Frontiers in Radio Astronomy - Scientific and Technical

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October, 2006

- Selected Scientific Frontiers
  - –Cosmic background microwave radiation
  - –Sub-nansosecond pulses
  - –Search for extraterrestial civilizations
- Technical Frontiers at Caltech
  - –Mission statement, imaging
  - –Large arrays
  - –Sensitivity and low noise
  - –Decade bandwidth antenna feeds

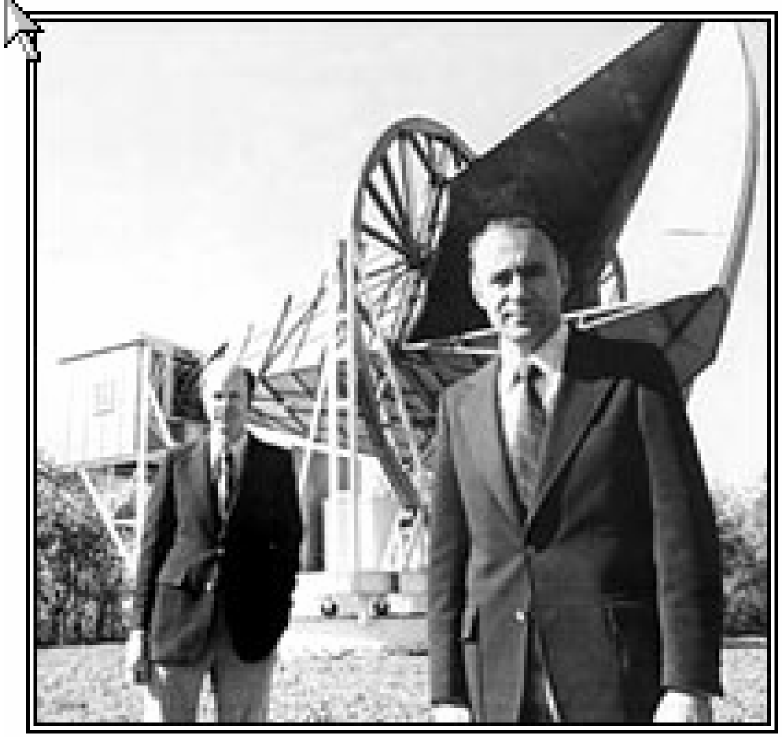
"A Measurement of Excess Antenna Temperature at 4080 Megacycles per Second"

A. Penzias and R. Wilson, Astrophysical Journal Letters, 1965

John Bahcall, a leading astrophysicist , said,

"The discovery of the cosmic microwave background radiation changed forever the nature of cosmology, from a subject that had many elements in common with theology to a fantastically exciting empirical study of the origins and evolution of the things that populate the physical universe."

He called it the most important achievement in astronomy since Hubble's discovery of the expansion of the universe.



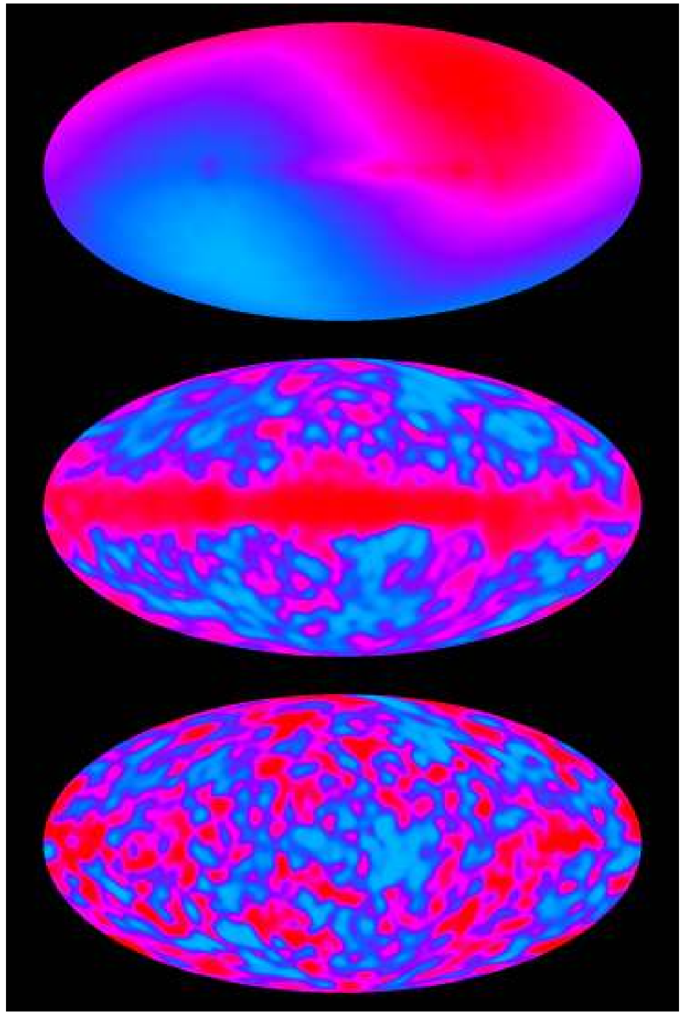
Microwave Sky Background Radiation

Sky Maps of Deviations from 2.725K

Data from the 31, 53, and 90 GHz radiometers on the COBE spacecraft

The 2006 Nobel Prize in Physics was awarded to Mather and Smoot for this measurement.

COBE was launched in 1989 and many other cosmic background instruments, space and ground based, have added much more information about the cosmic background.

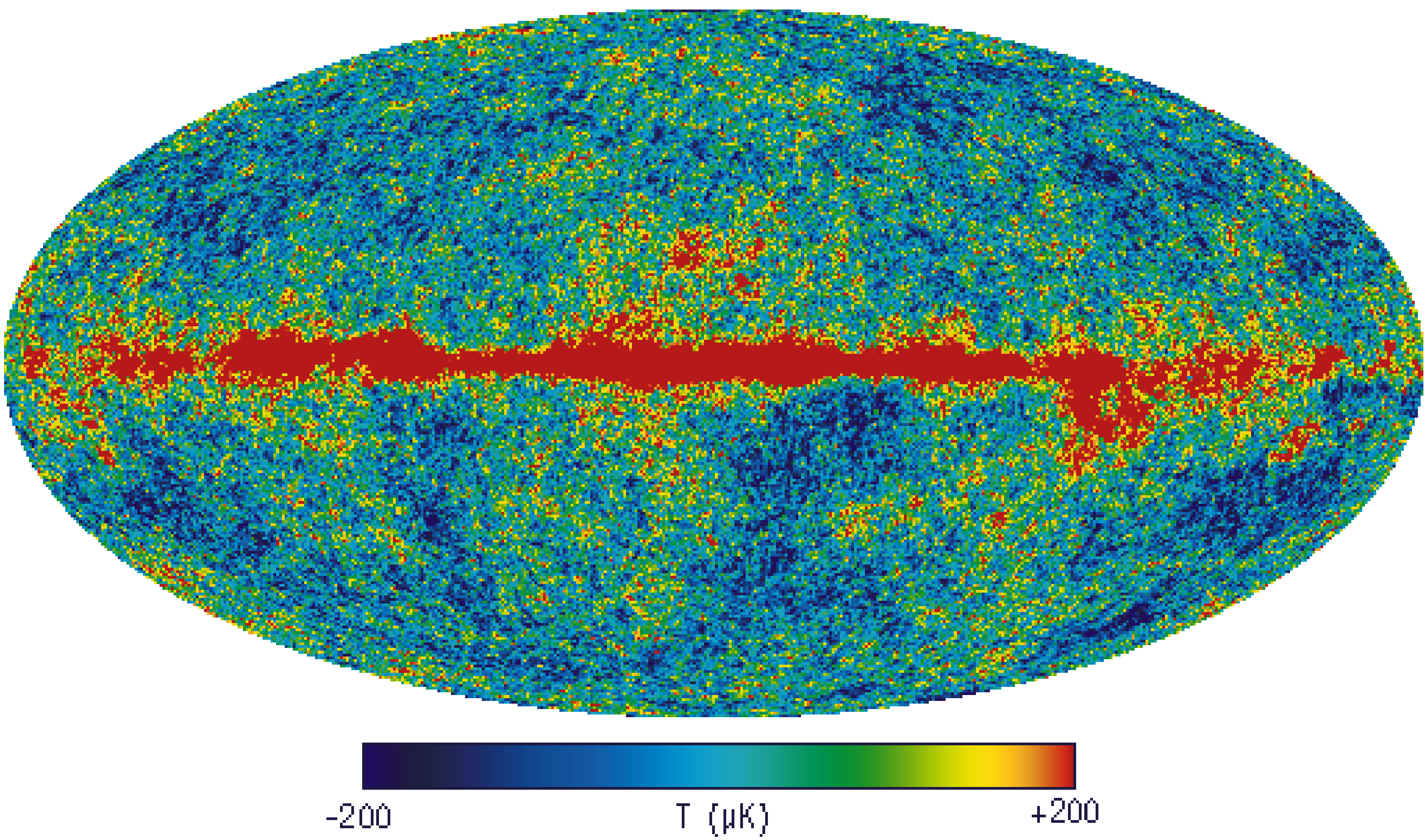


After subtraction of the 2.725K mean to reveal the mK dipole due to motion of our galaxy

After subtraction of the dipole moment to show radiation of our local galaxy.

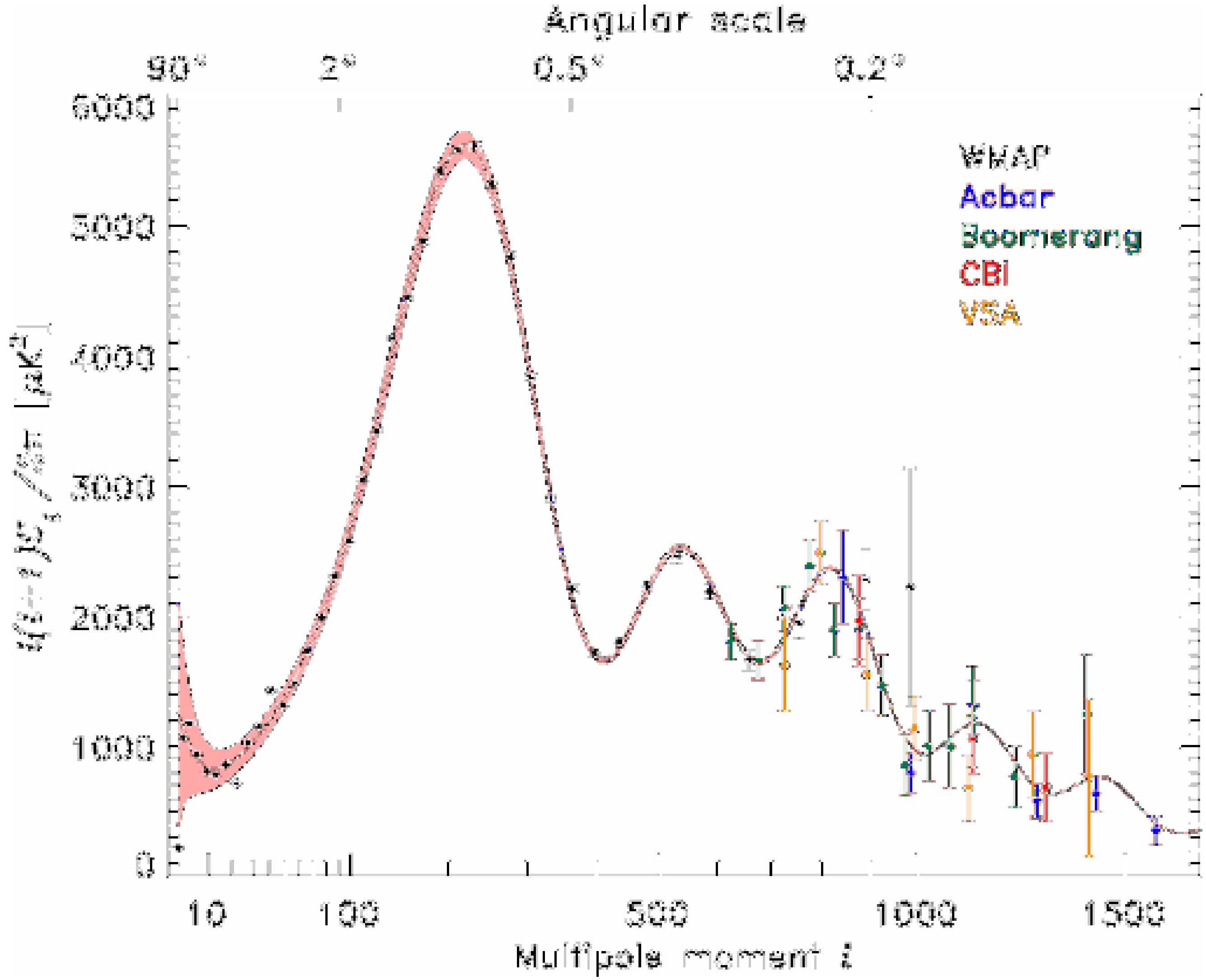
After subtraction of both the dipole and galactic emission to show the 100uK variations due to emission variations in the early universe

Cosmic Background Emission Measured by the Wilkinson Anisotropy Probe (WAP) at 61 GHz

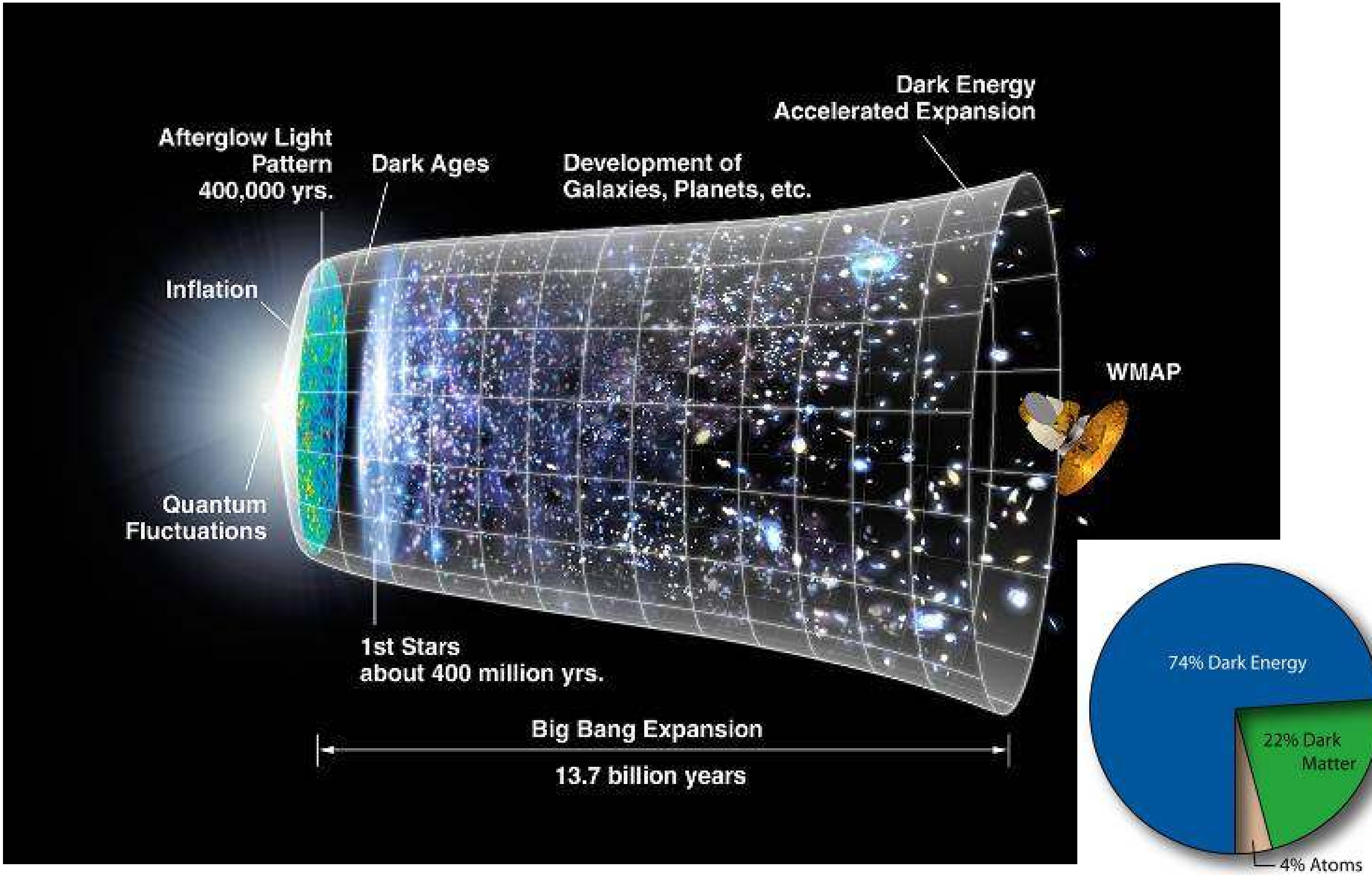


Spatial Spectrum of the Microwave Background

See: http://lambda.gsfc.nasa.gov



History and Content of the Universe



Parameters of the WMAP Spacecraft

Launched June 30, 2001

See: http://map.gsfc.nasa.gov/

WMAP Mission Characteristics:

