

Field test of two high frequency vibrators with two high frequency servovalves at two sites in Kansas with near-surface emphasis

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Summary

Field comparison of two commercially available high frequency vibrators built on identical vehicle frames but with significant differences in the weight of the reaction mass/baseplate and in hydraulic system capacity produced data with markedly different spectral characteristics and signal-to-noise ratios when recorded under identical conditions. A significant finding was the four-times increase in ground force at 200 Hz and 6 dB increase in overall signal strength in the larger mass/baseplate configuration. Physical limitations of the larger mass/baseplate restricted use at frequencies above 250 Hz where the smaller mass/baseplate design produced significant reflection energy at frequencies well in excess of 400 Hz. A high-output rotary valve design compared favorably to standard servovalves. Modern high-frequency low-maintenance vibrators have the potential to generate and propagate seismic signal to depths of over 1 km at frequencies in excess of 200 Hz and over 400 Hz signal to depths on the order of 100 to 200 m, depending on near-surface conditions and geologic setting.

Introduction

Near-surface applications of seismic reflection increasingly call for detection, delineation, and resolution of smaller and smaller targets at greater and greater depths. Along with these demands for higher resolution come limitations on the invasive characteristics and environmental impact of the overall survey, both from an economic as well as conservation perspective. With these more stringent requirements for higher resolving power with minimal impact and cost has come the

increased development and use of high-frequency vibroseis for near-surface problems.

Most appealing about vibroseis for the near-surface seismic community is its non-invasive nature and minimal cost per station for targets in the 100 m to 1000m depth range in comparison to comparable explosive sources. Pushing dominant and useable high frequencies into the 120 to 300 Hz range with vibrators requires significant increases in drive force as we move further and further from the resonance peak. For conventional vibroseis surveys using more standard exploration vibrators with 50,000 to 60,000 lbs of hold down (force output), typical mid-band ranges between 10 and 50 Hz with a resonance of around 25 Hz (Chapman et al., 1981); however, as we move to high resolution surveys and vibrators with 10,000 to 15,000 lbs of hold down, mid-bands of 20 to 100 Hz are common with resonance frequencies around 50 Hz (Figure 1). These specially designed small vibrators possess reaction masses with shorter strokes and large pistons, a necessity to sweep through frequencies as high as 500 Hz at desired force levels.

Moving conventional vibrator designs from bandwidths rarely exceeding 120 Hz to obtaining dominant frequencies above 150 Hz requires several changes to key components. Comparatively speaking these upgrades include a high-flow servovalve, a lightweight and rigid baseplate, and increased fluid resonance above the high-frequency design limit (Chapman et al., 1981).

Near-surface high-resolution vibroseis surveys have produced CMP stacked data with dominant reflection frequencies

