Want to get rid of distortion?

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Distortion in brief

A certain number of seismic equipment specifications seems overlooked by seismic data end-users. This is the case, for example, for distortion. In the facts, distortion corresponds to unwanted harmonic noise, which characteristics are dependent on the ones of the signal in a non-linear way. Distortion spreads over the entire seismic bandwidth of interest and contaminates the fundamental signal we wish to sense. The level of harmonic contamination increases with lower-frequency acquisitions (stronger amplitude distortion in low frequencies, and more harmonics generated within the bandwidth of interest), but can be mitigated with the use of performant equipment. A major difference between source and sensor distortion is however worth being noticed.

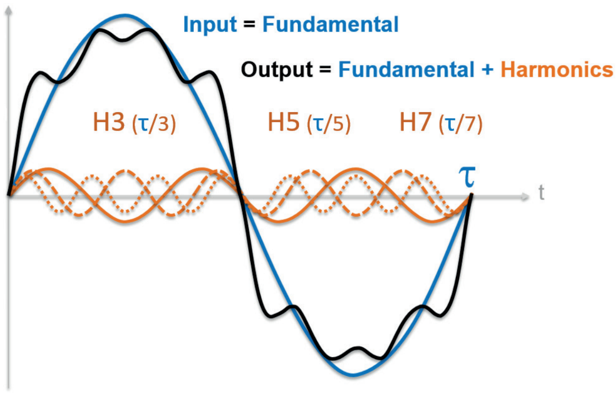

***Figure 1**: an illustration of distorted signal (Output), after the expected "ideal" seismic signal (Input of temporal period τ) has gone through a physical device (source or receiver)*

Source distortion

Vibrator distortion propagates into the subsurface (as a component of the seismic wavelet), and is continuously recorded and monitored. In this regards, some consider its use for imaging purposes, albeit studies are still at the exploratory stage. But more often than not, source distortion remains an unwanted signal, assimilated to a noise. Effective deterministic and statistical processing solutions exist to reduce the level of harmonic source contamination from the data. A more effective way to deal with the emission of distorted seismic wavelet is to reduce it at emission e.g. with the VE464 SmartLF add-on. This highly efficient solution removes the most damageable distortion generated by the vibrator sweeping low frequencies (figure 2). Such a solution frees the seismic wavelet from source harmonics over the low-frequency band. To get its full benefit, it is recommended to complement the acquisition chain with low-distortion sensors.

As for explosive sources, they are not concerned by distortion: receiver distortion will then be the main source of distortion in the seismic record.

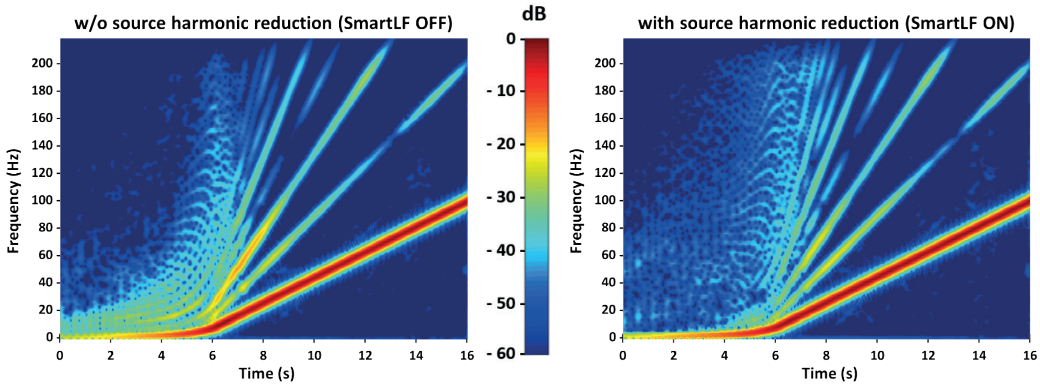

***Figure 2**: Spectrum of the ground force of a shot point, without (left) and with (right) VE464 SmartLF harmonic reduction at the signal emission stage.*

