Harmony

deeper possibilities

Harmony is a new source from Shearwater with enhanced low-frequencies. It consists of modified airguns tuned for bubble frequency locking of the pressure wavefield (Hopperstad et al., US patent 9360578), with a resultant shift of half to one octave of the dominant frequency, depending on the reference source design.

Harmony uses the position of one standard sub-array and so is operationally very flexible. It can be used in multi-source designs or combined with itself to increase output, or in conjunction with traditional sub-arrays to create a desired output frequency spectrum, tuned for the survey objectives.

Low Frequency Source

The enhanced low-frequency content of Harmony improves the wavelet resolving power. This has a positive impact on reservoir characterization and full-waveform inversion, leading to a better understanding of the sub-surface.

Operationally Flexible

Range of Applications

It is well known that highly non-linear data inversion processes can be unstable when reliable low frequency information is missing. This problem is known as cycle skipping, and often imposes complex pre-processing and the imposition of a-priori geological constraints to inversion results.

Improved Geological Understanding

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The Physics of Airgun Sources

Airgun arrays have been the mainstay of seismic surveys since the seventies because they are safe and reliable. However, a downside with airguns is the oscillation of the bubble of air released, which causes unwanted low-frequency ripples in emitted sound. The oscillation frequency is dependent on the volume of the gun, so we combine different gun volumes to "tune" the bubble ripples out through destructive interference, while the primary peaks sum through constructive interference.

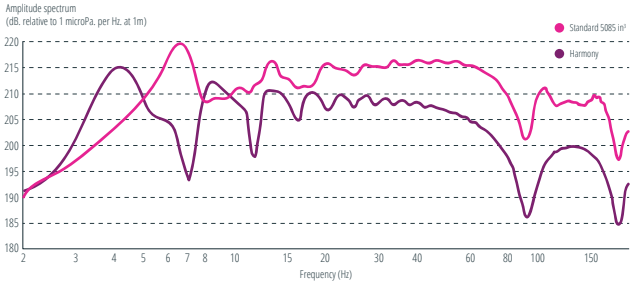
For the tuning to work, the individual gun elements need to be far enough apart so that the bubbles do not interact, and their bubble frequency is preserved for the desired destructive interference.

To help the tuning, we can place two guns close together, called a cluster, and the bubbles will then coalesce, resulting in a larger peak output and improved peak-to-bubble ratio as compared to a single gun of the same volume.

Frequency Locking

Between the fully coalescing bubbles and the fully separated bubbles, a physical phenomenon occurs where the bubbles interact through the pressure field. The result gives a very large effective bubble through (partial) frequency locking, which lowers the bubble frequency (Laws, Hatton and Haartsen, 1990). Hopperstaad 2012 exploited the idea of frequency locking to bring several small guns in proximity to create a low-frequency source named a "hypercluster" (US patent 9360578)

later commercialised for borehole geophysics by Schlumberger. To exploit frequency locking, Shearwater needed to make the source reliable, practical, safe, and compatible with existing equipment, ensuring it is available fleet-wide with minimal operational risk. This was achieved by the research team in our Oslo Shearwater Technology & Innovation Centre, working together with our operational team to develop Harmony to meet both the geophysical and usability targets.



Farfield Signature derived from nearfield hydrophones, 5085cuin (pink), Harmony (purple)

Shot gather spectra from a permanent reservoir monitoring system showing a 10 dB uplift at 4Hz, 5085cuin (pink), Harmony (purple)

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