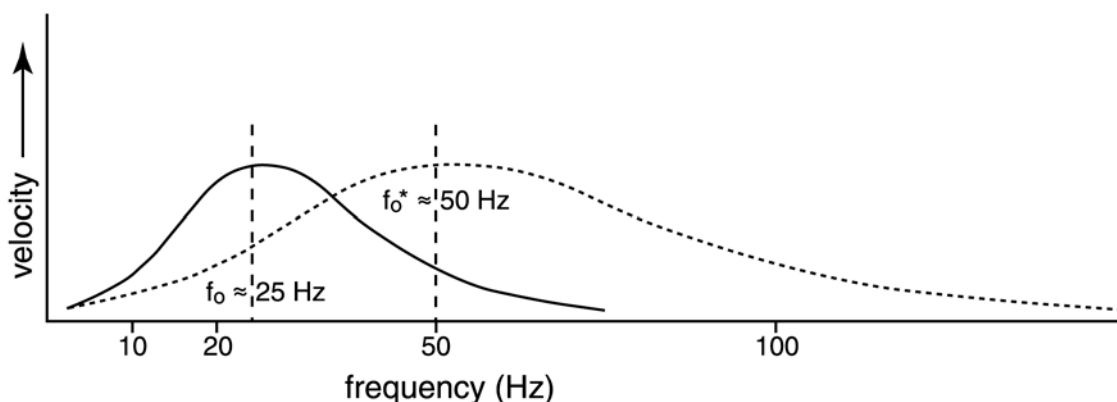


Figure 1. Resonant frequency f_0 for 50,000-lb vibrator, f_0^* for 13,000-lb vibrator, and typical response showing earth-vibrator interaction $f_0 \propto \sqrt{K/V_m}$ where K = earth spring constant and V_m = vibrator mass (modified from Chapman et al., 1981).

Field testing of high frequency vibrators and servovalves

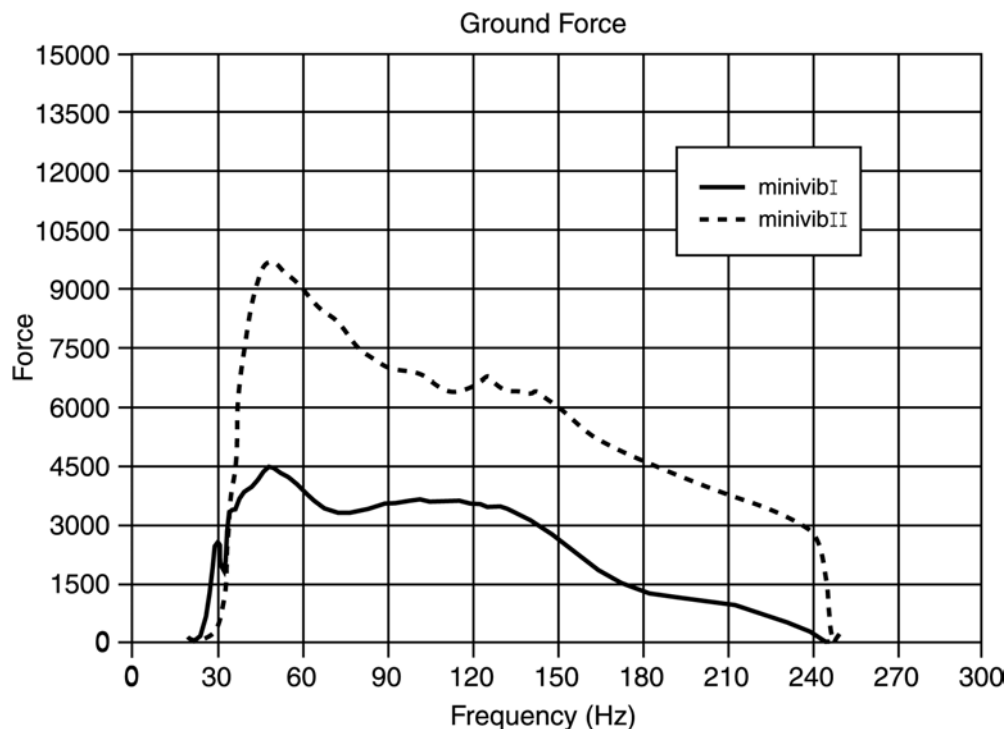


Figure 2. Ground force of minivibII (- - -) and minivibI (—) with standard valves as a function of frequency. Enhancement in ground force increases from two times greater at 50 Hz to four times greater at 210 Hz. Both vibrators possessed 13,000 lbs of hold-down on buggy-style frames.

above 100 Hz and useable upper corner frequencies as high as 200 Hz from depths ranging from 150 m to over 1000 m using specially designed vibrators (Gochioco, 2000; Miller and Xia, 2002; Miller et al., in press). Conoco was the first in developing a high-frequency vibrator capable of propagating useable frequencies greater than 100 Hz present at depths exceeding 1500 m (Chapman et al., 1981).