	K-Band[a]	Ka-Band[a]	Q-Band[a]	V-Band[a]	W-Band[a]
Wavelength (mm)[b]	13	9.1	7.3	4.9	3.2
Frequency (GHz)[b]	23	33	41	61	94
Bandwidth (GHz)[b, c]	5.5	7.0	8.3	14.0	20.5
Number of Differencing Assemblies	1	1	2	2	4
Number of Radiometers	2	2	4	4	8
Number of Channels	4	4	8	8	16
Beam Size (deg)[b, d]	0.88	0.66	0.51	0.35	0.22
System Temperature, *Tsys* (K)[b, e]	29	39	59	92	145
Sensitivity (mK $sec^{1/2}$)[b]	0.8	0.8	1.0	1.2	1.6

Sky Coverage	Full sky
Optical System	Back-to-Back Gregorian, 1.4 x 1.6 m primaries
Radiometric System	Differential polarization sensitive receivers
Detection	HEMT amplifiers
Radiometer Modulation	2.5 kHz phase switch
Spin Modulation	0.464 rpm = ~ 7.57 mHz spacecraft spin
Precession Modulation	1 rev hr^{-1} = ~ 0.3 mHz spacecraft precession
Calibration	In-flight: amplitude from dipole modulation, beam from Jupi
Cooling System	Passively cooled to ~ 90 K
Attitude Control	3-axis controlled, 3 wheels, gyros, star trackers, sun sensor
Propulsion	Blow-down hydrazine with 8 thrusters
RF Communication	2 GHz transponders, 667 kbps down-link to 70 m DSN
Power	419 Watts
Mass	840 kg
Launch	Delta II 7425-10 on June 30, 2001 at 3:46:46.183 EDT
Orbit	1° - 10° Lissajous orbit about second Lagrange point, L_2
Trajectory	3 Earth-Moon phasing loops, lunar gravity assist to L_2
Design Lifetime	27 months = 3 month trajectory + 2 yrs at L_2

Interesting New Topic in Radio Astronomy

Pulses from a neutron star in a supernova which exploded 6000 years ago.

Nanosecond radio bursts from strong plasma turbulence in the Crab pulsar

T. H. Hankins*, J. S. Kern*†, J. C. Weatherall* & J. A. Eilek*

* *Physics Department, New Mexico Tech, and † National Radio Astronomy Observatory, Socorro, New Mexico 87801, USA*

The Crab pulsar was discovered[1] by the occasional exceptionally bright radio pulses it emits, subsequently dubbed 'giant' pulses. Only two other pulsars are known to emit giant pulses[2,3]. There is no satisfactory explanation for the occurrence of giant pulses, nor is there a complete theory of the pulsar emission mechanism in general. Competing models for the radio emission mechanism can be distinguished by the temporal structure of their coherent emission. Here we report the discovery of isolated, highly polarized, two-nanosecond subpulses within the giant radio pulses from the Crab pulsar. The plasma structures responsible for these emissions must be smaller than one metre in size, making them by far the smallest objects ever detected and resolved outside the Solar System, and the brightest transient radio sources in the sky. Only one of the current models—the collapse of plasma-turbulent wave packets in the pulsar magnetosphere—can account for the nanopulses we observe.

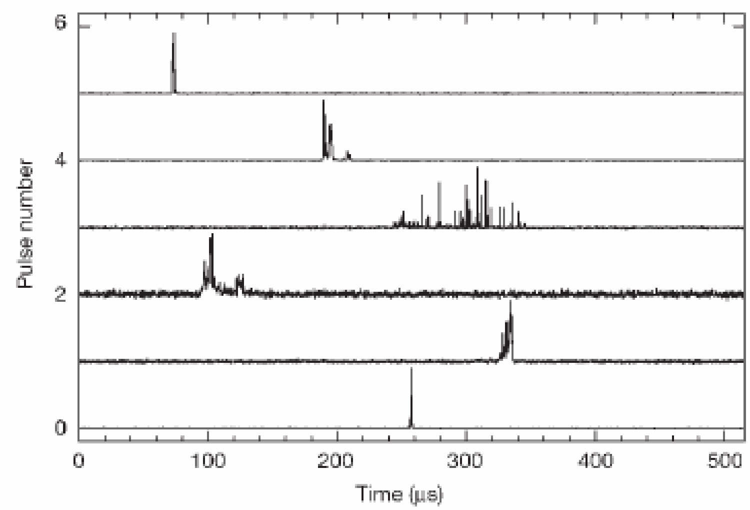


Figure 1 A sequence of dedispersed Crab giant pulses. The arrival time jitter and varied shapes of the total intensity are shown. The time axis origin is modulo one pulsar rotation period. Each pulse has been plotted with a time resolution of 250 ns and is normalized to the same maximum amplitude. The centre frequency is 5.5 GHz and the sampled bandwidth is 0.5 GHz. A square-law power detector with a 200-μs time constant was used to detect the presence of a giant pulse in the receiver pass band. A 2-ms time window, synchronous with the Doppler-shifted main pulse arrival times, was obtained from our separate pulsar timing system. When the detected intensity exceeded a preset threshold of eight times the r.m.s. off-pulse noise during the main pulse 2-ms window, a giant pulse was captured by digitally sampling the voltage of both orthogonal polarizations at 1 or 2×10^9 samples per second using a LeCroy 9354L or LC584L digital oscilloscope.

Chronology of the Crab Pulsar

5750 BC A star in the Crab Nebula collapses to form the bright flash of a supernova

1054 AD The flash is observed for days by Chinese and Arabian astronomers

1758 Messier discovers the supernova remnant, the Crab Nebula

1934 The existence of neutron stars is predicted by Zwicky

1967 The first pulsed radio waves from an astronomical object are detected by Anthony Hewish and Jocelyn Bell who suggest the pulses are from a rotating neutron star.

1968 Staelin and Reiffenstein discover the Crab pulsar

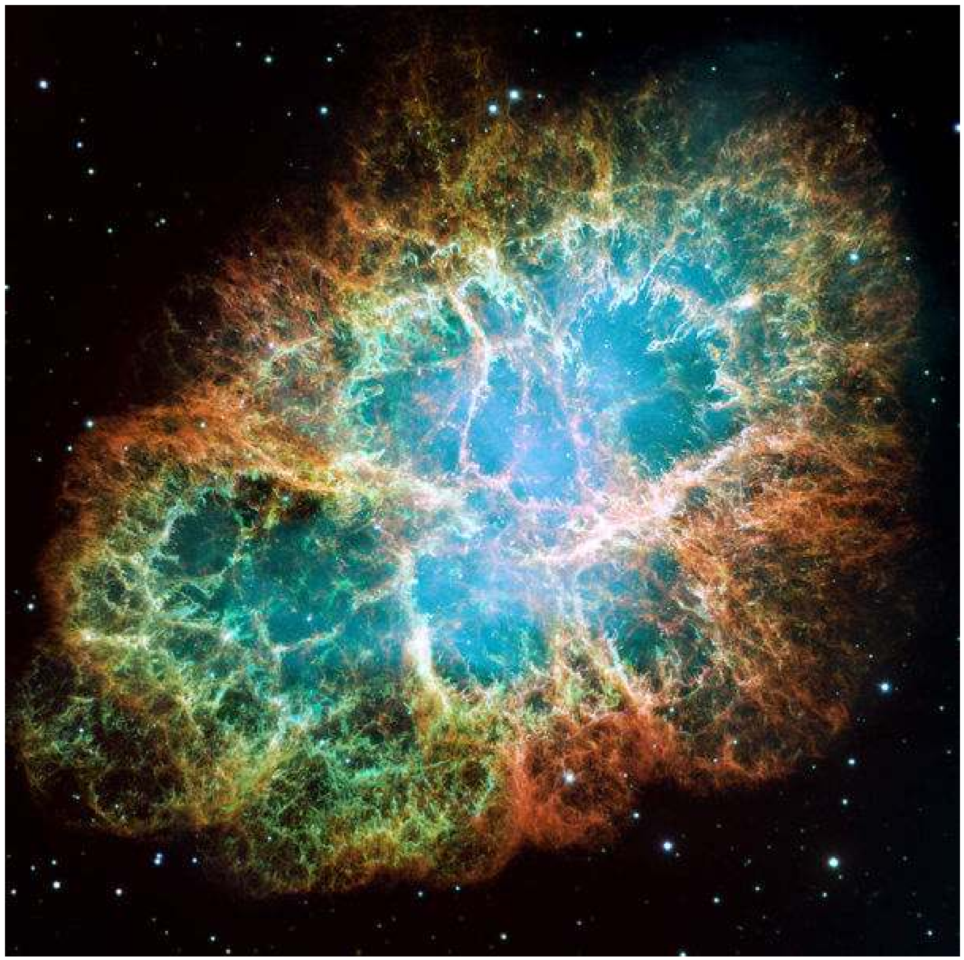
1974 Hewish receives the Nobel Prize in Physics for the pulsar discovery

2003 Hankins discovers pulses of < 1 ns duration from the Crab pulsar. These pulses left the neutron star in 4800 BC and have a dispersion of the order of 1ms between 8 and 9 GHz – about 2×10^{-15} of the transmission time. This is due to an electron content of .03 per cm^3 in the interstellar medium

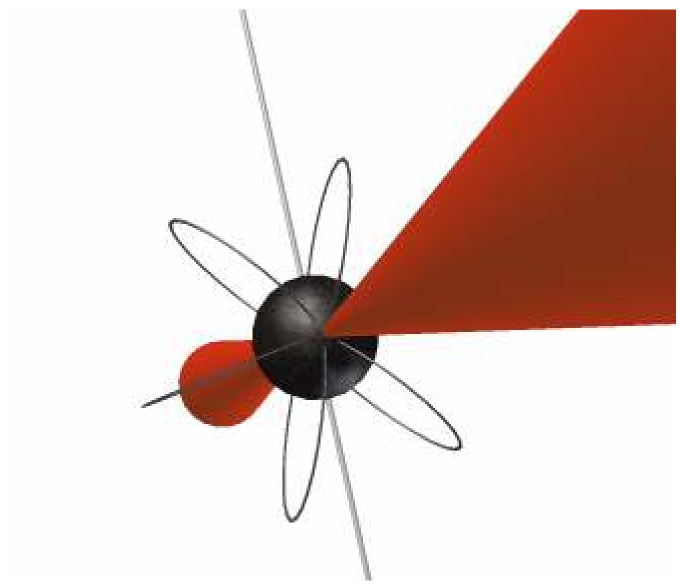
Nanosecond Pulses from the Crab Nebula Pulsar

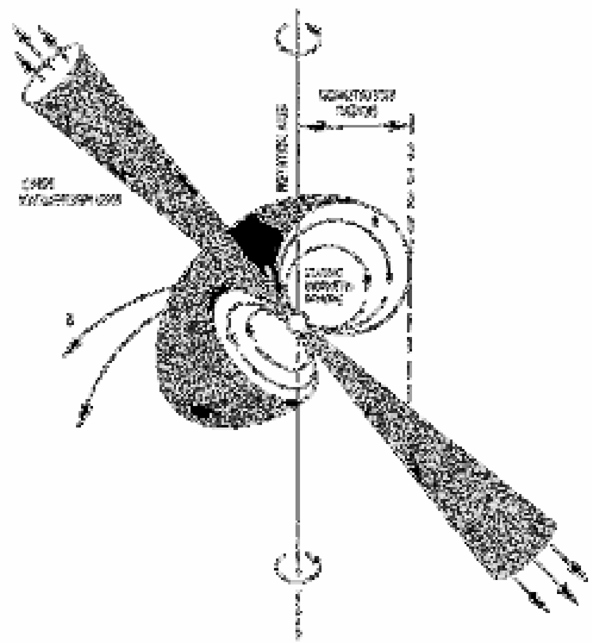
1 ns is the light travel time in 30 cm this limits the size of emitting region

From the strength observed on earth and the known distance and size, the luminosity or brightness can be determined to be the brightest object in the universe at 10^{37} K.



