Technology Concepts for Next Generation VLA
Workshop, Pasadena, April 9, 2015

LNA's for the 1.2 to 55 GHz Range

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1. Semiconductor technology applicable to cryogenic LNA's
2. Examples of discrete and integrated circuits
3. LNA for 1.2 to 8.4 GHz
4. Prototype LNA for 8 to 55 GHz
5. System noise

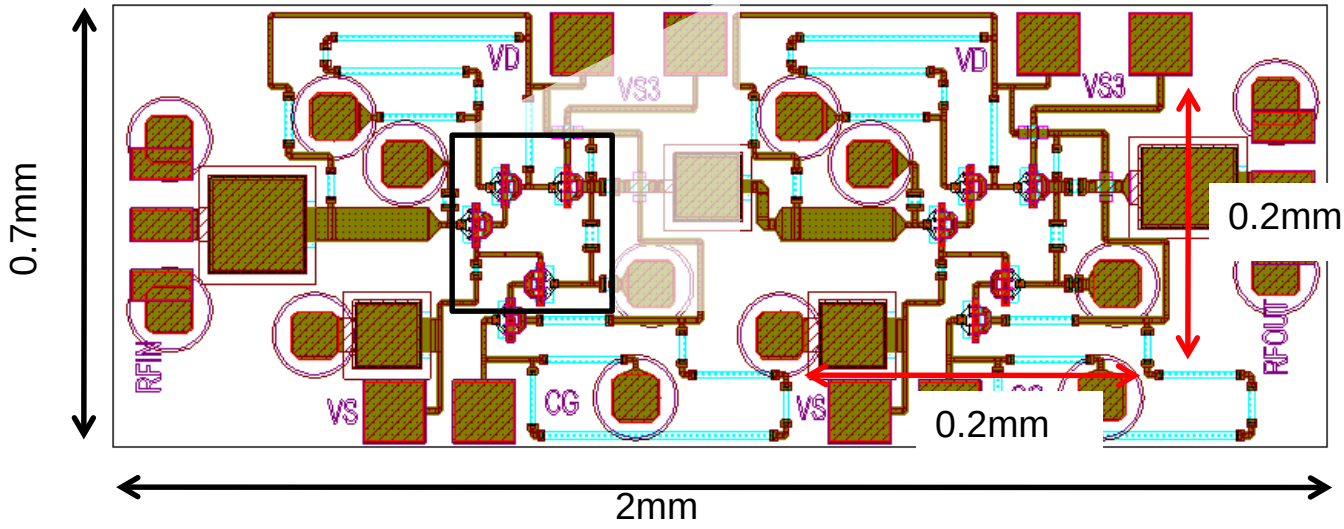
Cryogenic LNA Noise is Limited by the Transistors Available from Semiconductor Foundries

- Both HEMT and HBT transistors are used in radio astronomy LNA's
- Amplifiers can be constructed either from discrete transistors (MICs) or from monolithic integrated circuits. (MMICs)

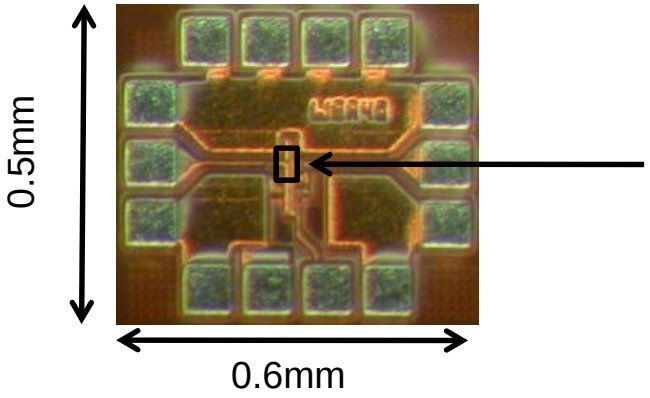
Semi-conductor	Application	Key Players	Development Pace	Key Factor
InP HEMT	Cooled, > 5 GHz	Northrop, HRL, Teledyne, IAF Chalmers	Slow	Yield,
GaAs HEMT	Cooled > 5 GHz	WIN, Triquint OMMIC	Slow	Noise
SiGe HBT	Cooled < 5 GHz	ST, IBM, NXP, Jazz, Infineon	Moderate	Beta
CMOS FET	Cooled < 20 GHz	Intel, IBM, TSMC	High	Needs Tests

