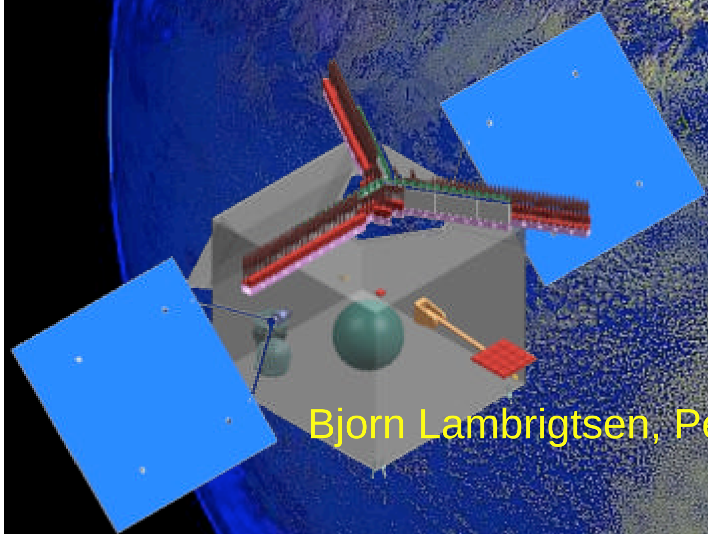
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR-II

technology development and risk reduction for PATH



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Jet Propulsion Laboratory – California Institute of Technology

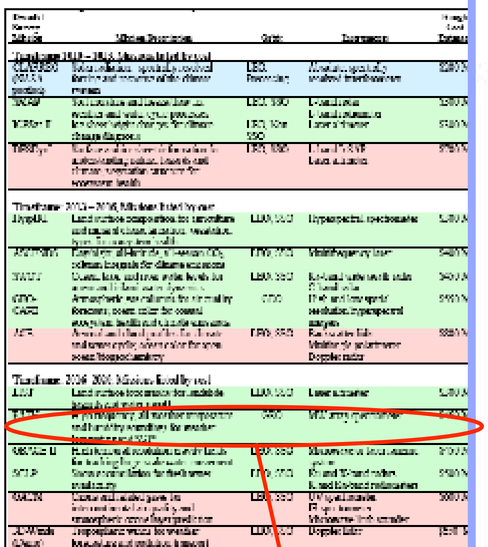
University of Michigan

June 24, 2010- ESTF2010

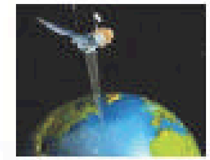
Outline

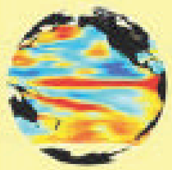
- PATH Requirements Overview
- GeoSTAR: Synthetic Thinned Aperture Radiometry Demonstration
- GeoSTAR-II : Technology risk reduction for PATH mission

NRC Decadal Survey PATH Mission

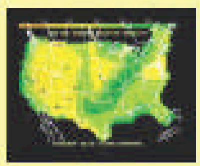


Precipitation and All-weather Temperature and Humidity (PATH)
Launch: 2016-2020
Mission Size: Medium



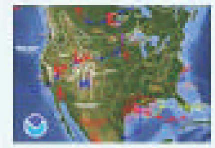


Sea surface temperature



Temperature and humidity profiles

Constraints on models for boundary layer, cloud, and precipitation processes



More accurate, longer-term weather forecasts

Improved storm track and intensification prediction and evacuation planning

Determination of geographic distribution and magnitude of storm surge and rain accumulation

PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer = GeoSTAR	$450 M

PATH Requirements Flow

Requirements

Functional
T(z), q(z), L(z), TPW, LWC
SST, Precip (all weather)

Temporal
15 min updates

Spatial
50km/25 km

Mission Characteristics

50-183 GHz Bands
<0.3 K Retrievals

Geostationary orbit

Large Eff Aperture

Mission Cost
Mass < 300 kg
Power<300 W
No moving parts

Measurement Approach

Interferometer Approach

Technology Needs

Low Noise mm Devices

Low Power Correlators

Low Power Digitizers

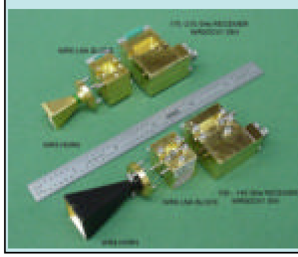
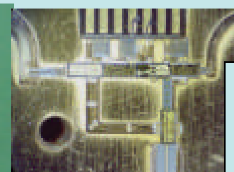
Low Mass Receivers

Integrated system Demos

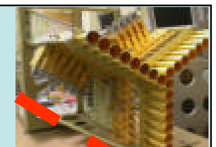
Builds on ESTO's Investments

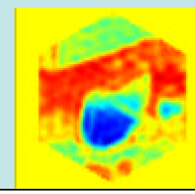
All required component technology is now at TRL 5-6
System TRL is near 6

IIP98- MATHS
Key demonstrations:
- 90-140 GHz receiver modules
- 160-190 GHz receiver modules (TRL 5)

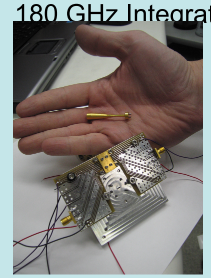
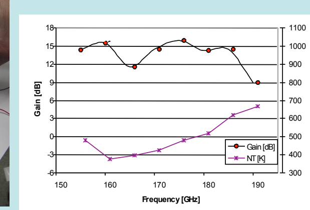



IIP03- GeoSTAR
Key demonstrations:
- 60 GHz modules
- FPGA based correlator
- Integrated STAR Array
- Imaging/sounding capability (TRL 6)





ACT06- MIMRAM
Key demonstrations:
- 180 GHz Noise (TRL 6)
- 180 GHz Integrated receiver (FY08-TRL 6)

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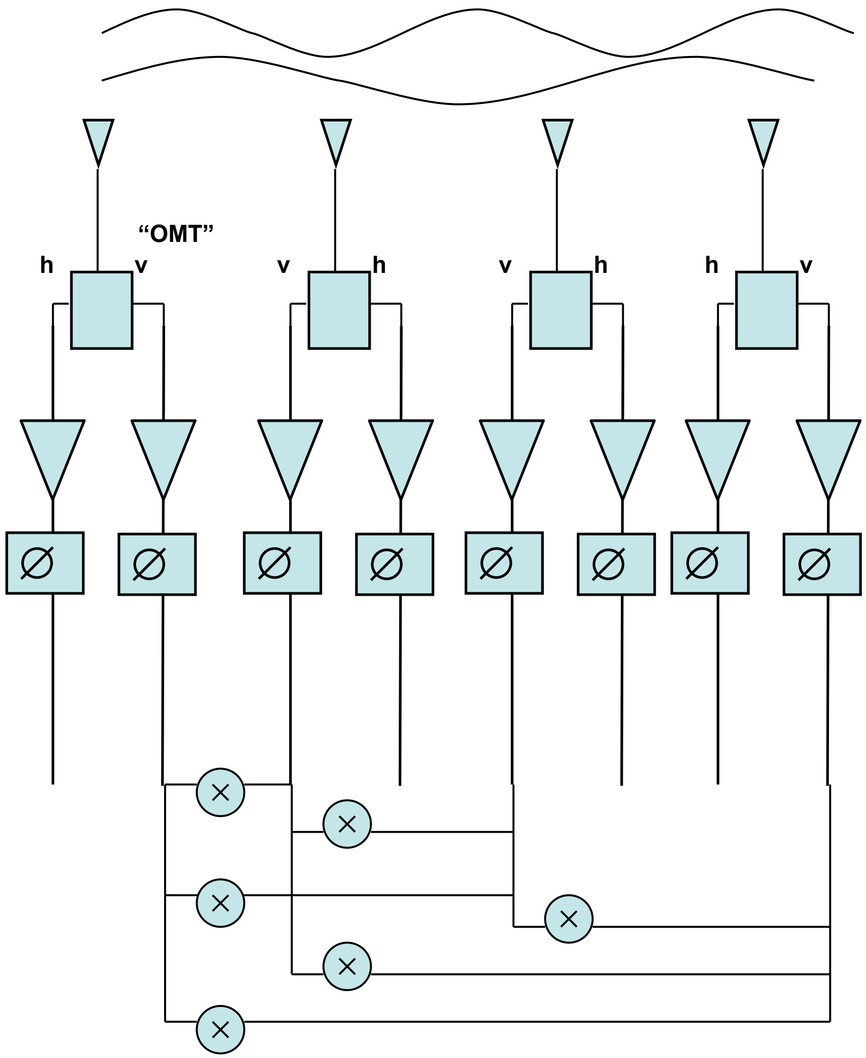
Interferometric Array Receivers



