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Alexandra Duel-Hallen

A Novel Pre-RAKE Multiuser Transmitter Precoding Technique for DS/CDMA Systems Aided by the Long Range Prediction[1]

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Abstract:- *Multipath-induced multiuser interference (MAI) is a major source of degradation in the downlink of a Direct-Sequence Code Division Multiple Access (DS/CDMA) system. This MAI can be eliminated using a transmitter precoding system. The Pre-RAKE transmitter precoding at the Base Station (BS) was proposed to achieve the multipath diversity without the need of the RAKE receiver at the Mobile Station (MS)***.** *We describe a novel approach to linear multiuser precoding at the BS that separates the functions of the pre-RAKE precoding and MAI cancellation. It achieves significantly lower complexity than previously investigated methods. We employ the long range fading prediction to enable this method for rapidly time varying multipath fading channels.*

SUMMARY

Multipath-induced MAI is the major source of performance degradation for DS/CDMA systems. To overcome this problem, many receiver (Rx) based multiuser detection (MUD) techniques have been proposed [1-5], which demand high computational complexity, power and knowledge of spreading codes of all users. As a result, in the downlink of a CDMA system it is not feasible to employ such methods at the MS. Alternatively, transmitter (Tx) based techniques were proposed to shift computational complexity and power consumption to the BS, where they can be afforded [6-8,18]. Although these methods are powerful, they are high in complexity since MAI cancellation filters need to be updated continuously as fading coefficients vary.

The RAKE receiver is required to achieve multipath diversity gain for the DS/CDMA systems, which increases the complexity and power consumption of the MS. Pre-RAKE diversity combining techniques [9-11] were proposed as a solution. With this method, RAKE combining is performed before transmission at the BS so that the MS can employ a simple matched filter receiver.

In this paper, we propose a novel pre-RAKE multiuser precoding method. In this approach, the functions of pre-RAKE combining and MAI cancellation are separated. Thus the MAI cancellation matrix does not depend on rapidly time-varying fading coefficients. This method has similar performance to other previously proposed linear precoding techniques but the complexity is much lower. The long range fading channel prediction can be used to forecast the fading profile of the channel and improve performance [12-14].

Assume a K user DS/CDMA system with L-path frequency selective fading channel for each user. First the transmitter applies the tap delay line pre-RAKE filtering as described in Figure 1. The linear multiuser pre-decorrelating filter **G** processes the outputs of these filters and the resulting signal is spread using the spreading filter **S**. The signal after spreading is scaled by S_f to keep the total transmitted power normalized and sent out to all mobile stations. The transmitted signal is then given by $x = S_f \mathbf{S}\mathbf{G}\mathbf{C}^H\mathbf{A}'\mathbf{b}$, where $\mathbf{A}'$ is the pre-RAKE scaled amplitudes matrix, **b** is the data bits vector and **C** is the pre-RAKE weighting matrix. For the zero forcing

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solution, the decorrelating filter is chosen to be $\mathbf{G} = \mathbf{R}^{-1}$, where $\mathbf{R}$ is the correlation matrix of the users' spreading sequences and their delayed versions. So that, at the receiver, the output of matched filter bank of all users (conventional detectors) is:

$$\mathbf{y} = S_f \mathbf{CRGC}^H \mathbf{A}'\mathbf{b} + \mathbf{n} = S_f \left(\mathbf{CC}^H\right)^{1/2} \mathbf{Ab} + \mathbf{n},$$

where $\mathbf{n}$ is the noise vector**.** The decorrelating filter $\mathbf{G}$ removes all multipath-induced interference and allows frequency diversity combining, resulting in simple matched filtering at the mobile. Moreover, the decorrelating matrix depends only on the signature sequences and the number of multipath components, not on channel gains. Thus the matrix inverse does not have to be updated as channel gains vary at the fading rate. Pre-RAKE coefficients and scaling factors are updated for each symbol transmitted (assuming channel is constant during one bit interval). For rapidly time-varying channels, to update the pre-RAKE coefficients, we employ the long range fading channel prediction algorithm, as has been investigated earlier for the single user system [15,16]. It was shown in [14-16] that the long range prediction based on the Minimum Mean Square Error criterion (MMSE) can be used to accurately estimate the future channel state information at least several milliseconds ahead for rapidly time varying fading channels.

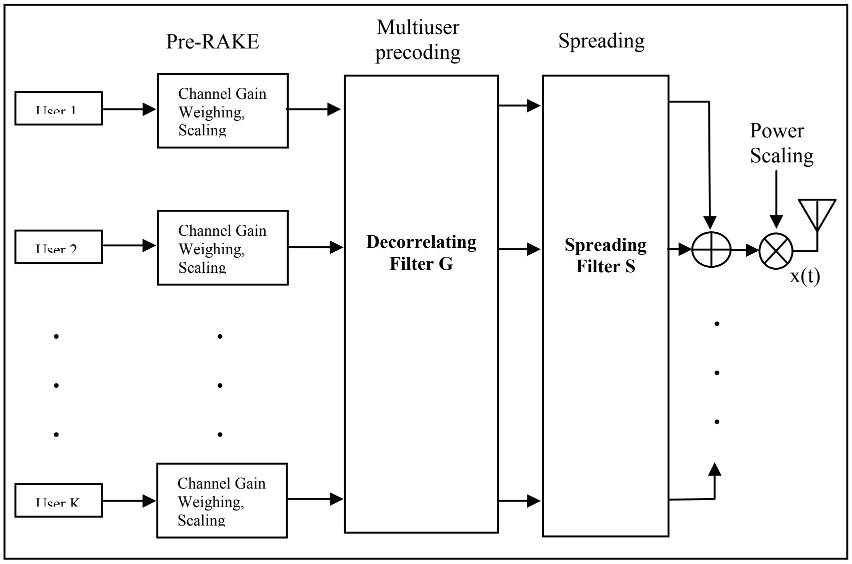

Figure 1. Pre-RAKE Multiuser Precoding

Performance of previously proposed receiver-based multiuser detection and transmitter-based multiuser precoding techniques is compared with that of the proposed pre-RAKE multiuser precoding method. Numerical and simulation results based on Wideband CDMA (WCDMA) specification [17] with realistic channel conditions are presented. It is observed that Tx based methods perform similarly to Rx based methods. All methods reduce the effects of MAI under severe conditions. Although the performance of these methods is similar, the level of complexity is not the same. The proposed method has the lowest complexity among precoding techniques investigated in the paper, since the MAI cancellation matrix does not depend on the rapidly time-varying fading coefficients.

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