Cable-free nodes: The next generation land seismic system

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One constant has characterized land seismic acquisition ever since the first crews set out to gather data early in the last century. That constant is challenge. Terrain is often treacherous, weather sometimes harsh and the equipment heavy and cumbersome. Equipment maintenance is another time-consuming task, and the modern-day demand for a small environmental footprint complicates seismic surveys still further. The good news is that concerted effort is being expended among geophysical equipment providers to develop more efficient and lightweight acquisition systems that are easier to deploy, operate, and maintain. The goal is to minimize or eliminate entirely the number of cables necessary to deploy during land acquisition.

Cable-free nodal systems are getting considerable attention for being perhaps the most innovative of all the new systems. In all likelihood, the next generation land system will be a self-contained, cable-free autonomous nodal system.

Seismic data acquisition using cable-free autonomous nodes has already succeeded offshore in deepwater. For example, Fairfield Industries' Z3000 system was used by BP at the Atlantis Field in the Gulf of Mexico. Nine hundred individual nodes were deployed—and later retrieved—in water depths down to 2200 m. A second deepwater Gulf program for Shell has recently completed the acquisition phase. A noteworthy aspect of this deepwater node system is the lack of any mechanical link between acquisition units, which enables it to overcome noise issues common to cable systems. Noise, whether at sea or on land, is even more of a problem today than in the past given the need for superior quality data to adequately evaluate increasingly difficult-to-image reservoirs.

Land exploration today is in a transitional phase similar in scale to that of the 1980s and 1990s when recording methodologies migrated from 2D to 3D. In fact, the industry is undergoing a profound shift from orthogonal line and swath surveys to free-form nodal surveys, replete with the myriad challenges that accompany advances in technology. Present-day acquisition methodology dictates that surveys be designed, systems engineered, and software developed to accommodate grid geometries—parallel lines of equally spaced receivers deployed in geometric arrays alongside another geometric array of parallel lines of equally spaced sources.

This approach works well in theory, but eventually the real world meets the artificial Euclidian geometry of our surveys. At that point we must apply innovative operational techniques and intricate software routines to "correct" the differences between our ideal survey and the real world it encounters. This form of seismic acquisition has evolved into systems that require an analog cable to connect multiple external sensors to an acquisition unit that can amplify, filter, and digitize the acquired analog signal. Additionally, an external cable and (usually) a series of connectors are needed to transfer the analog signals from the external sensors to each acquisition unit. For land seismic, 6 to 12—or more—geophones in a string may be used to create a sensor array (Figure 1). Many systems also require an external cable to subsequently transmit the digitized seismic data to a central recorder. Some systems use this same cable to provide power to the acquisition units.

Figure 1. Geophone string with connectors.

Figure 2. Land seismic acquistion system.

This complex configuration can be daunting for even the most seasoned seismic crew members, who often must spend the better part of a day troubleshooting the cables/connectors and the sensors to resolve varied issues, including leakage and continuity problems. These field components are easily damaged by a variety of sources both natural and cultural, exacerbating the maintenance requirements. When these problems occur, they compromise the efficiency of the survey which, in turn, impacts the bottom line by adding expense beyond the already high cost of the cables and related equipment.

The cables needed by a typical 4000-channel crew with a station spacing of 110 ft (plus 10%) would stretch over 484 000 ft, or 92 miles (Figure 2). This does not include any crossline cables that many 3D systems require. Typically, each end of a spread cable would require a connector to attach it to an acquisition unit, and each string of geophones would require a connector at each takeout. If each acquisition unit acquired six channels of seismic data, over 5300 connectors would be required (not including any needed to attach an external battery to the acquisition units). Additionally, if each string of geophones (4000 total) were 110 ft (plus 10%) in length, then 484 000 ft, or 92 miles, of geophone strings would be required. At least one connector would be required to attach each string to the spread cable takeout. All combined, this entails 184 miles of cable and more than 9300 connectors, which increase weight and reduce reliability of the system.

Another consideration is the up-front costs of the cables, sensors, and connectors along with daily maintenance costs. A typical set of cables, sensors, and connectors ordinarily can be used for five years (at best) before they must be replaced.

The ever-increasing number of recording channels used in seismic surveys is a major driving force in the move away from cables. The average field crew will be recording 30 000 channels in the very near future and likely as many as 250 000 channels by 2025. To deploy these numbers of sensors using cable would be unmanageable.

Currently, a number of minimal cable systems are commercially available from a variety of reputable manufacturers. These newly introduced systems do not require cables to interconnect the individual acquisition modules. In that regard, they are a step forward in the effort to do away with cables. Unfortunately, these systems still require cables to interconnect individual pieces of equipment, such as a battery, to the acquisition module and/or use a cable to connect a sensor (either a string of geophones or a MEMS device). In any case, these external cables and connectors are exposed and therefore susceptible to damage.

Another approach involves developing an autonomous land node. Such a system would be completely self-contained and include the sensor (typically a geophone), batteries, control circuitry, A/D converter, filter, memory and a highly accurate clock. The node would be entirely cable-free. Autonomous nodes would provide far greater flexibility and could be deployed in large numbers even in urban and environmentally sensitive areas, making for a very efficient exploration survey or a high-density production survey.

