PARALLEL INTERFERENCE CANCELLATION WITH NEURAL NETWORK IN THE CDMA SYSTEMS

Yalçın Işık
e-mail: isiky@erciyes.edu.tr
Kayseri Vocational High School, Erciyes University, 38039 Kayseri,Turkey

Necmi Taşpınar
e-mail: taspinar@erciyes.edu.tr
Department of Electronics Engineering, Erciyes University, 38039 Kayseri,Turkey

Key words: CDMA, Multi-user, Neural Network, PIC.

ABSTRACT

In this study, multi-user receiver with the parallel interference cancellation (PIC) that using neural network as a front-end stage in the code division multiple access (CDMA) systems is investigated. PIC is a method to decrease the multiple access interference (MAI) by canceling effects of the other users. In this paper, we propose one stage PIC with neural network that achieve BER values as well as the classical four-stage PIC.

I.INTRODUCTION

CDMA system is attractive for wireless multiple access communications, because it allows complete frequency re-use in a cellular network. But, multiple access interference (MAI) that produced by the other users is important limitation in terms of capacity in CDMA systems. The solution of this problem is to use multi-user detector. There are various multi-user receiver techniques. In the CDMA systems, matched filter bank is the common receiver type that has minimum complexity. But, matched filter receiver assumes other channels as background noise. For this reason, bit error rate (BER) of the desired user increases as the number of the active users increases. To achieve better BER values, various multi-user detection techniques have been developed.

The most common linear technique is the decorrelating detector that calculates effects of the other channels and subtracts it from desired channel. The minimum mean square error (MMSE) receiver is a similar technique but also considers the channel noise. Both of them have good BER performance, but the inverse process of cross correlation matrix is necessary and it increases complexity and time delay as the number of active users increases [1].

The common nonlinear techniques are multi-stage interference cancellation and neural network receiver. Neural network receiver was first made by Aazhang , Paris and Orsak [2]. Later, a lot of studies were made on neural network receivers [3-14]. Interference cancellation technique is realized in two different methods as successive interference cancellation (SIC) and parallel interference cancellation (PIC). Some studies on adaptive interference cancellation and parallel interference cancellation were made [15-19]. Also successive interference cancellation with neural network compensation was realized [20].

In the neural network receiver, output of the matched filter bank is used as network input, and network is trained for correct data. Then, trained neural network produces users data from matched filter bank output. In the SIC method, the output of the matched filter bank is investigated in each bit period, first of all, bit of the user that have biggest power is determined. Later, in order of power values, other users' bits are corrected by subtracting effects of the more powerful users from matched filter output. Since in each bit period one user's bit is decoded, this method has a lot of time delay. PIC is similar method, but in every bit period, all users' bits are corrected simultaneously , so this method have smaller time delay, but it has worse BER values, because of using other users' uncorrected bit values.

Generally, SIC and PIC stages are used after matched filter that do not have good BER performance. In this study, one stage PIC is used after neural network receiver that have much better BER performance than matched filter. Proposed receiver has BER performance as well as four-stage PIC receiver.

II.SYSTEM MODEL

The block diagram of synchronous CDMA system is shown in Figure 1. As a transmitter, random data in form +1,-1 for K users are generated and each users' data is multiplied with its spreading code and AWGN is added. So, CDMA signal in transmission environment is obtained such as:

$$y(t)=\sum_{k=1}^{K} A_k b_k S_k(t)+n(t) \qquad (1)$$

where b_k is the input bit of the k^{th} user, $b_k \in \{1,-1\}$, A_k is the received amplitude of the k^{th} user, n(t) is additive white Gaussian noise and $S_k(t)$ is k^{th} user's signature waveform, and it is defined for N bit length and BPSK modulation as:

$$S_k(t) = \sum_{k=0}^{N-1} a_k P_T(t - kT_c) \qquad (2)$$

where T is bit period, T_c is chip interval (bit period of spreading code), a_k is normalized spreading sequence.

The cross-correlation of the signature sequences are defined as:

$$\rho_{ij} = \langle s_i s_j \rangle = \sum_{k=1}^{N} s_i(k) s_j(k) \qquad (3)$$

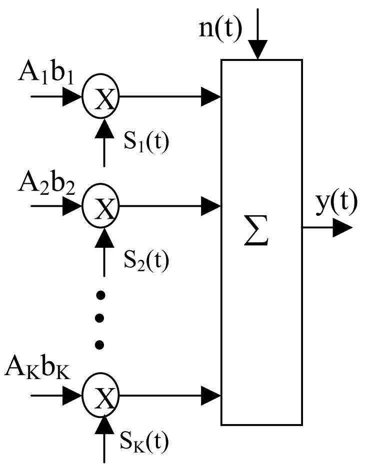

Figure 1: Synchronous CDMA system model.

