TEMPERATURE NOISE CONSTANTS EXTRACTION OF mm-WAVE FETs FROM MEASURED S- AND NOISE PARAMETERS

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ABSTRACT

For the first time, the temperature noise constants of the full semidistributed FET model [3] are extracted by a CAD-oriented method from measured S- and noise parameters, instead of curve fitting or by optimization procedure. Using extracted noise constants and their temperature variations, the temperature dependence of the noise parameters of the mm-wave FETs are here reported.

INTRODUCTION

Although some research has been done on the extraction of noise constants for lumped FET models [2], [5], the extraction of noise constants of the distributed FET model for mm-wave applications has not been accomplished so far. For the embedding case, the modified Rizzoli's approach [6] can be applied to determinate the noise contribution from passive parts and active slices [1]. But for the inverse case the de-embedding procedure fails, because of a matrix inversion problem (isolation between some nodes of the distributed model).

FULL SEMIDISTRIBUTED NOISE MODELLING PROCEDURE OF MESFETs AND HEMTs

Fig. 1 shows the noise model of each elementary cell of the full semidistributed model. For active slices the approach adopted by Pospiezalski [4] was used and the passive part was assumed to be at ambient temperature T_P. The noise of different slices are considered uncorrelated [7] and all having the same noise constants. The noise property of each element of a slice (cell) can be expressed as follows:

$$\langle e_{gg}^2\rangle = 4kT_PR_{gg}\Delta f \quad ; \quad \langle e_{dd}^2\rangle = 4kT_PR_{dd}\Delta f \qquad (1\text{-a})$$

$$\langle e_{ss}^2\rangle = 4kT_PR_{ss}\Delta f \quad ; \quad \langle e_{rd}^2\rangle = 4kT_Pr_d\Delta f \qquad (1\text{-b})$$

$$\langle e_{rs}^2\rangle = 4kT_Pr_s\Delta f \quad ; \quad \langle e_{ng}^2\rangle = 4kT_gR_{id}\Delta f \qquad (1\text{-c})$$

$$\langle i_{nd}^2\rangle = 4kT_dG_{dsd}\Delta f \quad ; \quad G_{dsd} = \frac{1}{R_{dsd}} \qquad (1\text{-d})$$

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For Fig. 2 that represents the noise modelling procedure of MESFETs and HEMTs one can write :

$$C_m^Y(V_{gs},\ V_{ds},\ f,\ T) = H_N.C_p^Y.H_N^\dagger + H_J.C_J^Y.H_J^\dagger \quad (2)$$

where

$C_m^Y(V_{gs},\ V_{ds},\ f,\ T)$: is the admittance noise correlation of the device (determined from measured S and noise parameters) at bias points (V_{gs}, V_{ds}), frequency f and temperature T.

C_p^Y : is the admittance noise correlation of the passive part (determined from signal matrix).

C_J^Y : is the admittance noise correlation of active slices (can be determined by this algorithm).

H_N and H_J : are the matrices that are computed from passive and active signal matrices.

H_J is a matrix with order 2xL (L = 3N : N active slice number) and $H_JH_J^\dagger$ is always a singular matrix.

$$H_J = \left[H_{J1} \ \vdots \ H_{J2} \ \vdots \ \cdots \ \vdots \ H_{JN}\right] \qquad (3)$$

where H_{Jk} ($k = 1,\ 2,\ \ldots,\ N$) are the sub-matrices with order 2x3.

For the extraction of C_J^Y we define the following matrices :

$$D \stackrel{\Delta}{=} C_m^Y(V_{gs},\ V_{ds},\ f,\ T) - H_N.C_p^Y.H_N^\dagger \qquad (4)$$

and

$$H_{Jk}\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -1 & -1 \end{bmatrix} \stackrel{\Delta}{=} \begin{bmatrix} h_{1k} & h_{2k} \\ l_{1k} & l_{2k} \end{bmatrix} \quad (k = 1,\ 2,\ \ldots,\ N) \qquad (5)$$

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therefore with assumption the uncorrelated noise slices we have :

$$D = H_J . C_J^Y . H_J^{\dagger} = \sum_{k=1}^{N} H_{Jk} . C_J^{(k)} H_{Jk}^{\dagger} = \sum_{k=1}^{N} HH_k . V_J \quad (6)$$

where

$$HH_k = \begin{bmatrix} |h_{1k}|^2 & h_{1k}h_{2k}^* & h_{2k}h_{1k}^* & |h_{2k}|^2 \\ h_{1k}l_{1k}^* & h_{1k}l_{2k}^* & h_{2k}l_{1k}^* & h_{2k}l_{2k}^* \\ l_{1k}h_{1k}^* & l_{1k}h_{2k}^* & l_{2k}h_{1k}^* & l_{2k}h_{2k}^* \\ |l_{1k}|^2 & l_{1k}l_{2k}^* & l_{2k}l_{1k}^* & |l_{2k}|^2 \end{bmatrix} \quad (7)$$

$$V_J = \begin{bmatrix} G_2 & cor_c & cor_c^* & G_1 \end{bmatrix}^t \quad (8)$$

and $C_J^{(k)}$ are the 3x3 slices noise current correlation sub-matrices located on the main diagonal of C_J^Y matrix.

