

## Increasing reflection SNRs on seismic field data acquired using multiple simultaneous vibrators driven by m-sequence pilots

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### Summary

Field tests with four vibrator sources simultaneously driven by quasi-orthogonal filtered m-sequence pilots produce debblended common-source gathers with reflections somewhat degraded by weak artifacts with moveouts running parallel to direct arrivals and by vibrator-to-vibrator crosstalk. We can minimize crosstalk by keeping the distance between adjacent vibrators to 100m or less. We show that localized slant stacking processes are effective in reducing both artifacts and crosstalk noise and so enhance signal-to-noise ratios of the reflections. By simultaneously running multiple vibrators controlled by filtered m-sequences and following the noise-reduction steps, we should be able to increase the efficiency of conducting high-resolution 3D surveys significantly without compromising the quality of final reflection images.

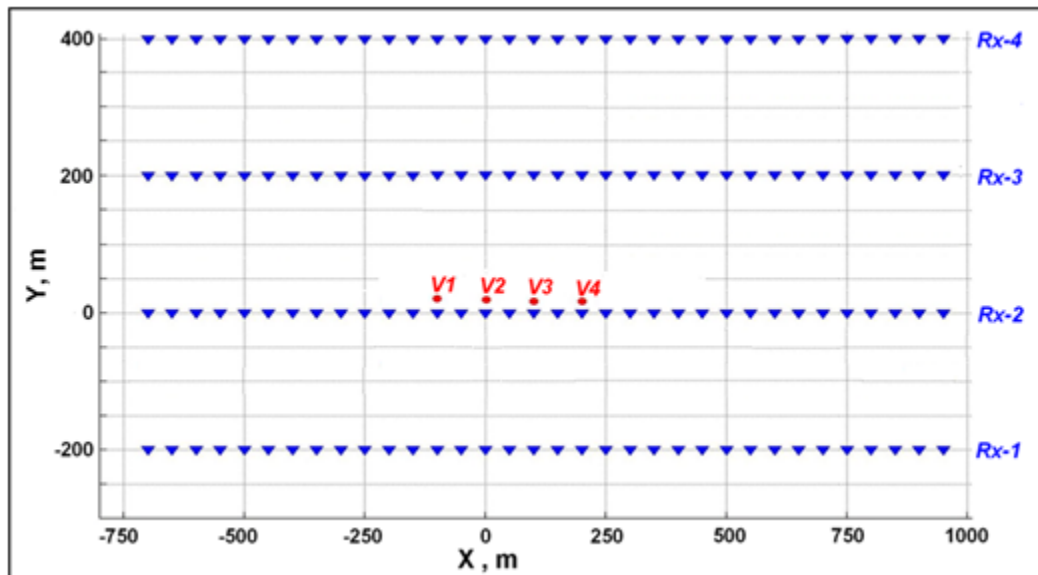


FIG. 1: Field configuration for testing four vibrators V1, V2, V3, and V4, separated by 100m and driven simultaneously by four quasi-orthogonal m-sequence pilots. The four receiver lines Rx-1 to Rx-4 are about 5800m long; the receiver interval is 50m. The distance between the line of vibrators and receiver line Rx-2 is about 5m.

### Method and Example

Wong and Langton (2014; 2015a,b) have shown that it is possible to conduct seismic surveys using two or four vibrators driven simultaneously by a set of filtered m-sequence pilot signals. Deblending of summed raw data recorded with simultaneous vibrators into separate common-source gathers (CSGs) occurs at the crosscorrelation step because the filtered m-sequence pilots are quasi-orthogonal with respect to crosscorrelation (i.e., within a restricted window of time lags, the autocorrelation of any member in the set closely approximates the delta function, while the crosscorrelation between any two different members in the set is very nearly zero). Other Vibroseis pilot signals that have been tested for crosscorrelation orthogonality in simultaneous-source acquisition are variphase sweeps (Krohn et al., 2010), modified Gold codes (Sallas et al., 2011), and Galois codes (Thomas et al., 2010; 2012). Dean (2014) reviewed a variety of pseudorandom signals and their suitability as Vibroseis pilots.

Figure 1 is a schematic representation of the acquisition geometry for field-testing four vibrators V1, V2, V3, and V4 running simultaneously with m-sequence pilots. The sweep times of the m-sequence pilots used in the field tests were designed to be 16.382 seconds. Acquisition was done with listen times (lengths of recorded raw data traces) of 22.000 seconds and a digital sampling interval of 2ms.

