A New Methodology for Efficient and Reliable Large-Signal Analysis of RF Power Devices

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Abstract

In RF power device design, much of the analysis is based on measurements. Complete analysis by simulation is often avoided because the high-frequency, large-signal operation makes device simulation unsuitable, and the difficulties in obtaining a good physical compact model make circuit simulation inaccurate. This work presents a methodology that overcomes these limitations by utilizing a combination of device and circuit simulations to characterize large-signal operation of RF power devices quickly and accurately. Results show that circuit simulations using an extracted Root model agree well with device simulation for the intrinsic device. It is also demonstrated that changes in device design are reflected in circuit-level RF performance.

1 Introduction

Presently, the development of radio-frequency (RF) power amplifier devices relies primarily on measurements for evaluation of designs. This is due to the fact that the metrics used to characterize RF power amplifier performance are difficult to obtain through other methods. While it would be desirable to determine these metrics *a priori* through device simulations, the high-frequency, large-signal operation of these power amplifiers often require impractically long simulation times, if convergence is achieved at all [1]. The other alternative would be to use circuit simulators, but the models used to represent the RF power devices are difficult to generate, and they are most often obtained through measurements of actual devices using equipment such as the Agilent Pulsed Modeling System. In order to overcome these issues, we propose in this work a methodology that utilizes both device simulation and circuit simulation, captures the important RF power device characteristics, and provides design insight, all in a reasonable amount of time.

2 Approach

In [2], a framework for a table-based device model for use in circuit simulators is provided. It has been shown that these Root models, extracted from measured devices, demonstrate accurate representation of the actual RF power device performance. Thus the weak points of this approach are that model extraction requires fabricated devices for measurements, and that direct design insight may not be obtained due to the table-based nature of this model.

However, by using device simulation as the data source for model extraction, the design loop may be closed without any fabrication or measurement. Also, due to the quick model generation capabilities, many models, each representing a different design, may be generated, and insight regarding device design changes may be obtained.

Once these models have been generated, they can be imported into circuit simulators such as Agilent ADS [3] for efficient characterization of the designs. Unlike device simulators, circuit simulators can quickly yield RF metrics such as output power, gain, efficiency, and intermodulation distortion, thus allowing fast evaluation of the performance of new device designs. Furthermore, the interaction between new device designs and different circuit-level optimizations and trade-offs can be studied efficiently.

Thus we propose a design flow as shown in Figure 1 for rapid analysis of new device designs through efficient generation and characterization of models for use in circuit simulations. Given a device profile, the device simulator can provide bias-dependent small-signal AC parameters, and from the device simulator output, a Root model is obtained through calculations yielding the table values. The Root model can then be entered into a circuit simulator, and all the RF analysis may be performed to determine the characteristics of the device design. As compared to the traditional methods shown on the left side of Figure 1, the method introduced in this work avoids the time-consuming and costly device fabrication step.

3 Results

For a demonstration of this methodology, we started with a generic nMOSFET in the device simulator TAURUS from Synopsys [4]. We extracted the Root model from the AC simulation results in TAURUS, and the model was fed into ADS. As a verification of the model properties, a transient simulation was performed in both TAURUS and ADS, using a voltage pulse at the transistor gate terminal. The resulting gate and drain terminal currents from both simulators are shown in Figure 2. It can be seen that the curves are basically identical, including the steps where the devices are responding to the rising and falling edges of the pulse.

Radio-frequency simulations in ADS using the extracted Root model were then performed, and the results of 1-tone and 2-tone harmonic balance simulations are shown in Figures 3 and 4, where the curves show typical RF characteristics, including an important sweet spot in the third order intermodulation distortion (IM3) curve. When this process was repeated with a device with a slightly different doping profile, the dotted curves in Figures 3 and 4 were obtained, demonstrating the changes in final RF performance caused by different device designs.

