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SENSORS SESSION

Why choosing an acoustically aided INS is not just a tick box exercise

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Abstract

Choosing the correct aided Inertial Navigation System (INS) architecture is important if all the operational benefits of this technology are to be fully realized. Various manufacturers use different terminology and interpretations resulting in a limited appreciation of the technical details outside of the DP community. Fitting INS can become a “tick-box” exercise resulting in potential for compromised implementation and poor quality or even hazardously misleading station keeping information being supplied to the DP desk. This can have a knock-on effect with the expected operational benefits not being realised, and unnecessary cost and delays incurred instead.

In a true tightly integrated system the INS has full access to all the raw acoustic measurements and associated low level quality metrics in their native format with effectively perfect timing. This allows a much more precise and optimal use of the available information which adds significant fault tolerance, particularly in challenging acoustic conditions, where good, useable acoustic observations can easily be identified, and poor signals rejected.

This paper will clearly explain the system architecture behind true “tight coupling” using terminology independently established across other domains and applied to DP with reference to the MTS “7-pillars” design philosophy.

The lessons learned from real world examples of sub-optimal implementations will be discussed in terms of station keeping integrity and operational efficiency. New autonomous integrity monitoring techniques will be discussed which will make it easier for the end user and operator to identify a poorly configured aided INS system.

Introduction

To avoid a tick box exercise, it is important to define why an inertial position reference is being specified, and what the operational objectives are so that the appropriate system can be selected, and meaningful tests can be defined to demonstrate the requirement has been met.

Reasons for installing inertial navigation might include: to add resilience against temporary loss of data from an existing PME, to add better detection of measurement errors, to increase weighting of an acoustic reference in the Dynamic Positioning System (DPS), or to reduce operation expenditure of running a PME.

DP tests should be designed to quantify the benefit that is actually delivered so that the effect of any change in configuration can be measured.

Choosing the correct INS architecture is important if the operational benefits listed above are to be fully realized. The first generation of acoustic-inertial systems were loosely integrated. The INS would in principle simply be inserted between the acoustic positioning system and the DP desk in order to reduce noise, increase update rate and bridge brief gaps in acoustic positioning. The performance depended not only on the position being generated by the acoustic system, but also it depended largely on whether the telegram being used by the acoustic system supplied reliable quality metrics for use in weighting the data within the INS.

Terminology

The correct terminology can be taken from [1] section 6.4, where definitions are included to foster consistency in understanding and application:

Loosely Coupled

The "Position" output from the GNSS or Acoustic system is used to aid, or couple with the INS. A loosely coupled system will reduce noise (USBL smoothing), increase update rate (LBL-INS) and bridge brief gaps in positioning. The performance depends on the GNSS or Acoustic system's ability to compute both a position and reliable quality metrics for use in weighting within the combined solution.

Tightly Coupled

Tight coupling is a term used to describe systems where the raw GNSS or raw Acoustic observations are used to aid, or couple with the INS. With this level of coupling the integrated solution has full access to the associated low level quality metrics from the specific PRS in their native format and with effectively perfect timing. Tightly coupled solutions are less impacted by the degradation of GNSS or Acoustic systems as the combined solution is not dependent on a standalone position.

Table 1 below details the tight and loosely coupled measurement types for common sensor types based on the definitions above.

Sensor type	***Loosely Coupled***	***Tightly Coupled***
GNSS	*GNSS geographical position*	*Ephemeris and Pseudo range data*
Acoustic	*Relative Cartesian (XYZ) or polar (r,φ,λ) position*	*Range, bearing and vertical angle*
Velocity log	*Velocity XYZ*	*Individual beam level velocity*

Table 1: Tight and loosely coupled measurement types.

Tightly coupled acoustic inertial data

In a tightly integrated system the INS has full access to the raw acoustic measurements and the associated low level quality metrics in their native format with effectively perfect timing. This allows a much more precise and optimal use of the available information and can add **fault tolerance** (one of the 7 pillars) [2] when the tight coupling involves modelling and tracking of individual raw observations so that erroneous measurements can be rejected. This is particularly important in challenging acoustic conditions as the good, useable acoustic observations can easily be identified.

