Title: Source spacing in virtual source imaging / Analysis of Treasure Island earthquake data using seismic interferometry

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Virtual source imaging (interferometric imaging) is a technique applied by Andrey Bakulin and Rodney Calvert at Shell to the Peace River data for imaging below the very complex near surface overburden without any knowledge of the overburden velocity or near surface changes. An important consideration in a virtual source imaging experiment is the spacing of the source locations. As in any other seismic experiment, the sources should be placed at fine enough intervals to prevent spatial aliasing. Stationary phase analysis is one approach to understand the optimum source spacing in order to prevent spatial aliasing. We carried out this analysis for a homogeneous isotropic medium and found that location of the receivers, depth of reflector and velocity determine the maximum source spacing.

Seismic interferometry is a powerful tool in extracting the response of ground motion. We show the use of seismic interferometry for analysis of an earthquake recorded by Treasure Island Geotechnical Array near San Francisco, California on 06/26/94. It was a magnitude 4.0 earthquake located at a depth of 6.6 km and distance of 12.6 km from the sensors in borehole. There were six 3-component sensors located at different depths. This problem is similar to the analysis by Snieder and Safak for the Robert A. Millikan Library in Pasadena, California where they deconvolve the recorded wavefield at each of the library floors with the top floor to see the upgoing and the downgoing waves and using that, estimate a shear velocity and a quality factor. They have also shown that for such applications of seismic interferometry, deconvolution of waveforms is superior to correlation. For the Treasure Island data, deconvolving the vertical component of the wavefield for each sensors with the sensor at the surface gives a similar superposition of an upgoing and a downgoing wave. The velocity of these waves agrees well with the compressional wave velocity. We compute the radial and the transverse components. When we window the shear wave arrivals in transverse components at each depth and deconvolve with the one on the surface, the resultant up and down going waves travel with the shear wave velocity. Similar windowing and deconvolution for the radial component also agrees with the shear wave velocity. However, when the radial component is windowed around the compressional waves and deconvolved, the up and the down going waves travel with the shear wave velocity suggesting that there is a conversion at a depth below the deepest sensor. Receiver functions, defined as the spectral ratio of the radial component with vertical component, can be used to characterize the converted waves. For the Treasure Island data, this spectral ratio shows an arrival at time close to t=0 for the deepest sensor located at 104 m depth indicating a P to S conversion very close to this sensor. The travel time of this propagating wave in the receiver function is in agreement with the calculated travel time of converted waves using the compressional and shear wave velocities. Hence, we show that simple deconvolution can be used to understand the velocity structure of the subsurface using earthquake data.