PESGB: Geophysical acquisition techniques and their impact on hydrocarbon exploration success

The advent and adoption of simultaneous source methods to towed streamer acquisition.

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Introduction.

In the last 10 years there have been fundamental changes to the way in which seismic data has been acquired, how the data is recorded, and how this has impacted the final interpretability of the subsequently processed results. It is well known that the quality and interpretability of the final seismic data is related to the density of data recorded. One particular technique that has enabled a large increase in the recorded data density, without resulting in a similar increase in cost of acquisition is simultaneous source acquisition. Conventional thinking was predicated on the idea that a source was activated (or fired), and then the response of the earth was recorded for a finite time depending on the depth of interest. This brief experiment was then repeated with the source either at a different location to try and build up better S/N in the data. The concept of introducing another source at the same time was not typically considered as this would have simply been thought of as additional noise that would degrade the recording.

However, simultaneous source acquisition has long been recognized as a possible strategy for achieving cost reductions in seismic acquisition, with history offshore that goes back to at least 1955. Initial work on simultaneous sources utilized different source signatures or source signal encoding to allow separation of sources, but today the preferred method of simultaneous source acquisition does not require source variations, but typically requires only source timing variations. While some of the earliest adoption of simultaneous source techniques were onshore, and some still argue that offshore methods should be limited to similar (but bottom referenced) acquisition, but success of simultaneous source methods involving towed streamer geometries have become widely reported.

Towed streamer acquisition

In towed streamer acquisition, simultaneous source work has been proposed for many different applications. Perhaps the most obvious is the use of sources on two vessels at the front and rear of streamers [1]. The benefit of this configuration is that the fold of data can be doubled. One obvious extension to this concept is to have both sources at the same end of the streamer but with vessels at different distances from the head of the streamer. The advantage of this is to be able to acquire data with longer offsets than would be possible given constraints on streamer length. More recently it has become obvious that the distance between sources is not necessarily a constraint on effective separation of overlapping or simultaneous records, and sources can be towed from the same vessel. This has led to work with three [2], five [3] or six [4] sources being towed from the same vessel, and allowing the shot records to overlap and interfere with each other.

Introducing randomness into shot timing

The success of simultaneous source methods typically relies on there being changes in the time between shots, and as a result, changes in the time between interfering shots. There are several ways in which this can be achieved for towed streamer operations:

Forced Dither: By firing one source with a regular interval (either in time or space), and firing a second source with slight time delays relative to the activation of the first source, and varying the time delay from shot to shot in a “random” fashion it is possible to separate the interfering source records when the data is gathered into common receiver domain or CDP domain. If the random timing is constrained to a relatively short window (+/- a few hundred ms), then the same finite length shot records can be maintained as would have been used for the single source acquisition. This has benefit if the seismic recording system requires data to be recorded as a set of discrete, sequential records. Methods which employ this technique are sometimes referred to as “forced dither” simultaneous source techniques since the timing variations are known and introduced deliberately. Figure 1 illustrates the effect of a forced dither of a common receiver gather (in this case a common trace for a single streamer). Note that the data is aligned with the timing of the fixed source interval, and the second source displays a random time, as each trace is associated with a separate shot. In this case the random forced dither window is -50ms to +150ms. Data can be realigned for the second source, in which case the interference from the first source would appear to be random within a 200msec window. It would however be difficult to separate the data in the shot domain, as both sources have energy which is coherent with significant overlap in moveout and dip. Separation in the common receiver domain is however much easier and could (potentially) be achieved by a simple noise attenuation process. This is however not how separation is typically achieved in processing.