Correctly implemented tightly integrated solutions have greater **autonomy** [2] as they do not require the DP to monitor position standard deviations. Instead, the internal integrity monitoring based on the abundance of acoustic and inertial observations can report an error for the DP to use and also flag a loss of integrity or confidence. Figure 1 below shows the functional difference between tight and loosely coupled for and acoustic reference system.

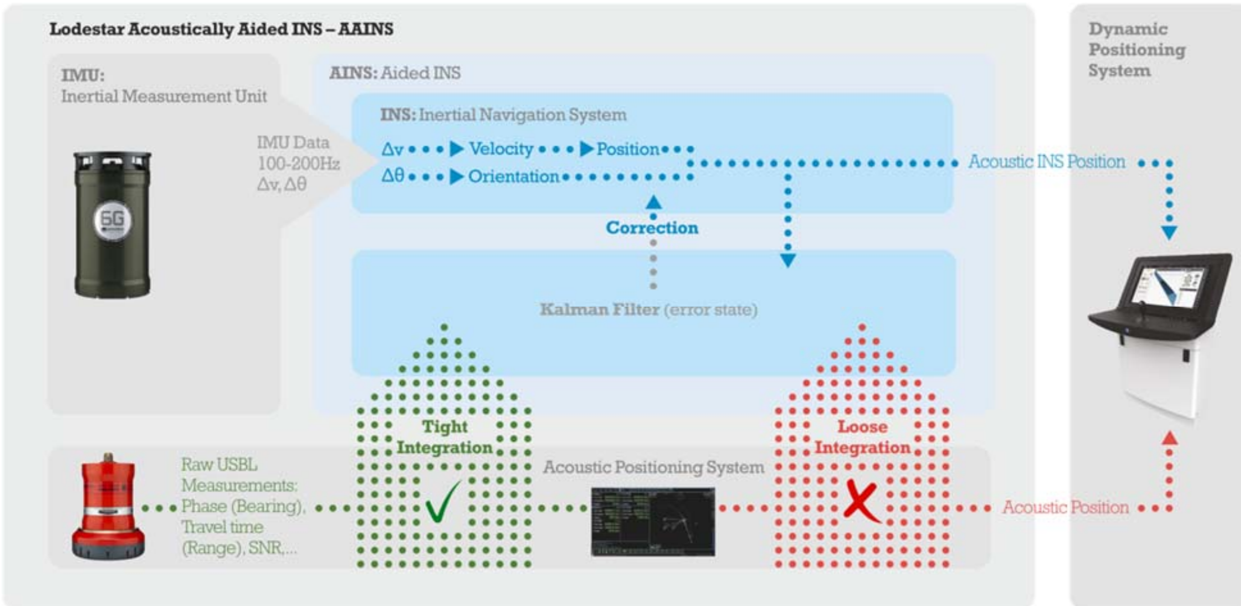

Figure 1 : Tight and loosely coupled architectures

In a tightly integrated solution the INS can model each individual measurement, and even use an individual range measurement, despite the fact that this would not be sufficient in itself to compute an acoustic position – it enables a tightly integrated system to continue operating in even the harshest environments long after a loosely coupled system would have lost integrity. Figure 2 below shows the **fault ride through** [2] advantages of a tightly compared to the loosely coupled solution.

