



Memo 77

SKA Antenna and Receiver Cost Optimization Including Survey Speed and Focal Plane Arrays

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05/06

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May 14, 2006

Introduction

There have been previous cost estimates of LNSD arrays as a function of antenna diameter, D , for achieving a specified point source sensitivity using a figure of merit of $A/T = 20,000 \text{ m}^2/\text{K}$. This memo is attempt to find cost curves including a survey sensitivity criteria with a figure of merit, $(A/T) * \sqrt{J} / D$, where J is the number of beams produced by a focal plane array. These beams can either be produced by horn clusters which produce non-contiguous beams or phased array feeds which can produce contiguous beams but with a greater cost of electronics, In this latter case each of the J beams requires a number of feeds and LNA's and appropriate analog or digital combining electronics.

Assumptions

At the outset it should be stated that cost estimates accurate to even +/-30% will require 3 to 5 years of design, prototyping, and manufacturing development. The cost figures used in this memo are order of magnitude estimates based upon knowledge of the ATA and DSN prototype arrays. The cost figures use a model described below for antenna and receivers and do not include costs for facilities, data transmission, correlation, software, management, and contingency; these may total of a cost of \$500M which is only weakly dependant upon antenna diameter and FPA's.

For antenna cost a model of $\$5\text{K} + 0.2\text{K} * D^{2.7}$ is used. This results in a cost of \$30K for a 6m antenna \$169K for a 12m antennas, and \$1194K for 25m antennas, all purchased in large quantities and after 5 years of cost optimization. . These figures are about a factor of 2 lower than current ATA and DSN array experience but are reasonable given further development and the quantity required.

The cost figures are for an SKA covering 0.15 to 25 GHz with $T_{\text{sys}} = 18\text{K}$ above 1 GHz and with 3 receivers on each element as follows::

- A) A 0.15 to 0.5 GHz single-beam prime focus uncooled receiver costing \$3K each. (This figure may be high but it has little effect upon totals).
- B) An uncooled 0.5 to 1.4 GHz focal plane array costing \$1K per beam
- C) A cooled 1.2 to 25 GHz receiver costing \$30K.

Thus, antenna + receiver cost = $\$500\text{M} + N * (\$35\text{K} + \$0.2\text{K} * D^{2.7} + J * \$1\text{K})$

This cost as functions of D , N , and J for constant point source figure of merit = A/T_{sys} is shown in Figure 1 and for constant survey speed figure of merit = $(A/T_{\text{sys}}) * (\sqrt{J} / D)$ in Figure 2. Table 1 compares interesting cases and Table 2 shows the effect of reducing frequency coverage to 3 GHz (no 1.2 to 25 GHz receiver and 25% less antenna cost).

