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Acoustic Positioning Systems

Multi-user Acoustic Positioning in the Deep Waters of Tomorrow

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Abstract

Today the offshore industry requires more from its navigation and positioning technology; demands include more accuracy, unlimited multi users, more integrity, frequency avoidance, more range or depth and more data. With the advent of super fast wireless communications in the home and office, it is often the case that the physical limitations of the environment in which we work underwater is less well understood, especially when you combine the demands for "More" with those of "Less" from the purse holders. This paper will deliver an insight into a technology that is being used by DP Vessels, ROV, AUV, Ships and subsea production hardware to, not only position and navigate underwater, but also too communicate, without the use of cables. The paper will describe the technologies that have been developed and provide details of recent implementations including the “Underwater GPS”.

Introduction

Floating operations utilising DP systems have a long history in using acoustic positioning systems as a primary reference sensor for station keeping. These acoustic positioning systems have traditionally relied on Long Base Line (LBL), Short Base Line (SBL) or Ultra Short Baseline (USBL) methodologies for position calculations. In some systems a combination of these techniques is used. In more recent years the advent of GPS and other above water relative reference sensors have been utilised, this has allowed the user to increased redundancy in the number of reference sensors. Most exploratory drilling vessels still utilise acoustic systems as the primary reference sensor for operations, where as smaller DP vessels have tended towards above water relative sensors to allow for offshore operations nearby the larger assets. The ultra deep water depths encountered in current and planned offshore areas are beginning to stretch the limits of the subsea technologies traditionally used for acoustic position reference. The inclusion of an unlimited user, large coverage area underwater GPS system is an intuitive solution to suit these increasing requirements. This paper will present such a system and summarise the recent trials and how this could be used for DP operations.

Traditional System Technology and Signalling Techniques

When utilizing conventional acoustic technologies, the main variable completely under the control of the designer is the source level of the transmissions. Over the last several years the industry has witnessed a marked increase in the output source level of the signals used in acoustic positioning systems. Beacons with output source levels of 202 dB are common and source levels as high as 214 dB are available. With the move towards the deeper working depths of the industry comes the requirement for longer battery life, yet at the same time an increased power output to meet the power demands outlined above. At such powers it is difficult, if not impossible, to provide the required battery life in a manageable unit. More importantly low transmission spread spectrum signals are significantly more environmentally friendly especially to citations.

There are some additional limitations to using conventional acoustics and these include but are not limited to:

- Limited number of channels resulting in frequency interference
- The inability to work with other systems in close proximity
- Poor immunity to propagation multi-path
- Inability to operate in high noise environments
- High Transmission power requirement
- Inadequate signalling reliability and security
- Lack of capability to operate over long ranges

Appreciating and understanding these issues, Nautronix launched a highly successful, multi-year acoustic development program, which included the development of an acoustic Spread Spectrum signalling technology that effectively minimizes problems encountered in traditional systems. It has been labelled Acoustic Digital Spread Spectrum, or ADS^2.

The improvement in performance has been sufficiently great that Nautronix is applying this technology to a number of new underwater commercial products was launched, as well as implementing a program of change that has lead to all of its commercial acoustic products being based on the improved signalling platform.

In simple terms the technology involves sending a specifically encoded signal which is captured by a receiver fitted with a filter specifically designed to process the coded waveform and to correlate it with the original. By matching the receiver to search for the unique signature, the ability to detect the signal is high and correspondingly, the ability to reject unwanted noise is also high. This means the required transmitted power can be lower than if using conventional technology for the same detection threshold. This also has the added benefit of reducing the source level of acoustic transmissions, hence reducing the noise pollution to the marine environment.

The introduction of this new signalling technology has led to a number of key benefits for acoustic system users and a summary is as follows:

- Allows a number of concurrent channels to co-exist in the same frequency band.
- Improved and simplified spectrum management, with real and significant additions to operational capability
- An ability to work with other systems in close proximity.
- High immunity to propagation multi-path, allowing improved reliability and accuracy.
- Ability to operate reliably in high noise environments including high vessel noise and thruster wash areas.
- Ability to operate reliably over long ranges using significantly lower transmission power, whilst maintaining high accuracy.
- Very secure and reliable signal channel integrity, allowing critical control applications to be implemented.

Subsea Navigation and Positioning

The availability of an underwater GPS (Global Positioning System) like navigation network to the DP operator could solve many of the issues described earlier. In particular it would increase the number and quality of the available sensors. Most offshore DP operations utilize USBL and LBL (Long Base Line) systems which are limited in performance and area coverage based on the signalling technology utilized. As the operations move into deeper water and more vessels are required to work in the same area the benefits of a passive receiver based underwater positioning systems become overwhelming.

