



International Committee on
Global Navigation Satellite Systems

GNSS, How it Works and Applications

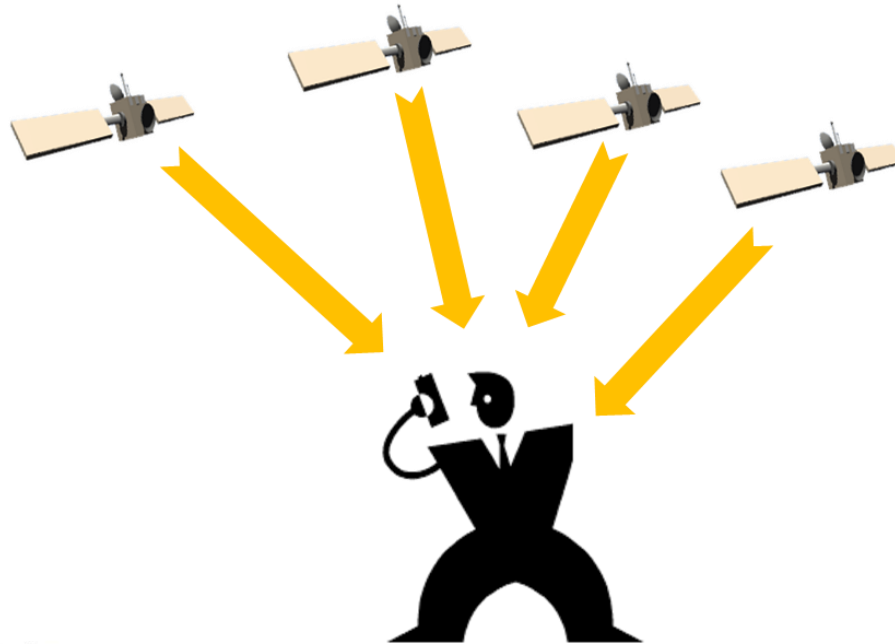
Historic Navigation

- Reference points in the sky used for navigation
 - The Sun
 - The Pole Star / North Star
 - Southern Cross
- Gives Direction, but not position
- Add a sextant to give latitude
- And a clock to give longitude



