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Temperature Dependence of PHEMT Noise Parameters

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ABSTRACT

To compute and optimize the temperature performance of low noise amplifiers requires not only the temperature coefficients of all the small signal equivalent circuit parameters at the operating bias, but also the temperature dependence of the noise parameters. Hence, we present an experimental study of noise parameters as function of temperature to fill in the lack of the little data in the scientific literature.

INTRODUCTION

Very low noise figures with high associated gain performance requirements are now being met by the submicrometer PHEMT transistors, which are replacing MESFETs because of their lower noise performance for the same gate length. To support the design of communication systems such as low noise receivers, operating in varied environments, accurate noise models are required, which can predict all the noise parameters of the transistor over a wide frequency range [1], but also over a wide temperature variation. In this paper, we present a procedure for modeling the temperature dependence of both the small signal model and the noise coefficients that characterize the equivalent gate and drain noise sources. Experimental results are reported for $0.5\text{x}200\mu m^2$ PHEMT, and the extracted temperature dependent noise model is compared to previous works [2][3] in the same area using the same kind of device.

MODELING VERSUS TEMPERATURE

The modeling procedure is based on the noise equivalent circuit of Figure -1-. The intrinsic noise sources are represented by a drain current source, $<i_d^2>$, in parallel with the output conductance g_{ds}, and by a gate current source $<i_g^2>$ in parallel with C_{gs} and R_i. These two equivalent noise sources are correlated, and can be expressed with the frequency independent coefficients P, R and C, defined by :

$$P=\frac{<i_d^2>}{4kT\Delta\ f\ g_m} \qquad (1)$$

$$R=\frac{g_m<i_g^2>}{4kT\Delta\ f\ C_{gs}^2\omega^2} \qquad (2)$$

$$jC=\frac{<i_g i_d^*>}{\sqrt{<i_g^2><i_d^2>}} \qquad (3)$$

where k is the Boltzmann's constant, T is the temperature of the noise source, g_m is the transconductance, and Δf is the bandwidth.

This noise modeling procedure requires the measurement of the S-parameters and the noise parameters, to extract the small signal equivalent circuit parameters and the noise coefficients, defined by P, R and C, together versus the temperature variation. The variation of the noise model parameters versus temperature is supposed to be quasi-linear, and can be approximated by the following relation [1] :

$$P(T)=P(To)(1+B(T-To)) \qquad (4)$$

where P(T) is the parameter value at the temperature of interest, P(To) is the reference temperature parameter value (To=296K), and B is the linear fitting coefficient to be determined.

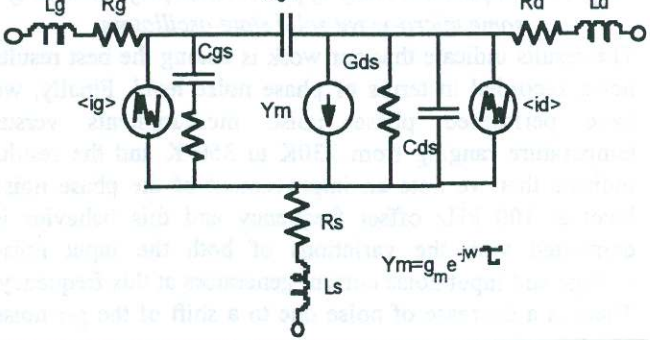

Fig-1- Small Signal and Noise Equivalent Circuit Parameter Model

EXPERIMENTAL RESULTS

To demonstrate the noise modeling procedure, S-parameter and noise parameter measurements were made on a 0.5x200µm^2 PHEMT from the PHILIPS PML-LEP foundry. The measurements were made using an on-wafer probe station (SET) with Cascade-Microtech HF probes, over a temperature range from -60°C to 140°C performed by the Thermo-Jet system (SAGEM). The S-parameter measurements were made from 100MHz to 26.5 GHz using the Wiltron 360B network analyzer, and the noise parameters measurements were performed between 2 and 12 GHz using a home made noise parameter test-set [4]. The calibrations were performed each time at the measurement temperature after chuck temperature stabilization.

The reported results of the noise modeling procedure is given for a drain current Ids=Idss. We have observed that the minimum noise figure (F_{min}) Figure 2, and the equivalent resistance (R_n) Figure 3, exhibit a larger relative increase with increasing temperature than the optimum reflection coefficient (Γopt) Figures 4. The same effect was observed for a drain current Ids=50% Idss.

The temperature dependence of the PRC factors is shown in figures 5 and 6 for two bias points Ids=Idss and Ids=50%Idss. We noticed that for a drain current Idss, the correlation coefficient seems to be temperature independent, and that P factor is proportional to the temperature variation. Whereas for a drain current Ids=50%Idss, the correlation coefficient increases with temperature so that the two noise sources become highly dependent to temperature.

The extracted values of the temperature coefficient B (10^{-3})/°C), for the parameters f_T, g_m, C_{gs}, R_{ds} and P, are of the same order of magnitude compared our results on 0.5x200µm^2 PHEMT (T1) to results obtained in the reference [2] for which the device under test is a 0.25x200µm^2 PHEMT (T2), and reference [3] is a 0.25x300µm^2 PHEMT (T3), biased at Ids=Idss. It demonstrates that for these parameters the extracted temperature coefficients are less sensitive to the modeling method and to the measurement errors than for the remainder of parameters. The temperature coefficients for R and C were expected to be different since the noise model is different between reference [2] and our work.

