DYNAMIC POSITIONING CONFERENCE
October 14-15, 2014

SENSORS SESSION

Moving Towards a Standardized Interface for Acoustic Inertial Reference Systems

By Mark Carter

DP and Drilling Manager, Sonardyne International Ltd

Sonardyne International Ltd

Return to Session Directory

Abstract

Modern tightly integrated acoustic-inertial position reference systems (PRS) now achieve GNSS levels of performance due to the integration of digital acoustic measurements and inertial navigation (INS) and have better accuracy, availability and integrity than ever before.

The full potential of these technological improvements to reduce vessel downtime and position measurement equipment (PME) related incidents have, in some cases, been hindered by limitations of legacy interfaces to the DP control system the majority of which date from the 1980's

This paper firstly examines the limitations of existing DP telegrams used by reference systems and then proposes updated telegram requirements that exploit the full potential of new technology such as inertial navigation systems. The paper then goes on to propose a standard for acoustic PME equipment installation considering the correct installation and integration of the deployment machine, inertial and acoustic sensors to maximize robustness.

To conclude, the benefits of an "open architecture" for PME integration using standardized interfaces is discussed and how the benefits of adopting such a standard will allow acoustic PMEs to operate to their full potential with any DP system (DPS) improving the integrity of DP operations irrespective of DP vessel type, configuration and operation.

Introduction

Our ability to reliably position an offshore vessel has improved significantly over recent years due to advancements in the fields of acoustics, inertial navigation and GNSS. As an example of a state of the art position reference system (PRS), the latest Sonardyne Marksman DP-INS acoustic inertial position reference is shown below in Figure 1.

