A Reconfigurable Prototyping System for Multiple-Input Multiple-Output Communications

by

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John William Dalton

For Claire and the children

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Contents

Abstract

This thesis demonstrates the process of building a system to test multiple-input multiple-output (MIMO) communications over-the-air. It covers the entire process, from concept to design and construction, culminating in transmitting space-time coded data packets and producing bit error rate (BER) performance curves.

A flexible modular architecture is designed, able to test current MIMO systems and to be upgraded as the field develops. Printed circuit boards for a field-programmable gate array (FPGA) based mainboard, 2.4 GHz transceivers and antennas are then designed, embodying the aforementioned architecture. The mainboard uses a Xilinx XC2S600E FPGA, with ~600,000 logic gates. Hardware is assembled and tested, forming a foundation for further layers of firmware and software. An abstraction layer, with associated test benches, is written in a hardware description language (VHDL), allowing the core logic of the FPGA to be written and simulated in a device-independent manner. Further VHDL is written and the testbed configured to transmit and receive bursts of data. A device driver is implemented, and abstract data types are layered on top of the driver, enabling high-level control of the testbed. Single antenna and MIMO data links are implemented using 1×1 binary phase-shift keying (BPSK) and 2×2 Alamouti encoded BPSK modulation respectively. Finally, data packets are transmitted and measured BER performance curves constructed.

Channel estimation is proved to work on a 2×2 MIMO channel over-the-air, the introduced loss of E_b/N_0 shown to be approximately 0.5 dB compared to perfect channel information. The analogue limitations of the hardware are investigated and bit error rate performance measured as a function of operating point. Finally single antenna communications and a 2×2 Alamouti MIMO scheme are compared over-the-air, the Alamouti scheme delivering a 3 dB improvement in E_b/N_0 performance. Satisfyingly the MIMO scheme also exceeds the best case theoretical performance bound of the single antenna case by a margin of 2 dB in E_b/N_0.