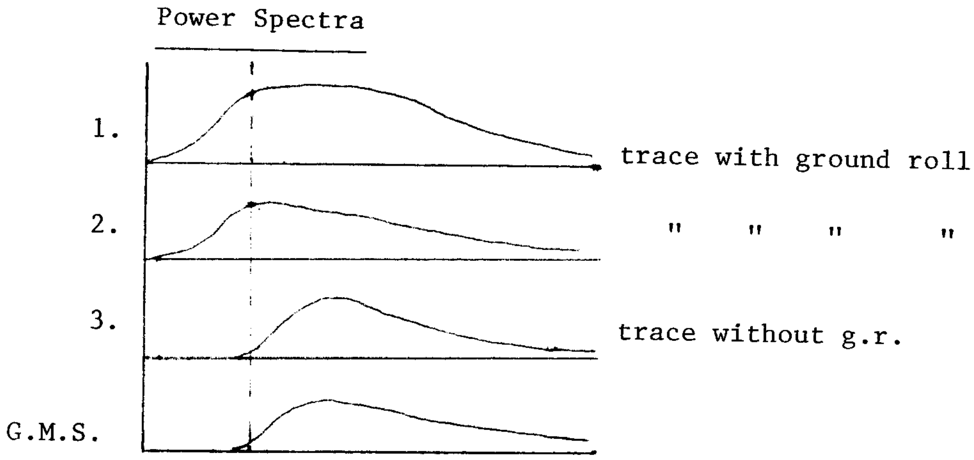
AN APPLICATION OF SPECTRAL BALANCING TO GROUND ROLL ATTENUATION

Larry Morley

On many land reflection seismic profiles (common shot gathers) ground roll is highly visible as coherent, low velocity energy. The usual approach to attenuating this undesirable noise is to apply an F-K filter to discriminate against low velocity events or, equivalently, to stack the data with a stacking velocity much greater than the ground roll velocity. It was thought that additional signal enhancement in such situations could be achieved for relatively shallow events using the method of Spectral Balancing [Claerbout - 1].

This method forces the amplitude spectrum of each trace on a profile to assume the geometric mean spectrum (GMS) of all traces in that profile. Since the reflection data on the far offsets is uncorrupted by low frequency ground roll noise at early times, we would expect the GMS to have a low frequency cutoff located at the low end of the useful signal passband but above the ground roll [see schematic in Figure 1]. This provides an automatic way of discriminating against ground roll prior to stack.

Figure 1.



If $x_k(z)$ is the z-transform of the k^{th} trace on a profile then the balanced trace is given by:

$$y_k(z) = x_k(z)\; A_k(z)/A_{ave}(z) \quad . \tag{1}$$

where $A_k(z)$ is the prediction error filter for the k^{th} trace and

$$\left| A_{ave}(z) \right| = \left\{ \prod_{k=1}^{N} \left| x_k(z) \right| \right\}^{1/N} \quad . \tag{2}$$

To test these concepts the x_kA_k's were computed in the time domain using the Wiener-Levinson deconvolution technique to obtain a whitened seismogram. The geometric mean amplitude spectrum $\left|x_{ave}(z)\right| = \left|A^{-1}_{ave}(z)\right|$ was computed by averaging the log-amplitude spectrum of the x_k's obtained by FFT methods. A discrete Hilbert transform was then used to get the phase spectrum of the minimum phase filter, $A^{-1}_{ave}(z)$.

Figure 2 shows the first two seconds of a profile of raw data heavily masked by ground roll. The near and far offsets are 50' and 4653' respectively with a group interval of 99'. Figure 3 shows a deconvolution of Figure 2 followed by a bandpass Butterworth filter with cutoff frequencies of 10 and 55Hz. The rolloff rates are 12 db/octave at either end. The deconvolution was done with a 1 step prediction error filter using an autocorrelation gate from 1.0 to 1.9 seconds and an 80 mil decon operator.

In Figure 3 we see that a conventional deconvolution followed by an arbitrary bandpass filter does a reasonably good job of suppressing the ground roll on the original section. If spectral balancing is to be a useful technique the results obtained from it should compare favorably with Figure 3.

