SKA-AAMID

System Design

André Gunst (ASTRON)

Ministerie van Economische Zaken, Landbouw en Innovatie

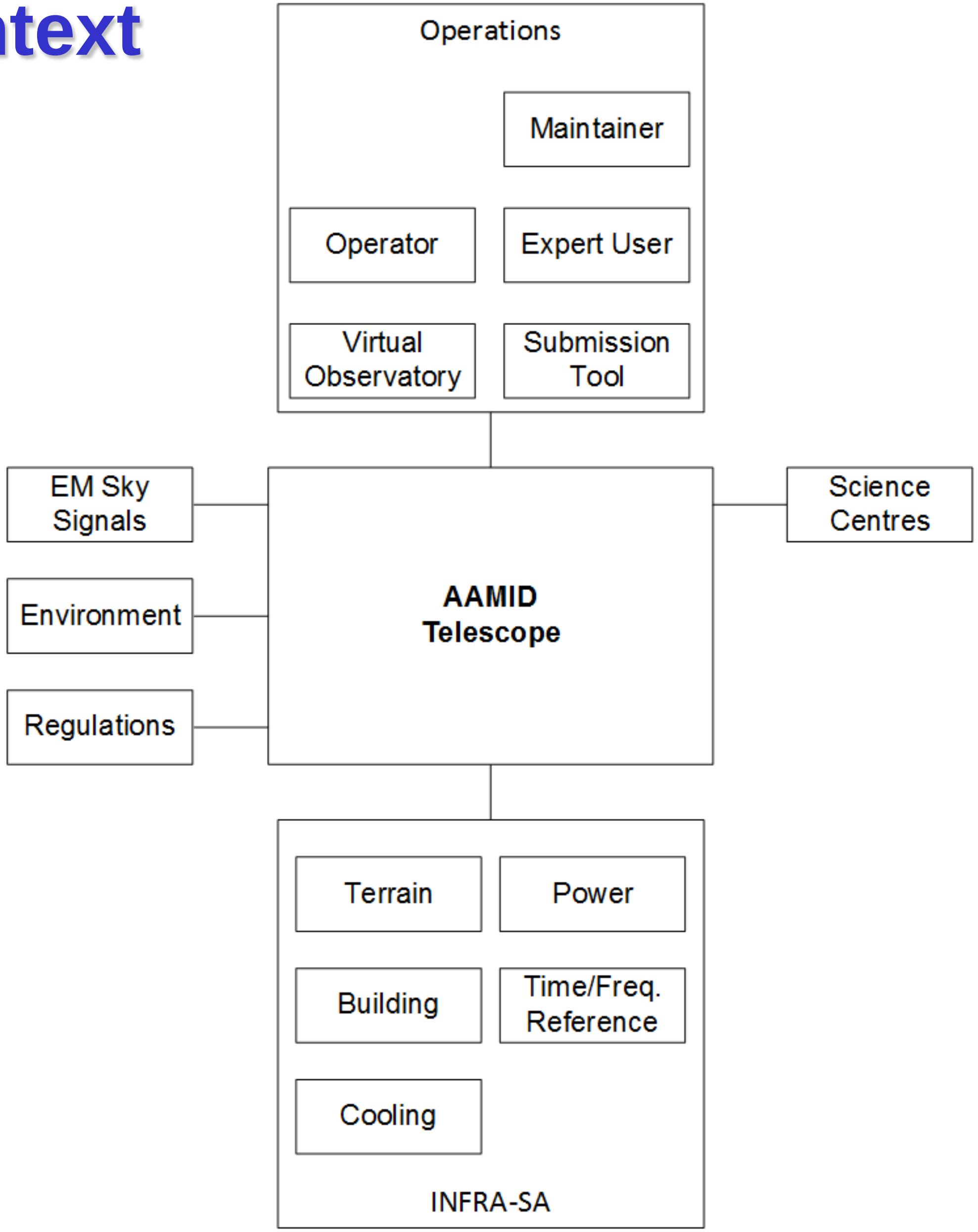
SNN

SKA-TSM is supported by subsidies from the The Northern Netherlands Provinces Alliance (SNN), Koers Noord and the Province of Drenthe.

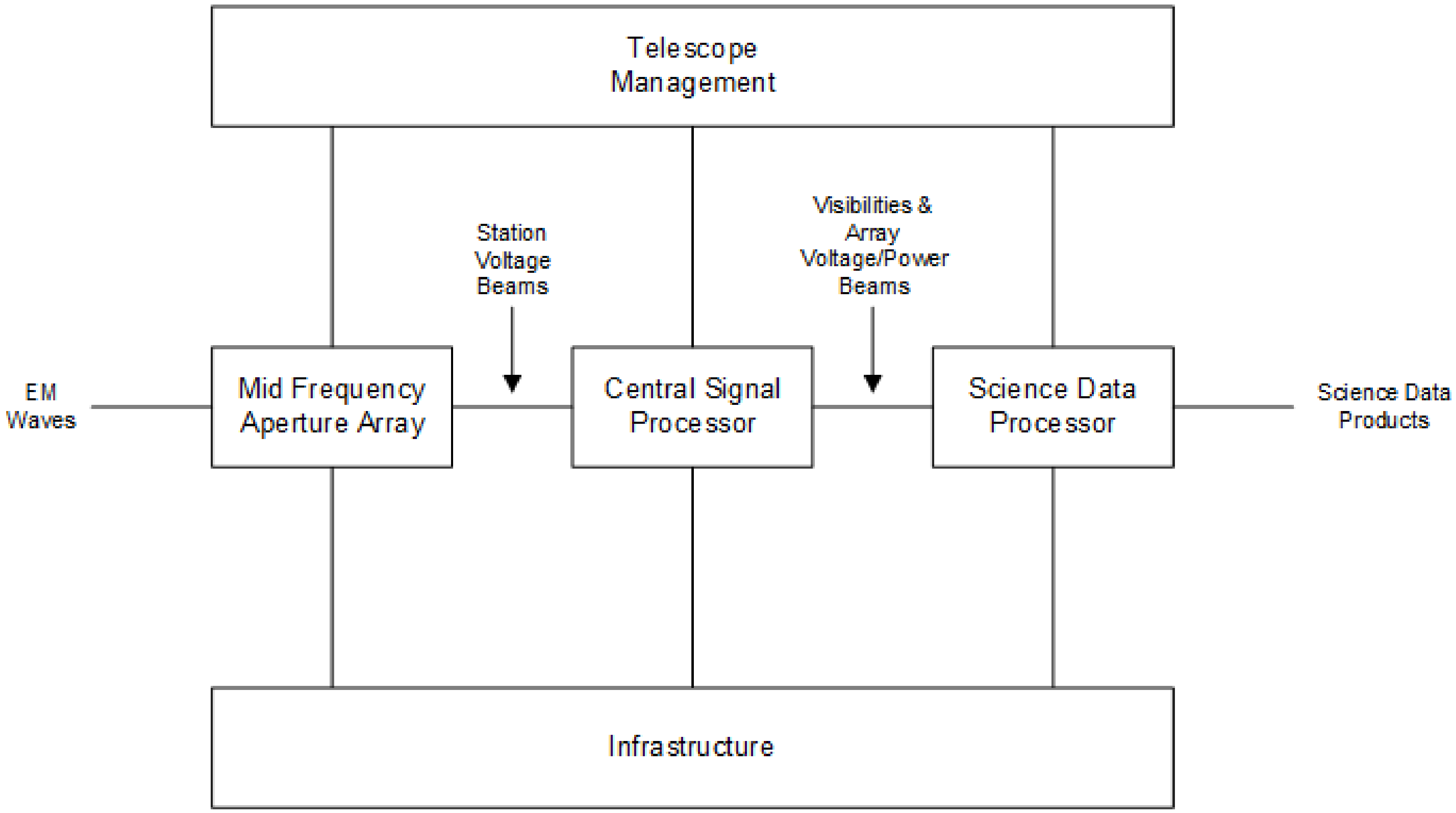
Contents

- AAMID
- MFAA
- Target requirements
- Trade-off
- Trade-off
- More trade-offs
- Even more trade-offs
- The last trade-off: AAMID
- Conclusions

