Design Considerations for the ngVLA Antennas

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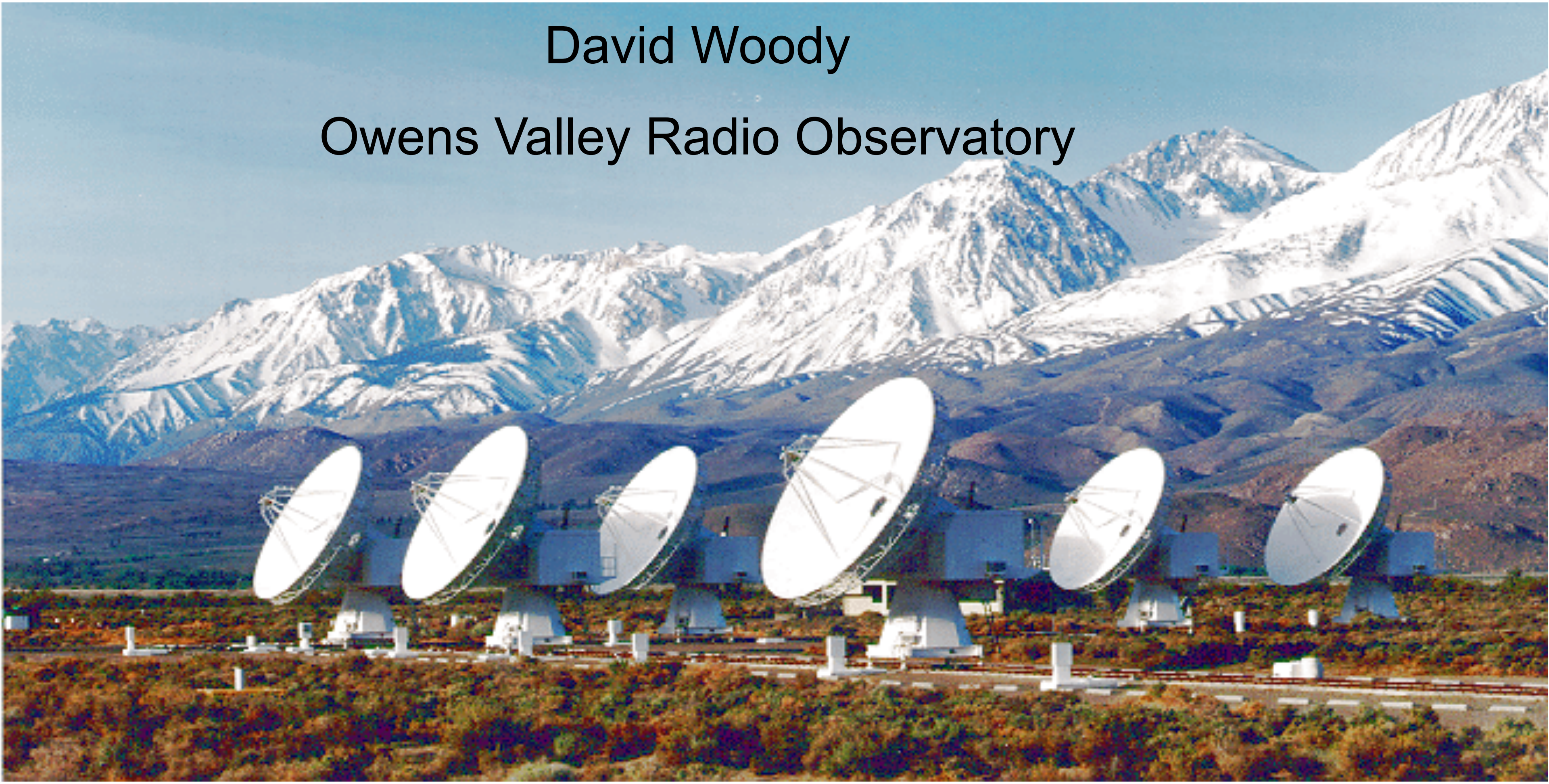


