GLOBAL POSITIONING SYSTEM

Abstract

Global Positioning System provides three dimensional positioning, navigation, timing services, velocity and altitude to users on a continuous worldwide coverage basis and it is independent of weather, day and night. GPS applications are wide in all fields. This chapter provides the basic knowledge about GPS technology and their application in agriculture.

Keywords: GPS, navigation, altitude, weather, applications, agriculture.

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I. INTRODUCTION

The Global Positioning System (GPS) is a constellation of satellites dedicated for the location services launched by United States of America, which provides three dimensional course reliable location, navigation, time, velocity and altitude on a continuous basis to users and it is independent of weather and time (Upreti and Kumar, 2008). It is a space-based radio navigation system consists of 24 satellites revolving around the earth in a particular orbit with a period of 12 hours (Kaplan, 1996). The satellites are placed across the six orbital planes at an angle of 55º and continuously transmit signals to the earth. GPS provides information based on the triangulation principle which calculates the user's location precisely. Earlier GPS was only for military applications, later in the 1980s, it was made available to public users. The GPS was formerly known as the NAVSTAR (Navigation Satellite Timing and Ranging).

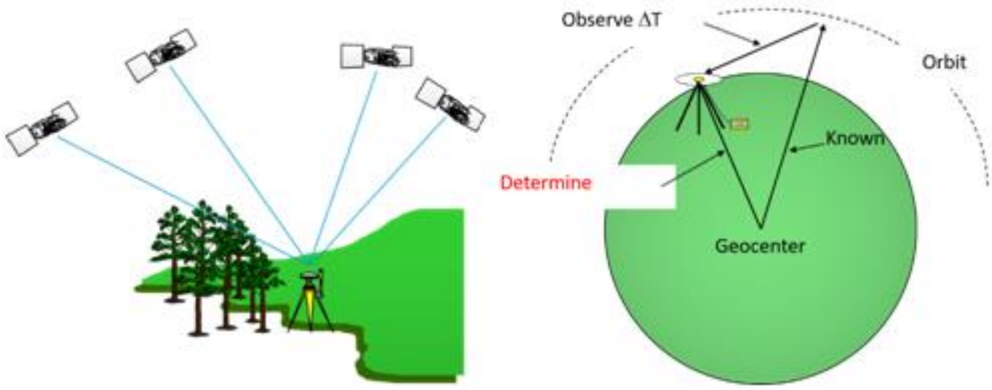


Figure 1: Receiving signals from GPS

II. GPS COMPONENTS

1. **Space segment:** The space segment comprising the constellation of GPS satellites or space vehicles revolving around the earth in an orbit. These satellite generates and transmits the signals and store and broadcast the navigation message. Stable atomic clocks in satellites regulate these transmissions.

2. **Control segment:** This segment is also referred as the ground segment which controls and regulate the operation of navigation satellite systems. This segment contains master control station, an alternative station, ground antennas and monitoring stations across the earth.

   Functions

   - It controls and maintains the status and configuration of the GPS satellites
   - It predicts signal transmissions and satellite clock evolution;
   - It keeps the corresponding navigation system time scale;
   - It updates the navigation details for all the satellites.

3. **User segment:** The user segment receives signals which determines the pseudoranges to solve the navigation equations to obtain accurate coordinates and time through GPS

