Broadband Delay System Demonstration for VLBI2010

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for the Broadband Delay Development Team

Geodetic VLBI

- Terrestrial reference frame ~ 1 cm
- Celestial reference frame
- Earth orientation parameters
  - UT1 (time)
  - Nutation
  - Polar motion
- Two 24-hr “Rapid” sessions per week
- Another ~1.5 sessions/week for TRF and R&D

Geodetic VLBI

- Number of sites for geodetic VLBI ~ 40
- Use only 8 – 15 antennas per session
- Limited by:
  - Amount of observation time at individual sites
  - Amount of recording media

Motivation for new network

- Current geodetic VLBI antennas and equipment are aging
- Radio frequency interference (RFI) is increasing
- Accuracy is limited by slow antennas
- GGOS requires geodetic position accuracy of 1 mm in 24 hours using VLBI, GPS, and SLR

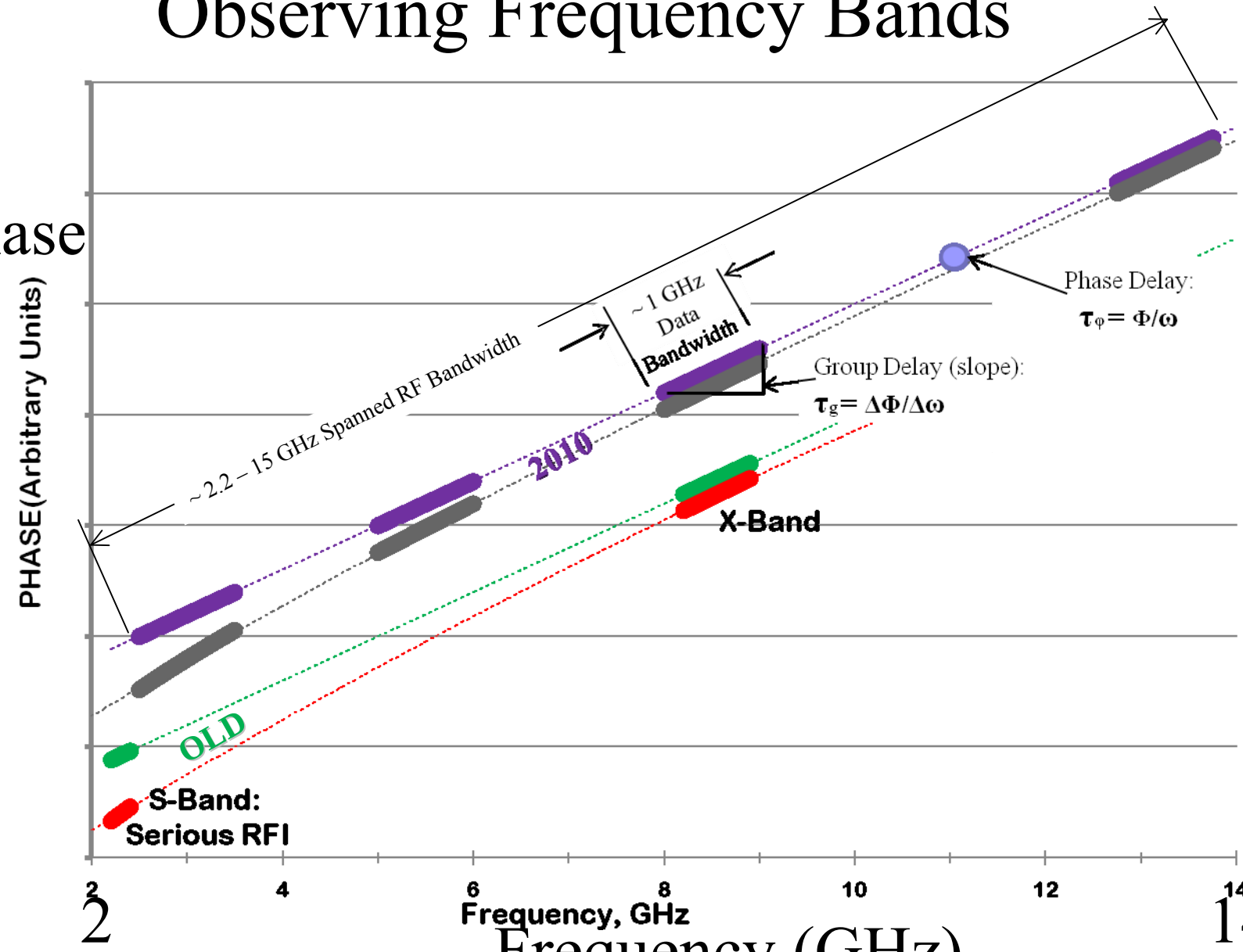
IVS VLBI2010 Committee

- Derive new system concept through simulations and sensitivity calculations
  - Turbulent atmosphere based on met data
  - Clock and frequency standard performance
  - System noise
- Recommend small fast antennas with high delay precision
- Implement in hardware to evaluate the concept

VLBI2010 Model

- Fast slewing ≥12 meter diameter antenna
- Network of 16 – 40 antennas globally
- Broad-band feed and amplifiers
- Multiple bands covering 2 GHz to ~15 GHz
- Data record rates of 8 gigabits per second and higher
- Ideally 24/7 operation and rapid results