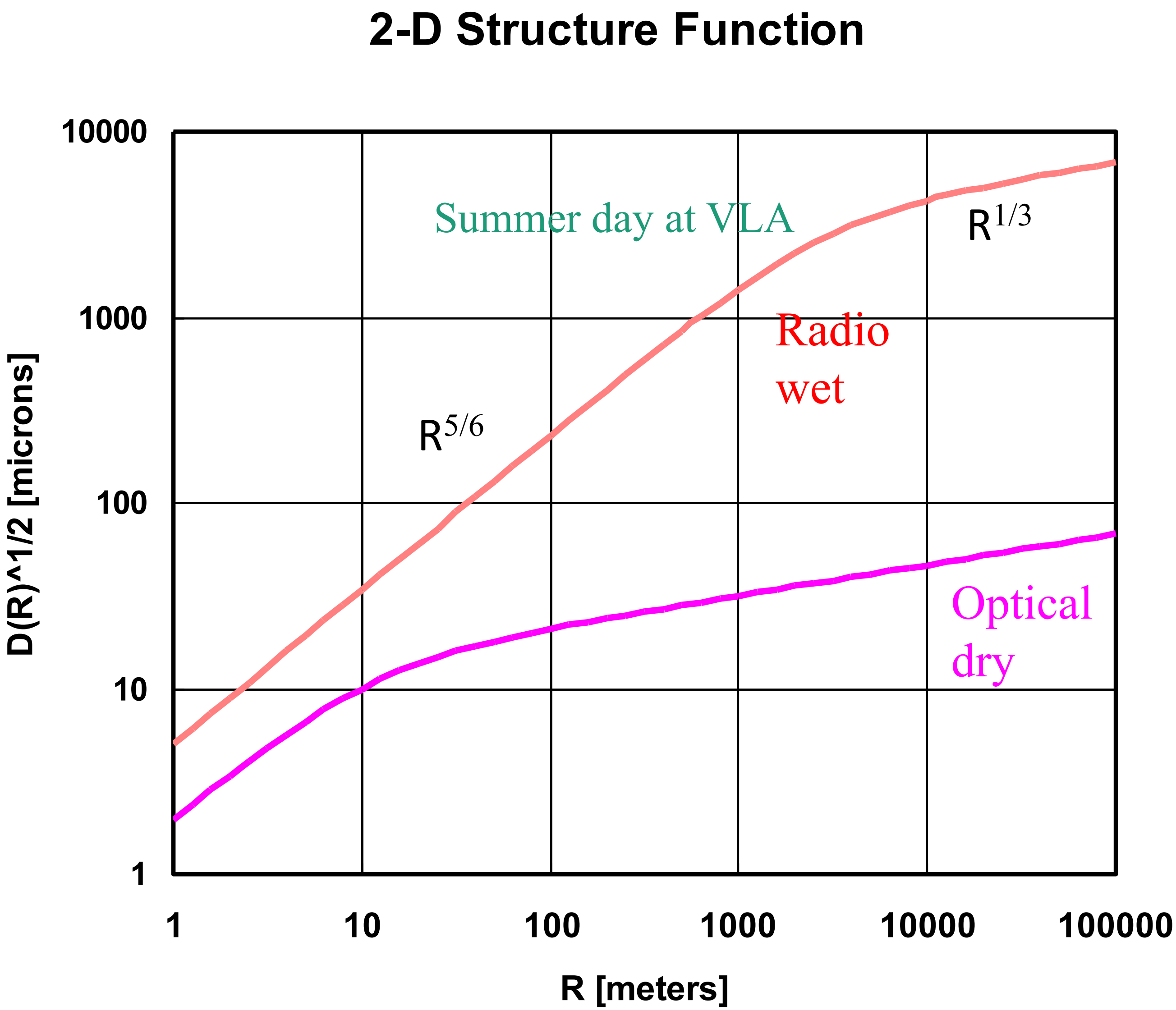
Antenna considerations

- Usual considerations
  - Collecting area
  - Antenna cost vs. diameter
  - Correlator cost vs. number of antennas
  - Infrastructure cost
- Usual performance criteria
  - Aperture efficiency
  - Pointing accuracy
  - Slew speed around the sky
  - Calibrator acquisition time
  - Wide field mapping

Atmospheric delay correction

- Self-calibration using a known source in the FoV
- Fast switching phase calibration
- Water vapor radiometer phase correction
- Calibration array