Synthetic Aperture Interferometer: SMOS, GeoSTAR

Synthesizes images by correlating signals in the Fourier domain. All viewed pixels are simultaneously mapped. ***No moving parts.***

$$\Delta T(r,s) \cong \left(\frac{\Omega\sqrt{1-r^2-s^2}}{A_u \left| f(r,s) \right|^2} \right) \frac{\pi}{2} \frac{T_S}{\sqrt{2\beta\tau}} 2n$$

(No redundancy)

Example: T_{sys}=1000K, [illegible]=200 MHz, n=300, N=90000 then [illegible]T= 47K-s$^{1/2}$.

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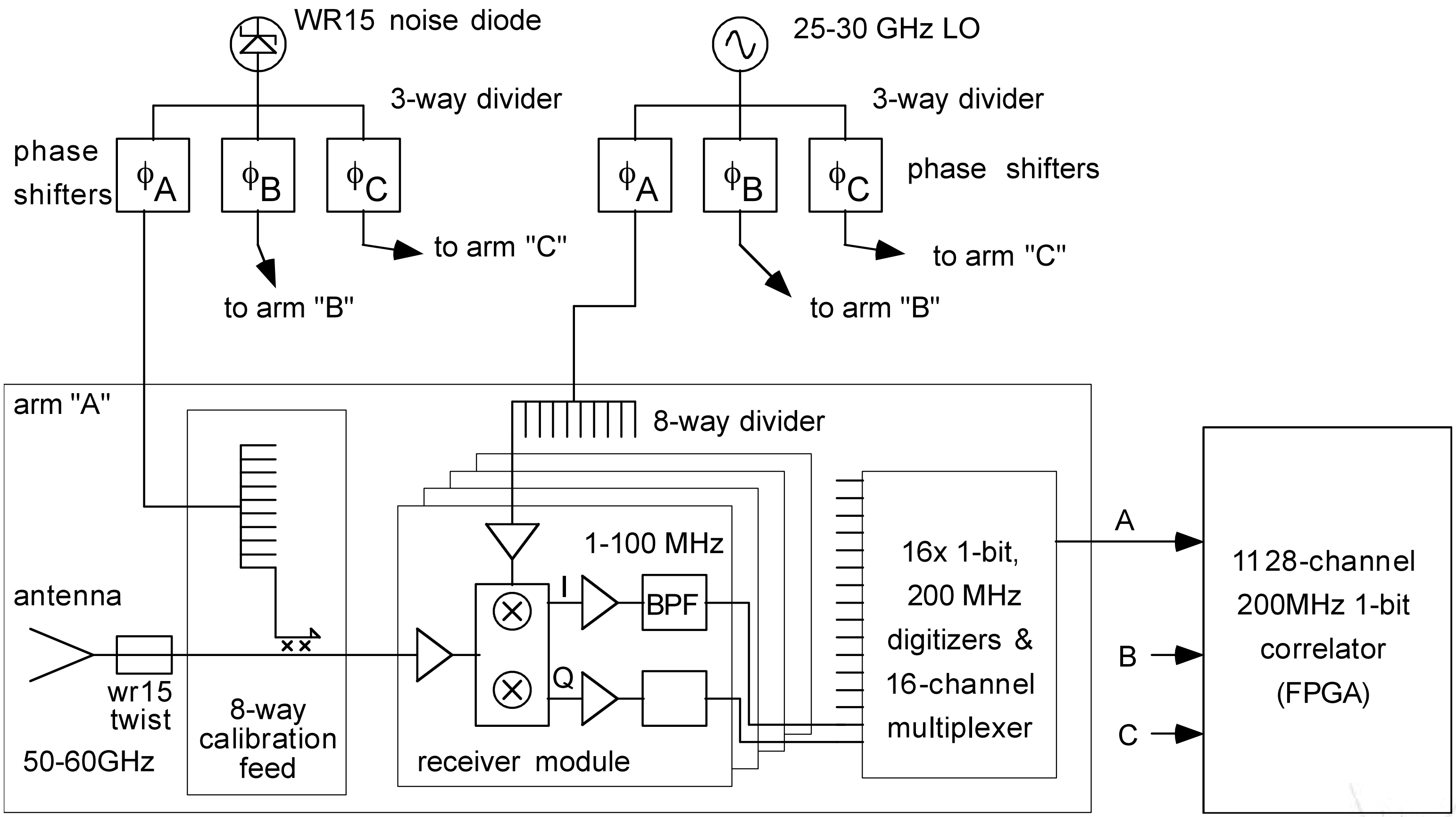
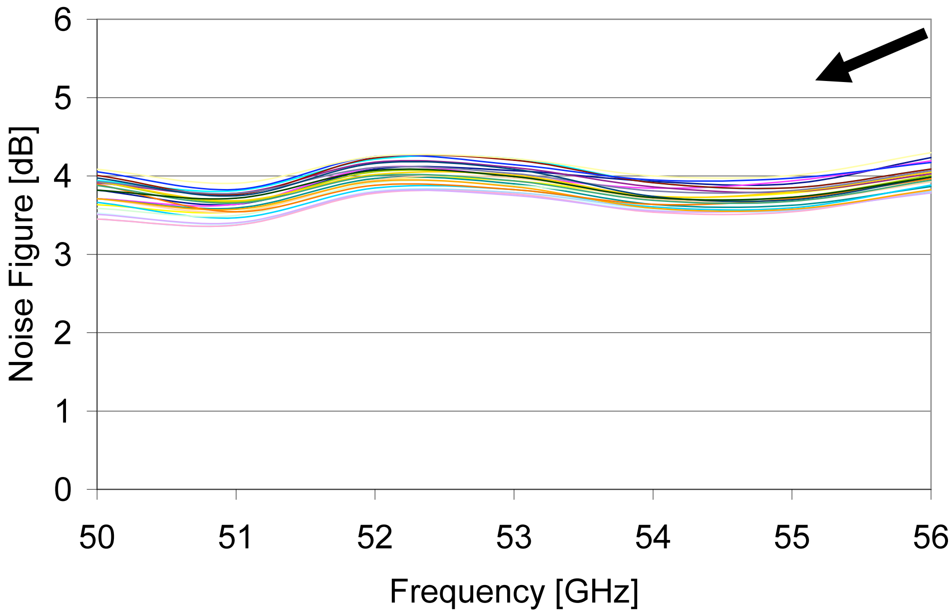
GeoSTAR Demonstrator Array

