OPTIMIZING HIGH FREQUENCY VIBROSEIS DATA

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Abstract

Vibratory sources used for seismic investigation are often subjected to coupling and transmission problems between the baseplate and actuator mass system and the ground surface. This results in dramatic force amplitude fluctuations at points throughout the sweep and excessive attenuation of intermediate and higher frequencies ranging from 200 to 500 Hz. This study is focused on determining if the baseplate of a commercial high frequency hydraulic vibrator behaves like a rigid body throughout its operational frequencies. Specialty accelerometers were strategically placed to determine optimal location that best matches ground response as measured by a buried geophone. This aided in discovering aberrations within the sweep spectra related to source configuration, and provided target enhancement opportunities for higher frequencies through optimized measurements of baseplate and ground coupling. The results show a significant variation in acceleration depending on where the accelerometer is positioned on the baseplate. Moreover, the baseplate accelerometer alone is sufficient for deconvolution.

Introduction

Good coupling of the baseplate to the ground is essential for efficient energy transfer (Brittle et al., 2001). The source pulse continuously attenuates as the seismic wave propagates through the earth and reflects back to the surface (Collins and Lee, 1956; Chapman et al., 1981). The amount of attenuation will differ depending on surficial characteristics including porosity, permeability (for sandstone) and clay content (Klimentos and McCann, 1990). By controlling the force output of the source relative to hold-down pressures, energy levels can be maintained that ensure decoupling does not occur (Sallas, 1984). Since the vibrator’s force output is a function of physical motion of the baseplate, the baseplate’s displacement, velocity and acceleration are known. If the baseplate ceases to act as a rigid body, then phase variations associated with machine specific baseplate flux will alter the transmitted seismic energy. Baseplate distortion can be detected through accelerometers placed on the baseplate. Comparisons of the ground force calculated using the various positions on the baseplate with recorded signal from a 28 Hz geophone buried in concrete below the baseplate allowed determination of specific accelerometer locations on the baseplate that more accurately represent the seismic waves going into the ground.

High resolution applications of reflection seismology continue to strive for increased imaging depths in the subsurface. In response to this need has come an increased demand for high-frequency vibroseis because it is non-invasive (Miller et al., 2004). To push dominant frequencies even higher (120 to 300 Hz), the vibrator must increase drive force. The ability and efficiency in delivering and recording high frequency energy to the ground is directly associated with the design of the vibratory source, therefore, electrical and mechanical modifications must be considered for increasing resolution of standard vibroseis units, such as reducing plastic deformation and phase variations across the baseplate (Chapman et al., 1981). The high fidelity vibratory seismic (HFVS) method has produced significant improvements to seismic data using inversion phase minimum deconvolution (Allen et al., 1998), including improved wavelet stability, reduction of side lobe deformation and expansion of bandwidth. The HFVS method generally deals with situations in which there is more than one vibrator sweeping. For time/cost purposes, deconvolution is done in the field, so phase locking is important. The vibrator used for these experiments has no phase lock and is an open-loop circuit, meaning that the corrections to the ground force drive for location specific variations is developed based on the last sweep transmitted. The open-loop circuit is not a concern because deconvolution is not done in the field.

