MMIC Low Noise Amplifiers

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Technology

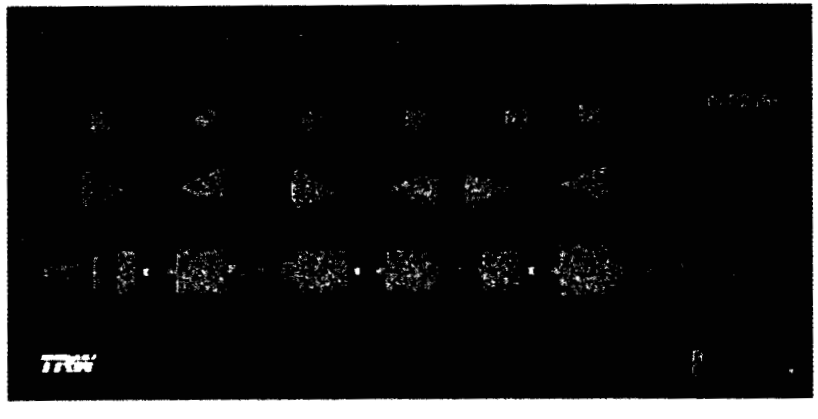
- Thus far, **InP HEMTs** are the low-noise-amplifiers to beat in terms of high gain, noise figure, and increasing performance with cooling
- Our discussion will be centered around room temperature noise figure and gain measurements
- Emerging technologies will also be discussed for their potential for better performance

