Sercel True Broadband: 8-Octave Capability

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Acquiring the broadest possible seismic data has become an industry must-have for the benefits it brings to seismic imaging, in particular in terms of vertical resolution, the ability to built accurate velocity models and perform state-of-the-art inversions, in particular full-wave inversions. However, different meanings are associated with the term "broadband". While it should reflect an overall extension of the signal bandwidth, it is regularly associated to an extension towards the low frequencies only, sometimes with limited concerns about the fidelity of the data within this new bandwidth. Nonetheless, the recording of high frequencies, ideally above the conventional 80 to 100 Hz, matters too for shallow imaging, in particular for new applications such as the monitoring of offshore wind farms, carbon capture and use (CCS) or deep-sea minerals. As a matter of fact, as each octave contains the same level of information, the quality of a dataset can be considered as proportional to the number of exploitable octaves it contains.

The acquisition of seismic data being a chain, any weak link within this chain can possibly compromise the expected outcome of a survey. From a hardware perspective, we thus consider true broadband as an eight octave-wide capability in generating and recording high-fidelity seismic signal, to address the huge majority of industry needs without compromises. True broadband is achievable only with a proper combination of hardware associated to its optimum field implementation with advanced acquisition scenarios, each of them contributing to the bandwidth extension and preservation of the signal quality. Significant advances in equipment design have been achieved over the last decade to accomplish this goal and meet the expectations of both seismic contractors and data end-users.

Land equipment for True Broadband

On the source side, seismic vibrator capability at low frequencies has been improved (1). However, an excessive focus on their low-frequency performance compromises their performance at high frequencies, making such vibrators narrow-band sources, suitable to acquisition strategies such as Dispersed Source Array but not to the majority of surveys. As a rule-of-thumb, a gain of 1 Hz in vibrator capability towards the low frequencies compromises around 100 Hz at the other end of the spectrum. This is not an option for Nomad vibrators, that are broadband sources owing to a wide range of unique features that enjoy the benefits of both low and high frequencies (2).

Using a broadband vibrator makes sense however only if it generates a truly broadband sweep, controlled by a vibrator electronic designed to preserve all frequencies. In this regard, only low-dwell sweeps prove efficient (***Figure 1***). These sweeps (1), previously mastered by a few players only, can now be designed by any user of VE464, using the SweepCreator stand-alone tool. As hydraulic vibrators generate more distortion at low frequencies, its due mitigation has become a must-have. This is now made possible straight at the acquisition stage with the SmartLF tool that efficiently removes most distortion up to about 15 Hz (***Figure 2***). Not requiring expertise or additional mechanical parts, SmartLF is a straightforward add-on to VE464 (3).