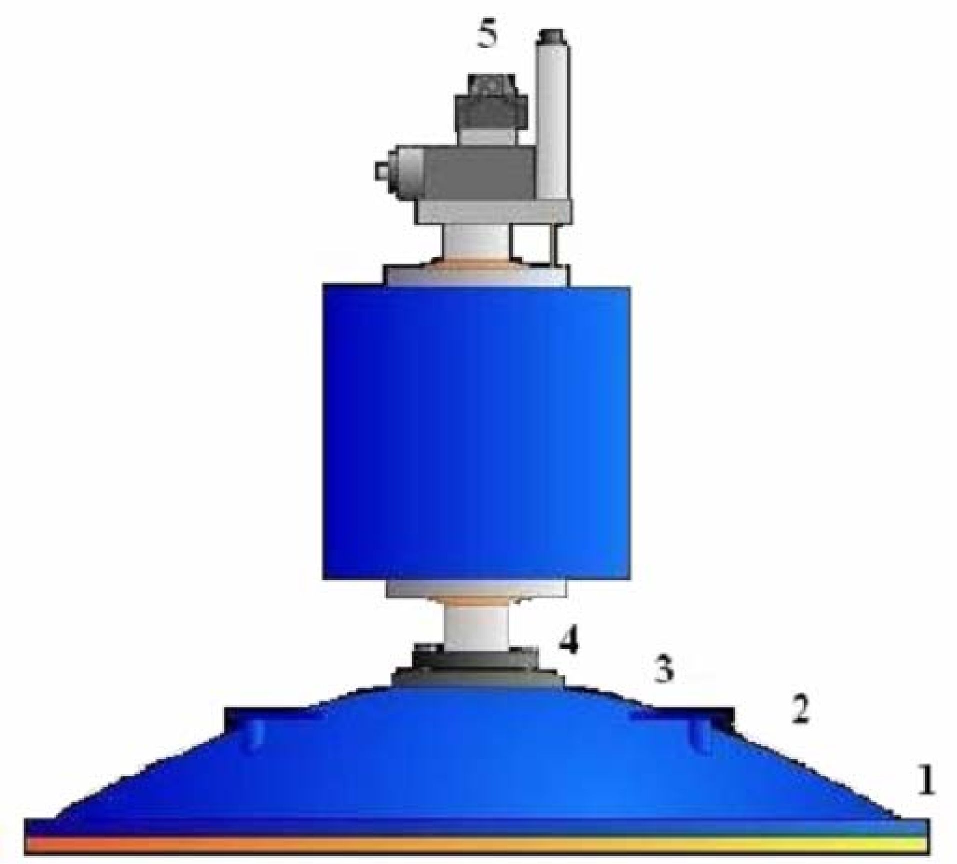
Achieving optimized high-frequency vibroseis data is done by deconvolving the recorded seismic energy with the ground force, which requires accurate measuring of the true ground force (Bickel, 1982). The measurements recorded by the accelerometers must be equivalent to the ground force that is actually propagating through the ground. Deviation from the true ground force so far has been attributed to accelerometer electrical noise, engine noise picked up by the baseplate accelerometer, and radio signal distortion. This study focuses on the position of the baseplate accelerometer and changes due to flexure, phase and amplitude changes.

Understanding vibrator-earth interaction is an important aspect for optimizing transmission of high frequencies (Seriff and Kim, 1970; Schrodt, 1985; Schrodt et al., 1987). Baseplate coupling with the ground will change depending on the surface type, such as sand, cement, and full or partial contact. Amplitude and phase control of vibrator output is significantly more difficult on rigid ground. To prove that high frequencies can be optimized for any given soil variation, the proof must be true for the worst-case scenario because it is the most convincing.

Baseplate flexure is another issue for concern. Brook and Crews (1991) did experiments on circular baseplates revealing up to a 20 degree phase shift from what was being measured between 32 different baseplate accelerometer locations. This study attempts to do something similar to Brook and Crews' experiment by choosing different locations for the accelerometer and comparing them to velocity measurements recorded by a buried geophone. HFVS makes the assumption that the derivative of the ground force is in phase with velocity measurements however, Allen et al. (1998) goes on to discuss a 60 degree phase shift at 140 Hz. Preliminary testing was done on accelerometer data and 90 degree shifted velocity data to determine if comparing accelerometer data to velocity data would be problematic. Testing revealed that phase shifted velocity data still correlated to 80% of the original accelerometer data, with 20% attributed to waveform differences. For these reasons, the assumption is made that the ground force can be compared to velocity data.

Acquisition

A 28 Hz geophone was planted below 2 ft of ground in cement. The Minivib's baseplate was placed over the geophone for the duration of the study. The assumption is made that during a sweep, the geophone would record the true signal transmitted into the ground. This signal could then be compared to the ground force calculated using the reaction mass and baseplate accelerometers and the similarity would be a measure of optimal instrumentation of vibrator response. Five positions on the baseplate were decided upon for the location of the Endevco specialty accelerometer (Figure 1). A 5 sec, linear up-sweep was generated from 200-500 Hz with a front taper of 0.25 s and end taper of 0.1 s. During the study, the baseplate accelerometer was systematically placed in each of the five predetermined locations. Comparisions were made with the 28 Hz geophone response to the Endevco accelerometer configurations along with a Dytran accelerometer, which has a higher noise threshold, the Dytran's corresponding pilot signal transmitted over the telemetry system and a synthetic sweep.

