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Sensors II SESSION

Including GNSS Based Heading in Inertial Aided GNSS DP Reference System

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Introduction

High precision GNSS are used as DP reference systems and 10 – 20 cm accuracy can be expected on a worldwide basis. However, these systems still have some limitations, mainly related to:

- GNSS systems are line-of-sight, radio navigation systems
- Measurements are subject to signal outages and interference

In addition to this DP relies on accurate heading information to work. Usually heading is provided by traditional gyros. This paper presents a solution providing GNSS based heading while overcoming some of the vulnerabilities of a GNSS DP reference system.

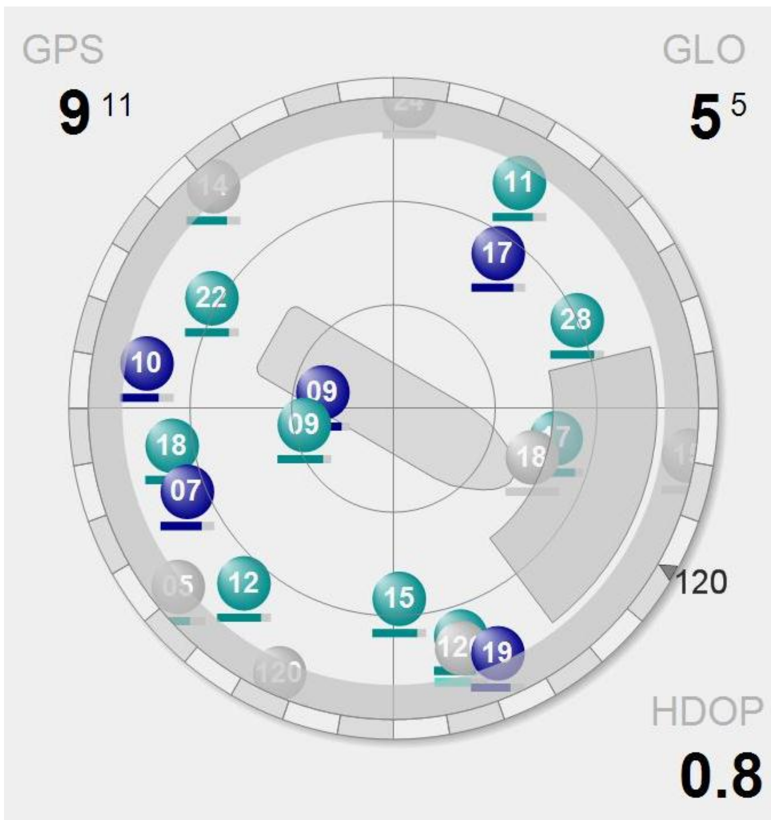

Figure 1: GPS and Glonass skyplot

Problem description

Inaccurate heading from the gyro results in errors in the GNSS antenna offset calculations with traditional DP reference systems. Problem increases with the length of the GNSS antenna offset vectors

Ex: Antenna vector 200 m and 0,1 degree gyro error causes ~40cm position error.

A DP usually uses data form several reference systems and monitor performance of the different systems both prior to using data and while using data. Some possible failure detection mechanisms are:

- Freeze test
- Variance test
- Prediction test
- Slow drift test
- Assembly assessment
- Divergence test
- Median test (voting)

Potential inaccuracies in the gyro will affect the variance and slow drift test. It is also important to be aware that gyro errors will increase as the vessel is moving further north in an exponential way.

