VLBI2010: An Overview

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Why VLBI2010?

- Significant limitations of existing VLBI systems
- More demanding scientific and operational requirements
- Enticing possibilities enabled by new technology

History

- IVS Working Group 3 (WG3) (2003-2005)
  - Set out goals for VLBI2010
  - Made initial recommendations
  - Suggested 13 studies and prototyping efforts

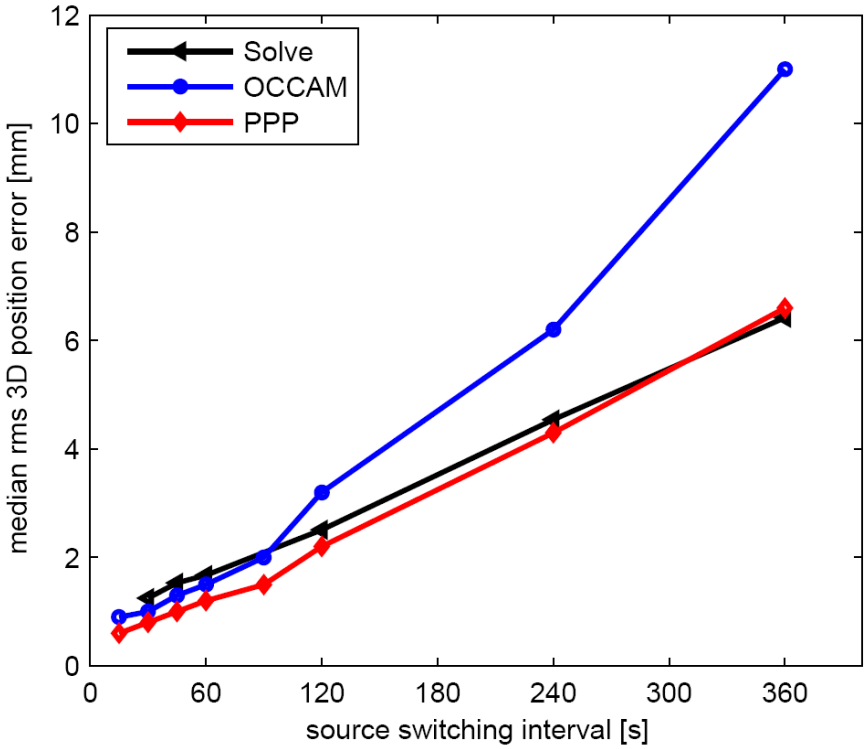
- VLBI2010 Committee (V2C) (2006-present)
  - Carry out WG3 studies and prototyping efforts
  - Encourage the realization of VLBI2010

VLBI2010 goals

- 1-mm position accuracy (*based on a 24-hour observation)*
- Continuous measurements of station position and EOP
- Turnaround to initial products < 24-hours

The big question!: How to move from 7-mm to 1-mm position accuracy

- Based on Monte Carlo studies:
  - Shorter source switching intervals are the answer
- Shorter source switching intervals require:
  - Shorter slew times between sources
    - Use smaller fast slewing antennas
  - Shorter on-source times



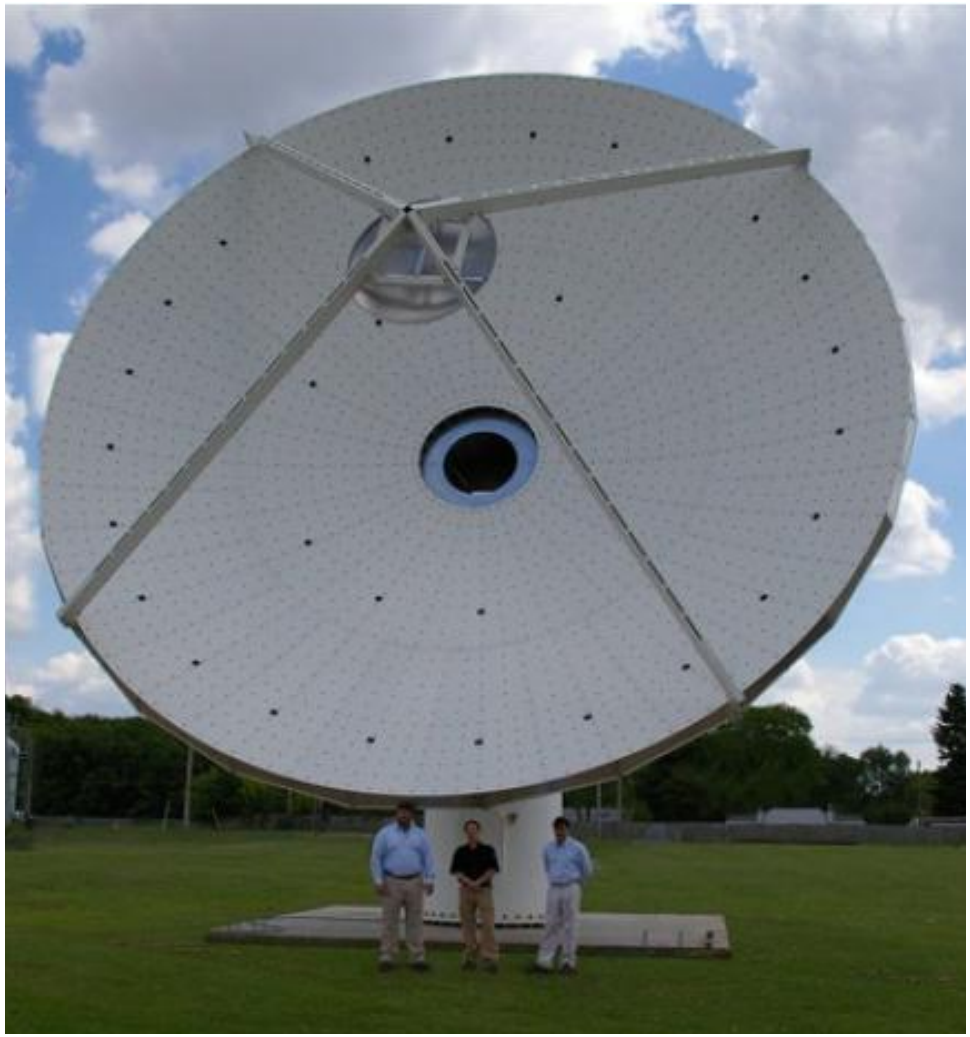
Fast-slewing antennas are already becoming a reality

