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DYNAMIC POSITIONING CONFERENCE
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Sensors I

Redundancy in Hydroacoustic Systems for DP Applications

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Redundancy in hydroacoustic positioning systems for DP applications.

Abstract :

Some DP applications have a specification for two redundant acoustic systems required up and running at all times, in some cases interpreted as four stand alone systems. Kongsberg Maritime has come to a solution with three acoustic systems being interfaced to each other in order to keep a minimum of two systems running at all times. They could be used in SSBL or LBL mode, depending on water depth. When multiple acoustic systems are used in LBL - to ensure a minimum of two separate position updates - there is also a need for separate seabed LBL networks. Hence, all working systems will need to have all LBL calibration files updated at all times.

In SSBL mode the most important sensor for the acoustic system is the Motion Reference Unit, and it has become common to use up to three separate MRU inputs, with automatic selection. The angle of the vessel motion is used to correct the angle at which the acoustic signal is received on the vessel transducer. Since a very small change/difference of angle output from the MRU's will result in a major position change at long ranges, a system of ruling and averaging is needed. When automatic changing from one MRU to another is implemented, this needs to be handled by a function where all are monitored and selected in a median solution. A jump in the acoustic position input to the DP, caused by selecting another MRU, will give the acoustic system lower weighting in the DP sensor voting, so the vessel position will not be directly affected by this.

New Technology like hydro acoustic inertial systems is also becoming more frequently used onboard DP vessels, as the acoustic position with inertial aid can have similar reference-weight as a corrected GPS signal. Inertial navigation is still part of the acoustic system, not a new third reference system, and needs to be handled as such, but it can give advantages as to transponder battery economy and less time used for transponder handling.

Redundancy in hydroacoustic positioning systems for DP applications.

Some Hydroacoustic/DP applications have strict requirements regarding system redundancy.
One of these is deepwater drilling, which is often performed in locations far from shore, where short range surface navigations systems etc. are not available. Thus the operators have to rely on DGPS and Hydroacoustic solutions. In some parts of the world, we know that GPS scintillation will be an increasing problem in the years to come, culminating in a few years. This will increase the need for reliable Hydroacoustic systems further, and system redundancy will become a dominant issue. Drilling vessel specs are already out with the requirement of two independent Hydroacoustic systems feeding the DP at all times, both with internal redundancy.
This has in some cases been interpreted as 4 complete systems, but we seem to have the understanding now that three systems is sufficient, one system acting as redundant back-up for the two in operation.

