A 230GHz MMIC-based Sideband Separating Receiver

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Abstract— **A sideband-separating receiver operating from 180 to 270 GHz is under development. This receiver utilizes 30nm InP HEMT MMICs for the front-end low-noise amplifiers and balanced mixers cryogenically cooled to 22 K. This paper presents the room temperature characterization of the individual components and the development of the cryogenic test system.**

I. INTRODUCTION

MMIC-based radiometers are very attractive for radio astronomy and Earth science applications since their limited cooling requirements and front-end gain simplifies instrument design compared to SIS-junction mixers. For space-borne instruments 20 K cooling is much lower risk because 4 K close-cycle coolers are power hungry and has limited flight heritage. Finally, the MMIC's sensitivity degrades gracefully as temperature increases whereas SIS receivers do not operate at all above their critical temperature, generally around 10 K.

The emergence of the Northrop Grumman's 30nm gate InP HEMT process has enabled MMIC technology above 300 GHz. These devices have f_T > 1000 GHz, enabling amplifiers up to 700 GHz [1]. These new devices also offer higher performance at lower frequencies, such as the amplifier used in this work, which offers 40% bandwidth centered at 225GHz. This paper presents the development of a cryogenically cooled MMIC-based single-sideband receiver operating from 180 to 270GHz.

II. RECEIVER DESIGN

The sideband separating receiver is shown in Fig. 1 and consists of a front-end LNA, a 90 deg hybrid, two MMIC balanced mixers and a Y-junction. The system consists of discrete blocks to ease testing and development of each component.

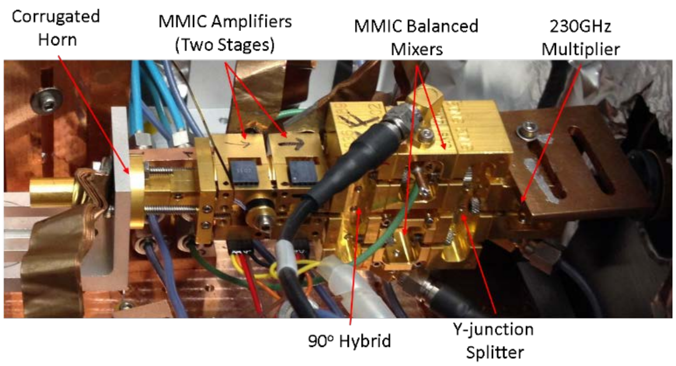

Figure 1: The 180-270GHz sideband-separating receiver mounted into the cryostat.

The LNA was designed and fabricated at Northrop Grumman Aerospace Systems in their 30nm InP HEMT process. This amplifier covers 180 to 270 GHz with a noise temperature below 150 K and a gain of 16dB when operated at 27K ambient as previously presented in [2].

The 90 degree hybrid and Y-junction splitters are traditional designs based on [3] and [4]. Overall amplitude and phase imbalance from these components is less than 1.5 dB and 4 deg, setting an upper limit on the sideband rejection ratio of 20 dB.

In anticipation of eventual monolithic fabrication of the mixer with the LNA, the mixer designed for this system is also fabricated in the InP MMIC process. It is fabricated as a discrete component to allow for individual testing of the device, as shown in Fig. 2. The balanced mixer pumps two transistors out of phase with a transmission line length difference of 180 degrees at 230 GHz. At room temperature the mixer provides 10dB conversion loss and 3000-6000 K DSB noise temperature. When cooled to 20K the noise temperature drops to 2000-3000K.

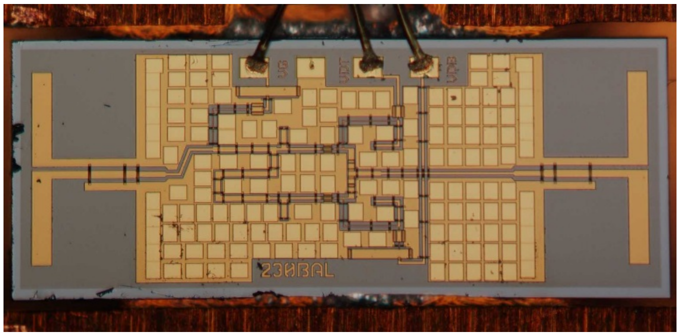

Figure 2: The 230GHz balanced mixer. LO power couples from the left waveguide probe and the RF coupled from the right.

III. Cryogenic Measurement Setup

A cryostat has been developed with an optical chopper and hot and cold loads inside the vacuum chamber to avoid the errors introduced by coupling out a window. Fig. 3 shows the vacuum chamber with the three optical paths selectable by the chopper blade: hot load (290K), cold load (120K, connected to the 77K cold stage of the refrigerator) and test signal (~100um). The system is cooled with a CTI-Cryogenics GM refrigerator capable of reaching 13 K.

The receiver is mounted to the cold plate along with the multiplier as shown in Fig. 1. The receiver is pumped from outside of the cryostat with an Agilent synthesizer W-band source module amplified by GaAs amplifier modules producing 80-100mW of power. The I&Q outputs of the two mixers are connected to a room temperature IF hybrid through a vacuum feedthrough.

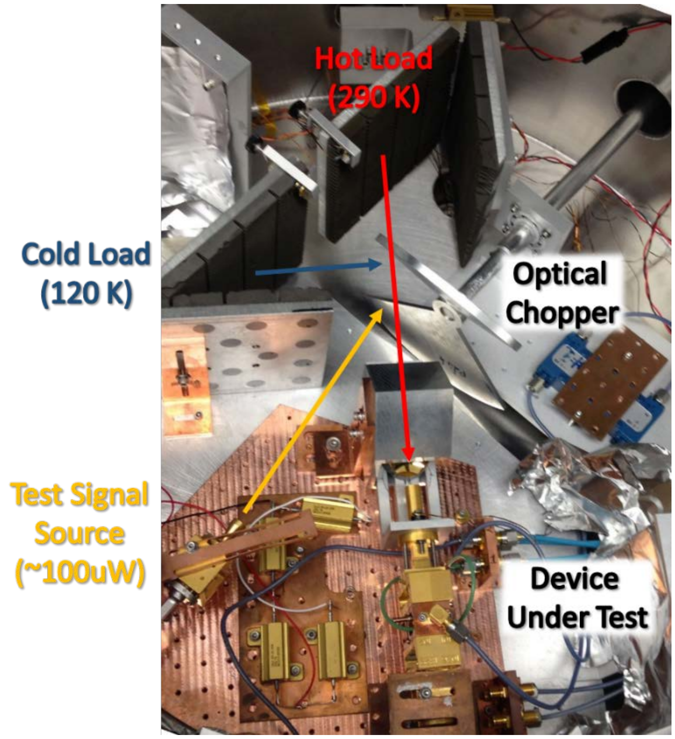

Figure 3: The optical setup inside the cryostat. The optical chopper can select three different optical paths to couple to either the hot load, cold load or a test signal.

IV. Conclusions

The paper presents the application of new HEMT MMIC technology to the development of a single-sideband receiver sensitive enough to replace SIS mixers. The individual components have been tested and an appropriate cryogenic test bench has been developed. Cryogenic measurements of the sideband separating receiver will be presented at the conference.

Acknowledgment

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References

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