Cryogenic MMIC Low Noise Amplifiers: Progress and Recent Results

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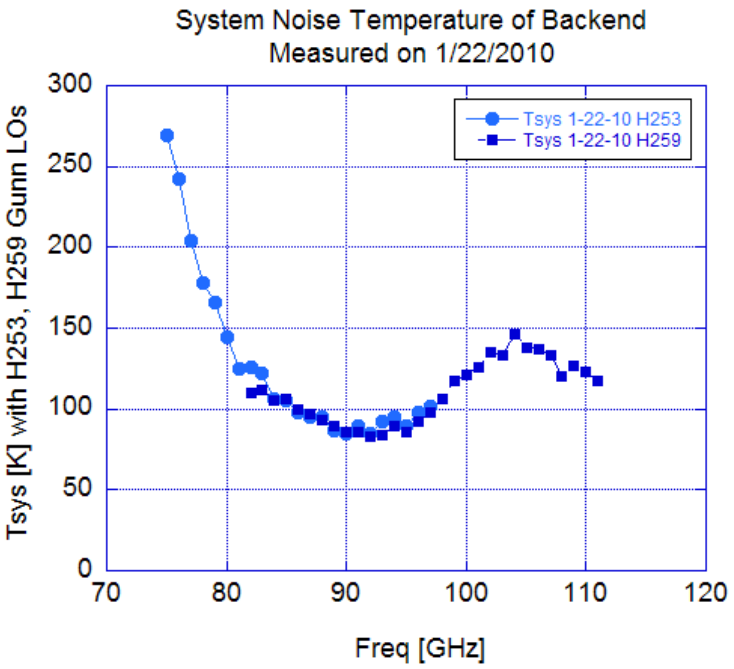
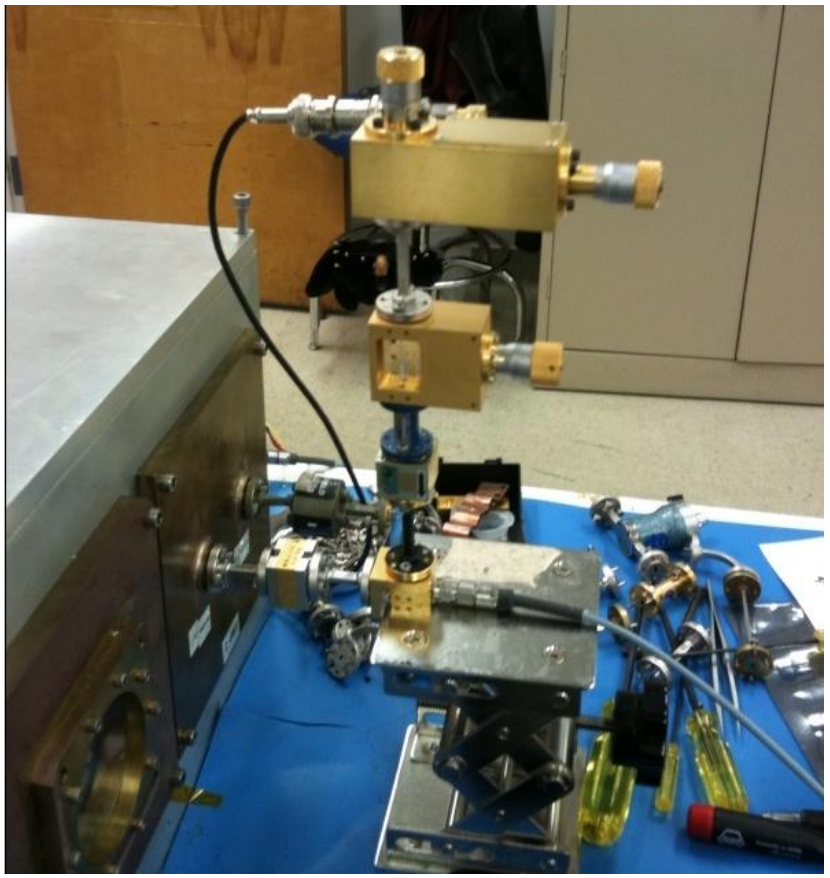
Summary of Noise Data in W-Band

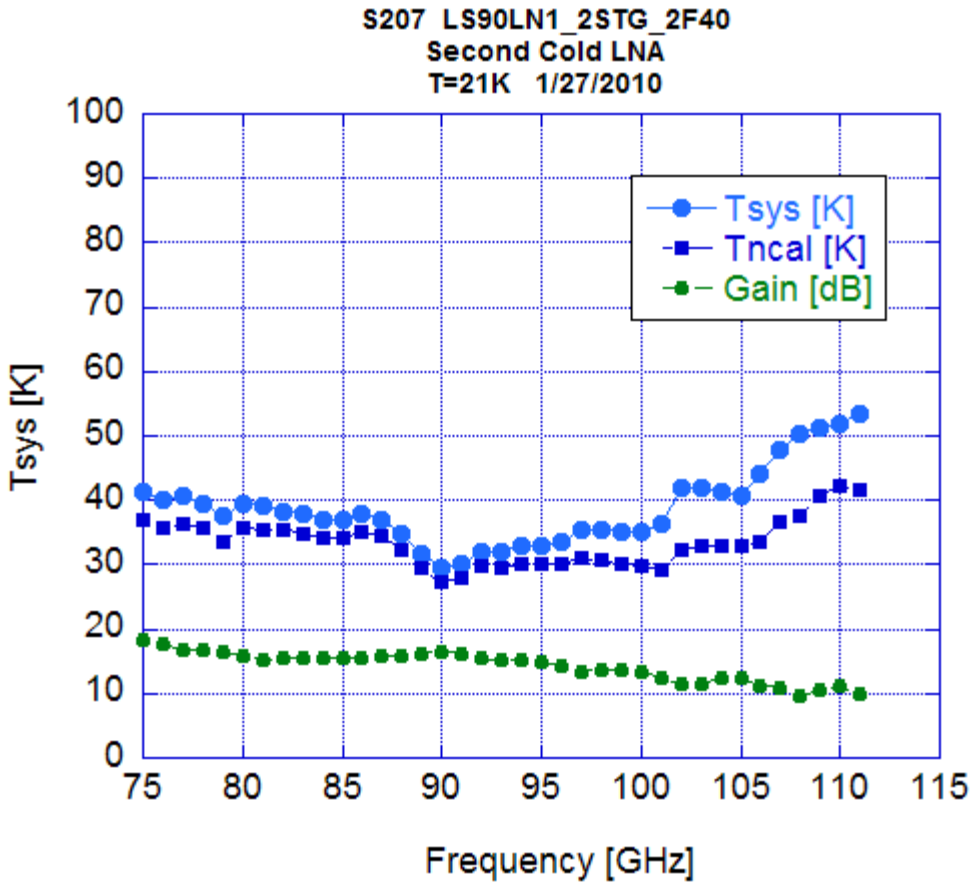
Measurements: Backend

- Two Cold LNAs were inserted in the dewar with an isolator between them.
- Isolators used between LO Gunn and Mixer
- Two Gunns used to span 75-110 GHz
- Tamb=21.6K
- IF bandwidth is ~500MHz wide





