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Review Article

Global Positioning System and Forestry Applications

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Abstract: With the developing technology, the use of GPS in forestry has become widespread and compulsory. Positional data are important in the processing and evaluation of data. The importance of global positioning systems developed to collect spatial data on satellite basis increases. Today, with the developing technology, there have been developments in GPS systems. Therefore, GPS systems have provided great convenience in map production. It is of great importance, especially since it provides an alternative to forestry works with large and difficult working conditions and is a less time-consuming and economical method in terrestrial measurements compared to other measuring devices. In this study, it is aimed to make a general evaluation about global positioning system and its use in forestry applications.

Keywords: GPS; forestry measurements, DGPS

Küresel Konumlandırma Sistemi ve Ormancılık Uygulamaları

Öz: Gelişen teknoloji ile birlikte ormancılık alanında GPS kullanımı yaygınlaşmıştır ve zorunlu hale gelmiştir. Verilerin işlenmesi ve değerlendirilmesinde konumsal veriler önem taşımaktadır. Konumsal verileri uydu bazlı toplamak amacıyla geliştirilen küresel konum belirleme sistemlerinin önemi arttırmaktadır. Günümüzde gelişen teknoloji ile birlikte GPS sistemlerinde de gelişmeler olmuştur. Bu yüzden GPS sistemleri harita üretilmesinde çok büyük kolaylık sağlamıştır. Özellikle geniş ve çalışma koşulları zor olan ormancılık çalışmalarına bir alternatif oluşturması ve yersel ölçmelerde diğer ölçüm cihazlarına oranla daha az zaman alıcı ve ekonomik bir yöntem olması nedeniyle büyük önem taşımaktadır. Bu çalışmada, küresel konumlandırma sistemi ve ormancılık uygulamalarında kullanımı hakkında genel bir değerlendirme yapılması amaçlanmıştır.

Anahtar Kelimeler: GPS; ormancılık ölçmeleri, DGPS

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1. Introduction

Engineering measurements are the first step of any project. Responsive, detailed, and fundamentally based engineering surveys make up a significant portion of project design costs. The forest engineering field of study requires a wide range of engineering measurements. It is a requirement of engineering to carry out the measurements in question using modern technological possibilities. However, measurements (ground measurements) in some engineering fields are still made with classical methods and therefore there are incompatibilities between institutions.

Today, with the developing technology, there have been developments in GPS systems. Therefore, GPS systems have provided great convenience in map production. It is of great importance, especially since it provides an alternative to forestry works with large and difficult working conditions and is a less time-consuming and economical method in terrestrial measurements compared to other measuring devices. In this study, it is aimed to make a general evaluation about the global positioning system and its use in forestry applications.

2. GPS (Global Positioning System)

In 1973, a project group was formed with representatives from the US Armed Forces and the Defense Mapping Agency to develop a new navigation and positioning system. This new system replaced the old DOPPLER or TRANSIT navigation system and became NAVSTAR GPS. NAVSTAR stands for Navigation by Satellite Time and Distance Measurement and Global Positioning System of GPS. The system was put into effect by the US Department of Defense for military applications and access was provided to civilian users with some restrictions. Today, the most used form is GPS. The development of GPS was born out of necessity, and as technology developed, GPS became what we use today. Without advances in rockets and satellites, the Global Positioning System would not exist. In fact, this development was due to the Soviet Union, which launched the first satellite, and the shooting down of the civilian airliner's KAL 007 plane, which accidentally entered the airspace of the Soviet Union with the cold war, in 1983. This event accelerated the US's Global Positioning System development program and led to its first civilian use. Today, GPS is encountered at every stage of life [1].

In fact, the emergence of the need for positioning goes back to the Second World War. The military felt the need to find a better way to navigate other than the stars and the weak radio signals emanating from the radio towers. While on flight missions, the pilots used radio signals while returning to the center. It was fine when the pilot or navigator was in the vicinity of their planned return route, but they had trouble picking up the home radio signal when they were off course. They had to be within a certain distance determined by the strength of the signal. In the early 1940s, the LORAN system was developed for both land and sea for military purposes[2].

When Sputnik was launched in 1957, a group of US scientists were monitoring its radio signals. They immediately noticed that due to the Doppler effect, Sputnik's signal was higher as the satellite approached, but lower as the satellite passed and moved away from them. They formulated that if they knew their fixed position on earth, they could find the exact position of the satellite by measuring the Doppler decay/translation. The US Navy first successfully tested a satellite navigation system (Transit) in 1960. This system consisted of five satellites orbiting the earth. The flaw of the system was that it did not give a navigation position before an hour. For GPS to work, they needed reliably accurate clocks in space. The US Navy achieved this by launching the Timation satellite in 1967 and took a step forward in the space race. The first worldwide ground-based navigation system began operating in the 1970s. It was called the Omega NAvigation System and was based on a single-phase comparison basis. Experimental GPS satellites called Blok I were launched in 1978, and ten more satellites followed by 1985. Modern Blok II satellites began to be launched in 1989. In January 1994, 24 satellites were orbiting at full operational capacity[2].

