Global Navigation Satellite Systems

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INTRODUCTION

There is a need to determine precise ground locations for use in a variety of innovative and emerging applications such as earth observation, mobile-phone technology, and rescue applications. Location information is pertinent to a large number of remote sensing applications, some of which support strategic tasks such as disaster management, earth monitoring, protecting the environment, management of natural resources, and food production. With the availability of high-resolution images, some applications will require a location precision down to 1 m (Kline, 2004). The global navigation satellite systems (GNSSs) provide signals that can serve this purpose; these signals can be incorporated into a large range of innovative applications with immense benefits for the users (Hollansworth, 1999). Satellite navigation is achieved by using a global network of satellites that transmit radio signals from approximately 11,000 miles in high earth orbit. The technology is accurate enough to pinpoint locations anywhere in the world, 24 hours a day. Positions are provided in latitude, longitude, and altitude. This article provides an overview of the GNSSs in operation along with their uses.

BACKGROUND: WHAT IS GNSS?

There are currently two global systems in operation: the Navigation Satellite Timing and Ranging system (NAVSTAR), commonly referred to as the Global Positioning System (GPS) and owned by the United States of America, and GLONASS (Global´naya Navigatsivannaya Sputnikovaya Sistema) of the Russian Federation. A third system called GALILEO is under development by the European Community (EC) countries. The United States and Russia have offered the international community free use of their respective systems. The business model for GALILEO will be similar to GPS for basic users; however, not all applications will be free as some applications that require a high quality of service will have to be paid for.

GNSS is revolutionizing and revitalizing the way nations operate in space, from guidance systems for the International Space Station's (ISS) return vehicle, to the management tracking and control of communication satellite constellations. Using space-borne GNSS and specialized algorithms, a satellite will soon be capable of self-navigation (Hollansworth, 1999). The underlying technologies of the GNSS infrastructure are very similar, and they have been designed to complement each other even though the initial systems were developed for military purposes. They each consist of three segments: the space segment (the satellites), the ground segment (control and monitoring stations), and the user segment (receiver technology). The GNSS satellites transmit codes generated by atomic clocks, navigation messages, and system-status information, modulated on two carrier frequencies.

The International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) have accepted GPS and GLONASS as the core of an international civil capability in satellite navigation. The frequency-spectrum bandwidth, allocated by the International Telecommunications Union (ITU) for GNSS-type applications, is 1,559 1,610 MHz. The unique ITU Aeronautical Radio Navigation Satellite Service allocation provides protection against interference from other sources required by civil aviation, maritime shipping, and other critical safety-of-life applications (Hollansworth, 1999).

CURRENT TRENDS: NAVSTAR GLOBAL POSITIONING SYSTEM

The NAVSTAR GPS was developed by the U.S. Department of Defense (DoD). It consists of a constellation of 24 to 27 satellites in operation at any one time (placed in six orbital planes) orbiting the earth at a high altitude (approximately 10,900 miles). Each plane is inclined 55 degrees relative to the equator. The satellites complete an orbit in approximately 12 hours. The signal from the satellite requires a direct line to GPS receivers and cannot penetrate water, soil, walls, or other obstacles such as trees, buildings, and bridges.

GPS satellites broadcast messages via radio signals. Radio signals travel at the speed of light: 186,000 miles per second (NAVSTAR, 2000). A 3-D position on the earth is calculated from distance measurements (using the travel time of the satellite messages) to three satellites. This requires clocks accurate to within a nanosecond on board the satellites. Since clocks in our GPS receivers are not as accurate, to obtain an accurate 3-D position, a fourth satellite measurement is used to compute the receiver clock-offset errors.

The ultimate accuracy of GPS is determined by the sum of several sources of error. Differential correction is required to reduce the error caused by atmospheric interference. This involves placing a GPS receiver on the ground in a known location acting as a static reference point; this is then utilized to identify errors in the satellite data. An error-correction message is transmitted to any other GPS receivers in the local area to correct their position solutions. This real-time differential correction requires radios to transmit the error-correction messages. Alternatively, postprocessed differential correction can be performed on a computer after the GPS data are collected.

Up until May 1, 2000, the U.S. government scrambled GPS signals for reasons of national security. This intentional signal degradation was called selective availability (SA). Because of SA, the positions computed by a single GPS receiver were in error by up to 100 m. Because of pressure from the civilian GPS user community and other reasons, the government agreed to remove SA.

GLONASS

The fully deployed GLONASS constellation is composed of 24 satellites in three orbital planes whose ascending nodes are 120 degrees apart (Glonass Information, 2003). Each satellite operates in circular 19,100-km orbits at an inclination angle of 64.8 degrees, and each satellite completes an orbit in approximately 11 hours and 15 minutes. The spacing of satellites in orbits is arranged so that a minimum of five satellites is in view to users worldwide. The GLONASS constellation provides continuous and global navigation coverage. Each GLONASS satellite transmits a radio-frequency navigation signal containing a navigation message for users. The first GLONASS satellites were launched into orbit in 1982; the deployment of the full constellation of satellites was completed in 1996, although GLONASS was officially declared operational on September 24, 1993. The system is complementary to the United States' GPS, and both systems share the same principles in the data-transmission and -positioning methods. GLONASS is managed for the Russian Federation government by the Russian Space Forces, and the system is operated by the Coordination Scientific Information Center (KNIT) of the Ministry of Defense of the Russian Federation (SPACE and TECH, 2004)

FUTURE TRENDS: GALILEO

GALILEO is the global navigation satellite system being developed by an initiative launched by the European Union and the European Space Agency (ESA). GALILEO will be fully operable by 2008, however, the signal transmission will start in 2005. This worldwide system will be interoperable with GPS and GLONASS, the two other global satellite navigation systems, providing a highly accurate, guaranteed global positioning service under civilian control. A user will be able to get a position with the same receiver from any of the satellites in any combination. GALILEO will deliver real-time positioning accuracy down to the meter range, which is unprecedented for a publicly available system.

It will guarantee availability of the service under all but the most extreme circumstances and will inform users within seconds of a failure of any satellite. This will make it suitable for applications where safety is crucial, such as running trains, guiding cars, and landing aircraft.

The fully deployed GALILEO system consists of 30 satellites (27 operational plus three active spares) positioned in three circular medium-earth-orbit (MEO) planes at an altitude of 23,616 km above the Earth, and with an inclination of the orbital planes of 56 degrees in reference to the equatorial plane.