5. SATELLITE-BASED POSITIONING - *B) PRINCIPLES*

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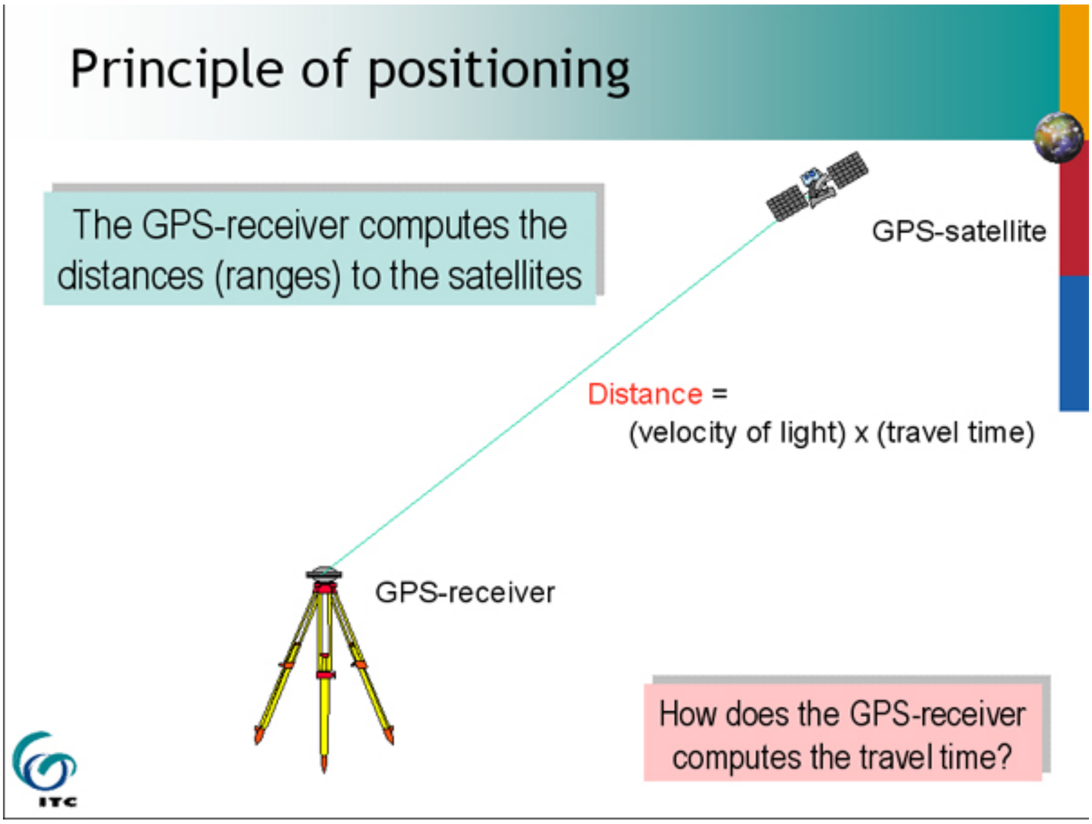
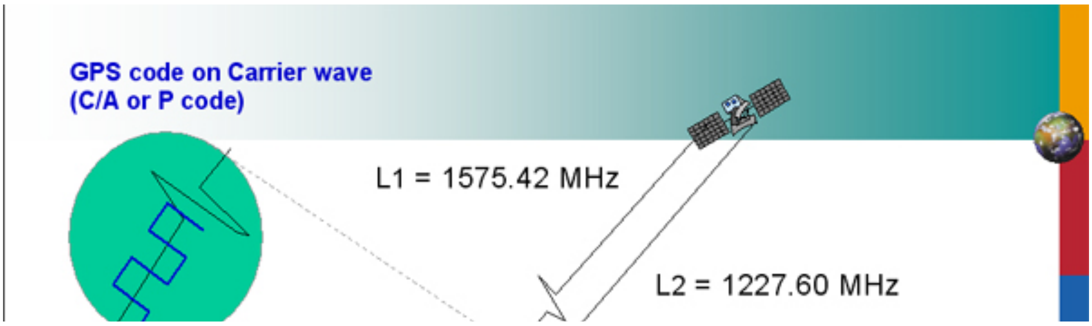
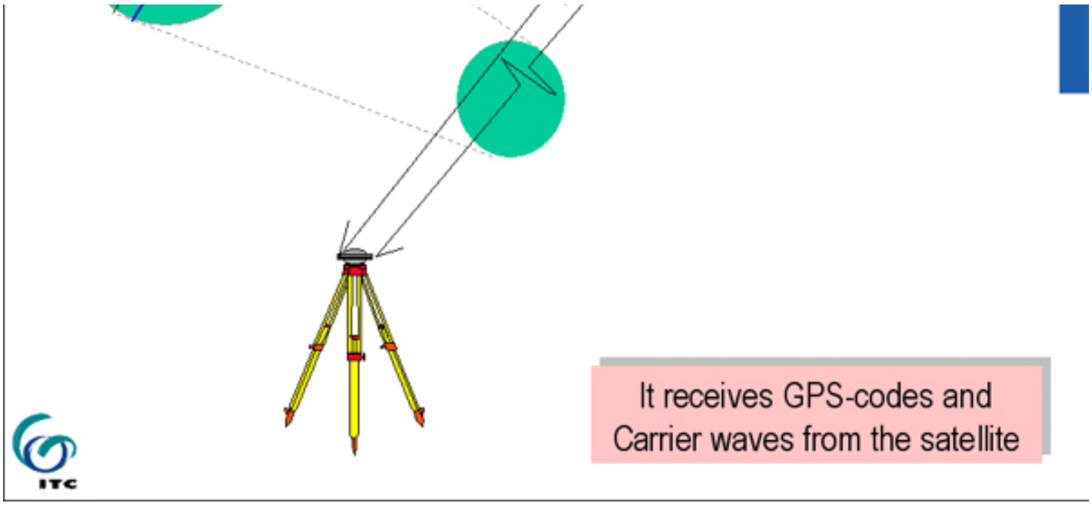
1) Basic concept of GPS - Absolute Positioning

