THE USE OF GNSS TO MONITOR THE DEFLECTIONS OF BRIDGES

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Presentation:

- To outline the use of GPS to monitor infrastructure – why use GPS?
- To demonstrate a track record in enabling this technology – what we can do now!
- To outline where this technology could go – future advances and potential applications………?

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What can be done?

- Fully 3-d position at very accurate time intervals
- Can detect location
- Can detect change in position
- …..and more

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Background

•Research into the use of mm precision real time kinematic GPS for bridge deflection monitoring, ongoing at Nottingham for almost 15 years.

•First trials with Brunel University on the Humber Bridge.

•Using survey grade dual frequency GPS receivers.

•Comparing the real data with FEM of the Bridge.

Kinematic GPS

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- Sub centimetre precision possible.
- Survey grade receivers required.
- The unknown (rover) GPS receiver is positioned relative to a GPS receiver located upon a known coordinate (reference).
- The data is processed, using an on the fly integer ambiguity resolution technique which allows the rover to be positioned relative to the reference with a precision of better than 1cm.
- This can be carried out in real time by introducing a data link, typically ½ watt UHF.

The Problems

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- GPS satellite signals require line of sight to the GPS receivers.
- Multipath introduces error into the GPS 3D results.
- No GPS satellites are ever seen due north in the UK or below the horizon due to the constellation, this introduces bad geometry.

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Case Study One: The Wilford Bridge

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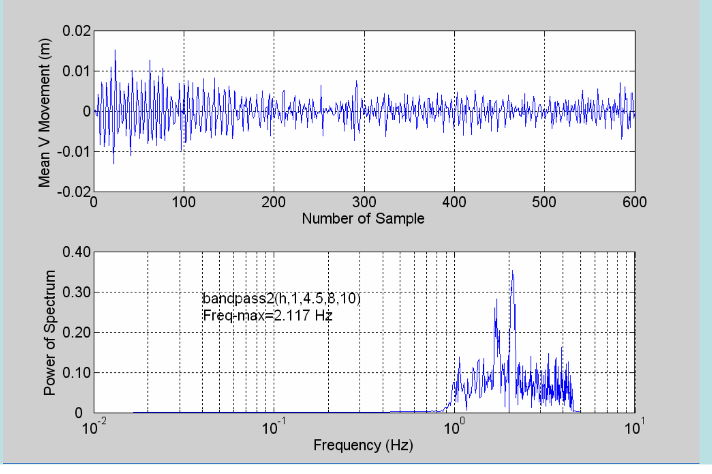
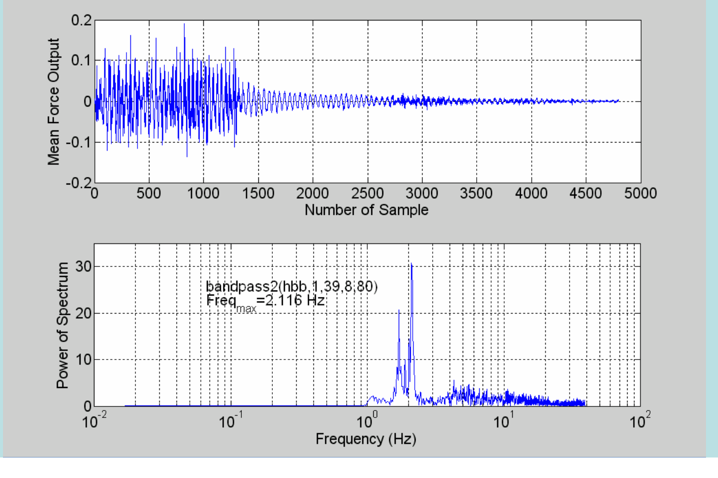
The Wilford Bridge

- A footbridge 4 km away from the campus, held up by two sets of suspension cables restrained by two massive masonry anchorages
- A span of 68 m long and 3.65 m wide, consisted of steel deck covered by a floor of wooden slats
- Three gas and water pipes laid underneath the deck for the local residents
- Several cm deflections under normal loading
- Used as a test bed by the IESSG since 2000