Figure 4 is a plot of the log-amplitude spectra of each trace and the geometric mean amplitude spectrum associated with this profile. Note that $\left|x_{ave}(f)\right|$ has a very narrow band of energy around 9 Hz which dominates the entire spectrum. Figure 5 shows the spectrally balanced profile consisting of W-L whitened traces filtered by the minimum phase GMS filter $x_{ave}(f)$. Since $x_{ave}(f)$ is so narrow band, the final product does not compare well with Figure 3.

Returning to Figure 4 we see that the narrowbandedness of $x_{ave}(f)$ is caused by a misalignment over offset of the main lobes of the geophone amplitude response. This could be due to variations of the receiver array response or near surface response with offset. Because of this the GMS is *not* characteristic of the true amplitude spectrum of the signal. However it could still be used to determine the low frequency cutoff of the post deconvolution filter.

Reference

[1] Claerbout, J. R., "Spectral Balancing," SEP-7, p. 172

Acknowledgement

The author would like to thank Don Riley of C.O.F.R.C. - La Habra for providing the field data used in this study.

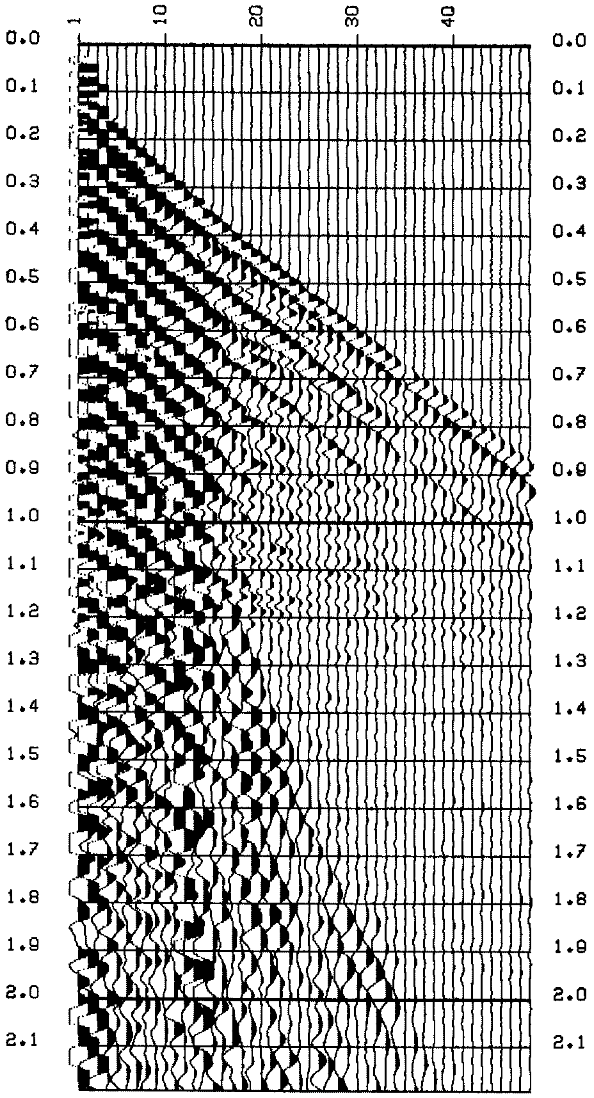


Figure 2 Unprocessed field data

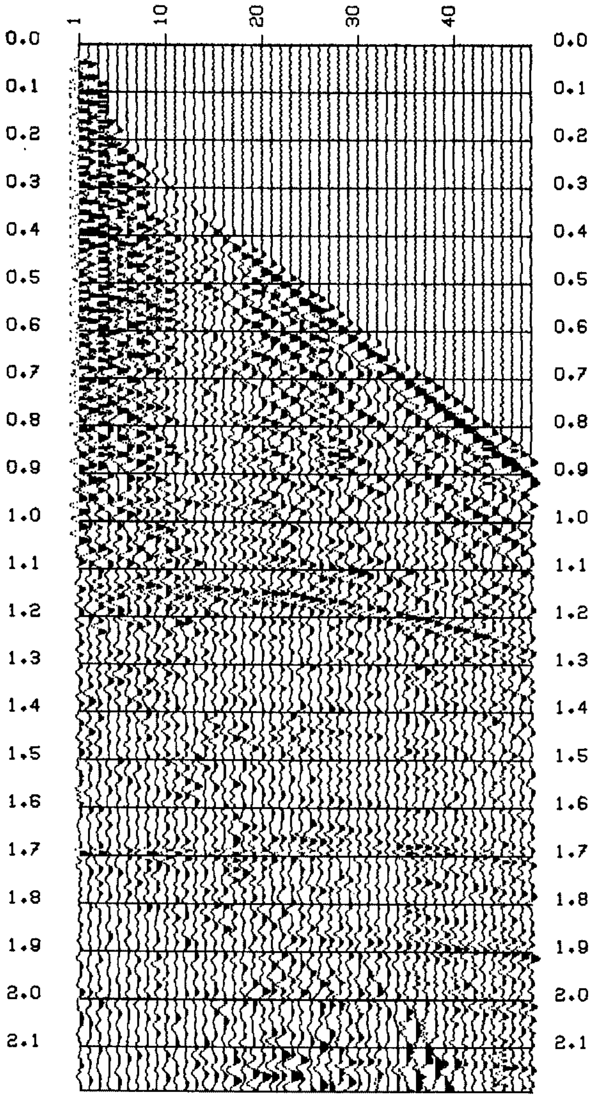


Figure 3 Wiener-Levinson deconvolution of Fig. 2 followed by 10/55 Hz band-pass filter. The autocorrelation window was from 1.0 to 1.9 seconds.