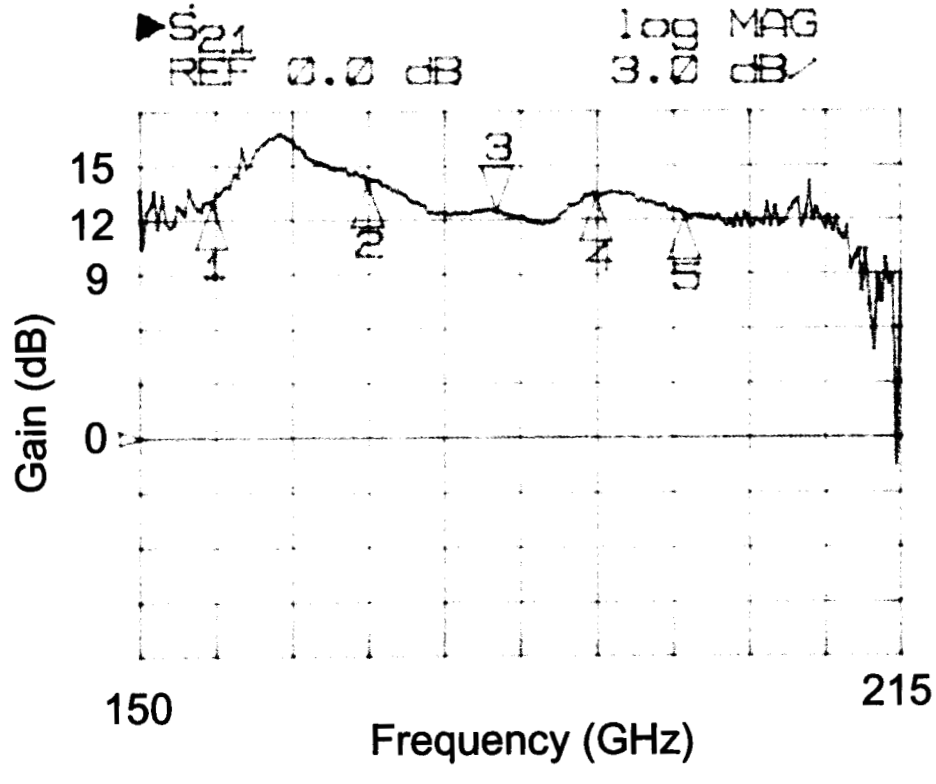
Highest Frequency InP HEMT LNA

NORTHROP GRUMMAN
Space Technology

Features

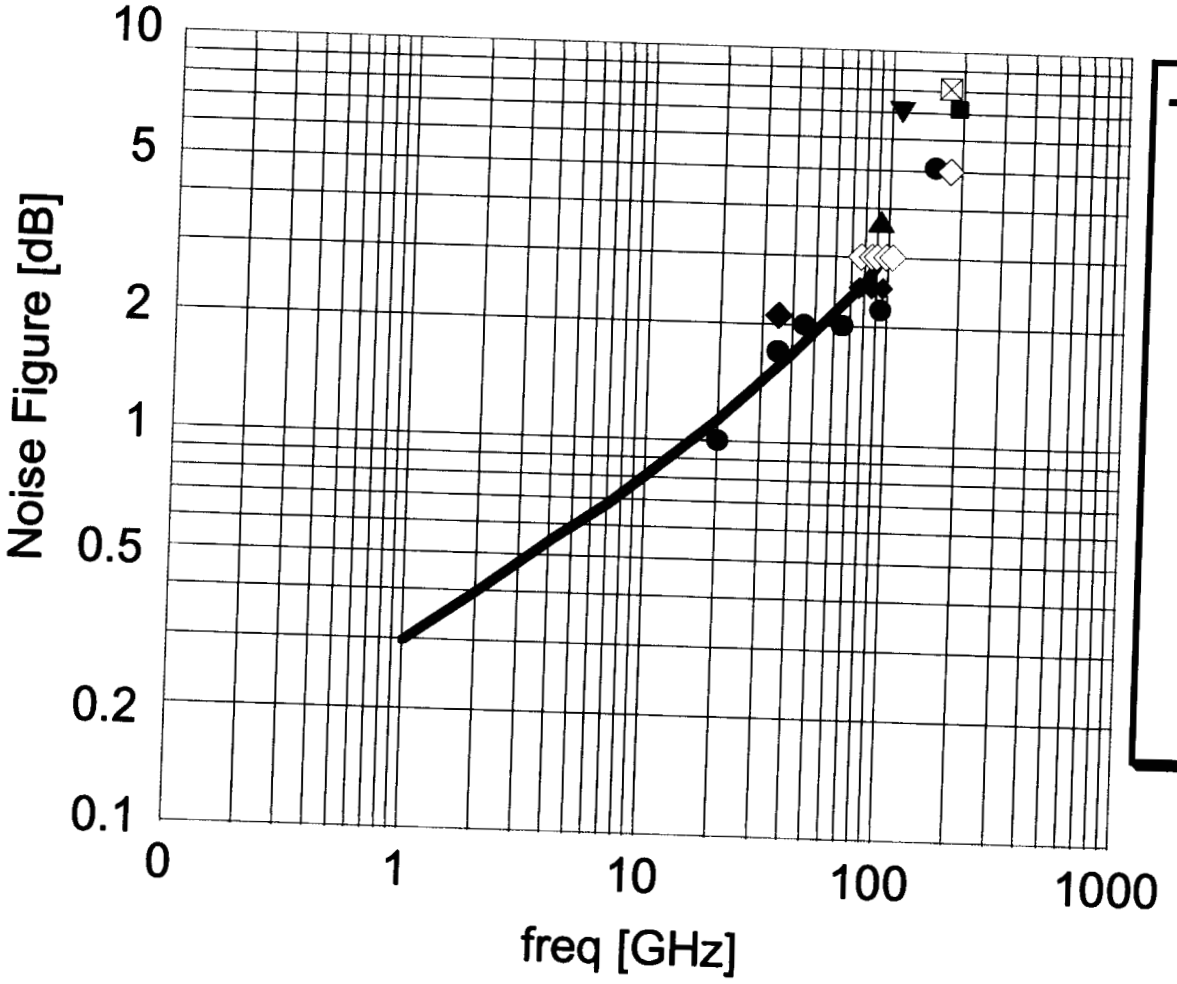
- 3 Stage Single-Ended LNA
- Gain ~12-16 dB
- Frequency 150-215 GHz
- 9 dB gain at 215 GHz
- 4 dB gain/stage is highest ever reported at 210 GHz