Vertex antenna for Twin Telescopes Wettzell

Diameter: 13.2 m
Azimuth rate: 12°/s
Elevation rate: 6°/s

Fully VLBI2010-compliant

Patriot Antenna



Diameter: 12 m
Azimuth rate: 5°/s
Elevation rate: 1.25°/s

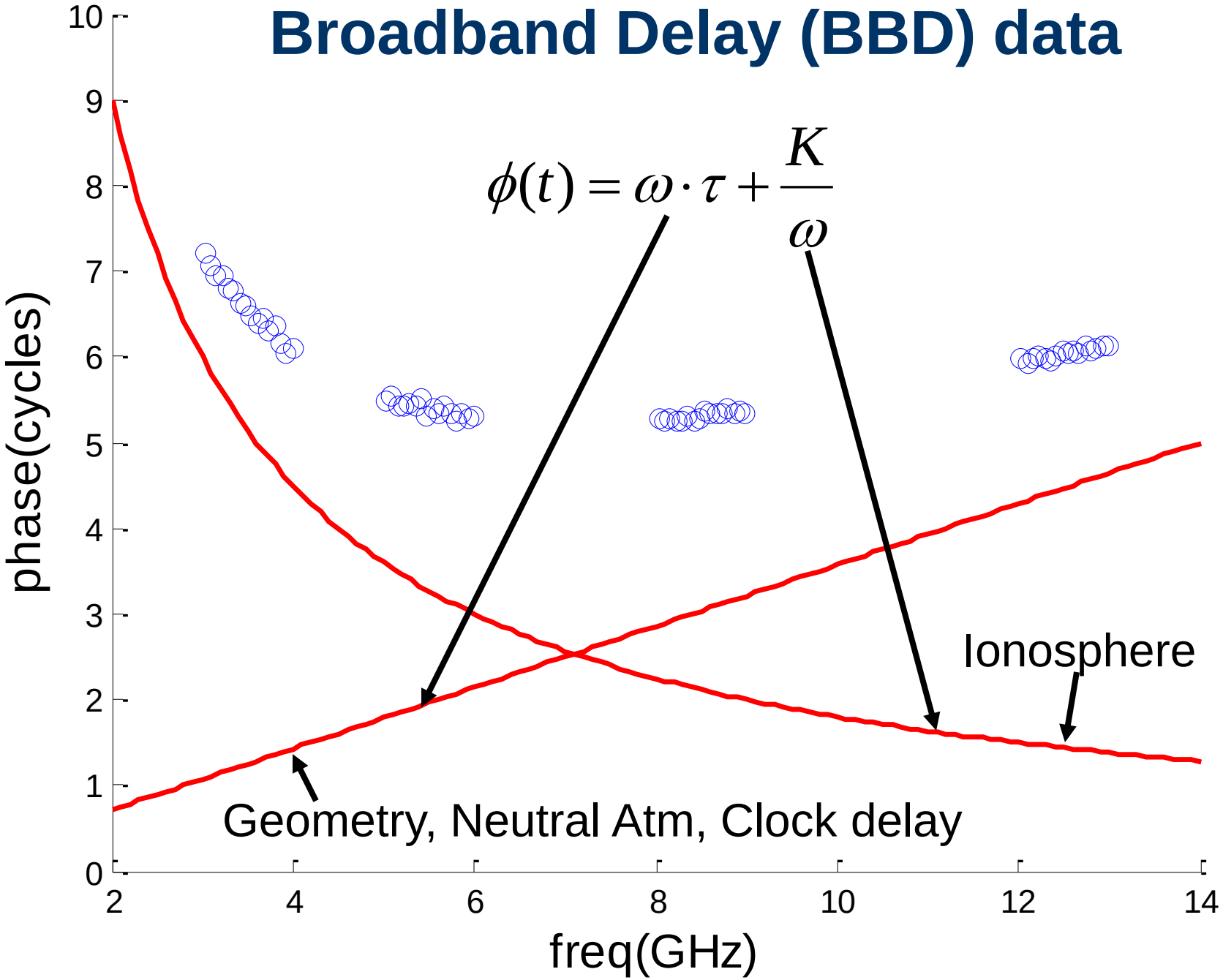
Less expensive

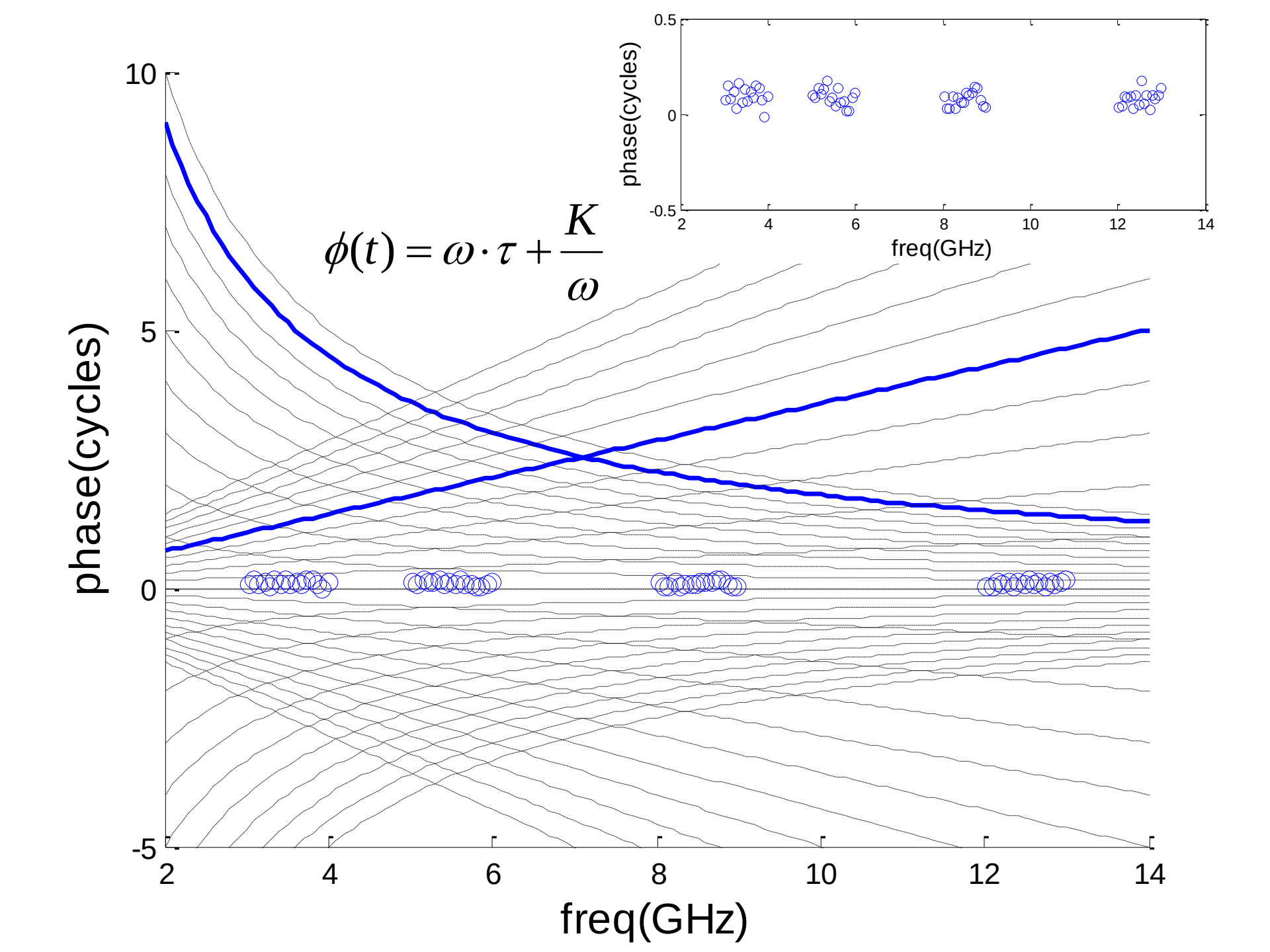
Already being delivered to VLBI2010 sites

Also need short on-source time. How do we get it?

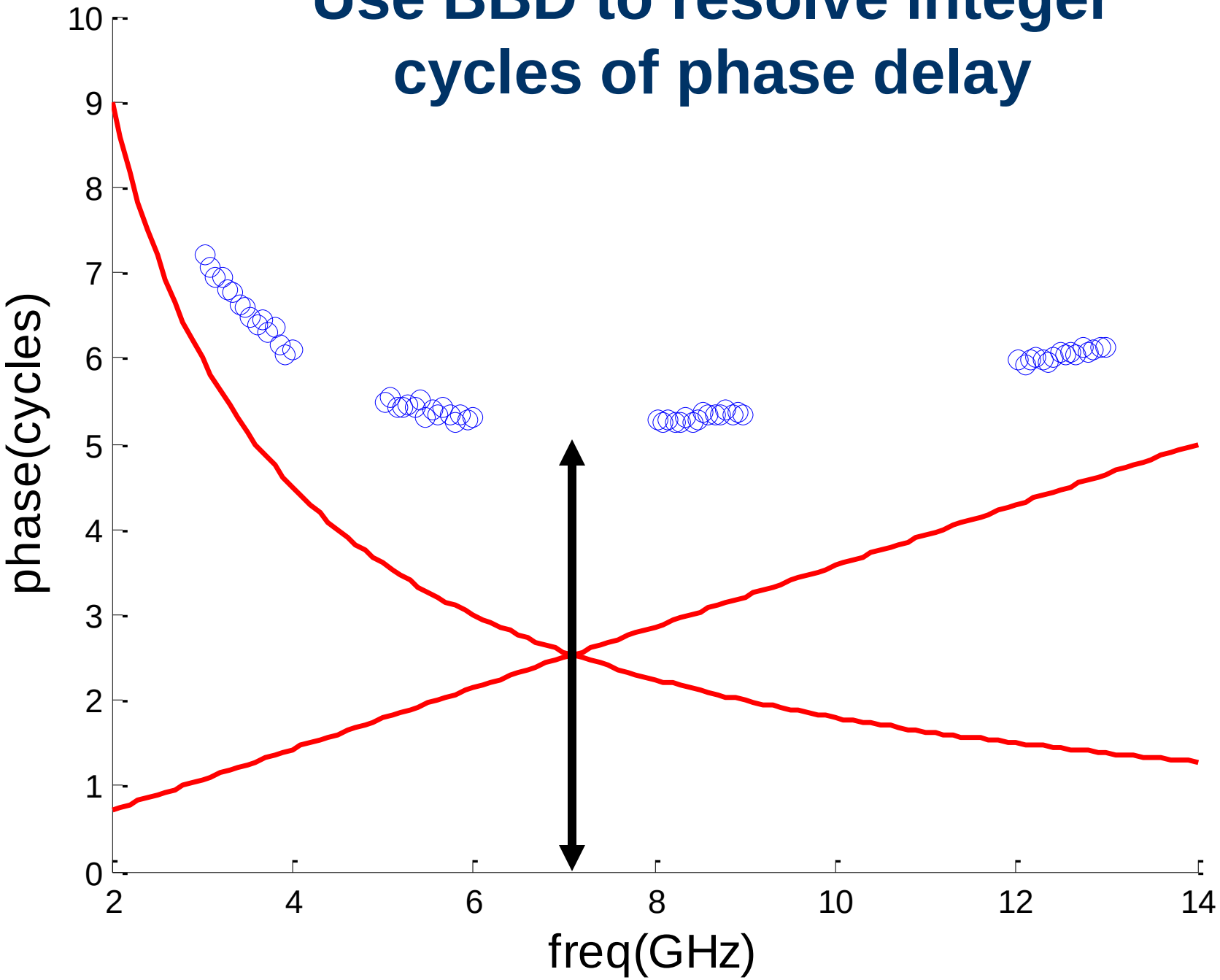
- "Burst" mode data acquisition
  - Very hi data rate (32 Gbps) into RAM while on-source
  - Lower rate (8 Gbps) to recorders while slewing
- Find a way to get very precise delay at a modest SNR
  - Resolve phase across a broad (2-14 GHz) input bandwidth using several (4) wide (1 GHz) optimally space bands
  - At the same, solve for the geometry and ionosphere delays ("Broadband" delay (BBD))
  - Use these values to resolve the integer cycles of the RF phase (resolved "Phase" delay, which is very precise)