Receiver distortion

Somehow surprisingly, receiver distortion has hardly been considered so far, except as a second-order phenomenon. However, this distortion does not carry any subsurface information: it is a pure recording noise. It can't be monitored on the field (lab conditions required) or even modelled (owing to its non-linearity, its dependency on tilt, signal characteristics...), and is consequently particularly difficult to mitigate at processing. As an example, the distortion associated with the sensing of the energetic low-frequency ground-roll will contaminate a significant part of the useful bandwidth, which is the case for Vibroseis, and even more for explosives. Sensor distortion is particularly detrimental for the signal-to-noise ratio of simultaneous sources operations (Figure 3). With a dynamic of more than 120 dB involved in seismic acquisition, the moderate to weak events are swamped in the sensor harmonic noise of the most energetic events. Since the sensor distortion cannot be modelled and so removed after deblending, it is therefore recommended to use sensors exhibiting the lowest possible distortion to preserve the underlying weaker seismic events.

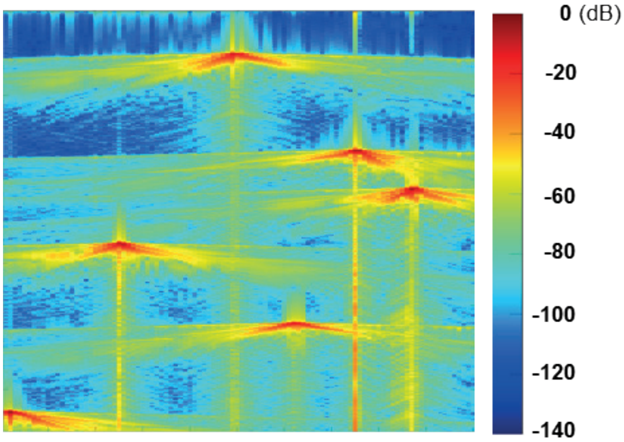

Figure 3*: Blended seismic operations involve the overlay of seismic signals showing more than 120 dB difference in amplitude.*

The distortion performance of a seismic sensor remains best-placed to avoid introducing excessive distortion noise into seismic datasets, performance which is mostly related to the sensing technology in use. Distortion specification in dB can however be misleading, its linearity not reflecting the huge gap that lies behind sensor performance:

- **A -90 dB** distortion (MEMS-based channel standard) corresponds to a rms amplitude of distortion equals to 1/31,600th of the amplitude of the signal fundamental. It may seem over-specified, but has to be put in relation with the dynamic of seismic wave fields, which is above 120 dB and in line with the dynamic range of acquisition systems.
- **At -60 dB** (geophone standard), the distortion noise to signal ratio reaches 1/1,000, which suits the majority of seismic acquisitions. Significant efforts had been made in the industry in the 90s' and early 00s' to achieve such a performance, mainly so as to grant the best possible outcome from impulsive sources acquisitions.
- **At -30 dB**, the distortion noise to signal ratio bursts up to ~1/31, a non-modelable noise level that will significantly affect the quality of the data recorded, in particular with impulsive sources but also in Vibroseis when an effective anti-distortion solution is in use at the emission stage. This -30 dB distortion level seems a best case for piezo-electric sensors: state-of-the-art, 1,000 $ piezo sensors are indeed specified at -40 dB, low-cost piezo exhibiting a much stronger distortion. The factual receiver distortion is however much higher than the sensor one, as the mechanical mounting of a sensor in a seismic receiver induces significant extra distortion (e.g., owing to the friction of the reaction mass). In this regards, a -10 to -30 dB distortion, according to the frequencies involved, can be expected for a piezo-based seismic channel.

Take-away

The equipment-induced distortion of the seismic wavefield is an issue for any acquisition. Though vibrator distortion is duly considered in the seismic industry, it is rarely the case for sensors. Sensor distortion is however a significant source of noise that will particularly affect not only explosive datasets, but also vibrator datasets acquired either in simultaneous shooting or with low-frequency expectations. Sensor distortion being a pure, non-modelable noise, the seismic wave field recorded with a high distortion receiver will exhibit a lesser quality and fidelity than when recorded with a receiver duly specified for distortion. This impacts the amplitudes recorded, images produced and velocity model built, in addition to more complex processing and interpretation.