6^{th} SEMESTER (MAJOR)

PAPER 604: PRINCIPLES AND APPLICATION OF REMOTE SENSING, GIS AND GPS

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FUNCTIONS AND WORKING PRINCIPLE OF GPS

The Global Positioning System (GPS) is a network of satellites that orbit the earth. At any given time, there are 24 active satellites in the constellation. The constellation is composed of six orbital planes, each containing four satellites. GPS receivers can compute positions on the Earth using time and ephemeris (i.e. orbital position) information provided by the satellites.

With the help of GPS Receivers, we can calculate the position of an object anywhere on Earth either in two – dimensional or three – dimensional space. For this, GPS receivers use a Mathematical method called Trilateration, a method using which the position of an object can be determined by measuring the distance between the object and few other object with already known positions.

So, in case of GPS Receivers, in order to find out the location of the receiver, the receiver module has to know the following two things:

- Location of the Satellites in the space and
- Distance between the Satellites and the GPS Receiver

1. Determining the Location of the Satellites

In order to determine the location of the satellites, the GPS Receivers makes use of two types of data transmitted by the GPS Satellites: the Almanac Data and the Ephemeris Data.

Almanac Data: The GPS Satellites continuously transmit its approximate position. This data is called the Almanac data, which is periodically updated as the satellite moves in the orbit. This data is received by the GPS Receiver and stored in its memory. With the help of Almanac data, the GPS Receiver can be able to determine the orbits of the satellites and also where the satellites are supposed to be.

Ephemeris Data: The conditions in the space cannot be predicted and there is a huge chance that the satellites might deviate from their actual path. The Master Control Station (MCS) along with the dedicated Monitor Stations (MS) track the path of the satellites along with other information like altitude, speed, orbit and location. If there is any error in any of the parameters, the corrected data is sent to the satellites so that they stay in exact position. This orbital data sent by the MCS to satellite is called Ephemeris Data. The satellite, upon receiving this data, corrects its position and also sends this data to the GPS Receiver.

With the help of both the data i.e. Almanac and Ephemeris, the GPS Receiver can be able to know the exact position of the satellites, all the time.

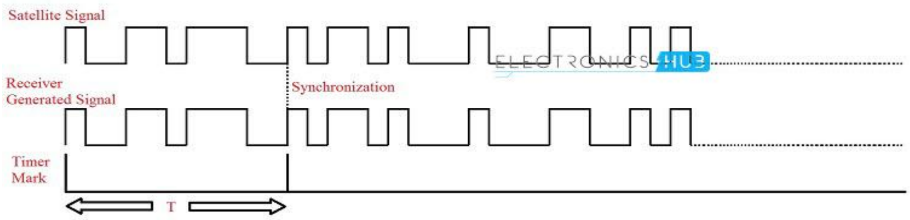
2. Determining Distance between the Satellites and GPS Receiver

In order to measure the distance between the GPS Receiver and the Satellites, time place a major role. The formula for calculating the distance of the satellite from the GPS Receiver is given below:

Distance = Velocity of Light x Transit Time of the Satellite Signal

Here, the Transit Time is the Time taken by the Satellite Signal (Signal in the form of Radio Waves, sent by the Satellite to GPS Receiver) to reach the Receiver. The velocity of the light is a constant value and is equal to C = 3 x 108 m/s. In order to calculate the time, first we need to understand the signal sent by the Satellite.

The Transcoded Signal transmitted by the Satellite is called Pseudo Random Noise (PRN). As the satellite generates this code and starts transmitting, the GPS Receiver also starts to generate the same code and tries to synchronize them. The GPS Receiver then calculates the amount of time delay the Receiver generated code has to undergo before getting synchronised with the satellite transmitted code.

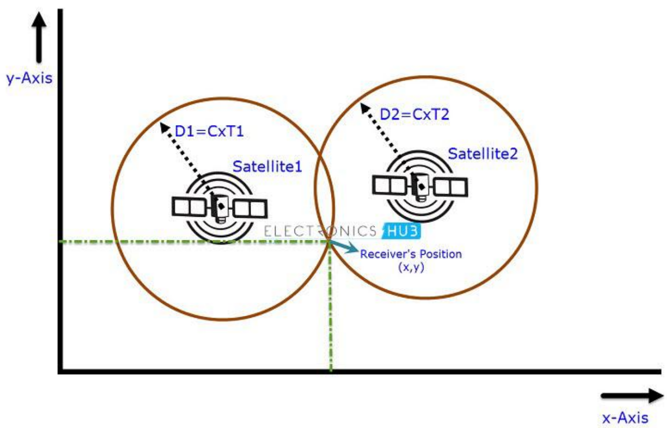


Once the location of the satellites and their distance from the GPS Receiver are known, then finding out the position of the GPS Receiver in either 2D Space or 3D Space can be done using the following method.

3. <u>Position of Receiver in 2-D Plane</u>

In order to find the position of the object or GPS Receiver in 2 – Dimensional space i.e. an X-Y Plane, all we need to find is the distance between the GPS receiver and two of the satellites. Let D1 and D2 be the distance of the Receiver from Satellite 1 and Satellite 2 respectively.

Now, with the satellites at the center and a radius of D1 and D2, draw two circles around them on an X-Y Plane. The pictorial representation of this case is shown in the following image.

