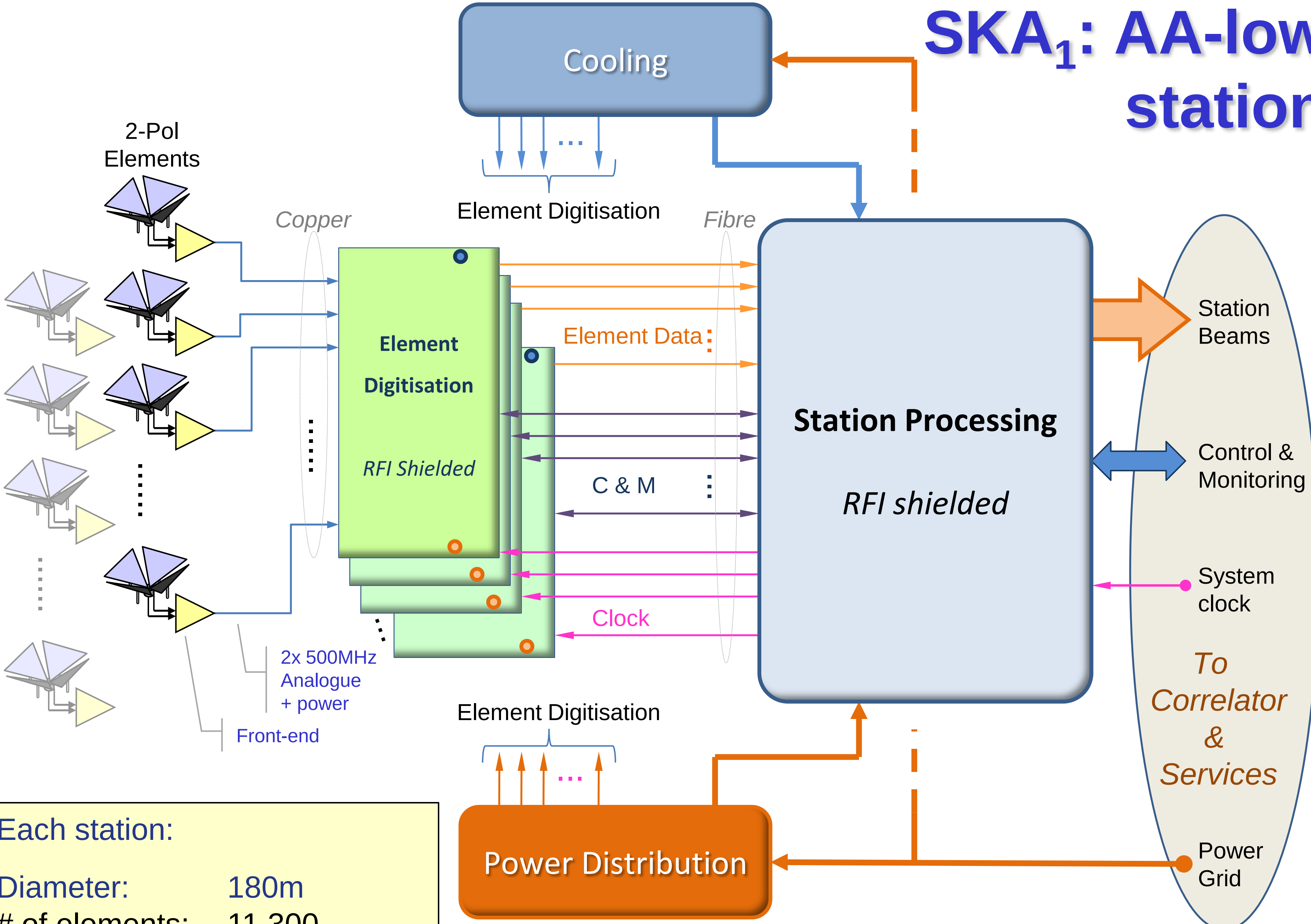
AA-low to SKA_1, spec, demonstrators and purpose

Andrew Faulkner / Jan Geralt Bij de Vaate

SKA$_1$: AA-low station



Each station:

Diameter:	180m
# of elements:	11,300
Element links:	Copper

Phase 1 AA-low array

- Limited specification available, memo125:
  - 70 – 450MHz
  - 2000 m^2 / K (z=10)

	AA-mid	AA-low
Low frequency	400 MHz	70 MHz
High Frequency	1400 MHz	450 MHz
AA Type	Dense	Sparse
Element	ORA or Vivaldi	Single (or dual)

Taking the knowledge from LOFAR, MWA , Paper etc.