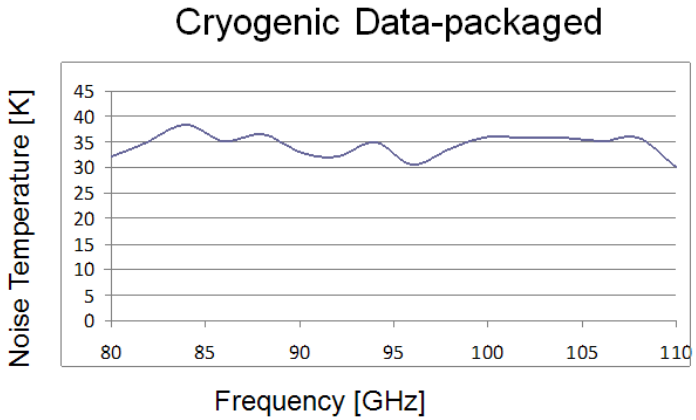
Full W-Band Noise Data of LS90LN1_2STG_2F40

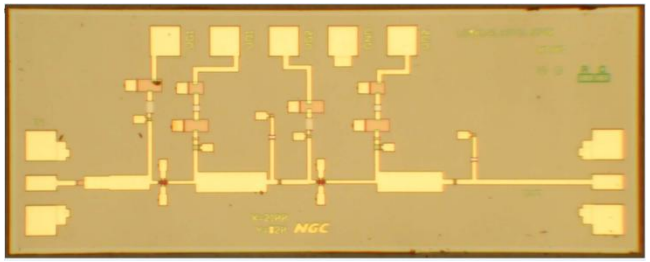


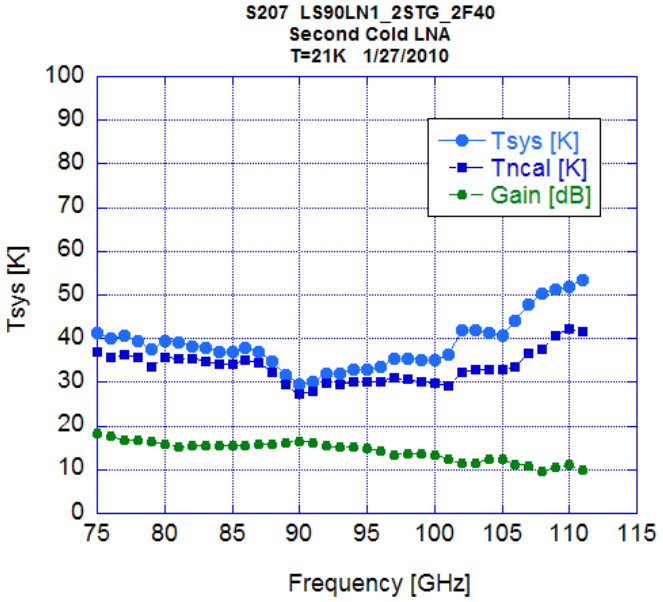
Chip has two stages of 2f40 HEMTs with 35 nm gates

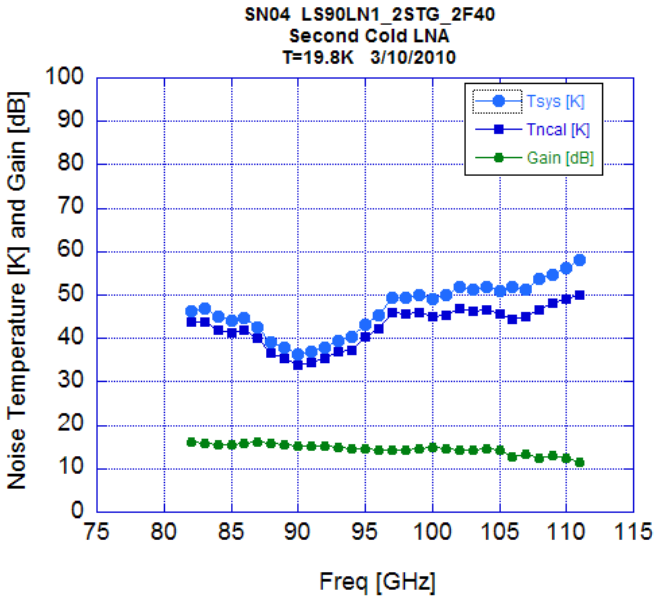
Full W-Band Noise Data of three separate 35 nm chips
S207 (original), S207 (new chip) and SN04 with 75% In Channel HEMTs

