.

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