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Sensors

Advantages of Using GNSS for Positioning in DP Applications

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ABSTRACT

The GPS system has now been fully operational for more than a decade and is becoming critical infrastructure due to its wide use in all kind of applications. The Russian GLONASS system has also been available for many years, but has lacked a full satellite constellation. GLONASS will be fully operational again in 2009. And the European Union is developing the Galileo GNSS system to be operational in 2011.

All these Global Satellite Navigation Systems contribute to improved performance for navigation and positioning in terms of:

- Independence
- Availability
- Reliability
- Accuracy

For DP applications these improvements in GNSS systems can be exploited through the use of additional independent reference systems for positioning, making operations less reliant on local surface and underwater reference systems.

Also DP operations close to structures will benefit from the added number of satellites, reducing the likelihood of accidents such as the Grane incident in 2005, where a supply vessel collided with the Grane platform. Investigations showed that blocking of GPS signals was a major contributor to the accident.

The 11 year solar cycle will have a peak in solar activity again in 2011. This will result in a disturbed ionosphere where increased number of GNSS satellites is an advantage.

INTRODUCTION

The US GPS (Global Positioning System) has been a huge success and is being widely used in all applications where navigation and positioning is required. The Russian GLONASS system has also been available for many years, but has been suffering from a reduced satellite constellation after the breakup of the Soviet Union.

As a consequence of satellite navigation becoming a part of the developed world’s critical infrastructure; additional satellite navigation systems are being launched. These systems are now being referred to as Global Navigation Satellite Systems, or GNSS. The Galileo system developed by the European Union will be operational in 5 years time.

Additional satellite navigation systems will mean improved performance in terms of:

- Satellites
    - Today about 40 satellites are available (28 GPS and 12 GLONASS)
    - In 5 years about 80 satellites will be available
- Frequencies
    - Today two frequencies are available
        - One tracked codeless with reduced tracking margin
    - In 5-8 years three frequencies will be available with full code tracking
- Interoperability
    - There is coordination between GNSS operators to ensure interoperability (frequencies, codes, coordinate reference frames, timing references)

Figure 1 shows the frequency band in the L-Band part of the spectrum used by satellite navigation systems.

