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Time Right For Simultaneous Sources

By Craig J. Beasley

HOUSTON–Simultaneous-source marine seismic data acquisition is an emerging technology that is developing rapidly, stimulating both geophysical research and commercial efforts. The technology has been successfully field tested with favorable results, including a recent project that deployed two pairs of simultaneous sources as part of a test to compare with a wide-azimuth 3-D survey in the Gulf of Mexico.

Simultaneous-source acquisition has long been recognized as a possible strategy for achieving dramatic cost reductions in the marine environment. This is especially true for large 3-D surveys, particularly when multiple vessels are employed (as in multiazimuth acquisition geometries designed to improve subsurface illumination and data quality). However, the main limitation in wide-azimuth techniques is the constraint imposed by the relationship between the number of sources, boat speed, shot spacing and record length. Minimizing this design constraint by shooting marine sources simultaneously rather than sequentially could improve economics by enabling faster and more efficient surveying, while also providing enhanced illumination and image quality.

The simultaneous-source approach is novel in that it does not require source-signature encoding (although encoding combined with this approach would be beneficial), but instead relies on spatial-source positioning to allow for signal separation in data processing. Appropriate data processing sequences are being developed to more effectively separate interfering signals.

The subject of dealing with interfering information is by no means new, be it in geophysics or other sciences and industries. In fact, one need only look to nature for numerous examples of species that have found it necessary for survival to be able to differentiate their offspring from others who look and sound identical. What is relatively new to marine geophysics, however, is the concept of purposely deploying multiple impulsive sources and firing them in such a way as to interfere with each other with the plan of separating the sources in subsequent data processing steps.

The motivation for using multiple sources is straightforward. If each source can yield distinct information, then the subsurface can be sampled more efficiently. Moreover, having multiple sources active in a survey provides other benefits such as flexibility in survey geometries. There are many potential benefits to this aspect, but a timely one is enabling azimuthal diversity in marine surveys. As a result, there is tremendous potential value in successfully developing and commercializing simultaneous-source acquisition technology.

Nonseismic Developments

The entire signal-to-noise problem could be viewed as one of interfering sources. Outside the seismic domain, other sciences have developed methods revolutionizing those disciplines by successfully tackling the interfering sources problem. Geophysicists can be encouraged that similar developments will be successful in seismic acquisition.

One relevant phenomenon outside the realm of geophysics is the "cocktail party effect," which relates to the fact that despite all of the loud noise from many sources at a crowded cocktail party, one is often able to focus on a particular person's speech. It is even more remarkable that it is possible even when that person is some distance away and interference levels are very high. Indeed studies indicate that as volume increases (as is known to happen as the evening wears on), the ability to separate is still powerful. Perhaps even more interesting is the listener's ability to "tune out" conversation, music and other noise in his immediate proximity to hear a conversation taking place on the other side of the room.

The cocktail party effect laid the groundwork for today's technology in speech recognition. It also led the way to a new understanding of human communication though developments such as the Broadbent filter theory, which holds that when information must be discarded, it is not discarded at random, and if some of the information is irrelevant, it is better for it to come from a different place, to be at a different loudness, to have different frequency characteristics, or to be presented to the eye instead of the ear. When no material is to be discarded, there is little advantage in using two or more sensory channels for presenting information.

The Broadbent filter theory is significant in that it foreshadows methods for separating interfering seismic signals. But before turning to the problem in geophysics, it is worthwhile to highlight a development from the telecommunications industry: a patent issued to a researcher at Bell Labs in 1998 on a breakthrough that overcomes the sampling theorem. Called Bell Labs Layered Space-Time (BLAST), the technology overcomes conventional relationships between frequency bandwidth and information content by employing multiple broadcasting and receiving antennae and exploiting propagation differences to separate the interfering signals.

Over the past decade, the telecommunications industry has commercialized this approach under the acronym MIMO (multiple input/multiple output), which has revolutionized wireless communications. There are obvious parallels between this kind of technology in telecommunications and the challenges with interfering signals in geophysics. Can simultaneous sources lead to a similar paradigm shift in marine data acquisition?

