Low Noise Amplifiers in InP Technology for Pseudo Correlating Millimeter Wave Radiometer

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Abstract **This decade will be very important for cosmology due to several missions to measure the cosmic microwave background radiation. These measurements require highly sensitive radiometers operating over a very wide frequency spectrum. The millimeter wave radiometers are best developed as pseudo correlating radiometers due to the inherent stability and high sensivity of this instrument. To miniaturize the size and power consumption of these radiometers we have developed the critical low noise amplifier and phase switch MMICs using high-performance InP technologies. The low noise amplifiers achieved record 2.3 dB noise figure over the 60-80GHz frequency band at room temperature and less than 25 K noise temperature at 20 K ambient temperature. These MMICs form the building blocks for 70GHz highly sensitive correlating radiometers, that are needed e.g. in the ESA Planck mission**

I. Introduction

The current decade will shed light to many of the fundamental problems of cosmology by measurements of the properties of the Cosmic Microwave Background (CMB). These CMB measurements require radiometric receivers with unprecedented stability and cryogenic noise temperature to obtain the required sensitivity. Several space missions to map the CMB are under operation or planning; COBE was the first of these (launched in 1989), it will be succeeded by Microwave Anisotropy Probe (MAP) within the first half of this decade and during the the second half of this decade by Planck. For these missions the development of InP HEMT technology has been of uttermost importance. Improvements in the HEMT device performance and integrated circuit processing yield and reliability enable the design of ever more complex instruments with large numbers of detectors. The COBE and MAP missions used discreet InP HEMT devices in the LNAs of the radiometers, however, the goal in future missions, such as Planck, is to use InP MMIC technology.

This study aims to address the development of InP MMIC LNAs for use in 60-80 GHz pseudo-correlating radiometer. The objectives of this paper are as follows: to demonstrate optimum microstrip and CPW LNA designs for minimum noise; to present design of these LNAs for gain and phase match between individual devices; and to present the design of these LNAs in minimum size to enable assembly of the MMICs in resonant free cavities.. Finally, the operation of the developed low noise amplifier MMICs are demonstrated in a 60-80GHz pseudo correlating radiometer.

II. Design of Low Noise Amplifiers

Low noise amplifiers are key components in the development of low noise receivers. The successful design of LNAs is possible only with high performance foundry processes. For this work we used the state-of-the-art InP process of TRW[1]. This process features 0.1µm gate-length, very high device transconductance above 1000mS/mm, cutoff frequencies above 200 GHz, thin film capacitors and resistors. The 75µm substrate enables both grounded CPW and microstrip design. This process has been used to develop 3dB noise figure broadband LNAs for W-band[2].

InP HEMT modeling is an important part of LNA development. Device models used in this work were based on hot and cold measurements of HEMTs[2] and on-wafer noise parameter measurements at 50-75GHz. These measurements were used to extract a Pospieszalski noise model [3].

The design of the LNAs incorporated four-stages of amplification. Each stage had an optimum size device to match the devices to noise minimum in each interstage matching network. The gain match was improved by using source inductance in each stage and employing thin-film 50Ω resistors in the gates of second to fourth stage. The layout of the CPW LNA is shown in Figure 1 and the

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microstrip LNA in Figure 2. The compact size of the designs make them inherently broadband, due to the short electrical distance between the amplification stages and, most importantly, reduced number of matching elements. The broadband nature of the LNAs and low number of matching networks improve also the phase matching between individual LNAs.

III. Experimental Results

The developed LNAs were measured on-wafer. Figure 3 shows the results of a typical microstrip LNA performance. These LNAs have the required flat gain and noise figure across the 60-80GHz frequency band. The CPW design measurement results (Fig. 4) indicate nearly similar results. The gain has some roll-off at the higher end of the frequency band, although not clearly visible in Figure 4. The CPW design noise figure is a few tenths of degree higher, potentially due to the inherent higher losses in CPW transmission lines than in microstrips.

These LNAs were mounted in packages that had WR-15 input and output waveguides. CPW to waveguide transitions on 100 µm alumina substrate were designed using FDTD electromagnetic simulations. These transitions were based on previous designs at W-band [4]. Figure 5 shows cryogenic noise of less than 25K over a narrow band and in a second amplifier, 35K over the desired frequency band. The transitions needed tuning with bonding wires to achieve these results and we expect to obtain broadband noise temperature of less than 30K with a redesign of the transitions.