Observing Frequency Bands

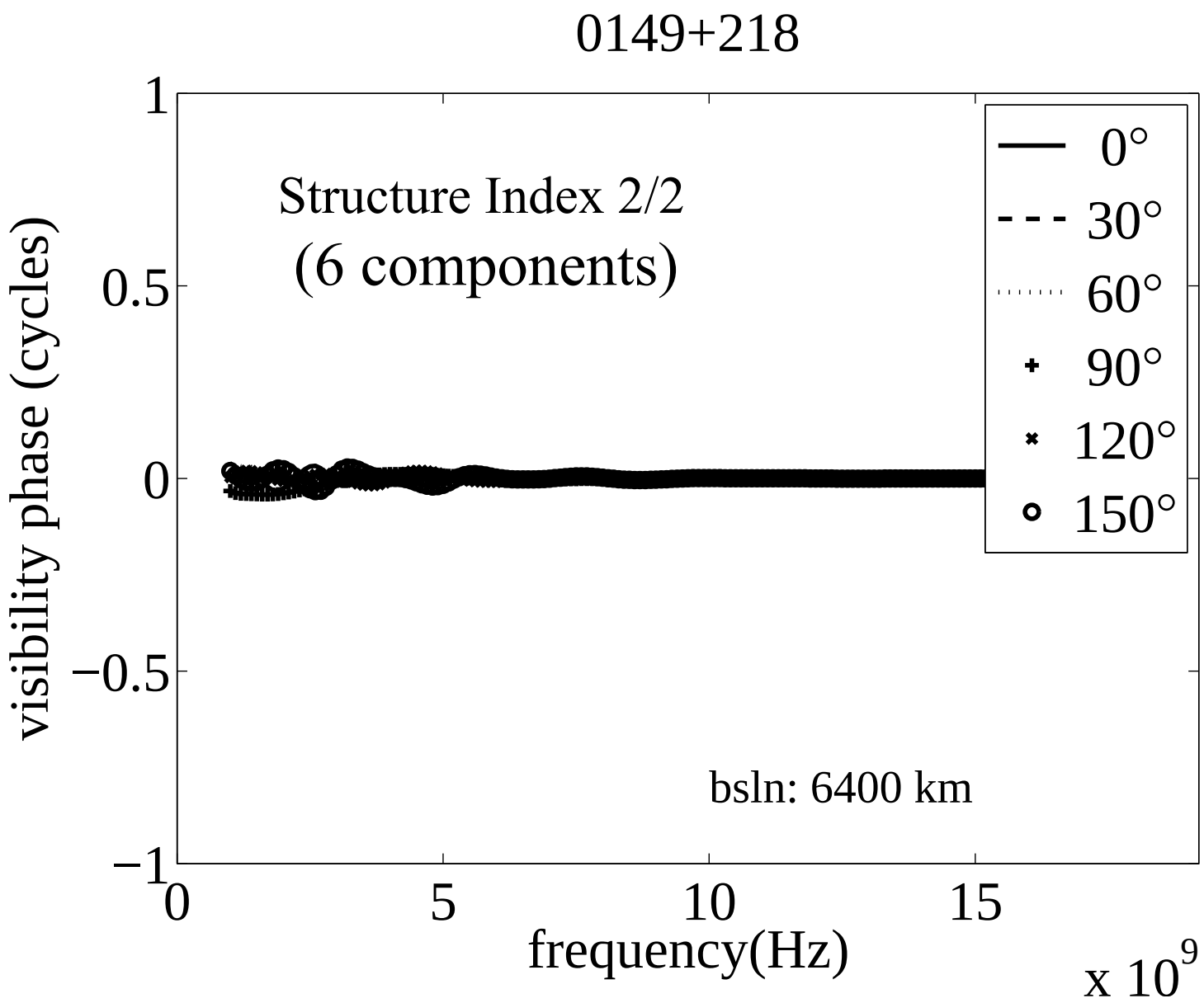


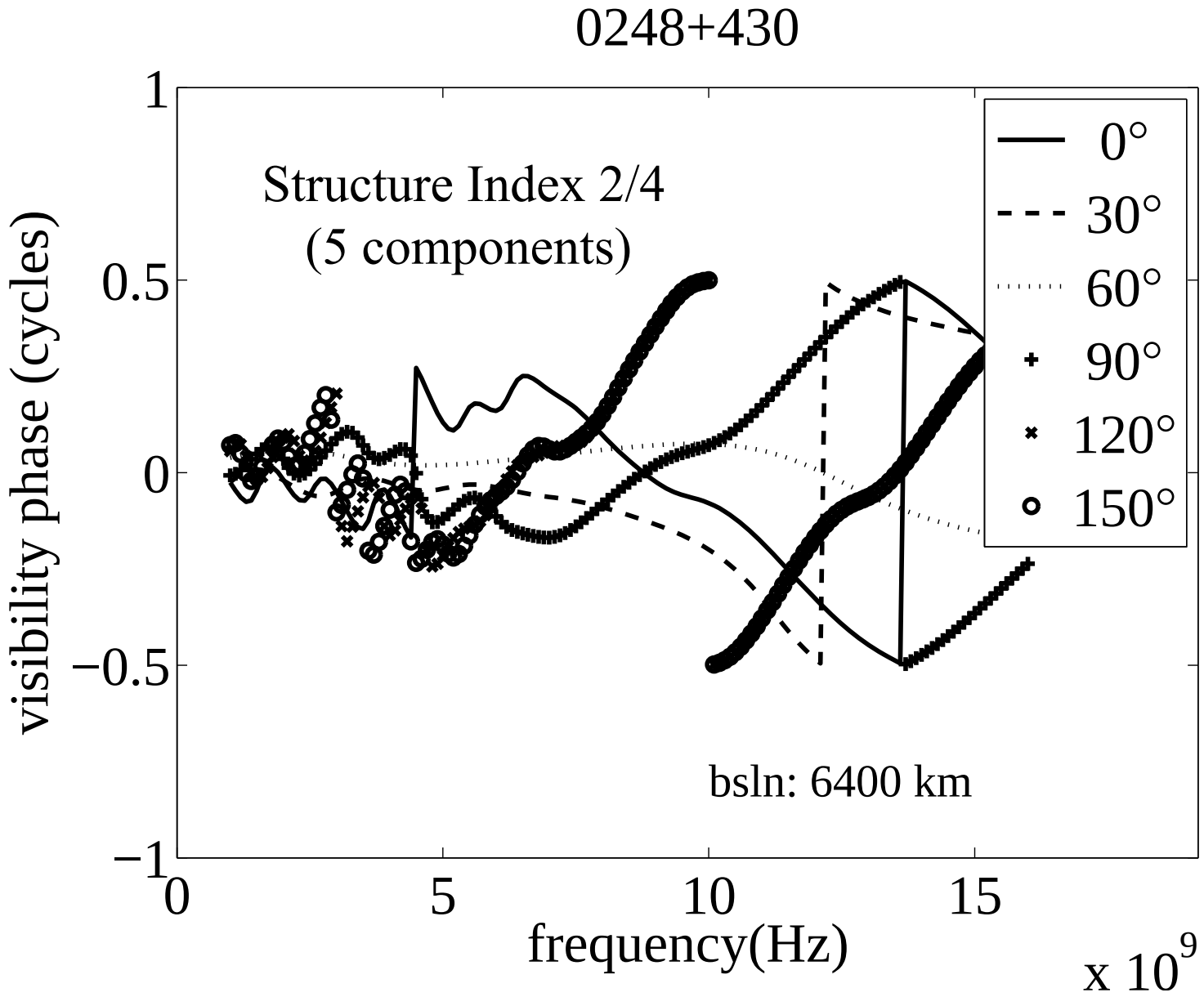
Main uncertainties

- Atmosphere effects
  - Turbulence in space and time
  - Mapping functions
- Source structure phase
  - Must correct for structure phase over frequency range ~2.2 GHz to 14 GHz.