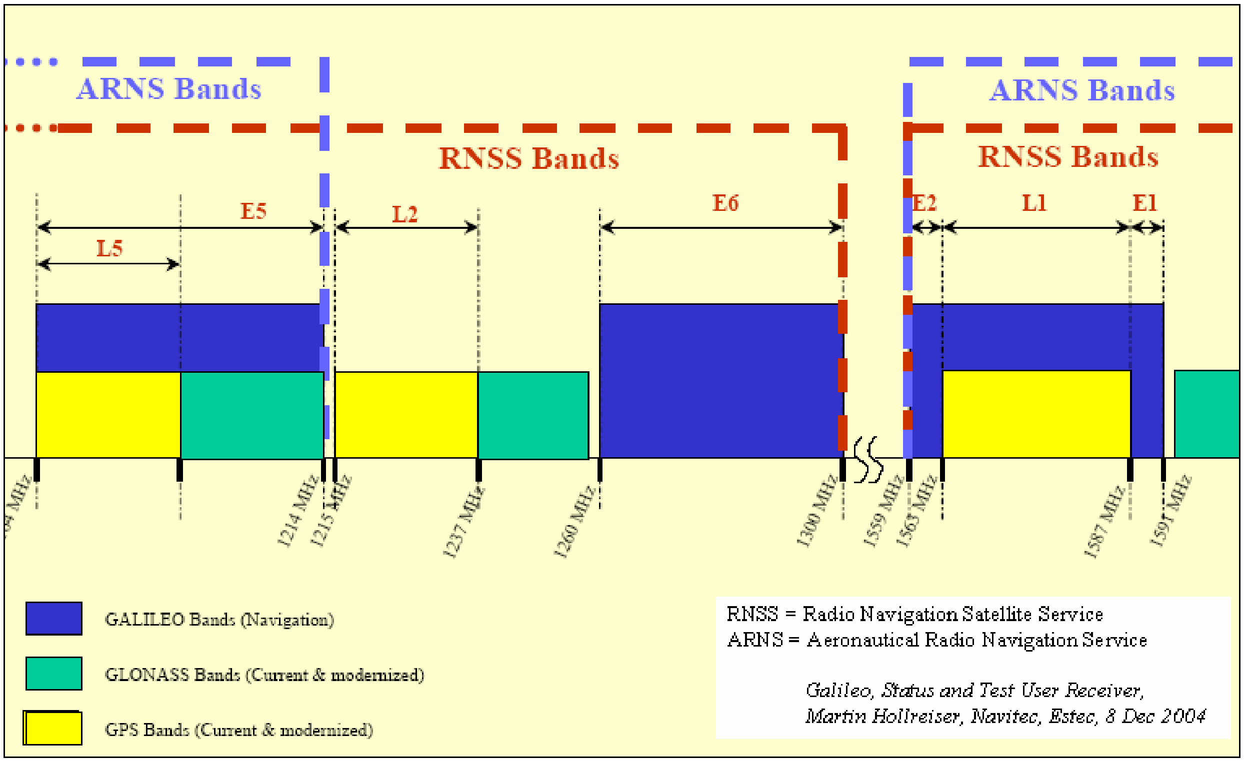

Figure 1: GPS/GLONASS/Galileo frequency bands.

SATELLITE NAVIGATION SYSTEMS STATUS

GPS

The GPS system was developed by the US military from 1973 and was declared fully operational in 1995.

The following are the main characteristics:

- Constellation: 24 satellites, 6 orbital planes
- Orbital altitude: 20200 km, Inclination: 55°
- Period of revolution: 12h (repeat ground track in one day)
- Code Division Multiple Access (CDMA):

The status today is:

- 29 Operational Satellites
- Global GPS availability was better than 99.99% in 2005
- GPS Accuracy 5-10 m 95%

Figure 2:GPS Constellation

The GPS system is being modernized, and the following are the major milestones:

- Block IIR-M: 2nd civilian signal(L2C)
  2005-2012
- Block IIF: 3rd civilian signal(L5)
  2008-2015
- Block III: 4th civilian signal, additional L1 signal (L1C)
  2023-2021

GLONASS

GLONASS was developed by the Soviet Union from the early 1980s. The GLONASS system had a full constellation of 24 satellites in 1995. However, the system was not replenished for the next several years, and in 2001 the constellation was down to 7 satellites. In 2001 a plan was approved to bring the constellation to full strength again. This plan was earlier this year accelerated on the order from President Putin after the successful launch of three satellites in Dec 2005.

The following are the main characteristics:

- Constellation: 24 satellites, 3 orbital planes
- Orbital altitude: 19100 km, Inclination: 64.8°
- Period of revolution: 11h 15m (repeat ground track in 17 days)
- Frequency Division Multiple Access (FDMA):
  - $L1i=1602+i\times0.5625$ [MHz]; $L2i=1246+i\times0.4375$ [MHz]
  - i = frequency number

The current status and plans for GLONASS are:

- 3 Satellites launched 26 December 2005
- 12-14 Operational
- Russian Aerospace Agency has approval for long term plan for GLONASS:
  - 18 Satellites by the end of 2007
  - 24 Satellites by the end of 2009
- GLONASS will also get more frequencies:
  - GLONASS M, second civilian frequency (from 2004)
  - GLONASS K, third civilian frequency (from 2008)

Galileo

Galileo is being developed by the European Union and will according to plan be fully operational in 2010. The following are the main characteristics:

- Constellation: 27 satellites plus 3 in orbit spares, 3 orbital planes
- Orbital altitude: 23222 km, Inclination: 56°
- Period of revolution: 14h 7m (repeat ground track in 10 days)
- Code Division Multiple Access (CDMA).

