

# Cryogenic Measurements of 183 GHz MMIC Low Noise Amplifiers

Douglas Dawson<sup>1</sup>, Todd Gaier<sup>1</sup>, Rohit Raja<sup>2</sup>, Matt Nishimoto<sup>2</sup>, Rich Lai<sup>2</sup>, Mary Wells<sup>1</sup>

<sup>1</sup> Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109-8099

<sup>2</sup> NGST One space Park Redmonds Beach, CA

**Abstract** — We report the packaging and first measurement of Indium Phosphide (InP) monolithic microwave integrated circuit (MMIC) low noise amplifiers (LNAs) operating at cryogenic temperatures above 140 GHz. The amplifiers were measured from 160 to 188 GHz at 20K and tested for noise temperature and gain, with noise temperatures of 160K. The packaging method and test setup will be described, as well as the detailed results at room and cryogenic temperatures.

## I. INTRODUCTION

Atmospheric humidity can be measured by monitoring emission at frequencies on and near molecular lines (e.g. H<sub>2</sub>O at 22 or 183 GHz). Observation of H<sub>2</sub>O at higher frequencies results in much smaller antennas for a given resolution. Additional data products in the 170-210 GHz band are, stratospheric ozone, and the abundance of ClO (the predominant form of reactive chlorine that destroys ozone), N<sub>2</sub>O, HNO<sub>3</sub>, and volcanically-ejected SO<sub>2</sub> [1-3].

Satellite millimeter wave remote sensing of these lines provides a powerful method for global atmospheric chemistry and climate science. The most sensitive receiver front end to detect these lines would be an SIS mixer. SIS mixers require cooling to a physical temperature of 4 K, necessitating high mass and power coolers in the spacecraft. Less complicated cooling technology is required to cool to 20 K. A MMIC based receiver at 20 K might be less sensitive than an SIS, but can provide valuable science data at much less system power and mass cost.

In order to quantify the noise temperature of such a MMIC based receiver, we have packaged and measured several InP MMIC LNAs from TRW [4], and tested them for noise and gain at 20K.

## II. MMIC LOW NOISE AMPLIFIER

The advancement of InP high electron mobility (HEMT) transistors [5] has allowed the production of low noise amplifier designs at over 100 GHz [4,6-7].

The highest frequency designs reported are by TRW[4] and JPL[7]. The TRW designs work well at 183 GHz, and were chosen for the cryogenic tests

## III. PACKAGING CONCEPT

Each individual MMIC was packaged in its own waveguide housing to allow for ease of assembly and troubleshooting. The basic housing has waveguide inputs and outputs that transition to microstrip guide through a 2mil thick Alumina planar transition [8]. The microstrip lines are then directly connected to the RF pads of the MMIC with ribbon bonds. The DC bias circuitry is connected to the MMIC with ribbon bonds, passed through 50pF bypass caps, and then sent to a DC board. The board has a 0.1 microfarad cap to ground on the drain line, and can incorporate resistive dividers if needed. A regulated power supply designed to power HEMTs is connected to the input of these DC boards. A picture of the MMIC in the housing cavity is shown below.

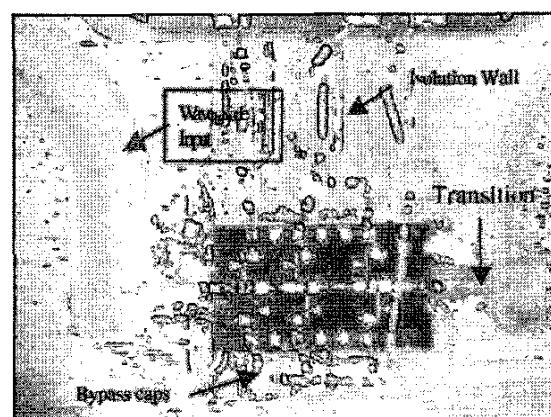


Fig. 1. TRW ALPH14 MMIC in waveguide package used for cryogenic testing.

The size of the chip cavity is too large to ensure that it is cutting off the unwanted cavity resonance modes, which have caused oscillations at certain bias points.