IV. Measurements in a Pseudo Correlating Radiometer

Packaged LNAs were selected for best gain and phase match to realize the pseudo correlation radiometer. It is important to have very good balance between the two legs of the radiometer to obtain sufficient isolation between the source and the reference signals. Figure 6 shows the measured isolation between the two legs of the radiometer in room temperature. This radiometer has now been installed in a cryogenic chamber for measurements in 20K ambient temperature. Figure 7 shows the cryogenic chamber assembly and topology diagram.

V. Conclusion

We have demonstrated the design of very low noise, broadband InP MMIC LNAs using microstrip transmission lines and in a separate design, grounded CPW lines. These LNAs provided 2.3dB noise figure and 24-27dB gain over a very broad frequency bandwidth. When cooled to 20 K, the LNAs had less than 25K noise temperature. These properties were critical in the realization of the pseudo correlation radiometer breadboard that demonstrated sufficient isolation and low noise performance at room temperature. The radiometer breadboard is currently in cryogenic testing.

VI. Acknowledgement

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VII. References

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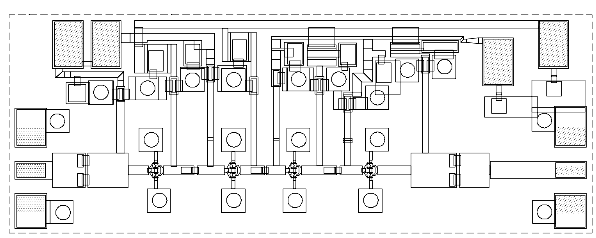


Figure 1. Layout of the microstrip LNA. Chip size is $2.1x0.8mm^2$.

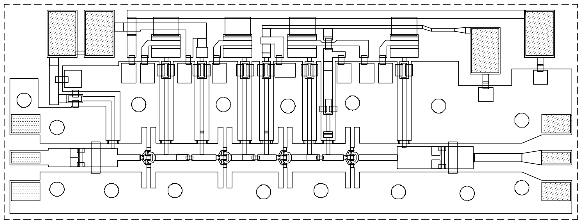


Figure 2. Layout of the CPW LNA. Chip size is 2.1x0.8mm^2.

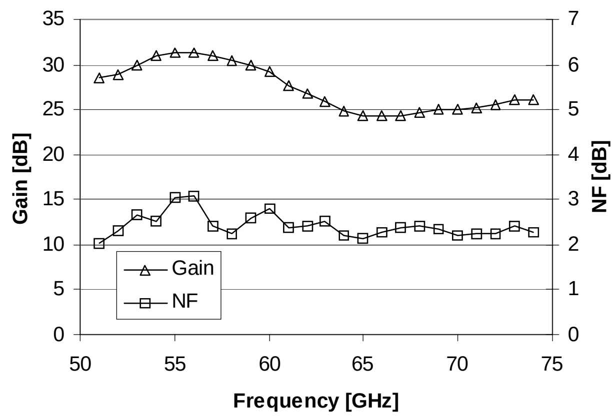


Figure 3. Measured gain and noise figure of the microstrip LNA. The gain is 24 to 27dB and noise figure 2.3 dB in the frequency range 60-80GHz. The MMIC is biased to Vd=0.7V, Id=28mA

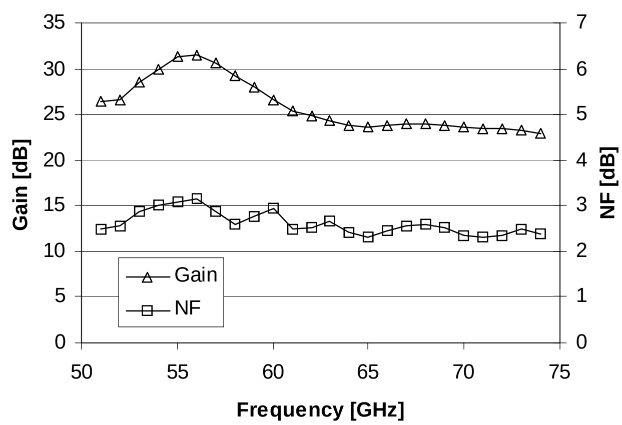


Figure 4. Measured gain and noise figure of the grounded CPW LNA. The gain is 23 to 26dB and noise figure 2.5 dB in the frequency range 60-80GHz. The MMIC is biased to Vd=0.7V, Id=28mA

