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A comparative field trial of a new nimble node and cabled systems in a desert environment

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Summary

BP, in collaboration with Rosneft and Schlumberger, have developed and tested a new nodal system (Manning et al, 2018) designed to enable unlimited channel count acquisition across all land environments, whether for high trace density or large coverage seismic surveys. To achieve these goals, the system offers the smallest and lightest fully autonomous node for land seismic acquisition, barely bigger than a conventional geophone, making it the preferred candidate to replace existing bulky cabled systems. In this field trial we designed and executed several 2D seismic surveys using three commercial cabled systems side-by-side with the new nodal system and carried out rigorous comparisons between the four systems on important aspects of seismic acquisition and processing. Results show that single sensor systems produce better images and offer more flexibility in processing than arrays, and that the new nimble node in particular delivers an indistinguishable trace-to-trace quality from conventional systems without the costly operational constrains imposed by cable systems.

Introduction

Recent changes in the energy industry have tightened the economic constraints on seismic acquisition, especially onshore where we know we need to acquire denser surveys to unlock the subsurface image and attributes (Ourabah et al., 2015). Unfortunately, the cost and time investment to acquire this type of survey has been prohibitive with existing acquisition systems, especially in difficult terrains. This has motivated the development of a new generation of nimble node systems to lift these constraints and make high density surveys a viable option on any terrain, including open desert where high channel count systems have become the state of the art. Although cabled solutions have achieved record survey densities, they have been slow, expensive and bulky. Management of cable equipment has always been a burden on seismic crews, slowing them down and increasing the chance of technical downtime. It is clearly inefficient that crew members spend much of their time transporting bulky equipment (cables & batteries) that do not themselves record seismic data, and although nodal systems have become good candidates to replace these systems, up until recently, they also included significant dead weight such as heavy batteries, bulky casings and were too expensive to achieve a very high channel count. However, the industry has been converging towards a new generation of nodal systems with smaller build and longer battery life (Dean et al., 2018) and recently a new generation of nimble nodes has emerged (Manning et al, 2018) that have the potential to overtake cable systems in terms of equipment size, weight, cost and operational efficiency.

On the road to building this new nimble node system, several field trials were acquired to test and verify the system (Brooks et al, 2018). In this paper we present a rigorous performance test against several existing commercially available cabled systems including important aspects of seismic acquisition and processing.

About the new nodal system

Figure 1 - The new nimble node is light and compact, dramatically improving deployment, retrieval and transportation.

Figure 2 – 1 km of acquisition equipment used for the 2D line layout, from left to right: single sensor cabled system, array cabled system 12 geophones, array cabled system 6 geophones, the new nimble node system at same scale (inset)

The new nimble nodal system is built around a small (13 x 4 cm cylinder), light weight node (150 g) (Figure 1), which can accept an optional spike or base plate. The sensor uses a piezoelectric accelerometer with a flat signature from 0.5 Hz up to its resonance frequency (~180 Hz in this tested version). The node's autonomy is about 30 days and can work in extreme temperatures ranging from -40 C to +60 C. Each node is independent and equipped with GNSS, temperature sensor and an optical communication port. The system is supported by containerized highly mobile 20 ft workshops which can each clean, download and charge ~ 20,000 nodes/day.

The field trial

The location of The System Integration Test (SIT) field trial was in the United Arab Emirates, selected with ADNOC at a location where recent high-density 3D seismic had been acquired to allow further comparison of the results. The charging and harvesting container – then still in a prototype stage – was situated in the base camp and the nodes were transported, deployed and retrieved every day at the survey location about one-hour drive away from the base.

The SIT was conducted in September 2017, with Vibroseis sources and three main receiver layouts: a 12 km 2D line, a very dense (2 m spacing) cross-spread and a box-wave test for noise analysis. The first two tests used the new nimble node system in parallel with three other commercially available cabled systems for comparison: two cabled geophone arrays and one cabled single sensor system, (Figure 2).

Operational results

It took more than a week for the three cabled systems to be laid out and ready to record mainly because of transportation and troubleshooting requirements. The new nodal system on the other hand was deployed in the morning of the acquisition day, with less people and vehicles, and retrieved in the evening to be taken to base camp for downloading and recharging. The seismic data was then combed and correlated in a prototype recording truck situated at the base camp.

Figure 3 - a 3-person crew deploying the new nimble node.

System	Crew Size	Time to deploy 12 km line (hours)	Equipment weight for 12km line (kg)	Truckloads of equipment
New nodes at 6.25m	6 (2 x 3 people)	12	333	1.7
Single sensor cabled at 6.25m	12 (2 x 6 people)	26	4538	11.1
Array Cabled at 25m (12 x 2.08m)	12 (2 x 6 people)	43	7154	19.0
Array Cabled at 25n (6 x 4.16m)	12 (2 x 6 people)	34	5690	12.9

Table 1 - Comparison of operational statistics for deployment of the 12 km 2D line of the 4 acquisition systems tested.

