An Overview of Global Positioning System (GPS)

The Global Positioning System (GPS) is a satellite–based radio–navigation system. GPS provides reliable positioning, navigation, and timing services to users on a continuous worldwide basis. The satellite system was built by the United States, but its services are freely available to everyone on the planet. For anyone with a GPS receiver, the system provides location and time. GPS provides accurate location and time information for an unlimited number of people in all weather, day or night, anywhere in the world.

The GPS is made up of three parts: satellites orbiting the Earth; control and monitoring stations on Earth; and the GPS receivers (either stand–alone devices or integrated sub–systems) operated by users. GPS satellites broadcast continuous signals which are picked up and identified by GPS receivers. Each GPS receiver then provides three–dimensional location information (latitude, longitude, and altitude), plus the current time. Equipped with a GPS receiver, any user can accurately locate where they are and easily navigate to where they want to go, whether walking, driving, flying, or boating.

GPS has become an important part of transportation systems worldwide, providing navigation for aviation, ground, and maritime operations. Disaster relief and emergency service agencies depend upon GPS for location and timing capabilities in their life–saving missions. Everyday activities such as banking, mobile phone operations, and even the control of power grids, are facilitated by the accurate timing provided by GPS. Farmers, surveyors, geologists and countless others perform their work more efficiently, safely, economically, and accurately using the free and open GPS signals.

GPS Timing

In addition to longitude, latitude, and altitude, the Global Positioning System (GPS) provides a critical fourth dimension – time. Each GPS satellite contains multiple atomic clocks that contribute very precise time data to the GPS signals. GPS receivers decode these signals, effectively synchronizing each receiver to the atomic clocks. This enables users to determine the current time to within 100 billionths of a second, without the cost of owning and operating atomic clocks.

Precise time is crucial to a variety of economic activities around the world. Communication systems, electrical power grids, and financial networks all rely on precision timing for synchronization and operational efficiency. The free availability of GPS time has enabled cost savings for companies that depend on precise time and has led to significant advances in capability. For example, wireless telephone and data networks use GPS time to keep all of their base stations in perfect synchronization. This allows mobile handsets to share limited radio spectrum more efficiently. Similarly, digital broadcast radio services use GPS time to ensure that the bits from all radio stations arrive at receivers in lockstep. This allows listeners to tune between stations with a minimum of delay.

Companies worldwide use GPS to time–stamp business transactions, providing a consistent and accurate way to maintain records and ensure their traceability. Major investment banks use GPS to synchronize their network computers located around the world. Large and small businesses are turning to automated systems that can track, update, and manage multiple transactions made by a global network of customers, and these require accurate timing information available through GPS. For example, the U.S. Federal Aviation Administration (FAA) uses GPS to synchronize reporting of hazardous weather from its 45 Terminal Doppler Weather Radars located throughout the United States.

Instrumentation is another application which requires precise timing. Distributed networks of instruments that must work together to precisely measure common events require timing sources that can guarantee accuracy at several points. GPS–based timing works exceptionally well for any application in which precise timing is required by devices that are dispersed over wide geographic areas. For example, integration of GPS time into seismic monitoring networks enables researchers to quickly locate the epicenters of earthquakes and other seismic events.

An Overview of Global Positioning System (GPS) (cont.)

Power companies and utilities have fundamental requirements for time and frequency to enable efficient power transmission and distribution. Repeated power blackouts have demonstrated to power companies the need for improved time synchronization throughout the power grid. Analyses of these blackouts have led many companies to place GPS–based time synchronization devices in power plants and substations. By analyzing the precise timing of an electrical anomaly as it propagates through a grid, engineers can trace back the exact location of a power line break.

Some users, such as national laboratories, require the time at a higher level of precision than GPS provides. These users routinely use GPS satellites not for direct time acquisition, but for communication of high–precision time over long distances. By simultaneously receiving the same GPS signal in two places and comparing the results, the atomic clock time at one location can be communicated to the other. National laboratories around the world use this “common view” technique to compare their time scales and establish Coordinated Universal Time (UTC). They use the same technique to disseminate their time scales to their own nations.

GPS Facts & Technology

The GPS is based on 24 satellites located in six orbital planes at a height of 20,200 km and circle the Earth every 12 hours. Each plane is inclined at 55º to the Earth’s equator and contains four satellites. The GPS positioning is based on one-way time-of-arrival ranging. Each satellite sends the universal time (UTC) and navigation data using a spread spectrum code division multiple access (CDMA) signal. A receiver can calculate its own position and speed by correlating the signal delays from any four satellites and combining the result with orbit correction data sent by the satellites. Two services are provided by GPS: a precise positioning service (P-code) whose use is restricted to military and a standard positioning service (coarse acquisition, C/A-code), less precise than the P-code but available to everyone.

All 24 satellites send on the same two frequencies: L1 is the primary frequency and carries the C/A-code, and L2 is the secondary frequency and carries the P-code. The two frequencies are derived from a 10.23-MHz atomic frequency standard. The frequency of L1 is 1575.42 MHz (154 times the atomic clock) and that of L2 is 1227.6 MHz (120 times the atomic clock). Interference between signals of different satellites is avoided using pseudorandom signals with cross-correlation for the CDMA modulation.

References:

GPS.gov

U.S. Naval Observatory (USNO) GPS Homepage

National Institute of Standards and Technology (NIST) Time and Frequency Division