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Jammer suppression in spread spectrum communication using novel independent component analysis approach

Jayasanthi Ranjith [a,*], Muniraj [b]

[a] Karpagam College of Engineering, Tamil Nadu, India
[b] Tejaa Shakthi Institute of Technology for Women, Tamil Nadu, India

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ABSTRACT

Spread spectrum communications is an increasingly popular technique for use in diversity of systems. They are based on signaling schemes which greatly expand the bandwidth of the transmitted spectrum relative to the information bandwidth. Though, the gain is sufficient for proper performance of the system in most of the cases, additional interference suppression capability is needed when interference plays a dominant role. A novel adaptive scheme for jammer mitigation in Direct Sequence Spread Spectrum communication (DSSS) systems using independent component analysis (ICA) is proposed in this paper. This blind separation method provides jammer mitigation and recovers the data sequence from Binary Phase Shift Keying (BPSK) modulated signal as they arrive in a blind fashion. Extraction of the transmitted sequence from the received sequence is done with improved convergence speed compared to existing ICA algorithms. Simulations are carried out to illustrate the achieved performance of the proposed scheme for variable sequence lengths and different values of jammer power. The merits and limitations of the proposed ICA assisted jammer suppression scheme in comparison to Fast ICA assisted one are also discussed. The proposed method provides better SNR value compared to simple DSSS, Fast ICA based DSSS and other interference suppression schemes presented in the literature.

1. Introduction

A spread-spectrum communication is a method of communication in which an extra data modulation technique expands the bandwidth of the signal beyond actually required bandwidth. A spread-spectrum communication system suppresses the interference, makes interception difficult, accommodates fading and multipath channels and provides multiple-access capability [1,2]. The most dominant and practical methods of spread-spectrum communication are frequency hopping of digital communications and direct sequence modulation. In Direct Sequence Spread Spectrum communications, the bandwidth of the transmitted waveform is intentionally made wider to transmit the data over the channel, by means of a code which is independent of the data. Synchronized reception of transmitted data and code is done at the receiver end to de-spread and recover the data sequence [3]. The ratio of transmission and data bandwidth is called the processing gain. Many types of interferences appear in commercial cellular spread spectrum and direct sequence code division multiple Access (DS-CDMA) systems. Interference Suppression discusses two classes of rejection schemes: One is based upon least mean square estimation techniques and another one is based upon transform domain processing structures [4]. In both of these techniques the improvement is achieved with a constraint that the interference is relatively narrow with respect to the direct sequence signals. The interference may be of multiuser interference inside each sector in a cell, inter-operator interference or unintentional jamming due to co-existing systems at the same band and intentional jamming that mainly arises in military applications. A popular evolutionary computation method based on Genetic algorithm has been adopted for multiuser detection in CDMA based spread spectrum technique [5–7].

Jamming can be alleviated by using multiple antenna sensors with spatial diversity. However, this method is not suitable for conventional array receivers. This is because the directions of arrival of signals must be first estimated which in turn requires exact prior knowledge about the positions of the receiving antenna sensors [8]. Blind techniques proposed in [9,10] relax this strict requirement and so it possible to achieve desired performance gain when the positions of the sensors are roughly known or not at all. The blind separation techniques are all based on the assumption that the original source signals are statistically independent of each

* Corresponding author. Tel.: +91 9629590251.
E-mail addresses: mjayasanthi@yahoo.co.in (J. Ranjith), njrmuniraj@yahoo.co.in (Muniraj).

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other. This assumption is obviously satisfied here as the jammer signal originates from a different physical source compared to the information bearing signal. Belouchrani and Amin [11,12] were the first to bring the idea of applying blind source separation (BSS) techniques for conventional detection in DSSS. However the receiver in [11] requires temporally correlated information and jamming signals while separating a set of independent information signals from their mixtures observed at the sensors. To alleviate this problem, BSS techniques based on independent component analysis instead of temporal correlations is proposed. FastICA algorithm is such an algorithm that is most popular ICA algorithm due to its high convergence speed. This method takes higher-order statistics into account by forcing statistical independence of the signals to enable jammer suppression under realistic conditions. It recovers required information sequence from the mixtures by finding a linear transformation which maximizes the non-gaussianity or mutual independence of the mixtures regardless of the probability distribution. Jammer is separated using this algorithm with a measure of non-gaussianity called kurtosis [13,14]. An iterative algorithm that generates a sequence of filter response for any positive definite input autocorrelation matrix and converges to the minimum-variance-distortion less-response (MVDR) is proposed in [15]. This simple, recursive algorithm is applied for interference suppression.

