ASTRON & IBM Center for Exascale Technology / IBM ZRL
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Imaging with SKA-AAMID: modeling of computing power

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SKA-AAMID analysis goal

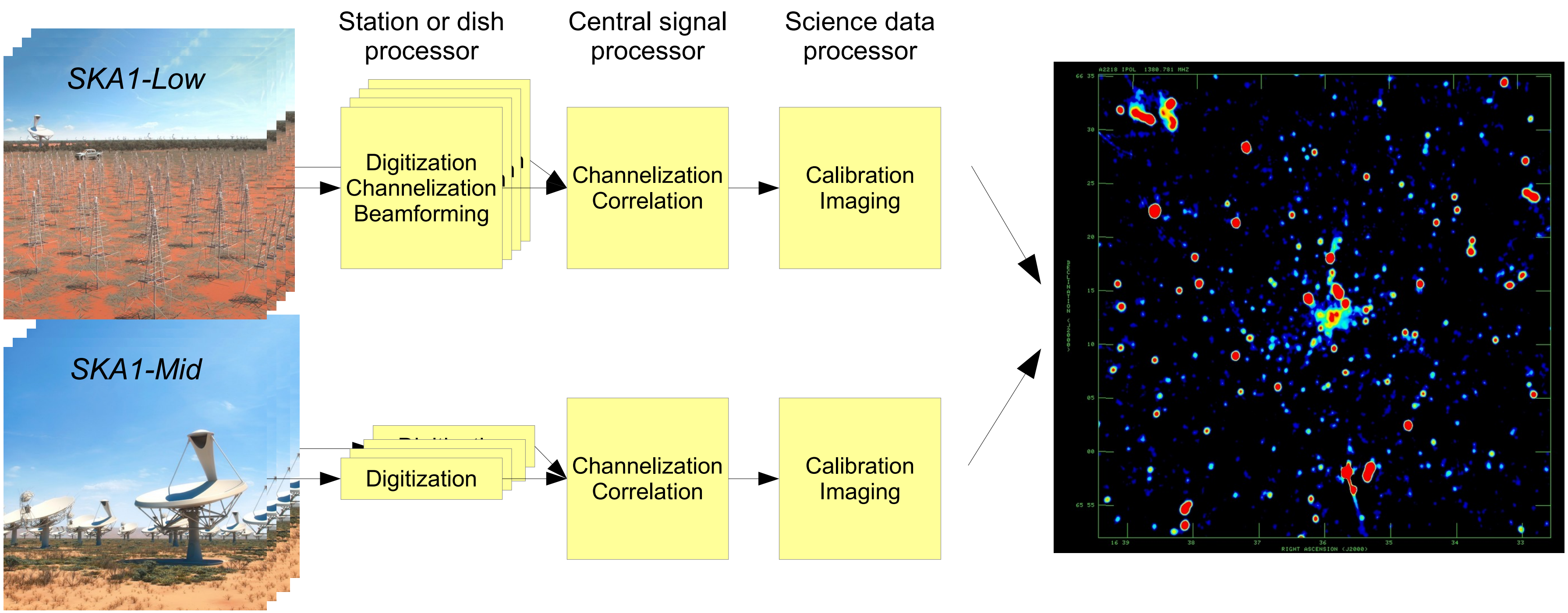
- Understand **computing distribution** for sky imaging for SKA-AAMID
  - Station processing
  - CSP
  - SDP
- Develop a **first-order power** model to understand power requirements
- Create a model to **optimize** the **SKA-AAMID system**
  - How to design the system to minimize processing cost in the **entire** chain?

Outline

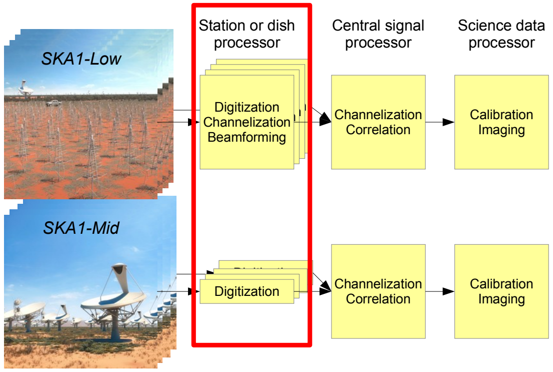
- Computing requirements analysis
- Station and CSP power analysis
- Conclusions

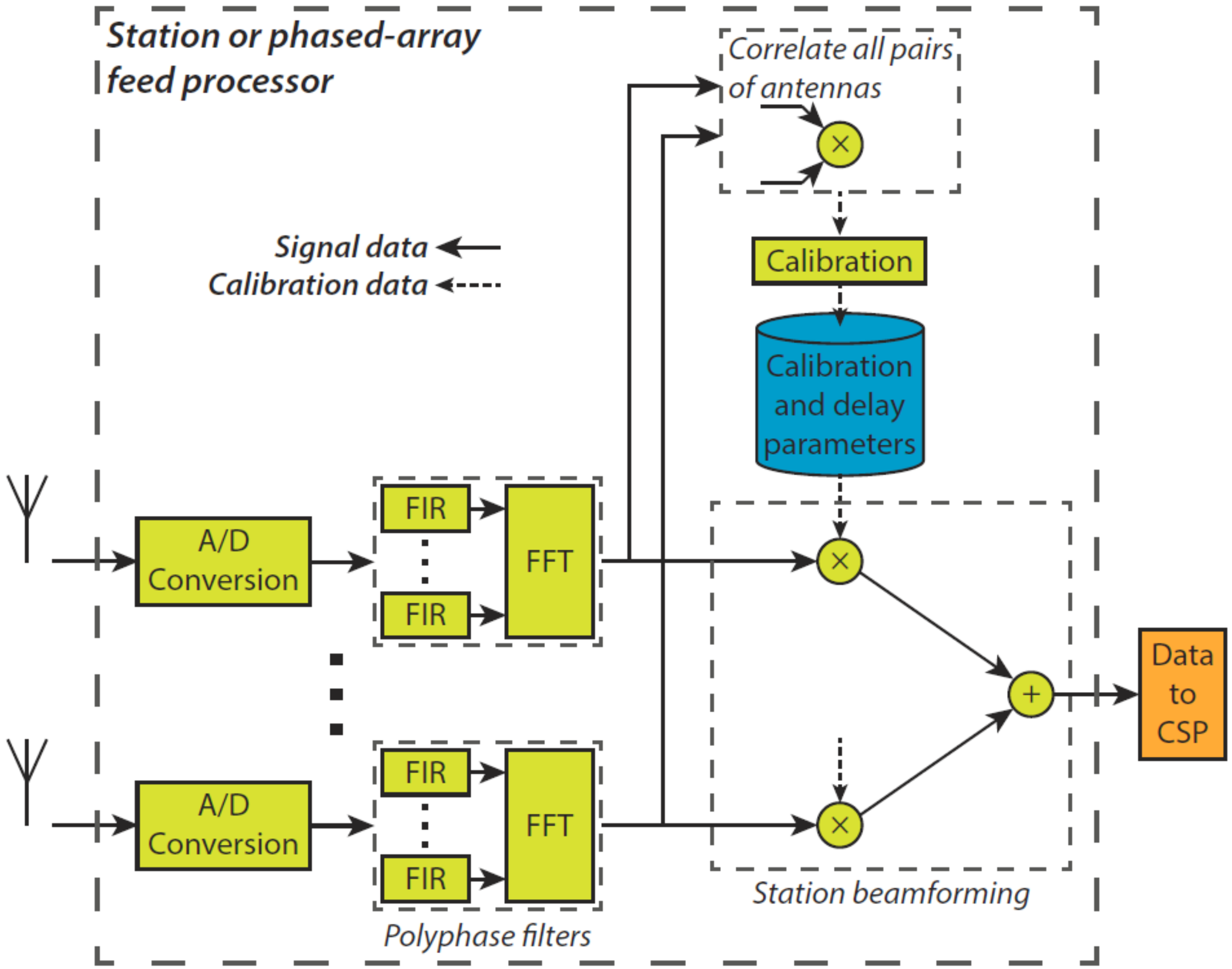
Computing requirements model based on SKA phase 1 work

