CONSIDERATIONS FOR GNSS MEASUREMENTS

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In the last period satellite positioning technology practical monopolized the determination of the coordinates of the position for local geodetic network and in particular the position for the points of detail. There are new constellation of satellites and some supports were set up to improve accuracy determinations in absolute system (Based Augmentation). Air navigation system, marine or road are the main beneficiaries of these supports that provide better accuracy. By increasing the accuracy of determination also increases the level of safety that any navigation system it wants, but especially aviation system that supports high performance set .
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1. GENERAL CONSIDERATIONS

A satellite positioning system with global coverage is called the Global Navigation Satellite System or GNSS.
Currently there are more satellite constellations that can emit radio signals that can be provided the positions of receivers.

1.1 GPS Constellation

The constellation known and used in the United States and Europe for nearly 25 years is GPS. It was designed and launched by the U.S. There are other constellation: GLONASS, Galileo and Compass launched by Russia, Europe and China respectively .
Global Positioning System GPS is on the move since 1973 under the direction of Joint Program Office of the U.S. Air Force Command 's, Los Angeles Force Base, the origin positioning system developed for the purpose and for military use, which became the shortly affordable and civil sector, gaining an extremely wide use in many countries, including our country after 1992.
The Global Positioning System works on the principle of the user receiving the radio signals emitted by a constellation of navigation satellites, specialized moving around the Earth in orbit around the Earth .
The system has been so designed that allow anytime and anywhere on Earth, a mobile moving or at rest, to be able to use appropriate equipment, to be able to determine in real time the position and speed for mobile and moving only for a mobile position at rest, in a three-dimensional geocentric coordinate system, proper positioning system GPS .

GPS positioning system is made up of three components and main parts, which ensures its operation as follows :
1. Space segment, consisting of the constellation of GPS satellites;
2. Control segment, consisting of ground stations that monitor the entire system;
3. User segment, composed of civilian and military users, who use recievers.

1.2. GLONASS Constellation

Global Navigation Satellite System (GLONASS) is based on a constellation of active satellites which continuously transmit coded signals in two frequency bands, which can be received by users anywhere on Earth to identify the position and speed in real time based on measurements of distances. The system is a counterpart to the U.S. Global Positioning System (GPS) and both systems have the same principles in data transmission and positioning methods. GLONASS is managed by the Russian Government by the Russian Space Forces and the system is operated by the Coordination Scientific Information Center (KNIT) in the Ministry of Defence of the Russian Federation .
GLONASS system control segment is entirely within the former Soviet Union. Control center of the segment and time standards are in Moscow and the telemetry and tracking stations are in St. Petersburg, Ternopol, Eniseisk , Komsomolsk -na- Amur.
By 2010, GLONASS has achieved 100% coverage in Russia. In February 2011, the constellation consists of 22 operational satellites. Two others were released at the end of 2010 but failed. In March 2011 one of the disturbed orbit satellites that had been repaired and thus had 23 satellites operate. There are currently 24 satellites in use. GLONASS satellites as models have undergone several upgrades, the latest version being GLONASS -K .

1.3. Galileo constellation

Galileo is the only European global satellite navigation. Until now, users of GNSS in Europe had no alternative but to use the GPS constellation U.S. or Russian GLONASS constellation. These two constellations are the main U.S. and Russian military beneficiary. During conflicts military, militarians operators of these systems have changed the signal from the satellites or even blocked him .
Meanwhile, satellite positioning has become a standard instrument and essential tool for positioning. If GNSS signals would stop, ships and aircraft from all over the world should revert to traditional navigation methods, which would be very difficult. Not only navigation would be affected but also human security .
Since 1990, the EU has felt the need to achieve a European satellite navigation system that can be used worldwide. European independence of positioning is the main reason to adopt this important step. Also being interoperable with GPS and GLONASS, Galileo will also be in a very real way, the cornerstone of the new global navigation satellite system (GNSS). This global system will be under civilian control. And its satellites complementary to existing GNSS systems, Galileo will allow precise positioning even in cities where satellite signals today are disrupted. Galileo will also offer a number of improvements to the signal to make it easy to follow and make it more resistant to interference and reflections. The European GNSS will provide more reliable and more accurate than American and Russian systems. This means

that Galileo and EGNOS will enable a whole new range and unlimited services, applications and business opportunities. Galileo will also achieve a better coverage at high latitudes by placing satellites in orbit at a greater inclination to the equatorial plane, so be completely covered and Northern Europe, an area that is not completely covered by GPS. [Peter Gutierrez 2011]
There are currently four operational satellites of the Galileo constellation .

