Satellite Navigation System GPS

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Abstract **– In this article description of satellite navigations system GPS and examples how it can be used are given.**

Keywords **– GPS, Navigation System**

I. WHAT IS GPS

GPS (Global Positioning System) is modern very quickly developing satellite navigation system using special satellite signals. It passes navigational coordinates in figure (X, Y, Z) and very precise time UTC (Universal Time Coordinated).

II. HISTORY

Year 1957 is considered as beginning existences this system. In this year the employees of John Hopkins University in Baltimore (USA) proved that determining of satellites' orbits by their own signals is possible. Opposite task was solved. To take advantage of radio signals transmitted by Soviet satellite Sputnik I proved that Earth's artificial satellites can help in navigations.

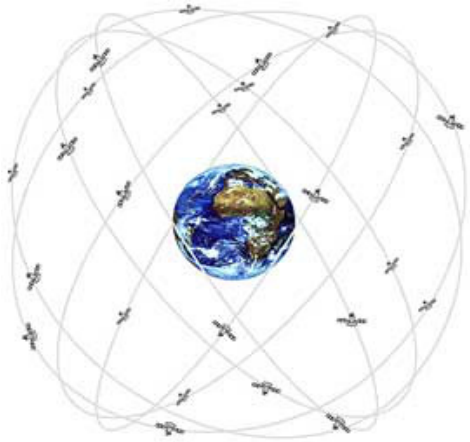

Fig.1 Satellite's orbits.
[source: http://archiwum.wiz.pl]

First navigation system was NNSS (Navy Navigation Satellite System or Transit) which arose in 1958-1962 in Applied Physics Laboratory of John Hopkins University.

The system consisted of six satellites surrounding the Earth on orbits which are on 1100 km high.

The small height of orbits comes from the fact that the system used the Doppler shift to calculate position.

The satellites used two frequencies to transmit signals: 150MHz and 400MHz. Precision of this system increase from 900m in 1962, 185m in 1969 to 35 m in 1971. Transit was used to show position of submarine in USA Navy. To estimate self position the submarine had to float on surface and move with solid speed during measurement lasting from 6 to 18 minutes. Because the time of measurement was so long, this system could not be use in air force. The US Navy sponsored second satellite-based positioning and navigation systems Timation. It was a prototype system that never left the ground. Simultaneously, the U.S. Air Force was conducting concept studies for a system called the System 621B. Ground tests were performed to validate the concept but before the system could be implemented, the U.S. Deputy Secretary of Defense, in April 1973, designated the Air Force as the executive service to coalesce the Timation and 621B systems into a single **D**efense **N**avigation **S**atellite **S**ystem (DNSS) supervised by **J**oint **P**rogram **O**ffice created by Defense Department of USA. JPO was created from all types of US armies: navy, air force, marines, DMA (Defense Mapping Agency) and USNO (United States Naval Observatory) responsible for time UTC. From this emerged a combined system concept designated the Navstar (for **Nav**igation **S**ystem with **T**iming **A**nd **R**anging) Global Positioning System, or simply GPS. This event began first from four phases of development GPS system.

At the beginning the GPS system was used only by military users.

They used the PPS (Precise Positioning Service) - highly accurate positioning, velocity and timing service that is designed primarily for the military and other authorized users, although under certain conditions can be used by civilians who have specialized equipment. When the GPS system became more popular and the GPS receivers were cheaper the civilian users wanted to use it.

Civilian access to the GPS signal, without charge to the user, was formally guaranteed by President Reagan in 1984 as a direct response to the shoot-down of the Korean Airline Flight KAL- 007 in 1983, when it strayed over the Soviet Union. They are represented in JPO by Transport Department. They used SPS (Standard Positioning Service) offers a base-line accuracy that is much lower than the PPS, but is available to all users with even the most inexpensive receivers. January 1st 2000 turned off a S/A - Selected Availability used to limiting precision of GPS. After this date accuracy of GPS increased from about 500m to 100m.

III. STRUCTURE OF GPS SYSTEM

Structure of GPS system can be split into three parts:

Space Segment - consisted of twenty four satellites surrounding the Earth on six orbits which are on 20162,61 km high over the equator. With reference to WGS-84 length of equator is equal 6378,137km. Each of the six orbits are inclined 55 degrees up from the equator, and are spaced 60 degrees apart, with four satellites located in each. The orbital period is 12 hours, meaning that each satellite completes two full orbits each 24-hour day.

