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Seismic Processing – Noise Attenuation Techniques For Relative Amplitude Processing

As E&P companies utilize a variety of methods to try and understand their reservoirs and maximize the recovery of hydrocarbons, the treatment of seismic data becomes critically important. Many factors influence the reliability of the seismic data to initially ensure drilling success and later to provide a better understanding of the reservoir characteristics. Adequate and proper noise attenuation methods help to maximize the potential benefit and contribution of the seismic data in exploration and development.

The perfect acquisition environment only exists in a synthetic model. In reality, we are faced with many sources of noise in marine, Ocean Bottom Cable (OBC), or land acquisition. One of the key components of seismic processing is determining which part of the recorded energy is noise and removing it from the data.

Why is noise attenuation important?

1- Very simply, removal of the noise allows for all other signal processes to work more effectively. Deterministic processes, such as deriving surface consistent amplitude corrections or deconvolution operators, rely heavily on the quality of the input data. Many summation processes related specifically to dual sensor OBC processing require calibration of the amplitude levels of each component for successful summation. This calibration cannot be correct in the presence of excessive noise.

2- Removal of the noise is a key component in preparing the data for pre-stack imaging. Common Depth Point (CDP) stack is obviously one of the most effective noise attenuation tools but not an option with pre-stack imaging. The noise must be addressed prior to imaging.

3- Properly addressing the noise provides the opportunity to track amplitude anomalies and stratagraphic objectives with confidence.

4- Effective noise removal, which preserves the original amplitude and phase characteristics of the data, provides the opportunity for advanced attribute work and inversion to better understand the reservoir.

Noise Analysis and Classification

The first step in noise attenuation is to analyze the seismic data to determine the sources of the noise and the noise characteristics. Regardless of the source of the noise, the characteristics generally fall into two categories:

1- Coherent noise – which can typically be modeled and subtracted from the data. Ground roll, strum noise, multiples, and even power-line noise would meet these criteria.

2- Random noise – which is any noise spikes or bursts which are not coherent in nature. This type of noise is addressed by isolating it as having different characteristics from the surrounding data in frequency and amplitude.

More important than identifying the specific source of the noise, is understanding its characteristics. In other words, how can it be measured?

Power-line noise is a class of noise often encountered in land acquisition in populated areas. It produces a characteristic 50 or 60 HZ sinusoidal noise on traces that can be measured. Its amplitude is relatively constant with recorded time, whereas the seismic data amplitudes decay with time. Notch filters were used in the past to attenuate this type of noise and were often applied in the recording of the data. The notch filter would attenuate all recorded data at a given frequency, not just the unwanted power-line noise. ION GX Technology's monochromatic filter provides an alternative that retains the primary signal. This tool derives a model sinusoid of some fixed frequency and adaptively determines both its amplitude and

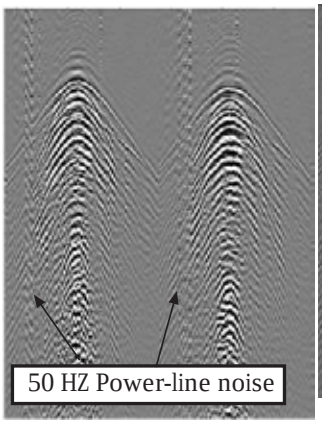

Figure 1 – shot record with 50 HZ power-line noise

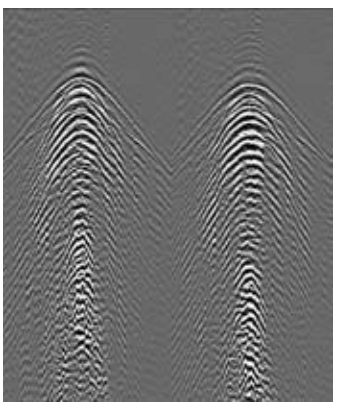
Figure 2 – shot record after monochromatic filter attenuating power-line noise

