

# Technology Facts for SKA

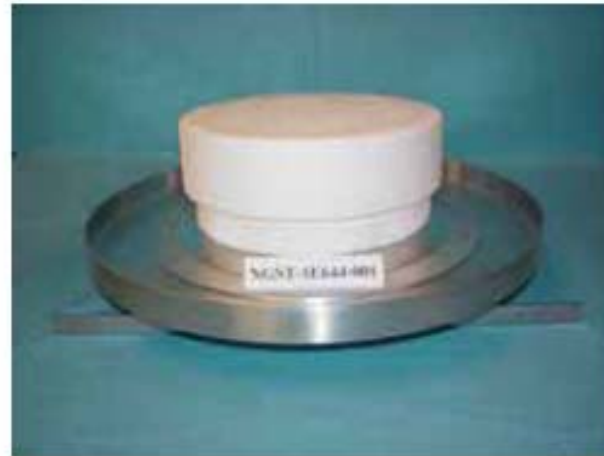
1. **Aperature arrays are currently too expensive for frequencies above 0.3 GHz .**  
An aperature array requires a very large number of antenna proportional to frequency squared. The effective area of any antenna with hemispherical field of view is  $\lambda^2 / 2\pi$  and thus to achieve 1 km<sup>2</sup> of array total area at 0.3 GHz, 6.3 million elements are needed. This may be feasible for under \$1B at 300 MHz but the financial basis for higher frequencies is too high a risk at this time considering the numbers of antennas, receivers, and signal processors required.
2. Reflector antennas in the 6m to 12m range for operation to 25 GHz are a proven array component with costs known to +/- 30 % (6m at \$50K, 12m at \$200K)
3. LNA's for wideband operation to 25 GHz are also a proven component with noise temperature of the order of 5 to 10K at cryogenic temperatures or 20 to 50K at 300K.
4. Wideband feeds performance is a significant unknown.
5. The most uncertain costs for the SKA are:
  - A. cryogenics
  - B. system integration
  - C. operations
  - D. Tsys which effects costs through increasing A for a specified A/Tsys.

## Candidate Decade-Bandwidth Feeds for the SKA

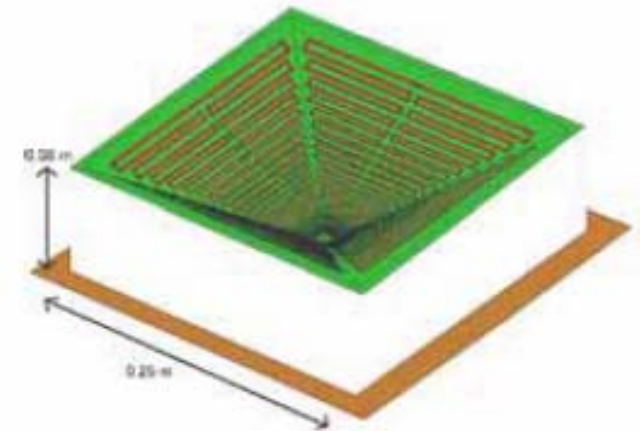
The entire 0.1 to 34 GHz frequency range can be covered with 3 wideband receivers.



ATA



Ingersen

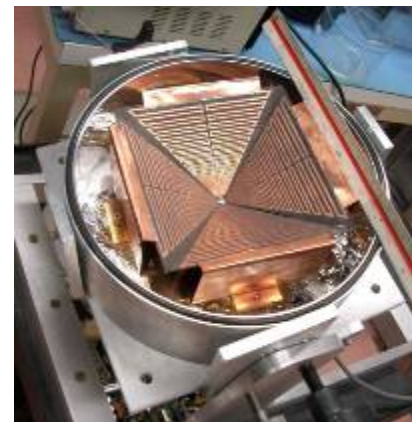


Kildal

**Figure IV.1.3** - Candidate feeds for the SKA. All have a width of approximately half the longest wavelength of operation but the ATA feed is much longer than the others. At present, the Ingersen and Kildal feeds have unacceptable impedance variations with frequency but the short length and terminal locations are much more compatible with low noise operation in a cryogenics dewar.