1.4 Compass constellation

Compass positioning system (also known as the Beidou -2, BD2) is a project launched by China to develop an independent global satellite positioning .
Compass is not an extension of the previously developed system Beidou -1, but it is a new GNSS constellation similar in principle to GPS , GLONASS , and Galileo .
The new system will be a constellation of 35 satellites, including five satellites in geostationary orbit (GEO) and 30 satellites on a medium Earth orbit (MEO) system that will provide complete coverage of the globe. Signals vary based on CDMA principle and have a complex structure typical of modernized GPS and Galileo constellation. As for other GNSS constellations, there will be two levels of positioning service: open and restricted (military). The signal should be available globally for any user. When all GNSS positioning systems currently provided will be completed, users will benefit from a total constellation of 75 satellites that will significantly enhance all aspects of positioning, especially the possibility of using GNSS receivers in the so- called "urban canyons". General designer of Compass navigation system is Sun Jiadong, who also designed the previous system Beidou navigation system.

2. POSSIBILITIES FOR POSITIONING GNSS AUGMENTATION

Positioning GNSS receiver is either relatively (to a point already known position) is absolutely depending only satellites visible at a time. Positioning to a point having known position is simple to perform and provides better precision. In our paper we will discuss only the absolute positioning system using only the visible satellites. And here we have two possibilities:
- receiver that decodes signals only from a constellation (GPS, GLONASS, Galileo and Compass)
- receiving that decodes signals from more than one constellation.

The receivers produced by known companies can decode signals from GPS, Galileo and GLONASS constellations. As is known, the accuracy of the position of a point in the absolute system from the visible satellites, is directly proportional to the number of visible satellites and the residence time for each point. The more satellites are visible and as it stationed more on point, the accuracy of the positioning is better.
Another element that gives good accuracy of determination is GNSS receiver type. If the receiver is geodesic class, the accuracy is better, if the receiver is tourist type (hand GNSS), the accuracy is much weaker .

These types of determinations of position is practiced mainly in navigation on maritime, river , road, especially in the air. Air navigation is to be replaced ILS landing system with GNSS technology. For this reason many countries or groups of countries have implemented a system by which to improve (increase) the accuracy of the GPS constellation in absolute system. In fact , according to the position amplifier are two types of augmentation :

- From space ;
- On the ground.

2.1 The amplified system from space of satellites GNSS signal (SBAS - Satellite Based Augmentation Systems).

2.1.1 QZSS - Quasi-Zenith Satellite System.

Quasi-Zenith Satellite System (QZSS) is a regional proposal for a system of three satellites to transfer time and too satellite base augmentation system (SBAS) for Global Positioning System (GPS), implemented in Japan. The first satellite "Michibiki" was released on September 11, 2010. Full constellation will be achieved by 2013.

2.1.2 WAAS - Wide Area amplification system

WAAS uses a network of ground reference stations in North America and Hawaii, to measure small variations in signals from GPS satellites in the Western Hemisphere. Measurements from the reference stations are routed to master stations (fixed primary) receiving deviation correction (DC) and send correction messages to geostationary WAAS satellites in time (every 5 seconds or even faster).These correction messages broadcast by satellites back to Earth. GPS receivers with WAAS enabled signal decoding time can use these corrections to improve the accuracy of their position.

Accuracy. By the system specifications, WAAS is obliged to provide positions accurate to 7.6 meters (25 ft) or more specific (for horizontal and vertical), at least 95 % of the time. Current measurements using the system showed that the precision obtained is less than 1.0 m (3 ft 3 in) horizontally and 1.5 meters (4 ft 11 in) vertically throughout the United States and much of Canada and Alaska. With these results, WAAS fall into that category I precision approach (for aircraft) to 16 meters (52 ft) horizontally and 4.0 meters (13.1 ft) vertically .

