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Spatial and temporal adaptive receiver for DS-CDMA systems

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ABSTRACT

The objective of this paper is to propose a reception scheme to improve the performance of DS-CDMA (Direct Sequence Code Division Multiple Access) systems, compared to conventional direct channel receivers. The technique employs a spatial and temporal adaptive receiver composed of *N* spatial processors (associated with *M* antennas) and *N* Decision Feedback Equalizers (DFE), both of which are trained using a TMDP (Time Multiplexed Dedicated Pilot) sequence. The spatial and temporal receiver associated with TMDP offers considerable benefits when compared to the conventional Rake-Finger receiver. Performance results and details of the functioning of the proposed reception scheme are presented.

1. Introduction

The use of adaptive schemes in DS-CDMA systems was initially proposed for the reverse channel. The first proposals for the direct channel employed adaptive equalizers in the symbol domain, rather than in the chip domain. However, the channel with Inter-Symbol Interference (ISI) removes the orthogonality of the spreading codes [1–5], so that the capacity of the system becomes limited by the Multiple-Access Interference (MAI). In the chip domain, spatial and temporal filters can therefore be seen as orthogonalizing filters for the spreading codes. Consequently, it becomes clear that spatial and temporal filters must be located before the despreading, at the chip level, in order to minimize the effect of MAI.

There have been several proposals for chip-controlled spatial and temporal adaptive filters [1–4,6–8]. However, reference signals at the symbol level are used, after the despreading process, which limits the performance of the equalizer so that the ISI is not adequately eliminated. Another important point is the adaptation speed of the spatial and temporal filter, given that most problems occur at the chip level. Spatial and temporal filters must also possess appropriate adaptation references. In the case of fast moving channels, techniques that employ calculation of error at the symbol level may present problems in terms of the speed of convergence of the adaptation algorithms.

Other alternatives DS-CDMA receiver using spatial processors and / or equalizers are presented in [9–13]. The schemes proposed in [9–13] needs the channel estimation (complex gains) to calculate the parameters of the equalizer and not using spatial processors (with beamforming) combined with the equalizer to minimize ISI and restore the orthogonality of the spreading codes.

This paper proposes a reception scheme based on a spatial and temporal filter that is here called the MT-STR (Multi-Target Space-Time Receiver). In our first proposal for such a receiver [14–18] we have used linear filters with an adaptation reference at the symbol level. The idea of the present proposal is to use DFE equalizers combined with a Time Multiplexed Dedicated Pilot (TMDP) sequence [19]. Given the need of a reference system for performance comparison, all the results presented here were simulated using the UMTS (Universal Mobile Telecommunications) system [20–23].

2. Characterization of the system

The complex symbols $a(n)=a_r(n)+a_{im}(n)$ are processed by the DS-CDMA transmission technique and transmitted at the chip domain as $z(p)$, in a channel represented by $h(p)$, subject to multipath and additive Gaussian noise $r(p)$ (Additive White Gaussian Noise – AWGN), as illustrated in Fig. 1. Variable n represents discrete-time symbol and p represents discrete-time chip.

For the DS-CDMA transmitter (shown in Fig. 2), the signal of a kth user is given by

$$y^k(p) = a^k(n)x^k_{ch}(p), \tag{1}$$

where $x^k_{ch}(p)$ is the kth spreading sequence (spreading code) of the kth user. A spreading sequence composed of Walsh codes of size SF

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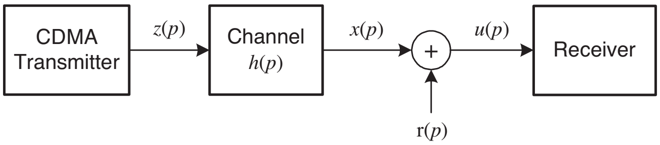

Fig. 1. Discrete baseband communication system with ISI and AWGN.

(SF is the spreading factor) [5,24–26] is normally used in the direct channel. These are orthogonal codes that follow the Hadamard matrices [24]. Hadamard matrices are quadratics and it is expected that for a spreading size SF, there are SF orthogonal codes. It can therefore be readily concluded that for a spreading size SF, SF users can be used in the same band at the same time. This signal is added to the other users, forming a multi-user signal given by

$$b(p) = \sum_{k=0}^{\mathrm{NU}-1} y^k(p) = \sum_{k=0}^{\mathrm{NU}-1} a^k(n) x^k_{ch}(p), \tag{2}$$

where NU is the number of simultaneous users.

The output signal of the transmitter (illustrated in Fig. 2) can then be characterized by

$$o(p) = \sum_{k=0}^{\mathrm{NU}-1} a^k(n) x^k_{ch}(p) x_{sc}(p), \tag{3}$$

where $x_{sc}(p)$ is known as the scrambling sequence (SCR). These sequences are generally used to decorrelate the transmitted signal (in the time) [24].

