

# MARINE VIBRATOR CONCEPTS FOR MODERN SEISMIC CHALLENGES

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Aside from fundamental issues of mechanical durability and efficiency, the design of marine vibrators for towed streamer operations are confronted by several very different possible applications: 1. High power alternatives to conventional air gun arrays for flexible and creative acquisition geometries, 2. Low power alternatives to air gun arrays for environmentally sensitive applications, and 3. High power, ultra-low frequency sources specific to Full Waveform Inversion (FWI) optimization.

One relevant consideration is the volume of water that must be displaced per cycle to achieve a desired Sound Pressure Level (SPL); increasing exponentially as the frequency of interest decreases, and becoming significant at frequencies less than about 5 Hz. This becomes particularly relevant for FWI optimization as the frequencies of interest are in the range of 1-6 Hz. Another consideration is that ultra-low frequency output theoretically benefits from deeper towing, enhanced by the well-known free-surface ghost effect, but in practice deeper towing is confronted by an air spring effect that increases the force required per cycle to generate a desired SPL, and is due to the surrounding hydrostatic pressure at depth. Other authors have published the design of an extremely large volume vibrator unit that is towed at about 60-120 m as a solution to the air spring effect. However, completely alternative vibrator concepts can be described that either use an array of units with high power drivers or that distribute the water displacement over a large surface area in a creatively efficient manner.

Environmental motivations to develop low power vibrator concepts are driven by regulatory restrictions upon received SPL, Sound Exposure Level (SEL), and cumulative SEL (SEL<sub>cum</sub>). We describe the design and application of several very different marine vibrator concepts for the three defined applications, and present results from both controlled testing and real data acquisition that illustrate various challenges and their industrial solutions.