Power amplifier characterization for predistortion in mobile transmitters

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INTRODUCTION

Digital predistortion of the power amplifier (PA) nonlinearity is a technique to improve signal quality and reduce power consumption in wireless transmitters. Basestation transmitters typically use adaptive predistortion methods, but the required feedback path is too expensive and power-hungry for implementation in a mobile wireless device.
A static nonlinearity is an attractive solution for predistortion in a mobile device because of its simplicity and robustness. The design of the predistorter requires knowledge of the amplifier's AM-AM and AM-PM characteristics. Typically, those are obtained through frequency- and powersweeps with a network analyzer. The results are accurate, but only as long as the bandwidth of the modulated signal during later operation is small. Modern communications systems use wide bandwidth signals. A wideband modulated signal experiences in average different AM-AM and AM-PM distortion than a continuous-wave test tone. As a consequence, a systematic error results from continuous-wave PA characterization, leading to a suboptimal predistorter design. Said error can be avoided by using a modulated test signal with statistics resembling those of the transmitted signal during normal operation.

MEASUREMENT AND MODELING

To characterize the PA, a 5 ms long cyclic test signal with 10 MHz bandwidth (SC-FDMA modulation, according to an early version of the LTE standard) was applied to the amplifier at 2 GHz. One cycle of equal length was sampled from the downconverted output signal. Input and output signal were aligned for maximum correlation using an FFT-based delay with subsample accuracy.
A polynomial-based nonlinearity model was constructed by adding powers of the input signal according to (1):

$$y = \sum_{i=1,3,5,\ldots}^{n} a_i x (xx^*)^{\frac{i-1}{2}} \tag{1}$$

x is one sample of the complex-valued baseband input signal, y is the output sample from the model. n is the order of the polynomial model.
The model is linear in its complex-valued coefficients a_i, and standard least-squares methods are used to determine the coefficients a_i that minimize the remaining error.
The 5 ms test signal was represented by 200000 samples, providing sufficient oversampling for higher-order nonlinear products. An order of 19 was chosen for the polynomial model. Terms for order $i > 7$ correspond to clipping distortion (saturation effects), and improve accuracy only marginally.

RESULTS

Fig. 1 shows the least-squares-optimal AM-AM and AM-PM curves of a GaAs PA with a nominal output power of 27 dBm.

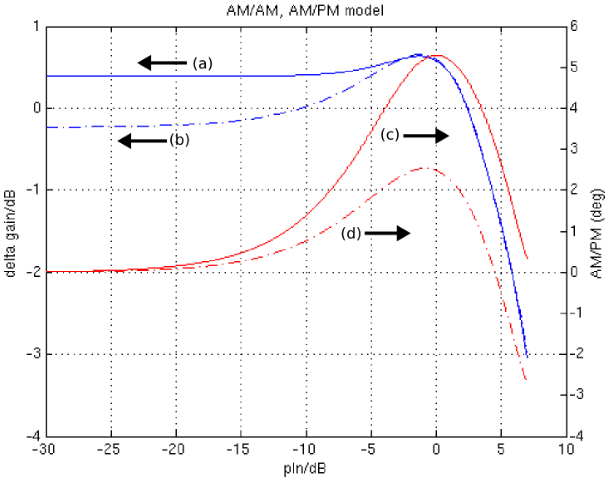

Figure 1: AM-AM and AM-PM characteristics

Trace a) and c) are based on measurement with the wideband test signal. In comparison, b) and e) were obtained with the same signal, at 1/1000 of the original bandwidth (5 seconds measurement time instead of 5 ms).
The systematic error that is caused by memory effects is clearly visible from the difference between traces. For example, the AM-PM distortion for the modulated test signal is more than twice the value obtained through continuous-wave testing.
Fig. 2 presents the spectra of the measured (a) and modeled (b) output signal, and the difference (c). For comparison, (d) shows the SC-FDMA input signal .

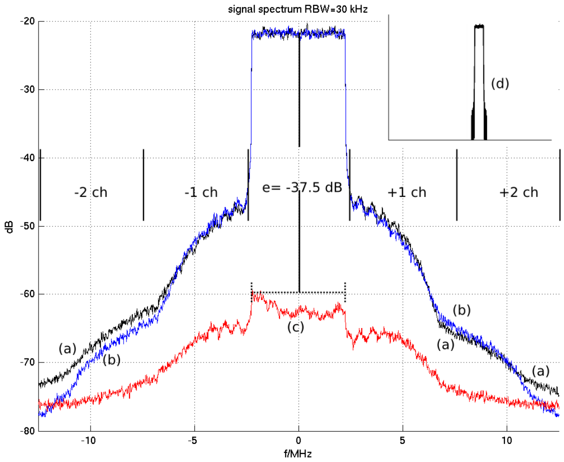

Figure 2: Measured and modeled output signal; error signal

The accuracy is an order of magnitude better than the EVM requirements on the target system. Therefore, the presented PA model is suitable for the design of a predistorter. Since the test signal can be generated by the transmitter’s own digital frontend and the test time is only milliseconds, the method is attractive for production calibration.