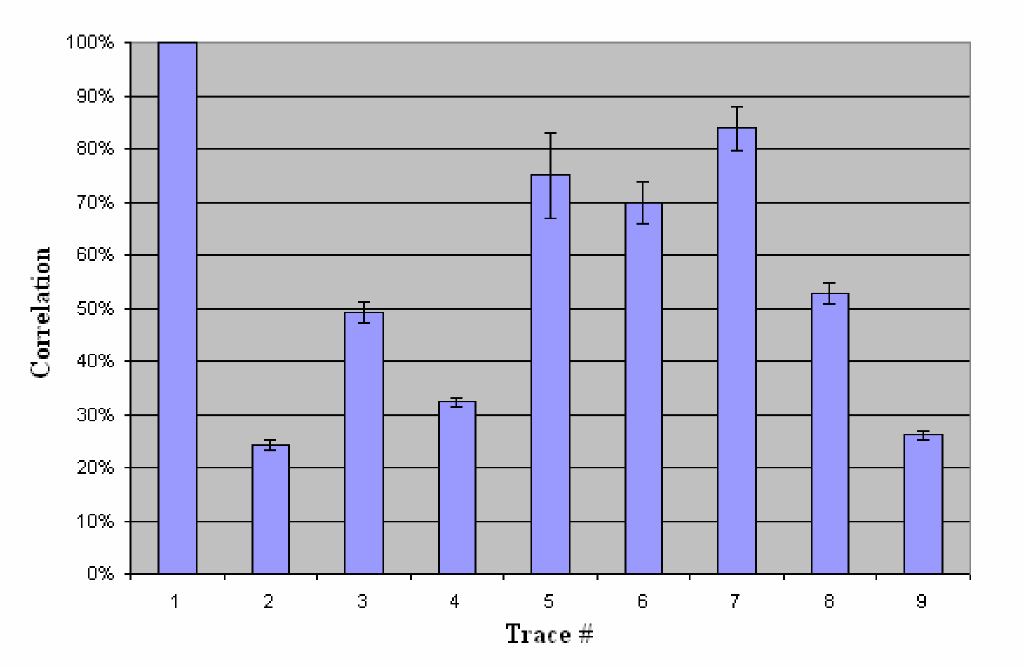


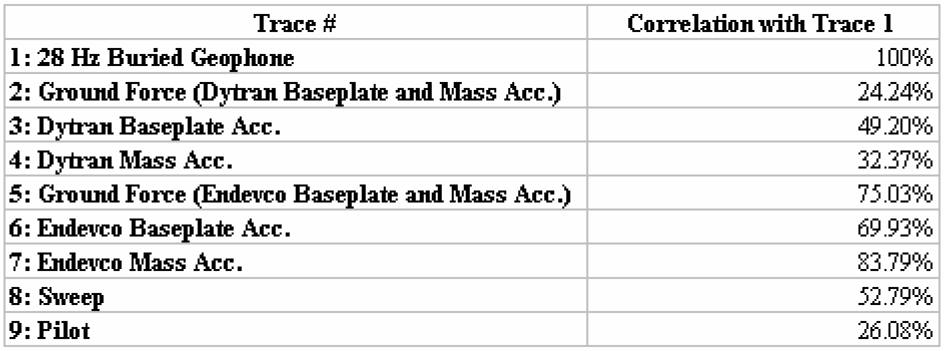
Endevco accelerometer location	Distance from center
Position 1	18"
Position 2	14.25"
Position 3	10.5"
Position 4	6.5"
Position 5	0"

Figure 1.: The five locations of the accelerometer on the baseplate.

