SKA Specification Revisions

Discussion at the EWG/SWG combined meeting in Paris

September 2006

History of Current Specifications

2002: Initial SKA technical specifications published (Ekers, SKA Memo 4)

2003: Working group* formed after the Geraldton workshop to revise and expand specifications

2003: Revised specifications discussed at Leiden meeting, based on the five key science projects (Gaensler, SKA Memo 44)

2004: Revised specs incorporating input from Leiden meeting published (Jones, SKA Memo 45)

2004: Feedback on specs from EWG at Penticton meeting

2004-6: “Magnificent memos” written in response to EWG

2006: Re-appraisal of the science-driven specs in light of engineering and fiscal reality (Paris)

* WG members: Carilli, Ekers, Gaensler, Jones, Kellermann, Reynolds, Schilizzi, Tarter, and Taylor

Science-driven specifications from 2004:

Attempted to cover needs of all aspects of the key science projects

Table 1 – Expanded SKA Science Requirements (version 9)

1.	**Frequency range**	100 MHz - 25 GHz Goal: 60 MHz - 35 GHz
2.	**Simultaneous independent observing bands**[2]	2 pairs (2 polarizations at each of two independent frequencies, with same FoV centers)
3.	**Max. freq. separation of observing bands**	Factor of 3 between observing band center frequencies (same FoV centers)
4.	**Instantaneous bandwidth of each observing band**	Full width = 25% of observing band center frequency, up to a maximum of 4 GHz BW for all frequencies above 16 GHz
5.	**Sensitivity at 45 degrees elevation (A/T)**	Goal: 2500 at 60 MHz 5000 at 200 MHz, 20000 between 0.5 and 5 GHz, 15000 at 15 GHz, and 10000 at 25 GHz Goal: 5000 at 35 GHz
6.	**Configuration**	Minimum baselines 20 meters, 20% of total collecting area within 1 km diameter, 50% of total collecting area within 5 km diameter, 75% of total collecting area within 150 km diameter, maximum baselines at least 3000 km from array core (angular resolution < $0.02 / f_{GHz}$ arcsec)
7.	**Image quality**	Dynamic range > 10^6 and image fidelity > 10^4 between 0.5 and 25 GHz, over a range of 90 degrees in declination and 100 in angular resolution
8.	**Contiguous imaging field of view (FoV)**	1 square degree within half power points at 1.4 GHz, scaling as λ^2, 200 sq. deg. within half power points at 0.7 GHz, scaling as λ^2 between 0.5-1.0 GHz
9.	**Number of separated fields of view**	1 with full sensitivity Goal: 4 with full sensitivity 10 simultaneous sub-arrays
10.	**Correlator and post-correlation processing**	Input bandwidth 25% of center frequency for frequencies below 16 GHz and 4 GHz for frequencies above 16 GHz (per observing band) Imaging of 1 square degree at 1.4 GHz with 0.1 arcsec angular resolution Imaging of 200 sq. degrees at 0.7 GHz with 0.2 arcsec angular resolution Imaging of 10^4 separate regions within the FoV, each covering at least 10^5 beam areas at full (maximum baseline) angular resolution Spectral resolution of 10^4 channels per observing band per baseline Minimum sampling interval 0.1 ms for wide-field pulsar searches
11.	**Beamformer capability**	50 simultaneous summed (phased array) beams within FoV, inner 5 km diameter of array. No time averaging, 8 bits/sample.
12.	**Survey speed**	FoV x $(A/T)^2$ x BW = 3×10^{17} deg^2 m^4 K^{-2} Hz^{-1} at 1.5 GHz FoV x $(A/T)^2$ x BW = 1.5×10^{19} deg^2 m^4 K^{-2} Hz^{-1} at 0.7 GHz
13.	**Antenna pointing and slewing**	Blind pointing < 0.1 HPBW, move between adjacent sky positions separated by 0.5 HPBW in 3 sec, move between sky positions sep. by 90 deg. in < 60 s
14.	**Instrumental polarization**	Polarization error / total intensity –40 dB at FoV center, -30 dB out to FoV edge (after routine calibration)
15.	**Spectral dynamic range**	10^4 (flatness of bandpass response after calibration)
16.	**Total power calibration**	Total power (zero-spacing) flux density measured with 5% error within 1 hr.