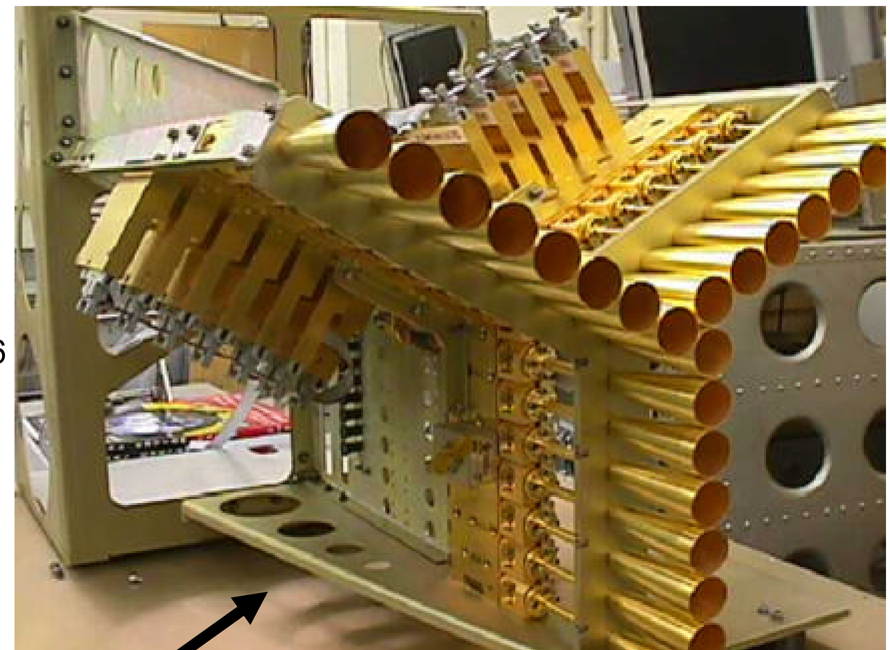
Demonstration prototype of a geostationary temperature and humidity sounder



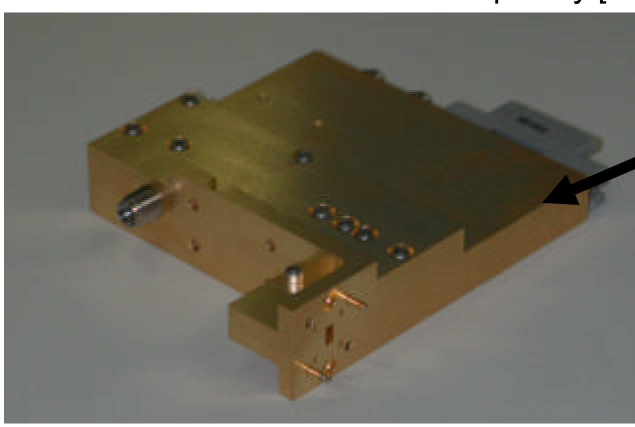
24-Element Array Production



Receiver noise of 24 modules



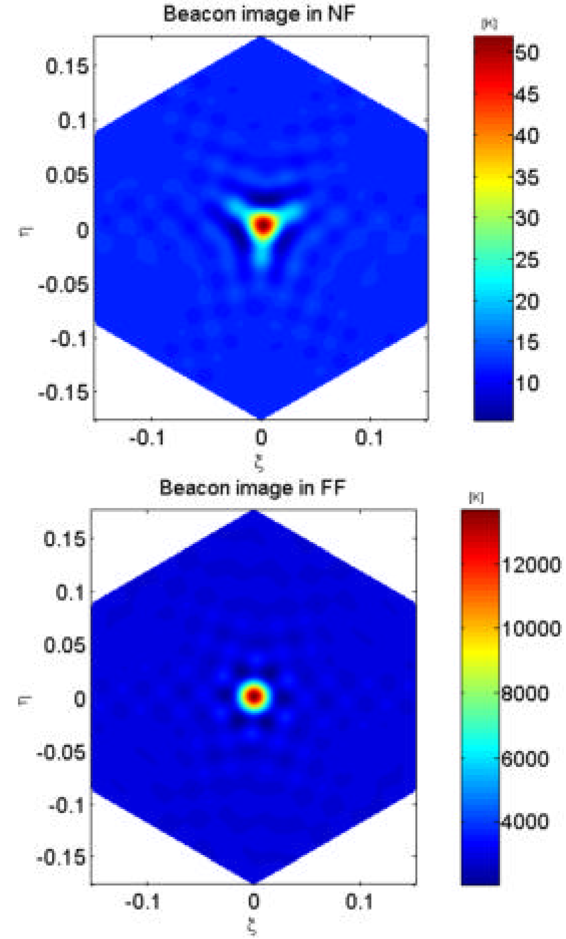
Integrated Array



Integrated module

Near Field measurement set-up

NF to FF transformation



$$\hat{V}_{kj}^{FF} = V_{kj}^{NF} e^{-j k_0 (r_k - r_j)} e^{-j 2\pi (u\xi + v\eta)}$$