And use latest technology.....

Proposed specification

- From draft SKA phase 1 system description, June 2010

Table 4: Representative System Performance Factors for Sparse AAs			
Antenna Efficiency		>90%	Beam former efficiency
Projection loss		0.5	Max at 30 degrees elevation
Minimum Elevation Angle		30 deg	Set by ant. design; determines max. core FF
T_{inst}		150	
T_{sys} at 130MHz		550	400 K average sky noise @ 130MHz
System Equiv. Flux Density (each Sparse AA station)			70MHz 450MHz
System Equiv. Flux Density (250 Sparse AA stations)			70MHz 450MHz
ΔS (1σ) @ 70MHz			Min. detectable cont. flux (Stokes I).
ΔS (1σ) @ 450MHz			Min. detectable cont. flux (Stokes I).
Field-of-View @ 2.3 m wavelength		700 deg[illegible]	Scales as λ^2 Beamforming on 5 x 5m tiles
A_e/T_{sys}		[illegible]65 m^2/K	130MHz, z=10, bore sight, A_e per antenna 1.8m^2
All Antennas			> 90 MHz & < 420 MHz
SSFoM @ λ = 4.3 m, T_{sys} = 2450K			
			Dual polarisation ant grouped into 50 stations.

Possible AA-low implementation

- From draft SKA phase 1 system description, June 2010

7 Sparse Aperture Array

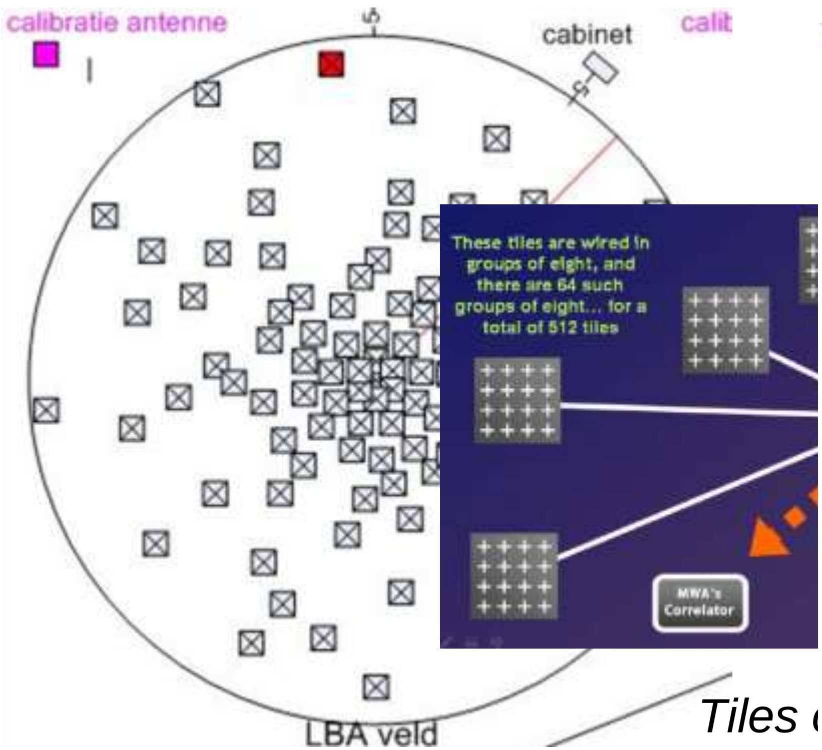
Table 3: Representative Implementation Based on Sparse Aperture Arrays			
Sparse Aperture Array			50, 180-m diameter stations
Lower Frequency		70 MHz	Dual pol'n (2 orthogonal)
Upper Frequency		450 MHz	
Number of antennas		11,300	Per station
Array Configuration		50 stations	
Core (radius <0.5 km)		~50% (25 stat.)	Fractional total number of AA stations.
Inner (1<radius<2.5 km)		~20% (10 stat.)	"
Mid (2.5<radius<180 km)		~30% (15 stat.)	In clusters of 5 stations (Total of 15 clusters)
Digital Outputs			
Sample streams		480	Max [illegible] sub-bands
bits per sample		4	RFI dependent
Signal Transport System			Optical fibre to central data processor
Radius < 100 km		4.38Tb/s *	Data rate per station
			Optimized layout, buried fibre, highly multiplexed.
Central Data Processing System			
Correlator			
Max Beams per station per coarse frequency channel			Nyquist sampled on a square grid

