Initial analysis of the effect of receiver arrays on wavelet estimation based on the Extinction Theorem

Lianzhong Feng, Jingfeng Zhang and Arthur B. Weglein
University of Houston

Abstract

We present initial numerical tests on the effect of receiver arrays on the wavelet estimation method presented by Weglein and Secrest (1990). The numerical tests demonstrate that for single sensor receivers, the estimation method is successful. However for group receivers, the results are unsatisfactory, especially when the intended use is for the inverse scattering subseries that are non-linear in the wavelet.

1 Introduction

In 1990, Weglein and Secrest presented the following wavelet estimation formula:

$$A(\omega) = \frac{1}{G_0^D(\vec{r},\vec{r}_s,\omega)} \cdot \oint_S \left[p\left(\vec{r}',\vec{r}_s,\omega\right) \frac{\partial G_0^D\left(\vec{r}',\vec{r},\omega\right)}{\partial \vec{n}'} - G_0^D\left(\vec{r}',\vec{r},\omega\right) \frac{\partial p\left(\vec{r}',\vec{r}_s,\omega\right)}{\partial \vec{n}'} \right] d\vec{s}' \quad (1)$$

where G_0^D is the Green's function which vanishes at the free surface. $\vec{r}$ is any point under the measurement surface and $\vec{r}_s$ is the position of the active source, which is above the measurement surface. $\vec{n}'$ is the unit vector on the measurement surface pointing towards the free surface.

In principle, equation (1) is exact. Tests on synthetic data demonstrated its robustness in the presence of finite aperture and sampling. But when equation (1) was applied to field data with under-over cables and arrays, the results were unsatisfactory. A possible explanation points to the effect of the receiver group. When the wave's propagation direction is near-horizontal, the combination of receivers suffers from the phase difference among the individual receivers in a group (Figure 1). That is, the field and derivative of the field in the above formula are both distorted resulting in a poor approximation of the wavelet.

In this report we provide numerical tests designed to establish whether this conjecture is correct. These tests indicate excellent result for single sensor receivers but even for a short array, harmful effects are observed.

We present the results of numerical tests in the following section which is followed by conclusions drawn from this exercise.

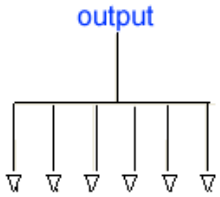

Figure 1: The receiver array.

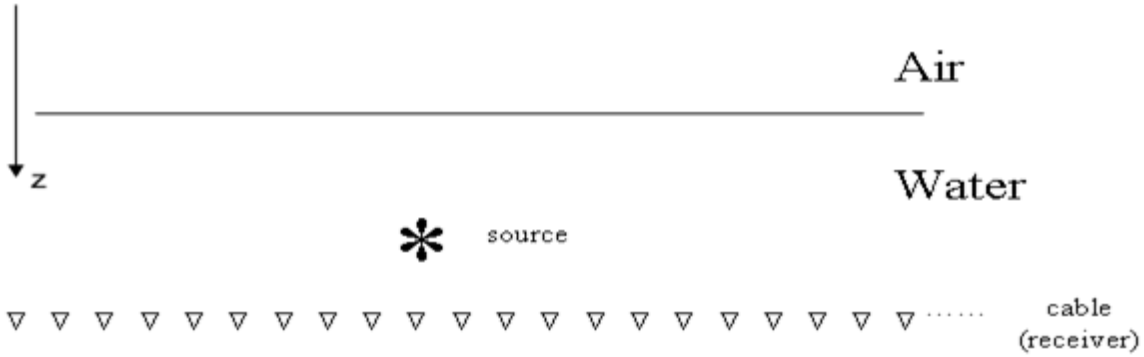

Figure 2: Synthetic model.

2 Numerical test

The synthetic model is showed in Figure.2 where the depth of the measurement surface is 10.0m. There is a perfect reflection on the free surface and this study assumes an infinite water column. The position of the active source is (0,6). We assume that we have the exact field and its derivative everywhere on the measurement surface. We evaluated equation at (0,100).

For single sensor receivers with interval 1.0m (geometry 1 in Figure 3), the resulted wavelet

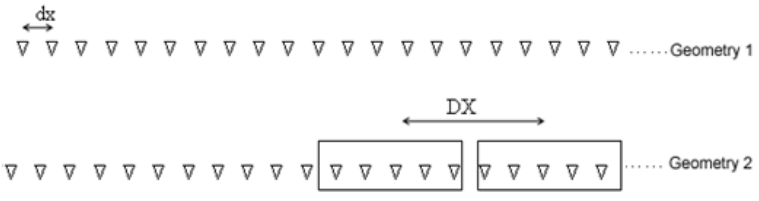

Figure 3: Receiver pattern.