Structure–phase vs frequency (simulation)

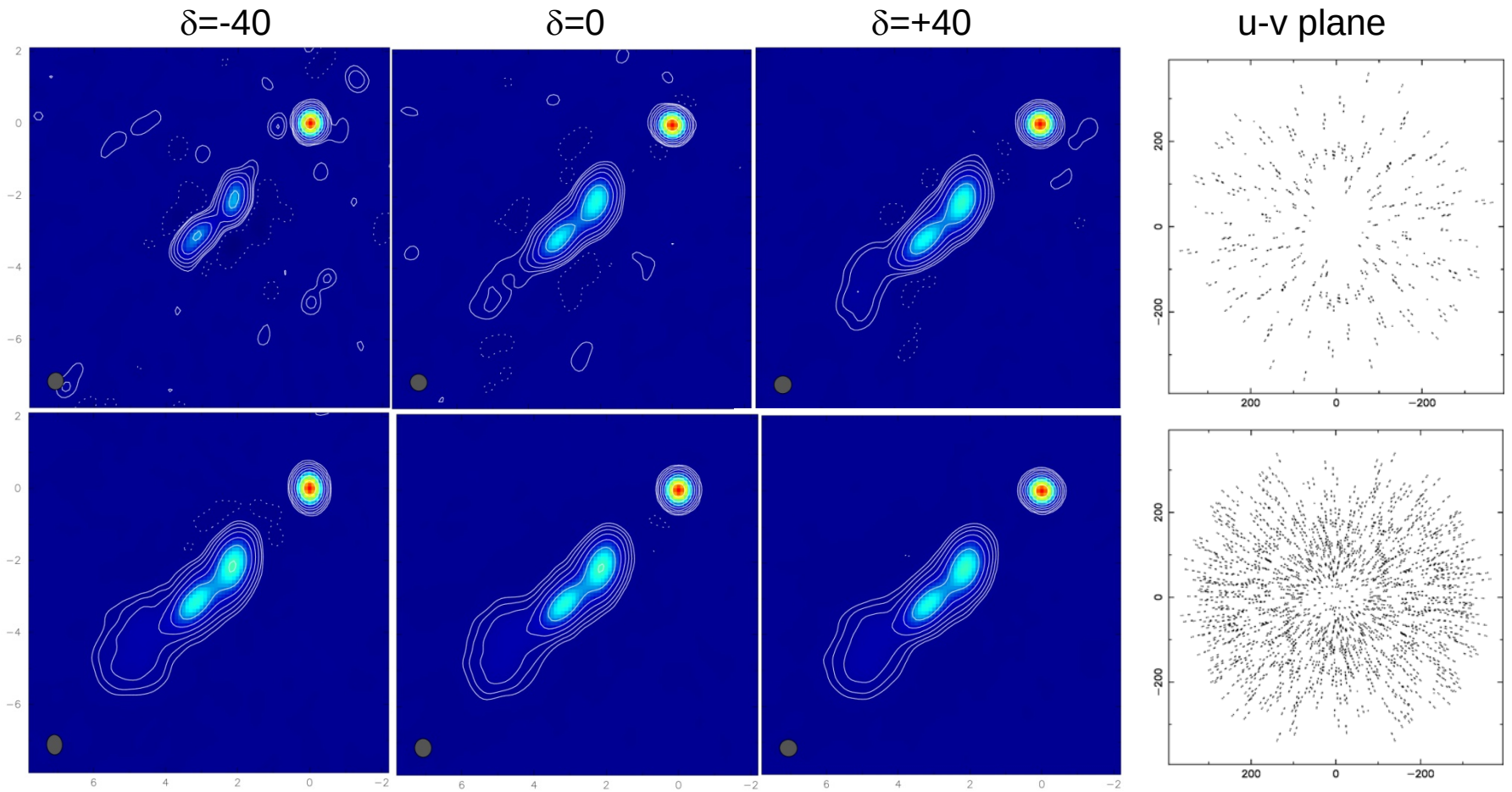
- Generate spectrum from 1 GHz to 15 GHz from S and X band maps (Fey and Charlot 2000) and approximated component spectra
- Calculate complex visibilities as function of frequency for 6400 km baseline at various orientations


