Understanding GPS

GPS Basics as seen by Orcam Systems

GPS positioning and navigation is basically a question of measuring distances. How that is done, and conditions affecting the performance of a GPS receiver is what we are discussing in this presentation. This presentation is primarily intended for those with no, or little previous GPS knowledge and does not contain any complicated formulas or mathematical expressions.

It simply explains a few basics important in order to understand the performance of a GPS-receiver.

Hope you will enjoy it anyway…

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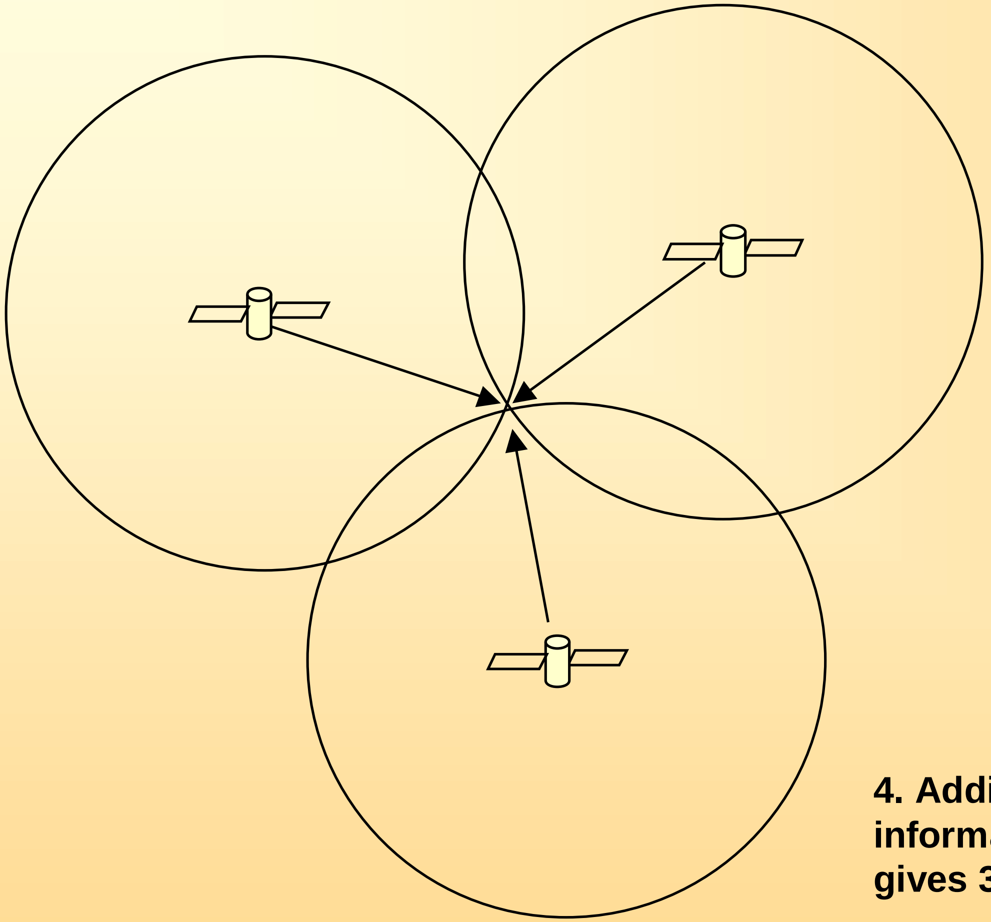
GPS – Basic principle of operation

Determining a position by estimating distances from a reference –
Distance = Speed of radio wave x time of travel



1. With one satellite, if you know exactly how long the radio wave has been traveling, the position can be anywhere on the surface of a sphere

2. With two satellites, the position can be anywhere on the edge of a circle where two spheres intersect

3. With three satellites, the position is the point common to where three spheres intersect.

4. Adding a 4:th satellite to the solution adds information about the altitude you are in and gives 3D navigation

But uncertainty in time, measurement, speed, reference – makes the intersection point a fuzzball volume. To know the exact positions of each reference, you need ephemeris information for each satellite.

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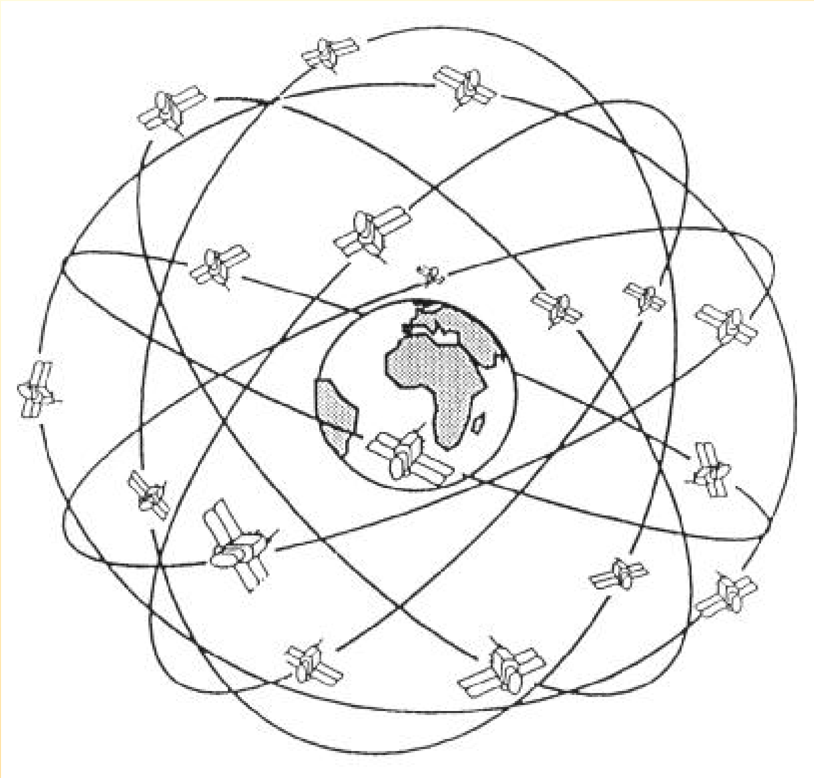
But, where are the Satellites ?



