MODELLING OF NARROWBAND HIGH POWER AMPLIFIER IN RADIO COMMUNICATION SYSTEM SIMULATION

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Abstract - A new behavioural amplifier model to characterise the AM/AM conversion of a solid-state high power amplifier in a mobile phone is introduced. The model is utilised in mobile communication system studies to investigate adjacent channel interference increase due to the spectral regrowth imposed by the nonlinear behaviour of the amplifier. The new model is compared to the existing widely used models.

Even though today's European mobile communication systems use modulation schemes with constant envelope, there is an interest towards linear modulation formats like OQPSK, π/4-DQPSK and OFDM. The linear schemes provide the system with greater spectrum efficiency, but they also indicate nonconstant signal envelope. Unfortunately, the signals with amplitude fluctuations are subject to spectrum regeneration and inband interference from nonlinearities in the transmit systems, causing adjacent channel and co-channel interference. Traditionally, the required linearity is guaranteed by backing off the amplifier, which, however, decreases the efficiency of DC-RF power conversion of the amplifier significantly. In mobile phones the situation is most severe, because low efficiency of the amplifier means short usage times and frequent battery recharging.

In a communication system simulation a high-level power amplifier model is needed to convert an input waveform to a correct enough output waveform without referring to the fundamental physics of the device. Additionally, there should be only a limited amount of parameters to adjust the functional behaviour of the model. The new bipolar amplifier model introduces an exponential behaviour in the amplitude transfer characteristics at low input voltages. This feature distinguishes it from previously presented nonlinearity models [1, 2]. In reality, the exponential behaviour is created by the base-emitter junction of the device, even though it is partly linearized by the source resistance and the feedback of an external emitter resistance. The introduction of an exponential characteristic in a PA model has been found to have quite an important and desirable impact on the two-tone test intermodulation products.

The exponential behaviour is created by applying the diode expression to the input voltage. Two parameters are used to control the steepness of the exponential curve and the operation class of the amplifier. Where the derivative of the exponential curve is equal to the nominal gain of the amplifier, the curve changes into linear. Rapp's model [2] is utilised to establish the saturation effect to the amplitude transfer characteristic. In the case of a fairly linear amplifier the AM/PM conversion is assumed to be small enough so that it can be neglected.

The effect of the exponential behaviour at low power levels is studied by comparing the simulation results given by the proposed model, ideal limiter model and Rapp's model in a 16QAM transmitter-receiver configuration. The parameters for the new model are found by fitting two-tone simulation results to the measured two-tone performance of a quite linear mobile phone power amplifier. The signal is root-raised cosine filtered with a roll-off factor $\alpha = 0.35$ and the output of the transmitter amplifier to be modelled is backed off by 3 dB.