Broadband Delay (BBD) data



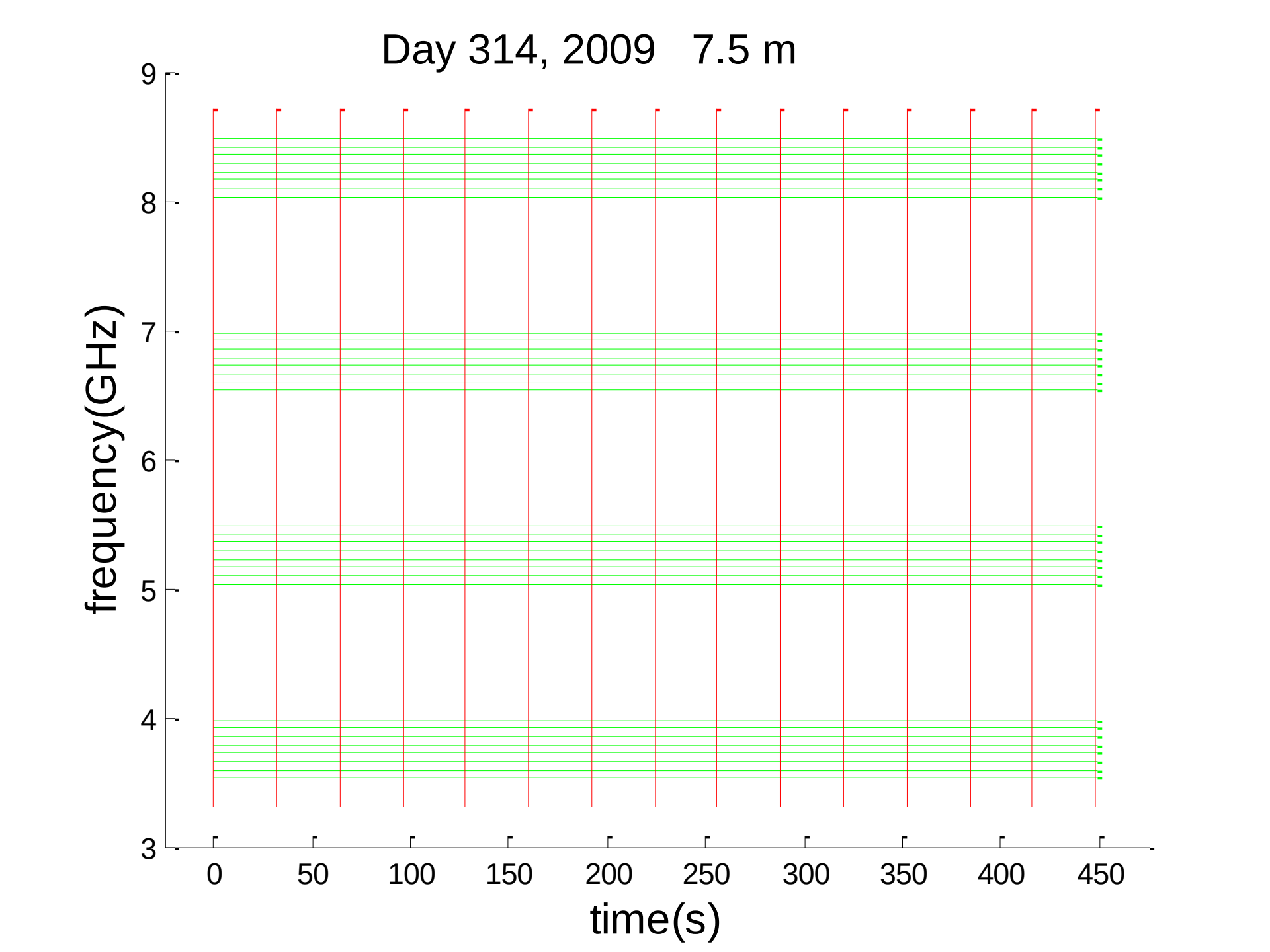

$\phi(t) = \omega \cdot \tau + \frac{K}{\omega}$
phase(cycles)
freq(GHz)
10
5
0
-5
2
4
6
8
10
12
14
0.5
0
-0.5