At the other end, generally in all kind of receivers type, input stage is a matched filter bank. Output of the matched filter bank is defined as:

$$y_k = A_k b_k + \sum_{\substack{j=1 \\ j \neq k}}^{K} A_j b_j \rho_{jk} + n_k \qquad (4)$$

where, A_k is amplitude of the desired user, b_k is bit value of the desired user, A_j is amplitude of the j^{th} user, b_j is bit value of j^{th} user and ρ_{jk} is cross-correlation coefficient between desired user and j^{th} user.

First term is desired output, others are multiple access interference (MAI) and noise. Matched filter takes the MAI as noise, for this reason its BER performance degrades as the number of active users increases. In the interference canceller, MAI is detected and subtracted from matched filter output of the desired user. In the SIC, the most powerful user's bit is assumed as correct and in order of power level other's bits are corrected. In the interference cancellation technique, if one user's bit is taken as wrong, error probability for other users increases. In each correction process, just corrected bits are considered. For this reason in the SIC, BER performance is better than PIC for one stage, but time delay is bigger.

In the PIC, correction process is done simultaneously for all users in one bit period. In the correction process, uncorrected bits are considered, so BER performance of one stage PIC is not good. For this reason, generally PIC is used as multi-stage, but in that case the system complexity increases. One stage PIC can be defined as:

$$A_k b_k = y_k - \sum_{\substack{j=1 \\ j \neq k}}^{K} A_j b_j \rho_{jk} \qquad (5)$$

PIC receiver is shown in Figure 2. In the PIC, output of the matched filter bank is taken as input stage. When the number of active users is increases, errors increase in the input of the PIC, so BER performance of the PIC degrades. In the receiver that we proposed, neural network (NN) decision device is used between matched filter output and PIC input . This receiver is shown in Figure 3. In that way, PIC starts correction process with more correct bits than classical way. So, one stage PIC with neural network performs like multi-stage PIC and computational complexity decreases.

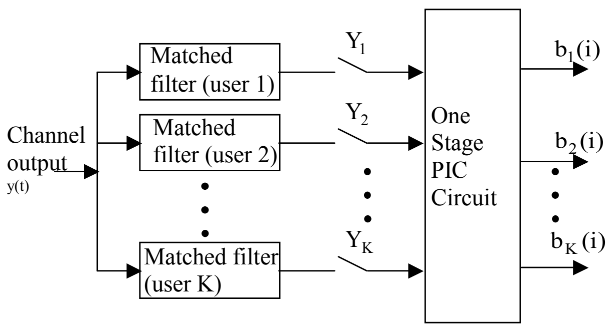

Figure 2: PIC receiver.

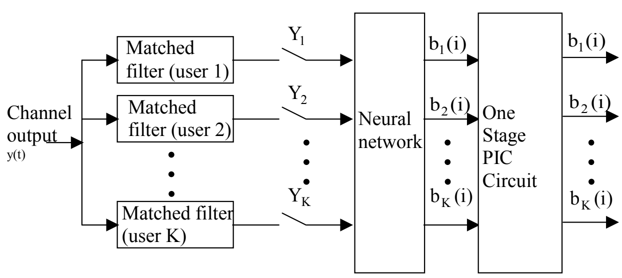

Figure 3: PIC with neural network receiver.

Neural networks (NN) can be arranged in desired number of layers and nodes, they can be trained by various algorithms. During the training process, weights between nodes are changed according to defined target. After that, neural network produces an output for any input in the system. In the NN receiver, computational complexity is low and it can be adapt to any changes due to its flexible structure. For two users situation, NN decision device that takes matched filter output y_1 and y_2 as input and produces b_1 and b_2 output data is shown in Figure 4. The number of input nodes and hidden layers can be set in various values, but number of output nodes must be in number of users.

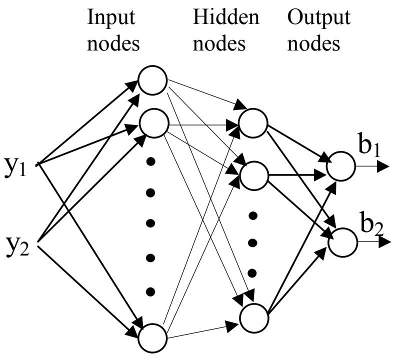

Figure 4: NN decision device for two users situation.

III.SIMULATION RESULTS

Simulations have been carried out in three different way: BER of desired user versus signal to noise ratio, BER of desired user versus near-far rate, BER of desired user versus the number of active users. In all of them, we consider synchronous AWGN channel. Simulations have been carried out through transmitter to receiver in all of the CDMA system. In the simulations, 31 bit length Gold code has been used. BER performance of PIC with NN is compared with classical receiver, decorrelator receiver, NN receiver and classical one stage PIC.

BER performance of desired user versus signal to noise ratio of desired user for synchronous AWGN channel with five users is shown in Figure 5. Perfect power control is assumed. NN have 15 input nodes, 8 hidden layer nodes and 5 output nodes. It is a feed forward network and it is trained by Levenberg-Marquardt algorithm. During the training, signal to noise ratio is assumed as 1 dB and 500 bits are used for training. It is shown from Figure 4. that PIC with NN have much better BER performance than the others. The similar simulation is shown in Figure.6 for matched filter, one stage PIC, three stage PIC, NN, PIC with NN. It is also shown that PIC with NN is better BER performance than the three stage PIC receiver.