Results

Correlation with the 28 Hz geophone reveals that the Endevco mass accelerometer is a configuration that chacterizes signal if the various baseplate positions are averaged with a value of 83.79% (Figure 2). Further analysis reveals that the Endevco baseplate accelerometer response is highly dependent on location, and moreover, yields the highest similarity with the 28 Hz geophone. Position 2 is the location that one would want to use for this particular frequency range because it correlates to 87.4% of the true signal (Figure 3). Positions 3 and 4 are very close in value to position 2. Moreover, position 2 yields a better reading than the ground force calculated using position 2, which has an average value of 84% ± 2%. Figure 4 further

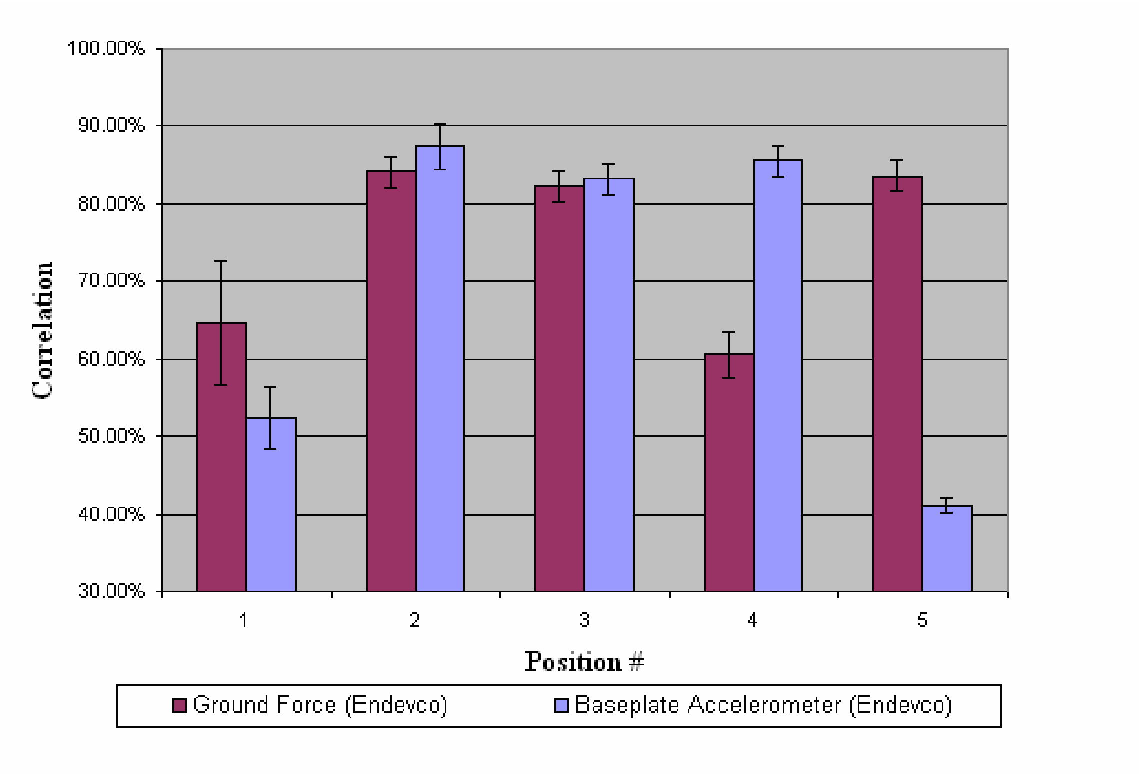




Trace #	Correlation with Trace 1
1: 28 Hz Buried Geophone	100%
2: Ground Force (Dytran Baseplate and Mass Acc.)	24.24%
3: Dytran Baseplate Acc.	49.20%
4: Dytran Mass Acc.	32.37%
5: Ground Force (Endevco Baseplate and Mass Acc.)	75.03%
6: Endevco Baseplate Acc.	69.93%
7: Endevco Mass Acc.	83.79%
8: Sweep	52.79%
9: Pilot	26.08%

Figure 2.: Correlation with the 28 Hz phone reveals that the Endevco mass accelerometer yields the highest fidelity of ground response when position is not accounted for on the baseplate.

reveals the resulting wavelets after deconvolution with the 28 Hz geophone. This confirms that the Endevco configurations yield the most accurate measurements.



Trace #	Positions of the Endevco Model on the Baseplate				
	Position 1 (18" from center)	Position 2 (14.25")	Position 3 (10.5")	Position 4 (6.5")	Position 5 (0")
5: Ground Force (Endevco Baseplate and Mass Acc.)	64.66%	84.10%	82.29%	60.58%	83.52%
6: Endevco Baseplate Acc.	52.47%	87.40%	83.18%	85.54%	41.04%

Figure 3.: Correlation with the 28 Hz geophone and the Endevco accelerometer located on the baseplate reveals that placement makes a difference in signal response. Position 2 yields the best response, beating out the mass accelerometer and the ground force.