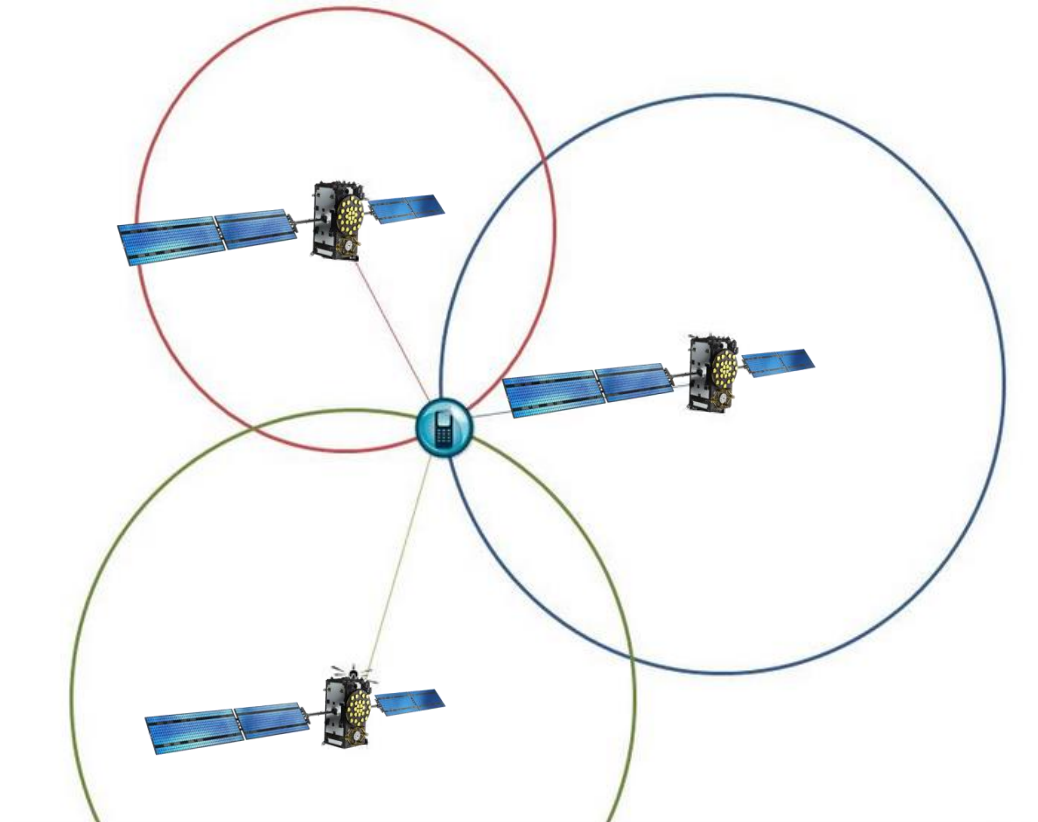
GNSS Principles

- GNSS satellites in the sky are the new reference points
- If my GNSS receiver "sees" 4 or more satellites, it can compute my position
 - "see" means track and process navigation signals



Satellites as Accurate Reference Points

- GNSS signals contain information about the satellites' positions
 - very accurate reference points
- Measure the distance from the satellites to the receiver
- Knowing at least three distances from three reference points gives position



How do you measure distance?

$$\text{speed} = \text{distance} / \text{time}$$

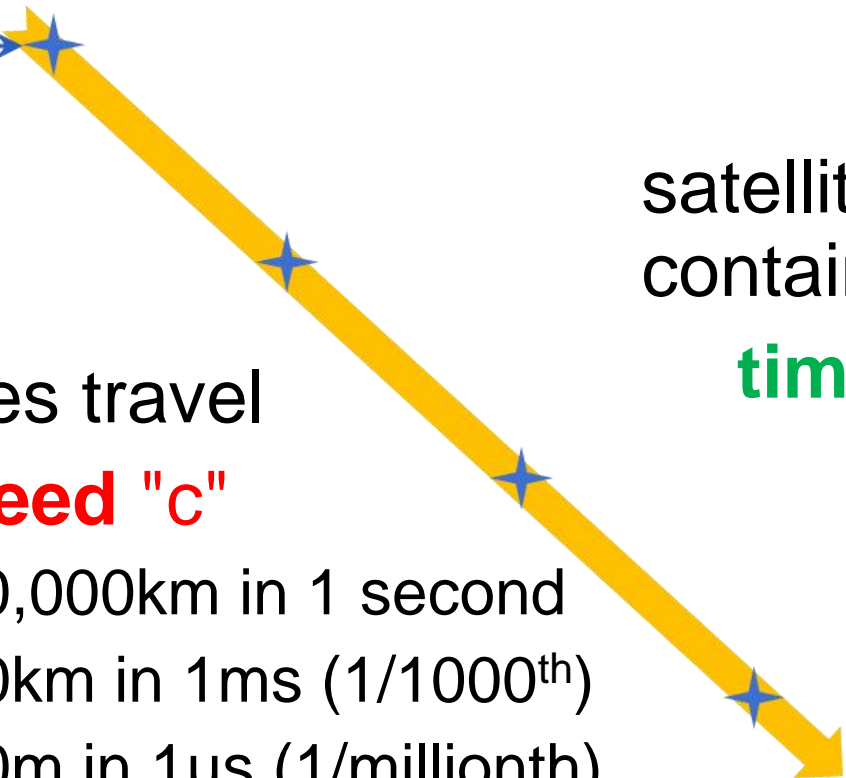
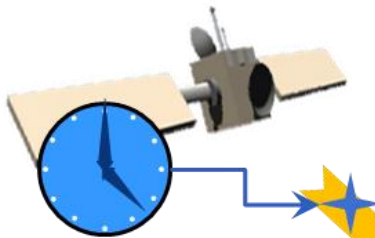
$$\Rightarrow \text{distance} = \text{speed} \times \text{time}$$