SKA AAMID Context

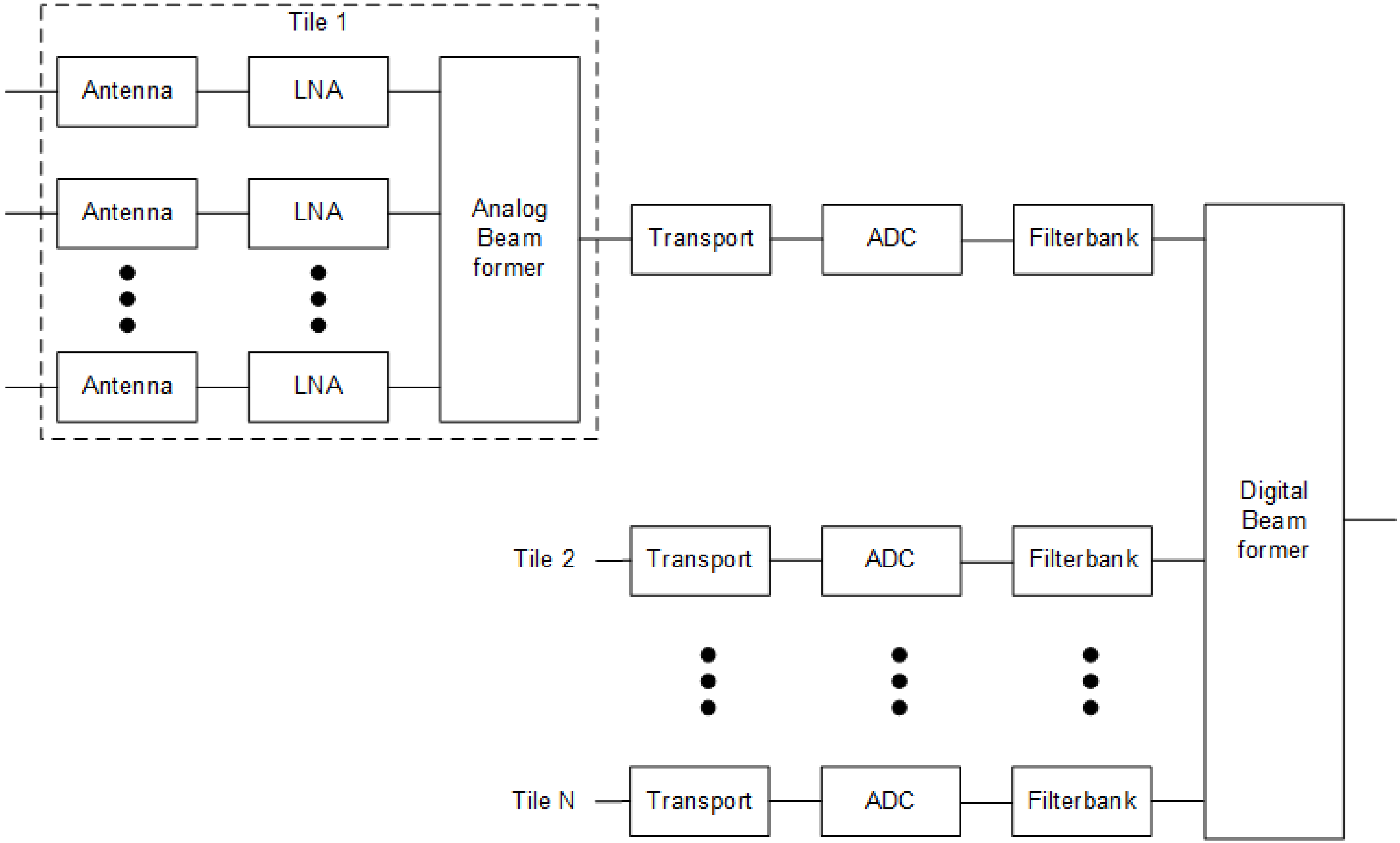


SKA AAMID



Telescope Management
Station Voltage Beams
Visibilities & Array Voltage/Power Beams
EM Waves
Mid Frequency Aperture Array
Central Signal Processor
Science Data Processor
Science Data Products
Infrastructure

MFAA Architecture



MFAA Architectural Concepts

- Analog tile - digital tile
- Analog beamforming - all digital
- Centralized – distributed architecture
- Sparse/irregular - dense/regular

Target AAMID Requirements

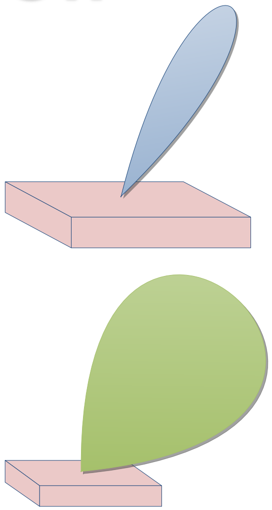
Parameter	Requirement	Unit
Frequency range	450 - 1450	MHz
Best effort for frequency from	400	MHz
Polarisation	2	
Instantaneous bandwidth	1000	MHz
Survey speed	> 1e10	sq. deg m^4/K^2
A/T target	> 10,000	m^2/K
Optical FoV @ 1 GHz	> 160	sq. deg
Processed FoV @ 1 GHz (500 MHz bandwidth)	> 100	sq. deg
Bandwidth beam product @ 1 GHz	500 * 100	MHz sq. deg
Buffer capability (500 MHz bandwidth)	> 10 - 40	seconds
Trade-off flexibility	bandwidth for FoV	
Number of TABs	10,000	
Station size	Flexible	
Scan angle from zenith	from - 60 to 60	deg
Upgradeable to optical FoV @ 1 GHz of	> 350	sq. deg

Comparison Assumptions

- Costs are identical
- Performance at zenith, unless otherwise stated

Tile Size Trade Off

- Tiles >, costs ↓
- Tiles <, oFoV ↑

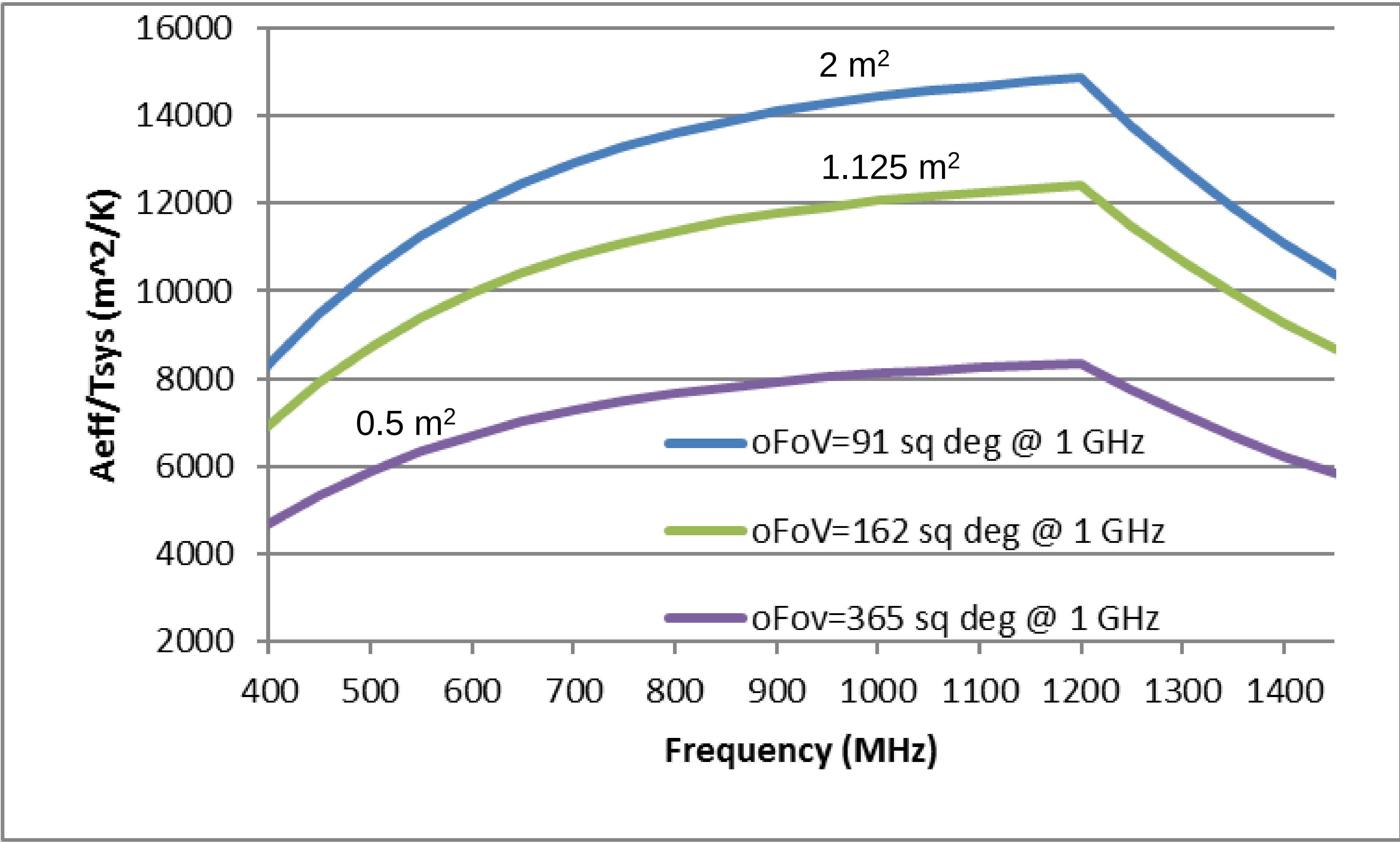


Previously …

- Dense/regular designs tailored such that
  - Optical FoV matches the processed FoV
  - Drives cost down
- Receiver noise temperature target reduced from 50 K to 30 K