After the Soviet downing of the Korean KAL 007 aircraft in 1983, President Ronald Reagan announced that the civilian population would also be able to use the GPS navigation system once the system was completed. During Bill Clinton's administration, he realised the importance of civilian as well as military use of the GPS system. Clinton set up a commission called the GPS Management Board to prepare the management and future plans of GPS. At this point, GPS really became a system for both military and civilian use. In 1998, Vice President Al Gore announced future plans to improve GPS by adding two new signals for civilian use, increasing its reliability and accuracy. In 2004, with an updated National policy, President George W. Bush announced the establishment of the National Space-Based Position, Navigation and Timing Management Committee to replace the GPS Management Board due to the importance of the GPS system in our daily lives. With the rapid technological advances in today's world, there will be many changes in the GPS sector, and it is an inevitable fact that GPS will enter our lives more and more as developments increase. GPS is a network of satellites developed by the USA in the 1970s as part of its defence programme. It is a system that allows you to track and locate objects or vehicles by providing precise location information (latitude, longitude and altitude) with 24 primary and 3 backup satellites orbiting in six orbits at an altitude of approximately 20200 km and an inclination of 55 degrees with the equator. GPS satellites have a full cycle of 11 hours 58 minutes and arrive at the same point 4 minutes before the same satellite distribution every day [2].

2.1. Section of GPS

Developed under the responsibility of the JPO (Joint Programme Office), a unit of the Space Division of the US Air Force Systems Command, GPS consists of three main parts.

2.1.1. Space section

The GPS space segment consists of satellites modulated on two different L1 and L2 frequencies, transmitting phase and code measurements and their orbital information. Each satellite transmits simultaneous signals and navigation message information on two carrier frequencies. Since 1973, many satellites have been launched into space and many more satellites have been put into service than planned. GPS satellites are located at an altitude of about 20200 km above the Earth's surface, in six parallel orbital planes with orbital placement at an inclination angle of 55°, and complete the circumference of the Earth in a period of about 12 hours (11h 58') (Figure 1).

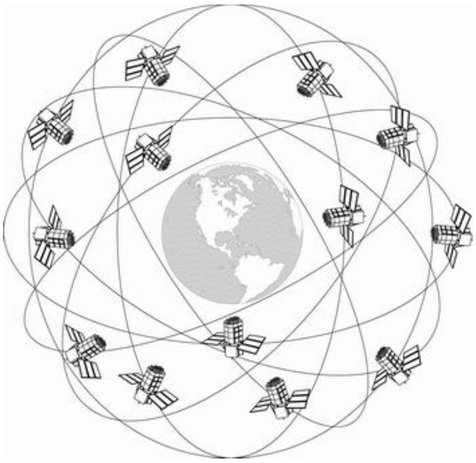

Figure 1. Representative representation of GPS satellites and orbits

The initial orbital placement of satellites was designed so that at least 4 satellites could be tracked from anywhere in the world and more time was spent over North America. However, with the increase in the number of satellites today, a sufficient number of satellites can be tracked for positioning. GPS satellites have been classified chronologically according to their launch dates and accordingly; the first group of satellites launched between 1978-1985 were called Block I, and the satellites launched since then were called Block II, Block IIA and Block IIR respectively. Each generation of satellites is designed to have higher technology and longer lifetime than the previous one. Today, modernisation efforts are continuing rapidly and these efforts have started with the upgrade of 12 Block IIR satellites. In these satellites, the military M code will be placed on L1 and L2 and these satellites will be named Block IIR-M [3].

The new L5 signal will be added to the Block IIF satellites and these satellites will be mainly used for life safety services. Compared to the C/A code on L1 today, the civil frequency L5 has high resistance to signal interference, four times more power, an extended data message and a wider bandwidth [4].

2.1.2. Control section

The control section consists of 1 main and 5 monitoring stations scattered around the globe. The main station is located in Colorado (USA); the monitoring stations are located in Hawaii, Ascension, Diego Garcia, Cape Canavaral and Kwajalein. All orbiting GPS satellites are monitored by six fixed tracking stations, which are conveniently distributed around the globe, equipped with very accurate clocks and whose location is well known. The task of these stations is to ensure the healthy operation of the satellites on a daily basis, to analyse the collected data to determine satellite orbits, to calculate satellite clock corrections and to upload information such as SA effects to the satellites. The main control station is responsible for the control of the entire system and the calculation of the satellite ephemeris information and clock corrections for each satellite. The other 5 stations act as observation stations and collect the data necessary for the determination of satellite ephemeris [5].

2.1.3. User section

The user section consists of the receiver and the antenna. Receivers are classified according to their intended use, area of application and structure.

a) According to their intended use;
  - Scientific purpose receivers;
  - Receivers for practical purposes.

b) According to usage areas;
  - Receivers for military purposes;
  - Civil type receivers.

c) According to their structure;
  - According to the number of channels;
  - According to their frequency.