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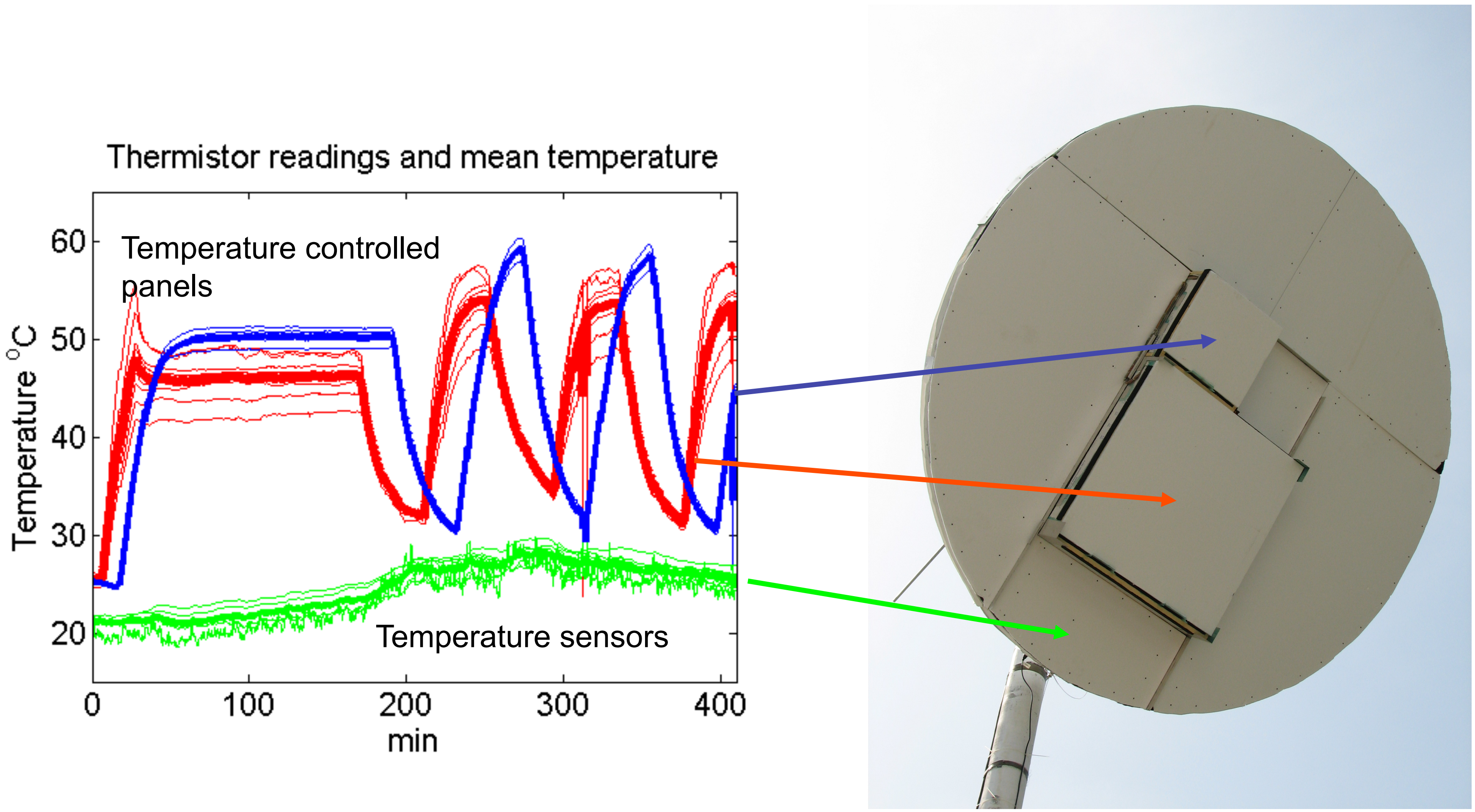
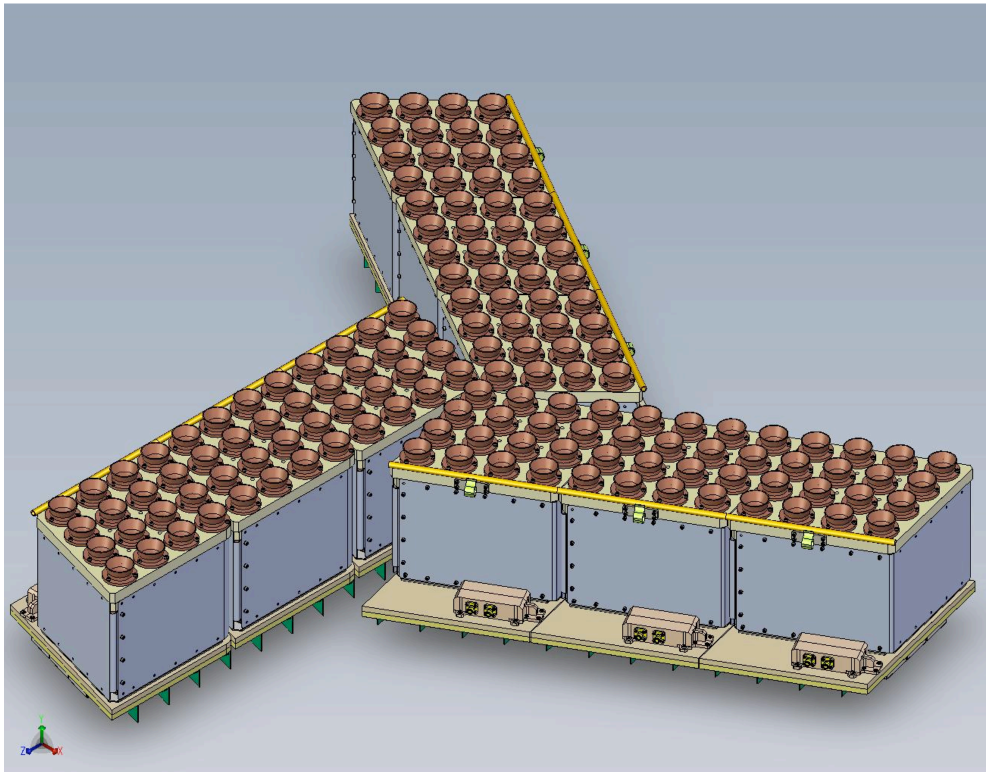
4m Calibrator



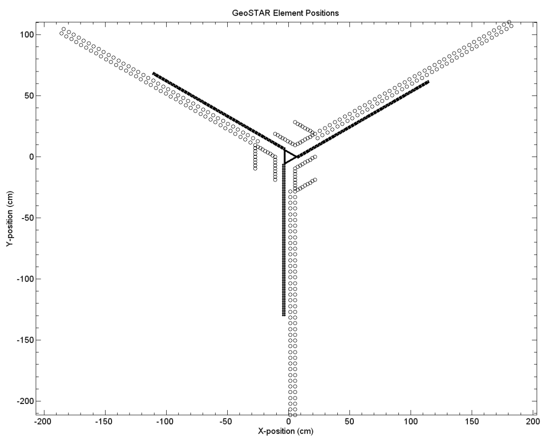
GeoSTAR-II Objectives

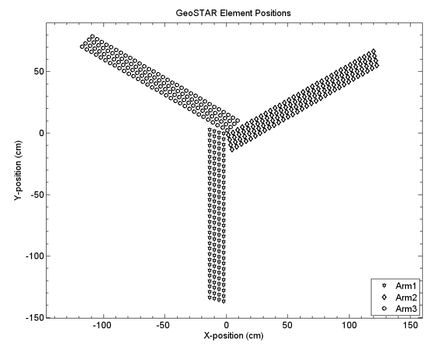


- Develop 50 low-noise 183-GHz receivers
- Develop 3 2x8-element receiver sub-array modules
- Develop low-power Application-Specific Integrated Circuit (ASIC) correlator chips
- Develop low-mass/power signal distribution system
- Perform functional 183-GHz subsystem tests (not full imaging)

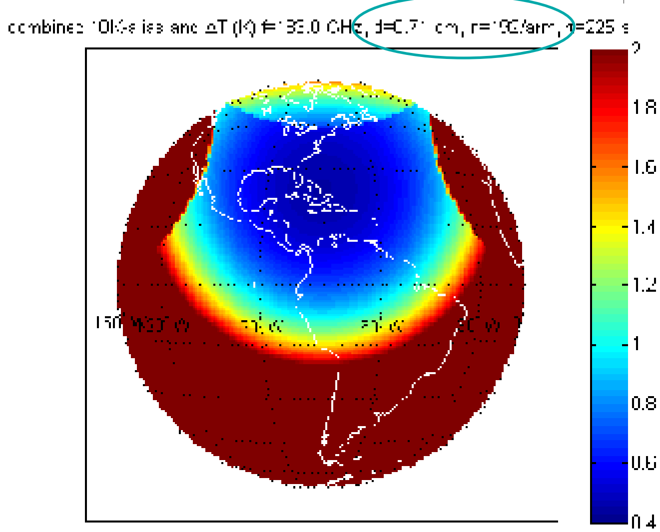
Design Refinement

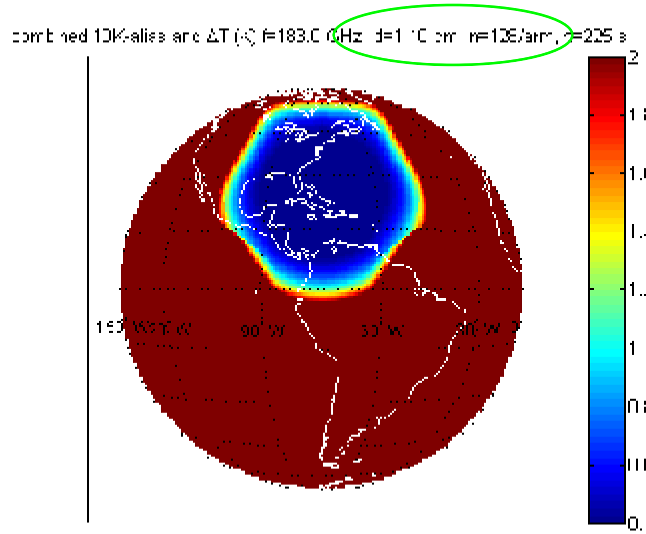
Science driven requirement of 0.3 K NEDT forced a reexamination system design



