The Allen Telescope Array (ATA)

May 11, 2001

John Dreher
Project Scientist
Project Manager (Acting)

ATA: What is It?

- Massively parallel array of small dishes
  - ***350 elements*** each 6.1 m in diameter
  - total collecting area ***larger than 100 m dish***
  - 0.5 - 11 GHz ***simultaneously***
  - ***multiple*** beams
- Must be ***much*** cheaper than existing arrays
- Joint project of SETI Institute and UCB
- Funded by private donations

ATA: What Will It Do?

- SETI
  - 100,000 FGK stars
  - Galactic plane survey?
- HI
  - All sky HI, $z < 0.03$, Milky Way at 100 σ
  - Large area to $z \sim 0.1$ or even 0.2
  - Zeeman
- Temporal Variables
  - Pulsar Timing Array
  - Pulsar survey followups
  - Extreme Scattering Events
  - Transients

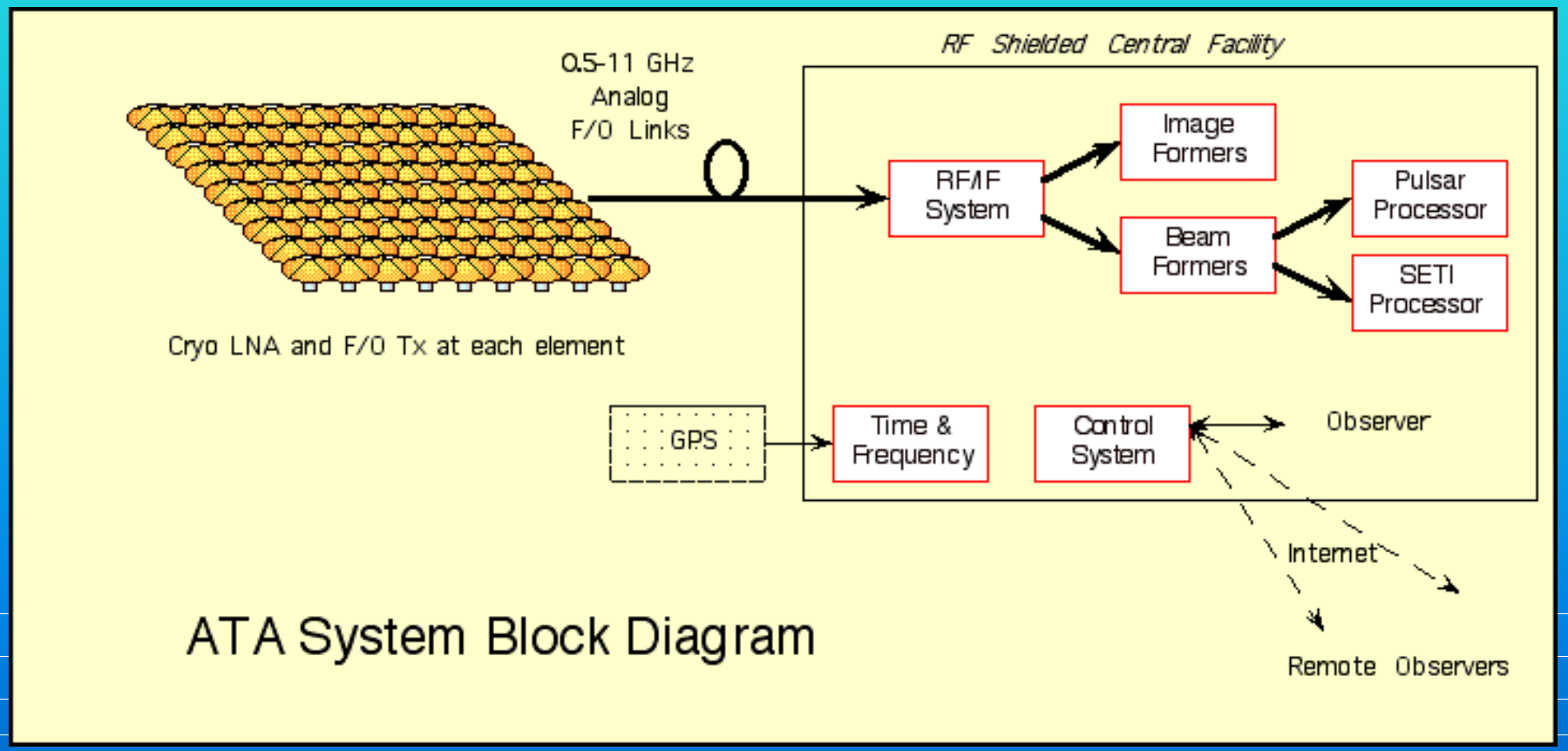
Not an exhaustive list!!

ATA: Performance

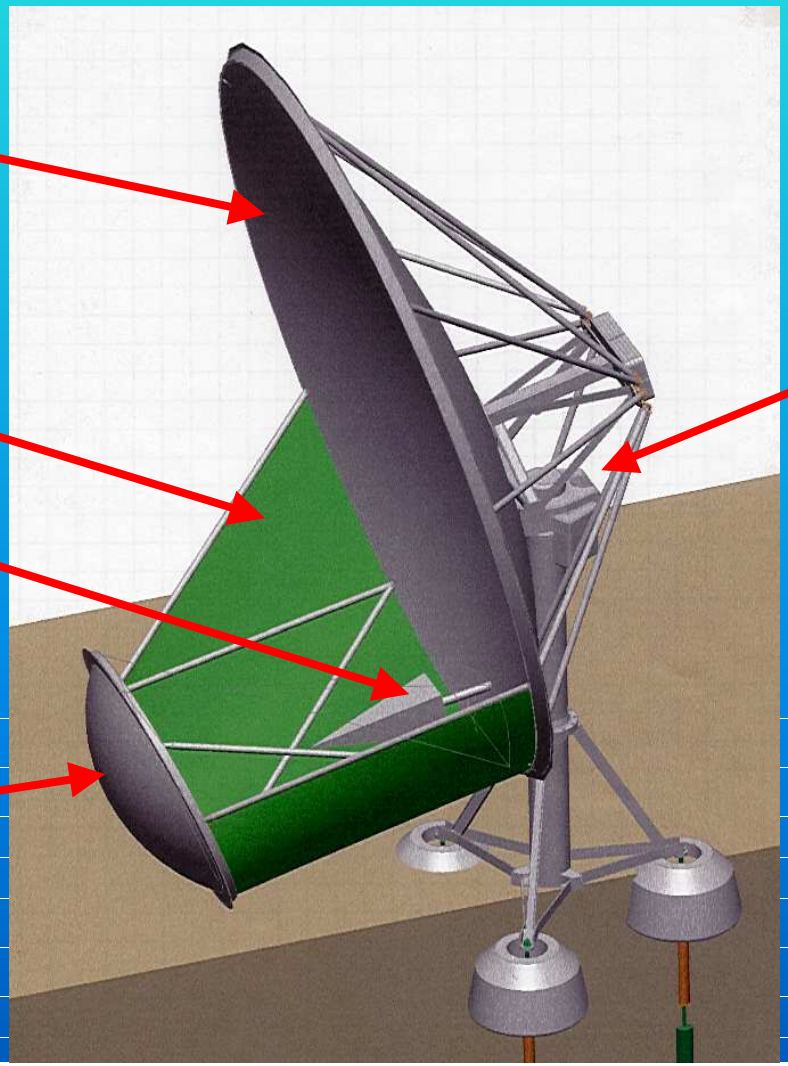
Number of Elements	350		
Element Diameter	6.10	m	
Total Geometric Area	1.02E+04	m^2	
Aperture Efficiency	63%		
Effective Area	6.44E+03	m^2	
	2.33	K/Jy	
System Temperature	43	K	
System Eqiv. Flux Density	18	Jy	
Ae/Tsys	150	m^2/K	
Effective Array Diameter	400	m	Natural Weighting
Frequency	1	10	GHz
Primary FoV	3.5	0.4	degree
Synthesized Beam Size	108	11	arc sec
Number of Beams	>4		
Continuum Sensitivity			
BW	0.2	GHz	Confusion
Flux Limit in 10 sec	0.41	mJy	0.1 mJy at 1.4 GHz
Spectral Line			
Resolution	10	km/s	
Frequency	1	10	GHz
BW	3.E+04	3.E+05	Hz
Integration Time	1000	1000	sec
RMS brightness	0.24	0.07	K

Scalable to much more

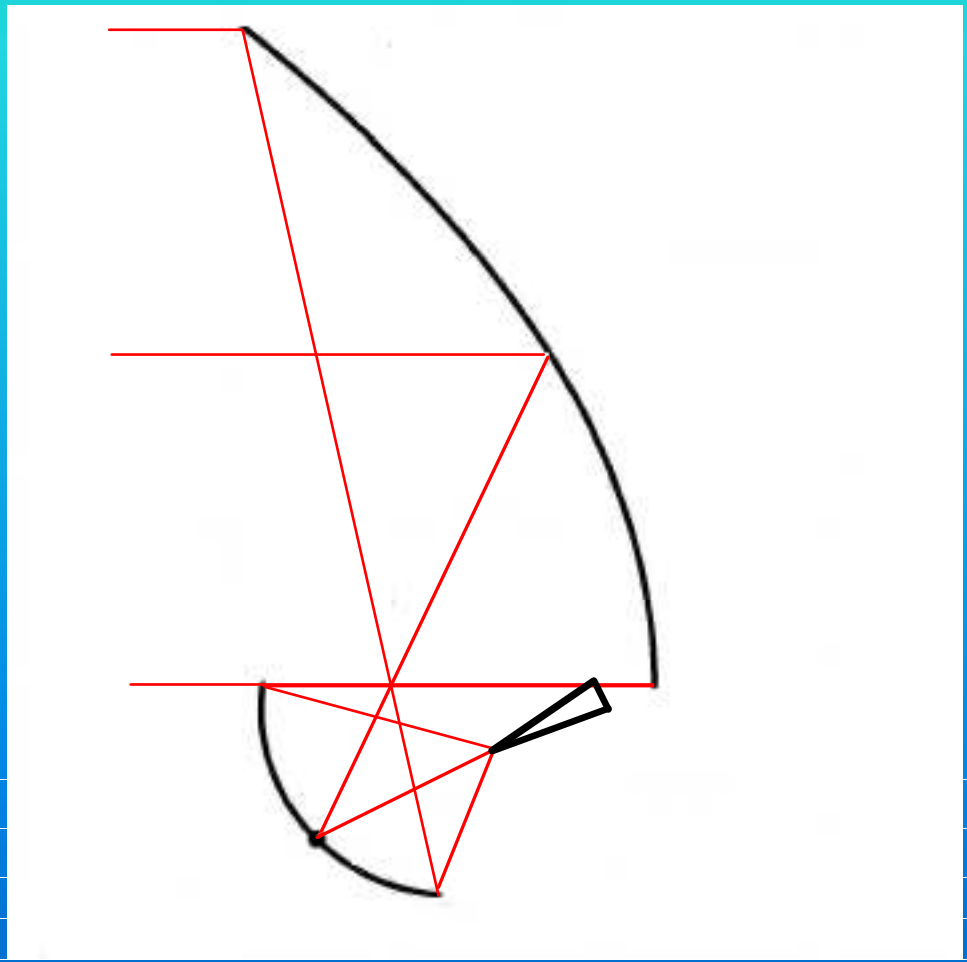
Overview


RF Shielded Central Facility
0.5-11 GHz
Analog
F/O Links
Cryo LNA and F/O Tx at each element
RF/IF System
Image Formers
Beam Formers
Pulsar Processor
SETI Processor
GPS
Time & Frequency
Control System
Observer
Internet
Remote Observers
ATA System Block Diagram

Offset Gregorian Antenna

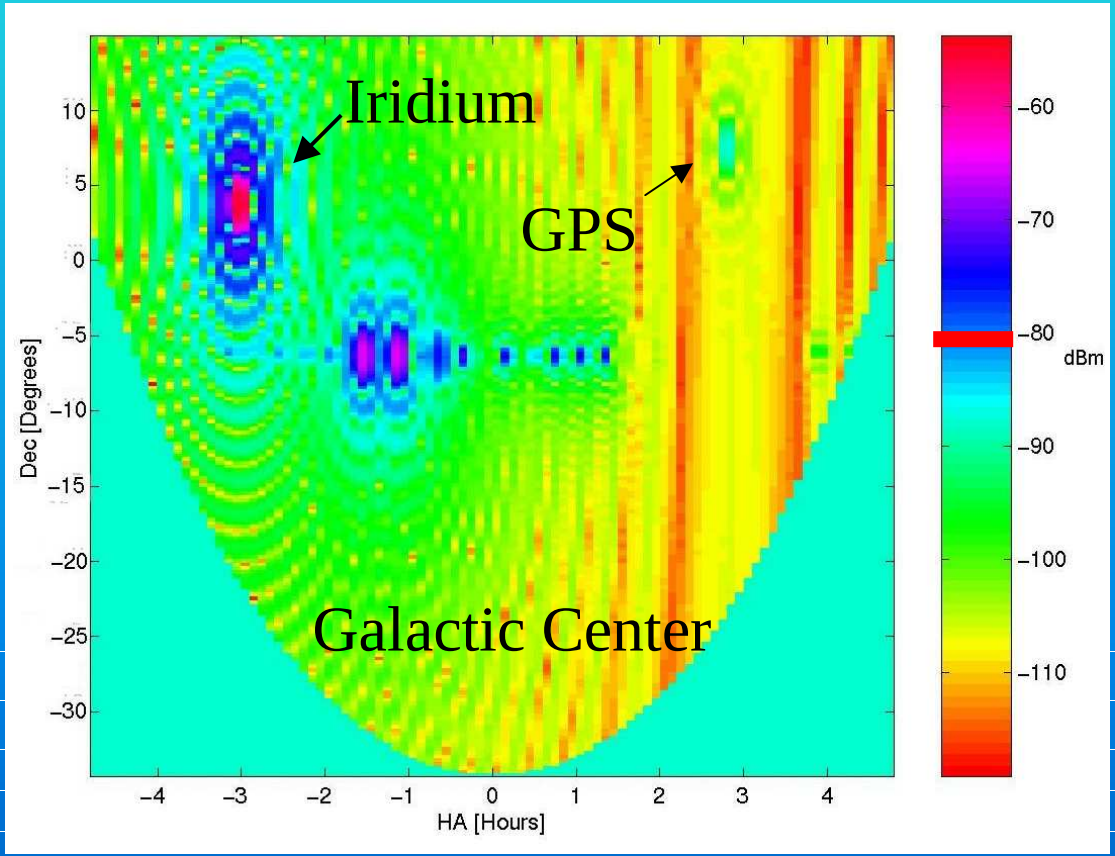


Ray Optics



Simulations of Geosynch Orbit Saturation

- Ofset design offers low sidelobes
- Won't lose any declinations due to the geosynch arc



Hydroformed Aluminum Surfaces

First antenna
due in October
From Andersen Mfg.