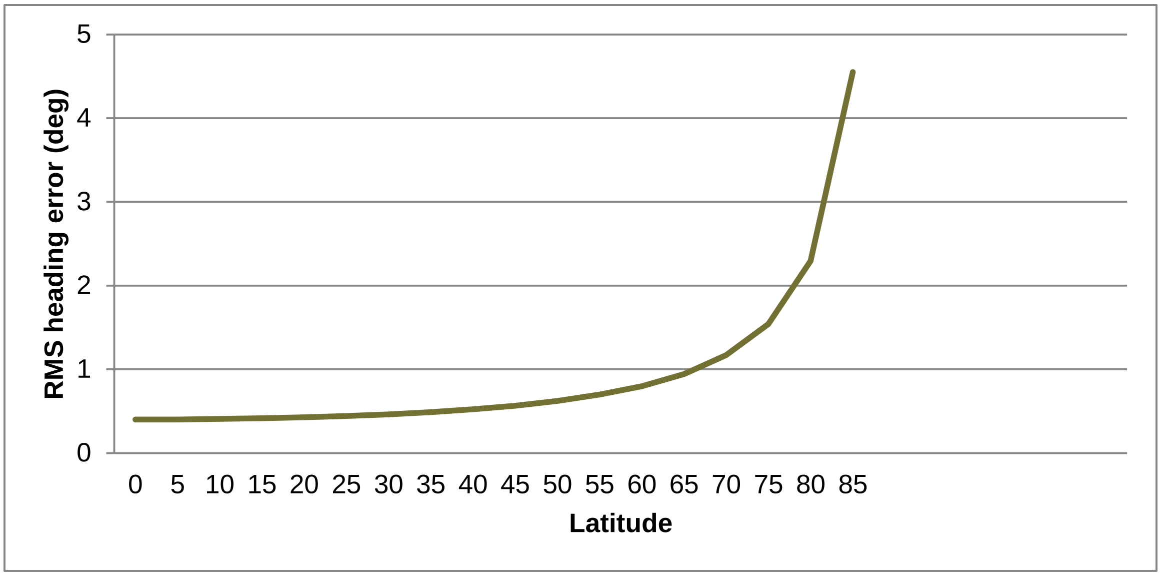

Figure 3: Example of gyro error as function of latitude

Some well-known problems related to GNSS reference systems are:

- Large structures on board may block satellite signals
- Interference from satellite communication equipment
- Shadowing from nearby vessels may block satellite signals
- Ionospheric activity may block or degrade satellite signals

It will always be important to try to find a good antennas location and make a proper installation, but for some large and complex vessels, it must be realized that the ideal GNSS antenna location does not exist.

Figure 4: Example of complex antenna installation

Technology

To overcome the limitations of traditional gyros and minimize the vulnerabilities of a GNSS based reference system, the system describe in the next figure is proposed.