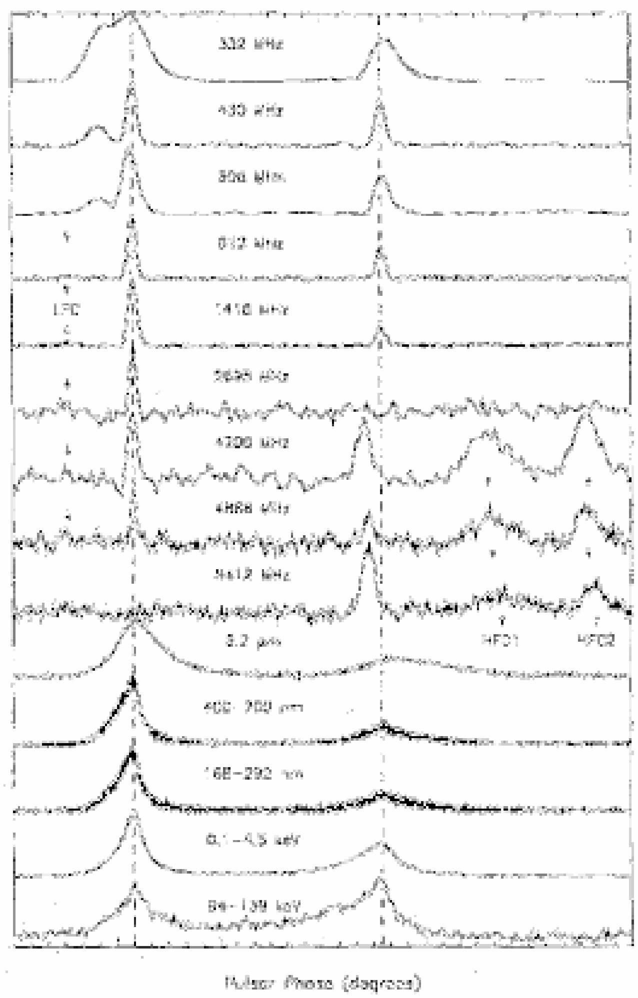
Rotating Neutron Star “Lighthouse” Model





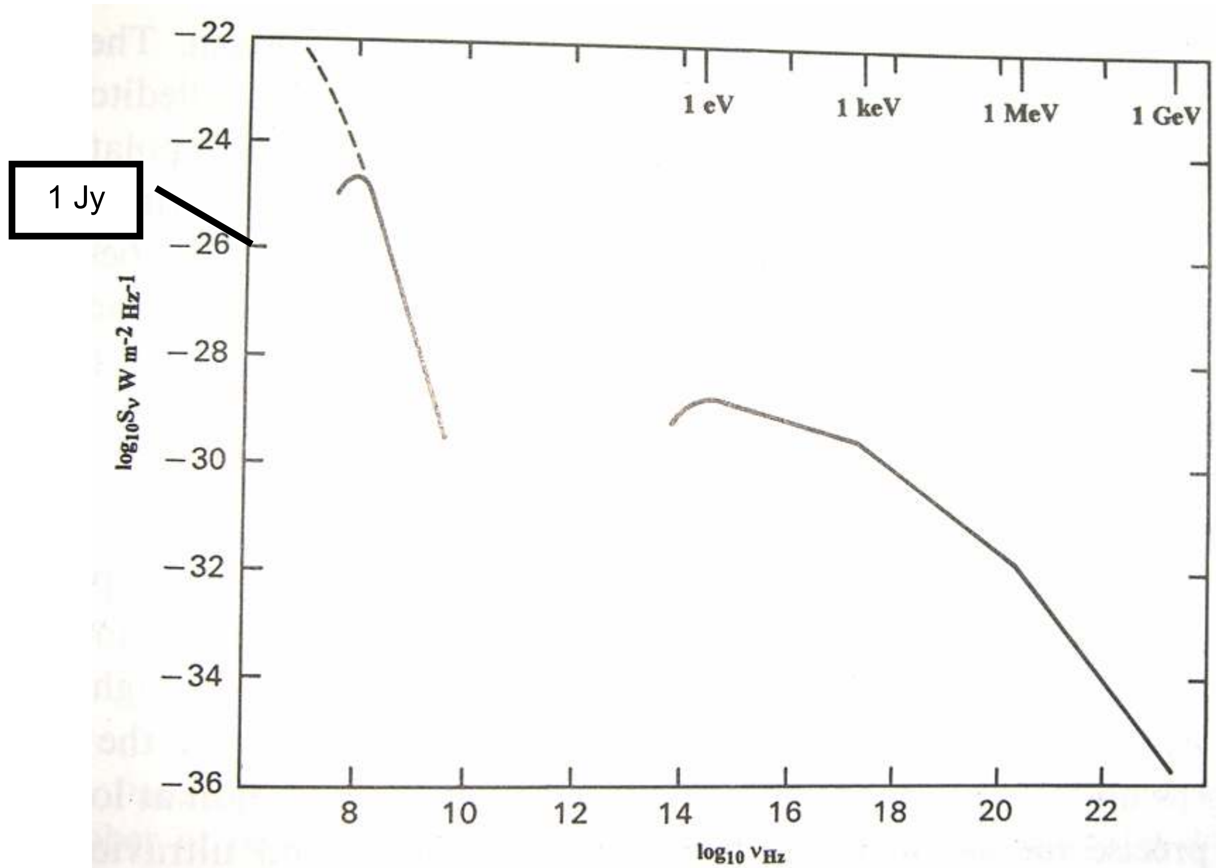
Crab Pulsar Spectrum

Radiation has been observed throughout the radio, IR, optical, and X-ray regions of the spectrum



From: Moffett & Hankins 1996 ApJ ***468,*** *779*

Spectral index ~ -2.7 at RF



From: Lyne & Graham-Smith, *Pulsar Astronomy* Cambridge, 1998

When Will Earth Communicate with Extraterrestrial LIfe? - SETI Chronology

- In the first 5 billion years the technology to communicate at stellar distances did not exist on earth
- We have only had radio technology for ~100 years
- It is only in the past several years that we have detected planets around other stars
- The Kepler spacecraft mission has the goal of detecting 50 earth-like planets by 2011. What is the next step?
- An SKA size array could increase the volume of space with detectable radio emission by a factor of ~350

Kepler mission, shown at right, will examine 100,000 stars looking for fluctuations due to planet occultation's

The Drake Equation

$$N = R\ fs\ fp\ Ne\ fl\ fi\ fc\ L$$

N = Number of communicative intelligent species in our galaxy

R = Average rate of star formation (stars/year)

fs = Fraction of starts that are "good" sun
fp = Fraction of good stars with planetary systems

Ne = Number of planets per star within ecoshell

fl = Fraction of ne on which life develops
fi = Fraction of living species that develop intelligence
fc = Fraction of intelligent species reaching an electromagnetic communicative phase

L = Lifetime in communicative phase (years)

$$N \approx L$$

Number of Detectable Extraterrestrial Transmitters vs Antenna Area on Earth

	Number of Stars at Detectable Distance and (Distance, Light Years)		
Extraterrestrial Transmitter⟶	**1MW Isotropic Leakage Signal**	**Beacon, 1KW**	**Beacon, 1MW**
2004 Technology Arecibo $A = 2 \times 10^4\ m^2$	0 (2.7 LY)	7 (19 LY)	216,000 (600 LY)
SKA Technology $A = 10^6\ m^2$	7 (19 LY)	2500 (135 LY)	74,000,000 (4200 LY)

Assumptions: 20K Receiver Noise, Arecibo type Beacon, 21cm Wavelength, 0 dB S/N at Detection in 1Hz Bandwidth

Why Search for Other Civilizations?

1) The most likely contact is with a civilization much more highly advanced than ours; those less advanced do not have the technology to communicate. This "mentor" civilization could advance our state of knowledge of science, technology, social concepts, and medicine by 50,000 years!

2) The mentor civilization may have immortal beings - they solved the death problem long ago! It is our one chance, however small, to live forever.

3) In the history of the human race, communication as opposed to invasion or colonization has helped to advance technology, reduce suffering, and increase compassion for other beings.

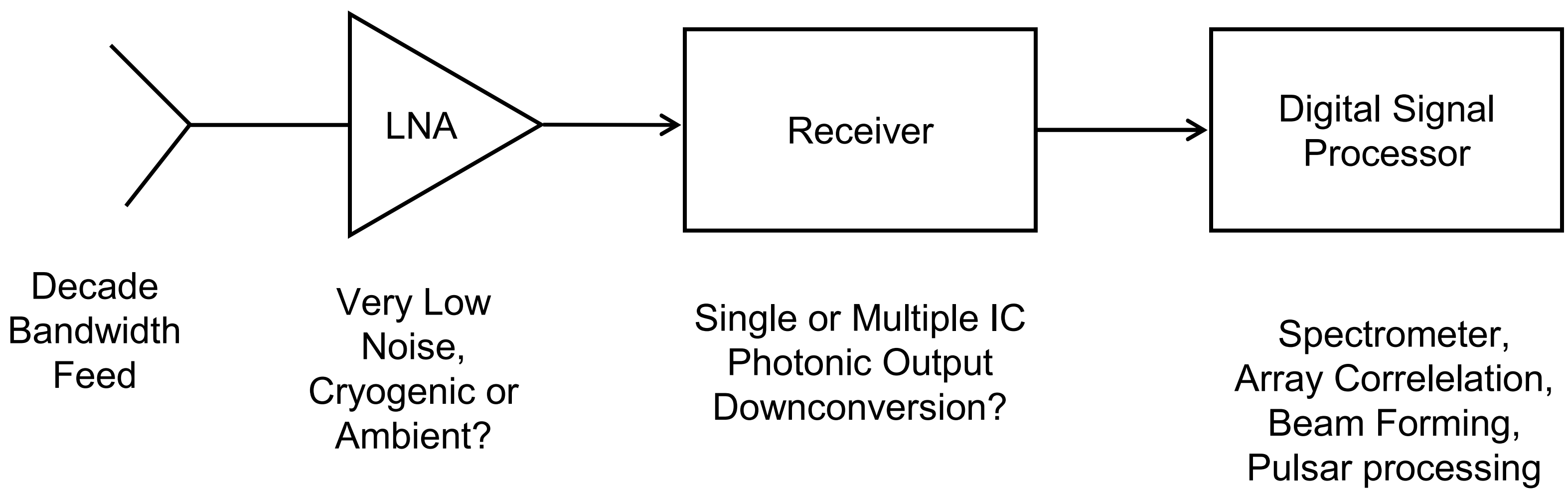
4) Colonization or invasion from a civilization in another solar system is extremely unlikely due to the extreme distance and enormous energy required to transport mass.

5) Curiosity! Most people are fascinated at the thought of another world and would have many questions about it.

Caltech EE Microwave Group

A Mission Statement

Develop technology to support the transition of radio astronomy from single-pixel observations to imaging systems with large field of view, wide simultaneous frequency coverage, and very large collecting area.



Radio Waves Impinge Upon the Earth from Many Distant Sources

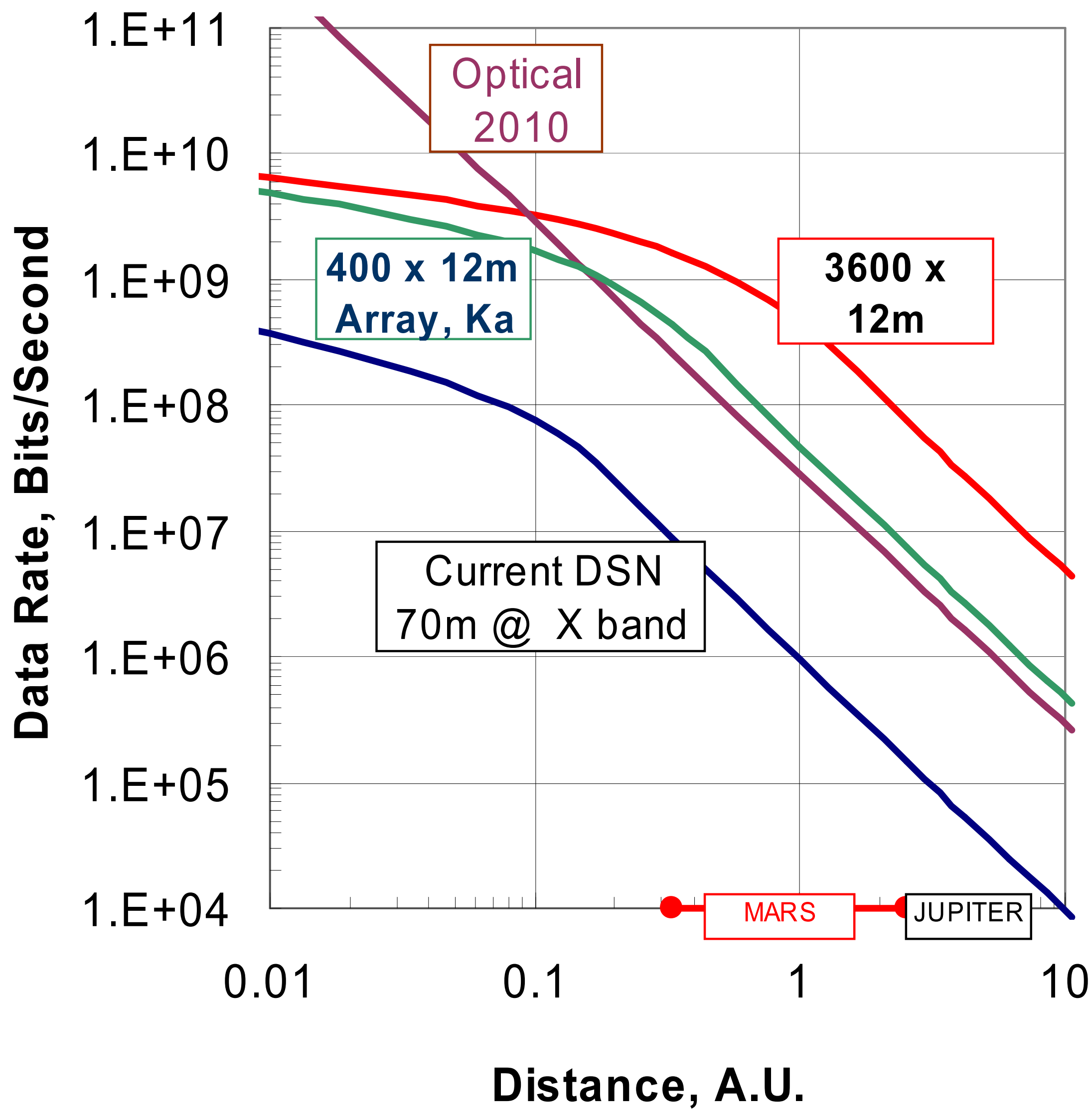
Our Sensitivity to These Waves is Proportional to the Collecting Area on Earth

Radio Astronomy -
Galaxies, quasars, pulsars

Space
Communications

SETI, Other
Civilizations

Large Arrays Can Greatly Expand the Data Rate from Distant Spacecraft

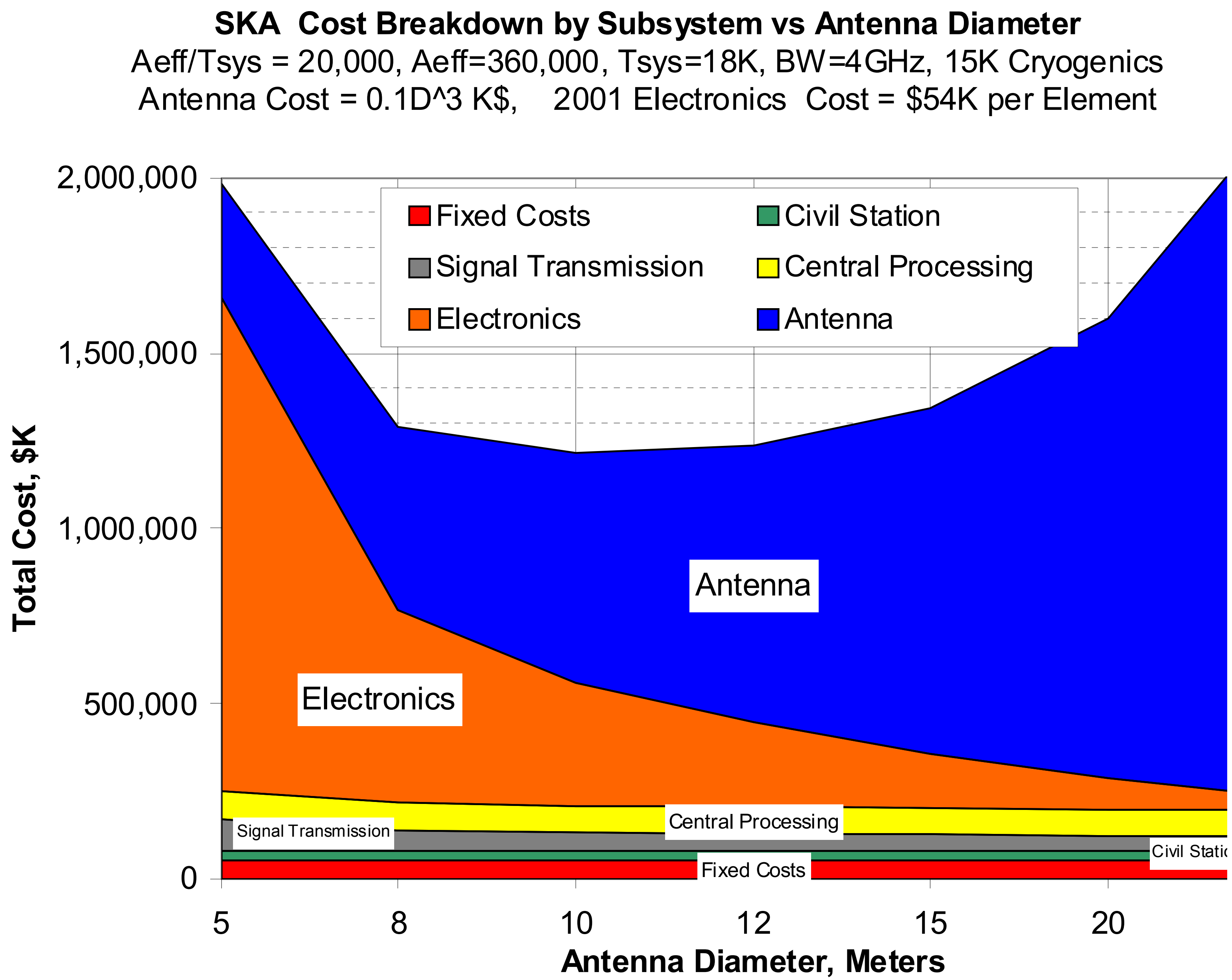


Methods to Increase Microwave Collecting Area

Larger Antennas or Arrays of Smaller Antennas?