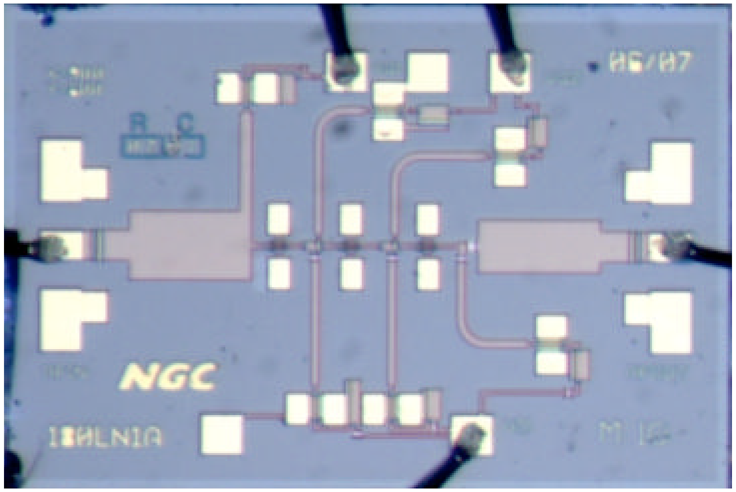


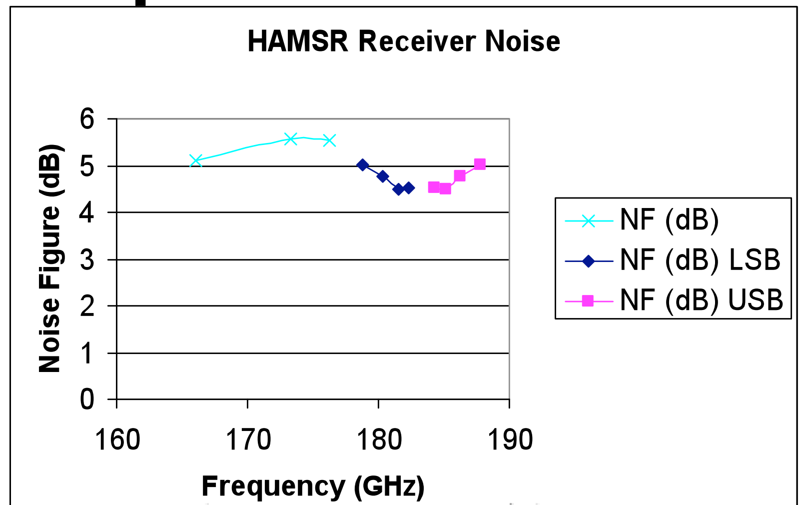
4-row design improves sensitivity in critical field, decreases number of receivers, eases array density

