# Wideband Signals the Future for Acoustic Positioning

The high accuracy and availability of GPS has enabled the offshore survey community to deliver benefits to customers and fuelled demand for a corresponding improvement in subsea acoustic positioning systems. This paper describes the benefits of Sonardyne Internationalâ€™s implementation of the same Wideband signal processing techniques that are used in GPS and discusses the fundamental difference between GPS measurement processes and acoustic positioning systems. **Narrowband Limitations**
Until recently the majority of acoustic positioning systems used narrowband toneburst signals and analogue signal processing methods which have suffered from weaknesses: a limited number of operating channels, susceptibility to noise and interference, and the trade-off between ranging precision and range of signal propagation. These limitations have become more significant as operâ€“ations in support of the offshore oil & gas industry extend into ever deeper waters and become increasingly dependent upon the reliable performance of acoustic positioning systems. The signal processing techniques used in GPS offer a solution to these limitations and have been incorporated into the design of the latest generation of Sonardyneâ€™s Medium Frequency product range.

**Digital Benefits**

GPS uses encoded signals to meet the system design requirements and provide a secure and robust signal architecture that is fit for military applications. The transmitted signals are encoded by phase modulation and can be described as â€˜Widebandâ€™, as the modulation has the effect of increasing signal bandwidth as compared to a simple narrowband signal. These signals are validated in a receiver using cross-correlation processing whereby received signals are compared with a replica of the required signal in the receiver. This is similar in manner to a door key and lock, where the teeth of the key represent the code; the key will only turn in the lock if all of the teeth correspond with the lock.
Digital signal processing has become ubiquitous in the modern world and is applied in a host of different mass-market applications, from mobile telephony to satellite communications. The adoption of digital signals by the mobile-telephone industry was driven by the market requirement to support more users within each cell using a limited signal bandwidth. Encoding of the carrier signal transmitted by each mast enables support for a far greater number of users, increases signal security and offers increased resistance to noise.

**Wideband Signals**

Sonardyne has introduced Wideband signals and telemetry in its core Long and Ultra Short Baseline (LBL & USBL) products to employ the benefits of digital-signal technology for subsea positioning. Wideband signals effectively resolve the interference problems experienced with the simultaneous use of conventional acoustic positioning systems by offering hundreds of unique, non-interfering operating channels. Correlation signal processing and encoded signals have improved system performance against noise and have been applied in the development of proprietary Wideband telemetry schemes to support much faster and more reliable data transfer.

The vastly increased bandwidth of Sonardyne Wideband signals significantly improves the precision of signal travel time estimates compared to narrowband tonebursts. This enables the same range measurement precision to be achieved using Medium Frequency (MF) signals that was formally obtainable only with Extra-High Frequency (EHF). __Wideband equipment has been deployed on numerous offshore construction projects since it was first used operationally on the Ormen Lange project in August 2005. The benefits of operating with Wideband signals have been demonstrated and proven in applications ranging from the calibration of field-wide transponder networks to manifold, template and flowline installations and spool-piece metrology.

**â€˜Underwater GPSâ€™**

The position computation in both GPS and LBL employs the distances between a mobile unit and a number of control stations (in the case of GPS, satellites) derived from signal travel time and an estimate of the speed of signal propagation. The accuracy of GPS is due to both the digital signal architecture employed in the system and the relatively predictable manner in which these signals propagate through the atmosphere. However, the underwater environment provides a considerably less predictable propagation medium than the atmosphere and represents significant challenges for the designers of acoustic positioning systems. The propagation speed of electromagnetic signals in the atmosphere is 200,000 times faster than that of acoustic signals in water and can be considered as constant for a given frequency. By contrast, the speed of sound in seawater can vary by up to 3% and the processes that result in changes in sound speed, particularly in deep water where there are significant practical difficulties in the accurate measurement of sound speed, are poorly understood and not easily modelled.

**Range Errors**

The factors affecting the accuracy of range determination and hence posâ€“itional accuracy using acoustic observations with LBL positioning systems are: receiver clock error, signal to noise ratio, bandwidth and error in the determination of the mean speed of sound along the signal travel path. Receiver clock error in Sonardyneâ€™s latest generation of LBL transponder, Compatt 5, is generally less than ten parts per million and is therefore not significant over the ranges typically measured for high accuracy work. The signal-to-noise ratio is largely scenario-based and determined by the energy of the signal at source, absorption, spreading losses and noise at the receiver. Bandwidth then becomes the principal variable parameter affecting precision. In a Wideband System it is possible to use carrier signals in the medium-frequency band to minimise signal absorption and still retain bandwidth, precision and a large number of operating channels.