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

- the time the message was transmitted
- precise orbital information (the ephemeris)
- the general system health and rough orbits of all GPS satellites (the almanac).







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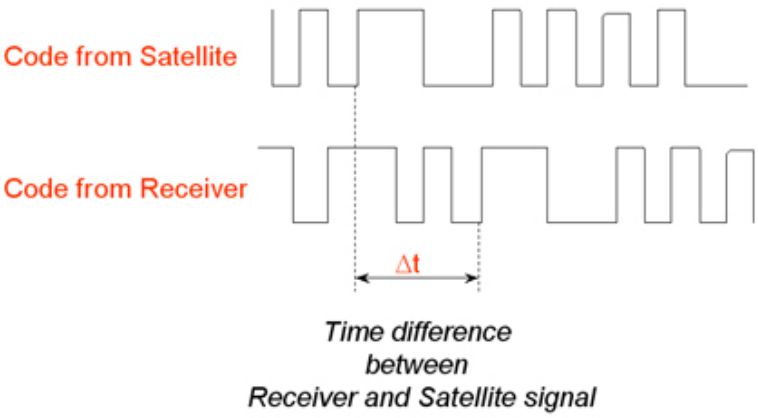
Then the codes are compared.



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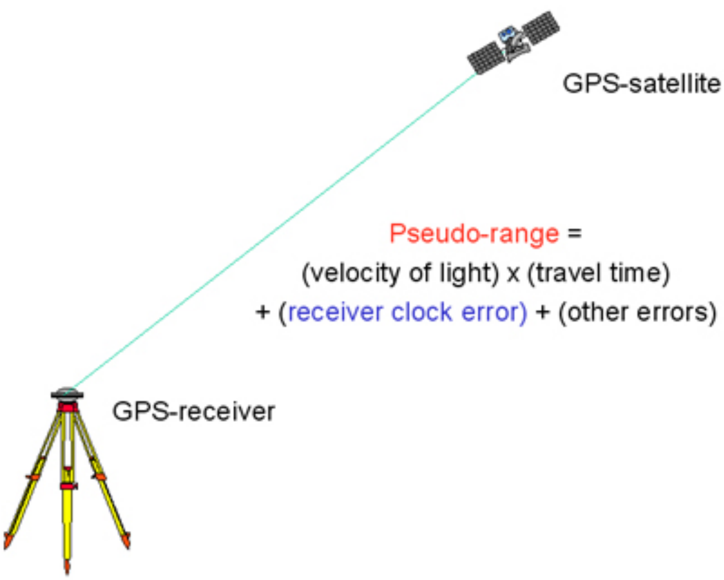
The GPS-receiver measures in fact pseudo distances (pseudo-ranges) to the satellites.



