Netherlands Institute for Radio Astronomy

Redundancy in the SKA core ?

Background and discussion topics for the CTF/SWG joint session
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Redundancy in WSRT

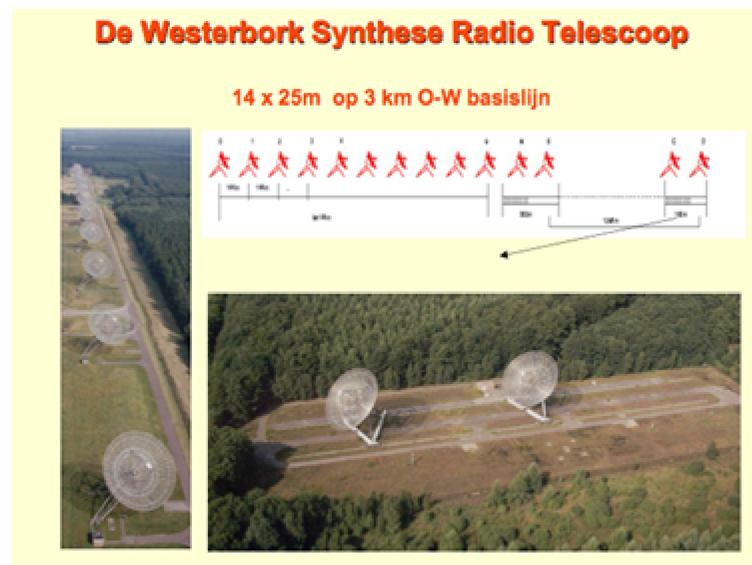
Redundant subarray: N_R=10 out of N=14 telescopes

Perfect EW-array (baseline ~ 1” off; 144m, accurate to ~0.5 cm)

Fractional uv-’loss’: 36/91 baselines (i.e. significant !)

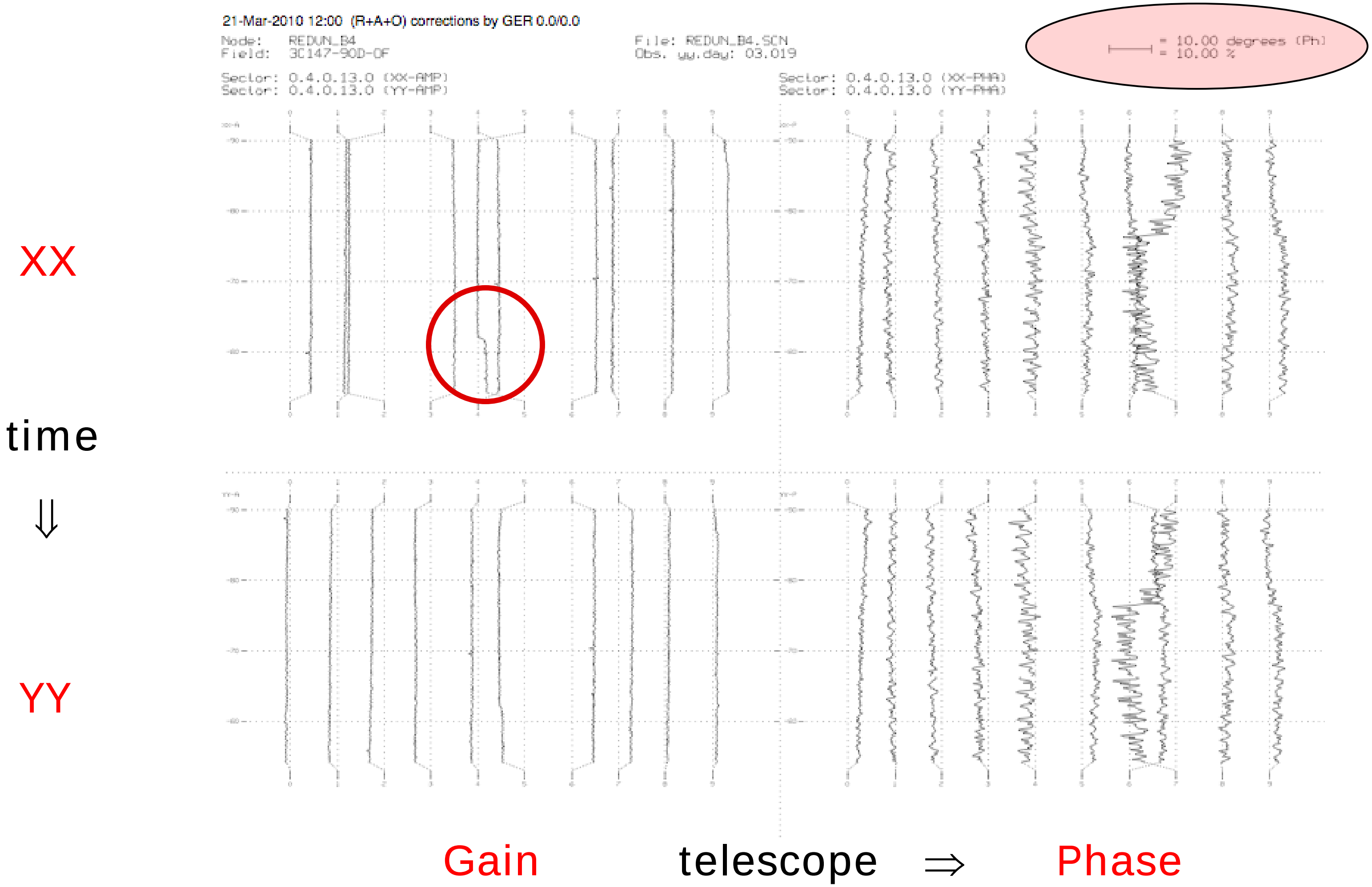
Use was very important for high DR work when selfcalibration/imaging still expensive *(e.g. Noordam & de Bruyn, Nature 1982)*