4 Conclusion

This work has shown that RF power amplifier device designs can be characterized in terms of large-signal RF metrics without resorting to measurements of fabricated devices. By capturing relevant device information from device simulation results, circuit simulation can yield all the RF characteristics of interest to the device designer.

References

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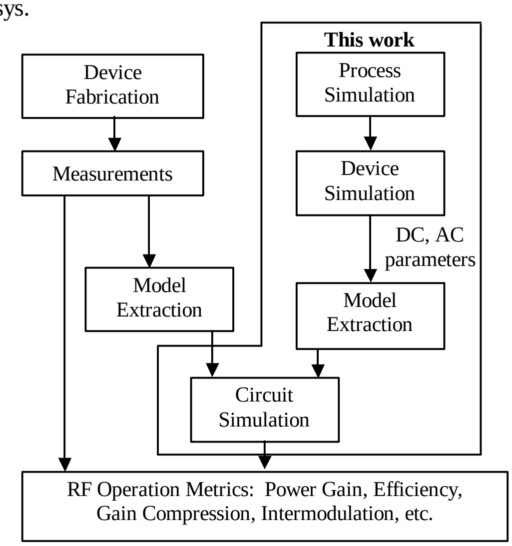

Figure 1. Comparison of traditional and new methodologies. The new work flow avoids costly and time-consuming device fabrication while yielding the same RF metrics.

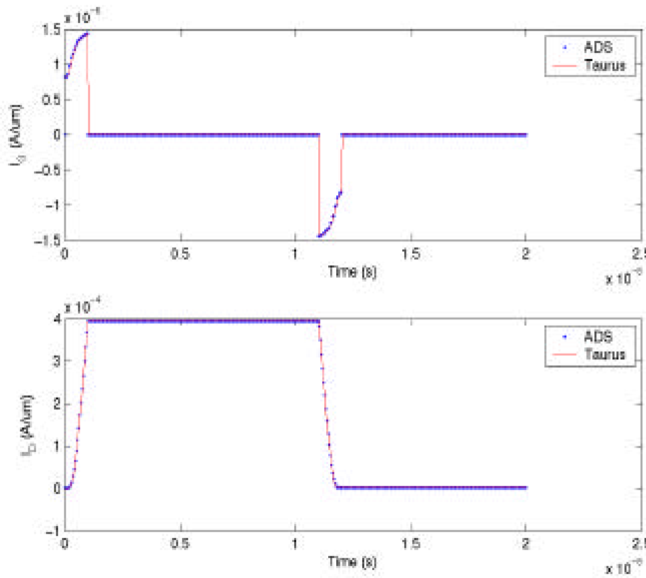

Figure 2. Gate and drain terminal currents as a response to a voltage pulse at the gate. The dots (ADS results), are identical to the lines (TAURUS results).

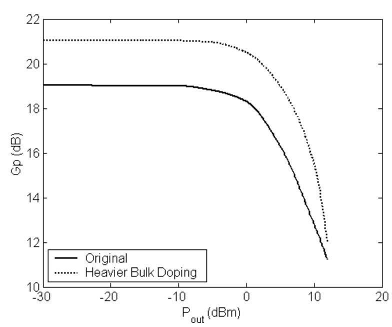

Figure 3. Circuit simulation results showing power gain against output power, for two device designs. Notice that the change in device design causes the gain characteristics to shift.

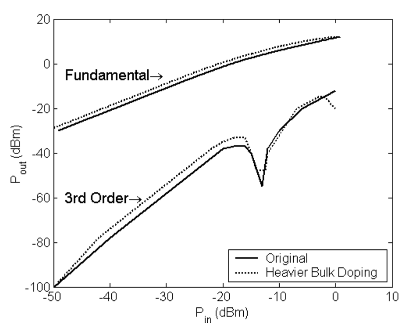

Figure 4. Two-tone circuit simulation results showing the fundamental and third order intermodulation (IM3) curves for different device designs. The change in device design causes shifts in both the fundamental and IM3.