Monolithic Integrated Circuit (MMIC) Amplifiers
Examples of HEMT and SiGe Chips

InP HEMT MMIC



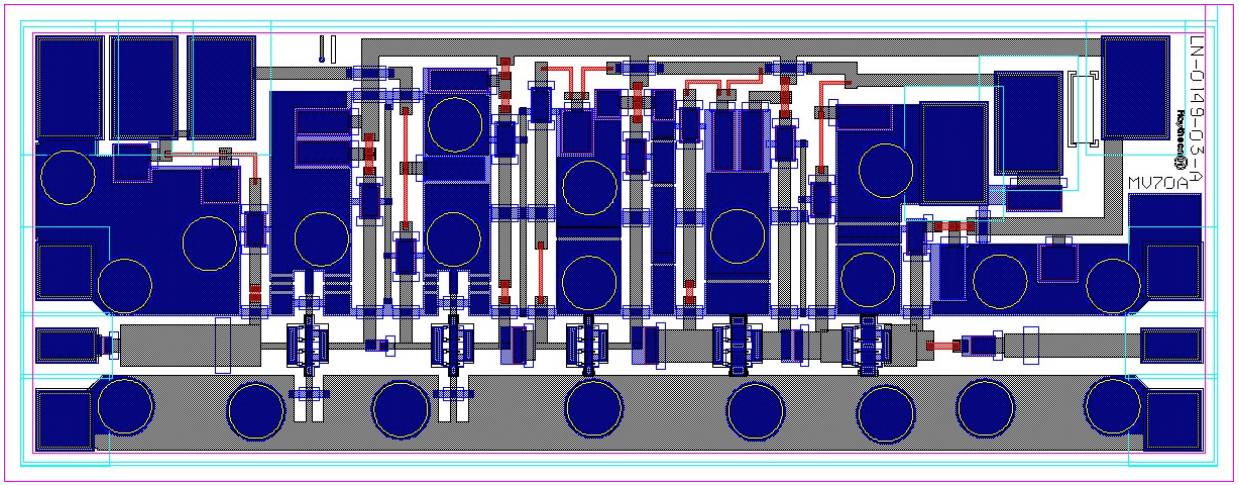
SiGe MMIC



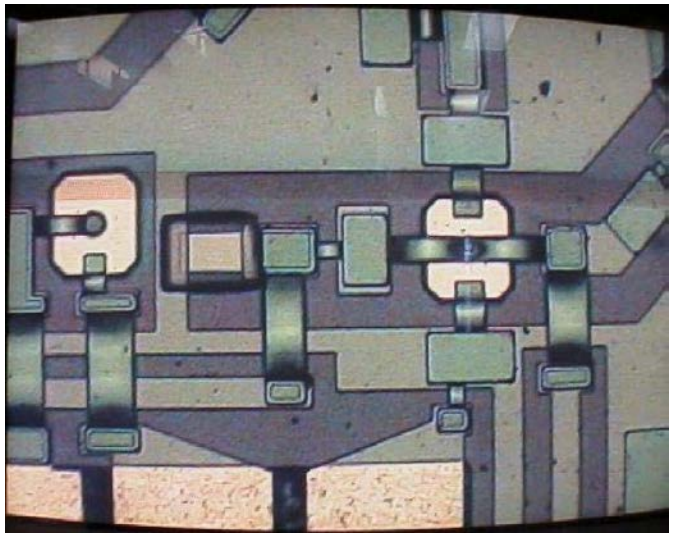
Entire active part of 2 stage amplifier
Including feedback loop within 50umx40um

Assuming an effective dielectric constant of 9, a 0.5mm path length will contribute a 90° phase shift at 40GHz! SiGe and CMOS processes allow for much more compact feedback loops!

Monolithic Millimeter-Wave Integrated Circuits



Example of a MMIC layout with transmission lines, capacitors, resistors, and active devices on a single substrate. Above chip's dimensions are 2.0 x 0.74 x 0.1 mm.