Instruments that record GPS Signals consist of 7 parts [5]. In the antenna and amplifier section, the antenna receives signals from the satellite, amplifies them and sends them to the signal processor section. The connection between the antenna and the signal processor is provided by a cable.

In the signal evaluation section, the signal received by the antenna and amplified and transmitted to the radio-frequency section via cables is evaluated by the signal processor. This evaluation is done with the channels in the signal processor. The pseudorange is determined by code measurements. Then the data ensembles are demodulated and converted back to their original form. The microprocessor is the part where the calculations are performed. Data logging is the part where the measurements are recorded. Recording can be done to the instrument, computer, floppy discs or cassettes. In the external communication section, there are keyboard and display units for manual use. The energy source provides the energy required for the operation of the instrument. The tools usually work with 12-volt energy. Internal battery and external battery are used. Oscillator is the part that converts the light current into electric current.

2.2. Advantages and Weaknesses of GPS Compared to Classical System

Advantages of GPS;

- There is no need to see between points. It is sufficient for the GPS receiver system to see the sky.
- Measuring points do not have to be selected at high elevations.
- GPS measurements are largely unaffected by weather conditions.
- Measurements can be made 24 hours a day and night.
- The position accuracy of the points is very high.

The weaknesses of GPS are;

- GPS signals are not as strong as microwave signals. Measurements cannot be made indoors, in densely wooded areas, under water, in densely built-up areas, in tunnels and mine galleries.
- Not effective in heavy rainfall, in areas with strong radio transmission or broadcast antennas.
- GPS coordinates are in WGS-84 datum. Conversion to country datum required.

- The heights obtained are not orthometric but ellipsoidal heights.

2.3. Signal Structure of GPS Satellites

In GPS measurements, the data transfer between the satellite and the receiver is carried out by signals broadcast by GPS satellites and located in the microwave part of the electromagnetic spectrum. Carrier waves and modulated codes are the components of these signals. Along with the satellite signals, the information necessary for finding the coordinates of the points on the earth's surface is also transmitted to the receiver and recorded.

GPS requires unidirectional measurement, providing service to an unlimited number of military and civilian users, providing accuracy and clarity, enabling real-time distance measurement, accurate carrier phase measurements, providing a broadcast message, ionospheric delay correction, enabling simultaneous observation of multiple satellites, and preventing signal interference. GPS signals contain components to meet these requirements [6].

GPS satellites transmit 2 basic carrier signals modulated with 2 types of codes and navigation messages. Taking the satellite frequency standard f_o=10.23 Mhz, "$L1= 154.f_o$" and "$L2= 120.f_o$" signals are obtained.

GPS signals are actually quite complex. This is because the signals contain a wide variety of data types. GPS provides a large number of users with precise and accurate length measurements, precise Doppler shift measurements, precise carrier phase measurements, position information and correction parameters due to ionospheric delay [7].

The S band is used to minimise the ionospheric influence between the control section and the satellites, and the L band is used between the satellite and user sections. The L1 and L2 signals are modulated with codes and navigation message data to provide information such as satellite clock corrections, orbital parameters, etc. to the receiver on the ground. In the modulation process, each satellite is assigned a unique PRN (Pseudo Random Noise) code number [8].

Although all satellites broadcast with the same carrier frequency, satellite signals are not interfered with each other by code modulation technique. P (Precision) code and C/A (Coarse/Acquisition) code were modulated on L1 and only P code was modulated on L2. The frequency of P code is f_o=10.23 MHz and the frequency of C/A code is 1.023 MHz.

The distance between the satellite and the receiver (pseudorange) since the transmission and arrival times of the P and C/A codes are known;

$P= c*(t_1 - t_o)$ can be calculated from the equation.

Pseudorange measurements;

In the calculation of the initial values of the position of the ground station,

- To determine the constant offset of the receiver with respect to GPS time;
- For the calculation of full-wavelength L1 (0.19 m) and L2 (0.244 m) carrier phase uncertainties (integer uncertainty) and full-wavelength L1 and L2 phase jumps, if any;
- Processing and calculation of kinematic GPS measurements;

Relative position determination below 1 metre in kinematic applications only with high quality P-code, independent of the carrier phase dimensions, is being used [9].

The reason for using two signals over GPS is that if one of the two signals fails, the other can be used and the ionospheric effect is reduced in this way. Users with single frequency receivers should be modelled using mathematical models that can only determine the ionospheric effect to a certain extent.

Length measurement accuracy is partly related to the wavelength of the chip in the PRN code. Higher precision can be achieved with a shorter wavelength. In order to obtain more precise results than with the C/A code, GPS satellites also transmit the P code [6].

2.4. GPS Signal Properties

In GPS measurements using satellites, electromagnetic waves are used to transmit data from satellites to users. Each GPS satellite has two basic frequencies for positioning purposes, namely L1 (Link1) and L2 (Link2).