0149+218
Structure Index 2/2
(6 components)
0°
30°
60°
90°
120°
150°
bsln: 6400 km
visibility phase (cycles)
frequency(Hz)
x 10^9
1
0.5
0
−0.5
−1
0
5
10
15


0248+430
Structure Index 2/4
(5 components)
bsln: 6400 km
0°
30°
60°
90°
120°
150°
visibility phase (cycles)
frequency(Hz)
x 10^9
1
0.5
0
−0.5
−1
0
5
10
15

Recovered source structure

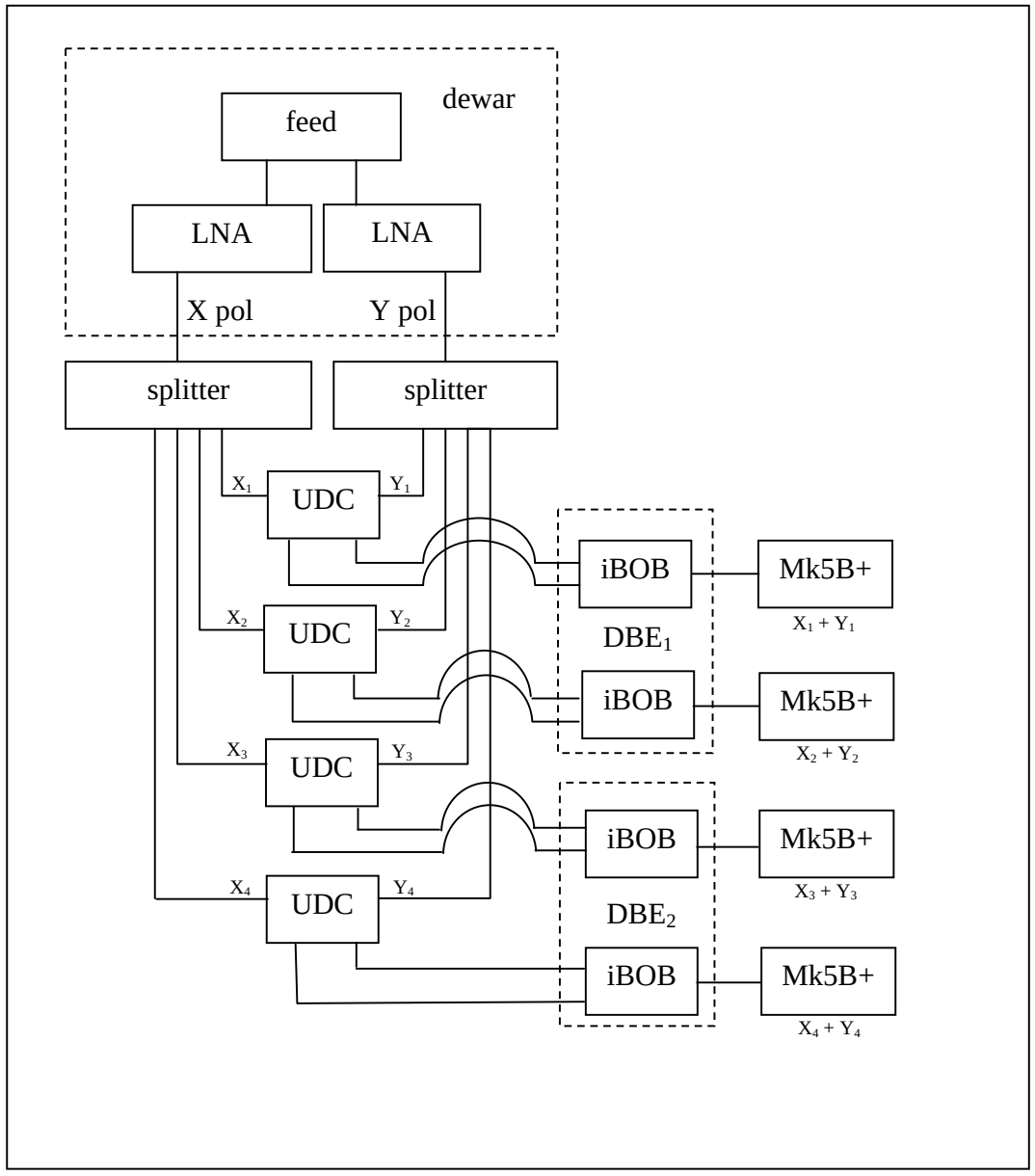
(Colliaud and Charlot 2008 IVS GM)