The V_J elements can be determined as a function of the signal parameters and the temperature noise constants T_g and T_d of each active slice [4].

From (4) and (6) one can find :

$$V_J = \left(\sum_{k=1}^{N} HH_k \right)^{-1} . V_D \quad (9)$$

with $V_D = \begin{bmatrix} D_{11} & D_{12} & D_{21} & D_{22} \end{bmatrix}^t$

and after calculation the V_J vector, the noise constants T_g and T_d can be extracted by reverse procedure of (8).

RESULTS

This procedure was used for the extraction of temperature noise constants of a FHX35X (HEMT) transistor. The transistor was biased at Vds=3 V, Ids=10 mA and the S-parameters were measured in the 2-26 GHz band using the HP 8510C Network analyzer in fixture measurement and the noise parameters were measured in the 2-18 GHz band. Using this algorithm the temperature noise constants are extracted at ten different frequencies (@T=24° C) and are reported in Fig. 3. By choosing the mean value of these constants their final value at this bias point can be determined. By insertion of the extracted value in the full distributed model of the device good agreement was obtained in comparison with measured noise parameters (@T=24° C) (see Fig. 4). Using the temperature dependence of the ECPs [8] and noise constants [9] in a distributed form, the temperature dependence prediction of the noise parameters of the full semidistributed model (taking into account the extrinsic elements) are also reported in Fig. 4. These results show the importance of temperature dependence for distributed modelling in mm-wave frequency ranges especially for the two important noise parameters F_{min} and R_n.

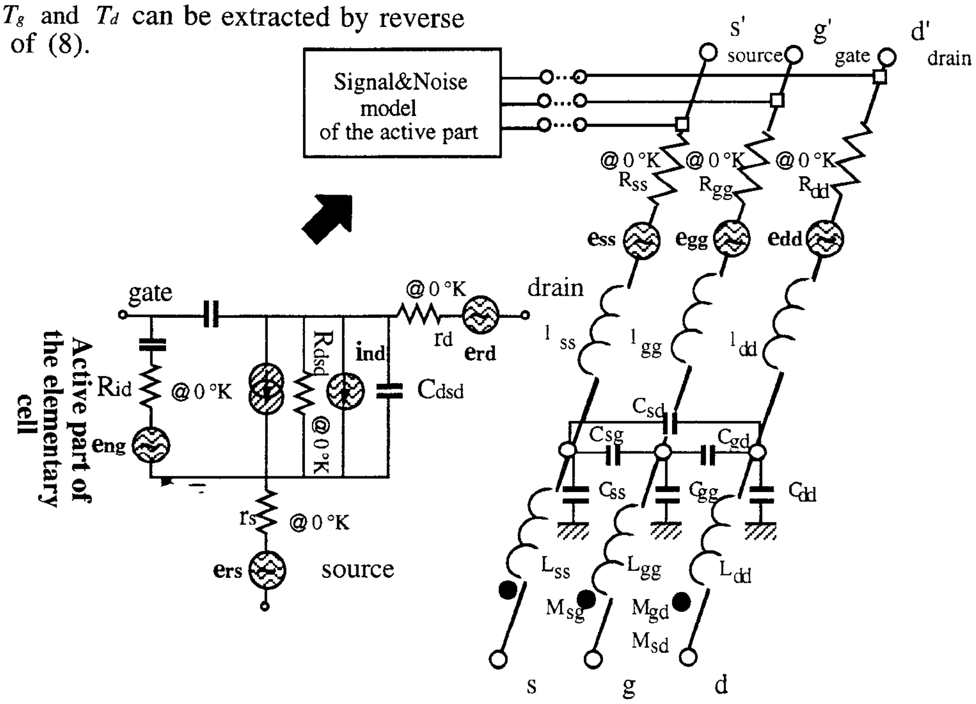

Fig. 1. Full semidistributed noise modeling of mm-wave FETs (elementary cell).