L1 and L2 frequencies are obtained by taking 154 and 120 integer multiples of the fundamental frequency of 10.23 MHz, L1 frequency is 1575.42 MHz and L2 frequency is 1227.60 MHz. Many carrier frequencies were analysed during the design phase of the GPS system. Comparisons were made especially between L-Band (1-2 GHz), UHF (400 MHz) and C-Band

(4-6GHz). In the end, L-Band was preferred due to the ease of frequency allocation and the fact that the ionospheric effects are much smaller than the other bands. In addition, the data flow between the Control Department and the satellites was carried out on S-Band (1783.74 and 2227.5 MHz).

Purposes of dual frequency in the GPS system;

- In the event that the L1 frequency is interrupted for any reason or is subjected to electronic jamming, the L2 frequency acts as a backup frequency;
- Providing ionospheric correction by utilising the dual frequency feature [10].

Due to the fact that the P-code is open to military users, civilian users can only use single frequency (L1-C/A code) and therefore cannot benefit from the dual frequency feature that provides ionospheric correction. As a result of intensive studies on this issue, in order to enable civilian users to benefit from the dual frequency advantages, Block IIR-M and all satellite models to be followed by Block IIR-M as of 2004 will broadcast C/A code (L2C; L2 Civil Signal) over the L2 frequency. As mentioned above, IIR-M satellites (12 in total) were planned to be launched into space starting from 2004, but for various reasons, the first IIR-M satellite was placed into orbit on 24 March 2009. With the launch of the IIR-M satellites, the number of satellite signals broadcast will be doubled. In addition, a third and new civilian frequency is allocated. This new frequency will be broadcast via Block IIF satellites, which are planned to be launched into space from 2010 onwards, and is called L5 (despite this plan, the L5 signal started to be broadcast from the IIR-M satellite PRN01 on 10.04.2009). The frequency of the L5 signal is 1176.45 MHz. Although it is planned to broadcast this signal on 18 satellites by 2012, it is thought that this will not be possible before 2016 due to delays in the launch of satellites into space. The L5 signal is planned to be used primarily for the safety-of- llfe navigation of aircraft, but will probably be available to all users. In addition, the L5 signal is expected to provide a significant benefit in terms of ionospheric effect, which is inversely proportional to the square of the signal frequency, and this benefit can be seen more clearly when it is taken into account that the ionospheric effect at L1 frequency is 65% higher than that at L2 and 79% higher than that at L5. In addition, the L5 signal is about 4 times stronger than the L2C signal, which means that better results can be obtained, especially in applications in adverse terrain conditions. With the L5 signal, it will be more appropriate to define receivers as tri-frequency instead of dual-frequency. Thus, the number of signals will increase to 7 with the L5 signal. Although the L2C signal will initially provide an advantage only for dual frequency receivers, it is hoped that it will also provide an advantage for single frequency receivers after at least 24 satellites have completed broadcasting this signal by 2013. The L1 and L2 carrier frequencies are modulated with codes and Navigation Message data in order to transmit information such as satellite clock corrections and orbital parameters to the receiver on the ground. In this modulation process, each satellite is assigned a unique PRN (Pseudo Random Noise) code number. PRN codes consist of 0 and l (binary) values and have a random characteristic. In reality, PRN codes are generated by special algorithms by devices called "tapped feedback shift register" in the receiver. Although all satellites broadcast data at the same carrier frequency, the satellite signals do not interfere with each other due to the PRN code modulation technique. Since the PRN code of each satellite is independent from the others (uncorrelated) and has a single meaning, satellite signals can be distinguished from each other with the CDMA (Code Division Multiple Access) technique. Two PRN codes and Navigation Message data are modulated on the L1 carrier frequency. These PRN codes are named as C/A (Coarse/Acquisition, Clear/Access) code and P (Precise/Protected Code) code. The L2 carrier frequency is modulated with only one PRN code (P-code) and the Navigation Message data. The L1 carrier frequency is modulated with C/A code, P-code and Navigation Message data, while the L2 carrier frequency is modulated with P-code and Navigation Message data. In other words, the C/A code available to civilian users is only available on L1. However, as mentioned before, it has been decided to broadcast the C/A code information on L2 via Block IIR satellites since 2003. The C/A and P code states are represented by binary values 0 and 1, which correspond to +1 and - 1 expressions. Each 0 or 1 is called a "chip". Since these do not carry any data, the name "chip" is used instead of "bit". The carrier in the normal state is 0 and 1 is obtained by shifting it by 180 degrees. In other words, every time there is a change in the code state, the carrier wave is shifted by 180 degrees and biphase modulation is performed. Each satellite broadcasts a specific series of codes, which are called "GOLD Codes". These codes allow the receiver to analyse the initial information of the recorded signals. This information is particularly important for simultaneous observations of multiple satellites. The oscillator controlling the carrier wave tracking loop in the receiver detects a frequency offset in the signal recorded (observed) by the receiver. This observed frequency will differ from the nominal L1 and L2 frequencies due to the Doppler effect caused by the relative motion of the satellite and the observer. In other words, if the source (satellites) and the observer (receiver) are moving relative to each other, the signal recorded by the receiver will be offset due to the Doppler effect. A satellite in the direction of the observer's zenith is closest to the observer (20183 km), and since the radial velocity is zero in this direction, the Doppler effect will be zero. On the other hand, a satellite passing over the horizon will have a maximum radial velocity and a satellite-receiver distance of 25783 km, resulting in a distance difference of approximately 5600.9 km (or 18.7 milliseconds). Considering that L1 and L2 frequencies are broadcast at 1227.60 MHz and 1575.42 MHz, respectively, if the radial velocity of a satellite passing through the horizon plane is assumed to be 0.9 km/second, the amount of shift in L1 frequency is calculated as 3.7.103 MHz and the amount of shift in L2 frequency is calculated as 4.7.103 MHz. These values mean a phase change of 3.7 and 4.7 wavelengths (cycles) in one millisecond, respectively [10].