VLBI2010 Broadband Demonstration

- Antennas - Westford 18 m and GGAO 5 m

Feed
Phase cal injection
Low noise amplifiers
} Cooled (20K)
Optical fiber
Splitter to 4 bands
Flexible local oscillators
Digital back ends
Mark5B+ recorders



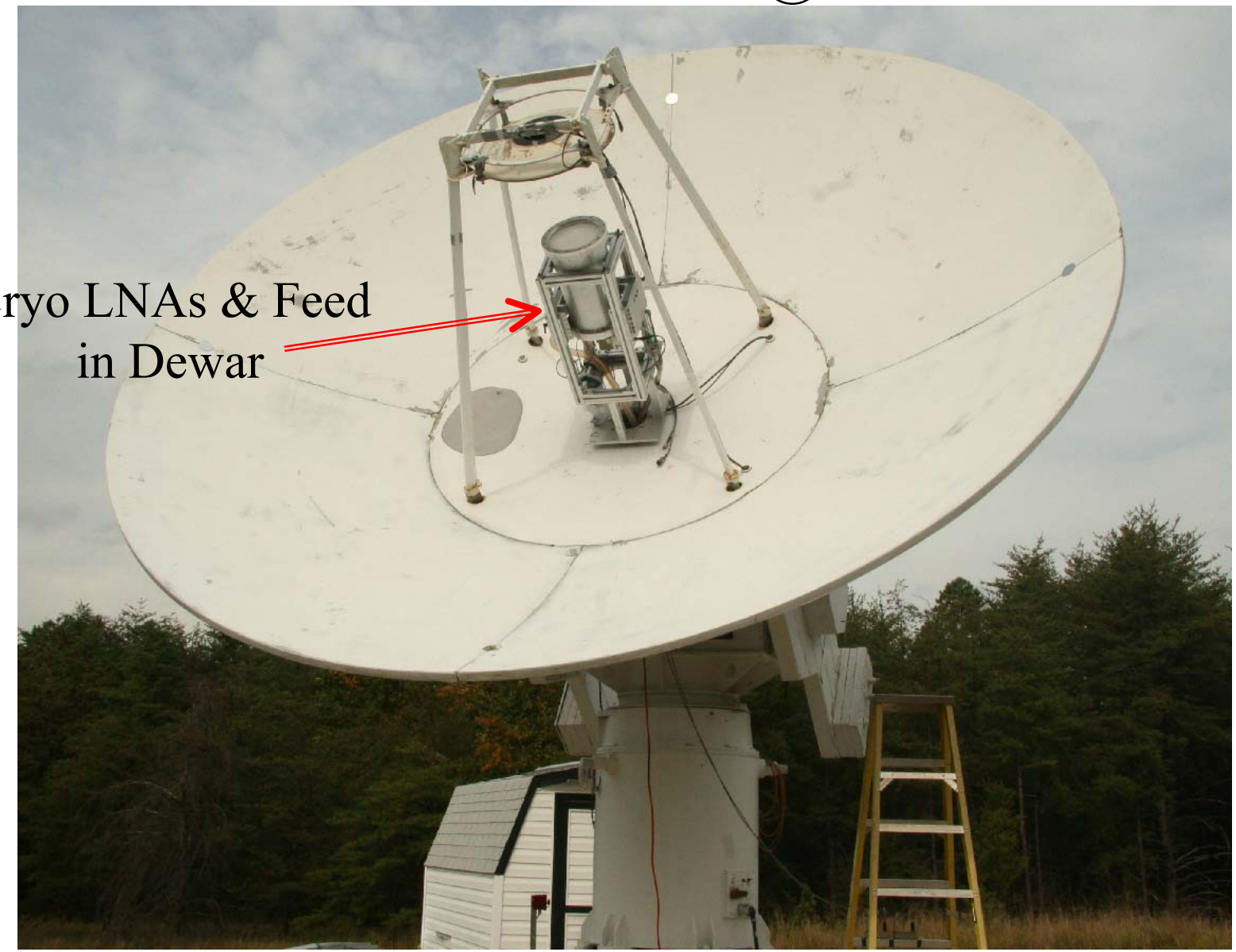
Feed and LNAs cooled to ~20K

Both senses of linear polarization used

2 gigabits/sec recorded on each Mk5B+

Total data rate: 8 gbps

MV-3 5M Antenna @ GGAO



8 gigabit/sec LOs and back end

Broadband Delay Team

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(in reverse alphabetical order)

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with thanks to Sandy Weinreb and Hamdi Mani, Caltech

