L-17 # 3D ACQUISITION FOOTPRINT REMOVAL

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Summary
Spatially periodic artifacts in stack volumes that correlate with the spatially periodic data acquisition geometry are well known. One of the methods to suppress such artifacts is to notch filter the spectral peaks on the frequency slices in the wavenumber transform domain. As long as the dip structure of the data is not complex this method is shown to work satisfactorily.

Introduction
Leakage of steeply dipping noise such as shot noise or multiple energy into stack volumes is well known. Figure 1 shows a portion of a CMP line from a deep water 3-D marine survey. Steeply dipping leakage caused by strong water bottom multiples is superimposed on gently dipping primary events. Such spatially periodic artifacts due to spatially periodic offset patterns can be considered "footprint." In the past field arrays in conjunction with CMP offset sampling, known as stack-array, was used to suppress such noise. The quest for high spatial resolution dictates small field arrays which, in turn, result in more noise leakage into the stack volumes. Of course, suppression of multiple energy before stack helps reduce such artifacts to a large degree. Figure 2 shows that interpolation alone can suppress such artifacts significantly. Here, F-K domain shot interpolation was used to produce missing offsets in each CMP (Gulunay and Chambers, 1998) showing that for this artifact interpolation minimized the problem. In addition to multiples, a variety of other offset-dependent phenomena were listed by Hill et al. (1999). However, even after careful preprocessing, some “footprint” is still left in the data. To minimize their effects Meunier and Belissent (1992) and Hampson (1994) proposed using deterministic filters that are derived from field geometry. Gulunay et al. (1994) suggested the use of data driven wavenumber domain notch filters on each frequency slice of data. An example of spatially periodic artifacts on land 3-D data is given in Figure 3. This stack volume was recorded with a zig-zag shooting pattern over an area of fairly flat structures. The sum of the wavenumber domain spectra for this 3-D volume is shown in Figure 4. The footprint manifest itself as small and organized local peaks (about 36 dB down with respect to the dominant zero dip event). Locations of such peaks can be determined from such a plot or can be picked automatically. Recently, Gulunay (1999) suggested a similar data driven method that is capable of handling dipping events as long as dip structure of the data is not complex. In this paper this improved technique is briefly described, practical aspects of the method are discussed and application to field data examples are given.

The method
The footprint model used by Gulunay (1999) assumes that it is spatially periodic both in amplitude and phase and can be modeled as convolution of the data with a modulated comb function. It is implicitly assumed that the spatial periodicity of the noise is not shared by the

underlying data. Since the wavenumber response of a comb function in space is also a comb function, each linear event in the time space domain is a suite of spikes in the frequency slices centered around each event. The amplitude of these spikes is dependent on the dips of the noise and the data and their frequency, yet their locations around each dominant event is the same. By allowing dip correction during spectral summation along frequencies, one can design a frequency independent notch filter from the data, and apply it, around each event in each frequency slice. During the filter design one can make use of thresholds for consistency of the peaks across frequencies, their amplitudes relative to the event and their ratio to their neighbors in each frequency slice so that spurious peaks are not picked. Of course, if the notch filter pattern can be estimated from the geometry, it can be applied in dip dependent fashion as well.

Data examples

Two data examples are presented in this paper. The first one is a 3-D migrated land data set. The acquisition geometry of the survey is shown in Figure 5. Horizontal lines are receiver lines and slanted vertical ones are shot lines. Figure 6 is a time slice (at 600 ms) from that volume. Diagonal striations are apparent, especially on the left side of the figure. These are due to the recording geometry shown in Figure 5. Receiver lines are 5-stations apart (10 CMPs) and shots are on a line perpendicular to the receiver lines, except that after every 5 shots they move to the right by two stations, leading to a slanted shot line pattern. The shot lines repeat laterally at 7-station intervals (14 CMPs). Figure 7 is the output of the acquisition geometry footprint suppression program. Figure 8 is the difference section showing the stripes taken out by the program.