The Wilford Bridge: Deflection Extraction from GPS Time Series



The Wilford Bridge: Deflection Extraction from Accelerometer Time Series



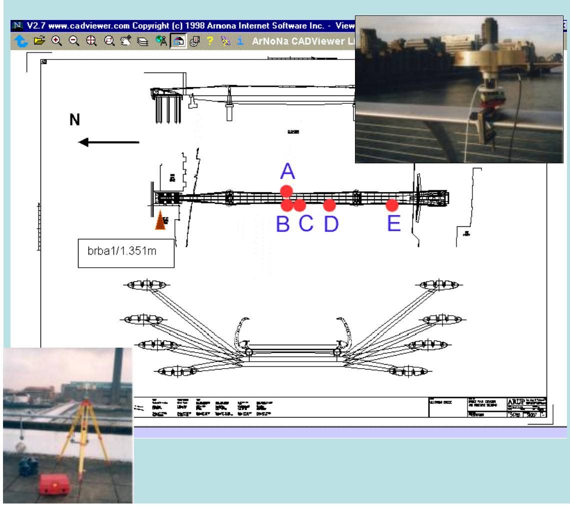
Case Study Two: The London Millennium Bridge

Designed by: Architect Sir Norman Foster
Sculptor: Sir Anthony Caro and Engineers Arup
Opened: 10th June 2000; Closed: 12th June 2000; Reopened: 27th February 2002
Length: 330m; Width: 4m
Height above river at high tide: 10.8m
Handrail height: 1.2m

Piers: Concrete and steel
Cables: 120mm locked coil
Decking: Aluminium
Handrail: Bead blast stainless steel

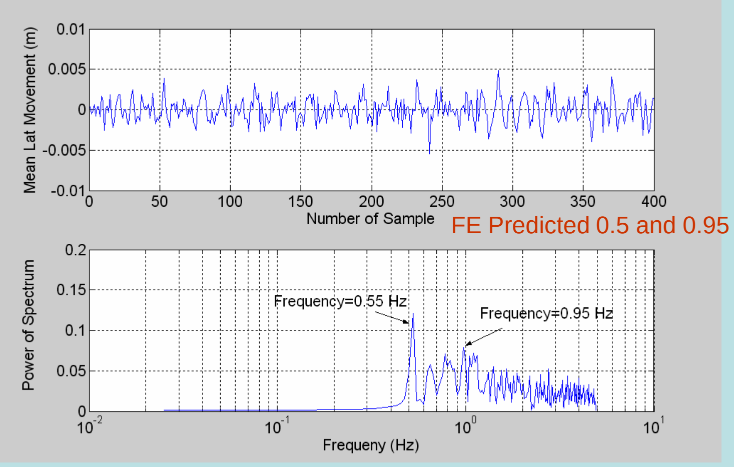
Construction cost: £18m
Subsequent modifications: £5m