0.050 inch RMS

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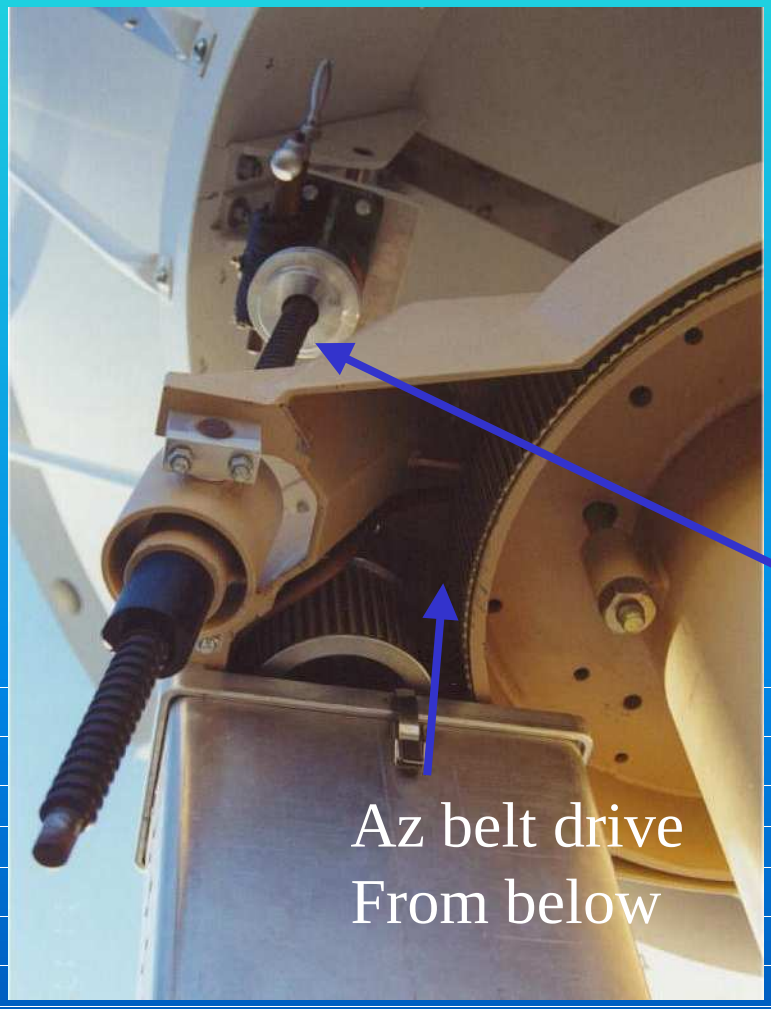
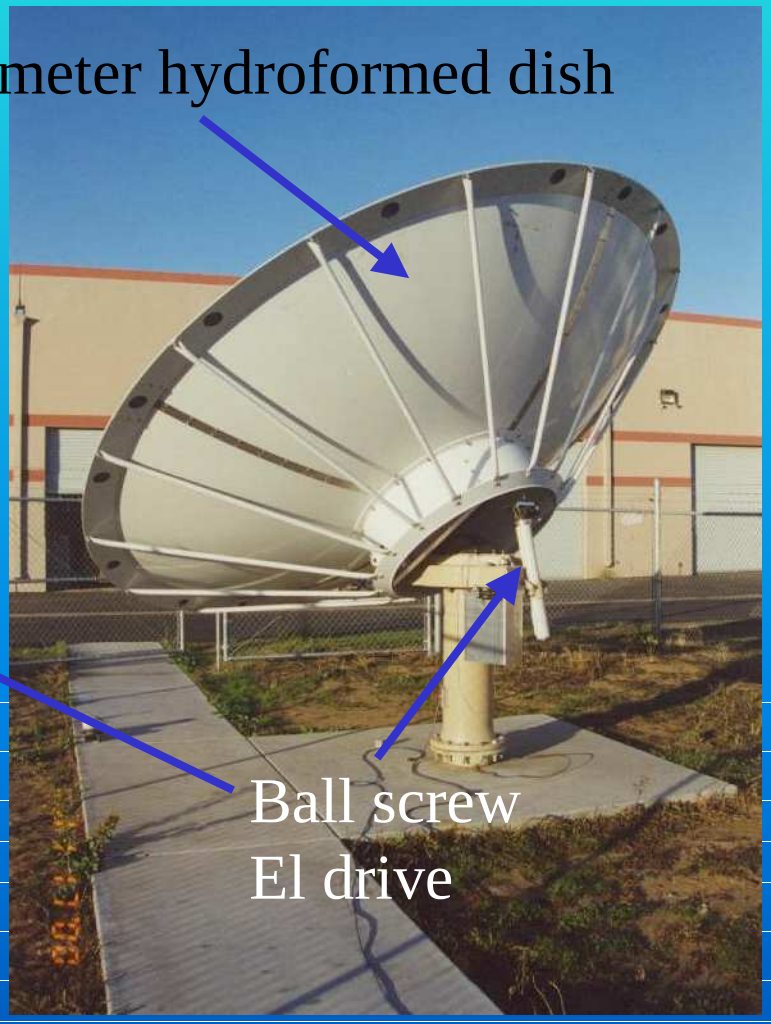
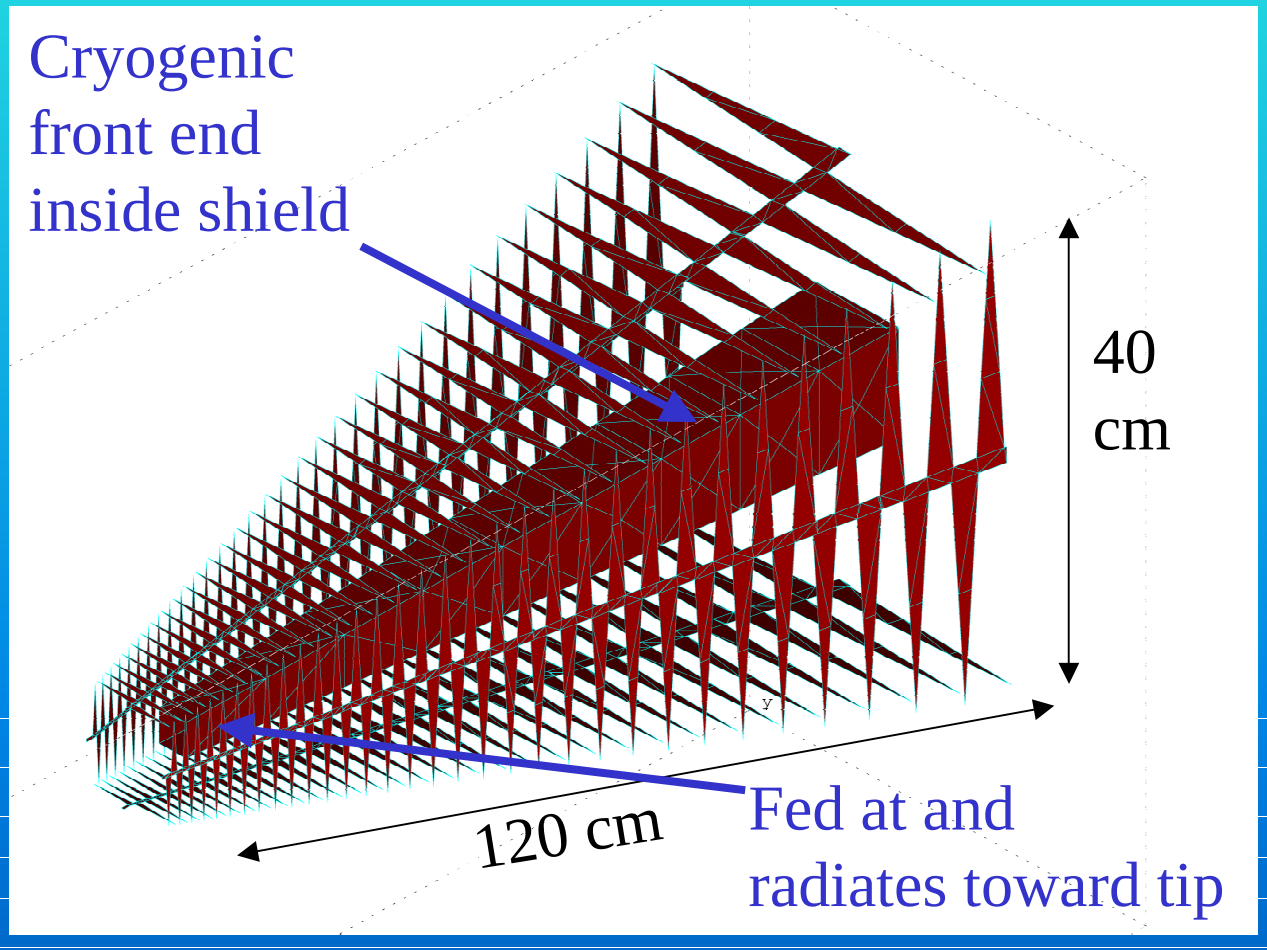
Az-El Mount Prototype