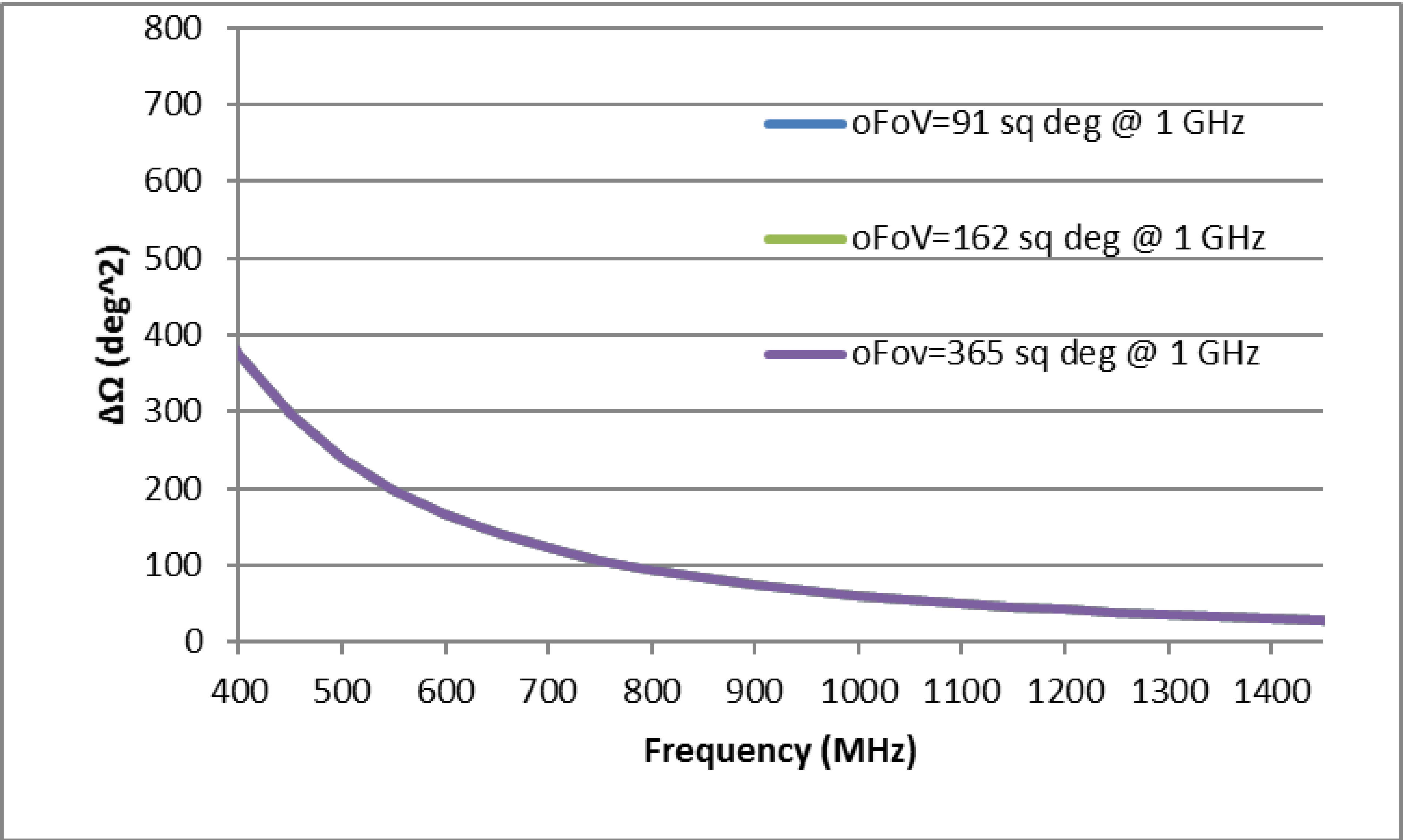
Scaling Tile Sizes

- Tiles from 0.5 – 2 m^2

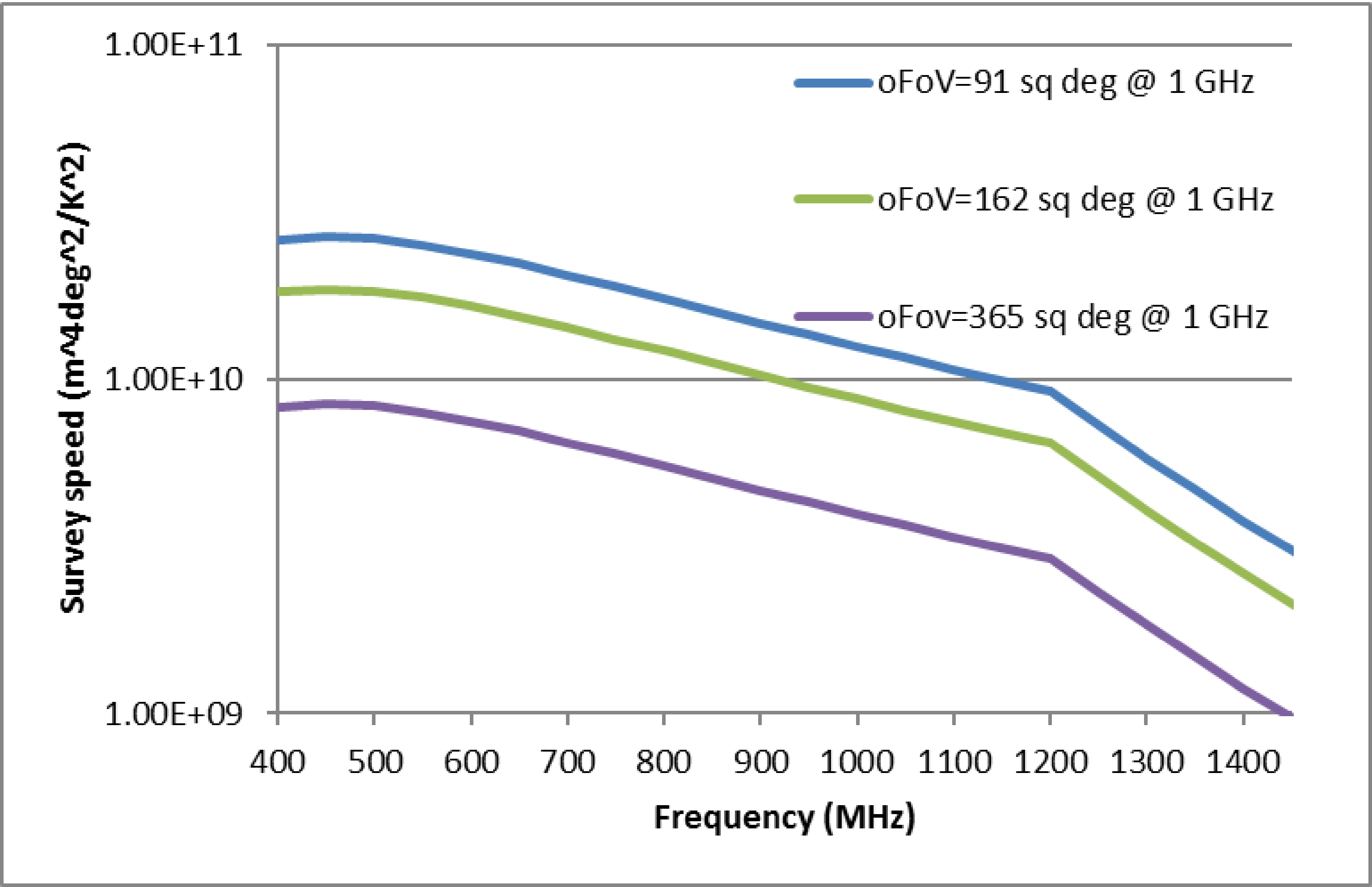


16000
14000
12000
10000
8000
6000
4000
2000
Aeff/Tsys (m^2/K)
400
500
600
700
800
900
1000
1100
1200
1300
1400
Frequency (MHz)
2 m²
1.125 m²
0.5 m²
oFoV=91 sq deg @ 1 GHz
oFoV=162 sq deg @ 1 GHz
oFov=365 sq deg @ 1 GHz

