Adaptive Lattice Step-Size Algorithm for Narrowband Interference Suppression in DS/CDMA Systems

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Abstract: The presence of narrowband interference (NBI) in Direct-sequence code division multiple access (DS/CDMA) systems is an inevitable problem when the interference is strong enough. The improvement in the system performance employs by adaptive narrowband interference suppression techniques. Basically there have been two types of method for narrowband interference suppression estimator/subtracter approaches and transform domain approaches. In this paper the focus is on the type of estimator/subtracter approaches. However, the binary direct sequence (DS) signal, that acts as noise in the prediction process is highly non-Gaussian. The case of a Gaussian interferer with known in an autoregressive (AR) signal or a digital signal and also in a sinusoidal signal (Tone) that included in is paper. The proposed NBI suppression is presence in an adaptive IIR notch filter for lattice structure and more powerful by using a variable step-size algorithm. The simulation results show that the proposed algorithm can significantly increase the convergence rate and improved system performance when compare with adaptive least mean square algorithm (LMS).

Keywords: Adaptive lattice filter, Variable step-size algorithm, Narrowband interference suppression, Direct-sequence spread spectrum systems, DS/CDMA.

1. INTRODUCTION

Direct-squence code division multiple access (DS/CDMA) has been widely studied in literature. Demodulating a given user in DS/CDMA network requires processing the received signal to minimize two types of interference namely, narrowband interference (NBI) and wideband multiple access interference (MAI) caused by other spread spectrum users in the channel. NBI is caused by the coexistence of spread spectrum signal with the conventional communication. In additional many other advantageous properties of spread spectrum techniques offer an effective way of combating NBI interference in DS/CDMA system [1]. The transmission bandwidths of spread spectrum signals are much greater than the message bandwidths. In a direct-sequence spread spectrum system, the spreading of message signal achieved by modulating it with a pseudonoise (PN) signal before transmission. At the receiver, the incoming signal is despread by correlating it PN sequence. This system has an inherent capability to reject interfering signals whose bandwidths are small compare to that spreading signal. However, if the interfering signal is strong enough the communication system becomes impossible even with the advantage of spectrum spreading. Several methods have been proposed to suppress the NBI interference in DS/SS transmission systems [2-6]. The effect of the NBI interfering can be reduced by subtracting predicted value obtained at each sampling instant from the received signal and using the resulting prediction error as the input to the correlator.

This paper is organized as follows. In Section Ⅱ presented a model for the spread spectrum signals of interest. In Section Ⅲ review of an adaptive filter based on the LMS algorithm. In section Ⅳ the proposed an adaptive IIR notch filter for lattice structure that using variable step-size algorithm is presented. Computer simulations indicated the advantage of the proposed algorithm over the LMS algorithm such as convergence rate and *SNR* improvement is described in Section Ⅴ. Finally is a brief conclusion.

2. THE MODEL FOR THE RECEIVED SIGNAL

We follow the model of received signal in DS/CDMA systems described in [7]. The low pass equivalent of Direct-sequence spread spectrum modulation is given by

$$m(t) = \sum_{k=0}^{N_c-1} c_k q(t - k\tau_c) \tag{1}$$

where N_c is the number of PN chips per message bit, τ_c is the chip interval, c_k is the $k-th$ chip of PN sequence and $q(t)$ is the rectangular pulse of duration τ_c. The transmitted signal is expressed as

$$s(t) = \sum_{k} b_k m(t - kT_b) \tag{2}$$

where b_k is the binary information sequence and $T_b = N_c\tau_c$ is the bit duration. The received signal is defined by

$$z(t) = \alpha s(t-\tau) + n(t) + i(t) \tag{3}$$

where α is an attenuation factor, τ is a delay offset, $n(t)$ is wideband Gaussian noise and $i(t)$ is the narrowband interference. For simplicity, let τ be zero and $\alpha = 1$. Suppose that the received signal is chip-matched and sampled at the chip rate of PN sequence. Thus, the discrete time of a sequence $z(k)$ is defined as

$$z(k) = s(k) + n(k) + i(k) \tag{4}$$

where $\{s(k)\}$, $\{n(k)\}$ and $\{i(k)\}$ are the discrete-time of the sequences from $\{s(t)\}$, $\{n(t)\}$ and $\{i(t)\}$ respectively. $\{s(k)\}$, $\{n(k)\}$ and $\{i(k)\}$ are assumed to be mutually independent. Since the PN sequence is random. We can consider $\{s(k)\}$ being a sequence of identically distributed (i.i.d.) random variable tracking values of +1 or –1 with equal probability.

