The Development of the VLBI2010 Global Observing System (VGOS)

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Geodetic VLBI: How does it work?

A network of antennas observes a Quasar.

The delay between times of arrival of a signal is measured.

Using the speed of light, the delay is interpreted as a distance.

The distance is the component of the baseline toward the source.

By observing many sources, all components of the baseline can be determined.
Launch of VGOS in March 2012
VLBI2010: Why do we need it?

- Aging systems
- New technology
- New requirements
- Phenomena to be observed have magnitudes of a few millimeters \( \text{mm} \) accuracy!
- **VLBI2010**: response of the IVS to significantly improve geodetic VLBI and reach this high level of accuracy
- 2003-2005:
  - IVS Working Group 3 „VLBI2010“
    - goals and requirements
    - strategies and recommendations
IVS WG 3 Final Report

- Vision paper
- Published Sept 2005

Goals of the next generation system

VLBI2010 Goals

1-mm position accuracy (*based on a 24-hour observation*)

Continuous measurements of station position and EOP

Turnaround time to initial products < 24-hrs
### Design Aspects of the VLBI2010 System

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>VLBI2010</th>
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<tbody>
<tr>
<td><strong>antenna size</strong></td>
<td>5–100 m dish</td>
<td>~ 12 m dish</td>
</tr>
<tr>
<td><strong>slew speed</strong></td>
<td>~20–200 deg/min</td>
<td>≥ 720 deg/min</td>
</tr>
<tr>
<td><strong>sensitivity</strong></td>
<td>200–15,000 SEFD</td>
<td>≤ 2,500 SEFD</td>
</tr>
<tr>
<td><strong>frequency range</strong></td>
<td>S/X band</td>
<td>~2–14 (18) GHz</td>
</tr>
<tr>
<td><strong>recording rate</strong></td>
<td>128, 256 Mbps</td>
<td>8–16 Gbps</td>
</tr>
<tr>
<td><strong>data transfer</strong></td>
<td>usually ship disks, some e-transfer</td>
<td>e-transfer, e-VLBI, ship disks when required</td>
</tr>
</tbody>
</table>

VGOS Network in 2012

-VLBI2010 very fast
  - radio telescope
  - twin radio telescope
-VLBI2010 fast
  - radio telescope
-upgrade legacy
  - radio telescope

[Hase et al., 2011]
VGOS Network in 2017

VLBI2010 very fast
- radio telescope
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VLBI2010 fast
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upgrade legacy
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[Hase et al., 2011]
Int’l VLBI Service for Geodesy and Astrometry
• The IVS currently has about **80 permanent components** supported by roughly **40 institutions** in **20 countries**.
GGAO 12-m antenna
Feed and LNAs cooled to ~20K

Both senses of linear polarization used

Odd channels from each pol’n for one band output to each Mk5C.

2 Gigabits/sec recorded on each Mk5C.

Total data rate: 8 Gbps
VLBI2010 signal chain

• Cooled broadband QRFH feed and LNAs (Caltech)
• UpDown Converters (4) (Haystack)
  – Select frequency bands in the range 2 to 12 GHz
• RDBE digital back ends (4) (Digicom)
  – PFB to get 16 32-MHz channels (8 from each pol’n)
  – Noise diode control for power measurement for Tsys
  – In use by VLBA and NASA
• Mark5C recorder (4) (Conduant)
  – In use by VLBA and NASA
Quad-Ridge Flared Horn (Caltech)
Observations

• Antennas
  – GGAO12M
    • 12m VLBI2010 antenna
    • At Goddard Space Flight Center, Maryland, USA
    • Full VLBI2010 signal chain
  – Westford
    • 18m prime focus antenna
    • At Haystack Observatory, Massachusetts, USA
    • Full VLBI2010 signal chain
  – Baseline length approximately 600 km.
Observations – 2012 Jan 19

- Objectives
  - Several hours on one source to check system.
  - Observe a source with polarization rotation
- Scans
  - Five minute scans for high SNR
  - Source 3C345
  - Approximately four hours total
- Frequency bands
  - Contiguous bands spanning 2 GHz: 6.4 – 8.4 GHz
Observations – 2012 May 16

• Objectives
  – Geodetic schedule
  – Observe a number of sources over entire sky

• Scans
  – 30-second observations
  – 6 hours total

• Frequency bands
  – Four bands at 3.5, 5.5, 6.6 and 9.6 GHz
Fully coherent ionosphere-corrected full-polarization delays using all four RF bands (100 scans, 6 hr)
WRMS post-fit residuals: 20 ps
Position formal errors: 8 mm vertical, 2 mm horizontal
New VLBI2010 antennas: TTW

- Twin Telescope Wettzell (Germany), Vertex Antennas
Twin Telescope Wettzell, April 2012