SKA: how many Array Stations?

Bruce MacA. Thomas, Michael I. Large & Mark H. Wieringa

Australia Telescope National Facility, CSIRO, Sydney.

Summary

Siting considerations and image quality are the principal factors which determine the number of SKA Array Stations. The optimum number for the complete instrument appears to be about 300. An evolutionary design is proposed, with initially 150 Array Stations located within a 100 km radius.

Specifications

Geometrical area ..... 10^6 m^2
System temperature ..... 30 K
Antenna efficiency 60%
Aeff/Tsys ..... 2 x 10^4 m^2/K

Site constraints

- Negotiations and/or purchase
- Establish a radio quiet reserve
- Infrastructure
  - power & communications
  - access roads & security
  - maintenance

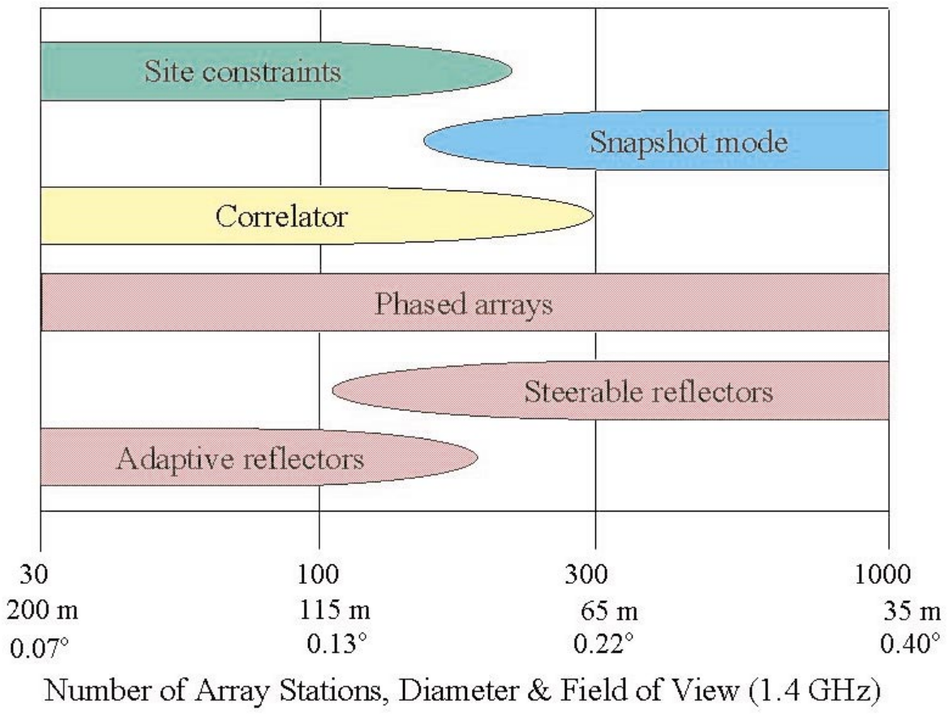
All siting costs will be greater per Array Station for remote sites than for the central site.
Minimise the number of geographically separate sites.

Continuous aperture antenna technology

If an Array Station consists of a single continuous aperture the field size is maximised and the sidelobe confusion is minimised.

- Phased array
  - No size limitations
  - Practical upper frequency limit
  - Multiple widely spaced beams
  - No limit on diameter and N
- Steerable reflectors
  - Constant beam shape
  - Engineering limit to diameter ~ 100 m
  - \ N > 130
- Adaptive reflectors
  - Limited sky coverage
  - Diameter > 75 m
  - \ N < 200

Some constraints on the number of Array Stations (N)



Number of Array Stations, Diameter & Field of View (1.4 GHz)

uv - coverage

- To go beyond the performance of the VLA, the number, N, of Array Stations (at fixed locations) should be greater than 150.
- Snapshot coverage is increasingly compromised for 300-km radius operation as N decreases significantly below 300.

