A DS-CDMA LINEAR RECEIVER FOR ASYNCHRONOUS NETWORKS

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Abstract: Abstract In a code division multiple access system, the users transmit the information simultaneously over a common channel, using different code signatures. Usually, the receiver "knows" the assigned signatures and correlates them with the received signal. In this paper, a LMS adaptive linear receiver for coherent demodulation in asynchronous networks is considered. The receiver needs no information about the signature waveforms and timing of other users.

I. INTRODUCTION

In most of CDMA systems, the crosscorrelation between the received signals coming from different users is nonzero [4]. To achieve a low level of multiple access interferences (MAI), often modeled as adaptive white Gaussian noise, orthogonal users signatures can be used in the system, but they are rather difficult to implement.
In order to achieve MAI cancellation, some receiver structures are presently used [2]. The matched filter, the multiuser and the centralized linear receivers can be enumerated. The computational complexity for data estimation increases exponentially or linearly with the number of users.

II. THE RECEIVER MODEL

A DS/CDMA system, with BPSK data and code modulation is considered. Because it consists of a transversal linear adaptive LMS filter and a decision block, the structure is as simple as of a single-user receiver. In contrast to the centralized linear receivers, the observation vector is not the output from a bank of matched filters, but the sampled signal itself. Thus, a ciclostationary character of MAI is preserved, which is essential for its removal. Moreover, the receiver model depends not of the number of users. The received signal has the following expression:

$$r(t)=\sum_{k=1}^{K}\sum_{n} d_k(n)c_k(t-nT-\tau_k)\cos(2\pi f_0 t+\theta_k)+n(t) \quad (1)$$

-ck(t), k =1, 2, ...K are the users signatures and K is their number;
-T represents the data symbol time interval and TC is the code chip interval;
-dk(n) is the data symbol transmitted by the user k, in the n-th data symbol time interval; θk is phase shift and τk is the time delay, corresponding to the user k;
The central frequency f0 is the same for all of the users. It is presumed that the carrier amplitude is equal to one.

The expression in (1.) is composed by the signal transmitted by the user of interest, presumed to be the user one r1(t), and MAI. So it can be written:

$$r(t) = r_1(t) + MAI \quad (2)$$

where:

$$r_1(t) = \sum_{i} d_1(i)c_1(t-iT-\tau_1)\cos(2\pi f_0 t+\theta_1) \quad (3)$$

$$MAI = \sum_{k=2}^{N}\sum_{i} d_k(i)c_k(t-iT-\tau_k)\cos(2\pi f_0 t+\theta_k) \quad (4)$$

The block diagram of the CDMA linear adaptive receiver is presented in fig.1.

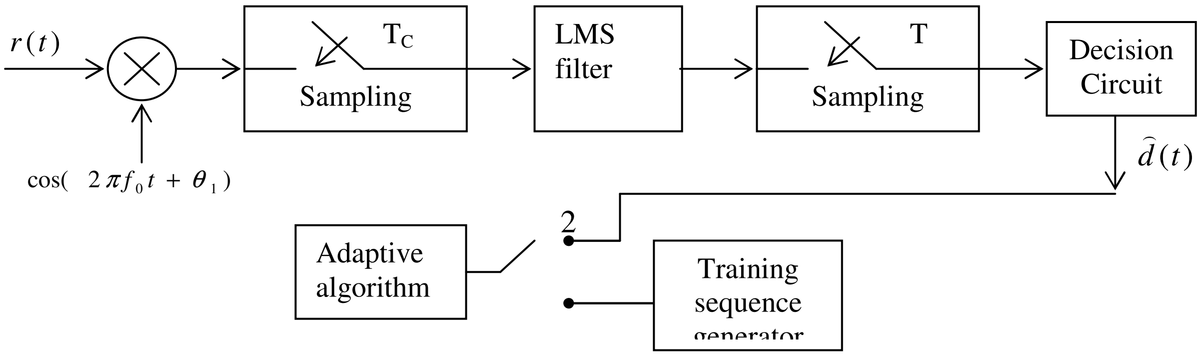

Fig. 1. Block diagram of the DS/CDMA LMS adaptive linear receiver

A base station is equipped with such a receiver for every user of the network. After down-conversion to the baseband, the signal is sampled every T_C seconds and then fed to the adaptive filter input. This is a linear minimum mean square error (MMSE) filter, performing the LMS algorithm. The MMSE adaptive filter eliminates interferences from other users. The filter output is sampled every T seconds. The output of the decision circuit is the estimate data symbol $\hat{d}_1(i)$.