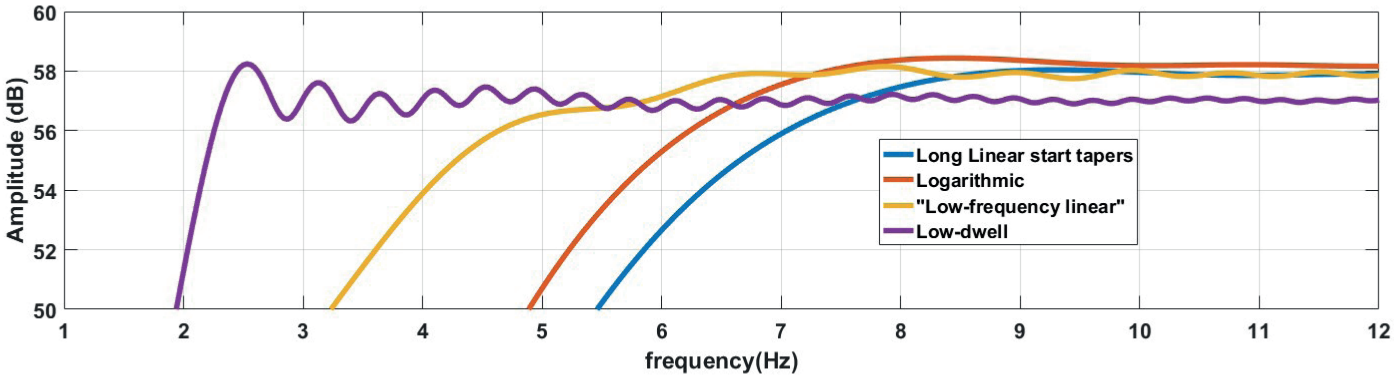

Figure 1*: Comparative performances of a low-dwell sweep (purple) with alternative sweeps claimed to be low-frequency. Example with a 2-80 Hz, 12 s, 80% sweep designed for the Nomad 65 Neo.*

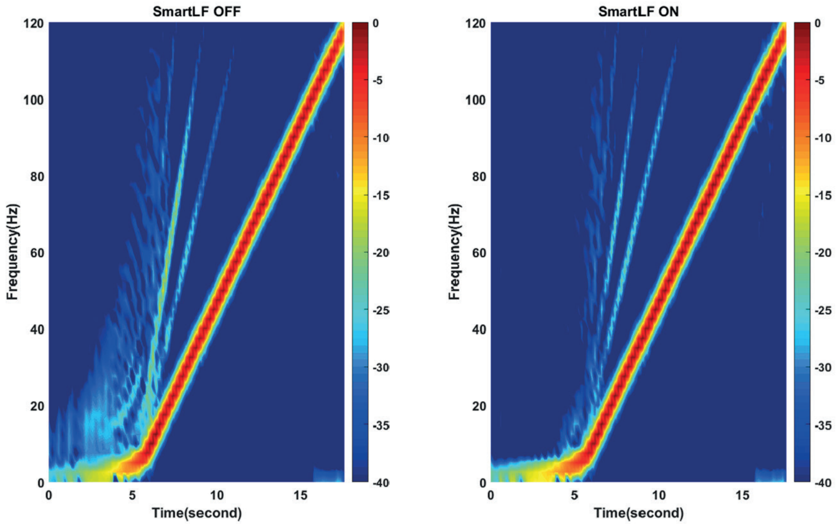

Figure 2: *Example of harmonic distortion reduction enabled by SmartLF: when activated, the low-frequency distortion falls below the -40 dB industry criteria up to around 15 Hz.*

Seismic sensors then prove paramount to record the true broadband signal that has been generated. Though geophones remain most commonly in use, the seismic data they acquire is affected by a poor fidelity in phase and amplitude, especially at low frequencies (a phenomenon known as "data jitter" (4)), and by resonant modes (known as spurious frequencies, the lowest one being a mandatory geophone specification) at high frequencies. This is not the case for MEMS sensors that enable true phase and amplitude sensing (***Figure 3***), without artefact, whatever the frequency recorded from 0 Hz to 400 Hz. While the industry has historically recognized their superior ability to preserve high-frequency signal, the 3rd generation of MEMS specified for seismic acquisition (QuietSeis®) has pushed the instrument noise to the same level as a high-sensitivity geophone connected to an excellent ADC. This ultra-low noise floor is particularly beneficial to the low frequencies, and makes it possible to record earthquakes 4000 km away from their epicentre (5). Owing to its unrivalled performances, the 3rd generation of MEMS has become the sensor of choice for all Sercel new equipment (***Figure 4***).

