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A NEW PARALLEL INTERFERENCE CANCELLATION ALGORITHM FOR RAKE SYSTEMS

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Abstract- In order to suppres the multi-path interference (MPI) in the DS CDMA system, a new RAKE receiver based on parallel interference elimination is first proposed in this paper data symbol tentative decision is obtained by linear decision; the multi-path interference are evaluated by tentative decision and known user information. Then the performance over Rayleigh fading channel are analyzed and compared to conventional parallel interference cancellation (PIC) and RAKE receiver. It is shown that RAKE receiver performance can be improved greatly by using this method with simple structure and easy implementation.

Keywords *- parallel interference cancellation; RAKE receiver; multi-path interference; Rayleigh fading.*

I. INTRODUCTION

When the Signal through the wireless channel, it will produce multiple path fading inevitably. Turin analysed the effects of multiple path interference to the receiver in spread spectrum communication and disussed some anti-interference techniques[1]. The common methods used to suppress the multiple path interference have as the back detect progression and the Rake receiver etc. In the DS CDMA systems, the time domain Rake receivers are used to distinguish, correct and combine different time delay multi-path signal so the inter-symbol interferences are overcome and the path diversity is obtained. By the signal energy of the every path, the Rake receiver obtains diversity gain and as an effective anti multi-path technique, it has become the non-absent key technique in the Third Mobile Communication. Meanwhile, because of the multi-path transmission in channels, multi-path interferences exist between different paths in the identity user. Especially, when the self-correlation between spread codes is worse, the performance about conventional Rake receiver will degrade. So combining the Rake receiver to multi-user detector especially nonlinear multi-user detector has become the research hotspot recently[2~5]. Based on these research, a new parallel interference cancellation method is proposed in this paper in order to eliminate further multi-access and multi-path interference and improve the performance of the Rake receiver in CDMA systems.

II. THE SYSTEM MODEL

A. THE TRANSMITTER MODEL

Considering a single district with K users, the baseband signal for the kth user is given by

$$s_k(t) = \sqrt{2E_{ck}}\, d_k(t) c_k(t) \cos(\omega_c t + \theta_k) \quad (1)$$

Where E_{ck} , d_k (t) stand for the signal power and information stream for the Kth user respectively, ω_c is the carrier frequency, θ_k is the carrier frequency phase, c_k (t) is the signature wave for the Kth user, T_c is the chip width, T_s is the every symbol width for user information stream. So the spread gain is obtained: $N = T_s/T_c$

B. THE CHANNEL MODEL

Rake receivers are designed as taking out delay line model in frequency-selective channel, so the complex lowpass equivalent impulse response can be written as

$$h(t) = \sum_{l=1}^{L} \alpha_l e^{j\beta_l} \delta(t - lT_c) \quad (2)$$

Here, L is resolvable path number, α_l and β_l is the gain and phase of the lth resolvable path respectively, α_l obeys to Rayleigh distribution in the Rayleigh channel.

C. THE RECEIVING SIGNAL

For simplicity, a synchronous uplink CDMA system in the Rayleigh channel is considered, the received signal can be written as

$$r(t) = \sum_{k=1}^{K} \sqrt{E_c} \sum_{l=1}^{L} \sum_{j=-\infty}^{\infty} \alpha_{l,k} b_k(i) c_k(t - \tau_{l,k}) \cos(\beta_{l,k} + \theta_k) + n(t) \quad (3)$$

In eq 3, $n(t)$ represents the Additive White Gaussian Noise(AWGN).

III. THE RECEIVER MODEL

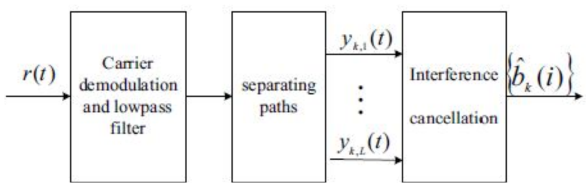

Fig. 1 : Rake parallel interference canceller receiver

The receiver diagram is shown in figure 1. After the received signal is demodulated by carrier correlation and low pass filtered, the paths are separated. So the output of the l^th path through the correlator is

$$y_{k,l}(i) = \int_{iT}^{(i+1)T} r(t)c_k(t-iT)dt \qquad (4)$$

Substituting eq 3 in eq 4

$$y_{k,l}(i) = N\sqrt{E_{ck}}\alpha_{k,l}b_k(i) + \sqrt{E_{ck}}\sum_{\substack{l'=1 \\ l'\neq l}}^{L}\alpha_{k,l'}\cos\theta_{k,l'} + \sum_{\substack{k'=1 \\ k'\neq k}}^{K}\sqrt{E_{ck}}\sum_{l=1}^{L}\alpha_{k',l}b_{k'}(i)\rho_{k',k} + n_k(i)$$

$$= \sqrt{E_{ck}}\alpha_{k,l}b_k(i) + I^P + I^M + n_k(i) \qquad (5)$$

Where:

$$\rho_{k',k} = \int_0^T c_k(t)c_{k'}(t)dt, \theta'_{k,l} = \theta_{k,l'} + \beta_{k,l'}$$

In the equation 5 the first item stands for signal, the second item is the multi-path interferences of the other (L-1) paths to the l^th path, shortening for MPI, the third is the multiple access interference(MAI) of the other (K-1) users to the k^th user, the last is the additive white Gaussian noise(AWGN). To traditional Rake receiver, the result using maximum ratio combining is: $y_k(i) = \sum_{l=1}^{L}\tilde{\alpha}_{l,k}y_{k,l}(i)$ (6)