Interfering Sources

The economics of seismic acquisition depend on the time and motion of the people and equipment involved in relation to the seismic survey area. This is a very complex topic and not the subject of this article, except, to note that the potential benefit of using more than one source at the same time during acquisition is well established. Indeed, the benefits of this approach are apparent on land using simultaneous vibrator sources, and are often cited as a motivation for developing marine vibrator sources.

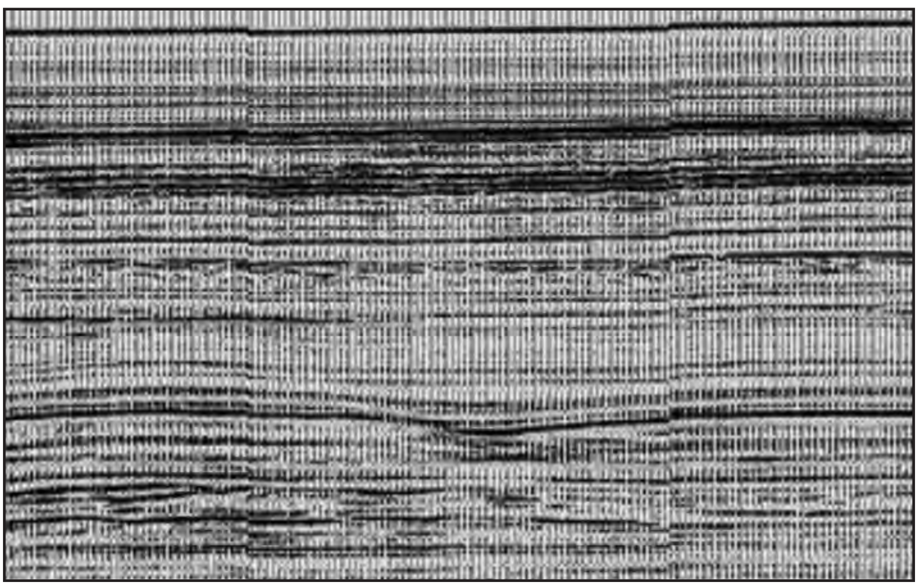
Land simultaneous source technology has been extended to the slip sweep technique, where vibrators are delayed rather than activated simultaneously, as well as commercial methods such as high-fidelity vibroseis. More recently, commercial applications of simultaneous sources on land that exploit distance between the sources–as is being discussed here for the marine case–have been implemented and judged to be faster, cheaper and better. Besides distance separation, a common thread in approaches to land simultaneous sources is using some sort of encoding mechanism to enable interfering signals to be separated from the seismic signal. Because this type of encoding generally has not been available with conventional marine sources, the land-based approaches have not migrated into the marine environment.

An early thrust of research on interfering sources in marine acquisition has been removing "crew noise," which comes from other boats shooting in the same area. To deal with crew noise in areas with multiple active surveys, time sharing rules require that only one boat shoot at a time when the noise specifications reach prescribed levels. Because of the cost involved in time sharing, many attempts have been made to relax these requirements to avoid time sharing.

Research has demonstrated that as long as the interfering shooting vessels do not have synchronized firing times, the interfering signals can be suppressed simply by stacking the data. Although the research did not contemplate purposely deploying interfering sources for use as signal, the key insight here is that while interfering shots appear coherent and unmanageable in the shot domain, interfering shots appear as incoherent arrivals in the common midpoint domain (a result of ensuring unsynchronized firing times–a type of "encoding" of interfering shots) and can be removed by filtering or stacking. This type of source encoding is a key element in techniques to separate and filter interfering sources.