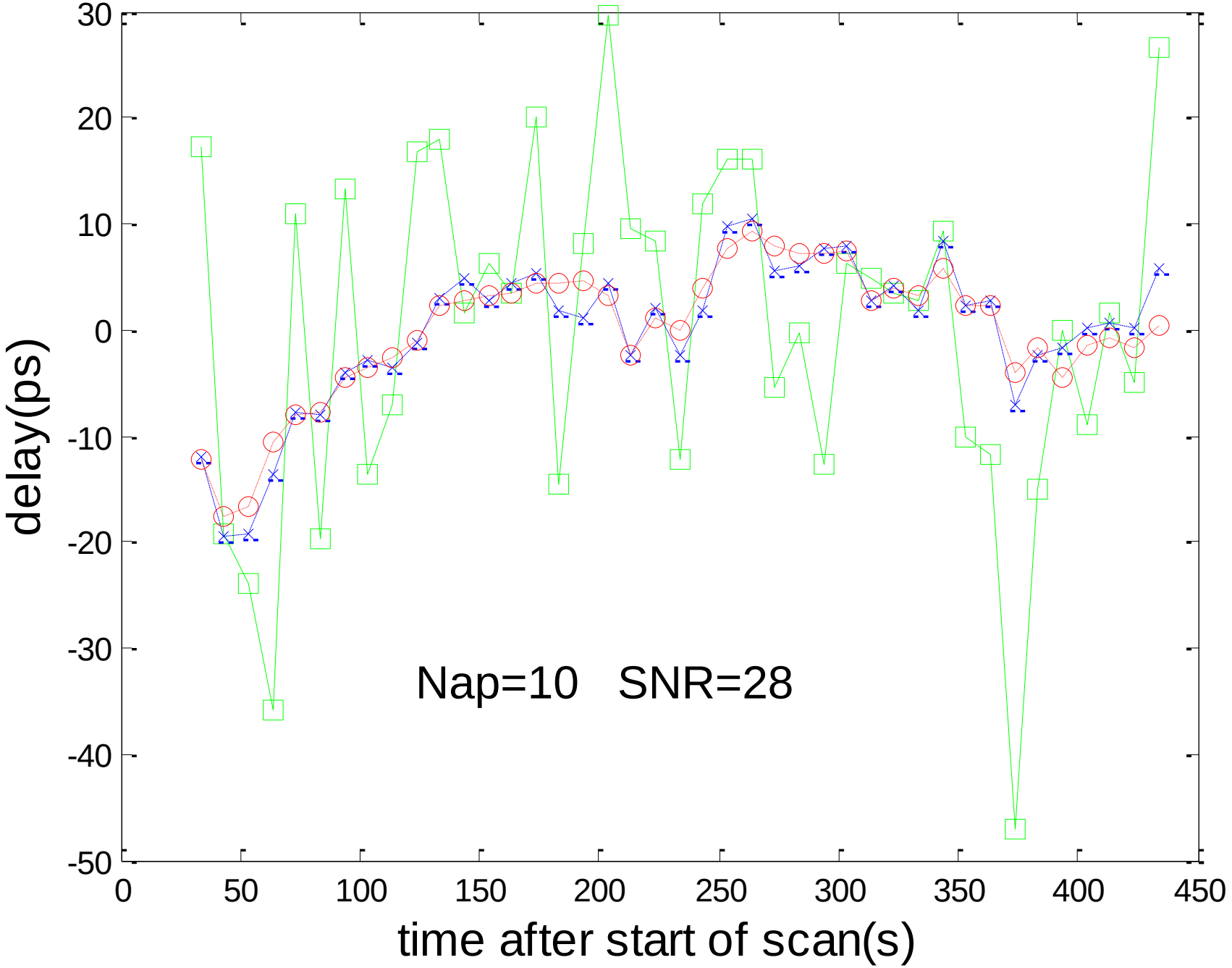
Use BBD to resolve integer cycles of phase delay