# Wideband Feed Development Status Report

1. Initial (2004) version of Kildal feed was tested for system noise in a cryogenic dewar and had poor performance ( $T_{\text{sys}}$  of 100 to 150K) due to loss, reflections, and thermal conductivity.
2. New version of Kildal feed scaled to 0.15 to 1.7 GHz is giving good results on NRAO 140' telescope but little qualitative data is available.
3. New version of Kildal feed (now called Eleven feed) for 1.2 to 13 GHz has been ordered by JPL for delivery by late 2006.
4. Quadridge/Vivaldi feeds are being investigated at Caltech as backups to the Eleven or ATA type feeds. A first quad-ridge test gave  $T_{\text{sys}}$  in the 10 to 15K range from 5.7 to 13 GHz.
5. The Lindgren quadridge/Vivaldi feed shown at right appears to have acceptable match and beamwidth variation from 2.2 to 14GHz. One will be delivered to Caltech next month and will be tested for patterns and cryogenic system noise.



**3164-05**

<a href="#">Electrical Specifications</a>
<a href="#">Physical Specifications</a>
<a href="#">Performance Charts</a>



**Key Features:**

- 2 GHz - 18 GHz Frequency Range
- Flat Gain For Upper 2/3 of Range
- Low Side Lobes
- Linear or Circular Polarization (With Hybrid)
- Compact Design
- Flexible Mounting Schemes
  - Flange for Wall Mounting
  - Bracket for Tripod Mounting

<a href="#">3164-05 Quadridge Horn PDF DATASHEET</a>
<a href="#">3164-05 PDF MANUAL</a>
<a href="#">Antenna Patterns</a>
<a href="#">Calibration Services</a>
<a href="#">Accessories</a>
<a href="#">Antenna RFQ</a>
<a href="#">1. Antenna Catalog - BiConilogs (p4 - 9) PDF</a>
<a href="#">2. Antenna Catalog -</a>

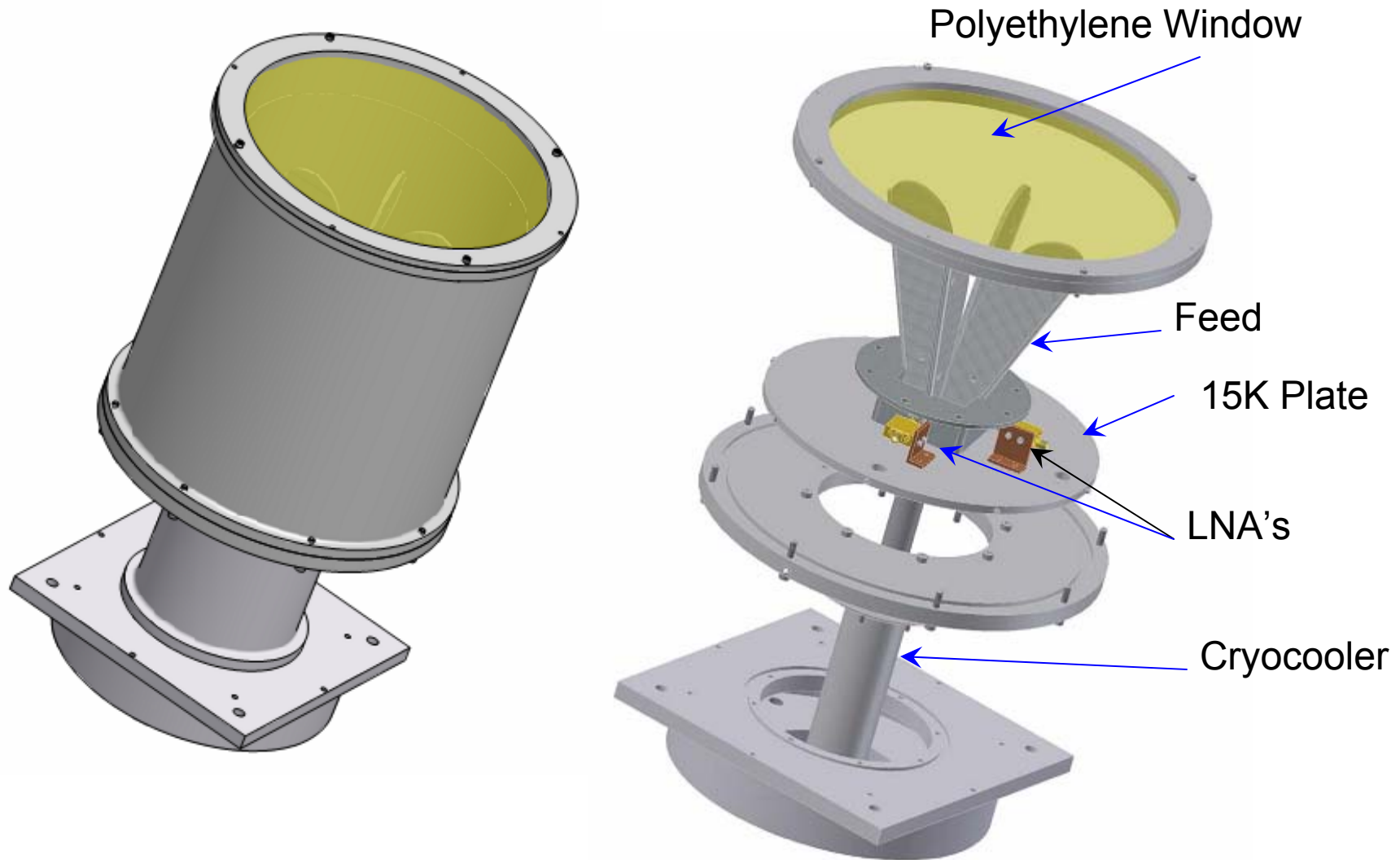
**The Model 3164-05 Open Boundary Quadridge Horn** is the newest in a series of quadridge horns from ETS-Lindgren. The "open boundary" design with its absence of side plates makes this antenna unique in both appearance and performance.