Striping can occur with marine data as well. Figure 9 shows a time slice (2380ms) from a migrated deepwater multi-cable marine data volume. There is slight banding around the water bottom time. Figure 10 is the output from the Geometry Footprint Suppression program with which the patterns of spatial periodicity were detected and suppressed using small time and space gates. Figure 11 is the difference plot between input and output. Jitter at the water bottom and migration swings above the water bottom are suppressed by the process. Vertical sections (not shown here) show that although there are significant dips in the data there was no significant signal attenuation.

Conclusion

In this presentation, a brief review of Gulunay's (1999) acquisition footprint algorithm is provided. Recent experience with two new field data examples are discussed and suggest that the data driven Kx-Ky notch filtering method applied on each frequency slice, can be effective in reducing acquisition footprints. Because notch filtering suppresses noise as well as some small proportion of the underlying signal, the method requires close QC to make sure that coherent events are not attenuated by the algorithm.

Acknowledgement

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References

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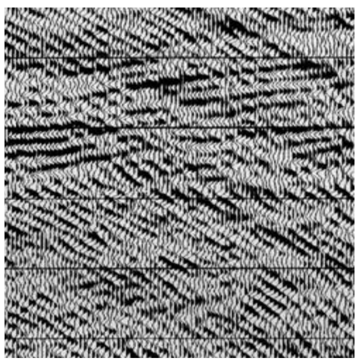

Figure 1 Stack of a CMP line from a deep water 3-D marine survey showing multiple interference. Time lines are 100ms apart.

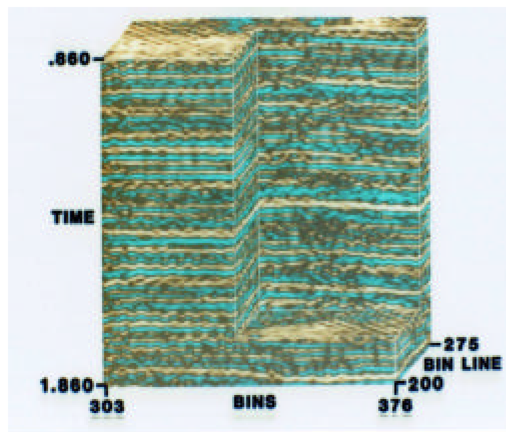

Figure 3 Stack Volume of a 3-D land survey recorded with a zig-zag shooting pattern.

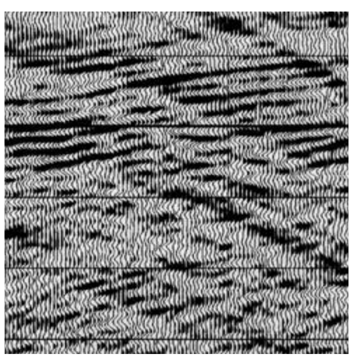

Figure 2 Stack after shot interpolation.

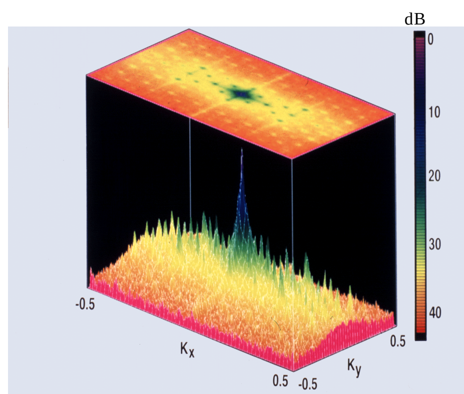

Figure 4 Kx-Ky spectra summed over frequencies.

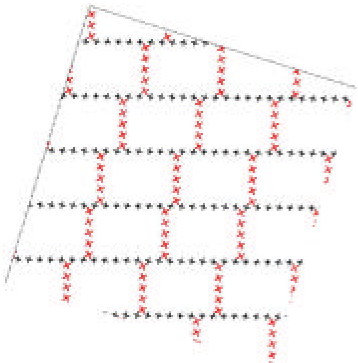

Figure 5 Acquisition geometry of the East Loving 3-D land survey.