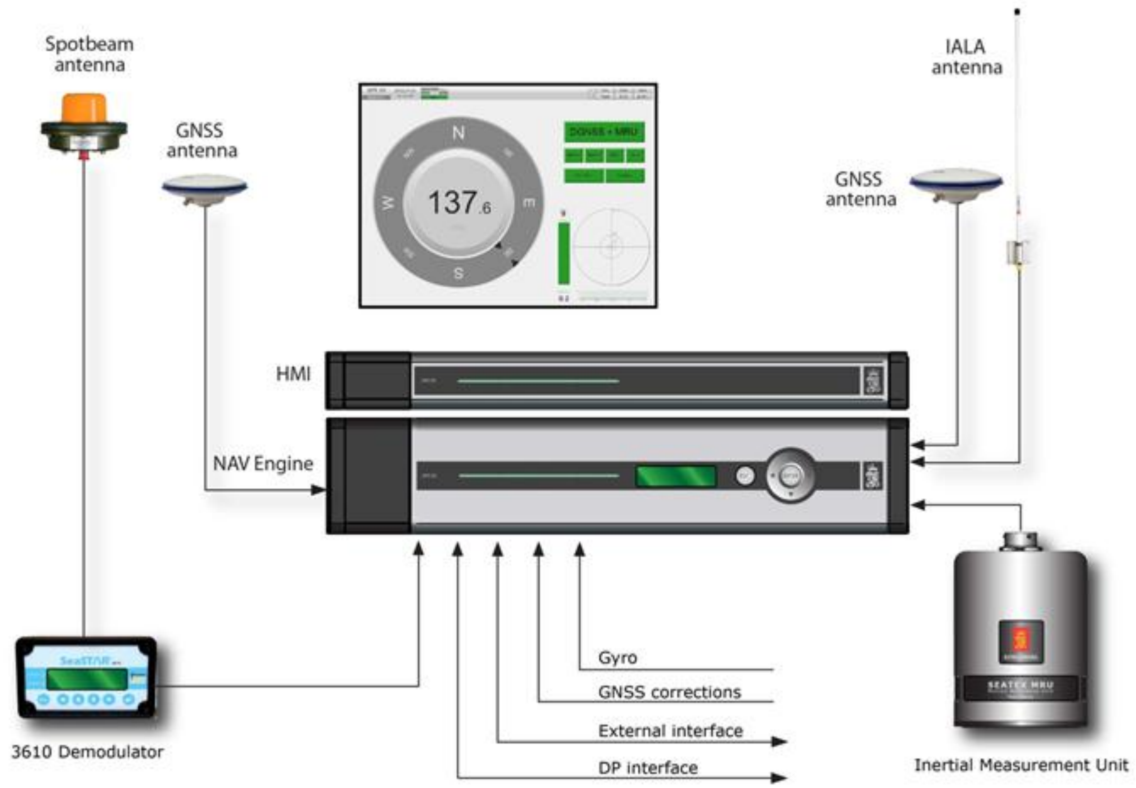

Figure 5: A hybrid GNSS based position, attitude and heading system

A summary of the features is:

- Increased GNSS availability on vessels with permanent or various shading/signal blocking
- Flexible antenna installation ensures optimum tracking conditions. Antenna separation 2.5 m – 100 m
- Mitigates interference (vertical and horizontal separation of the antennas)
- Two antennas separated with more than 5-10 m will experience different mulitpath conditions
- Accurate lever arm compensation (compensates GNSS antenna offsets for heading, pitch and roll
- Relative GNSS techniques can be used to calculate accurate vessel heading
- Heading accuracy down to <0.05 degrees (95 %)
- No need for calibration
- No degradation at high latitudes, unlike traditional gyros or compasses
- GNSS systems are line-of-sight, radio navigation systems, and the measurements are subject to signal outages and interference
- The IMU is a self-contained system that is completely independent of the surrounding environment, and hence virtually immune to external disturbances
- Complementary properties of GNSS system and IMU allow for more reliable and precise navigation solutions
- Combined use of a dual antenna GPS + GLONASS system and accurate motion measurements
- Calculates multiple positions based on data from the two GNSS receivers and the IMU, ensuring a high level of robustness and integrity in the position solution output to the DP

- The dual antenna configuration provides great advantages by improving the availability of GNSS signals
- Measures the heading of the vessel with higher accuracy than traditional gyros
- The IMU will continuously provide navigation information when both GNSS antennas experience short-term loss of signals

Validation

It is crucial for validation of a system like this to be able to operate over time in a challenging and representative environment.

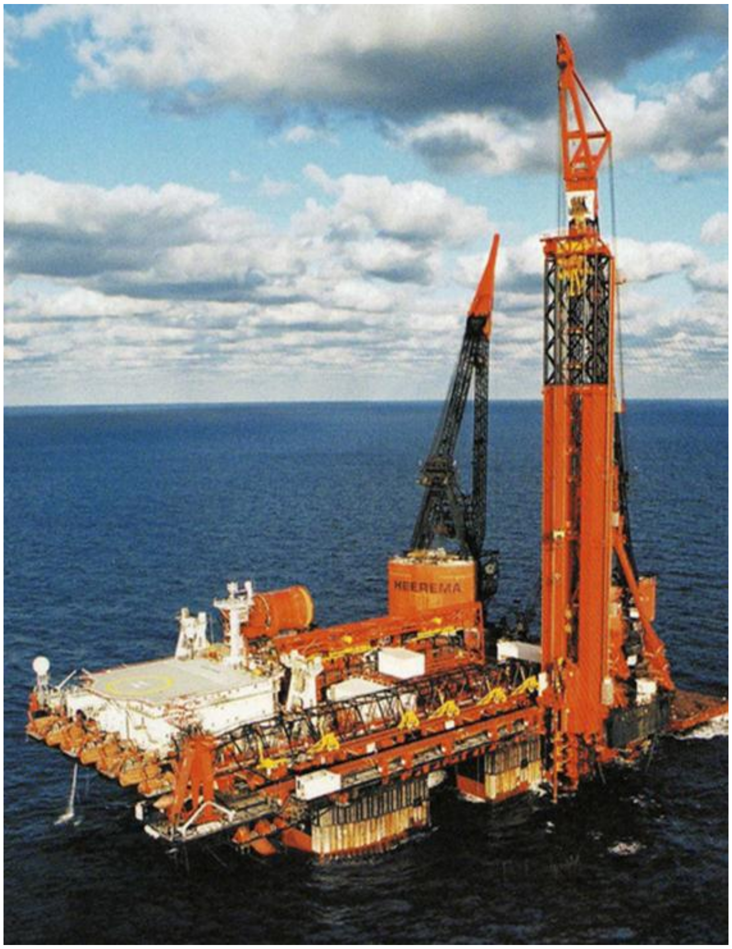

Figure 6: DVC Balder (by courtesy of Heerema Marine Contractors)

DVS Balder is an example of a construction that is extremely difficult with regards to installation of GNSS antennas.