Data furnished by Richard Lai, NGST and measured at JPL

300K Noise Figure HEMT LNA Data



- S. Weinreb, Trends 1999
- RWSC Sb-Based 2003
- NGST, 1997-2000
- NGST, 1999
- NGST, 2000
- NGST, 1998
- S. Weinreb, NGST 150-215 GHz amp, 1999
- S. Weinreb, 90-140 GHz amp, 1997
- HRL Labs, 2000
- HRL Labs, 2000

All Data are Measured

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MMIC LNA Technology: Chip Gain

Frequency (GHz)	Technology	LNA Description	Noise Figure	Gain
19-21	InP, 2000	2-stage (NGST)	1.0 dB	18 dB
33-37	InP, 1997	2-stage (NGST)	1.7 dB	18 dB
34-36	Sb-Based, 2003	3-stage (RWSC)	2.1 dB	22 dB
42-47	InP, 1998	3-stage (NGST)	2.0 dB	28 dB
55-75	InP, 1999	4-stage (NGST)	2.0 dB	20 dB
77-105	InP, 1999	4 stage (NGST)	3.0 dB	20 dB
91-97	InP 2000	1-stage (NGST)	2.2 dB	8 dB
85-119	InP, 2000	4-stage (HRL)	3.7 dB	20 dB
155	InP, 1997	3-stage (NGST)	5.1 dB	10 dB
150-215	InP, 1999	6-stage (Weinreb/NGST)	8.1 dB	15-27 dB
150-205	InP, 1999	8-stage (Weinreb/HRL)	?	17 dB
160-200	InP, 2000	2-stage (NGST)	5.0 dB	15 dB
150-215	InP, 2003	3-stage (NGST)	?	12 dB
175 GHz	InP HBT, 2003	1-stage (UCSB)	?	6 dB

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Comparisons and Trends

- Best HEMT LNA at 180 GHz is about 5-5.5 dB NF
- Room Temperature Schottky Mixer results at 180 GHz: 6-7 dB (HEMT is a little better!)
- Cooled HEMT LNA yields 1.6-2.5 dB Noise Figure at from 165-190 GHz, with 15-22 dB of gain. (Temperature 20K ambient) *(Source: D. Dawson, JPL)*
- Projected noise figures at 300 GHz in present InP technology (or using slightly short gate lengths) could be in the 8-13 dB range.

Emerging Technologies

- Antimony-based HEMTs are quickly being realized for LNAs. The first LNA data compare favorably with InP HEMTs, despite being a relatively immature technology. The low power dissipation makes them particularly suitable for arrays.
- J. Hacker and B. Brar from Rockwell Scientific have developed the first Ka-Band ABCS HEMT LNA with NF of 2.1 dB @35 GHz
- Projected cutoff frequencies for Sb-based HEMTS are theoretically as high as 400-500 GHz (Source: NGST), where they could be useful for LNAs in the 300 GHz range. Future work will determine whether they will ultimately be competitive with mixer technology at 300 GHz for receiver front-ends.

Ka-Band 3-Stage ABCS LNA
Vd=0.35V, Id=12mA
Gain = 24dB, Power=4.2mW
NF < 2.2 dB at 35 GHz

Emerging Technologies

- Don't rule out InP-based HBTs!
- While HBTs are not traditionally used for low noise amplifiers, several InP technologies are capable of ***very high gain per stage*** at 200 GHz, which may ultimately be competitive with HEMT technology.
- Cutoff frequencies for HBTs are also as high as 400-700 GHz *(Source: UCSB),* where they could be useful for LNAs in the 300 GHz range.

Array Issues with MMICs

- Power Dissipation: W-Band 1.5-1.8 Watt PA chips are power hungry – perhaps not so practical for 1 chip to drive one LO per pixel for a large array. Waveguide loss for distributing the power over several LO chains is likely to be high.
- Smaller periphery PAs dissipate .5W at higher frequency – might be more practical for driving a single pixel's LO chain
- PAs can drive doublers so there is no need to operate at the submm receiver frequency.
- LNA front end chips dissipate very little power, and chip sizes are small compared to PA chips.
- Front-end LNA must be competitive with mixer-only technology to be considered.
- Usefulness of PAs and LNAs over the next few years (but not necessarily long-term) is most likely limited to 300 GHz or less.