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FULL CHARACTERIZATION OF GaAs POWER MESFET AND ACCURATE LOAD-PULL CONTOURS PREDICTION

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Summary

A novel large-signal model implemented on the nonlinear time-domain program CIRCEC leads to accurate prediction of all the GaAs MESFET characteristics, needed for the design of a power amplifier.

The good agreement between measured and modeled load-pull contours validates the chosen trends.

Introduction

A novel large-signal model of the FET, which takes into account the gate-drain breakdown, the Gunn effect caused by overspeed of electrons in GaAs, and the frequency dependence of the drain impedance at low frequencies, has been developpped.

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In order to validate the model and the method of characterization of the model parameters (static and dynamic measurements), the nonlinear time-domain analysis program CIRCEC has been used to make a comparison between calculated and measured load-pull characteristics. The obtained results are satisfactory and show that power-limiting effects have been properly modeled. Combined with CIRCEC program, this model forms a general CAD tool wich will be used for the design of a power amplifier and for an accurate prediction of its performances.

Load-pull measurement

An automatic measurement system (fig. 1), based upon TAKAYAMA'S method ([1]), allows the measurement of a power device's gain and output power with respect to the complex load impedance. The load impedance is a fictitious one. The input power is reinjected at the output ; controlling both its phase and amplitude, a variable load is thus realized.

Measurements can be performed at any frequency in the 4 to 18 GHz range, for given biasing conditions and fixed input power.

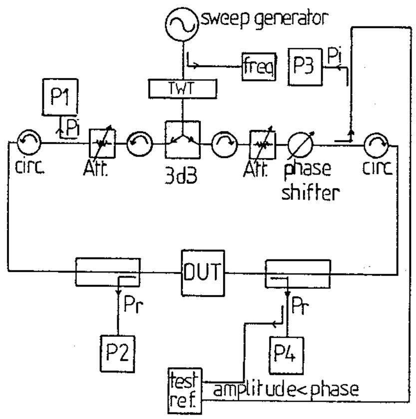


Fig. 1 : Load-pull measurement system

Nonlinear MESFET model

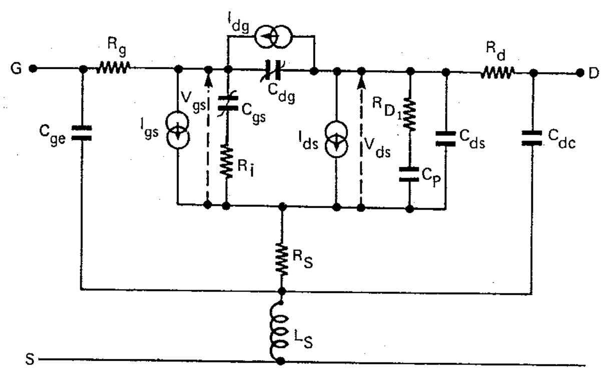


Fig. 2 : Nonlinear model implemented on CIRCEC

In the model shown in fig.2, the nonlinearities are given by the following elements :

* 3 current sources :

- Ids (Vgs, Vds) is the main nonlinearity of the model. GOPINATH'S formula ([2]) has been modified to take into account the Gunn effect and the nonuniformity of the doping profile by writing the slope factor and the exponent of saturation component as functions of Vgs.

These new formulas have been introduced as :

. Slope factor $K = Ko - \frac{Vgs}{A1} + \frac{(Vgs)^2}{A}$

. Exponent of saturation component

$$N = 0,5\ ((-Vgs/B) + C).$$

- Igs (Vgs) is the gate current which appears when the Schottky junction is forward biased and whose equation is :

$$Igs\ [Vgs(t)] = Igss\ (Exp[\alpha Vgs(t)]-1)$$

- Idg (Vgs, Vds) is the gate-drain breakdown current which flows in large-signal operation. The expression which has been used is given in [3] : Idg (Vgs(t), Vds(t))

$$= Idgss[1+C_1(Vds(t))^2]^{(C_2+C_3\ Vgs\ (t))}$$

* 2 junction capacitances :

Cgs (Vgs(t)), Cgd (Vgs(t), Vds(t)).

Determination of the model parameters

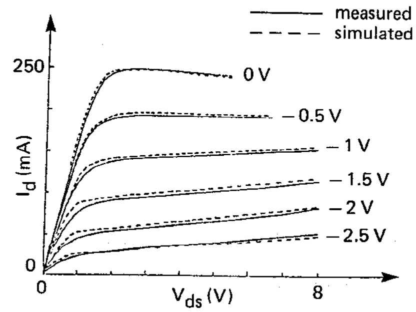


Fig. 3 : Static measurements Ids = f (Vgs, Vds) of RAYTHEON RPK 9027

Static measurements lead to the values of the current source parameters and the resistances Rs, Rg, Rd.

Drain conductance (gd) measurements are made from 50 Hz to 1 MHz in order to obtain RD_1 and Cp. From these measurements, the degradations of gd at microwave frequencies are known ([4]).

Small signal measurements of scattering parameters, achieved from 2 to 18 GHz for one bias point, lead to the values of all the other elements.

Measured and simulated data are compared in fig. 3 and 4.

