Global Navigation Satellite System (GNSS)
Global Navigation Satellite System (GNSS)

GNSS (Global Navigation Satellite System) is a satellite system that is used to pinpoint the geographic location of a user's receiver anywhere in the world.

- NAVSTAR GPS - United States of America
- GLONASS - Russia
- Galileo – European Union

GNSS will be used primarily for global, all weather, continuous, real-time positioning and for marine, air, and land navigation.
Global Navigation Satellite System (GNSS)

• Each of the GNSS system employs a constellation of orbiting satellites working in conjunction with a network of ground stations.

• Basically, the users of these systems simultaneously measure ranges to several satellites, and receive a broadcast data message containing information on satellites’ positions.

• If these position are known, in an earth-centered, earth-fixed (ECEF) coordinate system the user’s position can be computed either in Cartesian geocentric coordinates or, equivalently, in geographic coordinates.

• The ECEF-referenced satellite positions computed from the received data message depend on the configuration of the satellite orbits and the way the orbital data represented in the message.
Global Navigation Satellite System (GNSS)

- On February 22, 1978, the first GPS prototype satellite was launched into orbit by United States, starting a new era in satellite navigation.
- Four and a half years later on October 12, 1982, the first GLONASS satellites were placed in orbit by Soviet union.
- Since then the two satellite navigation systems have been built up slowly. Now the world will have two separate and independent tools for navigation and positioning of unprecedented accuracy and reliability.
NAVSTAR GPS
NAVSTAR GPS

• NAVigation by Satellite Timing And Ranging (NAVSTAR)
• The United States Department of Defense (DoD) has developed the Navstar GPS, which is an all-weather, space based navigation system to meet the needs of the USA military forces and accurately determine their position, velocity, and time in a common reference system, anywhere on or near the Earth on a continuous basis (Wooden, 1985).
• Started in February 22, 1978
• Initially developed as a military navigation system to assist US military later extended to civilian users.
• 24 Satellites orbiting the earth
• One Way communication
Segments of GPS

- **Space segment:** The Space Segment of the system consists of the GPS satellites; These space vehicles (SVs) send radio signals from space.

- **Control segment:** The Control Segment consists of a system of tracking stations located around the world.

- **User segment:** The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert space vehicle (SV) signals into position, velocity, and time estimates.
Satellite orbits

• Four GPS satellite will be unevenly distributed in each of six orbital planes.
• These planes are inclined to the equator by 55°, and are separated from each other by 60° in longitude.
• The satellite’s orbit are circular with a radius of about 26,500 kilometres.
• Kepler’s third law relates the orbital radius to orbital period, the time needed by satellite to travel full circle in its plane.
• GPS orbital period is exactly one half of a sidereal day. (A sidereal day is rotation period of the earth, and is equal to a calendar day minus four minutes).
• Therefore, after one sidereal day the geometric relationship between fixed spots on the earth and the satellites repeats.
• For an observer on the earth, all GPS satellite reappear in same part of the sky day after day, always four minutes earlier each day.
Calculate orbital period

Kepler's Third law of planetary motion

\[ \frac{P^2}{a^3} = \frac{4\pi^2}{GM} \]

- where \( P \) is period
- \( a \) is orbital radius
- \( GM \) is geocentric gravitational constant \( (GM) = 3.986005 \times 10^{14} \text{ m}^3/\text{s}^2 \)
Satellite signal

• The GPS user equipment receives the sum of the signals broadcast by all visible satellites. A particular signal can be tracked with a radio frequency channel in the GPS receiver by looking for the satellite’s unique pseudo random noise (PRN) codes modulation, thereby rejecting all signals with a different code.

• The procedure of separating the total incoming signals into the components transmitted by different satellites is called code division multiple access (CDMA).

• In order to decode the signal, the receiver must be aware of the PRN codes for each satellite.
All GPS satellites transmit the two carrier signals at the same L-band frequencies and modulates them with satellite-specific C/A-codes and P-codes.

