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DYNAMIC POSITIONING CONFERENCE
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Sensors II

Redundancy in Dynamic Positioning Systems Based on Satellite Navigation

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ABSTRACT

The use of Global Navigation Satellite System (GNSS) has become very important in DP applications where several independent reference systems are required. In most cases more than one GNSS based reference system is used. It is therefore vital that these systems are independent from corrections generation, via distribution and onwards to applying the corrections onboard the vessel.

This includes the following.

Independent generation and collection of reference data
Independent broadcasts
Independent onboard systems
Use of several GNSS (GPS, GLONASS, etc)
Use of different techniques to generate corrections (traditional network and orbit/clock corrections)

Fugro is developing a new service that uses dual frequency GPS and GLONASS data. The service is a decimeter level phase based orbit/clock system. Results from testing of the service are presented. The service will be introduced early 2009.

INTRODUCTION

Characteristics of the use of satellite navigation in the DP industry can be summed up as:

- Satellite navigation is the preferred position reference for today's rapidly expanding DP fleet.
- Most DP applications require several independent positioning reference systems
- Today, two Differential GPS systems are accepted if they are independent:
  - Independent provision of DGPS corrections.
  - Independent setups onboard the vessel.
- In addition to GPS, other Global Navigation Satellite Systems (GNSS) are under way:
  - The Russian GLONASS has 14+ satellites available today, and is expanding
  - The EU is developing Galileo
  - China is developing Compass
- Differential GNSS (DGNSS) will be the choice of the future

TRADITIONAL NETWORK VS ORBIT/CLOCK CORRECTION METHODS

Traditionally a network differential GNSS concept has been used in augmented satellite navigation system. This involves determining the error in the range measurement towards each satellite. These range corrections from each individual reference station are transmitted to the user.

The orbit/clock concept utilizes reference stations with a worldwide spread to calculate the orbit and the clock value of each GNSS satellite. The resulting orbit and clock corrections are transmitted to the user. The user software applies these corrections to the broadcast GNSS ephemeris.

Orbit/clock corrections are valid worldwide and the accuracy is dependent on the overall geometry of the reference station network, rather than the position of the user with respect to the reference stations.

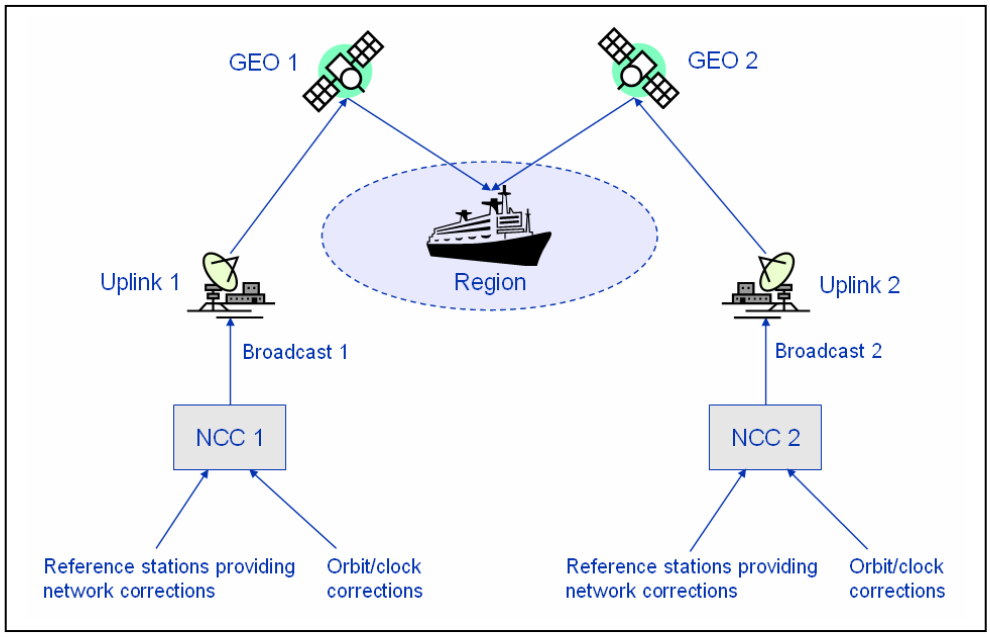

Figure 1: Independent dual broadcast services.

INPENDENT SERVICES

In DP applications high availability is vital. In order to ensure this, it is important that each region in the world is covered by dual broadcast DGNSS services. This includes:

- Different Network Control Centers (NCC)
- Different uplink sites
- Different geostationary satellites

Both services should carry both the traditional network corrections and the orbit clock corrections.

GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

Satellite navigation systems have become critical infrastructure, therefore there will be several systems in the future. The status and plans are:

- GPS (USA)
  - 30 satellites now
  - Operational since 1994
- GLONASS (Russia)
  - 14+ satellites now
  - Fully operational from 2011, will eventually have 30 satellites
- Galileo (EU)
  - Operational 2013+ with 30 satellites
- Compass (China)
  - Operational 2013 (?) with 35 satellites

Russia in particular is active in revitalizing their GLONASS system. It was fully operational in 1995, but due to the break up of the Soviet Union, it was poorly supported for many years. In 2001, with 7 satellites left in operation, it was decided to rebuild the system. The aim is to have full operation by 2011, eventually

expanding to 30 satellites. Figure 2 shows the number of satellites seen in Oslo on 20 Sept 2008 using GPS only, and using GPS GLONASS combined.

Three GLONASS satellites were launched 25 September 2008, with three more to be launched in December 2008. Both in 2009 and 2010 six satellites are planned to be launched. The current status of GLONASS can be found at:

http://www.glonass-ianc.rsa.ru/pls/htmldb/f?p=202:20:14868901511050409234::NO

The increased number of GNSS systems and satellites becoming available will greatly improve performance in many areas:

- **Independence**
  - When more systems become fully operational, they can be used as independent systems in safety critical applications
- **Availability**
  - Combined systems will improve availability of satellite navigation in situations where parts of the sky are blocked by structures. buildings, terrain, trees, etc. Also during ionospheric scintillation periods, additional available satellites will improve performance. Ionosperic scintillations will become more common during the upcoming peak of the 11 year solar cycle.
- **Reliability**
  - Increased position line redundancy of data will help to identify bad measurements
  - More resistant towards interference with more frequencies.
- **Accuracy**
  - Improved accuracy with more frequencies (ionospheric delay compensation) and satellites (improved geometry)
  - Improved convergence time in phase based decimeter level systems

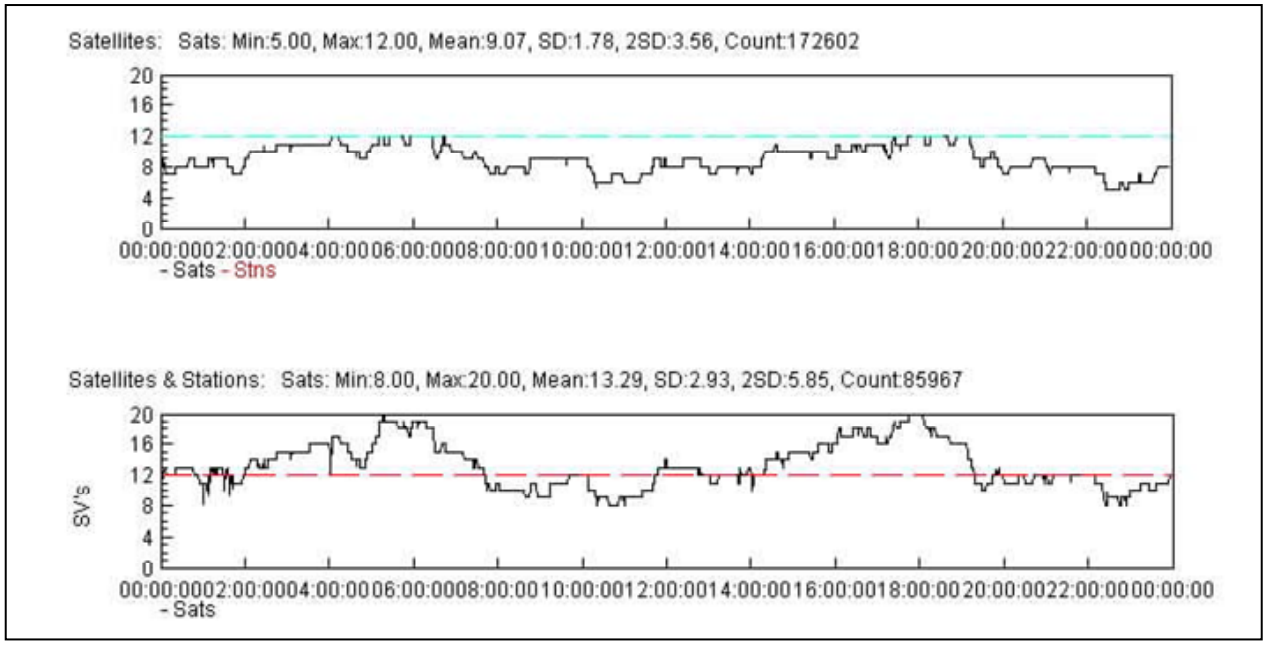

Figure 2: Number of available satellites using GPS only (top) and GPS plus GLONASS (bottom) in Oslo Norway on 20 Sept 2008. 8 deg elevation mask.