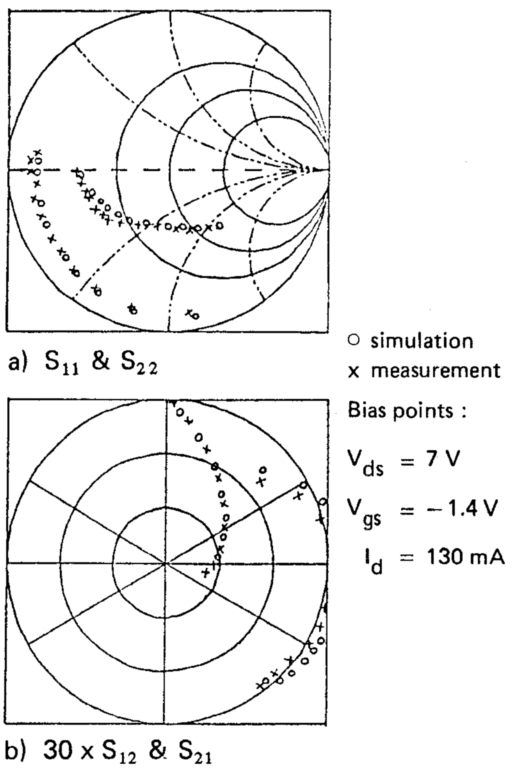


Fig. 4 : Scattering parameters measurements from 2 to 18 GHz of RAYTHEON RPK 9027

Nonlinear analysis program

The model described before has been implemented on CIRCEC. This program contains standard CAD analysis such as DC analysis, frequency response, transient analysis. Nonlinear circuits are analysed by a time-domain method.

The steady-state is obtained by integration of the integro-differential equations (GEAR method of 2^{nd} order) until the transient state has died out.

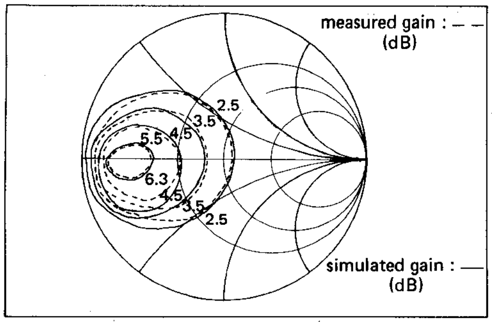
Comparison between simulations and measurements

The comparison has been performed with a commercially available MESFET by RAYTHEON (RPK 9027) designed to deliver 500 mW with 6 dB associated gain at 18 GHz. The large signal characterization has been achieved for 2 frequencies (12 and 17 GHz) and for 3 input power levels (50, 100, 200 mW). Results are shown in fig. 5 for f = 17 GHz. Very good agreement between measured and calculated data can be observed, especially concerning the maximum gain curve location on the Smith chart.

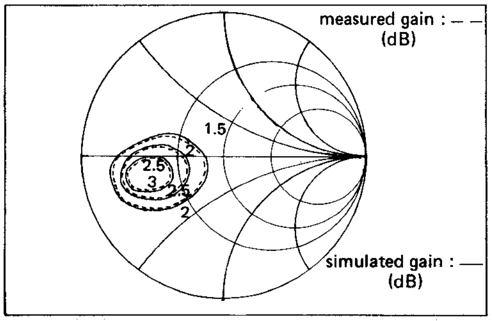
An optimum load impedance is obtained for each input power level. With these results, the design of the output circuit of a power amplifier will be established on a load impedance synthesis corresponding to :

. the available input power of the amplifier,

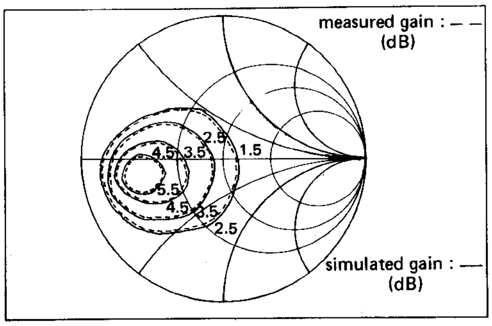
. the best compromise between gain and output power (fig. 6)



a) Input power : 17 dBm



b) Input power : 23dBm



c) Input power : 20 dBm

Fig. 5 : Load-pull results of RAYTHEON RPK 9027 for F = 17 GHz

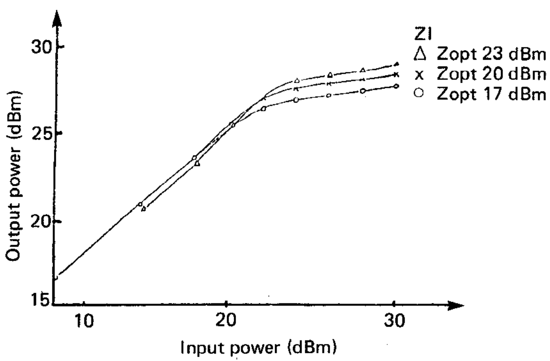


Fig. 6 : Saturated curves of RAYTHEON RPK 9027 at F = 17 GHz for different loading conditions

Conclusion

Good agreement between measured and predicted load-pull characteristics has been established on a commercially available MESFET from RAYTHEON up to 17 GHz, and in saturated behaviour (for 23 dBm input power).

The novel model implemented on CIRCEC associated with static and dynamic measurements leads to a full large-signal characterization essential for the design of nonlinear MESFET circuits.

References

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(2) A. GOPINATH - "Single-gate MESFET frequency doublers", IEEE MTT - June 1982.

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THIS WORK WAS SUPPORTED BY THE D.R.E.T. (Direction des Recherches Etudes et Techniques - FRANCE -)