The Millennium Bridge: GPS Campaign



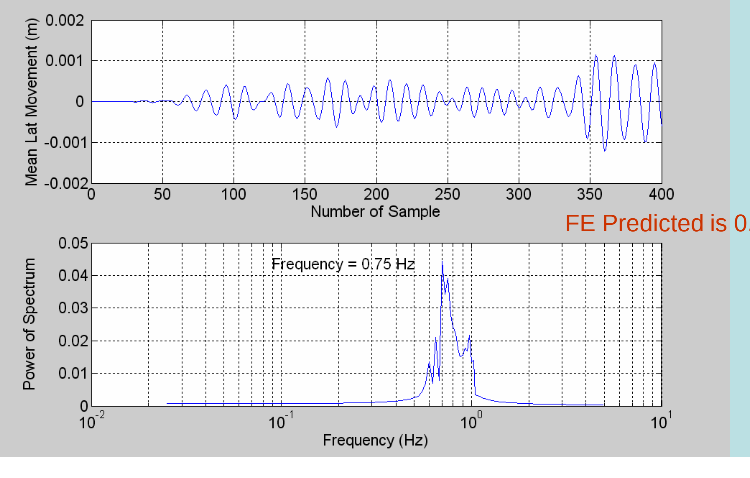
Date	Session No	Start Time	End Time	Antenna Location
22/11/00	1	14.35.42	16.25.52	A
	1	14.36.03	16.24.58	B
	1	14.35.52	16.25.26	C
	1	15.08.12	16.08.14	B (accelerometer)
23/11/00	2	09.51.23	12.13.26	B
	2	09.38.25	12.13.37	C
	2	09.38.58	12.13.22	D
	3	12.37.24	14.50.04	B
	3	12.39.24	14.50.21	C
	3	12.37.57	14.50.13	A
	3	12.42.08	13.42.10	B (accelerometer)
	3	13.46.26	14.46.28	B (accelerometer)
	4	15.14.24	16.47.12	B
	4	15.16.23	16.47.17	C
	4	15.15.24	16.47.28	A
24/11/00	5	08.56.09	12.06.13	B
	5	09.05.15	12.06.36	D
	5	09.15.28	12.07.20	E
	5	09.04.35	10.04.38	B (accelerometer)

The Millennium Bridge: Lateral Dynamics at Middle Span



FE Predicted 0.5 and 0.95 Hz

The Millennium Bridge: Lateral Dynamics at South Span



FE Predicted is 0.77 Hz

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Case Study Three: The Humber Bridge

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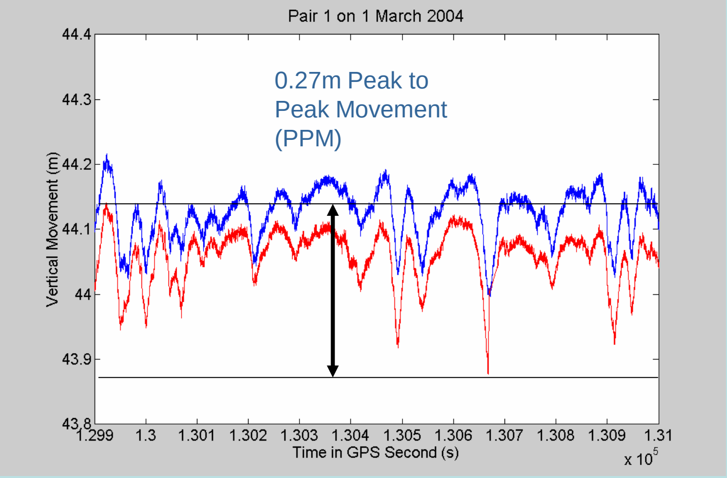
The Humber Bridge: Pair1 (Bdg1 and Bdg7)



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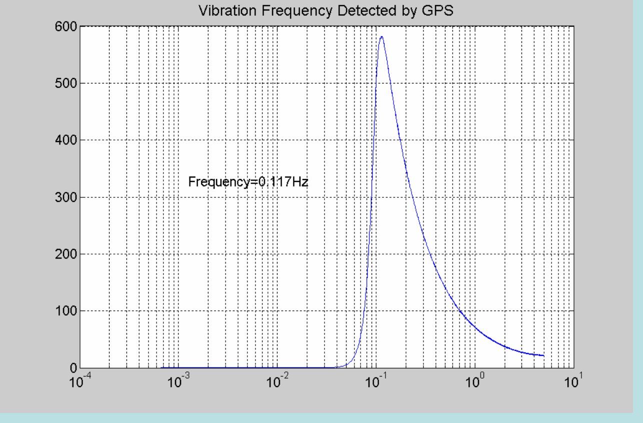
The Humber Bridge: Spectral Analysis



The first vertical vibration frequency predicted by a FE model created by Brunel University is 0.116 Hz

