SCALING NON LINEAR MODELS FOR LOW g_m MESFETS

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ABSTRACT

A new technique to scale down non linear Models for small gate width MESFETs is presented. The model is obtained from a larger device model scaled only on the total gate width and adjusting two DC parameters and three AC parameters to the measurements on typical small devices. The advantage of this model over classical scaling techniques is shown not only at the device level but also on the simulation of an active Voltage Controlled Reactance.

INTRODUCTION

Voltage controlled reactance (VCR) is useful to implement voltage controlled phase shifters and filters, and in printed antennas technology to reduce the patches size, mainly in low frequency bands. To implement VCRs in GaAs monolithic technology, usually active feedback FET based circuits are used, Zhang and Gautier (1), Sinsky and Westgate (2). For this purpose, small g_m MESFETs are needed. Usually, non linear models for small gate width (Wg) FETs are not available from the foundry libraries and the classical scaling rules lead to models with poor accuracy as it will be shown. Therefore, a model for small Wg FETs based on available larger Wg FET TOM model (TriQuint's Own Model, Statz et al (3), McCamant et al (4)), was derived for a 0.5 μm gate length GaAs MESFET technology, Cornelius (5).

SMALL MESFET MODEL EXTRACTION

Most of the scaling rules are obvious and the model elements values can be scaled on the total gate width Wg and number of fingers Nf, Golio (6). A first model was obtained by this classical analytical scaling. As a matter of fact, this scaling technique gives only a rough idea of the transistor behaviour when a specific model is not available. It was noticed for small devices scaled models some inconsistent physical behaviour. To increase the simulation accuracy, a new model based on DC and [S] parameters measurements was extracted. The TOM model was used since it allows an almost independent adjustment of the current generator parameters leading to a fast parameters extraction. The foundry 4 fingers TOM model valid for 4x50μm<Wg<4x150μm was scaled to small Wg values such as Wg=4x15μm=60μm, a typical value for VCRs implementation but far beyond the specified limits. The simulation results of this model was compared with the experimental DC and AC characteristics of one and two fingers devices with the same total Wg. The qualitative differences were physically consistent. Following, the model was adjusted in two steps.

■ In the first step, the DC parameters are adjusted by fitting equation (1) to the DC measurements.

On the fitting process we have considered that 1 finger device is physically different of the 2 and 4 fingers devices.

The α, β and γ DC parameters control the ohmic zone $I_D(V_{DS})$ slope, I_D current generator level and $I_D(V_{DS})$ slop in the saturation zone respectively.

$$I_{DS} \equiv \begin{cases} I_D \cdot \left\{1 - \left[1 - \dfrac{\alpha \cdot V_{DS}}{3}\right]^3\right\} & \text{for } 0 \langle V_{DS} \langle 3/\alpha \\ I_D & \text{for } V_{DS} \rangle 3/\alpha \end{cases} \tag{1}$$

where $I_D \equiv \dfrac{I_{DS0}}{1 + \delta \cdot V_{DS} \cdot I_{DS0}}$, $I_{DS0} \equiv \beta \cdot (V_{GS} - V_T)^Q \cdot \dfrac{\tanh(\alpha \cdot V_{DS})}{[1 + \beta \cdot (V_{GS} - V_T)]}$

and $V_T \equiv V_{T0} + \gamma \cdot V_{DS}$

It was noticed that adjusting only the parameters β and γ accurate DC models are obtained. Accordingly, the parameters α, Q, V_{T0} and δ have the values obtained from the 4 fingers model.

The reference values for β and γ (β_0 and γ_0) are also obtained from the 4 fingers scaled model. On the adjustment of these parameters we have to take into account the dependence on the V_{GS} voltage (3^{rd} order polynomial equation).

Following, from devices with total gate width from 25μm up to 60μm with 1 and 2 fingers, new DC parameters are presented.

For $V_{GS} \in [-1.5V, 0.5V]$, the β and γ parameters are adjusted with β_0 and γ_0 as reference values.