Green Bank 100m Antenna

Array of 12m Antennas



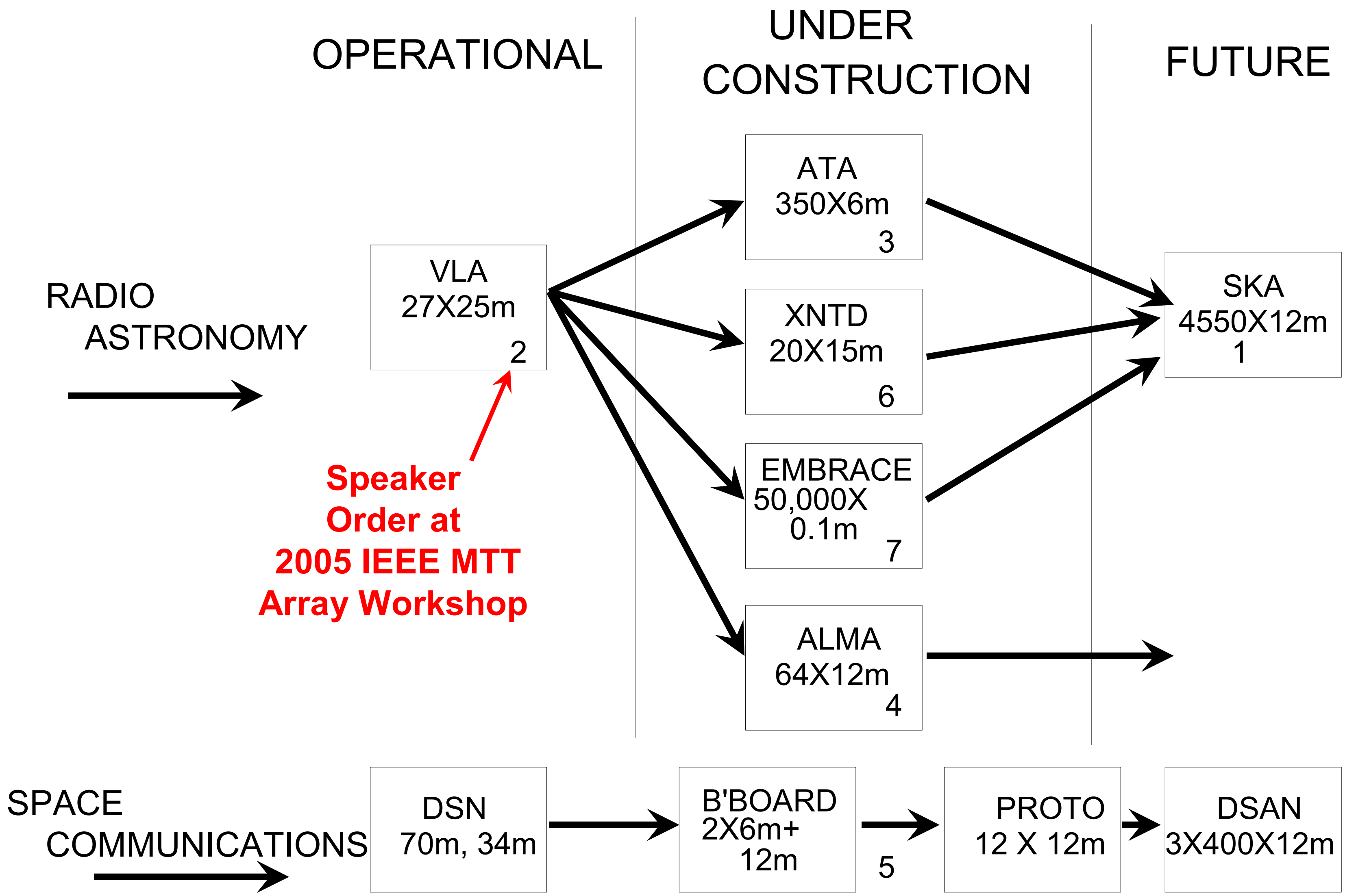
SKA Cost Breakdown by Subsystem vs Antenna Diameter
Aeff/Tsys = 20,000, Aeff=360,000, Tsys=18K, BW=4GHz, 15K Cryogenics
Antenna Cost = 0.1D^3 K$, 2001 Electronics Cost = $54K per Element
Fixed Costs
Civil Station
Signal Transmission
Central Processing
Electronics
Antenna
2,000,000
1,500,000
1,000,000
500,000
0
Total Cost, $K
Antenna
Electronics
Signal Transmission
Central Processing
Fixed Costs
Civil Statio
5
8
10
12
15
20
Antenna Diameter, Meters

Comparison of Existing Large Antennas and Future Arrays

Antenna	Elements	Effective Area	Upper Frequency	Tsys	**A/Tsys**	Year Finished
DSN 70m	1 x 70 m	2,607	8 GHz	18	**145**	1965
GBT	1 x 100 m	5,700	100 GHz	20	**285**	2000
VLA	27 x 25 m	8,978	43 GHz	32	**280**	1982
Arecibo	1 x 305 m	23,750	8 GHz	25	**950**	1970
ALMA	64 x 12 m	4,608	800 GHz	50	**92**	2011
ATA	350 x 6 m	6,703	11 GHz	35	**192**	2005
DSN	**400 x 12m**	**32,000**	**38 GHz**	**18@8GHz 42@32GHz**	**1760 754**	**2009**
SKA	**4550 x 12m**	**327,600**	**22 GHz**	**18**	**20,000**	**2016**

ATA - Allen Telescope Array
DSN - Deep Space Network
VLA - Very Large Array
SKA - Square Km Array

Global Large Array Plans



What is the SKA?

- An international project to design a very large area array for radio astronomy in the cm wavelength range.
- The web site, http://www.skatelescope.com, contains science justification and links to activities in several countries
- US approach is a large array (≈4,500) of small (≈12m) antennas , organized into a 1000km diameter spiral of ≈100 close packed stations

Key Specifications

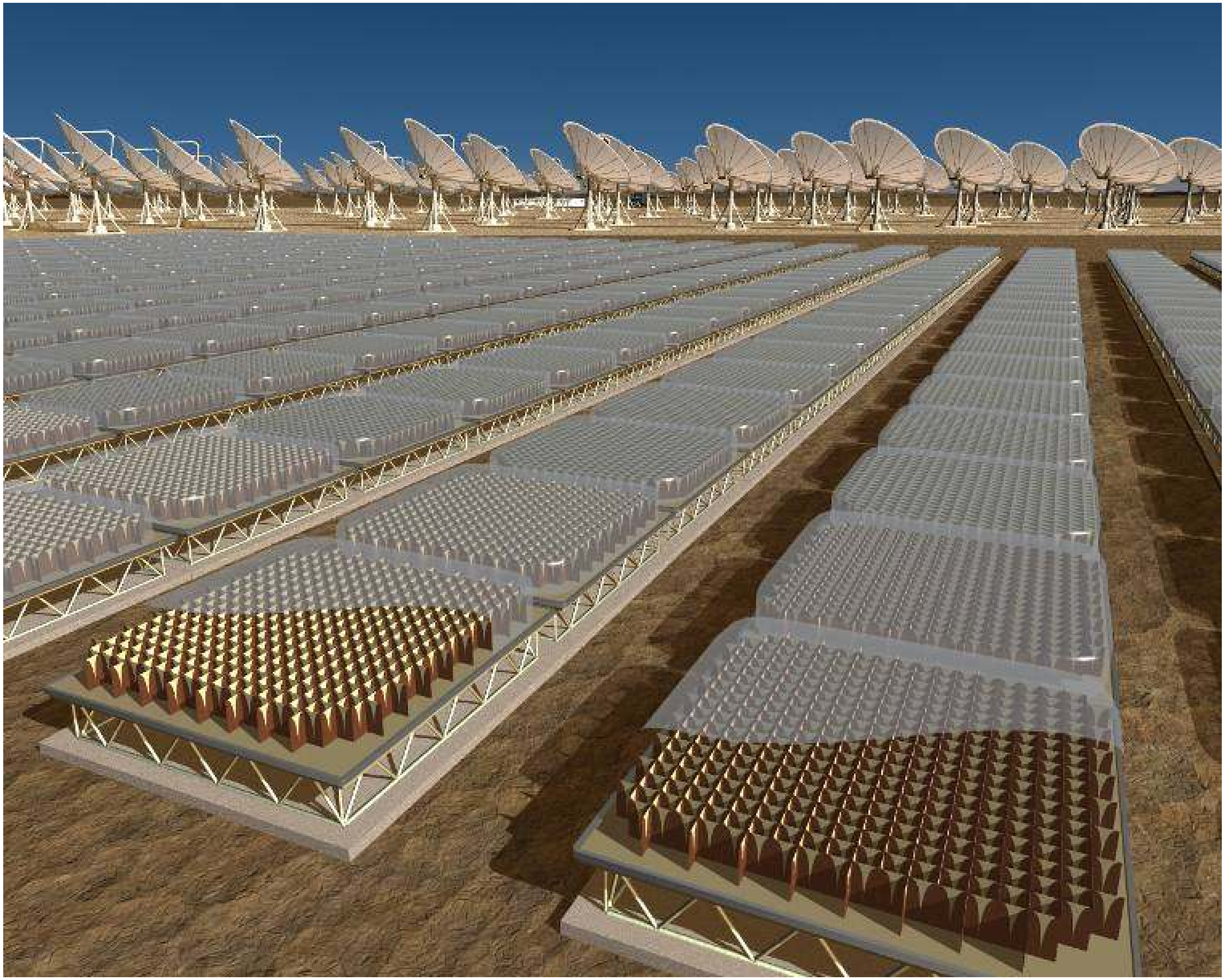
- Aeff/Tsys > 20,000 m^2/K

(1 square km with Tsys=50K)

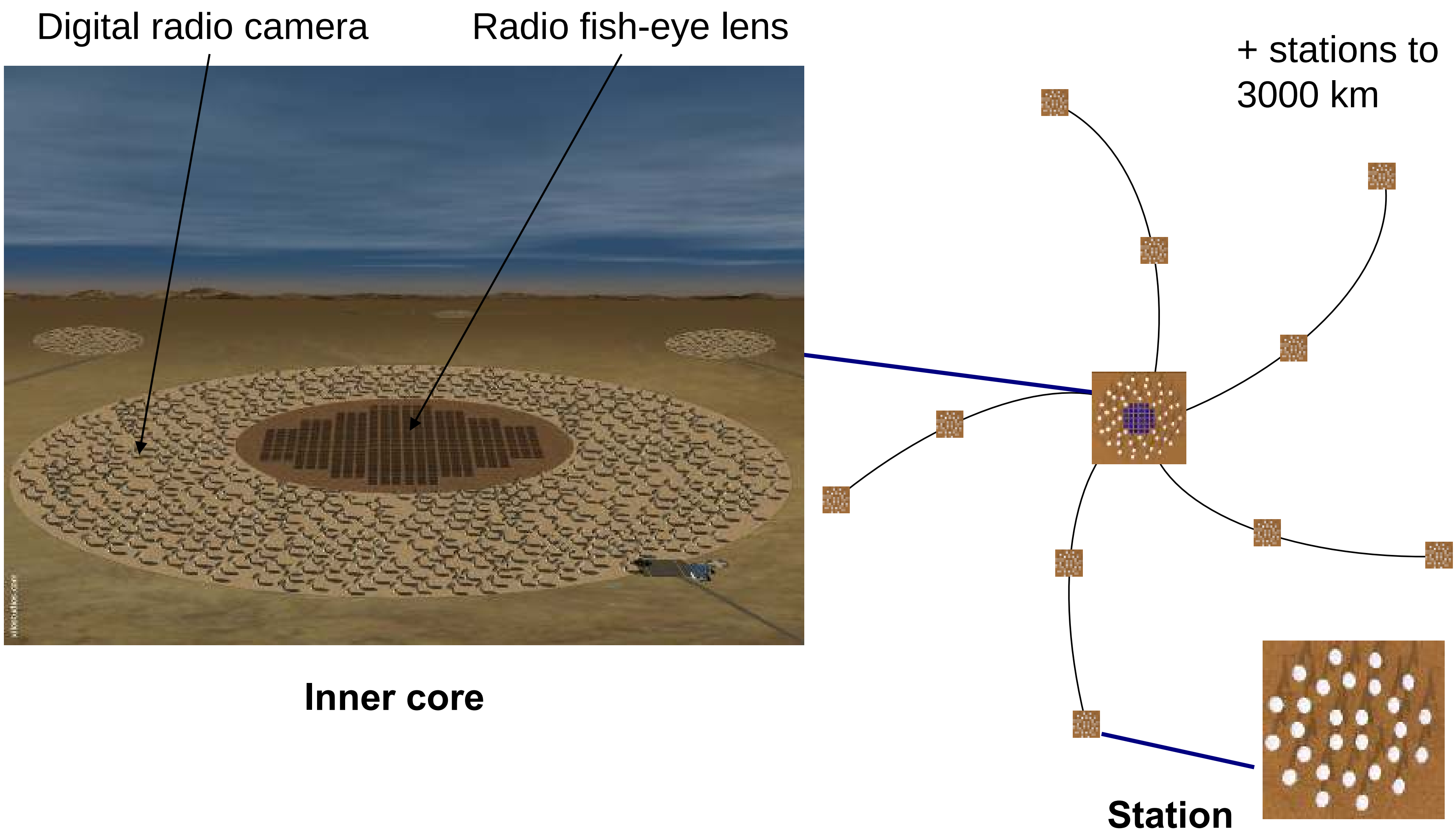
- Frequency, 0.15 –40 GHz
- Resolution 35 nano-radians

(5km beam at 1 A.U. at 20GHz)