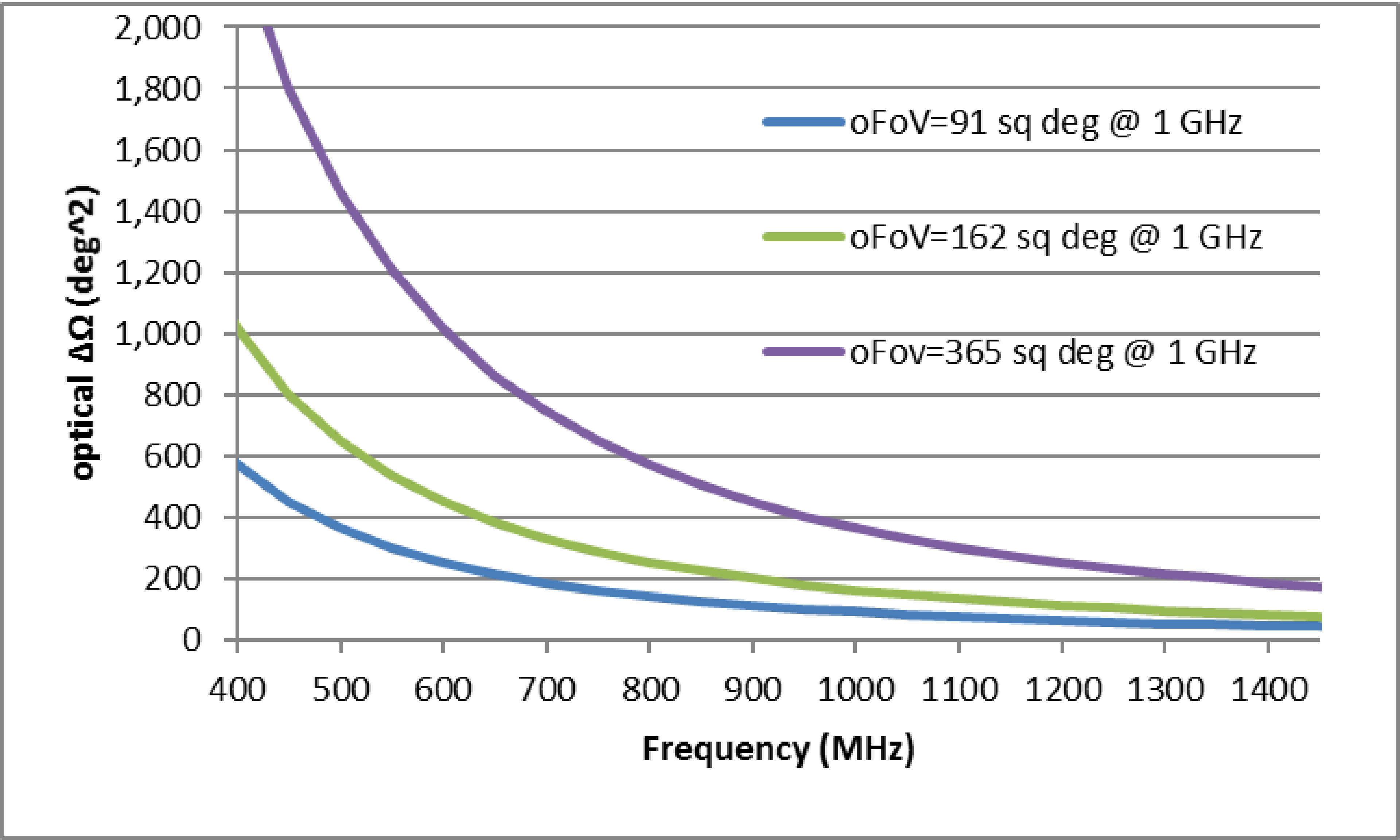
Processed Field of View



Survey Speed



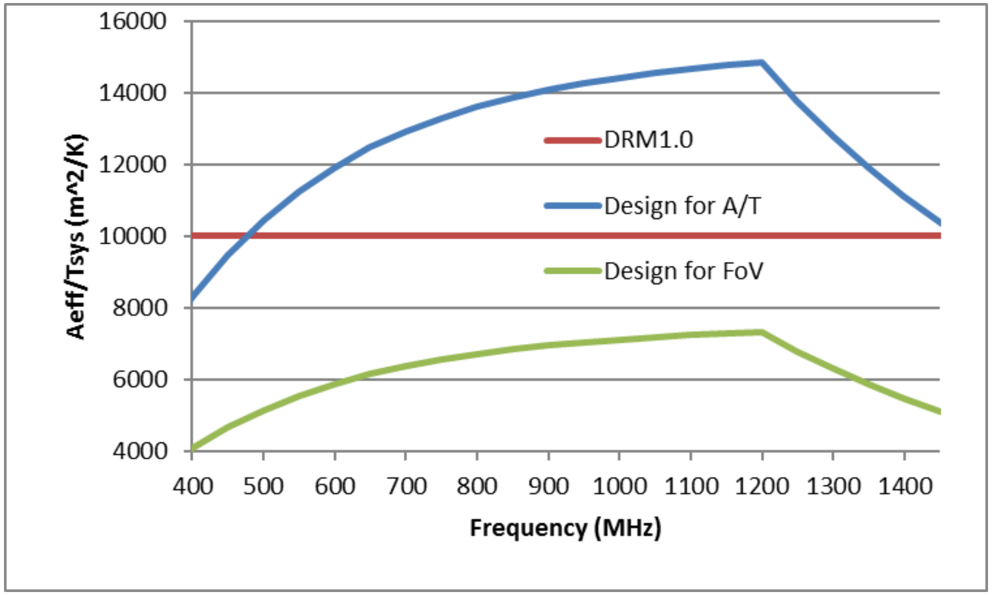
Optical Field of View (the Wow …)