2.4.1. C/A code properties

As mentioned before, the C/A code is modulated on the L1 carrier. This code is a 1 MHz PRN code and repeats at the end of each 1023 bit code (every millisecond). The purpose of choosing a very short C/A code period is to ensure that the GPS receivers lock on to the satellites as soon as possible. A different C/A code PRN is allocated for each satellite and these codes are selected from the so-called "Gold Codes". The C/A code is available to all users and is the basis for the civil standard positioning service SPS (Standard Positioning Service). It is also used to reduce the time it takes for P-code GPS receivers to lock on to the longer P-code. Since the PRN codes mentioned above do not carry any information, they are also called "chips". Therefore, if the C/A code length is expressed as "1023 chips", this repeats every millisecond. Thus, the time difference between two "chips" is approximately 1 microsecond (1 microsecond = 10-6 seconds), which corresponds to a "chip" length of approximately 293 metres [10]

With today's signal processing techniques, signal resolutions are about 1% of the wavelength of the observed signal. For P code and C/A code, the wavelength and "chip" length have the same meaning, the wavelength (chip length) of C/A code is 293 metres and its resolution is about 3 metres (Figure 2).

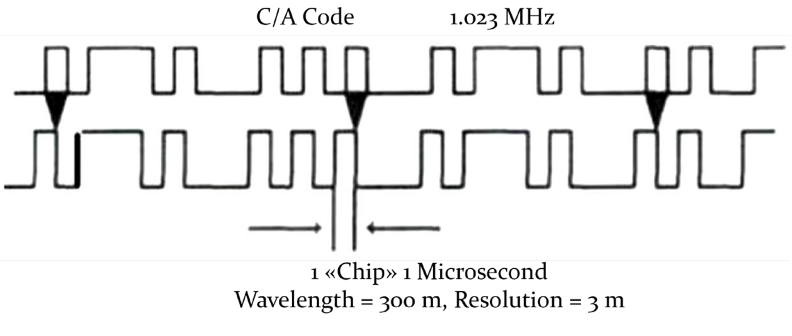

Figure 2. C/A code wavelength (chip length) and resolution.

2.4.2. P-code properties

The P-Code is modulated on both L1 and L2 carriers and has a code length of approximately 266.4 days. The entire code length is divided into a total of 37 one-week segments. Each satellite has been allocated a one-week portion of this 37-week Code, which corresponds to the satellite's PRN number. Thus, 37 separate PRN P-codes are allocated. The codes are repeated at the beginning of each GPS week (Saturday at midnight). If the P-code was not reset and rebroadcast every week, the total broadcast time would be approximately 37 weeks. However, the 37-week period is divided into one-week segments, with segments 1 to 32 allocated to a GPS satellite and segments 33 to 37 allocated to earth broadcasting stations (Pseudolites) (the same applies to the C/A Code) [10]. Thus, no partition code (PRN code) of the satellites can be confused or overlapped with the other. The P code "chip" has a length of 29.3 metres and a resolution of approximately 30 cm (Figure 3).

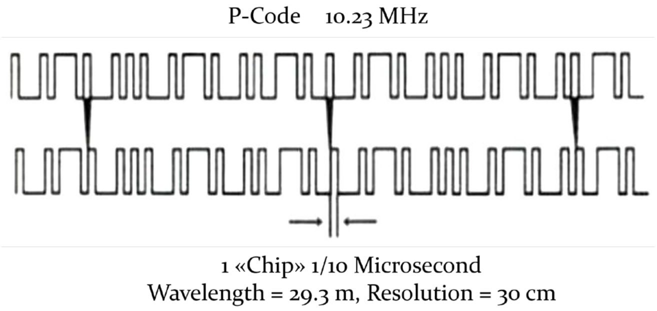

Figure 3. P code "chip" length and resolution.

