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# Towards low-cost broadband multiple-antenna systems using digital compensation

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## / Introduction

- The application of multiple antennas at both sides of the transmission link (MIMO) is promising for high speed wireless LAN.
- The combination of MIMO with orthogonal frequency division multiplexing (OFDM) creates a system, that is robust to the multipath and has a high spectral efficiency.
- Performance is affected by radio front-end impairments like IQ-imbalance, DC-offset, nonlinearities and phase noise.
- The application of multiple high quality radio front-ends jeopardizes the possibility of low-cost implementation → application of direct conversion; allows for monolithic integration.
- Adoption of digital compensation can considerably relieve specifications (and cost) of the radio front-end.

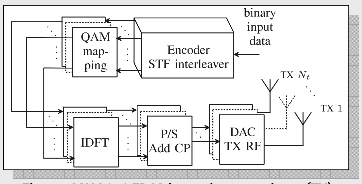


*Fig. 1. MIMO OFDM based transmitter (TX).*

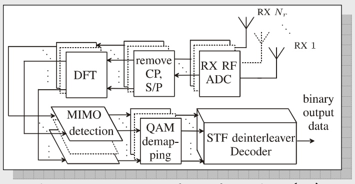


*Fig. 2. MIMO OFDM based receiver (RX).*

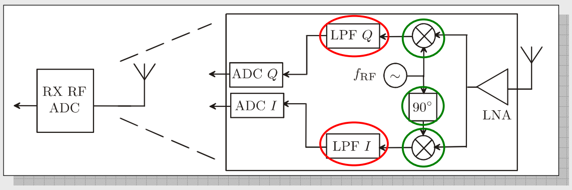


*Fig. 3. Direct conversion RF receiver front-end causing frequency flat and frequency selective IQ imbalance.*

## / Influence of IQ imbalance

- Caused by difference in amplitude and/or phase between the I and Q branches.
- Occurs in both TX and RX of the system. Every MIMO branch has its own IQ imbalance.
- Two kinds of IQ imbalance:
  - **Frequency flat:** caused by mixers, phase shifters and attenuation differences between I and Q arms.
  - **Frequency selective:** caused by difference in group delay and filters in I/Q arms. Prevails for high bandwidths (> 20 MHz), mainly for outer subcarriers.
- In zero-IF transceivers applying OFDM, IQ mismatch causes leakage of the mirror carrier into the wanted carrier (Fig. 4) . This is often referred to as limited image-rejection.
- System property and can be considered constant → exploited in the estimation / digital compensation approach.

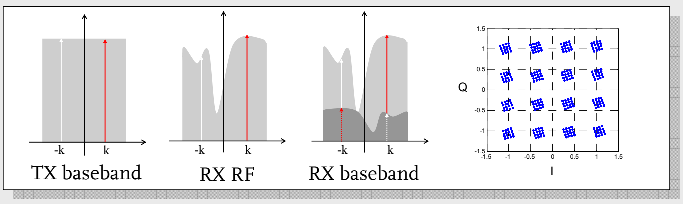


*Fig. 4. Influence of IQ imbalance in zero-IF RX on reception of 16-QAM.*

## / Suppression of IQ imbalance influence

- Two step approach: 1) data-aided compensation of frequency flat IQ imbalance (major source) and 2) decision-directed compensation for frequency selective (LPF) imbalance.
- In 1) simultaneous estimation/correction of the joint MIMO channel, TX and RX IQ imbalance is applied in the baseband of the RX. An orthogonal preamble is used, where orthogonality in space and frequency is achieved through the use of Hadamard matrices.
- Two algorithms are designed for 1). The first averages the IQ imbalance estimates over $P$ packets. The second is iterative and uses the imbalance estimates of the previous packet as input for the estimation of the current packet.
- Frequency selective IQ imbalance is removed by 2), where decisions on the received data are used to adjust an adaptive MIMO filter.

## / Performance evaluation

- BER performance has been evaluated using Monte Carlo simulations of a 2x2 extension of the IEEE 802.11a standard. As regards Fig. 5 a frequency selective fading channel is simulated. The results of Fig. 6 are based on the assumption of a perfect orthogonal AWGN channel.
- Figure 5 shows that the performance of a system using the iterative method, for a high number of packets $P$, approaches the ideal performance.
- The decision-directed approach improves beyond the ideal performance, as shown by Fig. 6, which is explained by the improved MIMO channel estimate.

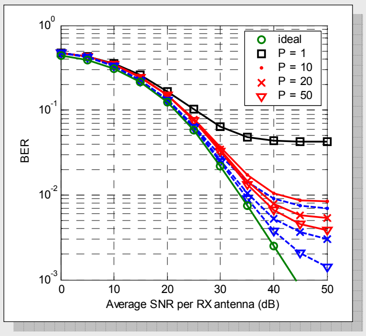


*Fig. 5. BER performance of a 2×2 ZF-based system in detection of uncoded 64-QAM for a system experiencing severe frequency flat TX and RX IQ imbalance. Results for averaging (solid lines) and iterative (dashed lines) algorithm.*

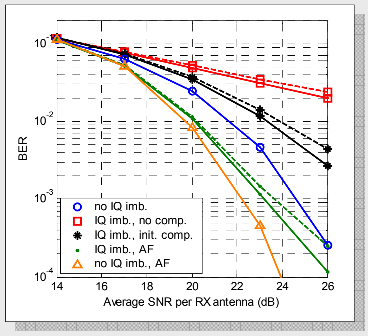


*Fig. 6. BER of a 2×2 ZF-based system in detection of uncoded 64-QAM applying initial compensation (init. comp.) and adaptive filtering (AF) for IQ imbalance. Results for frequency flat (solid lines) and frequency flat and selective (dashed lines) IQ imbalance.*

## / Conclusions and discussion

- The influence of both TX and RX IQ imbalance in MIMO OFDM systems can be considerably reduced using digital compensation.
- The proposed approach combines a data-aided and decision-directed approach to effectively compensate for both frequency flat and frequency selective IQ imbalance.
- Related research shows that digital compensation can also be successfully applied for other impairments, e.g., phase noise and nonlinearities.

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