Near-Optimum Iterative Multiuser Detection in Time-Frequency-Domain Spread Multicarrier DS-CDMA Systems

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Abstract— In this contribution we propose and study a novel iterative time-frequency-domain (TF-domain) multiuser detector (MUD) for the multicarrier direct-sequence code-division multiple-access system employing both T-domain and F-domain spreading, which, for brevity, is referred to as the TF/MC DS-CDMA system. The proposed iterative TF-domain MUD consists of a set of T-domain soft-input soft-output MUDs (SISO-MUDs) and a set of F-domain SISO-MUDs, which exchange information through two multiuser interference (MUI) cancellation units. Both the T-domain and F-domain SISO-MUDs are operated under the maximum a-posteriori (MAP) principles. In this contribution the complexity and bit error rate (BER) performance of the TF/MC DS-CDMA employing the proposed iterative TF-domain MUD are investigated and also compared with the other existing MUD schemes, including the optimum MUD and the joint/separate minimum mean-square error (MMSE) MUDs. Our study shows that the iterative TF-domain MUD is capable of achieving nearly the same BER performance as the optimum MUD, but at much lower complexity.

I. INTRODUCTION

Recently, multicarrier CDMA using both Time (T)-domain and Frequency (F)-domain spreading, namely the TF/MC DS-CDMA, has attracted wide attention in the field of broadband wireless communications [1–5]. More explicitly, in the TF/MC DS-CDMA the transmitted data stream is spread using two signature sequences, one implements the T-domain spreading and the other once implements the F-domain spreading [1,3]. The benefits of employing both T-domain spreading and F-domain spreading in the TF/MC DS-CDMA systems are multifold. Firstly, the TF/MC DS-CDMA uses relatively lower chip-rate and shorter spreading sequences than the conventional single-carrier DS-CDMA [2]. Hence, relatively low-rate signal processing techniques may be used for implementation of the TF/MC DS-CDMA. Secondly, owing to employing both the T-domain and F-domain spreading, the maximum number of users supportable by the TF/MC DS-CDMA does not have to make a trade-off with the frequency-diversity achieved by using F-domain repetition [4]. Furthermore, in the TF/MC DS-CDMA users can be distinguished either by their T-domain signatures or by their F-domain signatures, or by their joint TF-domain signatures. Therefore, signal detection in the TF/MC DS-CDMA has a high-flexibility, which may provide the design of wireless communications systems a good trade-off between complexity and achievable BER performance [2, 3, 5].

In this contribution we propose and investigate an iterative TF-domain MUD scheme for the TF/MC DS-CDMA, when communicating over multipath Rayleigh fading channels. The proposed iterative TF-domain MUD consists of a group of T-domain SISO-MUDs and a group of F-domain SISO-MUDs. Both the T-domain and F-domain SISO-MUDs are operated under the MAP principles. The T-domain SISO-MUDs and F-domain SISO-MUDs are connected through two group-level interference cancellation (GIC) units, where MUI cancellation [6, 7] is attempted. In this contribution the BER performance of the TF/MC DS-CDMA systems using the proposed iterative TF-domain MUD is investigated, when communicating over multipath Rayleigh fading channels. The BER performance and complexity of the proposed iterative TF-domain MUD are compared with the other existing MUD schemes, which include the optimum MUD [8], the joint and separate MMSE-MUDs [3, 4]. Our study and simulation results show that the iterative TF-domain MUD is capable of achieving a similar BER performance as the optimum MUD. However, the detection complexity of the iterative TF-domain MUD is significantly lower than that of the optimum MUD.

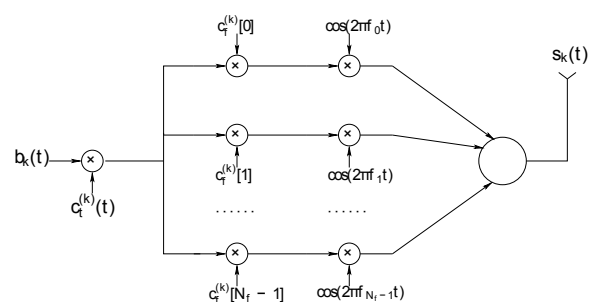## II. TIME-FREQUENCY-DOMAIN SPREAD MULTICARRIER DS-CDMA

Fig. 1. Transmitter model of MC DS-CDMA using both time- and frequence-domain spreading.

A. Transmitted Signal

The transmitter schematic block diagram for the kth uplink user supported by the TF/MC DS-CDMA is shown in Fig. 1.