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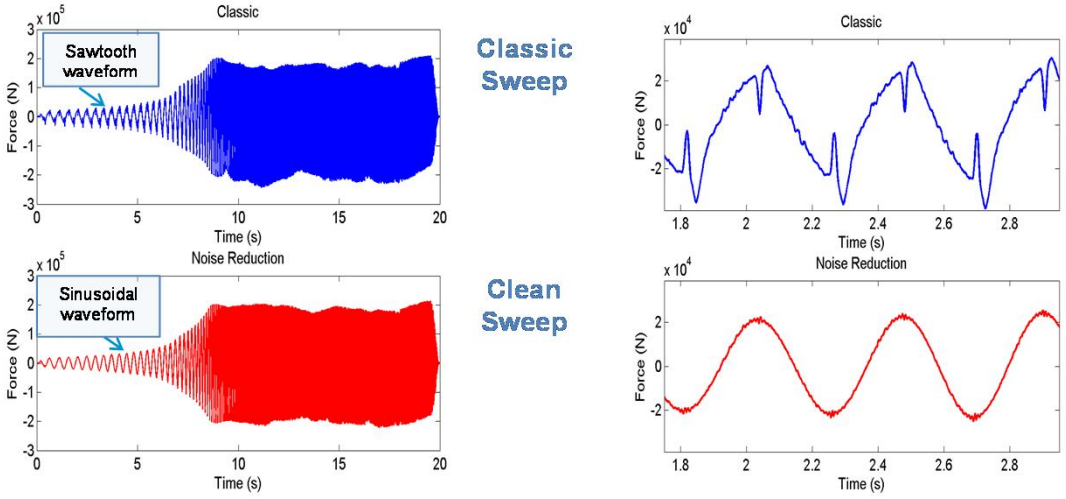
CleanSweep: A new technology in CGG portfolio

What is it?

CleanSweep is a new technology that reduces drastically the noise in the signal delivered by a seismic vibrator. The technique works particularly well at low frequency, which makes it particularly beneficial when used conjointly with **EmphaSeis** low-dwell sweeps. On slip-sweep acquisitions, unwanted harmonic distortion is first addressed during the sweep using this **CleanSweep** technique, then at a processing stage using **HPVA**. Using the two methods jointly allows the use of shorter slip-times, which lead to higher productivity, while maintaining at least equivalent data quality.

Seismic vibrators display intrinsically a nonlinear behavior mainly related to the nonlinear characteristics of the hydraulic servo-valve and to the nonlinear mechanical properties of the baseplate-ground contact. The significant ground-force distortion noise can be a limiting factor in vibroseis acquisition since it propagates into the soil. Whereas this problem is often handled during seismic data processing, **CleanSweep** is a noise-reduction method that applies on the source itself. The basic principle is to pre-distort adequately the input source signal: we measure the output noise and inject adaptively the opposite noise signal in the source input to converge towards an ideal output. This new method is a patented solution using an original approach on vibroseis control and shows efficient results for minimizing distortion noise from a seismic vibrator.



What are the benefits?

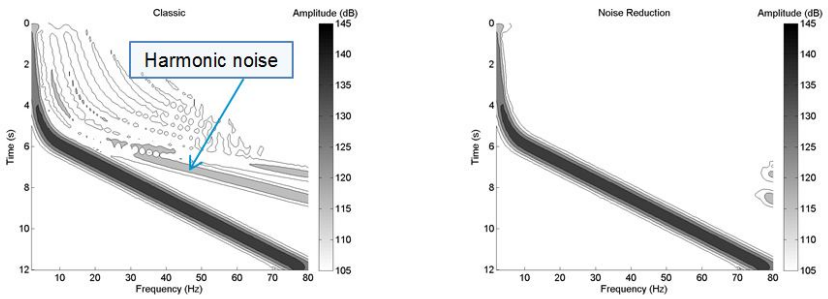
Vibroseis production rates are often limited by harmonic–noise contamination. The classical flip-flop acquisition technique consists in shooting sequentially two or more sources with the waiting time between each shot chosen to prevent any harmonic noise pollution between successive shots. To increase shot-productivity, the so-called slip sweep method consists in reducing the time between successive shots so-called slip time. In this case, the harmonic-noise contamination from one shot to another has to be handled.

By removing the harmonic-noise contamination from one shot to another at the emission, the proposed method allows either to reduce the time between successive shots or to extend the frequency bandwidth of the seismic data with no extra waiting-time cost.

The seismic source signal is improved since it exhibits less undesired distortion. The advantages can be two-fold: data quality and productivity.