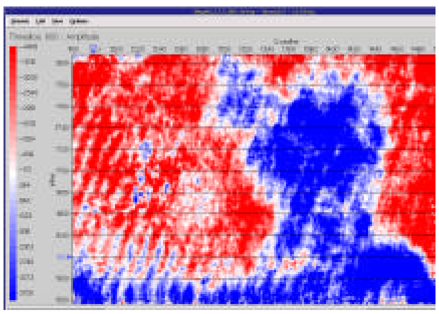

Figure 6 A time slice from the migrated stack.

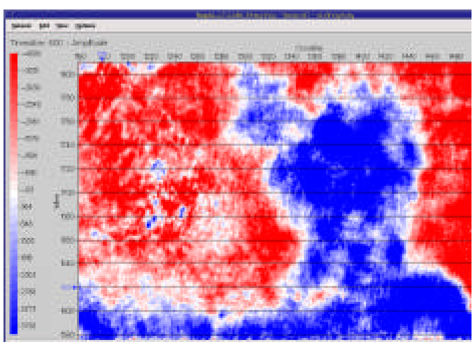

Figure 7 Same time slice as Figure 6 after footprint removal.

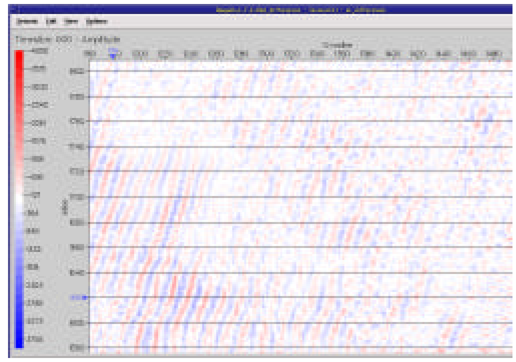

Figure 8 Removed footprint, from the time slice of Figure 6.

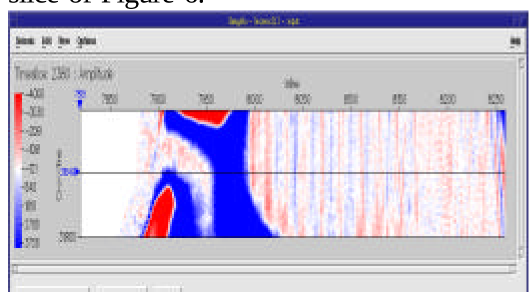

Figure 9 A time slice from a migrated stack volume of a Marine 3-D survey.

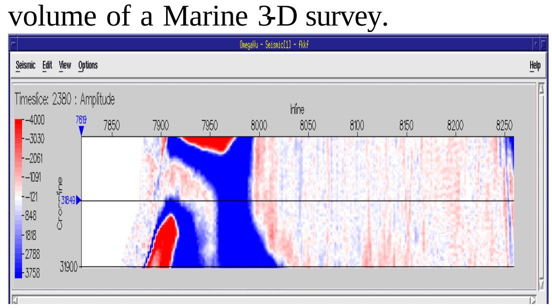

Figure 10 Same time slice as Figure 9 after footprint removal.

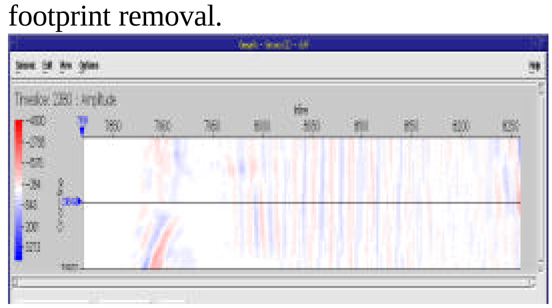

Figure 11 Footprint removed from the timeslice of Figure 9.