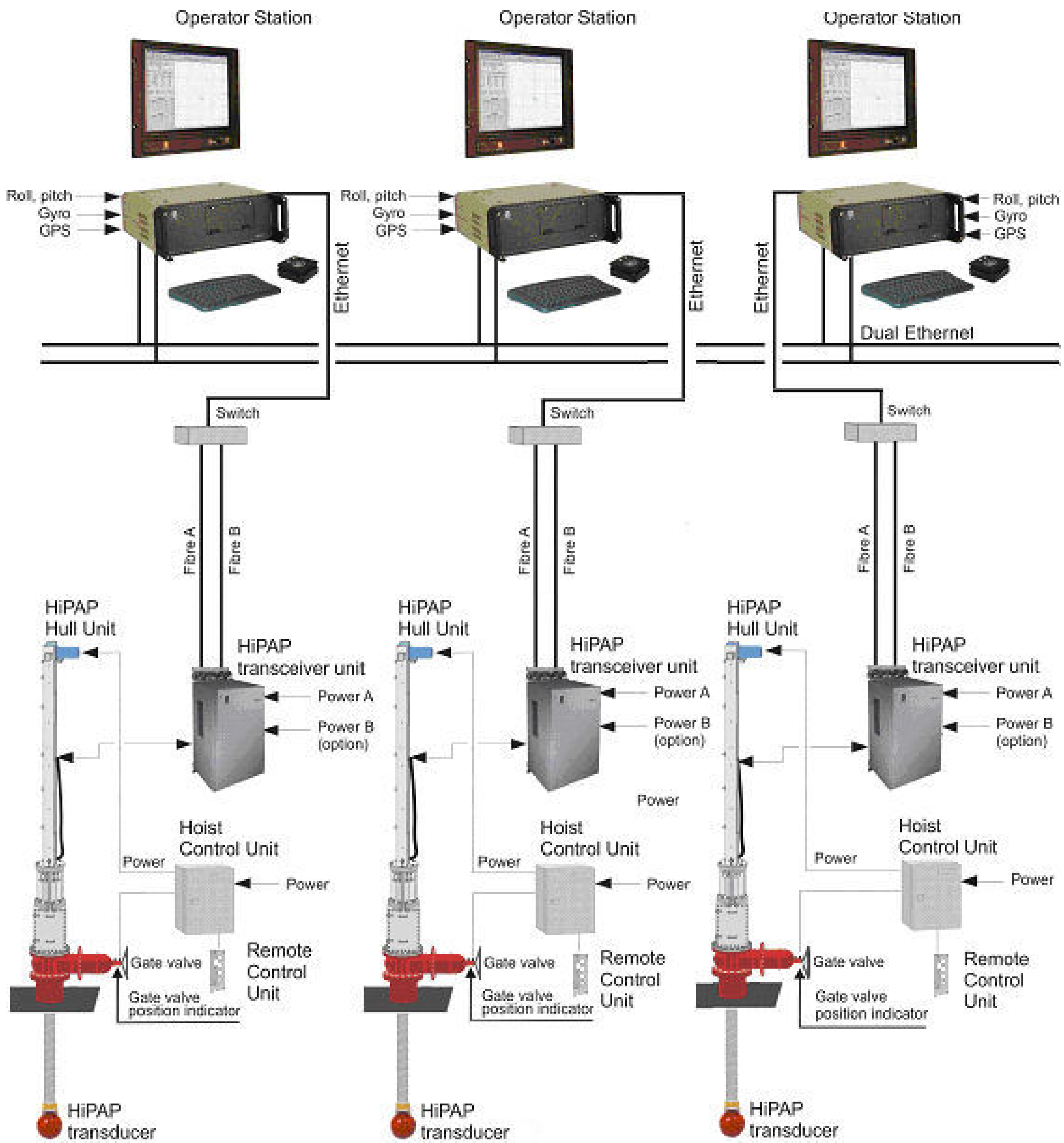
So – how can these systems be configured to give the best redundancy ?

Redundancy at system level :

All Hydroacoustic operator stations are able to operate all transceiver units, connected via single or dual network(s).One operator station is always primary (PS) and has the control of all systems. The operator(s) can at any time take over the control by pressing a button on the screen menu of any secondary station (SS). All systems can also be configured without the primary/secondary function. From each transceiver there's a dual optical fibre network going to a switchbox close to it's dedicated operator station, if one fibre fails, the other will automatically be selected.
The power supply inputs to all transceiver units are also redundant and alarm is given to the operator if one supply fails (the secondary supply will be automatically selected).

If the current primary station falls out of operation, one of the secondary stations will automatically take over control and continue the operation. All operator stations are always syncronized as to data needed for continuing the operation (LBL calibration data, active LBL/SSBL transponders, interrogation rates etc..). All operator stations are also connected to 1 – 3 external motion sensors, gyros and GPS'es.

If one transceiver unit falls out of operation, the system configuration will automatically start to use another available transceiver unit.
Limitation : One transceiver unit can only handle one LBL transponder array at a time. If two transceiver units are working towards one LBL array each, and one of them fails, we need a third transceiver unit to automatically take over the LBL-function from the faulty one, because the other operational transceiver is already busy working towards the other LBL array.



Redundancy in motion sensors/gyros.

All systems can be interfaced to 1 – 3 motion sensors/gyros. All sensors are read by the system continously. The operator selects the preferred sensor and an accept limit. The preferred sensor will be used until its output exceeds an accept limit. The accept limit is the operator selectable difference between the selected sensor output and the given sensor median value at all times.
The system will automatically select the new sensor which is closest to the median value,
and the operator will/can get a warning that a new sensor has been selected. The switching to another motion sensor with different output will give a position difference increasing with water depth.