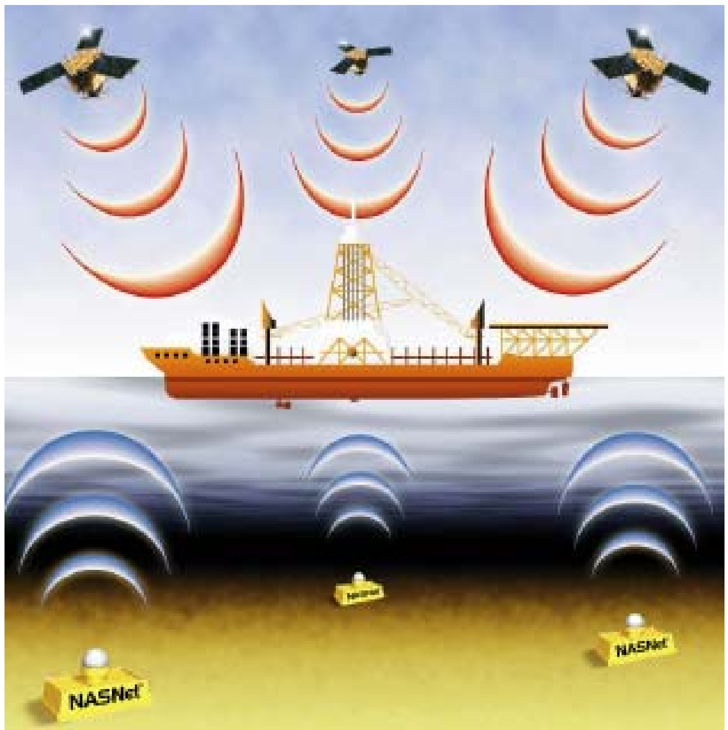

Figure 1 – Underwater GPS

NASNet™ (Nautronix Acoustic Subsea Network) is an implementation of the ADS^2 signalling techniques to provide a highly accurate, global field wide solution that operates under one single continuous coordinate system, and allows unlimited simultaneous users of one positioning service.

The system is designed to allow one grid to be laid, potentially for the life of field, and provides a common positioning service for multiple simultaneous subsea and surface users and operations. Six subsea Stations (transmitters) could provide coverage of up to 100 square kilometres, equivalent to almost four Gulf of Mexico offshore blocks.

In essence, NASNet™ can do for underwater positioning what satellite GPS has done for surface positioning, to provide a stable, long-term, common reference to multiple users simultaneously. This technology promises significant cost savings and overall performance improvements when used as a DP sensor input.

System Trials

The development program of NASNet™ involved rigorous testing and trials operations. This included a 200msw trial conducted 60km offshore Perth, Western Australia in 2003 followed up with a customer funded 2,000msw trial in the Gulf of Mexico in February 2004.

During both these trials the system was proven using a set of live hardware. For the Gulf of Mexico trial a 6 Station suite of equipment was deployed on BP's Green Canyon, Atlantis Field. The Stations were deployed in an average water depth of 2,040msw. During the course of the activity, comparisons were made with proven acoustic systems with no reported interference issues. Comparison of the position solution of the C-Nav GPS and the acoustic solution were logged during Station keeping operations.

The trials were very successful and exceeded the expectations of all parties involved. A summary of the results follows;

- The trials demonstrated the operational viability of the system as an efficient and cost effective acoustic positioning system for deep water operations including DP
- The trials demonstrated that deployment and recovery of the Subsea Stations can be performed in a safe and efficient manner
- The trials demonstrated that the pre-trials planning was an efficient and valuable exercise and the trials activities and processes met the timescales predicted
- Calibration was demonstrated using industry standard and well accepted survey box-in techniques
- The unique split head configuration is viable and the float did not suffer from excessive short term movement
- The network provided accurate and repeatable position solutions, within specification, for both surface and sub-surface users over a much larger area compared to any existing system
- The surface derived position shows that the position coincides with corrected GPS
- The sub-surface derived position provides a favourable comparison to EHF LBL systems
- The acoustic performance was exceptional and remained unaffected by adverse weather conditions during the trials, which required very high thruster activity on the support vessel
- Inter-station baseline measurements proved that the measured baselines were very stable and repeatable with typical standard deviation in the order of 0.04m
- The system remained unaffected by the simultaneous operation of Sonardyne EHF and Konsberg HiPAP systems and remained operational throughout the trials period

