Working and Applications of Global Positioning System

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Abstract- The most promising and fully operational GPS (Global Positioning System) is a navigation system based on a group of 24 satellites developed by U.S. Department of Defence. Every satellite sends data to the receiver in the form of signals, having some information about satellite and orbital information. This paper aims to discuss the potential of GPS as constantly global communication medium and gives insights in terms of its business and military applications. It focuses on the architecture of GPS, its working, changing signal conditions and discusses its technical applicability and uses current advanced applications of GPS like vehicle tracking, location-based services as a case study. Even in worst weather conditions this GPS system is used to find out exact location with respect to timing information anywhere on the surface of globe. The paper will also consider different weather and geographical conditions to prove the suitability and compatibility of the GPS. The paper will also compare GPS with other navigation systems and will discuss its advantages such as high precision and continuous coverage.
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1. Introduction

Tracking and locating is an important part in every field of life whether it is in commercial sector or is in industrial. For finding location of anyone in anywhere on the surface of Earth, a modernized system was to be designed with its most sophisticated and modernized functions. Global Positioning System provides all the tracking and locating facilities through its satellite based network in any weather condition in any signal level.

First of all, this system was designed specifically for military usage for security reasons. Today, this system's applicability is everywhere in daily life applications. Due to continuous moving of satellites in orbit using GPS, every entity is to be identified on the surface of Earth with its more precise and accurate level. As compared to other tracking systems, this system provides the better services of locating and positioning with its real-time tracking [2].

This paper focuses on the current implications of Global Positioning System, its architecture and also this manuscripts defines its operations and working with clear aim. The paper concludes that GPS played a pivotal role in every part of modern life and is a revolution in the positioning and navigation systems.

2. General Overview

GPS, a well known Global Positioning System, is a collection of total 27 satellites moving around the Earth in an elliptical path [1]. This system was designed by American Department of Defense for the sake of security in different applications of military in 1970s [3]. After that, modifications like accurate timing, velocity related information are to be done in this system for getting better precision and accuracy level. GPS is the fully compatible to provide signals for locality, movement measurement and tracking of vehicles and other type of transport anywhere on the surface of Earth to satellites [1].

Fig1.0. Satellites constellation orbiting the Earth [15]
Source: Bureau of Oceans and International Environmental and Scientific Affairs (2006)

As compared to other navigation systems, GPS has fully operational capabilities to define location and direction of receiver with full accuracy. Currently this system is used in many scientific as well as in civil applications like Surveying, GIS (Geographic Information System), Geology and Mobile Satellite Communications in modern way. Location can be determined through the time difference for each satellite signal through satellite receiver [5].

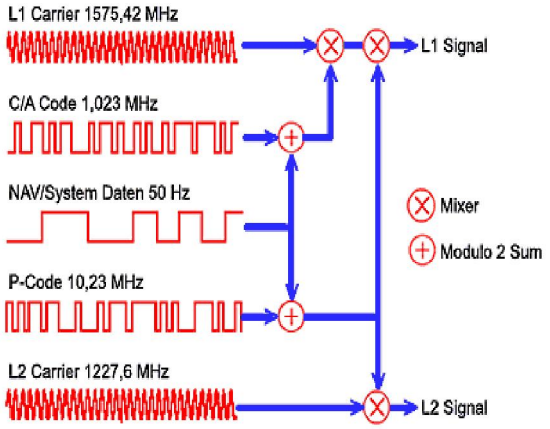

Fig 2.0. GPS Signal structure [16]
Source: Kowoma (2005)

A. GPS Background & Evaluation

GPS is a system having full capability of tracking and locating services with the help of its satellites, receivers and built in antennas on each receive [1].Initially, American Navy planned to develop navigation system in the name of "TRANSIT" to pilot their ships for military operations in early 1960s. There are different drawbacks in this system like inefficiency and slow speed. After the TRANSIT, another navigation system "TIMATION" consisting of seven low altitude satellites having additional feature of atomic clock inside each satellite. The big hole in this system was its inefficiency, poor accuracy and two-dimensional navigation system.