S. Xenos' original S207 data (2008)

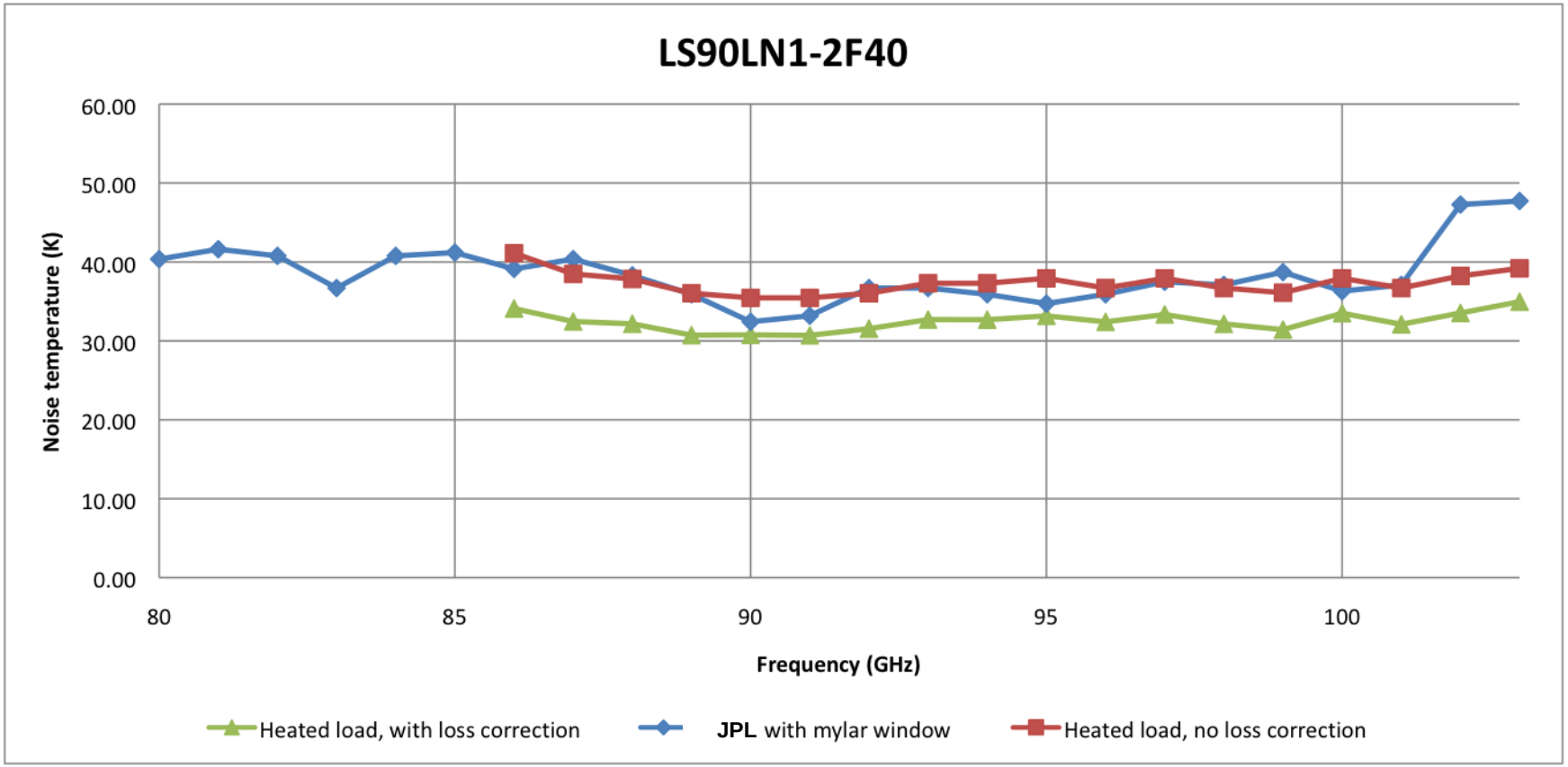








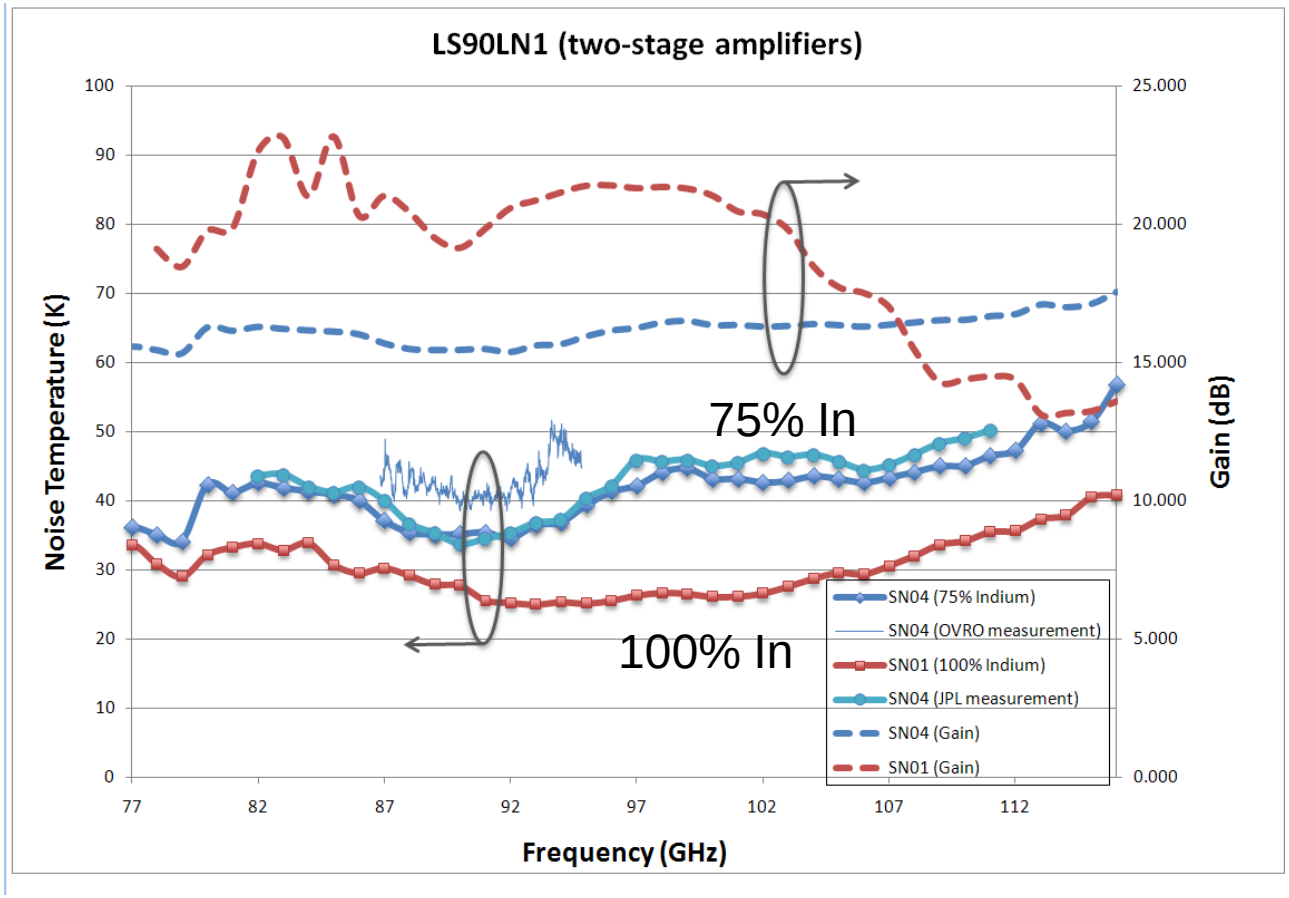
Caltech Repeated Measurement with Heated Load Method



(Block SN04, Cleary & Reeves)

Comparison is shown between horn/window method at JPL and Heated Load Method (corrected for Stainless Steel Waveguide at Caltech)