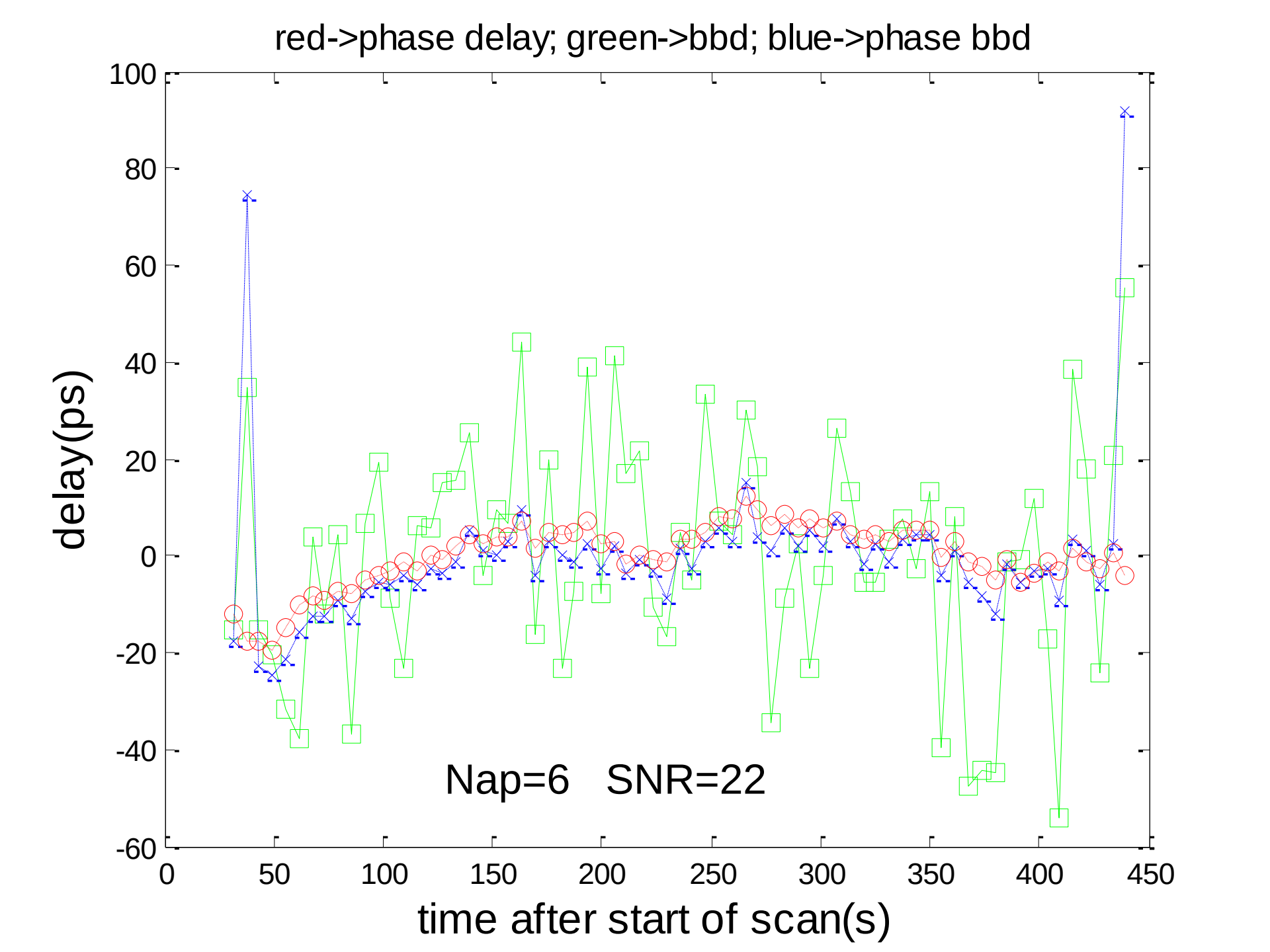


NASA Broadband Delay Proof-of-concept Development Project

- Purpose:
  - Prove that Broadband Delay can be used operationally to resolve phase delay.
  - Develop the first generation of VLBI2010 electronics.
  - Gain experience with new VLBI2010 subsystems.
- Status
  - Two complete VLBI2010-like signal paths are operational at:
    - 18-m antenna at Westford, MA
    - 5-m antenna at GGAO, Wash, DC


Day 314, 2009 7.5 m
frequency(GHz)
9
8
7
6
5
4
3
0
50
100
150
200
250
300
350
400
450
time(s)

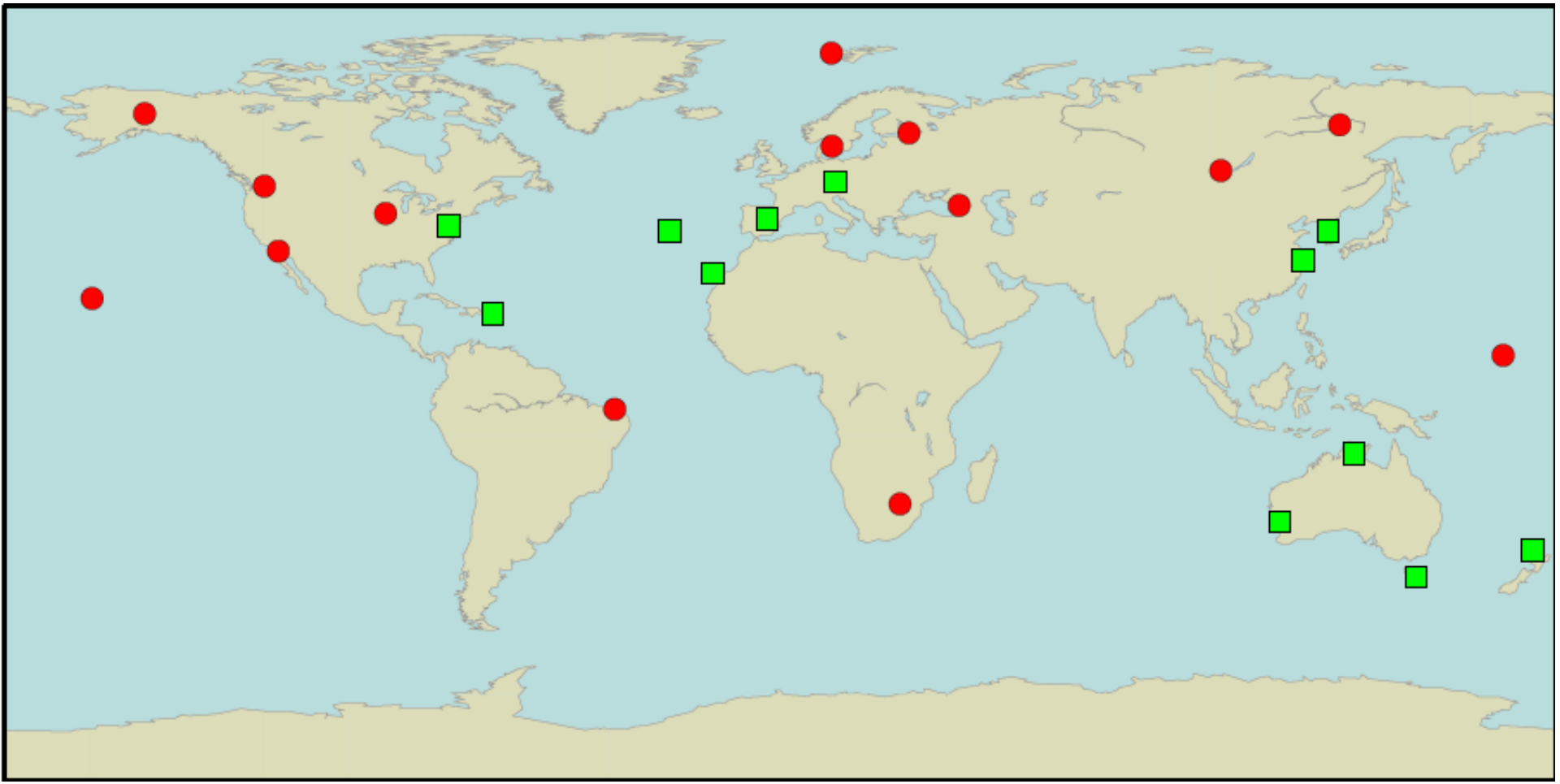

red->phase delay; green->bbd; blue->phase bbd
delay(ps)
time after start of scan(s)
Nap=10 SNR=28
30
20
10
0
-10
-20
-30
-40
-50
0
50
100
150
200
250
300
350
400
450


red->phase delay; green->bbd; blue->phase bbd
delay(ps)
time after start of scan(s)
Nap=6 SNR=22
100
80
60
40
20
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450