The current status and plans for Galileo are:

- One Test Satellite (GIOVE-A) launched December 2005 to secure frequency allocation.
- Second Test Satellite (GIOVE-B) to be launched in 2007.
- Four In Orbit Validation (IOV) satellites to be launched in 2008
- Full operational constellation by end of 2011.

The Galileo system will have several services as indicated below:

- **The Open Service** (OS) results from a combination of open signals, free of user charges, provides position and timing performances competitive with other GNSS systems.
- The Safety of Life Service (SoL) improves the open service performances providing timely warnings to the user when it fails to meet certain margins of accuracy (integrity). It is envisaged that a service guarantee will be provided for this service.
- **The Commercial Service** (CS) provides access to two additional signals, to allow for a higher data rate throughput and to enable users to improve accuracy. It is envisaged that a service guarantee will be provided for this service. This service also provides a limited broadcasting capacity for messages from service centers to users (in the order of 500 bits per second).
- **The Public Regulated Service** (PRS) provides position and timing to specific users requiring a high continuity of service, with controlled access. Two PRS navigation signals with encrypted ranging codes and data will be available.
- **The Search and Rescue Service** (SAR) broadcast globally the alert messages received from distress emitting beacons. It will contribute to enhance the performances of the international COSPAS-SARSAT Search and Rescue system.

(From: http://ec.europa.eu/dgs/energy_transport/galileo/programme/services_en.htm)

In addition to the GPS, GLONASS and Galileo systems, China has filed for frequencies for a GNSS system, called Compass, with 35 satellites. Possible operational date for this is not known.