satellite signals
contain 'time stamps'

$$\text{time} = t_{\text{sent}} - t_{\text{received}}$$

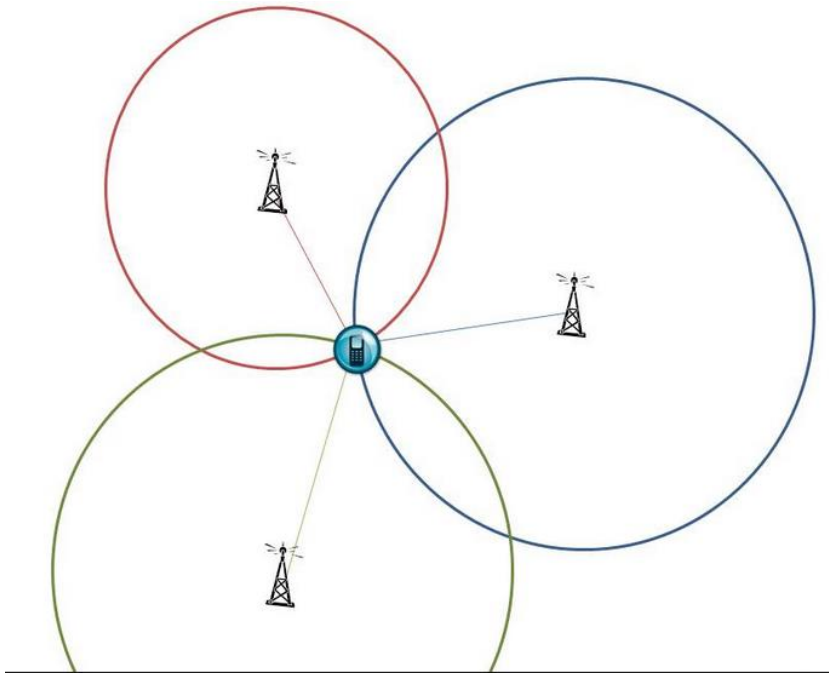
radio waves travel
at light **speed "c"**

- 300,000km in 1 second
- 300km in 1ms (1/1000th)
- 300m in 1 μ s (1/millionth)
- 300mm in 1ns



Compute position

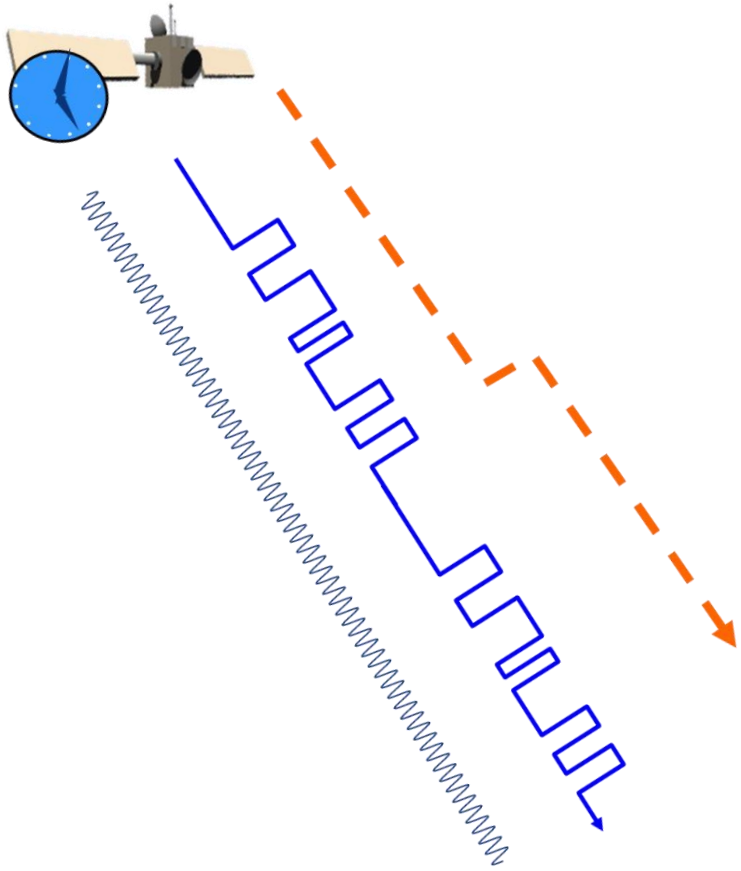
$$\text{distance} = \text{speed} \times \text{time}$$