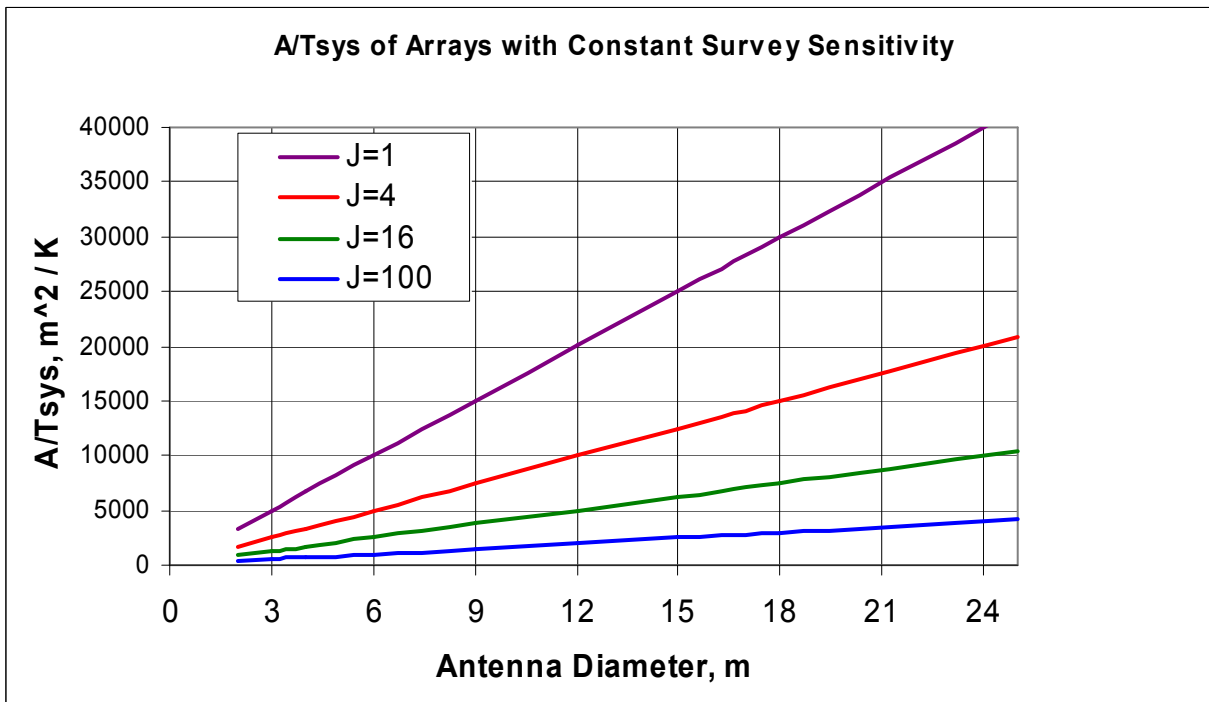
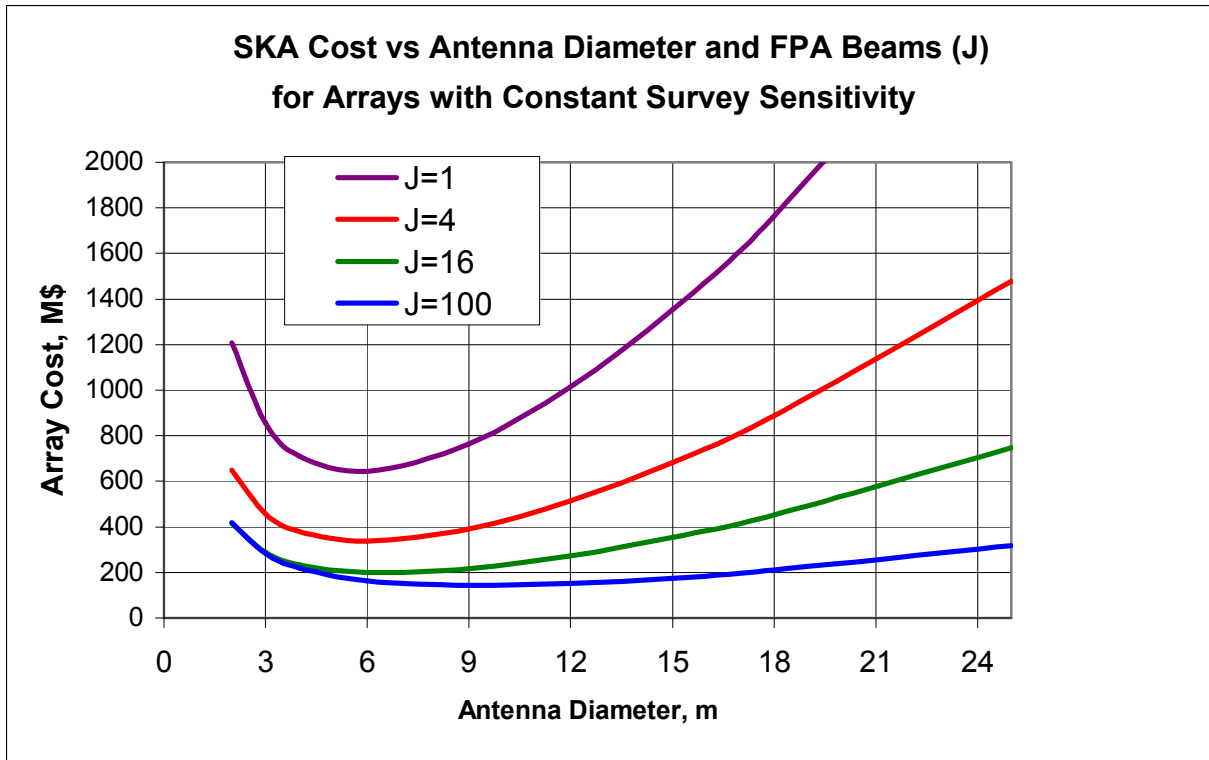


Figure 1 - (Top) Receiver and antenna cost to achieve a survey figure of merit, $(A/T) * \sqrt{J} / D = 1667 \text{ m/K}$, as a function of antenna diameter. (Bottom) Point source figure of merit, A/T , for the constant survey sensitivity arrays. The A/T goes down with increasing J because the number of antennas required for the survey sensitivity goes down.