- Model developed for SKA phase 1, based on LOFAR and other instruments
  - Close collaboration with SDP consortium
- Continuum and spectral line imaging
  - It is expected that for both we need to calibrate at full frequency resolution

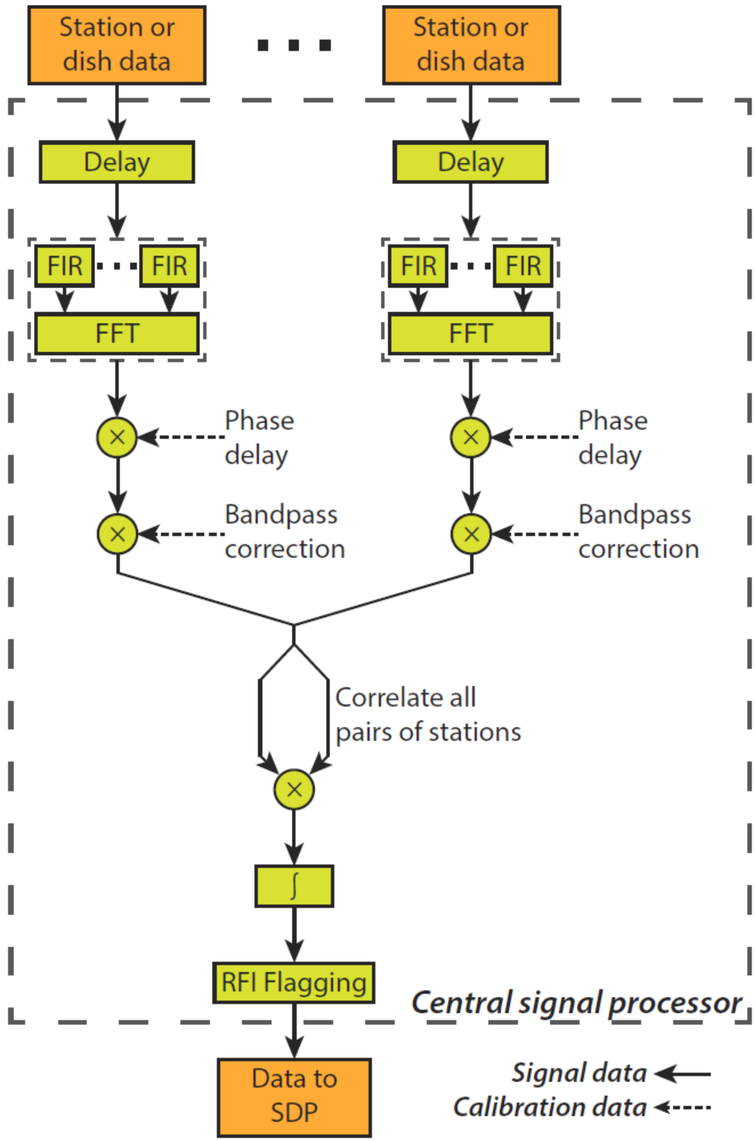


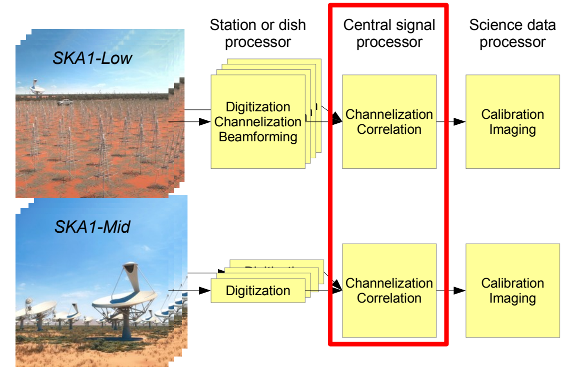
SKA station processing



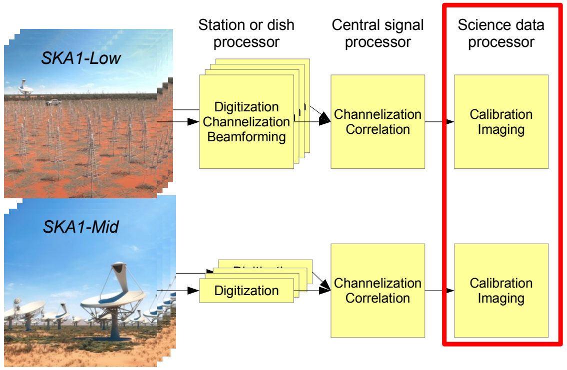


SKA central signal processor (CSP)

