Seismic interference noise attenuation

Necati Gulunay, Mag Magesan, and, Simon Baldock, CGG Americas Inc.*

Summary

Attenuation of seismic interference noise that overpowers seismic reflections can be achieved by making use of well-known f-x prediction filters and the non-predictability of interfering noise from shot to shot.

Introduction

The presence of seismic interference (SI) noise originating from other marine seismic crews surveying the same area and the difficulties this creates for seismic crews is a well-known problem. For reflection times greater than a few seconds below the water bottom time this high-energy noise overrides weak reflections and is harmful to many pre-stack processes, among them, surface multiple prediction, pre-stack migration, and AVO analysis. Therefore, such high amplitude noise needs to be attenuated beforehand.

In general, zones of data that contain such noise must first be identified (detection) and then the noise must be attenuated; during this process, one must make sure that the underlying signal is not attenuated. Seismic interference noise, while very coherent in the common shot domain, is incoherent in the common offset or common receiver domains, especially when small time windows are used, provided the shooting times of the recording vessel and the interfering vessel are not synchronized. Since we have a well-established tool, f-x prediction filtering (PF), to attenuate incoherent noise it is natural to use it to attenuate SI noise.

Huaien et al (1989) used common offset and common receiver domain f-x prediction filters to attenuate SI noise in these domains in a cascaded fashion. We might refer to this technique as a crossline f-x prediction method, crossline being the direction from shot to shot. This method, like many others in our industry, assumes the seismic signal is predictable in these domains. Recently, Gulunay and Pattberg (2001a, b) used magnitude threshold guided detection of noisy shots in the frequency-shot-receiver (f-x-y) domain followed by prediction and subtraction of inline coherent SI noise with very short (1-point forward or, equivalently, 3-point forward-backward) f-x prediction filters. They followed this by an application of an f-x-y prediction filter to the frequency slice. More recently, Guo and Lin (2003) similarly used inline PF filters but investigated adaptive subtraction processes instead of straight subtraction. In the same meeting, Fookes et al (2003) suggested a method consisting of the following steps: estimation of the location of the noise source, flattening the noise using these coordinates, and application of f-k or tau-p filters to attenuate flat events. For continuous noise sources, such as the propellers of other ships, they suggest the use of arrival times before primaries so that pure noise is used for location estimation. Primary free noise zones at earlier times were also used by Dragoset (1995) in modeling ship propeller noise and an adaptive subtraction technique was used to subtract this noise at later times.

The Method

In the method used by Huaien et al (1989), strong amplitudes in the samples contaminated with SI noise are likely to bias the PF estimate, reducing the effectiveness of the filter to attenuate SI noise and/or preserve the underlying signal. The amplitude threshold method used in Gulunay and Pattberg (2001a,b), i.e., comparing the average shot magnitude to the average slice magnitude as well as the average of magnitudes of the neighboring shots, may get into trouble when there is a linear trend in average shot magnitudes. This trend can be eliminated if one looks at the noise output of the crossline prediction filters. This is the first stage in our method. From these samples common shot noise magnitudes are calculated and shots that contain noise above a certain percentage of the average noise in the slice are flagged. On each flagged shot, a 3-point forward-backward PF is designed and applied to predict and subtract the SI noise. The output of this process is then used as the input to a second crossline PF and the results of this stage are retained only for shots that contain SI noise.

More specifically, let a matrix **A**=(A(m,n)) represent the samples of input data for a particular frequency slice, where, as our frequency slices are formed in the frequency-shot-offset domain instead of frequency-shot-receiver domain, rows are common shots (m=1,2,…,M where M is the number of shots in the space window) and columns are common offsets (n=1,2,…,N where N is the number of offsets in the space window). A crossline PEF is then run on each column of **A** to give a result, say, **B**=(B(m,n)). Average magnitudes for each row in **B** and their average (which is the average magnitude in the slice) are then generated to determine which rows of **A** are noisy. If we suppose that row 2 is noisy then a short PF is applied to this row, (A_{21}, A_{22}, …,A_{2N}), to predict and subtract the noise, the result is **C**=(C_1, C_2, …, C_N). Then the second row of matrix **A** is replaced with the vector **C**. This matrix then becomes the input to a new set of crossline PFs, i.e., PFs are designed and applied at each column of this matrix. Let the result of this be **D**=(D(m,n)). Since we only want to attenuate SI noise we use only the second row of **D** and keep the other samples of **A** intact.

