USER STORY

Alcatel-Lucent Develops DPD System for Multicarrier GSM Transceivers with Model-Based Design

An Alcatel-Lucent multicarrier transceiver.

The Challenge

Develop a highly efficient and linear multicarrier GSM transceiver

The Solution

Use Model-Based Design to model, simulate, test, and deploy digital predistortion filters and algorithms on FPGA and DSP hardware

The Results

- 30% reduction in development time
- Elimination of two hardware development cycles
- Approximately 90% algorithm reuse

The power amplifiers (PAs) in today's cellular base stations must be operated efficiently to minimize power dissipation and reduce the need for costly cooling equipment. At their most power-efficient operating point, however, PAs distort the signals they amplify. Digital predistortion (DPD) algorithms can correct this behavior, enabling PAs to operate with high efficiency and linearity.

Engineers must evaluate different algorithms to identify the one that best linearizes the PA output and so minimizes leakage into adjacent frequency channels. This capability is particularly important for a multicarrier global system for mobile communications (GSM), which has more stringent adjacent channel leakage ratio (ACLR) regulatory requirements than a typical 3G or 4G system.

Engineers at Alcatel-Lucent developed and implemented a DPD system for a multicarrier GSM transceiver using Model-Based Design. "With MATLAB and Simulink we can determine the effectiveness of an algorithm, first using simulation and hardware-in-the-loop and then testing on the real hardware," says Dr. Rudolf Wessel, engineering manager at Alcatel-Lucent Deutschland AG. "This approach enables us to rapidly evaluate several algorithms before generating code for the DSP and FPGA in our production system."

The Challenge

Single-carrier GSM transceivers typically work with fixed-amplitude signals and a bandwidth of approximately 200 kilohertz. In contrast, multicarrier GSM transceivers are mixed-signal systems with high peak-to-average power ratios and a bandwidth between 20 and 25 megahertz. "This project was our first multicarrier GSM product. Given the high ACLR regulatory requirements, designing a mixed-signal system with a bandwidth 10,000 times wider than traditional GSM products was a significant technical challenge," says Wessel.

The full transceiver chain for the Alcatel-Lucent multicarrier GSM required an FPGA-based nonlinear filter with coefficients set dynamically by algorithms running on a DSP. "Our algorithm developers needed to work closely with our FPGA hardware and DSP software engineers," says Ulrich Class, principal engineer at Alcatel-Lucent. "To reduce hardware development cycles and move quickly from simulation to production, we wanted to generate code for our FPGA and DSP platforms."

The Solution

Alcatel-Lucent used Model-Based Design with MATLAB® and Simulink® to model, simulate, test, and implement the DPD component of its multicarrier GSM transceiver.

Using MATLAB, the engineering team developed a model of the PA based on datasheet specifications and models of an up-converter and an analog-to-digital converter (ADC) for use in the transceiver. Next, they developed DPD algorithms using MATLAB and Signal Processing Toolbox™. The PA model enabled them to run and test several algorithm alternatives. When the actual PA became available, they tested the algorithm on the hardware.

MathWorks®

"Using MATLAB and Simulink, our development team quickly moved from algorithm simulation to testing on real hardware. This workflow was critical in reducing overall development time and hardware development cycles." —Dr. Rudolf Wessel, Alcatel-Lucent

During testing, the engineers acquired data from spectrum analyzers and controlled other test equipment using Instrument Control Toolbox™. They refined the PA model based on the third-order intercept point (IP3) and other measurements.

The team systematically replaced models of the ADC and other components in the transceiver with their hardware equivalents as these became available. Using their previous test results, they fine-tuned the DPD algorithms in MATLAB.

The team modeled the nonlinear filter in Simulink and generated VHDL® code for the FPGA using Xilinx® System Generator for DSP. Using Embedded Coder™, they generated C code for the core DPD algorithms, including matrix inversion operations. The code was deployed to a Texas Instruments™ C64+ DSP to calculate the dynamic coefficients used in the filter chain on the FPGA.

"The quality of the generated code was so high that we didn't make a single change in the production system," says Wessel.

The DPD system for the multicarrier GSM transceiver is already in field operation, and Alcatel-Lucent is reusing the algorithm and the implementation for the whole multicarrier transceiver family, covering 2G, 3G, 4G, and multistandard transceivers and different frequency bands.

The Results

30% reduction in development time. "From initial research to ongoing development efforts, we expected three years of development time using our traditional approach," says Wessel. "With MATLAB and Simulink we reduced that timeline by at least a year."

Elimination of two hardware development cycles. "MATLAB and Simulink simulations enabled us to provide immediate feedback to our hardware engineers," says Class. "We knew that if the simulation worked, the hardware would also work. Verification using simulation and hardware-in-the-loop testing eliminated two hardware development cycles, each of which would have taken three months or more."

Approximately 90% algorithm reuse. "With few changes, we are reusing the multicarrier GSM DPD algorithms in the development of 3G, 4G, and multistandard transceivers," says Wessel. "With this high level of reuse and our ability to generate code for FPGAs and DSPs, we are accelerating the development of these systems."

Industry

- Communications

Application Areas

- Data acquisition
- Mathematical modeling
- Algorithm development
- System design and simulation
- Embedded code generation
- HDL code generation and verification
- Embedded systems
- Communications systems
- FPGA design

Products Used

- MATLAB®
- Simulink®
- Embedded Coder™
- Instrument Control Toolbox™
- Signal Processing Toolbox™
- Xilinx® System Generator

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