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On the Achievable Rate of Stationary Fading Channels

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Preface

In typical mobile communication systems transmission takes place over a time-varying fading channel. The stochastic channel fading process can assumed to be bandlimited and its realization is usually unknown to the receiver. To allow for a coherent signal detection, the channel fading process is often estimated based on pilot symbols which are periodically inserted into the transmit symbols sequence. The achievable data rate with this approach depends on the dynamics of the channel fading process. For this conventional approach, i.e., performing channel estimation solely based on pilot symbols and using it for coherent detection (*synchronized detection*) in a second step, bounds on the achievable data rate are known. However, in recent years receiver structures got into the focus of research, where the channel estimation is iteratively enhanced based on the reliability information on data symbols (code-aided channel estimation). For this kind of systems, the bounds on the achievable data rate with synchronized detection based on a solely pilot based channel estimation are no longer valid.

The study of the possible performance gain when using such receivers with synchronized detection and a code-aided channel estimation in comparison to synchronized detection in combination with a solely pilot based channel estimation poses also the question on the capacity of stationary fading channels. Although such channels are typical for many practical mobile communication systems, already for the simple case of a Rayleigh flat-fading channel the capacity and the capacity-achieving input distribution are unknown. There exist bounds on the capacity, however, most of them are tight only in a limited SNR regime and rely on a peak power constraint.

Thinking of this, in the present thesis various aspects regarding the capacity/achievable data rate of stationary Rayleigh fading channels are treated. First, bounds on the achievable data rate with i.i.d. zero-mean proper Gaussian input symbols, which are capacity achieving in the coherent case, i.e., in case of perfect channel knowledge at the receiver, are derived. These bounds are tight in the sense that the difference between the upper and the lower bound is bounded for all SNRs. The lower bound converges to the coherent capacity for asymptotically small channel dynamics. Furthermore, these bounds are extended to the case of multiple-input multiple-output (MIMO) channels and to the case of frequency selective channels.

The comparison of these bounds on the achievable rate with i.i.d. zero-mean proper Gaussian input symbols to the achievable rate while using receivers with synchronized detection based on a solely pilot based channel estimation already gives an indication on the performance of such conventional receiver structures. However, for systems with receivers based on iterative code-aided channel estimation periodic pilot symbols are still used. Therefore, in a further part of the present work the achievable rate with receivers based on synchronized detection and a code-aided channel estimation is studied. For a specific type of such a receiver an approximate upper bound on the achievable rate is derived. The comparison of this approximate upper bound and the achievable data rate with receivers using synchronized detection based on a solely pilot based channel estimation gives an approximate upper bound on the possible gain by using this kind of code-aided channel estimation in comparison to the conventional receiver using a solely pilot based channel estimation. In addition, the achievable data rate with an optimal joint processing of pilot and data symbols is studied and a lower bound on the achievable rate for this case is derived. In this context, it is also shown which part of the mutual information of the transmitter and the receiver is discarded when using the conventional receiver with synchronized detection based on a solely pilot based channel estimation.

Concerning the typically applied periodic pilot symbols the question arises if these periodic pilot symbols are optimal from an information theoretic perspective. To address this question, the mutual information between transmitter and receiver is studied for a given discrete signaling set. The optimum input distribution, i.e., the one that maximizes the mutual information when restricting to the given signaling set, is given implicitly based on the Kullback-Leibler distance. Thereon it is shown that periodic pilot symbols are not capacity-achieving in general. However, for practical systems they allow for receivers with small computational complexity.

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