Field Data Examples

We have tested this method on quite a few sail lines from the Gulf of Mexico. An input gather from a line that was contaminated with SI noise is shown in Figure 1.

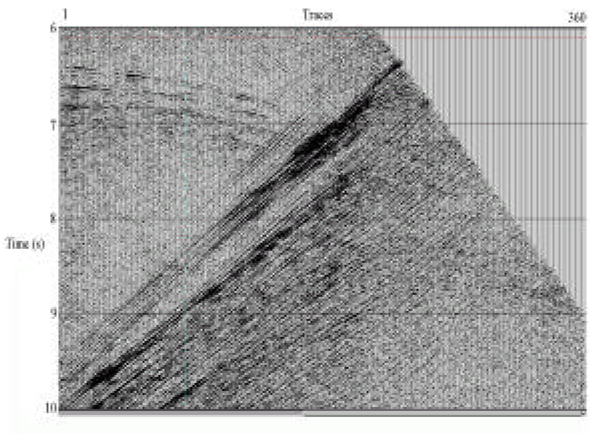

Figure 1: A shot with seismic interference noise.

The output of the process and the difference between input and output are given in Figures 2 and 3 respectively. At places where signal and high amplitude SI noise are present together, the process preserves signal while attenuating SI noise. Also, note the zero differences in windows where no data was flagged as noisy (upper left portion of Figure 3) demonstrating that the input was not altered.

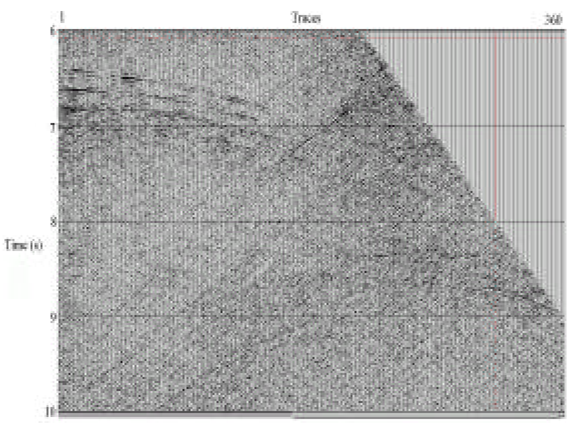

Figure 2: Same shot after seismic interference noise attenuation.

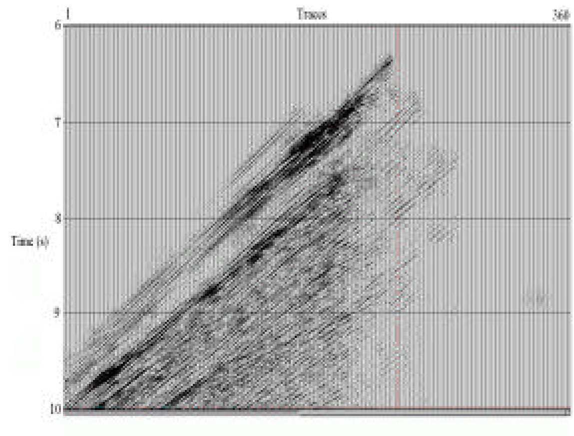

Figure 3: Seismic interference noise detected by the process.

Interference noise contaminates stack sections as well. Figure 4 shows the stack of seismic interference noise contaminated shots from another line in the Gulf of Mexico. Interference noise is clearly visible. Figure 5 is the stack of the seismic interference noise reduced shots. Figure 6 is the difference between Figures 4 and 5 which shows that seismic interference noise leakage to stack was significant and that it was detected and suppressed by the process.

Conclusions

We have presented a frequency-shot-offset (f-x-y) domain method that combines inline and crossline f-x prediction filters in detecting and attenuating strong seismic interference noise. The method is particularly suited to application at later times on the seismic record where the interfering noise has much higher amplitudes than the underlying reflections. After this process, noise residues are reduced to levels where they can be expected to pose no further problems to most pre-stack processes.