Advantages	Disadvantages
reduced mass and volume	low-Q passive elements
repeatable performance	limited power handling
low cost in large quantities	long design iteration time
fine-controlled dimensions through photolithography	limited post-fabrication tuning
easy to mass produce	requires specialized test and evaluation equipment
	difficult assembly and interconnection

Caltech ST Microelectronics SiGe Reticule, 2010

Size : 2.3 x 4.1 mm = 9.43 mm^2

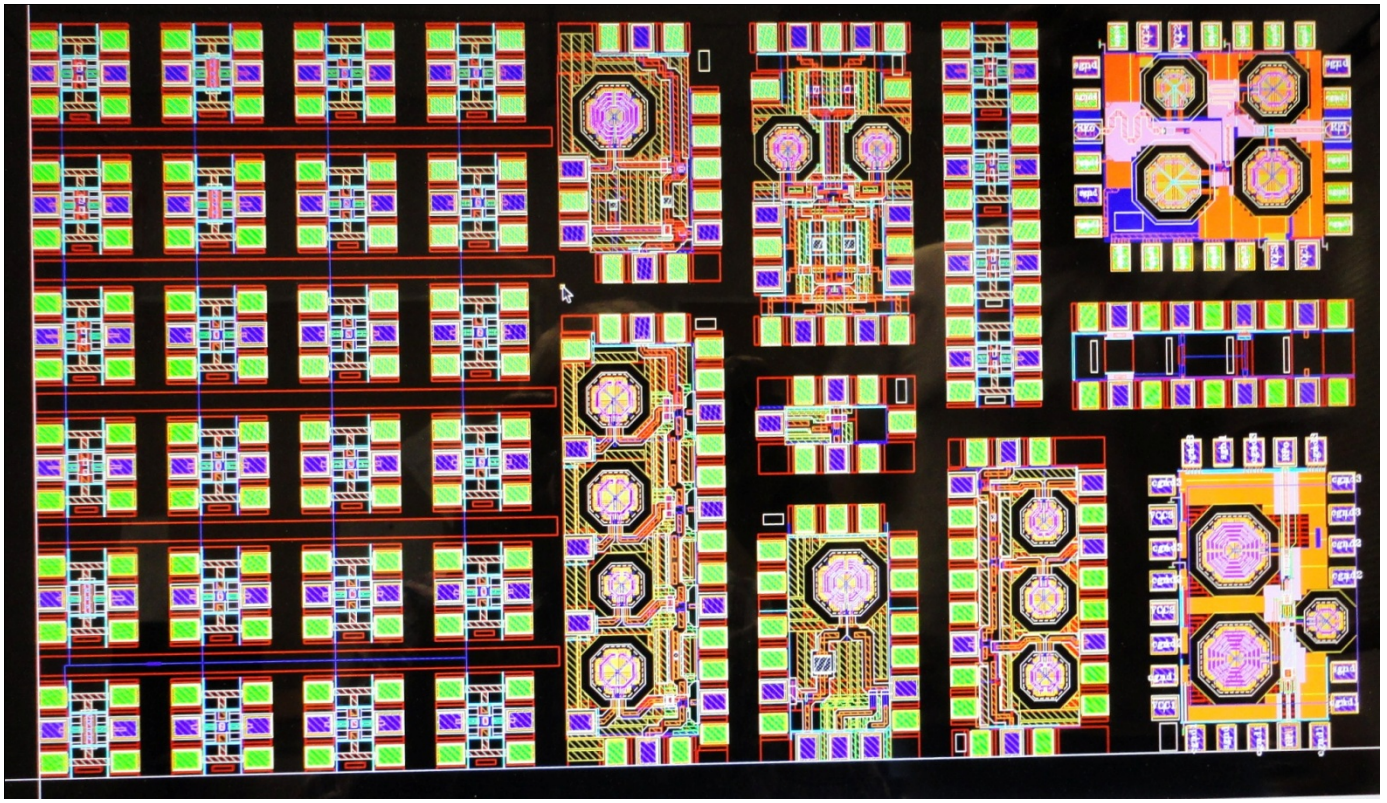
24 Discrete Transistors
0.3 x 0.3 mm

1-2 GHz

Dif LNA

CALS

11-26 LNA



R Tests
Salycide
N+Poly
P+Poly

16 – 5x 15um=75um
4 – 4x5x12um =240um
2 – 2x10um=20um