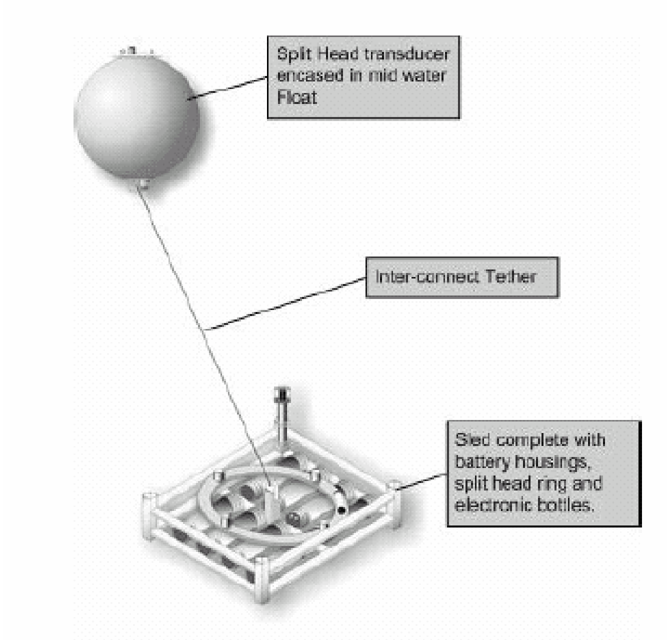

Figure 2 – Station Configuration

Operational Details

During the deep water trials the planned baseline between Stations was calculated to be circa 3,500m (10,000 feet) in length, which is the typical separation for the propagation conditions prevailing, based on the sound velocity profiles provided for the area. The centre of the network was arbitrarily chosen to be 1000 feet from the existing array, allowing all six Stations to be taken into the position solution. Each Station has two transmitters, one on the Station's base the other on the Buoy. The upper transmitter allows for complete acoustic esonification across the seafloor, whilst the base unit is more suited for surface positioning due to the propagation of the acoustic signals. The upper transmitter was set at approximately 100m above the Station.

During deployment the final location of the Stations was adjusted to fit around the existing drill centre, the southerly located Stations were deployed with a baseline of 3,500m, while the more northern locations were reduced to shorter baselines to fit within the nearby escarpment. It should be noted that the arrays deployed and shown might not reflect the maximum range obtainable for each system including NASNet^{TM}.

Calibration of the Stations was done firstly by a conventional 0.3 of water depth box in manoeuvre; however later in the trials a 'Top-Down' box-in calibration was undertaken and from which the trial's results and conclusions were derived. The route undertaken by the vessel during the calibration activity was roughly a figure 8 pattern around all six Stations and it should be noted that the weather conditions were such as to allow free transit manoeuvring, therefore heading, of the vessel during the calibration pattern. The entire top down calibration covered a 30km track and was completed in just over 8 hours.