NEW FUGRO GPS AND GLONASS SERVICE

Fugro is about to introduce a new combined GPS and GLONASS service with the following characteristics:

- Dual frequency GPS and GLONASS
- Carrier phase based decimetre level service
- Orbit and Clock service

Today tests on vessels are being performed. The operational introduction will be early 2009.

In order to show the performance of the combined GPS GLONASS solution under difficult conditions, a test was done where the elevation mask of the mobile was set to 25 degrees. In such a setup there are typically periods where the number of GPS satellites are less than the 4 needed to provide a solution. Similar cases will happen if a supply vessel is close to an oil production platform, or satellites lose track during ionospheric scintillation periods.

Figure 2 shows the result when only GPS is used and figure 3 when GPS and GLONASS are used. The top plot in each figure shows the number of satellites used, the middle plot is the reported standard deviation (this is how accurate the system think the position is), and the lower plot is the horizontal (radial) error. In figure 2 with only GPS, during the period with three satellites there is no good position. Also during the period with 4 satellites around 1100 UTC the position is bad. This is due to bad geometry of the satellites in view (high Horizontal Dilution of Precision, HDOP). In Figure 3 it is seen that during these periods with few GPS satellites due to the high elevation mask, three GLONASS satellites are used in addition to the GPS satellites. This provides sufficient number of satellites and good enough geometry to give a decimetre level position all the time.

Figure 5 shows a situation where only GLONASS satellites are used in the solution. With the current GLONASS constellation this happens a few hours every day. The top plot is the Data Quality indicator (DQI) showing a converged solution when it is 9. The second plot shows the number of satellites used and the third the dilution of precision values where HDOP and VDOP (Vertical dilution of precisions) are of most interest. The last plot shows that the position error in North (dN), East (dE) and height (dH) all are below 0.2 m when the solution is converged.

USER EQUIPMENT

The Kongsberg DPS232 system has the capability to use the GPS/GLONASS orbit clock corrections from Fugro. Tests are now being performed on a supply vessel in the North Sea using the DPS232. Figure 6 shows a display page from the DPS232 using GPS and GLONASS corrections.

Also the Fugro StarPack user equipment will use the new service. Other user equipment will follow.

SUMMARY

- Using different correction methods provides robustness
    - o Network corrections and Orbit/Clock corrections
- Dual independent high power deliveries in all regions of the world provide high availability
- Four Global Navigation Satellite Systems will provide 120 satellites in 5-10 years
- GLONASS is being revived with a full constellation in a couple of years
    - o 14+ satellites today
- Fugro will introduce dual frequency decimetre level GPS and GLONASS orbit/clock service in 2009. Vessel trials are going on in the North Sea.