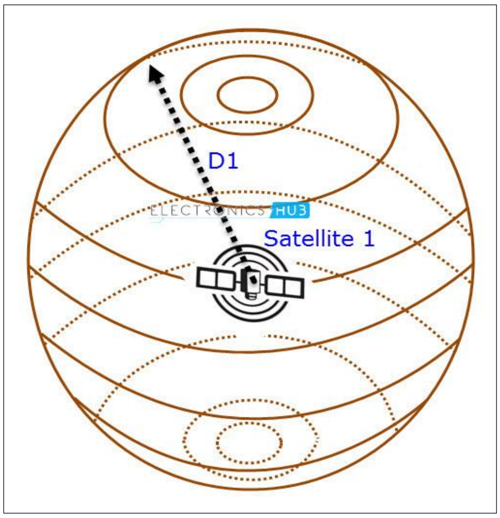


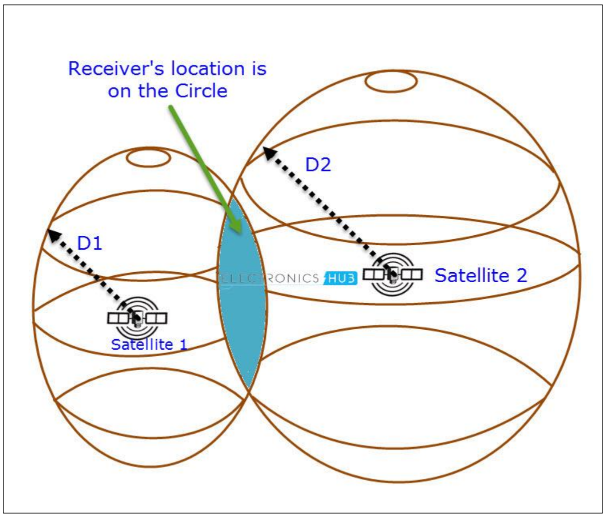
From the above image, it is clear that the GPS Receiver can be located at either of the two points where the two circles intersect. If the area above the satellites is excluded, we can pin point the position of the GPS Receiver at the point of intersection of the circles beneath the satellites.

The distance information from two satellites is sufficient in order to determine the position of the GPS Receiver in a 2-D or X-Y Plane. But the real world is a 3 – Dimensional Space and we need to determine the 3 – Dimensional position of the GPS Receiver i.e. its Latitude, Longitude and Altitude. We will see a step – by – step procedure to determine the 3 Dimensional location of the GPS Receiver.

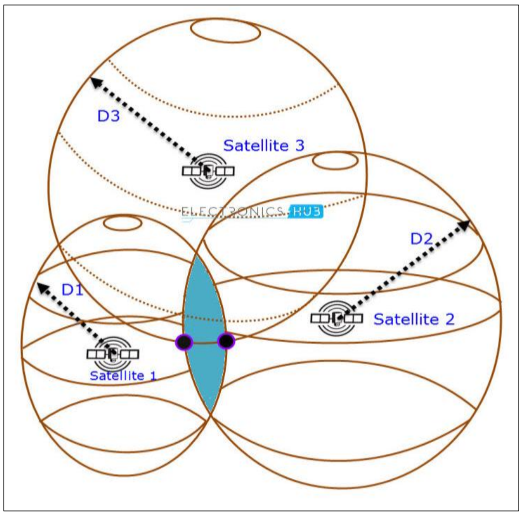
4. Position of the Receiver in 3D Space

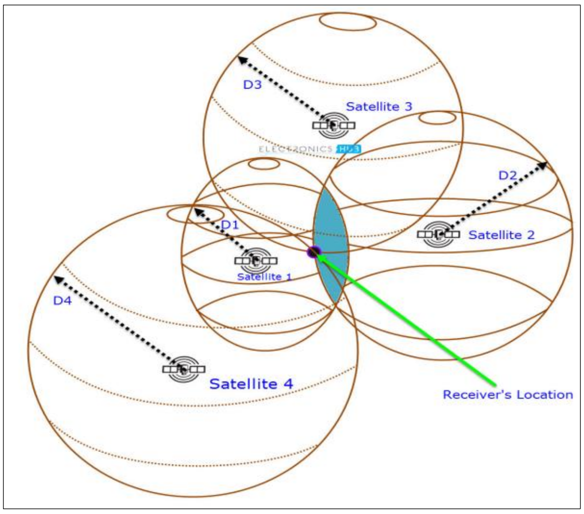
Let us assume that the locations of the satellites with respect to the GPS Receiver are already known. If Satellite 1 is at a distance of D1 from the Receiver, then it is clear that the position of the receiver can be anywhere of the surface of the sphere that is formed with satellite 1 as center and D1 as its radius.





If the distance of a second satellite (Satellite 2) from the receiver is D2, then the position of the receiver can be limited to the circle formed by the intersection of two spheres with radii D1 and D2 with Satellites 1 and 2 at the centres respectively. From the image, the position of the GPS Receiver can be narrowed down to a point on the circle of intersection. If we add a third satellite (Satellite 3) with a distance D3 from the GPS Receiver to the existing two satellites, then the location of the receiver is confined to the intersection of the three spheres i.e. either of the two points.





In real time situations, having the ambiguity of GPS Receiver located at one out of the two positions is not viable. This can be resolved by introducing a fourth satellite (Satellite 4) with a distance D4 from the receiver. The fourth satellite will be able to pin point the location of the GPS Receiver from the possible two locations which were determined earlier with only three satellites. Hence, in real time, a minimum of 4 satellites are required to determine the exact location of the object.

Practically, the GPS System works such that at least 6 satellites are always visible to an object (GPS Receiver) located anywhere on Earth.