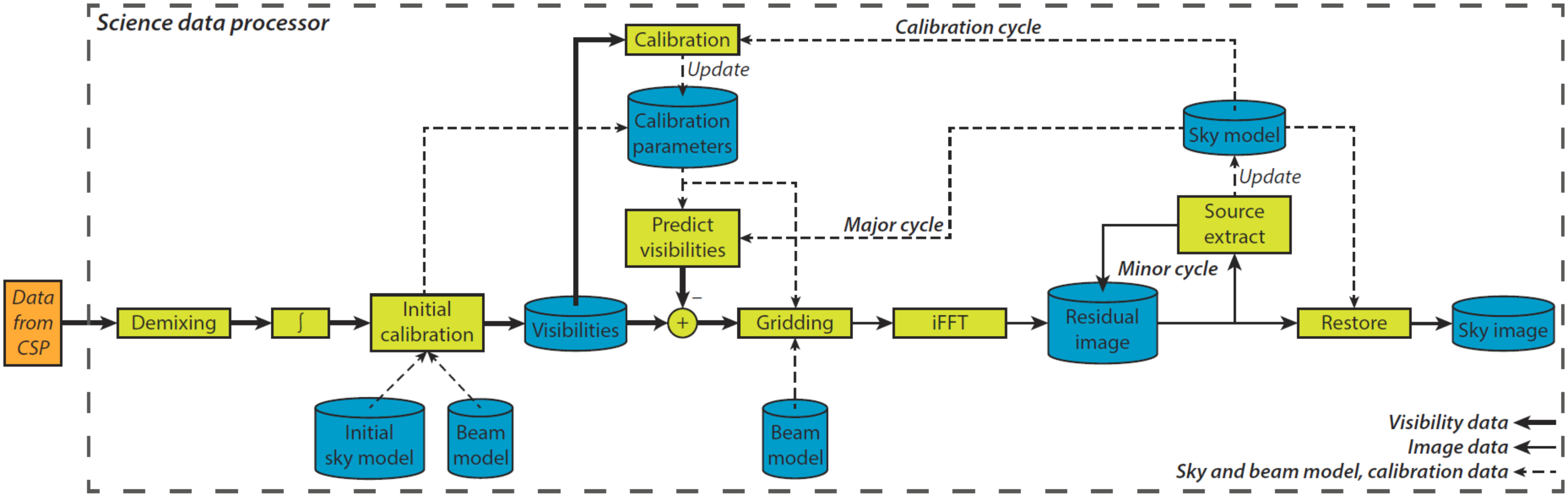




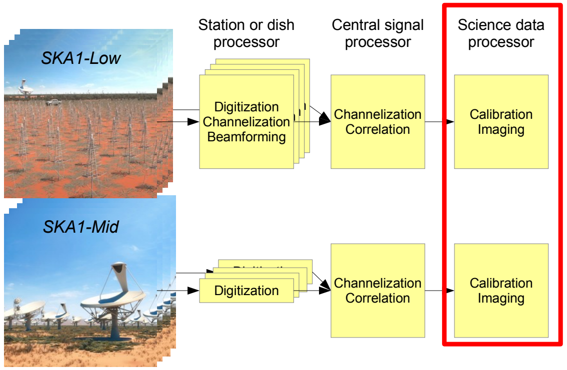
SKA science data processor (SDP)



- W-snapshots imaging



SKA science data processor (SDP)

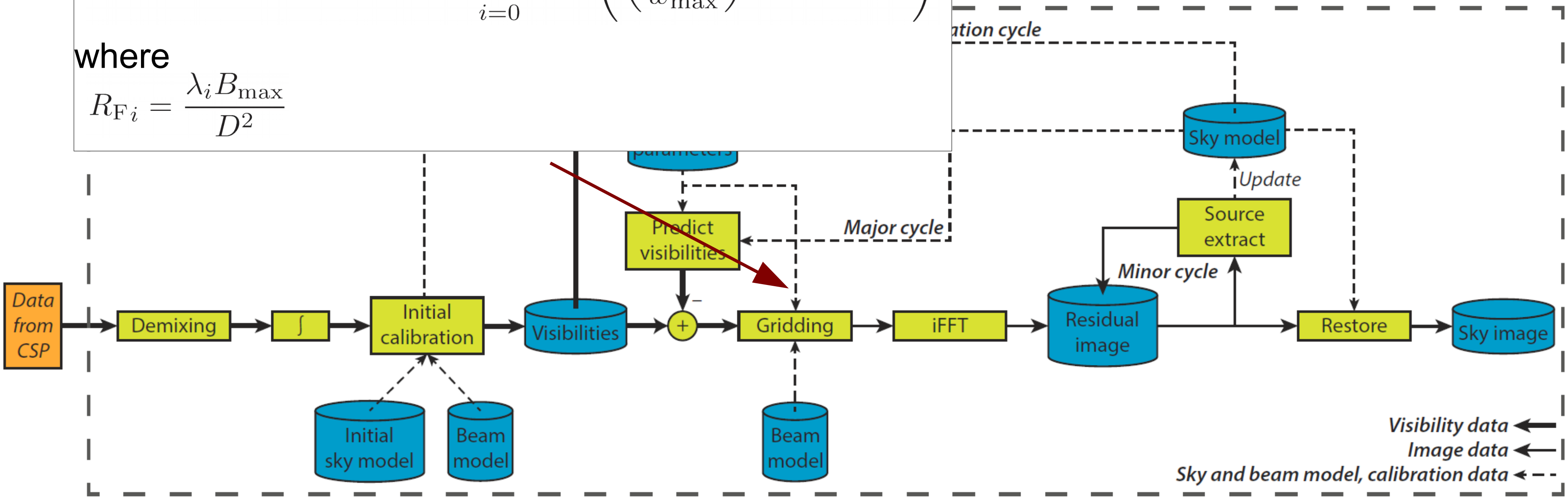


- W-snapshots imaging

$$C_{\text{grid}} = N_{\text{op}} 2 V_{\text{chan}} T_{\text{obs}} \sum_{i=0}^{N_{\text{image-chan}}-1} \left(\left(\frac{w_{\text{rms}}}{w_{\text{max}}} \right)^2 R_{\text{F}\,i}^2 + R_{\text{A}}^2 \right)$$