The actual antenna installation is shown in the following figure. GNSS antennas are separated by 16.6m vertically and 35.5m horizontally. Dependent on the position of the cranes, several GNSS shadowing sectors will exist for at least one of the antennas. An

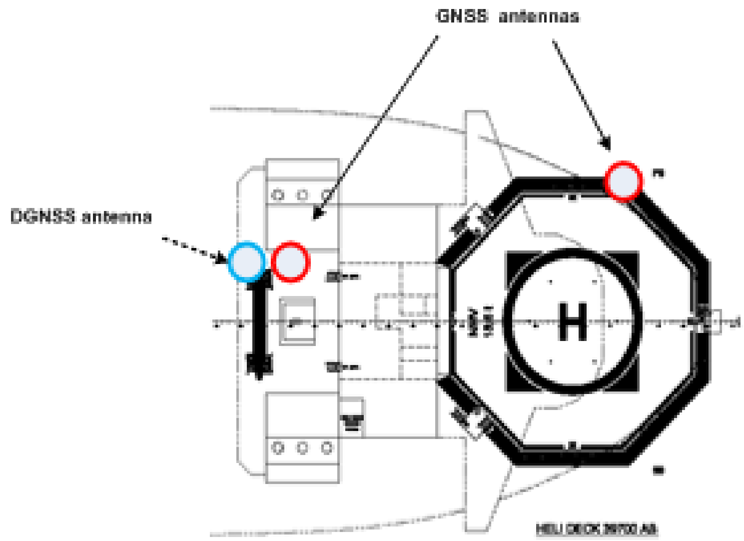

Figure 7: DVC Balder GNSS antenna installation

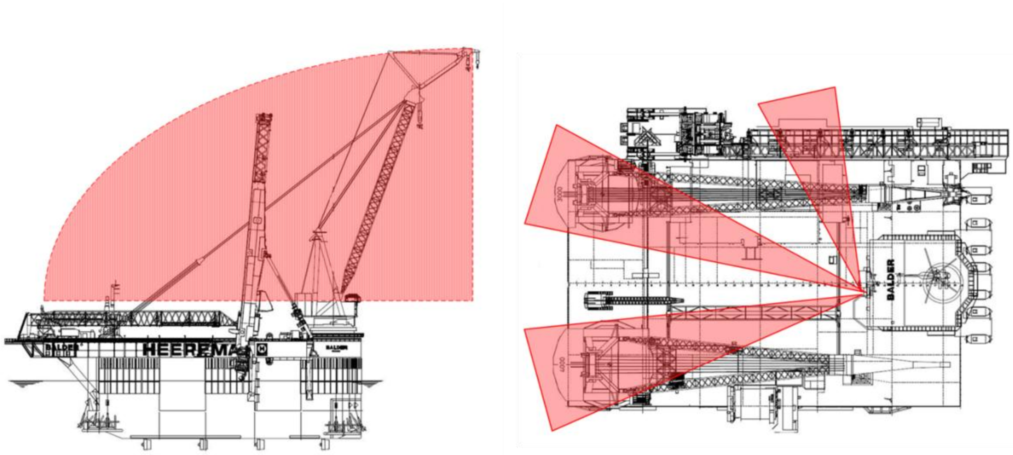

Figure 8: Potential GNSS shadow sectors

The effect of shadow sectors is minimized by using two antennas at different locations. Even if the signals at one antenna is completely blocked, the system will still provide a reliable system position, since data from the other antenna will be accurately transformed to a common, pre-defined reference point.

The effect of gyro error and roll/pitch transformation into position error is shown in the next figure. The red curve shows position error (north component) by making lever arm compensation using traditional gyro data. This causes a position error with a magnitude of up to two meters with a short term noise component of +/- 0.5 meters. The green curve is still using gyro but applying IMU data to compensate for roll/pitch. Then the noise component is removed, but and remaining position error is caused by slowly varying gyro error. The blue curve represents heading compensation based on GNSS heading. Then the error is down to 0.1 – 0.2 meters typical for orbit and clock type differential GNSS corrections.

