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Very Low Noise Amplifiers at 300K for 0.7 to 1.4 GHz

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Rationale

- **Array Receivers** - The cost of very low noise radio astronomy receivers in the low microwave range is largely in the cryogenics. This is especially important for focal-plane arrays or phased arrays which require large numbers of LNA's.

- **Decreased Cryogenic Advantage** - Transistor improvements have decreased the improvement due to cryogenic cooling. At 1.4 GHz and 300K/15K physical temperature the noise temperatures were 50K/10K in 1985 while they are now approximately 10K/2K.

- **Transistor Technologies** - There are two technologies for this application: GaAs or InP HEMT field-effect transistors and SiGe bipolar transistors. At present the HEMT's have better performance but the SiGe transistors are rapidly improving due to large investments for fast computer and other applications.

Very Low Noise without Cryogenics - Summary of Current Research Topics at Caltech

December, 2004

•Study of transistor types for low noise with cryogenics – topic of this talk

• Improvement of noise parameter measurement techniques

• Thermoelectric cooling of LNA’s – Glenn Jones talk in this session

• Active low noise baluns needed for balanced output of wideband feeds – Niklas Wadefalk talk in this session

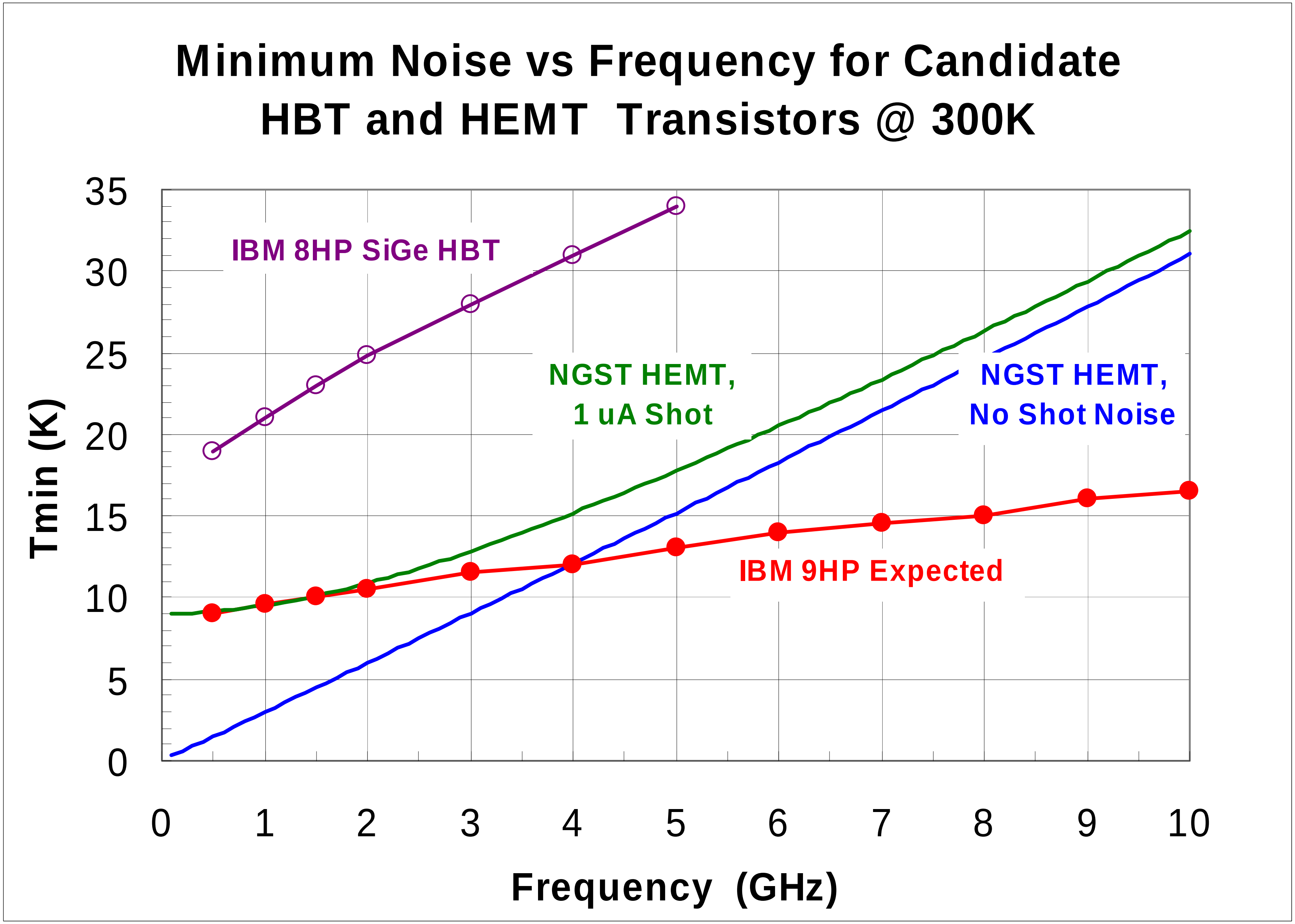
Goal is integration of all of the above to achieve decade-bandwidth microwave receivers with < 20K system noise.