3. THE ADAPTIVE FILTER BASED ON THE LMS ALGORITHM

The update equations of the LMS algorithm can be expressed as

$$w(k) = w(k-1) - 2\mu e(k) z(k) \tag{5}$$

$$e(k) = z(k) - y(k) \tag{6}$$

where $w(k)$ is the estimated tap weight at time n, μ is the fixed step-size parameter, $z(k)$ is the received signal, $y(k)$ is the output of NBI suppression filter and $e(k)$ is the prediction error.

4. THE ADAPTIVE LATTICE STEP-SIZE ALGORITHM

The effective NBI suppression filter should be able to adapt itself to variation in the interference characteristics. In this section we will consider adaptive lattice step-size algorithm with provided fast converging and effective to rejecting a single tone sinusoidal interferer.

$$w^L(k) = w^L(k-1) + \mu(k)\,\mathbf{sgn}\left\{\mathbf{sgn}\left[y(k)\right]\frac{\partial y(k)}{\partial w^L(k)}\right\} \tag{7}$$

$$\frac{\partial y(k)}{\partial w^L(k)} = 2U(k-1) \tag{8}$$

where $w^L(k)$ is the proposed filter coefficient, $\mu(k)$ is variable step-size parameter and the prediction value of the received signal $y(k)$ is expressed as follow:

$$y(k) = U(k) + 2w^L(k)U(k-1) + U(k-2) \tag{9}$$

$$U(k) = z(k) - w^L(k)(1+\rho)U(k-1) - \rho U(k-2) \tag{10}$$

The robust step-size algorithm that uses the predictions value power and the correlation of the prediction residual error to control adaptation to ensure low misadjustment expressed as follow:

$$\mu(k+1) = \alpha(k)\mu(k) + \gamma p^2(k) \tag{11}$$

$$\alpha(k) = \lambda\alpha(k-1) + (1-\lambda)e(k)\cdot e(k-1) \tag{12}$$

$$e(k) = y(k) - z(k) \tag{13}$$

$$p(k) = \sigma p(k-1) + (1-\sigma)y^2(k) \tag{14}$$

where $\alpha(k)$ and $p(k)$ give the step-size update $\mu(k)$ has the accurate step value in early adaptation process stage when it has contain large value of noise and not effect by independent disturbance noise for overall adaptation process. The parameters $\sigma, \alpha, \gamma, \lambda$ are constant in the range between 0 and 1. The σ is an exponential weighting parameter or forgetting factor.

5. THE SIMULATION RESULTS

In this section, we evaluate the performance of the proposed algorithm by computer simulations. We take single tone sinusoidal interference for example. The performance measures which the commonly used *SNR* improvement. We define this as follow:

$$SNR\ \ improvement = \frac{Output\ \ SNR}{Input\ \ SNR} = \frac{E\left\{(z(k)-s(k))^2\right\}}{E\left\{(z(k)-s(k)-\hat{z}(k))^2\right\}} \tag{15}$$

The frequency of interference signal is kept constant at $\frac{\pi}{5}$ radian and the initial phase is set to zero, i.e., $i(n) = \mathbf{sin}(0.15n)$. The channel noise power is kept constant at $\sigma^2 = 0.01$. The other parameters are given as $\mu(0) = 0.002$, $\alpha(0) = 0.95$, $\lambda = 0.95$, $\gamma = 0.8$, $\rho = 0.99$, $\sigma = 0.98$. Table 1 shows the simulation results for ***SNR*** improvement that the proposed algorithm performs slightly better than that of the LMS algorithm. Fig. 1 and Fig. 2 show the simulation results for the convergence properties of the two algorithms. We conclude that the proposed algorithm provides much faster convergence rate than the other one.

