Core-to halo ratio, station size and "sea(s) of elements"

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Outline

- Core-to-halo ratio
  - outer stations required for ionospheric calibration
  - outer stations required for imaging
- Station size
  - effect on psf sidelobe requirement
  - effect on ionospheric calibration
  - effect on observing capabilities
- Sea(s) of elements
  - effect on reconfigurability

Analysis of ionospheric calibration

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Analyses by Trott and Wijnholds answered the following questions:

- How many pierce points are required?
- How many pierce points are available?
- What is the SNR of those pierce points?
- How accurate can we solve ionospheric model parameters?

Key conclusions (motivated in the next slides):

- The current outer stations provide sufficient spatial coverage.
- We may want to move some antennas from remote sites to the core to enhance EoR/CD and pulsar science capabilities.

Ionospheric model per station

Wijnholds, SKA-low consultation, April 2015
Wijnholds, URSI AT-RASC, May 2015

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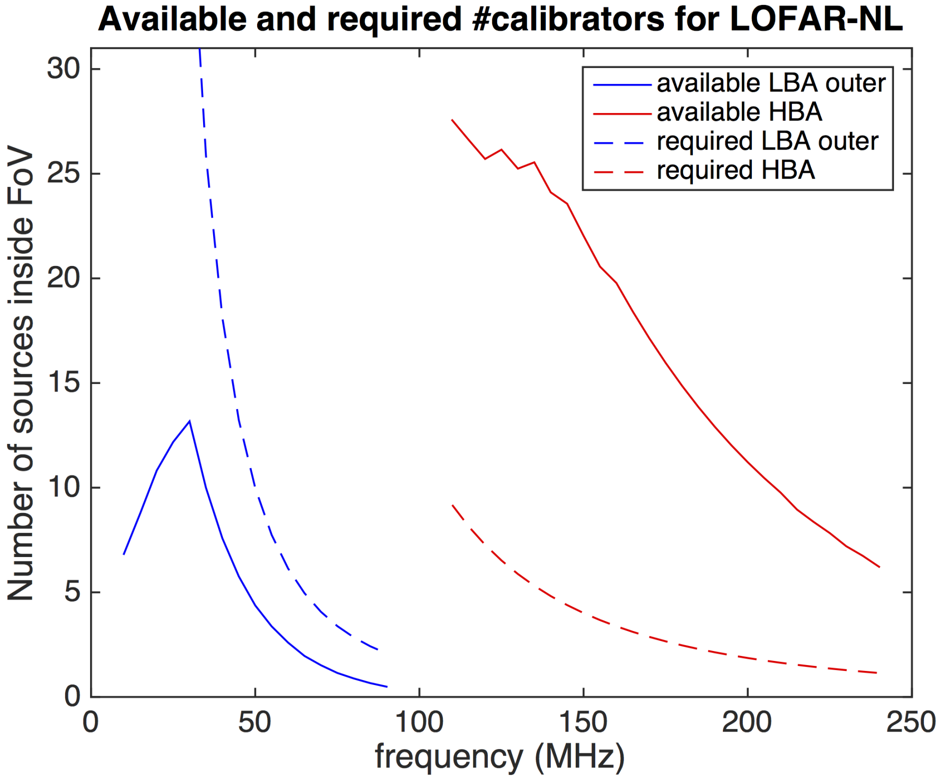
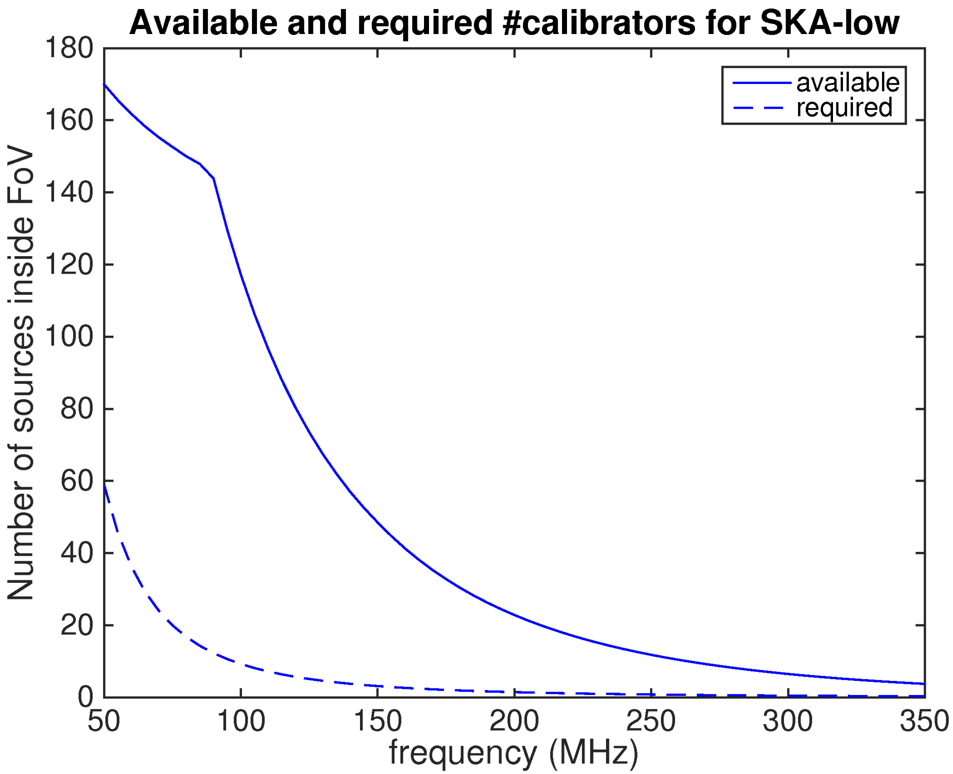
- For σ_{phase} = 0.3, we need SNR ≈ 2.5 (in 10 s, 1 MHz)
  - ☐ average #calibrators / FoV for LOFAR (l) and SKA-low (r)
- #required sources for fitting of 2-D parabolic model / patch
- TID model: h_{ion} = 200 km, ΔTEC = 0.1 TECU, λ_{TID} = 120 km)





