Study on the Diversity Method to Improve the Performance of the CDMA System in the Mobile Wireless Channel

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Abstract—This study proposes a new diversity algorithm to improve the signal-to-noise ratio. In the wireless channel, if fading occurs due to the multipaths, the performance of the system is apparently reduced. One of the methods to reduce fadings like this is the diversity method, and this study aims to improve the performance of the system by proposing a new diversity algorithm. This study applied rake receiver, and normalized the wireless channel from the Nakagami fading channel to the Rayleigh fading channel, which set the fading index as 1, because of the multipaths. It applied QPSK and OQPSK modulation methods and applied the convolutional codes, where the code rate is 1/2 and 1/3 and the constraint length is 9, and the turbo code where the constraint length is 4. Under these conditions, this study compared and analyzed the average error probability of direct spread multiple access system. The diversity algorithm proposed in this paper could be applied to the mobile communication and other wireless multimedia communications that require high quality and high reliability.

Index Terms—Diversity, Fading, CDMA, Digital modulation, wireless communications

I. INTRODUCTION

Generally, the history of mobile communication refers to the 1st generation of AMPS, the 2nd generation of cellular, the 2.5th generation of PCS and the 3rd generation of IMT2000 (WCDMA, CDMA2000), and is marked with such significant developments. At that time too, the study on the 4th system of OFDM (Orthogonal Frequency Division Multiplexing) was in progress[1]. From the 2nd generation, digital communication was the preferred communication method for the following reasons. First, the digital transmission, through efficient utilization of the frequency, can accommodate 3 to 5 times more subscribers compared to the previous analog method. Second, the use of digital communication requires less battery generation power and less number of chips for mobile station intelligence, so that it largely reduces the cost of the mobile station. Third, as it transmits the digital message, it enables the use of the code system and improves the level of privacy of the subscribers. Fourth, digital communication provides a wide range of services, including the transmission of data.

CDMA (Code Division Multiple Access) method, a kind of multiple access system, uses a different spectrum-spread codes to distinguish the users. The spectrum-spread methods include the DS (Direct Sequence) method and the FH (Frequency Hopping) method. The DS method uses orthogonal spread codes like WALSH function, so that N numbers of channels become multiplexing in the same frequency range during same hours. Since CDMA method is appropriate to the mobile wireless channels having heavy multipaths, it started to be used in new areas like IMT 2000, WLAN, and DMB.

This study aims to find out the bit error probability of CDMA system in the mobile wireless channel as proposed in the new diversity algorithm. For this, this study assumes that it resolves the wireless channels into multipaths and the receiving signal has Rayleigh distribution. This paper is organized as follows. In Chapter II, it explains wireless channels. In Chapter III, it proposes the diversity algorithm to assess the performance of the system. In Chapter IV, it compares and analyzes the system performance of the CDMA method using rake receiver. Finally, it describes the conclusion in Chapter V.

II. WIRELESS CHANNEL

A. DS/CDMA

The direct spread method causes the transmitting signals to be recognized as noise to other users but the receiver, making the data difficult to detect or extract. This method modulates the signals by spreading the data signal in the bandwidth using PN codes and modulates them again by spreading signals having wider bandwidth. There are two advantages of using the DS/CDMA methods[2]. First, it uses the simple spread method; second, the error is random. In other words, as its interference is spread in the receivers of DS/CDMA system, the interference within the bandwidth seems to increase the level of the noise on the receiver[3]. However, the voice signals without error correction have larger tolerance level for burst error, so that the information data is easily corrected by Trellis error correction and Viterbi decoder.