Newer versions of the chip, currently under test, will have a smaller footprint; allowing for a smaller cavity to shift the resonances frequencies out of band, or to allow for absorber to damp the potential resonances. The walls leading to the DC cavity provide isolation from the bias board, while still allowing room for the bypass caps.

#### IV. ROOM TEMPERATURE RESULTS

Two of the amplifier blocks were cascaded with a packaged filter to check the gain and noise temperature at room temperature. The overall noise figure is about 7 dB, which is 1.5 dB higher than the TRW result. Some of this is due to the architecture of placing a filter between the two amps.

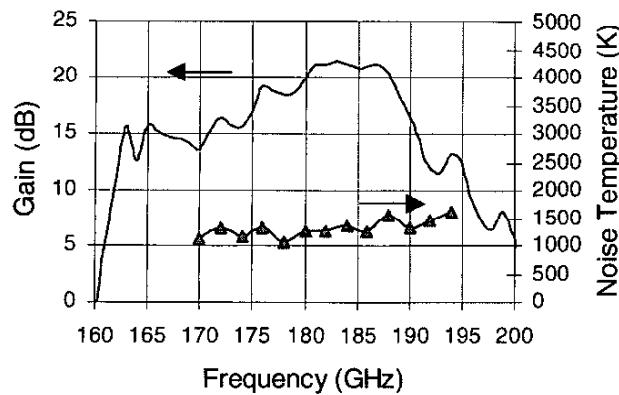


Fig. 1. Cascaded LNA blocks gain and noise figure at room temperature.

#### V. CRYOGENIC TEST SET

The cryogenic test was performed by placing two of the packaged amplifiers in a cryogenic chamber with a waveguide feed horn at the input, connecting them through thermally isolating stainless steel waveguide to an external amplifier and downconverter, and feeding that into an external noise test set up. A 3 mil mylar window into the chamber provides the path for using an external load as the added noise generator. The noise contributions of the back end components outside of the chamber were measured and removed from the results, and the downconverted output power was measured for calculating the Y factor. Fig. 2, below, shows the test set.

#### VI. CRYOGENIC RESULTS

Once the chamber was cooled to 20K, the noise of the two cooled amplifiers was optimized versus bias, and measured over frequency. No attempt was made to correct for the loss in the connecting waveguide after the amps inside the chamber, so the gain is actually 3-5 dB higher than measured. The window between the horn and the absorber caused an input mismatch, which shows clearly in the noise and gain data as ripple. We estimate the window is causing 10 to 30 K noise temperature error depending on the phase of the noise paths, but no correction for this has been attempted.

Fig 3 shows the noise temperature at 180 GHz and the drain currents at constant voltage bias as a function of physical temperature. The noise decreased from