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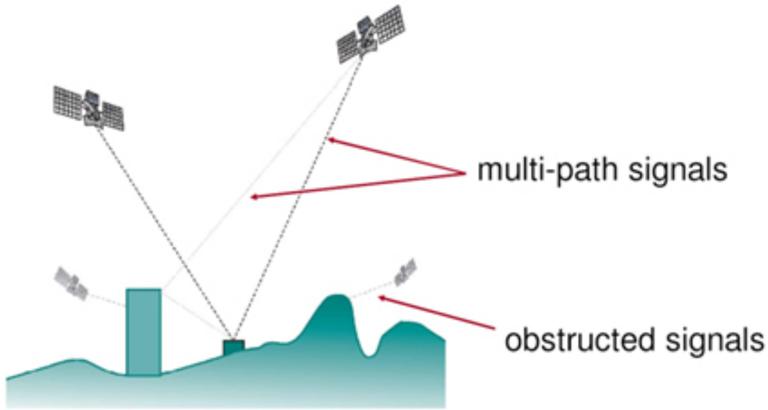
To determine a position in a three dimensional space it takes in theory three distance measurements from three satellites. But for accurate positioning an extra distance measurement from a fourth satellite toeliminate the receiver clock error, is required.

Error sources in the above absolute positioning due to:

- Selective availability
- Satellite clock and orbit errors

  One of the most significant error sources is the GPS receiver's clock. Because of the very large value of the speed of light, c, the estimated distances from the GPS receiver to the satellites (= the pseudoranges), are very sensitive to errors in the GPS receiver clock; for example an error of one microsecond (0.000 001 second) corresponds to an error of 300 metres (980 ft). This suggests that an extremely accurate and expensive clock is required for the GPS receiver to work.

- Ionospheric and tropospheric delays
- Receiver’s environment (multi-path)



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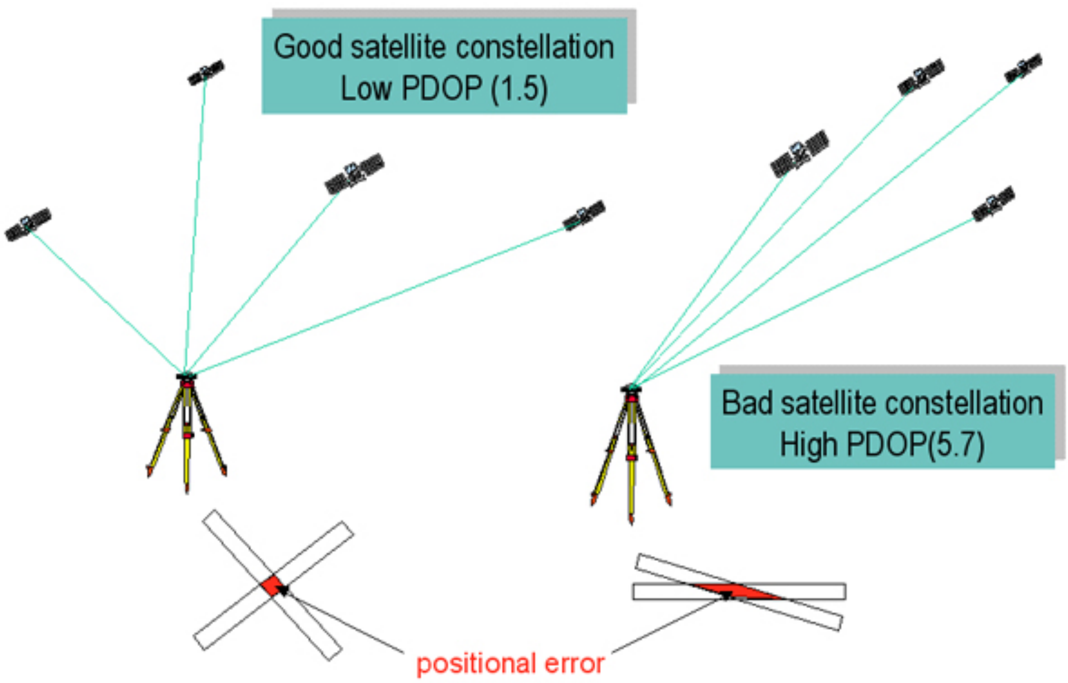
- Satellite constellation



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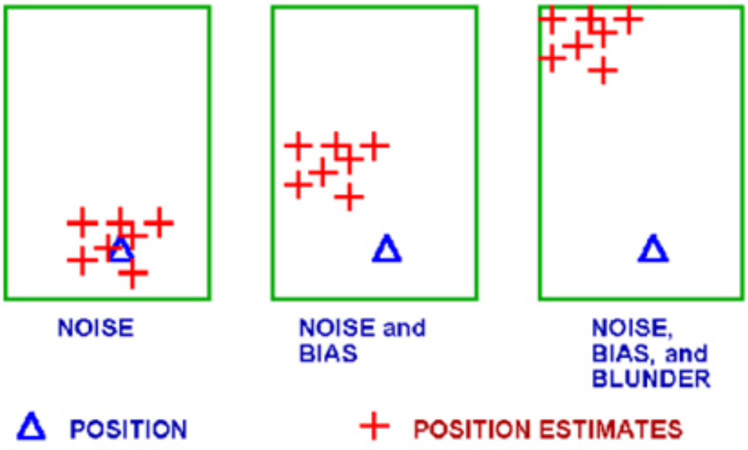
- Location errors (noise, bias and blunder)
  - Noise (random) errors: noise in code and noise in receiver, multi-path.
  - Bias (systematic) errors: clock, satellite position, ionosphere, troposphere, GDOP effects