Comparison between 75% InGaAs and 100% InAs Channel MMICs Cooled to 20K

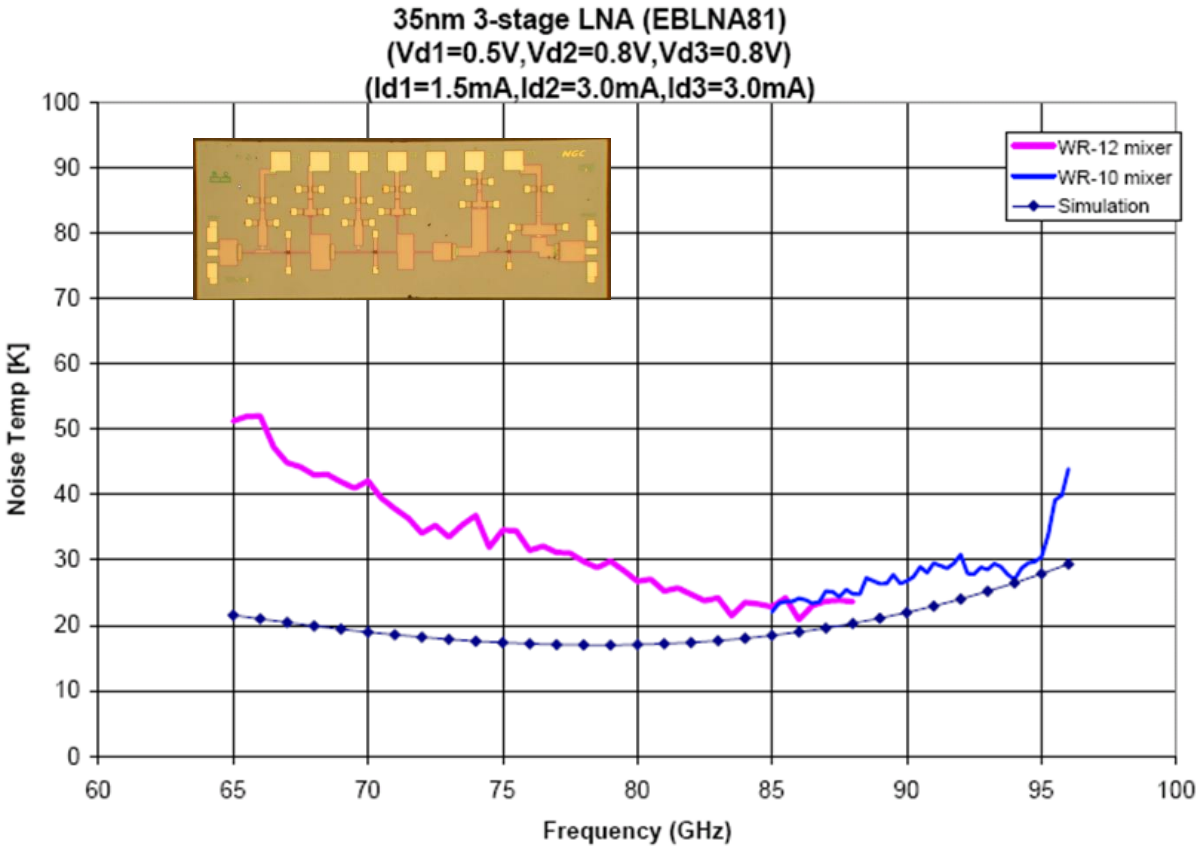


(R. Reeves, Caltech)

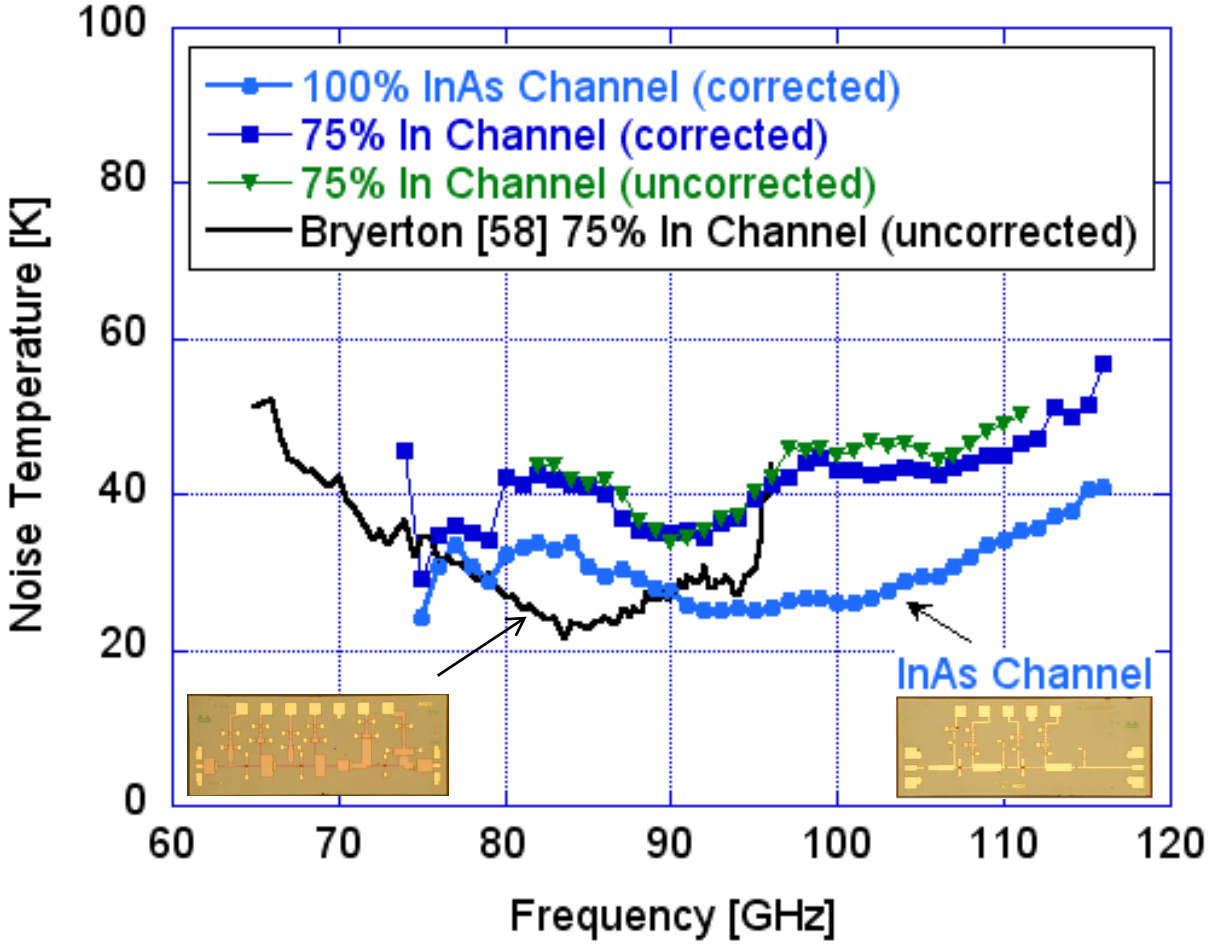
Tamp < 30K over 20 GHz of bandwidth with the new InAs Channel devices, and < 40K from 77-115 GHz.