Issues

- **Noise Measurement Error** – It is very difficult to measure a room temperature transistor or LNA with a NF error of less than +/- 0.1 dB or a noise temperature error of less than +/- 7K. This clouds the data on available transistors and LNA's.

- **Loss –** A loss of 0.1 dB between LNA and feed increases the noise by 7K. This encourages integrating the LNA and feed.

- **HEMT Leakage Current** – At low microwave frequencies the gate leakage current in a MESFET or HEMT transistor may limit the noise yet is an unspecified parameter which may vary greatly from one transistor to the next. It is uncertain at present whether to model the noise of this leakage current as shot noise or resistor thermal noise.

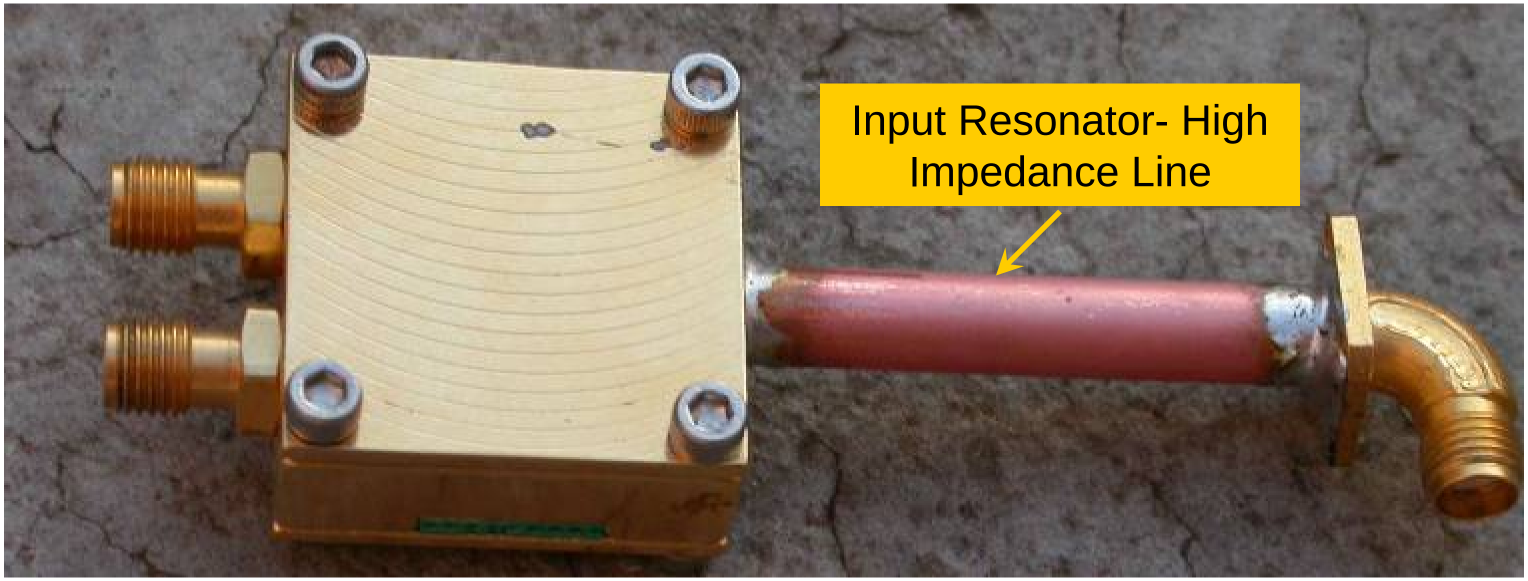


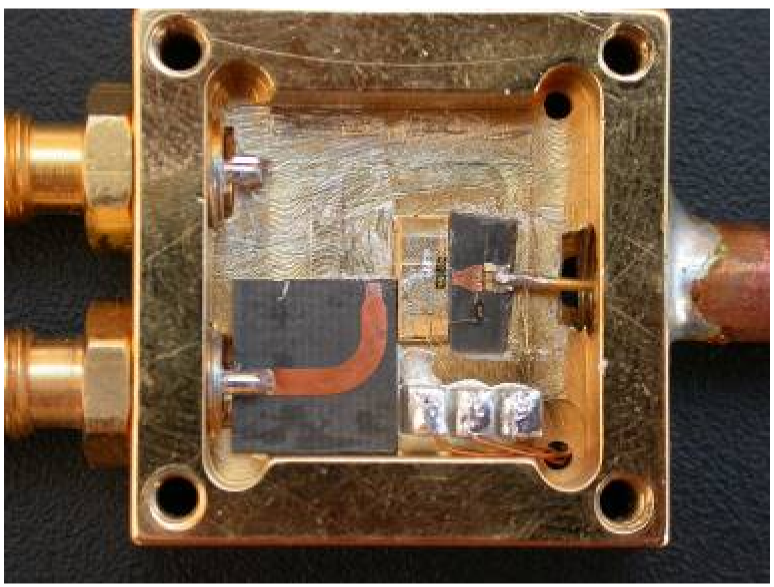
Minimum Noise vs Frequency for Candidate
HBT and HEMT Transistors @ 300K
Tmin (K)
Frequency (GHz)
IBM 8HP SiGe HBT
NGST HEMT,
1 uA Shot
NGST HEMT,
No Shot Noise
IBM 9HP Expected
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
7
8
9
10

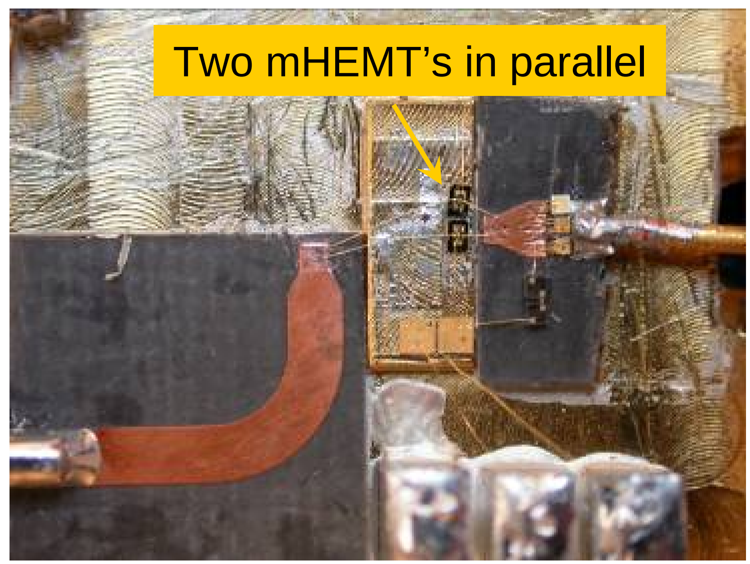
Noise Parameters of Candidate Very Low Noise Transistors