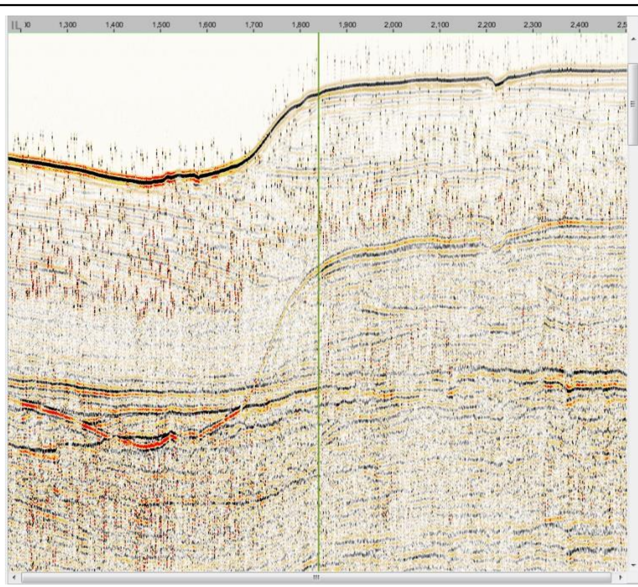

Figure 1: Common offset display with forced dither of a 2nd source

Natural Dither: Given that separation of data is possible within a small-time window of randomness it is worth examining the amount of random timing that is introduced simply through the variations of vessel speed when the source point interval is regular in space. While the intent of most marine seismic acquisition geometries is to generate regular shot intervals, this cannot perfectly be achieved in most practical situations. The navigation system on board the vessel has to predict when the source will achieve a particular position and activate the source at this point. However, small variations in speed which occur between the time that the vessel speed (a local average), and the actual speed in the last moments before the source reaches the desired position result in slight variations in timing between successive shots. Empirical observations suggest that the typical variation in timing from shot to shot has a standard deviation of ~100 to 200 msec. Figure 2 shows the standard deviation of shot interval from a real source line acquired during relatively calm seas. Higher sea states tend to cause slightly larger standard deviations in shot interval. The blue band shown in figure 2 indicates the range of deliberate dither introduced in the source of figure 1.

Continuous recording and random acquisition based on shot interval: Both forced dither techniques and reliance on natural timing variations involve relatively small windows of timing variation in the interfering source. A better way to generate interfering energy within a shot record is to make it completely random within the record time. This is not easily achieved in a towed streamer configuration where the vessel is moving continuously, as the same (airgun) source cannot be activated without sufficient time to recharge the source to full air pressure. However, it is possible to achieve complete randomization by changing the

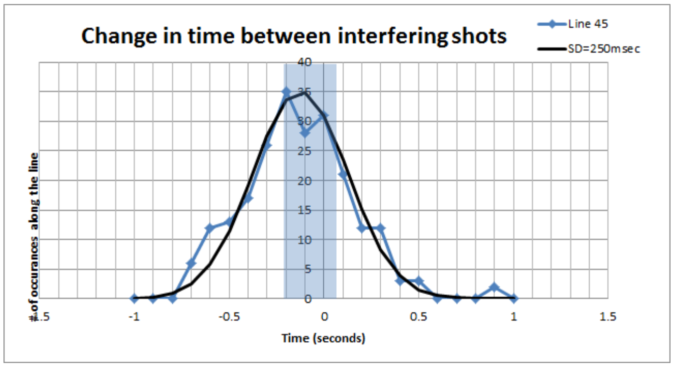

Figure 2: Spread of time delays between 2 sources fired on regular shot intervals

distance between source activations in a way that always allows the source sufficient time to recharge. This method is particularly effective if multiple vessels are involved, and arguably has better applicability to 2D acquisition.

Separation without randomization: There is one method of simultaneous source acquisition which does not involve randomization of the sources. Commonly referred to as "apparition" [5]. This involves keeping the source activations regular, but changing the "character" of alternate (or regular) sources by delaying them by a fixed time. For example, activating the second source at the same time as a primary source on even number shots, but delaying the second source by a fixed time on odd numbered shots. This has the effect of shifting data in the wavenumber direction in an F/K analysis, which results in good separation of lower frequencies. Higher frequencies can be separated if the shot interval is sufficiently small.