Global ionospheric model
Wijnholds, SKA-low consultation, April 2015

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- Assumptions
  - radius of array: 50 km
  - height of ionospheric phase screen: 200 km
  - HPBW of station: 0.17 rad (35-m station at 50 MHz)
  - patch size as fraction of TID wavelength: 0.1066
  - TID wavelength: 120 km
  - 5 puncture points per patch
- we need about 551 puncture points for full array
- Proposed: 36 sites in outer are and a core
- Only 15 calibration sources needed (instead of 60!)
- SKA-low can detect over 160 sources @50 MHz: **large headroom**

Accuracy of global solution

Analysis by Cathryn Trott

- More than sufficient calibration sources available (as expected)
- **Relative error unnecessarily small** for 10 s time scales
  - Clustering gives significant improvement at 50 MHz
  - Clustering reduces number of stations in inner area

configuration	frequency (MHz)	#calibrator	amplitude (rad)	precision (rad)	rel. error (%)
Random51	50	44	0.27	$2.7 \cdot 10^{-5}$	0.01
	150	67	0.03	$8.3 \cdot 10^{-6}$	0.03
	250	31	0.01	$3.8 \cdot 10^{-5}$	0.4
Spiral94b	50	45	0.27	$5.3 \cdot 10^{-6}$	0.002
	150	69	0.03	$3.6 \cdot 10^{-6}$	0.01
	250	32	0.01	$3.5 \cdot 10^{-5}$	0.3

Discussion core-to-halo ratio

Observations:

- ionospheric calibration feasible with less sensitivity at outer sites
- EoR / CD and pulsar science benefit from more core sensitivity
- LOFAR-NL: 14 remote 41-m stations with 768 HBAs
- Survey speed (SS) ~ Ω $(A/T)^2$
  - Even with 768-element stations, $SS_{SKA} > 7\ SS_{LOFAR}$

Recommendations:

- develop outer sites with 768 antennas (instead of 1536)
- add 27,648 antennas to core area

Result: 79%/83% (V4D/V4A) collecting area in core (was 58%/62%)