Substantial improvement over 75% In channel content devices

NRAO MMIC Design on NGC 35 nm Process



Courtesy E. Bryerton


100% InAs Channel (corrected)
75% In Channel (corrected)
75% In Channel (uncorrected)
Bryerton [58] 75% In Channel (uncorrected)
Noise Temperature [K]
Frequency [GHz]
InAs Channel
0
20
40
60
80
100
60
70
80
90
100
110
120

W-Band Summary

We have designed several LNAs to cover various parts of W-Band, including full W-Band. Noise data seem pretty consistent for 75% InGaAs channel devices.

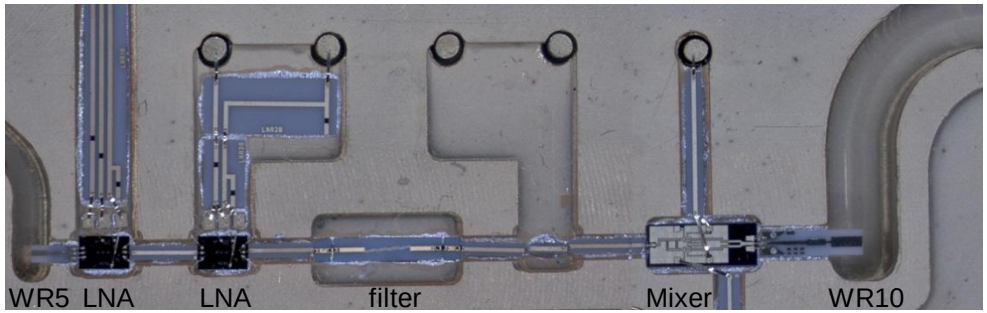
The most recently diced chips have 100% InAs channel HEMTs, and show a substantial improvement in noise over those with 75% InGaAs channel HEMTs.

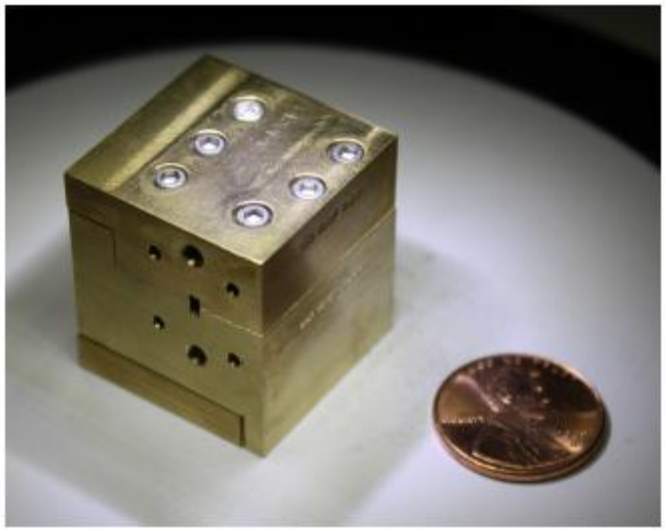
It is likely that the new chips from our APRA program (still to be diced) will improve further, as all of the designs appear on InAs channel wafers.

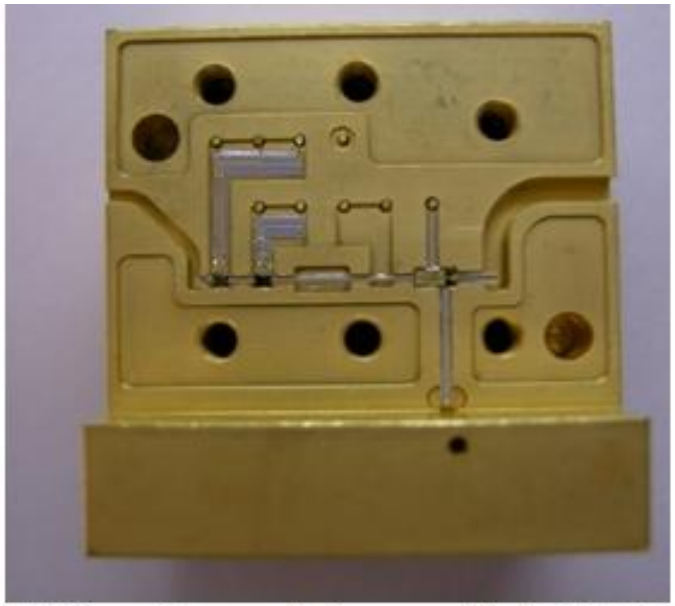
Less than 40K is possible across W-Band already with only a 2-stage design, with minimum noise in the mid-20K range.

New three stage designs (which were designed by Eric Bryerton, Matt Morgan, Lorene Samoska, and Pekka Kangaslahti, and Sandy Weinreb) will all be tested cryogenically in the near future.

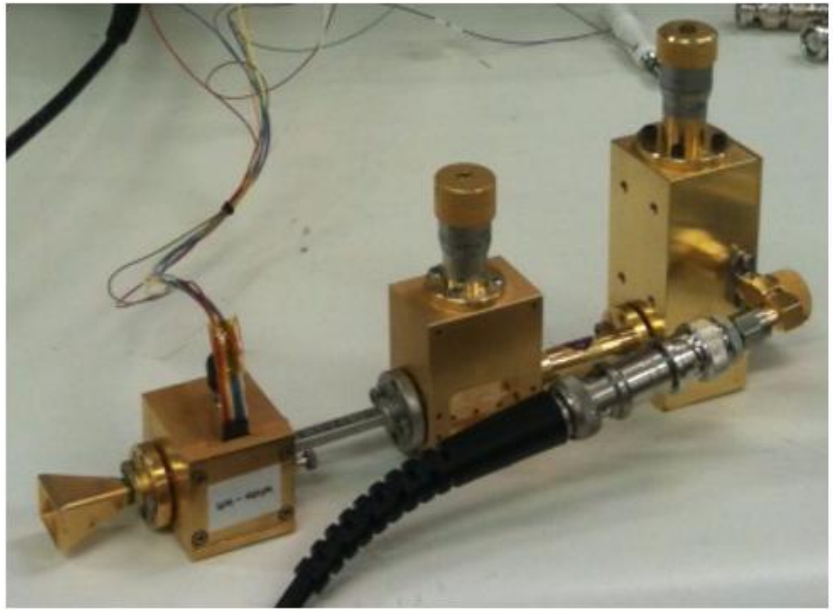
150 GHz Cryogenic Heterodyne Receiver Module