An extensive, oversampled spread would alleviate concern about waiting to see, or QC, the data upon node retrieval. The quantity of the units can be so great and the technology so reliable that a small percentage of failures would be insignificant to final data quality. The lack of any cables connected to the nodal units will significantly decrease wind and cultural noises that are induced from the cables into the sensors, thus increasing the system's signal-to-noise ratio. A crucial aspect of nodal system operations centers on battery life of the individual units which determines the length of time an individual node may be deployed. Owing to significant advances in electronic systems, both power consumption and size have decreased while functionality has increased and, as a result, system reliability has improved dramatically.

The tedious, usually challenging, process of data acquisition is only a part of the complex effort that characterizes a seismic program. After the acquired data are amplified, digitized and filtered, they must be "harvested" from the acquisition units. The harvested data must be placed onto a transferable type of storage medium (CD, DVD, HDD or other). Data telemetry and data storage are the harvesting techniques currently used.

All major manufacturers have developed systems that use data telemetry to harvest the acquired data. This requires each remote acquisition unit to acquire, digitize, filter, and ultimately transmit these data to a central recorder where they are placed onto the storage medium. This central recorder controls the timing and synchronization operations of the entire data acquisition system.

Each seismic acquisition equipment manufacturer's data telemetry system has its own method for transmitting data, using one of two telemetry modes: real time or reasonable time. Using real-time telemetry, all data acquired during one sample interval must be transmitted from the acquisition units to the central recorder prior to the next sample interval. Depending on the channel count of the survey, the required aggregate data telemetry rate or baud rate may be beyond the capacity of twisted pair copper telemetry cables. For example, a seismic data system acquiring 4000 channels of 24-bit delta sigma data every 2 ms will generate 12 000 bytes of data 500 times per second or 48 000 000 bits every second (48 megabits/second or bps). This data rate is beyond the capability of twisted pair copper cables, but it is within the range of fiber-optic telemetry. It is for this reason that mixed-mode telemetry systems are in use today where the fiber-optic method is typically used at the backbone or "crossing line units" where the amount of data is beyond the capacity of copper cables. Still, real-time telemetry is only a temporary data-transmission solution. Telemetry rates approaching one gigabyte per second will be needed to accommodate the 30 000-plus channel-count systems in the near future; real-time telemetry methodology will be near its limit for systems of that magnitude.

Reasonable-time telemetry uses the time lapse between acquisition records to send the data back to the central recorder. In other words, the data from one record are received by the central recorder while the remote acquisition units are acquiring data from the next record. This transmission system typically uses radio-frequency (RF) telemetry and allows additional time to transmit the acquired data. As a result, the required telemetry rate necessary to transmit data is significantly reduced.

As an example, a seismic system acquiring 4000 channels of 24-bit delta-sigma data for an 8-s record, with one record acquired every 60 s, calls for transmission of 48 000 000 bytes (or 384 000 000 bits) of data. In reasonable-time mode, this requires only a telemetry rate of just 6.4 mega-bps as opposed to 48 mega-bps for the real-time mode. However, this method is also pushing the limits of current RF technology and there is concern that both the real-time and reasonable-time telemetry techniques are rapidly approaching their limits as channel counts escalate.

The limitations of data telemetry have encouraged a number of equipment manufacturers to produce systems that "harvest" the acquired seismic data by means of data storage in the field. Using this approach, the remote acquisition units store the acquired data internally in flash memory, and the data are subsequently retrieved manually during operations.

In theory, this data-harvesting technique can accommodate an unlimited number of channels. Although the number of channels is theoretically unlimited, the user must ensure that a clear RF communication link is established between the recorder and each field unit to enable the recorder to transmit timing, configuration, and start and stop commands to the individual units. Repeaters are necessary in obstructed terrain, and, if a single repeater shuts down, all acquisition units and/or other repeaters that depend on that specific repeater also go down.

Regardless of whether it is real-time telemetry, reasonable-time telemetry, or data storage, battery life within the acquisition units is yet another issue that must be addressed. Depleted batteries must be replaced, which requires trips into the field, thereby adding time and cost to the survey and imposing a larger footprint on the environment.

The solution to overcome the limitations of acquisition systems that require communication between the central recorder and the acquisition units is to remove the requirement. In other words, the solution is a completely autonomous nodal system with exceptional battery life and reliability, i.e., a truly blind system that requires no communication at all between the multiple acquisition units and any central command station and also accommodates "one-stop" deployment and retrieval to eliminate additional visits to the location. Once deployed, the self-contained, cable-free nodes will independently acquire data until each swath, zipper, or patch being recorded is complete. Each node will continuously acquire and store data internally without the need for communication with a central recorder.

Having no need for a central recorder, this next generation land system will consist of remote acquisition units or nodes, a unit deployment pack, source coordinator, data harvester, and data sorter. The system must meet or exceed the analog specifications of current systems and must be capable of remaining in place where initially deployed until the time designated for pickup. To accomplish this, it must be capable of not less than 288 hours, or 12 days, of independent autonomous operation. Using a power-saving mode to switch the nodal units on and off can extend the operational life of the units. A 12-hour-on followed by a 12-hour-off cycle could extend the operational life up to 24 days in place before any need to retrieve the units. Eliminating the need to troubleshoot batteries, cables, and sensors yields more time to actually acquire seismic data and increase production.

The next-generation acquisition system for land must have the highest possible reliability with a failure rate equal to or less than 1.5% during a single deployment (for a 10 000 channel-count system, this would require a reliability rate of less than six unit failures per day). The use of autonomous nodes will provide a cost-effective solution for the high channel-count systems required in the future. TLE

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