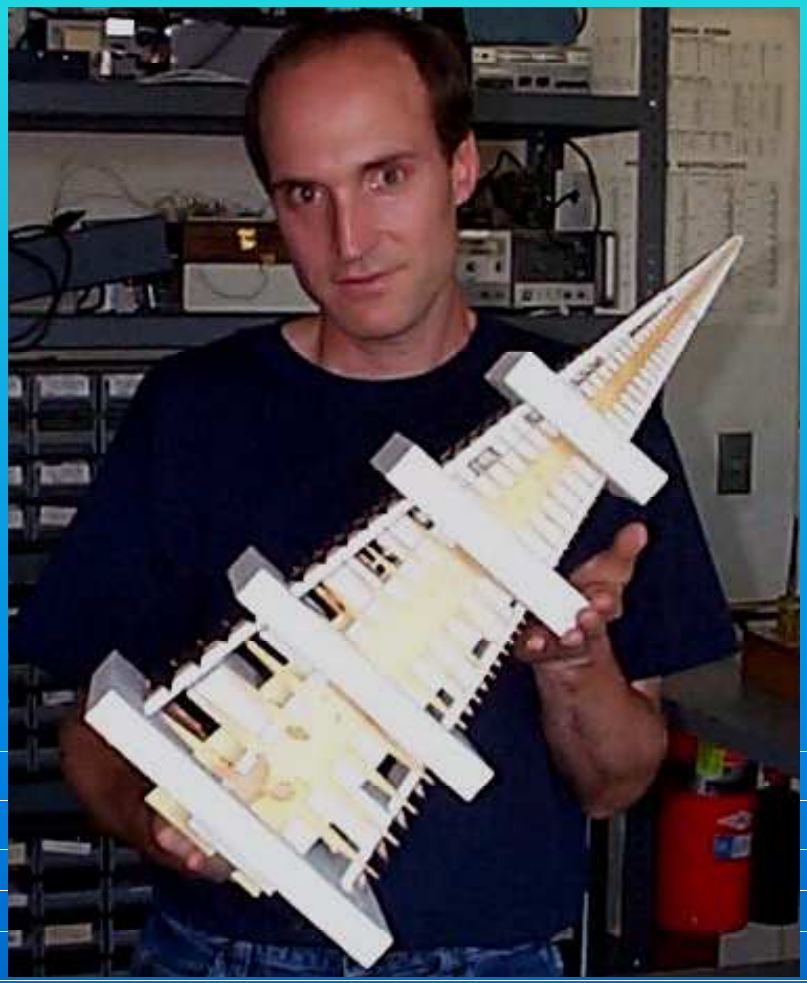


0.5-11 GHz Log Periodic Feed

Dual polarization



Prototype Feed for Tests



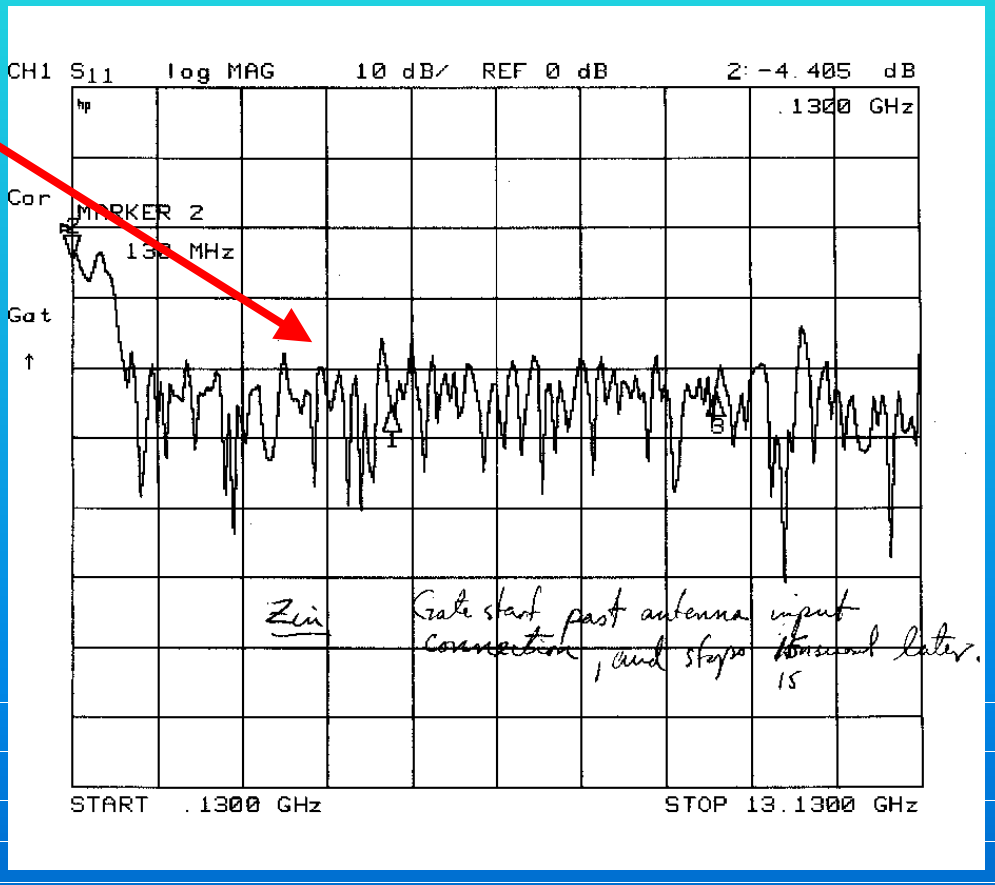
Constructed from thin brass shim and gold plated

Air spaced (with standoffs)

Optimization and packaging studies now in progress

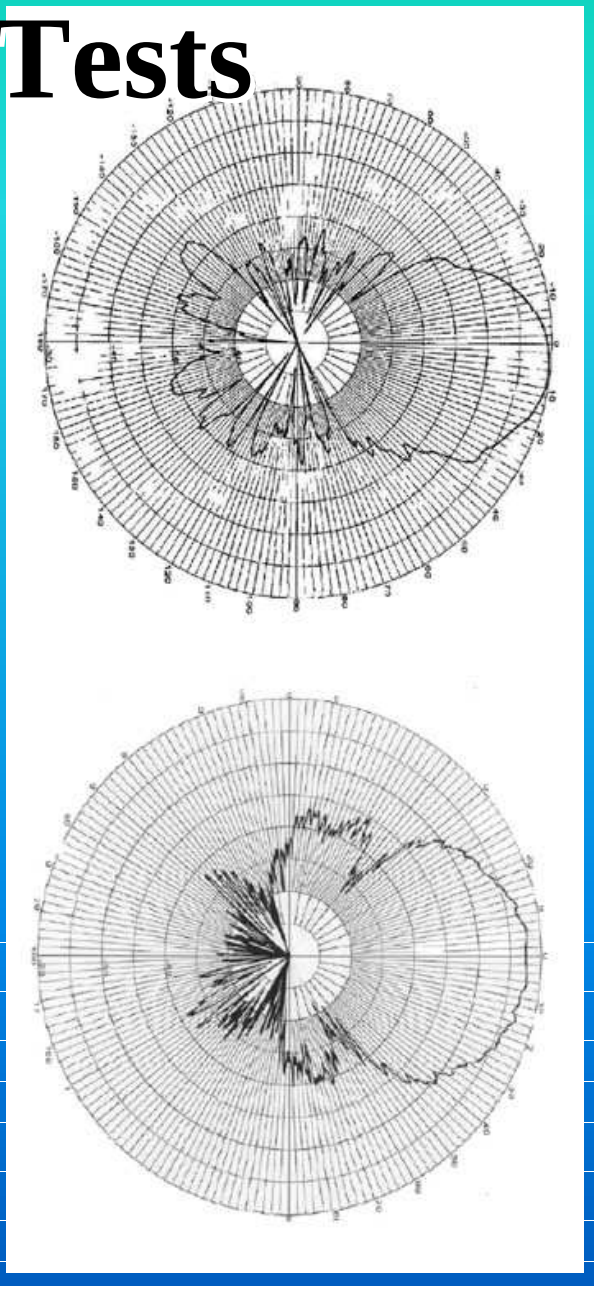
Preliminary Feed Tests

- Excellent (20 dB) match
- Agrees with EM calcs on
  - Impedance
  - Gain
  - Internal Loss



Preliminary Feed Tests

- Excellent (20 dB) match
- Agrees with EM calcs on
  - Impedance
  - Gain
  - Internal Loss
- Range Tested (preliminary)
- Optimizing with fin on boom to reduce ring lobe



Prototype InP MMIC LNA

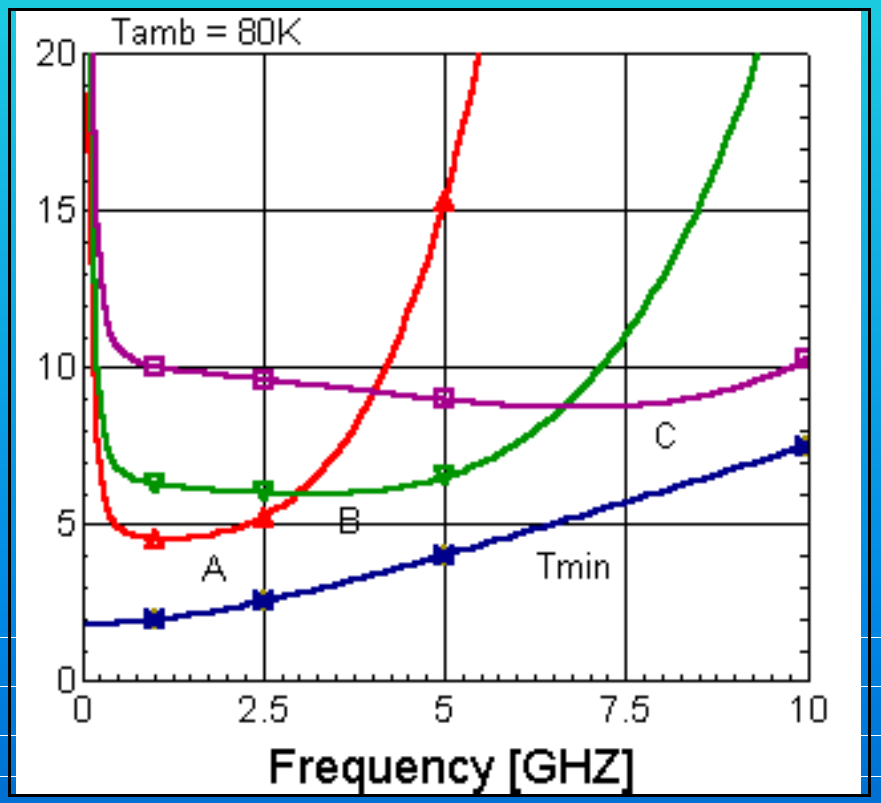
MMIC

InP PHEMT

0.18 microns

Weinreb design

Model T_{Rx} ~ 10 K



Prototype InP MMIC LNA

MMIC

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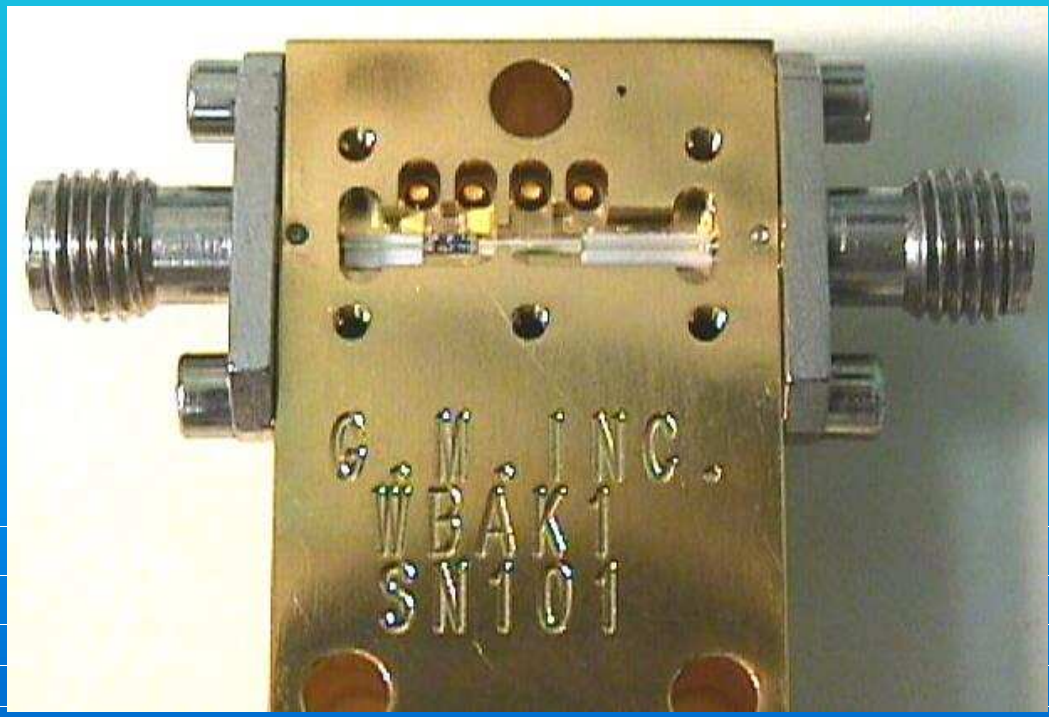
- Weinreb design