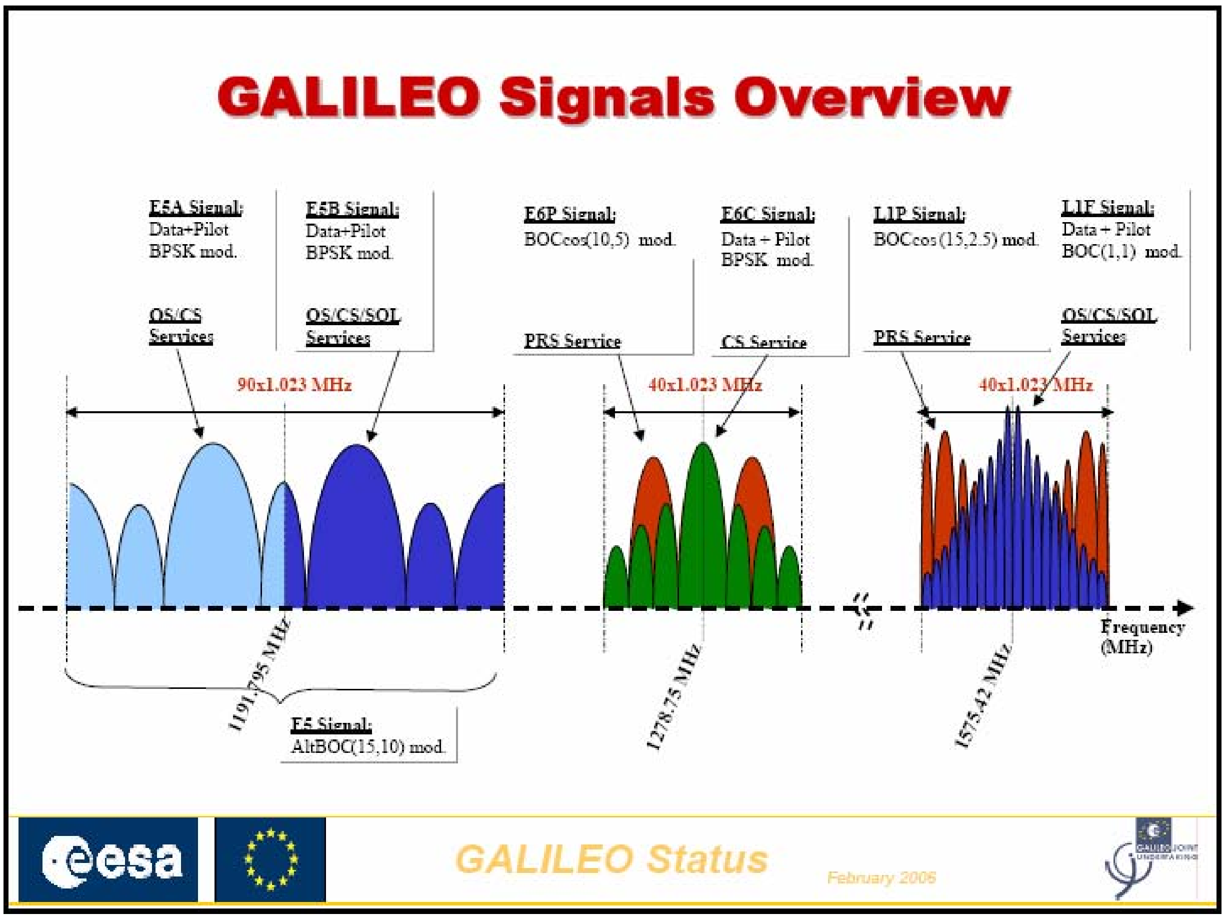

Figure 3: Galileo frequencies and services.

SPACE BASED AUGMENTATION SYSTEM (SBAS) AND REGIONAL SYSTEMS

A Space Based Augmentation System (SBAS) provides an overlay to the GNSS systems to enable them to meet the requirements for use in civil aviation. The most important requirement is the integrity requirement, providing information to the user within 6 seconds (most stringent requirement) if a satellite becomes unsafe to use. These systems provide differential corrections in addition to a GNSS-like ranging signal improving the satellite geometry for navigation.

Figure 4:SBAS services

Several SBAS services are available or planned:

- WAAS
  - Wide Area Augmentation Service, USA. Operational 2003
- EGNOS
  - European Geostationary Navigation Overlay Service, operational 2006-2007
- MSAS
  - MTSAT (Multi functional Transport Satellites) Satellite based Augmentation Systems (MSAS), Japanese SBAS, operational 2008
- GAGAN
  - GPS-Aided Geo Augmented Navigation, Indian SBAS, operational 2008

Regional satellite systems are also being developed. These are either complementing the GNSS systems or standalone systems in a region. These include:

- QZSS
  - Quasi Zenith Satellite System in Japan
  - Three additional satellites supplementing GPS/GLONASS/Galileo (CDR Dec 2006)
- IRNSS
  - Indian Regional Navigation Satellite System
  - Three geostationary satellites and four inclined orbit (29 deg inclination) (2013)
  - First satellite 2009
  - S-Band frequency
- Beidou ("Big Dipper")
  - Chinese military geostationary satellites
  - 2000-2010
  - 2.49175 GHz

Figure 5:QZSS Ground track

The IRNSS and the Beidou have signals that are available to "authorized users" and are not compatible with the other GNSS systems. They will probably be of limited commercial use.

QZSS will have L-Band signals. The L1 signal will be the same as L1C in GPSIII and the L1 Open Service in Galileo (Binary Offset Carrier, BOC(1,1)).

In additions to these governmental services, there are commercial space based differential GNSS services (without ranging signals). These systems typically differ from governmental augmentation services through higher accuracy and global coverage. Fugro, as one of the major suppliers of commercial differential GNSS services, plans to extend the augmentation capability for GLONASS, and Galileo when available.

GNSS RECIVER AVAILABILTY

Some commercial combined GPS/GLONASS receivers have been available for more than 10 years (Thales Navigation, Topcon). In 2006 all major receiver manufacturers launched a new generation of receivers, these are all capable of receiving at least two GNSS systems, and some are also prepared for Galileo. They also support the new GPS civilian signals (L2C, L5). Trimble and Novatel, both of whom had only GPS receivers earlier, both launched a receiver with GLONASS capability in early February 2006.

