Processing of Variable Depth Streamer Data with Examples from APAC

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Variable-depth streamer acquisition is a technique for providing broadband seismic data. It has been proven to produce high-quality images with better seismic resolution, stratigraphic detail and low-frequency penetration.

In conventional flat streamer acquisition, the water surface receiver ghost cancels or degrades the signal at some frequencies, resulting steep notches in amplitude-frequency spectrum at low as well as high frequency. By varying the receiver depth, variable-depth streamer acquisition introduces receiver ghost notch diversity over different offsets. Making use of the notch diversity, Soubaras (2010) developed a method for post migration deghosting. In this method, normal and mirror migrations are performed, and the two outputs are fed into a joint deconvolution process to form a broadband image. Very good results have been produced on the broadband data acquired in the basins worldwide using this workflow. Figure 1 shows an example from the South China Sea (Zhang et al. 2013). The broadband image shows structural details and stratigraphic layers with great resolution. With this method, in order to remove the ghost effectively and correctly post migration, the ghost must be protected during the pre-processing. Also the demultiple work-flow differs from the one for conventional data.

Receiver deghosting can also be done at pre-migration stage, using a bootstrap method (Wang & Peng, 2012; Wang, et al. 2013). The method is adaptive and does not require exact value of streamer depth. Figure 2 shows a shot gather before and after deghosting. The FX plot indicates very high quality deghosting. Pre-migration deghosting makes processing flow simpler and closer to conventional data workflow. Re-datuming can be achieved during the pre-migration deghosting to reference the data to water surface or any cable depth, which facilitates many applications, such as merging with flat streamer data and time-lapse processing with legacy conventional data as baseline. The pre-migration deghost method can be applied for both source and cable deghosting.

Receiver ghost is not the only limiting factor to bandwidth at acquisition stage. Water surface reflection also causes ghost on source side. A synchronized multi-level source has been designed to address this. The source guns are fired in such a way that the primary impulse is synchronized and the ghost reflection is defused, thus producing a source wavelet without a sharp ghost, and a notch-free spectrum. Designature for this broadband source requires a far-field source signature. The far-field source signature can be derived using Near Field Hydrophone (NFH) data, which is found to work better than other methods, such as modeling on the base of gun-array configuration, and extraction from seismic data (Poole, et al. 2013).

The broadband source allows the recording of very high frequency data, and produce very high resolution seismic image, broadening the spectrum further, up to over 200Hz at the high frequency end. Figure 3 is a broadband seismic image offshore India which was acquired with variable depth streamer and broadband source. It clearly shows very high resolution, a broad bandwidth (2 to above 200Hz) and remarkable low frequency penetration.

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Reference

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Figure 1 An example of post-migration deghosting. Variable-depth streamer data (right) shows better top of basement, better fault planes, clear indication of stratigraphic unit, and intrabasement reflections.

Figure 2 A shot gather before and after receiver deghosting. FX Plot gives a more global view of the quality of deghosting than amplitude spectra. In the FX plot, horizontal axis is frequency, vertical axis is channel number and the colour represents amplitude.

Figure 3 A seismic section imaged with variable depth streamer and broadband source, offshore India. The maximum frequency is above 200Hz.