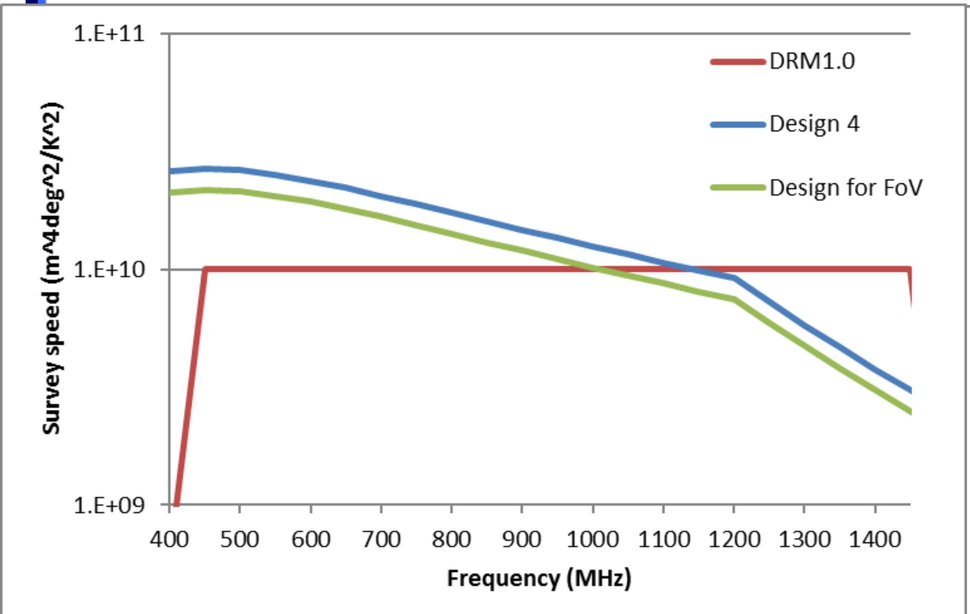


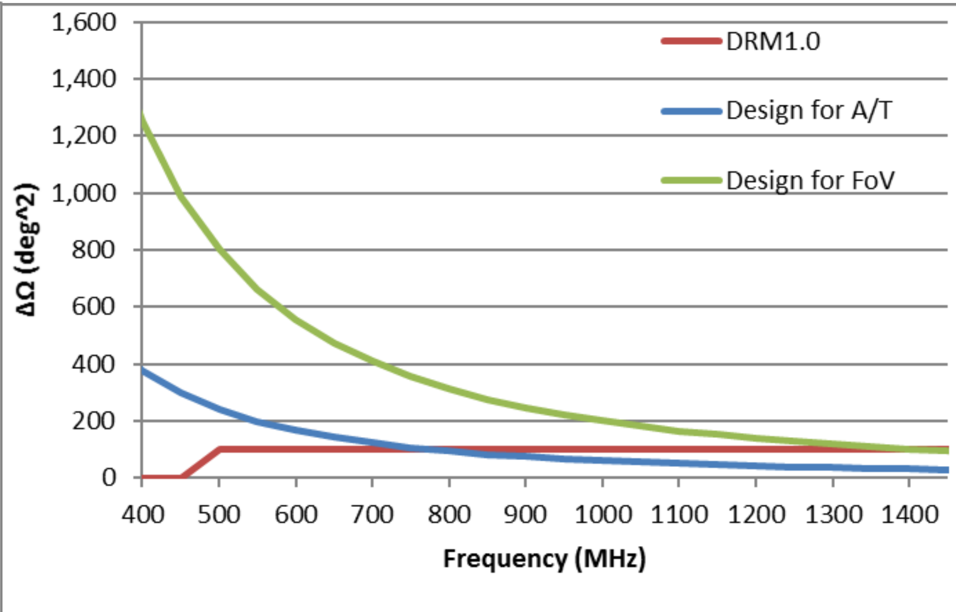
How to obtain the optical FoV …

- SKA Phase 2 is still “far” away > 2025
- Technology progress keeps on going
  - Data transport technologies (RFoF with multiple signals)
  - Digital tile
  - …
- Build upgradeable tiles
  - Composed from smaller basic “sub-tiles”
  - Bypass analog beamformer stages
  - Prepare transport links for extension

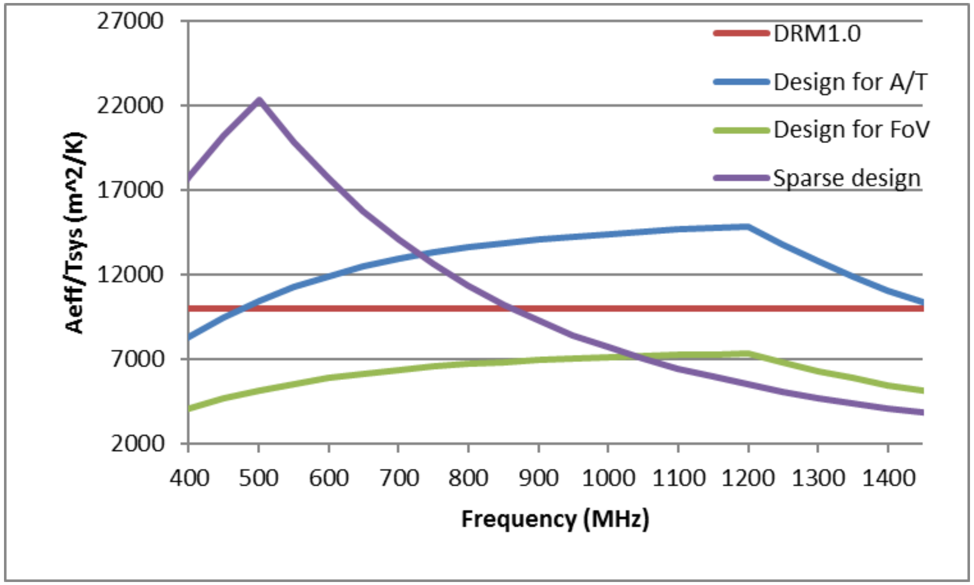
The Eternal A/T – FoV Trade-off





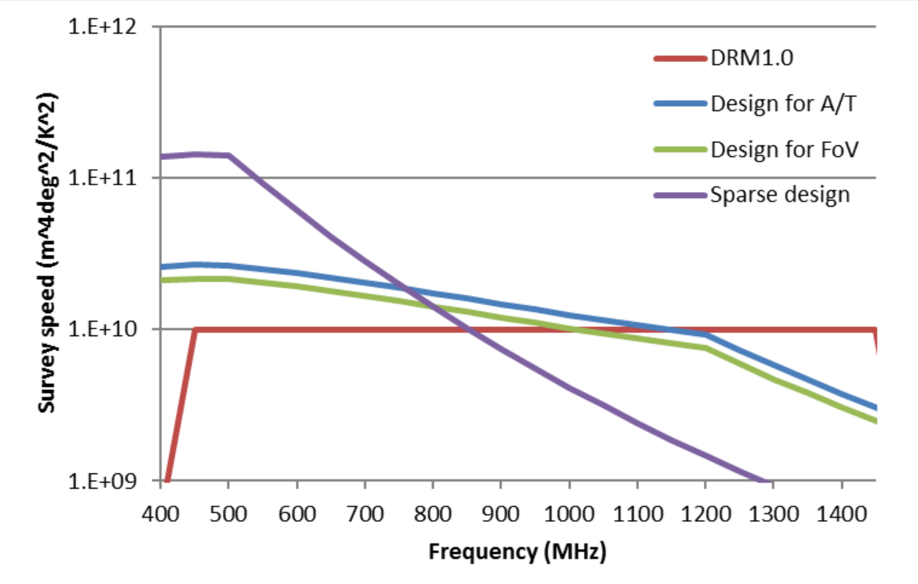


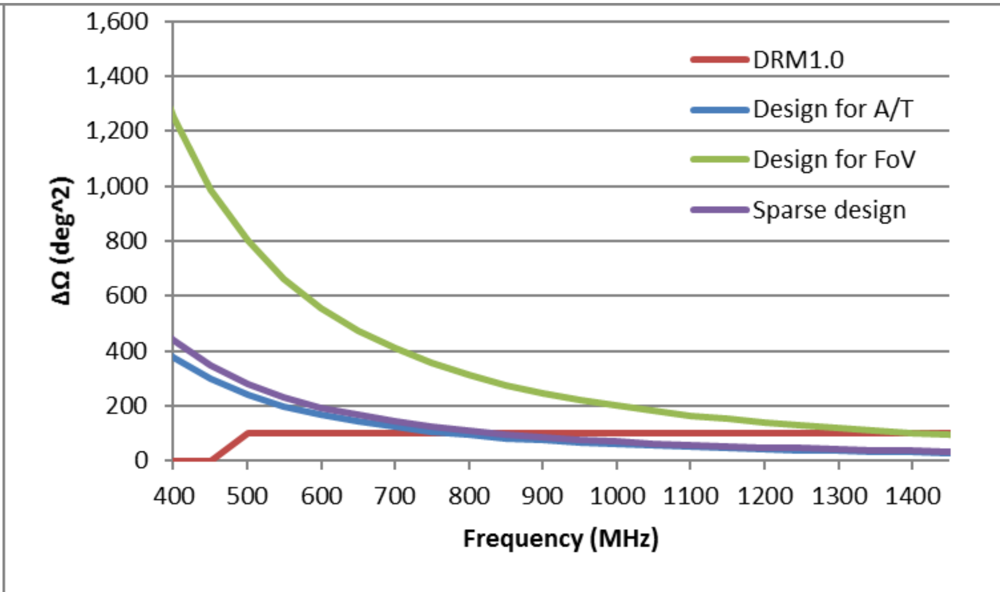
How to get more – sparse?



Pitch 30 cm

Not all digital!





