The Development and Initial Field Trials of a New High Frequency Seismic Vibrator

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Abstract

The cost of shot hole drilling is often more expensive than using vibratory energy sources in high resolution seismic surveying. However, such costs are often accepted since conventional vibrators cannot always provide the extreme imaging capacity required in high resolution work. Conventional seismic vibrators sweep in a range from 5 Hz to 250 Hz — the range of which is limited by the vibrator. The impulse train of the high resolution wacker used by the MiniSOSIE[1] system is also band limited, causing a reduction in imaging resolution. The ideal solution is to sweep a broad range of frequencies from the lower seismic range to as high as 500 Hz. This could offer a cost effective solution to the acquisition of broad band high resolution data.

In high resolution seismic profiling, explosives are commonly used as the source. Small charges below the weathered layer produce the highest frequency content (Ziolkowski and Lerwill, 1979). Unfortunately, the cost of drilling shot holes is a major component of the survey costs. For oil exploration in Australia/New Zealand, dynamite surveys average 43% more than Vibroseis[2] surveys in dollars per kilometre (Montgomery, 1987), despite more hardware being required for Vibroseis recording.

The MiniSOSIE system is also used for some high resolution surveys, because it is relatively cheap. However, this does not achieve equivalent results to small explosives. It will give worse results as the soil becomes softer, as the rebound from an impact takes longer, and hence the wavelet is broader.

An alternative to these sources is the hydraulic powered vibrator, which has sometimes been used for high resolution coal work in Europe. With vibrators, the spectrum is controllable within certain limits. The Vibroseis system can also produce zero phase wavelets, if used properly with its controllable frequency wave-train sweep; and with repeatable multiple sweeps this results in enhancement of signal to noise ratio together with the promise of the highest frequency returns. Zero phase wavelets have slightly better resolution than the same bandwidth minimum phase wavelets as produced by impulsive sources. The breadth (τ) of a zero phase Klauder wavelet with a boxcar spectrum can be predicted from the sweep start (f_S) and end (f_E) frequencies by the approximation:

$$\tau = 1/(f_S + f_E)$$

By sweeping 50 to 500 Hz, a wavelet 1.8 ms wide should result, which is the resolution required to locate faults with a throw of less than two metres. In practice, a wider wavelet may be obtained, due to absorption of the high frequency energy.

The Vibrator Seismic Source (VSS) is presented here in its first application of this new hydraulic powered vibratory source, which operates under different mechanical and electronic control than used heretofore by conventional vibratory sources. The VSS has been developed continuously since 1980 when an initial grant was received from NERDDC. During the intervening years till 1987, two more grants were received (Stewart, 1988).

A recent further NERDDC grant was received in 1988 jointly by ACIRL, Curtin University and University College ADFA for areal coal seam mapping by three-dimensional seismic reflection surveying, with an emphasis on high resolution imaging of faults.

The novelty of the VSS lies in the use of a single flow path for hydraulic oil through the flow stage of a Servo Popper Valve (SPV) (Stewart, 1986). This powers the vibrator by application of the oil to only one side of a piston in the linear actuator which produces the forced output of the vibrator on the surface of the earth. Conventional vibrators use a spool valve to alternately reverse the flow of oil into opposite chambers of a double acting cylinder. Hence the VSS has a fluid power advantage over conventional vibrators and this is evident by better performance at the higher frequencies. The VSS can sweep typically from 50 Hz to 500 Hz, and was initially field tested as a high resolution energy source. Innovations in both mechanical and electronic control systems are presented and results of the initial field trials of the VSS are compared to explosive seismic source results.

[1]Trade Mark of CGG [2]Trade Mark of Conoco