Options: tailoring gain

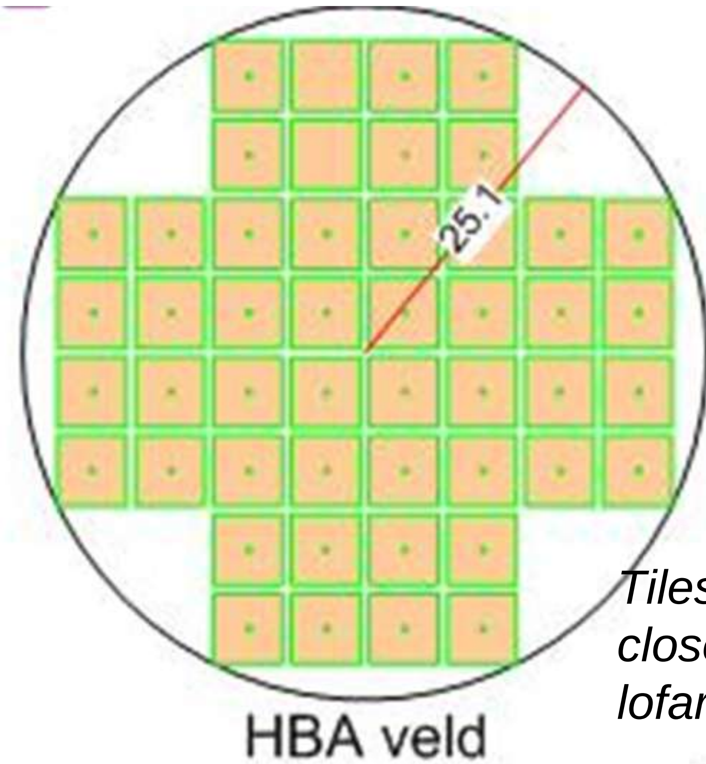
- Scan range
  - higher gain antennas possible when limited to 45 degrees
  - improves A_{eff} ~3dB
  - Reduces T_{sys}
  - 60 degrees scan will be degraded

Station configuration

- Station dynamic range: configuration



Tiles
mwa



Tiles on regular grid
closed packed
lofar high band

Trade offs

	Deployment cost	Freq bandwidth	A_{eff} / T_{sys}	Dynamic range
Random elements	High	Good	Optimal	Optimal
Random tiles	Moderate	Good	Good	Good
Regular grid tiles	Low	Optimal	Good	(strong gratings)

LOFAR, MWA, AAVP will need to confirm/complete the trade-offs

Table should be expanded: front-end / system study in AAVP

Key specifications for the AAVS1/2 AA-low designs

- A_{eff}/T_{sys} over the 70-450 MHz freq band:

  science priorities required

  50MHz??

- FoV requirement:

  sub station beamforming/data reduction.....

  – Output of a station (180mØ) will be between 150 and 1500 10Gb/s data channels
  – Uniboard2 type beamforming development

A_{eff} / T_{sys} options

Table 2. Peak sensitivity at Zenith

Freq	T_{sys}	A_{e8}/T_s	A_{e16}/T_s	A_{e32}/T_s	A_{e64}/T_s
MHz	K	$m^2 K^{-1}$	$m^2 K^{-1}$	$m^2 K^{-1}$	$m^2 K^{-1}$
69	2650	566	452	302	226
85	1595	940	752	502	376
98	1125	1334	1066	712	534
120	695	1446	1726	1150	864
138	500	1500	2400	1600	1200
170	322	**1538**	2460	2484	1864
196	238		**2520**	3360	2520
240	163		1840	3238	3680
276	120			3334	**5000**
392	75			2666	4000
538	50			2000	3000

- Bregman, June 2010
- Element packing density increases to the right colums: dense for the lower frequencies
- Resulting in
  - large bandwidth
  - Stable impedance for noise match
  - Lower A_{eff} at lower freq

Can optimise low freq for EoR or higher freq for Pulsars etc...