2-D structure function

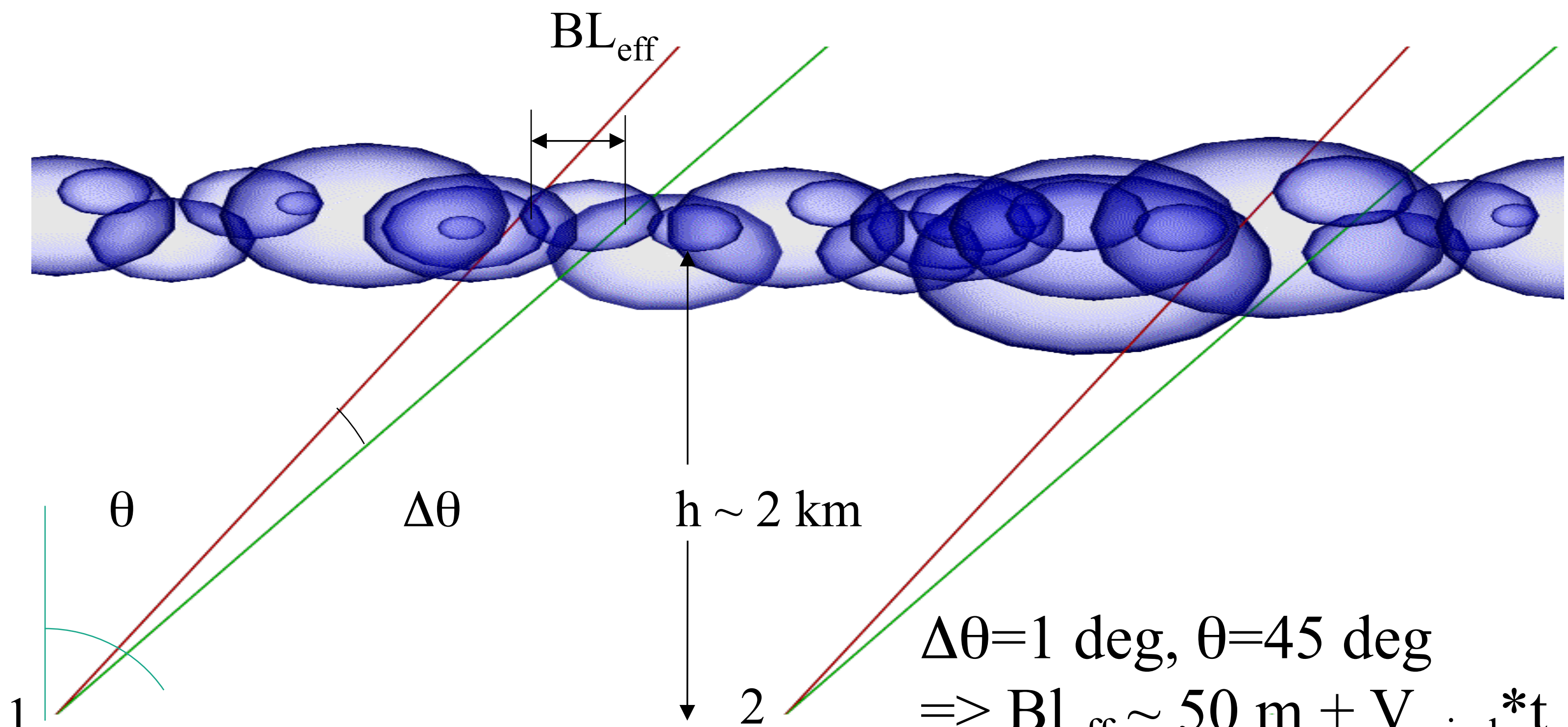


Fast switching

- Was proposed for ALMA and supported by a series of memos by Mark Holdaway and others
- Fast switching is a very good option for atmospheric phase correction for the ngVLA
  - Atmosphere phase correction is most important for the longest baselines where the delay changes are dominated by slow large scale structure in the atmosphere
  - Doesn’t require new equipment
  - **But does require antennas that can switch rapidly between calibrators and target source**
    - Also useful for wide field mapping

“Fast” calibration

Observe a nearby known “point” source to remove instrumental drifts and minimize the effect of baseline errors.
The telescope beams will pierce the water layer at different spots separated by $BL_{eff} \sim \Delta\theta\ h/\cos(\theta)$