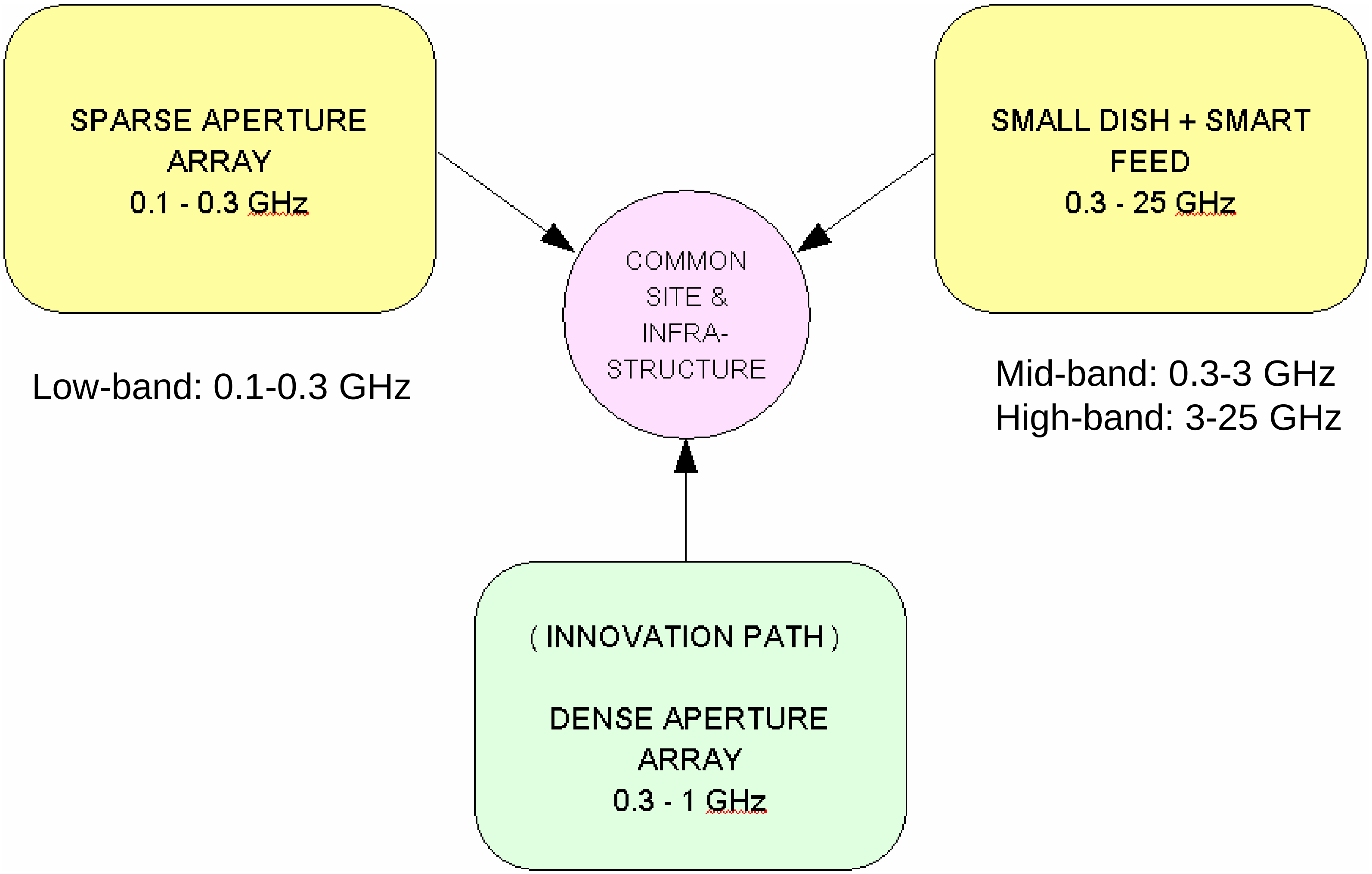
SKA Reference Design Concept



Reference Design



SKA Reference Design



Low-band: 0.1-0.3 GHz

Mid-band: 0.3-3 GHz
High-band: 3-25 GHz

SKA Science: 2005-6

from Brian Gaensler Presentation

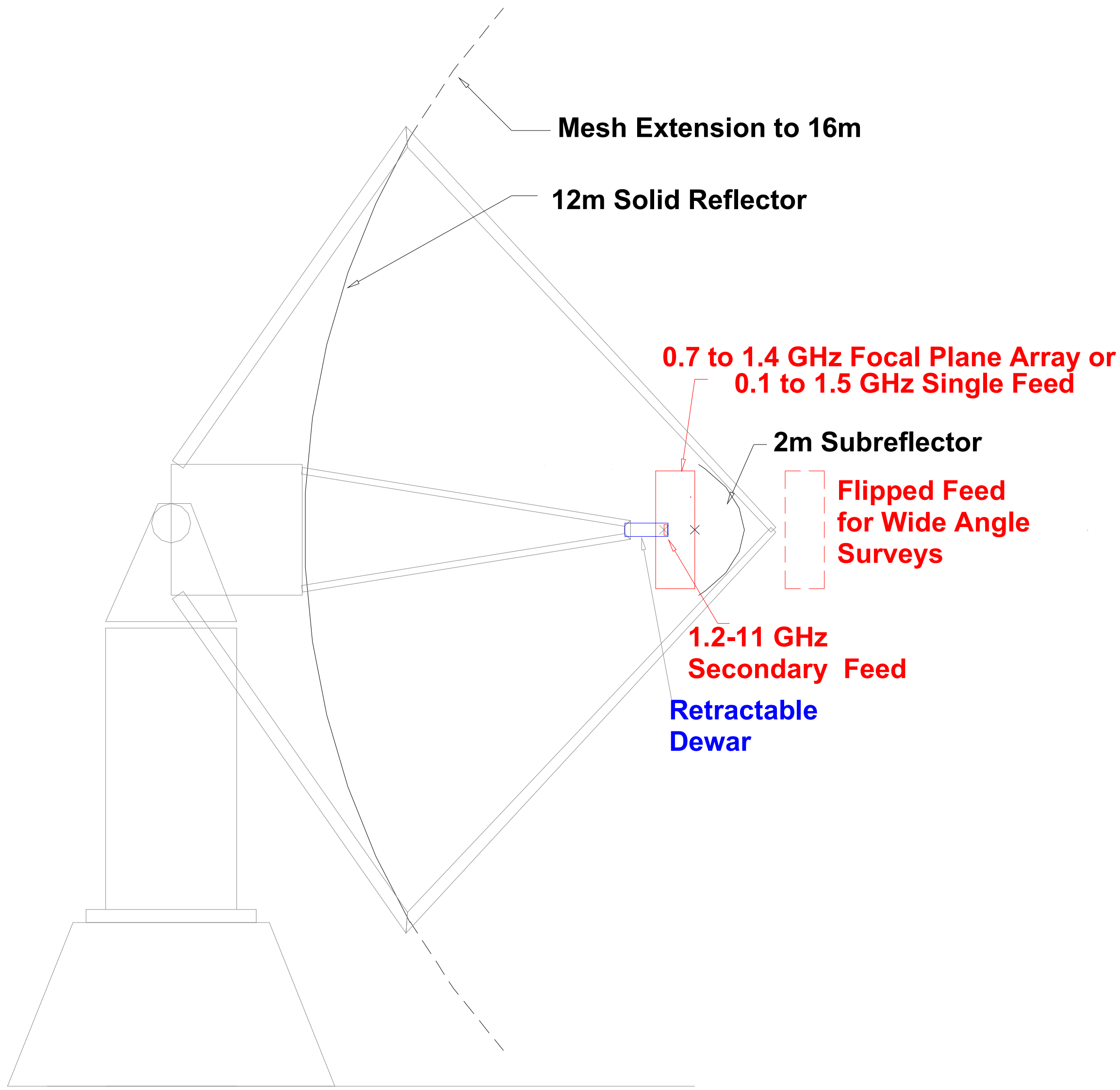
- "Prime driver" for each key science project:
  1. The Cradle of Life: planet formation in protoplanetary disks
  2. Gravity: general relativity and gravitational radiation
  3. Cosmic Magnetism: rotation measure grid
  4. Galaxies & Cosmology: H I galaxy / dark energy survey
  5. The Dark Ages: H I from epoch of reionisation

- Science case for Phase I SKA (10% collecting area, B_{max} = 50 km)
  A. First Light: The Epoch of Reionisation
  B. Building Galaxies: Hydrogen & Magnetism
  C. Pulsars & The Transient Sky

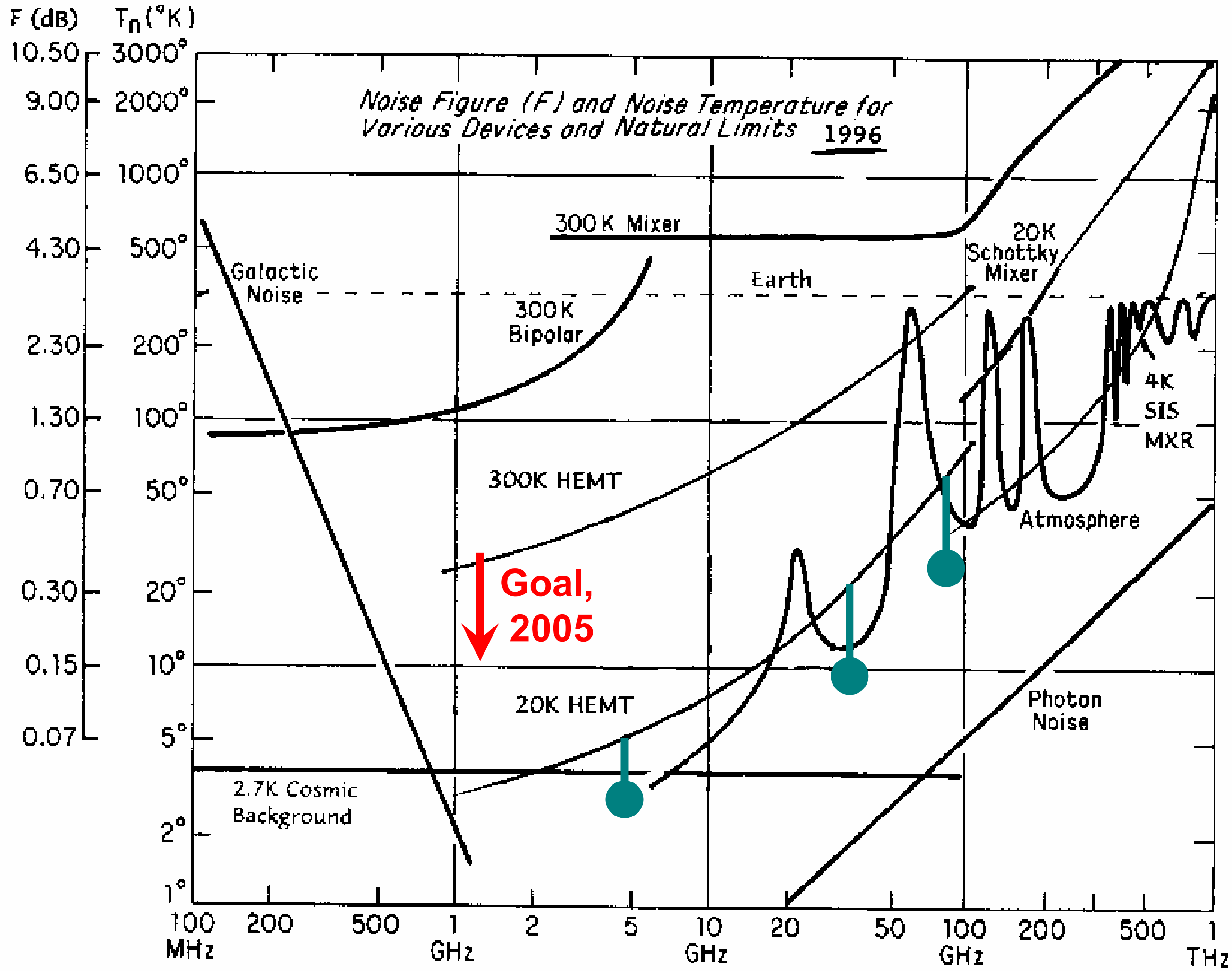
A 12m/16m Symmetric Antenna Concept

Outer mesh doubles sensitivity for frequencies < 1.5 GHz. Mesh has 0.1 of the cost and wind resistance of solid surface

Feeds for 12/16m Antenna Including 0.7 to 1.4 GHz Focal Plane Array



Receiver Noise and Natural Limits to Noise in Receiving Systems



Noise figures and temperatures are state-of-the-art receiver values and in the case of mixers, are single-sideband (SSB)