The parameter β is given by:

if {n=1} then $$\beta = \beta_0 \left[b_{31} V_{GS}^3 + b_{21} V_{GS}^2 + b_{11} V_{GS} + b_{01}\right] \tag{2}$$

if {n=2} then $$\beta = \beta_0 \left[b_{32} V_{GS}^3 + b_{22} V_{GS}^2 + b_{12} V_{GS} + b_{02}\right] \tag{3}$$

where	b_{01}= 0.9	b_{11}=0.233	b_{21}=-0.1	b_{31}=0.067
	b_{02}= 1	b_{12}=0.14	b_{22}=-0.08	b_{32}=0.08

The parameter γ is given by:

if {n=1} then $$\gamma = \gamma_0 \left[g_{31} V_{GS}^3 + g_{21} V_{GS}^2 + g_{11} V_{GS} + g_{01}\right] \tag{4}$$

if {n=2} then $$\gamma = \gamma_0 \left[g_{32} V_{GS}^3 + g_{22} V_{GS}^2 + g_{12} V_{GS} + g_{02}\right] \tag{5}$$

where	g_{01}= 1	g_{11}=-0.333	g_{21}=0.6	g_{31}=0.133
	g_{02}= 1	g_{12}=0	g_{21}=0	g_{31}=0.

As can be noticed γ don't need any adjustment for 2 fingers devices, probably due to the physical structure being similar to the 4 fingers device used as reference for the scaling process.

■ In the second step, the model [S] parameters are fitted to measurements by adjusting the intrinsic capacitors C_{gs}, C_{gd} and C_{ds}. The reference values C_{gs0}, C_{gd0} and C_{ds0}, obtained from the 4 fingers scaled device are multiplied by coefficients. For C_{ds} the coefficients are also dependent on v_{DS} voltage.

For C_{gs} and C_{gd} we have obtained

$C_{gs} = C_{gs0}\, a_1$ and $C_{gd} = C_{gd0}\, b_1$ (6)
where $a_1=1.8$ $b_1=1.5$.

For C_{ds} the following voltage dependent coefficients were obtained:

if $v_{DS}<1.2V$ then $C_{ds}=C_{ds0}\, c_3$ (7)
where $c_3=1$

if $v_{DS}>1.2V$ then | if n=1 then $C_{ds}=C_{ds0}\, c_1$ (8)
| if n=2 then $C_{ds}=C_{ds0}\, c_2$
where $c_1=3$ $c_2=1.5$

As expected, the bias dependent equations coefficients are also dependent on the number of fingers. However, it was noticed that they are independent of the scaling size, down to Wg=25μm.

On the AC parameters it is also noticed that the two fingers devices needs smaller corrections than one finger devices.

With this new scaled model, DC I(V) curves and [S] parameters simulations are close to the measurements showing its accuracy (Figure 1 and 2).

VOLTAGE CONTROLLED REACTANCE

To test the new scaled model accuracy not only at the device level but also at an application circuit a previous designed VCR was used.

The VCR was designed using an active feedback circuit with two 4x75μm gain devices and one 2x30μm small g_m control device. To avoid bulky choke inductors, single transistor active bias networks were used. Poor agreement between the VCR simulation and the measurements were obtained with the classical scaled model (Figure 3), Golio (6). However, the simulations with the new scaled model are in good agreement with the measurements (Figure 4).

CONCLUSION

A new approach to extract model parameters for small size MESFET was presented. Models for 1 and 2 fingers low gate width devices were obtained from an available 4x75μm transistor model. Only 2 parameters in DC and 3 parameters in AC were adjusted. With this technique, the time consuming devellopment of a fully new model is avoided. This model presents good accuracy not only at the device level but also when introduced on a multidevices circuit.