- L1: 1575.42 MHz (C/A-code and P-code)
- L2: 1227.60 MHz (P-code)

These dual frequencies are essential for eliminating the major source of error, i.e. the ionospheric refraction.

For positioning and timing, GPS provides two levels of services:

- Standard Positioning Service (SPS) with access for civilian users.
- Precise Positioning Service (PPS) with access for authorized users.
Satellite signal cont.

- The First code is the coarse/acquisition (C/A) code, which is available for civilian use.
- The C/A-code is designated as the standard positioning service (SPS).
- The C/A-code is presently modulated upon L1 only and is purposely omitted from L2. This omission allows to deny full system accuracy to non-military users.
- The second code is the precision (P) code, which has been reserved for US military and other authorised users.
- The P-code is designated as the precise positioning service (PPS).
- The P-code is modulated on both carriers L1 and L2.
Satellite signal cont.

A GPS signal contains three types of data

• **Unique pseudorandom noise (PRN) codes:**
The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information.

• **Satellite ephemerides data:**
which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

• **Almanac data:**
The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.
GPS Time

• GPS Time is based on an atomic time scale.

• The GPS clock data are transmitted in terms of clock offset, clock frequency offset, and clock frequency rate, and allow the calculation of the difference between the individual GPS satellite’s time and the GPS system time.

• Coordinated Universal Time as maintained by the U.S. Naval Observatory (UTC (USNO)) is also based on an atomic time scale, with an offset of an integer number of seconds with respect to GPS system Time.

• GPS system Time does not count leap seconds, and therefore an offset exists between UTC (USNO) and GPS system Time.
GPS Datum

Datum is a set of parameters (translations, rotations, and scale) used to establish the position of a reference ellipsoid with respect to points on the Earth’s crust.

• The satellite ephemerides broadcast by the GPS satellites contain the parameters of the satellite orbit in terms of a linearly varying ellipse, plus small correction terms accounting for irregularities in the orbit. The ephemeris data are updated every hour.

• From these, users can compute ECEF coordinates of the satellite for a particular measurement time using well-known equations. The resulting ECEF coordinates are referenced to the World Geodetic System 1984 (WGS-84).
The control segment consists of five Monitoring Stations (Hawaii, Kwajalein [West Pacific], Ascension Island [South Atlantic], Diego Garcia [Indian Ocean], Colorado Springs), three Ground Antennas (Ascension Island, Diego Garcia, Kwajalein).

The Master Control facility is located at Schriever Air Force Base (formerly Falcon AFB) in the State of Colorado, USA.

They measure the distances of the overhead satellites every 1.5 seconds and send the corrected data to Master control.

Orbits are precisely measured. Discrepancies between predicted orbits (almanac) and actual orbits are transmitted back to the satellites.
User Segment

• It consists of receivers that decode the signals from the satellites.
• The receiver performs following tasks:
  - Selecting one or more satellites
  - Acquiring GPS signals
  - Measuring and tracking
  - Recovering navigation data
Sources of GPS Signal Error

- Satellite geometry
- Satellite orbits
- Multipath
- Atmospheric effects
- Clock
- Selective Availability (S/A)
**Error : Satellite Geometry**

- Satellite Geometry refers to the relative position of the satellites at any given time.
- Ideal satellite geometry exists when the satellites are located at wide angles relative to each other.
- Poor geometry results when the satellites are located in a line or in a tight grouping.
- The best geometry, and least error, occurs when the satellites are equally distributed.
- Satellite geometry error occurs when the satellites are concentrated in one quadrant or in a line.
- Satellite geometry error is not measureable, it tends to enhance other errors.
Ideal Satellite Geometry
Good Satellite Geometry
Good Satellite Geometry
Poor Satellite Geometry
Poor Satellite Geometry
Poor Satellite Geometry
Error : Satellite Orbits

• Even though the satellites are positioned in very precise orbits, slight shifts are possible due to the gravitational influences of the sun and moon or solar wind.