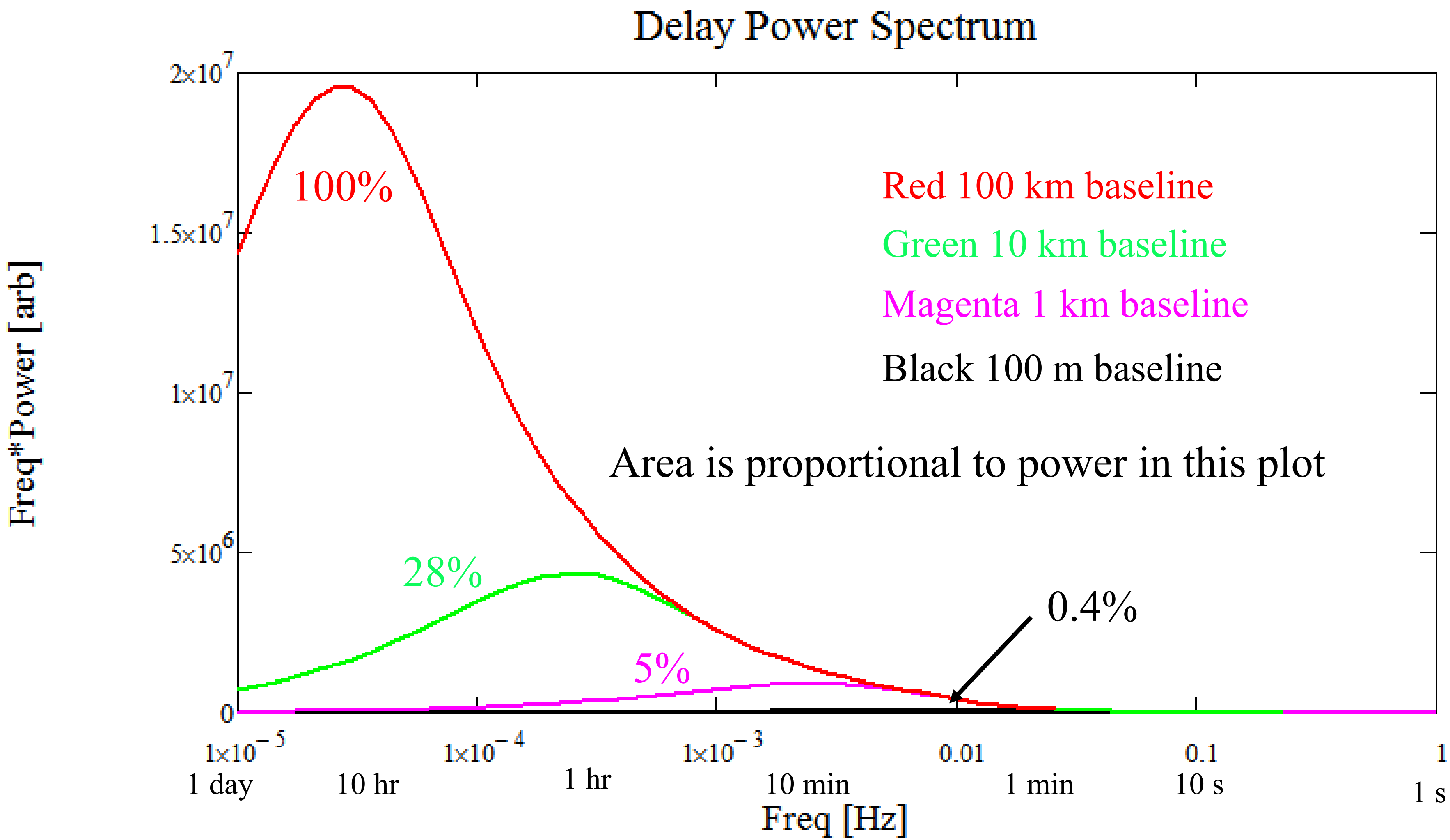


$\Delta\theta$=1 deg, θ=45 deg
=> $Bl_{eff} \sim 50\ m + V_{wind} * t_{cycle}$

Do this quickly on a nearby calibrator

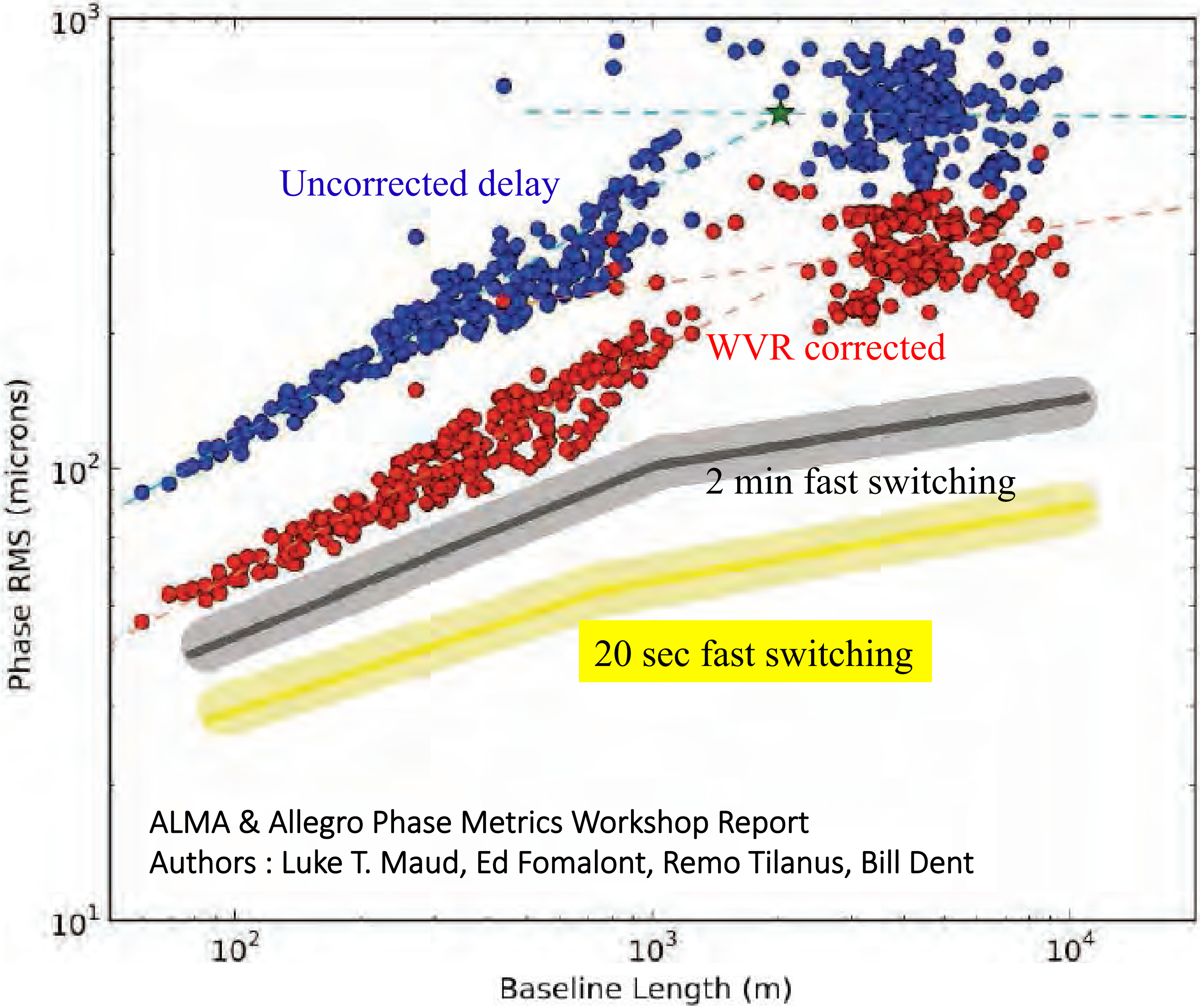
What an interferometer sees

Calculated power spectrum for 10 m/s wind and 1 km thick turbulent layer



The largest phase errors are on the longest baselines and are slow

ALMA Phase Correction



Fast Switching with the ngVLA

- Large collection area => nearby calibration sources
  - Measure phase in a few seconds (needs to be investigated for the ng VLA sensitivity)

- A nice goal: calibration cycle of 10-20 s within <2 deg

What does this mean for antenna design?