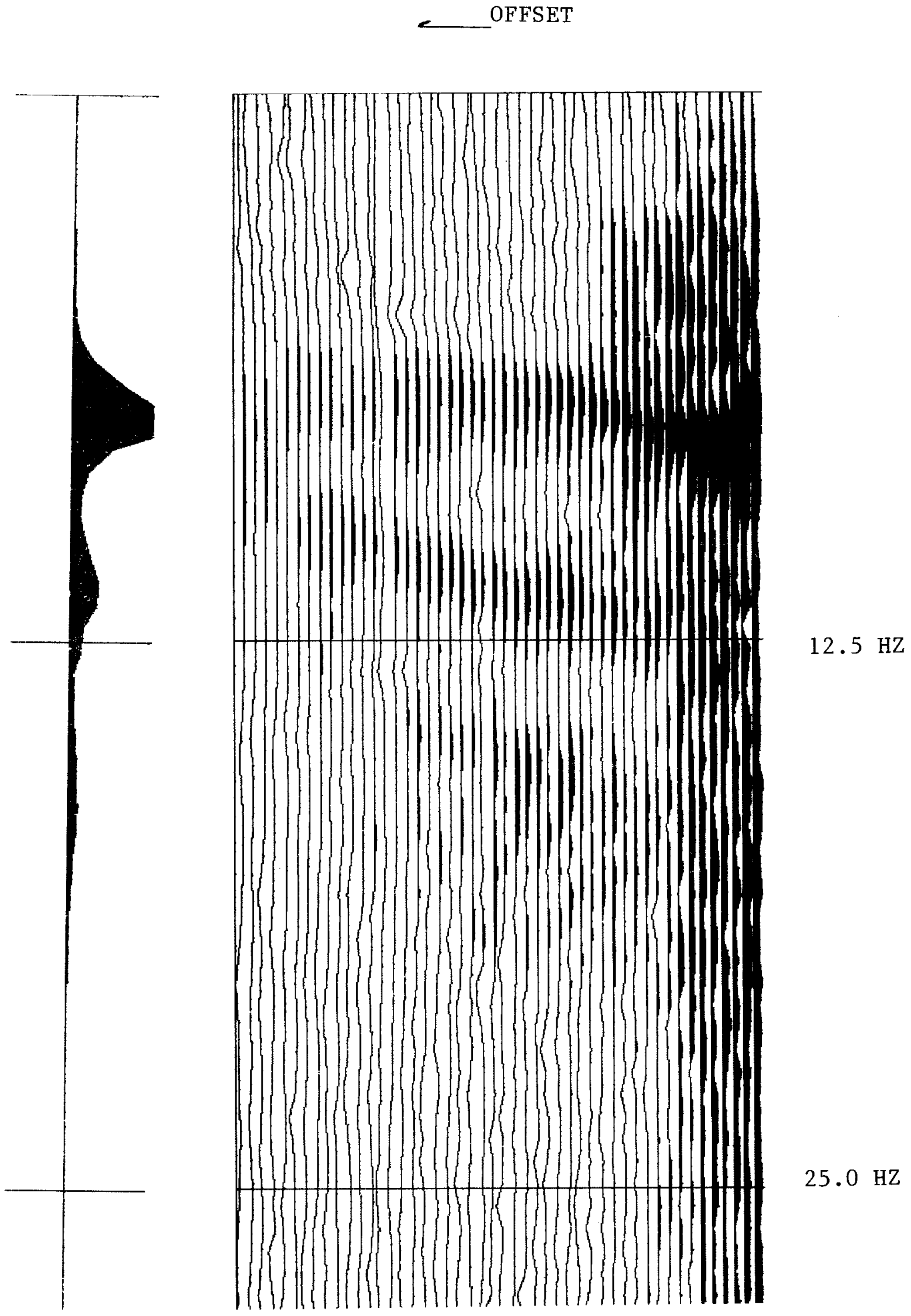


Figure 4 Log Amplitude Spectra of data in Fig. 2 computed over the time window 1.0 - 1.9 sec. The Geometric