• These Minor disturbances in satellite orbits also known as ephemeris errors.

• Orbit errors can be as high as 2 meters.
Error: Multipath

- Multipath errors are occurred when GPS signal is reflected off of objects before it reaches to the GPS receiver.
- Increment in travel time of signal due to reflection causes the errors.
- Increase chance of occurrence when around tall buildings.
- Satellite signals require a direct line to GPS receivers.
- The more satellites a GPS receiver can "see," the better the accuracy.
- Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all.
- GPS units typically will not work indoors, underwater or underground.
Error : Atmospheric effects

- Satellite signal travels at the speed of light in space, but slowed down as its passes through the atmosphere.
- Atmospheric errors are separated in two categories: the ionospheric effect and the tropospheric delay.
- The ionospheric effect is frequency dependent and it is caused by the region of the atmosphere between 50 and 1000 km above the surface of the Earth.
- The tropospheric delay is frequency independent, and it is caused by the lower part of the atmosphere, between the surface and 50 km.
- The majority of this effect can be eliminated by the receiver.
- The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.
Error : Clock

• Slight fluctuations in atomic clocks.
• In spite of the synchronization of the satellite and receiver clocks, and small amount of inaccuracy in timing remains.
• This can result in errors up to 1 meter.
• To keep clock errors to 1 meter or less, the time error must be limited to 20-30 nanoseconds.
• A receiver's built-in clock is not as accurate as the atomic clocks on-board the GPS satellites. Therefore, it may have very slight timing errors.
Error : Selective Availability (S/A)

• Selective Availability (SA) is an intentional degradation of the signals by time varying bias once imposed by the U.S. Department of Defence.

• SA was intended to prevent military adversaries from using the highly accurate GPS signals.

• The US DoD turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

• S/A could be reactivated at any time by the US DoD.
# Accuracy – Sources of Error

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount of Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionosphere effect</td>
<td>± 5 meters</td>
</tr>
<tr>
<td>Troposphere effect</td>
<td>± 0.5 meters</td>
</tr>
<tr>
<td>Multipath distortion</td>
<td>± 1 meter</td>
</tr>
<tr>
<td>Satellite clock drift</td>
<td>± 2 meters</td>
</tr>
<tr>
<td>Ephemeris errors</td>
<td>± 2.5 meters</td>
</tr>
<tr>
<td>Numerical errors</td>
<td>± 1 meter</td>
</tr>
<tr>
<td>Total GPS accuracy</td>
<td>≈ 15 meters</td>
</tr>
</tbody>
</table>
How Does GPS Work?
GPS Receiver : Basic Principle

- The receiver collects, decodes and processes the satellite signals.
- The basic receiver does not include a transmitter.
- The receiver determines its location by trilateration.
- Trilateration works by using the distance from known positions.
- Triangulation works by using the angles from known positions.
Calculating a Position

- A GPS receiver calculates its position by a technique called satellite ranging, which involves measuring the distance between the GPS receiver and the GPS satellites it is tracking.
- The range (the range a receiver calculates is actually a pseudo range, or an estimate of range rather than a true range) or distance, is measured as elapsed transit time.
- The position of each satellite is known, and the satellites transmit their positions as part of the "messages" they send via radio waves.
- The GPS receiver on the ground is the unknown point, and must compute its position based on the information it receives from the satellites.
Measuring Distance (Pseudo Range) to Satellites

• Measuring the distance between the GPS receiver and a satellite requires measuring the time it takes for the signal to travel from the satellite to the receiver.

• Once the receiver knows how much time has elapsed, it multiplies the travel time of the signal times the speed of light (because the satellite signals travel at the speed of light) to compute the distance.

• Distance measurements to four satellites are required to compute a 3-dimensional (latitude, longitude and altitude) position.

• In order to measure the travel time of the satellite signal, we have to know when the signal left the satellite AND when the signal reached the receiver. Presumably our receiver "knows" when it receives a signal, but how does it know when the signal left the satellite?