In the meanwhile, U.S. Air Force decided to develop 612B system having three dimensional capabilities in the form of altitude, latitude and longitude coordinates. The other developed navigation systems were not full operational worldwide. In 1973, American Air force and Navy decided to make a system in the name entitled NAVSTAR Global Positioning System with full operational capabilities. This system was premeditated by American Defence Authority for its military safety particularly in Persian Gulf War. This satellites constellation was launched into orbit in 1980 and aftermath of this was in the form of better precision and exactness. Onwards, this fully operational designed navigation system is to be used in many civil applications worldwide.

B. Characteristics of GPS

GPS has been renowned due to its prominent and advanced features in civil applications and some business point of view. The first and foremost feature of GPS is its accurate description of location with the respect of 3 dimensional co-ordinates up to 100m but this accuracy can be more refined further up to 3cm with the help of DGPS (Differential Global Positioning System). This modernized system not only uses the satellites but also use the base stations on Earth [5].

GPS uses the triangulation method for finding more accurate position and precise timing with the help of timing clocks built on GPS satellites on the surface of Earth between GPS receiver and GPS satellite.

According to Theiss et al (2005), "The atomic clocks on the satellites are accurate to within a nanosecond. The receivers contain only a quartz clock, but are very accurate due to the constant synchronization with the satellite' atomic clocks".

Fig 3.0. Satellite sending the navigation messages [14]
Source: Kintner 2004

GPS receivers have latest features and compatible with its satellites through different techniques. The atomic clock used in GPS satellites are much costly as compared to quartz clock used in receiver but the clocks are much accurate and synchronized with GPS satellites due to its advanced built up features. GPS receivers can show the exact direction of satellites orbiting the Earth and also depicts the signal strength coming from GPS satellites. Another built up advanced feature in GPS receiver is to add graphical latitude and altitude coordinated in the shape of map datum [8] [5].

3. GPS Structural Design

Fundamentally, GPS comprises of basic three segments like space segment, user segment and control segment having their own working independently [3].

System time and orbital location is to be known very precisely through each satellite on-board computer and navigation message generator. The information coming from GPS receivers is broadcasted with the speed of light in the navigation messages to satellite for calculation of approximate ranges from each satellite. The messages used in satellite system travel in two code sequence like C/A- code with the bit length of 1023 and other encrypted code with the bit length of 6 trillion.

The system time and position of each individual satellite can be measured on the basis of these types of codes. The information coming from satellites are transported to control system through L-band frequency and the signals are uploaded to space segment through S-band frequency. Satellites use L-band frequencies to minimize the level of interference, ionospheric effect on the transmission of GPS signals. Now, all the segments contained by GPS will be discussed separately.

A. Space Segment

The space segment plays the pivotal role in this whole system and all the major functionalities are dependant on this part of GPS. This segment is a constellation of 27 satellites moving around the Earth in an elliptical path at an height of 11,000 nautical miles having the total no of six orbital planes with the inclination angle of 55• each other. Currently, this segment is further divided into four blocks and a 5th block is to still under development. These blocks are to be shown diagrammatically here separately:

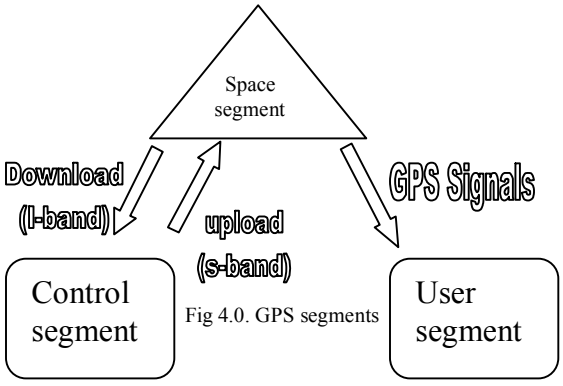

Fig 4.0. GPS segments

1) Block I / II

The initial version of GPS testing was in the shape of Block I satellites comprising of 10 satellites with the capability of storing navigation messages for 14 days. In this system, there was no capacity of having on-board momentum management [9].

The system having the average life capacity was five years and based on the Cesium and Rubidium frequency standards. After the working on the Block I, the need is to avoid satellite system from the cosmic rays effects. The Block II system with average life of 7.5years was designed for high security of military in support of extra features like selective availability and antispoof.

