NONLINEAR GaAs MESFET MODELING USING PULSED GATE MEASUREMENTS

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ABSTRACT

The effects of traps in GaAs MESFETs are studied using a pulsed gate measurement system. The devices are pulsed into the active region for $1\mu s$ and are held in the cut-off region for the rest of a $1ms$ period. While the devices are on, the drain current is sampled and a series of "pulsed gate" I-V curves are obtained and compared to conventional static I-V curves. The static and pulsed gate curves were used in a nonlinear time domain analysis model to predict harmonic content. The results showed that models which used the pulsed gate I-V curves to represent the nonlinear drain current yielded better predictions of harmonic distortion than models which used conventional I- V curves.

INTRODUCTION

Present nonlinear modeling techniques for GaAs MESFETs use DC I-V characteristics to represent the nonlinear drain current. Recent evidence suggests that these curves may not accurately represent the large signal response of a device. Camacho-Penalosa et al. reported that the output resistance of a MESFET varies as a function of frequency from DC to about 100 KHz and attributed this variation to the presence of traps at the epilayer-substrate interface (1). Smith et al. developed a technique for measuring the nonlinear characteristics based on RF measurements and reported good results in predicting harmonic content, however their setup was elaborate and difficult to implement (2).

In our work we developed a simple means of representing the nonlinear drain current at microwave frequencies based on pulsed gate measurements of I_{ds} vs. V_{ds}. The devices are biased in cut-off most of the time and are pulsed on only for a short period of time. The drain current is sampled while the device is on and the value is held using a sample and hold type circuit. Hence a series of pulsed gate curves are obtained and compared to the conventional static transfer curves.

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EXPERIMENTAL SETUP

The overall block diagram of the circuit used to obtain our pulsed gate measurements is shown in Figure 1. The function of a sample and hold circuit is to determine the magnitude of a signal at a given instant and hold that value for future processing without providing a load to the signal source. In our setup we used the commercially available Harris HA-5320 S/H amplifier which met the experimental criteria for acquisition time (time required for the output voltage to match the input voltage to within a certain percentage during the sample phase) and drop rate (voltage drop during hold phase).

The timing sequence starts with a pulse generator biasing the device into the active region for a $1\mu s$ period. The particular V_{gs} is determined by the pulse amplitude. The leading edge of this pulse also goes to trigger a second pulse generator, which after a very slight delay provides a signal to drive the S/H amplifier into the sample mode. The delay is provided to ensure the device is fully on and to allow for any response time of the current probe. The output of the current probe (proportional to I_{ds}) is the signal input of the S/H amplifier and is sampled during this period. The device is then biased into the cutoff region for a relatively long period of $1ms$ and the value of I_{ds} is held by the S/H amplifier. The cycle repeats all the while ramping V_{ds}. Since the ramping speed is slow compared to $1ms$, a set of smooth I_{ds} vs. V_{ds} pulsed gate curves are produced for various V_{gs}.

RESULTS

We tested our pulsed gate measurement system on several different types of discrete devices and found that in each case the pulsed gate curves differed from the static curves. Figure 2 shows the results for Avantek AT12535. To check the accuracy of our system we measured the output resistance of the device as a function of frequency (Figure 3). The measured value of Ro at 1MHz agreed well with the value obtained graphically from the pulsed gate curves and from optimizing a small signal model to the microwave S-parameter data.

In our work we used the nonlinear time domain model of Curtice (3,4). A cubic fit, hyperbolic tangent function is used to represent the drain current:

$$I_{ds} = (A_0 + A_1 V_1 + A_2 V_1^2 + A_3 V_1^3) tanh(\gamma V_{out})$$
$$V_1 = V_{in}\left[1 + \beta(V_{BIAS} - V_{out})\right]$$

Where A_0 etc. are the fitting coefficients, γ is a hyperbolic tangent fitting parameter, β is the coefficient for pinchoff change, and V_{BIAS} is the DC bias point at which the parameters were evaluated.

Two sets of Spice analyses were conducted to predict harmonic content, one using static I-V curves and one using pulsed gate I-V curves, and the results were compared to measured values (Figure 4). The parameters used in the two analyses were identical except the fitting parameters to represent the nonlinear drain current. The results indicate that the analysis based on static I-V curves gave adequate predictions in the linear region for the fundamental output power. However, analysis based on the pulsed gate measurements gave much better results in predicting the 1 dB compression point and in predicting the second and third harmonic output power levels.

The conclusion reached is that for large signal and/or nonlinear analysis, pulsed gate I-V curves give a better representation of the nonlinear drain current than static I-V curves due to the presence of traps. Because the emission rate of the traps is slow compared to the microwave signal the number of filled traps at a given instantaneous voltage in the microwave cycle will be different from the number of filled traps at the corresponding DC condition.