• GPS satellites generate a unique pseudo random noise (PRN) codes that actually repeat every millisecond. The trick is that the GPS satellites and our receivers are synchronized so they're generating the same code at exactly the same time.

• So, when a GPS receiver receives codes from a satellite, it looks back to see how long ago it (the receiver) generated the same code. The time difference is how long the signal took to get from the satellite to the receiver. In other words, the receiver compares how "late" the received satellite code is, compared to the code generated by the receiver itself.
Pseudo Random Noise Code

Time Difference

Satellite PRN

Receiver PRN
Measuring Distance to Satellites cont.

• Distance is calculated using the velocity equation.

\[
\text{Velocity} = \frac{\text{Distance}}{\text{Time}}
\]

• Rearranging the equation for distance:

\[
\text{Distance} = \text{Velocity} \times \text{Time}
\]

• If the system knows the velocity of a signal and the time it takes for the signal to travel from the sender to the receiver, the distance between the sender and the receiver can be determined.
Measuring Distance to Satellites cont.

• The signals from the GPS satellites travel at the speed of light—3,000,000 kilometers/second.

• How far apart are the sender and the receiver if the signal travel time was 0.23 seconds?

\[
\text{Distance (ft)} = \text{Velocity (km/sec)} \times \text{Time (sec)}
\]

\[
= 3,000,000 \dfrac{\text{km}}{\text{sec}} \times 0.7 \text{ sec} = 2,100,000 \text{ km}
\]

• It should be clear that this system requires very accurate measurement of time and synchronization of clocks.

• These time errors limit the precision of this system.
GPS : Trilateration/Triangulation

- Each satellite knows its position and its distance from the center of the earth.
- Each satellite constantly broadcasts this information.
- With this information and the calculated distance, the receiver calculates its position.
- Just knowing the distance to one satellite doesn’t provide enough information.
When the receiver knows its distance from only one satellite, its location could be anywhere on the earth's surface that is an equal distance from the satellite.

Circle in the illustration.

The receiver must have additional information.
GPS : Trilateration/Triangulation cont.

With signals from two satellites, the receiver can narrow down its location to just two points on the earths surface.

Were the two circles intersect.
GPS : Trilateration/Triangulation cont.

- Knowing its distance from three satellites, the receiver can determine its location because there is only two possible combinations and one of them is out in space.
- In this example, the receiver is located at b.
- The more satellite that are used, the greater the potential accuracy of the position location.
GPS : Trilateration/Triangulation cont.

- GPS satellites transmit time information derived from high accuracy atomic clocks but the GPS receivers cannot afford such high precision clocks.
- The first three measurements narrow down our position. In practice, a fourth measurement is needed to correct for clock error.
- A fourth satellite must be applied correction to compensate for the difference between the satellite and receiver clocks.
- There are four GPS satellite signals that are used to compute positions in three dimensions and the time offset in the receiver clock.
- The next four slides show graphically how the timing offset correction works.
Note: The explanation of correcting for timing offset will be shown in two dimensions for illustration. Remember that in reality it takes three measurements to locate a point in three dimensions.

In an ideal situation there would be no timing error. Let's say we're 4 seconds from satellite A and 6 seconds from satellite B: our position is where the 2 circles intersect.
If the receiver clock is one second fast (it's ahead one second from the satellite clock) the receiver will "think" the distance from satellite A is 5 seconds and the distance from satellite B is 7 seconds. And it "thinks" our position is where the two dotted circles intersect.
Back to the ideal situation with no timing error: if we have accurate clocks, and we add a third measurement, all three circles intersect at the correct point, because the circles represent the true ranges from the three satellites.
But with inaccurate clocks, the circles cannot intersect: there is no point that can be 5 seconds from A, 7 seconds from B and 9 seconds from C.

When the receiver gets a series of measurements that cannot intersect at a single point, it finds the adjustment to all measurements that lets the ranges go through one point. In this example, subtracting 1 second from all three measurements makes the circles intersect at a point.