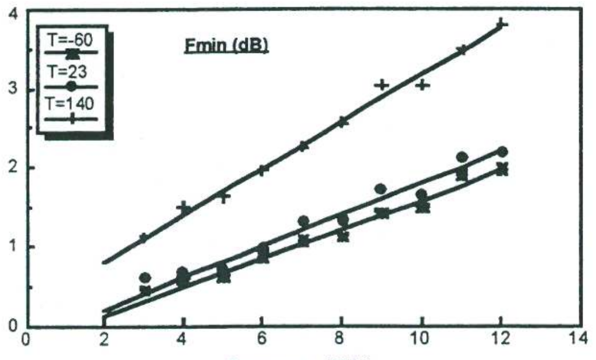

Fig-2- Measured Temperature Dependent.

Variation of Fmin at Id= Idss

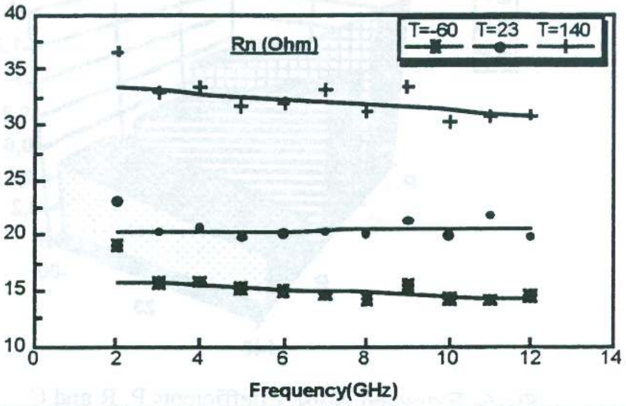

Fig-3- Measured Temperature Dependent Variation of Rn at Id= Idss

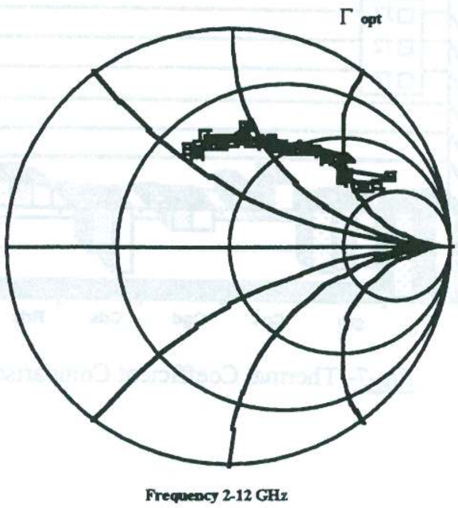

Fig-4- Measured Temperature Dependent Variation of Γopt at Id= Idss.

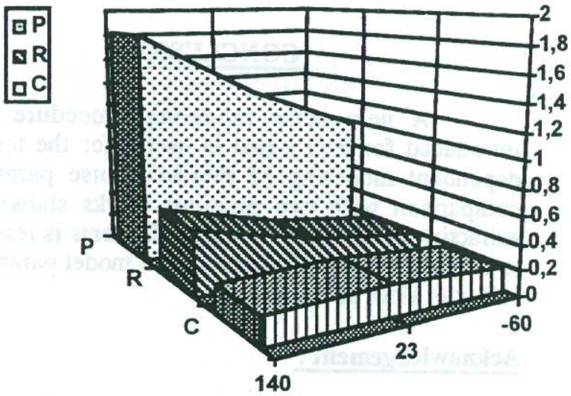

Fig-5- Extracted Noise Coefficients P, R and C versus Temperature at Ids=Idss

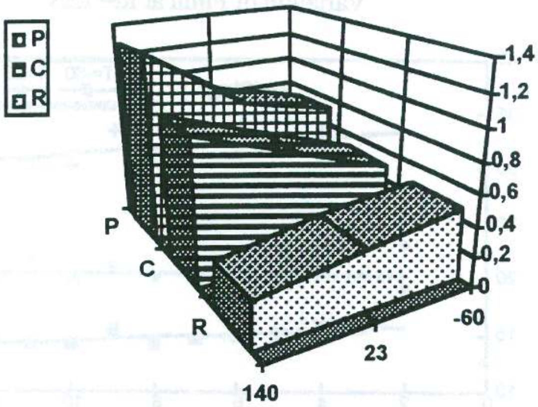

Fig-6- Extracted Noise Coefficients P, R and C versus Temperature at Ids=50%.Idss

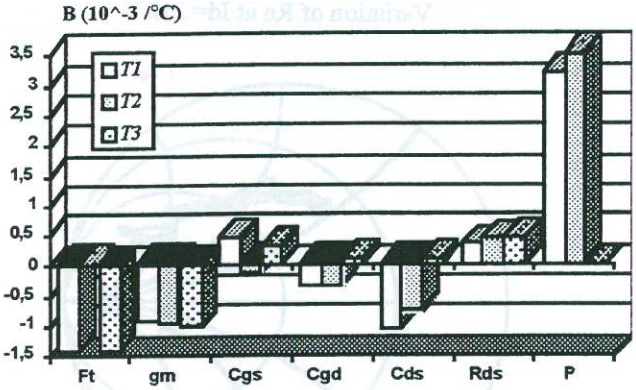

Fig-7- Thermal Coefficient Comparison

CONCLUSION

A new noise modeling procedure has been introduced for FET's that is useful for the temperature dependent modeling of PHEMT noise parameters. A comparison with two previous works shown that the extraction of the temperature coefficients is less sensitive to the used method for some of the model parameters, but still critical for some others.

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