This error generally dominates for observations over a range of two to three hundred metres. A typical CTD probe can be employed to determine sound speed with an accuracy of approximately 0.5m/s, which equates to an error of 1m over 3km not consistent with sub-metre accuracy position computation. The latest generation of direct reading sound speed sensors offer increased measurement accuracy but remain point-measurement devices that cannot reliably determine the mean sound speed along the signal travel path. The effective management of sound speed error in an LBL system requires appropriate array planning and data-processing methods that are consistent with the required positional accuracy.

## Validating Accuracy

Introduced in the early 1990s, the Sonardyne Mk4 Extra High Frequency (EHF) Compatt transponder became a primary tool for subsea construction and survey. It supported a ranging accuracy of better than 5cm in quiet conditions, which enabled the completion of the most demanding of subsea engineering tasks, such as spool-piece metrology, which requires highly accurate and reliable distance measurement over short ranges. However, in common with other systems using tonebursts, Mk4 EHF signals were subject to fade and significantly degraded by noise and interference. The use of EHF equipment is also compromised in water depths of greater than 1,000m by the limited range of propagation of high-frequency signals, which precludes control and calibration of seabed transponders and utilisation of vessel-based MF systems. If Wideband systems could achieve similar results in the MF band it would offer significant advantages by removing the requirement to use EHF equipment for high-accuracy operations.
In order to confirm the accuracy of MF Compatt 5 using Wideband signals, a controlled trial was conducted in a dry dock in May 2006. The distances derived from acoustic measurements were validated through comparison with highly accurate dimensional control survey results. To ensure redundancy and evaluate the performance of multiple units, four standard Compatt 5 transponders were deployed on the bed of the dock, mounted in rigid positions in tripods bolted onto substantial wood and steel â€˜dock basesâ€™ as pictured in Figure 2. A deployment plan was devised to Compatt positions to provide baselines between pairs of Compatts that varied from ten to thirty metres in length and would reduce the impact of reflected signals in the highly reverberant environment of the flooded dock.

Controlling the systematic range-dependent error due to error in the speed of sound was critical to the success of the trial. Two calibrated Valeport 50mm mini SVS sound-speed sensors were cable-connected to two of the Compatts in the dock to measure the speed of sound directly at transducer depth to the highest possible accuracy. The Compatts provided the SVS units with power and also enabled the recovery of data via acoustic telemetry. The theoretical measurement accuracy for the mini SVS sensor quoted by Valeport is Â±0.06m/s, which equates to an error of a millimetre over a range of 30m. The speed of sound was observed at regular intervals throughout the collection of acoustic observations.
An independent company was commissioned to determine the precise relative positions of the Compatt transducers both before flooding of the dock and after de-watering, through dimensional control surveys. These surveys were completed using a recently calibrated Leica TCRA 1102 Plus Total Station, a 1-second instrument with a ranging accuracy of +/-2mm. The results are presented in the Table and confirmed that difference in range determined by the dimensional control survey and derived from repeated acoustic observations using Wideband signals in the MF band was within the quoted accuracy for Compatt 5: 3cm.

## Concluding Remarks

The cost of installing equipment on the seabed in deep water requires the optimal deployment of transponders for LBL positioning. In devising the maximum range to be observed a trade-off must be reached between ranging accuracy and coverage for a given number of transponders. The laws of physics remain unchanged and the effect of sound-speed error will apply to any acoustic positioning system, regardless of signal architecture or processing technique. Wideband equipment enables ranging accurâ€“acies previously achievable only with EHF using standard MF Compatts. Achieving these results requires appropriate procedures and instrumentation to control bias due to error in the speed of sound used to determine range from acoustic travel time. Sonardyne Compatts can optionally be instrumented with direct-reading sound-speed sensors integrated within the sensor endcap to support the most accurate measurement solution.

The conduct of offshore oil & gas exploration and production operations in ever deeper water depths places an increased reliance on the use of acoustic positioning systems. The development of Wideband transponders and transceivers operating in the Medium Frequency band has significantly enhanced the performance of Sonardyneâ€™s USBL and LBL systems to increase efficiency and reduce risk in subsea positioning operations:
- the hundreds of non-interfering signals supported by Wideband systems simplify frequency management and the simultaneous operations of acoustic systems by different vessels within interference range
- the improved resistance of Wideband signals and telemetry to noise and interference increases the speed and reliability of acoustic positioning operations.

Positional accuracies required for subsea construction generally require the use of LBL in water depths in excess of 1,000m, where errors associated with vessel-based acoustic positioning systems typically exceed the required positional tolerances. The engineering challenges that typify deepwater operations, imposed by more rugged seabed topography and diver-less operations, have in many cases reduced positional and measurement tolerances. Wideband signal architectures have enabled the development of appropriate acoustic positioning systems to support these new challenges.