Mfg	Type	Tmin	Ropt	Ref
Agilent	ATF34143 pHEMT	9.5K@ 1.5GHz	36	Mfg data
Mitsubishi	MGF4953 pHEMT	15K@ 4 GHz	46	Mfg data
NEC	NE321000 pHEMT	15K@ 4 GHz	350	Mfg data
WIN	WP105E015 mHEMT	7K@ 1.5 GHz	185	CIT Model, .15x300x2um^2
IBM	8HP SiGe HBT (2004), Beta=350	23@ 1,5 GHz	90	CIT Model .12x20x10um^2
IBM	9HP SiGe HBT (2005), Beta=1200	10@ 1.5 GHz	218	CIT Model .12x20x10um^2

Test Fixture for Noise Measurement of WIN mHEMT Transistor





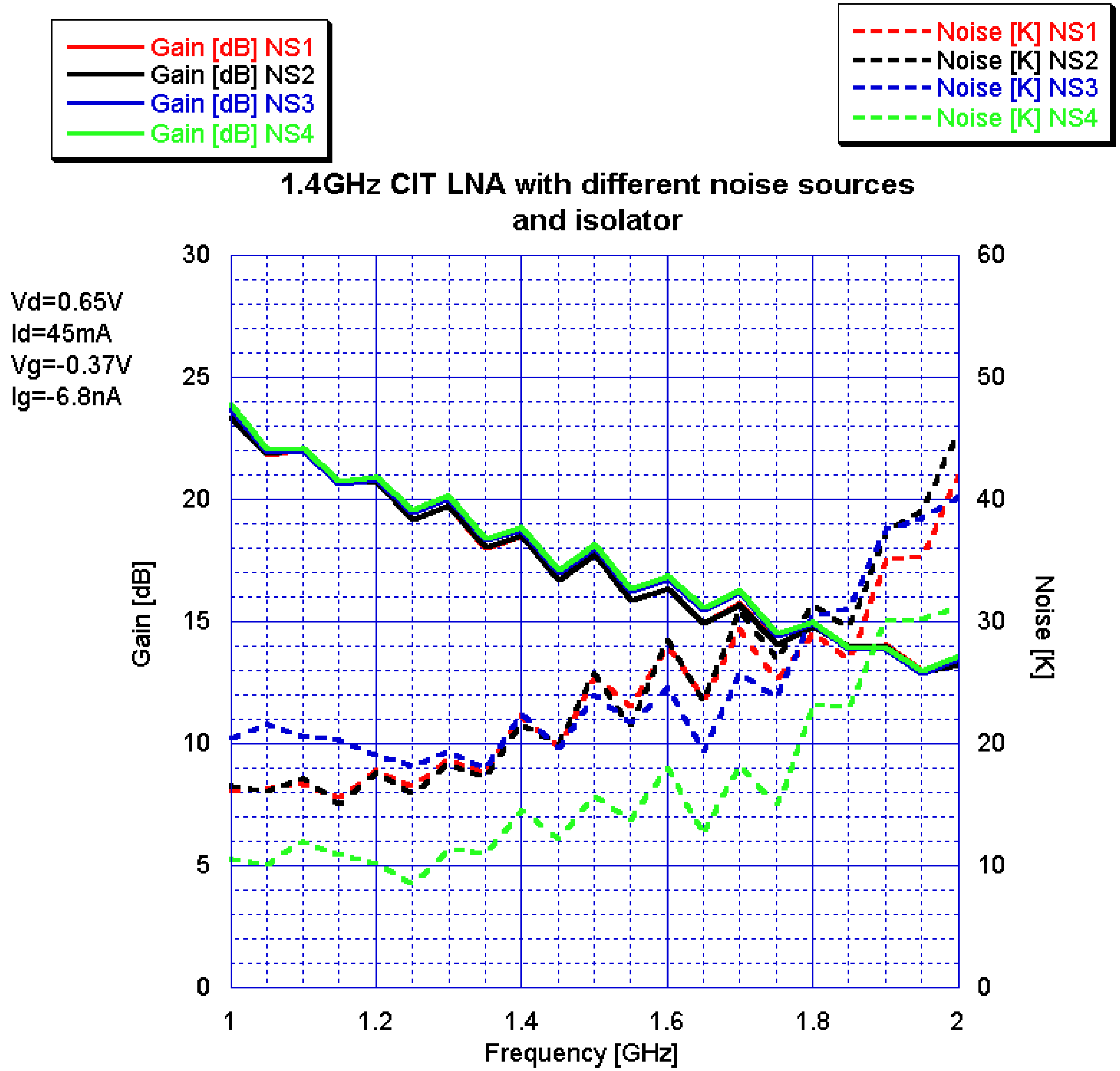


Test Data of Noise and Gain of LNA at 300K with WIN mHEMT

Jan 3, 2005

- Four different Agilent noise sources used with 3 agreeing at ~ 18K noise in the 1.2 to 1.4 GHz range.

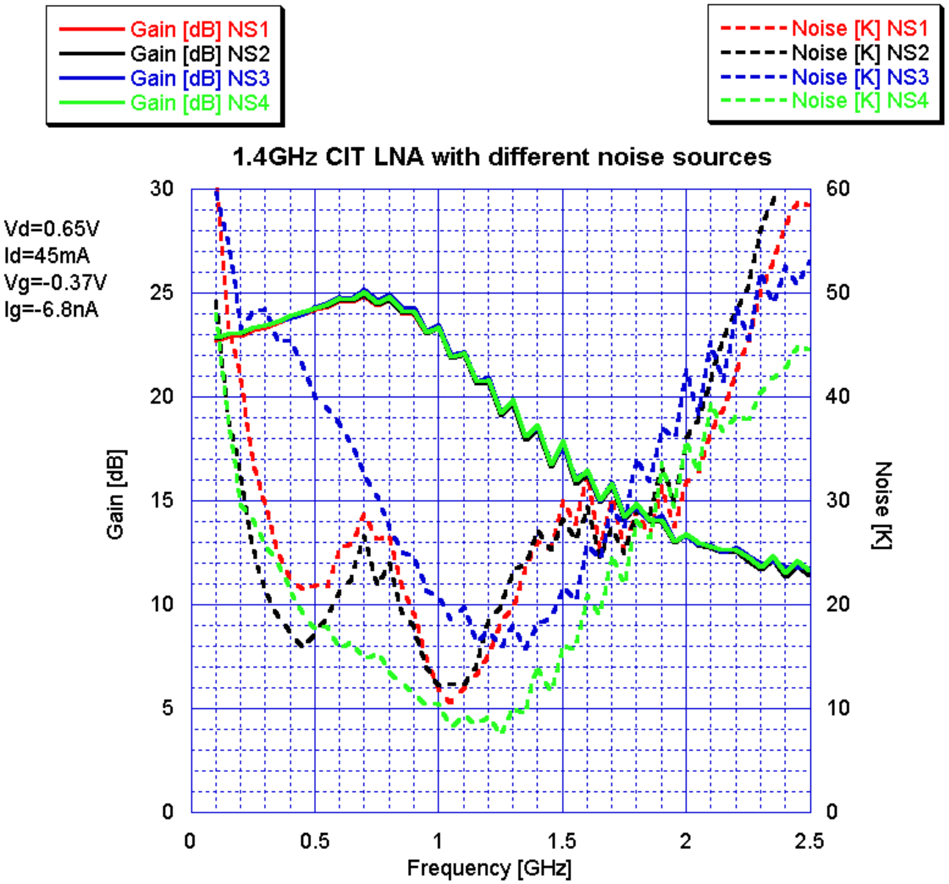
- This data is with an isolator between the noise sources and the LNA to reduce the effects of noise source on/off impedance upon gain.