The nimble node system was deployed by 3-person crews using an ergonomically designed backpack that can carry 90 nodes at a time. Figure 3 shows an example of the deployment: the person in front has a rack of 30 nodes and initializes a node every time he reaches a planned receiver station position as indicated on the hand-held tablet; the node is initialised and then handed over to the 2nd person who attaches it to a string while the lead worker moves to the next station. The 3rd person was preparing the hard Sabkha before planting but was not required when the ground was soft as the 2nd person could plant the node directly. As shown in Table 1, the deployment of the new nimble node was very rapid: with half the people, it was twice as fast to deploy than the cabled digital single sensor system, and three times faster to deploy than the cabled system with geophone arrays; retrieval was even faster and less labour intensive than any other system: a two-person crew retrieved 1 km of nodes and string every 20 minutes. The field trial demonstrated the significant advantage this new system provides regarding transporting equipment from the base to the field. Moderate sized pick-up trucks were used to transport line equipment. The cable systems required over 5 times the truckloads used for transporting the new nimble nodes equipment.

Processing results

Coherence analysis of raw traces comparing the new nodal system to adjacent cabled single sensors showed values of at least 0.95 between adjacent sensor pairs in the main seismic bandwidth (Figure 4). Considering minor coupling changes and strong ambient noise from nearby heavy road traffic and quarrying activity, this is viewed as an excellent match. Comparison of the raw shot gathers also showed very small differences making it impossible to distinguish between the two single sensor systems (Figure 5 A&B); this observation remained true throughout the duration of the field trial where the new nodal system performed very well. The raw data comparison with the array cable system was more challenging to evaluate in the field due to the effect of the array and the cabled array geophone response (attenuating frequencies below 10 Hz). However, later in the processing stage, digital array forming was applied to a 2.08 m spaced

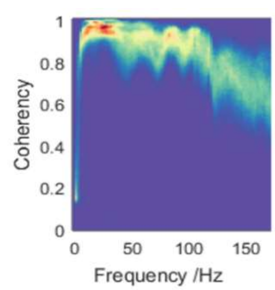

Figure 4 - Coherency vs Frequency of the new nimble node and a single sensor cabled system.

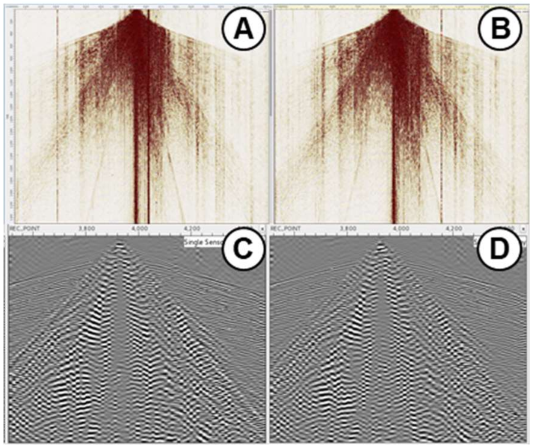

Figure 5 – Shot gathers from: A) new nimble node system (12.5m) B) Cabled single sensor system (12.5m), C) new nimble node system (2.08m) after digital array forming to 25m, D) the 12-geophone array cabled system at 25m.

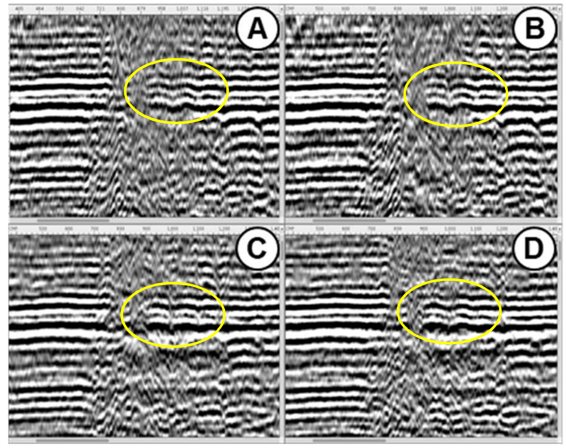

Figure 6 - PSTM images of the 12 km 2D line: A) new nimble node at 6.25 m, B) single sensor cable at 6.25 m, C) 6-geophone array cable at 25 m, D) 12-geophone array cable at 25 m.

dataset from the nimble node system, which matches the 12-geophone cable system with 25 m geophone spacing (2.08 m group-element spacing) and delivered very similar seismic traces (Figure 5 C&D), with the added benefit of keeping the low frequencies thanks to the flat instrument response of the new nimble node.