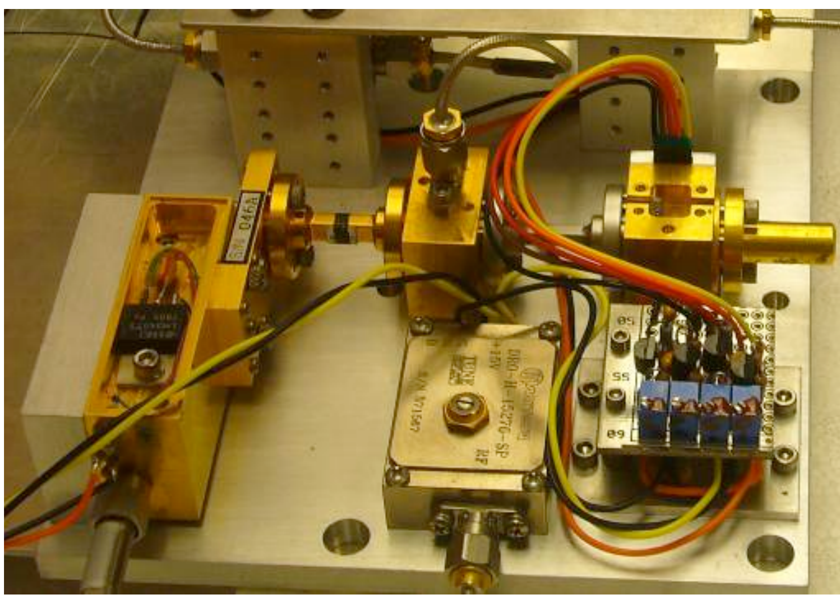


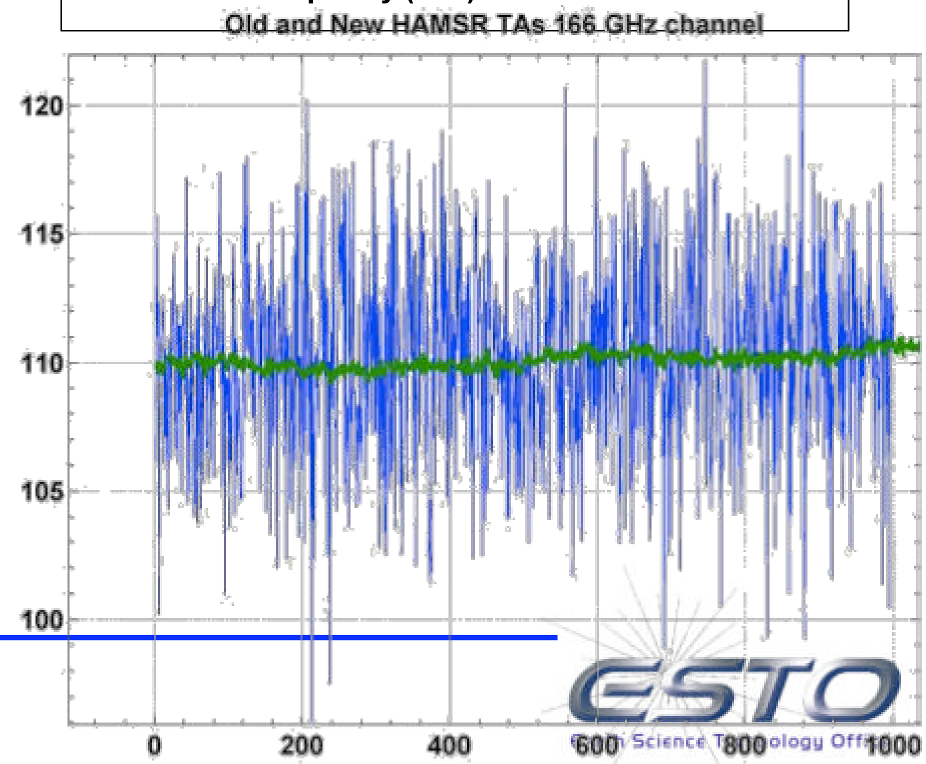


Low Noise Amplifiers



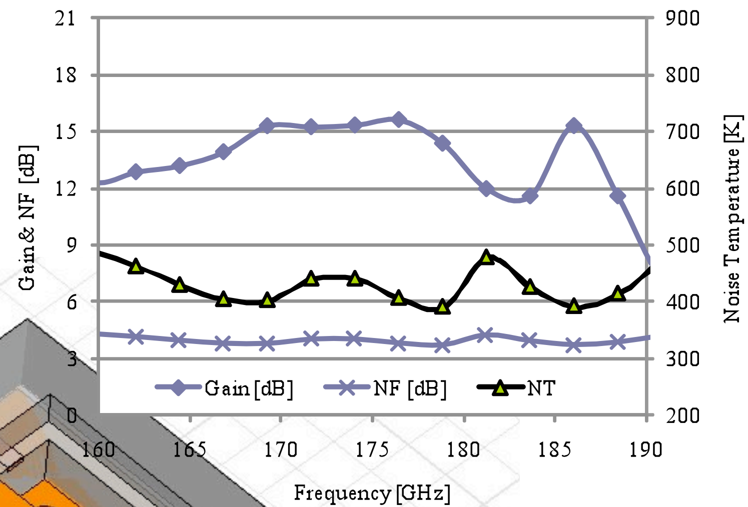


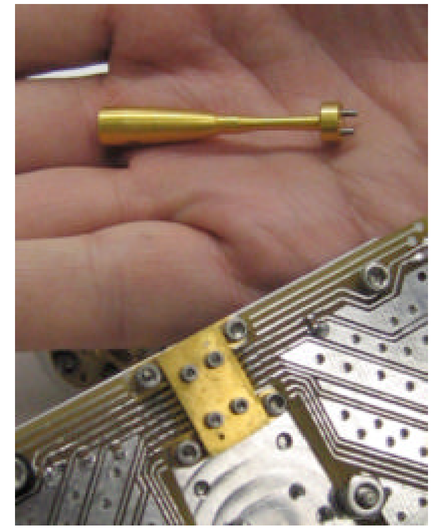


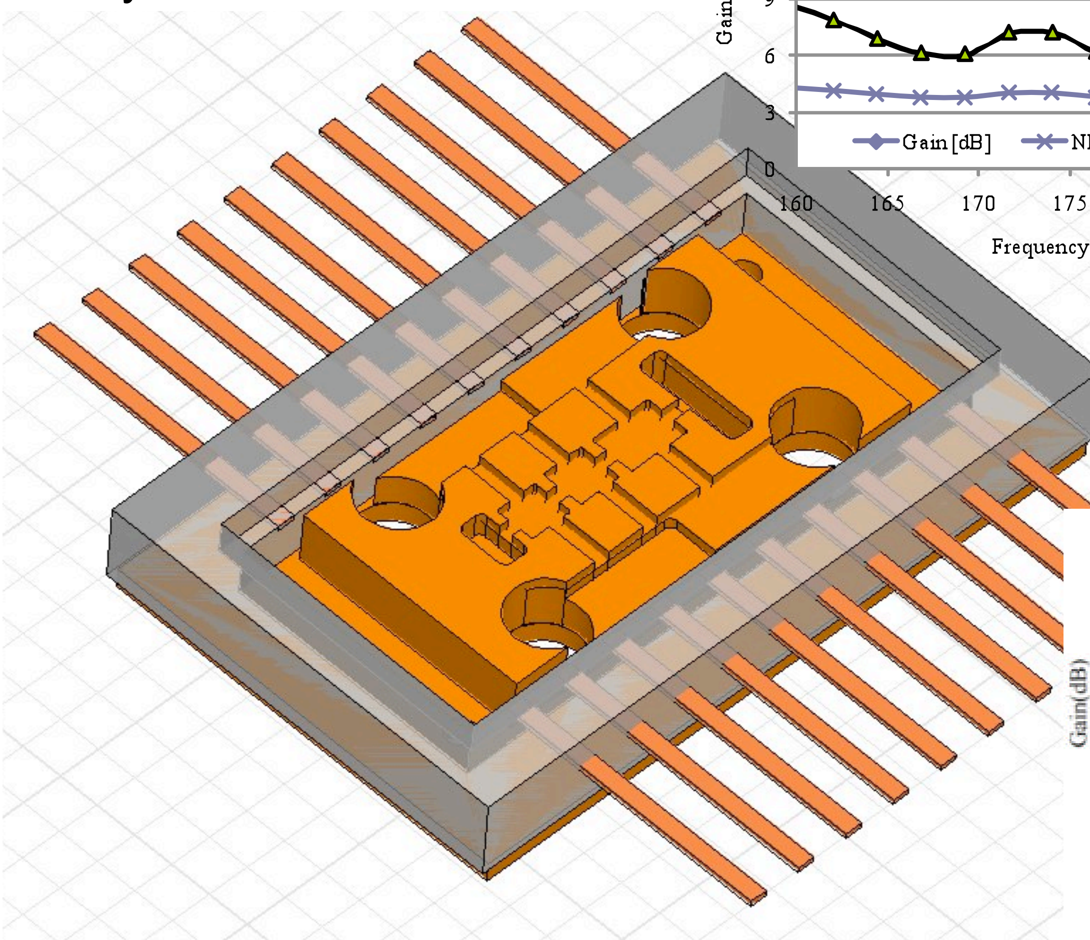


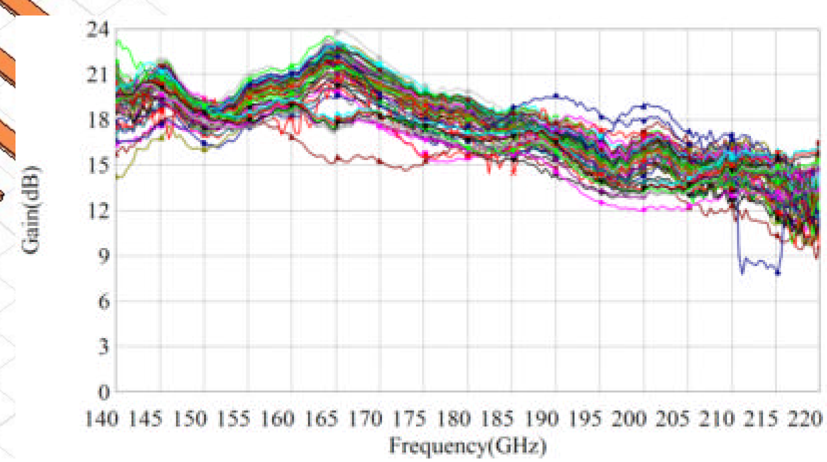
Receiver Board Design

- Conversion gain 10 dB
- Power consumption <60mW
- Mass <3g
- Physical size .375”x.3”x.2”