The advantages of our measuring system are that it is convenient to set up (commercially available sample and hold amplifiers are available as ICs), it gives a set of curves which can readily be compared to static I-V curves and an accurate value of the output resistance can be obtained.

SUMMARY

A relatively simple means of generating a set of pulsed gate I-V curves is presented. For nonlinear or large signal analysis these curves give a better representation of the nonlinear drain current that conventional static I-V curves due to the presence of traps.

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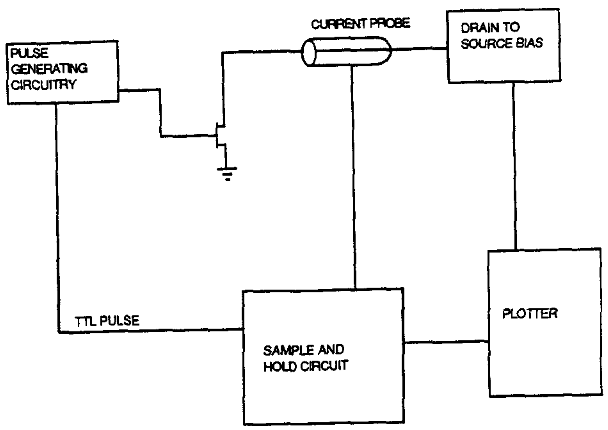

Fig. 1 - Schematic Diagram of Pulsed I-V Measurement Set-up.

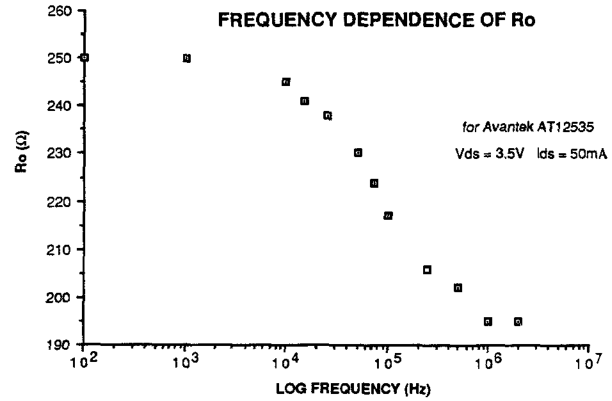

Fig. 2 - Frequency dependance of small signal output resistance.

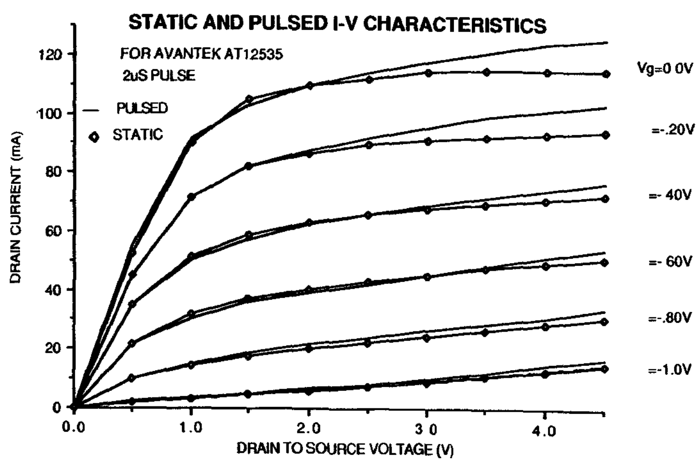

Fig. 3 - Comparison of Static and Pulsed Drain Characteristics.

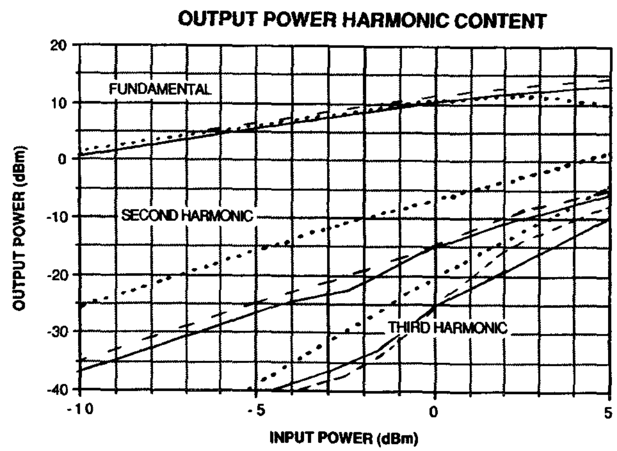

Fig. 4 - Comparison of fundamental power and harmonic distortions
—— Microwave measurement
- - - Predicted using pulsed I-V characteristics
. . . Predicted using static I-V characteristics