ON-LINE NOISE CHARACTERIZATION

G. DAMBRINE, F. DANNEVILLE, J.M. BELQUIN, and A. CAPPY

Institut d'Electronique et de Microélectronique du Nord
U.M.R. C.N.R.S. N° 9929
Département Hyperfréquences et Semiconducteurs
Avenue Poincaré
59652 Villeneuve d'Ascq Cedex

Abstract

A new method for systematic measurements of noise parameters of field effect devices has been developed. This method can be easily implemented with a conventional on-wafer station. Since no tuner is needed, this technique does not require a long time of measurement and it is well suited for in line noise characterization.

Theoretical approach

For the design of microwave and millimeter wave circuits using MESFETs, HEMTs, or HBTs, a model of the noise performance of these devices is required. In order to develop and check the validity of such noise model, several measurements of noise parameters as function of the bias conditions are needed. For systematic noise measurements, commercially available systems are commonly used. These systems are based on the measurements of noise powers, at the output of the device under test (D.U.T.), corresponding to different generator impedances. Although these techniques are well suited for on-line characterizations of any kind of two-ports, these noise measurement systems are rather expensive while the results are strongly dependent on the choice of the different impedances and the the fit method. For these reasons, a new method for systematic measurements of noise parameters of MESFETs and HEMTs has been developed [1]. This method is based on the fact that a field effect device is a particular two-ports in term of noise. From the physics behaviour of noise in field effect device, it is shown that two noise parameters can be directly obtained from the frequency variation of the noise figure F50 corresponding to a generator resistance (for instance 50 Ω). As a matter of fact, for any generator admittance $Y_g=G_g+j.B_g$, the noise figure is given by the well known expression:

$$F = F_{min} + \frac{R_n}{G_g} . |Y_g - Y_{opt}|^2$$

$$\text{with } F_{min} = 1 + 2.R_n.(G_{opt}+G_{cor})$$

In the case of a 50 Ω generator impedance ($Y_g=G_o=20$mS), the noise figure F_{50} becomes:

$$F_{50} = [1 + R_n.G_o] + \frac{R_n}{G_o} . [2.G_o.G_{cor} + |Y_{opt}|^2]$$

This expression is very important for two reasons:

(i) In the case of low parasitics elements (gate inductance, pad capacitance), R_n is almost frequency independant while G_{cor} and $|Y_{opt}|^2$ vary as ω^2. Consequently the plot of F_{50} versus ω^2 is linear and the F_{50} value at $\omega=0$ is $[1 + R_n.G_o]$. Thus R_n can be easily deduced from F_{50} extrapolation at $\omega=0$.

(ii) The slope of F_{50} versus ω^2 provides a second noise coefficient: $[2.G_o.G_{cor} + |Y_{opt}|^2]$.

If a conventional on-wafer noise measurement bench is available, these two noise parameters, can be used to reduce the number of unknowns. A higher measurement accuracy is then expected as compared with the conventional method. But, even with the proposed improvement, the conventional noise measurement technique, based on several noise power measurements and a least square fit, remains rather complicated. So, it seems interesting to develop another method using the measurement of F_{50} associated with a theoretical model which is used to give additional ralations.

As shown previously, the measurement of F_{50} versus frequency provides two noise parameters, then two additional informations are needed to provide the four commonly used noise parameters F_{min},R_n and G_{opt}. For this purpose, the theoretical noise model proposed by Pospieszalski [2] is very well suited. In this analysis, it is assumed that only two uncorrelated noise sources are sufficient to described the intrinsic FET noise behaviour. The validity of this noise model has been shown in [2] from experiments and more recently the validity of this assumption has been shown from a theoretical point of view, using an uniform active line model [3]. however, this model only concerns the intrinsic part of the device and the extrinsic elements (access resitances, inductances and pad capacitances) have to be known for calculating the extrinsic noise parameters of the device.

To summarize, the characterization of the four noise parameters of MESFETs and HEMTs can be obtained by the F_{50} and S-parameters measurements versus frequency if the extrinsic elements of the device are known.

This measurement technique is very simple, no tuner is needed, this method can be easely developed using a conventional on-wafer station. Using this technique, the measurement accuracy is expected to be high. This accuracy mainly depends of the accuracy of noise figure measurements and of the microwave performance of the bench. Moreover this method does not required a long time of measurement, consequently this technique is very well suited for systematic noise characterizations.

Experimental results

A. Microwave performance of the bench

The microwave accuracy mainly depends on the microwave performance of the noise receiver and the microwave components used in the bench. The two main characteristics of a bench for noise measurement are:

(i) the noise characteristics of the two-port preceeding the device under test (D.U.T.); the losses of this two-port will be a major limitation of accurate measurements in the case of low noise figure device characterization. The noise figure of this input two-port is less than 2dB at 20 GHz which is half of the noise figure corresponding to an input head tuner used in a conventional noise parameters test system. Moreover with such performance, the accuracy of the S-parameters measurements and then the extrinsic elements determination are not strongly altered.

(ii) the noise figure of the noise receiver is less than 4 dB in the 4-18 GHz frequency range. In order to reduce the mismatch effect at the input of the noise receiver, a high quality broadband (8-18 GHz) isolator is used.

B. Results

The variations of the minimum noise figure F_{min} and the equivalent noise resistance R_n are respectively shown in Fig. 1 and Fig. 2 as functions of the bias conditions. The device investigated is a $0.15*120\mu m^2$ AlGaAs/InGaAs/GaAs pseudomorphic HEMT.