The channel impulse response, $h(p)$, with the influence of noise, is given by

$$h(p) = \sum_{i=0}^{L-1} \alpha_i(p) \delta(p - \tau_i(p)), \tag{4}$$

where L is the number of the channel path, $\alpha_i(p)$ is the complex gain of the ith path, $\tau_i(p)$ is an integer representing the delay of the ith path at instant p.

The receiver (Fig. 1) processes the resulting channel signal, $u(p)$, expressed by

$$u(p) = \sum_{i=0}^{L-1} \alpha_i(p) o(p - \tau_i(p)) + r(p) \tag{5}$$

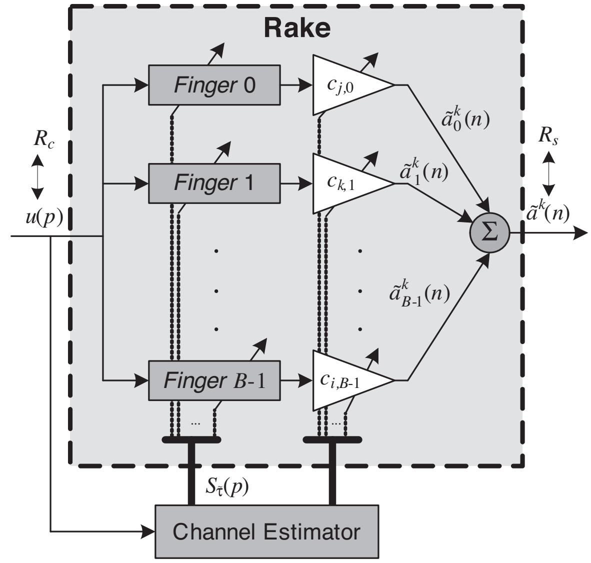

Fig. 3. Schematic of a Rake-Finger receiver with B fingers.

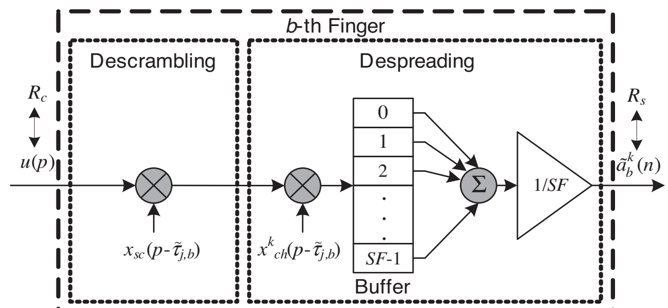

Fig. 4. Schematic of the bth finger.

where $o(p)$ is the symbol processed by the DS-CDMA transmission technique and $r(p)$ is the Gaussian white noise with variance $\frac{N_0}{2}$ where N_0 is power spectral density. Now suppose that the signal $u(p)$ is received by the conventional Rake-Finger DS-CDMA receiver, illustrated in Figs. 3 and 4.

The Rake-Finger to combine receive signals from the $B-1$ fingers and use of the signal diversity inherently provided by

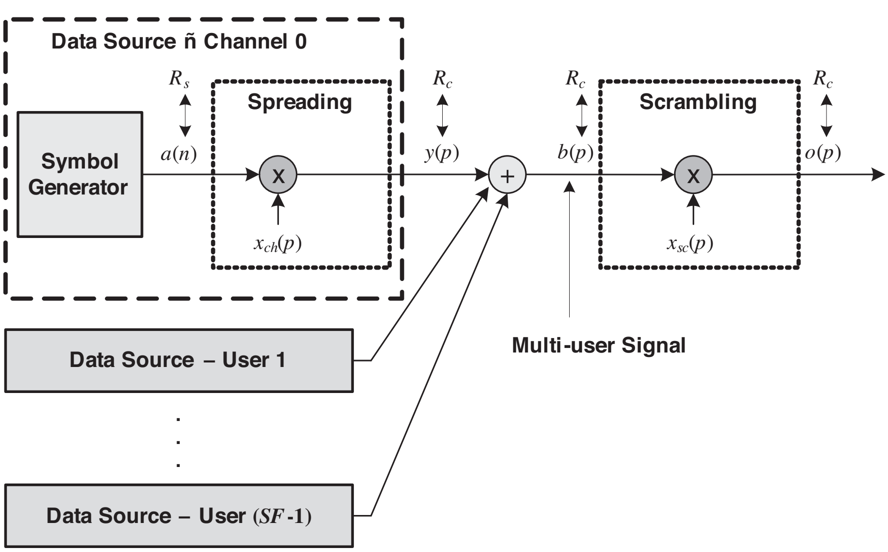

Fig. 2. Simplified structure of a DS-CDMA transmitter (direct channel) with SF channels.