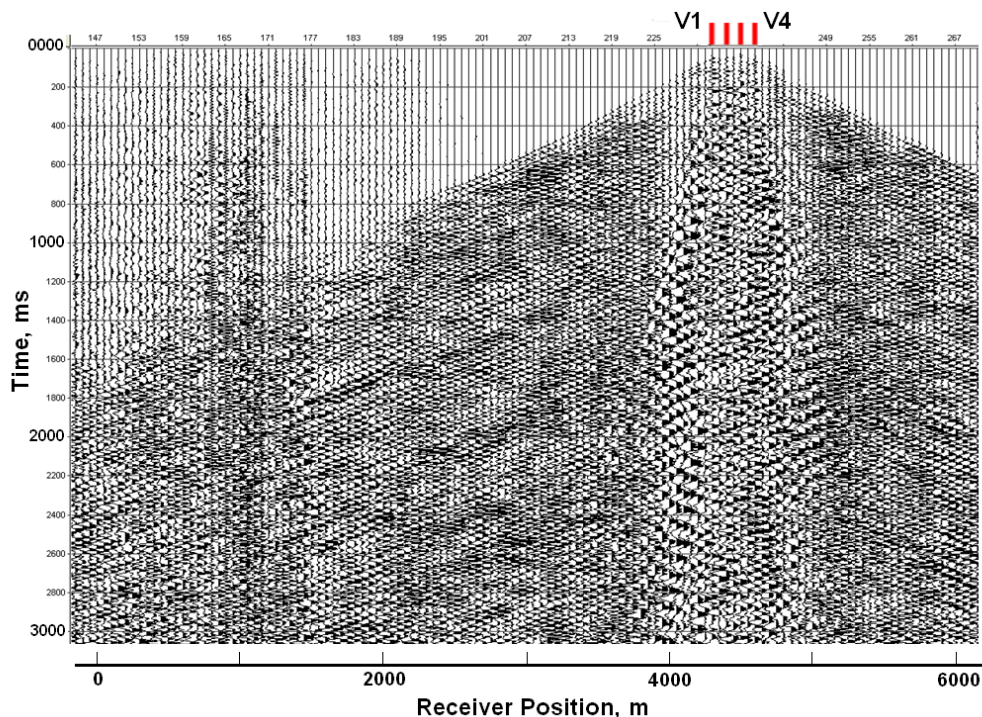


FIG. 2: Trace-normalized plot of the first 3000ms of blended raw field data for receiver line Rx-2, recorded with four vibrators (source interval = 100m). Red bars show the positions of the four vibrators V1, V2, V3, and V4.

Figure 2 displays blended uncorrelated field data recorded for receiver line Rx-2. The strong low-frequency ground-roll noise for receivers inside the “noise cone” (i.e., at positions closest to the vibrators) can be reduced by applying a bandpass filter with corners at [15-30-100-150] Hz. Crosscorrelation of the blended raw field data with the appropriate m-sequence pilots extracts the debledned CSGs for the four vibrators (left side of Figure 3). On these initial CSGs, we see artifacts resembling weak multiples of the direct arrivals as well as crosstalk noise. Both of these degrade the clarity of reflection events.

Crosstalk exists because the filtered m-sequence pilots are not perfectly orthogonal, and arises from the large-amplitude ground roll and direct arrivals produced by adjacent and nearby vibrators. In a four-vibrator array, crosstalk noise can be kept to manageable levels by limiting the spacing between adjacent vibrators to 100m or less. The right side of Figure 3 displays the debledned CSGs after simple processes to reduce the direct-arrival artifacts and to increase reflection amplitudes. Both processes involve localized slant stacking (equivalent to three-trace averaging along a range of slopes), and they work to improve the signal-to-noise ratios (SNRs) of the deeper weak reflections. Figure 4 gives details for both,

## Conclusion

We have conducted field tests confirming that multiple hydraulically-powered land vibrators can be operated simultaneously if controlled by quasi-orthogonal m-sequence pilots. Ordinary CSGs are extracted from blended field data recorded with simultaneous vibrators by crosscorrelation with the m-sequence pilots. They show weak artifacts and crosstalk noise that degrade the quality of reflections. Simple processes involving localized slant stacking are effective for increasing the SNR levels of weak reflections.