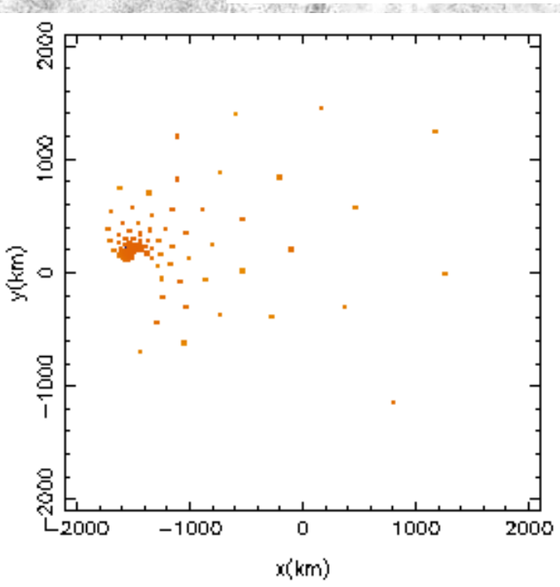
Self calibration

For antenna based self-calibration, individual radio sources must be detectable with sufficient signal to noise by every antenna pair. If the minimum antenna diameter for this purpose is taken to be 25 m, then the self-cal requirements imply N < 2000.

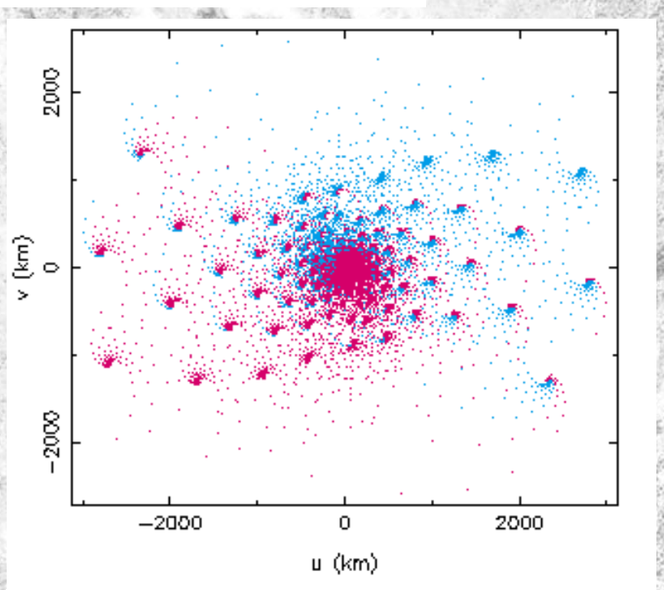
Correlator

- The number (N) of Array Stations in the SKA is not in principle limited by the correlator.
- Realistically however, correlators are limited in size by practical considerations. With present day technology, it is arguable that N < 50.
- The rate of development of electronics and photonics suggests that within a decade or so the correlator limit on N could be N < 500.

N = 300 is a good compromise!



Spiral distribution for N = 300



uv-coverage for N=300

Distribution of array-stations and configuration characteristics
(each array station is a 65-m diameter continuous aperture)

Radius * (km)	Description	Number of Array Stations	Characteristics
< 3	Close-packed array	150	High surface-brightness sensitivity
3 - 30	Radio-quiet reserve	55	70% on radio-quiet reserve
30 - 300	0.1" resolution, 1.4 GHz	50	Good snapshot images
300 - 3000	VLBI array	45	Good images ~ 8 hrs.
	Total	300	

* Distance from close-packed array.

Reference: M Wieringa
(www.narrabri.atnf.csiro.au/~mwiering/skasim/)

An evolutionary development for the SKA

Advantages:

Produces good science for minimum cost from day 1
Once initial configuration is operational, add array-stations in an ongoing "growth" phase.

What is number of array-stations (N) for an initial configuration?

N = 150 ("Half-SKA") has
- 10 x GMRT area
- 20 x VLBI/VLA (upgraded) area.

A growth path leading to the N=300 configuration for SKA

Radius (km)	"Half-SKA" (initial configuration)	Typical intermediate configuration	SKA (final configuration)
< 3	75	100	150
3 - 30	50	55	55
30 - 300	25	45	50
300 -3000	0	0	45
Total	150	200	300
Max. radius	100 km	300 km	3000 km

Advantages of "growth" model:

uv-coverage of the array to 100 km approximates a scaled version of the final uv-coverage

Science projects requiring only moderate resolutions could start immediately, with higher-resolution projects as the array grows.

Prior to completion of the "Half-SKA", initial testing can commence with array-stations being constructed only on the radio-quiet reserve (radius < 30 km).

Conclusion

Considerations of SKA image quality (uv-coverage) and field of view argue for a large number of Array Stations, perhaps thousands. However practical factors, notably the size of the correlator and the difficulty of acquiring and maintaining remote sites, argue for a smaller number of Array Stations. An optimum design might be 300 Array Stations with 15% located over continental distances.

A first stage in an evolving SKA could be 150 Array Stations within a 100 km radius. This would be a powerful instrument from the outset. Its sensitivity and resolving power would increase as further remote sites were acquired and the number of Array Stations increased.