Summary

Conventional marine seismic data are acquired using hard-wired groups of receivers. In this approach the output of the different hydrophones in the group is simply summed, with no preprocessing being applied. In contrast, point receiver acquisition allows the use of adaptive filters to attenuate coherent noise provided that the noise wavefield is adequately sampled. An example is the removal of swell noise, which is a major cause of downtime during marine operations. Swell noise has a significant low frequency content and can be attenuated using adaptive filters to give data more suitable for inversion than obtained using low cut filters. The ability of adaptive filtering of point receiver data to attenuate coherent noise without damaging the signal will be quantified by superimposing “noise only” data acquired during point receiver acquisition on both synthetic seismic data and real seismic data acquired under conditions of low noise. Point receiver recording can deliver high quality seismic data with a reduction in coherent noise when compared to data acquired with hard-wired groups. This will reduce the financial risk associated with advanced seismic processing for fluid/lithology discrimination and the imaging of saturation and pressure changes using time-lapse seismic data.

Introduction

The need to use seismic data for the predrill determination of reservoir lithology and fluid content, as well as the use of time-lapse seismic data to image saturation and pressure changes due to production, requires high quality prestack seismic data. Conventionally, marine seismic data are acquired using hard-wired groups of receivers. In this approach the output of the different hydrophones in the group is simply summed, with no preprocessing being applied. Hard-wired conventional groups act as wavenumber domain filters, and are independent of frequency and time. Errors in the position and sensitivity of the individual receivers will degrade the output of hard-wired groups (Newman and Mahoney, 1973; Ongkiehong and Huizer, 1987; Martin et al., 2000) and, if uncorrected, will introduce pseudo-random “noise behind the signal” upon array forming. Also, the amplitude of swell noise changes significantly within a single record and from record to record. Hard-wired groups are unable to adapt to such a changing noise pattern. In contrast, point receiver acquisition allows the use of adaptive filters to attenuate coherent noise provided that the noise wavefield is adequately sampled. In the presentation, the ability of adaptive filtering of point receiver data to attenuate coherent noise without damaging the signal will be quantified by superimposing “noise only” gatherings acquired during point receiver acquisition on both synthetic seismic data and real seismic data acquired under conditions of low noise and examining the difference between the seismic data and the data+noise after adaptive filtering. A particularly important type of coherent noise present in marine seismic data is swell noise which is a major cause of downtime during marine operations. Attenuation of swell noise is important for inversion since swell noise has a significant low frequency content which is conventionally attenuated using techniques which impose low cut filters. The ability of data adaptive filters to attenuate this low frequency noise without the need for low cut filters will improve the dynamic range of the signal (Martin et al., 2000) and increase the reliability of results from inversion.

Coherent Noise Attenuation

Özbek (2000) has recently introduced two classes of data adaptive signal processing techniques to attenuate coherent noise in seismic data. These multichannel methods were designed to attenuate dispersive and nonstationary coherent noise in the presence of amplitude and phase perturbations. In the following, the method called LACONA (Özbek, 2000) is used. LACONA is a linearly constrained adaptive beamformer, implemented as a multi-channel adaptive filter bank. The objective is to preserve signal from a range of target directions, while suppressing interferences from other directions. LACONA can be thought of as an adaptive f-k filter that is adaptive in those parts of the frequency-wavenumber space that contain noise, but fixed in the regions of the f-k space that contain signal to be preserved (Özbek, 2000).

Point Receiver Acquisition

Swell noise on conventional data acquired using hard-wired groups generally shows little coherence along the streamer. This is why previous methods for swell noise attenuation after grouping have treated the swell noise as spatially impulsive noise, by blanking out the worst affected portions of the data and interpolating. Analysis of data recorded using point receiver acquisition has shown that swell noise is actually coherent over short distances along the streamer. To exploit this property, processing has to be carried out before group forming. Point receiver data were acquired in the Gulf of Mexico to investigate the potential of point receiver acquisition for coherent noise removal.

Fig. 1 shows typical “noise only” data acquired during this test before and after application of digital group forming.
Digital group forming (DGF) combines LACONA applied over a range of low frequencies and a K filter applied over the higher frequencies. Spatial subsampling of the data may be done after DGF.

Figure 1. (left) “Noise only” data acquired during point receiver acquisition. (right) Result after application of DGF.

Figure 2 shows a close-up of Figure 1, while Figure 3 shows a plot of the root mean square amplitude in a window from 7 to 8 seconds before and after application of DGF. Figures 4 and 5 show the result of applying DGF to a data record.

Figure 2. Close-up of Figure 1.

Figure 4. Data record before and after application of DGF. Data are gained using a ‘t-squared’ function.

Figure 5. Window of data from the record in Figure 4. (left) Data have been processed with a K filter emulating the array effect of a typical hydrophone group and then sub-sampled to 12.5 m interval. (right) Data after DGF and sub-sampling to 12.5 m interval.

In the presentation, the effect of the data adaptive filter on the signal will be quantified by superimposing “noise only” gathers acquired during point receiver acquisition on both synthetic seismic data and real seismic data acquired under conditions of low noise and examining the difference between the seismic data and the data+noise after adaptive filtering.

Conclusion

Conventional hard-wired groups act as wavenumber domain filters, and are independent of frequency and time. Errors in the position and sensitivity of the individual receivers will degrade the output of hard-wired groups.
Signal Preserving Swell Noise Removal

(Newman and Mahoney, 1973; Ongkiehong and Huizer, 1987; Martin et al., 2000) and, if uncorrected, will introduce pseudo-random “noise behind the signal” upon array forming. In the presentation, the ability of data adaptive signal processing methods, recently introduced by Özbek (2000) to attenuate coherent noise in marine seismic data while leaving the signal undamaged, will be quantified by superimposing “noise only” gathers acquired during point receiver acquisition on both synthetic seismic data and real seismic data acquired under conditions of low noise and examining the difference between the seismic data and the data+noise after adaptive filtering. The ability of point receiver recording to deliver high quality seismic data in which coherent noise is much attenuated when compared to data acquired with hard-wired groups will reduce the financial risk associated with advanced seismic processing for fluid/lithology discrimination and the imaging of saturation and pressure changes using time-lapse seismic data.

References


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