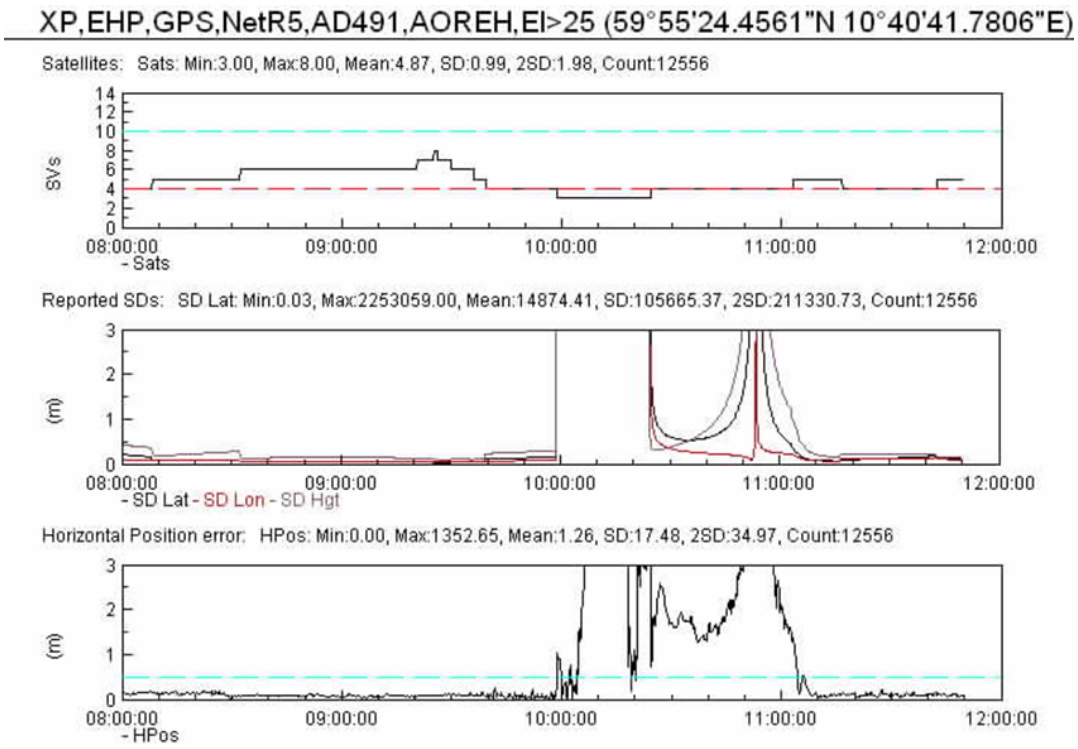

Figure 3: GPS only orbit/clock solution with elevation mask 25 deg. Oslo 20 Sept2008.

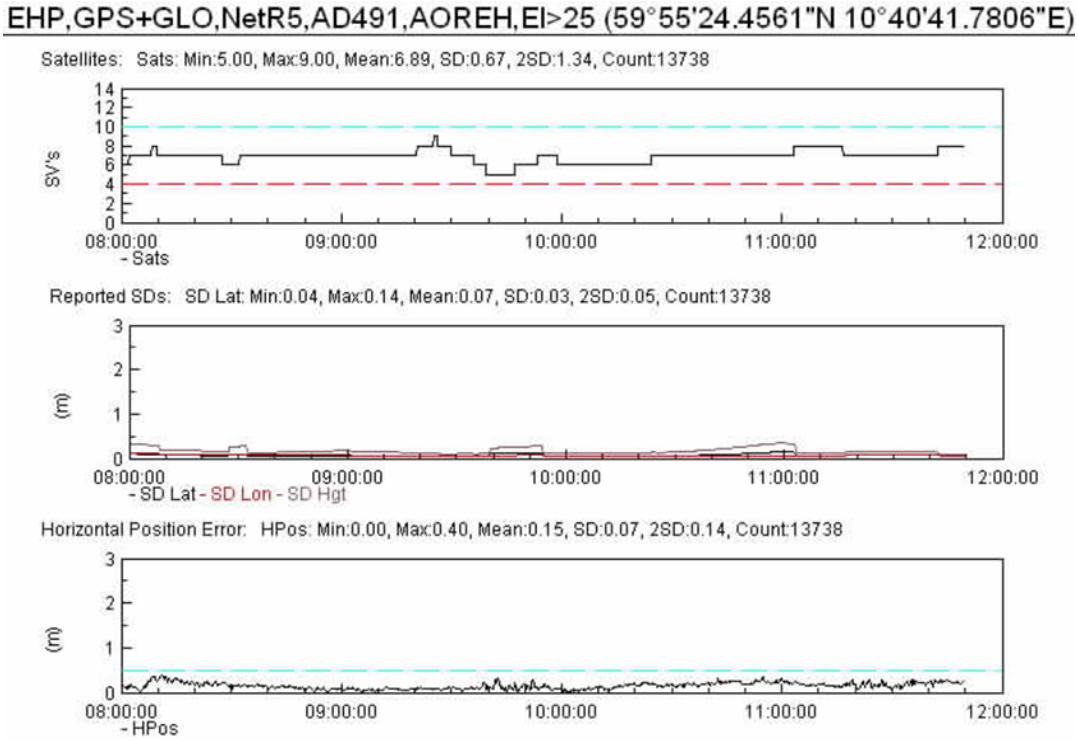

Figure 4: GPS/GLONASS orbit/clock solution with elevation mask 25 deg. Oslo 20 Sept2008.

