B.A. (Prog.) Semster IV

Remote Sensing and GPS based Project Report (Practical)

Unit 5. Global Positioning System (GPS) – Principles and Uses

Background

GPS, which stands for Global Positioning System, is a radio navigation system that allows land, sea, and airborne users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world. The capabilities of today's system render other well-known navigation and positioning "technologies"—namely the magnetic compass, the sextant, the chronometer, and radio-based devices—impractical and obsolete. GPS is used to support a broad range of military, commercial, and consumer applications.

24 GPS satellites (21 active, 3 spare) are in orbit at 10,600 miles above the earth. The satellites are spaced so that from any point on earth, four satellites will be above the horizon. Each satellite contains a computer, an atomic clock, and a radio. With an understanding of its own orbit and the clock, the satellite continually broadcasts its changing position and time. (Once a day, each satellite checks its own sense of time and position with a ground station and makes any minor correction.) On the ground, any GPS receiver contains a computer that "triangulates" its own position by getting bearings from three of the four satellites. The result is provided in the form of a geographic position - longitude and latitude - to, for most receivers, within a few meters.

If the receiver is also equipped with a display screen that shows a map, the position can be shown on the map. If a fourth satellite can be received, the receiver/computer can figure out the altitude as well as the geographic position. If you are moving, your receiver may also be able to calculate your speed and direction of travel and give you estimated times of arrival to specified destinations. Some specialized GPS receivers can also store data for use in Geographic Information Systems (GIS) and map making.

History of GPS

The United States military first used GPS as a navigation tool in the 1970s. In the 1980s, the U.S. government made GPS available to the general public, free of charge, with one catch: A special mode, called Selective Availability, would be enabled to purposefully reduce the accuracy of GPS for public users, reserving only the most accurate version of GPS for the military.

In 2000, under the Clinton administration, selective availability was turned off, and the same accuracy that the military had benefited from was made available to the general public.

GPS Components

The GPS system has three components: The space segment, control segment, and user segments.

The space component consists of about 31 GPS satellites. The United States Air Force operates these 31 satellites, plus three to four decommissioned satellites that can be reactivated if needed. At any given moment, a minimum of 24 satellites is operational in a specially designed orbit. This orbit ensures that at least four satellites are in view at the same time from almost any point on earth. The complete coverage that satellites offer makes the GPS system the most reliable navigation system in modern aviation.

The control segment is made up of a series of ground stations used to interpret and relay satellite signals to various receivers. Ground stations include a master control station, an alternate master control station, 12 ground antennas, and 16 monitoring stations.

The user segment of the GPS system involves various receivers from all different types of industries. National security, agriculture, space, surveying, and mapping are all examples of end-users in the GPS system. In aviation, the user is typically the pilot, who views GPS data on display in the cockpit of the aircraft.

Functioning

GPS satellites orbit about 12,000 miles above us and complete one orbit every 12 hours. They are solar-powered, fly in medium Earth orbit and transmit radio signals to receivers on the ground.

Ground stations use the signals to track and monitor satellites, and these stations provide the master control station (MCS) with data. The MCS then provides precise position data to the satellites.

The receiver in an aircraft receives time data from the satellites' atomic clocks. It compares the time it takes for the signal to go from the satellite to the receiver, and calculates distance based on that very accurate and specific time. GPS receivers use triangulation—date from at three satellites—to determine a precise two-dimensional location. With at least four satellites in view and operational, three-dimensional location data can be obtained.

GPS Errors

Ionosphere interference: the signal from the satellites actually slows down as it passes through the Earth's atmosphere. GPS technology accounts for this error by taking an average time, which means the error still exists but is limited.

Clock error: The clock on the GPS receiver might not be as accurate as the atomic clock on the GPS satellite, creating a very slight accuracy problem.

Orbital error: Orbit calculations can be inaccurate, causing ambiguity in determining the satellite's exact location.

Position error: GPS signals can bounce off of buildings, terrain, and even electrical interference can occur. GPS signals are only available when the receiver can "see" the satellite, meaning the data will be missing or inaccurate among tall buildings, dense terrain, and underground.

Applications of GPS

The free global availability and accuracy of GPS signals for positioning and timing, combined with the low cost of receiver chipsets, has made GPS the preferred solution for a very wide and growing range of applications.