Control Segment of the Global Positioning System consists of one Master Control Station (MCS) located at Falcon Air Force Base in Colorado Springs, Colorado, and five unmanned monitor stations (MS) located strategically around the world. One is located at Hawaii, another at the Tiny Ascension Island off the West Coast of Africa (population 7 19), another at Diego Garcia off of the southern tip of India, and the fourth at Kwajalein, part of the Marshall Islands group in the Western Pacific. The three upload ground antennas are co-located with the monitor stations at Ascension Island, Diego Garcia, and Kwajalein.

User Segment is made up of all people used GPS receivers. All users are divided to two main groups: military users who can use two frequencies L1 and L2, and civilian users who can use only L1 frequency. GPS is a passive system what mean that transmission of signal is only in one way – from satellite to GPS receiver. Number of users in not limited. GPS system protects users from jamming and spoofing.

IV. GPS SIGNALS

GPS signals are created by multiply one basic frequency equal 10,23MHz. GPS satellites broadcast two signals in two channels:

- L1 equal 1575,42 MHz what is 154 × 10,23 MHz
- L2 equal 1227,60 MHz what is 120 × 10,23 MHz

In GPS system are using three types of signal modulations: C/A – Coarse Acquisition Code, P-Code – Protected Code and Y which is using together with P-code and his name is P(Y). This codes are created using different bases and are transmitted with different speed.

V. GPS POSITION

The GPS receiver need to have signals from minimum four satellites to calculate 3-D position. After identification every one of them receiver calculates distance from satellite to him (pseudo distance). Position of GPS receiver is fixed by solving a system of equations:

$$\begin{aligned}
(x_1 - x)^2 + (y_1 - y)^2 + (z_1 - z)^2 &= [c(\Delta t_{c1} - \Delta t_z)]^2 \\
(x_2 - x)^2 + (y_2 - y)^2 + (z_2 - z)^2 &= [c(\Delta t_{c2} - \Delta t_z)]^2 \\
(x_3 - x)^2 + (y_3 - y)^2 + (z_3 - z)^2 &= [c(\Delta t_{c3} - \Delta t_z)]^2 \\
(x_4 - x)^2 + (y_4 - y)^2 + (z_4 - z)^2 &= [c(\Delta t_{c4} - \Delta t_z)]^2
\end{aligned} \quad (1)$$

In this equations unknowns are three co-ordinates (X, Y, Z) and the same for all satellites clock error Δt_z.

VI. GPS PROJECT

I create small application in VHDL language. This application show quantity of visible satellites in given place. I wrote equation of sphere which radius was equal radius of Earth. It was Earth model. I wrote also sphere which radius was equal distance between satellite's orbits and center of Earth. In this application was also 6 equations of plane including satellite's orbits inclined 55 degrees up from the equator, and are spaced 60 degrees apart, with four satellites located in each. To calculate how many satellites are visible over the horizon I inserted plane including point on the Earth where was GPS receiver and perpendicular to radius of Earth's model. If satellite is visible in GPS system it means that it is 5° over the horizon line.

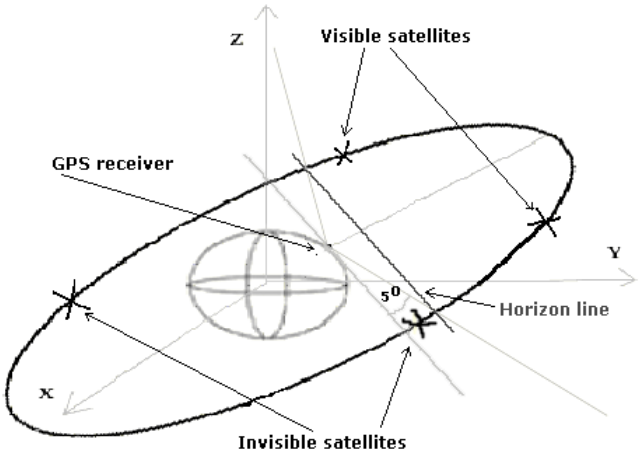

Fig.2 Project guidelines

This application checks for all satellites equations if the co-ordinates of GPS satellite belongs to horizon's plane. In figure 2 we can see that if the plane's equation is bigger than zero then means that satellite is over the horizon's plane and satellite is visible. In reverse the satellite is invisible for GPS receiver. Additionally it was mandatory to take into consideration that the Earth is not static but it rotate around her own axle. In figure 3 we can see part of output graph of this application.

This application has some restriction and faults. Satellite's orbits aren't ideal circles. Trajectory of GPS satellites are changed. They are dependent on many factors like sun activity which is changing in 12 years cycle. As a result of this faults quantity of visible satellites in this application can be little different from real number of visible satellites.

