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Antenna Selection for Bridge Deformation Monitoring:

Comparison of Multipath Mitigation Characteristics for Three Types of Antennas

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18th – 22nd of May 2011
FIG Working Week 2011, Marrakech, Morocco

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Introduction

- The use of GNSS for bridge deformation monitoring has become increasingly wide spread. A significant amount of research has been conducted in this field.
- With multiple constellations in addition to GPS in the form of GLONASS, COMPASS and Galileo available currently or in the near future along with regional augmentation systems. This enables increased availability of a position solution and improved reliability.

GPS monitoring of the Humber Suspension Bridge

- GNSS provides a stable three dimensional measurement of the dynamics of structures such as bridges.

Introduction

- However the GNSS signal is affected by multipath errors.
- In a bridge environment there are many sources of multipath. From the bridge super-structure to vehicles, cyclist and pedestrians, as well as even the water surface.
- These locations are also exposed to the elements and subject to the buffeting of the wind and other elements.
- In addition, it is required that local vibrations from the antenna attachment should be kept at a minimum as it is the bridge dynamics that is required to be captured, also ease of installation and long term stability of the installed hardware is required.
- The multipath also 'contaminates' the FFT results as it shows up as a signal which does not correlate to the bridge dynamics.
- Therefore an antenna which is small and light-weight but with good multipath mitigation characteristics is required.

Antenna Details

- Three Antennas were tested and their characteristics are given below:

Table 1: Dimensions And Other Details Of The Three Antenna Types (Leica, 2005)

Antenna Type	Design	Dimensions (dia x ht)	Weight
AX1202	SmartTrack+, Built-in ground-plane	170mm x 62mm	0.44kg
AT503 choke-ring	Dorne Margolin, JPL design	300mm x 75mm	2.45kg
AT504 choke-ring	Dorne Margolin, JPL design	380mm x 140mm	4.3kg

- It can be seen that the standard AT504 choke-ring antenna is more than 8 times heavier than the AX1202 antenna.
- The aim of the test is to compare the multipath mitigation quality of the lighter antennas with the standard AT504 choke-ring.

GNSS Bridge Monitoring

- The following figures show the light-weight AT503 and the standard AT504 choke-ring antenna in use during tests on the Avonmouth Viaduct and Severn Suspension Bridge.

AT503 Antenna Attached to Main Cable on Severn Crossing Suspension Bridge

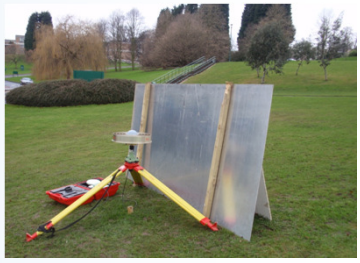
Leica AT503 GPS Antenna Set-up with Clamp and Tribrach Attachment on the Avonmouth Viaduct

AT504 Choke Ring at One of the Reference Stations at the Avonmouth Harbour

Procedure

- Test conducted over three days.
- Each point was occupied using the AX1202, AT504 and AT503 on each consecutive day at roughly the same time of day.
- Two test points:
  - IESSG
  - GRASS
- GPS 1200 receiver used with antennas
- Point IESSG:
  - Located close to the old IESSG building, on the North West side
- Point GRASS:
  - Located on a grassy area which was fairly open but with trees about 10 – 15m away.
  - A large metal sheet was placed close to the antenna in order to induce a high level of multipath.

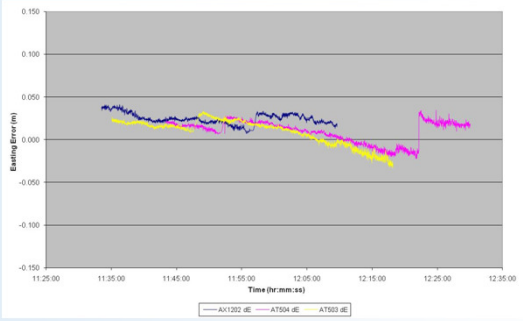
Location of pt. IESSG



Antenna Set-up with Metal Reflector Sheet at pt. GRASS

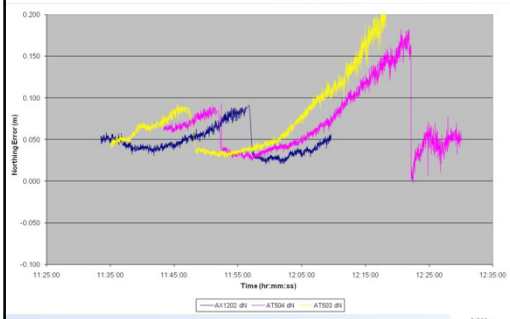
Results: IESSG

- The data collected from the three antennas on the three consecutive days was processed in Leica GeOffice in RTK mode. The eastings, northings and height results are shown:



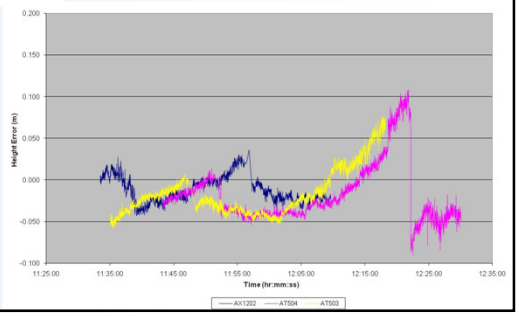
- It can be seen that the results from each antenna collected on consecutive days exhibit a similar pattern with about a 4 minute offset.