NB: redundancy in X,Y,Z required to get identical u,v AND w



Redundancy calibration implemented in Newstar (Brouw, Noordam)

An example of WSRT REDUN-output and its diagnostic content



Redundant baselines in the 5-km SKA core?

Why bother ?

Here are some reasons:

- Calibratability: # selfcalibration cycles and convergence
- SKA images are very complex: Galactic plane, filled images in all Stokes !
- Easy and fast real-time diagnostics on system malfunctioning, closure errors,..
- Save on computing costs? But they scale as (baseline)^3 (Cornwell, 2004)
- 2-D redundancy superior to 1-D case for high DR imaging
- Why not !?

NB: WITHIN (regular) Aperture Array stations use of redundancy is obvious

(e.g. in LOFAR HBA-stations, see Noorishad & Wijnholds poster)

1-D versus 2-D redundancy

Calibration steps in 1-D East-West array:

1) make redundancy solution per snapshot ($< t_{coh}$)
2) form an image from the many perfect 1-D snapshots
3) make model and 'align' snapshots on position and flux
4) solve for non-redundant telescopes
5) iterate over steps 2-4

In 1-D case convergence is very slow if significant G/Ph drifts occur during synthesis time AND the dominant source(s) is resolved at the PSF-scale. It is very easy in pointsource dominated fields (like 3C147, see Smirnov talk in afternoon)

Calibration steps in a 2-D redundant SKA-core array (N_R and N_{NR})

1) make redundancy solution, for redundant subset N_R
2) image, create model, 'align' perfect snapshots (= centre position and total flux)
3) solve for non-redundant telescopes N_{NR} (several fast approaches possible…)
4) make final image with full telescope set

A simple proposal (following Bolton et al, memo-Jan10)

Define a regular 2-D grid for all N_R stations (or even all stations)

Put fraction f_R of dishes/stations on a sub-grid with redundant baselines but extending over 5-km core. A fraction $f_R=0.2$ could already be sufficient (TBD)

A very simple thought experiment (Jaap B.) has e.g. $N_R=400$ on a 20x20 regular grid spreading across whole core

NB: The fractional loss in uv-coverage will be $< 1-(1-f_R)^2$, but note that the sample density per uv-cell is >>1 anyway, hence only slight loss of sensitivity !

The subset of baselines involving redundantly calibrated stations can then be used to **perfectly image** the FOV at full core-resolution but still with relatively high sidelobes.

Bringing in the large non-redundant subset, and improve the sidelobe level, can be done using a variety of fast methods: e.g.

- a MVDR beamformer technique to isolate brightest source (Stefan W)

Some discussion issues

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- Fractional loss of uv-coverage and/or sensitivity
- Terrain flatness, acceptable deviations of perfect redundancy (e.g. Liu et al, 2010, astro-ph 1001.5268v2)
- Required accuracy depends on Baseline length and location of sources ($<\lambda/D$?)
- Compare Dish (N=1500) and Aperture Array (N=256 ?) cases
- Fast methods to calibrate the non-redundant subset
- Effects of small direction-dependent errors on redundancy calibration
- Cost of DDE's in the overall processing could dominate...

Important to remember that in the SKA 5-km core imaging:

- We are always classical-confusion-limited (~ 2048^2 pixels)
- All images are also 'filled' in ALL Stokes at $\nu < 1.5$ GHz (due to Galaxy !)

Some recommendations

Initiate program of simulations to:

- — determine acceptable fraction f_R
- — optimize locations of the redundant subset (given terrain-topologies)
- — investigate effects/mitigation imperfect redundancy (e.g. Liu etal, 2010)
- — assess possible savings (in computing, operations ..)
- — investigate effects of significant DD-effects (e.g. pointing, differences between stations) on all of the above
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Next stop: CALIM2010, ASTRON, Dwingeloo, 23-27 August 2010