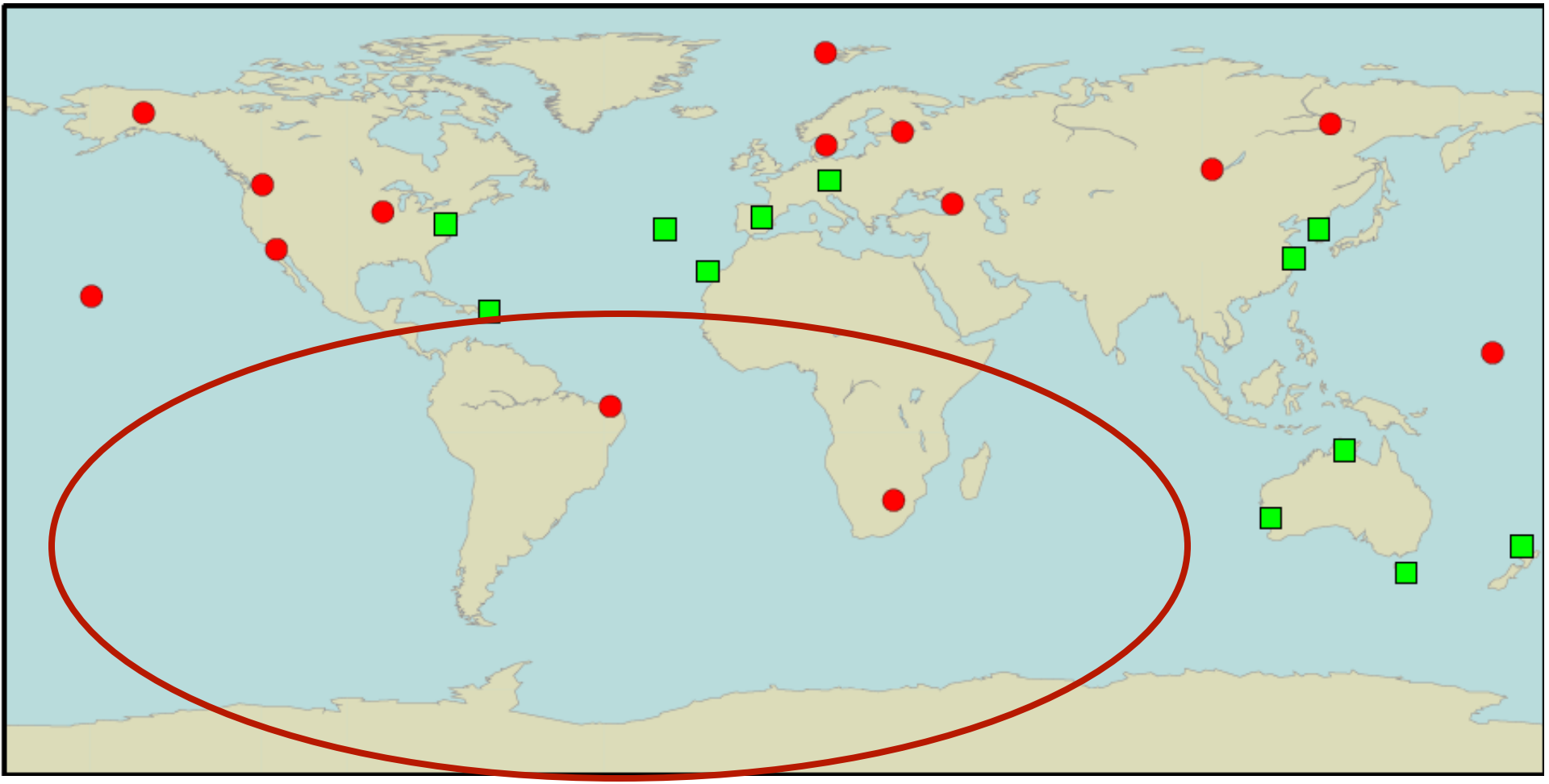
BBD is becoming a reality!

- Great first step but…. still lots of room for improvement
  - Use full 2-14 GHz range
  - Use an optimized sequence
  - Use 1-GHz bands
- Must still be tested under many other conditions, e.g.:
  - Baselines much longer than 597 km
  - A wide variety of sources
  - Much longer time periods (24-hours)
  - A more unstable ionosphere
  - Different RFI conditions