In equation 6 $\tilde{\alpha}_{l,k}$ is evaluation value for k^th user in the l^th path. When equation 6 is decided, the tentative test value about the symbol is obtained as

$$\tilde{b}_k(i) = D(y_k(i)) \qquad (7)$$

Here D(.) stands for decision function, which may be hard decision or soft decision. Traditional PIC adopts hard decision. In this thesis simple soft decision linear decision is used.In order to eliminate the MPI and MAI in the above equation, a new parallel interference cancellation arithmetic is proposed as shown in the below figure 5.2

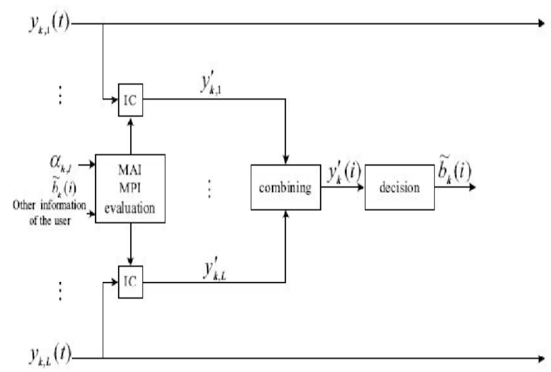

Fig. 2: A New PIC receiver

In the figure 2 taking the i^th symbol decision of the k^th user as example. It can be seen that interference estimators estimate the MAI and MPI of each channel path according to the tentative test value and other known user information (as the spread frequency codes of other users, signal amplitude, phrase etc) in the interference cancellation stage and subtract them, then the correlated outputs after interference cancellation for each path are combined, finally, the symbol decision result is given in the interference cancelling stage, MPI and MAI are reconstructed firstly, supposed that test value $\tilde{b}_k(i)$ can be given by paper [9] and [10]

$$\tilde{b}_k(i) \approx \begin{cases} \lambda_k(b_k(i))/2, & \lambda_k(b_k(i)) \le 2 \\ \mathrm{sgn}(\lambda_k(b_k(i))), & \lambda_k(b_k(i)) \ge 2 \end{cases} \qquad (8)$$

Where $\lambda_k(b_k(i)) = \ln\frac{P(y_{k,l}(i)|b_k(i) = +1}{P(y_{k,l}(i)|b_k(i) = -1}$

To the l^th path, according to and other users information, reconstructed MPI and MAI can be written as respectively:

MPI: $\hat{I}^p = \tilde{\alpha}_{l,k}\tilde{b}(i)\cos(\tilde{\theta}'_{l,k})$

MAI: $\hat{I}^A = \sum_{\substack{k'=1 \\ k'\neq k}}^{K}\sqrt{E_{ck}}\rho_{k',k}\tilde{b}_{k'}(i)$

When reconstructed interference being subtracted and it can be obtained

$$y'_{k,l}(i) = y_{k,l}(i) - \tilde{\alpha}_{k,l}(i)\tilde{b}_k(i)\cos(\tilde{\theta}'_{l,k}) - \sqrt{E_c}\sum_{\substack{k'=1 \\ k'\neq k}}^{K}\sqrt{E_{ck}}\rho_{k',k}\tilde{b}_{k'}(i) \qquad (9)$$

Finally we obtain the received vector as

$$y_k'(i) = \sum_{l=1}^{L}\tilde{\alpha}_{k,l}y'_{k,l}(i) \qquad (10)$$

The final decision for the ith symbol of kth user is

$$\hat{b}_k(i) = \mathrm{sgn}(y_k'(i)) \qquad (11)$$

IV. SIMULATION RESULTS

The figure 3 is the BER performance of conventional PIC receiver and the proposed PIC in this thesis. It can be seen from Figure that when the signal noise ratio (SNR) is lower, the two kind receivers show little difference, but with the SNR increasing, the proposed PIC show superior performance than traditional PIC and the PIC system proposed in this paper appears the best performance.

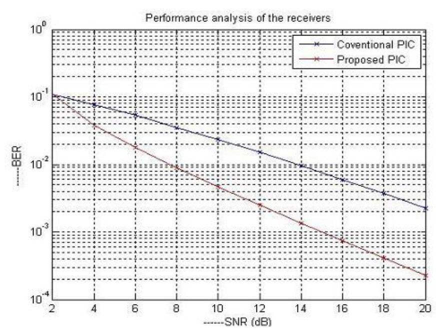

Fig. 3 : BER versus SNR for performance comparison of the two different receivers

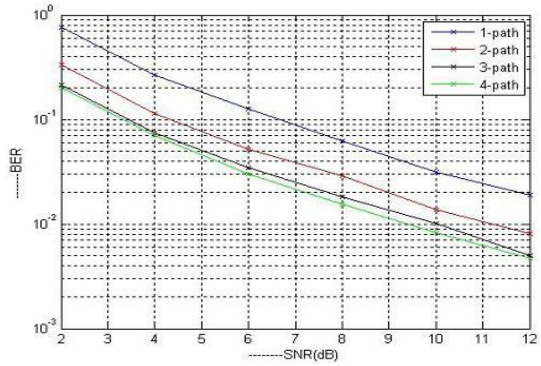

Fig. 4 : BER versus SNR for performance comparison for different values of L.

In Figure 4 the bit error ratios(BER) of the system for different path numbers are compared. It can be seen that when L=1, the system appears the worst performance because only MAI is eliminated. When L=3, the performance of the system is better than L=2; when L=4, the performance can not be improved obviously. So in MPI system, we usually set L=3. Because each path power is impossible same in practical channel, the receiver performance can be improve obviously only through eliminating those paths which SNR reach a certain threshold.

V. CONCLUSION

In this paper, a Rake PIC based on linear decision is proposed. The theory and simulation indicate that this technique can improve greatly the receiver performance in the multipath fading channel and have lower realization complexity, which will very suit for mobile single user receiver restricted by volume and hardware.

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