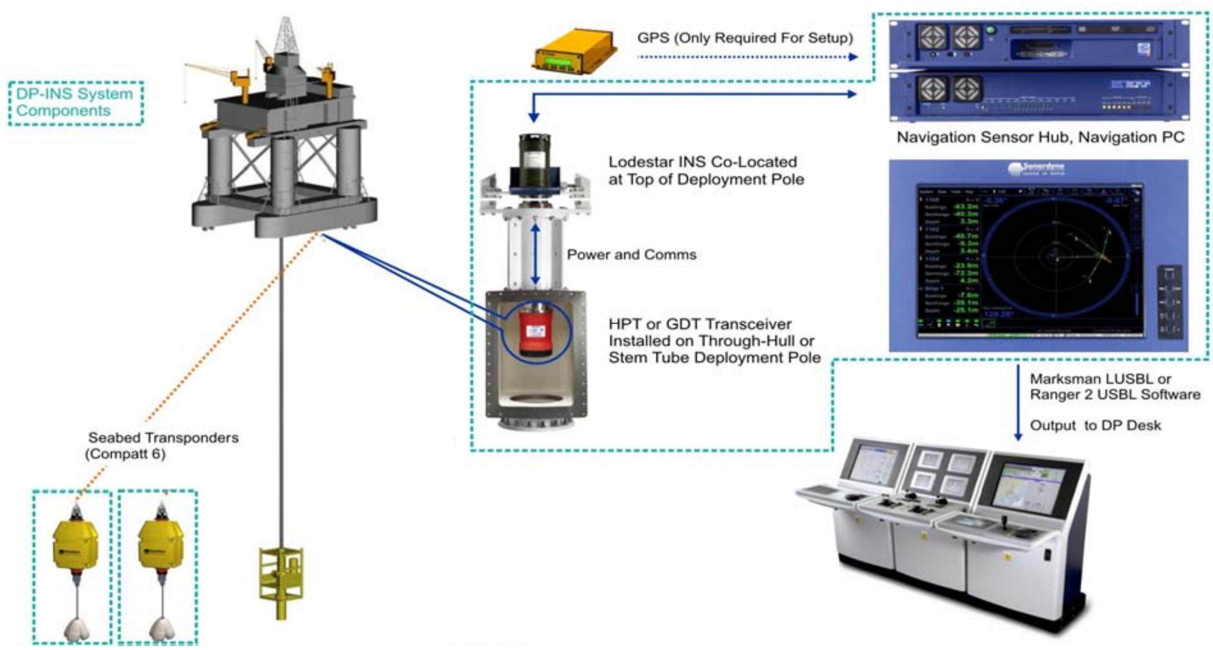

Figure 1 : Marksman DP-INS

At the heart of the Marksman DP-INS system is a tightly integrated acoustic-inertial navigation system that provides accuracy, update rate, robustness and hence DP weighting that is on par with state-of-the-art GNSS (GPS) when operating within a conventional array of transponders. This increased performance can also be used to reduce the number of transponders and the acoustic update rate. This extends the battery life of seabed equipment and reduces operational cost by saving vessel time [1].

The HPT acoustic transceiver and seabed transponders in Figure 1 represents the latest in acoustic positioning performance. Acoustic positioning systems are now more reliable than ever before due to Sonardyne's 6th Generation (6G) hardware and Wideband 2 signal processing that offers increased resilience to noise and multipath combined with greater positioning precision.

The advantages offered by systems such as Marksman DP-INS are evident on numerous vessels world-wide ranging from survey construction vessels such as the Oceaneering Ocean Intervention II to the latest generation drill ships such as Vantage Drilling's Tungsten Explorer where Marksman DP-INS has been operational for some time and results have been widely reported at previous DP Conferences [1],[2]. However, the full potential of these technological improvements to reduce vessel downtime and position measurement equipment (PME) related incidents are, in some cases, not fully realised. Performance can sometimes be limited by the interaction between the PRS and its environment with factors such as poor installation, out-dated DP telegrams and human factors such ease of use compromising performance.

This paper explores the effect of these external interactions and interfaces acting on an acoustic reference system using real-world experiences gained from operational use Marksman DP-INS. The key interface requirements are identified that will allow state of the art performance to be realised on all vessels regardless of DP manufacturer, type and operation.

Acoustic reference system interfaces

The key external interactions and interfaces with Marksman DP-INS are shown below in Figure 2 and some key interface requirements to extract maximum performance listed.

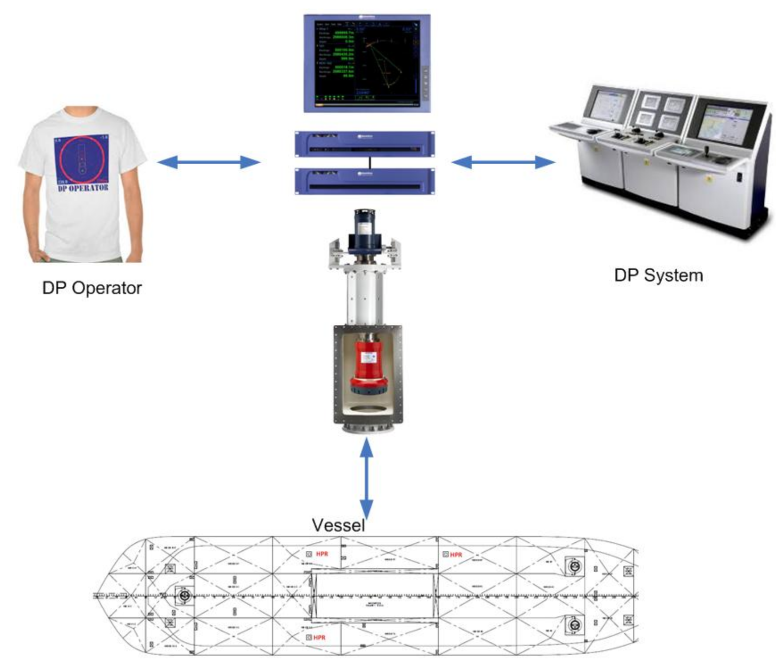

Figure 2: Key interfaces to Marksman DP-INS

1) **DP System interface.**
DP telegrams sent from the PRS to the DP system need to be capable of communicating position and error information to adequate resolution and support additional parameters that confirm the integrity of the reported position and error information. Some legacy telegrams are barely adequate for the latest acoustic inertial systems

2) **The Human Machine Interface (HMI)**
HMIs need to be intuitive, presenting critical information clearly and concisely in a familiar format. As technical complexity increases it is important to maintain ease of use

3) **The interface between equipment and vessel**
The vessel interface includes correct equipment installation and calibration and use or appropriate external sensors where appropriate. Control of deployment poles and gate valves needs to be flexible across manufacturers.