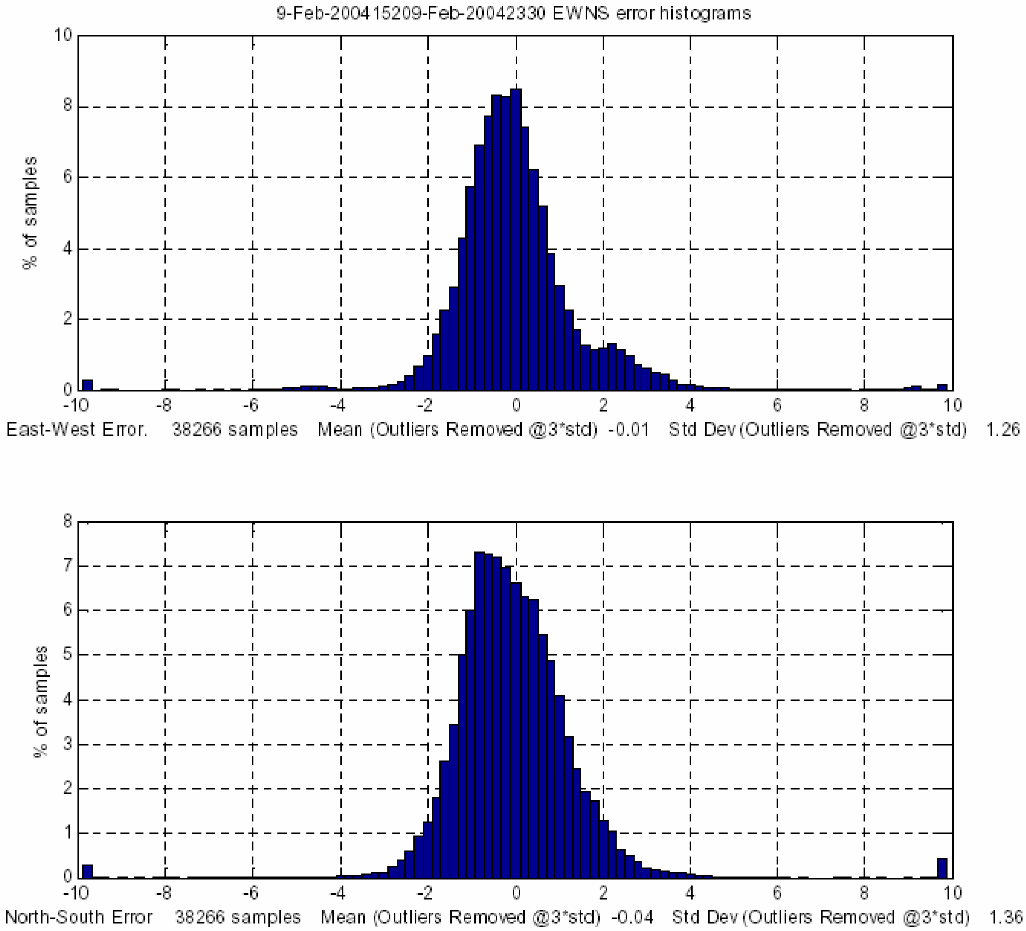

Figure 4 – Surface Position Accuracies

The surface position was analysed and summarised as an East-West (across track) Std Dev 1.26m and North-South (along track) Std Dev 1.36m and shows that over the sample, NASNet™ and GPS virtually coincide, within 1 and 4 centimetres respectively. The associated Standard Deviation of the sample deltas are well inside the expected value of 2.5m. The surface positioning performance of the system is exceptionally good given the, length of the transit both inside and outside of the array, the Pitch and Roll conditions encountered during the track and the significant time over which the data was collected.

Operational Data in Stationary DP Mode

During the deepwater trials data was collected in DP simulation mode, the data of the supplied GPS system and the NASNet™ solution were collected for the same period, each showing a similar distribution of 1m rms. The data in Figure 5 was collected during period in which the vessel was holding station for a prolonged period and shows the raw calculated position from NASNet™. Noting that the below grid is set to 1m , the compactness of the distribution and repeatability of the solution show that the NASNet™ solution is valid as a high quality position reference sensor.

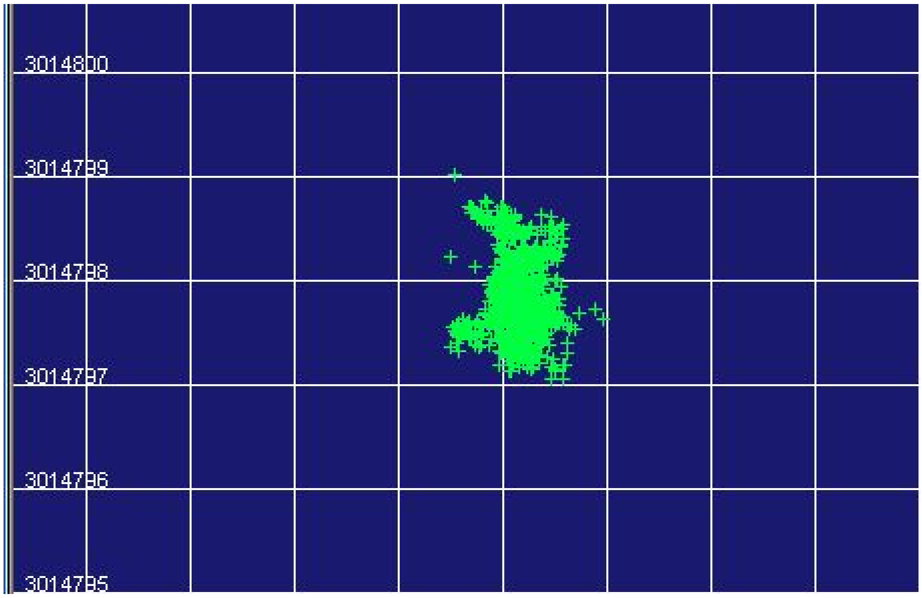

Figure 5 - NASNet™ Data during DP Operations

How does the system operate for DP Operations?