Mean Spectrum is displayed on the left.

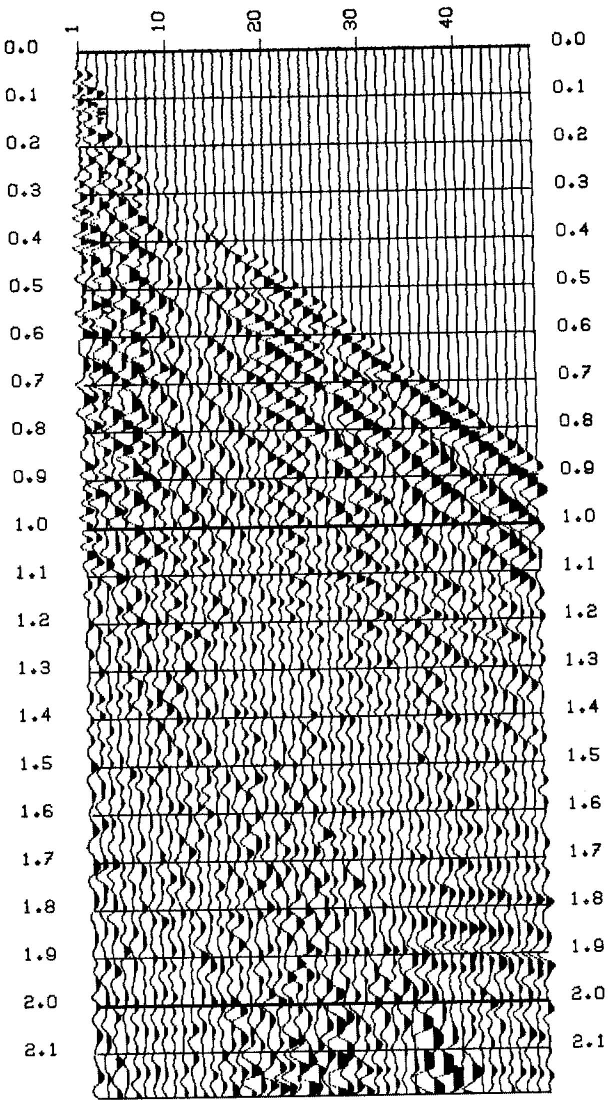


Figure 5 Result of Spectral Balancing Process on the data of Figure 2.