- **speed** = 3×10^8 m/s
- **time** = $t_{\text{sent}} - t_{\text{received}}$
- but, receiver time not accurately known
- so the time stamp from a fourth satellite is measured
- compensates for the missing receiver time



Example GNSS Signal

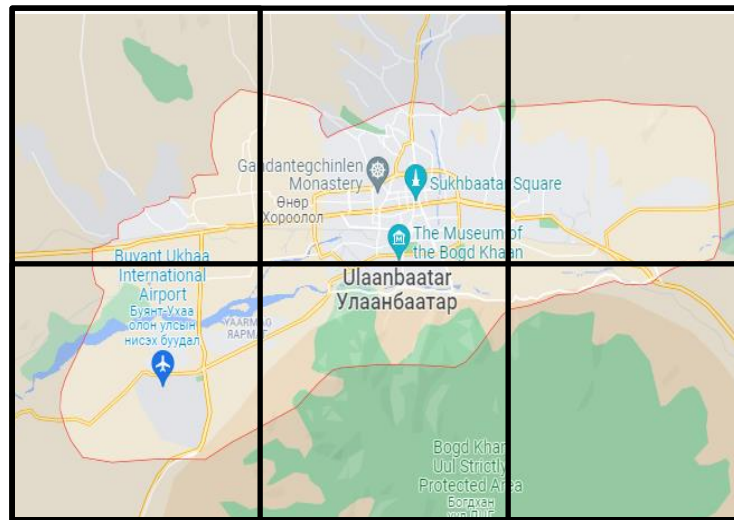


- radio frequency at "L-band"
 - typically 1575MHz
- at satellite: signal energy spread by a code
- at receiver: spread signal energy is unlocked and refocused
 - "code gain"
- allows simple antennas to receive low power signals
- and to share the frequency with other satellites/systems



Position relative to?

- A position is pointless without having a ground reference
- A world reference is used, eg WGS84
 - World Geodetic System 1984
- Allows position fix to be placed on a World grid
- Maps can be referenced to the same grid
- you can determine where you are on a map



What is GNSS used for?

PNT

- Positioning... surveying and mapping
 - location based services
 - air traffic management
 - search and rescue
- Navigation... a given. cars, ships, cranes
 - remember GNSS gives position, you still need reliable/up-to-date maps and routing software
- Timing?... most large networks synchronised
 - telecoms
 - electricity distribution
 - banking... microseconds matter for transactions!



What about?

- Monitoring sea/lake/snow levels
 - uses GNSS reflections seen into a fixed receiver
- Atmospheric measurements
 - GNSS signals change as they pass through atmosphere: air quality, gaseous content, etc
- Space weather monitoring
 - measuring changes in the ionosphere
- Soil and vegetation moisture measurements
- Volcanic plume density measurements
 - atmospheric ash uncertainty after eruptions
- Sea surface roughness, wind direction and more
- Earthquake/tsunami monitoring....