We conclude that efficiently conducting high-resolution 3D seismic surveys using up to four simultaneous vibrators controlled by filtered m-sequence pilots is possible without compromising the quality of reflections.

## Acknowledgements

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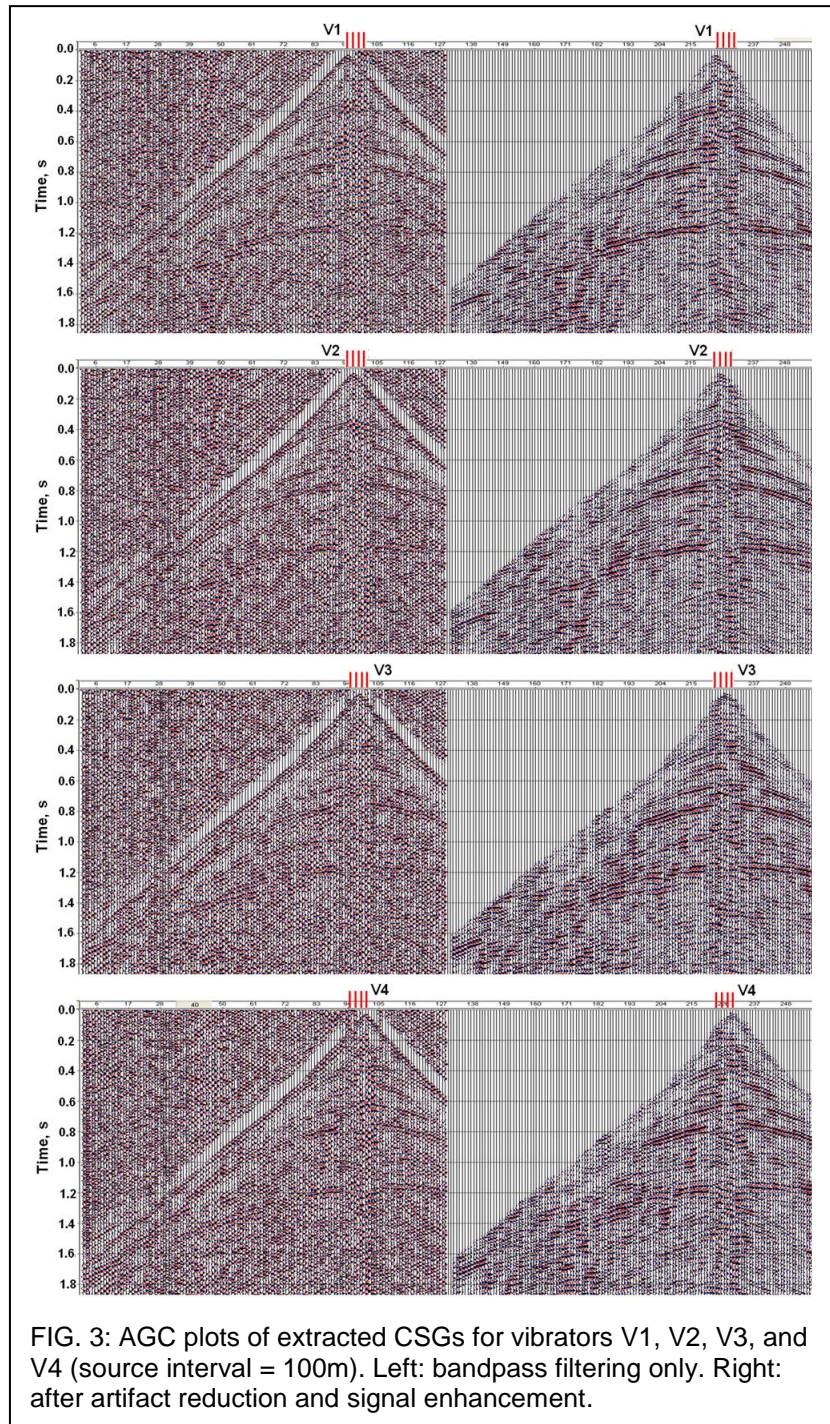


FIG. 3: AGC plots of extracted CSGs for vibrators V1, V2, V3, and V4 (source interval = 100m). Left: bandpass filtering only. Right: after artifact reduction and signal enhancement.