ACKNOWLEDGMENT

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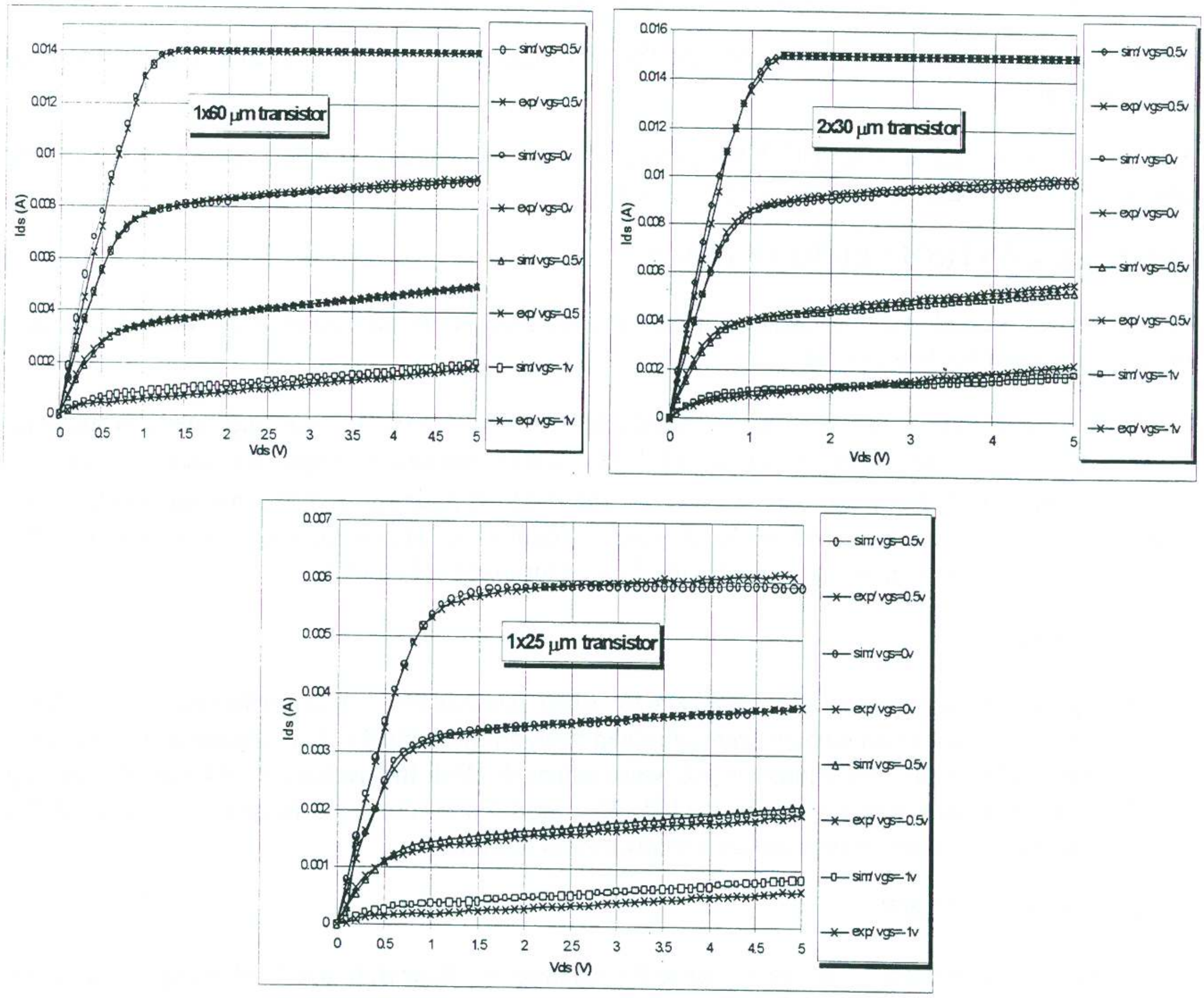

Figure 1: DC characteristic of the new scaled model and experiments for 1x60μm, 2x30μm and 1x25μm MESFETs