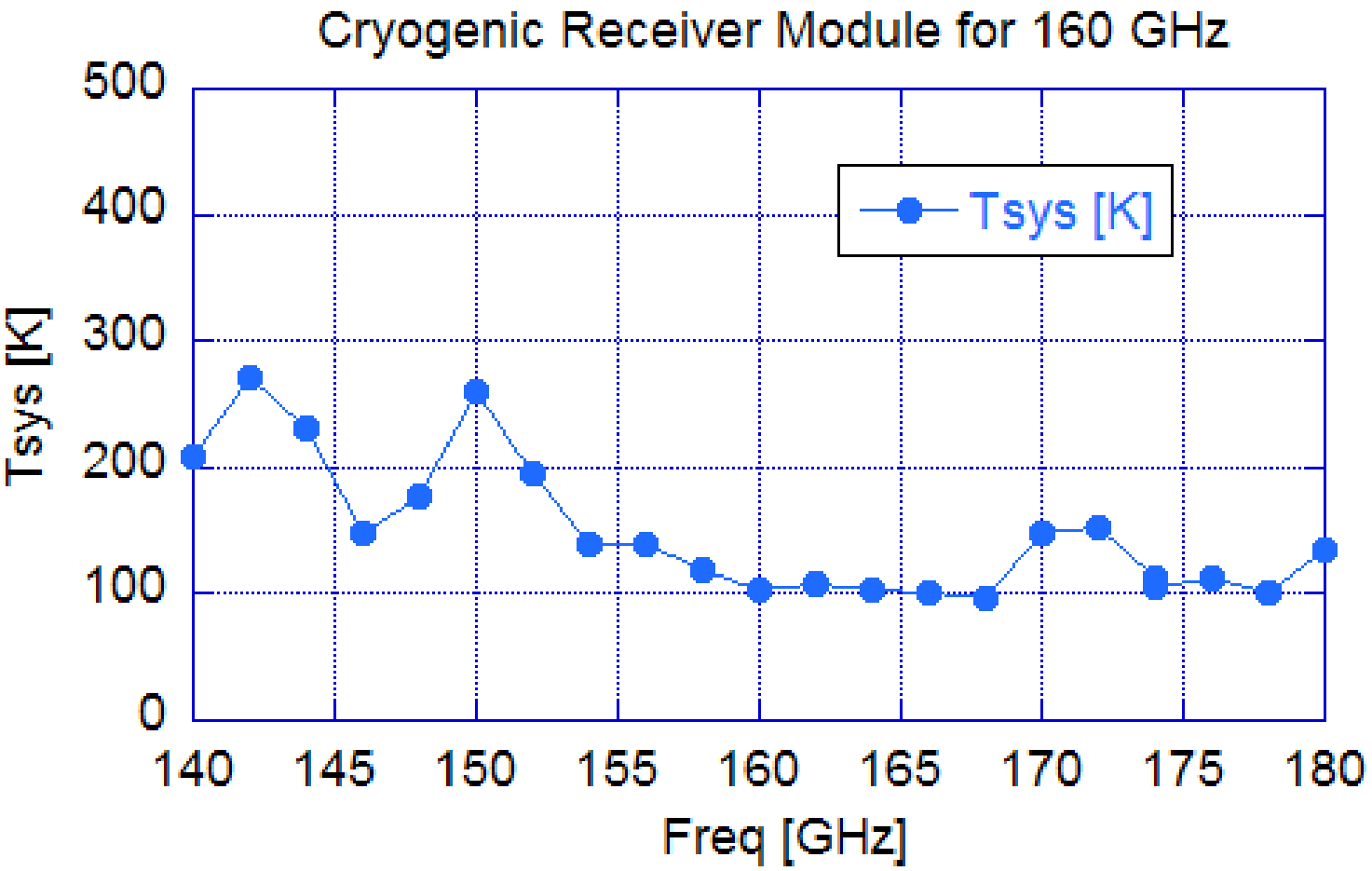


150 GHz MMIC receiver module, assembled with lid open.



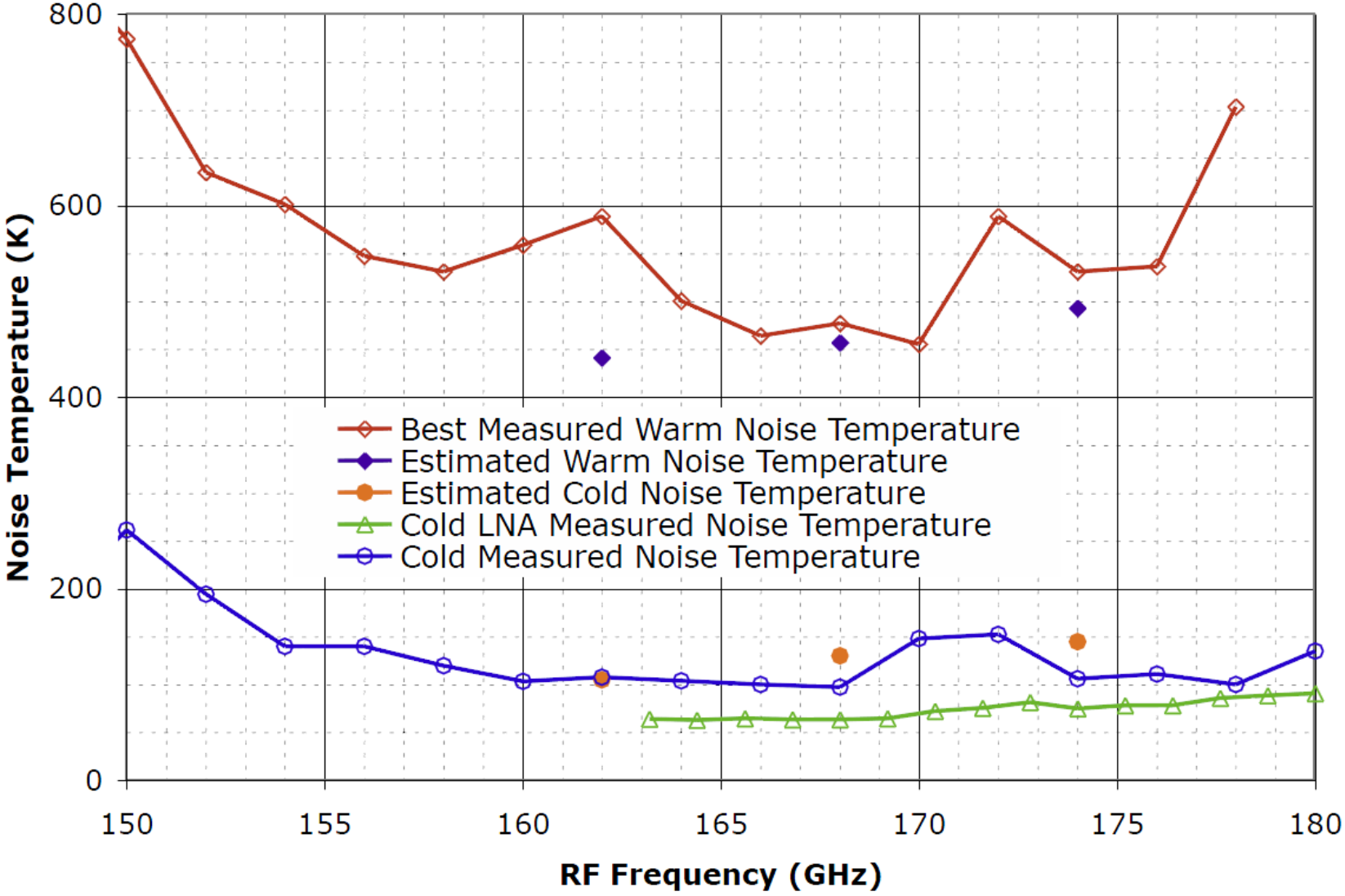
150 GHz MMIC receiver module, with local oscillator applied.

