Adaptive Interference Cancellation Using CMA-Correlation Normalized LMS for WCDMA System

Yong Sik Han, Woon Geun Yang, *Member, KIMICS*

***Abstract*— In this article, we proposed a new interference canceller using the adaptive algorithm. We designed constant modulus algorithm-correlation normailized least mean square (CMA-CNLMS) for wireless system. This structure is normalized LMS algorithm using correlation between the desired and input signal for cancelling the interference signals in the wideband code division multiple access (WCDMA) system. We showed that the proposed algorithm could improve the Mean Square Error (MSE) performance of LMS algorithm. MATLAB (Matrix Laboratory) is employed to analyze the proposed algorithm and to compare it with the experimental results. The MSE value of the LMS with mu=0.0001 was measured as - 12.5 dB, and that of the proposed algrithm was -19.5 dB which showed an improvement of 7dB.**

***Index Terms*—Interference Cancellation System (ICS), LMS algorithm, Radio Frequency (RF) repeater.**

I. INTRODUCTION

In the wireless communication system, the interference signals may result in the degradation of the network performance. Adaptive filtering has been a general technique to cancel such interference signals in the communication network. Wideband Code Division Multiple Access (WCDMA) using the spread-spectrum signaling has gained increased interests for application in communication systems. Advantages of the WCDMA are asynchronous operation, a better channel usage compared with other techniques that allow a single user to be transmitted over the channel at a certain time. The interference signal is caused by communication systems. When the interference signals is detected, one solution to inhibit the divergence of the tap coefficients can be obtained by setting the step size of the adopted adaptive algorithm to zero [1].

In this paper, we propose a Constant Modulus Algorithm combined with the Correlation Normalized Least Mean Square (CMA-CNLMS) algorithm. The proposed CMA-CNLMS algorithm utilizes correlation between the desired and input signals to adjust the step sizes, for canceling the interference signals in the WCDMA system. The proposed algorithm commonly provides better Mean Square Error (MSE) performance than the conventional LMS algorithm.

Utilizing an efficient method to calculate the tap input power required in the NLMS algorithm, a small increase of the computational complexity relative to the conventional LMS algorithm is required for updating the filter coefficients in adaptive algorithm [2]. Ref. [3] used several step sizes for an algorithm. The proposed detector uses the CMA-CNLMS algorithm with two different step sizes. The proposed algorithm is more flexible and more adaptive in multipath environment. In this structure, errors which are obtained from each group are compared, and a minimum error is chosen to the selection block. The structure has a fast convergence and mean square error performance improvement simultaneously.

The rest of this paper is organized as follows. We present basic structure for the proposed adaptive algorithm in chapter 2. Simulation and measurement results will be in chapter 3 and conclusion follows in chapter 4.

II. PROPOSED ALGORITHM

We propose a CMA-CNLMS algorithm. The cost function of CMA is a measure of the derivation of the modulus of the output $y(n)$ according to Eq.(1).

$$J_{pq} = E\left[\left|\|y(n)\|^{p} - 1\right|^{q}\right] \tag{1}$$

Where the filter output $y(n)$ results from the weight vector $W(n)$ operating on the input signal $x(n)$, i.e.,

$$y(n) = W^{T}(n)x(n) \tag{2}$$

For practical reasons, p and q are positive integers and limited to 1 and 2. Then the corresponding algorithm has yielded useful adaptive form and they are referred to as CMA_{p-q} algorithm. To minimize the cost function over the space of weight vectors, a stochastic approximation to the steepest descent algorithm is used

Manuscript received March 2, 2010; revised March 15, 2010; accepted March 29, 2010.
Yong Sik Han is with the Department of Electronics Engineering, University of Incheon, Incheon, 406-772, Korea (Tel: +82-32-835-4767, Email: cdma2002@incheon.ac.kr)
Woon Geun Yang is with the Department of Electronics Engineering, University of Incheon, Incheon, 406-772, Korea (Tel: +82-32-835-4767, Email: wgyang@incheon.ac.kr)

Weight vectors are updated as Eq.(3).

$$W(n+1) = W(n) - \mu \nabla J_{pq}(n) \tag{3}$$

Where μ is a small real scalar named step size and $\nabla J_{pq}(n)$ is an unbiased estimate of the gradient of the cost function with respect to W.