S. Weinreb, U. of Massacchusetts, 1996

Caltech-Developed Cryogenic LNA’s

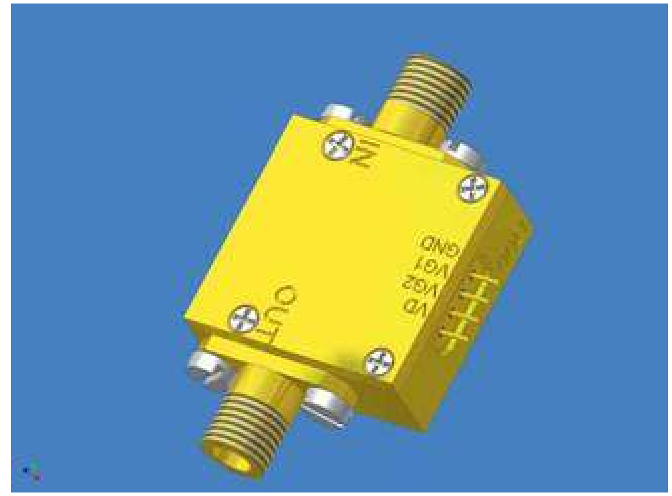
4 Models, @ 12K

0.5 to 11 GHz, Tn < 5K

4 to 14 GHz, Tn < 8K

6 to 20 GHz, Tn < 12K

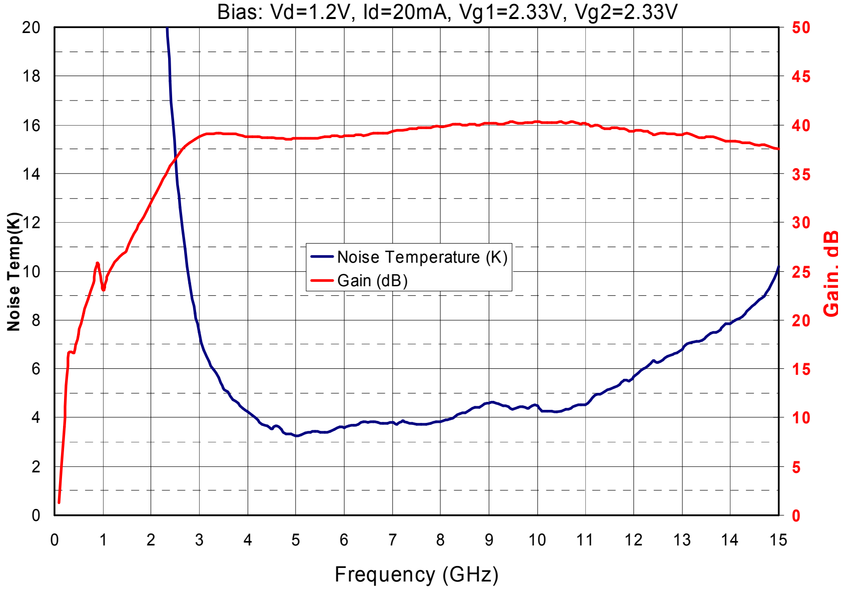
11 to 34 GHz, Tn < 20K



4-12GHz LNA #82D at 12K

MMIC: WBA13, CIT1 4254-065 , R8C2

Bias: Vd=1.2V, Id=20mA, Vg1=2.33V, Vg2=2.33V

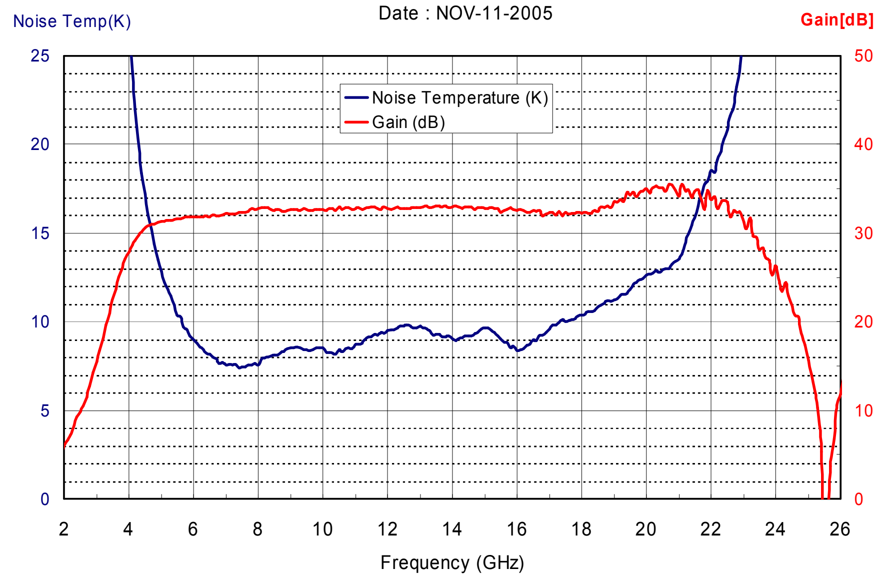


6-18GHz LNA #40A03 at 12K

MMIC WBA618 R7C1M0 CRYO10-4292-014, Bias: Vd=0.65V, Id=16mA

, Vg1=1.9V , Vg2=1.9V

Date : NOV-11-2005



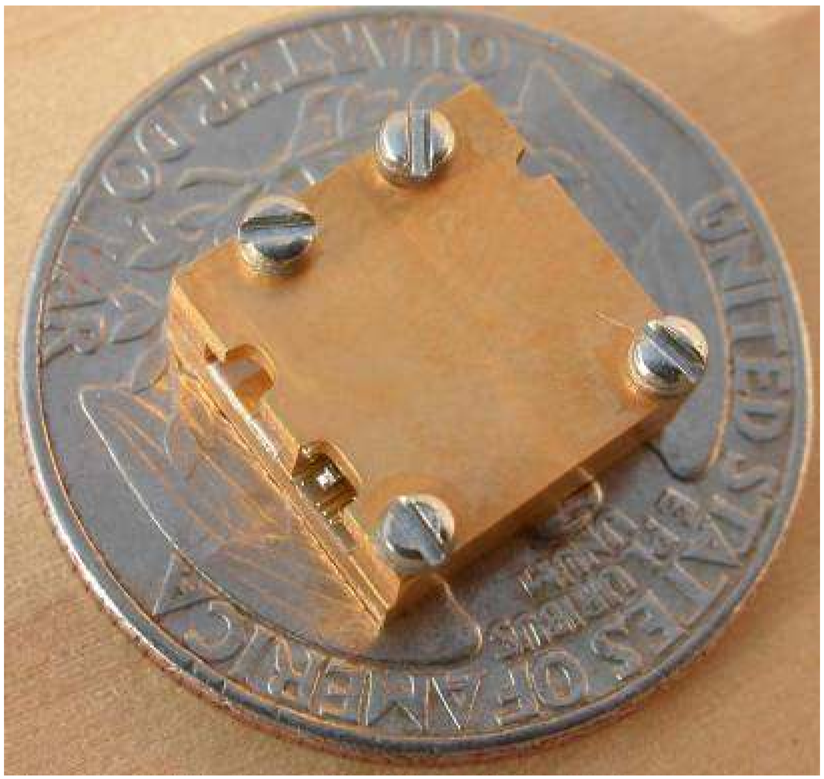
Caltech EE has Delivered 133 LNA's to Other Research Centers During the Past 4 Years

This does not include LNA's for the 350 element ATA or 64 element Supercam

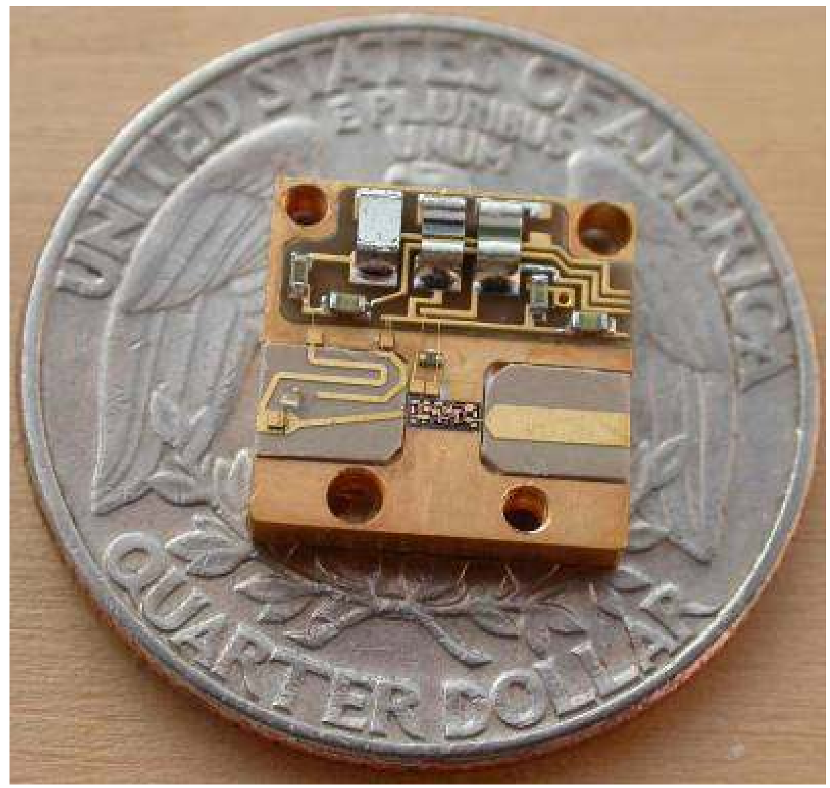
#	S/N	Type	Customer	Substrate	Housing	MMIC	Comment	Date Ordered	Delivery Target	Date Shipped	Payment
98	ABB037	0.5-11	SETI		Aluminium	CIT1 4254-065				18-Oct-05	
99	ABB043	0.5-11	SETI		Aluminium	CIT1 4254-065				18-Oct-05	
100	108D	0.5-11	Jose/JPL	6002	Aluminium	CIT1 4254-065	Loaned to JPL			25-Oct-05	
101	85D	4-12GHz	Jacobs, Cologne	6002	Aluminium	CIT1 4254-065	Karl Jacobs			9-Nov-05	
102	3L	0.5-11	RAL Berkeley	6002	Aluminium	CIT1 4254-065	Repaired unit			NOV-10-05	
103	2B	0.5-11	RAL Berkeley	6002	Aluminium	CIT1 4254-065	Repaired unit			NOV-10-05	
104	10B	0.5-11	RAL Berkeley	6002	Aluminium	CIT1 4254-065	Repaired unit			NOV-10-05	
105	78D	0.5-11	UC Santa Barbara	6002	Aluminium	CIT1-4254-068	John Martinis UCSB			NOV-15-2005	
106	40A00	11-34GHz	Hartogh, MPI	CQ	Brass	CRYO10-4292-014				NOV -29-2005	MPI/CIT Contract
107	40A00	11-34GHz	Hartogh, MPI	CQ	Brass	CRYO10-4292-014				July -24-2006	MPI/CIT Contract
108	40A00	11-34GHz	Hartogh, MPI	CQ	Brass	CRYO10-4292-014				July -24-2006	MPI/CIT Contract
109	40A00	11-34GHz	Hartogh, MPI	CQ	Brass	CRYO10-4292-014				July -24-2006	MPI/CIT Contract
110	40A02	? 11-34GHz	Stek, JPL	CQ	Brass	CRYO10-4292-014				NOV-29-2005	JPL, 102723 3.2
111	94D	4-12 GHz	Ben Mazen Caltech	6002	Brass	CIT1 4254-065	Ben Mazen(replacement for the broken 90D)			JAN 23 2006	
112	100D	0.5-11GHz	Miguel ,Berkeley	6002	Aluminum	CIT1 4254-065				MAR-02-2005	?
113	101D	0.5-11	Andreas ETH	6002	Aluminum	CIT1 4254-065	Andreas Wallraff			March-29-2006	?
114	109D	0.5-11	Andreas ETH	6002	Aluminum	CIT1 4254-065	Andreas Wallraff			March-29-2006	?
115	93D	4-12 GHz	Robert Shoelkopf	6002	Aluminum	CIT1 4254-065	Yale university			March-29-2006	Yale/CIT Contract
116	106	4-12 GHz	Robert Shoelkopf	6002	Aluminum	CIT1 4254-065	Yale university			March-29-2006	Yale/CIT Contract
117	102D	S band	Fernandez, JPL	6002	Aluminum	CIT1 4254-065		Mar-1-2006		March-10-2006	By JPL/CIT Award
119	?	S band	Fernandez, JPL	6002	Aluminum			Mar-1-2006		?	By JPL/CIT Award
120		S band	Fernandez, JPL	6002	Aluminum			Mar-1-2006			By JPL/CIT Award
121		S band	Fernandez, JPL	6002	Aluminum			Mar-1-2006			By JPL/CIT Award
122		S band	Fernandez, JPL	6002	Aluminum			Mar-1-2006			By JPL/CIT Award
123	98D	4-12 GHz	Peter Day ,JPL	6002	Aluminum	CIT1 4254-065	JPL	Mar-1-2006		April-14-2006	JPL Account
124	91D	4-12 GHz	Peter Day ,JPL	6002	Aluminum	CIT1 4254-065	JPL	Mar-1-2006		April-14-2006	JPL Account
125	99D	0.5-11	Shoelkopf, Yale	6002	Aluminum	CIT1 4254-065	Yale university			March-29-2006	Yale/CIT Contract
126	95D	0.5-11	Shoelkopf, Yale	6002	Aluminum	CIT1 4254-065	Yale university			March-29-2006	Yale/CIT Contract
127	40A07	6-18GHz	Shoelkopf, Yale	Quartz	Aluminum	CRYO10-4292-014	Yale university			MAY 02 2006	Yale/CIT Contract
128	40A24	6-18GHz	Shoelkopf, Yale	Quartz	Aluminum	CRYO10-4292-014	Yale university			MAY 02 2006	Yale/CIT Contract
129	122	0.5-11	Pertti, Helsinki	6002	Aluminum					10-Jul-06	Barter
130	124	0.5-11	Pertti, Helsinki	6002	Aluminum					10-Jul-06	Barter
131		6-18 GHz	Steck, JPL					June, 2006	Sep, 2006		JPL, 102723 3.2
132		6-18 GHz	Steck, JPL					June, 2006	Sep, 2006		JPL, 102723 3.2
133		4-12 GHz	Yasunobu, NEC					28-Jun-06			Barter

Caltech 4-12 GHz LNA's for Integration with 345 GHz SIS Mixers

LNA with cover on



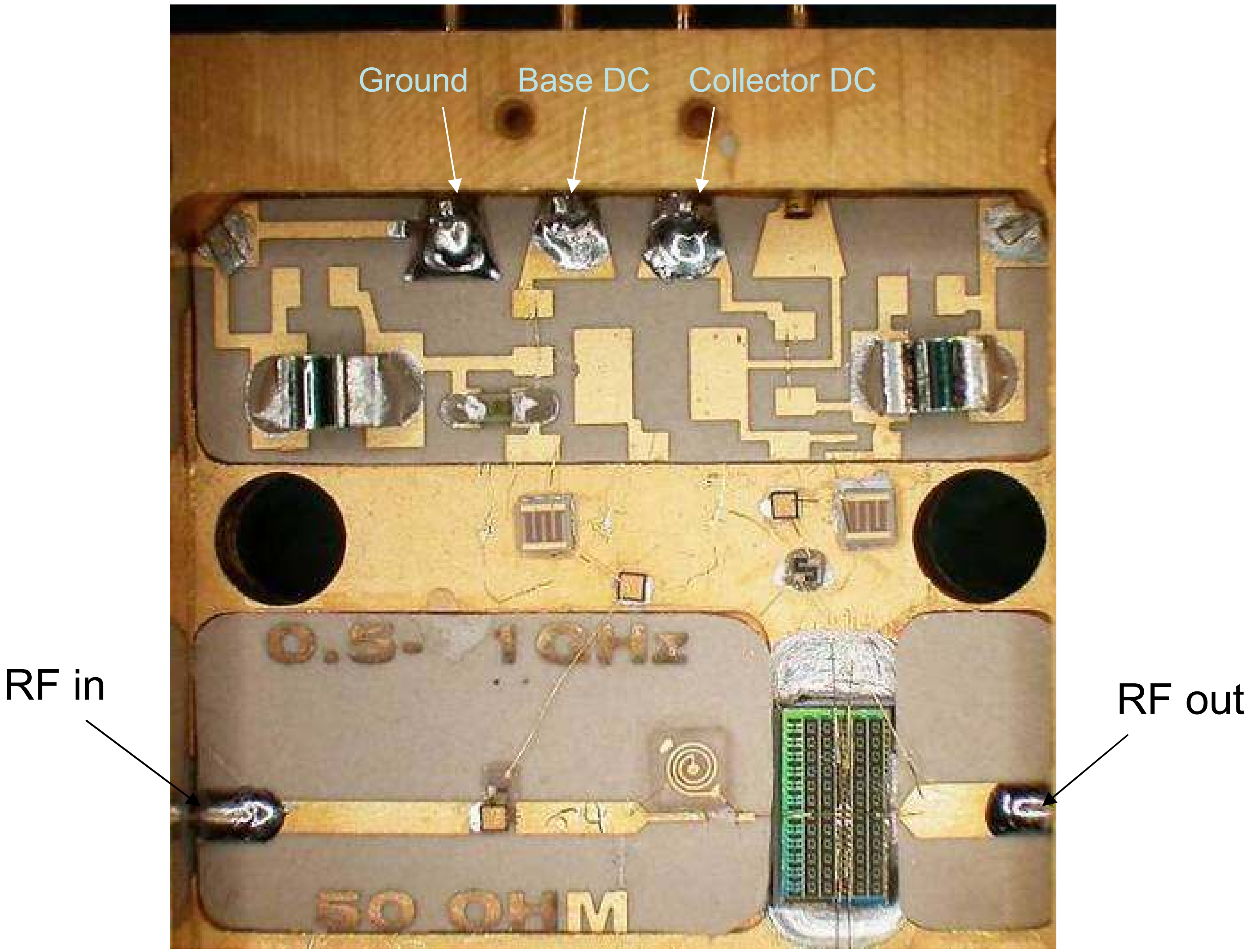
Input circuit including SIS bias, MMIC LNA chip, output line, and, at top, bias filter network