DP System Interface

Due to the number of Marksman DP-INS retrofits and upgrades, installations need to be compatible with existing DP telegrams. Kongsberg's HPR418BCD and various other legacy proprietary NMEA style strings are commonly used by DP vessels for the transfer of data from the DP-INS to the DPS.

The legacy telegrams support at least position information and some indication of accuracy and can therefore be populated with the DP-INS positon information making the integration fairly straightforward. However, when using legacy telegrams with Marksman DP-INS, great care needs to be taken with the setup to make sure the integrity is not lost as the old strings don't support all the available DP-INS metrics.

An example of where problems with legacy telegrams can arise is shown in Figure 3 using data from a deep water drillship operating in benign conditions. Due to the precision of the Marksman DP-INS system the reported position in the telegram is only changing by +/- 1cm for 20 seconds. This can trigger “Freeze alarms” in some DP systems due to a legacy failure mode which was intended to protect the DP against a failed PRS outputting frozen data, but are now being falsely triggered. As a result, some DP systems need to be reconfigured to expect the higher precision and update rate of an inertial reference system and simply adopting a legacy telegram can cause problems.

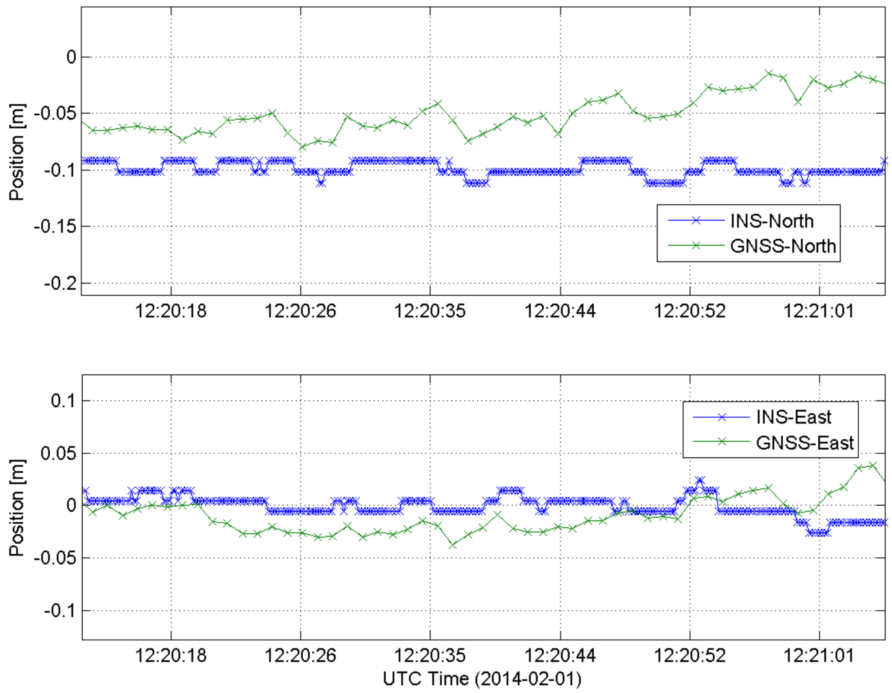

Figure 3 : Simply adopting legacy interfaces can cause "freeze alarms" in some DP systems due to the different characteristics of INS data

Accuracy

Accuracy is the most commonly used term to measure navigation system performance and is the easiest to understand. It is a measure of the error in position or the deviation of the reported position from the true position. However, real-time positioning systems have no knowledge of the true position so accuracy is reported as a statistical quantity associated with the distribution of the position error. This is more correctly termed "precision" but the terms are often used interchangeably in DP. Various terms are used to express the accuracy, each with a confidence level. Marksman DP-INS reports a one dimensional root mean square error (1DRMS) or radial error at the 68% confidence level.