Weight vectors are updated approximately as Eq.(4) [4].

$$W(n+1) = W(n) - 2\mu e(n)x(n) \tag{4}$$

Where $e(n)$ is error signal given as Eq.(5).

The difference between the desired signal $d(n)$ and the filter output $y(n)$ is the error signal given by Eq.(5).

$$e(n) = d(n) - y(n) = d(n) - W^T(n)x(n) \tag{5}$$

In the LMS algorithm, the MSE $E[e^2(n)]$ is minimized by continuously updating the weight vector $W(n)$ as each new data sample is received, according to the Eq.(6).

$$W(n+1) = W(n) + \psi e(n)x(n) \tag{6}$$

Where ψ is a positive constant that governs the rate of convergence. The NLMS algorithm is realized by changing the ψ as Eq.(7).

$$\psi = \frac{\alpha}{x^T(n)x(n)+\beta}, 0 < \alpha < 2 \tag{7}$$

Where α is a positive constant used to ensure stable convergence, β is a positive constant used to avoid that the denominator results in zero values [2].

In this paper, the new structure proposed is based on the processing of autocorrelation function of the input signal and the cross correlation of the input signal and desired signal. The autocorrelation function $R_{xx}(n,k)$ for the input signal, with time-lag k, is defined as Eq.(8).

$$R_{xx}(n,k) = \sum_{j=0}^{n} x(j)x(j-k) \tag{8}$$

Also the cross-correlation between the desired and input signals is calculated as Eq.(9).

$$R_{dx}(n,k) = \sum_{j=0}^{n} d(j)x(j-k) \tag{9}$$

Where $x(n)$ is input signal of the adaptive filter and $d(n)$ is the desired signal.

Assuming that there is no correlation between the far-end signal $s(n)$ and the near-end signal $u(n)$, i.e. $R_{su}(n,k) \approx 0$, the cross-correlation will be obtained as follows.

$$R_{dx}(n,k) = \sum_{i=0}^{n} r_i R_{xx}(n,k-i) \tag{10}$$

Where r_i is the impulse response.

We need to process the autocorrelation values of the input by an adaptive filter to estimate $R_{dx}(n,0)$.

$$\widetilde{R}_{dx}(n,0) = \sum_{i=0}^{n} W_i(n) R_{xx}(n,i) \tag{11}$$

Where $\widetilde{R}_{dx}(n,0)$ is the estimation of the cross-correlation for time-lag k=0. $R_{dx}(n,0)$ is estimated by adjusting weight vector W_i in the same manner as the LMS algorithm.

The estimation error $g(n)$ for the correlation function is defined as follows.

$$g(n) = R_{dx}(n) - \widetilde{R}_{dx}(n) \tag{12}$$

We used the minimum of the MSE for tap adaptation in the correlation adaptive filter. MSE of the correlation function is given as Eq.(13).

$$MSE = E[|R_{dx}(n) - \widetilde{R}_{dx}(n)|^2] \tag{13}$$

The gradient of the MSE is

$$\nabla_j[MSE] = -2E[g(n)R_{xx}(n,j)], 0 \le j \le N-1 \tag{14}$$

Weight vector is updated as Eq.(15) in NLMS algorithm.

$$W(n+1) = W(n) + \frac{2\mu_0}{1+x^T(n)x(n)} e(n)x(n) \tag{15}$$

Where μ_0 is the step size for tap coefficients adaptation [5]. In the NLMS algorithm[6,7], normalization is used to ensure sufficient conditions for convergence.

Fig. 1 shows the proposed algorithm. Errrs which are obtained from each group are compared in selection part, and a minimum error is chosen. In Fig. 1, error signal $e_1(n)$ is given as Eq.(16), and $e_2(n)$ is given as Eq.(17).

$$e_1(n) = d(n) - y_1(n) \quad (16)$$

$$e_2(n) = (y_2^2(n) - R_c^2(n)) \cdot y_2(n) \quad (17)$$

In the proposed CMA-CNLMS algorithm, filter coefficients for each group are updated by using output information of the selection block. In the proposed CMA-CNLMS algorithm, step size is used by group. So this algorithm is more flexible and adapt itself accordingly to retain the desirable performance characteristics of fast convergence and low steady-state error.