To know what satellite to look for, the GPS-receiver needs;

- Time
  - Is transmitted by every Satellite
- Almanac
  - Contains information about all satellites theoretical position in the sky at any given time and is transmitted by every satellite
- Ephemeris
  - Is information specific to one single satellite about orbital and clock corrections, necessary for the GPS receiver to calculate its position with acceptable accuracy.

So in order to get a position fix – we need to get Time, Almanac and Ephemeris from at least three Satellites

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Yeah – but why does it take so long for my GPS to start ?

To answer this - we need to look at the message the GPS Satellite sends

MASTER FRAME = 25 frames, 37,500 bits (12.5 minutes)

<u>Frame</u>
1500 bits
30 secs

1	2	3	4	5
Satellite health, GPS Week #, Satellite clock corrections	Orbit parameters	Orbit parameters	Almanacs for SVs 25-32 Health for SVs 25-32 Ionosphere model and UTC data	Almanacs for SVs 1-24 Health of SVs 1-24

<u>Subframes</u>
5 @ 300 bits
6 seconds each

Data unique to each SV,
Primarily Ephemeris Info

Common data sent by all SVs

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And… ???

Remember the last slide ? A frame takes 30 sec to load, and we need at least a full frame to collect ephemeries.

Fortunately GPS receivers are intelligent and learn from past experiences – this is why we have Cold, Warm and Hot Starts

- Cold Start – No time, no ephemeries, no current almanac, all data has to be collected from the satellites. Typically takes 45s to complete for the Orcam GPS25 & GPS26 receivers.
- Warm Start – We have time and almanac in memory, but no or too old ephemeris.This scenario occurs when you GPS receiver has been ”out of touch” for more than approx. 5 min. Typically takes 38 s to complete.
- Hot Start – We have time, current ephemeris and almanac. This is true if your GPS receiver has been ”out of touch” for less than 5 min, like driving through a tunnel. Typically takes 2 – 8 s to complete.

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Anything else I need to know ?

Yes, there are many more factors that affects the GPS-receiver and it's ability to navigate, some of the most important are;

- Enough number of satellites in view
  - We need at least three for 2D navigation and four for 3D navigation, but to get a reliable position 5 – 6 satellites are often needed.
- DOP value (Dilution Of Precision)
  - We need a DOP < 50 to get a valid position
- Relative Signal Strength C/N_o
  - C/N_o is a measure of how strong the signal from the satellite is relative to the background noise, and is measured in dB-Hz. The requirements on C/N_o varies depending on the task the receiver is doing. Tracking a known set of satellites require a lover C/N_o while collecting ephemeris in a warm- or cold start requires a higher value.

On the next slide, lets discuss DOP

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DOP = Dilution Of Precison

DOP, simply put, is a value representing how reliable the position reported by the GPS receiver is. A low DOP value means a reliable position, a high DOP value means a less reliable position.

DOP is affected by:

- Received signal strength
- Inaccuracies in time & frequency
- The geometry of the satellite configuration the receiver is tracking

Let’s look closer at the importance of the satellite positions

1. Picture a ball hanging from the roof in a piece of string – push and it changes position easily = High DOP situation, the balls position is not stable
2. Now add three more strings, attach them to each corner of the roof and the ball becomes mor difficult to move = lower DOP, more stable position
3. Now add 4 more strings and attach them to each corner of the floor and you cant move the ball = Lowest DOP, the perfect navigation solution, but not realistic as the corners of the floor represents satellites below the horizon
4. In real life, we will have to rely on the ”strings” from the roof, and the most stable position of the ball is with as many strings as possible attached as far apart as possible on the roof. Move the stringscloser together and the ball is easier to move = DOP increases.

In the Orcam receivers, we reject positions with a DOP > 50 as they are too uncertain

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So, how does all this relate to real life ?

In an open environment, with a good view of the sky, most GPS receivers today provides a position with good precision and reliability.

As conditions deteriorate (obstructed view of the sky, reflected signals from buildings and other structures or electrically noisy environment) any GPS receiver will have more difficult to get a valid position fix, resulting in longer time to first fix and greater uncertainty in the position.

In a more difficult environment the receiver sensitivity (usually measured in dBm) becomes more important, equally or more important though is the GPS antenna – a poor antenna, improperly placed will ruin the performance of the most sensitive receiver.

To get optimum GPS performance

- Use a good quality GPS receiver with proven navigation firmware and good enough sensitivity

- Select an antenna that in open sky conditions is capable of delivering an input signal to the GPS receiver with a C/N_0 of ~ 47 dB-Hz

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Thank you !

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