Network is becoming a reality



Network progress but… Southern Hemisphere is still a challenge

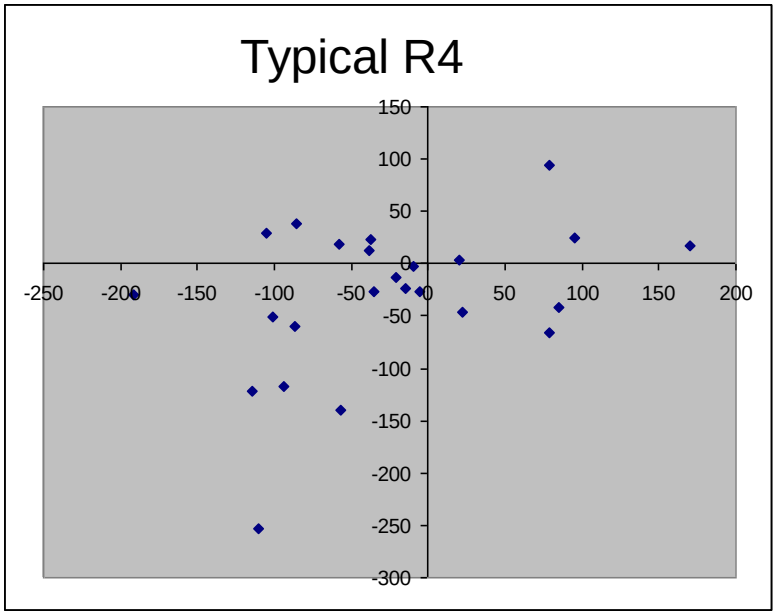


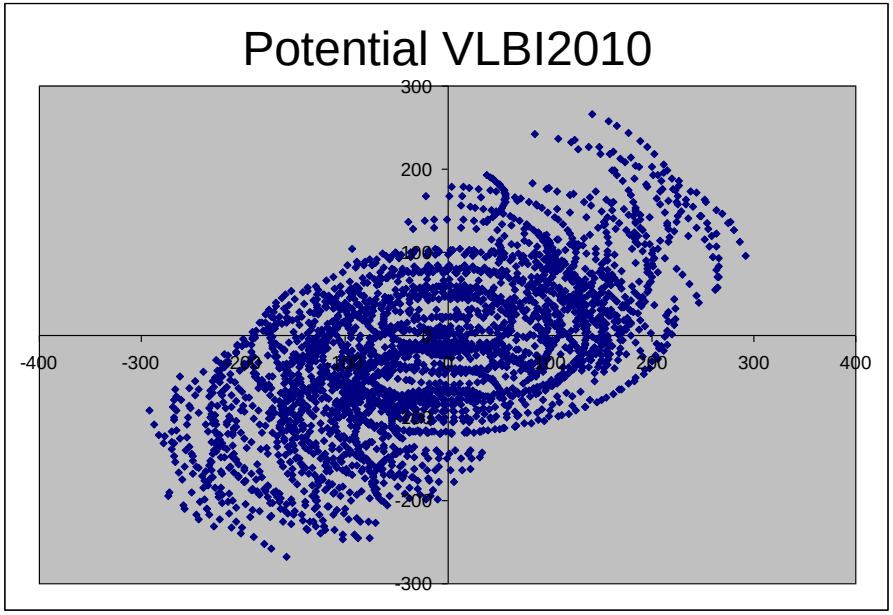
Sources of VLB I Systematic Errors are being tackled

- Instrumentation
  - updated calibration systems
- Radio source structure
  - New source lists, e.g. ICRF2
  - Source structure corrections are a possibility
- Antenna thermal and gravitational deformations (and site ties)
  - Careful measurements of antenna deformations.
  - Use of a small antenna to redefine the reference point and monitor deformations.

Source structure corrections

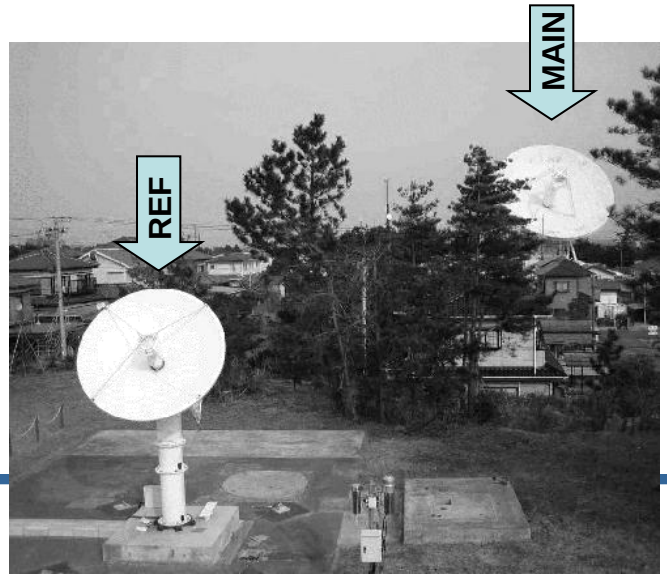
- VLBI2010 has greatly improved uv coverage due to:
  - Faster antennas
  - Higher data rates
  - Larger networks
- Source structure corrections may be possible





Antenna deformations and site ties

- Use connected element interferometry to a small nearby antenna to:
  - Develop thermal and gravitational models for the VLBI2010 antenna
  - Measure to the “effective” reference point of the VLBI2010 antenna
- Use the small antenna to observe GNSS satellites:
  - develop GNSS antenna offsets
  - Measure to the “effective” reference point of the GNSS antenna.
- The intersection of axes of the small antenna becomes the reference point for both VLBI and GNSS and ties the techniques.



VLBI2010: How far have we come?

- Faster slewing antennas are becoming a reality
- BBD technique is becoming a reality
  - 8-GHz acquisition and record rates (no “burst” mode)
  - 3.5-8.5 GHz frequency range (2.2-10.5 GHz soon?)
- Network is becoming a reality
- Systematic errors are being tackled
- eVLBI expanding
- Automation and remote-control of sites progressing
- New data structures are being handled by WG4
- Updated analysis packages under development
- Analysis automation working well for intensives

VLBI2010 Needs high visibility goal to first operations

- One suggestion: Aim to operate expanded VLBI2010 Intensives by 2013
  - E.g. 7-10 stations observe daily for a few hours
  - With faster antennas and a greater number of stations, performance may even approach R1/R4… but be continuous
  - The continuous EOP and station position series will be a high visibility advance for VLBI2010.
- Having this goal will push us to focus our efforts

Please stay tuned to this session to hear more about these topics!