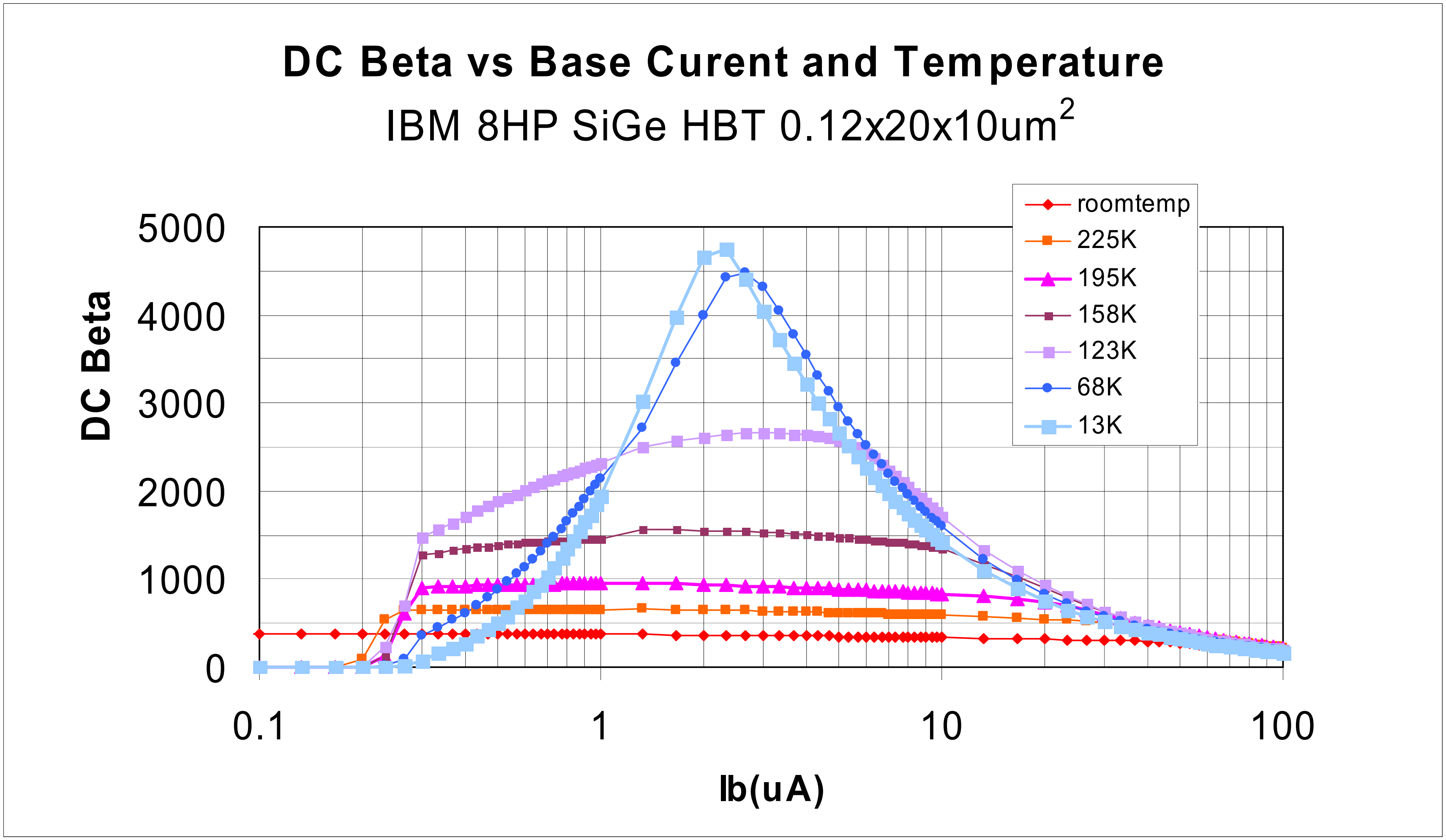
Very Low Noise Amplifier Development Status - 2006

- Indium-phosphide (InP) high-electron-mobility transistors (HEMTs) have been implemented in almost all low-noise amplifiers in radio astronomy for the past 10 years with little change in performance.
- As a function of frequency at 15K InP HEMT LNA’s have 2K noise at 1.4 GHz, 5K at 5 GHz, and 30K at 100 GHz. As a function of temperature at 5 GHz noise is 30K at 300K, 10K at 77K, and 5K at 15K.
- The cost of the large number of receivers required by arrays could be greatly reduced if LNA’S with sufficiently low noise could be realized at room temperature. Transistor device improvements may enable this. A current goal is < 10K of noise (0.14 dB NF) at 1.4 GHz.
- Decade bandwidth feeds have outputs balanced with respect to ground and this can be accommodated with differential input LNA’s, termed “Active Baluns or ABLNA’s) which have been developed at Caltech.
- A promising new transistor, the SiGe HBT, is being rapidly developed for high speed computer and communication applications and may replace the InP HEMT in radio astronomy in the next several years. .

HBT Noise Test Module
With Ga Tech Supplied SiGe Transistor



Effect of Cooling on SiGe HBT Current Gain



Decade Bandwidth Antenna Feeds

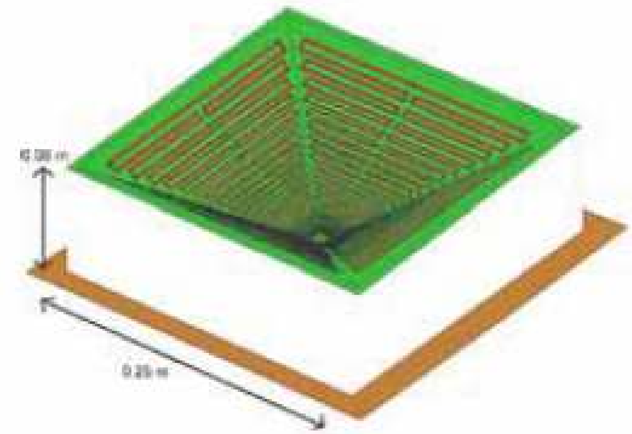
- Current antenna feeds and receivers used in radio astronomy are << octave bandwidth
- Many science questions can be much more efficiently performed with decade bandwidth feeds.
- The cost of large arrays to cover a wide frequency range is greatly reduced if the number of receivers per antenna is reduced.
- The key issues with decade bandwidth feeds are beamwidth variation, impedance match, and loss.

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.

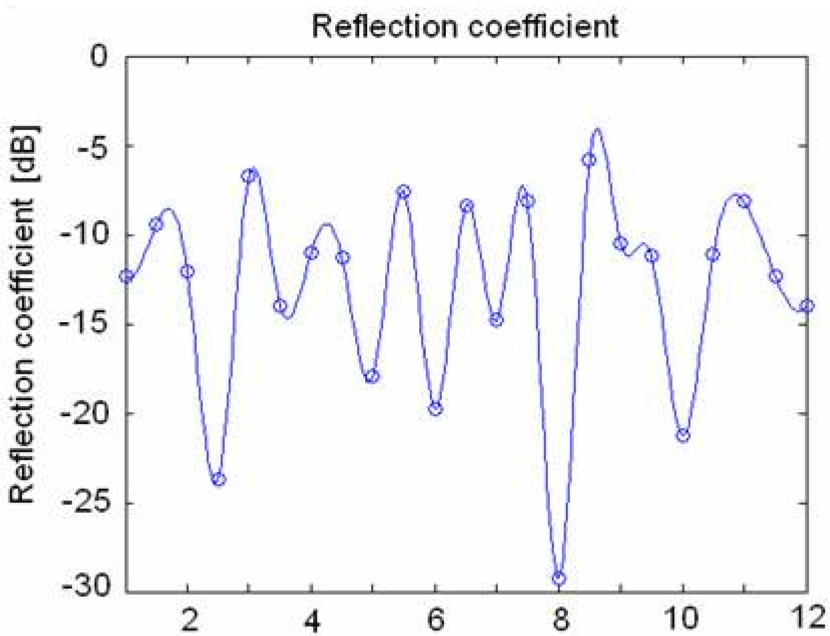
Chalmers 1.2 to 11 GHz Feed

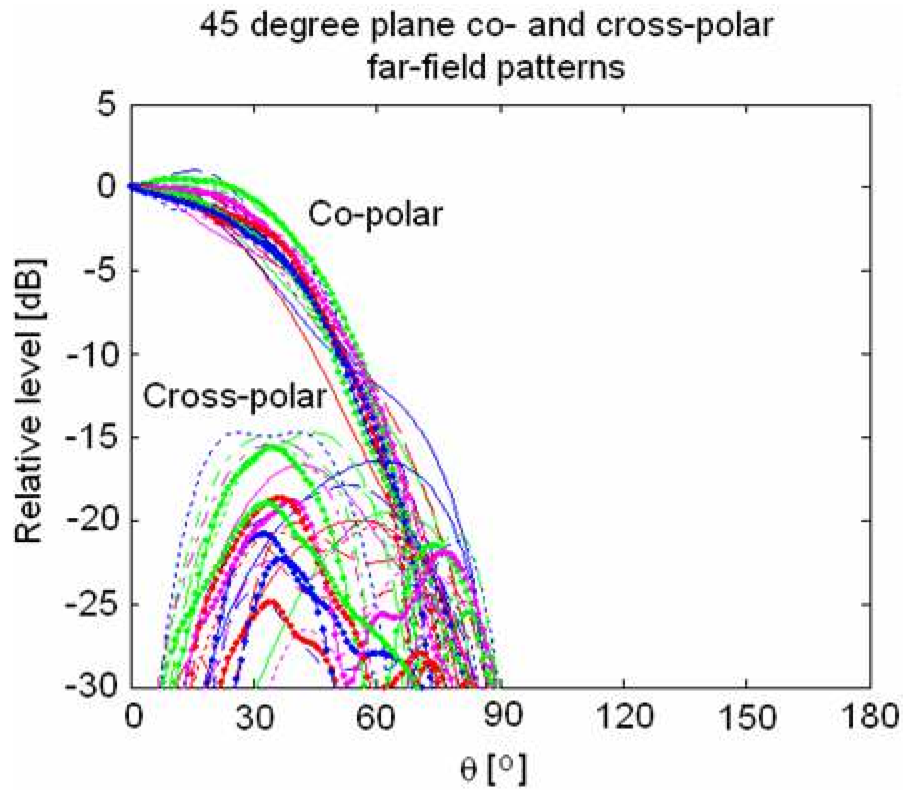
Feed is under tests at Chalmers and can be integrated with a cryogenic active balun and tested on an ATA antenna in early phases of the TDP.

Chalmers Feed Study Computed Results

- Calculated pattern gives 57% prime focus efficiency, 3K spillover, and 0.3K mesh leakage in 12/16m symmetric antenna from 0.5 to 1.5 GHz

- Gain is 10.5 +/- 0.5 dB and reflection coefficient better than 6 dB over 1:12 frequency range. Provides 65% efficiency at half-angles of 42^{O} to 55^{O}





ETS·LINDGREN™
An ESCO Technologies Company

Antennas

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3164-05

- Electrical Specifications
- Physical Specifications
- Performance Charts

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

- 3164-05 Quadridge Horn PDF DATASHEET
- 3164-05 PDF MANUAL
- Antenna Patterns
- Calibration Services
- Accessories
- Antenna RFQ
- 1. Antenna Catalog - BiConilogs (p4 - 9) PDF
- 2. Antenna Catalog -

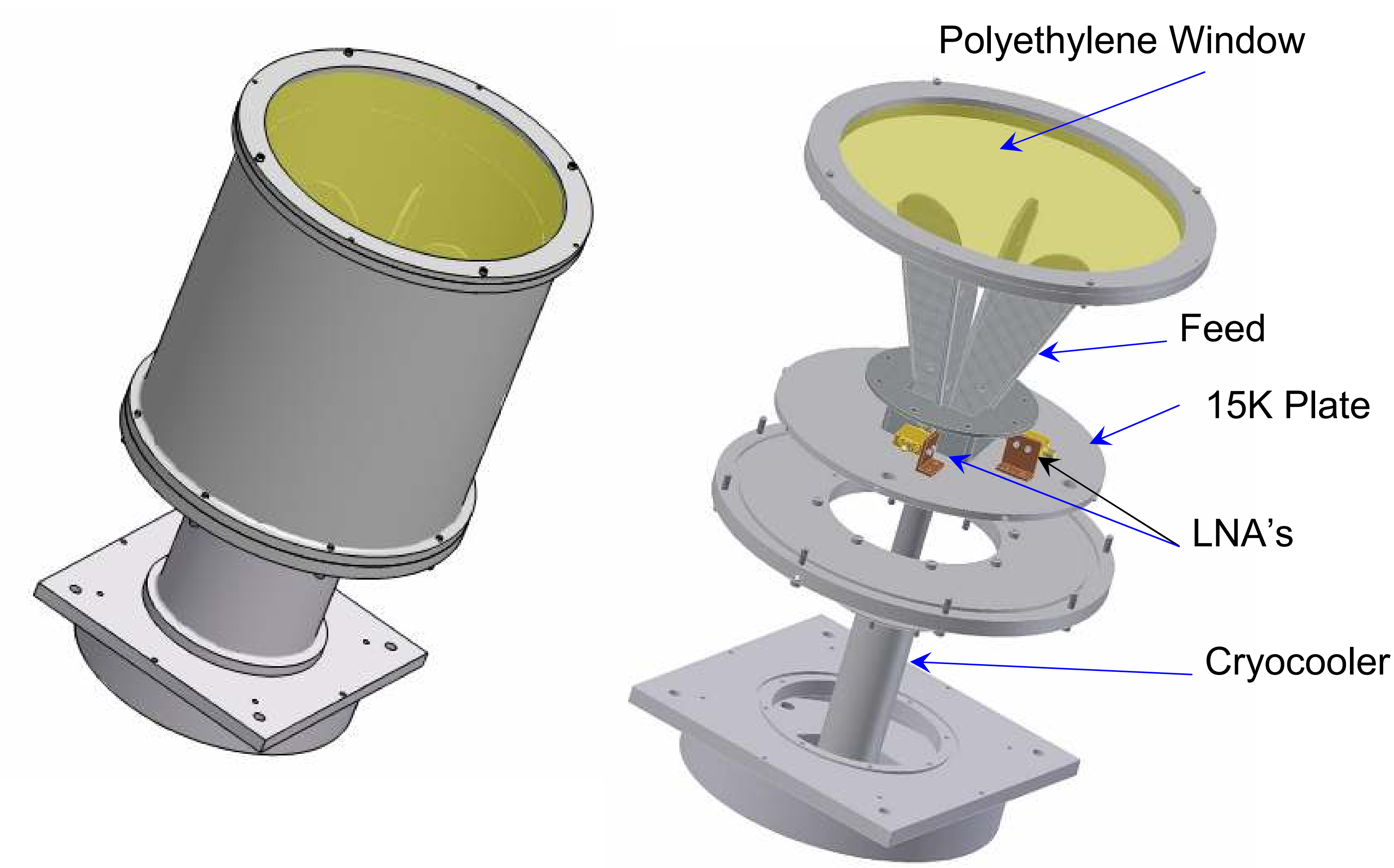
The Model 3164-05 Open Boundary Quadridge Horn is the newest in a series of quadridge horns from ETS-Lindgren. The "open boundary" design with its absence of side plates makes this antenna unique in both appearance and performance.