- Fast switching will be more difficult for larger telescopes
  - If the net collecting area is held constant then the required calibrator flux is the same and the distance to the requisite calibrator is the same
- Stiff structure with high resonant frequency
  - $f_{res} \sim 4\ (D/10m)^{-0.7}$
- Higher torque and faster drives
  - Moment of inertia will scale as $D^{\sim 5}$, mass $D^{\sim 3} \times R^2$
  - Torque and hence drive costs will scale as $D^{\sim 5}$

Other issues

- Drive costs could come to dominate the antenna costs which typically are assumed to scale as $D^{\sim 2.5}$
  - Very rough guess drive cost ~ \$100k $(D/10m)^{\sim 5}$

- Also impacts the power requirements

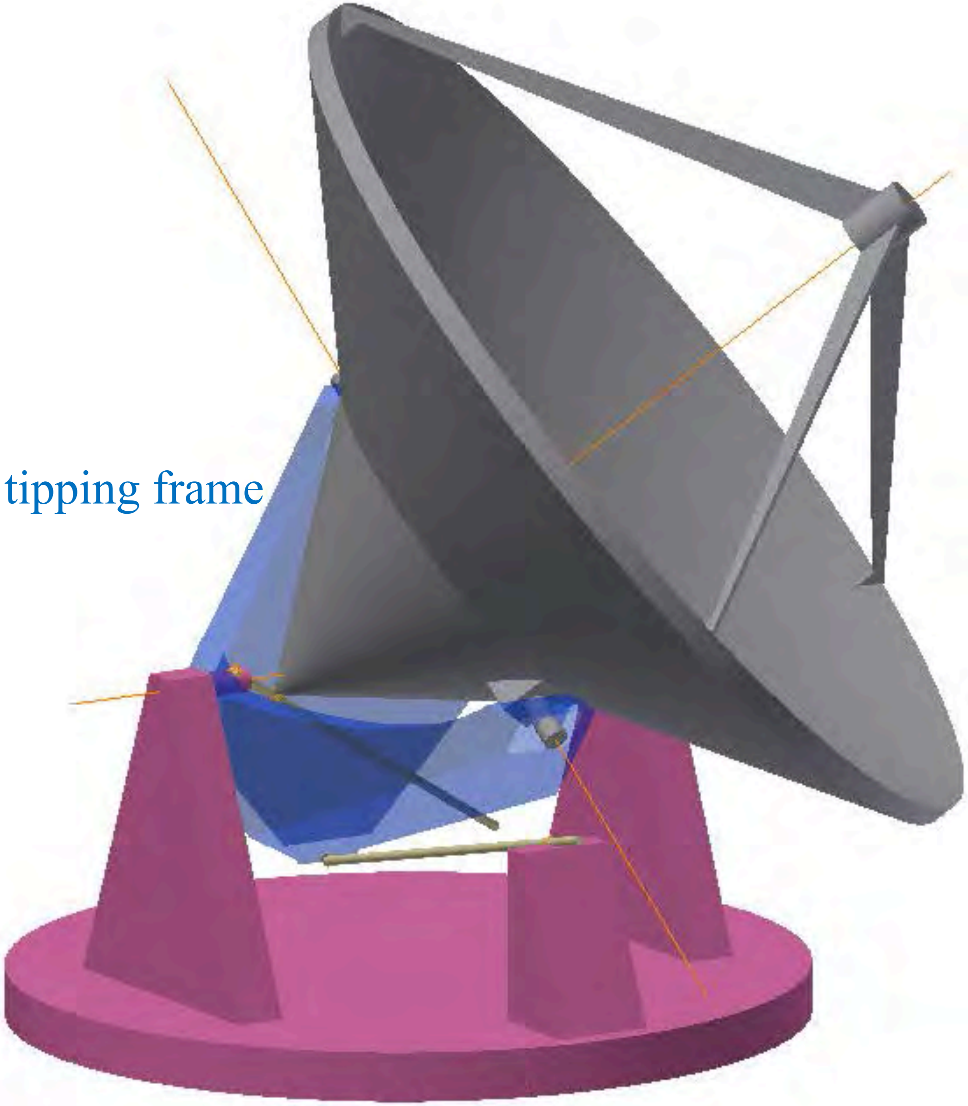
- Note that the pointing precision is also more stringent for larger antennas

