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Nyquist Windowing, Peak-Power Reduction, and Synchronization

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OFDM for Wireless Communications:

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The baseband algorithms presented in this thesis are designed for an Orthogonal Frequency-Division Multiplexing (OFDM) broadband communications system with data rates of 10 to 20 Mbit/s like in the German research project "ATMmobil". An unconsumed guard interval is identified as potential source for moderate gains and a modified preamble structure is found to offer advantages in single-shot burst or packet synchronization. Further, distortionless transmitter algorithms for peak-power reduction are discussed. Some of the proposed solutions are also suitable for HiperLAN/2.

General OFDM transmission is analyzed, and these results are specialized to conventional OFDM. The loss of mutual subcarrier orthogonality is quantified and minimum requirements for synchronization accuracy are obtained.

Conventional OFDM receivers disregard the guard interval even in situations with small channel dispersion. Signal samples received during the unconsumed portion of the guard interval can be exploited to enable improved and more robust demodulation. A Nyquist-shaped receiver window preserves subcarrier orthogonality and its shape is optimized.

The behaviour of the discrete-time and the continuous-time OFDM transmit signal are studied. The statistical properties of the discrete-time crest factor of OFDM are analyzed and compared to theoretical limits. Two distortionless, flexible, and highly effective peak-power reduction schemes for OFDM are proposed, which employ a small amount of additional complexity and almost vanishing redundancy. The schemes are called selected mapping (SLM) and partial transmit sequences (PTS). These techniques could also be used in single-carrier modulation or with other multiplex schemes. An interesting novel variant of SLM is introduced, which does not require transmission of explicit side information. An oversampled processing in the transmitter mitigates the mismatch between discrete-time predictions and actual continuous-time signal behaviour. The improved peak-power statistics of the new OFDM schemes are covered by simulations, and the effect on out-of-band spectral content due to nonlinearities is studied.

Finally, frame and frequency synchronization in OFDM is covered. Two competitive structures for a repetition preamble — to enable coarse frame and frequency synchronization — are introduced, analyzed, and compared to each other. Optimum metrics for detection of repetition preambles with extended guard interval are derived, which allow a significant improvement in synchronization performance. Several strategies to enlarge the frequency estimation range are discussed and analyzed. A novel technique which first estimates a fine offset and subsequently resolves frequency ambiguity by use of further correlation terms is shown to be advantageous for the parameter settings of ATMmobil.

Often, the initial frame offset estimate is too inaccurate for high-level modulation schemes, making an additional frequency-domain frame synchronization necessary, which can significantly improve the initial estimate. A suitable approach is described and the estimator properties are analyzed.