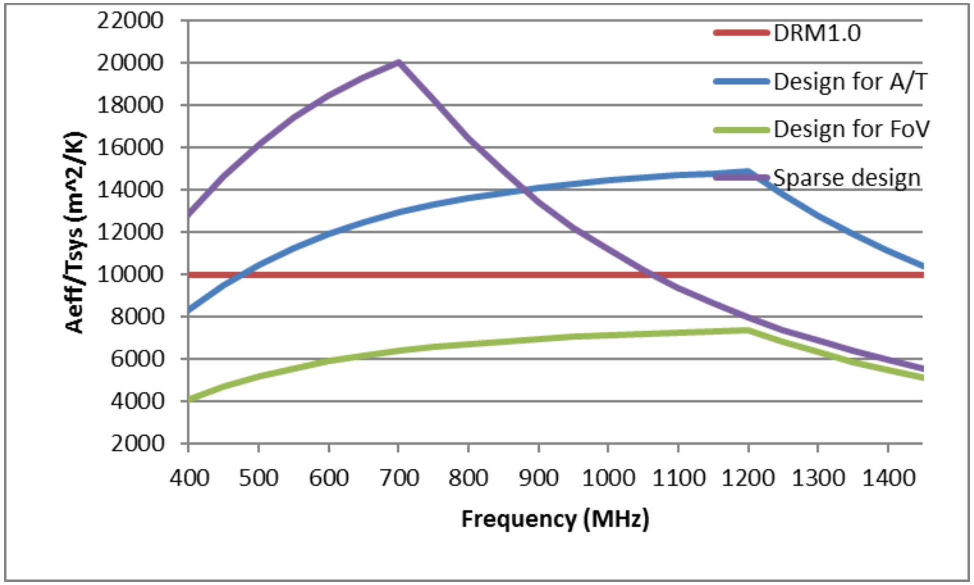
How to get even more: more Forward Gain

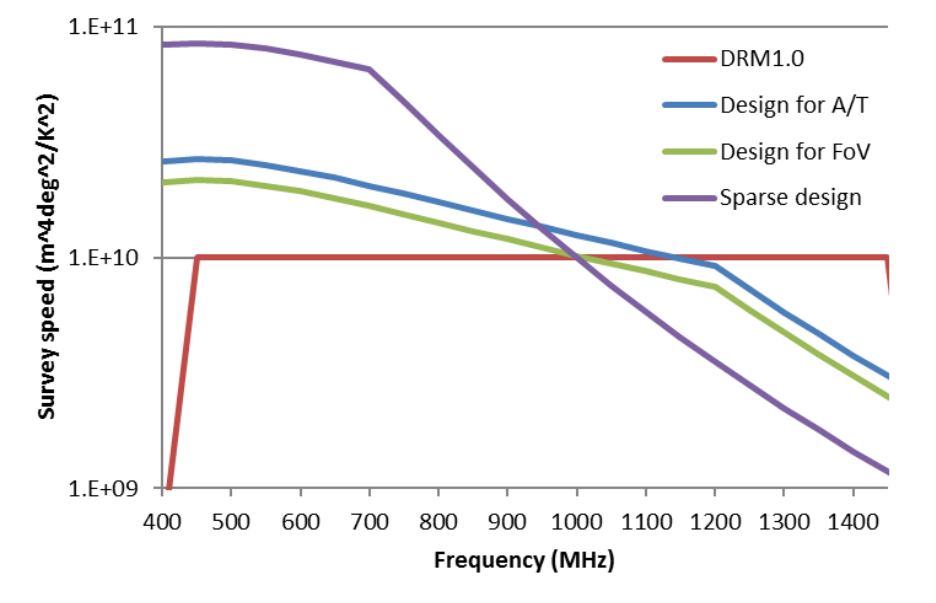
- Warning: Integral of gain over all scan angles is constant
- Air pillow effect
- Gain goes down > $\cos^2(\theta)$

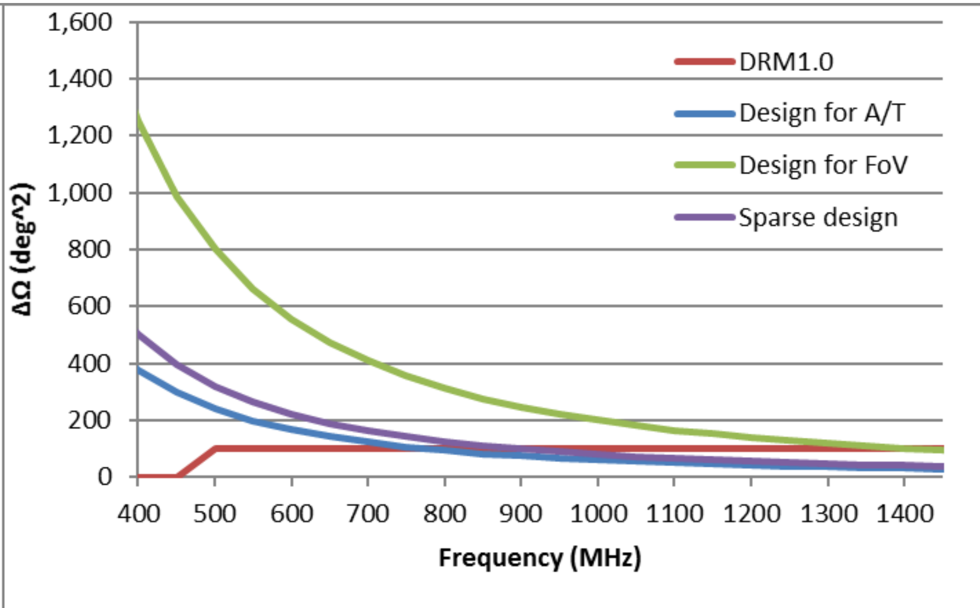
(θ is scan angle from zenith)

Sparse, with more forward gain

Zenith performance only







Features of sparse

- Excellent A/T for low frequencies in zenith
- A/T goes with f^{-2} within the band
- Survey speed goes with f^{-6} within the band
- A/T drops > $\cos^2(\theta)$
- Individual antenna beam patterns matter
- Beam model less smooth as dense
- Beam model less predictable as dense
- Grating lobes within the band

- In case of all digital: costs >>

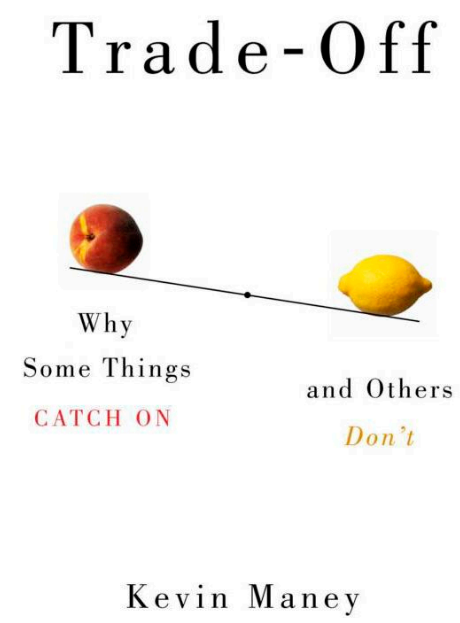
Sparse (irregular) or Dense (regular)?

- Smirnov during Aveiro meeting in 2015:

“It’s all about the primary beam”

and

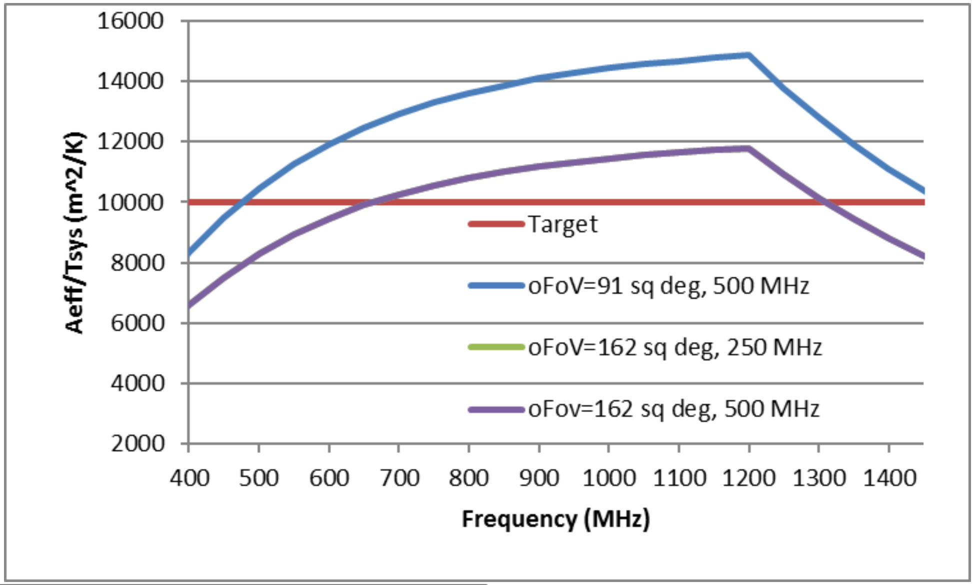
“Going from 3M to 5M has been a PB story” (about HDR)

