RESOURCE NOTES

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Understanding GPS Technology: System History, Architecture, and Fundamentals

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Global Positioning Technologies Provide Essential Exploration Tool
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Background

In the 1960s, the U.S. Air Force and Navy began developing a space-based positioning service, with the potential for a worldwide, continuous, all weather tracking system. On April 17, 1973, the Deputy Secretary of Defense combined all of the systems into a comprehensive Department of Defense system, named Navstar GPS.

The Navstar GPS Joint Program Office (JPO) was established on July 1, 1973, to manage the new system. Now fully operational, GPS provides suitably equipped users with accurate 3D positions, velocity, and time parameters. The service allows for simultaneous, unlimited numbers of users and is provided globally, continuously, and throughout all weather conditions. Today, GPS allows for instantaneous positioning to within an accuracy of 100 m (95%) in the horizontal and 140 m (95%) in the vertical for most commercial activities.

GPS Constellation

GPS comprises three major segments: space, control, and users. The role of the space segment is to provide a sufficient number of satellites such that a receiver may observe four satellites anywhere in the world at any time. To obtain this coverage, the GPS constellation consists of 24 operating satellites that are arranged in six near circular orbital planes with four satellites located in each plane at an orbit height of almost 20,200 km (10,900 nautical miles). This height is such that the satellites follow a ground track that repeats every 23 hrs, 56 min.

The control segment's main functions consist of tracking the satellites for orbit and clock determination, prediction modeling, time synchronization, and data uploading to each satellite.

The GPS user segment consists of a number of military and civilian receivers that can receive, understand, and process the radio frequencies transmitted by the GPS satellites. They may be used for a variety of applications such as navigation, positioning, time transfer, surveying, and attitude determination.

GPS Systems

Standalone GPS. At the low end of the market, simple, small, and inexpensive (possibly hand-held) receivers can deliver 100 m level absolute positions instantaneously and independently (only using signals broadcast by the satellites). This is often referred to as "standalone GPS," or pseudorange point positioning. Receivers are now widely available and can cost as little as $200.

Differential GPS. Digital GPS involves the use of a stationary reference receiver located at a known fixed point and an unknown remote, possibly mobile, receiver. To determine a set of corrections, the pseudoranges observed at the reference receiver are compared to expected transmissions. These corrections can then be broadcast to the remote receiver, and if applied to its observed pseudoranges, can improve the positional fix. Typical distances from reference station to mobile station are on the order of 1,000 km.

Combined GPS. The use of a combined reference station DGPS position solution is now widely used. This essentially utilizes differential corrections from a number of reference stations, which are combined in either the position, adjustment, or correction domain to give an overall solution. The precision of the position fix is not necessarily improved from the DGPS solution, however, multiple reference station solutions provide a more stable position fix, improved quality control, and reliability measures.

RTK GPS

If the carrier-phase data are used, the precision of the position fix can be dramatically improved. In this case, a similar scenario to DGPS is employed with a static reference station at known coordinates and an unknown remote, possibly mobile, receiver. The reference receiver broadcasts the phase data to the remote receiver, which enables it to compute its position relative to the reference station coordinates. The precision of the position fix can be on the order of 1 cm; however, the reference station to remote station distance must typically be 10 km to achieve such results.

Very Precise GPS. At the top end of GPS-positioning technology, data collected by sophisticated receivers located at several points over several days, or even continuously and permanently, can deliver relative positions with millimeter accuracy.

GPS Accuracy

One of the most interesting (yet often misunderstood) features of GPS is the enormous range in the accuracy with which it can be utilized. It ranges from 100 m to 1 mm - a total of five orders of magnitude. No other surveying system offers such possibilities, and the key to the potential user is to identify the positioning requirements in order to obtain the most suitable system. There are essentially two methods of positioning with GPS using either pseudoranges or carrier phases. However, the differences between these two are becoming less distinguishable.

Differential GPS

Differential GPS typically provides a horizontal positional precision of 1 5m (95%). Because there are difficulties over radio licensing and distances between reference and mobile receivers, a number of companies have established Differential GPS services. Such services comprise a network of reference stations constantly transmitting encrypted DGPS corrections via land or satellite-based radio communication links.

Users of the system subscribe to the service, allowing them to demodulate and unscramble the incoming signal and feed the corrections into a GPS receiver, or third-party software.

System Service Providers

There are a number of DGPS service providers. For example, the U.S. Coast Guard operates a free maritime DGPS service, broadcasting differential corrections from a number of reference receivers around the U.S. Horizontal positioning is guaranteed to 10 m (95%), and integrity alerts within 10 sec. The USCG DGPS system was originally planned to cover only coastal and Great Lake regions; however, this has now been expanded to cover inland waterways.

In addition, Racal Survey provides a satellite-based DGPS service, known as Land Star. DGPS corrections are generated at each of the reference stations, combined, then uplinked to a high-power, spot beam satellite. Users are equipped with a receiver and antenna to receive both the GPS signals and the DGPS corrections from the Land Star satellite. The service costs about $500 per day.

Fugro also operates a similar satellite-based DGPS service to Racal known as OmniStar.

Alternatives

Other alternative systems that may soon become viable include the Russian and European satellite systems. The Global Navigation Sputnik System (Glosnass) is the Russian Equivalent to GPS. Satellite launches began October 12, 1982, and more than 70 now orbit the earth. As of May 1999, only 15 satellites were still in operation.

A Note of Caution

Although GPS offers many benefits over traditional survey techniques, it is also a system that should be treated with a great deal of care. For example, setting up a high-resolution form of GPS, such as a differential GPS (DGPS) network, can be difficult and expensive, requiring expert geodetic knowledge. However, like all technologically advanced systems, gross and systematic errors can be readily introduced from the peripheral systems such as GPS receivers and navigation software.

The U.S. Department of Transportation is the primary interface for all civil GPS matters, creating the Civil GPS Service Interface Committee to meet this obligation. Relevant information, such as a list of receiver manufacturers and points of contact can be found on the USCG Navigation Center's web site: (http://www.navcen.uscg.mil)

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