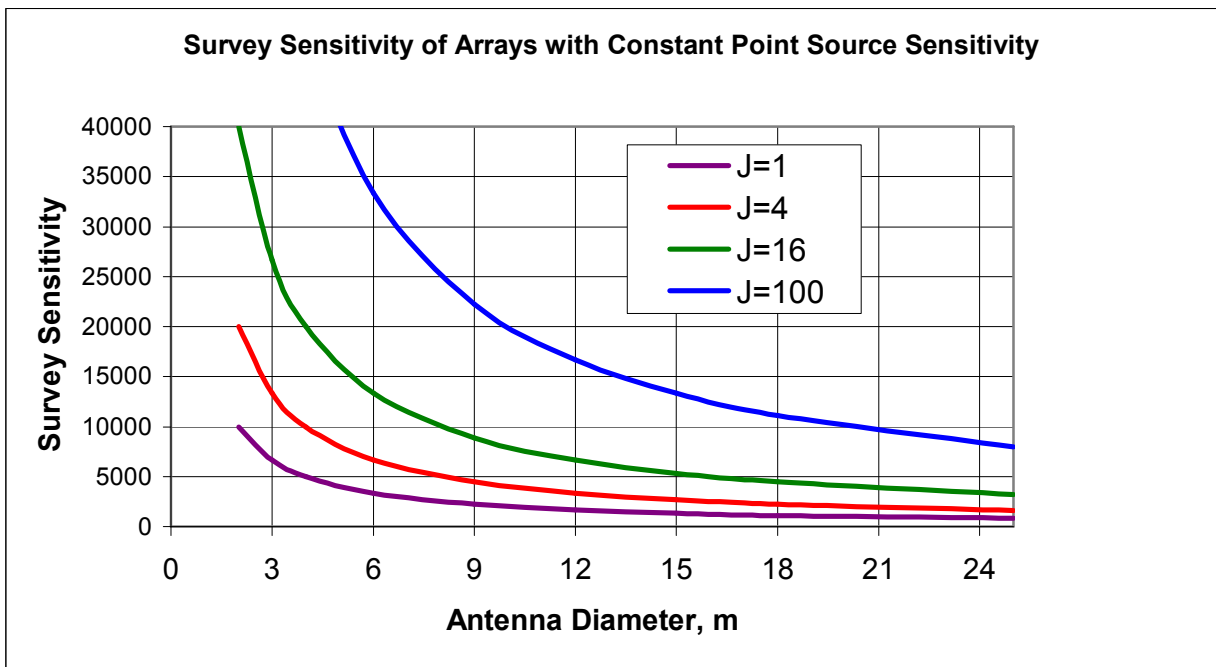
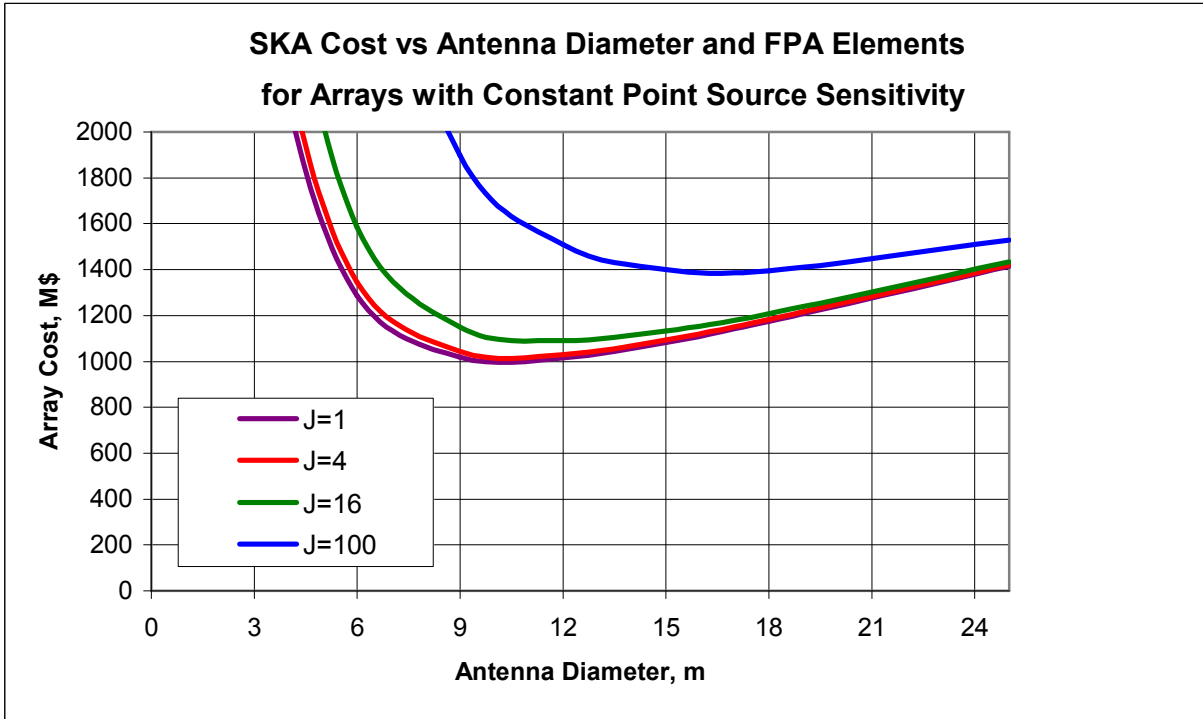


