

ABSTRACT

The emergence of seismic acquisition technologies aimed at increasing trace density with single-sensor nodes is challenging the way quality control (QC) and processing are carried out in the field. Traditional setups using multiple-geophone arrays have long been designed to attenuate source-generated noise — such as ground rolls — and ambient noise, while enhancing the signal-to-noise ratio (S/N) of deeper reflectors through the stacking power of the array. The resulting clean records are familiar to operators and lend themselves to visual or statistical QC; however, they have always carried hidden problems tied to the "blind" stacking of array elements, including high-frequency loss, the contribution of faulty elements, and phase instability (data jitter) — effects that are unrecoverable once the array has been stacked. Single-sensor data, by contrast, exhibits a lower raw S/N and often reveals events that would otherwise be invisible after array stacking. Thanks to its high spatial sampling, attenuation of unwanted events becomes much more tractable in processing, offering greater control to adapt to the variability of noise across the survey. In this presentation we discuss the pros and cons of both methodologies and introduce Digital Group Forming (DGF) as an intermediate solution — reducing single-sensor data volumes to a size comparable to array systems while preserving the flexibility to condition the data before the array stack

Introduction

Recent advances in seismic acquisition technologies have been increasingly driven by the need to improve spatial trace density through the deployment of single-sensor nodes. This development represents a significant shift from conventional acquisition systems based on multiple-geophone arrays; with natural frequency response around 10 Hz each one and assuming signals of interest were only reflected energy; in such arrays were traditionally been designed to enhance the signal-to-noise ratio and attenuate source-generated noise, such as ground roll, as well as ambient noise. In these conventional systems, the stacking effect of the array produces cleaner-looking records that are familiar to field operators and well suited for comparative analysis or statistical quality control procedures.

However, geophone arrays also introduce inherent limitations associated with the physical or “blind” stacking of individual elements. Once the array response has been combined in the field, several undesirable effects become impossible to recover or correct. These include the loss of high-frequency content, the contribution of faulty or poorly coupled elements, and phase instability, often referred to as data jitter.

On the other hand, single-sensor acquisition preserves the response of each individual receiver and thus provides a more detailed representation of the recorded wavefield, with a broader frequency range (1–125 Hz), suitable not only for the oil and gas industries but also for other geophysical technologies such as geothermal, geological hazards, and carbon capture, utilization, and storage (CCUS). Although raw data from a single sensor typically exhibits a lower apparent signal-to-noise ratio, they can also reveal coherent or incoherent events that would otherwise be masked, distorted, or eliminated by conventional array stacking. Furthermore, the high spatial sampling provided by single-sensor systems makes the attenuation of unwanted events more manageable during processing, allowing noise reduction strategies to be tailored to the spatial variability of noise conditions throughout the survey, as near surface conditions and coupling receiver-ground may change spatially.

Geophone Array (DAF) vs Single Sensor (DGF)

A digital array corresponds in a set of several individual geophones connected to one another that function as a single recording channel. This digital array is configured with a spatial layout that acts as an antenna capable of filtering out ambient noise and amplifying the signal. This process is done inside the recording system.

In single-sensor acquisition systems, it allows for the capture of more detailed subsurface information without the “smoothing effect” that occurs when averaging multiple signals, as in digital array formation (DAF); here it is better to introduce the concept of digital group formation, a technique that emulates a physical array by combining data from individual sensors within the processing sequence. In theory, there is no predefined geometry as in DAF; in this methodology, the field processor can test and design an optimal group formation that best suits the near-surface conditions and the exploration objective, from the surface layers to the deepest ones.

In the following data field example, Figure 1, is shown the benefits of the single sensor DGF compared with the Geophone Array (DAF).