Model T_{Rx} ~ 10 K

First try

- works fine
- T_{Rx} ~ 20 K



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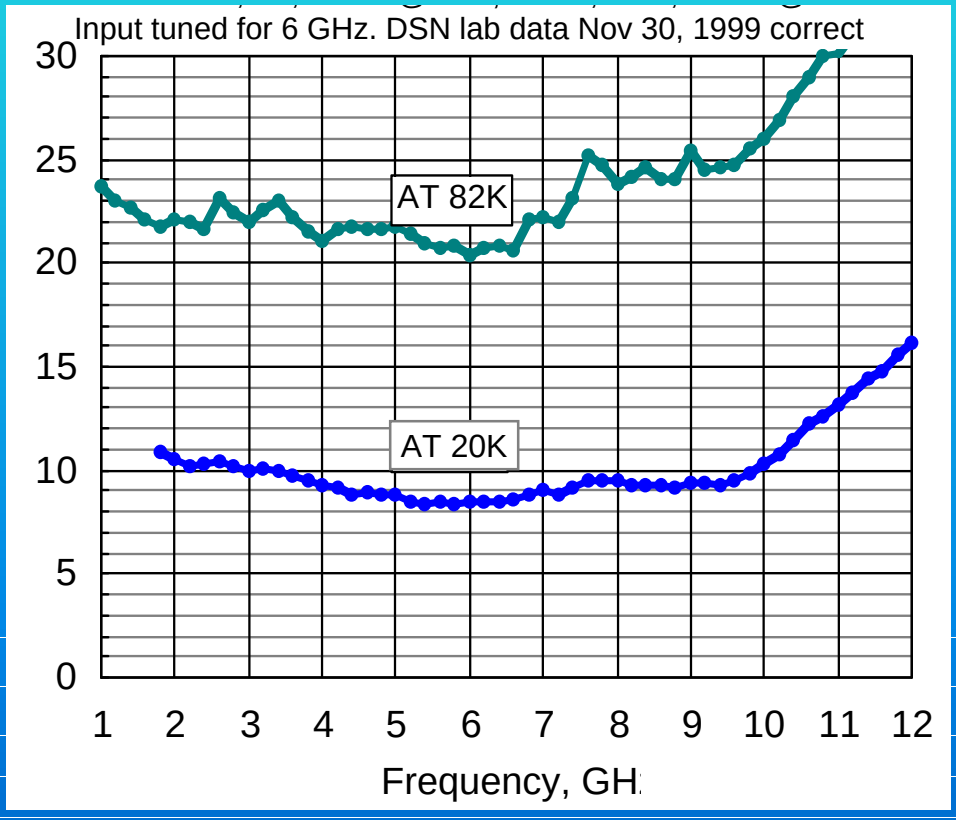
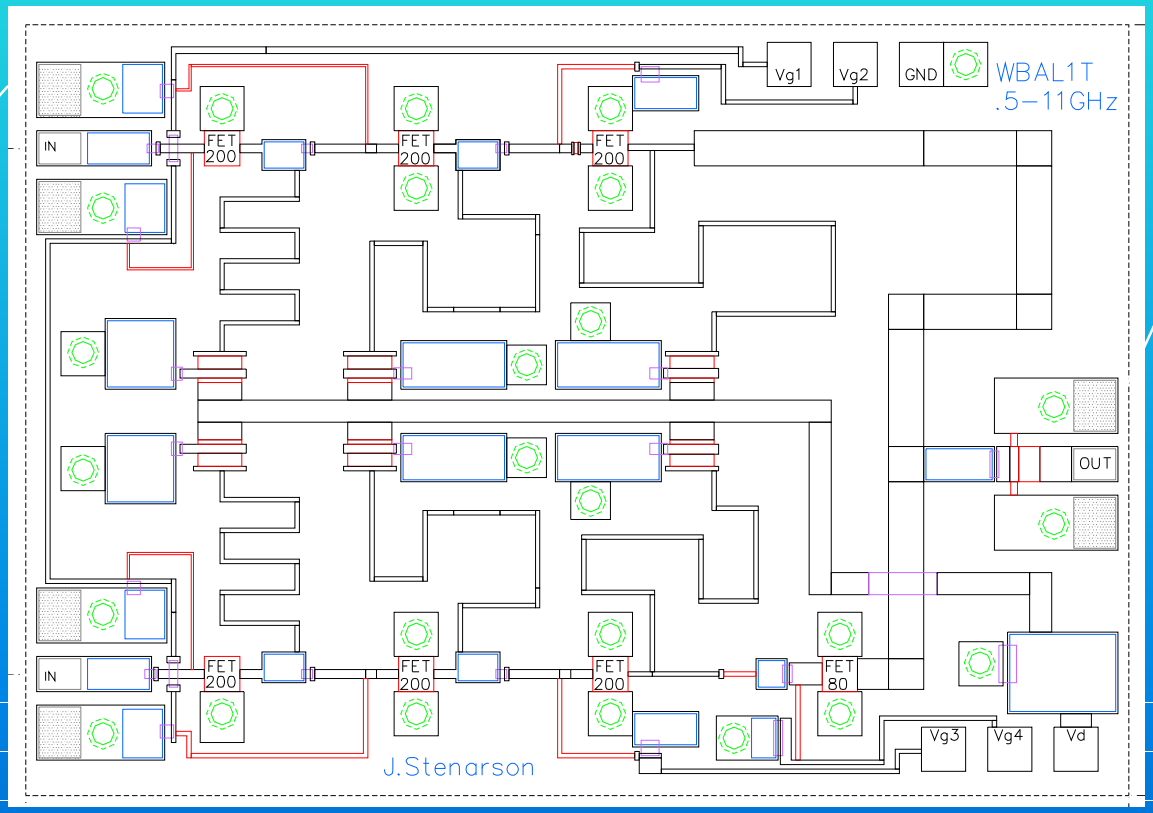


Improved versions in fab line

Layout of MMIC Active Balun (TRW version)

InP Chip Size: 2.5 x 1.75 x .075 mm

Balanced Inputs

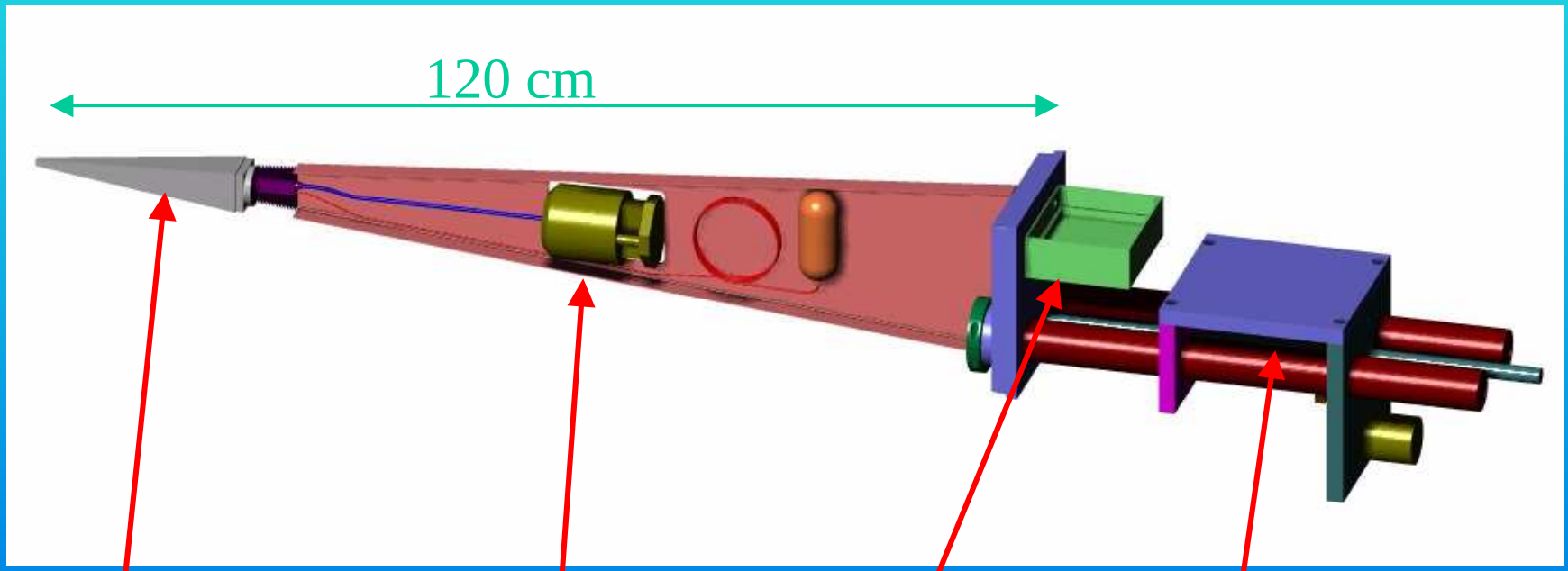


Unbalanced Output

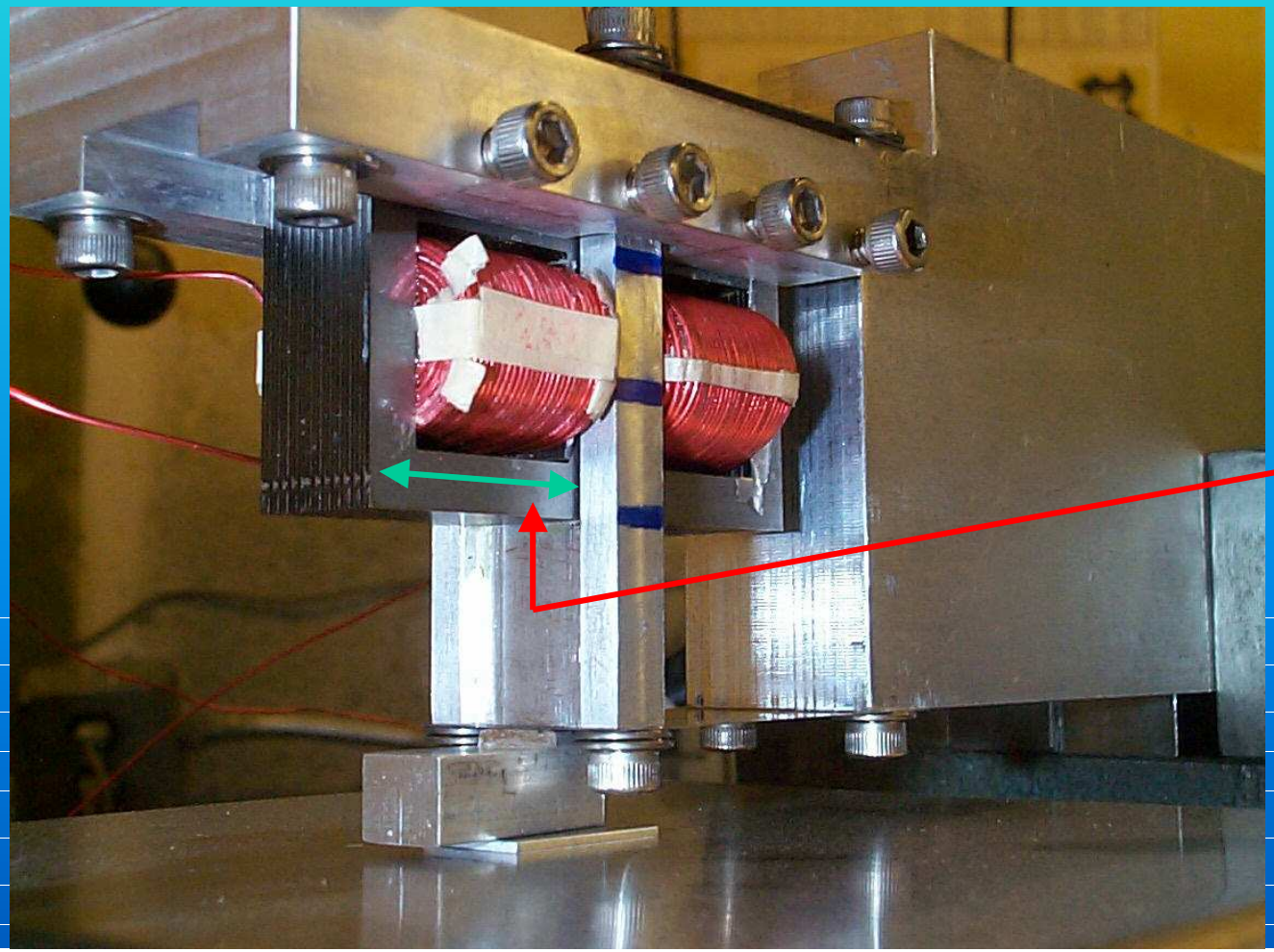
80 K Cryogenics

- Must be
  - Small (to fit inside shield)
  - Reliable (> 10 yr MTBF)
  - Cheap (< few K$)
- In-house solution
  - Pulse tube cooler (no moving parts) NIST
  - Clearance seal compressor with voice coil motor
  - “vacuum tube” style dewar with getter
- Commercial solution still possible

Cryogenics Inside Feed



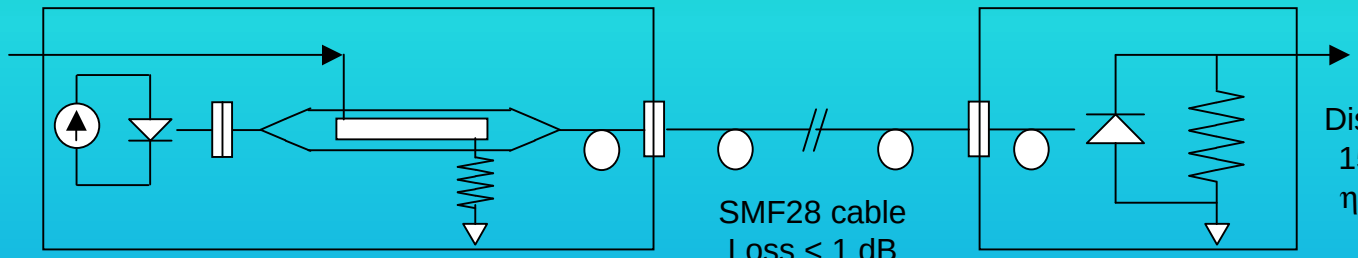
Test Coils for Compressor Motor



0.5-11 GHz Analog F/O Links

- Off the shelf units too expensive now
- Reduced component costs soon due to recent massive investments by industry
- Laser progress "Real Soon Now"
  - Cheaper DFB, e.g. Ortel "Daytona"
  - 1310 nm VCSEL (Gore, Novalux, Cielo, Agilent, Infineon)
- External modulators as fallback