So, by adding one extra measurement we can cancel out any consistent clock error the receiver might have. Remember that in 3 dimensions this means we really need 4 measurements to cancel out any error.
4 Measurements: 4 Variables

• GPS has made a considerable impact on almost all positioning, navigation, timing and monitoring applications. It provides particularly coded satellite signals that can be processed in a GPS receiver, allowing the receiver to estimate position, velocity and time (Hofmann-Wellenhof et al., 2001).

• In order to determine a position in GPS-only mode the receiver must track a minimum of four satellites, representing the four unknowns of 3-D position and time.

• If only 3 satellites are present, the receiver will guess at elevation and compute latitude and longitude.

• Distance measurements to 4 satellites are required to compute a 3-D position (Latitude, Longitude and Altitude).
4 Measurements: 4 Variables
- Latitude (X)
- Longitude (Y)
- Altitude / Elevation (Z)
- Time (T)

Therefore, you need information from four satellites.

\[
\rho_1 = \sqrt{(x_1-x)^2+(y_1-y)^2+(z_1-z)^2}
\]
\[
\rho_2 = \sqrt{(x_2-x)^2+(y_2-y)^2+(z_2-z)^2}
\]
\[
\rho_3 = \sqrt{(x_3-x)^2+(y_3-y)^2+(z_3-z)^2}
\]
GLONASS
GLONASS

• GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema), the Russian Federation's Global Navigation Satellite System (GNSS), is the Russian version of a global positioning system.
• Started in October 12, 1982 with the launch of the Kosmos-1413.
• 24 Satellites orbiting the earth, where 21 satellites are considered active satellites and the three remaining ones are active on orbit spares.
• A minimum of four satellites in view allows a GLONASS receiver to compute its position in three dimensions, as well as become synchronized to the system time.
Satellite orbits

- GLONASS constellation consists of three orbital planes with eight satellites evenly distributed in each plane.
- The planes have a nominal inclination of 64.8° and are spaced by 120° in longitude.
- The satellite’s orbit are circular with a radius of about 25,508 kilometres.
- The shorter orbital radius yields a shorter orbital period of 8/17 of a sidereal* day such that, after eight sidereal days, the GLONASS satellites have completed exactly 17 orbital revolutions.
- For an observer on the earth, a particular satellite will reappear at the same place in the sky after eight sidereal days. Because each orbital planes contains eight equally spaced satellites, one of the satellites will be at the same spot in the sky at the same sidereal time each day.

*A sidereal day is the rotation period of the Earth relative to the equinox and is equal to one calendar day (the mean solar day) minus approximately four minutes.
Satellite signal

• All GLONASS satellites transmit carrier signals in different L-band channels, that is, at different frequencies.

• A GLONASS receiver separates the total incoming signal from all visible satellites by assigning different frequencies to its tracking channels.

• This procedure is called frequency division multiple access (FDMA). Because FDMA does not need to distinguish satellites by their unique signal modulation, all GLONASS satellites broadcast the same codes.
Satellite signal Cont.

• GLONASS, as a dual-use system, provides a high accuracy signal for military use and a standard-accuracy signal for civil use free of charge.

• Each GLONASS satellite continuously provides navigation signals: standard-accuracy signal, i.e. the C/A-code (also denoted as S-code), and the high accuracy signal, i.e., the P-code, in two carrier frequencies of the L-band, denoted as G1 and G2.
  - G1: \((1,602 + k \times 9/16)\) MHz (C/A-code and P-code)
  - G2: \((1,246 + k \times 7/16)\) MHz (P-code)
    \(k=\) Channel number

• Note that this denotation enables a better distinction from the GPS carriers L1 and L2.

• The C/A-code is modulated onto G1 only, whereas the P-code is modulated onto G1 and G2.
Satellite signal Cont.

• For positioning and timing, GPS provides two levels of services:
  • Standard Precision Service (SP) with access for civilian users.
  • High Precision Service (HP) with access for authorized users.

