1. Introduction

In variable-spreading-factor (VSF) multirate CDMA systems, users transmit using the same chip rate and employ different processing gains in order to achieve different data rates. The linear minimum mean-square error (LMMSE) detector for VSF-CDMA has been shown to be a periodically time varying (PTV) filter [1-4]. However, all of the previously proposed PTV-LMMSE are based on a translation series representation (TSR) structure which has drawbacks for adaptive implementations.

In this paper we propose a new adaptive detector based on the harmonic series representation (HSR) of the PTV-LMMSE detector. The new detector operates adaptively without training data requiring only the timing and spreading code of the user of interest.

2. System Model

We consider the baseband asynchronous VSF code-on-pulse BPSK DS-CDMA system where $K$ users simultaneously transmit binary data over an AWGN channel. The received signal is given by

$$r(t) = \sum_{k=1}^{K} A_k \sum_{i=-\infty}^{\infty} b_k^{(i)} s_k(t - iT_k - \tau_k) + n(t)$$  \hspace{1cm} (1)

where $b_k^{(i)} \in \{-1, +1\}$ is the $k$th user’s $i$th data bit assumed to be independent and equiprobable, $A_k$ is the $k$th user’s received amplitude, $T_k$ is the $k$th user’s bit duration, $\tau_k \in [0, T_k]$ is the $k$th user’s delay, and $n(t)$ is AWGN. The signature waveform for user $k$ is

$$s_k(t) = \sum_{n=0}^{N_k-1} s_k^{(n)} \Psi(t - nT_c)$$  \hspace{1cm} (2)

where $T_c$ is the chip duration, $N_k = T_k / T_c$ is the $k$th user’s processing gain, $s_k^{(n)} \in \{-1, +1\}$ is the $n$th chip in the $k$th user’s spreading code, and $\Psi(t)$ is the unit-energy chip waveform.

The second order statistics of $r(t)$ are periodic with period $pT_i$, where $p$ is the smallest integer such that $pT_i / T_k$ is a positive integer for all $1 < k \leq K$. Since all processing gains $\{N_k\}$ are integers and all users have the same chip rate, all ratios $\{T_i / T_k\}$ are rational and the period $pT_i$ will be finite.

3. Proposed Detector

The proposed detector processes a discrete-time version of the received signal obtained by chip-matched filtering and subsequent chip-rate sampling synchronized to the user of interest. The received signal is processed in finite windows of length $L$ centered about the
bit of interest. The new adaptive HSR detector is shown in Figure 1. For the $i$th bit it decides $\hat{y}^{(i)} = \text{sgn}(\text{re} \{ y^{(i)} \})$ where the decision statistic $y^{(i)}$ is given by

$$y^{(i)} = \sum_{n=0}^{p-1} h_n^{(i)} r^{(i)} e^{2\pi jn/p}$$

(3)

where $h_n^{(i)}$ is the impulse response of the $n$th branch of the detector at iteration $i$, and $r^{(i)}$ is the vector of samples from the processing window for the $i$th bit.

The $p$ detector branches are adapted to minimize the energy in the decision statistic with $h_0^{(i)}$ constrained so that desired signal can not be canceled. That is,

$$\min_h E \{ |y|^2 \}, \quad \text{subject to: } h_0^{T} \tilde{s}_i = 0$$

(4)

where $\tilde{s}_i$ is user of interest’s spreading code symmetrically zero-augmented to length $L$. Using stochastic gradient descent, the branches may be recursively updated as follows

$$h_n^{(i+1)} = \begin{cases} h_n^{(i)} - \mu y^{(i)}(r^{(i)} - \tilde{s}_i r^{(i)}\tilde{s}_i^T), & n = 0 \\ h_n^{(i)} - \mu y^{(i)}(r^{(i)} e^{2\pi jn/p}), & n \geq 1 \end{cases}$$

(5)

where $\mu$ is the LMS step size. The same constrained minimum output energy (CMOE) adaptation applied to the time invariant detector was shown in [5] to converge (within a scale factor) to the LMMSE detector for single-rate CDMA.

4. Simulation Results

Monte Carlo simulation was performed comparing the new HSR detector to the TSR detector in [4] and to the time invariant adaptive detector from [5]. There were three $+10$ dB interferers employing length 32 spreading codes derived from length 31 Gold codes augmented with a single random chip. The user of interest employs a length 8 code which is a sub-sequence of a similarly derived 32 chip code. The delays were uniformly distributed, independent random variables and the results shown are ensemble averages from 100 realizations. The signal-to-noise ratio was 10 dB. The HSR and TSR detectors each used $p = 4$ branches. The results are shown in Figure 2. Clearly the adaptive HSR detector achieves the same minimum error as the adaptive TSR detector, however it converges much faster. The improvement over the time invariant detector under multirate interference is obvious.

References


Figure 1: HSR detector