Figure 4 shows data from a deep water drillship operating in Asia in 1100m water depth and the typical accuracy achieved over a 30 minute sample period. The top chart shows the DP_INS position of the vessel compared to the GNSS. The lower chart shows the difference between the positions and also the computed 1 DRMS of the DP-INS with respect to the GNSS. It can be seen from the 1DRMS (bright green) that an accuracy of approximately 20 cm is achievable compared to a Precise Point Position (PPP) GNSS solution that has been taken as "truth". The enlarged portion of Figure 4 shows close correlation between the independent Marksman DP-INS and GNSS solutions.

These results highlight the precision, accuracy and update rates achievable from Marksman DP-INS and the resulting resolution needed for DP telegrams to support these parameters in full when sending data to the DP system if performance is to be maintained.

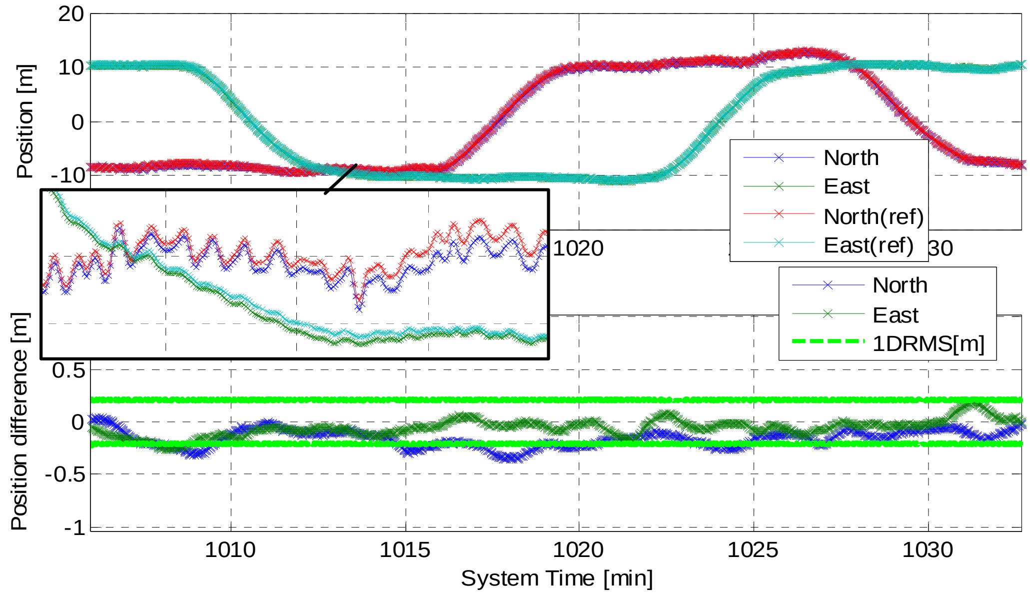

Figure 4 : Telegrams need to reflect the accuracy and Precision of systems such as Marksman DP-INS

As well as supporting typical conditions such as those in Figure 4 the DP telegram needs to support parameters needed for more challenging operational conditions and cope with failure modes such as loss of aiding data to the INS.

It is well-known that an inertial navigation solution will drift with time unless it is constrained by aiding data [2]. In the event of loss of aiding data the reported 1DRMS error will increase with time even though the precision over a few seconds will remain very good. For this reason, it is important that the DP systems make use of the reported position error rather than internally computing the error from position alone with limited hysteresis. It is also helpful if the DP system has knowledge of the aiding source (L/USBL / GPS / None) and time since the last valid aiding update was received. A telegram supporting these additional parameters allows the DP manufacturer to implement logic to stop using an INS based solution after INS aiding is lost for a period of time and display appropriate alarms to the DP operator.
Legacy telegrams designed before the introduction of INS offshore do not support these parameters so the same logic has been implemented in Marksman DP INS as shown by the alarms display in Figure 5.

