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?

\[ \text{speed} = \frac{\text{distance}}{\text{time}} \]

\[ \Rightarrow \text{distance} = \text{speed} \times \text{time} \]

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\( \mu \)s (1/millionth)
- 300mm in 1ns
Compute position

distance = speed x time

- speed = $3 \times 10^8$ 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….

etc, etc……