• The C/A-code is designated as the Standard Precision Service.
• The C/A-code is presently modulated upon G1 only.
• The P-code is designated as the High Precision Service.
• The P-code is modulated on both carriers G1 and G2.
GLONASS Time

- GLONASS system time is based on an atomic time scale similar to GPS. This time scale is UTC as maintained by Russia (UTC (SU)).
- In contrast to GPS, the broadcast GLONASS clock and clock frequency offset yield the difference between the individual GLONASS satellite’s time and the GLONASS system time.
- Unlike GPS, the GLONASS time scale is not continuous and must be adjusted for periodic leap seconds.
- Leap seconds are applied to all UTC time references as specified by the International Earth Rotation and Reference System Service (IERS). Leap seconds are used to keep UTC close to mean solar time. Mean solar time, based on the spin of the Earth on its axis, is not uniform and its rate is gradually changing due to tidal friction and other factors such as motions of the Earth's fluid core.
- Moscow offsets GLONASS system time from UTC (SU) by plus three hours.
GLONASS Datum

Datum is a set of parameters (translations, rotations, and scale) used to establish the position of a reference ellipsoid with respect to points on the Earth’s crust.

- GLONASS has a different way of transmitting satellite orbit information. For every half hour epoch, each satellite directly broadcasts its three-dimensional ECEF position, velocity, and acceleration.

- For a measurement time somewhere between these half-hour epochs, the user interpolates the satellite’s coordinates using position, velocity, and acceleration data from the half-hour marks before and after the measurement time.

- The resulting ECEF coordinates are referenced to a different geocentric datum Parametry Zemli 1990 (PZ-90) or in English translation, Parameters of the Earth 1990, PE-90) geodetic datum.
How Does GLONASS Work?
Segments of GLONASS

- The GLONASS system design consists of three parts:
  - The Control segment
  - The Space segment
  - The User segment
- All these parts operate together to provide accurate three-dimensional positioning, timing and velocity data to users worldwide.
• **The Control Segment**

The Control Segment consists of the system control center and a network of command tracking stations across Russia. The GLONASS control segment, similar to GPS, must monitor the status of satellites, determine the ephemerides and satellite clock offsets with respect to GLONASS time and UTC (Coordinated Universal Time), and twice a day upload the navigation data to the satellites.

• **The Space Segment**

The Space Segment is the portion of the GLONASS system that is located in space, that is, the GLONASS satellites that provide GLONASS ranging information. When complete, this segment will consist of 24 satellites in three orbital planes, with eight satellites per plane.

• **The User Segment**

The User Segment consists of equipment that tracks and receives the satellite signals. This equipment must be capable of simultaneously processing the signals from a minimum of four satellites to obtain accurate position, velocity and timing measurements. Like GPS, GLONASS is a dual military/civilian-use system. The system’s potential civil applications are many and mirror those of GPS.
The GLONASS satellite signal identifies the satellite and provides:

• position, velocity and acceleration vectors at a reference epoch to compute satellite locations
• synchronization bits, data age and satellite health
• offset of GLONASS time from UTC (SU) (formerly Soviet Union and now Russia)
• almanacs of all other GLONASS satellites
Comparison between GPS and GLONASS
## Compare Nominal satellite orbits