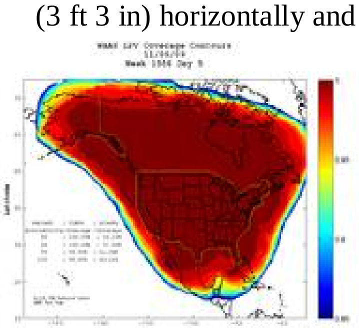

Figure 2.1. WAAS service area . Dark red indicates the WAAS coverage . Color coating services change over time depending on satellite geometry and ionospheric conditions. (Figure is taken from wikipedia , September 2011)

Integrity. The integrity of a navigation system include the ability to provide timely warnings when the signal provides erroneous data (incorrect position and so the plane could miss the runway) and that could create potential hazards. By the system specifications, WAAS can detect errors in the GPS network and inform users in 6.2 seconds. Certification stating that WAAS is safe for instrument flight rules (IFR - instrument flight rules) (ie flying blind - no pilot) required to prove that there is only a very small probability that errors exceeding accuracy requirements are not detected. Specifically , the probability is 1 × 10-7 , and is equivalent to 3 seconds of bad data per year. It provides information integrity equivalent to / or better than reception autonomous integrity monitoring (RAIM - reciever autonomous integrity monitoring).

2.1.3 EGNOS - European Geostationary Navigation Overlay Service

EGNOS - European Geostationary Navigation Overlay Service, was the first trial in Europe using satellite positioning and improves range of public services provided by the U.S. GPS. EGNOS improves GPS service makes it particularly suitable for safety critical applications such as flying aircraft or ships (navigation) through narrow channels. Basically it is similar to WAAS in Europe.

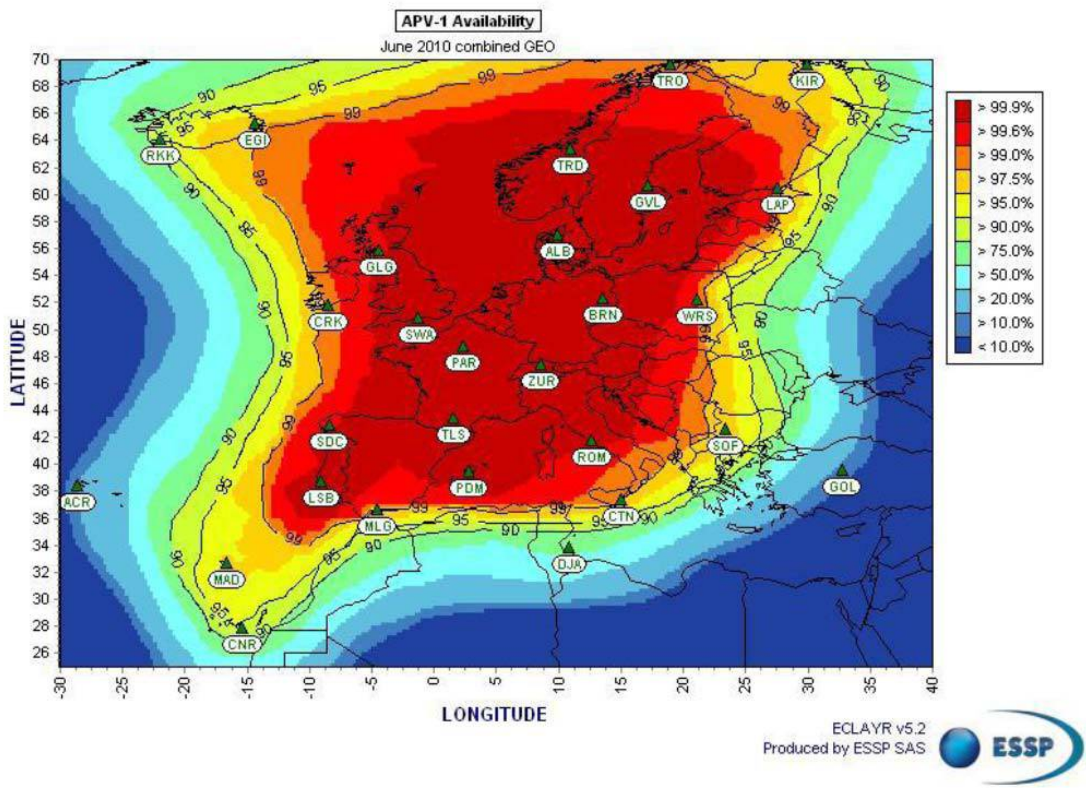

Figure 2.2. The range of EGNOS. (Figure is taken from wikipedia, September 2011)

2.1.4 MSAS - Multi-Functional Satellite Augmentation System Satellite

MSAS is a SBAS system released by the Japanese government. It is a satellite positioning system that helps differential GPS (DGPS) that complements the GPS system. This assistance is intended to improve the reception of satellite signals to get a better position in the area covered by type MSAS satellites. Ad in the WAAS and EGNOS systems as described above, the main beneficiary of MSAS system is air and maritime navigation. Thus, in the side of the area covered, the accuracy of 20 meters achieved only by using GPS system reaches 1.5 to 2 meters (planimetric and altimetric position) by introducing MSAS. After the tests have been passed, the system was commissioned aviation September 27, 2007.