2) Block IIA / IIR

After the successful launching of above mentioned system, more modifications are to be done in the result of Block I IA and I IR with upgraded results. The promising feature in case of Block I IA was the enhancement of on-board storage capability in the range of 14-180 days. The drawback of this system was wholly dependable on ground control system. Block I IR series satellites were launched in 1998 after the careful consideration of more 20 satellites in Earth orbit with full accuracy having the average design life of 10 years [9].

3) Block IIF

The final version in the name of Block IIF of GPS constellation is under consideration and the existing positioning system will be replaced with the support of 33 I IF satellites. This enhanced version of the system with the support of second coded civil signal and enhanced cross link capability is less dependant on the ground control system [10][9]. Block IIF satellites have the average design life of 15 years.

B. Operational Control Segment

This is most important part of the GPS and plays a pivotal role in this whole scenario. All the activities supported by the satellites orbiting the Earth are to be managed through this control segment. It comprises of Master Control Station, Monitor stations and collectively different antenna system. The important atmospheric data, location of satellite etc. is uploaded via control segment to satellites through S-band frequency level.

This part of GPS is ground based and monitors all the movement of satellites moving around the Earth through intelligent built in software packages and hardware. The software used in Master Control Station is responsible for handling Block IIR satellites' functioning and is capable of handling 20 monitor stations at a time. The growing monitoring network results in the better precision and accuracy level.

C. User Segment

The third part of this system consists of user equipments like GPS receivers which are directly interact with the satellites. The signals transmitted by satellites are to be processed by receivers in L-band frequency range to evaluate user's direction, time etc.

GPS signals are to be received and manipulated through its receiver and predict the position of the user anywhere on the surface of Earth with the help of maximum four satellites. Now, more and more modern applications like air traffic management surveying and

tracking are to be facilitated through this astonishing technology.

4. GPS Operation and its Working

As described in the above mentioned discussion, GPS is a navigation system which is used for tracking and locating of objects. Location can be identified anywhere on the surface of Earth through the concept of resection with the help of at least three satellites and a point from a GPS receiver [3]. Signals generated by each satellite continuously are composed of two carriers, encrypted or decrypted codes and a navigation message. GPS receiver has a built up antenna and it receives the signals directly coming from satellites through this antenna. The antenna' receivers process the signals automatically coming directly from satellites.

A. Errors sources in GPS

There are various sources of errors faced by GPS measurement. These errors may be caused by satellites, GPS receiver or signal propagation level. Different factors like signal strength, atmospheric changes, multi-path and sudden climate changes, system clocks error built in satellites play role in originating the errors. These sources of errors are to be eliminated through mathematical modelling, different algorithms and intelligent software etc. Next section will discuss the different levels of errors and the ways to eradicate these errors as follows,

1) *Multi-path errors*

The prominent feature in signal propagation through free source is multi-path and sometime this results in the deterioration of the signal strength and other variations. The signals coming from satellites to GPS receiver follow direct LOS and also in NLOS (Non-Line-of-Sight). Multi-path signals coming from various ways distort the original signal strength and results in errors. These types of errors are to be overcome through advanced built up features in GPS receiver by Strobe correlator and the MEDLL technologies [19]. These types of errors can be eliminated by these technologies even in the reflective environment [13].

2) Ionospheric Errors

Ionospheric effect happens due to the presence of free negative and positive charges in atmosphere at the height of above 50km from Earth. The Ionosphere medium directly effects on the GPS radio signals and deteriorate the signal strength coming from different Ionospheric layers. The medium slows down the speed of signals before reaching to GPS receivers coming from satellites and results in range error [3].

3) Satellite and receiver clock errors

Each individual Satellite and GPS receiver uses their own clocks separately and these clocks are to be managed for getting better precision and accuracy. Satellite uses atomic clock and GPS receiver uses Quartz clock which is less accurate as compared to atomic clock but is cheaper than atomic clocks. The error range in satellite atomic clock is to be measured through multiplication of error clock with the speed of light. The core part of the satellite, "Ground Control System" monitors and checks all the errors occurred in the system.