Long period codes such as P-codes are very difficult to be received directly by receivers on the ground without any support. For this reason, a Z-count has been defined to minimise the time interval during the direct reception of the P-code. The Z-count is used to calculate the number of 1.5-second epochs from the beginning of the first GPS week (midnight on 5 January 1980) to the time of measurement. Therefore, the Z-counter is reset every 1024 weeks. Each sub-section of the navigation message lasts 6 seconds (4x1.5 s). In addition, in order to lock the GPS receiver to the P-code, the word HOW (Hand-Over-Word) is used in each 6-second sub-section of the Navigation Message. The HOW word is the second word of each sub-section, and is used to indicate the time tag for the next sub-section and the part of the P-code used to generate the next sub-section. Therefore, the word HOW multiplied by 4 gives the Z-counter (or TOW; Time of Week) value at the start of the next sub-section. Thus, the GPS receiver first locks on to the C/A code and receives the time information, then determines the HOW words and the sub-section epochs, and then locks on to the P-Code for the next sub-section epoch. On the other hand, another option to directly access the P-Code without the help of the C/A code is to know the GPS receiver position and GPS time information very precisely and to enter it into the receiver. In order to protect the P-Code against electronic jamming and spoofing, it is encrypted using the A-S (Anti Spoofing) feature. The encrypted code is known as W-Code and the encrypted P-Code is called Y-Code. Therefore, the use of the Y-Code is only open to authorised (military and civilian security) users. The transition from Y-Code to P-Code requires special hardware (AOC: Auxiliary Output Chip, SM: Security Module) and software in GPS receivers. A-S feature is not implemented for C/A-code [10].

2.4.3. PNR code

The Pseudo Random Noise Code is generated differently by each satellite with a special mathematical function and is subjected to the modulation process after being collected with the data to be sent. By associating this code with the data, the communication of the whole system is ensured over a single frequency without interference. Each satellite generates a unique PRN code. This code, which replaces the ID of the satellites, must also be generated in GPS receivers. However, the information associated with the PRN sent from the satellite comes to the receivers with a certain time delay. If the receiver generates this code simultaneously with the satellite, the processing of the information signal will be incorrect due to the time delay. For this reason, GPS receivers compare the PRN code generated by the receiver with the PRN code received from GPS satellites. It applies a correlation process to the signal until it is the same and thus detects the time delay. When we multiply the time delay by the speed of light, we find the distance between the satellite and the receiver [11].

2.4.4. CM code, CL code, CNAV code

The CM code, CL code and CNAV code, which were created within the framework of GPS modernisation, were planned to be sent by overlaying on the L2C carrier. CM code is a code consisting of 10230 bits, repeating itself every 20ms and modulated with message information. The CL code is a 767250-bit code synchronised with the z counter that repeats itself every 1.5 s. The CNAV code is a version of the navigation message superimposed on the L5 carrier [11].

2.4.5. GPS navigation message

The navigation message is superimposed on the P-Code and C/A-Code at a data rate of 50 bit/sec. The entire message is 1500 bits long and consists of 5 sub-sections of 300 bits each. A sub-section is broadcast in a total of 6 seconds and contains 10 words of 30 bits each. Each sub-section starts with the word TLM (Telemetry). The TLM word contains information required for the Control Section and is not used by standard GPS receivers. The second word of each subsection is HOW (Hand-Over-Word). The word HOW, multiplied by the number 4, gives the time-of-the-week (TOW) for the start of the next sub-section. The TOW counter gives the sum of the time intervals of 1.5 seconds from the start of the GPS week at the time of the measurement. As explained earlier, the Z-counter is the total number of 1.5 second epochs from the start of the GPS week (midnight on 5 January 1980) to zero at the time of the measurement. The Z-counter totals 29 bits, of which 19 bits represent the TOW counter and the remaining 10 bits represent the number of weeks since the first GPS week. The entire Navigation Message consists of a total of 25 pages and takes a total of 12.5 minutes to publish [10].

2.4.6. Almanac information

The Almanac data includes a partial set of ephemeris and clock parameters. Its purpose is to provide satellite coordinates with very low accuracy, which are necessary for the GPS receiver to quickly lock on to satellites when it is first switched on to start a survey. It is also used for plotting satellite visibility graphs for survey planning. Almanac data is published by each satellite and contains approximate position information of all satellites. The Almanac data is also updated by the Control Department at least every 6 days and is valid for a long period of time (if the satellites do not change or degrade). For current GPS satellites this is 180 days [10].

2.5. Coordinate Systems Used in GPS

The main purpose of geodesy is to determine the three-dimensional positions of points on the earth. When determining coordinates based on satellites, two basic coordinate systems are used [5].

- Space fixed coordinate system;
- Earth fixed coordinate system.

Reference systems are maintained by IERS under the organisation of the International Association of Geodesy (IAG) and the International Astronomical Union (IAU). IERS analysis centres have been established for each satellite geodetic technique. This central office consolidates and publishes the results. Defines the ICRF and ITRF systems.