The Tsing Ma Bridge in Hong Kong with same span has 0.117 Hz first vertical vibration frequency

GPS is a viable tool for precisely detecting vibration frequencies

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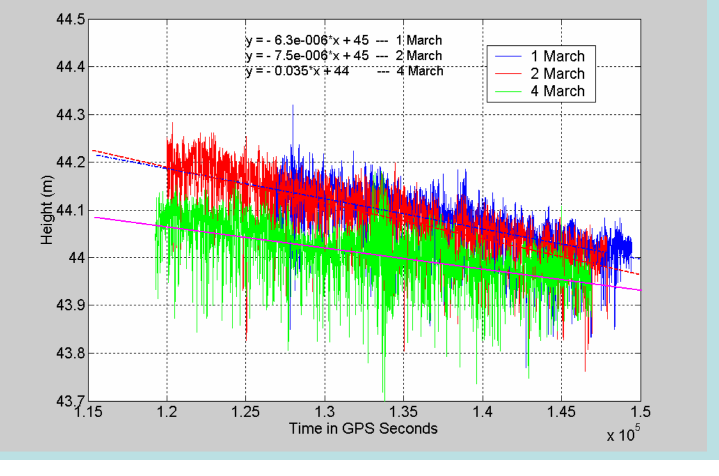
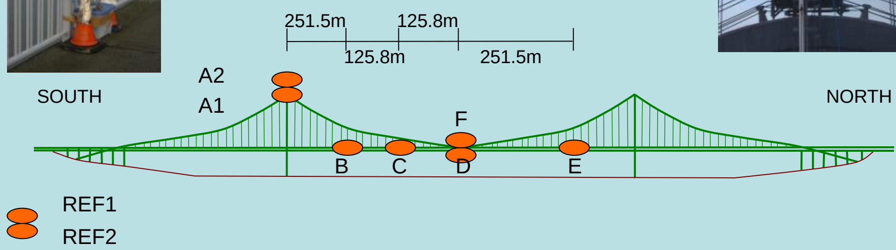
The Humber Bridge: Thermal Effect