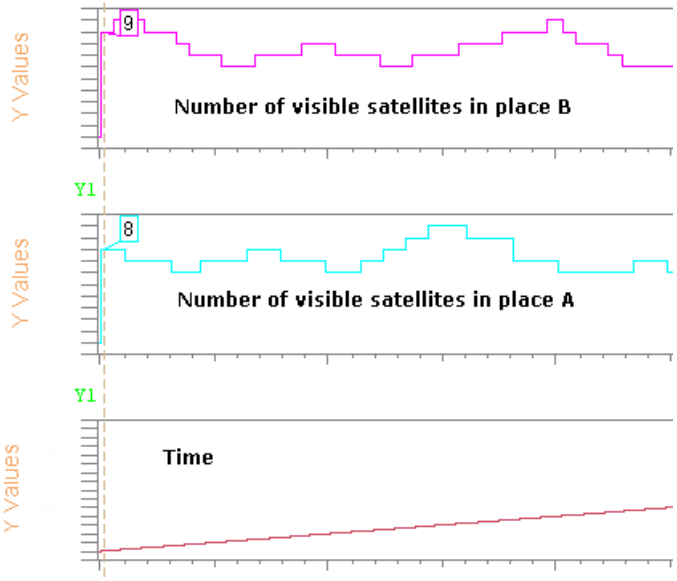

Fig.3 Part of output graph in my application

VII. GPS APPLICATIONS

Quick development GPS technology was possible thanks of quick development of microelectronics. First GPS receivers were very heavy, big and expensive. They cost a thousands of dollars.

Breakthrough in GPS receivers was when it was possible to use integrated circuits which caused that the receivers became smaller, lighter and cheaper.

At the beginning GPS system was used only to display position of receiver in WGS-84 system. Development of microelectronics caused development of GPS receivers which have LCD displayers and digital road maps. GPS system is integrated with other systems.

Most popular branch used GPS is Car Navigation. It is build of GPS system and digital map. Similar branches used GPS systems are Car Monitoring Systems. This services are used to show car position and history of car road.

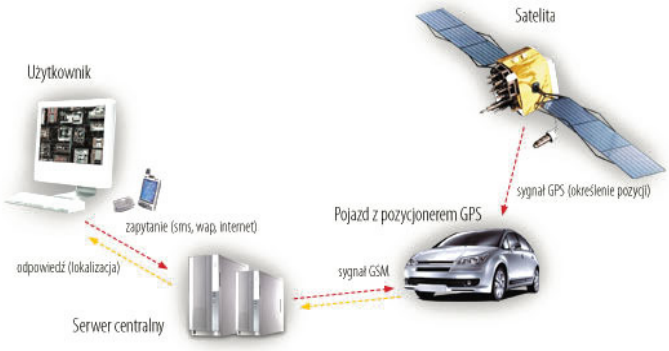

Fig.4 Car Monitoring System.
[source: www.gps24.pl]

GPS system is used on the land, in the air and on the sea. It is a standard equipment almost all planes and shipping. Use the GPS system gives new possibility to assign position no matter what the weather conditions are. It is very helpful in rescue actions in which the start place is very important. This system integrated with other systems is used in archeology, construction industry, photogrammetry – branch of science used to create a big photo map. It is composed of many picture. When this photos are taken the GPS receiver is used to calculate position of camera. After this the photos are join in one big photomap. GPS system is also used in the environment to monitoring of protected animals, in cash machines to calculate time when customer withdraw money or in geodesy which is very specific branch using GPS system. In this case very important is precision of position (less then one centimeter) but time of measurement is not very important. GPS receivers are very small. It can be part of watch for athlete or a part of mobile phone.

System of satellite navigation GPS is still evolving and has new uses. This system is integrated with new systems to improve them. In the future it will be used in new branch of life. It will be integrated with new systems and devices. From 2005 GPS system is used with accelerometers to measure the angle, speed and g-force during a run in drifting (motor sport). This takes the guesswork out of judging the angle and speed of the drift. Nokia Company produced phone series N95 with GPS receiver. In this phone installed maps of 100 countries and voice navigation. It will be available since first quarter of this year. The company MiGRAF from Gdańsk (Poland) produced "Navigation eye" – satellites guide for the blind. It is build from GPS receiver and device given hints how to walk to some place. It uses voice to inform the blind.

There are planes to use GNSS (Global Navigation Satellite System) which is consisted of all three satellite navigation systems – GPS, GLONAS and Galileo to charge for using highways. The condition of using this system to charge is that all cars will be equipped in GPS receivers. This system will be used to supervise prisoner. Small criminals will be equipped in necklace or bracelet with GPS receiver. It will be helpful to supervise them by probation officers.

As we can see GPS system is becoming very popular in many branch of our life. It can be very helpful and useful. It integrates with new systems and finds new applications.

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