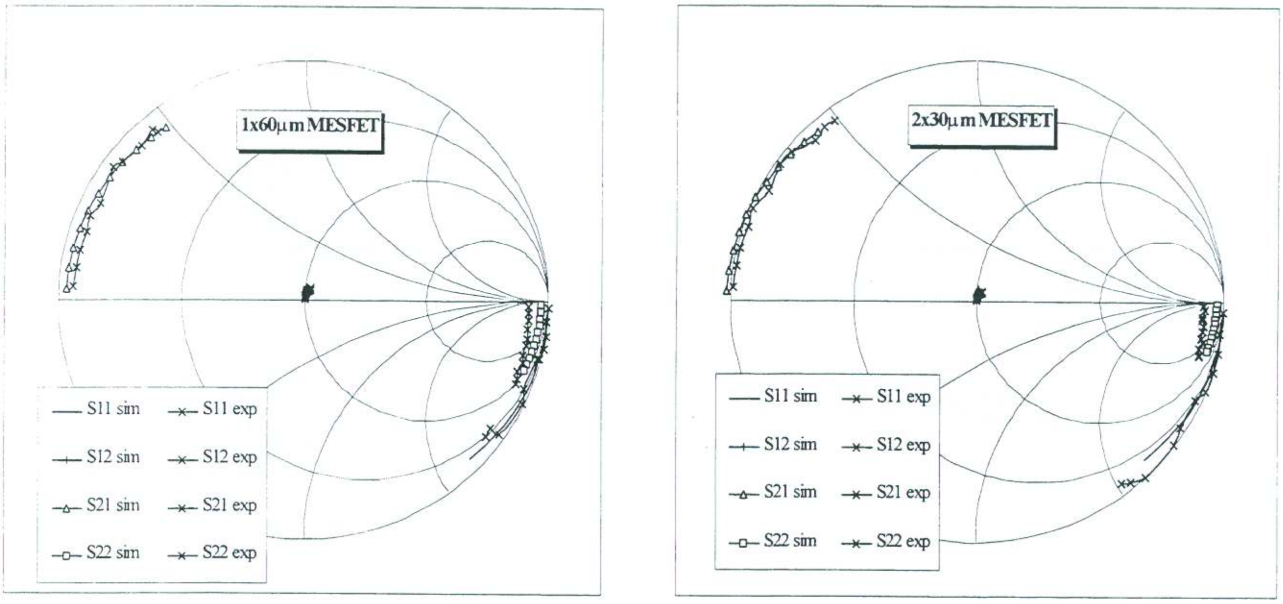

Figure 2: [S] parameters measured and simulated with the new scaled model from 0.5 to 10 GHz.