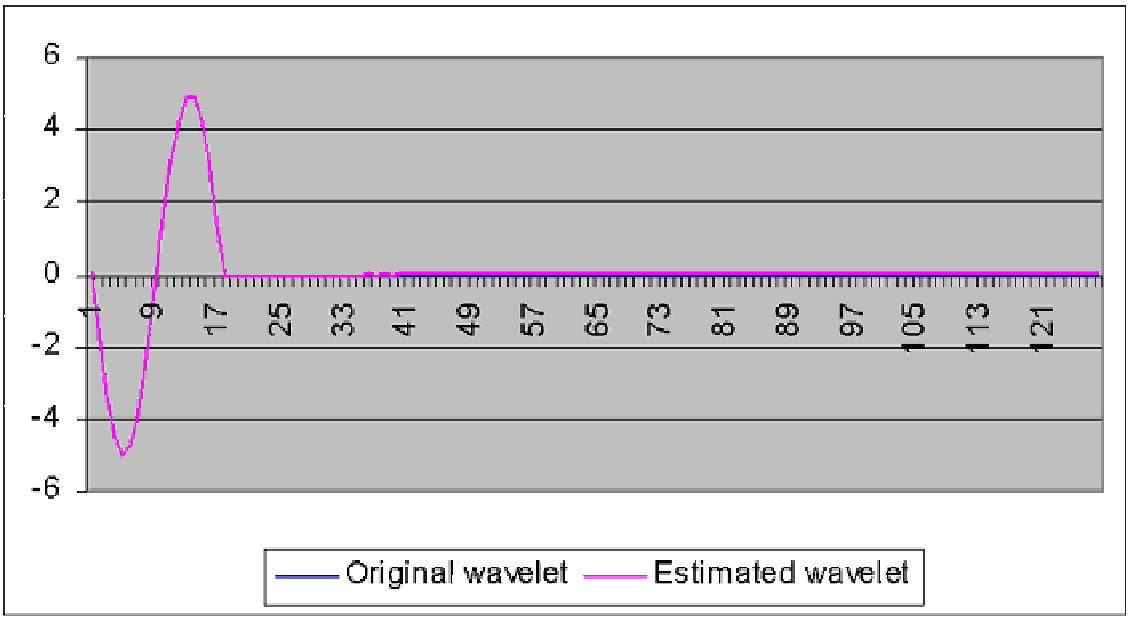

Figure 4: Comparing the original wavelet with the calculated wavelet for geometry 1 (dx=1.0m).

from the equation (1) is compared with the exact wavelet in Figure 4. There is no visible difference between these two signals.

For group receivers (geometry 2 in Figure 3), we consider the case that interval between single receivers is 1.0m and there are 9 receivers in one group. Therefore the group interval will be 9.0m. The results are shown in Figure 5. Clearly, the results are unsatisfactory. In Fig.6, the exact wavelet is compared with the calculated wavelet divided by the number of receivers in an array. The result is also unsatisfactory.

3 Conclusion

We have presented initial numerical tests showing that, even for a small array (9 receivers, 8 meters), using a receiver group can have a deleterious effect on the wavelet estimation methods that are reconstructing the reference wave and canceling the scattered wavefield. The industry trend toward ever-smaller receiver arrays and single sensors is an opportunity to exploit those multidimensional wave theoretic wavelet estimation methods precluded by earlier acquisition formats. For single sensor receivers, the results are acceptable as expected.