BER performance of desired user versus near-far rate between desired user and second user in five users synchronous AWGN channel is shown in Figure 7. SNR of desired user is assumed as -3 dB and amplitudes of other users are assumed as equal. All conditions about NN is the same with preceding simulation. As it shown, PIC with NN have much better BER performance than the others until the ratio of A_2/A_1 is 7.5. After this value, decorrelator receiver is better than PIC with NN receiver.

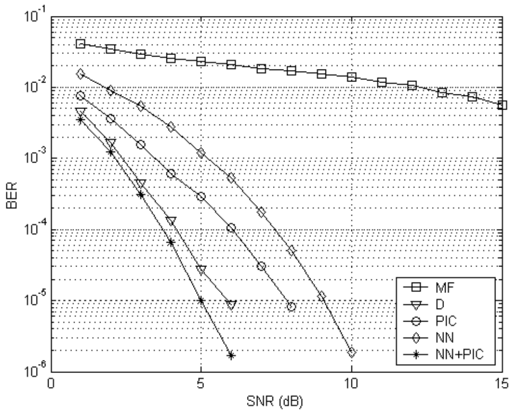

Figure 5: BER versus signal to noise ratio of desired user for matched filter (MF), decorrelator (D), PIC, NN and PIC with NN(NN+PIC).

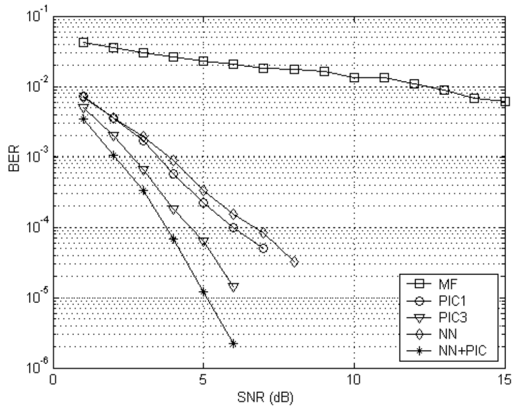

Figure 6: BER versus signal to noise ratio of desired user for matched filter (MF), one stage PIC (PIC1), three stage PIC (PIC3), NN and PIC with NN (NN+PIC).

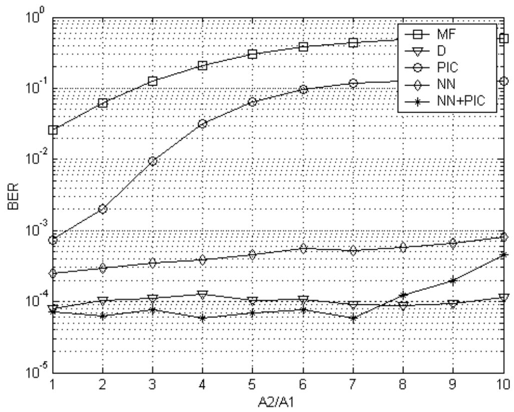

Figure 7: BER of desired user versus near-far rate between desired user and second user for matched filter, decorrelator, PIC and PIC with NN.

BER performance of desired user versus number of active users in synchronous AWGN channel is shown in Figure 8. Perfect power control is assumed. All conditions about NN is the same with preceding simulations. But, the number of nodes in input, hidden layer and output is depends on the number of active users in the system. As it shown, PIC with NN have much better BER performance than the others.

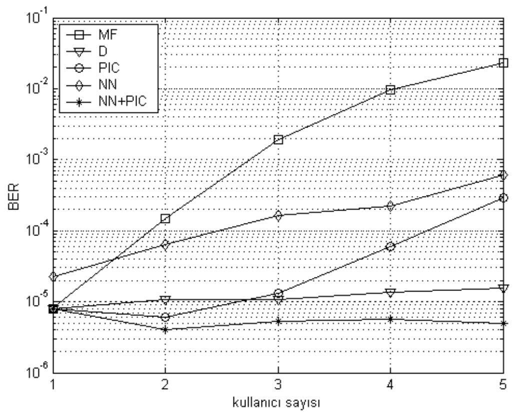

Figure 8: BER of desired user versus number of active users for matched filter, decorrelator, PIC,NN and PIC with NN.

IV.CONCLUSIONS

We proposed a PIC with NN to get better BER performances according to classical receiver, decorrelator receiver and also one stage PIC. Actually, similar BER performance can be obtained with classical multi-stage PIC, but in that case, complexity of the system increases. We used a NN and one stage PIC instead of classical multi-stage PIC. NN has lower computational complexity than classical multi-stage PIC. So, we got better BER performance with lower computational complexity. To get same BER performance of PIC with NN, it is necessary about 4 stage classical PIC.

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