

GNSS, How it Works and Applications

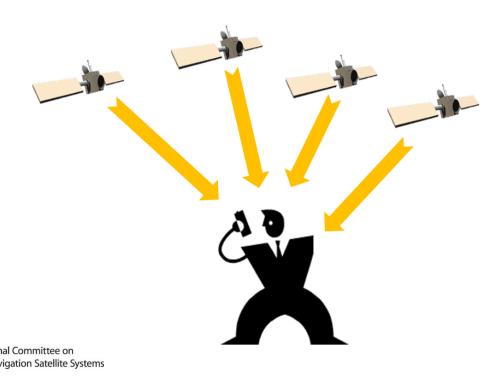
Historic Navigation

- 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

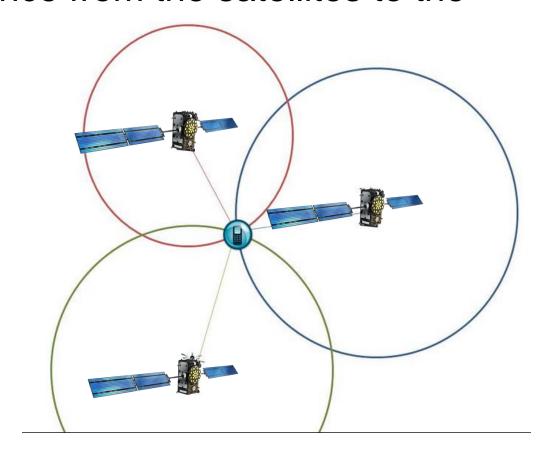
GNSS signals contain information about the satellites' positions

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?



⇒ distance = speed x time

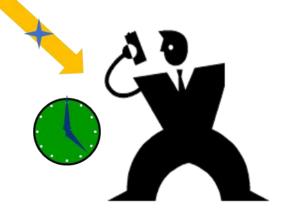
satellite signals contain 'time stamps'

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

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

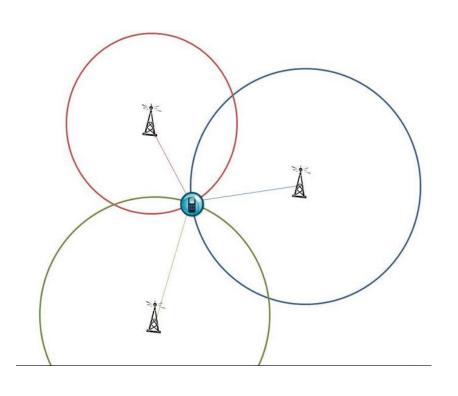
- 300,000km in 1 second
- -300km in 1ms (1/1000th)
- 300m in 1µs (1/millionth)
- 300mm in 1ns





Compute position

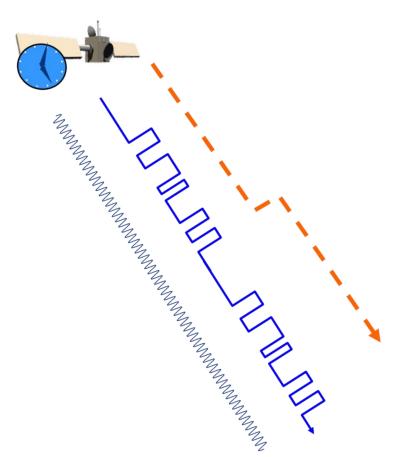
distance = speed x time



- **speed** = $3x10^8$ m/s
- $time = t_{sent} t_{received}$
- 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....



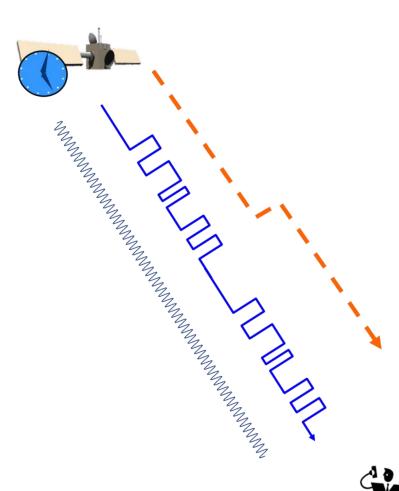
etc, etc.....



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/_{distance²}
- at 23,000 km, GNSS signal reduced by a factor of about 10¹⁸!
 - 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 10¹¹
 - at 1km, reduced by 10⁹
 compared to the GNSS signal (10¹⁸ 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 10⁹
 still 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