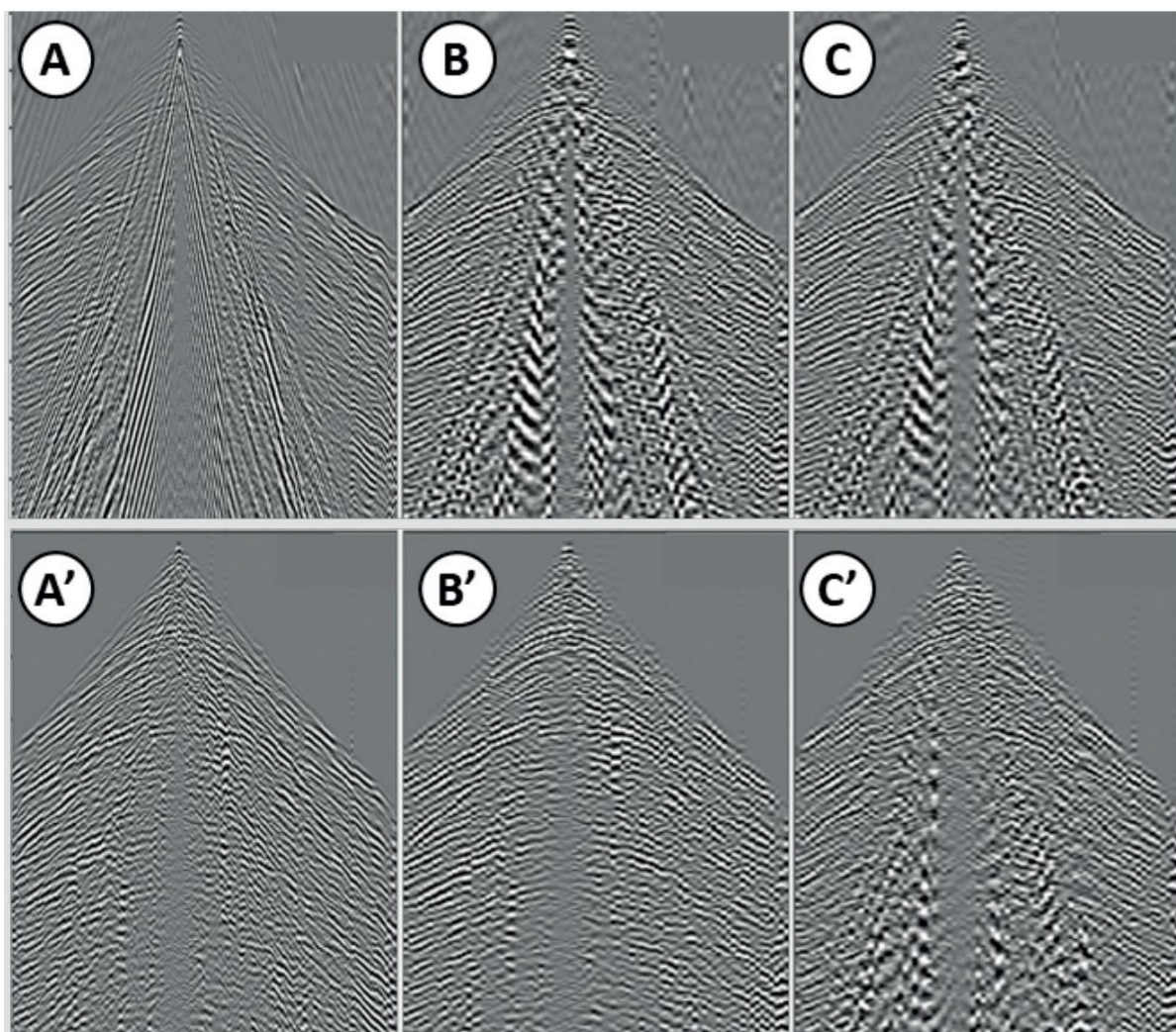


Figure 1 This is an example Shot gathers from: A) single-sensor node system at 2 m spacing B) after digital array forming to 25 m (12 traces stack) C) real 12-geophone array cabled system at 25 m alongside A. A') after GR removed with FK, B') DAF filter applied after GR removal with FK. C') FK applied on 12-geophone array. We note the enhanced reflection of the DAF after filtering (B')

compared to both filtered single-sensor(A') and filtered 12-geophone array data (C'). Ourabah, A. [2024].

Conclusions

This paper discusses the advantages and limitations of both acquisition methodologies, with particular emphasis on their impact on field quality control, data conditioning, and seismic signal preservation. In addition, we introduce Digital Group Forming (DGF) as an intermediate approach between conventional array-based acquisition and full single-sensor processing. DGF reduces single-sensor data volumes to levels comparable to those of conventional array systems while preserving the ability to condition the data prior to digital stacking. In doing so, this approach aims to combine the operational efficiency of geophone arrays with the increased flexibility and signal fidelity offered by high-density single-sensor acquisition.

References

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