Arizona State University Ultra High Gain Low Distortion Cryogenic Low Noise Amplifier

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***Abstract*— Arizona State University's radio astronomy lab has developed several cutting edge custom low-noise amplifiers (LNAs) over the past year. These LNAs cover a range of bandwidths and operate at room and cryogenic temperatures. Here we present one of the custom LNAs that is a multichannel, high-gain amplifier for use at baseband frequencies in terahertz heterodyne receivers. The LNA has wide a bandwidth of 0.1-3 GHz, low noise (NF < 1 dB) and an impressive gain of 90 dB. This LNA uses cost-effective, commercially available components and is packaged for easy integration into receivers in a custom compact enclosure that divides each channel into three isolated compartments to prevent crosstalk and oscillations. A combination of Silicon Germanium (SiGe) HBT and Gallium Arsenide (GaAs) HEMT transistors have been used to achieve the desired performance levels. A bias-dependent gain flatness of less than +/- 1 dB has been measured on the 0.5-3 GHz band. Power consumption per channel ranges from 195.5 mW at 90 dB of gain down to 71.5 mW at 80 dB of gain while maintaining state-of-the-art levels of power dissipation.**

***Index Terms*—Baseband, Cryogenic, High Gain, LNA, Low Noise Amplifier, Wideband**

I. INTRODUCTION

For the past decade Arizona State University (ASU) has been on the cutting edge of custom made cryogenic low noise amplifiers (LNA). The standard LNA's built have a frequency range of 10MHz to 2GHz and 0.5GHz to 3GHz. Both yield a gain of 30dB at relatively low power consumption (300K: P_{2GHz} = ~40mW, 10K: P_{2GHz} = ~13mW; 300K: P_{3GHz} = ~70mW, 10K: P_{3GHz} = ~10mW). This LNA was a custom build, created for a project called Comets Observation & Mapping Terahertz Spectrometer (COMETS), a Terahertz Mapping spectrometer satellite. The project is led by NASA JPL [1]. The LNA uses commercially off the shelf components to achieve its high gain flatness.

II. MATERIALS & METHODS

Using commercially off the shelf components, from the standard LNAs that are built at ASU, such as Silicon Germanium (SiGe) Heterojunction Bipolar Transistor (HBT), Gallium Arsenide (GaAs) High Electron Mobility Transistor (HEMT) and gold wire bonds, were chosen to achieve these performance levels. A bandwidth of 0.1 to 3GHz and a noise factor of <1 that has a bias dependent gain flatness of ±1 dB. Each channel is separated into three compartments in a custom designed compact enclosure. Its noise temperature is ~80K at room temperature and can be easily integrated as an effective IF amplifier for terahertz receivers.

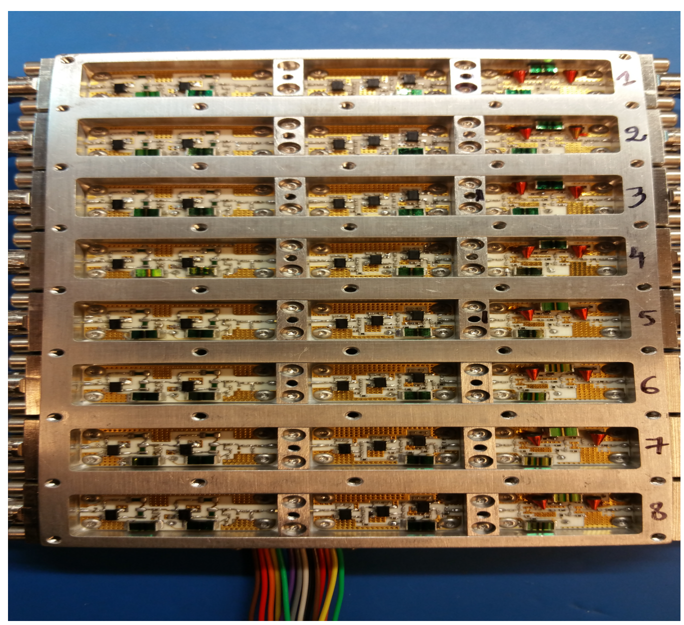


Fig 1. Shows the 8 channels and their individual and separated amplifier PCB's.