Numerically modeled, the Model 3164's open boundary design is similar to two Vivaldi PCB antennas placed orthogonally to each other. The antenna's surprisingly compact size offers improved pattern and gain when compared with enclosed quadridge horns of similar dimensions. The compact size also means there is only small shift on the Model 3164's phase center as frequency changes.

The Model 3164-05 has exceptional bandwidth. While the frequency band for optimum performance is 2 GHz to 18 GHz, the antenna is usable from 1.5 GHz. Two orthogonally placed input feeds allow this antenna to generate both linear and circular polarized measurements across the entire frequency band.

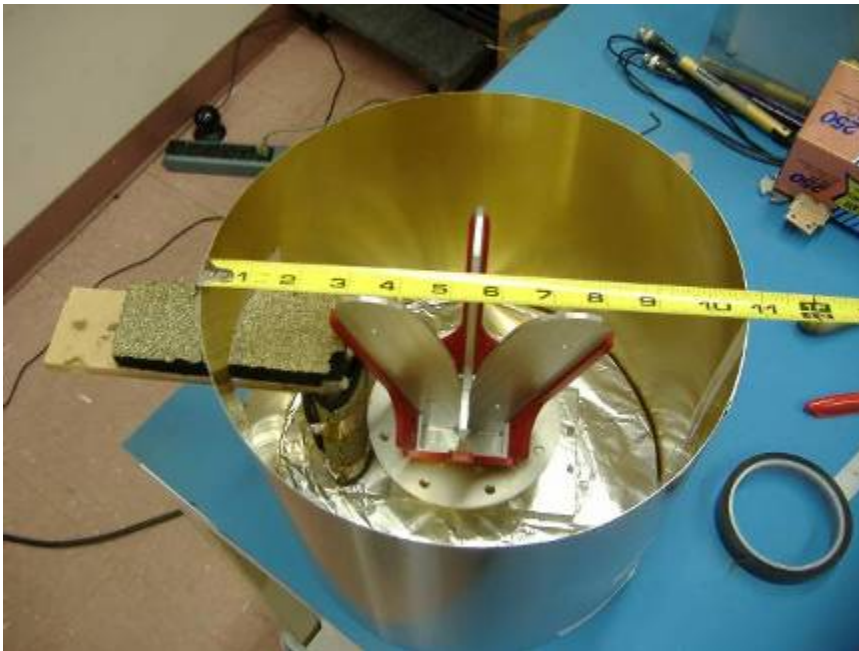
Reference: V. Rodriguez, "A Multi-Octave Open-Boundary Quad-Ridge Horn Antenna for Use in the S- to Ku-Bands", Microwave Journal, March, 2006. pp.84-92