Projected Link Performance

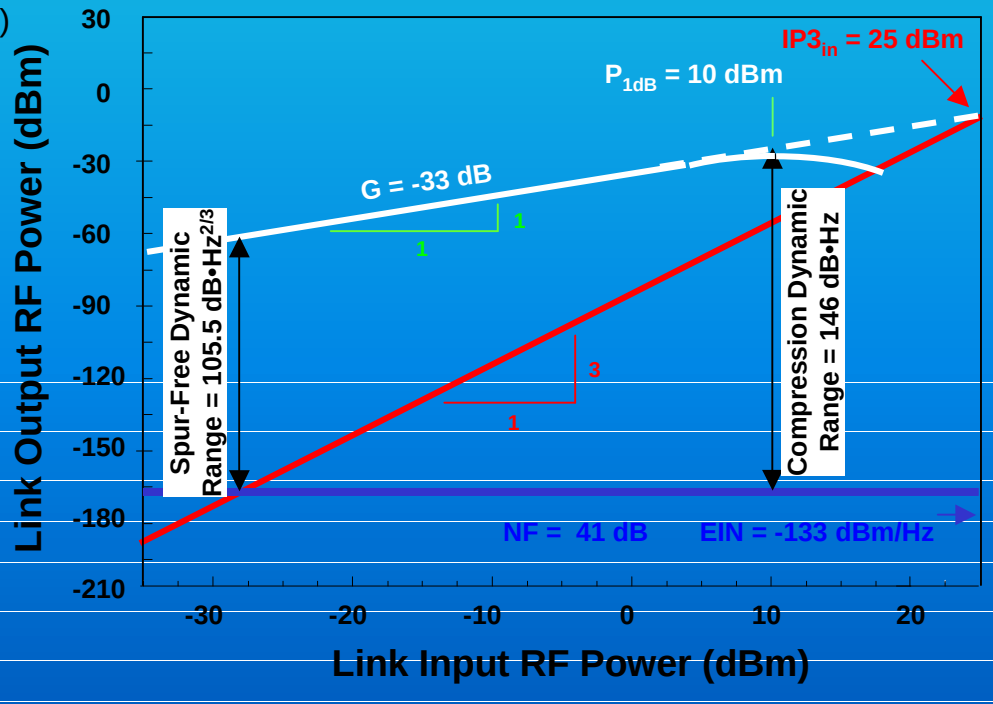


SMF28 cable
Loss < 1 dB

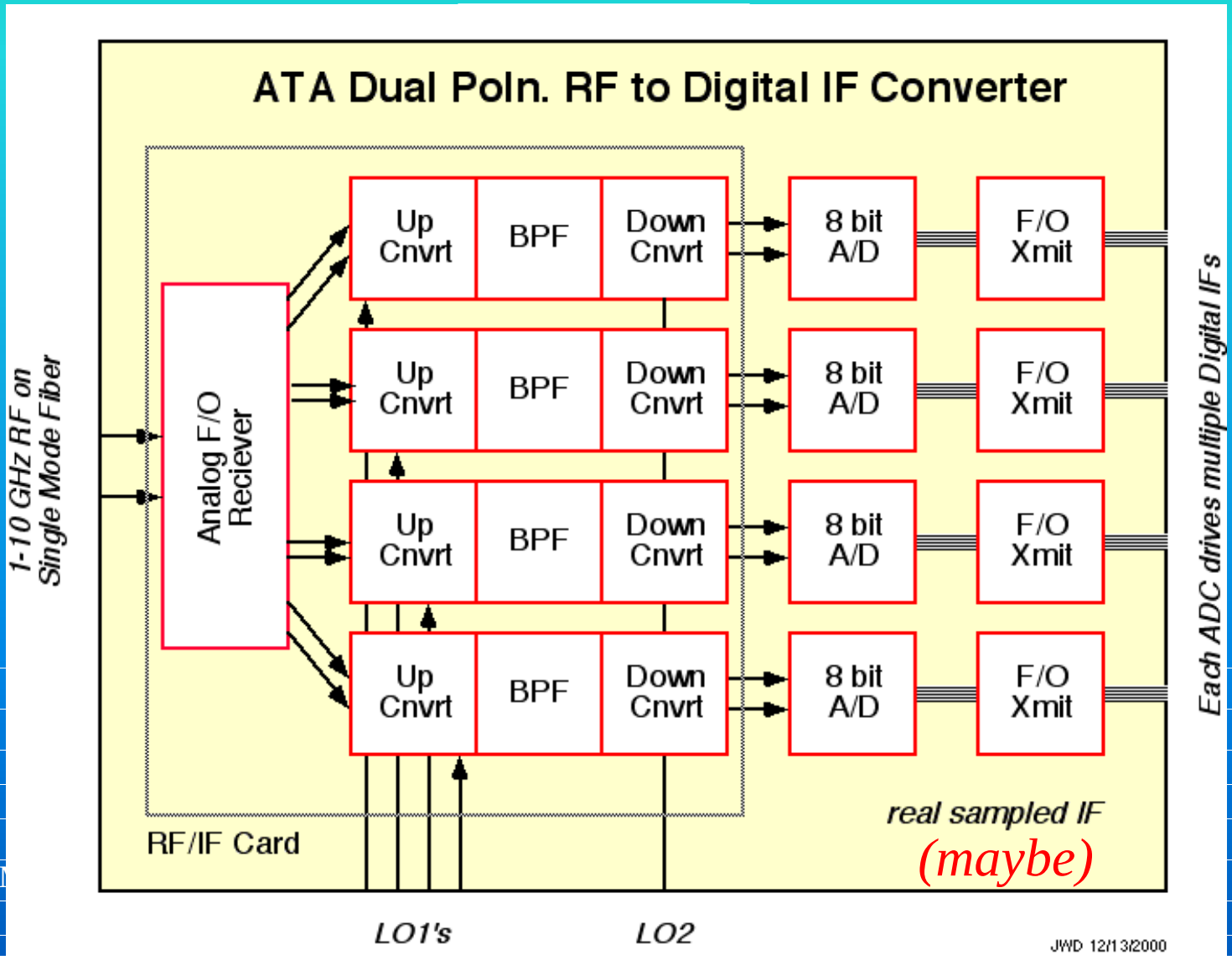
Discovery Semiconductor
1550nm pin photodiode
η_D=0.75 A/W, I_D~ 2 mA

Excelite PM-fiber-pigtailed DFB laser
λ = 1550 nm, RIN < -155 dB/Hz, P_L = 20 mW,

Codeon or JDSU MZ modulator (PM input fiber)
V_π = 6.5 V, I_L = 5 dB, ϕ_{bias} = 90°,
$IP3_{in}$ = 25 dBm, P_{1dB} ~ 10 dBm



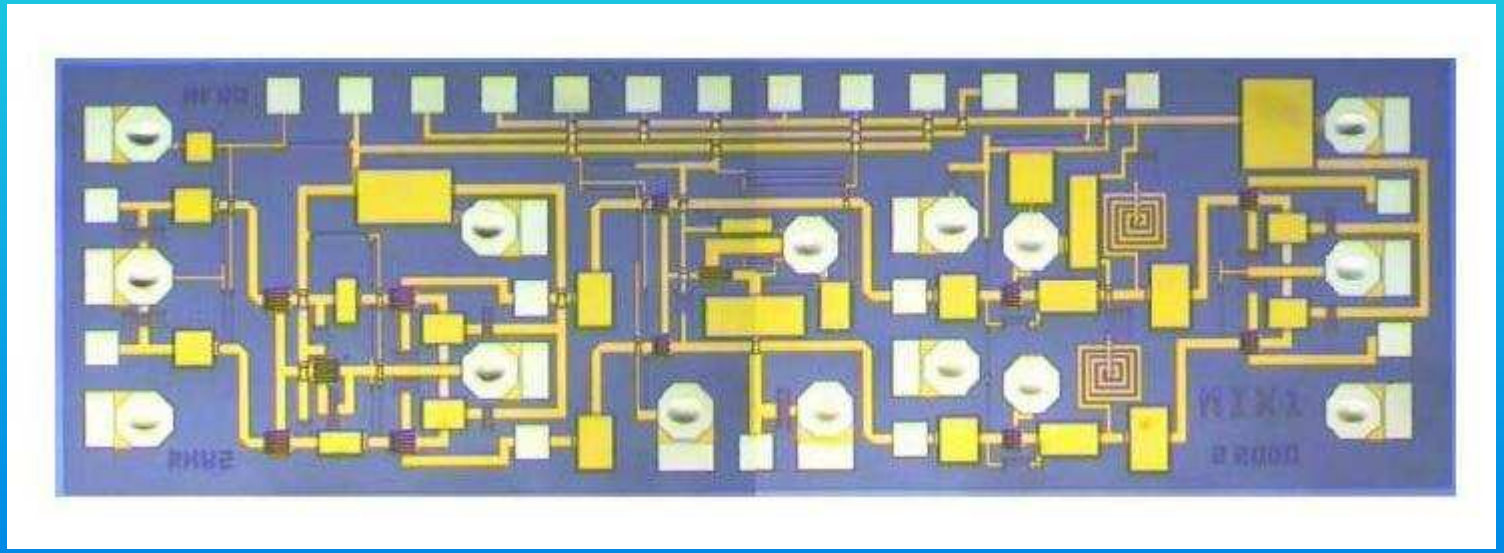
Signal Processing



Up/Down Converter

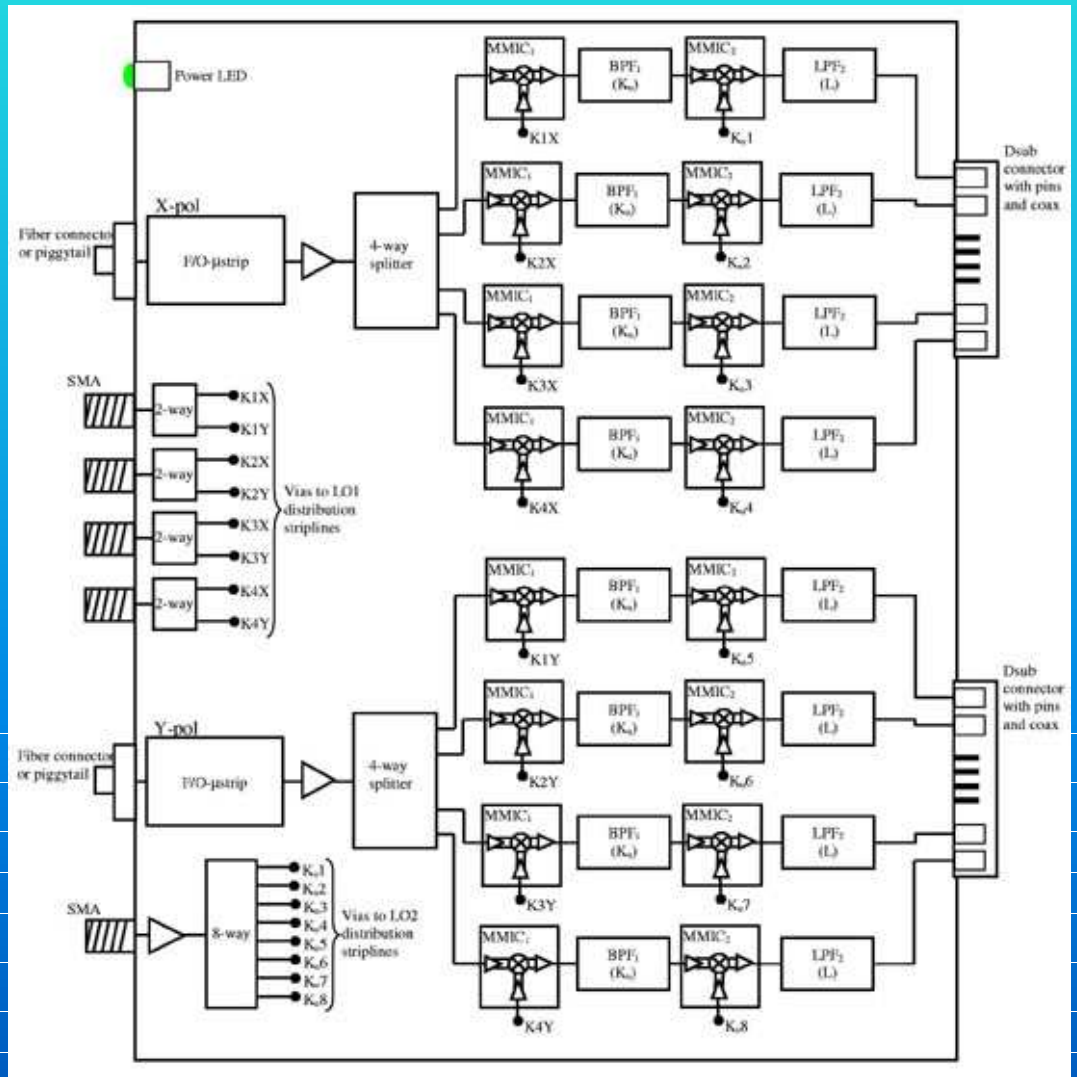
- Ultrawideband Active Mixer
  - PsHEMT GaAs MMIC
  - Development at ASTRON
  - 1st version of mixer has been tested
  - Revised mixer in fab
- Multichannel RF/IF Card