III. RESULTS

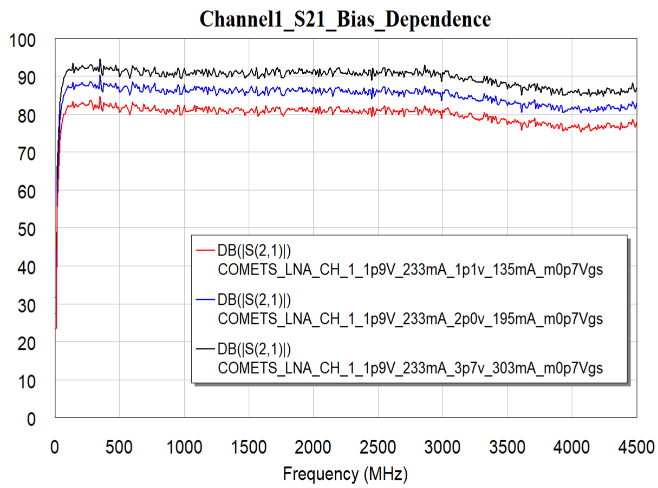


Fig. 2. S-parameters showing the bias dependency and the gain flatness for Ultra High Gain Low Distortion Cryogenic Low Noise Amplifier

Figure 1 plots the gain through the amplifier at three separate biases. At full bias (~195.5 mW per channel), a stable 90 dB gain was continuous across the entire bandwidth with a gain flatness of (+/-) 1 dB. The lowest bias tested (~71.5 mW per channel) still was able to maintain 80 dB of gain across the bandwidth with a similarly impressive gain flatness. The LNA can be biased between these power levels as well for intermediate gain.

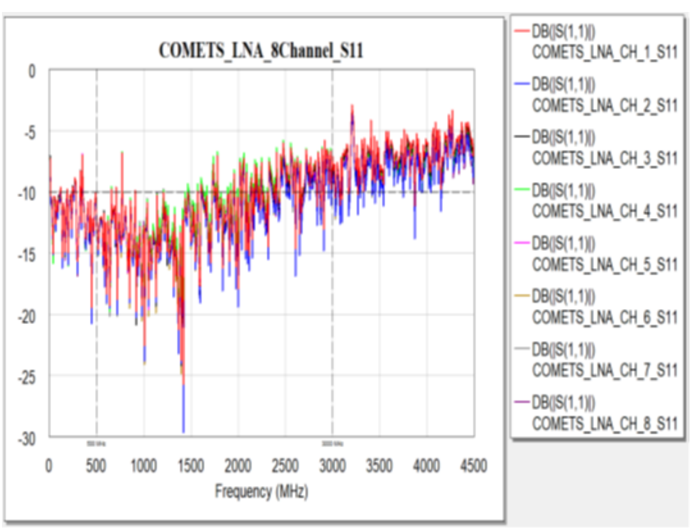


Fig. 3. A plot of the S11 vs Frequency. As Seen, S11 Is below -5 dB across the 0.5 to 3 GHz span.

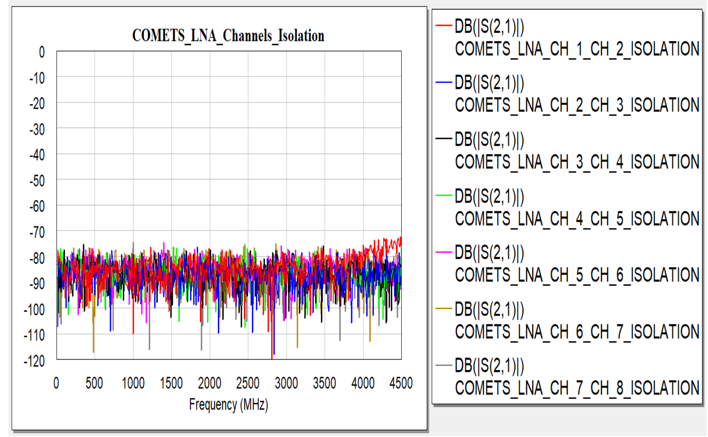


Fig. 4. Isolation across the 8 channels of the amplifier show that there is no crosstalk.