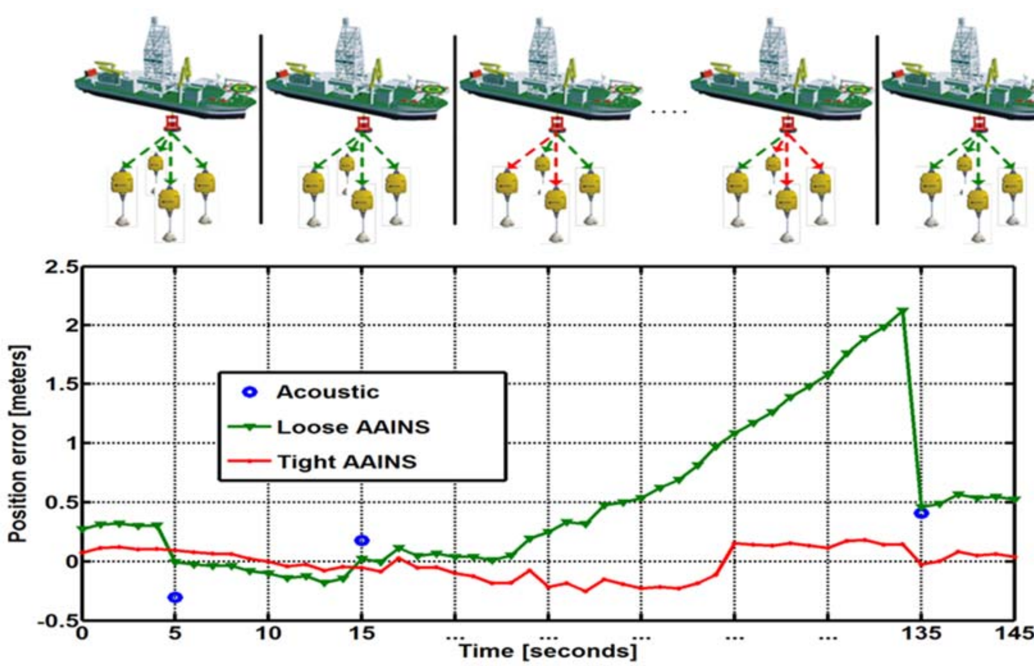

Figure 2 : Fault ride through advantage of tightly coupled

Initially, replies are received every 10s from all transponders (green lines), but for a period of time some kind of interference (possibly noise of thruster wash from a workboat coming alongside) prevents 2 or 3 replies being detected (indicated by red returns). Sonardyne has learned from early implementations that the loosely coupled solution quickly loses aiding in these marginal acoustic conditions and the expected operational advantages are not achieved. As shown in Figure 3, the tightly coupled is able to maintain integrity using the remaining useable measurements.

Tests to confirm tightly coupled integration

When an inertial navigation system is installed onboard a vessel a series of tests can be completed that will confirm correct inertial performance as part of the "setting to work" tests. It is important to confirm the expected performance gains are being achieved in the real world.

Good acoustic aiding

To benchmark system performance single transponder USBL position aiding should be enabled. This will use a single set of range and bearing measurements to constrain INS drift. The DP telegram from the acoustic reference sensors should be accepted by the DP, even in deep water although position error will be relatively high as the algorithms are forced to make use of direction observations.

The green line in Figure 4 below shows the position error of the Ocean Intervention 3 when working in 3000m of water using a single reference. The Lodestar INS "smooths" the noisy USBL that would typically be accurate to +/- 3m 1DRMS at best in 3000m of water and makes it suitable for use as a DP Reference with an improvement of 3-5 times. However the "fault ride through" capability is entirely dependent on the quality of the inertial sensors in free inertial mode and as a partial acoustic observation set does not fully constrain inertial drift.