Impact station size on PSN
Wijnholds & Bregman, URSI GASS, August 2014

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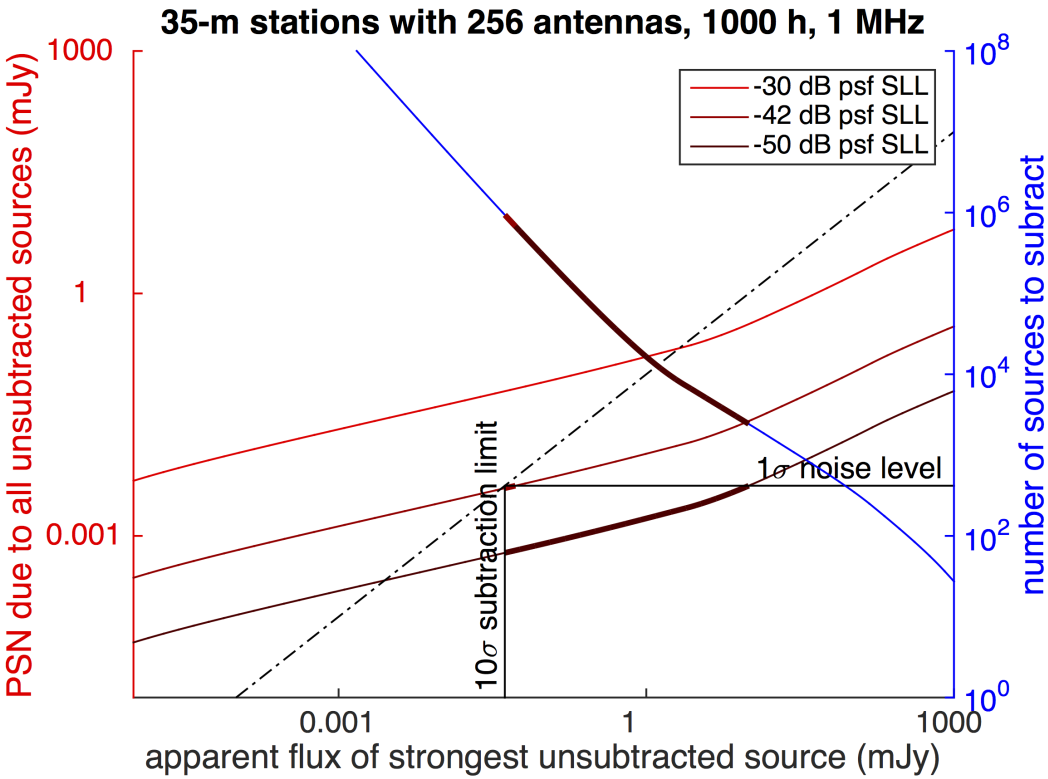
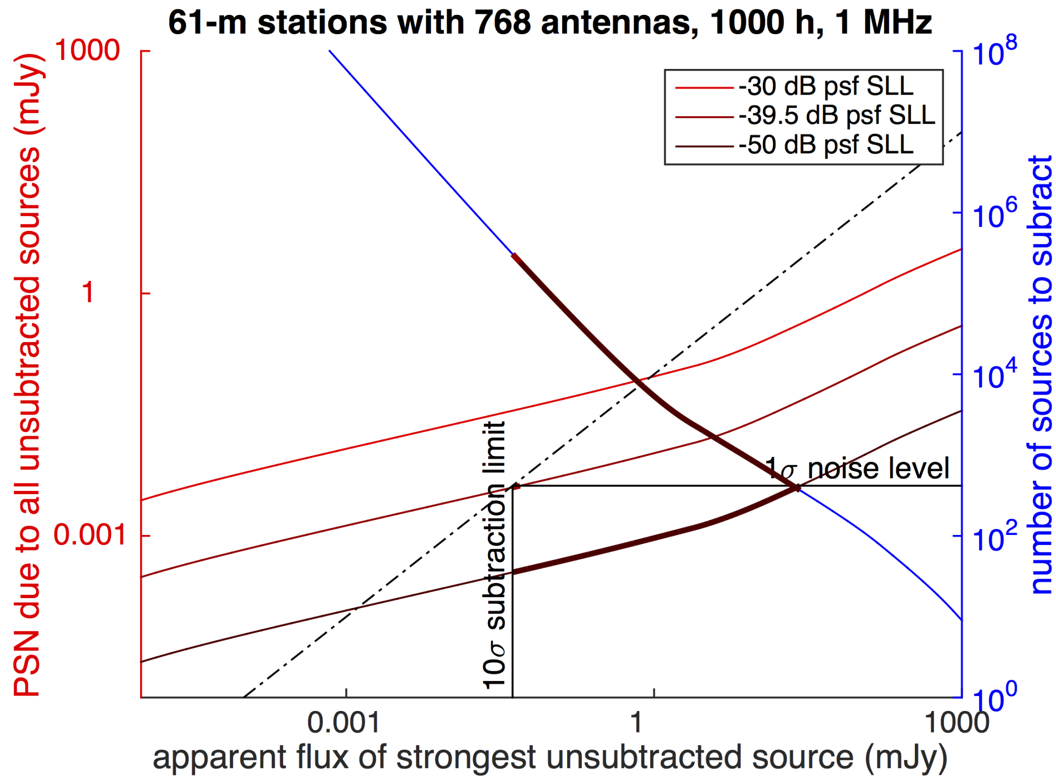
- Option 1: 35-m stations with 256 antennas
- Option 2: 61-m stations with 768 antennas (same antenna density)
- larger stations: higher psf SLL, fewer subtractions for same psf SLL





Discussion on station size

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- Large stations have smaller FoV
  - Puts lower requirement on psf SLL
  - Reduction of gridding costs (scales as D^{-2} to D^{-6})
  - Simplified ionospheric calibration (fewer patches)
- Large stations provide more reconfigurability
  - Use of substations
  - Tapering

Sea(s) of elements

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- In V4A, each station consists of 6 substations
  - Correlating all substations requires 36x larger correlator
  - Observing with all substations not likely
  - Observing with substations will be done at lower sensitivity
  - Hence, we will likely not use all antennas
- Large stations / sea of elements in the core can be subdivided
  - Optimal: 20% – 25% of antennas not used
  - Subdivision is not restricted to “hard-wired” stations
  - Sea of elements (e.g., 200-m “superstation”) can provide many different station sizes / short baseline lengths
- Naturally, one would not opt for clumpy station configuration

Conclusions / recommendations

- Configuration with 768 antennas on sites in outer area
    - 61-m stations have density of 256-antenna 35-m stations
- Add 27,648 antennas to core area
- Consider stations larger than 35 m, small seas of elements
    - Advantageous for imaging, calibration and reconfigurability
- Consider a sea of elements / superstation of ~ 200 m in center
    - Substation size ranging from few meters to station size
    - Large number of diverse short baselines
    - Stations can be tapered to match substation size
    - Overall sensitivity still limited by correlator capacity
    - Very reconfigurable system: robust to new insights