# Cryogenic Dewar Design for Lindgren Antenna



## Pattern Tests of Lindgren 3164-05 Antenna in Simulated Cryogenics Dewar

Feed in aluminum 25cm diameter cylinder to simulate cryogenics dewar

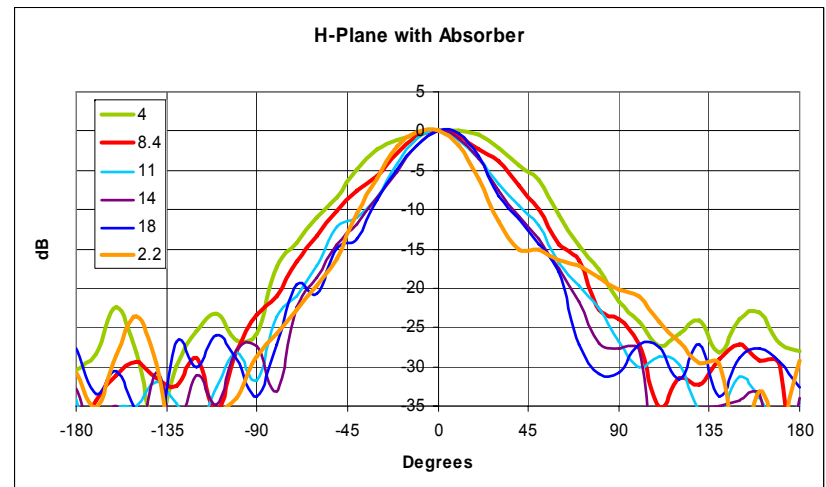
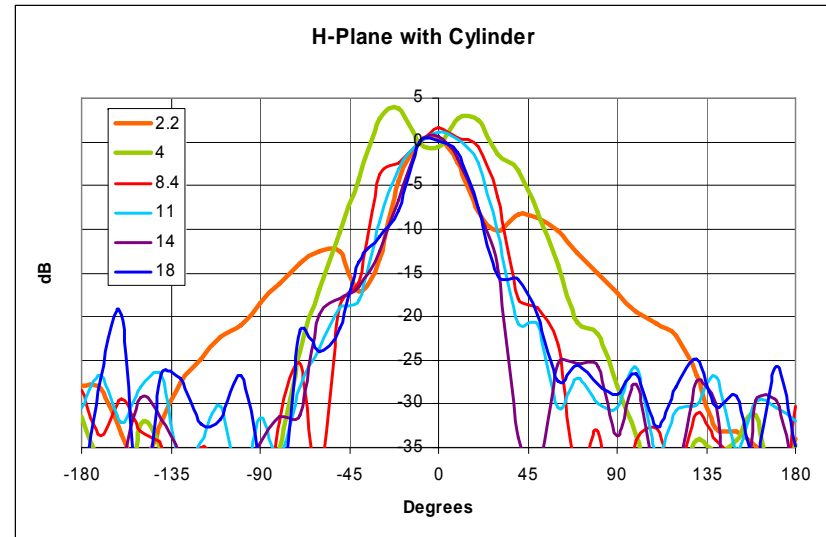
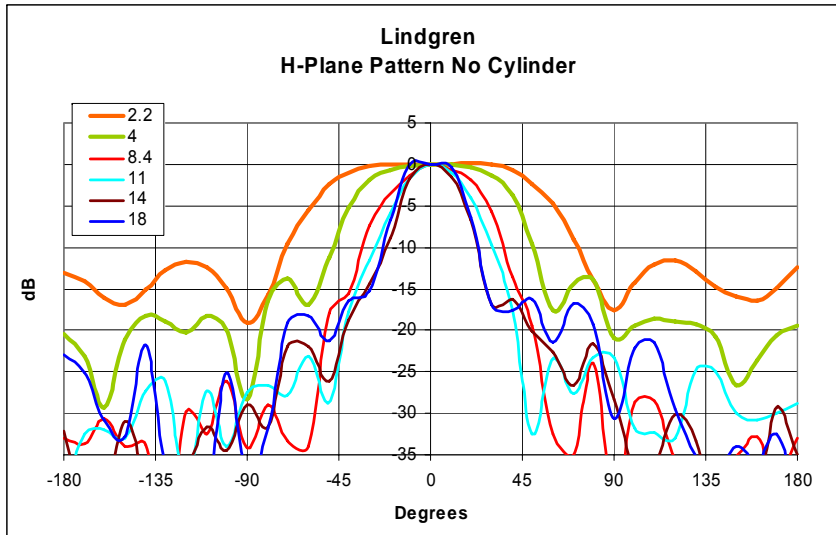


