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OPTIMIZING RESOURCES

Estimation of Marsh Geophone Coupling Signatures using Tightly Coupled Geophones

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Summary

The coupling of land geophones in the field is know to cause resonant frequencies which are often in the 100 to 200 hertz range. The paper presents a method of tightly couping a geophone to the ground and compares typical marsh geophone plants with more tightly coupled geophones using the same elements. The results illustrate problems achieving consistent coupling on a point to point basis. Potential impacts on program design decisions are discussed.

Introduction

Effects of poor geophone coupling on land data are commonly seen on raw records as trace to trace variations in frequency and noise content. Surface consistent deconvolution allows us to normalize these effects during processing but the receiver coupling effect is not normally separable from other effects such as the source signature, earth attenuation, and reflection coefficients.

Geophone coupling effects were investigated more than 20 years ago by Hoover and O'Brien (1980) and Krohn(1984). Both studies proposed the coupling effect to be, by approximation, a visco-elastic effect which was parameterized by a resonant frequency and a damping factor. The two studies found a broad range for these parameters. By "pinging" geophones (measuring the impulse response from a ball bearing impact) resonant frequencies were found to be above 100 hz. At that time, this would have been considered more than adequate for exploration seismology.

More recently, many seismic surveys done for shallow targets have achieved frequency content well above 100 hz. Also the emergence of 3C surveys brings up the issue of determining the resonant responses are on the horizontal axes of geophones. Bland et al (2004) show that not only do the same effects occur on the horizontal axes but that the resonant frequencies may be substantially different from that measured on the vertical axis. For this reason, it is important to revisit these effects which are commonly known to occur on land seismic surveys.

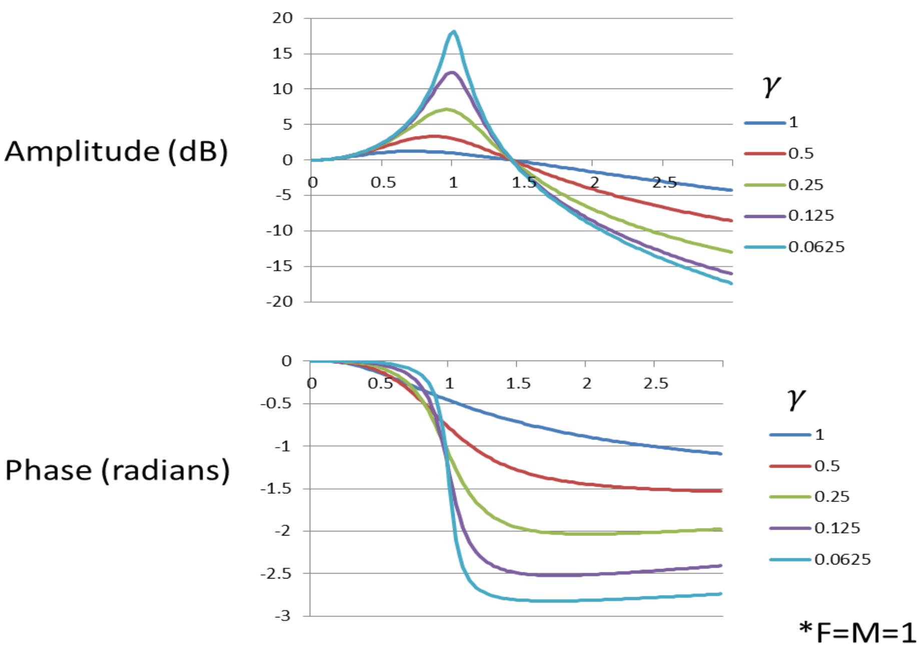
Tests are done in which we measure the coupling effects through the relative measurements against a reference geophone. This reference geophone, which uses an earth screw for coupling, increases the resonant frequencies to 2 or 3 times that of a conventionally deployed marsh geophone and therefore provides "perfect" coupling in the limited bandwidth where we expect these effects. It also allows us to remove significant wind and other air coupled noise sources from the seismic record.

Theory

Hoover and O'Brien (1980) simplify the response of a mass on a free surface to a damped oscillatory coupling represented by the equation (vertical axis only):

$$U_{zg} = \frac{1+i\left(\frac{\omega}{\omega_g}\right)\eta_g}{1-\left(\frac{\omega}{\omega_g}\right)^2+i\left(\frac{\omega}{\omega_g}\right)\eta_g}, \qquad \omega_g=\sqrt{\frac{K}{M}}, \quad \eta_g = \frac{2\gamma}{\omega_g}, \quad \gamma = \frac{\zeta}{2M}$$

where K = an elastic constant for the geophone interface, M = the mass of the geophone, ζ= a damping constant, and U_{zg} = the transfer function or coupling signature of the geophone. The following graph represents the frequency and phase responses of the coupling signature for a range of damping values.