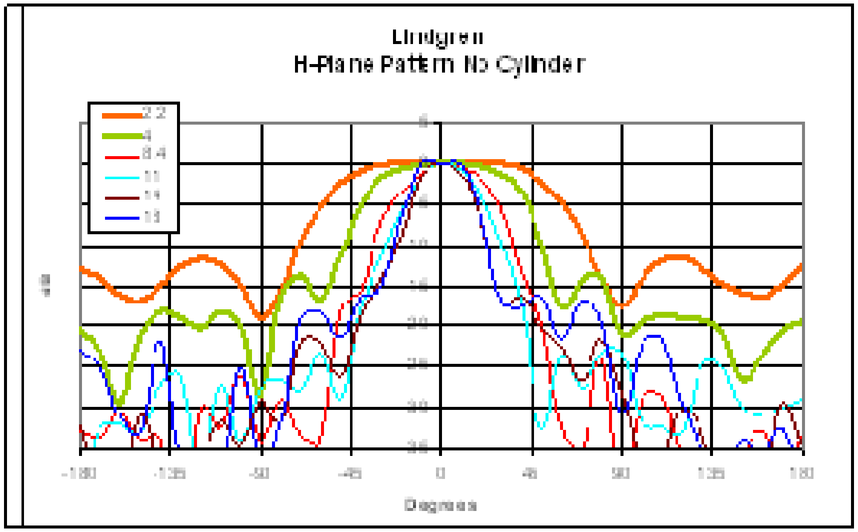
Numerically modeled, the Model 3164 s open boundary design is similar to two Vivaldi PCB antennas placed orthogonally to each other. The antenna s surprisingly compact size offers improved pattern and gain when compared with enclosed quadridge horns of similar dimensions. The compact size also means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

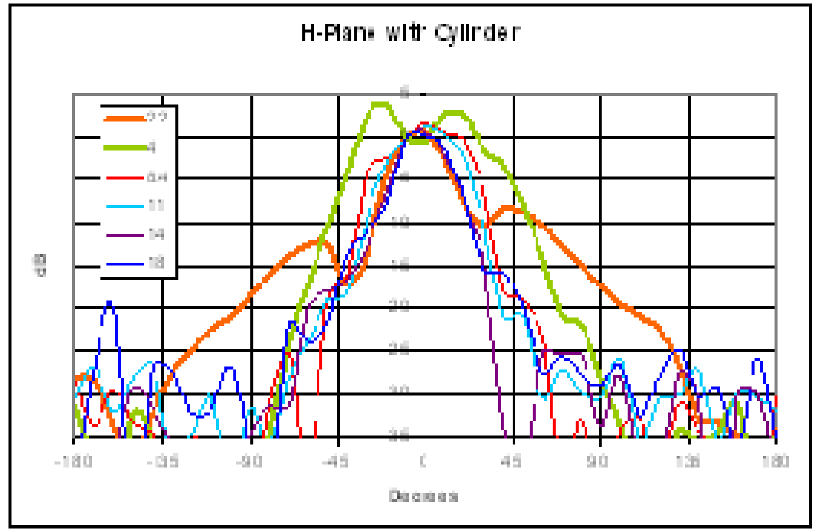
The Model 3164-05 has exceptional bandwidth. While the frequency band for optimum performance is 2 GHz to 18 GHz, the antenna is usable from 1.5 GHz. Two orthogonally placed input feeds allow this antenna to generate both linear and circular polarized measurements across the entire frequency band.

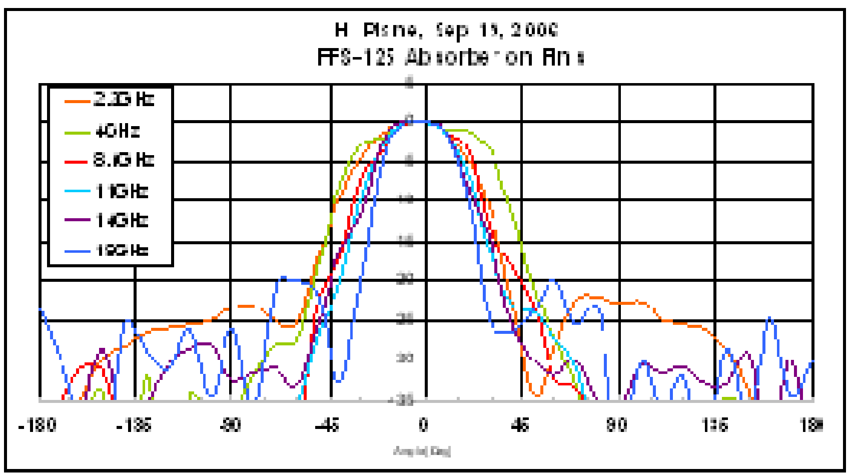
Reference: V. Rodriguez, “A Multi-Octave Open-Boundary Quad-Ridge Horn Antenna for Use in the S- to Ku-Bands”, Microwave Journal, March, 2006. pp.84-92

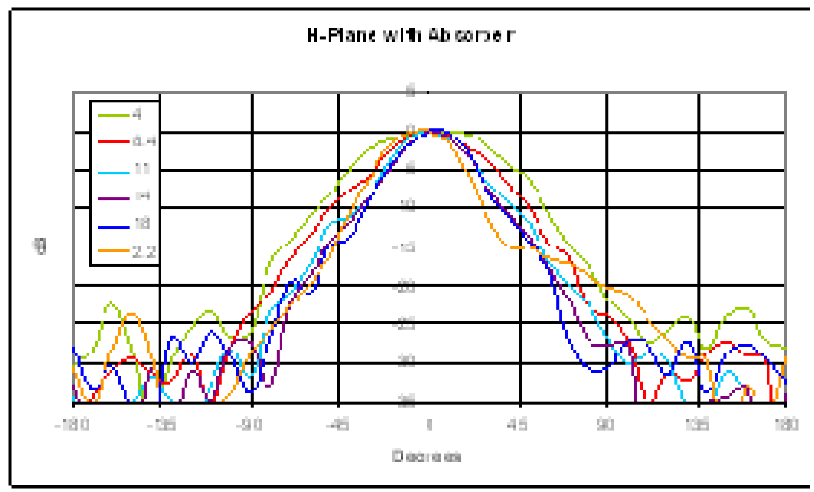
Cryogenic Dewar Design for Lindgren Antenna

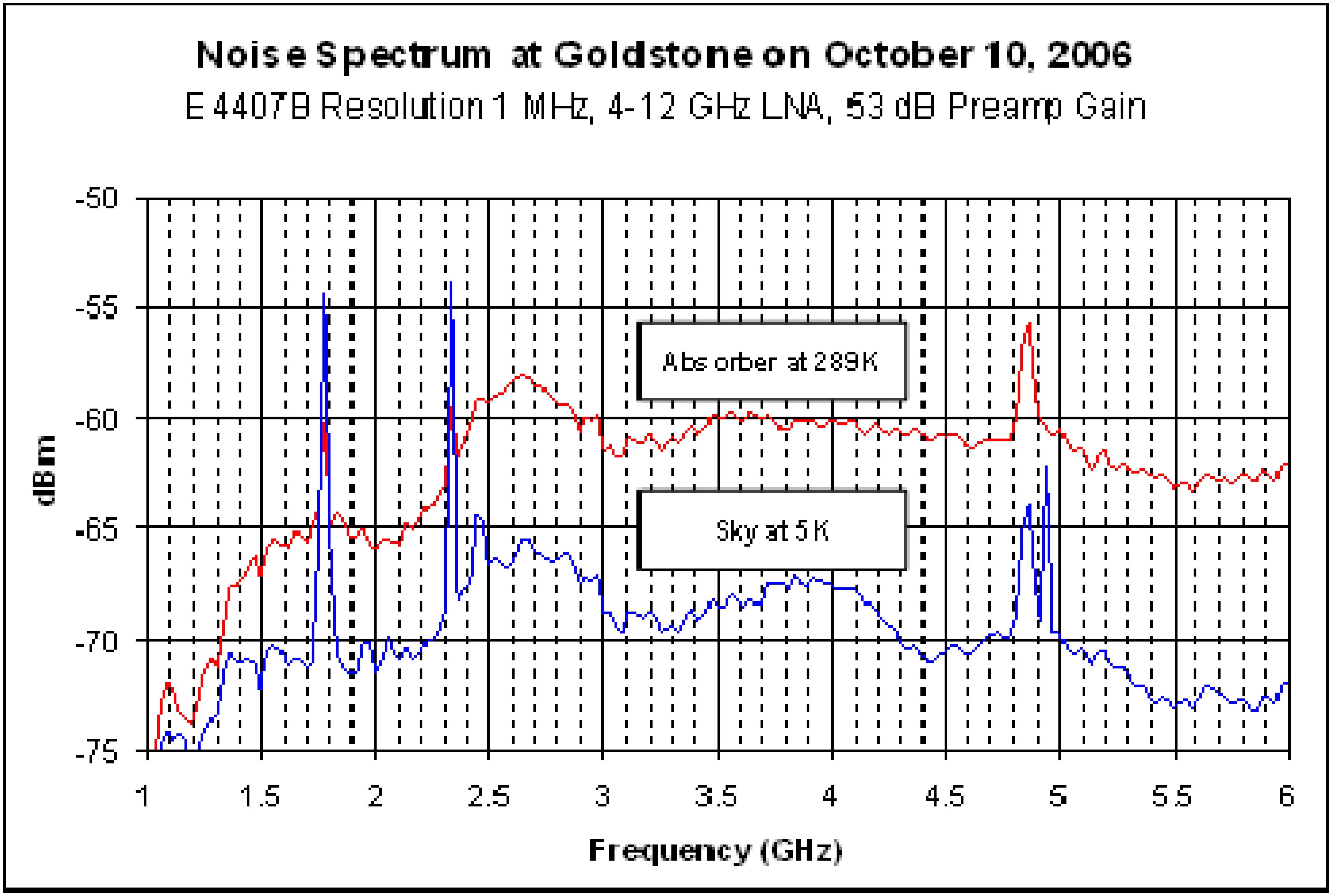



Lindgren
H-Plane Pattern No Cylinder
2.2
4
8.4
11
14
18
dB
-180
-135
-90
-45
0
45
90
135
180
Degrees

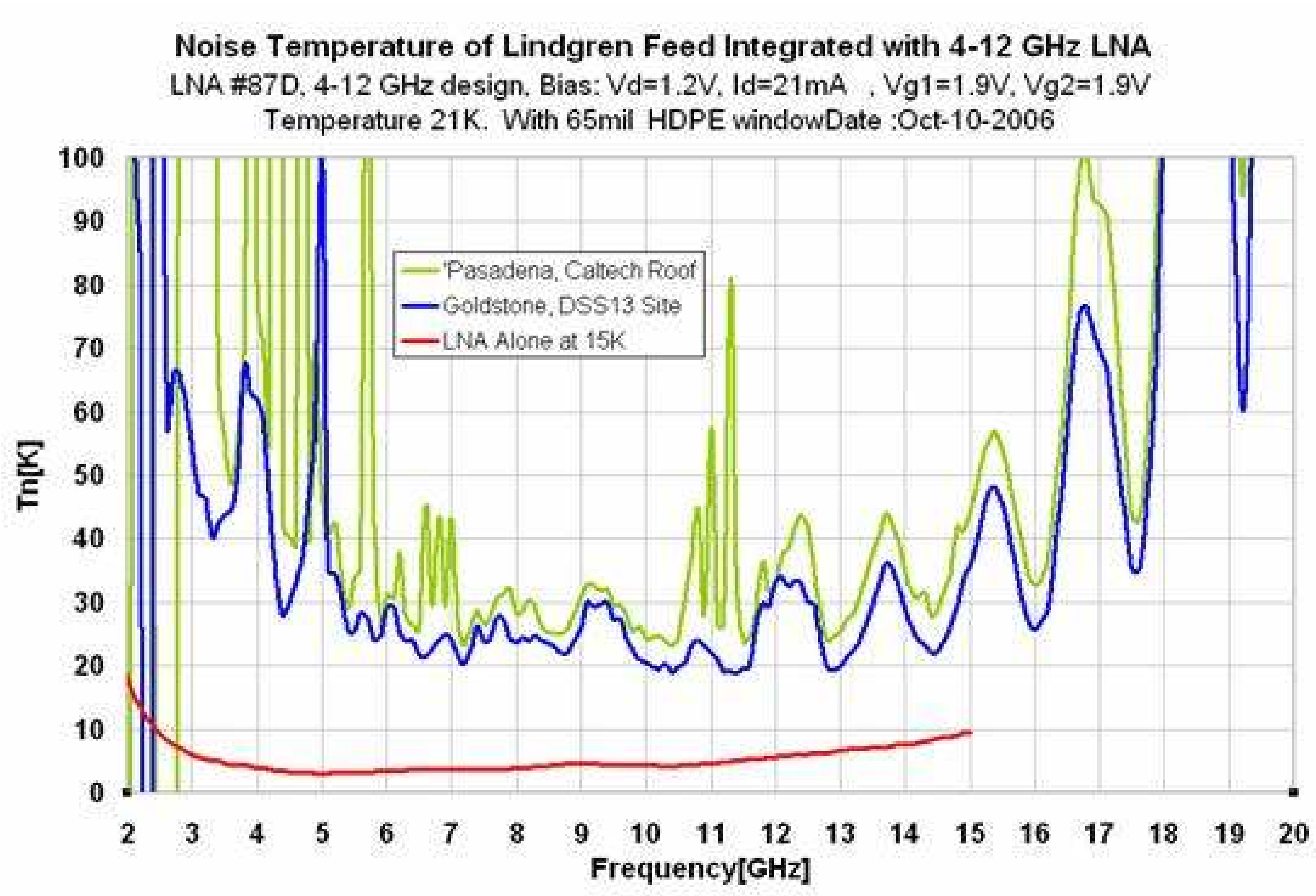

H-Plane with Cylinder
2.2
4
8.4
11
14
18
dB
-180
-135
-90
-45
0
45
90
135
180
Degrees


H Plane
FFS-125 Absorber on Fins
2.2GHz
4GHz
8.4GHz
11GHz
14GHz
18GHz
-180
-135
-90
-45
0
45
90
135
180


H-Plane with Absorber
4
8.4
11
14
18
2.2
dB
-180
-135
-90
-45
0
45
90
135
180
Degrees



Noise Spectrum at Goldstone on October 10, 2006
E4407B Resolution 1 MHz, 4-12 GHz LNA, 53 dB Preamp Gain
-50
-55
-60
-65
-70
-75
dBm
Absorber at 289K
Sky at 5 K
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
Frequency (GHz)



Noise Temperature of Lindgren Feed Integrated with 4-12 GHz LNA
LNA #87D, 4-12 GHz design, Bias: Vd=1.2V, Id=21mA , Vg1=1.9V, Vg2=1.9V
Temperature 21K. With 65mil HDPE windowDate :Oct-10-2006
'Pasadena, Caltech Roof
Goldstone, DSS13 Site
LNA Alone at 15K
Tn[K]
0
10
20
30
40
50
60
70
80
90
100
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Frequency[GHz]

Supercam 64-Pixel 345 GHz Camera

U. of Arizona Heinrich Hertz
10.4m Radio Telescope

- Multi-University, NSF Sponsored Project led by Chris Walker, U. of Arizona
- System design, optics, integration and micro-machining at UAZ
- Superconducting SIS junctions by UVA
- Mixer design by UMass and others
- Caltech Tasks
  1) **Develop a packaging technique to accommodate 64 cryogenic MMIC low noise 4-12 GHz amplifiers integrated in a vacuum dewar with SIS mixers**
  2) **Fabricate, test, and deliver a 64 LNA's**
  3) **Support the integration and test of the low noise amplifiers in the radio astronomy system.**
  4) **Design, fabricate, and deliver 64 IF converters**

Supercam – Optics and Focal Plane Configuration