Micro Photograph of Mixer



Test Version

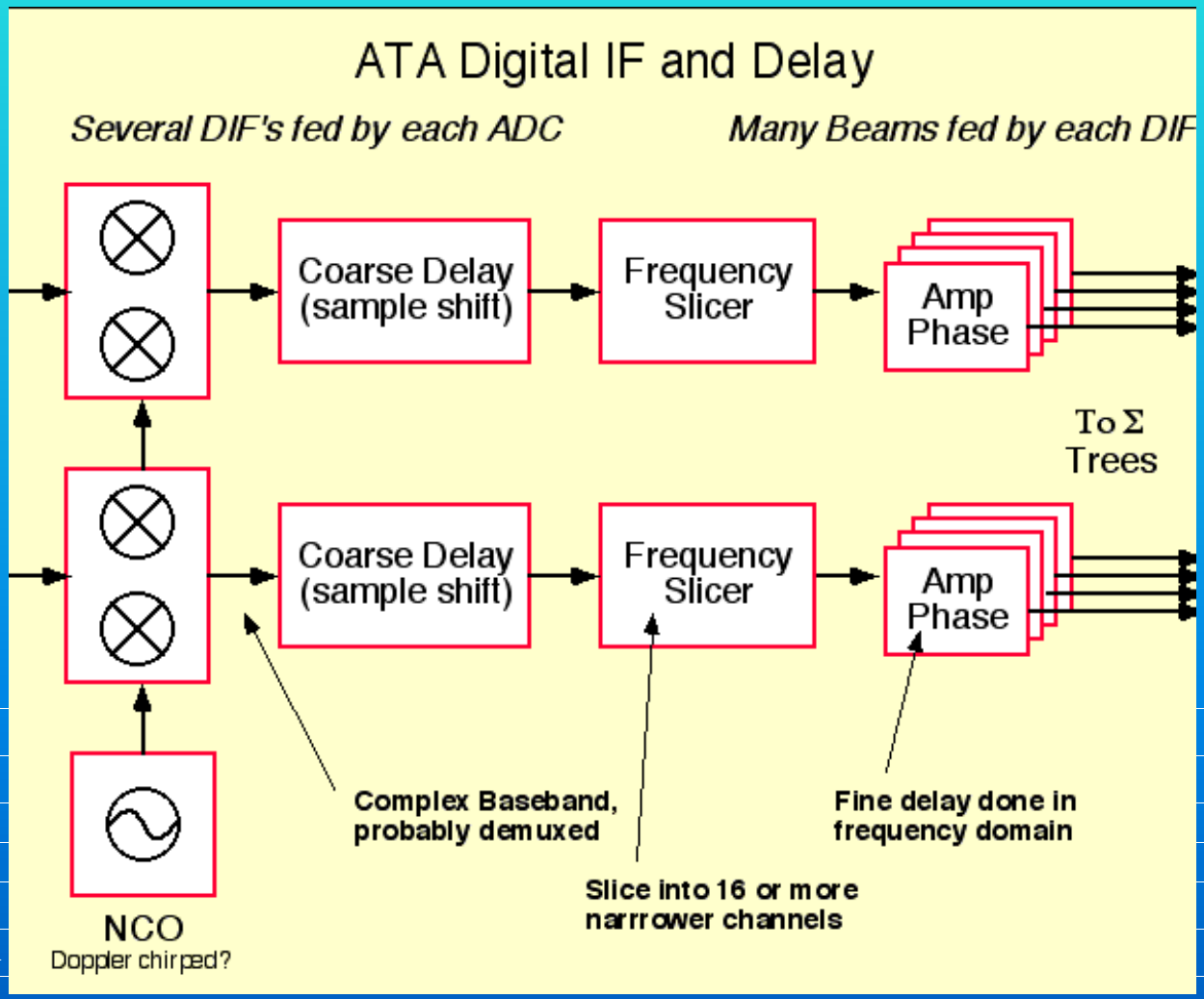
RF/IF Card



Conceptual Layout

Digital IF and Delay

One of several concepts



Imager for Radio Astronomy

- Image entire primary FOV with full spatial resolution
- Achievable BW will be set by cost of computing
- Large number of antennas is a challenge
- Proposal submitted by UCB-RAL to NSF ITR
- Potential for using industry terabit switching

FX Correlator with 4N(N-1)/2 Baselines

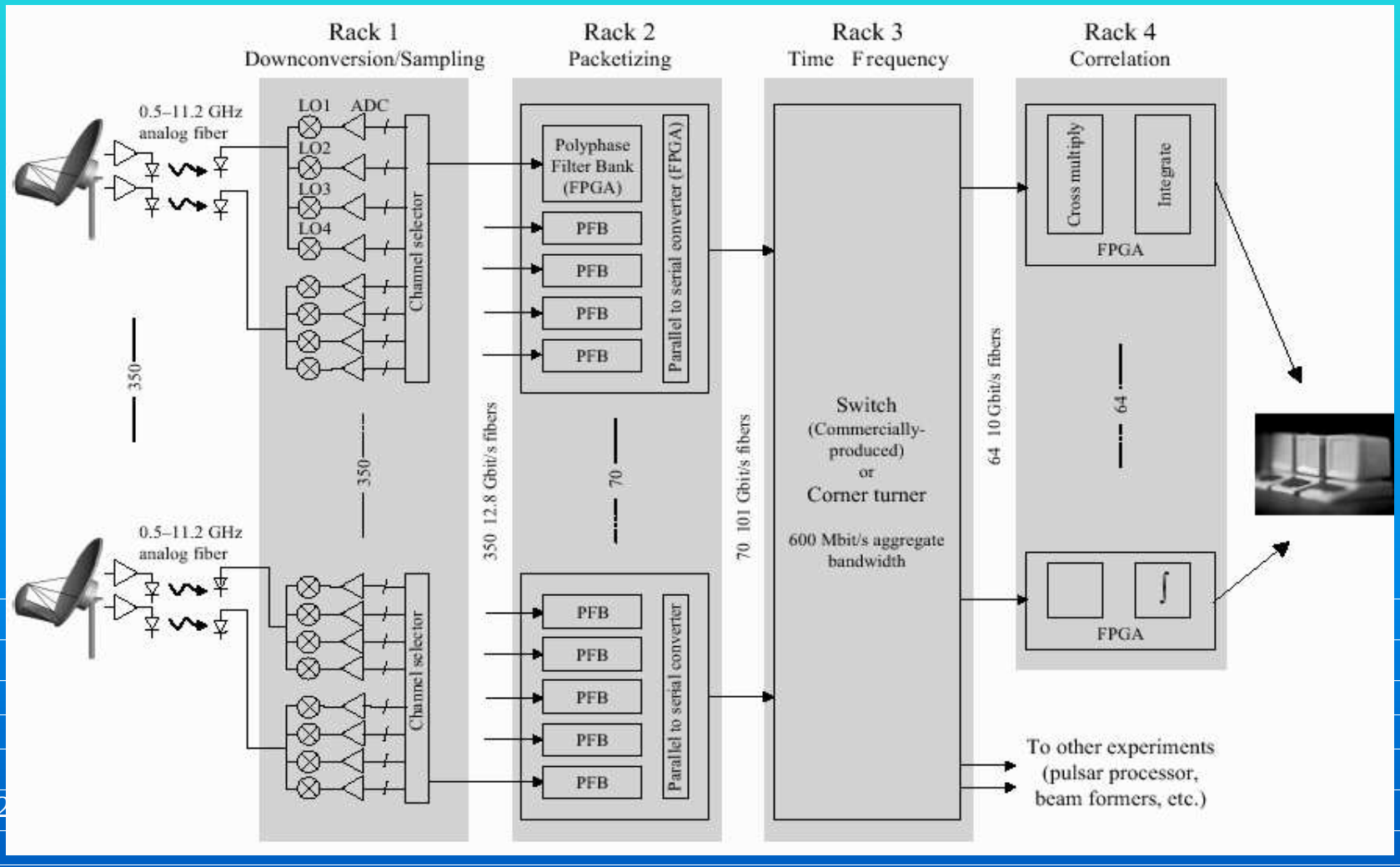


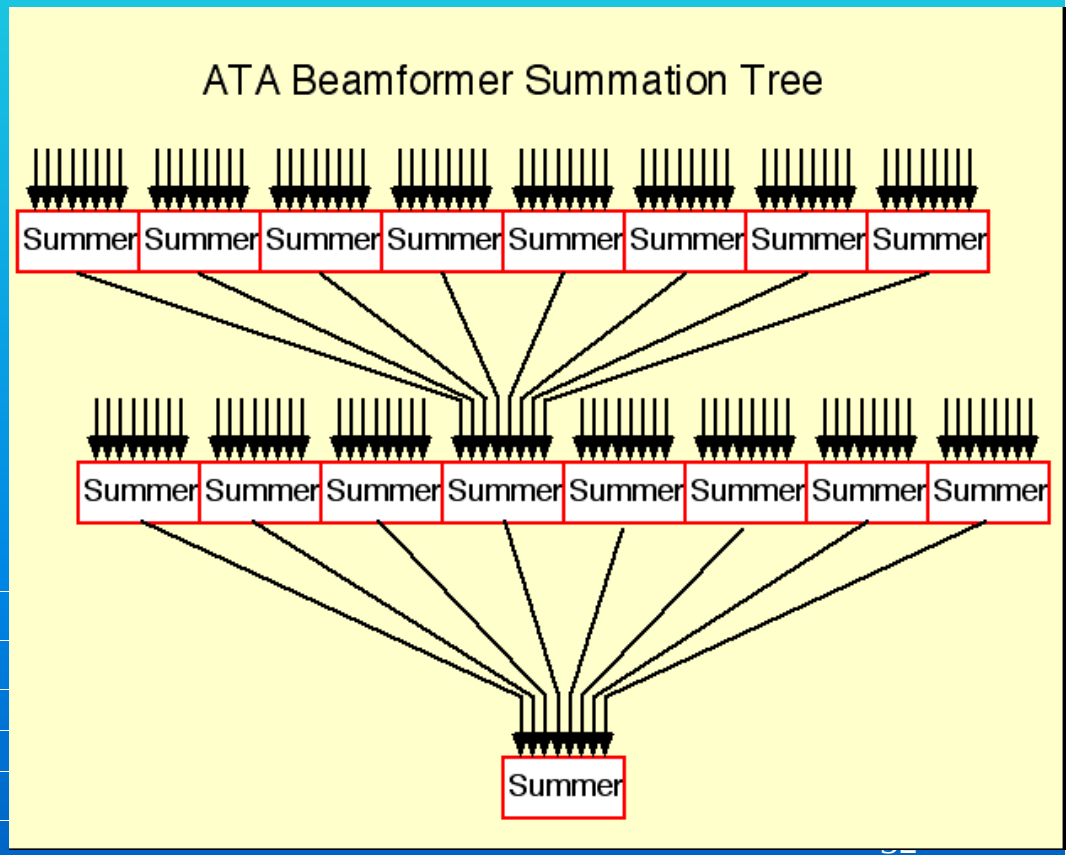
TABLE 1 - OBSERVING MODES

Bandwidth	Channels	Polarization products	Bits	Polyphase
400 MHz	256	2	1	no
200 MHz	512	2	2	yes
100 MHz	1024	2	4	yes
200 MHz	256	4	1	yes
100 MHz	512	4	2	yes
50 MHz	512	4	4	yes

Forming Beams

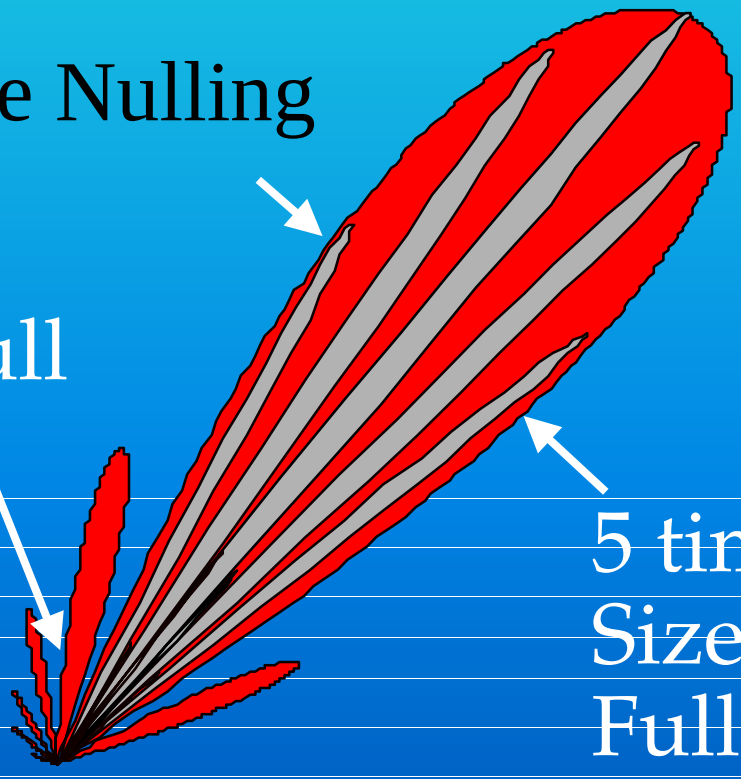
One of several concepts

- Beamformer
  - Phase for fine delay
  - Amp for equalization
- ≥ 4 beams at first light
  - 3 for SETI (includes “off”)
  - 1 for RA or “off”



Beamforming

- Exploits Large Primary FOV
- Enables Simultaneous SETI and RA
- Satellite Nulling



Steer the null beam onto satellite

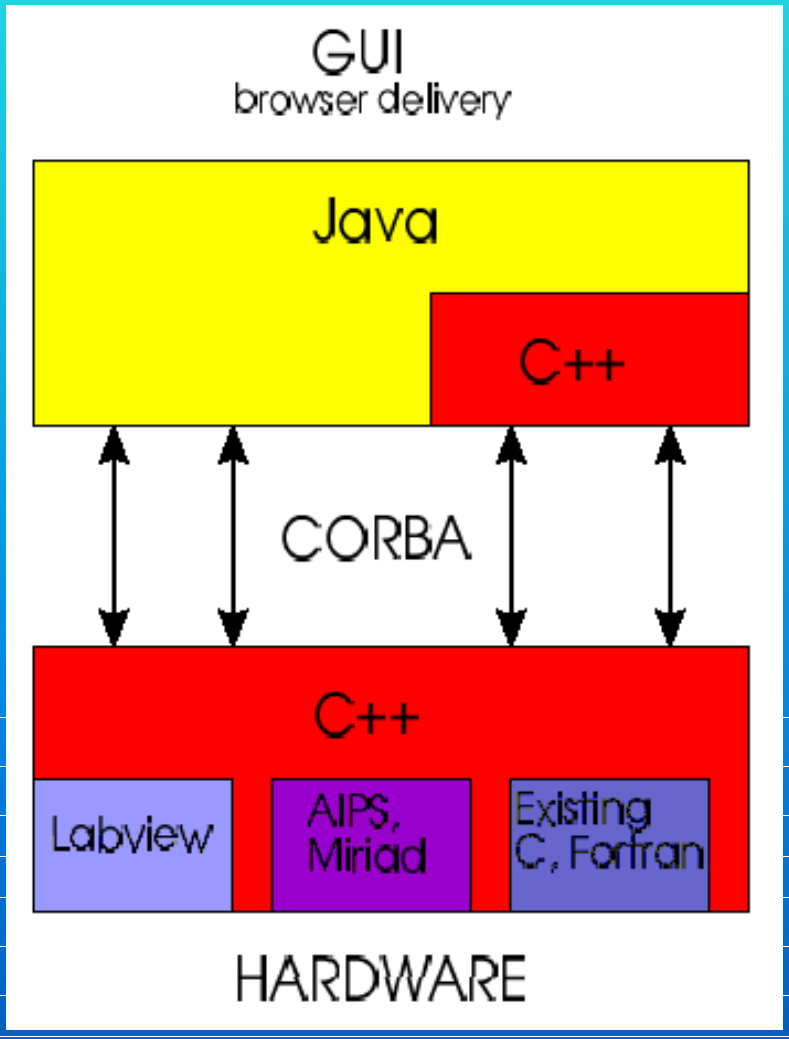
5 times Size of Full moon

SETI and RA Processors for Beams

- Multiple beams speeds up SETI searches
  - More than 1 star per FOV or more than 1 band
- Pulsar research will be supported by ATA
- RA spectrometer
- Active RFI suppression (maybe)
- Every beam needs a backend processor

