AMCAD Engineering

White Paper

Advanced Modeling for Computer-Aided Design

Behavioral modelling challenges for RF system simulation

Helping our customers to design smart and safe communication systems !

Behavioral modelling challenges for RF system simulation

Introduction

The fast and ever-increasing demand for high-speed data services has been motivating and leading to define the next generation of cellular mobile communications, referred to as 5G New Radio. To take advantage of the opportunities offered by 5G NR, methods and techniques to design telecommunication systems must continue to evolve to meet, on the one hand, the spectral and energy efficiency requirements and, on the other hand, cost and time to market reduction.

Current research proposes significant developments to achieve higher transmission rates—first, the use of Millimeter-wave bands, which gives access to larger frequency bandwidths. Second, deployment of new transmission techniques, to be integrated into future 5G radio interfaces, including multi-level modulation schemes and multi-carrier (MC) technologies such as Filter Bank Multicarrier (FBMC) or variants of Orthogonal Frequency-division Multiplexing (OFDM). One of the fundamental problems in the application of these techniques is the strong amplitude fluctuation present in the time domain representation of the signal, resulting in a high Peak to Average Power Ratio (PAPR). The high value of PAPR linked to the presence of non-linear elements in the transmission chain, particularly Power Amplifiers (PA), leads to in-band and out-of-band signal distortions, as well as a degradation of the Bit Error Rate (BER).

Problematic

The Power amplifier represents one of the most critical elements in telecommunication systems. As the primary energy consumption circuit, it has the most significant impact on the overall efficiency of wireless transmitters. In other words, an efficient PA reduces the power consumption cost of a base station and increases the battery life of a mobile transmitter. For such, the PA should work in its saturation region. However, increasing the efficiency degrades the linearity and creates signal distortion at the output.

Indeed, the linearity of a highly compressed and efficient power amplifier is sufficiently low to require some sort of error correction. Nowadays, the methods of linearization are mature, particularly digital pre-distortion techniques (DPD), which are the most popular. System Designers or PA manufacturers can choose from a variety of commercial solutions to improve the performance of their amplifier modules or implement their custom DPD solution. However, although offering good performance, the DPD has a high cost. The implementation of a DPD system requires substantial engineering resources and system knowledge to assemble the different digital and analog parts. Indeed, this requires the use, on the one hand, of high-performance DSP units, and on the other hand, analog RF components such as mixers or ADC / DAC (Fig.1). Added to this are the various challenges that emerging applications bring. First, the new 5G standards and markets call for increasingly broadband linearization that traditional DPDs are unable to provide. Secondly, the active antenna architectures no longer make it possible to accommodate DPD systems both in terms of form factor and overall consumption.

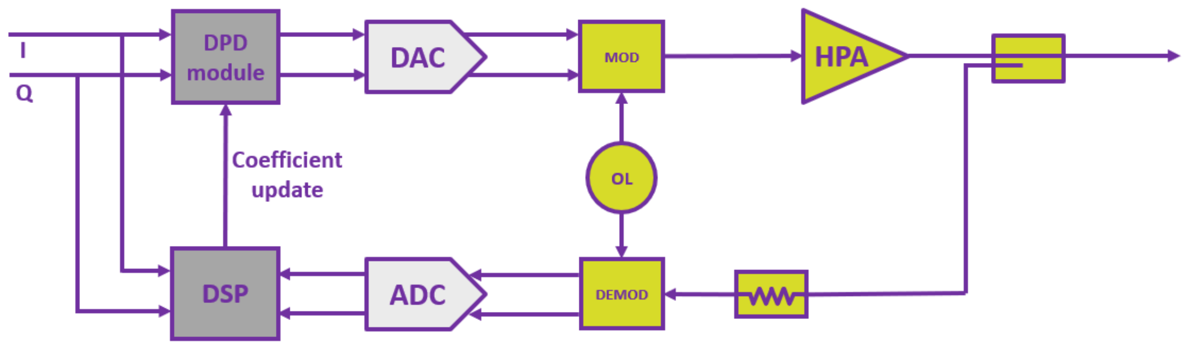

Figure 1- DPD system topology

DPD is, therefore, proving to be a critical technological challenge in new generations of communication systems and is the subject of significant financial and human R&D investment. In practice, DPD development follows specific steps which can be summarized hereunder:

- Step 1: Evaluation of the DPD algorithm in simulation

- Step 2: Implementation of the algorithm on an ASIC or an FPGA

- Step 3: Verification of the DPD system in a real situation using a PA module

Each step is essential to the final development and involves several specialized engineers, especially in design, simulation, and measurement, which leads to a high development cost. Test benches are implemented for each step to speed up development. However, if the DPD system does not meet the linearization requirements of the PA, a new iteration is necessary. It can considerably increase costs and time to market, which can jeopardize the viability of the project. The observed mismatch between simulation and measurement results can be explained by the use of simple behavioral models of PA during "step 1" of the design flow.

To assess the impact of Power Amplifiers on the baseband modulation, engineers use data-flow simulation environments. These simulators offer advanced 5G signal libraries, time, and spectrum-based analysis (BER, SER, ACPR) as well as analytical RF circuit models. However, these models prove to be insufficient to represent the nonlinearity, the frequency dispersion, and the memory effects of PA at the same time.

To deal with such challenges, many research groups focused on behavioral modeling to simulate complex designs and predict their performances under modulated signals in data flow simulators.

This document features:

1. Problematic

2. Illustration
   - Highlighting nonlinearity and memory effects
   - Limitation of PHD model
   - Limitation of PA behavioral model from data-flow simulator

3. Solution
   - VISION model extraction
   - Simulation Results
   - Export feature to other system simulators

4. DPD application example

If you want to get more details

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