Impact and Mitigation of Analog Impairments in Multiple Antenna Wireless Communications

Jian Liu

Multi-Input Multi-Output (MIMO) is a promising technology for future wireless communication systems. MIMO technologies improve signal-to-noise-ratio (SNR) by providing diversity in a fading environment, or increase the link capacity by spatial multiplexing. Orthogonal Frequency Division Multiplexing (OFDM) exploits multi-subcarriers to transform a frequency selective fading channel into flat fading subchannels, so as to simplify receiver equalizer design. MIMO combined with OFDM exploits both the space and frequency diversity, to enable low-complexity space-frequency processing and to boost the spectral efficiency as well as the performance. MIMO-OFDM has been adopted by the IEEE 802.11n high-throughput Wireless Local Access Network (WLAN) standard; the standardization process of 802.11n is expected to be completed by the second half of 2006.

Because of the multiple parallel radios in MIMO, the multiple analog transceiver front-ends contribute to most of the cost of MIMO. To enable low-cost radios in MIMO implementation, the mixed-signal design, i.e. the digital and analog co-design, is the solution. Therefore the impact of analog front-end in MIMO and digital compensation techniques for analog front-end impairments in MIMO are the concern of this PhD research, with the final goal of investigating the low-cost radio implementation.

For Single-Input Single-Output (SISO) systems, the impact and mitigation of analog front-end impairments have been well studied and documented. Unfortunately it was not the case for MIMO. Consequently in this thesis, an end-to-end mixed-signal data-flow simulation environment for MIMO was composed, including all the important WLAN building blocks for baseband processing and major analog front-end impairments, therefore it is directly relevant to a real-world environment. This simulation environment can provide the design reference for analog front-end in MIMO. Through this simulation environment, the different impact of analog front-end impairments (e.g. I/Q mismatch, Phase Noise, Amplifier non-linearity, etc.) on MIMO and SISO were compared. For the MIMO specific multi-antenna gain/phase mismatch, both simulation and quasi-analytical approach were carried out to check the impact and required matching accuracy in MIMO with Transmit-only processing and MIMO with Joint-processing. Two types of multi-antenna gain/phase mismatches were identified, which are intra-mismatch and inter-mismatch. For the inter-mismatch, which causes multi-stream-interference (hence severe performance degradation) in MIMO with Transmit-only processing, two calibration schemes were proposed. The initial scheme has been worked out and demonstrated, which shows 5 dB signal-to-interference-and-noise-ratio improvement; the final scheme has been proposed and compared with the initial scheme with necessary hardware measurements. The final scheme is very simple and has low-cost, which is applicable for both the access point and the user terminal and it is promising for the MIMO implementation.