Results: IESSG



- *The eastings error is within +/- 4cm while the Northings error increases up to 20cm with the height errors at +/- 10cm*
- *The AT504 was more robust and able to maintain phase lock where the other two antennas were only able to provide code solution.*

The large deviations in position especially towards the latter part of the dataset was due to the combined effect of multipath and poor Position Dilution of Precision (PDOP)



Results: IESSG

- Summary of results from point IESSG:

	AX1202		
	dE	dN	dH
Mean Error	0.023	0.047	-0.011
2 SD	0.011	0.038	0.029
RMS Error	0.024	0.051	0.018
RMS Vector	**0.059**		
	AT504		
	dE	dN	dH
Mean	0.017	0.050	-0.030
2 SD	0.010	0.036	0.030
RMS Error	0.017	0.053	0.033
RMS Vector	**0.065**		
	AT503		
	dE	dN	dH
Mean	0.019	0.050	-0.029
2 SD	0.005	0.018	0.013
RMS Error	0.020	0.054	0.032
RMS Vector	**0.065**		

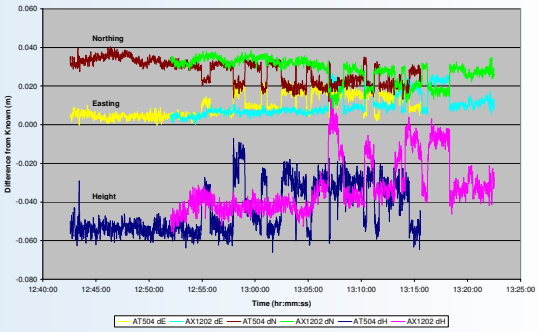
- *The AX1202 has the smallest RMS error vector*
- *Because the summary statistic in the Table was computed only for the period when a phase solution was possible. It does not reflect the robustness of the AT504 which can be seen in the earlier Figures.*

- The RMS error vector is computed as:

$$[(\text{RMS dE})^2 + (\text{RMS dN})^2 + (\text{RMS dH})^2]^{½}$$

Results: GRASS

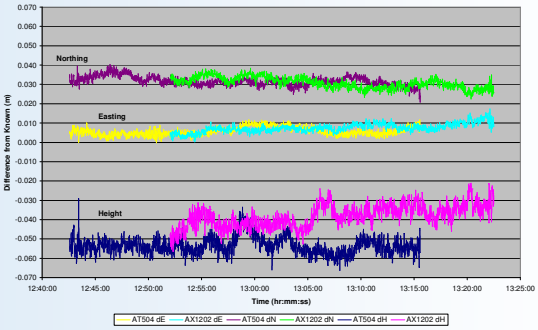
- The AT504 data was collected first then on the following day the AX1202 was used. The data collection for the AX1202 started about 10 mins after the start time of the AT504.



Difference in Coordinates from Truth (using all the satellites in view)

Results: GRASS

- The jumps in the previous graph are likely to be due to cycle slips caused by multipath in the PRN28 data, as this satellite was at a low elevation angle.



Difference in Coordinates from Truth (removing PRN28 from the processing)

Results: GRASS

- Summary of results at point GRASS:

	AT504			AX1202		
	dE	dN	dH	dE	dN	dH
Mean	0.010	0.028	-0.044	0.010	0.028	-0.032
2*SD	0.012	0.012	0.025	0.012	0.013	0.028

Summary of Results at GRASS – using all satellites available

	AT504 w/o PRN28			AX1202 w/o PRN28		
	dE	dN	dH	dE	dN	dH
Mean	0.006	0.032	-0.054	0.008	0.031	-0.038
2*SD	0.004	0.005	0.009	0.005	0.006	0.011

Summary of Results at GRASS – removing PRN28 data from the processing

Conclusion

- The AT503 shows similar performance to the AT504, although in severe multipath condition during the latter part of the test at point IESSG it was unable to maintain lock on the carrier phase.
- The results showed that the AX1202 compared favourably with the other two choke ring antennas under medium to high multipath conditions, with even better results than the AT504 in the test at point GRASS.
- However under severe multipath the AT504 appeared more robust compared to the others.



Conclusion

- This suggests that where it is critical to have a lightweight antenna for bridge deformation monitoring, the AX1202 shows good multipath mitigation characteristic and can be used in conjunction with a standard choke ring antenna at the base station.
- **There is still a requirement for a robust multipath mitigation algorithm when processing GNSS data from difficult high multipath environments.**
- As shown in the tests even where the data collected using the AT504 choke-ring antenna was able to produce centimetre level positions, these positions still deviated from the truth by up to about 10cm in severe conditions.
- Some of this error was due to the effect of PDOP, using a multi-constellation receiver would help to improve this.

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Thank You.

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