A NASNet array is normally pre-deployed and calibrated in the area of operation and is controlled by the field operator, under a dedicated service and maintenance agreement for the area. This means there is no set up or calibration overhead and the DP vessel can be operational as soon as it is onsite.

To receive the positioning information within the field the DP vessel needs to install a suitable receiver, this is in the form of a hydrophone which is designed to mount on existing standard hydrophone mounts. The output from the system is in standard GGA or GLL format, and can be handled by the DP in a similar way to any other Acoustic system.

Figure 6 NASNet™ Hydrophone

For added redundancy the vessel may be fitted with more than one hydrophone, If separate signal processors were installed the seabed array could provide two independent Position solutions to the DP system, allowing the system to be used on in situations which require for Class 2 operations.

Each time a pulse or LOP (Line of Position) is processed by the surface processor a position update is provided to the DP system. For example if the DP Operator was in a field which had 6 stations deployed, and the stations were set to transmit once every 4 seconds, when receiving all six signals the DP operation would receive 6 updates every 4 seconds. The transmit pulse interval is controlled by the field manager and can be increase or decreased based on operational requirements. If utilising a conventional LBL system in water depths of 3000msw, each update would only be available to the DP operator at best every 4 seconds. The delay in time is largely due to the physical limitation of the speed of sound in water of 1500m/sec, a higher update rate increases the performance of the DP system via having more data available to the DP's filtering algorithms. Higher update rates are obtainable by some LBL system but they invariably involve frequency management issues.

The signals used in the array are similar to used in Mobile (cell) phone operations; the nature of Spread Spectrum signalling allows multiple users to use the same frequency bandwidth at the same time without interference. This can be seen with the common mobile phone in that several people may be talking on the phones as the same time, all using the same Frequency Bandwidth , but each uses a specific encoding which allows each signal to be unique in a digital realm.

The subsea network benefits are best seen when more than one operation is to be conducted in the same area at the same time. Presently if several vessel are using conventional acoustics for individual positioning careful prior planning and knowledge of all the frequencies to be used by each vessel is required. Often this involves the field operator taking an active role in the asset management to allow individual vessel contractors to work. At times vessels may be required to time share even on critical operations.

Some offshore field owners have already seem the cost savings involved in operating and controlling a seabed array, in deepwater offshore fields in Brazil and West Africa. These field have a dedicated array deployed in which each vessel is contractually requested to use it for positioning information when working in that area. This issue reduced the problems of frequency management but doesn't not overcome the issues with large area and multi-user operations.

During the 2000msw trials of the NASNet™ systems, signals were detected well outside the array. As operations move into deeper water, issues of cross interference between vessel working several miles away increase, and the proximity within which vessel can work safely using conventional systems also increases. During the trials no interference was seen by the NASNet system, thus avoiding this situation.

If using a common interrogation shared LBL systems, all the vessels receiving the signals rely on the interrogations of the controller and must be within range of it. This may not be seen as a safe DP operation due to the lack of control and knowledge of the operations onboard that vessel. The NASNet system does not require the network to be polled for operation as each station continues to transmit. The field manager does not need to be present to operate the system, his main task being a monitoring one.

SUMMARY

Acoustic signalling technology has not changed much since its early use as a subsea position reference for DP vessels. Significant demands are now made on underwater operations, in particular developments in ever deeper water. As a result the associated positioning costs are large when using conventional techniques. Nautronix as a manufacturer of Acoustic systems have recognized these increasing demands, and the fact that they cannot be met by traditional acoustic signalling methods.

The performance of DP systems is significantly constrained by the quality of the reference sensor information on which they rely. As DP operations move into deeper water, and the demands put on them increase, the requirement for reliable sensors also increases. DGPS has to some extent solved the problem for a surface position reference, but Subsea references are being stretched to their limits and often beyond them. Some effort has been used in

Through an extensive development program Nautronix have successfully overcome the not insignificant hurdles associated with developing Acoustic Digital Spread Spectrum (ADS^2) signalling for positioning. The result is a suite of acoustic positioning products which are capable of providing significantly increased range, accuracy, reliability, and noise immunity over existing systems.

This paper has shown how 21^{st} century acoustics Positioning, Communication, and Navigation Systems based on new technologies solve the problem of unreliable acoustic systems for use in DP operations. By explaining the limitations of existing acoustic signalling techniques and demonstrating the advantages shown and proven performance of one system using ADS2 signalling to achieve true multi-user positioning, the paper has shown, we are well on our way to meeting the growing demands and challenges of the industry.

References

NASNet™ Deep Water Trials at BP Atlantis in Green Canyon Block GC 743 – Nautronix, Various Authors