2.1.5 Gagan - The GPS Aided Geo Augmented Navigation or GPS and Geo Augmented Navigation system

GPS positioning system assisted by improvement (Gagan) is a planned implementation of a regional system of satellites known as the base satellite amplification system (SBAS) by the Indian government. It is a system that improves the accuracy of a GNSS receiver by providing reference signals (correction). The project is implemented in three stages beginning in 2008 by the Airport Authority of India, with Indian Space Research Organisation (ISRO) on support space technology. The aim is to provide positioning navigation for all phases of a flight over Indian airspace and in the vicinity. It is applicable for lifesaving operations, and meets performance requirements of regulatory organism of international civil aviation. Gagan operational phase of the system was completed in May 2011. The system will be complete in 2014. Gagan is a Hindi word of Sanskrit origin and means sky.

2.2 The amplification of ground GNSS satellite signal (GBAS - Ground Based Augmentation Systems)

2.2.1 LAAS - Local Area Augmentation System

Local Area Augmentation System for GPS accuracy (LAAS) is a guide to landing the aircraft in any weather, based on real-time differential correction of the GPS signal. It is implemented in the U.S. and Canada. GPS receivers in the area are located on points with positions (coordinates) known. These points determine the difference between the determined position of the signals from the GPS satellites and the position known. Correction data are transmitted to a central location at the airport. These data are used to formulate a correction message, which is then transmitted to users via VHF waves. A receiver on an aircraft uses this information to correct the signals from the GPS satellites, which then provides an accuracy comparable to classic ILS landing. International Civil Aviation Organization (ICAO) asks this type of system (GBAS) .

Figure 4.3. LAAS system, similar in concept to JPALS, LDGPS (fixed base category) (Figure is taken from wikipedia, sept. 2011)

LAAS attenuates the imprecision of the GPS signal in local areas with a much higher accuracy than WAAS system and thus provides a higher level of service that can not be achieved by WAAS. VHF signal of the LAAS system is currently scheduled to share the frequency band from 108 MHz to 118 MHz with existing ILS tracking system and VOR navigation system. LAAS system uses the TDMA (Time Division Multiple Access), and serve the entire airport by providing a single frequency. By replacing the ILS system in the future, LAAS will reduce VHF NAV band which is very busy.

2.2.2 JPALS-Joint Precision Approach and Landing System

Precision landing system (JPALS) is a military landing in all weather conditions based on real -time differential correction of the GPS signal, amplified by a local correction message transmitted by secure means. Onboard GPS receiver compares the current derived position with the correction signal local. This correction comes from a three-dimensional point very precisely positioned to help the pilot to land in all weather conditions using a screen like as ILS mode. JPALS is similar LAAS, but primarily for use by the military. However, some elements of JPALS can be used by civilians to help protect important civilian operations, but unauthorized changes of signal may occur.

2.2.3 StarFire Navigation System

StarFire is a wide area differential GPS system developed by John Deere form Navcom and by a group that wants to develop an agriculture based on accurate position determination. StarFire additional issue "corrections" on the L bands of GPS satellites around the world, allowing a user equipped with a StarFire receiver to determine its position with sub-meter accuracy and precision provides a 24-hour period less than 4.5 cm. StarFire is similar to FAA GPS differential correction described in the chapter on WAAS, but considerably more accurate because of techniques that improve processing receiver.

Figure 4.11. Two receivers Navcom SF-2040G (Figure is taken from wikipedia, in September. 2011)

Misstatements arising GPS position is primarily due to "waves" (ripple) that waves do when passing through the ionosphere, they produce propagation delays and thus appears on the receiver position than it actually is. GPS is often cited as having 15 m accuracy, although the signal itself can give a position about 3 m from 12 m error Basically, 5 m is given by ionospheric distortion. Other 3-4 are given the errors in the satellite ephemeris data used to calculate the positions of the GPS satellite orbits and internal satellites clocks deviation.