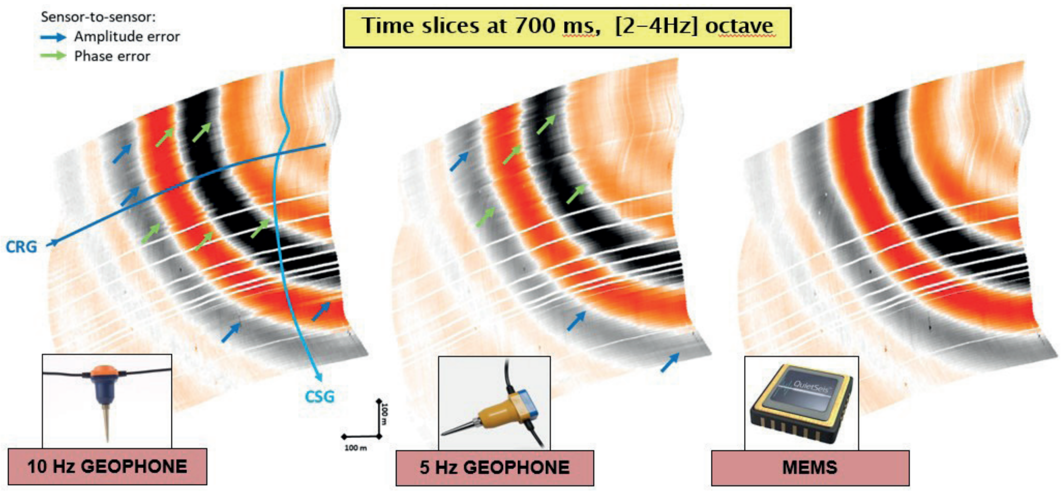

Figure 3: *Illustration of the data jitter phenomenon: while phase and amplitudes are exact on the time slice produced with MEMS sensors, its geophone counterparts exhibit significant phase and amplitude errors.*

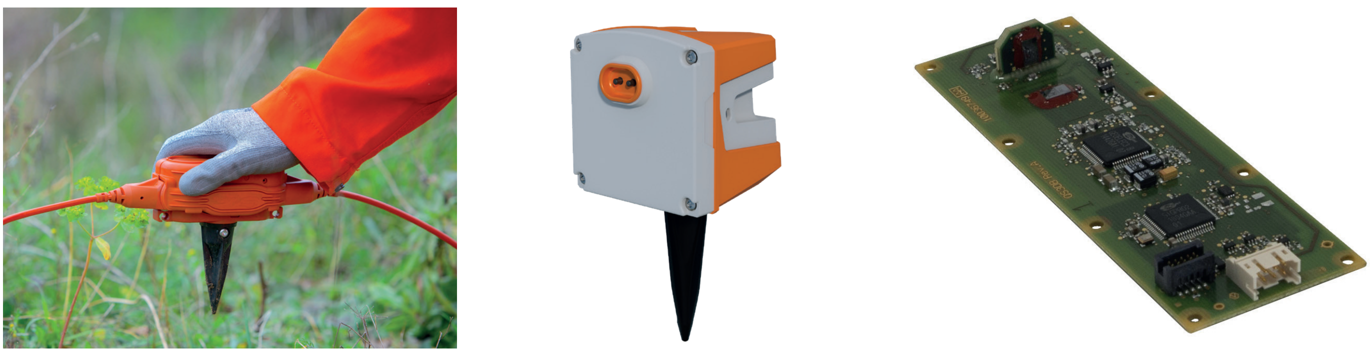

Figure 4: *The DSU-508, WiNG DFU and QS3 board are the three land products equipped with state-of-the-art 3rd generation of MEMS sensors.*

Marine equipment for True Broadband

While conventional pneumatic source arrays have a bubble period of 7-8 Hz, the yet commercial Tuned Pulse Source (TPS™, ***figure 5***) has a bubble period of 2.8 Hz only, thus extending the recoverable useful signal down to 1.4 Hz (6). To achieve this, the TPS operates with pressures twice lower than conventional arrays of pneumatic sources, but with a much larger volume. Such a disruptive design has another consequence: a reduced output at high frequencies, that places the TPS ahead of any configuration of pneumatic source array in terms of potential environmental impact (7). As for conventional pneumatic sources, the G-Source II offers a wide range of volumes (***Figure 6***). Source arrays can be optimized to mimic complementary bubble characteristics, hence enabling broader and more consistent energy spectra.