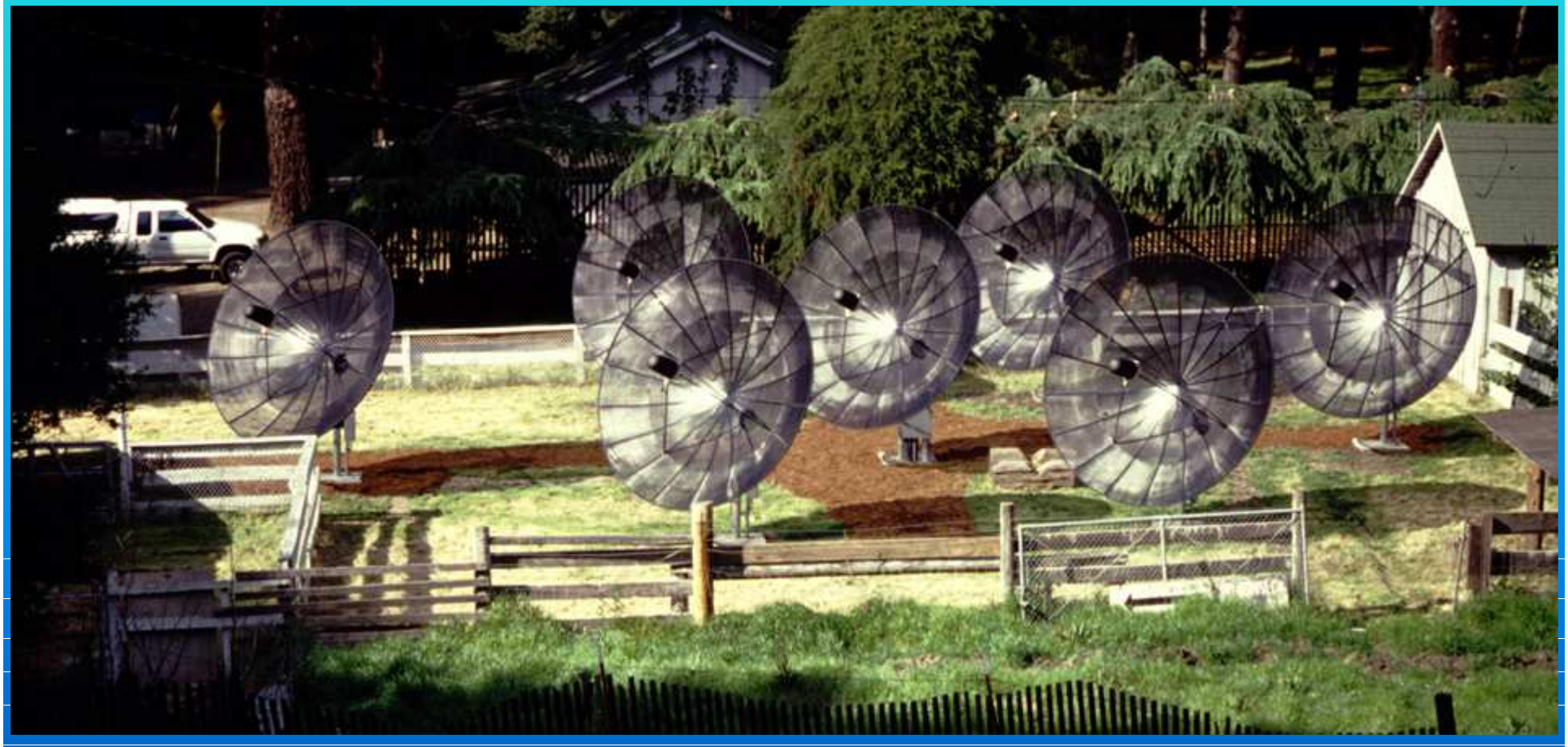
Software Component Technology

- OO design
  - C++
  - Java
- Use standard tools and products (where possible)
- Distributed, multiplatform design (where appropriate)



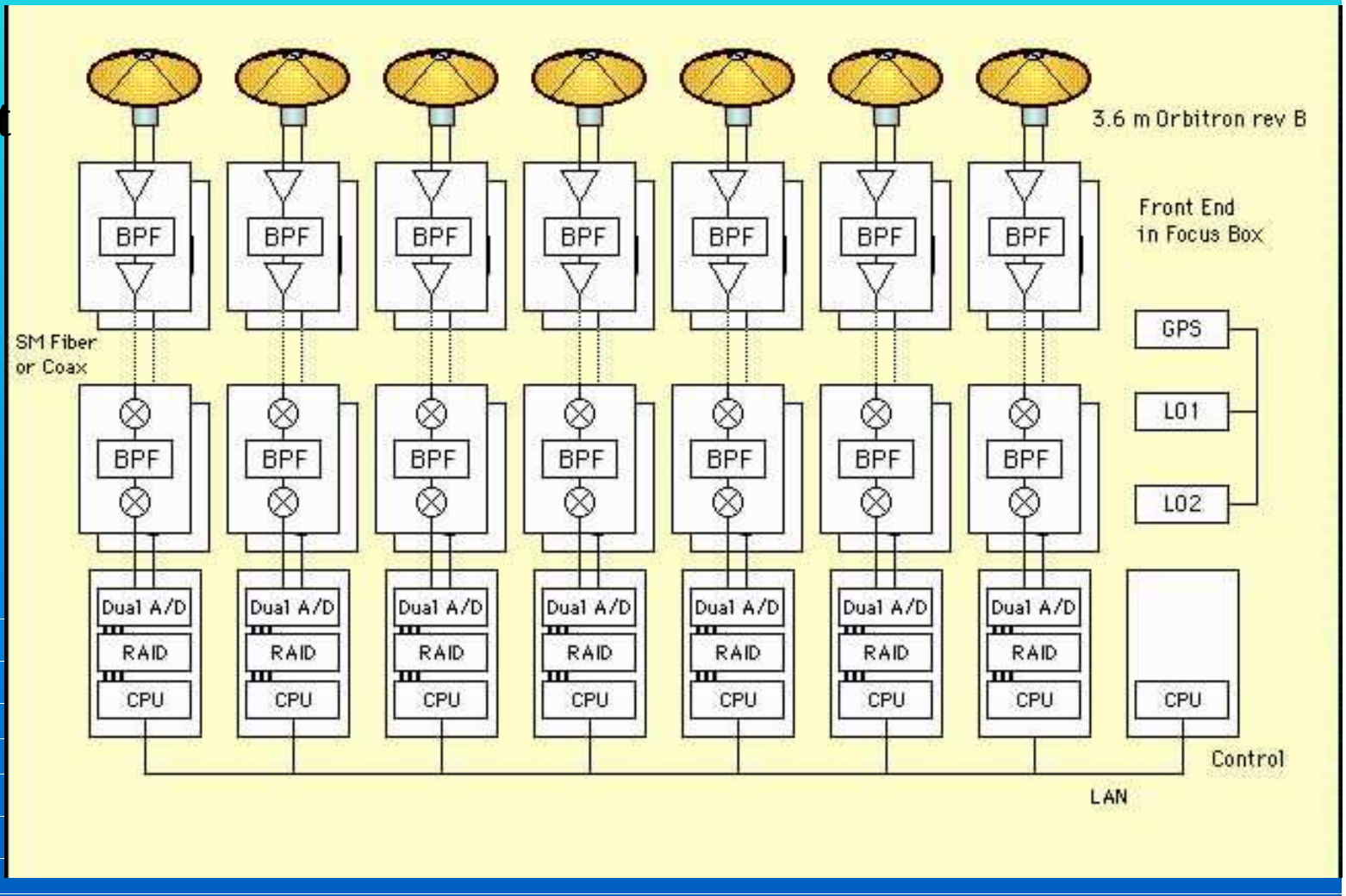
RPA - Rapid Prototyping Array

Software development and RFI Mitigation Experiments



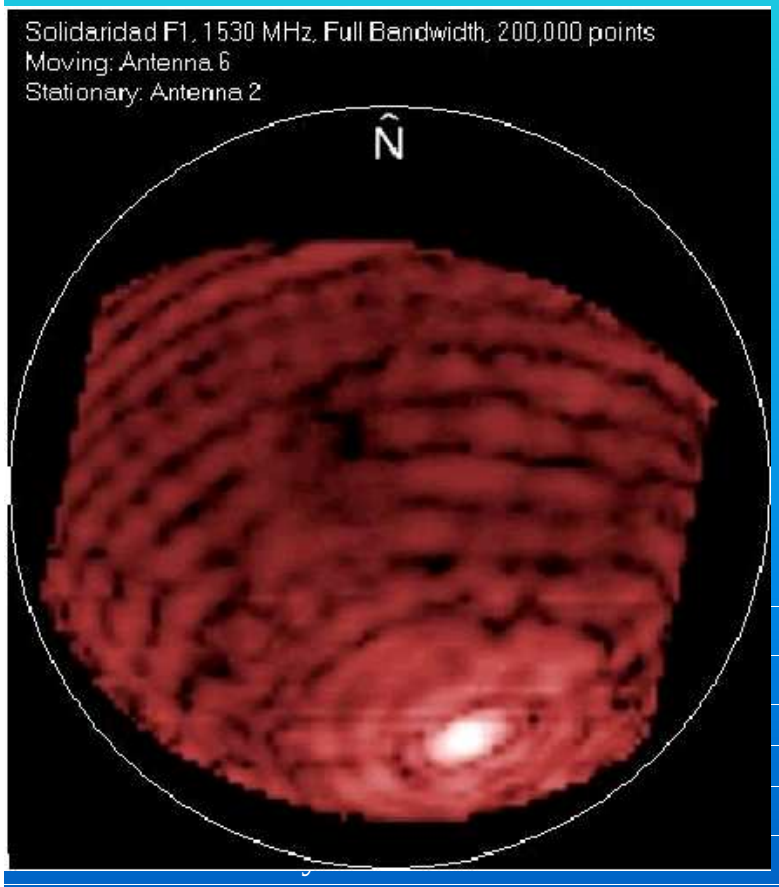
RPA - Rapid Prototyping Array

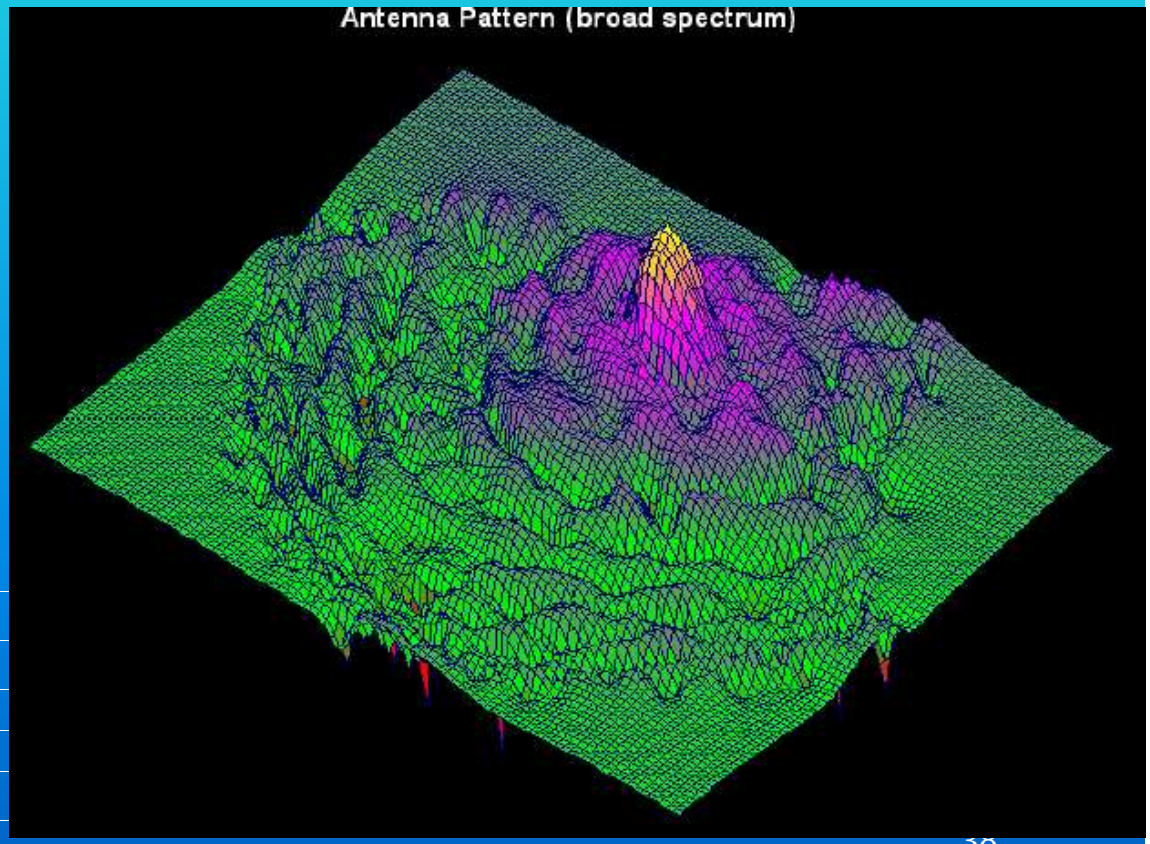
Small amount of time series data can be processed repeatedly