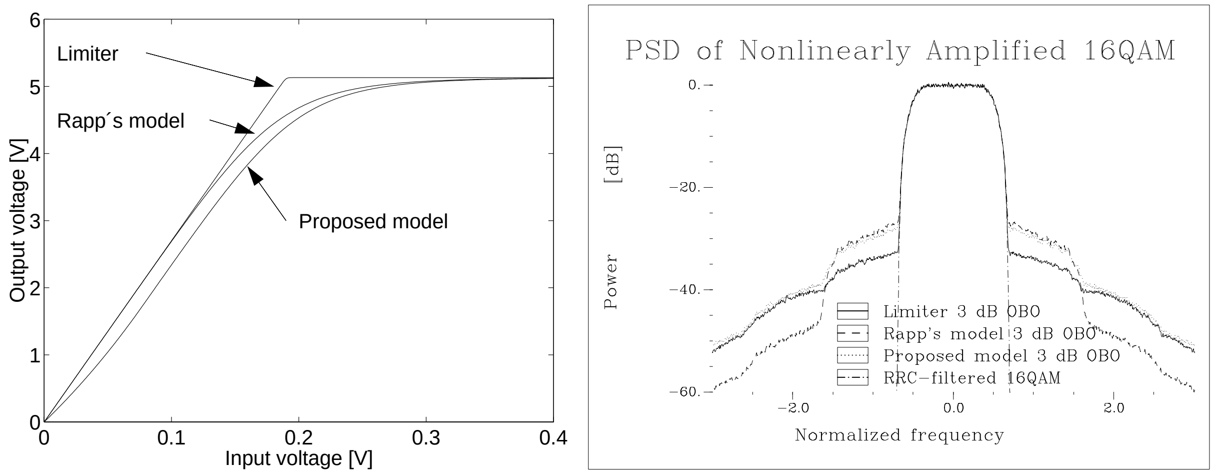

Figure 1: a) Amplitude transfer characteristics of different nonlinear power amplifier models *b)* Power spectral density of a root-raised cosine filtered 16QAM signal applied to nonlinearity models with 3 dB output back-off

In the simulations the co-channel interference induced by nonlinearity has been found to have only minor significance, while remarkable difference between Rapp's model and the proposed model can be seen in the power spectral density (*Fig. 1b*) and in the adjacent channel simulations (*Fig. 2*). Particularly, the second adjacent channel interference seems to be significantly underestimated by Rapp's model. Because of its ideal nature, the limiter model gives too optimistic spectral regrowth results in the case of the first adjacent channel.

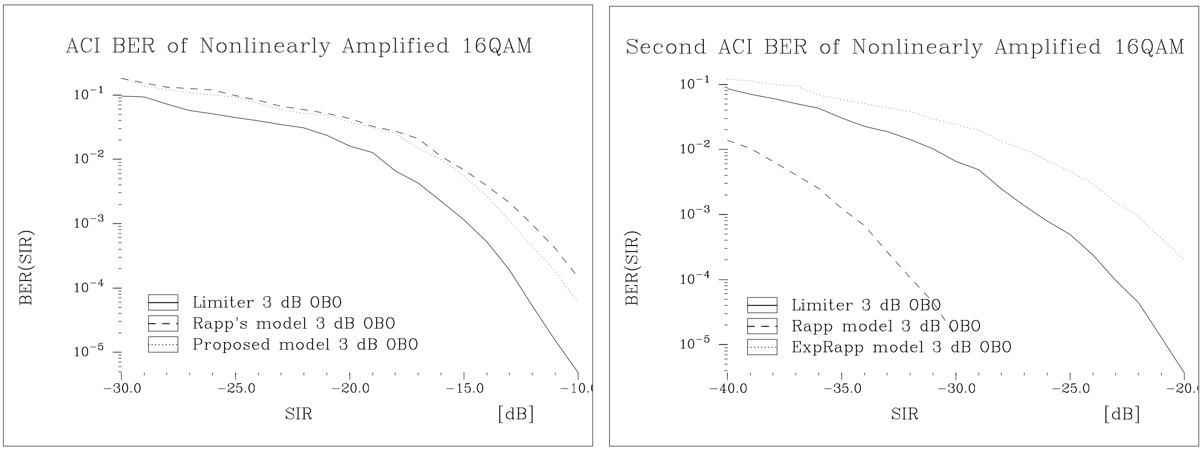

Figure 2: a) Bit error ratio caused by the first adjacent channel and *b)* the second adjacent channel interference due to the spectral regrowth. The channel separation is $(1+\alpha)R_s$, where α is the roll-off factor and R_s is the symbol rate.

REFERENCES

[1] M. C Jeruchim, P.Balaban and K. S. Shanmugan, *Simulation of Communication Systems*, Plenum Press, New York 1992, 731 pp.

[2] C. Rapp, "Effects of HPA-Nonlinearity on a 4-DPSK/OFDM-Signal for a Digital Sound Broadcasting System", *Proceedings Second European Conference on Satellite Communications*, Liege, Belgium, 22-24 October 1991