where

$$R_{\text{F}\,i} = \frac{\lambda_i B_{\text{max}}}{D^2}$$



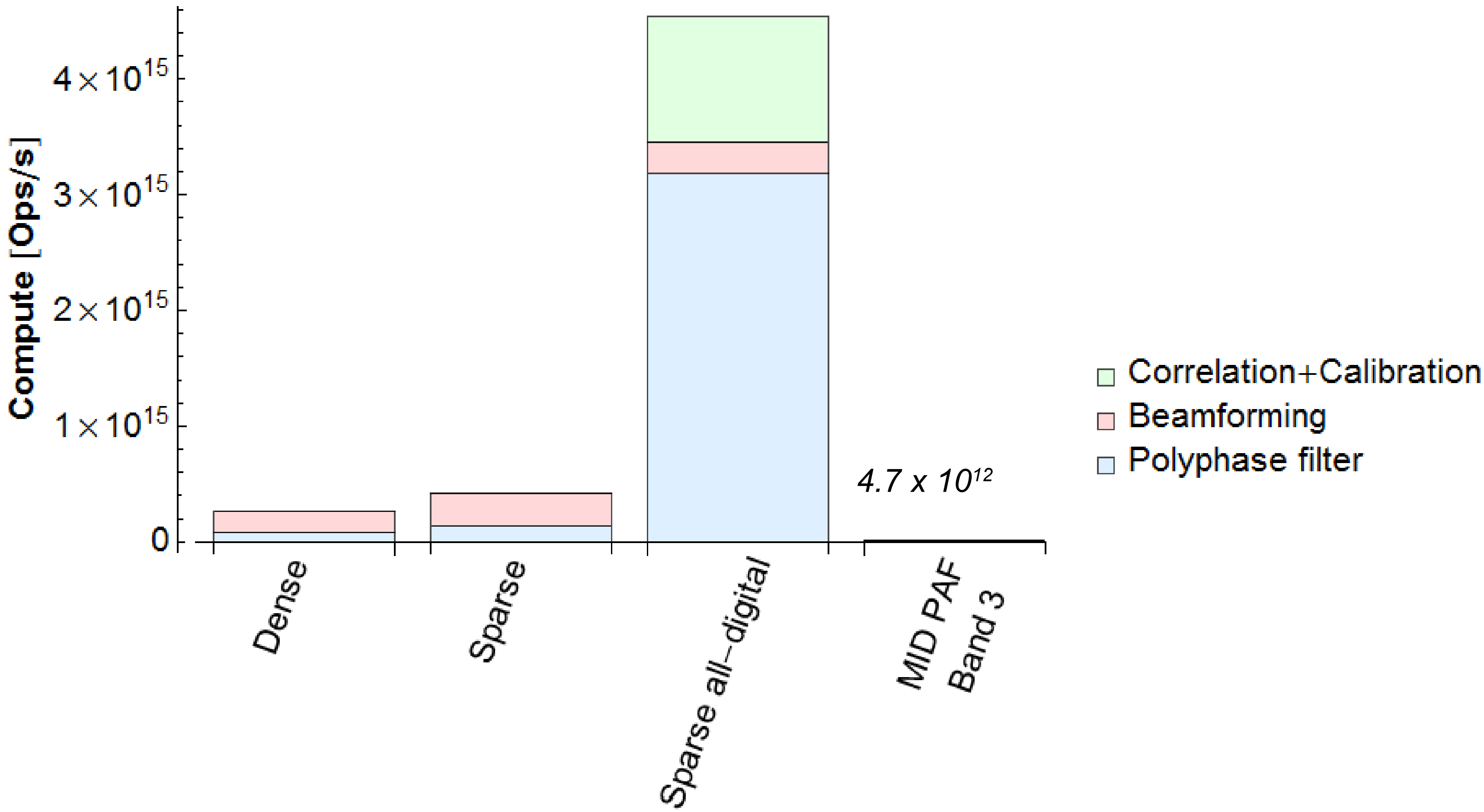
SKA-AAMID designs

- For all designs: **survey speed around 10^{10} m^4deg^2/K^2 at 1 GHz**
- Aperture arrays:
  - Dense design
  - Sparse design with and without analog tile beamformers
- Tentative PAF instrument based on SKA1-Survey dishes
  - *Huge dish count for high survey speed!*

	Dense	Sparse	Sparse All-digital	PAF
Stations	250	250	250	6000
Diameter	51 m	67 m	67 m	12 m
Tile size (x2 pol)	128	22	-	-
Signal paths (x2 pol)	1,024	1,764	38,808 1st BF: 22 2nd BF: 1,764	36
Beams	1,059	912	912	4 to 30
Max baseline	80 km	80 km	80 km	80 km

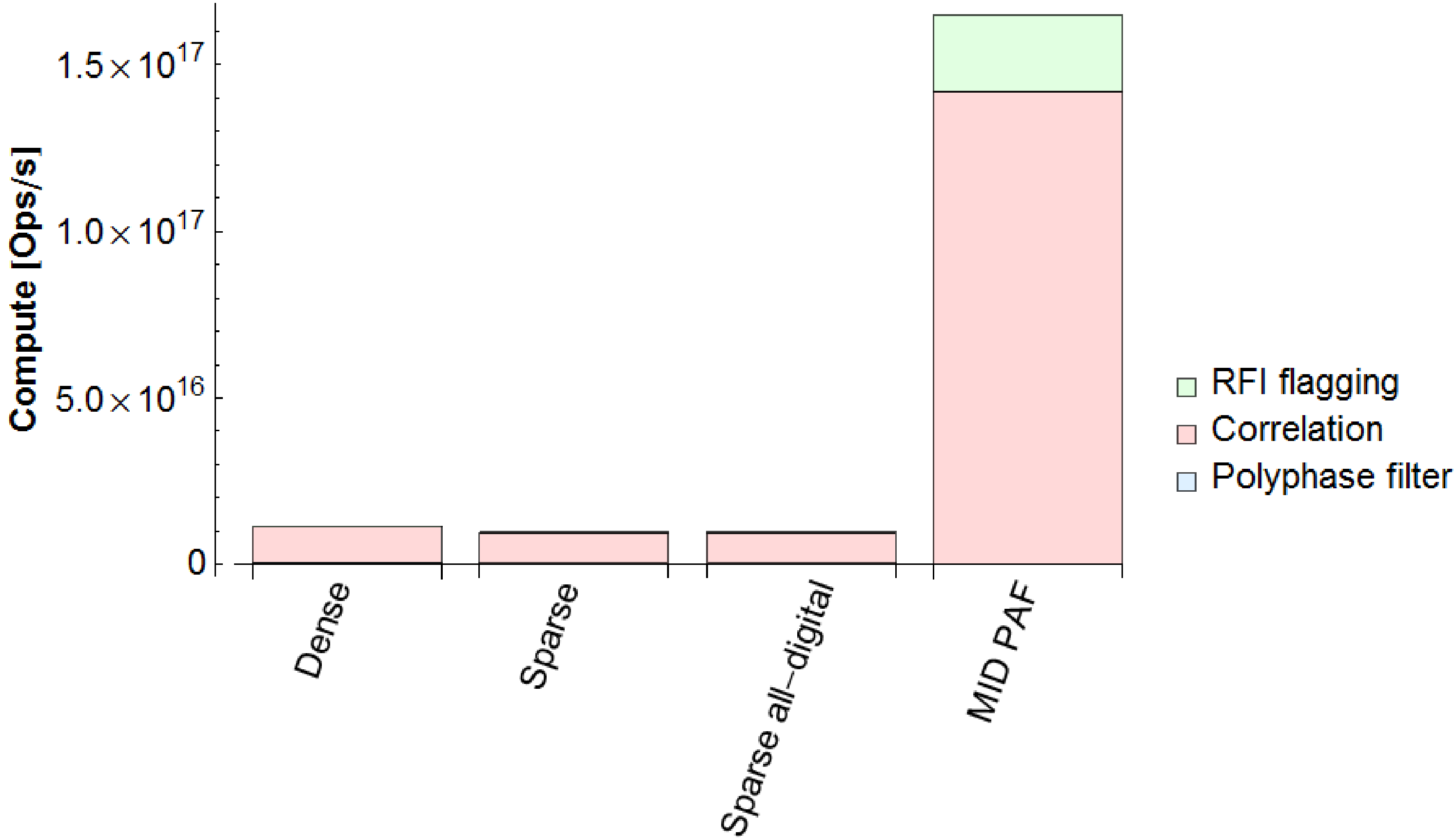
Station processing for one station or dish