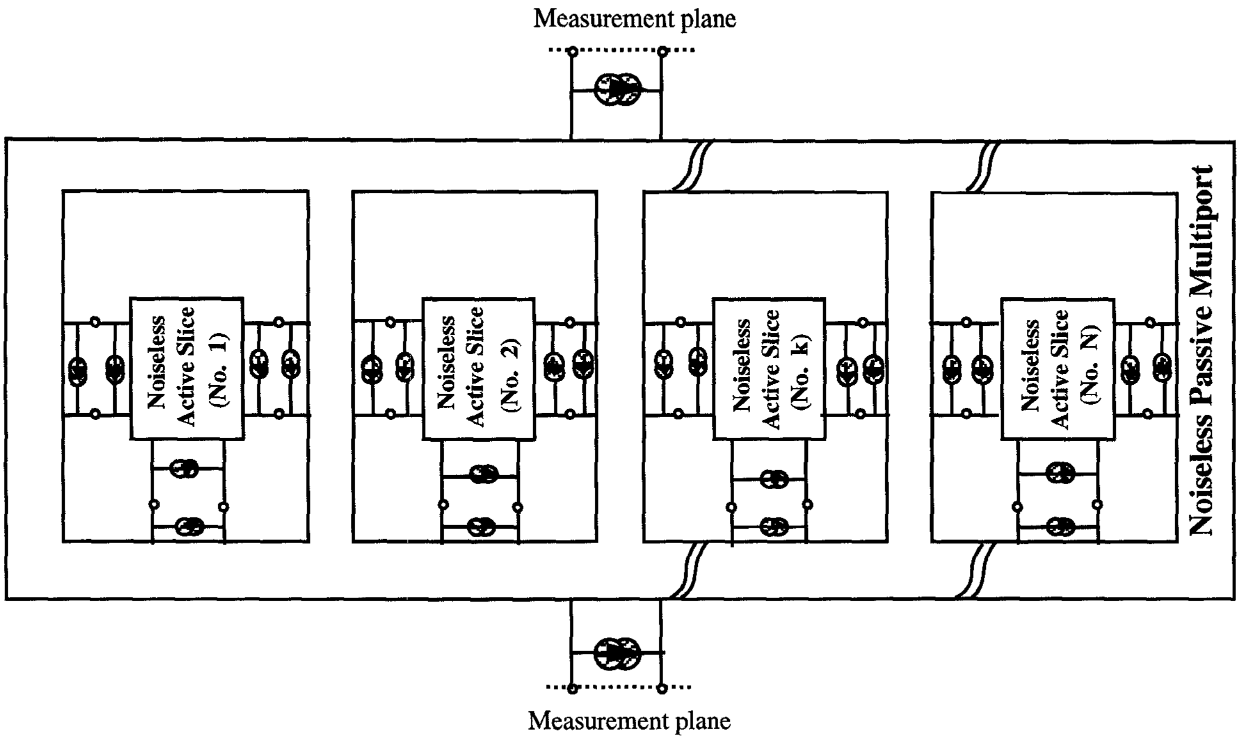

Fig. 2. Decomposition of the FET into N active slices and a passive multiport for mm-wave signal & noise modelling.

CONCLUSION

This work presents a method for the extraction of temperature noise constants of the full semidistributed FET model for mm-wave applications. The temperature parameters can be implanted in this algorithm in order to determine the signal and noise performance of the device as a function of the ambient temperature by considering wave propagation effects. Finally, the travelling-wave FETs noise performances can be investigated by using this approach.

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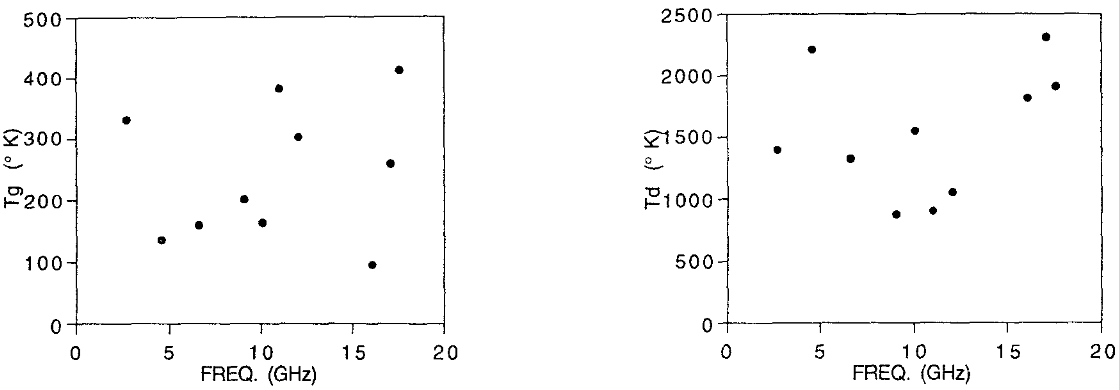

Fig. 3. Extracted temperature noise constants of the full semidistributed FET model at different frequencies. Device FHX35X (HEMT) , V_{ds}=3 V, I_{ds}=10 mA.