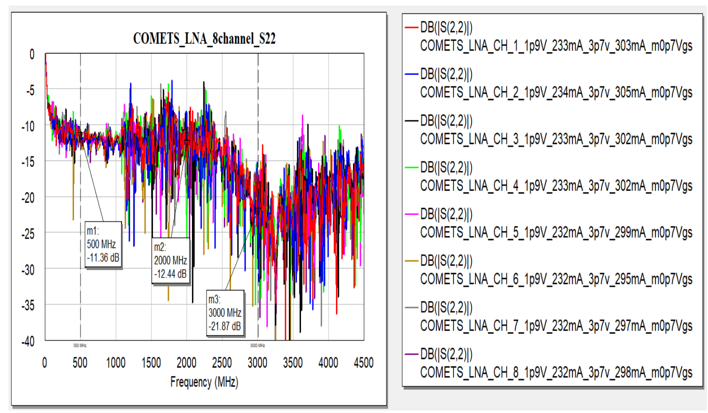


Fig. 5. A plot of the S22 vs Frequency. Seen, is the amplifier around -10 dB with partial spikes showing up barely exceeding -5 dB

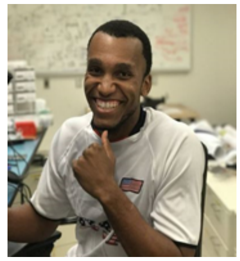
Referring to figure 2, we see the gain (S21), with ±1 dB gain flatness. Figure 3, shows the amplifier's reflection (S11), which stays below -10 dB from 0 to about 2 GHz, but stays below -7 dB from 0 to 3 GHz. Figure 4, illustrates that there is negligible crosstalk between the 8 channels of the amplifier when all channels are powered at the same time. Last we have figure 5; showing the reflection at the tail end of the amplifier measurement (S22), which stays below -10 dB with a few spikes here and there that barely exceed -5 dB.

IV. DISCUSSION/CONCLUSION

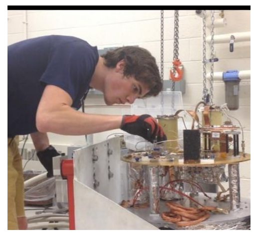
The data has come to fruition through days of design and testing using a 10K cryostat and off the shelf components. After significant designing, building, and testing, the JPL COMETS LNA has fulfilled all intended goals. What was achieved was a bias dependent amplifier whose frequency spans from 0.1 to 3 GHz and has a flatness of ±1 dB. It can achieve 90 dB of gain at relatively low power consumption. The minimum power that was tested was 71.5 mW yielding 80 dB of gain and the max at 195.5 mW yielding 90 dB of Gain. With a noise temperature tested at room temperature is at ~80K and the believed noise factor is <1.

Future endeavors for this amplifier, is to build several stand-alone single channel versions to show repeatability not only among the gain but also with the P1dB and IP3. To see the amplifier in use, a similar amplifier will be used for ASTHROS.

Hamdi Mani worked in the electrical engineering department at Caltech as a research assistant from 2005 to 2010 developing cryogenically cooled low noise amplifiers for radio astronomy. He graduated from Arizona State University with a B.S in Physics and works in the Radio Astronomy Terhertz laboratory at ASU. He is an RF/Microwave engineer developing RF/Microwave instruments for an assortment of radio telescope receivers and projects that operate at different wavelengths. His main work and interest is in extremely low noise amplifiers (LNAs) operating at room and cryogenic temperatures along with noise measurement techniques for ultrasensitive LNAs.



Justin L. Mathewson received a B.S. from Arizona State University from the School of Earth & Space Exploration in Exploration Systems Design in 2015. He works in the Radio Astronomy Terahertz laboratory as a Research Specialist at ASU. His main work is in designing, building and testing room and cryogenic low noise amplifiers for radio telescope receivers and projects that operate at different wavelengths.



Jonathan R. Hoh is a Ph.D candidate in astrophysics and a Master's student in Microwave engineering at Arizona State University, School of Earth and Space Exploration. His academic interests include the design and miniaturization of Terahertz frequency heterodyne detection systems along with the implementation and readout of microwave kinetic inductance detector.