Processing 10 MHz bandwidth around 1 GHz:



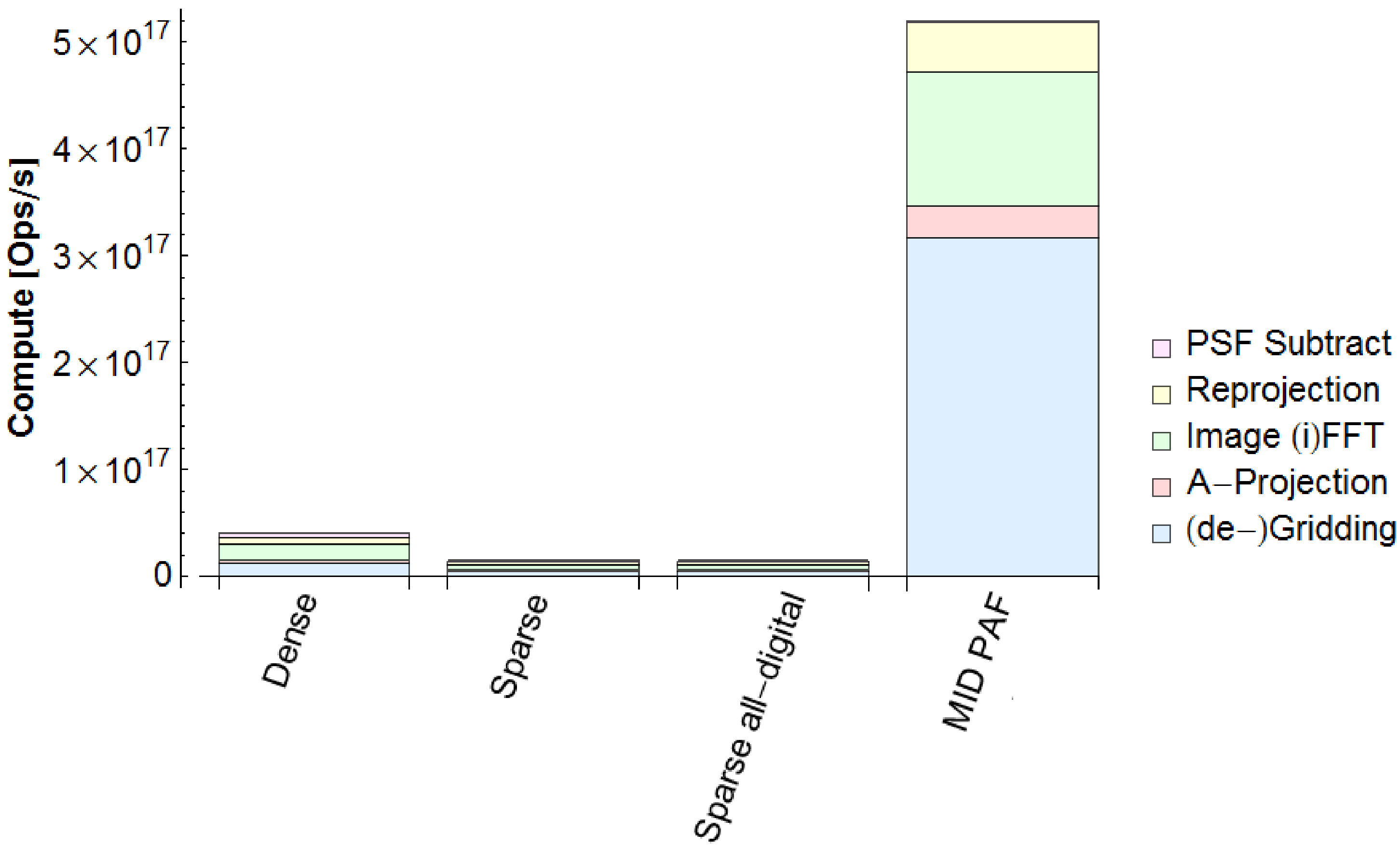
Central signal processor

Processing 10 MHz bandwidth around 1 GHz:



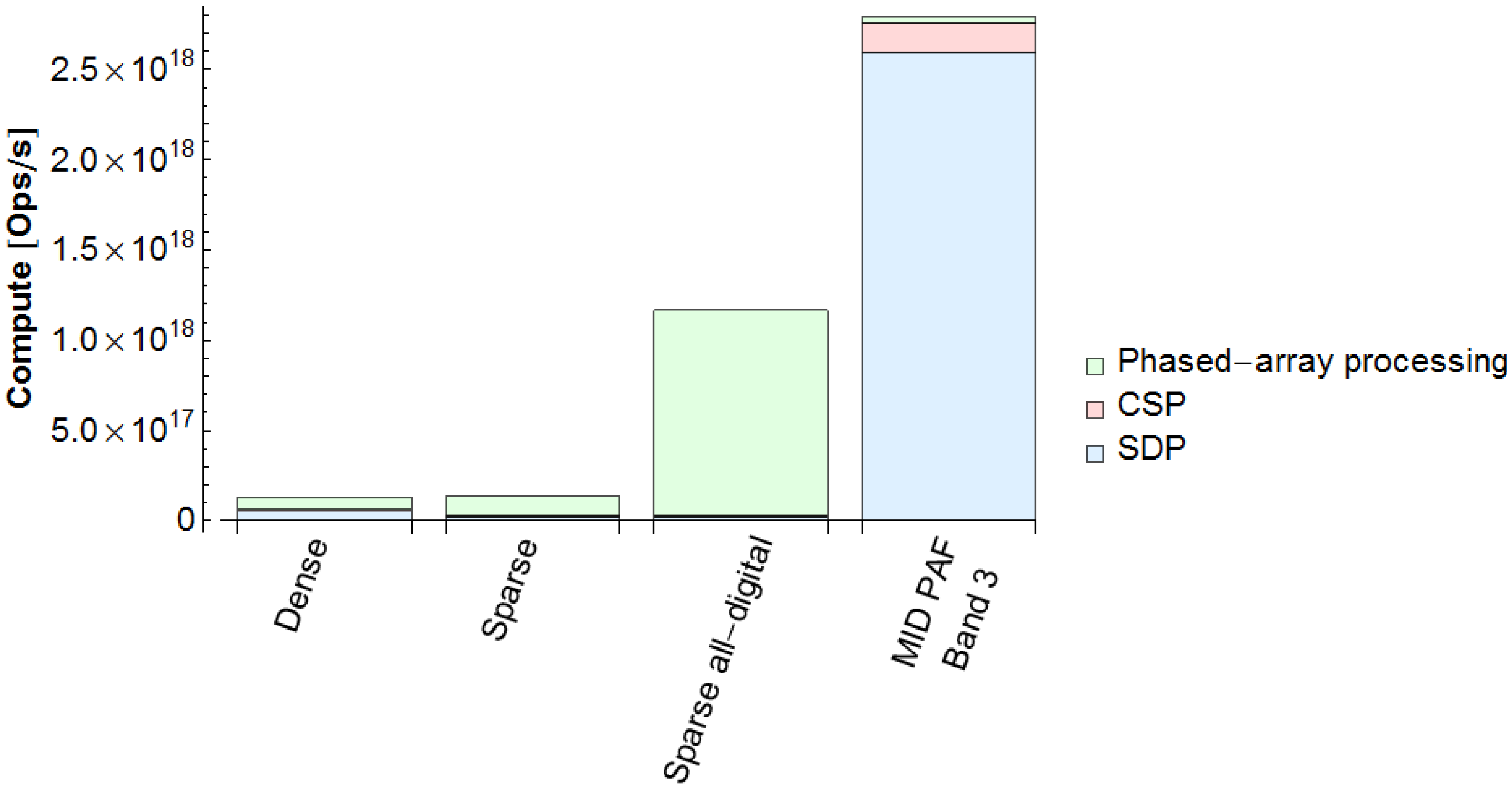
Science data processor

Processing 10 MHz bandwidth around 1 GHz:



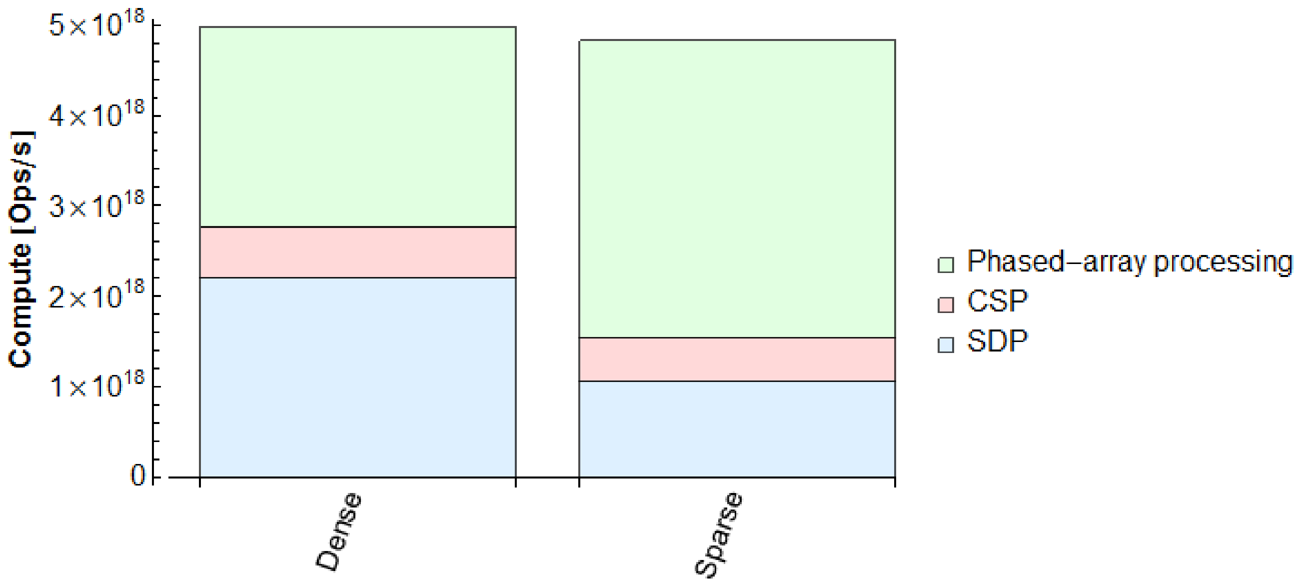
Total computing requirement

Processing 10 MHz bandwidth around 1 GHz:



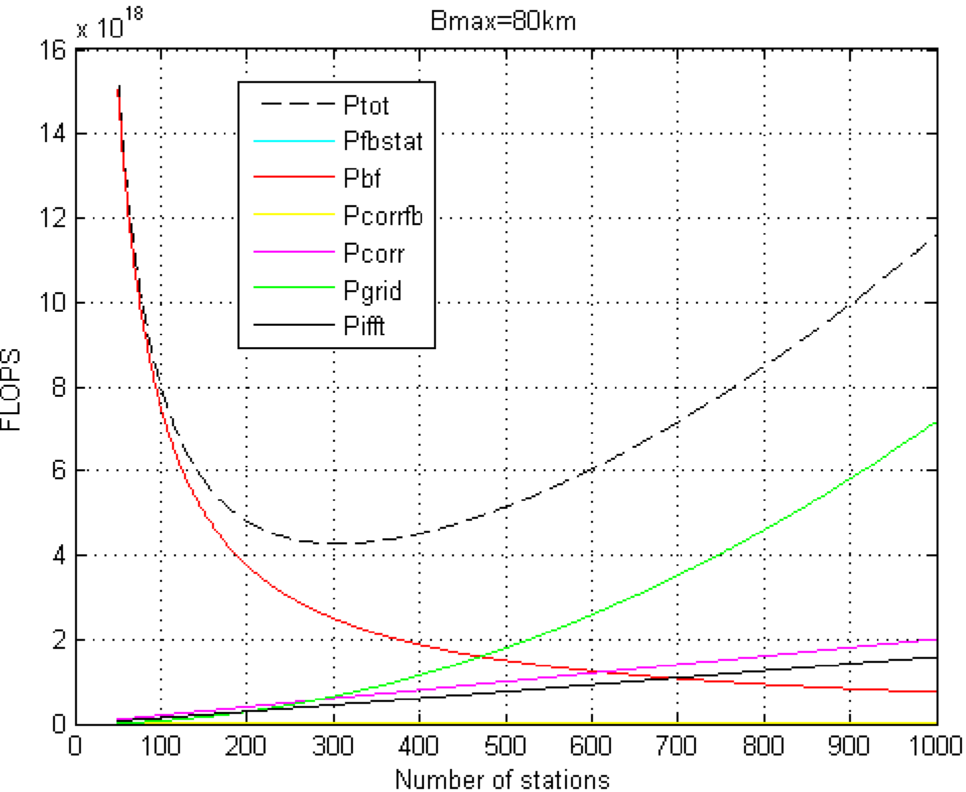
Total computing for 500 MHz bandwidth

- Lowest frequency band, analog+digital beamforming for both dense and sparse
- Survey speed not the same for the instruments!