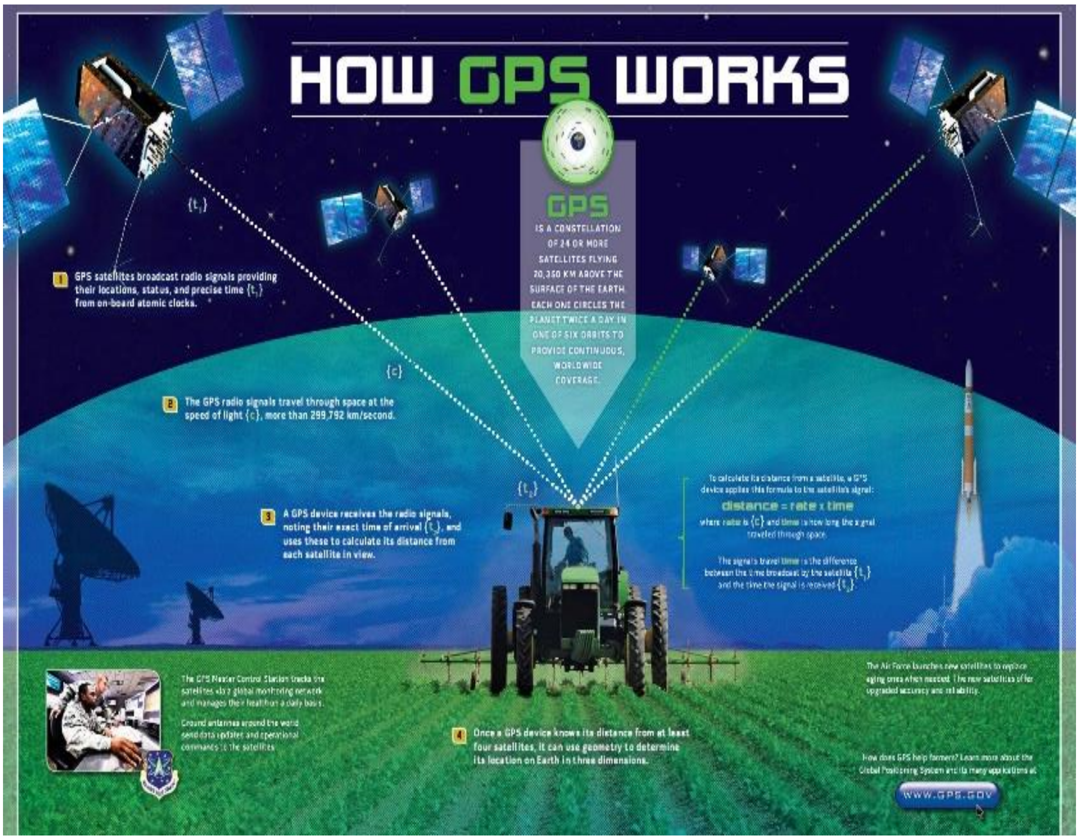
receiver. Each GPS receiver is identified by the three-dimensional location (latitude, longitude, and altitude) plus the time.

III. GPS WORKING PRINCIPLE

Trilateration is a basic geometric principle that allows finding one location with a known distance from other, already known locations. The basis of GPS is the measurement of pseudoranges between the receiver and the four satellites (Seeber, 2003). The ground-based stations monitor the signal transmission time between the four satellites and the receiver and provide precise tracking of the satellite's orbit at every level. It records precise direction, position, and speed measurements.

Steps

1. One-way range signals are received by the GPS receiver from a number of satellites; each transmission is time-tagged and provides the satellite's location information.
2. The arrival time of the signal is compared with transmission time of a signal.
3. The range is calculated by
   - **Range = [(Transmission time of signal – Reception time of signal) × Speed of light] (1)**
4. By intersecting many of these ranges, one may determine the current location of the user on the sphere surrounding the satellite.



(Source: GPS.gov)

Figure 2: Working of GPS

IV. ACCURACY OF GPS

GPS accuracy is based on the precision of signals that transmitted from the satellites to receivers. The precision and accuracy of GPS are also determined by the number of hindrance that the receiver can obscure and also based on the types of receivers. The GPS receivers have an accuracy of about 10 meters. Differential Global Positioning Systems (DGPS) are the most accurate forms of GPS receivers.

V. ERRORS IN GPS

Table 1: Sources of error in GPS

Source of error	Amount of error
Atomic clocks in satellite	1.5 to 3.6 meters
Orbital errors	< 1 meter
Ionosphere interactions	5.0 to 7.0 meters
Troposphere interactions	5.0 to 7.0 meters
Receiver noise	0.3 to 1.5 meters
Multipath	0.6 to 1.2 meters
Selective Availability	depends
Receiver error	1 kilometer or more

VI. NAVIGATION SATELLITE SYSTEMS

Sl. No	Name of satellite system	Acronym	Origin	No of Satellites
Global Navigation Satellite System				
1	Navigation Satellite Timing and Ranging System GPS	NAVSTAR GPS	USA	30
2	Global Navigation Satellite System	GLONASS	Russia	24
3	BeiDou Navigation Satellite System	BEIDOU	China	30
4	European Global Satellite Navigation System	GALILEO	European Union	35
Regional Navigation Satellite System				
5	Indian Regional Navigation Satellite System	IRNSS	India	7
6	Quazi-Zenith Satellite System	QZSS	Japan	5