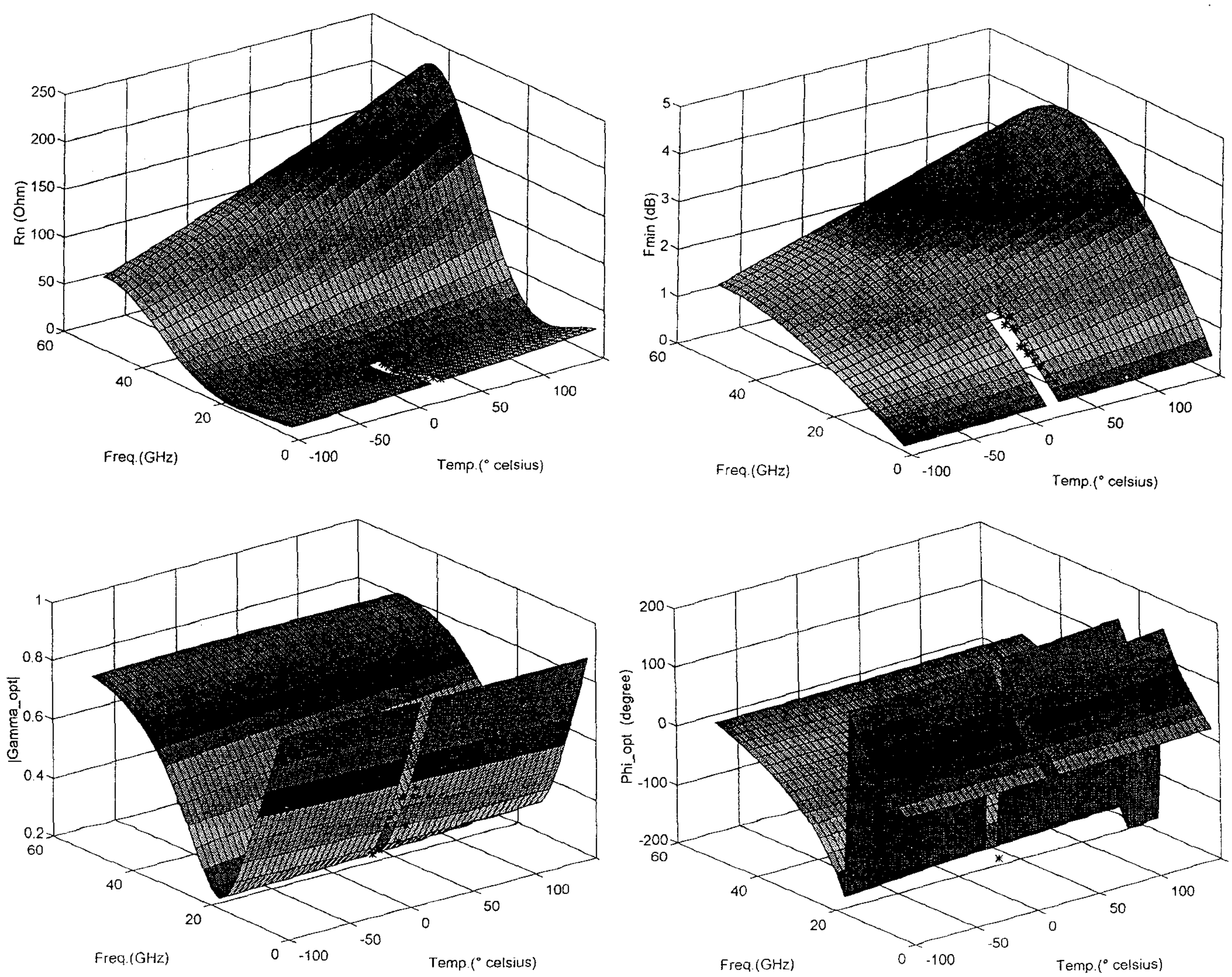

Fig. 4. Variation of the noise parameters against frequency and working temperature for full semidistributed modeling. Device FHX35X (HEMT), V_{ds}=3 V, I_{ds}=10 mA. * measured data @ T=24 °C