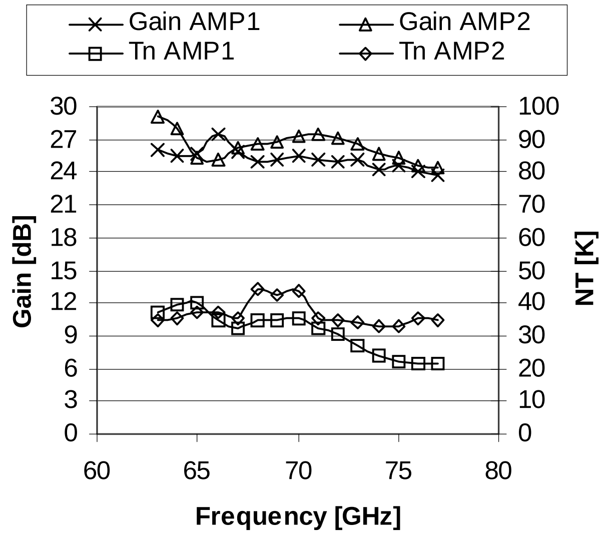


Figure 5. Measured gain and noise temperature of two packaged LNAs at 20K ambient temperature. The gain is 24 to 27dB and noise temperature is less than 25K from 73 to 77GHz. In the frequency range 60-80GHz the noise temperature is 35K. The LNAs are biased to Vd=0.8V, Id=8mA.

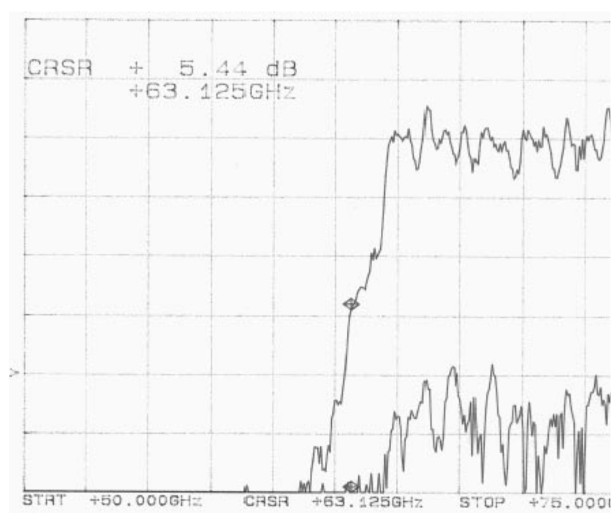
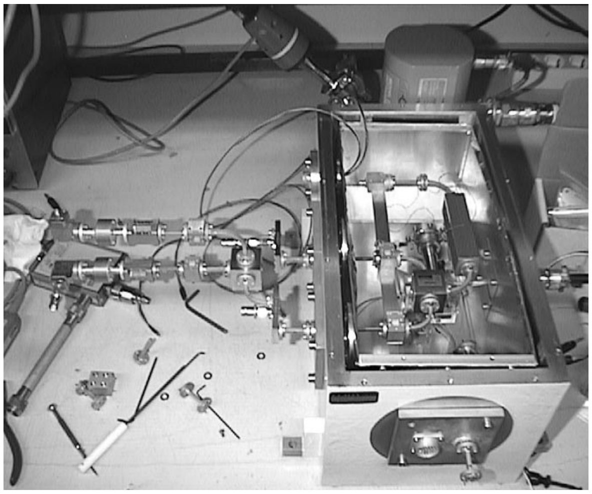


Figure 6. Measured isolation between the legs of the radiometer. The scale is 5dB per division and frequency range is 50 to 75GHz. The radiometer has 20dB isolation between the signal and the reference. The room temperature noise temperature of the radiometer is Tn=430K. The frequency band of the radiometer is limited to 65-80GHz by a bandpass filter.



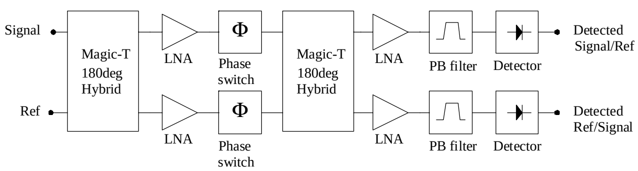


Figure 7. In the photograph the radiometer is shown assembled in a cryostat. The topology of the radiometer is described in the schematic diagram.