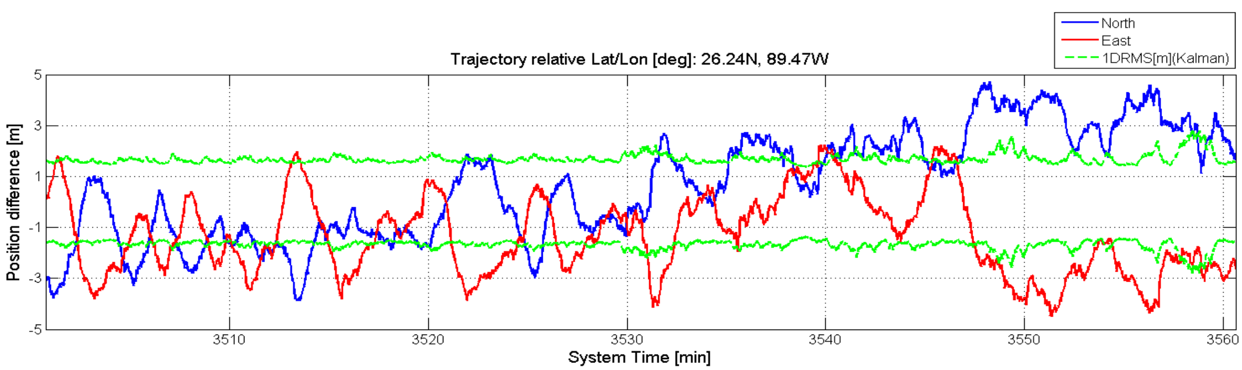

Figure 4: Single transponder loosely coupled, 3000m water depth

Free Inertial tests

Disabling all sources of aiding will measure the free inertial drift rate of the INS. Position error will increase with time when in this state and a warning should be raised in the DP when an INS becomes unaided for more than the expected aiding interval, followed by automatic de-selection of the reference after the reported position error exceeds a pre-set threshold. Figure 5 below shows the free inertial test being repeated a number of times as the true 2d radial error relative to GNSS varies run to run. This variation is due to a random, in-run component to the gyro and accelerometers biases so multiple tests are needed to benchmark performance.

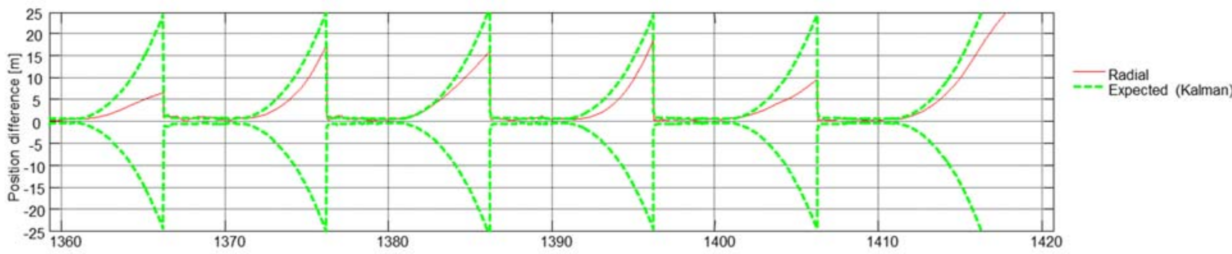

Figure 5: Free inertial drift rates

Degraded acoustic aiding

It needs to be possible to artificially disable the use of elevation and bearing measurements via the reference system HMI. Using 3 or more seabed transponders without direction information results in a range only, long baseline (LBL) solution. As shown below in Figure 6 in a deep water drillship example operating in Asia, the accuracy achieved during DP-INS commissioning over a 30 minute sample period with 3 transponders and disabled direction information is approximately 20 cm compared to GNSS.