Absorber material inserted in cylinder for additional tests



# H-Plane Magnitude Patterns as Cylinder and Absorber are Added

(Note Absorber Makes the H-Plane Pattern More Uniform at Low Frequencies)



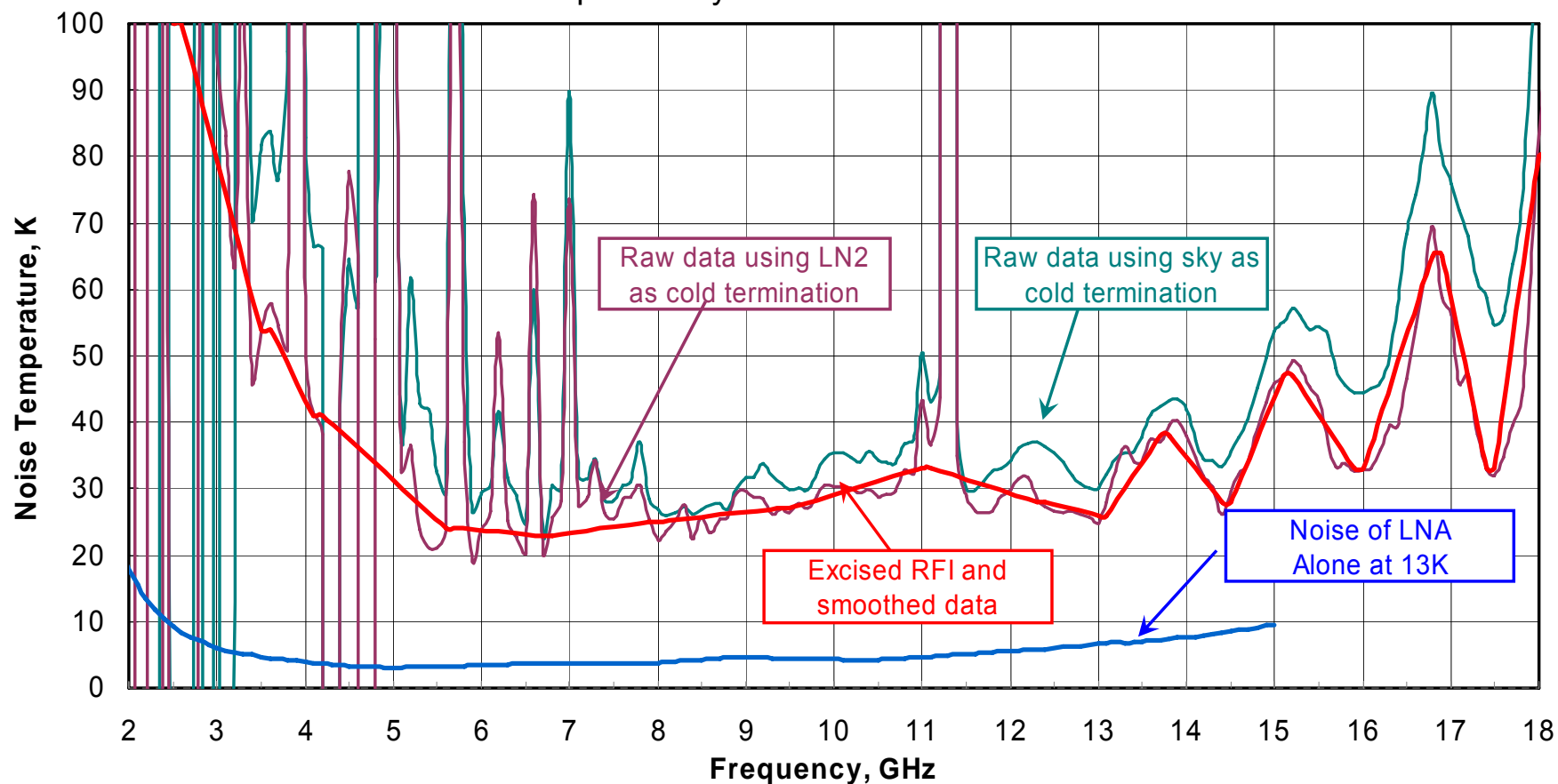
## Noise of Lindren Feed with Caltech InP HEMT LNA at 31K