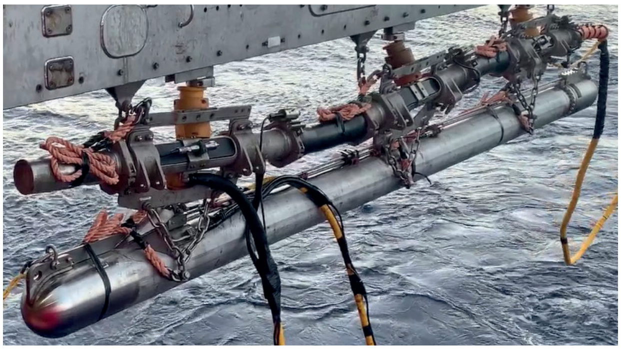

Figure 5: *TPS ready for deployment with a rigid float from a boom. TPS is also compliant with a flexible float for a deployment from a slip-way.*

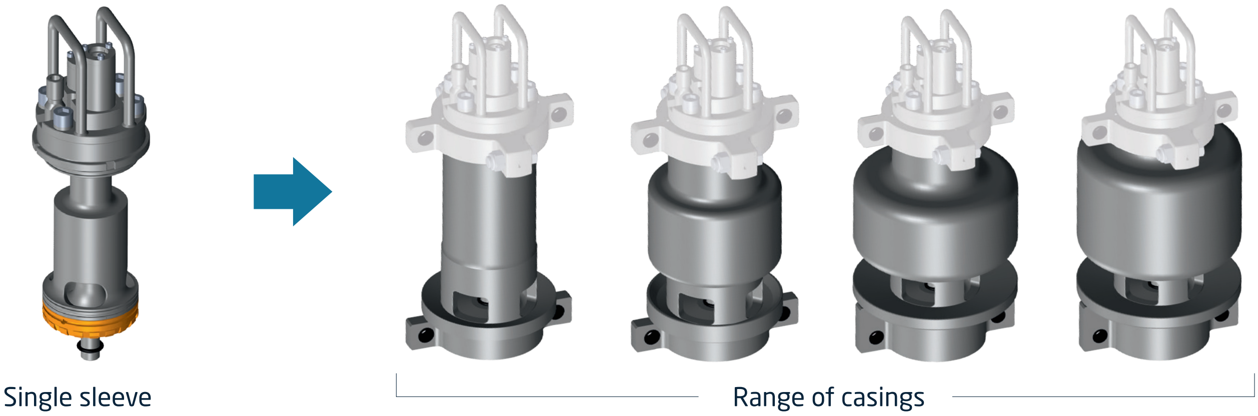

Figure 6: *The 4 sleeves of the G-Source II support 23 casing of different volumes, ranging from 45 to 520 cu in. Swapping casings is as fast a maintaining the source (< 30 min.). In addition, the G-Source II is the lightest of its class, and is not subject to auto-firing.*

The use of solid streamers significantly reduces the noise associated with equipment tow. In addition, they can be towed deeper, further from the noisy surface. In addition to these features, the Sentinel®*MS* (8) is equipped with additional sensors intended to fulfil the hydrophone notches, an at-best fulfilment thanks to a thorough design of sensor groups. A lower noise and better deghosting (***Figure 7***) are key contributors to recover at best seismic signal, in particular at both sides of the spectrum.

In OBN, the use of 3C MEMS to complement the hydrophone measurements gives access not only to their capability to record seismic signal with true amplitude and phase. Indeed, 3C MEMS OBN, recently introduced to the industry, provides also true verticality and true vector fidelity sensing (9), without prior pre-processing. The denoising is consequently much more efficient, notches better filed and the overall signal bandwidth extended when compared to 3C geophones. This unique industry feature is now available in the GPR^NT OBN and the MicrOBS^NT free-fall node (***Figure 8***).

