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Low Complexity Block Processing Algorithms for Robust Adaptive Channel Estimation in OFDM Systems

Block-basierte Algorithmen mit niedriger Komplexität
zur robusten adaptiven Kanalschätzung in OFDM Systemen

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Abstract

This work focuses on adaptive algorithms for pilot-aided channel estimation in orthogonal frequency-division multiplexing (OFDM) transmission systems. The algorithm development is subject to a trade-off of the following requirements: close-to-optimum estimation performance by linear filtering, low complexity to allow for an efficient implementation, and robustness to cope with severe channel conditions and distortion due to noise and interference. In this context, the provided thesis comprises two research parts. Theoretical considerations prove the optimality of the algorithm approaches and, secondly, suitable adaptive algorithms are deduced which satisfy the stated demands.

Based on the fundamentals of the linear two-dimensional (2D) Wiener filtering for channel estimation, which is optimum in the sense of a minimum mean-squared error (MMSE), related methods with lower complexity are benchmarked analytically. These algorithms feature different combinations of two times one-dimensional (2×1D) filtering, real-valued filtering, or exploiting special assumptions to decrease the computational effort. It is verified analytically as well as numerically, that 2×1D Wiener filtering can provide the same accuracy as the optimal 2D Wiener filtering, for which conditions for the approximate equivalence are derived. Furthermore, the enhanced real-valued Wiener filtering is proposed to achieve close to the optimum complex-valued Wiener filtering.

With this theoretical considerations on performance dependencies, the standard normalized least-mean-square (NLMS) as well as the recursive least-squares (RLS) algorithms are chosen as basis for further improvements, because they guarantee convergence towards the optimum Wiener solution. As the first innovation step, these algorithms are extended to block processing w.r.t. the filter update calculations. I.e., they are able to exploit a plurality of training subcarriers, which increases the robustness due to the noise averaging effect. However, the block processing algorithms introduce higher computational effort. This is combated by the next innovation step, the development of algorithm simplifications and the adaptation of real-valued filter coefficients. These algorithm types provide a significant reduction of the complexity at two locations within the receiver. The algorithm implementation itself is simplified and the number of operations for the filtering process for channel estimation is reduced.

The mean-squared error (MSE) simulation results show that the convergence speed and the asymptotic misadjustment relative to the optimum MMSE performance are significantly enhanced by the introduced block processing, where the simplified approaches achieve almost the same performance as their optimal counterparts. Even slight gains are observed for the application of real-valued filters compared to complex-valued filters. The robustness of the adaptive algorithms is proved successfully by a high Doppler test, which classifies the achievable bit-error performance under strong Doppler-induced interference. In conclusion, the proposed algorithms provide a good compromise between low complexity and near-optimum estimation accuracy.