Factors affecting GNSS heighting

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GPS

- GPS signals are weak (20,200km away)
- Amplifiers raise signal from noise but can’t position indoors
- Can’t calibrate a GPS receiver
- GPS positioning is vulnerable

Positioning Modes

Handheld point positioning using pseudorange (code) measurements

Differential positioning using pseudorange (code) measurements - static

Real time differential positioning using carrier phase or code measurements

Differential positioning using carrier phase measurements - static

GPS position modes and accuracies

- **Point positioning** (SPS) ±5-10m (100-150m with SA)
- Point positioning (PPS) ±2-5 metres (not for civil users)

- **Differential GPS** >1 metre
  - WADGPS (wide area differential GPS)
  - LADGPS (local area differential GPS)

- **Static Surveying** Carrier Phase GPS
  - Relative
  - Highest accuracy
    - Horizontal: ±5 mm + 1 ppm
    - Vertical: ±10 mm + 2 ppm

- **Real-time Kinematic** (with OTF (on-the-fly) algorithms)
  - Risk in the determination of wrong integer ambiguity
  - Highest productivity
    - Horizontal: ±10 mm + 1 ppm
    - Vertical: ±20 mm + 2 ppm
What is GNSS?
Global Navigation Satellite Systems

MSAS
IRNSS
QZSS
etc...
**GNSS Status**

- GPS – Full Operational Capability (FOC)
- GLONASS - Full Operational Capability (FOC)
- BEIDOU – 16 Operational SVs in GEO, IGSO and MEO orbits
- GALILEO – 6 Operational test satellites

Glonass does not improve precision/accuracy of positioning only robustness.

Galileo and Beidou will have better ranging precision and stronger signals = higher precision positioning and better multipath resistance

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**GNSS Heighting**

GPS is weak in height. Generally 2x worse than position.

Image of distance between you and four satellites

A point where four distances meet

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ISNSW Southern Group, June conference, Bowral 19 June 2015
**GNSS Errors**

As baseline lengths increase ionosphere and troposphere inhibit fast and reliable ambiguity resolution - *initialisation*

**Atmospheric Errors**

- GPS Satellite ~ 20,200km (zenith) from surface
- Troposphere – Neutral layer ~ 0 – 50km from surface
- Ionosphere – Electrical layer ~ 50 – 1000km from surface
Multipath

- Multipath is the reflection of the GPS signal as it travels from the satellite before arriving at the antenna.
- Reflective sources include roofs, walls, trees, water & vehicles.
- Multipath at base will propagate to rover.

Multipath

- Pseudorange multipath can be up to 10m.
- Carrier phase multipath up to $\frac{1}{4} \lambda = 5-6$ cm.
- Multipath "averages out" over a period from several minutes to a quarter of an hour due to changing satellite geometry.
- RTK multipath can be dangerous.
- Multipath repeats on a daily basis (~4 mins) for the same baseline.
- GPS manufacturers who claim to mitigate multipath do so only for the pseudorange measurements.
Avoiding Multipath

- Make a careful selection of antenna site in order to avoid reflective environments.
- Use a good quality antenna that is multipath-resistant.
- Use an antenna groundplane or choke-ring assembly.
- Use a receiver that can internally digitally filter out the effect of multipath signal disturbance.
- Do not observe low elevation satellites (signals are more susceptible to multipath).
- In the case of carrier phase positioning, longer observation sessions will tend to diminish the impact of multipath on the final baseline results.

Antenna Phase Centre Variation

- Unique to each antenna type
- Two components
  - Offset up to 100mm
  - Zenith dependent up to 15mm
- Different for L1 & L2
- Old models relative, new models are absolute
- Models differentiated by IGS naming convention
  - Make sure your Rx recognises the name!!

(Courtesy Clark & Schupler, 1996)
Antenna Phase Centre Models

APCV general model

Ashtech model for Nowra CORSnet NSW site

20 Character IGS antenna name

Concept of a null antenna

Tip 5: Antenna Models & Heights

- Only use an absolute (relative) antenna model.
- Use IGS models.
- Talk to your local GNSS dealer.

Antenna Heights:
- vertical
- cm & inches
- fixed / change
- ARP
Elevation Mask Angle to reduce errors

Usually set 15° to aid initialisation. Reduces errors from:
- Troposphere, Ionosphere & Multipath

Multipath at the base is sent to the rover
- Up to 6 cm for phase measurements
- Does not average out for RTK surveying

Does GPS work under trees?

- Nowadays due to improved satellite tracking technology, weaker signals can be observed under trees, BUT…
- Signals are noisier, weaker and therefore more likely to be subject to multipath and diffraction.
- Positions may not be accurate despite quality indicators showing good solutions.
- L2C** promises better results and L5 better again.

**Tested with student thesis project. Results showed a slight improvement with L2C. (MacGillivray, 2012)**
Signals passing through trees will show increased RMS and maybe SD. Sometimes position remains accurate but height is vulnerable (empirical testing only).

Data set from Volker Janssen

- Date: 4th – 6th January 2011
- Site: Macquarie University
- Instrument: 6 Leica Viva GS15 GNSS receivers
- ‘swing’ located at ~13:15 to 13:45
- ‘swing’ magnitude of 100mm
Analysis

- Date: 4th January 2011
- Time: 11:45 to 13:59
- Site: Macquarie University
- Software: Leica Geo Office
- CORSnet sites: CWN2, PBOT and VLWD

<table>
<thead>
<tr>
<th>Site: Macquarie University</th>
<th>Single Base @17km</th>
<th>Single Base @21km</th>
<th>Single Base @24km</th>
</tr>
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<tbody>
<tr>
<td>Date: 4th January 2011</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time: 11:45 to 13:59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Obs. Within ± 10mm</td>
<td>39.0%</td>
<td>40.9%</td>
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<td>% Obs. Within ± 25mm</td>
<td>93.0%</td>
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<td>% Obs. Within ± 50mm</td>
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<tr>
<td>Numb of obs</td>
<td>7215</td>
<td>7215</td>
<td>7214</td>
</tr>
</tbody>
</table>

**Statistics of the vertical component of the data

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Analysis

**Elevation of GPS satellites on 4th January 2011 from noon to 2pm**

Reference site: CWN2
Analysis

Vertical component precision 4th January 2011
Reference site: PBOT

**Elevation of GPS satellites on 4th January 2011 from noon to 2pm**

Vertical component precision 4th January 2011
Reference site: VLWD

**Elevation of GPS satellites on 4th January 2011 from noon to 2pm**
What accuracy can we claim?

- ????
- Do your checks on known control. Site transformation?
- Double occupy
- How many sats do you have? How quickly is it initialising?
- Is it a multipath free environment?
- Are there any radio interuptors in the region?
- RTK ±20mm, Static (20 mins) should be better ±10mm.
- Check with Total station but also limited by distance.

Over to you Dave