Basically , the system calculates some DGPS corrections orbit satellites which will then forward them to all users. A receiver is placed at a point with coordinates very well known. From the satellite signals calculates its position. Between this calculated position and the position known before some differences appear. These differences are converted to a given satellite corrections. Corrections are transmitted to all other users of

GPS receivers in this way obtain a very precise position for their receivers. Correction mainly reduce errors due to ephemeris and clocks. For ionosphere corrections are good for receivers placed near the receiver that transmits corrections. The receiver that receives the correction is furthest from the base, the ionospheric correction is less accurate, and so the position error is higher. To obtain more precise corrections on a larger area would require more ground reference stations that would transmit more data. For example WAAS system uses twenty-five stations in the United States and wants to make a grid of 5 º x5 º. StarFire instead uses an advanced receiver to correct internal the errors ionospheric effects. To achieve this it capture signal P (Y) and is broadcast it on two frequencies, L1 and L2, and comparing the effects of the ionosphere on the propagation time of the two frequencies. With this information , ionospheric effects can be calculated with a high degree of precision, which is the Starfire DGPS can compensate for variations in propagation delay. The second signal P (Y) is encrypted and can't be used by civilian receivers directly, but Starfire does not use the data contained in the signal, but instead only compares the phase of two signals . This is expensive in terms of the electronics , which requires a second tuner and a good stability to be useful signal , so that the solution Starfire is not used on a large scale (at least when it was created) .

3. CASE STUDY

Case study is to determine the position of a point in the WGS84 coordinate system in various ways.
1.To determine the position of a point in function of a point with a known position EUREF89 .
2. Determining points position using GPS satellites only (single processing point) .
3. Determine the position of points using both GPS satellites and satellite constellations and other EGNOS (single processing point) .
We used Class geodetic receivers (L1 , L2 and L5), but different residence time.
Coordinates were calculated originally in WGS84 system and transformation in the Stereographic 1970 system using TRANSDAT program.
In the process of measurements revealed the following values.
The reference value obtained from measurements from the permanent station is:
x = 561003.190 m
y = 459691.003 m
h = 317.100 m
Following values are obtained by processing the single point method.

Table 3.1

Constellations used	stay time	north coordinate [m]	east coordinate [m]	altitude [m]	difference of measurement from permanent stations [m]	[m]	[m]
GPS+GLONAS	7h	561004.047	459691.761	315.92	-0.857	-0.758	1.183
GPS		561003.560	459691.538	315.98	-0.370	-0.535	1.119
GLONAS		561004.518	459689.691	323.89	-1.328	1.312	-6.787
GPS+GLONAS	3h	561004.037	459691.735	317.19	-0.847	-0.732	-0.089
GPS		561003.468	459691.361	316.75	-0.278	-0.358	0.346

GLONAS		561004.627	459690.382	320.33	-1.437	0.621	-3.231
GPS+GLONAS	1h	561006.364	459692.245	316.52	-3.174	-1.242	0.584
GPS		561004.468	459691.91	315.69	-1.278	-0.907	1.413
GLONAS		561008.679	459691.693	315.86	-5.489	-0.690	1.245
GPS+GLONAS	15 min	561006.439	459693.303	317.38	-3.249	-2.300	-0.284
GPS		561003.218	459692.439	316.72	-0.028	-1.436	0.378
GLONAS		561009.183	459690.907	320.11	-5.993	0.096	-3.009

4. CONCLUSIONS

As shown in Table 3.1, the coordinate values calculated for point studied , differ significantly depending on the residence time and the election of satellite constellations. Although the best solution would have to be given to the processing GPS and GLONASS constellations during its stay of 7 hours, the practice has not happened. The closest position to the true position is determined by processing only GPS constellation over a period of 3 hours.
The time of 7 hours processed only with GPS constellation, although it is longer, the result is worse. This is because at this time the satellite configuration is not optimal (GDOP). Thus, in the computing processing errors were introduced due to geometry .
We also notice that all combinations containing GLONASS constellation are far from fair value. This proves that constellation GLONASS ephemeris are not as good as the GPS constellation .
In conclusion, single point data processing system is optimal when using only GPS constellation over a period of 3 hours and a very good GDOP .

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