Prototype Software Example

Full sky pattern measurement of one RPA dish

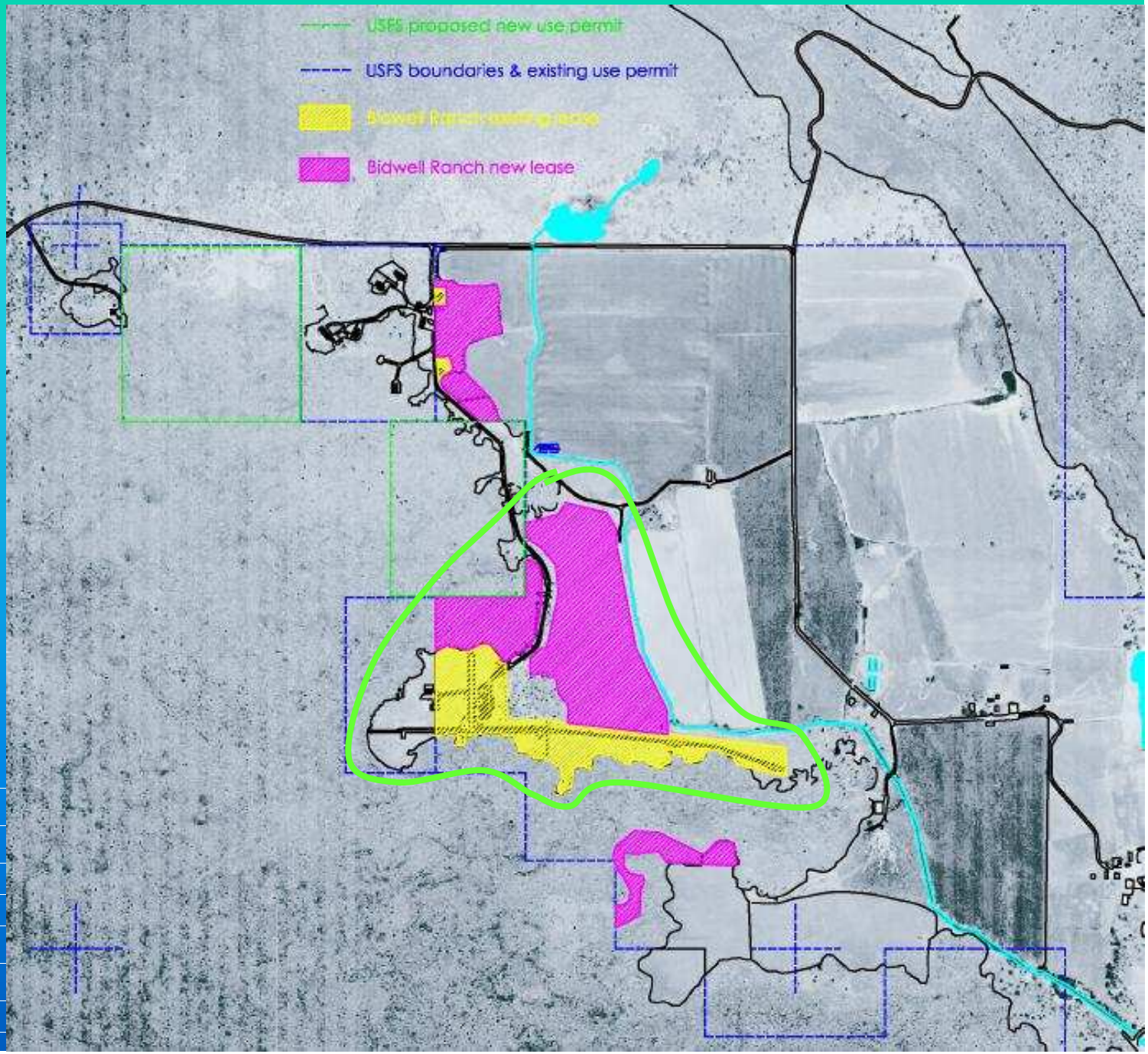




Configuration Studies for Hat Creek

Application for extended use permit from National Forest in progress

Existing lease extended and new lease contract with local rancher executed



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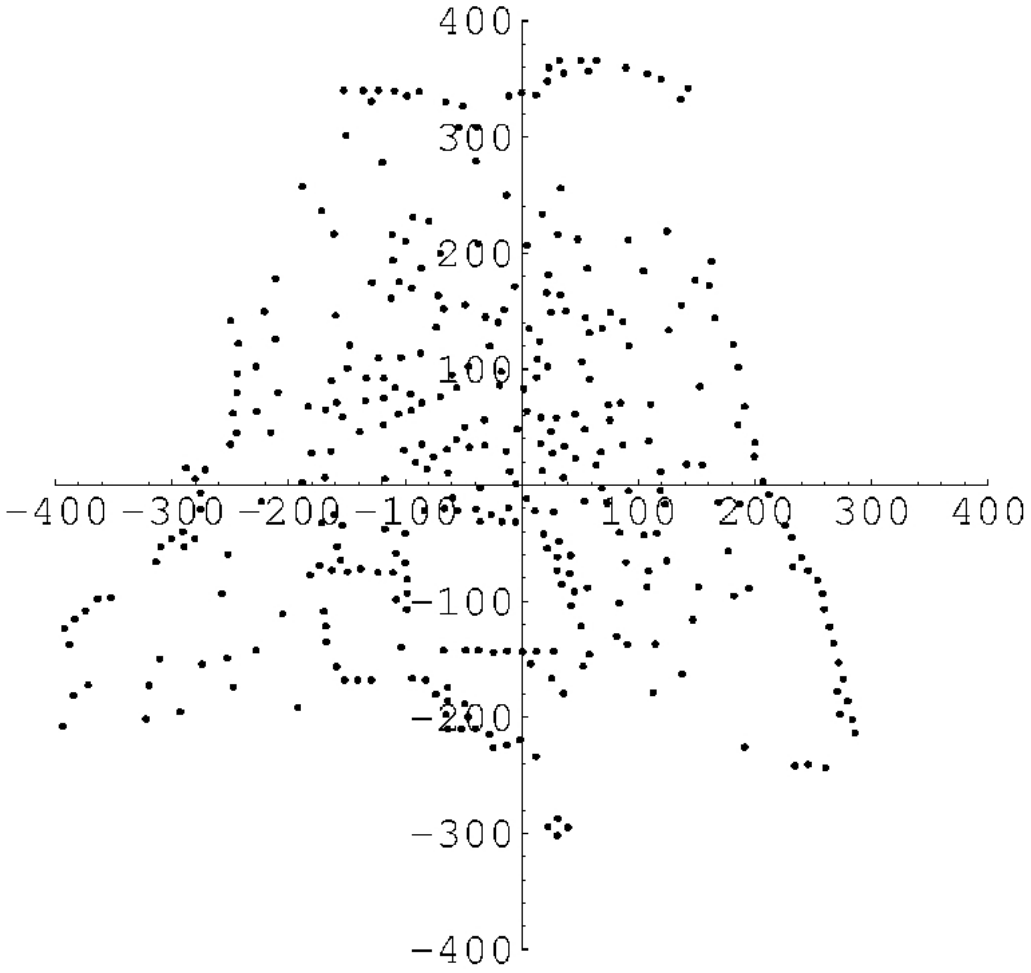
Configuration for ATA



- Nearly circular beam
- 76 arcsec at 1.4 GHz
- Near-in sidelobes peak at 1%
- Far-out sidelobe ~ 1/N

Timeline for ATA

1999-2000

- R&D Phase
- Rapid Prototype Array built
- Selected site, began approval processes
- PDRs: Optics, Front End, Analog, Antenna, System
- Design staffing complete

Timeline for ATA

2001-2002

- PDRs for Software and Digital Processor
- CDR
- Build Production Test Array
- Operational tests begin
- Develop tools and contracts

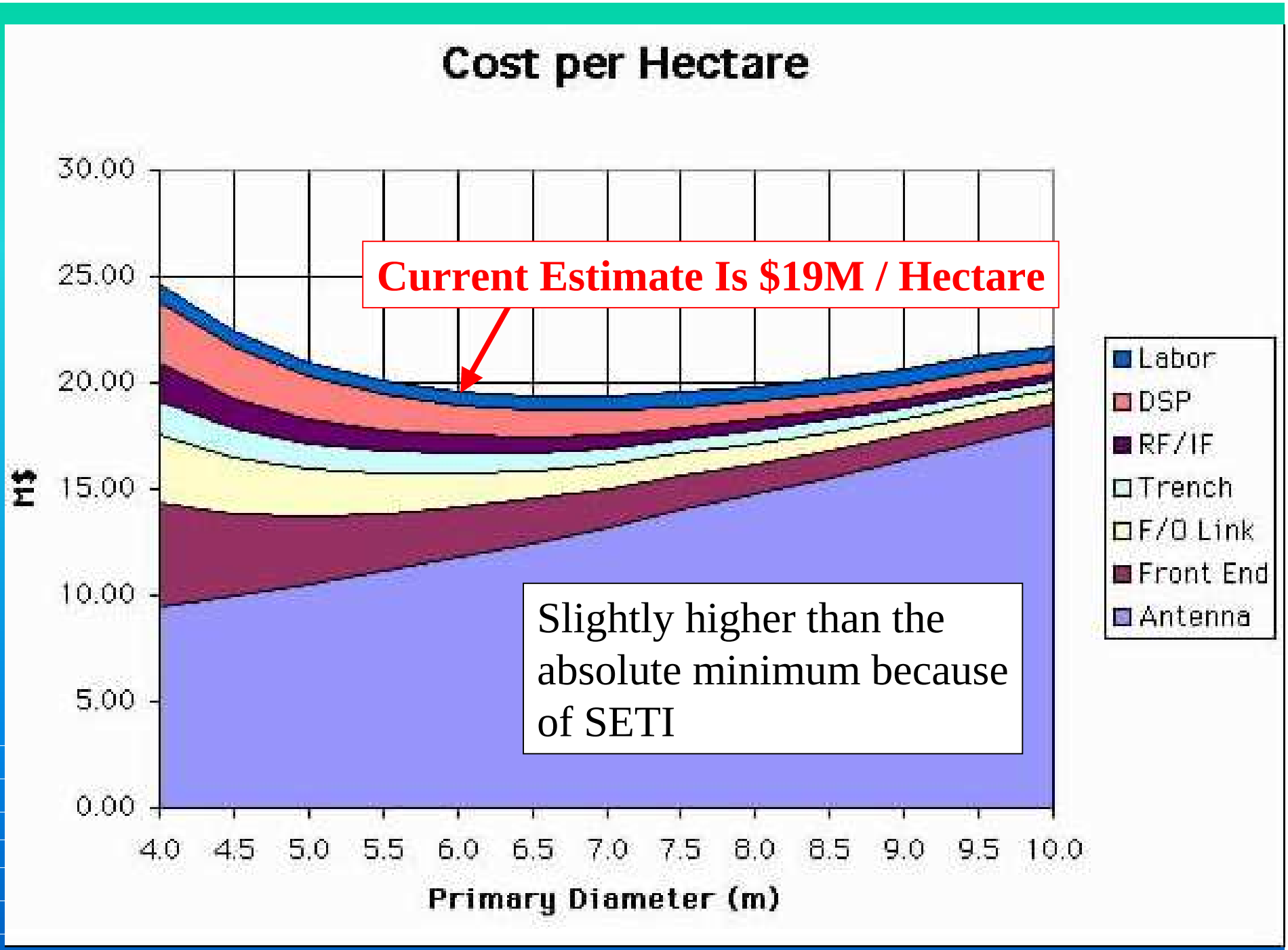
Timeline for ATA

2003-2004

- Begin construction
- First use of partial array

2005

- Array complete - extensions begin
- Feed into SKA technology decision point


Cost per Hectare
Current Estimate Is $19M / Hectare
Slightly higher than the absolute minimum because of SETI
M$
30.00
25.00
20.00
15.00
10.00
5.00
0.00
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
Primary Diameter (m)
Labor
DSP
RF/IF
Trench
F/O Link
Front End
Antenna