NOISE MEASUREMENTS OF INDIVIDUALLY PACKAGED 70 GHZ RADIO ASTRONOMICAL AMPLIFIERS FOR THE PLANCK SATELLITE MISSION

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ABSTRACT
A noise and gain responses of the individually packed cryogenic V-band INP-HEMT amplifiers was measured. The effect of the bias point to noise, gain and power dissipation was studied. An averaged 25 K noise temperature and over 20 dB gain was achieved over 20 % WR-15 waveguide operation bandwidth at 20 K physical temperature.

INTRODUCTION

During the last decade a new generation of INP-based cryogenic HEMT LNAs have given promising result from the space industry point of view e.g. [1]-[7]. The Planck satellite LFI (Low Frequency Instrument) 70 GHz receivers are based on INP HEMT LNAs [8],[9]. The required relative sensitivity ~$3.6 \cdot 10^{-6}$ of the 70 GHz receiver with 40 second integration time and with 20 % frequency bandwidth demand the system noise temperature to be below 25 K at 20 K physical temperature [10]. At the same time maximum power dissipation of one MMIC LNA is 15mW [10]. The effect of bias point of four stage 70GHz INP-HEMT-LNAs to meet the requirements are studied.

DESCRIPTION OF THE NOISE MEASUREMENT SYSTEM

The noise measurements are based on commercial HP 8970B noise measurement test system, block diagram in Fig. 1.

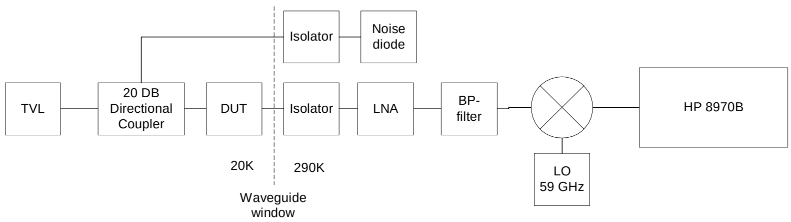

Fig. 1. A block diagram of the individual LNA noise measurement test system.

A HP 83557A mm-signal source module was used to generate LO frequency to external mixer. A similar LNA to the DUT was used as preamplifier before the mixer to increase measurements accuracy. A Millitech WR-15 biased mixer was used as the external mixer. A personal computer was used to control temperatures of the DUT and temperature variable waveguide load (TVL).

Waveguide parts inside the cryogenic chamber were measured with a VNA at room temperature. A coupling and insertion loss of the selected directional coupler and the return loss of the TVL are shown in Fig. 2a and 2b, respectively.

Fig. 2. a) 20 dB coupler coupling and directivity. B) Temperature variable load reflection loss.

Used directional coupler was Ylinen Electronics multihole WR-15 waveguide coupler. The design was made to optimize the insertion losses at 63 – 77 GHz frequency bandwidth. Coupling factor was selected to be ~20 dB because of the high noise temperature of the noise diode used. The temperature variable load was made of Eccosorb MF-117 absorber material at Ylinen Electronics.

MEASUREMENTS

Noise temperature of the DUT was measured by heating the TVL from 20 K to 50 K temperature and measuring SSB total power with 200 MHz frequency bandwidth over the operation frequency bandwidth (63-77 GHz) at 1 GHz increments. The noise diode was switched on while the TVL was at 20 K and 50 K temperatures. Noise temperature of the DUT, Fig. 3, was calculated from LNA output power levels, using Y-factor method and correcting the result with measured losses of the waveguides, physical loss temperatures, back end gain and noise temperature. 2 K physical temperature increment was noted while TVL was heated from 20 K to 50 K.

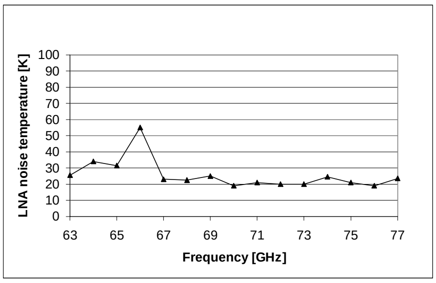

Fig. 3. Noise temperature of the DUT (AMP_02) at 20 K physical temperature.