NS1: Agilent N4002A 15 dB ENR with Anritsu 10.10dB attenuator
NS2: HP 346C 15 dB ENR with Anritsu 10.1dB attenuator
NS3: Agilent N4000A 5dB ENR
NS4: HP 346A 5 dB ENR

Noise Measurements of Two LNA’s with Four Different Noise Standards

Data a left is for CIT LNA with 2 x 300um WIN mHEMT; data at right is for Berkshire LNA with older Fujitsu pHEMT device. CIT LNA has noise < 20K over most of 0.3 to 1.4 GHz



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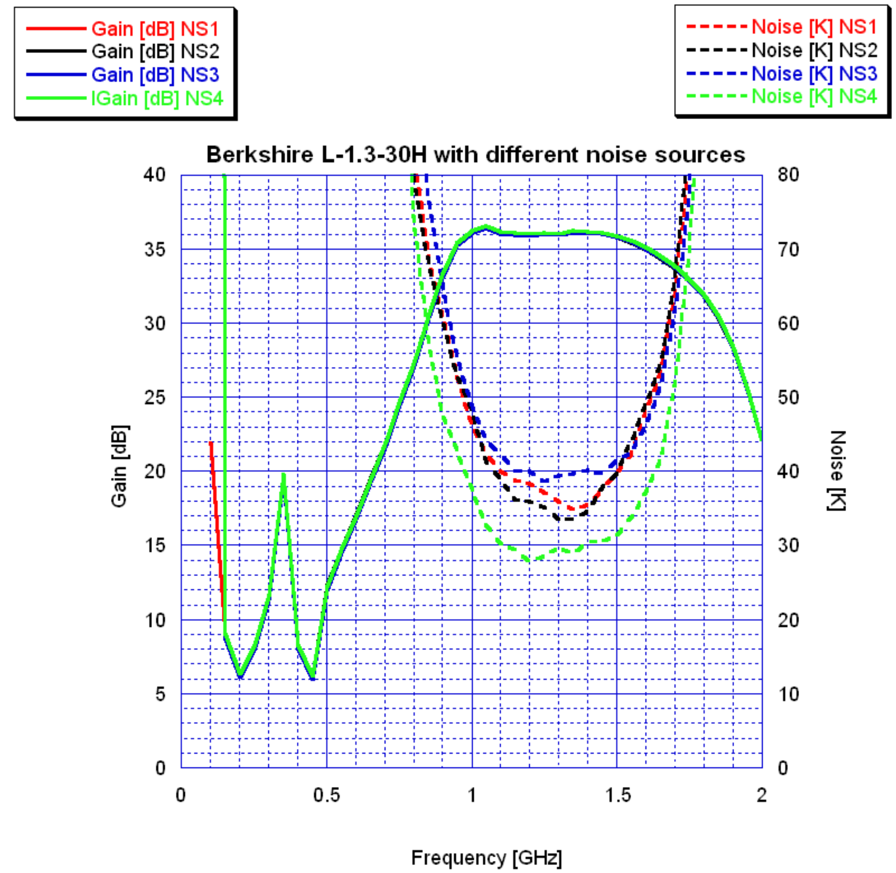

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Test Configuration for LNA Evaluation by Using Sky Noise vs 290K Noise

Dec 27, 2004, Roof of Caltech Moore, Weather with Storm Clouds

Work in Progress – Stay Tuned!

Conclusions

- New SiGe and HEMT transistor technology has potential for 300K LNA’s with < 10K noise for frequency < 2 GHz

- Current best measured result at Caltech is 18K +/- 5K @ 1.4 GHz with a WIN (Taiwanese) mHEMT transistor

- Lower noise expected within 1 year

- Key issues are measurement error and loss between transistor and antenna.