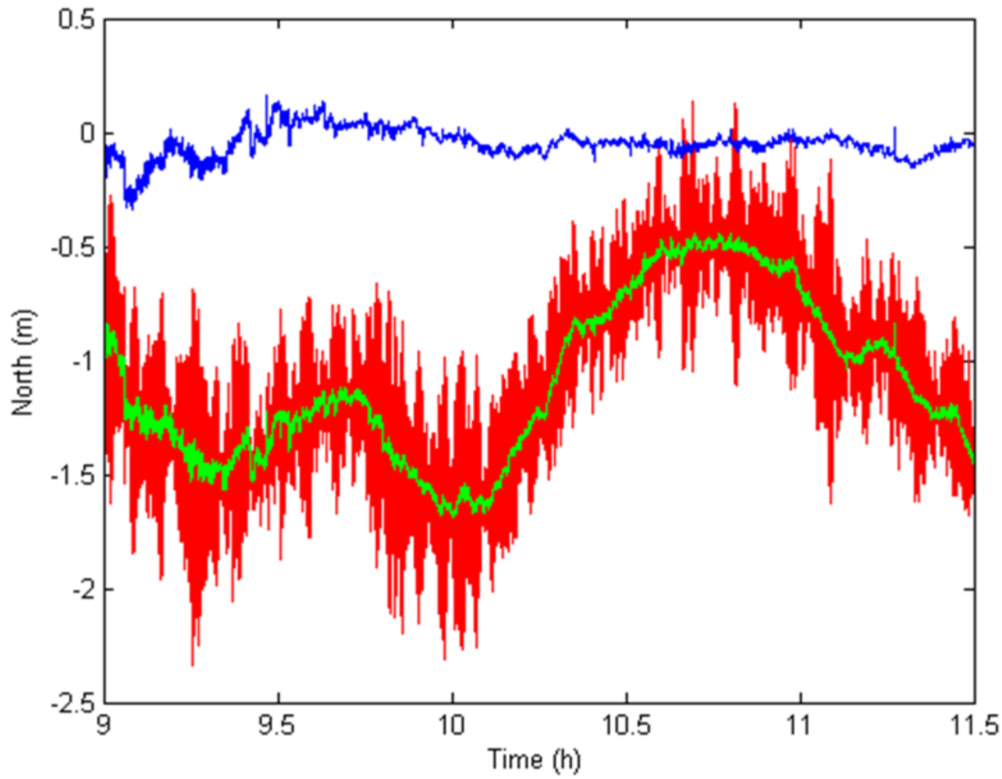

Figure 9: The effect of gyro and attitude errors to position error

Another feature of a dual antenna GNSS reference system is the ability to measure the flexing of a hull based on accurate GNSS measurements. The measurement noise is about 1- 2 cm, which means that hull flexing of that magnitude can be measured by a dual antenna GNSS solution.

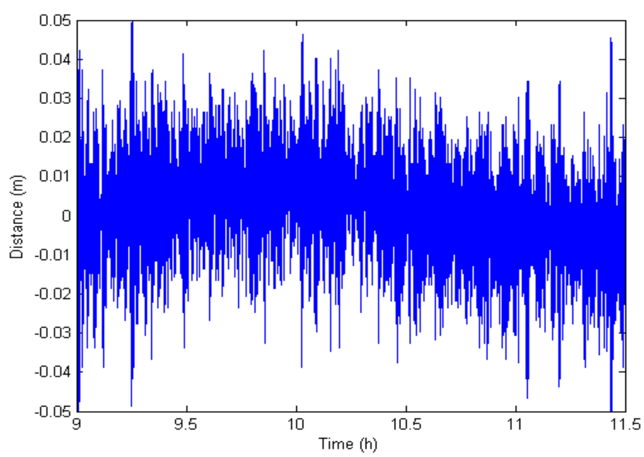

Figure 10: Measurement of relative distance between GNSS antennas onboard a vessel

Conclusion

The paper describes a dual antenna GNSS position reference system for DP. The main advantages compared to traditional GNSS reference systems are:

- A GNSS based heading combined with inertial aided GNSS gives superior results for the most complex installations
- The dual antenna solution minimizes risk of interference and improves availability in periods with signal shading

The new system is focusing on features making the best out of the DP.