Adaptive Turbo Multiuser Decision Feedback Detection for DS-CDMA on Unknown Multi-path Channels

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In this paper we propose an adaptive turbo multiuser detection (MUD) on unknown multi-path channels. The analyzed multi-user scheme is Successive Decision Feedback Detector (S-DFD), which means that users are detected on one-by-one basis and they are cancelled successively by use of decision feedback. An adaptive LMS algorithm is used to estimate MUD coefficients. Binary Phase Shift Keying (BPSK) in combination with Direct Sequence Code Division Multiple Access (DS-CDMA) is analyzed, which means that information is first coded using convolutional encoder, and then modulated and spread using randomly chosen spreading sequences for each user.

Our analysis shows that the adaptive realization employing the LMS adaptive algorithm, out- performs (in terms of Bit Error rate (BER)) the conventional detection that combines a standard Minimum Mean Square Error (MMSE) solution and decoding concatenated in a turbo scheme. A standard solution means that the MUD coefficients are obtained applying the MMSE criterion and assuming perfect knowledge about the received spreading sequences after multi-path propagation and perfect decision feedback.

The reason behind this is that during the Turbo detection process the assumption about perfect decision feedback becomes highly unreliable that must be taken into account while determining S-DFD coefficients. Decision feedback error propagation becomes particularly severe at low Signal-to Noise Ratio (SNR) or highly loaded, heavy interference systems when number of users exceeds the spreading gain. On the other hand, the adaptive LMS detection does not assume the perfect decision feedback while adjusting the filter coefficients and it always set the coefficients providing that the output error is orthogonal on the received sequence. This means that it automatically takes into account the feedback error propagation providing an unbiased MMSE solution that does not assume perfect feedback and, consequently, deliver better BER results. In addition to better BER performance, another advantage of the adaptive detection is that it does not require knowledge about system parameters, such as spreading sequences, multi-path channels etc, but the MUD parameters are estimated during the training process.

In our work, we analyze various multi-user scenarios. This includes unsaturated systems, where number of users K is smaller than the spreading gain N ($\rho = K/N < 1$) and overloaded case, i.e., the number of users K is larger than the spreading gain ($\rho > 1$). We also analyze single- and multi-cell cases. In single cell situation, all users are assumed to be within one cell and during the multiuser detection process multi-user turbo detector detects all signals, one-by-one, in a turbo-like process. However, in a multi-cell scenario, there is a certain number of users located outside the cell of interest that cannot be detected and, consequently, they represent unknown interferers whose influence may significantly degrade the performance of the analyzed turbo MUD. Our simulation results show that the adaptive turbo MUD always exhibits better or at least identical BER performance relative to the conventional MMSE turbo MUD. We show that SNR gain grows with the increasing number of users within the system and the most remarkable improvement is obtained for the overloaded case. For this particular scenario, the conventional MMSE turbo MUD cannot perform detection properly, while the adaptive detector still achieves relatively good BER performance.