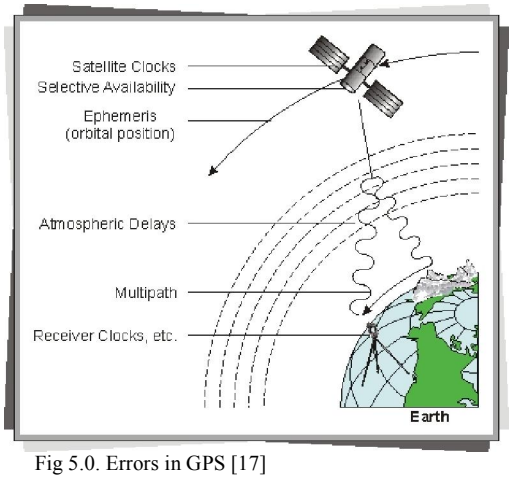

Fig 5.0. Errors in GPS [17]

4) Human errors

There are some types of errors caused by satellites Engineers. According to recent news in BBC, Engineers lost contact with the satellites. NASA (National Aeronautics Space Administration) found that faulty change made to the space craft's computer memory caused the battery to overheat and resulted in much loss [18].

5. GPS Applications

In the past, GPS (Global Positioning System) was limited for the military purposes with the use of different satellites. Now, there are many applications in industrial as well in commercial sectors. The system having full potential of precision and accuracy gives cost effective solution of tracking and locating. The most exciting feature of this system is to be monitored and controlled automatically through "Operational Control System". This section describes the various applications from the areas of Transporting, Engineering, Tracking, Weather forecasting etc.

A. Accurate and Precise Timing

GPS has been applied to determine exact timing in civil application whether it is dynamic or static. The most precise and accurate timing is really important in any electric company or electrical system. The most

prominent American electric company has applied the GPS technology for minimising the extra consumption of power and electricity.

Accurate and precise timing is required for generation and transfer of power with the help of modern Global Positioning System. For getting and analysis of appropriate information regarding electric company, GPS time tags are required. In contrast of GPS satellites, its receivers are useful for determining exact location where power goes down.

B. Surveying and Mapping

GPS is also a good tool for practical surveying and mapping of different utilities like water, gas etc. With the help of this system, distance between two locations can be determined. GPS can provide solution of water mapping and better location can be traced and verified for utility mapping through this attractive positioning system.

This provides cost effective solution for exact location of utility installation and mapping with the help of GIS (Geography Information System) and no extra ground marking is required. For mining industry in oil drilling purposes, this system provides the precise place for this and this eradicates the extra cost.

C. Traffic management and logistics usage

Another advanced feature of this navigation system is in the area of traffic management and logistics. In logistics, GPS plays also its own role with the efficient usage in big cargo companies. Space for shipping containers is to be carefully monitored with accurate and precise space to a few centimetres. Real time tracking is also possible with the help of this emerging technology and acknowledges back to the base station with accurate position.

The system provides strategic advantages to the companies having support of this technology with the cost effective solution. In transportation era, Global Positioning System also helps for management of traffic in the efficient way. Currently, an efficient named as traffic manager consisting GPS receiver provides updated information in case of jamming of traffic occurs and traces alternative routes for this case. Owing to this tremendous achievement in transportation management, better and cost effective solutions are available [2].

D. Security Measurement

In today's modern technology world, security plays a core role in any sort of application. GPS provides the solution for different companies and businesses to enhance security. Security is highly concerned in case of transporting and big vehicular companies.

All dangerous and toxic materials like weapons are uploaded through big cargo companies and highly monitored and keep in touch continuously with GPS base station. There are two cargo companies like PAR Logistics and Savi have the built in Global Positioning System for providing high security in case of hijacking and kidnapping [15][5].

E. GPS Vehicle Navigation and tracking

Most interesting and upcoming application done by GPS (Global Positioning System) is in the form of vehicular navigation or vehicular tracking and this technique provides an efficient solution for drivers having unfamiliarity with routes or roads. Before this technology, road drivers use paper road maps for identification of proper routes. Having inefficiency of this system in busy areas, this technique does not provide better solution for route tracking.

With the advancement of new GPS technology in this area having digital road map and a computer navigated system results in easily manipulation of road tracking electronically with the touch of button[16]. The digital road map having built in information regarding street names, road direction, airports gives the solution of easy and safe tracking continuously.

