AT4 wireless Increases Internal Test Coverage to Over 90% for LTE Physical Layer Test Equipment Designs

AT4 wireless LTE layer 1 tester.

The Challenge

Develop test systems for LTE wireless equipment

The Solution

Use MATLAB and Simulink to design and simulate the LTE physical layer, verify the FPGA implementation, and analyze test results

The Results

- Internal test coverage increased to over 90%
- Test harness reused throughout the project life cycle
- Development effort reduced by 25–30%

Long Term Evolution (LTE), a next-generation wireless communications technology enhancement of the Universal Mobile Telecommunications System (UMTS), promises high throughput, low latency, and improved spectral efficiency.

Based in Málaga, Spain, AT4 wireless develops test systems for manufacturers that design and build LTE handsets. These test systems emulate a base station on the LTE cellular network, enabling AT4 wireless customers to test their user equipment for LTE conformance.

AT4 wireless built the entire reference model for the LTE test system's physical layer using MATLAB® and Simulink®.

"We reused the Simulink model as a test harness throughout the life cycle of the project, generating test points for FPGA cosimulation and hardware-in-the-loop testing," explains Francisco Javier Campos, FPGA architect at AT4 wireless. "This approach enabled us not only to verify our hardware implementation, but also to improve test coverage and automate previously manual test processes."

The Challenge

"One of our primary goals was to improve test coverage," says Marco Pausini, physical engineer at AT4 wireless. On similar previous projects, AT4 wireless engineers relied on time-consuming manual tests to verify the implementation, which made it difficult to test all aspects of the design. Lacking a reference model that implemented the standard, the team was often unable to identify errors until integration testing.

AT4 wireless wanted a model that would enable better understanding of the LTE standard and support a well-documented test process in which they could reuse test vectors for individual components as well as for the complete system.

The FPGA implementation of the LTE physical layer would enable test equipment to acquire test data in real time.

The Solution

AT4 wireless engineers used MATLAB and Simulink to model, simulate, and verify the LTE physical layer implementation.

Before beginning development, the engineers attended two MathWorks training courses: a two-day course on signal processing and a one-day course on communications systems.

The engineers generated their first version of the algorithms with MATLAB and the integrated functions in Signal Processing Toolbox™ and Communications System Toolbox™. They developed convolutional encoders, Viterbi decoders, and other blocks in the transport and physical channels of the LTE physical layer.

After integrating their MATLAB based algorithms into Simulink, they assembled the complete transmission chain in Simulink containing a transmitter, a receiver, and a channel and ran frame-based simulations to verify that the design conformed to LTE specifications. To enable bit-true simulation of downlink components, AT4 wireless engineers converted their floating-point models to fixed point using Fixed-Point Toolbox™.

MathWorks®

"MATLAB is a universal language that makes it easy to exchange algorithms and test results across our team. Our physical layer model in MATLAB and Simulink enabled us to better understand the LTE specifications, and Model-Based Design enabled us to verify that our FPGA implementation conformed to those specifications." —Francisco Javier Campos, AT4 wireless

The engineers used this reference model to create input test vectors for the overall transmitter and receiver as well as for individual blocks. In each case, they used simulation results to create a set of corresponding output vectors. The team used these input and output vectors to verify their implementation model and the final FPGA implementation.

In AT4 wireless test systems, output signals from the hardware are passed through an analog-to-digital converter. The results are saved for offline processing. AT4 wireless engineers developed data analysis algorithms in MATLAB to measure equalization and channel estimation using this test data.

To process the data, AT4 wireless provides testing software as an add-on to their test systems. They integrate their MATLAB algorithms into the software by using MATLAB Compiler™ to convert the code to DLLs.

AT4 wireless has completed initial versions of the LTE physical layer implementation and the testing software. The group is now working on including the technology in several LTE testing products.

The Results

Internal test coverage increased to over 90%. "Manual testing took so long that we were unable to complete all the tests we wanted to," says Campos. "Reusing the Simulink based test bench throughout design, we automated more steps and achieved greater than 90% test coverage—about four times more than we had before."

Test harness reused throughout the project life cycle. "All the test points we generated with the MATLAB model were inputs for the hardware cosimulation on the FPGA," says Campos. "Because we're using the same test vectors and test harnesses, we are virtually 100% confident that the FPGA and the model are behaving the same way."

Development effort reduced by 25–30%. "It was not easy to debug an elaborate chain of operations," notes Pausini. "Now, we can quickly isolate implementation issues by extracting the input and output for each block in our Simulink model and comparing that output with the test results. Each iteration is much faster, and our overall development effort has been reduced by 25–30%."

Industry

- Communications

Application Areas

- Data analysis
- System design and simulation
- Verification, validation, and test
- Communications systems

Products Used

- MATLAB®
- Simulink®
- Communications System Toolbox™
- Fixed-Point Toolbox™
- MATLAB Compiler™
- Signal Processing Toolbox™

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