2 – 1x10um=10um

WBA20
0.1 -12
GHz

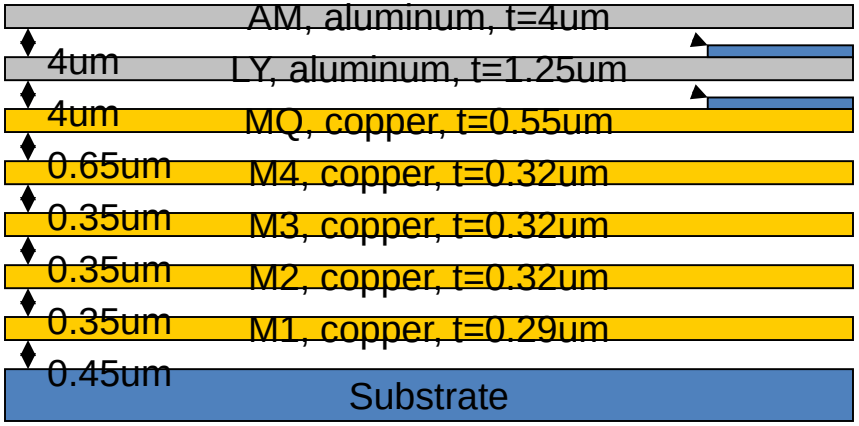
ASU Low
Power

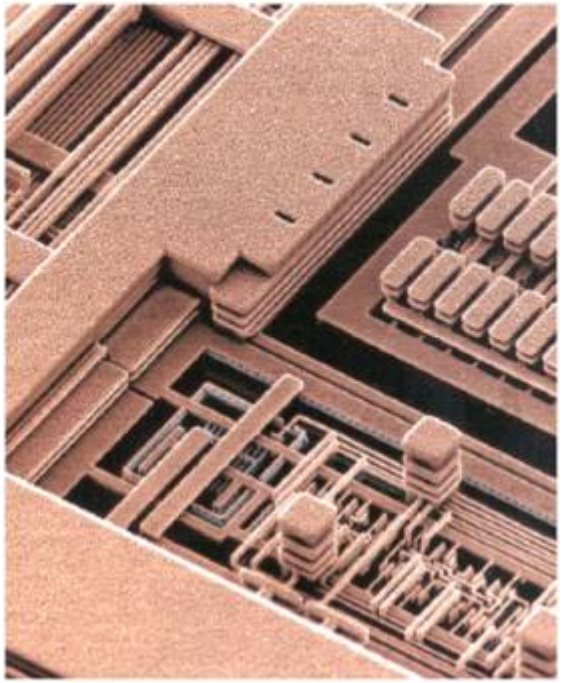
WBA21
0.1-12
GHz

0.5-3 GHz

SiGe IC Cross-Section

Many interconnect layers enable complex circuits





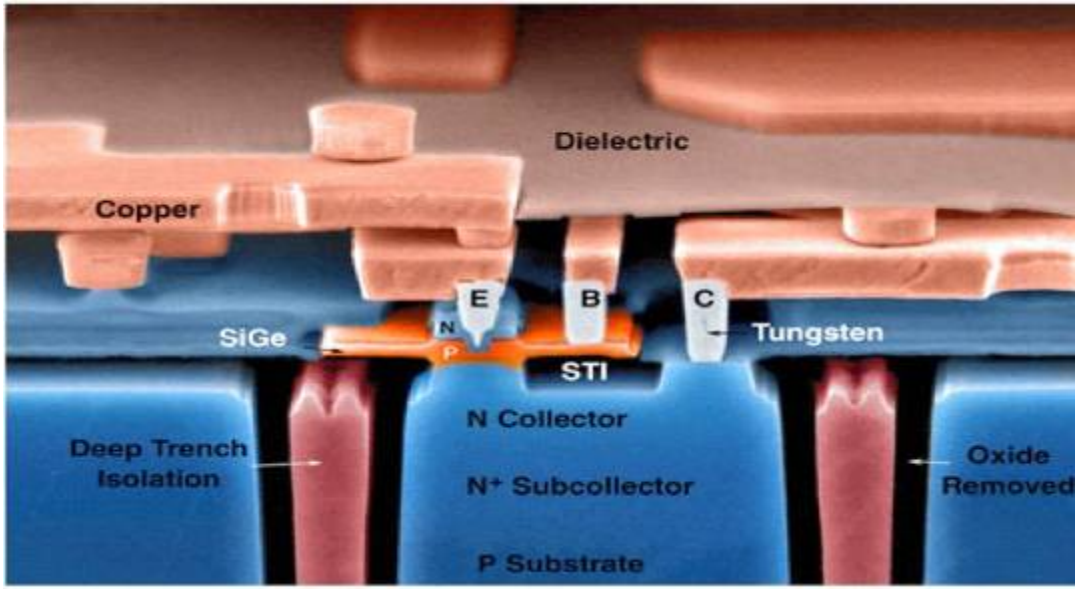
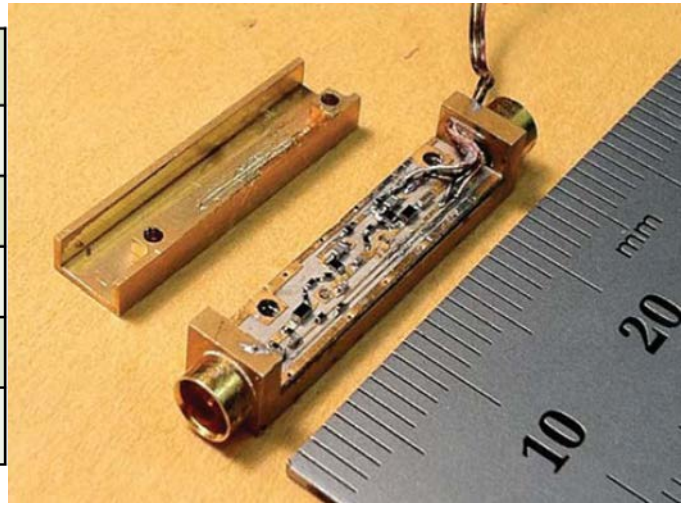