Tambient = 21K, Two LNAs in module



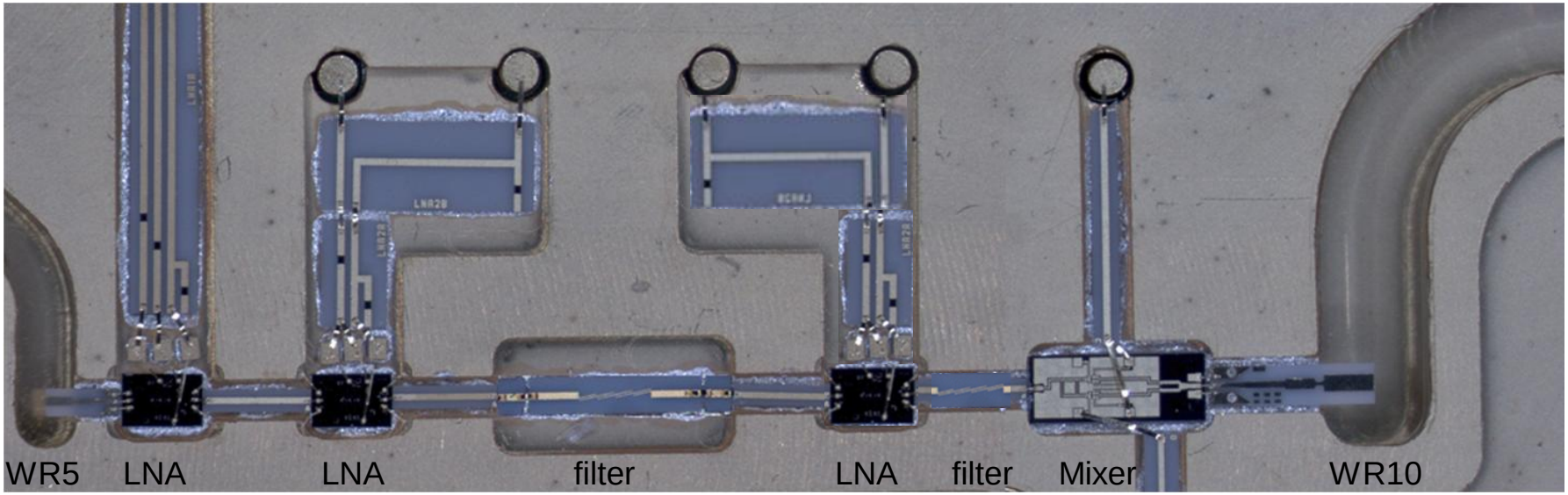
Cryogenic Measurements obtained 10-1-2010, using Horn and 1 mil mylar window. There is no attempt at backend correction or correction for the window.