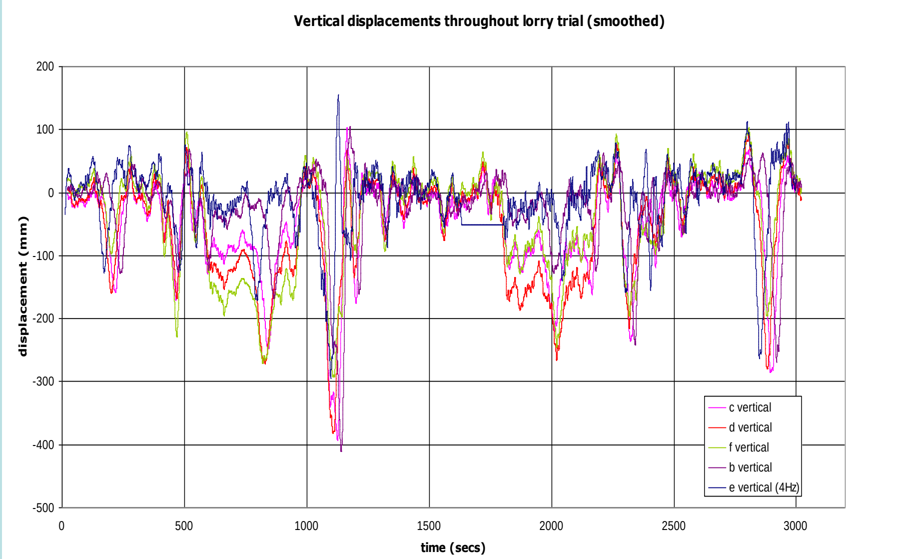


Case Study Four: The Forth Road Bridge

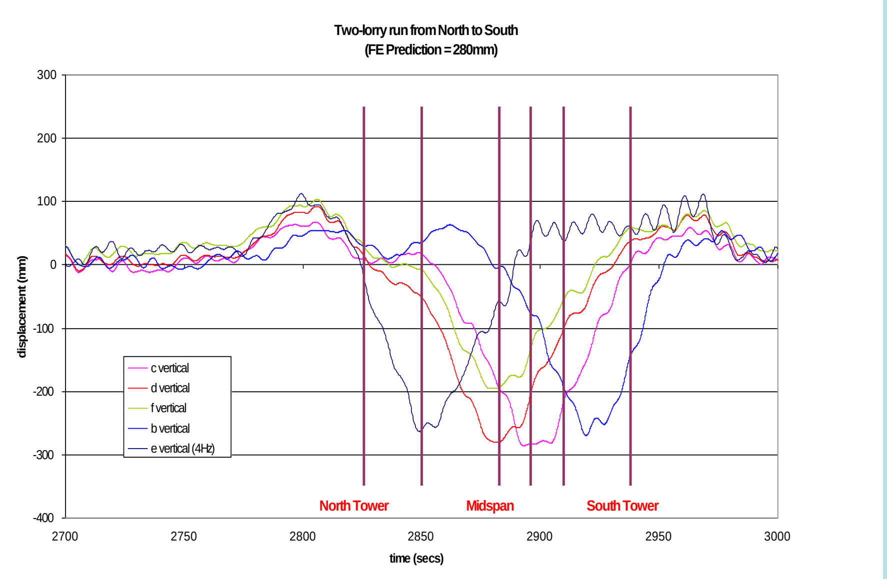
Instrument layout for the bridge test



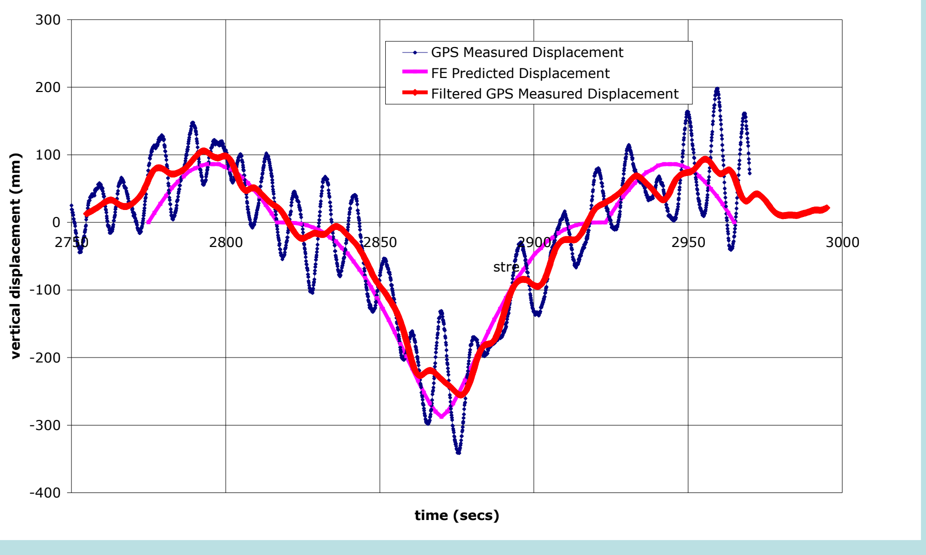
Vertical Displacements



Vertical Displacements



Vertical Displacements



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Case Study Five: Motorway Viaduct

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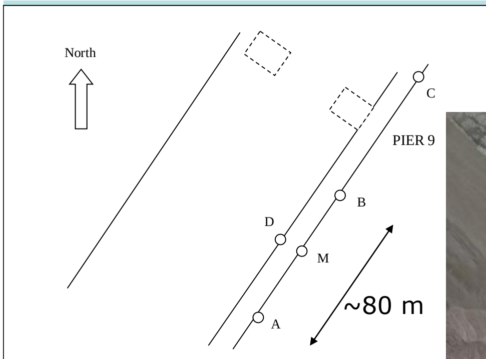