Figure 5 : Alarms reporting loss of aiding and exceeding error thresholds

Although this approach is functional, improved ease of use as well as better engineering design (avoid cascading alarms) results if the DP telegram contains enough information for the logic in Figure 5 to be implemented in the DP system. The DP could then gradually reduce the weight given to the inertial position as the reported 1 DRMS increased, rather than applying full weight to the data up to the point that it is rejected.

Beyond Accuracy

Although accuracy is easy to understand it has some limitations as a metric for measuring navigation system performance in a DP context. In deep water a position accuracy of a few meters is often acceptable (based, for example, on riser angle tolerances) and the latest Marksman DP-INS systems are well within the accuracy requirements of today's specifications of typically between 0.2% and 0.5% water depth.

A second metric, as important to mission critical applications but often ignored, is the integrity of the navigation solution. Integrity relates to the level of trust that can be placed in the reported position and position error. If the reported error is less than the actual error then it can be said that there is a loss of integrity as the PRS is reporting misleading information. Maintaining integrity is key to the correct functioning of a PRS and DP system and has been at the forefront of the Marksman DP-INS design philosophy since day one.

Firstly, the 1DRMS error estimates associated with the position information reported by Marksman DP-INS are intentionally conservative. As can be seen in Figure 6, the 63rd percentile 1DRMS reported error (bright green line) is actually closer to the peak error when compared to a GNSS "truth" than the 63rd percentile.

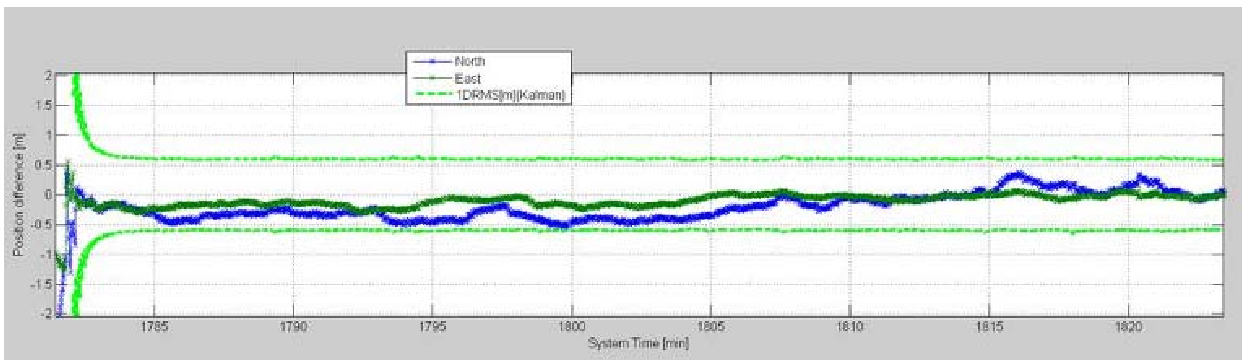

Figure 6 : Conservative error estimates ensures integrity

In order to maintain these conservative error estimates and therefore the integrity of the Marksman DP-INS solution it is important to correctly configure the Marksman DP-INS system by deploying enough transponders considering the criticality of the application and maintain an appropriate acoustic update rate. For example at least 3 seabed transponders are recommended with an acoustic update rate of at least 12 seconds to ensure integrity during drilling operations [1].