2.5.1. Earth-centred inertial coordinate system (ECI)

The ECI coordinate system is used to measure and determine the satellite orbits used in GPS technique. The starting point of this coordinate system is the centre of the earth. In this system, GPS satellites move around the earth according to Newton's Laws. In the ECI coordinate system, the XY plane is coincident with the equatorial plane of the earth and the Y axis is in the direction of the north pole. While defining the ECI coordinate system, some problems arise due to the irregular movements of the earth. Due to the gravitational effect of the Moon and the Sun on the equator, the equatorial plane is in motion relative to the celestial sphere. Since the X axis is defined according to the celestial sphere and the Z axis is defined according to the equatorial plane, the irregularities in the motion of the earth around the sun cause the ECI system not to be fully inverted as defined above. To solve this problem, the orientation of the coordinate system axes is defined according to a specific moment or epoch. The GPS ECI coordinate system is also referred to as J.2000.00 at 12:00 on 01 January 2000 and is considered to coincide with the mean equator and equinox. The coordinate system defined in this way is called the Mean Celestial Reference System (MCRS) or the Conventional Celestial Reference System (CCRS) [5].

2.5.2. Earth-centred fixed coordinate system (ECEF)

The coordinates of a point measured on the earth are defined in a coordinate system that rotates with the earth. This coordinate system is called Earth Centred Earth Fixed (ECEF) coordinate system. ECEF coordinate system is also called CTRS. The ECEF coordinate system is defined as follows [5].

- The centre of the ECEF coordinate system coincides with the centre of mass of the earth;
- The Z axis is perpendicular to the equatorial plane in the geographical north direction;
- The X axis is coincident with the mean Greenwich meridian and its direction is zero degrees longitude;
- The Y axis is in the 90° east longitude direction and forms the right-hand coordinate system.

According to these definitions, X, Y axes rotate with the earth. CTRF is defined by geocentric coordinates (X, Y, Z) determined by measurements made at a large number of ground control points, known as reference (fixed) physical points. SLR and VLBI instruments are installed at most of these fixed points. An example of this reference system is IERS. The reference system so established by IERS is called ITRF. IERS utilises a number of satellite techniques to determine the rotation para-meters each year and to establish the ITRF system. The DOMES numbering system was adopted to avoid confusion of ITRF points. This numbering system was first used in the MERIT project. Conversion between CTRS, the geocentric geostationary coordinate system, and CCRS, the geocentric inertial coordinate system [5].

2.5.3. WGS 84 system

This system is also defined as the World Geodetic System 1984. The founder of this system is the US Department of Defence (DoD). The satellite orbit information in the navigation message broadcast from GPS satellites is in the WGS-84 system. The WGS-84 system was initially developed based on transit doppler observations. In 1987, it started to be used in sensitive ephemeris calculations for transit satellites. The origin of the WGS-84 system is the centre of gravity of the earth's mass (G). This point is also the centre of gravity of the ellipsoid. The Z axis is coincident with the earth's axis of rotation and passes through the conventional terrestrial pole (CTP). The X axis passes through the intersection of the Greenwhich meridian plane and the equatorial plane for the beginning of 1984. The Y axis is in right-hand system with the X and Z axes. The parameters forming the ellipsoid are shown below [5].

Major semi-axis of the ellipsoid : a=6378137m
Kurtosis of the ellipsoid : f=1/298.257223563
Pole Radius of Curvature : c=6399593.6258m

WGS84 system is a system that is not used in our country. GRS80 ellipsoid is taken as basis for this datum. GRS80 was also chosen as the reference ellipsoid for ITRF. WGS84 is a national datum, but since GPS satellite orbits are published in this datum, the relationship of this system with other systems should be established [5].

2.5.4. ED-50 system

ED 50 is a geodetic vertical coordinate system based on the Hayford ellipsoid; an international ellipsoid also used in Turkey. The beginning of the system is point O, the centre of the ellipsoid. This starting point does not coincide with the geocentre. In this system, the Z axis coincides with the small semi-axis of the ellipsoid. The X axis passes through the intersection of the Greenwich meridian plane and the equatorial plane. The Y axis is in a right-hand system with the X and Z axes. The coordinates obtained by GPS are WGS-84 coordinates and there are differences between the coordinate systems in which geodetic and engineering studies are carried out. In this respect, it is necessary to make a datum conversion as a result of GPS measurements and proceed to the calculation of local coordinates [5].

2.5.5. ITRF system

1988 by IERS. It was calculated by evaluating the measurements at VLBI, SLR and LLR stations together. It was first named ITRF-88, and as it was updated, ITRF-89, ITRF-90, ITRF-2000 coordinate system and stations' quadratic-Tesian coordinates and velocity vectors were calculated. Transformations between updates of ITRF are performed using the transformation parameters and velocity vectors. Axes are orientated as WGS-84 system [5].

2.5.6. Local coordinate system (LGS)

The starting point of the coordinate system is the point on which the GPS receiver antenna is mounted. This system is also called "topocentric coordinate system". The coordinate axes are denoted by the letters n, e, u;

- n-axis points to geodetic north;
- The e-axis points geodetic east;
- The u-axis is the ellipsoid normal of the point where the receiving antenna is installed.