A comparison designed to evaluate the spectral and signal strength characteristics of two vibrators and two servovalves at two field sites included both 2-D CMP stacked data and shot gathers, pre- and post-correlation. In particular, testing focused on an interest in the increased fluid flow capacity of a new rotary valve design over conventional servovalves and improvements in signal strength within a specific high frequency band (20 to 250 Hz) for vibrators with the about the same hold down but an approximately three times difference reaction mass/baseplate weights.

Testing Parameters

Initial comparisons of high frequency source equipment came from shot gathers recorded using a 240-channel, 3-D geophone deployment with source settings and locations selected

to allow relative, qualitative comparisons of source specific data characteristics. Each shot gather was recorded under identical conditions but with a different combination of IVI vibrator (minivibI and minivibII) and servovalve (Moog and Atlas high output valve). Resulting data allowed comparison of valve and vibrator performance. Ground force was used as a measure of vibrator performance at the baseplate/ground contact (Sallas, 1984).

A 20 to 250 Hz linear upsweep delivered once by each combination—minivibI with the Moog valve, minivibI with the Atlas rotary valve, minivibII with the Moog valve, minivibII with the Atlas rotary valve—were individually recorded using a fixed 2-D array of geophones deployed for a 3-D survey in Russell County, Kansas, and once into a single one-kilometer line of geophones deployed for a 2-D survey in Franklin County, Kansas. Additionally, at the Franklin County site sweeps were optimized for different target depths and vibrator capabilities; this included a 50 to 500 Hz linear upsweep with the minivibI with each servovalve to establish maximum frequency, ground force, and data resolution potential of the available equipment. These two test sites provided dozens of head-to-head comparisons significant to the near-surface explorationist designing a survey.

