Chapter 18
Comparative Study of Adaptive Multiuser Detections in Hybrid Direct-Sequence Time-Hopping Ultrawide Bandwidth Systems

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ABSTRACT
This chapter considers low-complexity detection in hybrid Direct-Sequence Time-Hopping (DS-TH) Ultrawide Bandwidth (UWB) systems. A range of Minimum Mean-Square Error (MMSE) assisted Multiuser Detection (MUD) schemes are comparatively investigated with emphasis on the low-complexity adaptive MMSE-MUDs, which are free from channel estimation. In this contribution, three types of adaptive MUDs are considered, which are derived based on the principles of Least Mean-Square (LMS), Normalized Least Mean-Square (NLMS), and Recursive Least-Square (RLS), respectively. The authors study comparatively the achievable Bit Error-Rate (BER) performance of these adaptive MUDs and of the ideal MMSE-MUD, which requires ideal knowledge about the UWB channels and the signature sequences of all active users. Both the advantages and disadvantages of the various adaptive MUDs are analyzed when communicating over indoor UWB channels modeled by the Saleh-Valenzuela (S-V) channel model. Furthermore, the complexity of the adaptive MUDs is analyzed and compared with that of the single-user RAKE receiver and also with that of the ideal MMSE-MUD. The study and simulation results show that the considered adaptive MUDs constitute feasible detection techniques for deployment in practical UWB systems. It can be shown that, with the aid of a training sequence of reasonable length, an adaptive MUD is capable of achieving a similar BER performance as the ideal MMSE-MUD while requiring a complexity that is even lower than that of a corresponding RAKE receiver.

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1. INTRODUCTION

In recent years ultrawide bandwidth (UWB) communications have drawn wide interest in both research and industry communities (Molisch, 2005; Scholtz, 1993). Initially, UWB signaling has been implemented using solely carrier-less time-hopping pulse-position modulation (TH-PPM) (Scholtz, 1993), which, for convenience, is referred to as the pure TH-UWB scheme. Then, the conventional direct-sequence spread-spectrum (DS-SS) scheme has been introduced for implementation of UWB communications (Foerster, 2002), which is referred to as the pure DS-UWB scheme. Explicitly, both these pulse-based UWB schemes employ their advantages and disadvantages, when communicating over the UWB channels, which are highly dispersive (Molisch, 2005; Fishler, 2005). Therefore, it might be desirable to adopt in one UWB system both the DS-SS and TH, forming a so-called hybrid DS-TH UWB communications scheme (Ahmed et al., 2007), in order to take the advantages of both the pure DS-UWB and pure TH-UWB, while, simultaneously, to avoid their shortcomings. Note that, the hybrid DS-TH UWB scheme may be viewed as a generalized pulse-based UWB scheme, which includes both the pure DS-UWB and pure TH-UWB schemes as its special examples (Ahmed et al., 2007). Additionally, the hybrid DS-TH UWB scheme employs a higher number of degrees-of-freedom than either the pure DS-UWB or pure TH-UWB scheme, which may be beneficial to the design and reconfiguration in order to achieve high-flexibility UWB communications.

Pulse-based UWB schemes constitute a range of promising alternatives to be employed for home, personal-area, sensor network, etc. applications, where devices are required to consume minimum power while maintaining low-complexity (Reed et al., 2005; Breining, 1999). Due to its low-complexity in the context of conventional wideband communications (Proakis, 2000), RAKE receiver has naturally been considered for detection in UWB systems (Win & Scholtz, 1998; Mireles, 2002). However, UWB channels are highly dispersive, resulting in that a UWB receiver typically receives a high number of resolvable paths with each resolvable path conveying only a small portion of the transmitted energy. Hence, in order to capture efficiently the transmitted energy, a large number of RAKE fingers are required, which substantially increases the detection complexity (Li & Rusch, 2002; Honig & Tsatsanis, 2000). Furthermore, for achieving coherent combining (Simon & Alouini, 2005), the RAKE receiver requires to estimate a huge number of multipath component channels, which is highly-complex and impractical. Additionally, when communicating over multiuser communications scenarios, multiuser interference (MUI) and inter-symbol interference (ISI) may severely degrade the achievable BER performance of the UWB systems (Yang & Giannakis, 2004).

Due to the above-mentioned considerations, in this contribution we propose and investigate a range of minimum mean-square error (MMSE) assisted multiuser detection (MUD) schemes for the hybrid DS-TH UWB systems. We focus our attention on the three types of low-complexity adaptive MUDs, which are implemented based on the principles of least mean-square (LMS), normalized least mean-square (NLMS) and recursive least-square (RLS), respectively (Haykin et al., 2002). As our forthcoming discourse shown, these adaptive MUDs are free from channel estimation and are capable of achieving the approximate MMSE solutions with the aid of training sequences of certain length. In this contribution we investigate comparatively the achievable BER performance of the adaptive MUDs as well as of the ideal MMSE-MUD (Moshavi, 1996), which demands ideal knowledge about the UWB channels and the signature sequences of all active users (Woodward & Vucetic, 1998; Moshavi, 1996). The BER performance of the hybrid DS-TH UWB, pure DS-UWB and pure TH-UWB systems, which employ the above-mentioned adaptive/ideal MMSE-MUDs, is investigated, when communi-
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