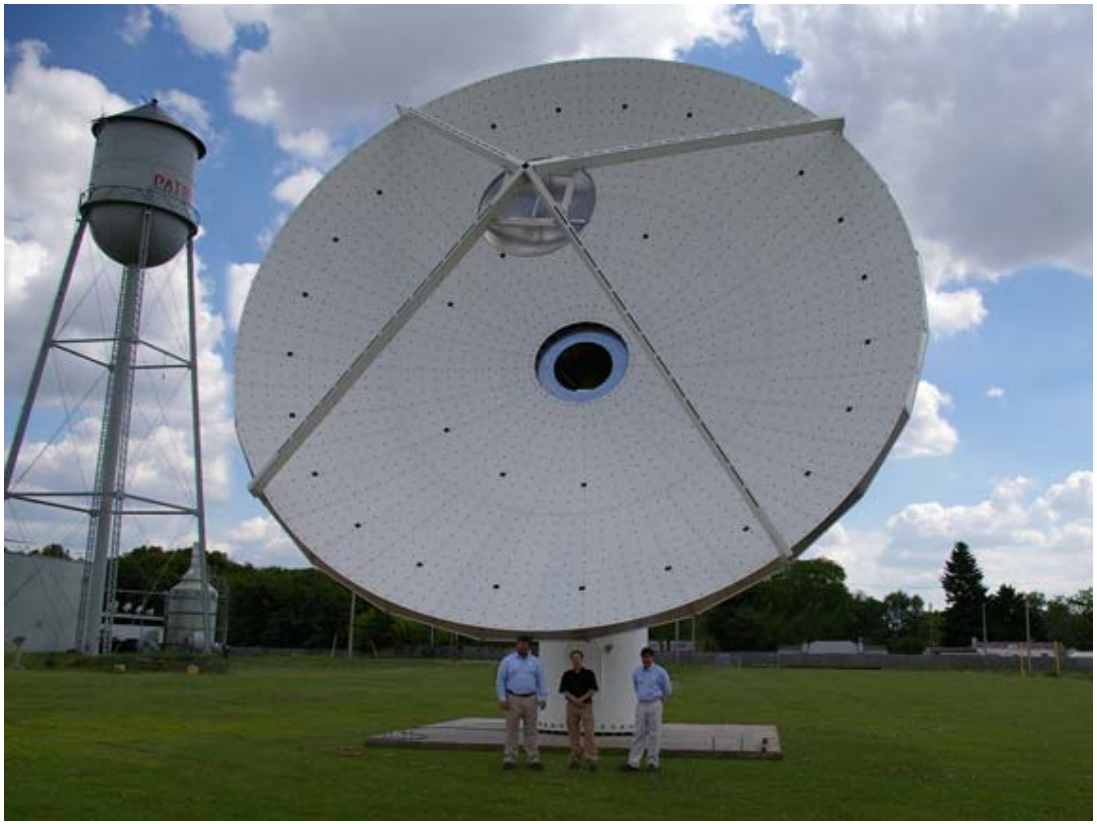
Status and plans - 2008 September

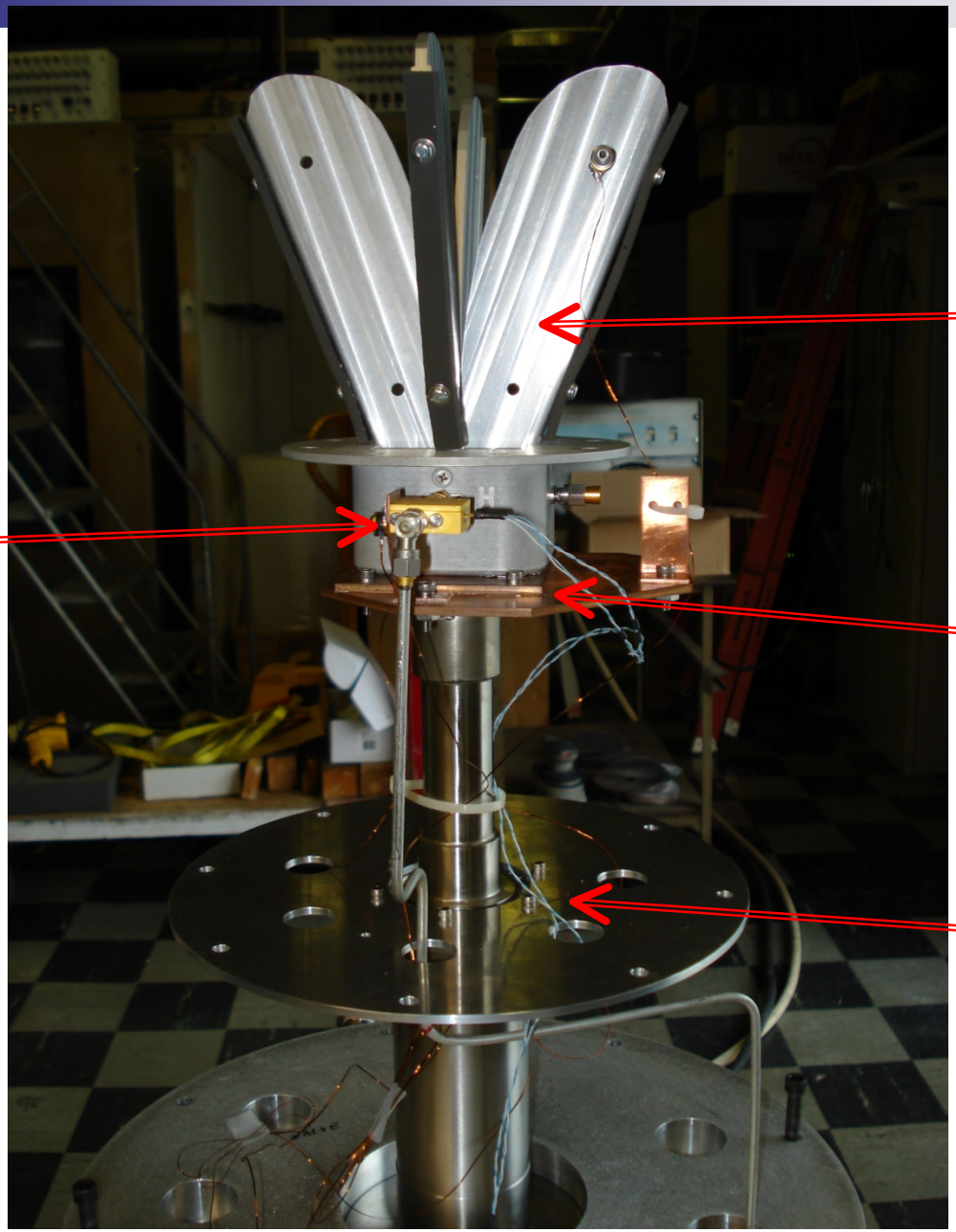
- Fringes have been demonstrated for X-band
- Both sites set up for four-band observation
- Phase cal testing in progress
  - Phase cal is critical for phase delay
- First multi-band observations planned for next two weeks

Next steps

- Set all four bands at same frequency
- Spread bands to demonstrate phase connection on simple source
- Look at effect of complex source structure
- Improve sensitivity of 5 m antenna
- Order 12 m antenna to replace 5 m antenna near Washington, D.C., probably similar to NZ and AuScope antennas.

12 m Antenna




Lindgren feed
(linear pol'n)
LNA
Cryo
Refrigerator
20K Station
77K Station