The variations of the equivalent noise temperatures as defined in [2] are shown in Fig. 3. versus drain and gate voltages It can be noted that the drain noise temperature is much higher than the gate noise temperature. These results are in good agreement with [2]

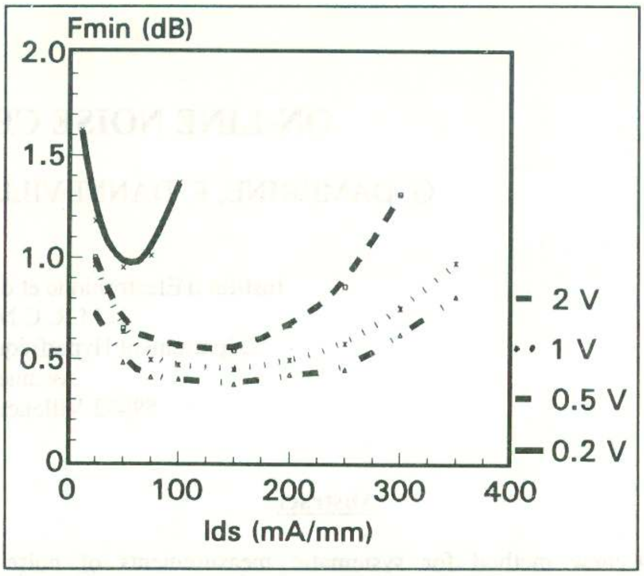

Fig. 1 : Variations of F_{min} versus I_{ds} and V_{ds}, for a $0.15*120\ \mu m^2$ P-HEMT at 17 GHz

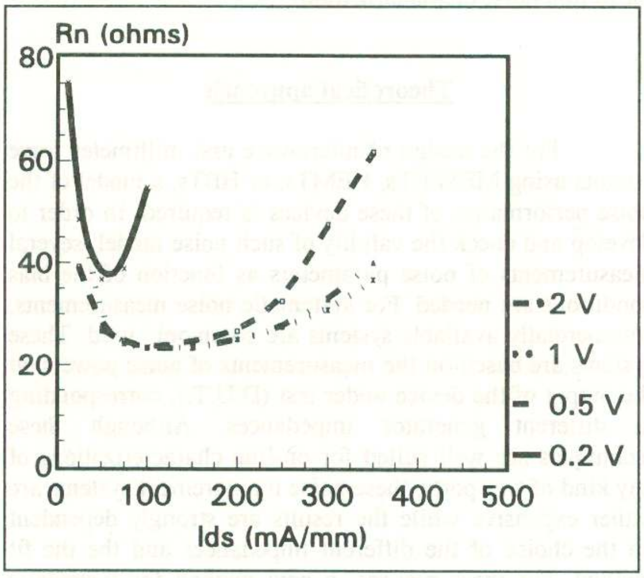

Fig. 2 : Variations of R_n versus I_{ds} and V_{ds}, for a $0.15*120\ \mu m^2$ P-HEMT at 17 GHz

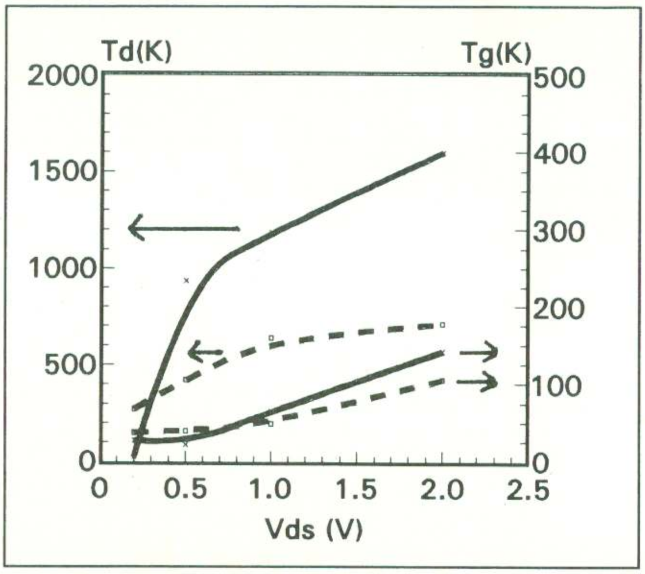

Fig. 3 : Variations of T_g and T_d noise temperatures versus V_{ds} and V_{gs}.
Solid line: $V_{gs} = 0.2$ V
Dashed line: $V_{gs} = 0$ V

Conclusion

A New Method For measuring the noise parameters of MESFETs and HEMTs has been described. This method is fast, as accurate as the conventional one. It is well suited for systematic measurements with an on-wafer prober. Using a different theoretical model, this method can be extented to the noise characterization of HBTs

References:

[1] G. DAMBRINE, H. HAPPY, F. DANNEVILLE and A. CAPPY: "Anew method for on-wafer noise measurement"
I.E.E.E.-MTT, Vol. 41, n° 3, pp.375-381, March 93.

[2] M.W. POSPIESZALSKI: "Modeling of noise paraemters of MESFET's and MODFET's and their frequency and temperature dependence"
I.E.E.E.-MTT, Vol. 37, n°9, pp. 1340-1350, September 1989.

[3] F. DANNEVILLE, H. HAPPY, G. DAMBRINE, J.M. BELQUIN, and A. CAPPY. "Microscopic noise modeling and macroscopic noise models: How good a connection?"
I.E.E.E.-ED to be published.