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Field Tests:

- Two day feasibility trial
- Concrete Motorway viaduct, 173.7m long
- GPS, dual freq 10 and 20 Hz

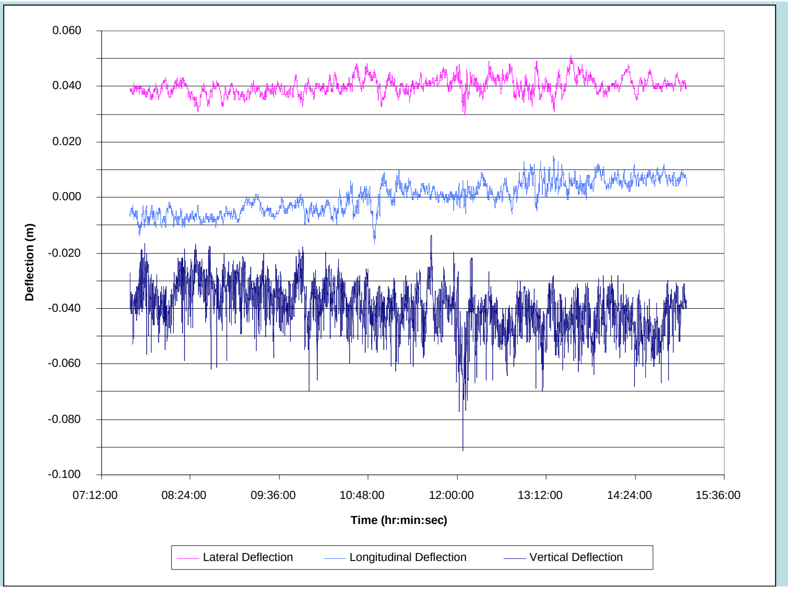
Antenna Locations

Antenna Locations

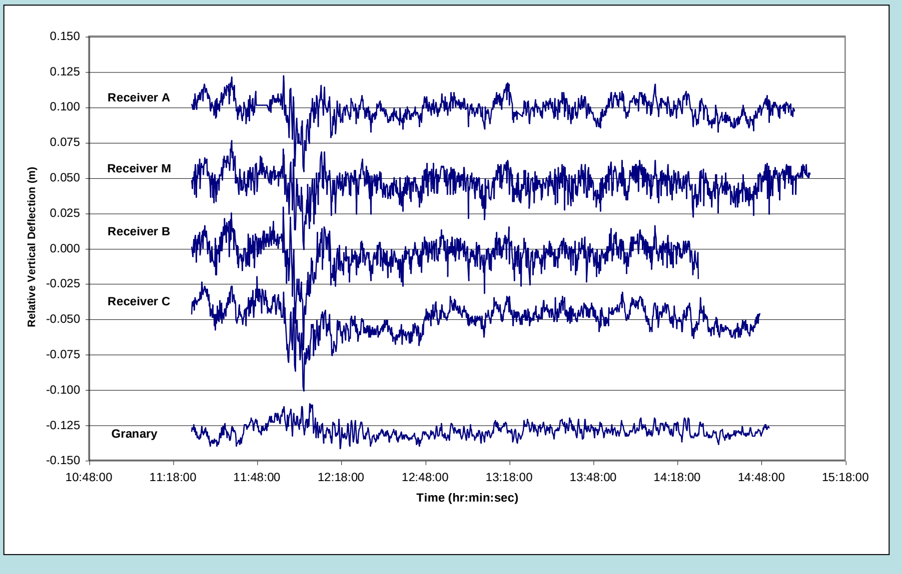
Reference Station

Granary Station

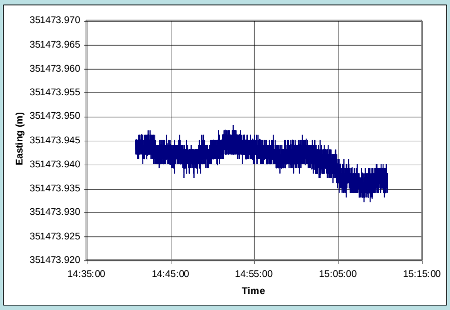
Midspan Movement

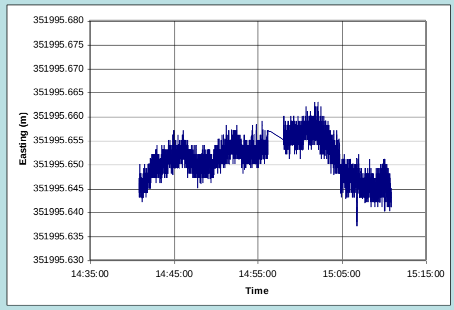


Vertical Displacements



Eastings

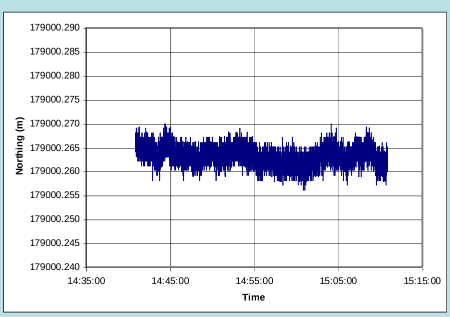


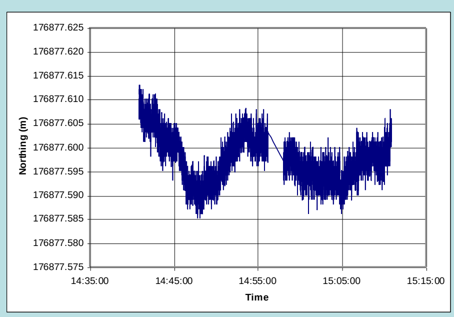


Granary

Bridge Mid Point

Northings

