Global Navigation Satellite Systems (GNSS)

Chakshu Raj; Pankaj Kumar & Viplav Yadav

Dronacharya College of Engineering, Gurgaon, India

Email: chandra.pankaj30@gmail.com

Abstract:

GNSS (Global Navigation Satellite Systems) was started with the launch of the U.S Department of Defense Global Positioning System (GPS) in the late 1970's. Global Navigation Satellite System (GNSS) is basically a composed of some non-geostationary satellites such as

- *GPS (United States)*
- *GLONASS (Russia)*
- *Galileo (European Union)*
- *BeiDou (China)*

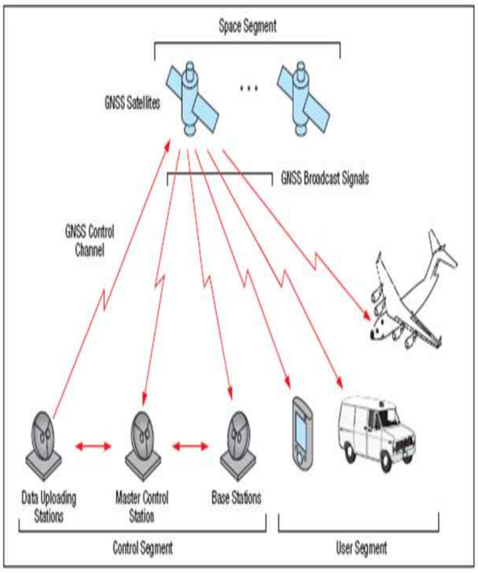
Introduction:

Global Navigation Satellite System (GNSS) is currently composed of two non-geostationary satellite constellations, and the augmentations for those two systems. Constellations: Global Positioning System (GPS); United States; more than 24 SV; 11,000 nm orbit Global Navigation Satellite System (GLONASS); Russian Federation; 16 satellites (SVs), expect to increase the number of SVs with the establishment of a special "Global Navigation System" program Future possibilities … Galileo, China, Japan. Augmentations are the part to improve signal availability, accuracy, integrity which are: ABAS confirms integrity through a consistency check across all satellites. It cannot improve accuracy, and has limited availability since extra satellites are needed to support this check (also called Receiver Autonomous Integrity Monitoring = RAIM).Satellite-based providing wide area coverage. LPV now, one state implementing approaches equivalent to Category I ILS. Ground-based providing very good local corrections and short time-to-alert values. CAT I systems in development, expected to be approved in 2008. Standards for CAT II/III are under development.

Architecture:

GNSS satellite systems consists of three major components or "segments:

- Space Segment
- Control Segment
- User Segment



Space segment includes GNSS satellites, orbiting about 20,000 km above the earth. Each GNSS has its own constellation of satellites. The control segment The control segment comprises of a ground-based network of master control stations, data uploading stations, and monitor stations. Master control stations adjust the satellites' orbit parameters and on-board high-precision clocks when necessary to maintain accuracy Monitor stations monitor the satellites' signal and status, and relay this information to the master control station Uploading stations uploads any change in satellite status back to the satellites User segment consists of GNSS antennas and receivers used to determine information such as position, velocity, and time

Satellite and navigation:

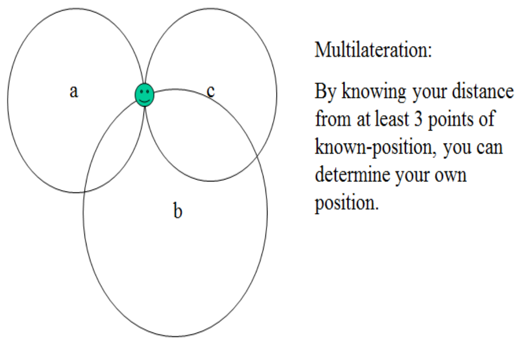
Satellite navigation is basically multilateration. The user receives the satellite position and time in the form of a broadcast almanac. All of the satellite clocks are closely synchronized, however the user may not be. As a result, with at least 4 satellites in view the user can solve for the four "unknowns" of latitude, longitude, altitude and time.

GNSS satellites know their time and orbit ephemerides very accurately

Timing accuracy is very important. The time it takes a GNSS signal to travel from satellites to receiver is used to determine distances (range) to satellites

1 microsecond = 300m, 1 nanosecond = 30 cm.