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>GLONASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of satellites</td>
<td>21 + 3 spares</td>
<td>21 + 3 spares</td>
</tr>
<tr>
<td>Number of Orbital planes</td>
<td>6, spaced by 60°</td>
<td>3, spaced by 120°</td>
</tr>
<tr>
<td>Satellites per orbital plane</td>
<td>4, unevenly spaced</td>
<td>8, evenly spaced</td>
</tr>
<tr>
<td>Orbital plane inclination</td>
<td>55°</td>
<td>64.8°</td>
</tr>
<tr>
<td>Orbital radius</td>
<td>26,560 km</td>
<td>25,508 km</td>
</tr>
<tr>
<td>Orbital period</td>
<td>½ of a sidereal day</td>
<td>8/17 of a sidereal day</td>
</tr>
<tr>
<td></td>
<td>≈ 11 hours 58 minutes</td>
<td>≈ 11 hours 16 minutes</td>
</tr>
<tr>
<td>Repeat of ground track</td>
<td>Every sidereal day</td>
<td>Every 8 sidereal days</td>
</tr>
<tr>
<td>Position reference (geodetic datum)</td>
<td>WGS84</td>
<td>PZ-90</td>
</tr>
<tr>
<td>Time reference</td>
<td>UTC (USNO)</td>
<td>UTC (SU)</td>
</tr>
</tbody>
</table>
• In the both systems, The satellites broadcast two carrier signals, L1 and L2, in the L-band of the radio frequency spectrum. These signals are modulated by two binary codes, the C/A code and the P-Code, and by the data message.

• In the both systems, the C/A-code is modulated onto the L1 carrier only, whereas the P-code appears on both L1 and L2. Accordingly, C/A-code receivers can use only the L1 signal for ranging, and P-code receivers can measures ranges on both frequencies to correct for ionospheric refraction.

• In the both systems, the frequency of the C/A-codes is 10 times lower than the P-code frequency.

• As a general rule, higher signal frequencies yield a better range-measuring accuracy than low frequencies. Thus, both GPS and GLONASS have precise mode of operation with the P-code and less accurate mode using the C/A-code.
• Each satellite in both system transmits, at a rate of 50 bits per second, a data stream containing a wealth of information regarding the status of the individual broadcasting satellite and the whole satellite configuration.

• Of primary importance from a user’s point of view are two particular subsets of the message, the data describing the satellite’s clock error and the data representing the satellite’s position, called the satellite ephemeris.

• Receiver need both data type to make computation with the range measurements.
## Compare Nominal satellite Signal Characteristics

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>GLONASS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carrier signals</strong></td>
<td>L1: 1,575.42 MHz</td>
<td>L1: (1,602 + k x 9/16) MHz</td>
</tr>
<tr>
<td></td>
<td>L2: 1,227.60 MHz</td>
<td>L2: (1,246 + k x 7/16) MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>k= Channel number</td>
</tr>
<tr>
<td><strong>Codes</strong></td>
<td>Different for each satellite</td>
<td>Same for all satellites</td>
</tr>
<tr>
<td></td>
<td>C/A – code on L1</td>
<td>C/A – code on L1</td>
</tr>
<tr>
<td></td>
<td>P – code on L1 and L2</td>
<td>P – code on L1 and L2</td>
</tr>
<tr>
<td><strong>Code frequency</strong></td>
<td>C/A – code : 1.023 MHz</td>
<td>C/A – code : 0.511 MHz</td>
</tr>
<tr>
<td></td>
<td>P – code : 10.23 MHz</td>
<td>P – code : 5.11 MHz</td>
</tr>
<tr>
<td><strong>Signal separation technique</strong></td>
<td>CDMA</td>
<td>FDMA</td>
</tr>
<tr>
<td><strong>Clock data</strong></td>
<td>Clock offset, frequency offset, frequency rate</td>
<td>Clock and frequency offset</td>
</tr>
<tr>
<td><strong>Orbital data</strong></td>
<td>Modified Keplerian orbital elements each hour</td>
<td>Satellite position, velocity, and acceleration every half hour</td>
</tr>
</tbody>
</table>
• Both GPS and GLONASS are basically one-way ranging system serving the same purpose, they exhibit a very similar radio-signal structure.

• The GPS satellites are identifiable by their Pseudorandom Noise code number (PRN)

• Unlike GPS, all GLONASS satellites transmit the same code at different frequencies.

• Each of them consists mainly of three segments: (a) space segment, (b) control segment and (c) user segment.

• At least 6 and up to 11 satellites will be visible at any place on earth from either system at any time.
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