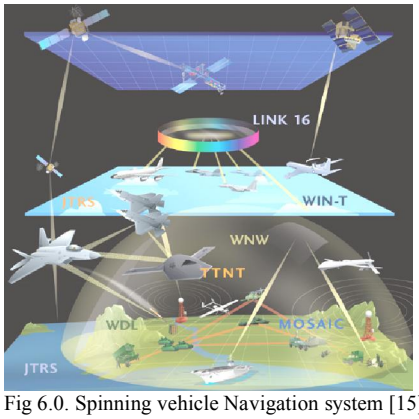

Fig 6.0. Spinning vehicle Navigation system [15]
Source: Rockwell Collins

F. GPS Weather forecasting

Weather forecasting is an important application predicted by the modern Global Positioning System. It predicts the accurate weather forecast through its intelligent system. Accurate weather forecast and improvement of weather data is possible through the establishment of GPS [18]. Meteorologists predict the accurate weather forecast on the basis of signals change coming directly from satellites. This application is also an important factor for prediction of future threats in case of storm, tornadoes, hurricanes etc.

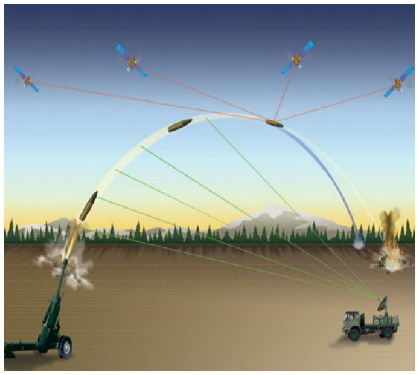

Fig 7.0. Vehicle navigation structure [15]
Source: Rockwell Collins

G. GPS for precision farming

The more precise and modernized positioning system in the name DGPS (Differential Global Positioning System) revolutionized the farming industry. Different attributes like soil sample collection, harvesting machinery can be controlled this technique. Vehicular steering system used in this application is directly interlinked with the satellite.

For spraying purposes, aerial guided system integrated with GPS can be used for right spots and location in the farms with less overlap and with accurate rate. The steering system built on automatic system is used for much time and controlled directly through satellites. Mapping of crop yields is to be done through this integrated positioning system [12].Yield rates are to be calculated through Differential Global Positioning System through mapping and now this system is available in existing market.

6. Comparison of Different Positioning System

Like GPS, there are other navigations systems like Galileo, Beidou and GLONASS developed by Europe, China and Russia respectively. All these navigation systems play their own role with less coverage as compared to GPS developed by U.S.A. Basically, GLONASS works like GPS and each satellite transmits signals having L-band carriers and a navigation message. Beidou is the navigation system and the satellites are placed in geostationary orbits with the maximum altitude of 36,000km above Earth surface. Galileo satellite based positioning system proposed by European standard bodies.

In this future based system, all of constellation types like LEO (low Earth orbit), MEO (medium Earth orbit) and IGSO (inclined geosynchronous orbits) are to be analysed. Galileo has an edge over other two GLONASS and Beidou due to its high security measures and two levels of services: free and chargeable.

7. Conclusion and Implications

In the consequences of all above mentioned discussion, GPS played a pivotal role in every part of modern life and revolutionized in the positioning and navigation systems. After careful considerations, one should have a good knowledge about its working, its applicabilities in civil as well as in military side. This up and coming technology benefited the businessmen and they flourished their businesses due to this astonishing and cost effective navigation system.

As compared to other positioning systems like Galileo, Beidou and GLONASS etc, Global Positioning System provides more accurate and precise measurements with the support of more than two dozens satellites.

For future perspective, Global Positioning System has indulged in every walk of life and more and more applications are under considerations in this context. The problem faced by GPS is line of sight and this can be overcome through the use of special types of antenna on its receivers. Future implications and betterments in this system are possible through modern techniques like DGPS (Differential Global Positioning System), Precise monitoring. Another latest achievement in the form of GPS modernization is expected in coming few years in 2013 with the help of new civil signals and military code.

In this paper, I described the general overview of the Global Positioning System, its different applications, its working. Finally, this manuscript discussed the future implications and the ways of its betterment and enhancement. In a nutshell, this growing technology will be adopted by everyone in every part of life.

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