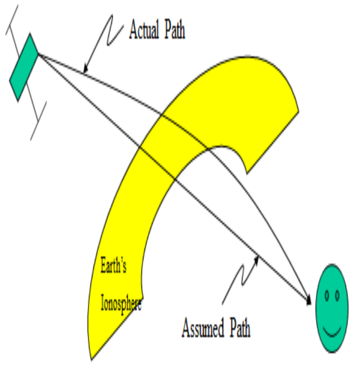
Small deviations in time can result in large position errors



For Satellite Navigation: a, b & c are satellites, and a fourth is needed to solve for clock variations.

Propogation and ranging:

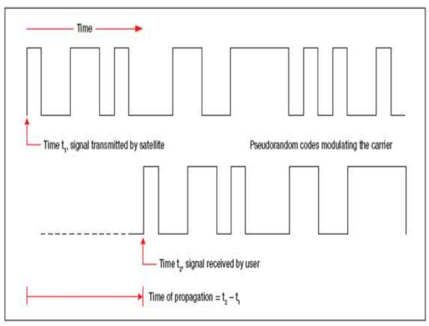
To determine accurate positions, we need to know the range to the satellite. This is the direct path distance from the satellite to the user equipment. The signal will "bend" when traveling through the earth's atmosphere. This "bending" increases the amount of time the signal takes to travel from the satellite to the receiver. The computed range will contain this propagation time error, or atmospheric error. Since the computed range contains errors and is not exactly equal to the actual range, we refer to it as a “pseudorange”.



The ionosphere contributes to most of the atmospheric error. It resides at 70 to 1000 km above the earth’s surface. Free electrons resides in the ionosphere, influencing electromagnetic wave propagationIonospheric delay are frequency dependent. It can be virtually eliminated by calculating the range using both L1 and L2.The troposphere, the lowest layer of the Earth’s atmosphere, contributes to delays due to local temperature, pressure and relative humidity. Tropospheric delay cannot be eliminated the way ionospheric delay can be.It is possible to model the tropospheric delay then predict and compensate for much of the error. Signals can be reflected on the way to the receiver. This is called “multipath propagation. ”These reflected signals are delayed from the direct signal, and if strong enough, can interfere with the direct signal Techniques have been developed whereby the receiver only considers the earliest-arriving signals and ignore multipath signals, which arrives later. It cannot be entirely eliminated.GNSS modernization is expected to provide a second protected civil signal in the 1164-1215 MHz band. At that time corrections could be made in the aircraft. Augmentations may still be required to meet signal integrity and availability requirements.

Reception:

Receivers need at least 4 satellites to obtain a position. If more are available, these additional observations can be used to improve the position solution.GNSS signals are modulated by a unique pseudorandom digital sequence, or code. Each satellite uses a different pseudorandom code.Pseudorandom means that the signal appears random, but actually repeats itself after a period of time.Receivers know the pseudorandom code for each satellite. This allows receivers to correlate (synchronize) with the GNSS signal to a particular satellite.For each satellite tracked, the receiver determines the propagation time.



The above figure shows the transmission of a pseudorandom code from a satellite. The receiver can determine the time of propagation by comparing the transmit time to the receive time.

- GNSS frequency bands:
- Currently most of GNSS occurs in 1559-1610 MHz with GBAS broadcast in the upper part of the VHF navigation band. As noted in previous slides, the 1215-1240 MHz band is used at SBAS ground reference stations to enable ionospheric corrections. At this point the L2 signal cannot be reliably used in aircraft as the band is not controlled by aviation and is heavily used for radar. Ground use can be protected on a site-by-site basis. The signal corrections and integrity information for SBAS are transmitted in the 1559-1610 MHz band.
- Future GNSS modernization will result in the addition of new civil signals in the 1164-1215 MHz band. These available to civil users and occurring in frequency bands with allocations identical to those in 1559-1610 MHz, will allow airborne users to perform their own ionospheric corrections.

GNSS Frequency Bands

Frequency (MHz)	Function
108-117.975	GBAS/GRAS broadcast link
1164-1215	GPS L5, Galileo E5, future SBAS, GLONASS L3
1215-1240	GPS L2 (site-by-site ground use only)
1559-1610	SBAS, GPS L1, GLONASS, Galileo E1

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