Secondly, Marksman has its own, inbuilt, integrity monitoring. One of the unique advantages of the Lodestar INS is the independent attitude, heading reference system (AHRS) and INS algorithms running in parallel within the unit. Both of these algorithms compute pitch, roll, heading, with the AHRS algorithm being extremely robust and immune to bias that can be introduced by external aiding sources. The difference between the two pitch, roll, heading calculations are continuously monitored in real time and any divergence is a potential indication of loss of integrity. A further check is the on-going monitoring of the gyro and accelerometer biases. Bias estimates that exceed fixed thresholds based on the gyro manufacturer's technical specifications could potentially indicate a loss of integrity or a hardware fault. The internal integrity monitoring can be viewed on the detailed diagnostic pages in some system variants as shown in Figure 7.

Alarms are automatically raised in the system where integrity is lost. Communicating loss of integrity to the DP system is another important parameter to be included in the DP telegram so that appropriate action can be taken.

Figure 7 : Marksman DP-INS Internal integrity monitoring

High Integrity DP telegrams

The accuracy and integrity parameters discussed so far that need to be transmitted in a high integrity DP telegram are summarized in Table 1. The additional parameters needed for optimum performance are highlighted. This information is at an architectural level and further work is needed with DP manufacturers to fully define this interface.

	Existing Telegram	High integrity telegram	Comment
Header	Y	Y	
Time	Y	Y	
Target ID	Y	Y	
Integrity	N	Y	PRS can flag loss of integrity
Last aided	N	Y	Time since last acoustic update
Position	Y	Y	Resolution to reflect precision of latest systems
Position error	Y	Y	Used by the DP system to weight inputs
Depth	Y	Y	
Speed	N	Y	Speed information can refine control
Speed error	N	Y	

Pitch	Y	Y	
Roll	Y	Y	
Heading	Y	Y	
Aiding source	N	Y	Check for unaided INS

Table 1: Definition of a basic high integrity DP telegram

Human Machine interface

The second interface defined in Figure 2 is the Human Machine Interface (HMI). The Marksman HMI has been designed to be easy to use with features such as “traffic light” status indicators for all connected sensors, concise displays for critical text and graphical information and intuitive icons to make configuration menus accessible. As a result the Marksman DP-INS native user interface is usually the primary HMI for system operation and needs to remain to meet some class society rules.

However, considering Marksman DP-INS is designed to operate with all DP systems including, but not limited to GE, Kongsberg, Rolls Royce, MT and L3, some flexibility is needed to present information in the individual style of the DP manufactures HMI.

A remote control interface is available to all DP manufacturers to control key Marksman DP-INS functions using client software over a standard encoded interface. It is also possible to provide status information over and above what is included in the DP telegram for display in the DP manufacturer HMI in accordance with individual styles and themes. An example is shown in Figure 8 of how critical parameters can be displayed in the DP manufactures HMI style.

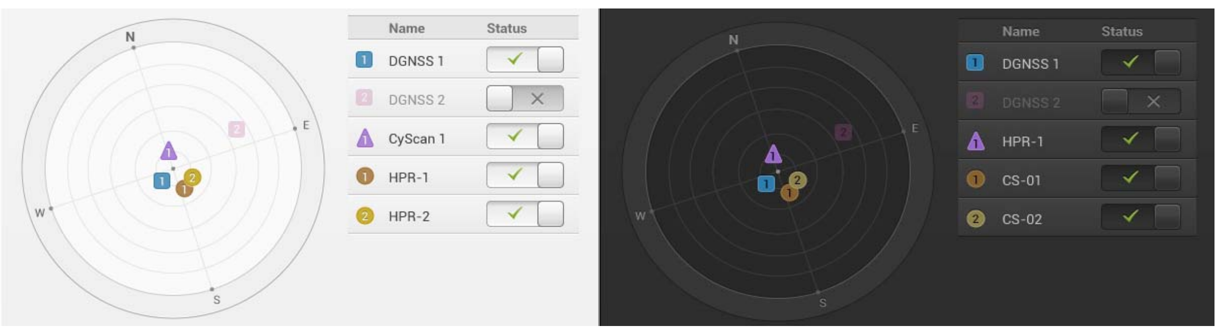

Figure 8: Critical parameters displayed in the DP manufacturers HMI for ease of use

The result is improved ease of use with all critical information displayed in the DP desk and a common “look and feel” to the user interface. This will help minimise the risk of incidents as a result of a lack of familiarity with the Marksman DP-INS system and through critical information being displayed in different places.