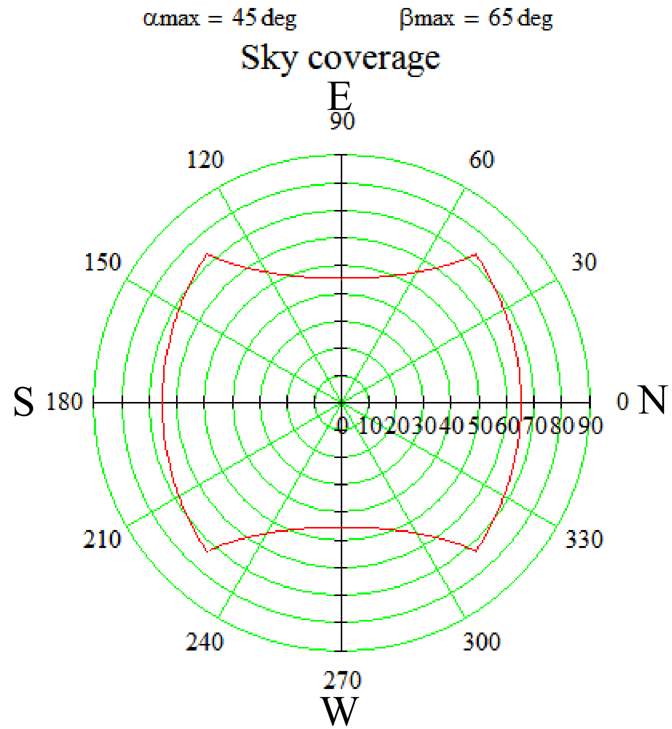
Do we need all sky coverage?

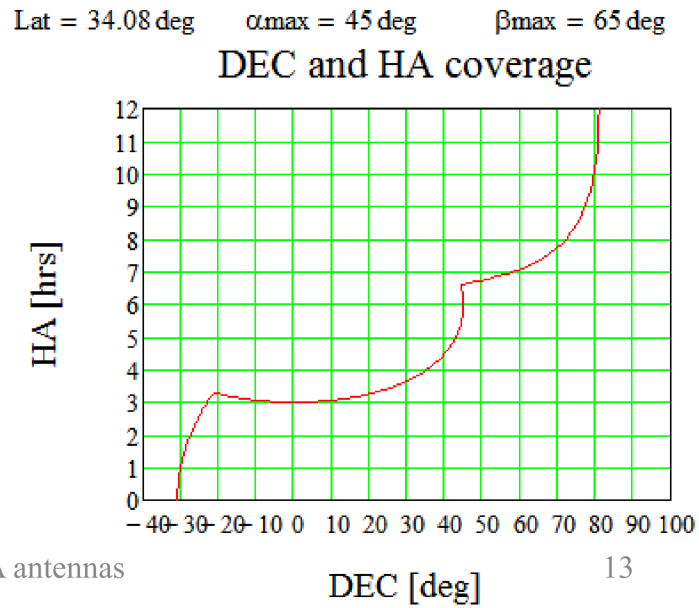
- One way to try to save costs is to consider whether full hemisphere coverage is required
- Do we need to track sources from horizon to horizon?
- Operating to low elevation often drives the mount design towards a less stiff and hence lower resonant frequency