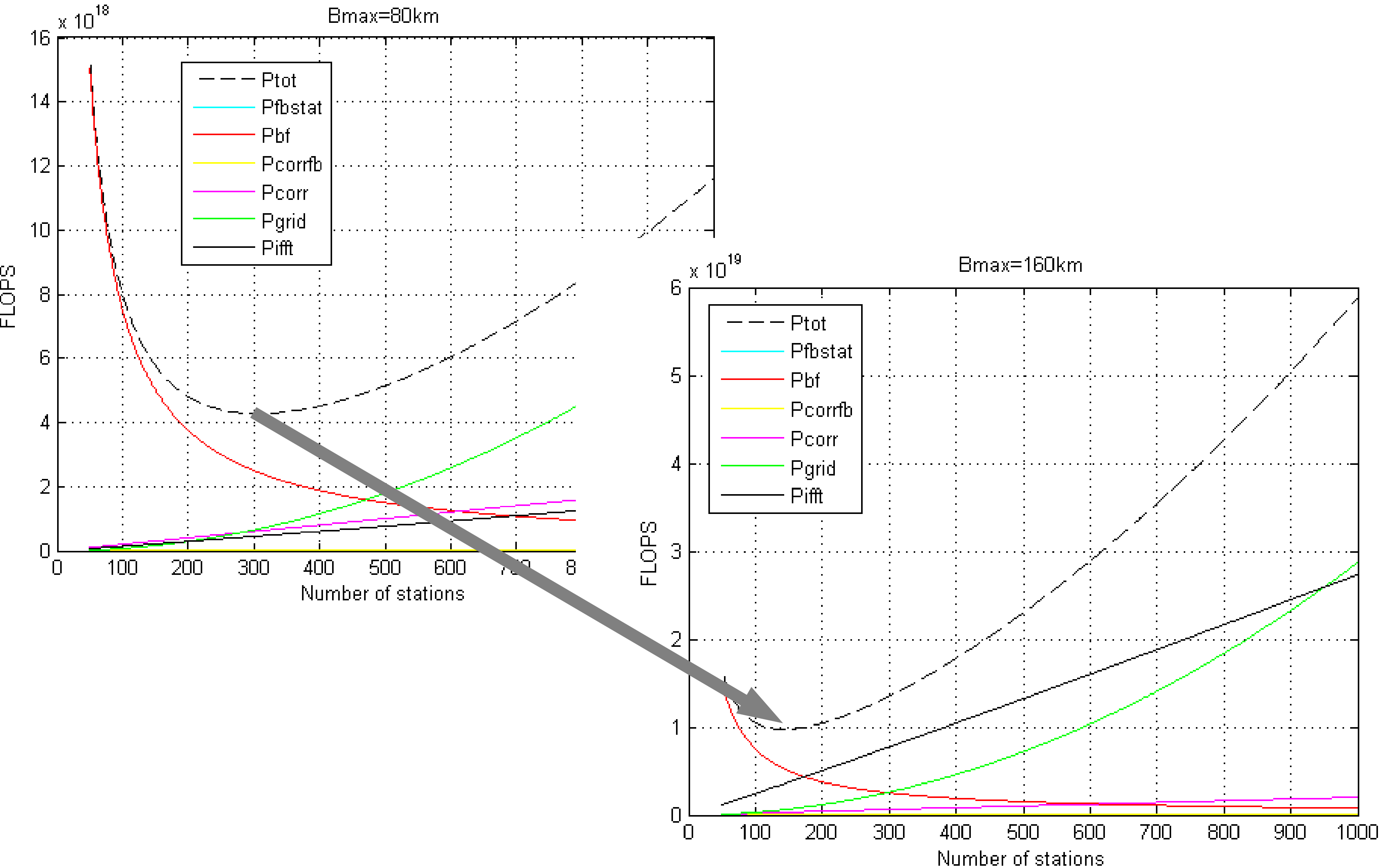


- Note: be careful when comparing SDP computing with the others:
  - SDP has more expensive floating-point operations
  - Energy cost in the desert is likely higher

Effect of baseline size on optimal number of stations



Effect of baseline size on optimal number of stations



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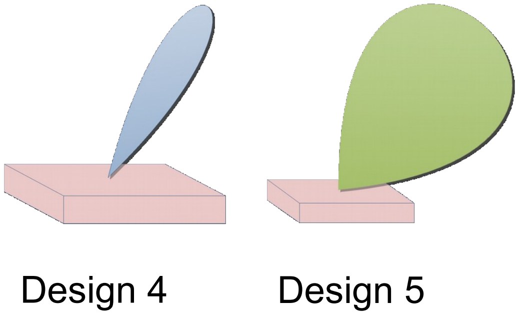
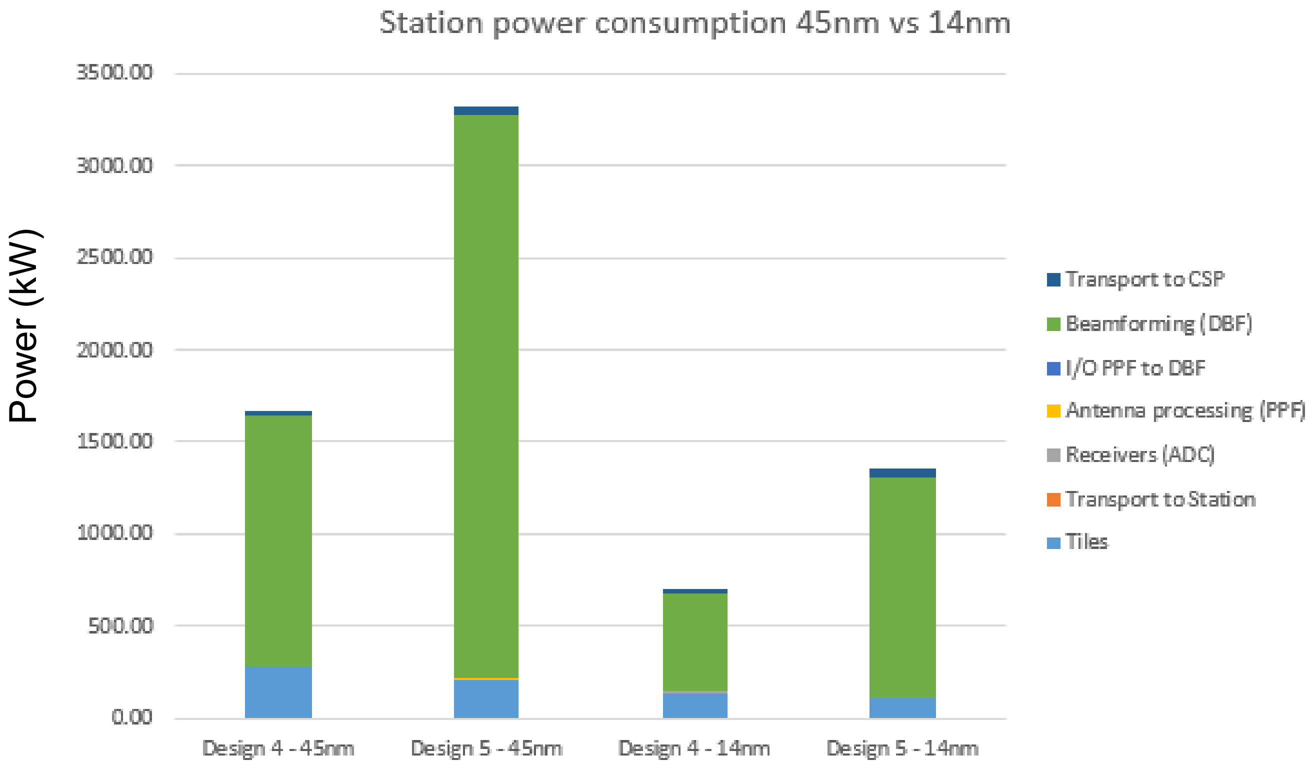
Objectives & contributions