Noise diode ENR-values were calibrated with the TVL using measured DUT noise temperatures and measured waveguide losses. The tuning of the DUT was done with calibrated ENR-values. Similar noise temperatures of DUT were measured with noise diode and TVL.

RESULTS

A DUT bias point was selected to be optimum for gain, noise and power dissipation performance. From that point bias voltages (V_{drain}, V_{gate1} or V_{gate2}) were tuned while the others were kept at the optimum value. The noise temperature was measured with the noise diode. As an example AMP2 cryo02 70LN5A measurement results are shown in Fig. 4-6.

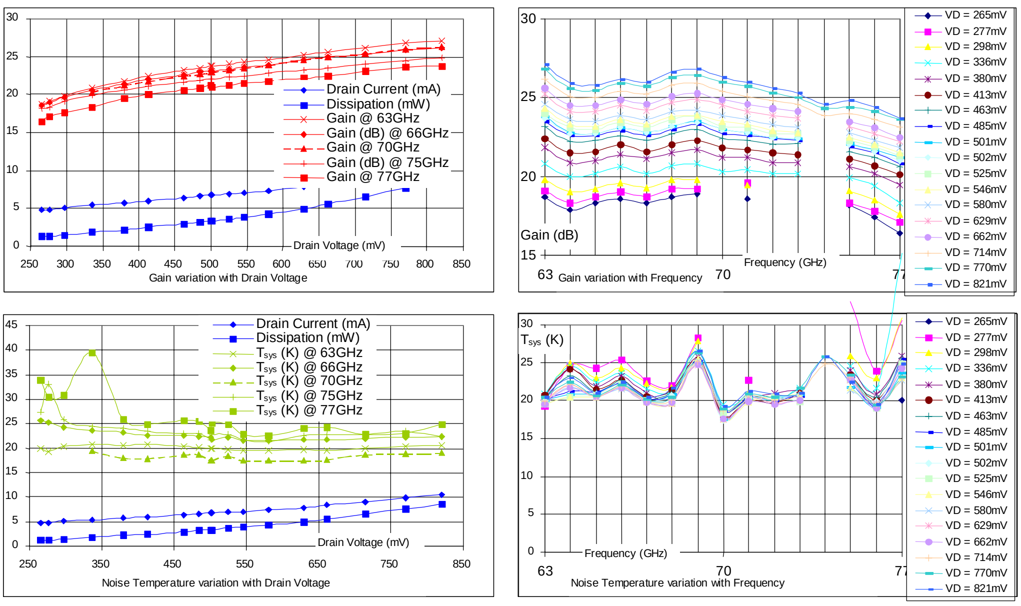

Fig. 4. AMP_02 T_{sys}, gain and power dissipation variation with tuned V_{drain}.