Road Transport

Based on the number of GPS receivers sold globally, road transport applications are the majority users of GPS positioning – for commercial fleet management and freight tracking, taxi services, public transport monitoring and passenger information, and emergency vehicle location, dispatch and navigation. Private car owners have also widely adopted in-car GPS navigation systems and most automobile manufacturers now release new vehicles with optional factory-fitted GPS.

Aviation

In commercial aviation, most aircraft now use GPS for en-route navigation and GPS is increasingly being used for initial approach and non-precision approach to specified airfields. Automatic Dependent Surveillance - Broadcast (ADS-B) is being developed globally as the preferred future technology for commercial air traffic control; this involves aircraft calculating their position using GPS and broadcasting it to other aircraft. GPS is also widely used for navigation of unmanned aerial vehicles (UAVs) for professional applications such as resource mapping and aerial surveying – imaging tasks previously performed by satellites such as NASA's Landsat.

Shipping & Rail Transport

Maritime applications include ocean and inshore navigation, dredging, port approaches, harbour entrance and docking, Vessel Traffic Services (VTS), Automatic Identification System (AIS), hydrography, and cargo handling. Railway applications include the management of rolling stock, passenger information, preventing doors opening until the carriage is alongside the platform, cargo tracking signalling, train integrity and level crossing approach.

Science

Scientific applications of GPS are widespread and include environmental and atmospheric monitoring, animal behavior studies, botanical specimen location, meteorology and climate research. GPS is used in agriculture and fisheries for land area mapping, yield monitoring, precision planting of crops, spraying and harvesting, autonomous vehicle control and to monitor fishing limits.

Security

Security applications include tracking of vehicles, containers, other valuable cargoes and covert tracking of suspects.

Heavy Vehicle Guidance

GPS is being used increasingly to guide and track heavy vehicles in engineering applications such as mining and construction. For example, in highway construction, surveyors and marker pegs have been replaced with in-cabin vehicle guidance and control systems for excavators, graders, bulldozers and road paving machines that allow drivers to follow a surveyor's pre-programmed site plans and achieve close tolerances for position, level and gradient.

In open-cut mines, GPS is integrated into applications developed by companies such as Leica Geosystems, Topcon Positioning Systems and Trimble/Caterpillar for vehicle guidance and tracking, and mine asset management systems.

In these professional applications, GPS information is captured by sophisticated IT systems and meshed with other engineering applications to provide multifunction guidance and control.

Surveying, Mapping and Geophysics

Professional, survey-grade GPS receivers, capable of utilising signals from both L1 and L2 GPS frequencies, can be used to position survey markers, buildings, bridges and other large infrastructure. GPS is widely used in mapping, including aerial mapping, and other Geographical Information System (GIS) applications. In geophysics, GPS is used to time stamp seismic activity and to monitor position changes in sensitive physical formations such as volcanoes and earthquake fault lines.

Telecommunications

GPS timing is important for telecommunications applications, particularly for mobile telephone networks. Synchronous technologies are much more efficient than asynchronous technologies but require a time source with appropriate accuracy, stability and reliability to operate effectively or at all, and GPS satellites can provide this. While ground-based clocks are accurate enough for this purpose (especially with the availability of chip scale atomic clocks (CSAC)), the synchronisation of many such clocks is problematic. GPS allows the derivation of synchronised UTC time through resolving the signals from a number of atomic clock sources at known locations.

Financial Services

Global financial systems increasingly need precise timing systems to schedule and prioritise local and international money transfers, settlements and trades and to provide an audit trail for financial transactions. For example, the time signal provided by the atomic clocks on board the GPS satellites is used by financial institutions worldwide for providing date and time stamps for Electronic Funds Transfers. In some developed countries up to 80% of retail transactions involve either credit or debit cards. With millions of these transactions occurring every minute, a very high level of timing accuracy has become a critical component of financial trading networks.

Social Activities

Widely available, low-cost hand-held GPS receivers have enabled a numerous variety of social activities. The most ubiquitous application is in-car navigation, but there are dozens of other applications: GPS-based social networking, geotagging photographs, cross country cycling, hiking, skiing, paragliding, skydiving, geocaching, geodashing and other gaming activities