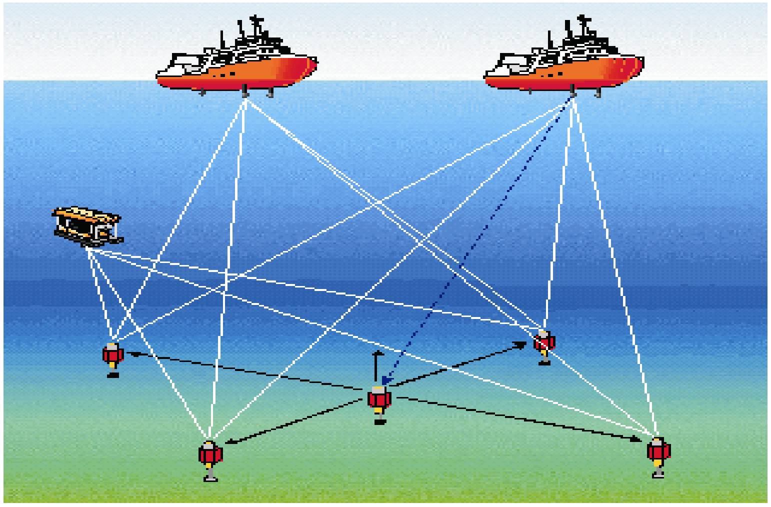
This position difference will – when fed to the DP reference input – be rejected if it's too big.

Redundancy in transponders.

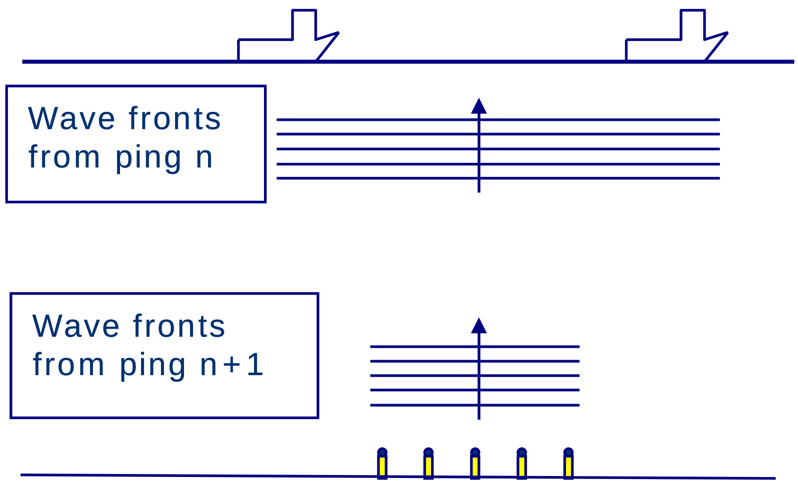
Several soultions can be used to give the best redundancy as to transponders. In shallow water applications, it could be convenient to have one system working in SSBL, with one seabed transponder (and one or more as backup) and the other system working in LBL (with one or more complete arrays – one at a time, or with one complete array, and additional transponders for redundancy). In deepwater operations, two (or more) redundant LBL arrays is apparently the preferred way, most common seems to be10 transponders, configured as two arrays of 4, with one redundant transponder in each array.
One limiting factor in deepwater operations is the sound propagation time, making the update rate to the DP slower with water depth. The Hydroacoustic update rate can match the GPS (once per second) only down to approx 700 m of water. At greater depths, special measures have to be considered to give the best update rate, such as :

Multi User mode

To make multiple transceiver units work towards one transponder array, the system(s) need to be set up in Multi User mode. That requires an additional transponder on the seabed acting as the master. The master transponder interrogates the other array transponders. The Hydroacoustic system transceiver/transducers on the vessel(s) will be in listening mode, and position calculation is based on the delta ranges from the array transponders. If SSBL transducers, the <u>directions</u> of the incoming signals are also used to improve accuracy. The array transponder replies, generated by the master transponder triggering will arrive at the vessel transducers as “trains” of replies, and the repetition rate of these “trains” will be independent of water depth (several “trains” may be underway through the water at great depths, but the surface transducers/systems will only process one “train” at a time, to give the vessel LBL position). Multiple transceivers can be set up to work in this mode, even subsea transceivers mounted on ROV's etc, or other vessels. All transceivers receiving ranges in Multi-user mode, must know the calibration geometry of the LBL array, as well as all individual transponder turn-around delays etc. (turn-around delay is an operator selectable delay for each transponder between interrogation and transmission of reply signal, used to avoid that more than one transponder transmission is received at the listening transducer(s) at the same time.
Systems are set up to give optimal timing, transponders may have different turn-around delays etc depending on the geometry of the LBL array.



