Computing Cost of Sensitivity and Survey Speed for AA and PAF systems

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Outline

- **Comparison between SKA subsystems** in terms of
  - point source sensitivity
  - survey speed
  - computing costs for correlation and imaging
- **Conclusions**
  - tuning of SKA design may improve system performance for the same computing costs
  - need for end-to-end system design including processing
  - need for algorithm development

Physical performance

- Point source sensitivity (A_{eff} / T_{sys})
  - system temperature

    $$T_{sys} = T_{rec} + (\lambda / 0.2008\,m)^{2.55} + (f / 10\,GHz)^{1.8} + 2.7\,K$$

  - effective area AA: constrained by physical area at low freqs.

    $$A_{eff,AA} = N_{stat}\ N_{elem}\ \min\{\frac{1}{4}\pi D_{Stat}^2 / N_{elem}, \lambda^2/3\}$$

  - effective area dishes

    $$A_{eff,dish} = \eta\ N_{dish}\ (\frac{1}{4}\pi D_{dish}^2)$$

- Survey speed

  $$SS = (A_{eff} / T_{sys})^2 \times FoV$$

Computing costs

Simple model focussing on

- correlator processing

$$P_{cor} = 4\ \Delta f\ \left(4 N_{stat}^2\right)$$

- image processing, particularly gridding. For 1 MHz:

$$P_{imager} = N_{op} \underbrace{\frac{10^5}{3} \frac{T_{obs} N_{stat}^2}{f_{min}} \frac{B_{max}^2}{D_{stat}^2}}_{\text{number of visibilities}} \left(\frac{\lambda_{max}^2 B_{max}^2}{D_{stat}^4} + N_{kernel}^2 \right)$$