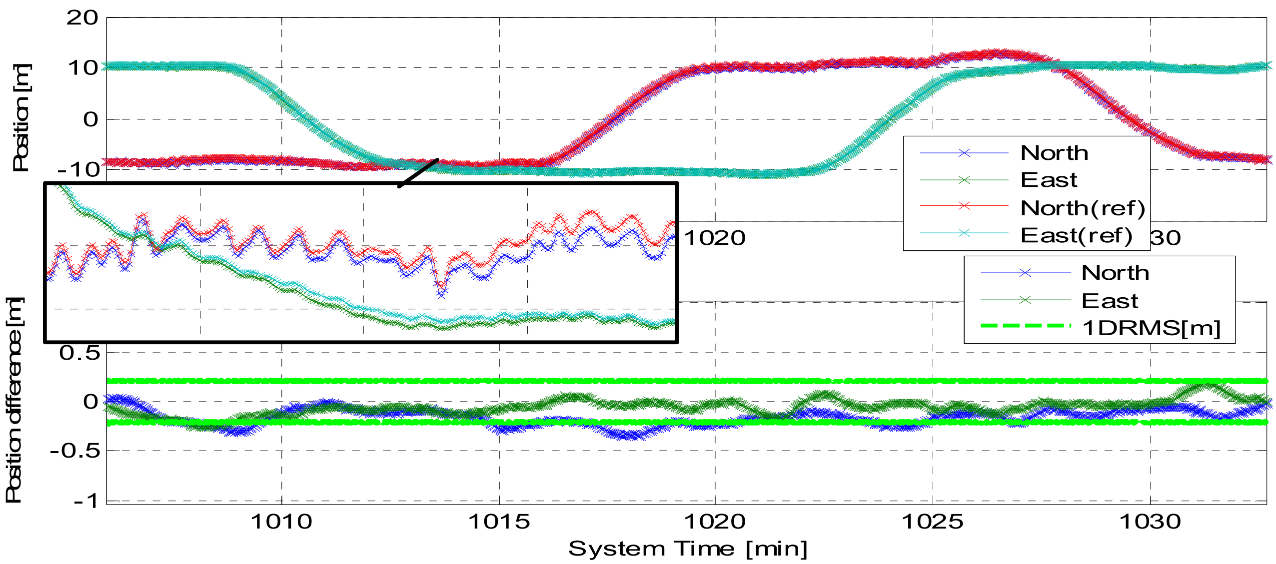

Figure 6: Long baseline solution

Operational advantages of tightly coupled

As previously reported in [3] the superior performance of tightly coupled DP-INS can be used to reduce the number of seabed transponders from 5 per system to 3 without compromising position data integrity.

Recent upgrades on a drilling rig working in India have seen operational savings by using a "multi-user" mode in the customer's existing 6th Generation of subsea transponders. As shown in Figure 7, Multi User assigns independent interrogate and reply signals to up to 4 independent users of the same seabed array. **Segregation** of signals in this way ensures no acoustic single points of failure exist due to interference and eliminates the risk of false detections from another system. There is also a reduced risk of interference affecting both systems due to physical separation of each USBL transceiver..

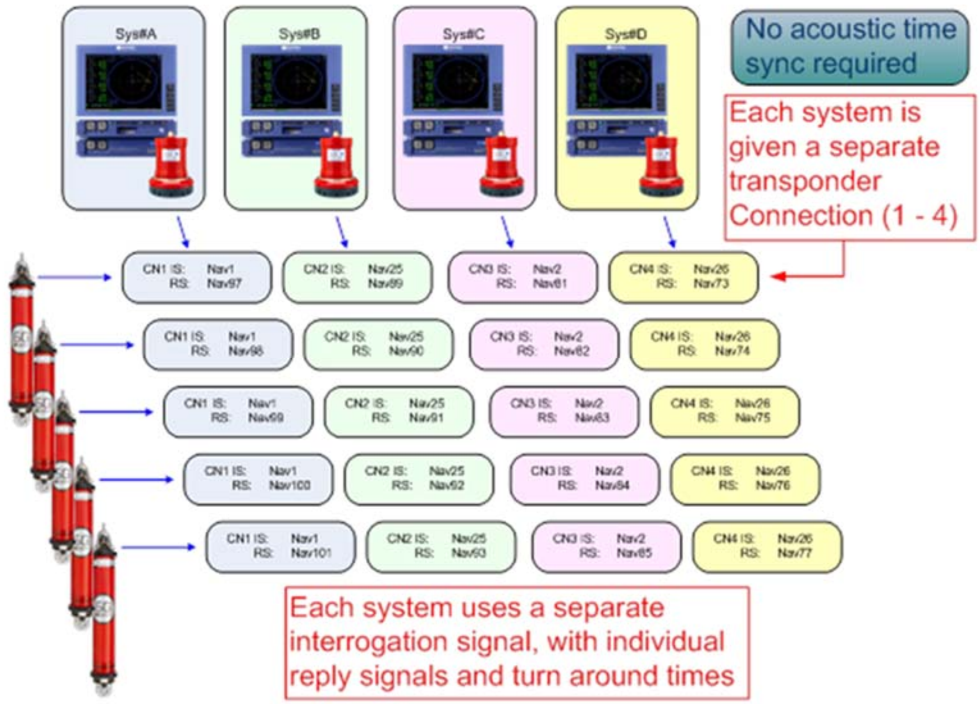

Figure 7: Multi -User system architecture

In the example of a DP3 vessel with a dual independent acoustic system installed, the number of seabed references could be halved if a shared array of multi-user transponders is deployed as shown in Figure 8.