A training sequence, which is a replica of the filter "desired" response, is stored in the receiver, so as to form the error signal, needed for LMS algorithm [1]. It is proper to every user and consists of several hundreds data symbols. The training sequence allows the receiver to achieve the convergence, for data estimation.

First the receiver operates in the training mode, which allows the adaptive filter to achieve the convergence and to compute the filter weighting coefficients. Then the receiver switches in the decision directed mode, when it attempts "to learn" by employing its own data symbol estimates $\hat{d}_1(i)$.

The role of the decision device is twofold: to produce the estimated data flow and the local reference sequence for the adaptive algorithm, in the direct decision mode. After the training sequence is finished, the estimated data flow, by the receiver itself, will become the reference sequence for the LMS adaptive filter. Therefore, the receiver needs no knowledge of either its own or other users signatures.

At the output of the first sampling circuit, a sampled signal *r(mT*$_C$*)* is obtained:

$$r(mT_C) = \sum_{k=1}^{K} \sum_{i} d_k(i) c_k(mT_C - iT - \tau_k) + n(mT_C) \qquad (5)$$

where n(mT_C) is the aditive Gaussian noise sample. In (5.), the baseband signal, after down-conversion, it was considered.

The signal r(mT_C) represents the input of the LMS adaptive filter, composed of 2M+1 delay elements. The estimated data symbol is expressed by:

$$\hat{d}(nT) = \sum_{m=-M}^{M} f_m r(nT - mT_C) \qquad (6)$$

where f_m are the LMS filter coefficients. The received data flow is a stochastic process, with a zero mean value.

III. RESULTS

The receiver structure leads to a good efficience in multiple access interferences cancellation and depends not of the users number. The number of subscribers, for a given spreading gain, and the system resistance at MAI can be increased by signature overlapping. Gold sequences can be used as users signatures. It is shown in literature [5] that the capacity limitation of a CDMA system, imposed by MAI, is a consequence of the signal detection method, rather than the inherent property of the CDMA system. This limitation can be overcomed by a linear receiver.

The received signal is sampled once for each rectangular chip interval, but a fractionally spaced structure can be also adopted, that can make the receiver insensitive to time differences in the signal arrival moments, for various users.

The convergence speed is an important parameter, since it determines the multipath fading rate that can be handled succesfully, for real channels. Recursive least square algorithm (RLS) is faster, but LMS was adopted as the simplest tool to obtain the filter coefficients satifying the MMSE criterion.

The adaptive filter is also able, somehow, to correct the carrier frequency and phase shifts, but an aditional carrier recovery loop is commonly used [4].

IV. CONCLUSIONS

A LMS adaptive linear receiver for asynchronous DS/CDMA systems was proposed. An application of the MMSE criterion to a single-user adaptive DS/CDMA receiver is of primary concern in this paper and discussions of relative merits of various adaptive algorithms is omitted. The receiver is trained by a known training sequence, prior to data transmission, and continuously adjusted by a LMS algorithm during data transmission. The complexity of the adaptive receiver is slightly higher than the complexity of a conventional receiver.

The receiver achieves essential advantages with respect to timing recovery, multiple access interferences elimination, near-far effect, narrowband and frequency selective fading interference suppression, and user privacy. A distinguishing property of the receiver is that timing, signatures, and carrier phase information are not needed for data estimation. An assumption is made that the variations of channel multipath parameters are much slower compared to the convergence speed of the adaptive receiver.

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