For slip-sweep, the cross-talk noise between vibrator fleets consists exclusively of harmonic energy and is reduced at the sweep emission with the proposed method. When the source starts at very low frequency, the « self-harmonic noise » ghost is very close to the primary events and may cause processing and/or interpretation issues. Source deconvolution techniques could address those issues but they are currently deemed too expensive or impractical because they require uncorrelated data, often several times bigger than correlated data. This "self-harmonic noise" is not even emitted using the featured technology, leading to clean correlated records. For a given low-dwell sweep, we expect a gain of productivity.

The noise reduction permits to decrease the time between successive shots by considering the low frequency noiseless zone in the correlated time-frequency domain. Used jointly, **CleanSweep** and **HPVA** safeguard data quality during aggressive slip-time acquisitions.



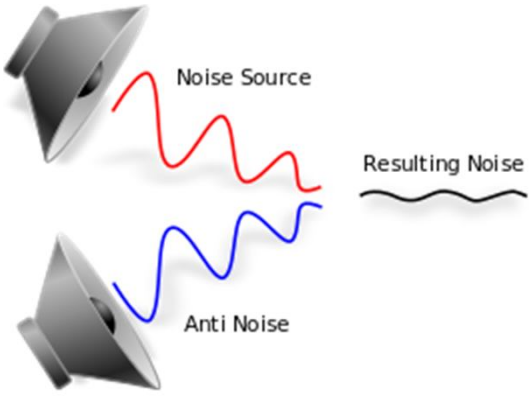
Time-frequency plots for a classical EmphaSeis ground force signal (left) and for a CleanSweep EmphaSeis ground force signal after a convergence process (right).

How does it work?

Harmonic-noise reduction is addressed during emission, in the vibrator truck. Until now, the source harmonic noise was only handled during post-acquisition using **HPVA** processing in slip-sweep crews. **CleanSweep** allows now reducing this noise before emission and it can lead to increased productivity and data quality.

CleanSweep method consists in designing an accurately tuned pre-distorted custom sweep inducing reduced harmonic distortion in the measured ground force. Basically, the principle is to measure the noise in the ground force and use it to compute a new custom sweep that gives a clean ground force. The computation of the anti-distortion custom sweep is not a real time process. It is obtained by several iterations of a converging process: on a static location, many vibrations are repeated until the convergence of an anti-distortion custom sweep is reached. For each vibration, the ground force is measured and its overall harmonic distortion is estimated. An operator estimated from the ground force harmonic noise is computed and applied to the initial custom sweep to get a noise correction signal. A fraction of this noise correction signal is removed from the previous custom sweep resulting in a new corrected anti-distortion custom computed for the next step.

The anti-distortion custom is efficient whatever the ground impedance. This important result shows that this method can be applied for production purposes because the computation does not need to be repeated at each VP. Even if the computation of the anti-distortion custom can take some time, once it is calibrated, it can be used directly as it is at any location. The anti-distortion pilot is computed for a given sweep with a fixed set of parameter values. The noise-reduction is efficient even if we change the vibrating point location (ground impedance variation) and/or the vibrator inclination.



CleanSweep

Key points

Harmonic distortion has always been a pillar of vibroseismic quality control. Harmonic Noise is one of the most important VibroSeis source contraints in term of data quality and productivity. Due to high distortion in ground force, vibrators are often stopped and removed from production, or reshooting is requested by the client.

On conventional crews, nothing was done beyond ensuring vibrator sweep QC thresholds were met. On slip-sweep crews, cross-talk harmonic noise is generally handled post-acquisition using **HPVA**.

Distortion pollution was handled in flip-flop acquisition by doing an upsweep and waiting a long time between successive shots. For increased productivity, when the time between successive shots was reduced in slip-sweep acquisition, CGG developed **HPVA** a post-acquisition denoising method. Removing the harmonic noise during processing is efficient but, in the recent years, the apparition of broadband sweeps prompted a need for improved distortion control, especially at low frequency. **CleanSweep** addresses now directly the noise reduction at the emission.

CGG sells **HPVA** to remove the harmonic noise from the records in slip-sweep acquisition. **HPVA** is still necessary but less noise is emitted using **CleanSweep**. In particular, at low frequency, the noise is perfectly removed where **EmphaSeis** sweeps leads to self-record noise contamination. **CleanSweep** allows reducing slip-time especially when low-frequency **EmphaSeis** sweep is used.

In the near future, **CleanSweep** should be generalized on all crews. **CleanSweep** delivers better images over the full bandwidth and is totally efficient at low frequency (fully integrated in **UltraSeis** Broadband strategy). The integration of **CleanSweep** with **Emphaseis** sweeps and the resulting quality improvements at low frequency corresponds to **CGG** Broadband strategy.

Reduction of harmonic distortion at the emission gives:

- **Improved delivered data** (« self-harmonic noise » pollution for low-dwell sweeps (**EmphaSeis**) not even emitted) easier to process, especially clean first arrivals eases Full-Waveform Inversion
- **Increased productivity** in slip-sweep acquisition : slip-time can be decreased because low-frequency are cleaned