Table 2: GNSS satellites and their characteristics

Parameter	NAVSTAR GPS	GLONASS	Galileo	Beidou1/2
Position (m)	10-20	10-20	~10-20	~10-20
Velocity (m/s)	0.1	0.1	0.2	0.2/0.4
Time (n/s)	15	20	20	20/50
Ellipsoid	WGS84	PZ# - 90.11	GTRF	CGCS2000
Master Control	1 station in US	1 in Russia	2 in EU	1 MCS / 2 UPLOAD St.
Surveillance	11 stations	7	30-40	30
No of Satellites	30	24	30	35
Orbital planes	6 Minm 4 sat Ø=15°	3(120°/45°)	3(9+1-40°)	7
Inclination angle	55°	64.8°	56°	55°
Altitude (Km)	20180near-25820far	19100-24680	23222-28920	21528
Repetition	1 day	7d 23h 27m28s	10 days	~1/7 days / @ after 13 orbits in 10 days
Orbital period	11h 57m 58s	11h 15m 44s	14h 4min	12h 53min 24s
Selective Availability	Off	No	No	-
Anti-spoofing	YES	No	No	YES
Services	2(SPS,PPS)	2(SPS,HPS)	OS, SoL, CS, PRS, SAR	OS (B1, B2), Authorized Service (B1, B3)
Frequency bands	3/8(L1,L2,L3,L4,L5,L1C,L2C,M)	3 (L1,L2, L3)	5(L1,E5a, E5b,E6,L6)	B1I, B2I, B3I*, B1C, B2a
Velocity, c=299792458m/s	3870	3950	3675	~3020
Propagation Time (T-ms)	67-86	64-82	77-96	71 (21528) -120 (36000)
Distance travelled during T (m)	260-333	252-325	285-355	D=V*t (as per orbit selected)

(Source: Mod. from Nel Samama)

VII. INDIAN REGIONAL NAVIGATION SATELLITE SYSTEM (IRNSS)

Indian Regional Navigation Satellite System (IRNSS) was own navigation system fully developed and controlled by ISRO. The first satellite IRNSS 1A was launched on Jul 01, 2013. IRNSS was renamed as Navigation Indian Constellation (NavIC) in 2016. NavIC system consists of 8 satellites orbiting at a distance of 36,000 km, approximately. At present, only 7 satellites are active of which 3 satellites orbit in Geostationary Orbit and 5 satellites orbit in Geosynchronous Orbit, it uses the WGS 84 coordinate system for the calculation of user position. It provides the dual frequency user with a targeted position accuracy of better than 20 meters in the coverage area. The objectives of the system is to provide accurate and reliable position and time in and around India at about 1500 km. Most of the constellation is seen by the users all the time and it is independent of existing GNSS systems.

VIII. GPS APPLICATIONS

1. Military surveillance
2. Aviation, Maritime and Terrestrial Navigation purpose
3. Disaster management and emergency services
4. Precision Agriculture
5. Monitoring and preservation of endangered species
6. Crustal and seismic monitoring
7. Mapping and Geodetic data capture
8. Mining operations
9. Vehicle tracking and fleet management
10. Future of Intelligent Transportation Systems
11. Terrestrial navigation aid travelers
12. Assists in navigation for drivers

IX. GPS IN AGRICULTURE

Precision agriculture or site-specific farm management is possible only through the integration of remote sensing, Geographic Information Systems (GIS) and Global Positioning System (GPS). With the help of these technologies, massive volumes of geospatial data may be effectively handled and analyzed while being collected in real-time and with precise positional data. The information needed for the improvement of natural resources can be collected easily. It is useful for planning, mapping fields, soil sampling, guiding tractors, scouting crops, site-specific input applications, and yield mapping (Abulude et al., 2015).

Site-specific soil sampling, data collection, and data analysis help in site specific application of nutrients will be very much useful for the farmer’s community. GPS enabled data collection from the field to map the accurate location of pest, insect, and weed infestations useful for Crop advisories. Accurate field navigation reduces the repeated applications and skipped areas, and maximum ground coverage is possible within a short period.

Accurate yield data will be useful for future site-specific field preparation. The correlation between the crop production techniques and crop yields with land variability is helpful to develop effective soil/plant treatment strategies enhancing crop productivity. The timely availability of spatial information on soil and plant requirements is helpful for site-specific management to increase the agricultural productivity and safegaurd the environment. Farmers can obtain benefits by combining improved fertilizer and soil amendment use, calculating the economic threshold for insect and weed infestation treatment, and conserving the resources for future.

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