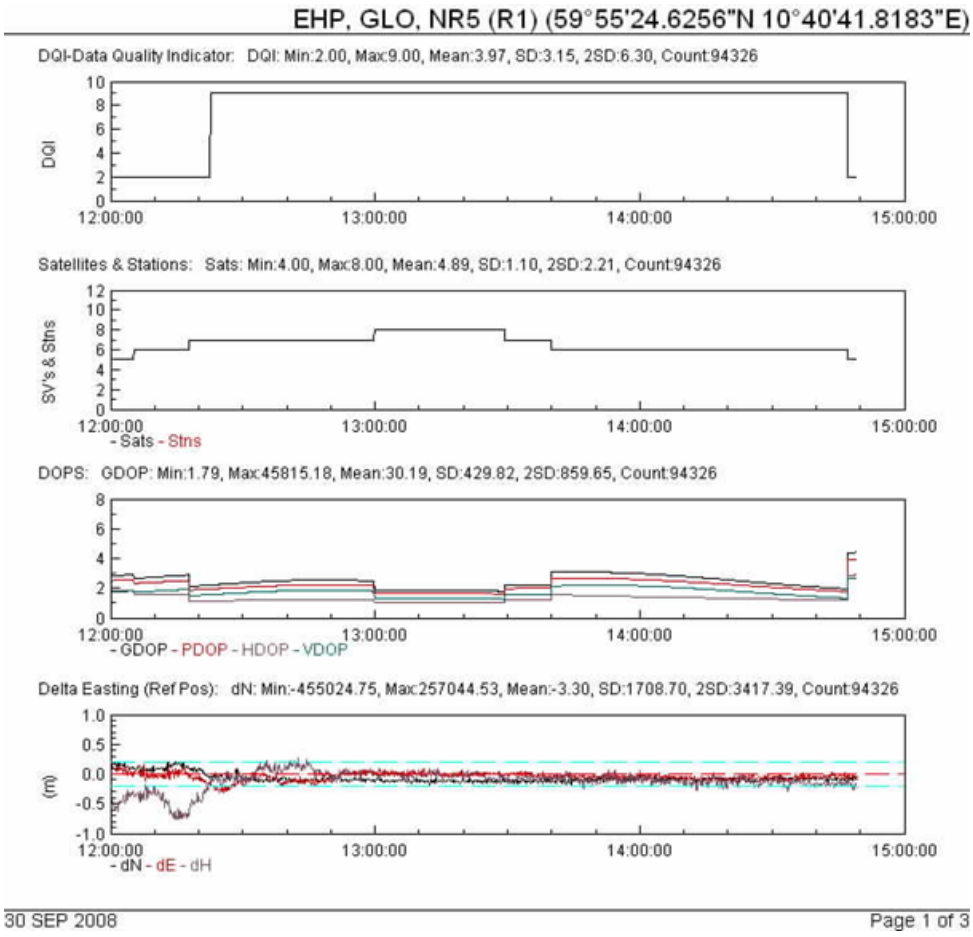

Figure 5: GLONASS only orbit/clock solution in Oslo 30 Sept2008.

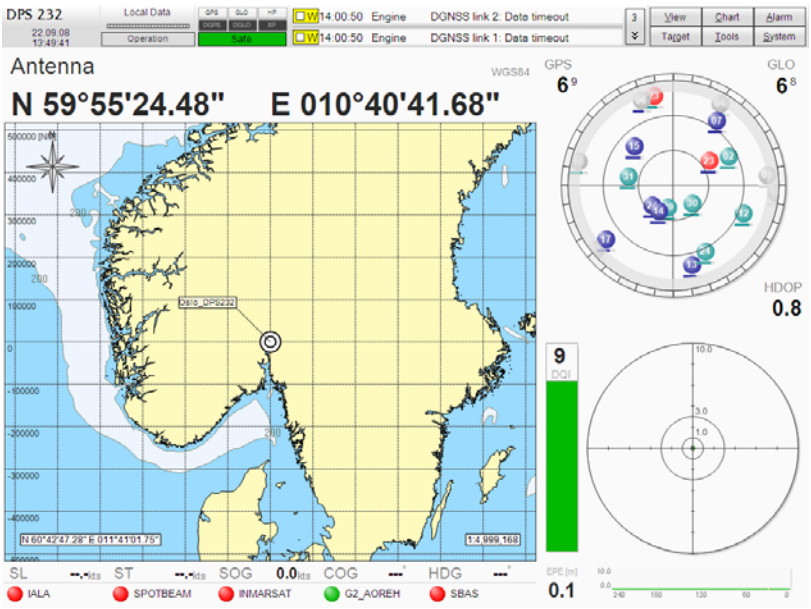

Figure 6: Print screen from the Kongsberg Seatex DPS232 using GPS and GLONASS.