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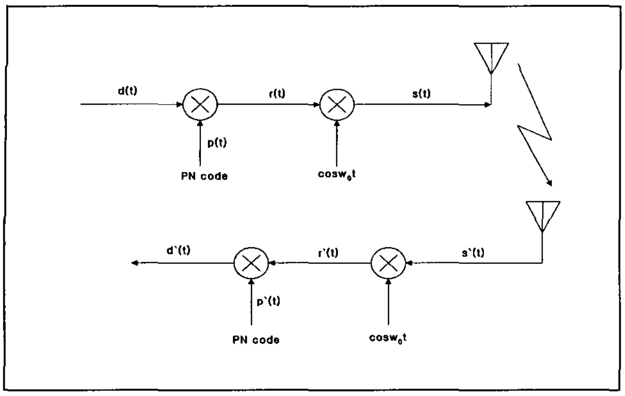

Fig. 1 DS/CDMA Transmitter and receiver Block

B. Rayleigh Distribution

In the mobile wireless communication system, multipaths are formed due to the reflection, refraction, and scattering of signals affected by buildings, man-made constructions, or natural environment. Likewise, it is difficult for the signals received from a mobile device to have line-of-sight waves from the sender. These waves are the sum of signals, which were scattered by disarranged obstacles, causing diminution and phases differences on each signal received. When there is no line-of-sight wave and only reflective waves exist, it is referred to as Rayleigh fading. Rayleigh fading has Rayleigh distribution and the equation of Rayleigh distribution is as follows[4].

$$p(r) = \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma_r^2}\right) \tag{1}$$

C. Fading Channel

When we think of the multipath fading of two different frequencies separated within a system bandwidth, in case where the interval of those two frequencies are small enough, those two waves pass almost in the same electromagnetic paths so that they have almost same amplitude and changes in phase. However, the bigger the interval between those two frequencies is, the smaller the level of the correlation between the patterns of the changes of those two frequencies becomes. This is because the changes of phases between two frequencies are different upon each path in the multipath environment. This phenomenon, which shows different fading according to the frequency, is called frequency selective fading. The bandwidth, which has small enough level of correlation of fading between two frequencies, is called Coherence Bandwidth. This coherence bandwidth is related to the delay spread. In the areas with large delay spread, the coherence bandwidth becomes smaller because the phases of signal received have large differences even though the interval between two frequencies is small. While in the area which has small delay spread, the bandwidth becomes larger.

III. DIVERSITY RECEIVER

Rake receiver is the receiver used in the frequency selective fading channel having diversity effect. It receives the signals in a pace similar to that of collecting dried leaves with hooks, that adds a certain time delay, Doppler spectrum and AWGN applies average electric power of diminution upon the time delay on each tap of signals received through each different path. It sums up all the signals received and demodulates them[4].

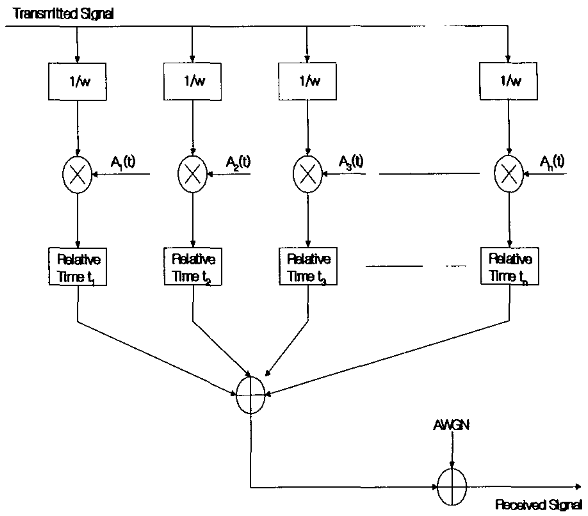

Fig. 2 Rake receiver

A. Signal Model

Fig. 3 is the DS/CDMA communication system model showing that K number of users exist[5][6][7].