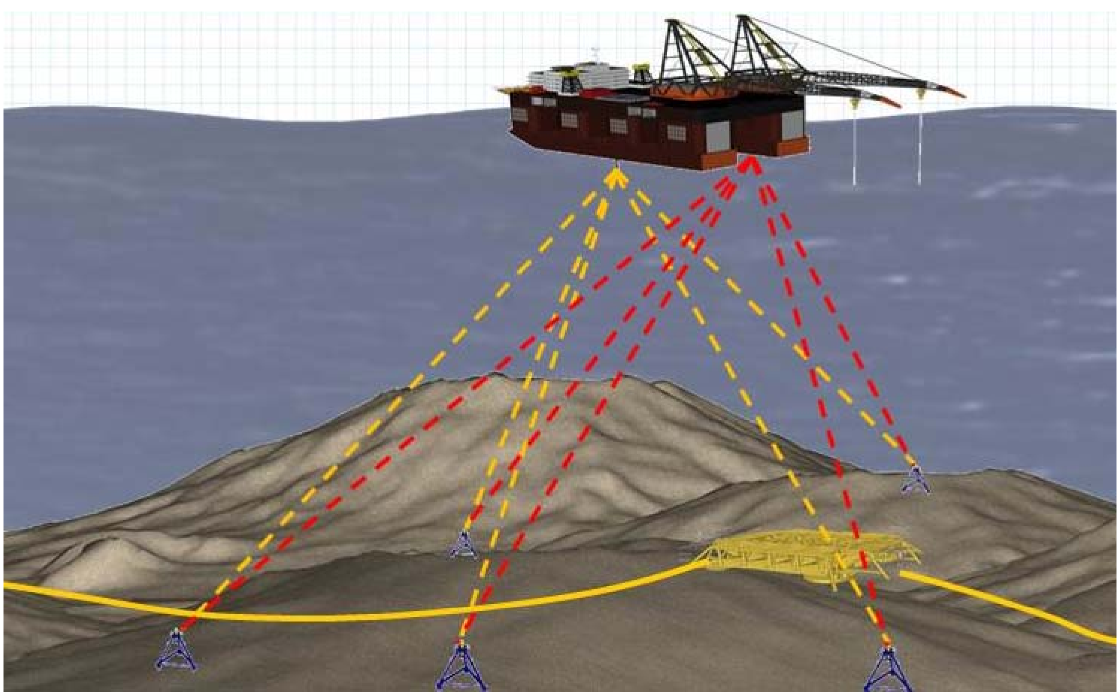

Figure 8 : A dual independent acoustic system sharing a seabed array with Multi-User transponders

Based on data taken from a customer drill rig, operating in the Gulf of Mexico and drilling 5 wells per year, the operational saving shown in Table 2 equates to a saving of 2 days per year. Savings on smaller vessels will be greater as transponders are deployed and recovered more frequently.

Acoustic Reference System	**Original**	**L/USBL**	**DP-INS**
Set-up	Dual Independent		
Generation	5G	6G	6G
Transponder type	Standard	Long Life, Multi User	
Acoustic Update rate	6	6	12
Deployment and calibration			
Number of transponders	10	5	4
ROV payload (tpdrs)	4	5	4
ROV trips	3	2	1
Average array set-up time (hours)	18	14	9

Table 2 : Operational saving due to reduced transponder numbers

Conclusion

As inertial navigation has become more widely used in offshore oil and gas the number of vendor implementations has increased. It is not enough to simply specify "inertial navigation" as tightly and loosely coupled architectures deliver different levels of performance and operational savings. When specifying tightly coupled INS it is important to reference definitions of terminology such as the MTS Techop to aid understanding. During commissioning, a series of tests need to be done to make sure performance is benchmarked for the marginal conditions where the technology delivers benefit rather than benign scenarios with only good data. Once specified, installed and commissioned correctly tightly coupled INS will then offer efficiency savings which can be delivered for both vessel owner and contracting Oil Company.

Where possible acoustic failure modes have been discussed in the context of the 7 pillars of incident free DP operations as laid out in MTS documents to show how the efficiency savings can be achieved whilst maintaining or extending DP performance.

References

[1] Technical And Operational Guidance (Techop) Techop_Odp_14_(D) (Prs And Dpcs Handling Of Prs) September 2017

[2] Marine Technology Society, Dynamic Positioning Committee, DP Vessel Design Philosophy Guidelines

[3] Towards Safer and More Efficient Acoustic DP Reference Systems Dynamic Positioning Conference 2016, Mark Carter