SKA subsystems

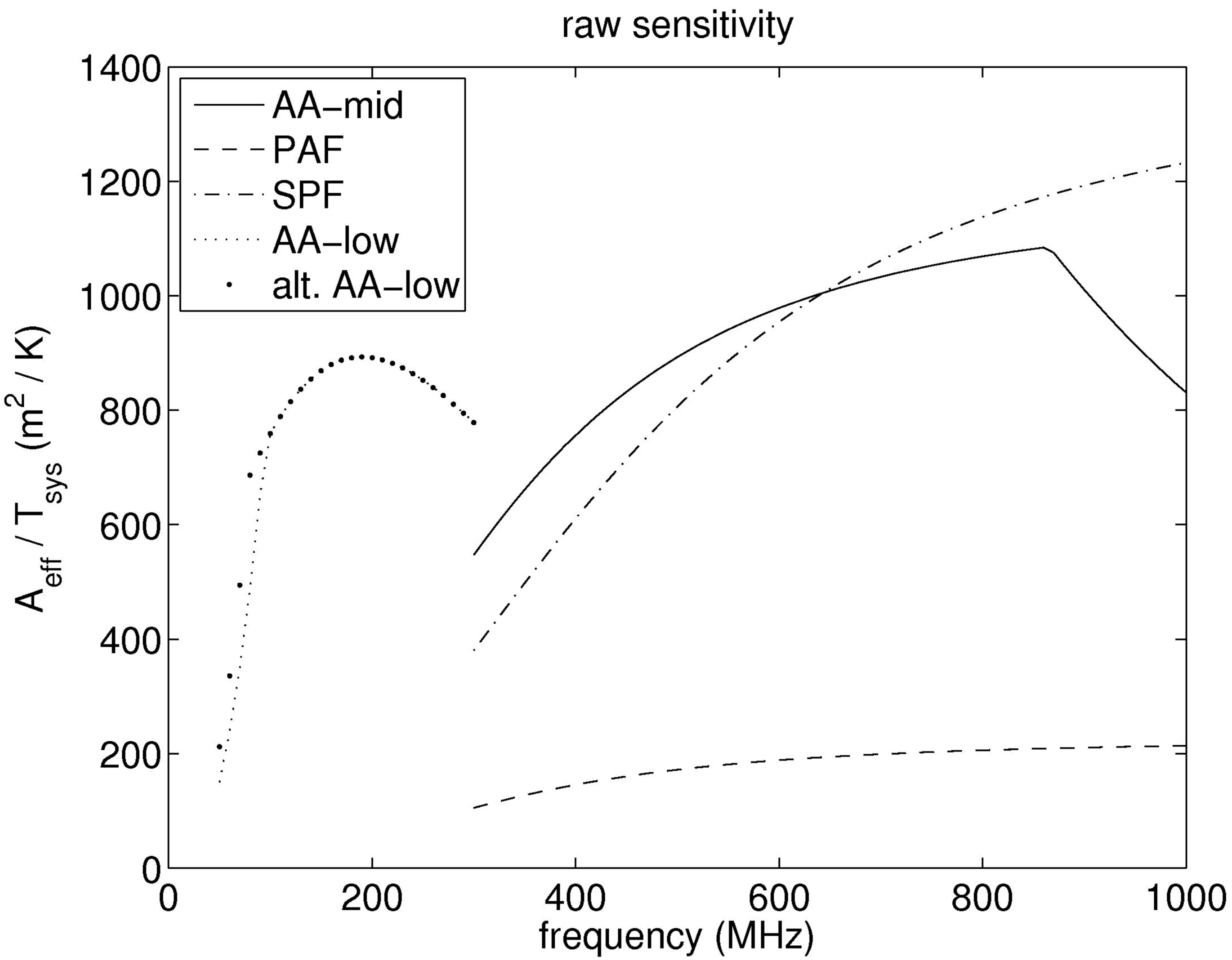
ASTRON

	AA-low	alt. AA-low	SKA-dish	SKA-survey	AA-mid
N_{stat}	911	280	254	96	64
N_{elem}	289	940	1	64	376
D_{stat} (m)	35	75	15	15	35
Freq (MHz)	50-300	50-300	300-1000	300-1000	300-1000
B_{max} (km)	50	50	200	50	50
T_{rec} (K)	50	50	20	50	50
BF bits	8	8	8	8	8

Sensitivity comparison

low: both systems provide equal sensitivity for most frequencies

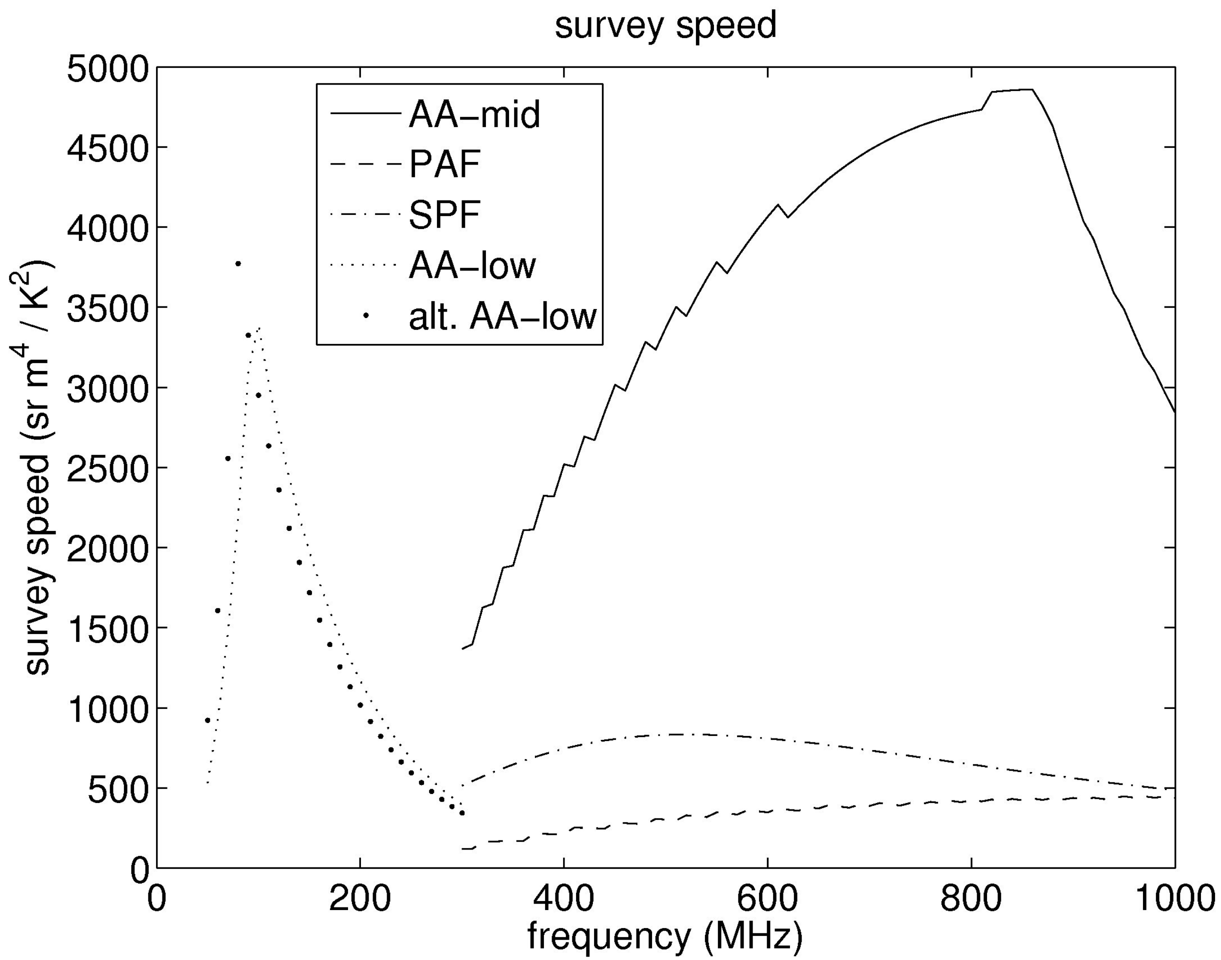
mid: SKA-dish and AA-mid perform factor 3-6 better than SKA-survey