- Estimate power consumption by analytical modeling of the processing pipeline
  - *Analyze trends between different dense MFAA designs*
- Detailed modeling of station processor and CSP
  - Analog and digital beamforming, data transport, digitization, channelization, correlation
- FPGA in two technology nodes: 45 and 14 nm



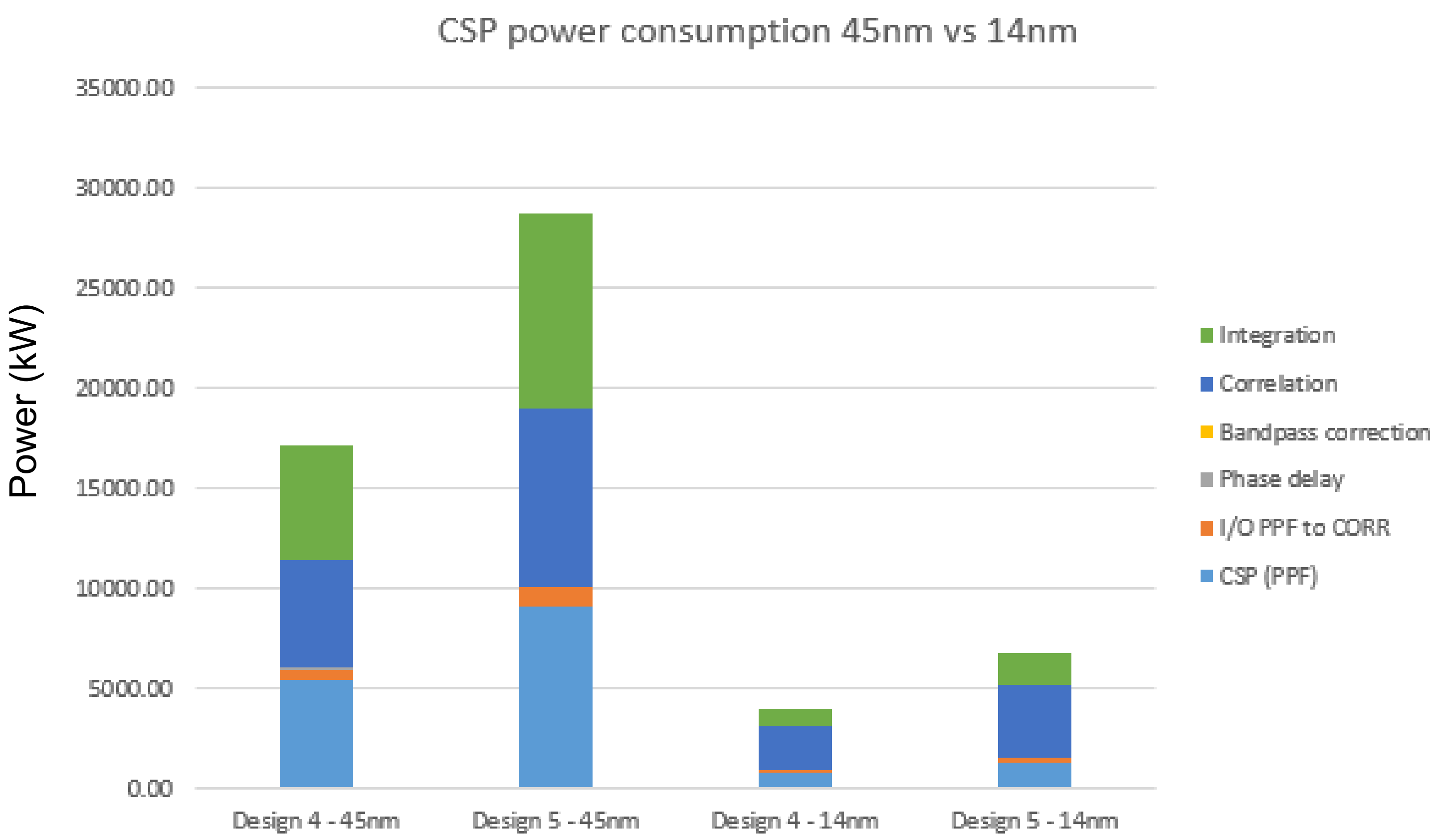
	Design 4 – A/T	Design 5 - FoV
Stations	250	250
Diameter	53 m	40 m
Tile size	72 x 2 pol	36 x 2 pol
Tiles	1,936	2,601
Beams	1,764	2,945
Max baseline	80 km	80 km
Instantaneous bandwidth	250 MHz	250 MHz

FPGA power results per station



- One station in 14nm consumes 702 kW (design 4) and 1.35 MW (design 5)
- Digital beamforming consumes most power

FPGA power results for the CSP



- The CSP in 14 nm consumes 4 MW (design 4) and 6.7 MW (design 5)

Conclusions

- Station digital **beamforming** is a **dominant** kernel
  - Both in absolute **computing** numbers and **power** consumption
- For 250 MFAA stations, in terms of absolute computing:
  - **Dense** and **sparse** MFAAs have a **similar** computing load
  - **Dense**: **phased-array processing** is **similar** to the **SDP**
  - **Sparse**: phased-array processing is **more demanding** than the SDP
- A **tentative PAF** instrument requires **18x more FLOPS**
- **All-digital** requires **7x more processing** compared to hybrid beamforming