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# Performance analysis of a spreading sequence estimator for spread spectrum transmissions

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## Abstract

Direct sequence spread spectrum transmissions (DS-SS) are now widely used for secure communications, as well as for multiple access. They have many interesting properties, including low probability of interception. Indeed, DS-SS transmitters use a periodical pseudo-random sequence to modulate the baseband signal before transmission. A receiver which does not know the sequence cannot demodulate the signal.

In this paper, we propose a new method which can estimate the spreading sequence in a noncooperative context. The method is based on eigenanalysis techniques. The received signal is divided into windows, from which a covariance matrix is computed. We show that the sequence can be reconstructed from the two first eigenvectors of this matrix, and that useful information, such as desynchronisation time, can be extracted from the eigenvalues.

The main achievement of the present paper is a performance analysis of the proposed spreading sequence estimation procedure. An analytical approach is first considered owing to matrix perturbation theory and Wishart matrix properties. Then, complementary Monte Carlo simulations are performed to show the effectiveness of the proposed method.

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*Keywords:* Digital communications; Direct sequence spread spectrum; Blind estimation; Performance analysis; Wishart matrix; Gold sequence

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## 1. Introduction

Spread spectrum transmissions have been in practical use since the 1950s. They found many applications in military systems due to their suitability for covert message transmission and resistance to jamming [1]. In the early 1980s, spread spectrum technology was proposed for private and commercial use, especially in code division multiple access (CDMA) transmissions. CDMA system has been adopted for use in commercially available wireless local area networks (WLANs) [2]. Another useful feature of CDMA for indoor systems is its low power spectral density. This allows a CDMA system to coexist with licensed communications systems in environments where low levels of electromagnetic interference are desirable, such as hospital. In such environments, CDMA is ideally suited to high data rates being transmitted over hostile fading channels with the minimum of interference to sensitive equipments [3].

DS-SS is a transmission technique in which a pseudo-random sequence or pseudo-noise (PN) code [4], independent of the information data, is employed as a modulation waveform to spread the signal energy over a bandwidth much greater than the information signal bandwidth [5]. In practical systems, the bandwidth expansion factor, which is the ratio between the chip rate  $F_C$  and the data symbol rate  $F_S$ , is usually an integer. The amplitude, and thus the power in the spread spectrum signal, is the same as in the information signal. Due to the increased bandwidth of the spread spectrum signal, the power spectral density must be lower and can then be below the noise level [6]. Furthermore, the autocorrelation of a PN code has properties similar to those of white noise, so the spread spectrum signal looks like a white noise, hence it is very difficult to intercept. At the receiver, the signal is despread using a synchronized replica of the pseudo-noise sequence used at the transmitter. The optimum multiple user CDMA receiver is based on a correlator, or a bank of sequence matched filters, each followed by maximum likelihood sequence estimation detectors (MLSE). The objective of the MLSE is to find the input sequence that maximizes the conditional probability, or likelihood of the given output sequence [7].

In the context of spectrum surveillance, the pseudo-random sequence used by the transmitter is unknown, as well as other transmitter parameters such as duration of the sequence, symbol frequency and carrier frequency. Moreover, the longer the period of the pseudo-noise code is, the closer the transmitted signal will be to a truly random binary wave, and the harder it is to detect [8]. In this context, only Tsatsanis et al. [9] have proposed a reliable method to recover the convolution of the spreading sequence and the channel response in multipath environment. Their approach uses a multichannel identification technique due to Moulines et al. [10], where the orthogonality property between the signal and noise subspaces is exploited to yield the desired estimate.

In this paper, we propose a new method for estimating the pseudo-random sequence without prior knowledge about the transmitter. Our procedure does not rely on a multichannel framework and is computationally less expensive than that of

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