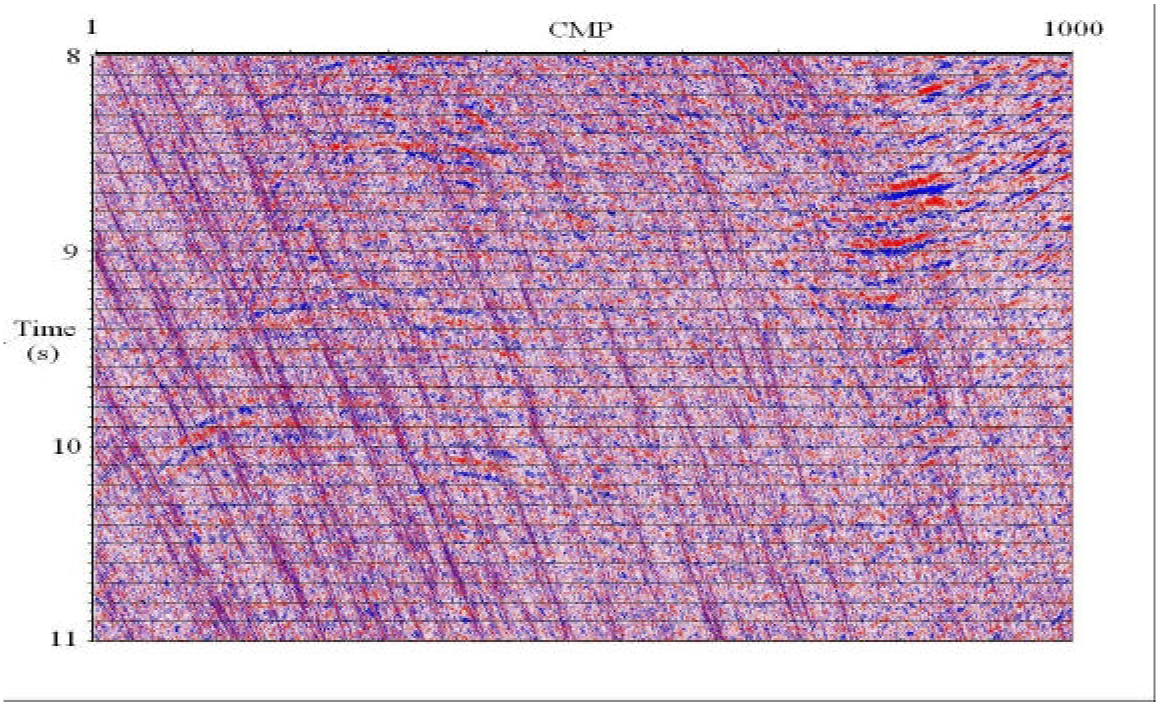

Figure 4: Stack of noisy shots.