Photo reproduced from: http://users.ece.gatech.edu/~cressler/

Wideband Cryogenic LNA Development at Caltech

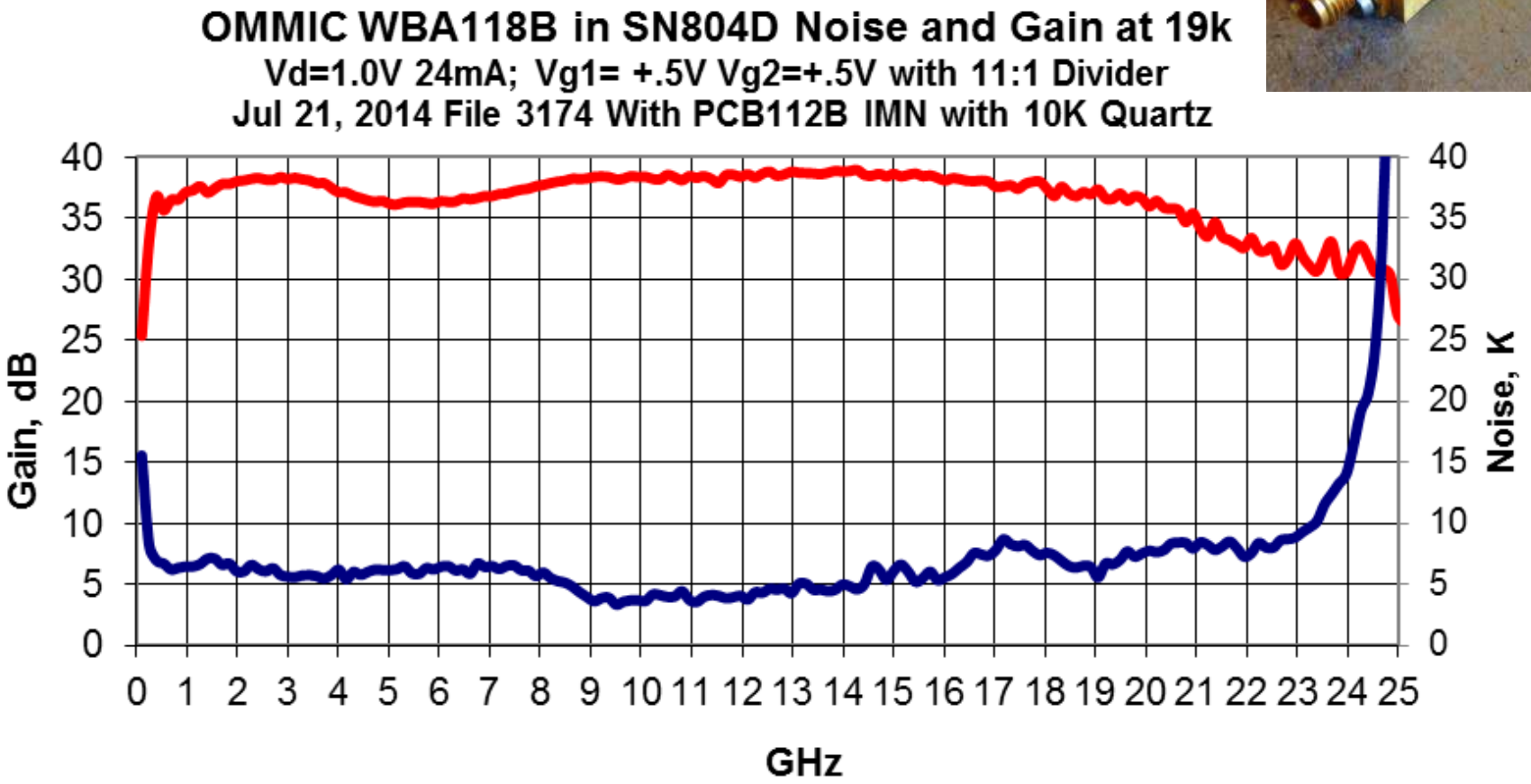
- In a 10 year period over 1200 cryogenic LNA's in the 0.1 to 50 GHz range have been supplied by Caltech to international radio astronomy and quantum physics research groups.
- The LNA's incorporate InP, GaAs, and SiGe transistors and integrated circuits developed in 4 Ph.D. theses at Caltech
- Cryogenic LNA's for 75 to 115 GHz have been developed at Caltech and JPL and have achieve noise temperatures as low as 25K
- Data and a photograph of on a 1 to 25 GHz LNA is shown below.

Country or Institution and Number Sold			
Japan	83	US	335
Germany	77	Caltech/JPL	72
Korea	63	Harvard/SAO	39
China	51	Berkeley	33
France	47	Yale	13