The multiple satellite system implementations in the new generation receivers are prompted by the revitalization of GLONASS. This added availability of receivers very important for acceptance of use of combined systems.

IMPROVEMENT IN PERFORMANCE

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.
- **Reliability**
  - Increased position line redundancy (additional lines of position) 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 regional phase based decimeter level systems

As GNSS services are becoming critical infrastructure, it is important that the GNSS services are available from several independent systems.

The GPS system, even though being fully operational, has in parts of the world during certain periods reduced availability of satellites and poor geometry. This is especially true during periods where one or more satellites are unavailable due to maintenance. Also, use of satellite navigation in areas with reduced visibility of the sky (e.g. urban canyons) availability is greatly improved using combined systems.

IMPLICATIONS FOR DP OPERATIONS

This section will comment on implications for Dynamic Positioning (DP) operations of added GNSS services. This will include use of added redundancy in reference systems, and added availability close to structures and during increased ionospheric activity in the upcoming solar cycle no. 24.

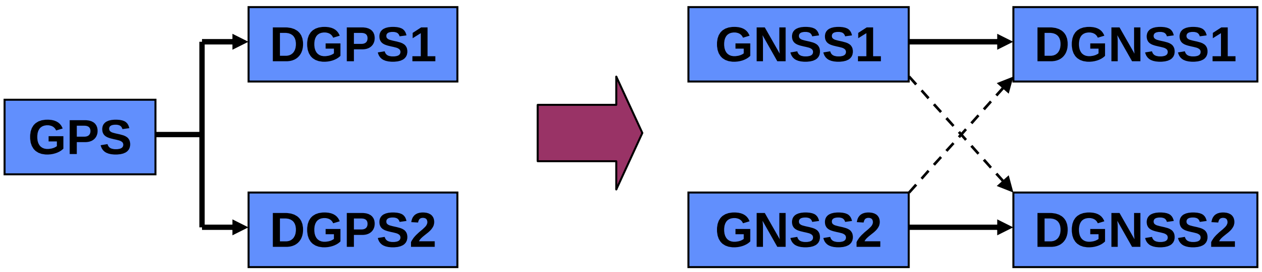

Figure 6: Setup for increased independence with several GNSS systems and Differential GNSS systems.

Today GPS is used as basis in all satellite navigation reference systems. With multiple GNSS Systems, it will be possible to configure several totally independent reference systems with corresponding Differential GNSS (DGNSS) systems for DP applications.

During the buildup phase of new GNSS systems, combined solutions will be used to take advantage of the added number of satellites.

GNSS systems are preferred options for reference systems for a rapidly increasing DP fleet operating world-wide. GNSS systems are much more versatile than local surface or underwater reference systems in an operations area.

An example of a collision due to blockage of GPS satellites is the incident on the Grane field in the Norwegian sector 6 May 2005.

- Supply Vessel “Island Ranger” collided with Grane Platform during loading
    - Minor damage to Supply Vessel
- From the investigation:
    - The problems with the DGPS’s were caused by the position of the vessel close to the platform causing shielding of GPS satellites.
    - The vessel should not have operated on DP due to lack of positioning system redundancy
- Problems would have been mitigated with additional satellites providing safer operations.