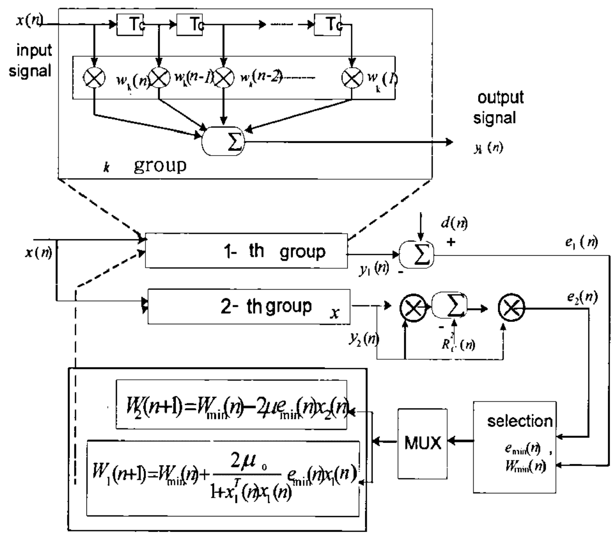


Fig. 1. Structure of the proposed interference canceller.

III. SIMULATION AND MEASUREMENT RESULTS

Fig. 2 shows the simulation results for comparing the performance of the proposed CMA-CNLMS algorithm with LMS algorithm. From the Fig. 2, we can see that convergence times for the about the same performance are about the same for two algorithms. However, the proposed algorithm has better steady state MSE performances by 7 to 13.5 dB than LMS algorithm.

Fig. 3 shows the comparison for mean square error vs. iteration time for NLMS, Normalized Constant Modulus Algorithm (NCMA), Variable Step Size LMS (VSSLMS) algorithms and the proposed algorithm. The proposed algorithm has a little longer iteration time than other algorithms, but the proposed algorithm has better steady state MSE performances by 2.5 to 10 dB than other algorithms.

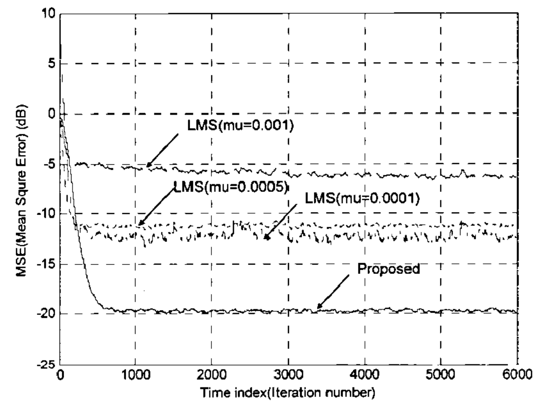


Fig. 2. Mean square error and convergence performance of the proposed algorithm and LMS algorithm with different step sizes.

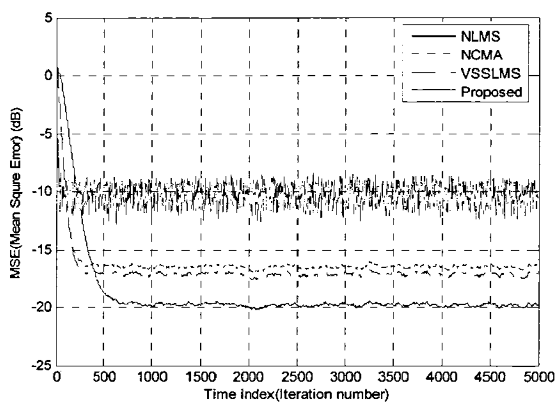


Fig. 3. Mean square error and convergence performance of the proposed algorithm and other algorithms.

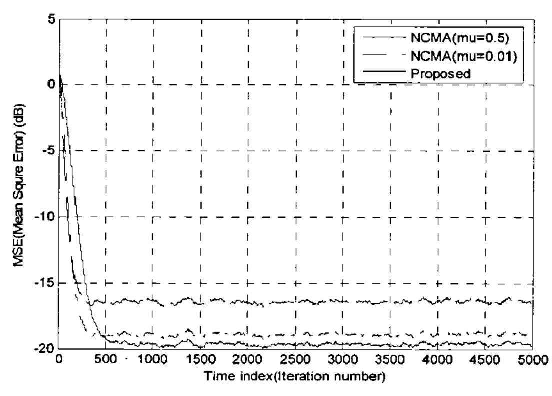


Fig. 4. Mean square error and convergence performance of the proposed algorithm and NCMA algorithm with different step sizes.