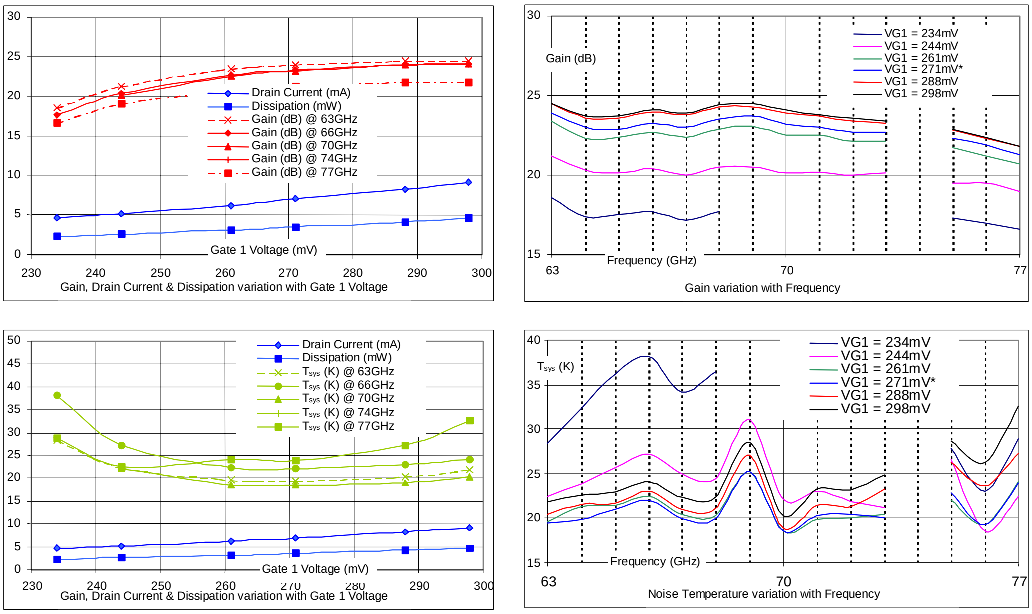

Fig. 5. AMP_02 T_{sys} , gain and power dissipation variation with tuned V_{gate1}.

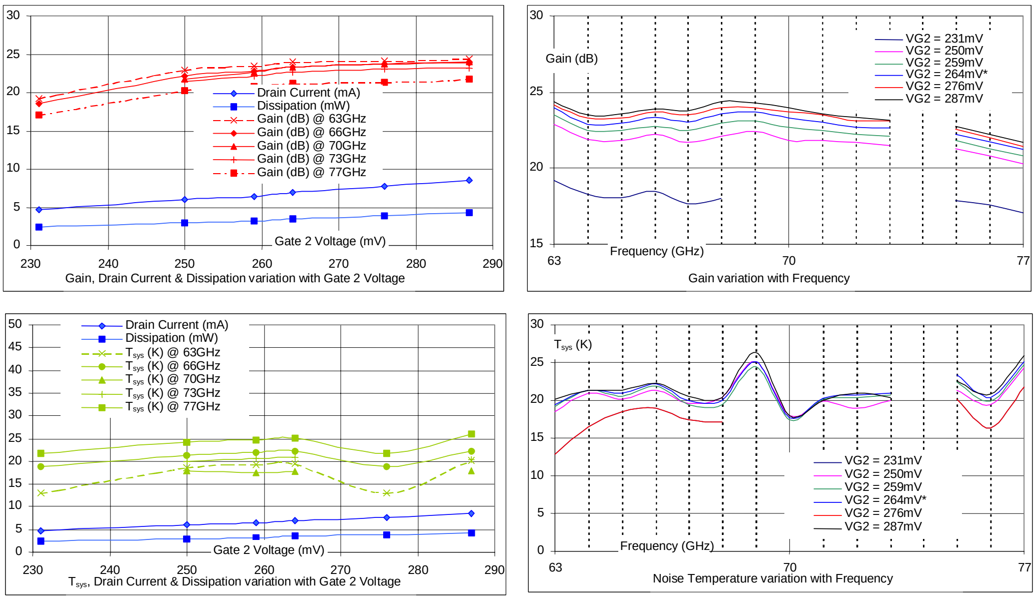

Fig. 6. AMP_02 T_{sys}, gain and power dissipation variation with tuned V_{gate2}.

From the figure 4, the drain voltage affects mainly the gain and power dissipation of the amplifiers. Gate 1 voltage which controls the first two gates of the LNA, most significantly affects mostly to the noise temperature. Gate 2 voltage provides only minor changes to the noise temperature and the gain.

An error estimation of the noise measurements was done with Monte Carlo method. The 10 and 90 % probability limits for the error estimations were ±2 K for TVL and ±4 K for noise diode measurements.

CONCLUSIONS

Very low noise packaged cryogenic V-band INP-HEMT-amplifiers were measured. At optimum bias setting 25 dB gain and 25 K noise temperature can be reached over 20% waveguide bandwidth. The drain voltage tuning provides a gain variation of 18-25 dB. Gate 1 voltage adjustment gives a 18-30 K noise temperature variation. LNA performance is much less sensitive to Gate 2 voltage tuning.

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