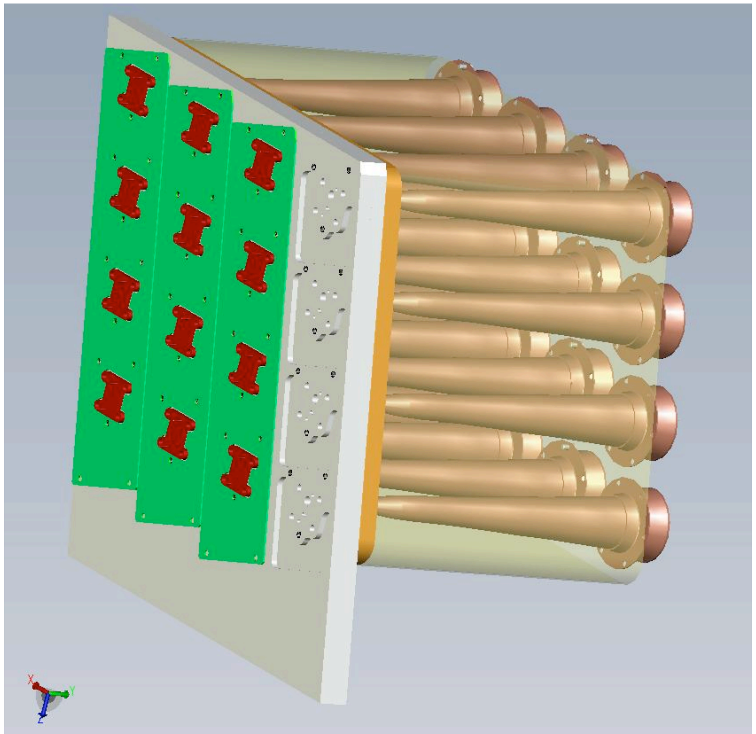


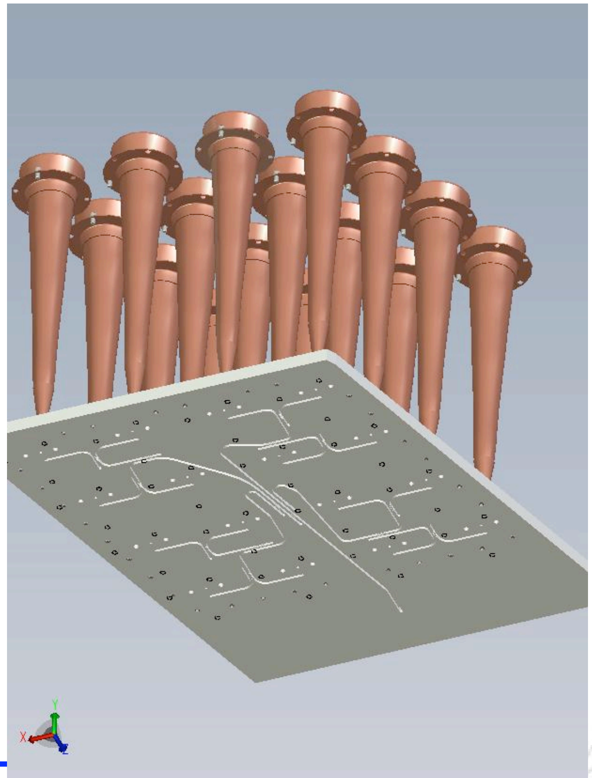


Sub-Array Module

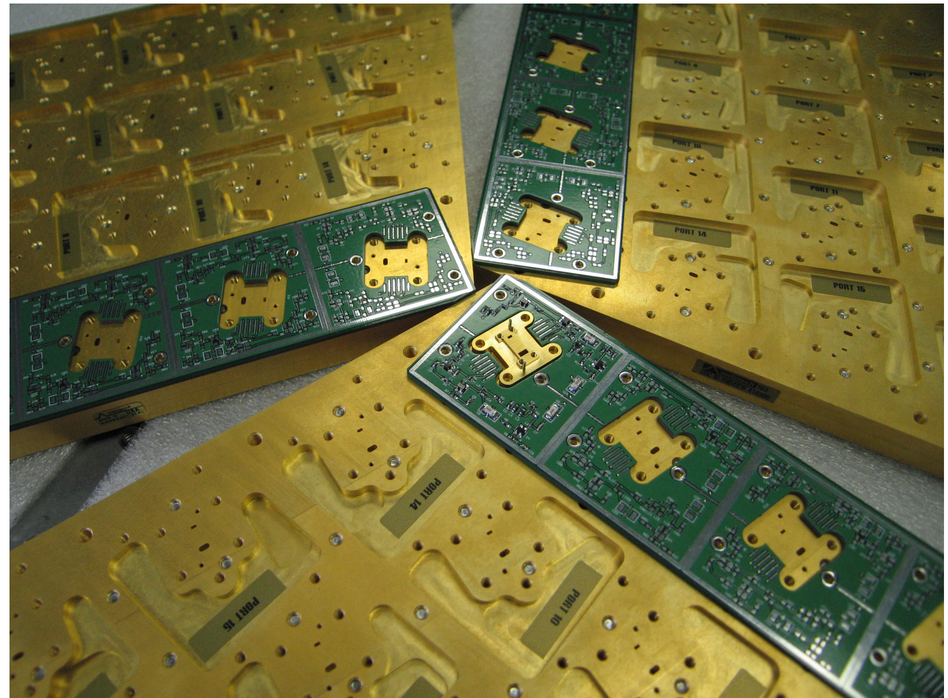
Manifold is structural basis of GeoSTAR sub-array which integrates:

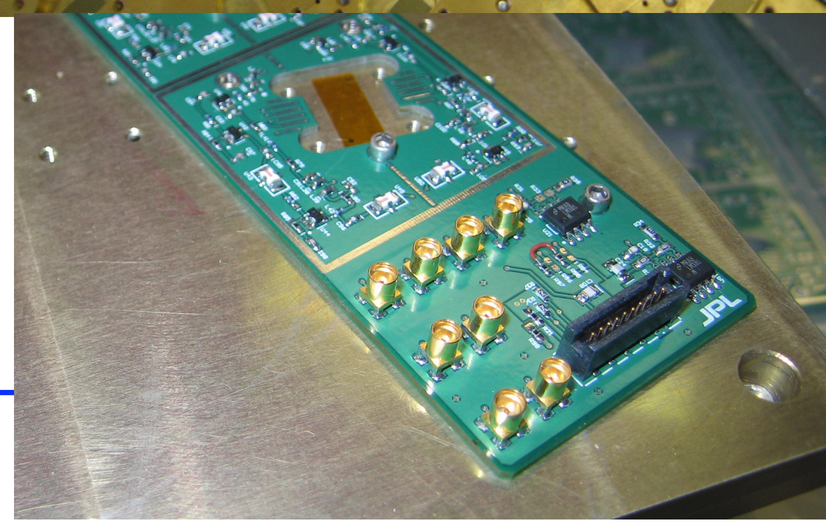
- WR10 Local Oscillator distribution
- WR5 “twists” (+/- 60 degree and 0; unique to ea array)
- WR5 circular transitions
- all interfaces for IF PCBs, MIMRAM modules, horns, LO