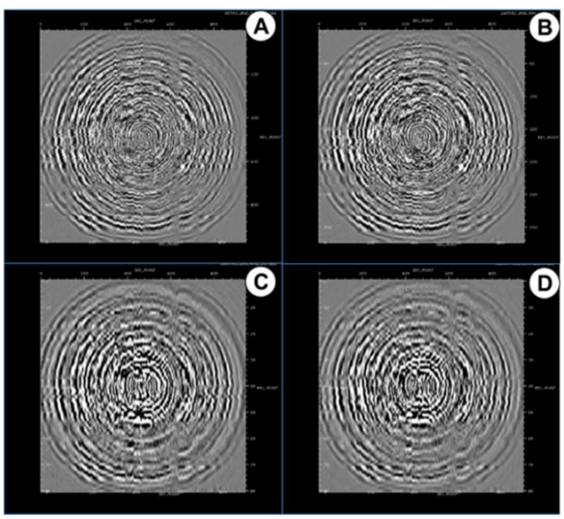

Figure 7 - Time slices from the ultra-dense cross-spread, A) the new nimble node system at 2.08 m, B) the single sensor cabled system at 6.25 m, C) 6-geophone array cabled system at 25 m, D) 12-geophone array cabled system at 25 m.

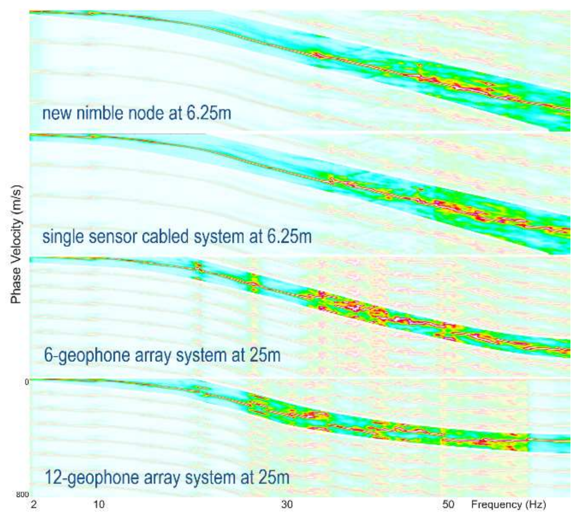

Figure 8 - Dispersion curves used in surface waves inversion (aliased modes masked out). Note the similarity and continuity of the curves on both single sensor systems compared to the discontinuous curves on the array systems.

It is widely-accepted that having access to single sensor traces before array forming offers many opportunities to improve the data in processing, which physical array forming does not allow. This data was later processed by two independent teams using conventional processing sequences and both teams arrived at the same conclusion: the new nimble node system delivered a nearly identical image to the cabled single sensor system and a better image than the array systems with standard processing tools (Figure 6). Throughout the processing work, it was interesting to observe the benefit of single sensor sampling especially for ground-roll removal and linear noise attenuation. Interference noise was particularly bad in the area due to road traffic and an active quarry nearby, but the fine sampling of the receiver space was in this case very useful and proves again the benefit of an affordable high-density acquisition. Time-slices from the cross-spread test clearly show how single sensor systems record the wavefield without modification (Figure 7 A&B) while the arrays attenuate, without discrimination, all events that fall within the targeted frequency/dip (Figure 7 C&D). This effect is also visible on dispersion curves (Figure 8) which are highly valuable to model the near surface.

The coordinates of every receiver station were recorded at deployment by the hand-held device which is connected to a sophisticated positioning system, it was therefore interesting to test the positioning accuracy of the internal node GNSS and see how it compares to the former. The results were very encouraging as a simple median over a number of measurements was sufficient to provide a 1 m accuracy in X and Y directions and 1 to 2 m accuracy in the Z direction (Figure 9). In other words, this system is able to self-position with sufficient accuracy for seismic imaging which offers further opportunities for deployment efficiency as channel counts increase. Note that a small number of nodes planted in wet salty Sabkha had difficulties achieving a GNSS lock; improvements to the node design implemented in the next version as well as a change in planting procedure are expected to improve the reliability of achieving a GNSS lock in such terrain.

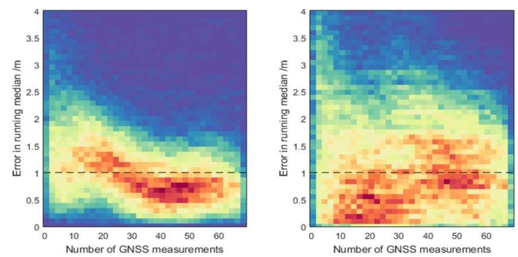

Figure 9 - Left, error in XY (m) vs number of measurements used in calculation. Right, same graph for the Z direction.

Conclusion

This paper reviews the first fully comparative acquisition and processing experiment with a new nimble node system that uses the lightest and smallest node in the industry. The results have shown the benefits of using single sensors instead of arrays and have proven that the single trace recorded by the new nodal system is equivalent to that recorded by commonly used cabled systems with the potential of delivering high-density, wide azimuth surveys in a much more efficient way.
This new nimble node system was designed to fulfill a vison: making high quality seismic safer, simpler and more affordable in any terrain and in any environment. Currently there is a strong demand for such an enabling technology whether it is for ultra-high-density, large coverage or difficult terrain surveys, and is expected to allow the industry to access new areas for exploration or acquire those denser surveys that are not financially viable with existing systems.

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