Figure 7: The Grane offshore platform and Island Ranger supply vessel

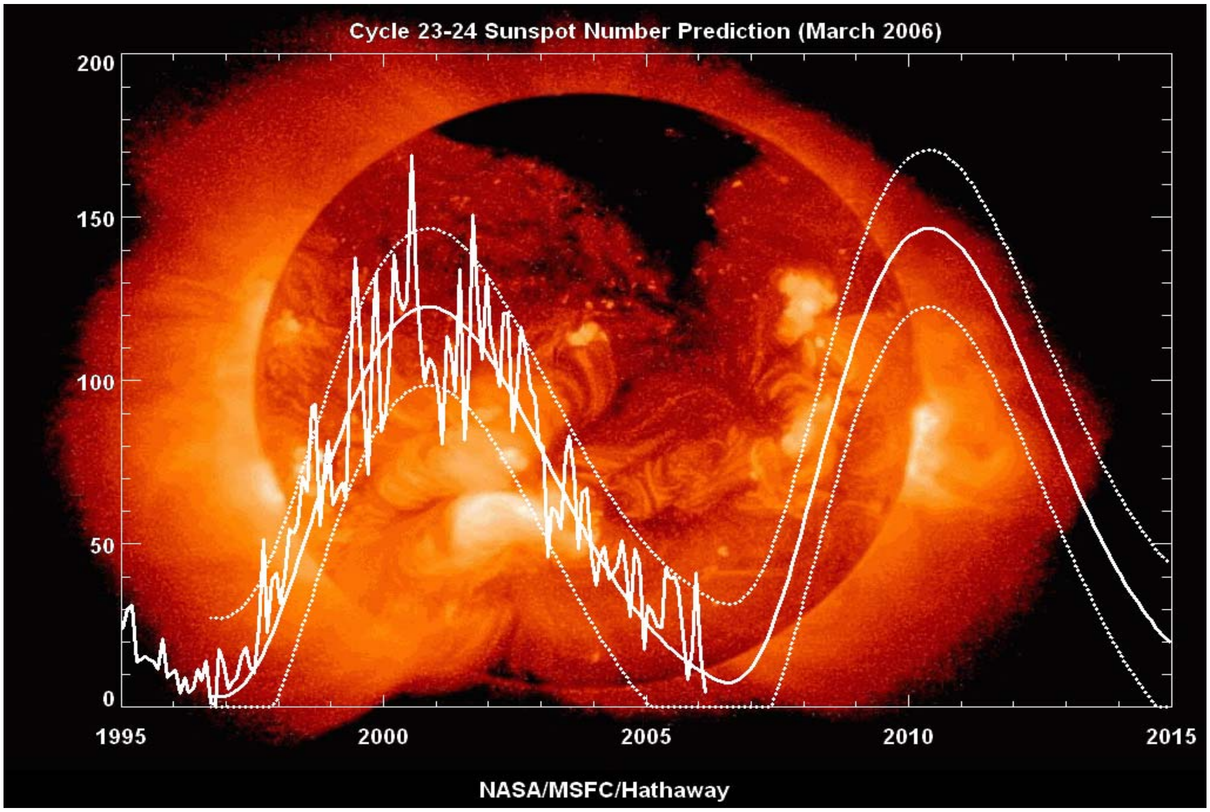

Figure 8: The Solar Cycle 24 starts early 2007 with a maximum in 2011. (http://www.nasa.gov/vision/universe/solarsystem/solar_cycle_graphics.html)

Another example of improved performance from combining GNSS services is when operating during disturbed ionospheric conditions. These disturbances are particularly severe in equatorial regions during high sunspot activity, but they can occur also during low activity. We are now at the bottom of the 11 year solar cycle, and the next cycle (no. 24) will start early 2007. The disturbances affecting GNSS systems are both scintillations, making a GNSS receiver loose lock on a satellite signal, mitigated by added number of satellites, and unpredictable ionospheric Total Electron Content (TEC), causing delay in GNSS signal, mitigated by use of several frequencies.

DP operations in equatorial regions were heavily affected during the previous solar cycle. As a result Petrobras specified use of GPS+GLONASS for certain operations in Brazil.

SUMMARY

The GPS system has now been fully operational for more than a decade and is becoming critical infrastructure due to its wide use in all kind of applications. The Russian GLONASS system has also been available for many years, but has lacked a full satellite constellation. GLONASS will be fully operational again in 2009. And the European Union is developing the Galileo GNSS system to be operational in 2011.

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