Ghost-free Imaging: Synchronized Multi-level Source & Variable-depth Streamer Acquisition

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Presentation Outline

Variable-depth streamer acquisition is a key solution for broadband marine seismic allowing for a drastic increase in the available frequency bandwidth, in both the low and high ends of the frequency spectrum, from 2.5 Hz to the source ghost notch. During acquisition, the direct and ghost arrivals at the receiver side creates a well-known interference pattern, which includes the receiver ghost notch, where frequency loss at the notch frequency depends directly on the receiver depths. As a consequence of this, a clear strong notch will always occur with a conventional flat-streamer acquisition. On the contrary, varying the receiver depths along a streamer allows recording a wide diversity of receiver ghosts or notches. Additionally, the sea-state noise level decreases as the cable is towed deeper: this technique thus benefits from towing solid streamers at what is generally considered as extreme depths (up to 50 meters), which allows recording superior signals to noise ratio at low frequencies. Rather than using a linear increase in streamer depth with offset (original slant streamer geometry), a custom profile is designed in order to provide the optimum receiver ghost diversity, particularly for shallow events, and can be tuned to provide the maximum possible bandwidth for a given geological setting and water depth.

This receiver-side technique is still limited by the source notch imposed by a one-level conventional source. This leads to a complementary solution to the variable-depth streamer method, where a similar model can be applied on the source-side, by deploying guns at more than one depth. With variable gun depth geometry arranged within the three sub-arrays at an optimised configuration, gun timings are then synchronised such that, the deeper guns fire when the down-going wave-front (generated by the slightly earlier firing of the shallow guns) reaches them, creating a single synchronized down-going wave-front. The consequence of this is that the resulting source ghost is defocussed, by filling the source notch at frequency domain. The notchless far-field of the source allows a full recovering of the bandwidth through the designature of acquired seismic data. Moreover the optimized spatial distribution of airguns allows well-balanced directivity of generated wavefield for all frequencies. Such a multi-level source generates similar low frequencies as a conventional source, while extending the spectrum to higher frequencies as far as 200 Hz, the current upper limit imposed by the 2 ms anti-alias filter. Thanks to an accurate designature process, the recorded data can be processed with the flow already developed for variable-depth streamer data.

A synchronized multi-level source combined with variable-depth streamer has been successfully tested and applied in various 2D and 3D cases, in both shallow and deep water environments, with real data examples from some of these acquisitions given in the presentation slides.

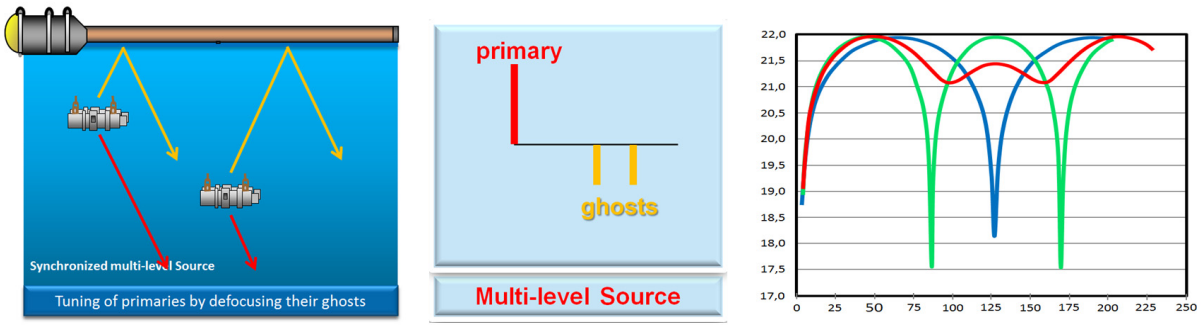

Figure 1 *Schematic multi-level source with synchronized gun timing (left). Theoretical sources signatures (right) generated by* ***a conventional source at 6m****,* ***a conventional source at 9m*** *and* ***a synchronized multi-level source****.*

This compact broadband source can be deployed in the same way as any conventional source, compatible with dual-source, WAZ or 4D acquisitions.

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