Vessel Interface considerations

As the accuracy of Marksman DP-INS and other PRS improves, greater attention needs to be given to the third interface in Figure 2, between the PRS and the vessel.

The significance of the inertial and acoustic systems experiencing the same dynamic motion has already been discussed [1] along with the recommendation that the Lodestar INS and USBL transceiver should be co-located on the same deployment pole, rigidly mounted to the vessel.

The result of a trial that highlights the importance of this is summarized in Figure 9. The figure compares the pitch and roll measured by a Lodestar on the bridge and a Lodestar co-located with the transceiver over a 1 minute period during a vessel maneuver. When thruster wash from a thruster 50m away is directed towards the transceiver, pole movement in pitch and roll is observed. The pole resonates in the roll axis at around 2Hz and exhibits a bias of up to 0.3 degrees in pitch which equates to 15m of position error in 3000m of water.

Persistent biases such as this can be difficult to detect and will degrade the Marksman DP-INS performance.

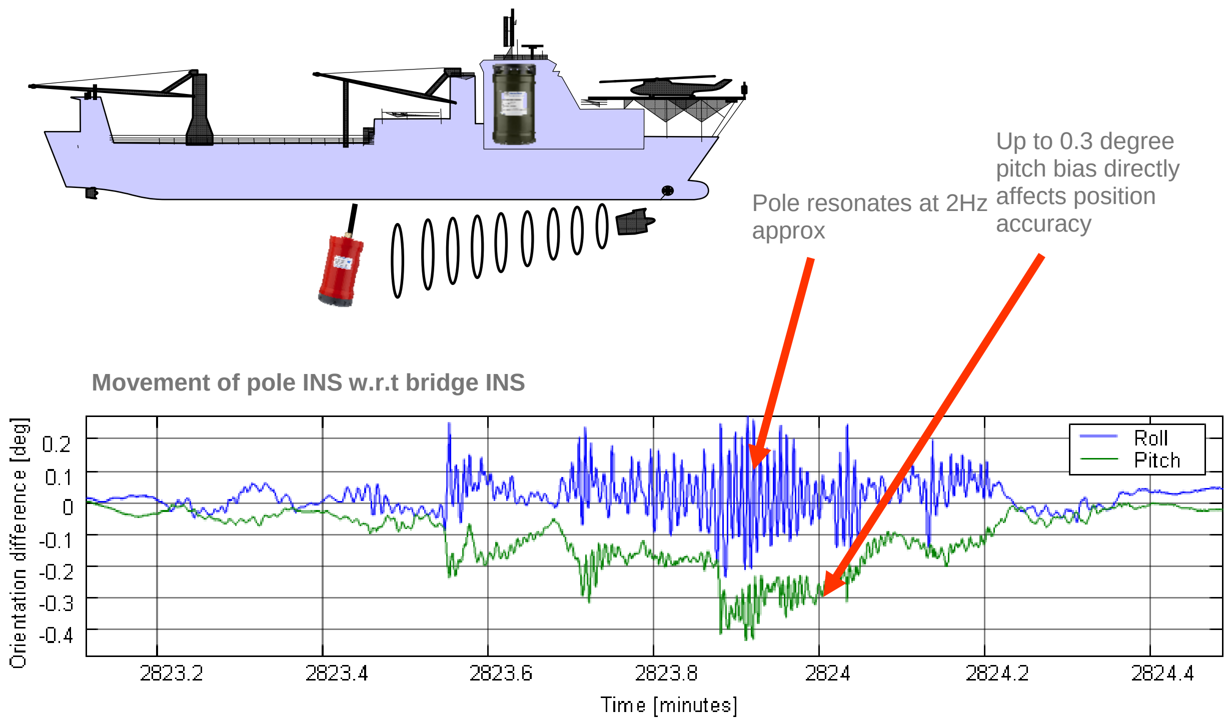

Figure 9: Movement of pole w.r.t. Bridge INS

In addition to the correct installation of the INS on the deployment pole, flexibility is required across manufacturers to easily control deployment machines and gate valves using standard control panels that are independent from manufacturer specific software. Figure 10 below highlights the limitations of using 3rd party deployment poles with proprietary control. The additional bridge software and transceiver unit, both highlighted in yellow, are purely for control of the deployment pole and gate valve and are taking up valuable space as well as adding complexity for the user. This increases the risk of damage to equipment or poor performance due to incorrect pole deployment.

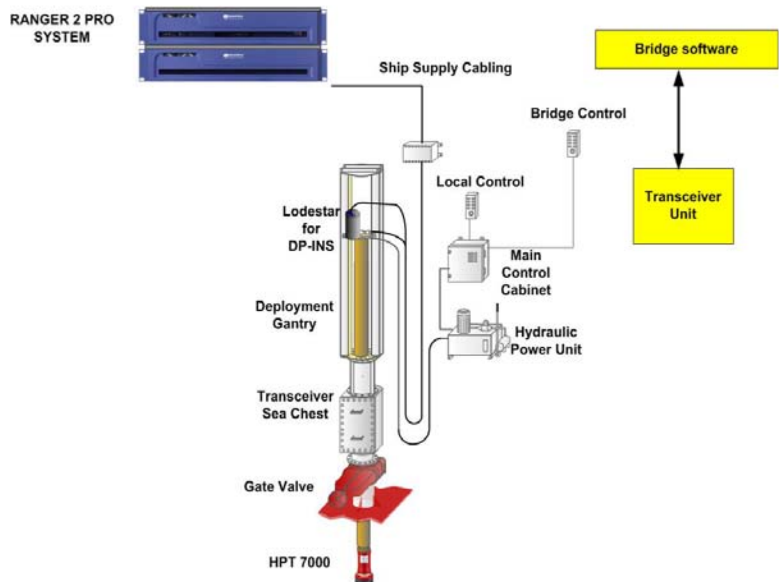

Figure 10 : Complexity of using 3rd party deployment poles with proprietary control