Consider novel or crazy designs

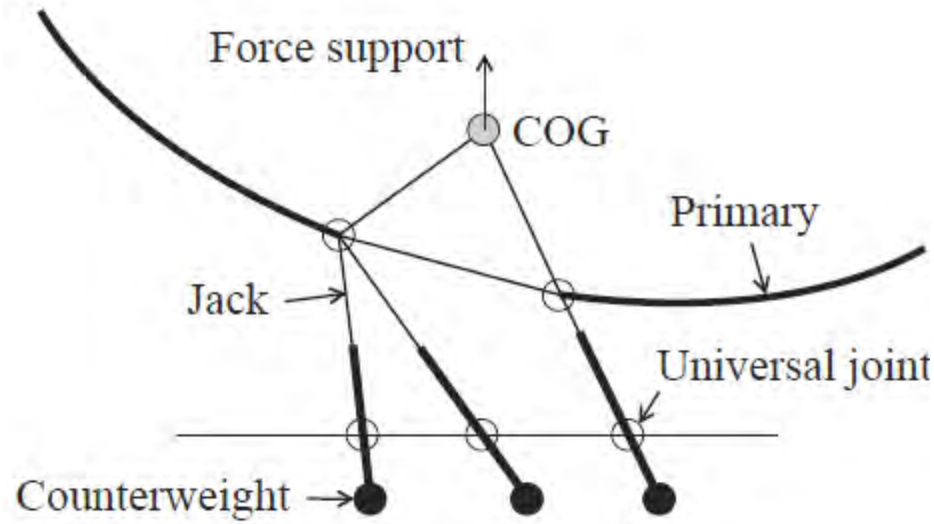
XY tipping frame

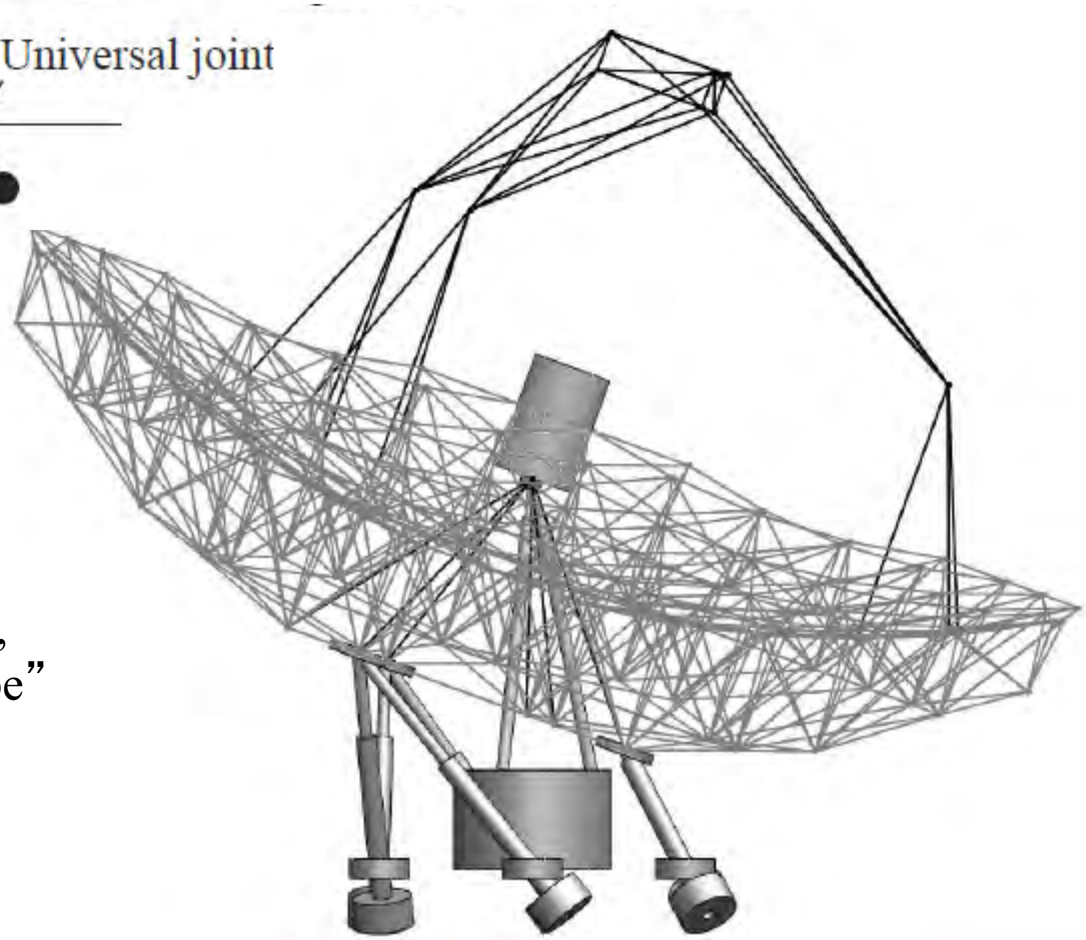






Hexapod type mount





“Inexpensive mount for a large, millimeter-wavelength telescope”
By Steve Padin, 2014

Conclusion

- Include fast switching in telescope specifications
- Carefully consider sky coverage in specifications
- Explore novel designs

- You will only build the telescopes once but the receivers, electronics and backend may evolve or be replaced during the lifetime of the instrument

- => more smaller telescopes