Similarly, a response for wind noise can be obtained as well:

$$U_z = \frac{F_w}{K * \left(1 + i\left(\frac{\omega}{\omega_0}\right)\eta - \left(\frac{\omega}{\omega_0}\right)^2\right)}$$

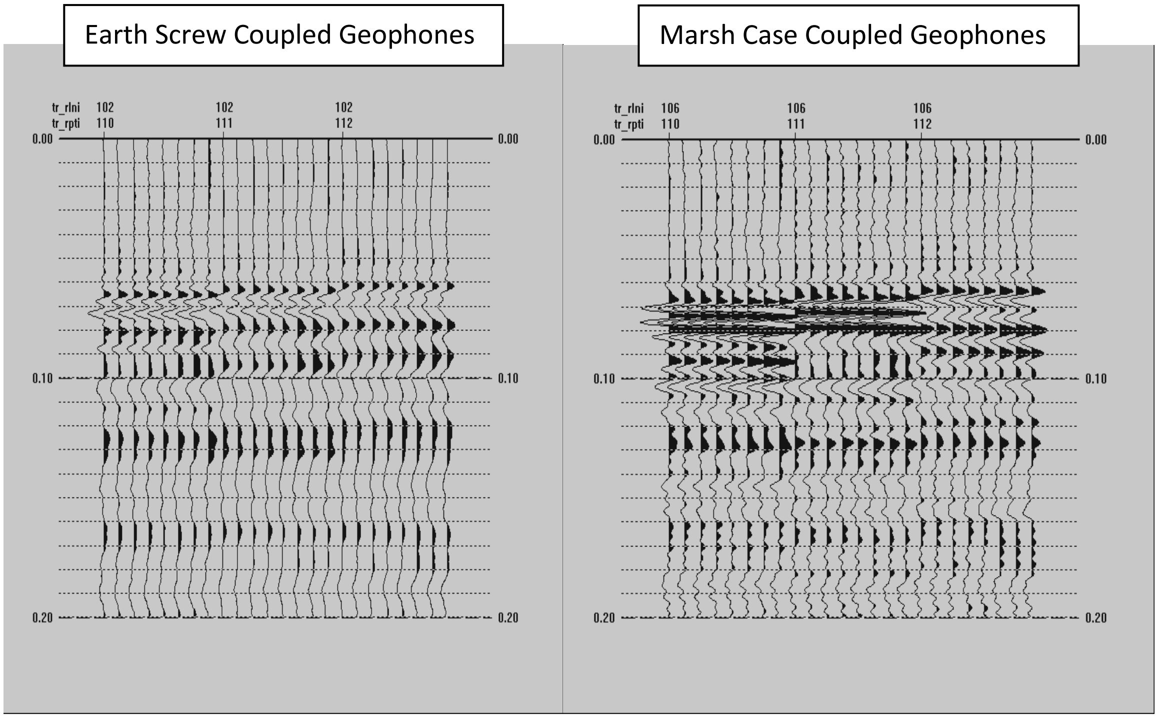
Where F_w = the force exerted on the geophone by the wind.