Field testing of high frequency vibrators and servovalves

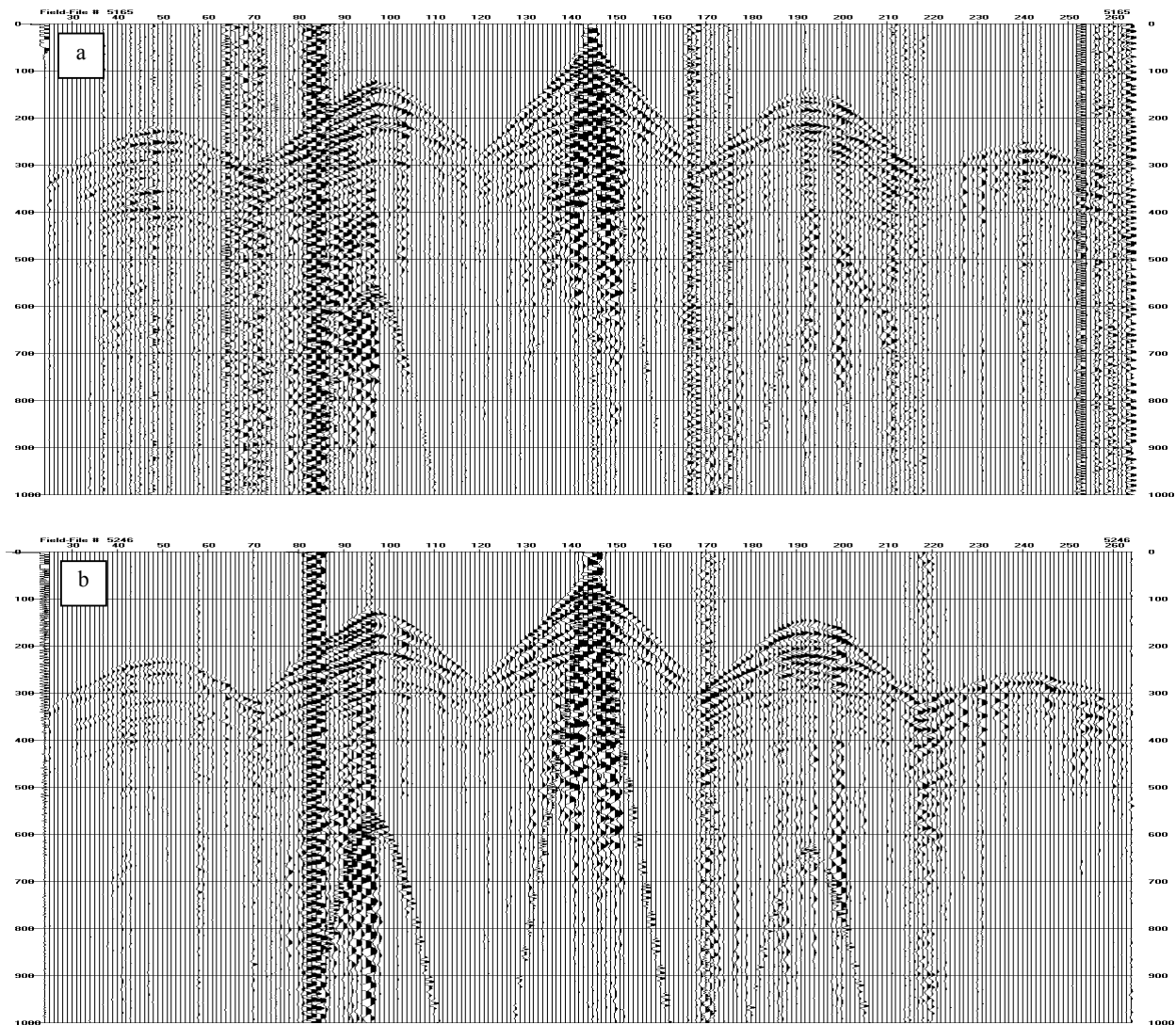


Figure 3. (a) minivibI, (b) minivibII, both with standard servovalve. Sections are plotted true amplitude with (a) 6 dB higher gain than (b).

Data Comparisons

With identical ground conditions and vibrator operations optimally tuned, data from the larger reaction mass/baseplate vibrator possess about twice the overall signal levels. In general, for this vehicle design increasing the weight of the vibrator's reaction mass and baseplate by about three times (baseplate surface area was similarly increased) ground force increases by about four times at 200 Hz (Figure 2). Force curves produced when the vibrators were operating on a packed dirt road at the Russell Kansas 3-D site closely match design expectations for these two vibrator systems which are

identical in all ways except mass and size of components and increased fluid volume.

Shot gathers recorded have subtle differences in reflection wavelet characteristics (Figure 3). Signal-to-noise ratio of the minivibII is superior to the minivibI within the recorded frequency band and reflection amplitudes are about 6 dB greater at 200 msec (300 m at this site). However, the increased weight of the mass and baseplate and increased fluid demands of the minivibII limits its maximum usable frequency to around 250 Hz.

Field testing of high frequency vibrators and servovalves

CMP profiles concentrated on optimizing vibrator and valve for unique target intervals. The minivibI was operated with both servovalves through a 10-second upsweep ranging from 25 to 500 Hz. With the minivibII both servovalves swept for 10 seconds between 20 and 250 Hz. This eastern Kansas field site possesses around 1000 m of cyclic Pennsylvanian limestones and shales overlying similar cyclic Mississippian rocks. Bedrock is around 10 ft with a weathered shale near-surface. Each source configuration possesses a unique imageable depth range and resolution potential.

Conclusions

Equipment currently available can be optimally configured to deliver high frequency sweeps applicable to the resolution requirements of a variety of near-surface investigations. Relative differences in ground force as measured at the vibrator (reaction mass and baseplate) between different servovalve designs do not necessarily translate linearly to similar differences in recorded reflection characteristics. Clearly the volume of fluid a servovalve can output during the highest frequency portions of a sweep is the primary controlling factor in improving the performance of either of the two high-frequency vibrators tested.

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