Abstract

To cater to the ever increasing demand of high throughput, future wireless networks must be designed to provide orders of magnitude increased data rates as compared to contemporary wireless networks. Massive multiple-input multiple-output (MIMO) systems, which are equipped with a large number of antennas, can provide significantly increased throughput and have gained significant research interest in the last decade. For practical implementation of a massive MIMO system, the most efficient architecture in terms of cost and energy is the hybrid beamforming system (HBFS) in which a small number of RF chains are connected to a large antenna array through an analog network. The cost of a massive MIMO HBFS can further be reduced by using inexpensive components, which however are less precise and result in several types of hardware imperfections. In-phase and quadrature-phase imbalance or IQ imbalance (IQI) is one such hardware impairment. In this thesis, we study the performance of the point-to-point and multi-user (MU) HBFSs in the presence of IQI and we propose novel IQI compensation algorithms for the corresponding HBFSs.

Firstly, we focus on HBFSs affected by only transmitter IQI (Tx-IQI). For a Tx-IQI impaired point-to-point mm-wave HBFS, we study the impact of Tx-IQI on the achievable rate and we propose an algorithm to estimate the channel and Tx-IQI parameters. We also propose a Tx-IQI pre-compensation algorithm which is implemented at the transmitter and perfectly mitigate the effects of Tx-IQI in a point-to-point HBFS. Next, we consider the uplink (UL) of a Tx-IQI impaired MU-HBFS and it is shown that uncompensated Tx-IQI causes a finite ceiling of the UL achievable sum-rate at high SNR. Therefore, we propose a zero-forcing (ZF) based Tx-IQI compensation algorithm and provide the sum-rate analysis with the proposed Tx-IQI compensation. Through simulations, it is shown that the proposed Tx-IQI compensation algorithm

effectively mitigates the undesired effects of both amplitude and phase mismatch even when different channel models are assumed. Thereafter, we have incorporated the effect of imperfect estimates and propose an algorithm to estimate the true channel coefficients and the user equipment (UE)'s Tx-IQI parameters at the base station (BS). We modify the Tx-IQI compensation algorithm for the imperfect channel state information (CSI) scenario and evaluate the sum-rate performance numerically. It is shown that with imperfect CSI, uncompensated Tx-IQI causes a finite ceiling of the UL sum-rate at high SNR, whereas there is no ceiling of the UL sum-rate with the proposed Tx-IQI compensation. However, inaccuracy in the estimated Tx-IQI parameters causes a performance gap between the sum-rates of an IQI-free system and that with the proposed Tx-IQI compensation.

We next focus on HBFSs affected by only receiver IQI (Rx-IQI). For an Rx-IQI impaired point-to-point mm-wave HBFS, we propose a method to estimate the channel and Rx-IQI parameters. We also propose an Rx-IQI compensation algorithm which is implemented at the receiver and perfectly alleviate the effects of Rx-IQI in a point-to-point HBFS. Next, we consider the downlink (DL) of an Rx-IQI impaired MU-HBFS for which we propose an Rx-IQI pre-compensation algorithm to be implemented at the BS and derive the closed-form DL sum-rate expressions for the ZF hybrid precoder. Through simulations, it is verified that the proposed Rx-IQI pre-compensation algorithm almost achieves the performance of an IQI-free HBFS, whereas uncompensated Rx-IQI causes a finite ceiling of the DL achievable sum-rate at high SNR. Thereafter, we consider the effect of imperfect estimates and propose an algorithm to estimate the channel coefficients and the UE's Rx-IQI parameters at the BS. We also modify the Rx-IQI pre-compensation algorithm for the imperfect CSI scenario and evaluate the sum-rate performance of the considered DL MU-HBFS numerically. It is shown that with imperfect CSI, uncompensated Rx-IQI causes a finite ceiling of the DL achievable sum-rate at high SNR, whereas there is no ceiling of the achievable sum-rate in the Rx-IQI pre-compensated HBFS. However, the error in the estimation of Rx-IQI parameters results in a performance gap between the sum-rates of an IQI-free system and that of a HBFS with the proposed Rx-IQI pre-compensation.