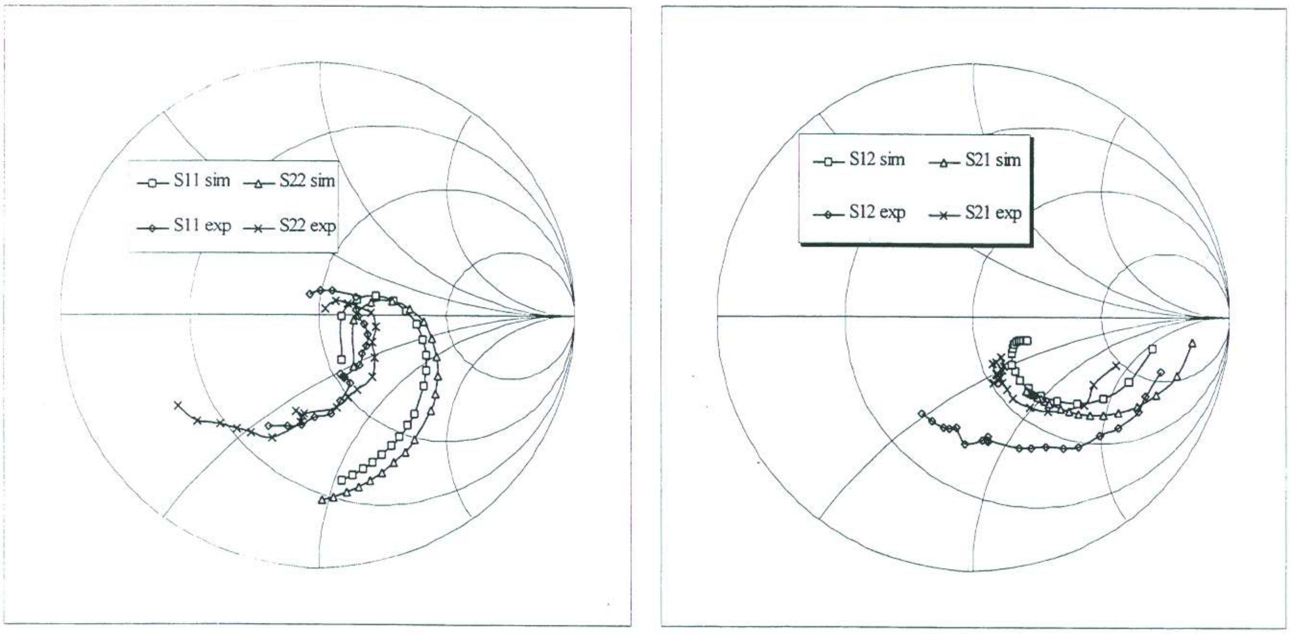

Figure 3: VCR [S] parameters simulated and measured with classical scaled model from 0.5 to 10 GHz.

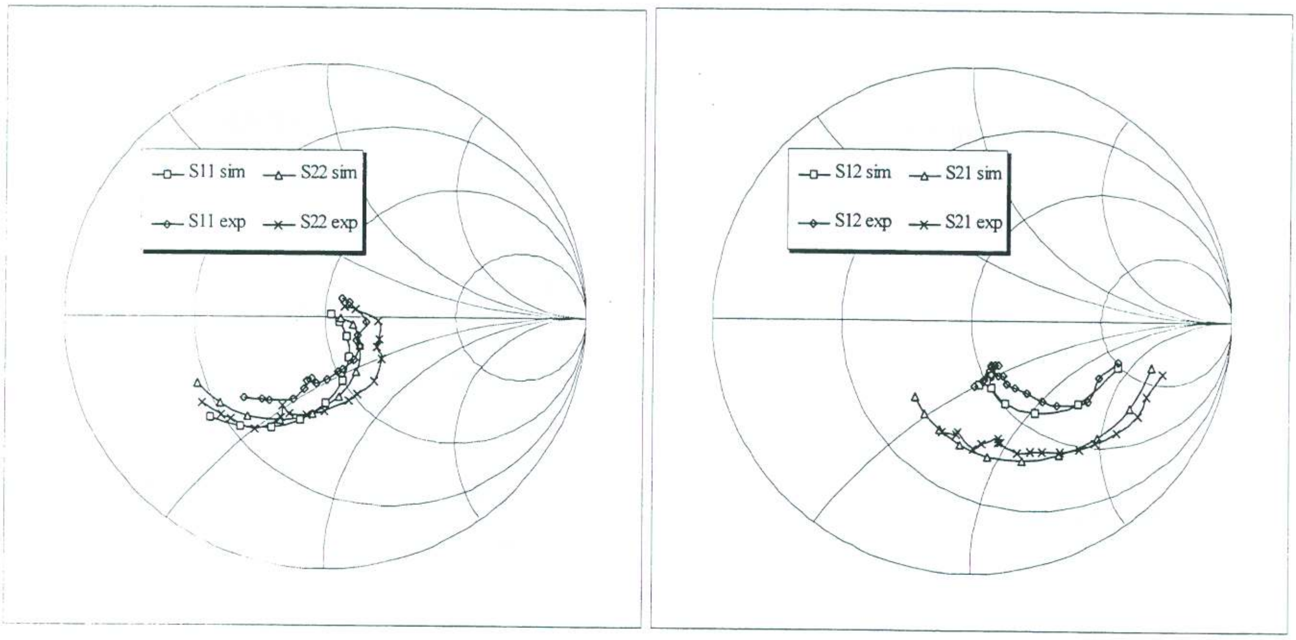

Figure 4: VCR [S] parameters simulated and measured with the new scaled model from 0.5 to 10 GHz.