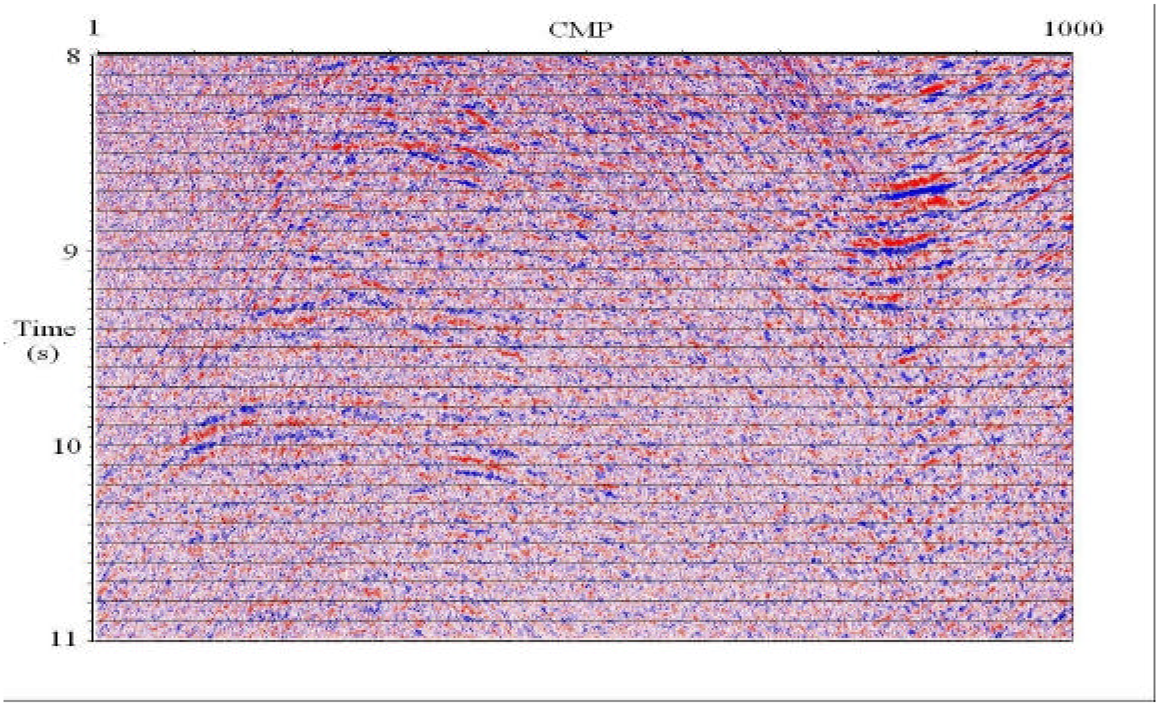

Figure 5: Stack of seismic interference noise attenuated shots.

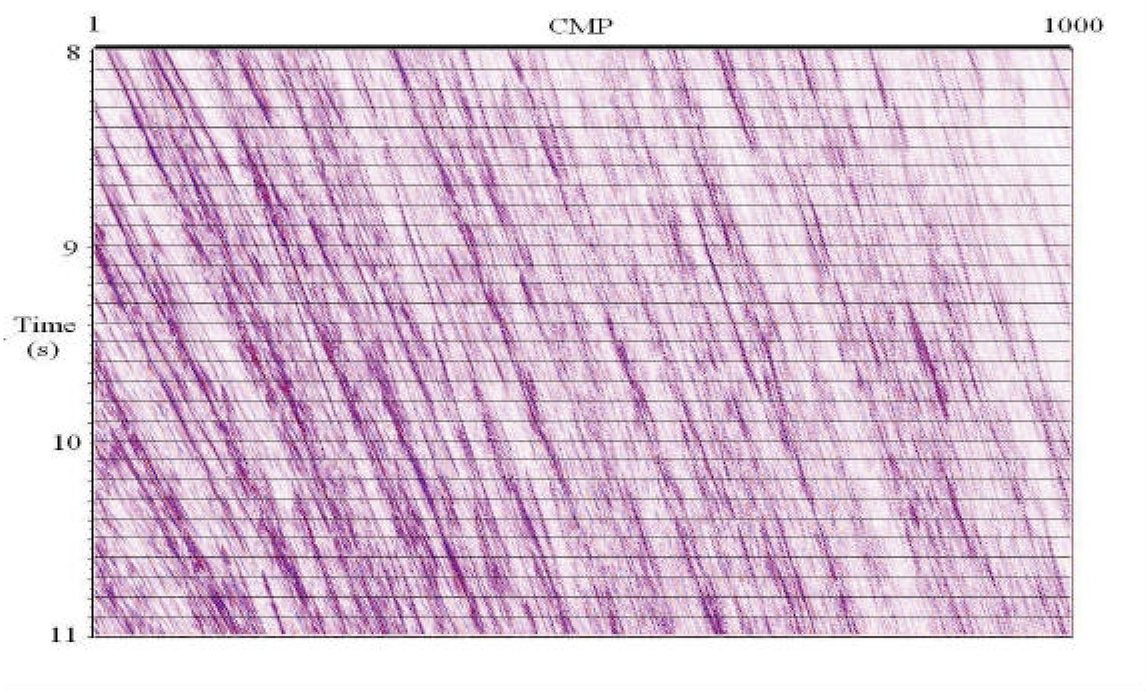

Figure 6: The difference between stack of noisy shots and stack of seismic interference noise attenuated shots.

References

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Acknowledgments

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