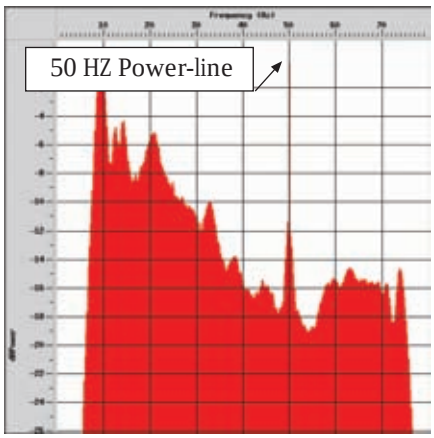

Figure 3 – Spectral analysis of shot record from figure 1

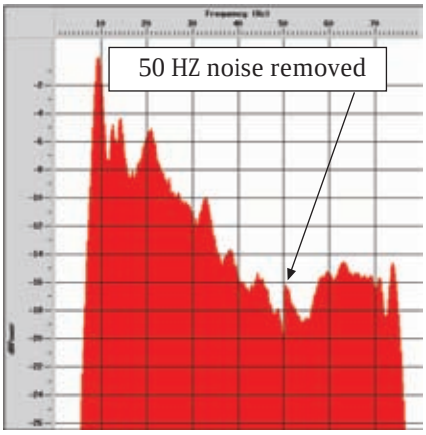

Figure 4 - Spectral analysis of shot record from figure 2 after application of monochromatic filter

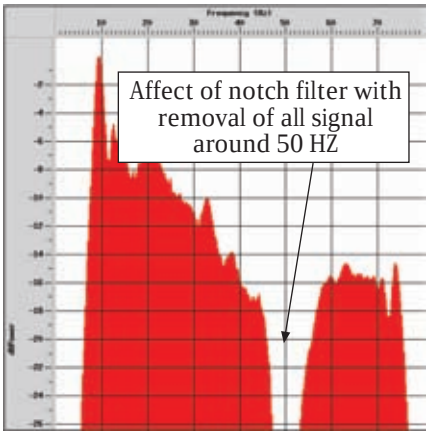

Figure 5 – Notch filter application

phase to remove both the primary occurrence and its harmonics, if applicable. This provides near exclusive attenuation of the 50 HZ noise without compromising any 50 HZ signal as would a notch filter. Figures 1-2 show examples of two cables of a land shot from Egypt before and after removal of the powerline noise with a monochromatic filter. Figures 3-5 show the spectral analysis before and after application of the monochromatic filter compared to a notch filter application.

Coherent noise such as ground roll can be measured at a specific velocity or suite of velocities. The noise can then be removed from the data based on velocity. Historically, F-K filters were used for this type of noise removal, but the F-K filter makes certain assumptions that are not necessarily appropriate for 3D data. Also, the F-K filter can produce artifacts which reduce the reliability of seismic attributes. An F-K filter assumes equal distance between input traces. This assumption is inappropriate for orthogonal land shooting geometries.

GXT's radial filter, Radfilt, uses the actual offset of each trace and maps the data to the radial domain (apparent velocity versus time), where the energy of a given velocity maps to a single trace. In this domain, the noise is typically represented by a very low frequency trend and is filtered out and transformed back to x-t domain. Unlike an F-K filter, which assumes equal distance between input traces, the radial filter uses the actual offset of each trace and is perfectly compatible with 3D geometries, including typical orthogonal land geometries.

Figures 6-8 show a land 3D shot record from Egypt before and after coherent noise attenuation using a radial filter and the noise removed.

Random noise bursts and spikes must also be addressed in processing seismic data at an early stage. GXT has many algorithms for handling this noise effectively. GXT's SWDnoise is a very effective tool for random noise attenuation in marine, OBC, or land acquisition environments. This process works in the frequency domain within an ensemble in overlapping time and space windows to scale down noise within a given frequency band. The type of ensemble, whether shot, receiver, CMP, etc., is determined by which domain will best randomize the noise. Typically the process is run in narrow frequency bands, such as 2 hertz bands. If amplitudes exceed a given threshold above the median value within the window for that frequency band, it is scaled down to the median value. This process can be run in multiple domains to attenuate various types of noise. Thresholds and spatial windows can vary with time to optimize the noise attenuation. Because the process works in narrow frequency bands, it is a very conservative method for attenuation and will maintain the original amplitude characteristics of the signal.

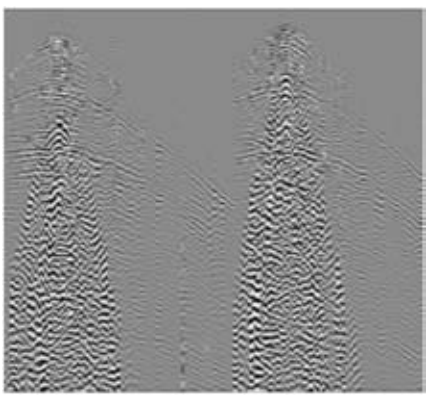

Figure 6- 2 cables of a raw 3D shot record

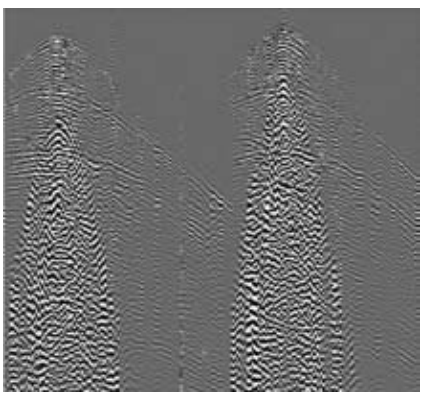

Figure 7 - 2 cables of a 3D shot record after radial filter for coherent noise removal