Method

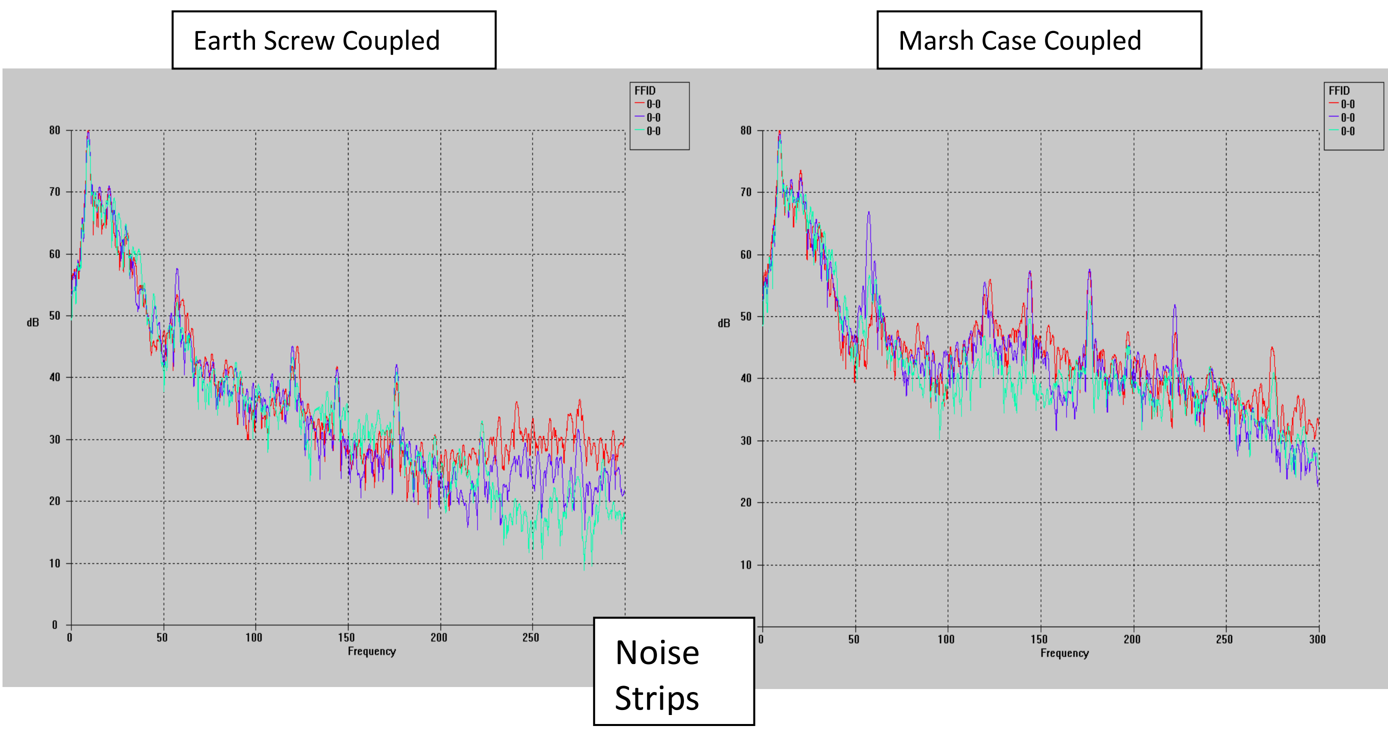
Three ground screws were loaded with 3 GS-One steel case marsh geophones which were then secured in place using paraffin. Three locations were chosen approximately 10 meters apart and one marsh geophone and one earth screw coupled geophone were planted at each location. Eight sweeps were recorded with an EnviroVib approximately 100 meters from the receivers. The sweep used was a 24 second sweep, 10 – 200 hz, and a 3 second listen. These were processed into a number of shot records which were analyzed.

Results

The earth screw coupled units are lower amplitude than the marsh case coupled geophones and show substantial phase reversals which are consistent with better coupling using the earth screws. There is also greater consistency in the phase/ amplitude relationships between locations using the earth screws.



Background ambient noise is also substantially reduced in the data associated with the earth screws.



Conclusions

The results of this experiment confirm the results of earlier authors which predict substantial changes in the response of marsh geophones due to the coupling of the unit to the ground. These experiments also confirm substantially higher wind and air coupled noise energy in the marsh geophones.

These results tend to explain the current trend towards single geophones and away from geophone strings, particularly for high frequency work. The summation of responses from a number of geophones with variable phase and amplitude responses in would not stack for higher frequencies if significant resonant responses were included. Recording with single geophones may allow the coupling resonant responses to be removed through surface consistent deconvolution if the signal to noise level is right.

This paper also provides a cautionary note about judging geophone coupling by the frequency content on field records. Higher frequencies may more often indicate poorer coupling as opposed to better coupling. In particular, the bias towards shooting programs on frozen ground rather than on non-frozen ground may require re-evaluation. Higher frequencies seen from raw data acquired on frozen ground may simply indicate the presence of geophone coupling problems.

The geophysical industry has produced two competing technologies which do not seem to have an overall advantage on each other: MEMS accelerometers and conventional coil based geophones. This may be explained by the overriding problem of coupling for which vendors have not provided equivalent improvements in coupling. Assuming that most other geophone casing designs also have coupling effects in the same frequency range, most of the advantages from higher frequency geophones would be lost to coupling effects.

Acknowledgements

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