Figure 2 - (Top) Cost of arrays with constant point source sensitivity figure of merit, $A/T = 20,000 \text{ m}^2/\text{K}$. (Bottom) Survey sensitivity figure of merit, $(A/T) * \sqrt{J} / D$ for the constant point source sensitivity arrays.

Table 1 - Example 25 GHz Arrays

(Cost column is for antennas and receivers; add of the order of \$500M for total cost at A/T =20,000, less at lower A/T)

Case	D	Number	Beams J	Point Source, A/T	Survey Sensitivity, (A/T) * \sqrt{J} / D	Cost M\$	Comment
A1	12	5,000	1	20,000	1667	1000	US SKA Baseline
B1	6	10,000	1	10,000	1667	612	6m, same survey merit as baseline
B2	6	20,000	1	20,000	3334	1224	6m to meet A/T
B3	6	20,000	4	20,000	6668	1304	Add FPA to 6m
A2	12	5,000	4	20,000	3334	1020	Add 4x FPA to baseline
A3	12	5,000	16	20,000	6668	1080	Add 16x FPA to baseline
C1	12	2,500	1	10,000	833	500	Cut A/T to reduce cost
C4	12	2,500	4	10,000	1667	510	Increase FPA
C16	12	2,500	16	10,000	3334	540	Increase FPA
C100	12	2,500	100	10,000	8330	750	Large FPA
D	12	400	1	1,600	133	80	10% demonstrator
V	25	27	1	469	19	32	VLA per cost model
VX	25	1151	1	20,000	810	1364	VLA expanded with 25m
VY	25	575	1	10,000	405	682	As VX but with 1/2 A/T
T	6	450	1	450	75	75	ATA to 25 GHz

Table 2- Example 3 GHz Arrays

(Cost column is for antennas and receivers with no cooled receivers but 25% less cost for antennas; add of the order of \$400M for total cost at A/T =20,000, less at lower A/T)

Case	D	Number	Beams J	Point Source, A/T	Survey Sensitivity, (A/T) * \sqrt{J} / D	Cost M\$	Comment
B2L	6	20,000	1	20,000	3334	534	6m optimum to meet A/T
B3L	6	20,000	4	20,000	6668	594	Add FPA to 6m
A2L	12	5,000	4	20,000	3334	669	Add 4x FPA to baseline 12m
A3L	12	5,000	16	20,000	6668	729	Add 16x FPA to baseline
E	15	3,200	16	20,000	4000	792	15m array

Conclusions

- 1) For the 25 GHz array, optimum D is 12m, and FPA's can be added to increase survey speed at < 1.7 GHz. An affordable compromise is case C4 which achieves A/T of 10,000 at an estimated total cost of \$850M. The same A/T and survey speeds with 6m antennas, case B1 would cost \$102M more, or with 25m antennas and lower survey speed, case VY, \$172M more.
- 2) For a 3 GHz array, optimum D is 6m with a total cost estimate of \$934M for A/T of 20,000 or \$567M for A/T of 10,000.
- 3) Reducing frequency coverage from 25 GHz to 3 GHz saves \$283M at A/T = 10,000 and \$566M at A/T = 20,000.