Window: 2.4mm HDPE, over Gortex over 10 layers of 50um PTFE

LNA #87D  $V_d=1.8V$ ,  $I_d=50mA$ ,  $V_{g1}=1.8V$ ,  $V_{g2}=1.8V$

Caltech Roof, July 16, 2006 10PM

Total noise can be explained by 1 dB of absorber loss at 60K and TLNA of 10K



# Assumptions for Cost Study

- Antenna Cost =  $\$5K + 0.2K * D^{2.7}$  - This is  $\$30K$  for 6m,  $\$169K$  for 12m which are about  $\frac{1}{2}$  of present small quantity costs
- Focal Plane Array Cost =  $\$1K * J$  where J is the number of beams and the frequency range is 0.5 to 1.4 GHz
- Receiver Cost =  $\$30K$  for 1.2 to 25 GHz cooled receiver,  $\$3K$  for 0.15 to 0.5 GHz uncooled receiver
- Array “Fixed” Cost =  $\$500M$  for design, signal transmission, signal processing, software, and facilities.

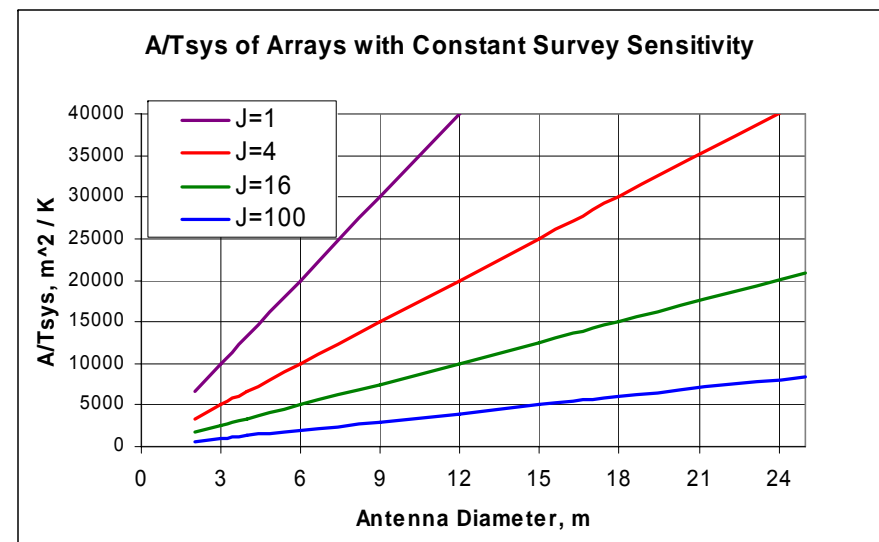
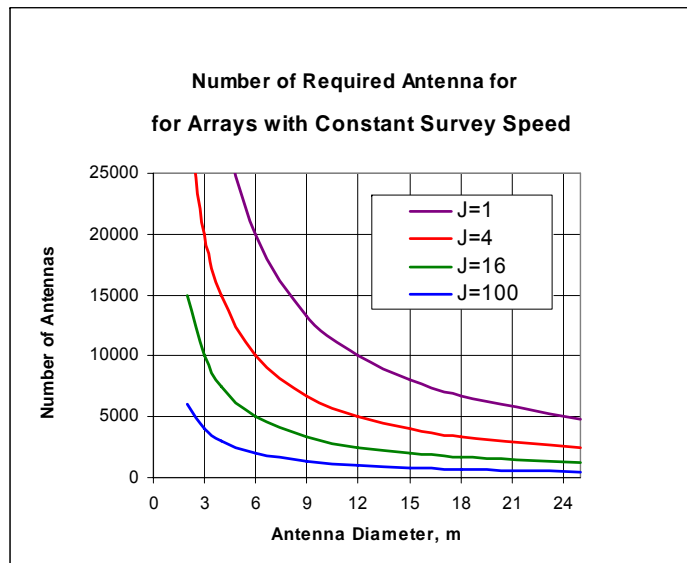
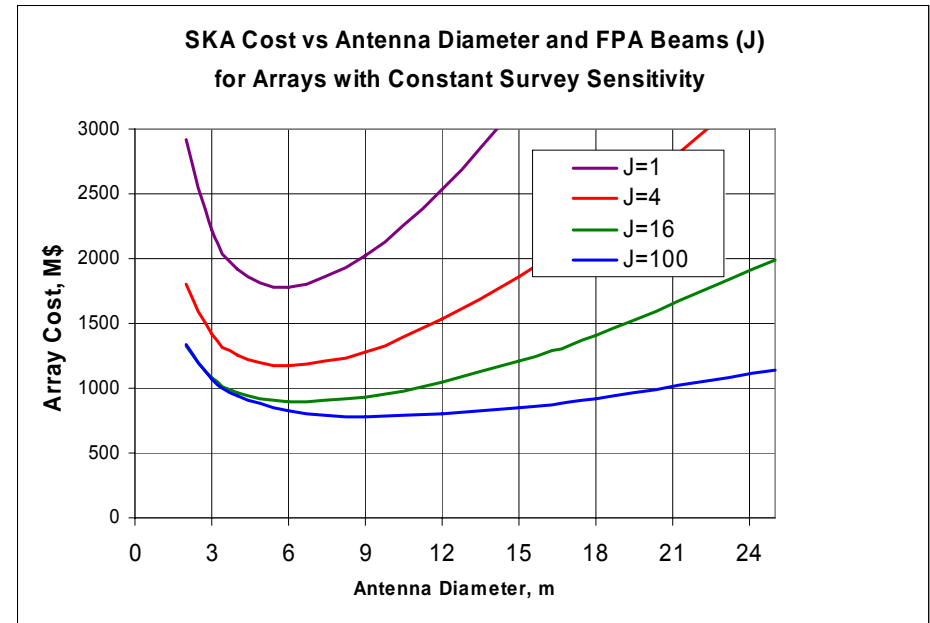
$$\text{Total Cost} = \$500M + N * (\$35K + \$0.2K * D^{2.7} + J * \$1K)$$