6. CONCLUSION

In this paper, we proposed an adaptive lattice step-size algorithm for narrowband interference suppression in DS/CDMA systems. The proposed algorithm provides high convergence rate and from the comparison of ***SNR*** improvement shows that the performance of the proposed algorithm is better than that of the LMS algorithm.

Table 1 The Comparison of *SNR* Improvement

Input ***SNR*** (dB)	***SNR*** Improvement (dB)	
	LMS Algorithm	Adaptive Variable Step-Size Lattice algorithm
-30	11.9754	40.0540
-24	10.2802	39.1210
-20	8.6763	37.4631
-16	6.7545	32.1355
-12	5.9950	26.3541
-10	5.5472	24.3816
-8	5.2304	22.5989
-4	3.8972	19.2887

REFERENCES

[1] J.W. Keltchum and J. G. Proakis, "Adaptive algorithms for estimating and suppressing narrow-band interference in PN spread-spectrum systems", *IEEE Trans. Commun.,* vol. COM-30, pp. 913-924, May 1982.

[2] L. M. Li and L. B. Milstein, "Rejection of the narrow-band interference in PN spread-spectrum systems using transversal filters", *IEEE Trans. Commun.,* vol. COM-30, pp. 925-928, May 1982.

[3] R. A. Iltis and L. B. Milstein, "Performance analysis of narrow-band interference rejection techniques in DS spread-spectrum systems", *IEEE Trans. Commun.,* vol. COM-32, pp. 1169-1177, Nov. 1984.

[4] E. Masry, "Closed-form analytical results for the refection of narrow-band interference in PN spread-spectrum systems- Part I: Linear prediction filter", *IEEE Trans. Commun.,* vol. COM-32, pp. 888-896, Nov. 1984.

[5] E. Masry, "Closed-form analytical results for the refection of narrow-band interference in PN spread-spectrum systems- Part II: Linear interpolation filter", *IEEE Trans. Commun.,* vol. COM-33, pp. 10-19, Jan. 1985.

[6] R. Vijayan and H. V. Poor, "Nonlinear techniques for the interference suppression in spread-spectrum systems", *IEEE Trans. Commun.,* vol. 38, pp. 1060-1065, July. 1990.

[7] G.R. Cooper and C.D. McGillem, *Modern Communications and Spread Spectrum.* New York: McGraw-Hill, 1986.

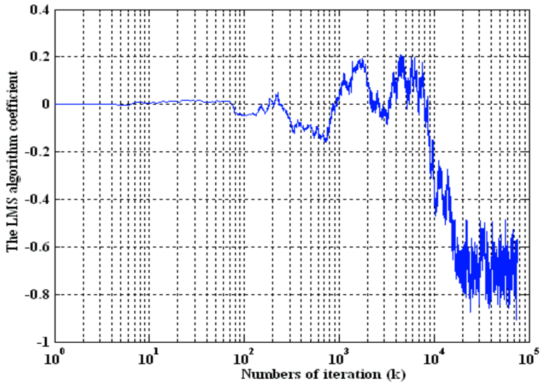

Fig. 1 The convergence properties of the LMS algorithm

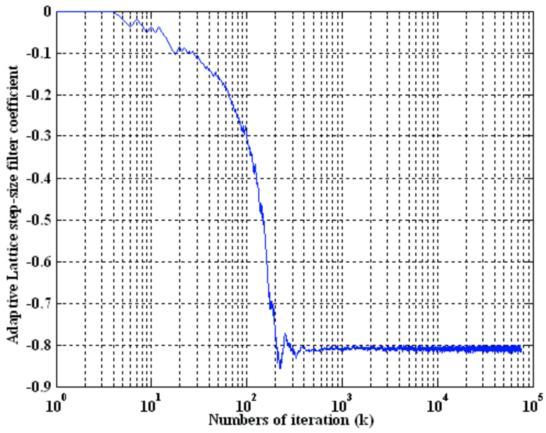

Fig. 2 The convergence properties of the adaptive lattice step-size algorithm