CITY UNIVERSITY OF HONG KONG
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Linear Transceiver Designs for Multi-Antenna Systems
多天線系統線性收發器設計

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I Abstract

By processing signals in the spatial domain besides the time and frequency domain, multiple antenna techniques play an important role in modern wireless communications systems, such as 4G Long Term Evolution (LTE) standard. Utilizing multiple antenna elements, multiple-input multiple-output (MIMO) systems can provide three well-known advantages over their single antenna counterparts: spatial multiplexing gain, diversity gain, and array gain. When channel state information is available at the transmitter side of MIMO systems, one important issue to achieve such advantages is the joint transmitter and receiver design. In this thesis, we investigate the joint transceiver design for multiple antenna systems, which aim at optimizing some kind of system performance criteria under transmit power constraint and transceiver structure constraint.

Although much effort has been put into the joint transceiver designs for multiple antenna systems, there are still some open issues. For example, there is no general solution for designing diagonal precoding matrix optimizing the minimum Euclidean distance between received signal points, which is an important criterion when the maximum likelihood (ML) receiver is adopted in MIMO systems. Besides, both feedback overhead of channel state information and inter-carrier interference (ICI) need to be considered when designing transceivers for multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) systems, especially in time-varying environments. Directly applying MIMO transceivers on each subcarrier of MIMO-OFDM systems will not only cause heavy feedback overhead due to the large number of subcarriers, but also can't achieve optimal system performance when ICI is non-negligible.

In summary, the main contribution of this thesis can be summarized as the following three parts:

Firstly, a diagonal precoding matrix is designed for MIMO systems to improve the

minimum square Euclidean distance (MSED) between received signal points. The basic idea of the proposed power control technique is to allocate an evenly divided portion of power to the transmit antenna which will give the maximum system MSED during each iteration. With such greedy power allocation method, the system MSED can be increased to the greatest extent by the allocation of all available power.

In the second contribution, linear transceivers are designed for time-invariant MIMO-OFDM systems with consideration of reducing feedback overhead. Due to the large number of subcarriers in MIMO-OFDM systems, the precoder feedback overhead is usually heavy. Many limited feedback transceivers are proposed, which mainly focus on unitary precoding schemes. Based on the fact that the channel matrices of neighboring subcarriers in MIMO-OFDM systems are correlated, an alternative transceiver is proposed. Non-unitary precoders shared by several adjacent subcarriers, and the corresponding individual equalizers are jointly designed under partial CSI. As the number of precoding matrices is smaller, the feedback overhead can be reduced. The transceivers are designed to minimize the detection mean-squared error (MSE) under the total transmit power constraint. A convergent iterative algorithm based on the Lagrange multipliers method is proposed. The necessary conditions for an optimal transceiver, Karush-Kuhn-Tucker (KKT) conditions, are satisfied in each iteration. It is verified that the proposed transceiver can significantly reduce the feedback overhead without severe performance degradation.

In the third contribution, transceivers are designed for time-varying MIMO-OFDM systems with consideration of ICI reduction:

(a) A joint design of precoder and equalizer of a linear transceiver for MIMO-OFDM systems in the presence of intercarrier interference is presented. The matrix structures of the precoder and equalizer are banded for the sake of reducing the computational complexity and feedback overhead of channel state information from the receiver to the transmitter. The design criterion is to minimize the mean squared error subject to a total

transmitted power constraint of which the power is allocated over space and frequency domains in the precoder. We use the Karush-Kuhn-Tucker conditions to derive an iterative procedure to obtain a convergent solution and a closed-form procedure for optimal full-size transceiver. Numerical results show that the banded precoding is an efficient scheme to improve the bit error rate of the transceiver by simply increasing its band size and can provide better BER performance than that of the existing jointly designed full-size transceiver in the presence of ICI. With small band size, the proposed transceiver can give performance close to the jointly designed full-size transceiver but with lower implementation complexity and feedback overhead.

(b) The inter-carrier interference is taken into account by transceiver design in the framework of game theory for MIMO-OFDM systems. In the presence of statistical channel state information at the transmitter, two kinds of transceivers are designed based on minimal mean-squared-error equalizers and minimal mean-squared-error decision-feedback equalizers respectively. With the objective to minimize the expectation of detection mean squared error, the transceiver design problem becomes a complicated strategic non-cooperative game. Heuristic algorithms based on the best reply dynamic in game theory are proposed, of which convergence to Nash equilibrium are numerically verified. Compared with traditional transceivers which ignore ICI effect by assuming perfect orthogonality between subcarriers, a moderate design complexity increase is required in ours. However, the proposed transceivers themselves have the same implementation complexity as their traditional counterparts. The numerical results verified that the proposed transceivers are more robust to ICI effect from the perspective of minimizing bit error rate.

Keywords- Multiple-input multiple-output (MIMO), orthogonal frequency division multiplexing (OFDM), precoder, inter-carrier interference (ICI), feedback overhead.

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