“Tile” Hardware





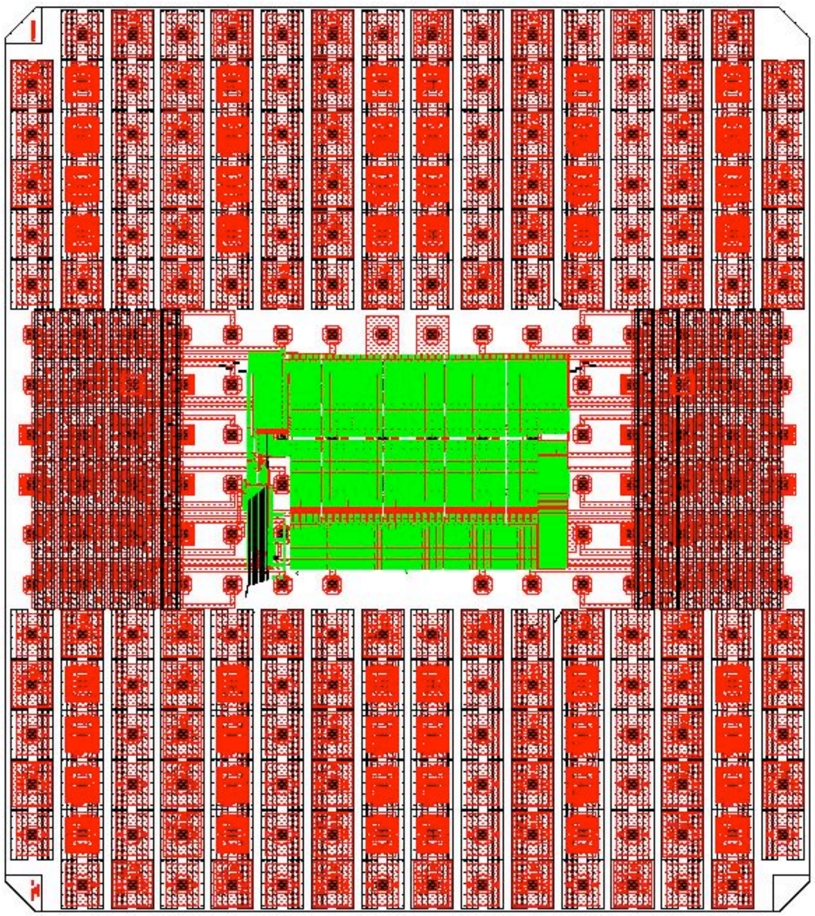
Office

High Speed Low Power ASICs

Correlator Proof of Concept

- Cross correlation for 3 arms of antennas
  - 17 antennas/arm
  - 2 signals/antenna (I/Q)
  - 2-bit signed
  - 3x17x2x1=102 digital antenna inputs
- Correlations per antenna pair
  - 4 (In*Im,In*Qm,Qn*Im, and Qn*Qm)
  - Antenna pairs on same arm not cross-correlated
  - Number of antenna pairs to be correlated 3x17^2=867
  - Number of total correlations 4x867=3,468

  12 ASIC chips required
  - 3,468/12=289 correlations/ASIC
- 1GHz sample rate
- 1 second integration period
- 10msec accumulator readout
- 250uW/correlation at 1GHz
- Processed on TAPO IBM 90SL CMOS Initial tests look good

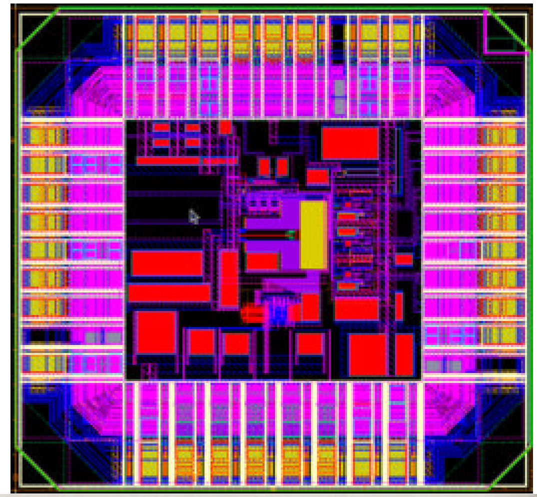


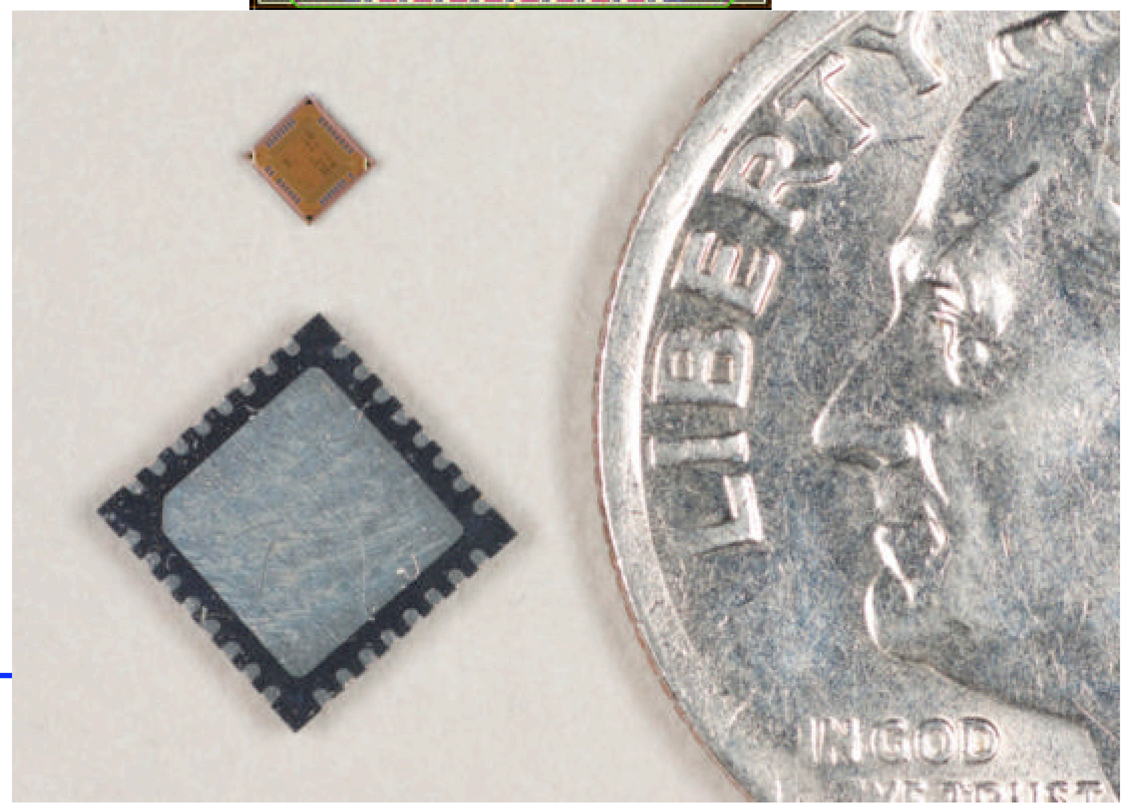
ESTO Earth Science Technology Office

High Speed, Low Power ASICs

A/D Proof of Concept

- Assumptions:
  - 1GHz sample clock
  - 1V supply voltage
  - 40 μA current reference
- Input Common Mode Range ($Vin^+ + Vin^-$)/2
- 650mV – 850mV
- Differential Input Range (Vin^+ - $Vin)^-$
- 200mV to +200mV
- 2 bit ADC, with independent threshold control
- 6 bit offset control for top and bottom thresholds
- 8 bit offset control for centre threshold
- LVDS output drivers
- SPI control bus
- 90nm digital CMOS process





Performance Metrics

Correlator		Goal	CBE
	Power	250 uW/corr	224 uW/corr*
	BW	500 MHz	375 MHz
Module Boards			
	Gain	15 dB	~10 dB
	BW	165-183 GHz	165-183GHz*
	Noise	400 K (3.7 dB)	~500K(4.3dB)
	Power	42mW	60 mW
Sub-Array Module			
	Mass	2kg	3.5 kg
	Mech Tol	0.001”	tbd
IF Subsystem			
	Mass (harness)	20 kg	~15 kg
	BW	>500 MHz	>1 GHz
	Gain	>40 dB	>40 dB
	Power	0.94 mW/dB	0.69 mW/dB

ESTO
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Summary

NASA has made steady progress on PATH Technologies

- Imaging capability has been demonstrated at 50-60 GHz
- Compact receiver technologies demonstrated up to 183 GHz
- ASIC Technologies (correlators and A/D) are being tested
- Key array technologies being demonstrated
- 183 GHz subsystem demonstration by end of year