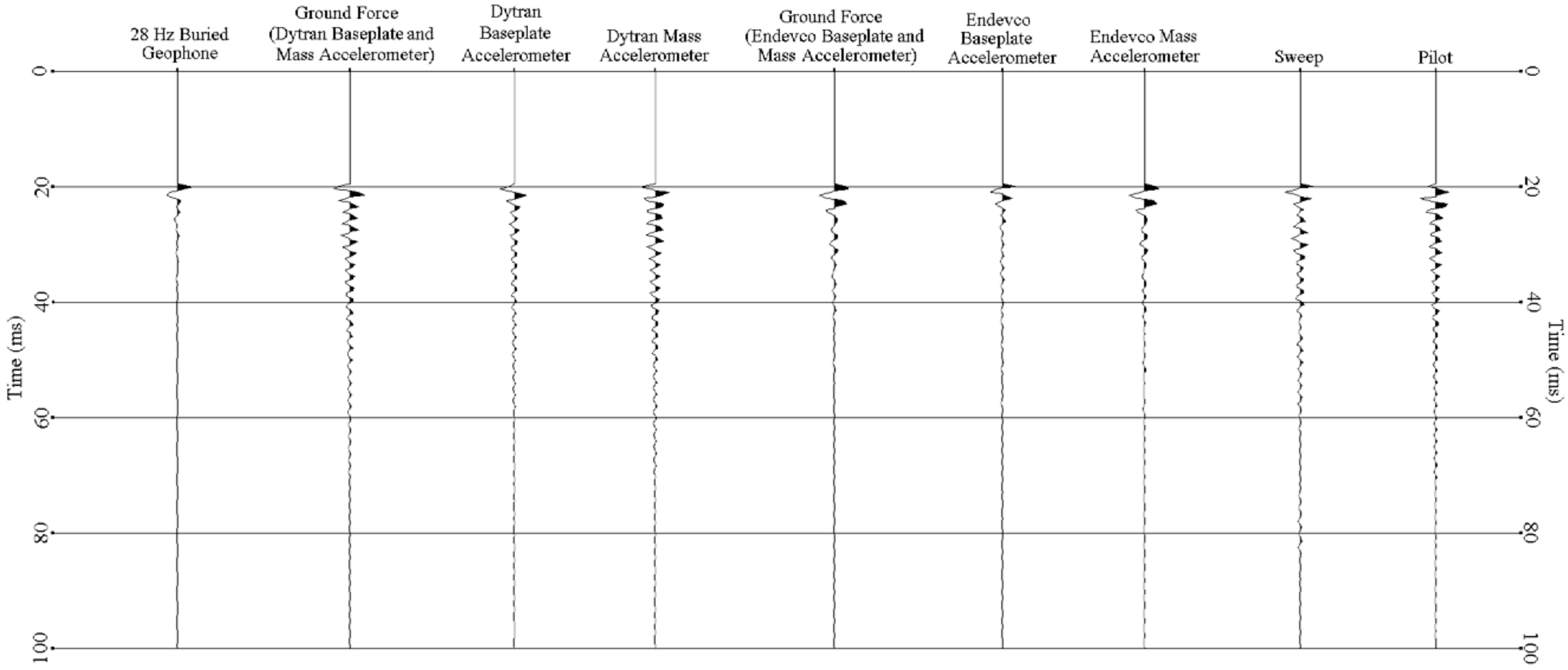


Figure 4.: Deconvolution with the 28 Hz buried geophone for a linear upsweep with a frequency range 200-500 Hz. This visually supports how the waveform of the Endevco baseplate accelerometer is the best measurement of the true ground force.

Conclusions

Above 200 Hz, position 2 yielded the best performance although positions 3 and 4 will consistently produce similar values. However, in every case, the accelerometer measured poorly in the positions on the rim and on top of the column. Interestingly enough, using the baseplate accelerometer alone gives the best measurement of true source signal.

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