Marine Vibrators: Seismic Data Processing Implications Of New Survey Designs


Abstract

Objectives/Scope: Marine seismic vibrators are considered serious contenders to airgun arrays and are attractive as environmentally friendly sources for seismic exploration. Substantial research and development for a new marine vibrator system are ongoing (Gerez et al. 2021), both on the equipment and data processing fronts. This paper reviews the latest developments of marine vibrator data processing technologies.

Methods, Procedures, Process: The high-precision signal control that marine vibrators achieve allows for novel strategies in survey design. An array of vibrators will typically entail several projector units deployed at different depths, each active in a frequency band that maximises constructive source ghost interference and minimises rough-sea effects. The use of diverse frequency bands and phase encoding allows for numerous projector units to be simultaneously and continuously active. The sweep length of each frequency band determines the source effort, and low frequencies will typically have longer sweep lengths than higher frequencies. Sweeps can be designed to achieve a desired signal-to-noise-ratio (SNR).

Results, Observations, Conclusions: Marine vibrators offer a range of exciting survey design and data processing opportunities. Several units can be simultaneously active, with de-blending taking place at the processing stage. It is also possible to operate a pair of projector units alternatively in phase and anti-phase, therefore generating both omni-directional and gradient sweeps that provide additional constraints for the interpolation of source lines. The processing challenges associated with these novel designs are the estimation of the sweep signature, the compensation of source motion and rough sea effects, sweep deconvolution and de-ghosting, and the de-blending of signals from several phase-encoded sources. Sparse inversion of all acquisition effects is feasible. Sparse inversion can reshape marine vibrator data to impulsive-source data with equivalent SNR, as shown in Figure 1. The interplay between the various acquisition effects calls for a joint inversion with sparsity constraints. The continuous sound emissions and differential deployment depths and sweep lengths for differing frequency bands stabilize this inverse problem. Phase rotations can be used to shift signals in the wavenumber-frequency (f-k) domain, therefore facilitating their de-blending.
**Novel/Additive Information:** Data processing technologies for marine vibrators are in rapid development and are taking place in close association with the engineering of new equipment. This paper presents the latest developments on the processing front by demonstrating them on synthetic data simulated for a multi-vibrator source array.

![Figure 1](image) Synthetic common-receiver gather generated using the SEAM phase 1 model at 25m sweep spacing and frequency range of 3-150Hz. a) raw marine vibrator data using an array of two high-band units and one low-band unit including phase encoding, source ghost, source motion effect and alternative omnidirectional and gradient sources. b) data after phase and sweep deconvolution, and c) data after processing i.e., removal of ghost and source-motion effects. Wavenumbers are normalized, scaled by the sweep spacing.