Noncoherent Coded Modulation

Codierte Modulation für inkohärente digitale Übertragungsverfahren

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Abstract

Noncoherent coded modulation is the synthesis of forward error-correction coding for non-binary signaling with noncoherent detection techniques. Such a configuration naturally arises if power- and bandwidth-efficient communication is desired in a hostile fading channel environment.

In this thesis, noncoherent coded modulation for frequency-nonselective fading channels in the absence of channel state information (CSI) at the transmitter and at the receiver side is studied. Two particular approaches are investigated in detail, which are based on two different noncoherent detection strategies: *multiple-symbol differential detection (MSDD)* and *decision-feedback differential detection (DFDD)*. The underlying principle of both MSDD and DFDD is to utilize an increased observation window size of $N > 2$ consecutively received symbols to yield decision variables. In this way, the channel memory is more completely taken into account and consequently, power efficiency of noncoherent detection without CSI can be improved over conventional differential detection (CDD) with $N = 2$.

For coded transmission with MSDD we devise the application of *multilevel coding (MLC)* with *multistage decoding (MSD)* as coded modulation scheme optimum with respect to channel capacity. As well-established for coherent transmission, the appropriate rate design for the MLC component codes orientates on the capacities of the corresponding equivalent channels. The large number of levels, which increases linearly with the observation window size N, constitutes the main drawback of MLC. In particular, the implementation is complicated by the high number of different encoders and decoders, and the code lengths of the component codes become relatively small, even in case of moderate constraints on decoding delay. In order to overcome these limitations, we propose to judiciously merge levels of MLC, which leads us to *hybrid coded modulation (HCM)* schemes. HCM is almost as efficient as MLC in terms of capacity and shows a superior performance in terms of word-error rate derived from the random coding exponent taking delay constraints into account. The extreme case of only one remaining level, which is *bit-interleaved coded modulation (BICM)*, turns out to be ill-suited to MSDD with $N > 2$.

On the other hand, simple BICM using convolutional codes can be successfully combined with noncoherent receivers using decision feedback. More specifically, adapting the idea of DFDD to bit-interleaved coded transmission we present a *low-complexity* iterative decoding

algorithm which applies standard Viterbi decoding and hard-decision feedback. This *iterative decision-feedback differential demodulation (DFDM)* requires only a very moderate increase in computational complexity compared to CDD when increasing N, but offers great advantages in power efficiency. Furthermore, employing prediction-based metric calculation the iterative DFDM is perfectly suited for low-complexity implementation without *a priori* knowledge of the fading statistics.

The different concepts of noncoherent coded modulation are applied to both single-antenna and multiple-antenna differential modulation. Besides conventional differential phase-shift keying (DPSK) combined amplitude and phase modulation formats are introduced for the single-antenna case to accomplish power- *and* bandwidth-efficient transmission. For multiple-antenna transmission *differential space-time modulation (DSTM)* offering full transmit diversity is adopted.

The presented information theoretical and bit-error rate results show in good agreement the feasibility of both capacity achieving and low-complexity noncoherent coded modulation.