Measuring modeling and realization of amplifiers

The goal of this work is to arm designers with the necessary insight in the nonlinear behavior of their designs such that they can take the different specifications that are put on the nonlinear behavior correctly into account at every level of their design. The contributions of this work make it possible to achieve this goal. It covers the design at transistor level, the analysis of complete circuits and the high-level modeling of devices to be used in system-level simulations.

Design at transistor level

Nonlinear behavior does not only depend on the system, but also on the excitation signal. Therefore, in order to take the nonlinear behavior of the circuit correctly into account, the excitation signal used should resemble the actual communication signal as closely as possible.

Working with real communication signals is not practical during the design process. As an alternative, multi-tone signals are introduced in the design loop.

Multi-tone signals are frequently used in the frequency domain identification, but by means of several examples, we also show that they are very useful in the design loop.

One such example is the load-pull experiment. During the load-pull procedure in the design of a power amplifier, the multi-tone excitation signals lead to a different optimum value for the load impedance than the one obtained with a standard single-tone load-pull procedure.

The single-input single-output best linear approximation shows its usefulness during the transistor level design procedure. With a feedback low-noise amplifier, it was possible to identify the transistor contributing most to the overall nonlinear behavior. The best linear approximation could be integrated in an optimization process, thereby drastically improving the circuit’s linearity.

The multi-tone signals and the single-input single-output best linear approximation can be easily integrated in many designs. They improve the designer’s insight in the circuit’s behavior, thereby speeding up the design of complex circuits.

Analysis of complete circuits

By means of simulations on a 741 operational amplifier, we show how the best linear approximation can be used to characterize the linear and the nonlinear behavior using only a few simulations. The characteristics can directly be compared with the design specifications.

Power amplifiers can also be analyzed using the best linear approximation. Introducing the multiple-input, multiple-output best linear approximation allows identifying the nonlinear contributions of the different stages in a two-stage amplifier. This classification could be performed while the different stages were kept connected, therefore not removing their mutual influence.

The analysis using the best linear approximation is a huge gain for designers.

First, they can verify whether or not the design complies with the specifications. Second, if the design does not comply, they have a technique to identify where it goes wrong.

High-level models

System-level designers are in need for high-level models. Mostly, they have contradicting demands: on the one hand, the model has to describe the systems performance well, but on the other hand, it has to evaluate fast.

The amount of research in the field of high-level models for power amplifiers shows their importance. Plenty of those high-level models do have huge drawbacks. Plenty of them do not take the communication signal correctly into account. Others are only valid for a specific type of power amplifier, for example a class-AB amplifier in a bipolar technology. The high-level models based on a parameterized version of the best linear approximations overcome the limitations. The result is a very fast evaluating model with a very close description of the linear as well as the nonlinear behavior of the device. Since it is not depending on any circuit structure, it can
be easily employed to model other circuits as well. The high-level model is also a simple model to understand. Therefore, the user does not have to study complex theories to understand the limitations of this high-level model.