Timeline *(under discussion.....)*

Date	Milestone/event	Description
2010Q3	SKA1 definition published	AA-lo highlighted selected for Phase 1
2011Q1	**CoDR**: Aperture Array	Design review covering AA-low and AA-mid
2011Q1	AAVS test requirements	Agree tests required of the AAVS
2011Q2	AA element review	Review status of the alternative AA elements
2011Q4	AA-mid front-end design	Incl. element, LNA and analogue beamforming
2011Q4	AA-lo element performance review	Select elements that will be tested on AAVS1
2011Q4	AAVS1 digitisation and beamformer design complete	Digital tile beamformer for AA-low and AA-mid
2011Q4	**CDR**: AAVS1	Approve AAVS1
2012Q2	**PR**: AAVS1	Approval for AAVS1 production
2012Q3	AAVS1 sub-system production	Industry builds AAVS1 single array subsystems.
2012Q3	Construct AAVS1	Build AAVS1 central processing,
		Install AA-low antennas
		Install AA-mid tiles
2012Q4	Commission AAVS1	AAVS1 proving and calibration
2013Q2	**PDR**: AAVS2	Approve design of AAVS2 with knowledge from AAVS1
2013Q2	AAVS1 reports (+all verifications...)	Evaluation of AAVS1 –lo and –mid
2013Q3	**CDR**: AAVS2	Design completed for AAVS2 -lo and –mid
2013Q4	**PR**: AAVS2	Approval for AAVS2 production
2014Q1	Construct AAVS2	
2014Q3	Commission AAVS2	*Need to consider other site prep going on*
2014Q4	AAVS2 –low	Evaluation of early AAVS2 –low using tooling
2015Q1	SKA1 pre-production systems	Complete the manufacture of SKA1 systems using production tooling (AA-low & Dishes)
2015Q2	**PDRs**: AA-mid; SP-WBF, PAF	PDR for advanced technology selection, to inform SKA2 decision
2015Q4	**PR**: SKA1	Final production reviews of all aspects SKA1
2016Q1	Start SKA1 production	

AAVS1: AA-low

- Demonstrate electromagnetic and front end performance
  - Built on low RFI site, ideally chosen SKA site
  - Sufficient collecting area, possibly two versions
  - Focus on **broadband** antenna and front-end design
  - Evaluation using existing early processing - UNIBOARD

  - Establish antenna, tile and station configuration
    - Extensive station simulations required and checked

  - Critical Design Review 31-12-2011
  - Commissioning 31-12-2012
  - Reporting 30-6-2013

AAVS2: AA-low

- Pre production phase:
  - Preparing for mass-production

- AAVS2 prototype
  - Test the tooled, production components
  - SKA_1 performance compliance
  - Bandwidth, Tsys, stability, signal processing, calibratebility etc..

  - Critical Design Review 30-9-2013
  - Construction 2014
  - Commisioning 2015
  - Reporting for SKA1 PR 31-12-2015

AAVS2 requirements

- In order to ramp-up production in 2016, AAVS2 should be as large as possible: e.g. 1-2% SKA_1
- Built with SKA_1 tooling
- Approaching180 meter diameter station including digital station beamforming
- On the SKA site

- Acceptance tests of this station should be considered in absence of correlator

Schedule is tight: custom MMICs, photonic links, signal processing boards

Message is:

- This is a *very* tight timeline
- Must have specification stability ASAP
- The window for changes is passing....

AAVP Workshop

Cambridge

8-10 December 2010

A workshop to discuss the detailed science, technical design, performance and implementation plan for aperture arrays in Phase 1 and Phase 2 of the SKA. In particular we will emphasise the achievable requirements for the low frequency aperture array for SKA_1 and discuss the evolution to AA-mid in SKA_2

www.mrao.cam.ac.uk/projects/aavp