The performance of reduced-rank linear filtering based on multistage Wiener filter (MSWF) is analyzed for the suppression of multiple-access interference [16]. In this method, the received signal is projected onto a lower dimensional subspace, and then filter optimization occurs within this subspace. This approach provides SNR value for different rankings as 8 dB. The performance is examined in the context of direct-sequence (DS) code division multiple access (CDMA)[17]. Another scheme that operates on a bank of full-rank adaptive filters with low MSE is proposed in [18]. Joint and iterative interpolation, decimation and Filtering based adaptive reduced-rank signal processing technique is proposed in [19]. The proposed algorithm was applied to interference suppression in code-division multiple-access (CDMA) systems. Another reduced-rank interference-suppression scheme based on a joint iterative optimization of parameter vectors is proposed which consists of a joint iterative optimization of a projection matrix. It performs dimensionality reduction to estimate symbols without singular value decomposition (SVD) [20].

- In this paper, the framework proposed in [8] is extended in the following respects.
- Convergent speed of jammer separation is improved using the novel ICA method.
- The timely determination of converged weight vector improves the operating frequency of the system.
- The proposed novel architecture is also efficient in terms of area and power. It also improves the precision and SNR of the signals with reduced bit error rate.

This paper is organized as follows. Section 2 describes about the spread spectrum communication systems. Section 3 explains spread spectrum communication systems with the proposed ICA algorithm for jammer mitigation. Section 4 demonstrates the simulation results and analysis of BER and SNR values. Finally, conclusions are drawn in Section 5.

2. Direct Sequence Spread Spectrum communication systems

A spread spectrum system is categorized largely by the type of coding scheme it uses. The type of coding sequence employed, the length of the sequence and its chip-rate all together define the overall DSSS system parameters. In order to alter the spreading capability of the system, it is necessary to alter the coding arrangement. In DSSS systems, sequence that is used for spreading the bandwidth is superimposed upon the data bits to increase the bandwidth of the data to be transmitted. This spreading sequence is a pseudorandom noise (PN) sequence often generated from a linear feedback shift register (LFSR).

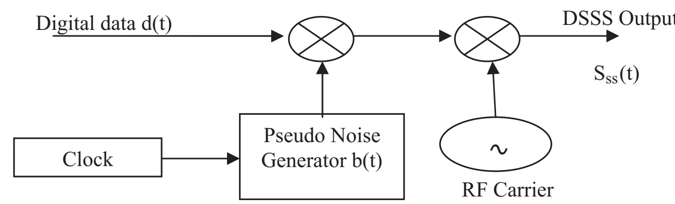

Fig. 1. DSSS transmitter.

Fig. 1 shows the transmitter model with BPSK modulation of narrow band data signal $d(t)$ and wide band sequence $b(t)$. Here the incoming data sequence $d(t)$ is spread by multiplying it with a binary valued spreading pseudo random noise like (PN) bit sequence $b(t)$ so that the bandwidth of the transmitted signal increases by a factor of the processing gain. The processing gain is the ratio of the symbol duration (T_s) to chip duration (T_c) and is given by

$$G = \frac{T_s}{T_c}$$

The carrier is transmitted with a particular phase when the code is a “one” and with its 180° phase shifted version when the code is a “zero”. With the assumption of synchronism between the transmitter’s code and receiver’s code, the received signal is represented by

$$S(t) = \sqrt{\frac{2E_S}{T_S}} d(t) b(t) \cos(2\pi f_c t + \theta) \quad (1)$$

where θ is carrier phase angle at $t = 0$, f_c is the carrier frequency.

Under the assumption of synchronization between the chip and symbol, the received signal is passed through the wide band filter and multiplied by the synchronized local replica of synchronized $b(t)$ as in Fig. 2. This multiplication offers the despread signal $S1(t)$. This is then applied to the input of the demodulator for extraction of the data symbols.

$$S1(t) = b(t) * S(t) = \sqrt{\frac{2E_S}{T_S}} d(t) \cos(2\pi f_c t + \theta) \quad (2)$$

When the received signal $S(t)$ is multiplied by the spreading waveform $b(t)$, the desired signal bandwidth is reduced to $1/T_s$ and the interference energy is spread over a bandwidth $1/T_c$. As the filtering action at the demodulator removes most of the interference energy that does not overlap the signal energy, most of the interference energy is eliminated from the received signal.

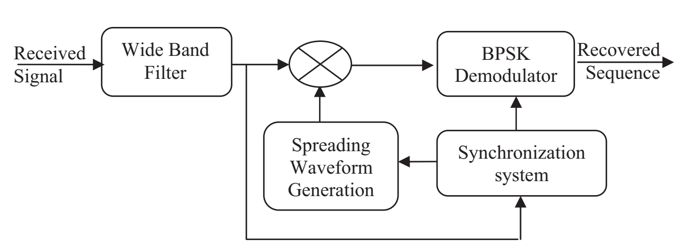

Fig. 2. DSSS receiver.