FIGURE 1

Vintage 2-D Line Shot with Interfering Sources Composited with Conventional Line



Field Experiments

One of the first field experiments to test the possibility of using simultaneous marine sources was conducted by WesternGeco in 1997. The motivation was similar in many respects to the challenges facing geophysics today in the Gulf of Mexico: illumination deficiencies in conventional marine acquisition. The root causes of subsurface illumination deficiencies were documented as a result of the deleterious effects on imaging algorithms and were determined to be related to acquisition geometry. This field test demonstrated that even if sources were fired simultaneously with synchronized firing times, if the sources were spatially separated, filtering related to the different geometries (including imaging algorithms such as dip move out and prestack migration) can suppress the interfering sources.

Figure 1 shows a composite of the same 2-D line (nearly) shot first with a conventional single source and then a second time with interfering sources. The results are nearly indistinguishable. The central one-third of the section is the line shot with interfering sources, and the outer two-thirds is from the line shot conventionally. Data processing included filtering to remove the interfering sources, dip move out and migration. Small misties are attributed to 3-D effects from cable feathering, and not interfering sources.

In 2008, WesternGeco acquired a small WAZ 3-D data set that use simultaneous sources over a geologically complex area that had been previously surveyed with a standard single-source WAZ configuration. Even though the simultaneous-source data were processed without any explicit separation procedure, the migrated images of the two data sets are virtually identical, except that the simultaneous-source data has a better signal-to-noise ratio at depth because of the improved spatial sampling. The results are highly encouraging for simultaneous-source acquisition, especially considering the potential of future developments in data acquisition and separation procedures.

Other field tests have been conducted by operators as well as geophysical contractors, generating growing optimism for the commercial application of simultaneous sources.

Significant Future Role

The seismic challenges posed by subsalt-related plays in the Gulf of Mexico are addressed with field efforts unimaginable only a few years ago. To collect WAZ surveys efficiently, multiple vessels are employed in a dizzying array of configurations–sometimes with several boats recording, and usually with several boats shooting. As a result, operators find that they must time share among their own vessels. This results in underutilization of equipment, and while the desired azimuth characteristics are obtained, other sampling quantities may be degraded. For example, if four boats are shooting and the nominal shot spacing is 37.5 meters, time sharing results in shot spacing within one shot line of 150 meters, which poses challenges in data processing.

If one could shoot the sources simultaneously, in pairs, shot spacing would be reduced to 75 meters and the fold would double. In other words, if the interfering sources can be separated successfully, data quality can be improved with little extra field effort. In general, if the sources generate independent information, survey efficiency increases nearly linearly as the number of sources firing simultaneously increases. This efficiency factor can be used to reduce cost and improve data quality.

It appears very likely that simultaneous sources will play a significant role in large-scale marine acquisition projects. However, once a new paradigm invades a technology, it grows and spreads rapidly. Similar acquisition schemes can adopt simultaneous sources. For example, ocean-bottom systems, for which costs are generally high relative to towed-streamer acquisition because of the time required to shoot the survey, could become more efficient by cutting acquisition times and lowering costs. Similarly, bore hole seismic surveys, for which costs are impacted significantly by idle rig time, could benefit from faster acquisition that could be achieved with simultaneous source technology.

Moreover, it is certainly clear that the separation algorithms being developed today will find use in land acquisition, and could cause a rethinking of how simultaneous sources are deployed on land.

While these are exciting prospects, they represent only the first stage of development. In the future, acquisition systems could be redesigned and optimized for simultaneous source acquisition. In particular, a rethinking of sources would seem to be in order and would likely bear fruit. Going even farther into the blue sky realm, it is clear that this technology is not only about marine acquisition, but relates to acoustic communication theory in general. It has the potential to play a role in acoustics similar to that of the breakthrough wireless communications research pioneered at Bell Labs in the late 1990s.

The demands being placed on geophysics by complex marine environments such as the ultradeepwater Lower Tertiary trend is pushing seismic technology to a tipping point where it is becoming necessary to introduce a paradigm shift in seismic acquisition. The potential benefits of increased acquisition efficiency are of such magnitude that they provide strong incentive for commercializing simultaneous-source technology. Consequently, the time has come for simultaneous sources in geophysics, and the technology can be expected to play a major role in marine surveying in the near future. ❐

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