- Bias (systematic) errors: clock, satellite position, ionosphere, troposphere, GDOP effects.
- Blunder: incorrect geodetic datum, software failures, hardware problems etc.



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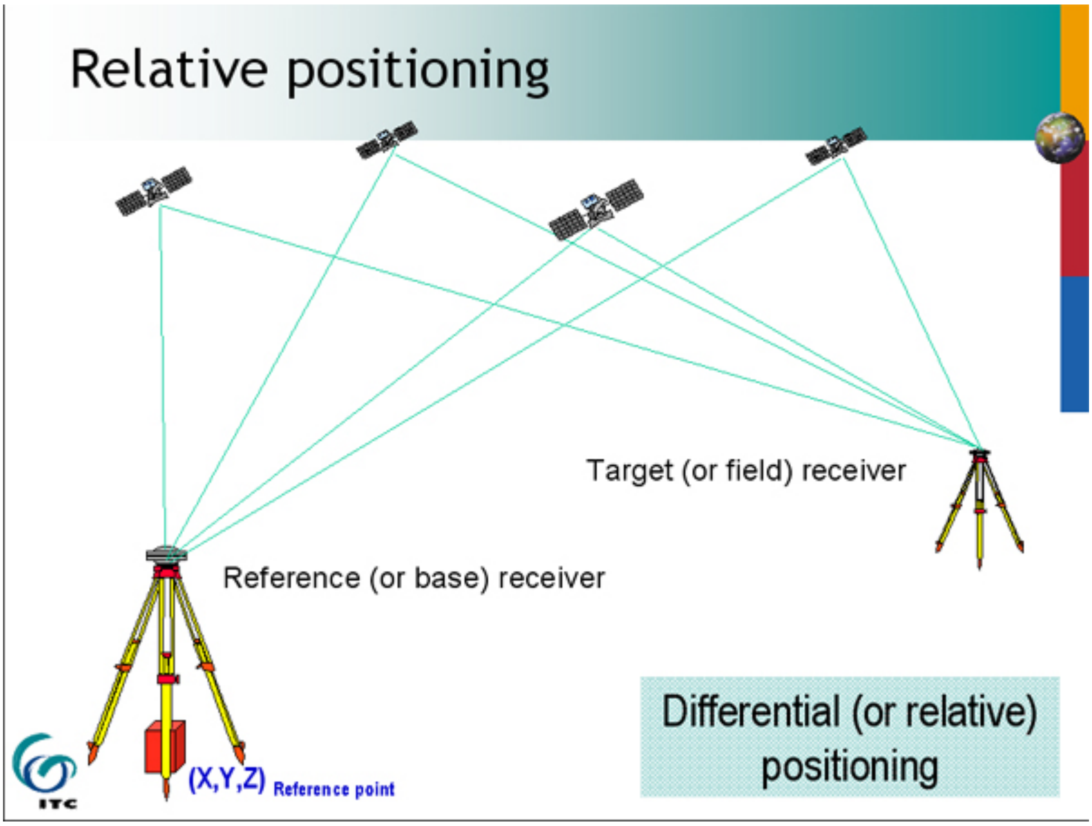
Positional *accuracy* in *absolute* positioning (based on code measurements):

Typical error: **5-10 m** (horizontal accuracy)

Typical error: **2-5 m** (horizontal accuracy) when using a dual-frequency receiver or the encrypted military signals (P-code)

2) Relative (or differential) positioning

Differential Global Positioning System (DGPS) is an enhancement to the absolute "Global Positioning System" that uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudoranges and actual (internally computed) pseudoranges, and receiver stations may correct their pseudoranges by the same amount.



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Positional *accuracy* in *relative* positioning

Typical error: **0.5 - 5m** (horizontal accuracy), based on code measurements

Typical error: **2mm – 2cm** (horizontal accuracy), based on carrier phase measurements.

Carrier phase measurement is a technique to measure the range (distance) of a satellite by determine the number of cycles of the (sine-shaped) radio signal between sender and receiver. The number of cycles is determined in a long observation session.

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