Survey speed comparison

low: both AA-systems offer the same performance

mid: AA-mid factor 3-10 better than SKA-dish and SKA-survey



Computing costs 300 – 1000 MHz

ASTRON

	Tbps	Tops	Tbps	Pops
SKA-dish	5.7	723	28.5	**7000**
SKA-survey	31.0	**1486**	3.7	56.6
AA-mid	47.2	**1511**	0.7	**0.367**

- correlator load balanced between SKA-survey and AA-mid
- total correlator I/O similar for all systems
- **SKA-dish requires 7-Exa-ops imaging platform**
- **AA-mid significantly reduces costs of imaging**

Computing costs 50 – 300 MHz

	Tbps	Tops	Tbps	Pops
AA-low	7.3	**3320**	9.0	**169**
alt. AA-low	9.0	1254	0.7	**0.67**

- correlator size alt. AA-low comparable to SKA-survey
- **AA-low system requires biggest correlator of the SKA**
- **alt. AA-low system significantly reduces imaging costs**
- Can we balance science demands and computational feasibility?

AA-low core and remote stations?

- Dark ages science requires 35-m stations …
- … but only up to ~5 km baseline
- pulsar surveys require dense core
- calibratability requires larger stations on longer baselines
- idea: distinction between core and remote stations (like LOFAR)
  - core: radius of 3 km
    - 727 35-m stations with 289 antennas
  - remote: baselines up to 50 km (for comparison)
    - 46 70-m stations with 1156 antennas
    - remote stations form 4 beams to maintain FoV
  - practically same survey speed and sensitivity

Computing costs 50 – 300 MHz (2)

	Tbps	Tops	Tbps	Pops
AA-low	7.3	3320	9.0	**169**
alt. AA-low	9.0	1254	0.7	**0.67**
core / remote	7.3	3218	2.2	**7.7**

Introducing core and remote stations provides

- minor decrease in correlator compute load
- **factor 4 decrease in correlator output data rate**
- **factor 22 decrease in imaging compute load**

Computing costs analysis

- This presentation: very simplistic model
- DOME: working on more refined model
  - end-to-end: ADC → final data products
  - processing and data transport incl. energy consumption
  - based on current state-of-the-art algorithms
- upcoming algorithmic improvements
  - StEFCal (Stef Salvini et al.)
    - I/O intensive instead of compute intensive calibr.
  - snapshot imaging (MWA, Jaap Bregman)
  - w-snapshots (Tim Cornwell et al.)

Conclusions

- **tuning of SKA design may improve system performance for the same computing costs**
  - What is the added value of SKA-survey over SKA-dish?
    - SKA-dish provides similar survey speed
    - SKA-dish provides much higher sensitivity
  - AA-low design with core and remote stations
  - AA-mid array for 300 – 1000 MHz frequency range
- **need for end-to-end system design including processing**
- **need for algorithm development**