Thus, the n and e axes form the local geodetic horizon plane. The orientation of the LGS system in space is based on geodetic latitude and longitude. Since the LGS coordinate system is a left-handed system and the CTRS coordinate system is a right-handed system, the transformation between these two systems requires the use of the reflection matrix (P2). In other words, the LGS coordinate system is first transformed into the right-hand system using the reflection matrix [5].

2.6. GPS Position Determination Methods

There are two types of position determination methods with GPS (Alçay, 2010). These are;

- Absolute position determination method;
- Relative position determination method.

2.6.1. Absolute position determination

In absolute position determination, the coordinates of the point where the receiver is located are determined by making code observations from at least four satellites with a single GPS receiver (Figure 4).

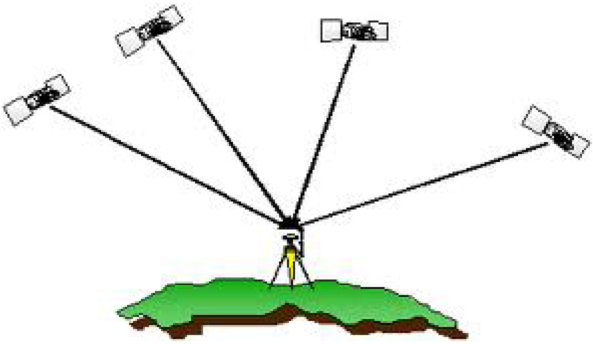

Figure 4. Absolute position determination.

The essence of the method is based on back estimation from space with the help of satellite-receiver distances and known coordinates of the satellites, which are calculated by scaling the time from the signal leaving the satellite until it reaches the receiver with the speed of light.

2.6.2. Relative position determination

Here, the receivers at the points to be located must simultaneously observe the same satellites as the receivers measuring at the reference points. Point coordinates are obtained as a result of the evaluation of the measurements made in GPS software (Figure 5).

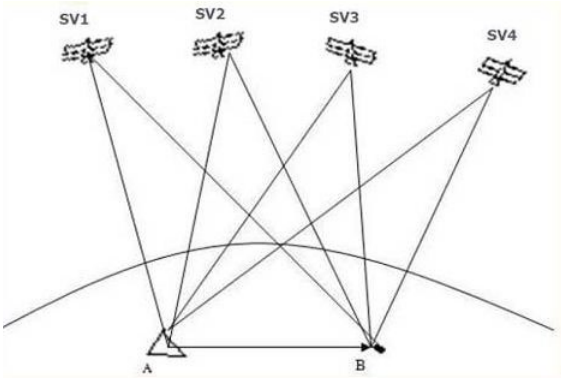

Figure 5. Relative position determination.

As can be seen from the figure, point A is a reference (fixed) point whose coordinates are known and point B is the other point whose coordinates will be calculated.

Göreli konum belirleme yöntemleri;

- Static measurement method
- Fast static measurement method
- Repeated measurement method
- Stop-and-go measurement method
- Kinematic measurement method consists of 5 groups [12].

3. The Use of GPS in Forestry Studies

As it is known, cadastral services (General Cadastre, Forest Cadastre) in our country are carried out by triangulation network based and local method. Due to the characteristics of the method, the work and operations to be carried out on the earth take a long time and the cost increases accordingly. These operations are of great importance especially in forestry works. When working with the classical method;

- Night work is generally not possible;
- Effective weather conditions;
- Measurements are based on a triangulation network;
- Long distances cannot be read;
- Measurement time is long and requires a large team;
- It is possible to mention the existence of many negative factors such as the necessity for the measurement points to see each other [13].

While GPS is not used sufficiently in our country, many developed countries use GPS in various civil application areas (cartography, oil exploration, ground motion detection, dam deformation, etc.) as well as in forestry studies. The data obtained as a result of the use of GPS in forestry (boundary and area values of forest and stand types, forest road lines, locations of monumental trees, etc.) are transferred to the computer environment and very important information is provided for GIS (Geographical Information System). In the researches carried out, results were obtained with an error of 2% in the area calculations made with GPS in the forest [14], [15].

Information systems are developed and named according to the fields of information required by the society. The common application area of information systems is the segment related to the living environment. In this field, information systems are created for different purposes [16].

In the field of forestry, geographical data should be digitised either by making field measurements in person or by locating the location with GPS instruments and satellites [17].

Geographical Information Systems provide great convenience in daily life. The use of spatial data is increasing in almost every field of social life. Rapid access to large amounts of high-quality information is possible with GIS. GIS also makes it economical by making it significantly easier to carry out spatial analyses, planning, etc. for various purposes with the information managed here [18].

GPS also provides highly sensitive information for geographical information systems. In the researches carried out on this subject, it has been concluded that GPS can provide highly sensitive data to the forest information system [19].

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