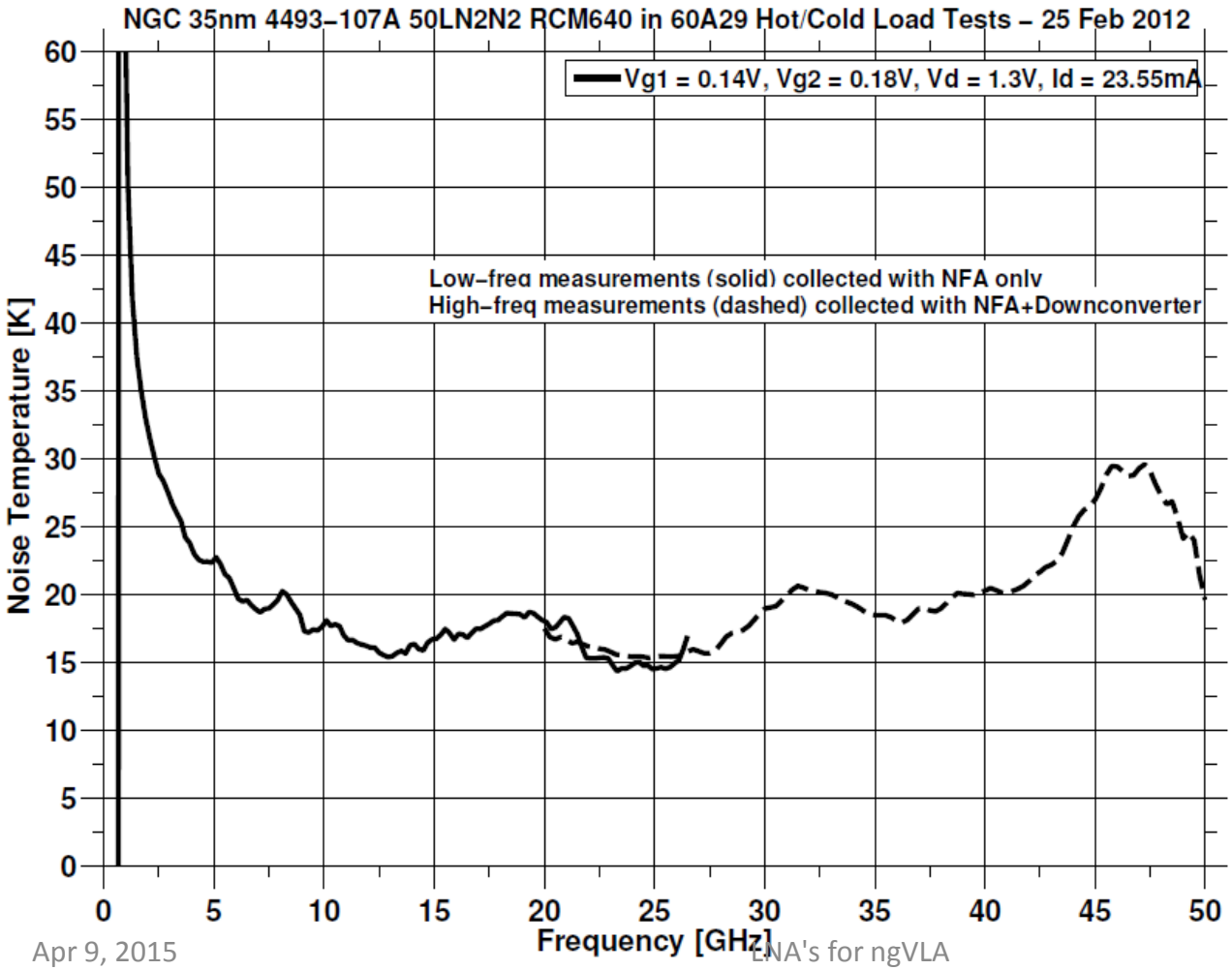
Caltech LNA for ngVLA 1.2 to 8.4 GHz Band

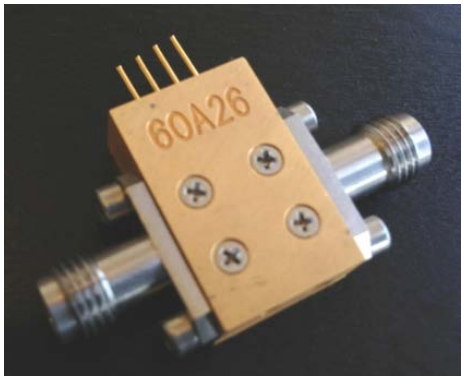
- Noise <6K from 0.8 to 16 GHz
- Utilizes OMMIC GaAs MMIC available in large quantities
- Amplifier is very stable and repeatable; over 20 in use
- Input power for 1dB gain compression is -36 dBm



Prototype of of ngVLA 8 to 55 GHz LNA

- An 8 to 50 GHz MMIC InP HEMT LNA was deigned and tested at Caltech in 2012 and show potential for under 20K noise.
- Amplifier utilizes a Northrop InP MMIC process





Total System Noise Estimate

Noise, K, due to component	**Remarks**	**Tsys 1.4 GHz**	**Tsys 10 GHz**	**Tsys 40 GHz**	**Tsys 80 GHz**
Sky	Background + atmosphere	4	6	20	55
Spillover & Blockage	Reduce with offset antenna	10	7	7	7
Feed loss	Estimate 0.3 dB @80K for 1.4 GHz @20K for 8-116 GHz	5	1	3	3
Window loss	Mylar windows	2	3	3	3
Feed to LNA	0.30 dB	5	1	2	1
LNA	Robust LNA measured at connector	3	6	15	25
Total	**Estimate, +/- 5K**	**29**	**24**	**50**	**94**

Atmospheric Noise is Appreciable for the ngVLA

- Noise above 40 GHz is weather and altitude dependent; curves below are for zenith at sea level
- The 55-70 GHz range is not covered by receivers.