Typical Multi User configuration (one array with master transponder in the middle).
Multiple transceivers in listening mode.



Transponder replies from more than one master interrogation
underway through the water column……

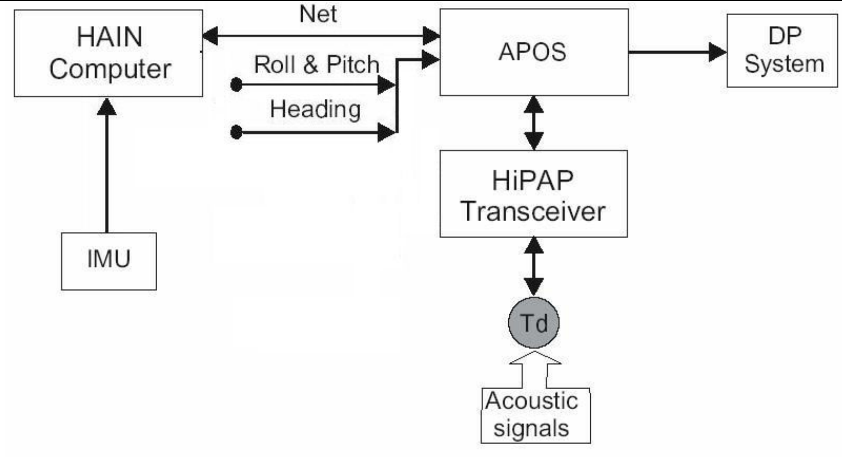
Another way of achieving good update rate of the Hydracoustic position input to the DP is :

Hydroacoustically aided Inertial navigation

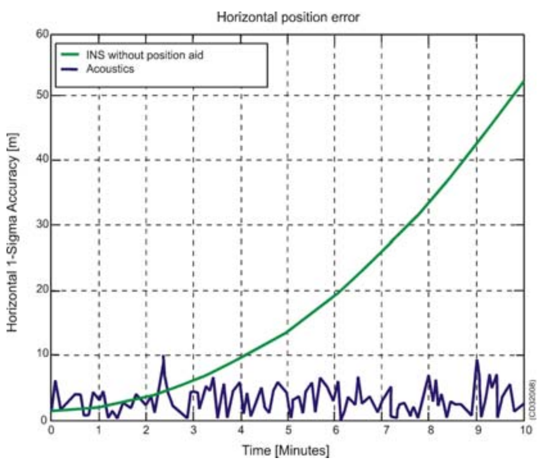
By combining Hydroacoustics and Inertial navigation, we utilize the best from both principles :

Hydroacoustics : Positions overlayed by white noise (position jumps), but no long time drift.
Inertial navigation : Very accurate short term positions (very little white noise), but big drift over time.

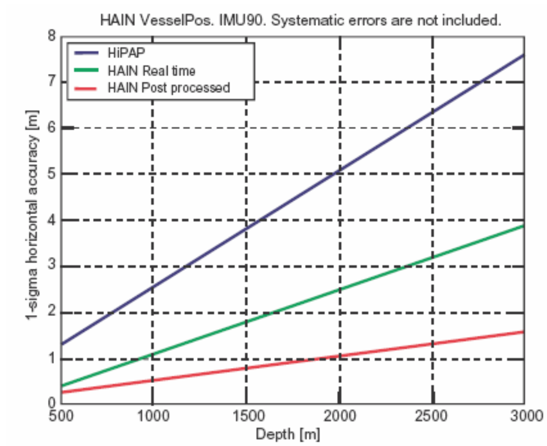
If we combine these principles, we can get a very good position output which has very little white noise, and which does not drift over time. In addition – and not less important – we can get a DP update rate independent of water depth, typically once a second, even if we reduce the acoustic SSBL/LBL update rate significantly. Thus the acoustics can get a DP weight figure similar to today's DGPS – and it will not deteriorate with the expected scintillation.



Configuration of a Hydroacoustic aided inertial system,
one extra computer is needed to calculate the aided positions.



The nature of Hydroacoustics versus inertial navigation



The benefits of using Hydroacoustically aided inertial navigation

The Hydroacoustically aided Inertial navigation principle is very well suited for deepwater operations. Not only does it give good update rate to the DP regardless of water depth. We also see that it gives good operational economy, because transponder interrogation rate can be reduced, thus giving longer battery life-time, and less time spent in transponder handling.

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