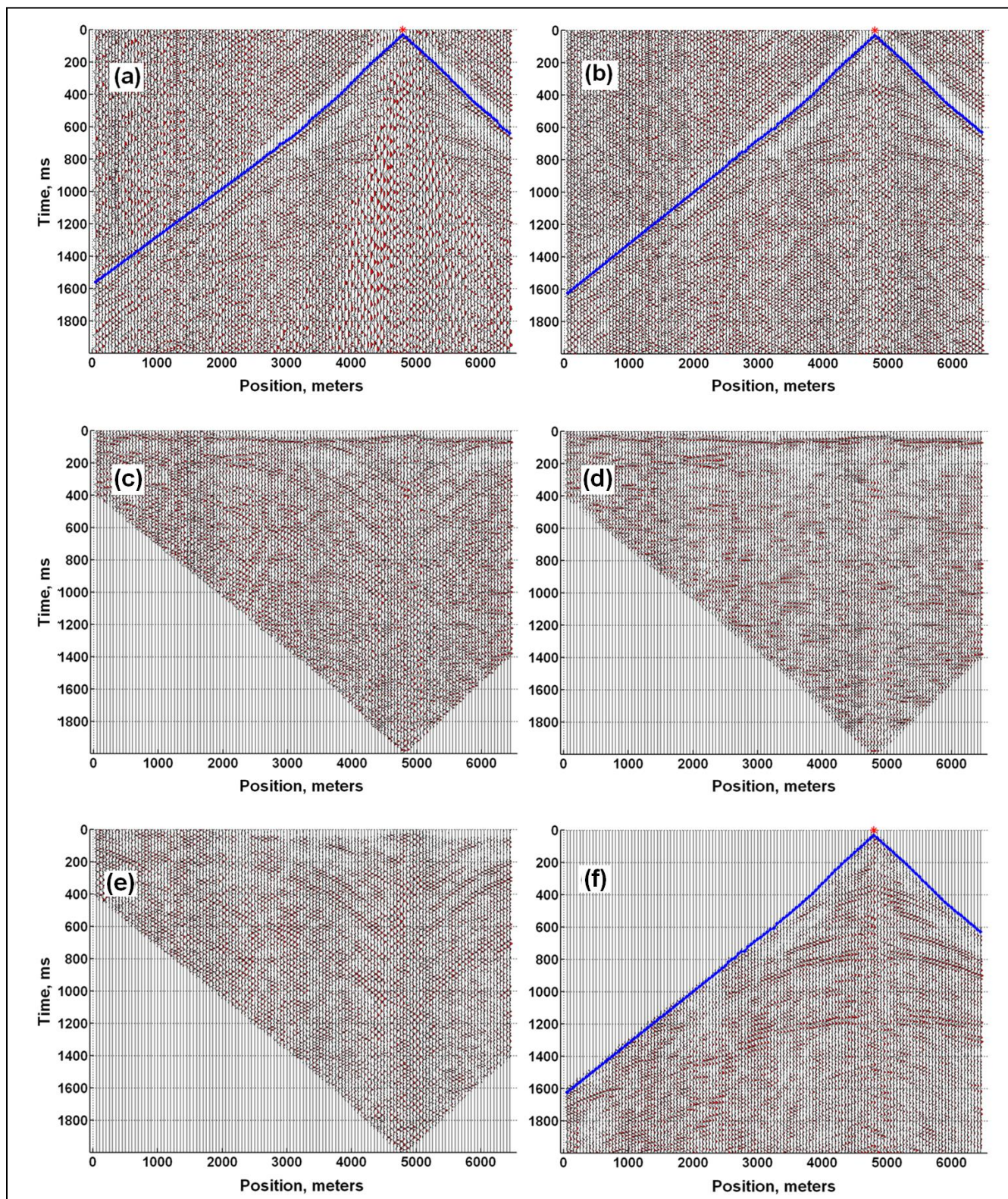


FIG. 4: (a) Unfiltered deblended CSG. (b) Deblended CSG after bandpass filtering; blue lines = accurate first-break time picks. (c) Filtered CSG after aligning to first-break times. (d) Direct-arrival artifacts estimated by a three-trace average of c. (e) The difference CSG = c - d. (f) Enhanced CSG after artifact reduction, alignment reversal, and three-trace average over a range of slopes (retaining the sum with maximum absolute value and its sign over this range). Compare f to b to see increased reflection SNRs after artifact reduction and localized slant stacking.