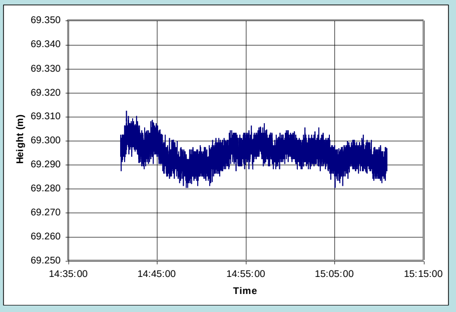




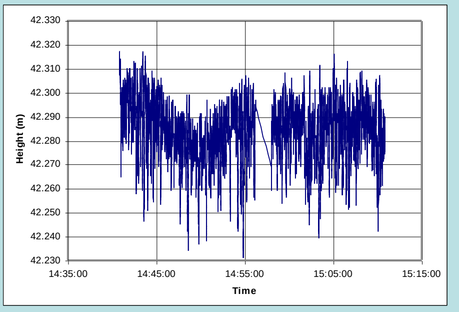
Granary

Bridge Mid Point

Height

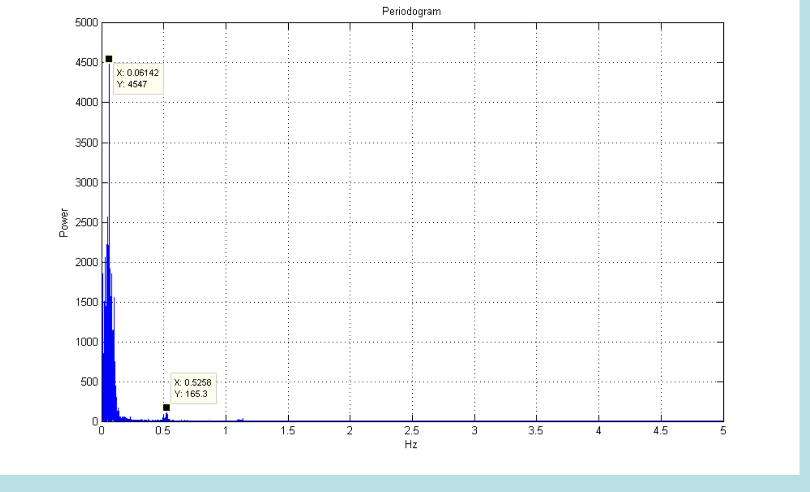


Granary

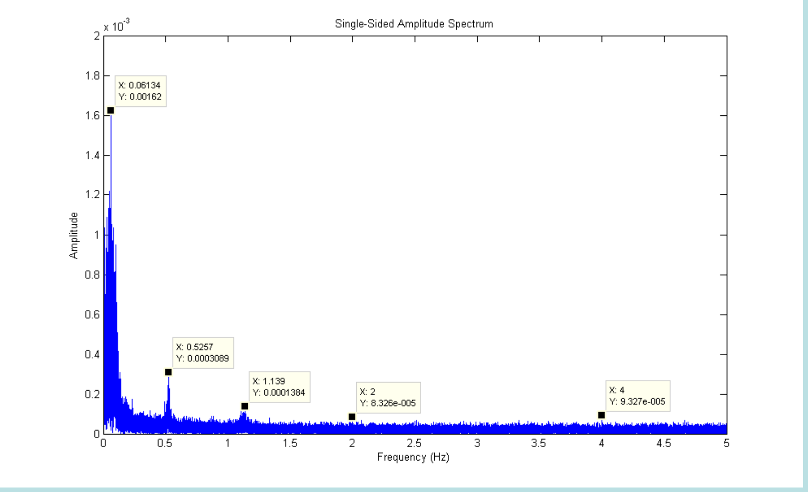


Bridge Mid Point

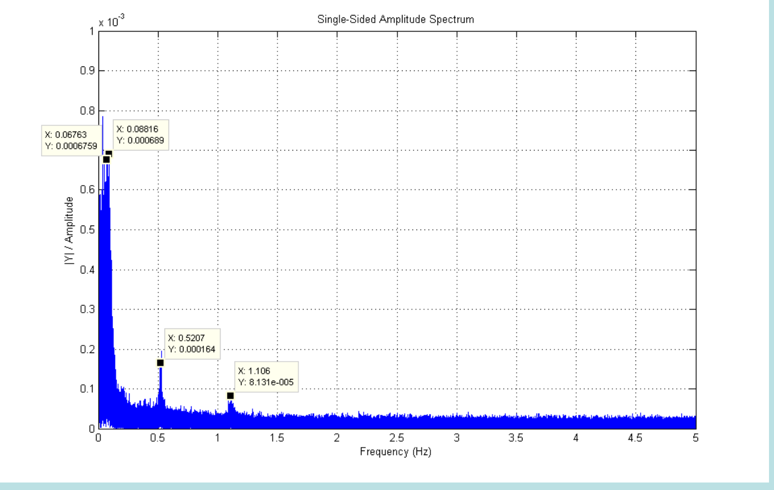
Vertical FFT



Vert Amplitude Spectrum, day1



Vert Amplitude Spectrum, day2



Concluding Remarks

- Trials have shown the feasibility of GPS on structures
- Synchronized and at least10 Hz
- Demonstrates the capability to monitor in difficult locations

Concluding Remarks

- Results come in two parts
  - The primary signal
    - Is the infrastructure still there??!!
    - Is it moving? If so, by how much?
    - Where exactly is it?
  - The secondary signal (noise)
    - Is it vibrating?
      - if so, at what frequency?

Future perspectives

- What is possible?
  - Currently expensive equipment and post-processed results
    - (but only because that's what resources have limited us to!)
  - Development will enable very cheap (hand-held) monitoring devices, remote sensing, relayed signal, and intelligent interpretation.

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