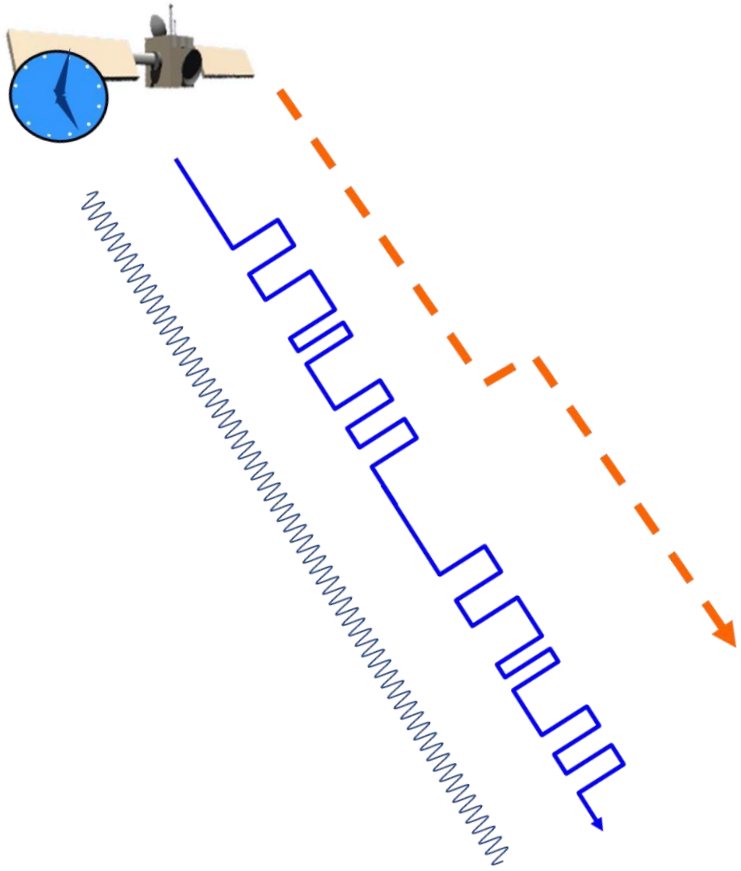




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GNSS compared to terrestrial signals (why GNSS is vulnerable)

GNSS signal power



- radio waves disperse energy as they propagate
- satellites are 23,000km away
- signal emitted at about 30W
- signal strength proportional to: $1/distance^2$
- at 23,000 km, GNSS signal reduced by a factor of about 10^{18} !
- Imagine trying to see a lightbulb 23,000km away
signal levels are below the natural background radiation



Terrestrial signal powers

- mobile phone base station
 - typical transmit power, 10-100W
 - signal power reduction depends on range
 - at 10km, signal power reduced by factor of 10^{11}
 - at 1km, reduced by 10^9compared to the GNSS signal (10^{18} reduction) it is over billion times stronger
- mobile phone, typical transmit power, 0.1-1W connected to a cell tower at 1km
 - typical signal reduction 10^9still over a million times stronger than the GNSS signal!



Expected receiver signal power levels

- GNSS receivers expect to receive and can operate at signal levels even below the natural background radiation level, the "noise floor"
- **GNSS receivers** need a minimum power level "**-130dBm**"
 - GNSS receivers designed to work at these low levels
 - provided they are not overloaded by other signals
 - modern GNSS receivers can use even lower levels!
- **Mobile phones** (eg GSM) expect a minimum "**-104dBm**"
 - around a thousand times higher than GNSS



Consequences of the different levels

- The large difference between GNSS and mobile signal levels make GNSS receivers comparatively more susceptible to interference
 - mobile network devices also have the luxury of being able to raise their power levels in steps to cope with obstructions and poor radio environments - GNSS cannot, the low power level is fixed
- If GNSS signals shared frequencies with mobile systems, they would be swamped by interference
- **GNSS reception would not be possible**



How do you avoid interference?

- To avoid such interference, the **Radio Regulations*** separate different types of services (eg terrestrial mobile, satcoms, TV) into different frequency bands
 - eg mobile at 900MHz
 - TV at 600MHz
 - satcoms at 1650MHz
 - GNSS at 1575MHz
- However, when high power services operate in nearby frequencies, interference to GNSS is still possible (covered later)

* the Radio Regulations is treaty text agreed between the 195 member states of the International Telecommunication Union