We will examine total cost as functions of D, N, and J for constant point source figure of merit =  $A/T_{\text{sys}}$  and for constant survey speed figure of merit =  $(A/T_{\text{sys}}) * (\sqrt{J} / D)$

# Cost and A/Tsys of Arrays with Constant Survey Speed as Function of Diameter and Beams, J

## Conclusions

- Cost goes down as beams increase because less antennas are required for given survey speed; however this reduces point source sensitivity
- Minimum cost at J=1 is for 20,000 x 6m giving A/Tsys = 10,000.



# Cost of Arrays with Constant Point Source Sensitivity

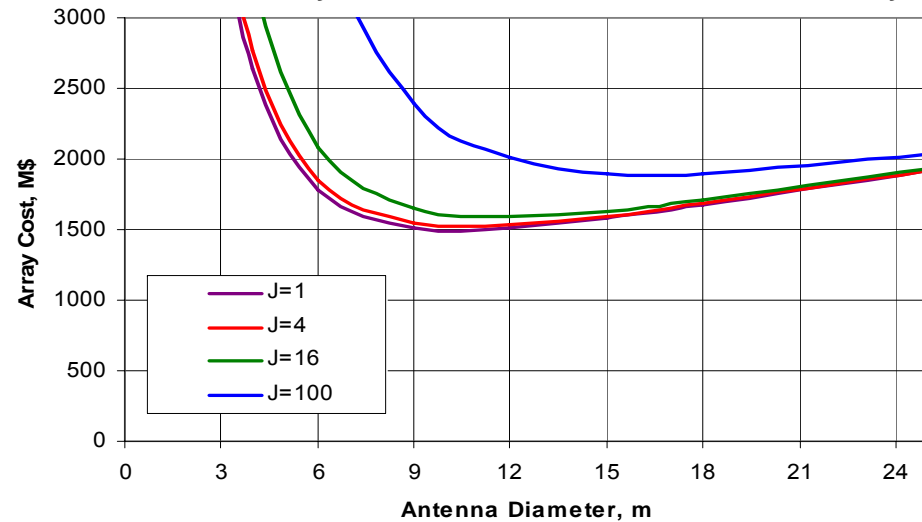
## Conclusions

- Minimum cost is at  $J = 1$  and  $D$  in the 9m to 12m range
- Increasing  $J$  increases cost but increases survey speed
- Equal survey speeds and point source sensitivity are achieved with the following:  
20,000 6m at  $J=1$  for \$1785M  
5,000 12m at  $J=4$  for \$1530M

## Overall Conclusion

Optimize  $D = 12\text{m}$  for point source sensitivity and choose  $J$  for desired survey speed

SKA Cost vs Antenna Diameter and FPA Elements for Arrays with Constant Point Source Sensitivity



Survey Sensitivity of Arrays with Constant Point Source Sensitivity