Comparison: Room Temperature vs. 20K Data

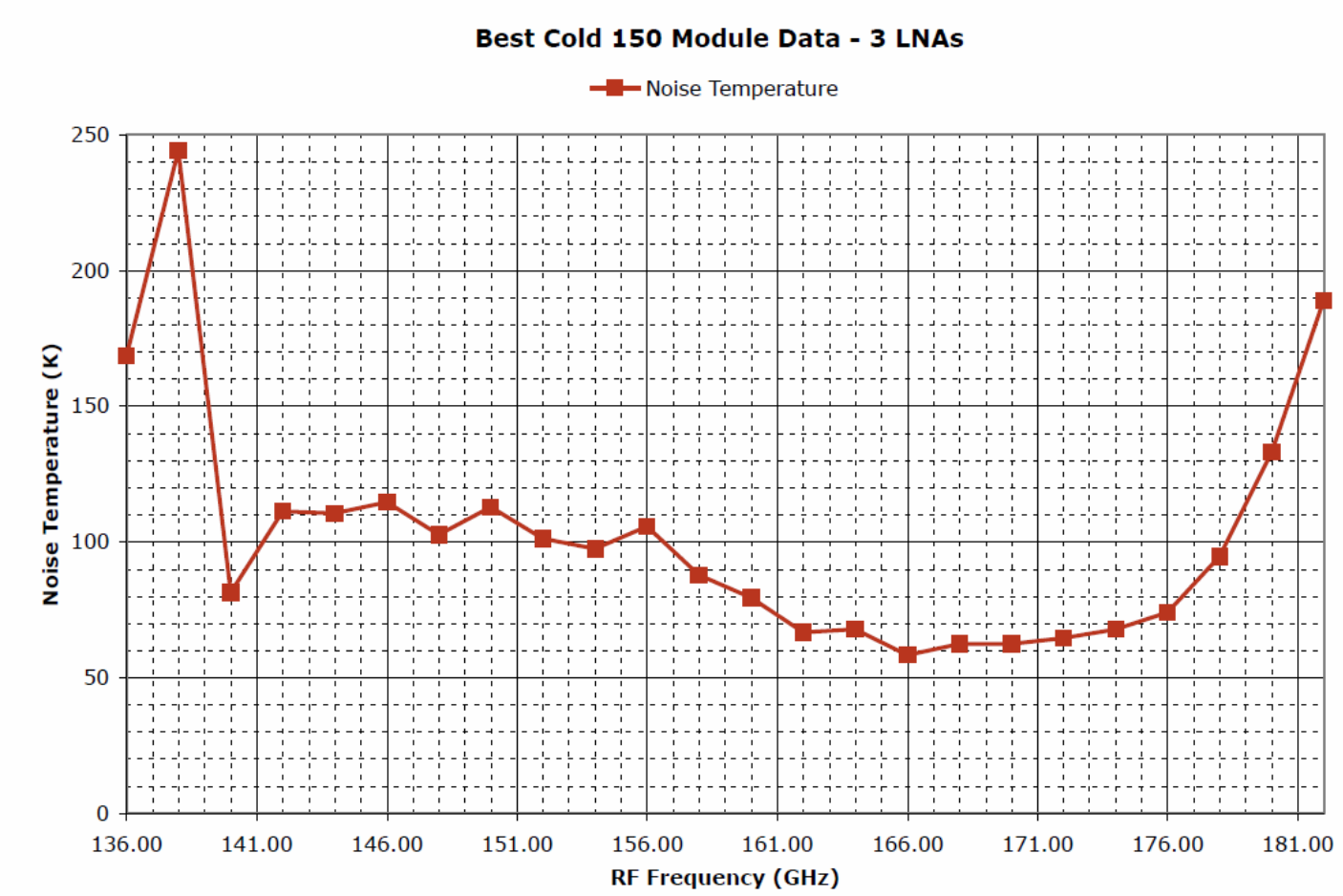


Note: Measured 20K amplifier-only data (obtained by T. Gaier) is shown in green, corrected for backend noise. Noise is as low as 60K.

A third LNA of the same type was added to the module to improve the overall module receiver gain and noise.

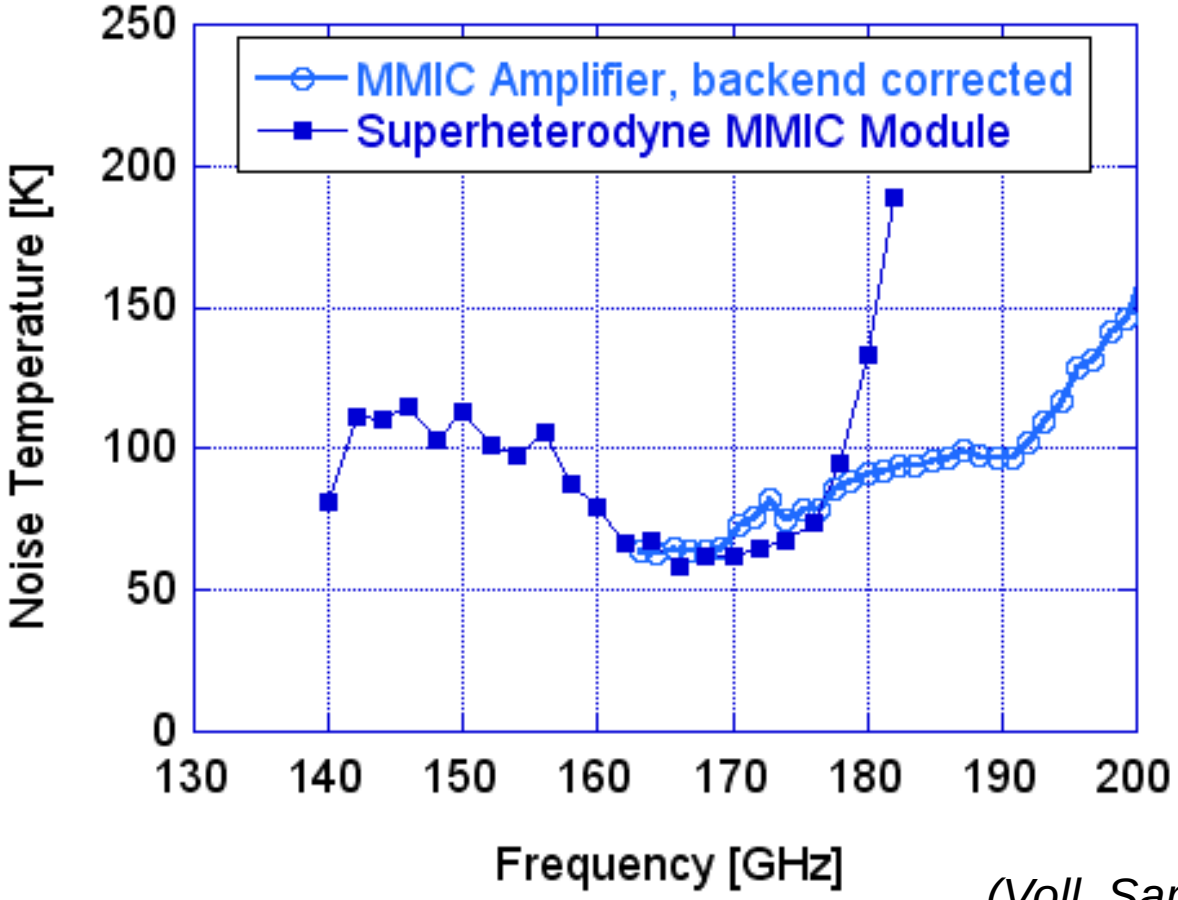


Tambient = 21K



Cryogenic Measurements obtained 12-10-2010 with 3 LNAs in the module, using Horn and 1 mil mylar window. There is no attempt at backend correction or correction for the window. Trec of 60K is obtained at 166 GHz. *(Voll & Samoska)*

Comparison of Single LNA vs. Superheterodyne Module



(Voll, Samoska, Gaier)

Addition of a third LNA improves the overall receiver gain and module noise. The noise is nearly identical to prior backend-corrected amplifier noise data in the 163-178 GHz range. The filter is responsible for the noise increase above 180 GHz, designed to block out the 183 GHz line.

Summary to Date

We have designed, built and tested cryogenic MMIC Receiver module for 140-180 GHz

The module appears to be stable when cooled to 21K.

This noise data (Tsys~60K at 166 GHz) will likely improve with an improved mixer chip. Replacing the LNA with a 100% InAs channel device may improve the noise further.

Comparison with an amplifier-only module, corrected for backend noise, shows that 60-70K is possible not only from individual LNA modules, but for a full receiver module.