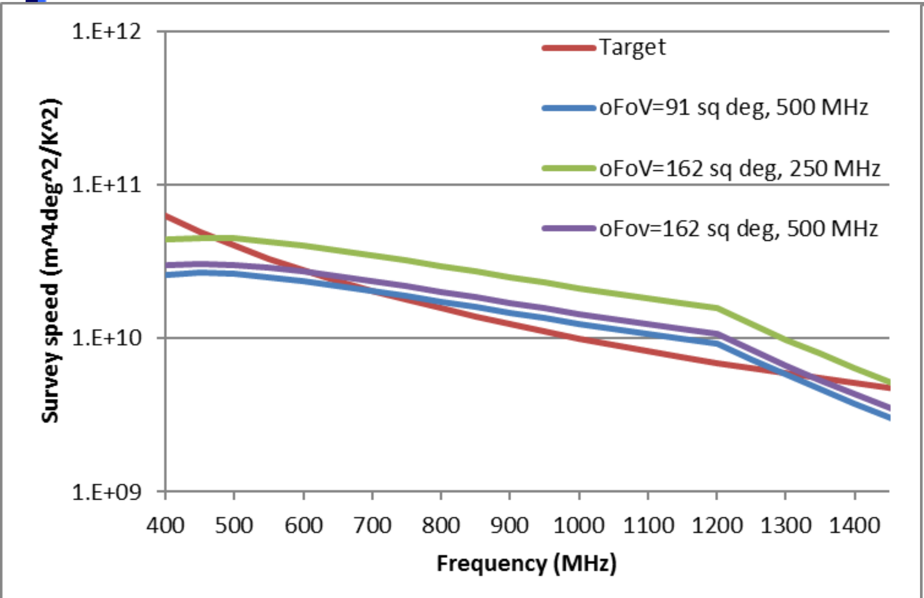


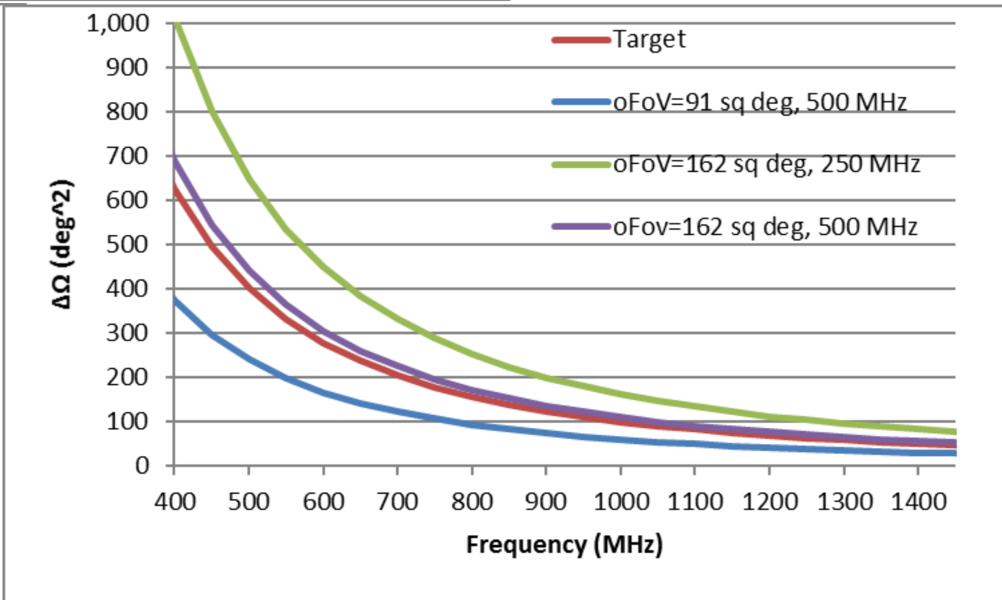
Bandwidth trade-off

in 2025

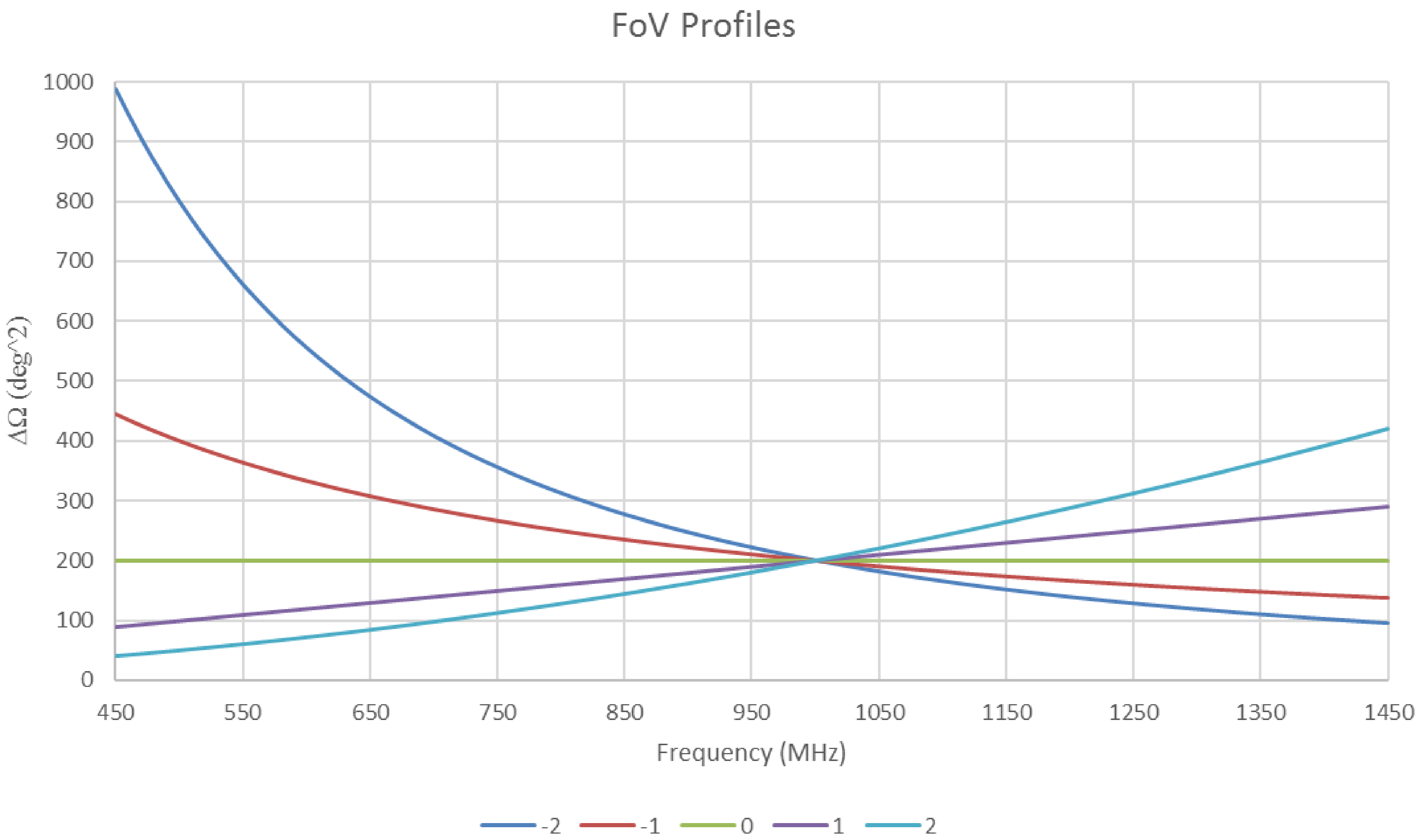
Current Trade-off Status



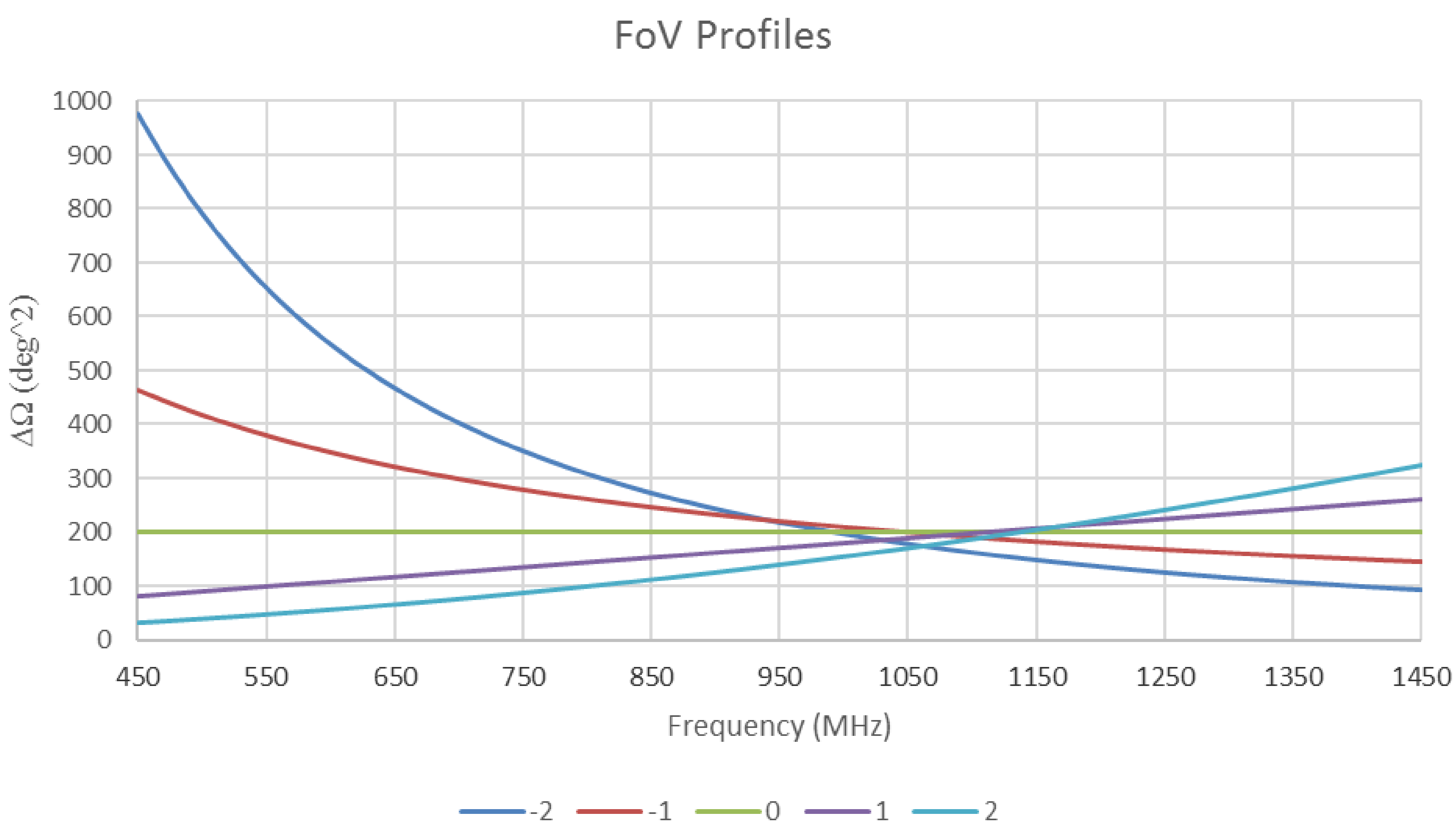




The Astronomers Dream …



Compensated for reality …

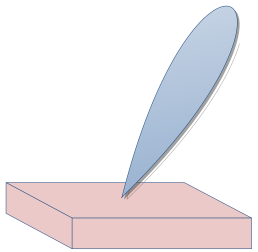


AAMID System Trade-off (imaging only)

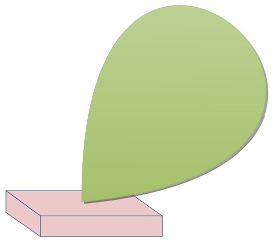
- Assumptions:
  - Processed FoV fixed
  - A/T fixed

Number of MFAA Stations Trade-off

- Large stations
  - small station beams
  - more digital beams required to synthesize the FoV
  - smaller amount of stations to correlate



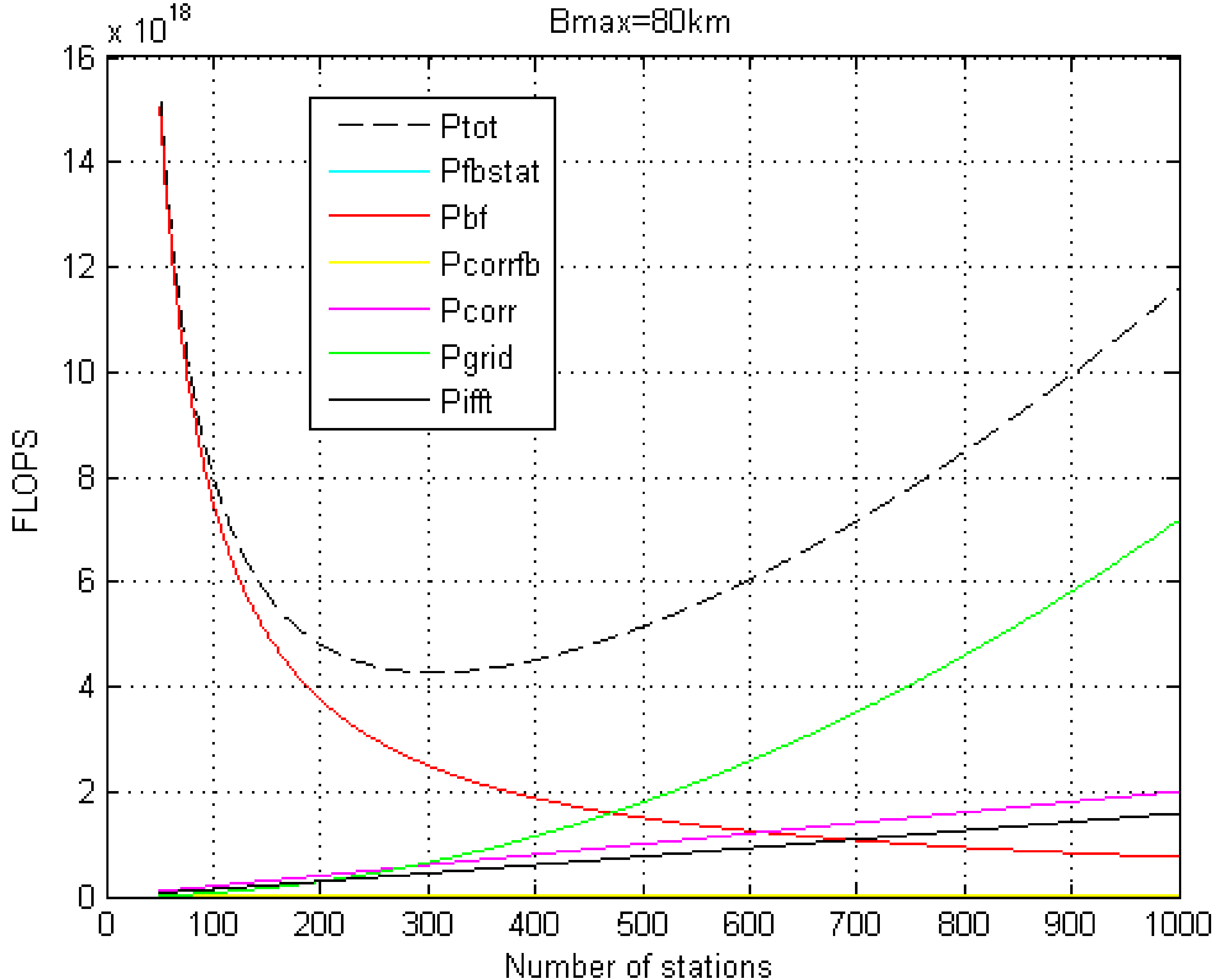
- Small stations
  - large station beams
  - less digital beams required to synthesize the FoV
  - more stations to correlate



- Interesting fact
  - total data rate from MFAA to correlator is constant

Relations as function of Ns

- MFAA
  - Filterbank: constant
  - Beamformer: ~ Ns^{-1}
- Central Signal Processor
  - Filterbank: constant
  - Correlator: ~ Ns
- Science Data Processor (only driving ones)
  - Gridder: ~ Ns^{2}
  - iFFT: Ns


Bmax=80km
x 10^18
16
14
12
10
8
6
4
2
0
FLOPS
0
100
200
300
400
500
600
700
800
900
1000
Number of stations
Ptot
Pfbstat
Pbf
Pcorrfb
Pcorr
Pgrid
Pifft

Exa Flops is a lot, but …

- SKA Phase 2 is still “far” away > 2025

- Technology progress keeps on going
  - Advances in digital processing (more Moore please)
  - Algorithm development in the science data processing

Conclusions

- Preferably equalize optical and processed FoV
- AAMID offers lots of flexibility
- Number of stations driven by processing costs

The End

Contact details

gunst@astron.nl