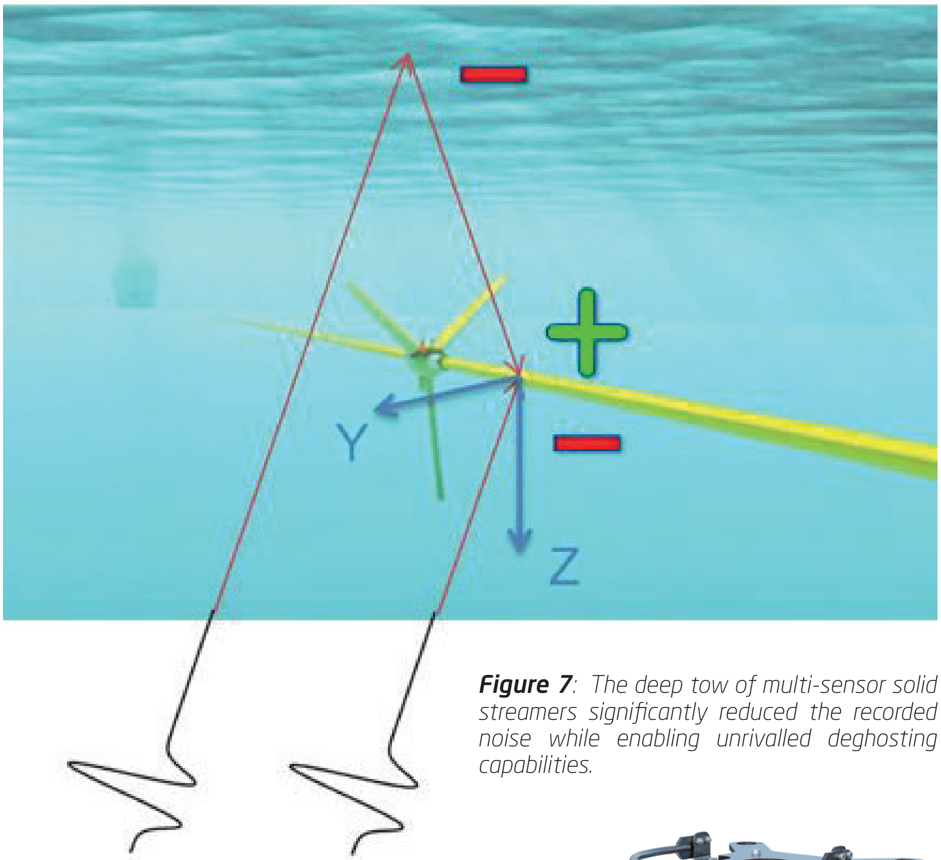

Figure 7: *The deep tow of multi-sensor solid streamers significantly reduced the recorded noise while enabling unrivalled deghosting capabilities.*

Figure 8: *The GPR[NT] (max rated depth 300 m or 1500 m) and MicrOBS[NT] (max rated depth 6000 m) are the only OBN on the seismic market enabling to get the benefits of 3C MEMS.*

Learning more about equipment for True Broadband

LAND

(1) Low-frequency Vibroseis: current achievements and the road ahead? / First Break January 2015.
(2) Practical solutions for effective vibrator high-frequency generation / SEG 2015.
(3) SmartLF for robust and straightforward reduction of low-frequency distortion / SEG 2019.
(4) Single-sensor acquisition without data jitter: a comparative sensor study / First Break January 2021.
(5) High-quality signal recording down to 0.001 Hz with standard MEMS accelerometers / SEG 2018.

MARINE

(6) Tuned Pulse Source - a new low frequency seismic source / SEG 2017
(7) A New Wave in Marine Seismic Source Technology / First Break November 2021 (Publication pending)
(8) A new MultiSensor Solid Streamer / SEG 2014.
(9) True vertical and orthogonal OBN sensing with 3C MEMS sensors / SEG 2020, marine acquisition workshop.