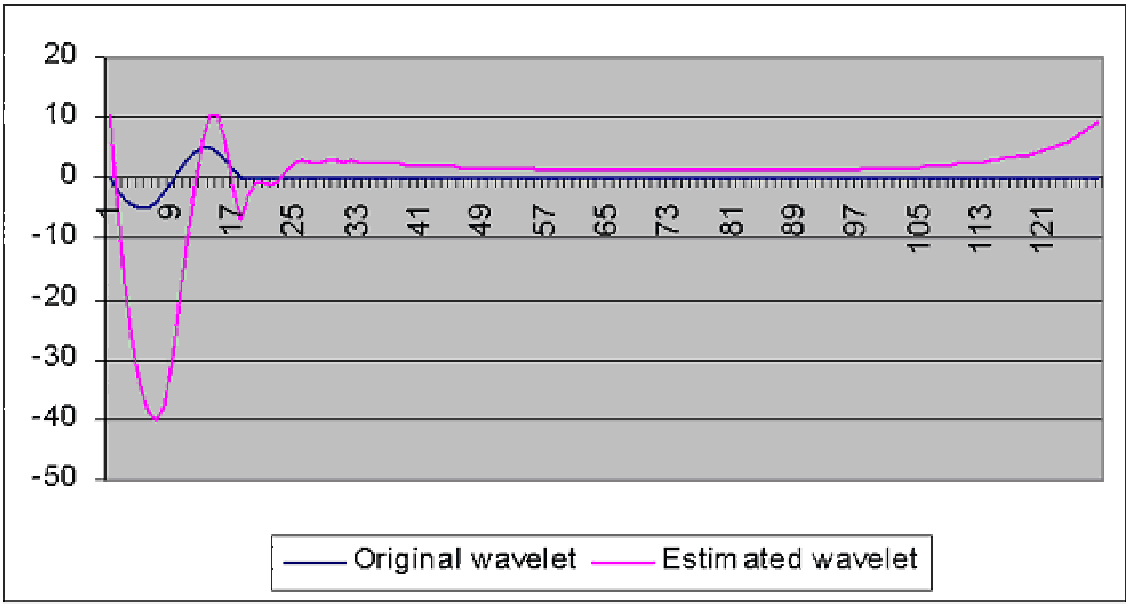

Figure 5: Comparing the original wavelet with the calculated wavelet for geometry 2 (dx=1.0m, nine receivers, DX=9.0m).

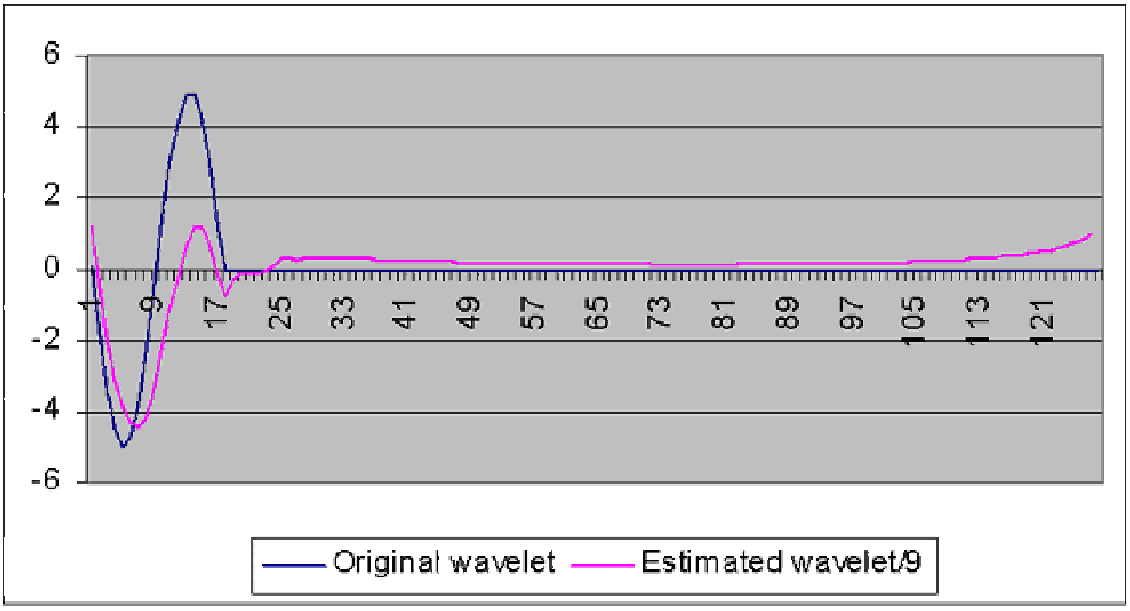

Figure 6: Comparing the original wavelet with the calculated wavelet for geometry 2 (the calculated wavelet has been divided by the number of receivers in one group) (dx=1.0m, nine receivers, DX=9.0m).

References

1. Delima, G. R., Weglein, A. B., Porsani, M. J., and Ulrych, T. J., 1990, Robustness of a new source-signature estimation method under realistic data condition: A deterministic-statistical approach: 60th Ann. Internat. Mtg. Soc. Expl. Geophys, Expanded Abstract, 1658-1660

2. Weglein, A. B. and Secrest, G., 1990, Wavelet estimation for multidimensional acoustic or elastic earth: Geophysics, 55, P.902-913

General reading

1. Tan, T.H., 1992, Source signature estimation: Presented at the Internat. Conf. And Expo. Of Expl. And Development Geophys., Moscow, Russia

2. Tan, T.H., 1999, Wavelet spectrum estimation: Geophysics, **64**, 6, 1836-1846