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?

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

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

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

Satellite signals contain 'time stamps'

\[ \text{time} = t_{\text{sent}} - t_{\text{received}} \]
Compute position

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

- \textbf{speed} = 3 \times 10^8 \text{ m/s}
- \textbf{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

etc, etc