[2] An "observing band" is a contiguous set of frequencies that pass through all processing steps simultaneously.

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Areas of Controversy

- Frequency range
  - Very wide frequency range implies multiple antenna techologies, high cost
- Field of view
  - Dark energy surveys require large increase in FoV
- Sensitivity
  - To what extent can this parameter be traded against frequency range, FoV, and other parameters

Carole Jackson's matrix summarizes requirements by project/experiment – important to see distributions

One Approach: Look for Gaps

- Gaps in frequency
  - EoR frequencies vs. everything else
  - Less than 3-10 GHz vs. 20-30 GHz
- Gaps in field of view
  - 1 (or a few) deg^2 vs. ~100 deg^2
- Gaps in sensitivity
  - Nearly a square km vs. ~0.1 km^2

Keep “Exploration of the Unknown” in mind: Coverage of observational parameter space and flexibility are valuable.

Decisions

Priority of EoR (0.1 vs 0.3 GHz)

Priority of Cradle of Life (~10 vs 25 GHz)

Priority of deep HI survey (FoV)

Priority of raw sensitivity (collecting area) vs. other observing parameters

Strawman Design (2006):

A good starting point

One implementation of the SKA Reference Design – A discussion strawman (PJH, 14.7. 06)

Controversial Characteristic	**Value**	**Assumptions/Comments**
Antennas	4000 x 12 m dishes; solid surface; 2.5 mm rms Feeds, inner array (<5 km) 0.3-3 GHz PAF in 2 bands 3-10 GHz WBF Feeds, outer array (>5 km) 0.3 – 10 GHz WBF(s) (single pixel)	€100k antenna; leaves way open for higher frequencies if 22 GHz antenna can be supplied within budget. Still builds enough low freq area to be interesting in that case. If f>3 GHz definitely not interesting, could aim for 15m (mesh?) dishes at same cost, giving factor of 1.6 in A/T. Can aim to extend PAFs to outer antennas as evolutionary path.
Aeff/Tsys	~ 10,000 at 1.4 GHz ~7,000 at 10 GHz	Tsys ~ 30K.
Maximum FOV expansion factor for PAFs in inner (<5 km) array	40	Gives ~35 deg^2 at 1.4 GHz. Deliberate limit on beamforming complexity.
PAF beamforming	Digital, in focal package	Ref sig transport TF comparisons
Polarization, max. bandwidth	Dual poln, 2.5 GHz/poln	
Configuration	200 stations, 5 arm spiral. SKA-owned fibre network inside 150 km diameter. 3000 km max baselines. 20 antennas/station. 2000 antennas inside 5 km dia. Stn placement to be agreed.	Maybe push owned array to 250 km after prelim cost study
Signal aggregation	All antennas inside 5 km array individually correlated	Maybe push limit out depending on prelim correlator affordability study
Station size	< 150 m diameter, random element placing	Small as possible given unshadowed 30 deg elev limit
Computing and software	Capped at €150M	Initial complexity limitations, and plan for evolving capability, to be stated and accepted as part of SKA specification
Innovation path: 0.3-1 GHz dense aperture array (AA), centrally concentrated. Initial area Number of independent FOVs	 100 000 m^2 (physical) 8	 With Tsys=50K, 75% aperture efficiency, gives single FOV sensitivity equal to Arecibo. Aim to expand area as cost of AA falls.

Specs of Strawman Design

- Frequency range 0.3-10 GHz
- Wide FoV for inner core only, 0.3-3 GHz PAFs in 2 bands, ~35 deg^2 at 1.4 GHz
- Sensitivity (A/T) half of previous spec (10,000)

Questions for this meeting:

Can we live with this?

Is it an appropriate balance?

If not, how can we afford more?