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Spatial Diversity in MIMO Communication Systems with Distributed or Co-located Antennas

Ph.D. Thesis

Abstract

THE USE OF multiple antennas in wireless communication systems has gained much attention during the last decade. It was shown that multiple-antenna systems, called multiple-input multiple-output (MIMO) systems, offer huge advantages over single-antenna systems, both with regard to capacity and error performance.

Typically, quite restrictive assumptions are made in the literature on MIMO systems concerning the spacing of the individual antenna elements. On the one hand, it is typically assumed that the antenna elements at the transmitter and the receiver are co-located, i.e., they belong to some sort of antenna array. On the other hand, it is often assumed that the antenna spacings are sufficiently large, so as to justify the assumption of independent fading on the individual transmission links. From numerous publications it is known that spatially correlated links caused by insufficient antenna spacings lead to a loss in capacity and error performance. In the first part of the thesis, it is shown that this is also the case when the individual transmit or receive antennas are spatially distributed on a large scale. Possible applications include simulcast networks, reach-back links for wireless sensors, as well as wireless networks with cooperating relays. Specifically, it is proven that any spatially correlated MIMO system can be transformed into an equivalent (with regard to the resulting capacity distribution) spatially distributed MIMO system, and vice versa. Moreover, the asymptotic equivalence with regard to the pairwise error probability of space-time codes is proven. Correspondingly, MIMO systems with distributed antennas and MIMO systems with co-located antennas can be treated in a single, unifying framework.

This fact is utilized in the second part of the thesis, where appropriate transmit power allocation strategies are developed for MIMO systems with distributed or co-located transmit antennas. In particular, fading scenarios are taken into account that occur especially in distributed MIMO systems. Focus is on power allocation schemes that require solely statistical channel knowledge at the transmitter side, which can easily be acquired in practical systems. By means of analytical results, it is shown that significant performance gains in comparison to equal power allocation are achieved.

The third part of the thesis focuses on two problems that are of particular interest for MIMO systems with distributed transmit antennas. First, due to the distributed nature of the system, independent local oscillators are employed for up-converting the individual transmitted signals. This causes frequency offsets between the transmission links, which results in time-varying channel impulse responses. The impact of frequency offsets on the performance of different space-time coding techniques is analyzed, and possible counter measures are considered. Second, if the transmit antennas are spaced very far apart and no timing advance techniques are employed, significantly different propagation delays occur that lead to intersymbol interference effects. To this end, suitable space-time coding and equalization techniques are identified, so as to maintain the diversity advantage over a single-antenna system.

Keywords: Wireless communications, MIMO systems, space-time codes, spatial fading correlation, distributed antennas, performance analysis, transmit power allocation, equalization, frequency offset. $\diamond$