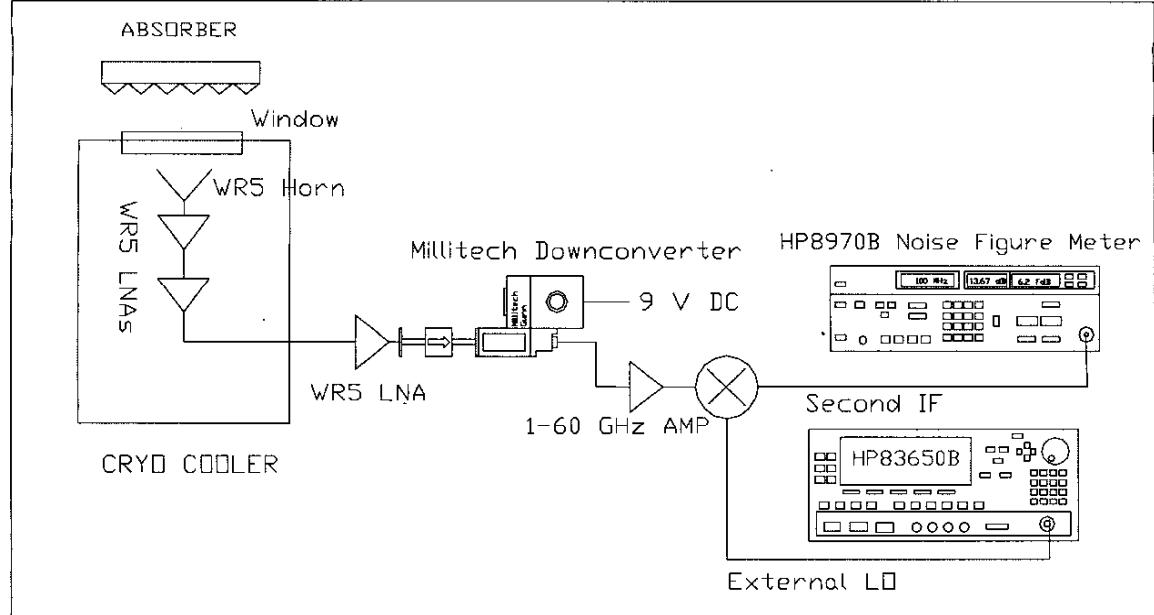


Fig. 2. Cryogenic Test Set

approximately 1000K to 200K, and the drain currents dropped by a factor of 2. Fig. 4 shows the optimized noise temperature and gain of the cascaded blocks at 20 K, as a function of frequency. The noise temperature is 130-230 K across the band, and the gain is 15-22 dB.

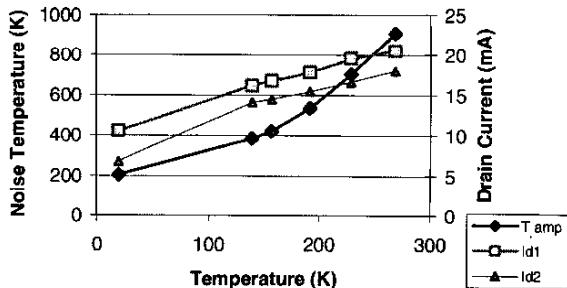


Fig. 3. Cascaded LNA blocks noise and drain current vs temperature.

## VII. CONCLUSION

We have packaged and measured the first reported cryogenic noise temperature and gain for a MMIC LNA at 180 GHz. The noise temperature is 130-230 K across the band, and the gain is 15-22 dB.

## VIII. ACKNOWLEDGMENT

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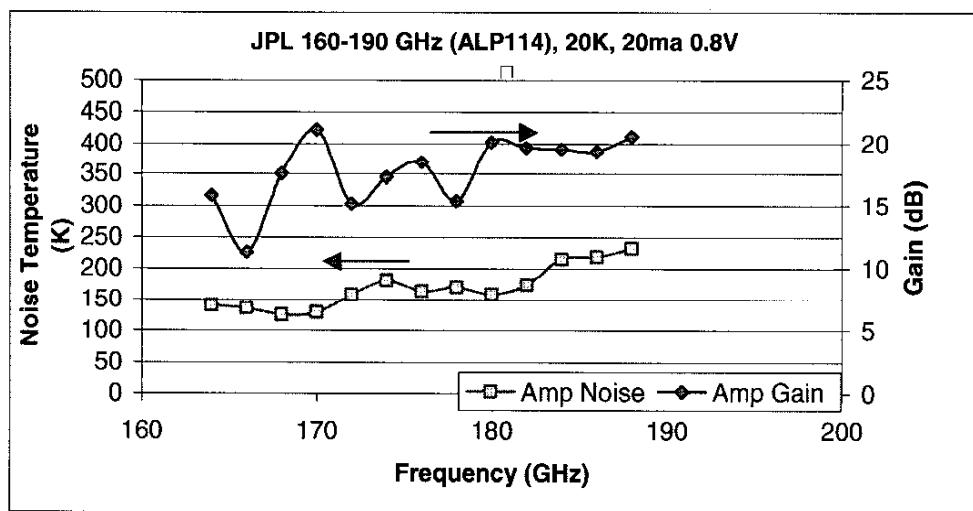


Fig. 4. Cascaded LNA blocks noise and gain at 20K vs frequency