Conclusion

The move to a tightly coupled acoustic inertial integration in Marksman DP-INS has resulted in GNSS levels of accuracy with only three seabed transponders [1]. Marksman DP-INS also has inbuilt monitoring to identify a loss of integrity. The full potential of these technological improvements to reduce vessel downtime and position reference system related incidents can be fully realized if the interfaces to and from the PRS are carefully considered.

1) The electrical connection to the DP system (DP telegram) needs to be a high integrity telegram that includes the position error, aiding source, time since last aiding and integrity parameters. The DP systems can then use these parameters to appropriately weight the position information and raise alarms if accuracy degrades or integrity is compromised.

2) The Human Machine Interface to Marksman DP-INS has been designed around ease of use but due to the need to integrate with all DP manufacturers systems, remote control and display functions can be utilized to improve the user interface by providing a common look and feel and compatibility with other user interface styles and themes.

3) The interface between the PRS and the vessel needs increasing care as errors due to pole movement, vessel flexure and offset measurement errors can easily be a large contributor to the overall error budget considering the accuracy of the Marksman DP-INS system. Standard interfaces to control deployment machines and gate valves will reduce installation and operational risk where 3rd party poles are used.

Standardization in these areas will result in the maximum performance being extracted from every installation regardless of vessel type, operation or DP system manufacturer.

References

[1] Tightly Integrated Second Generation Acoustic-Inertial Position Reference System - Deep Water Operational Results, Mikael Bliksted Larsen, Sonardyne International Ltd, 2013

[2] DP INS – A Paradigm Shift, Mark Carter, Sonardyne International Ltd, 2011