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array. In this situation a tuned array is acceptable, but what happens when these arrays are used with bottom-referenced receivers? The asymmetry of the tapered, tuned array results in an asymmetric distribution of energy and significant variation of phase and amplitude with azimuth, thus introducing wavelet differences into a bottom-collected dataset based on sail-line direction alone. With the increasing interest in repeat 3-D surveys for reservoir monitoring where the primary focus of the experiment is to minimize known differences in recording equipment and technique to enhance the visibility of subtle differences in the reservoir, this symmetry offers important improvements over conventional arrays.

## Features

The symmetry of the TriCluster™ array generates an output wavelet with a broad frequency spectrum that is identical for any pair of reciprocal azimuths, thus removing the immediate differences introduced to a dataset by a conventional tapered array. The symmetry of the array also generates an output wavelet that is the same for port or starboard evaluation at the same azimuth to the boat direction in a towed situation.

The multi-plane arrangement of the guns in the TriCluster™ array and the sequential firing of the gun planes yield a system with additional signature improvement over conventional towed source arrays. Firing the planes in sequence, the upper plane followed by the lower planes synchronized with the down-going wavefront, enables constructive interference of the down-going wavefront while the delay between the up-going wavefronts reduces the severity of the ghost notch, enabling a flatter, broader output spectrum. Firing times for the different levels can be adjusted to maximize the energy in the desired frequency range for the output far field wavelet. The proximity of the four guns in the center cluster further improves the array output through bubble interaction that reduces unwanted bubble noise.

In addition to the symmetry issues, the TriCluster™ gun suspension system offers additional signature repeatability and stability. Compared with a conventionally suspended airgun, where individual guns are free to swing and jump while towing and/or firing, the TriCluster™ system maintains proper gun positions with sprung shock mounts, enabling consistent and repeatable bubble interaction and hence consistent and repeatable array output. An added benefit of the suspension system is that it prevents collision of adjacent guns, and collision of guns and suspension equipment, thus extending the life of guns, hoses and control electronics. The rigidity of the TriCluster™ also removes any limiting minimum tow speed to maintain array characteristics. The removal of boat speed limitations from shotpoint intervals; means that TriCluster™ may be used as a static array for applications such as VSP shooting, where the source is suspended from a fixed point.