Fig. 4 shows the comparison for mean square error vs. iteration number between NCMA with constant step sizes and the proposed algorithm. Also, the proposed algorithm has better MSE performances than NCMA.

IV. CONCLUSIONS

We proposed the CMA-CNLMS algorithm which utilized the correlation between the desired and input signal to adjust the step sizes. Error sequence is utilized to accelerate the speed of convergence. And, we investigated and compared the performance of the proposed CMA-CNLMS algorithm with conventional LMS, NLMS, NCMA, VSSLMS. The results showed that the proposed algorithm had a better performance in view point of steady state MSE. Comparing with conventional LMS algorithm, the proposed one showed about the same convergence time for the about same MSE performance and showed a better steady state MSE performance. The proposed algorithm should be useful for wireless system such as WCDMA systems.

REFERENCES

[1] WKaren Egiazarian and Pauli Kuosmanen, "Variable Step-Size LMS adaptive filters for CDMA Multiuser detection", *IEEE TELSIKS Serbia and Montenegro*, October 1-3, pp. 259-264, 2003.

[2] Yusuke Tsuda and Testsuya Shimamura, "An Improved NLMS Algorithm for channel equalization", *IEEE International Symposium*, vol. 5, pp. V-353 - V-356, 2002.

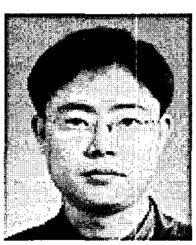
[3] Byung Goo Choi, Yong Wan Park, and Jeong Hee Choi, "The Adaptive Least Mean Square Algorithm Using Several Step Size for Multiuser Detection", *IEEE VTS-Fall VTC*, vol. 6, pp. 2822-2825, 2000.

[4] Guo Li, Li Ning, Guo Yan, and Zhou Jilngpan, "Convergence behavior of the constant modulus algorithm controlled by special stepsize", *IEEE Signal Processing International Conference*, vol. 1, pp. 390-392, 2003.

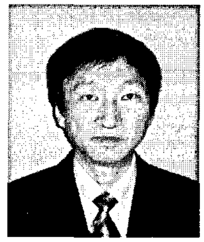
[5] Rui Chen, E. Zhifeng, Jiawen Hu, and Asharif Mohammad Reza, "Adaptive filter by using proportionate frequency domain extended correlation LMS algorithm in the double-talk condition", *IEEE Signal Processing International Conference*, pp. 1826-1829, 2008.

[6] C. Paleologu, S. Ciochina, and J. Benesty "Variable Step-Size NLMS Algorithm for Under Modeling Acoustic Echo Cancellation," *IEEE signal processing Letters*, vol.15, pp. 5-8, 2008.

[7] S.C. Chan and Y. Zhou, "on the Convergence Analysis of the Normalized LMS and the Normalized Least Mean M-Estimate Algorithms," *IEEE International Symposium*, vol. 15-18, pp. 1048-1053, 2007.



Yong Sik Han received his B.S. degree in electronics engineering from the Kyungil University, Kyoungbuk, South Korea, in 1994, and M.S. degree in information & communication engineering from the Youngnam University, Kyoungbuk, South Korea, in 2003. Since March 2006, he has been a Ph. D. student in electronics engineering, University of Incheon, South Korea. His research interests include mobile communication system, RF repeater, electromagnetic wave propagation.



Woon Geun Yang received his B.S., M.S. and Ph.D. degrees in electronics engineering from the Seoul National University, Seoul, South Korea, in 1983, 1985 and 1994, respectively. From 1988, he has been the faculty of Dept. of electronics engineering, University of Incheon, Incheon, South Korea. From March, 1997 to Dec., 2001, and from Feb., 2004 to Jan., 2005, he had been a consulting professor for LG Electronics Inc. including LG Information & Communications Co., Ltd. From May, 2001 to Feb., 2002, he was an invited researcher in ETRI (Electronics and Telecommunications Research Institute). His name has been listed in the "Who's Who in the World" since 2003. His research interests include mobile communication, antenna, RFID, SAR.