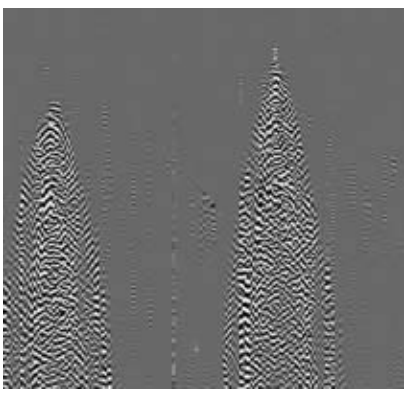

Figure 8 – Noise removed by radial filter

After each pass of noise attenuation, data should be analyzed to ensure no primary signal is attenuated in the process. Below are examples of a land 3D dataset from Egypt that show relative amplitude stacks with no noise attenuation, all pre-deconvolution noise attenuation applied, and the difference between the two sections. Significant noise has been removed from this dataset prior to surface consistent amplitude and deconvolution computation so these signal processes will work optimally.

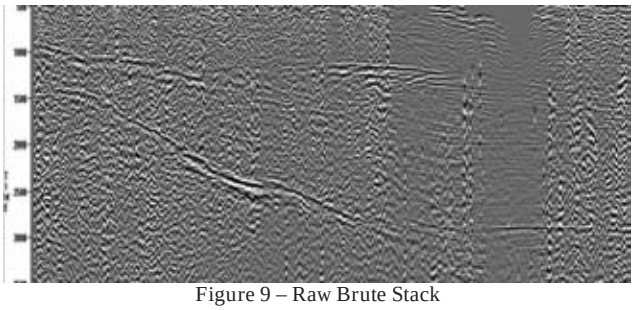

Figure 9 – Raw Brute Stack

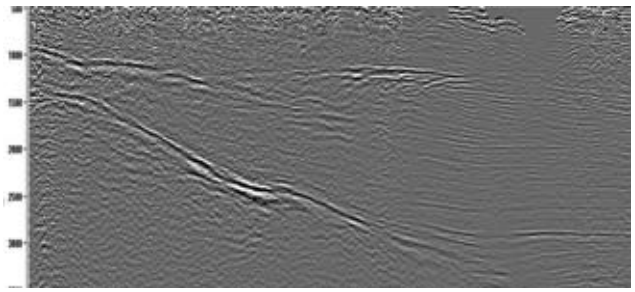

Figure 10 - Noise Attenuated Brute Stack

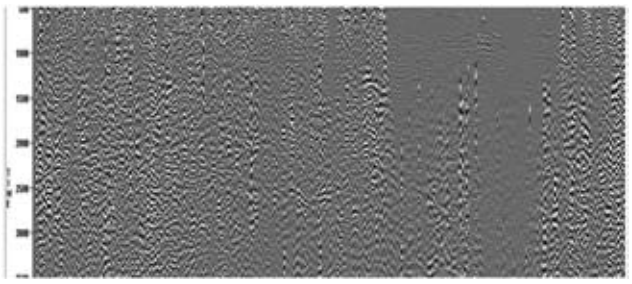

Figure 11 - Noise Removed Stack

Benefits of Proper Noise Attenuation

A critical goal for pre-processing of seismic data in many environments is to minimize all artifacts that are not part of the seismic signal, such as noise, including multiples, acquisition irregularities, and navigational errors. Many geographical areas where the primary targets were originally structural plays are now being re-evaluated. Secondary targets or potential targets are being observed that have stratigraphic or amplitude characteristics that require special consideration in processing.

In these areas, proper noise attenuation that maintains the amplitude and phase characteristics of the primary signal is key. It affords E&P companies the opportunity to extract the maximum benefit of seismic data in meeting their exploration and development targets by providing quality data for pre-stack imaging techniques, and appropriate data for such reservoir characterization techniques as rock properties, attribute analysis and inversion. The net effect is increasing the level of confidence with which drilling decisions are made.