Deblending technique differences

Up to this point we have simply assumed that the data that is recorded with simultaneous sources can be well separated in seismic processing. However, it is important to distinguish between different separation methods and point out some potential shortcomings and how they might be identified.

Although noise attenuation methods have in some cases produced promising results most modern "deblending" methods use inversion techniques to separate simultaneous source data. Some authors have suggested that there is a lower limit to the frequency which can be successfully separated using inversion methods [6], and indeed inspection of the low frequency components of the resultant data can often reveal inadequacies in separation schemes, where some deficiencies may not be obvious when a full bandwidth section is examined. An example of different deblending methods produced on a common receiver gather is shown in Figure 3, which shows a comparison of simulated towed streamer overlapping source (natural dither) data separated by different methods, to illustrate some of the potential problems that may be observed with full bandwidth data. It should be noted that the key to successful separation of data is preservation of signal, and not necessarily attenuation of interference.

Summary

It has taken many years for the potential of Simultaneous Source work to come to fruition. The motivation for using multiple simultaneous or overlapping sources is straightforward. If the sources will each yield distinct information, then the subsurface can be sampled more efficiently. Having multiple sources in a survey provides other benefits such as flexibility in survey geometries. There are many potential benefits to this aspect including enabling azimuthal diversity in marine surveys. As a result, there is tremendous potential value to the seismic industry if this approach can continue to be successfully developed and commercialized. The potential benefits are obvious and simultaneous source methods should always be evaluated when designing a new survey offshore regardless of whether this is towed streamer, OBN, Marine Vibroseis or impulsive source.

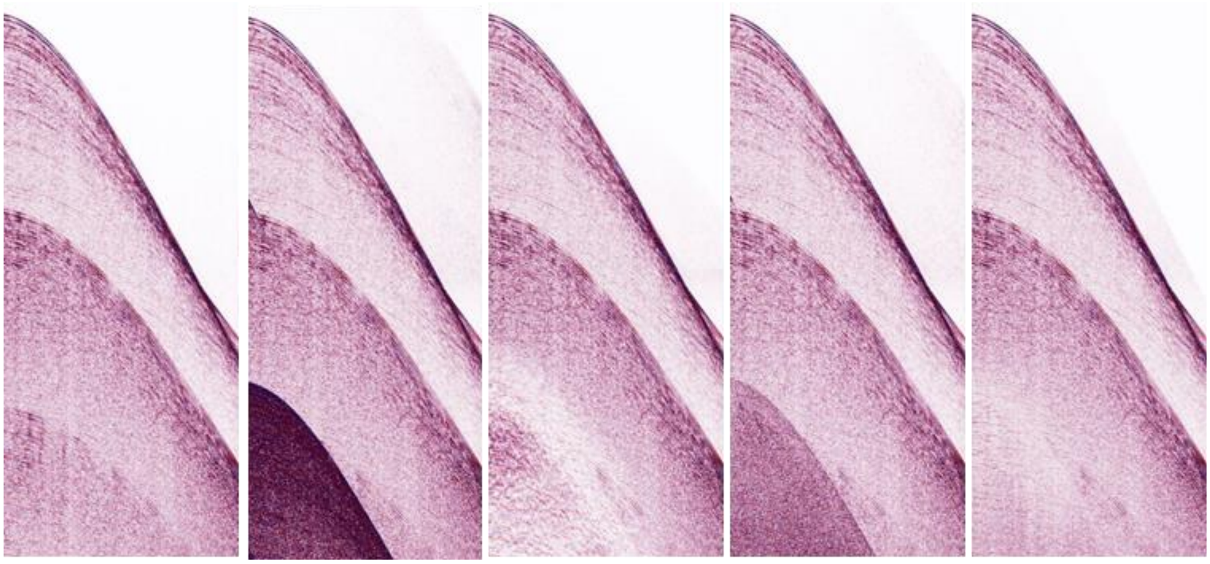

Figure 3: Impact of different deblending techniques. From Left to Right: Unblended data, Data with interfering shot, 3 examples of separated results showing obvious differences

References

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