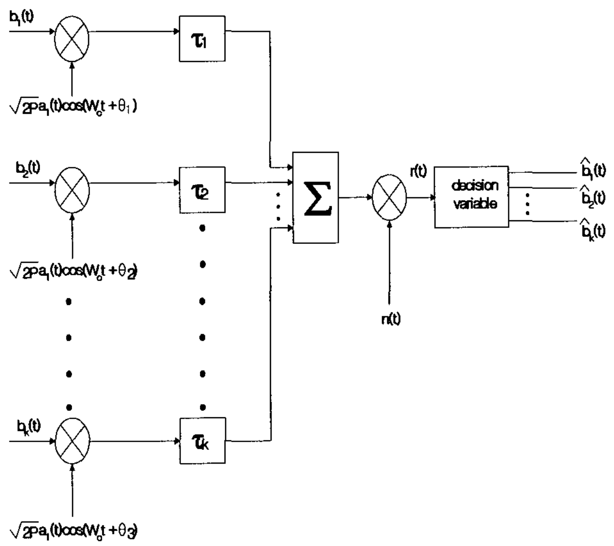

Fig. 3 Receiver model

The data signal of the users, $b_k(t)$, is a rectangle wave wand's sequence having +1 and −1 of values for T seconds of the section and displayed as follows.

$$b_k(t) = \sum_{l=-\infty}^{\infty} b_{k,l} P_T(t - lT) \qquad (2)$$

Here, the $b_{k,l}$ is the l^{th} data of k^{th} user. When $t = T$, the output of correlation receiver is displayed as follows.

$$Z_i = \sqrt{P/2}\left\{ b_{i,0}T + \sum_{\substack{k=1\\k\neq i}}^{K}[b_{k-1}R_{k,i}(\tau_k) + b_{k,0}\hat{R}_{k,i}(\tau_k)]\cos\phi_k \right\} + \int_0^T n(t)a_i(t)\cos\omega_c(t)dt \qquad (3)$$

The Z_i distribution can be displayed as follows.

$$\mathrm{var}\{Z_i\} = \frac{PT^2}{12N^3}\left(\sum_{\substack{k=1\\k\neq i}}^{k} r_{k,i}\right) + \frac{1}{4}N_0T \qquad (4)$$

The average signal-to-noise ratio input in the receiver is as follows.

$$\gamma_c = \left\{ (6N^3)^{-1}\sum_{\substack{k=1\\k\neq i}}^{K}\left[2u_{k,i}(0) + u_{k,i}(1)\right] + \frac{N_0}{2E_b} \right\}^{-1} \qquad (5)$$

In Equation (5), it was normalized when the value of K value was large,

$$(6N^3)^{-1}\sum_{\substack{k=1\\k\neq i}}^{K}\left[2u_{k,i}(0) + u_{k,i}(1)\right] \cong \frac{(k-1)}{3N} \qquad (6)$$

and the average signal-to-noise ratio input in the receiver is displayed as follows.

$$\gamma_c = \left(\frac{K-1}{3N} + \frac{N_0}{2E_b} \right)^{-1} \qquad (7)$$

Here, k is the number of users, and N is the code sequence.

B. System Performance Analysis

The error probability of QPSK in the AWGN, P_e, can be displayed as follows.

$$p_e(\gamma) = \frac{1}{2}erfc(\sqrt{\gamma}) \qquad (8)$$

The signal-to-noise ratio in cases where the diversity method was introduced in the multipath fading channel can be described as follows.

$$\gamma = M \cdot \gamma_c \qquad (9)$$

Here, γ is the bit per signal-to-noise ratio and γ_c is the channel per signal-to-noise ratio. It used a rake receiver and applied maximum synthesis method. In this case, the number of antennas was An. If there is L number of incidence signal paths, the total number of diversity of this system can be displayed as follows.

$$M = E_s \cdot L \qquad (10)$$

If it is frequency selective slow fading channel, L is described as follows.

$$L = T_m \cdot W + 1 \qquad (11)$$

The bit per signal-to-noise ratio can be described as follows.

$$\gamma = (T_m \cdot W + 1)\left(\frac{(K-1)}{3N} + \frac{N_0}{2E_b} \right)^{-1} \qquad (12)$$

The average error probability P when QPSK signal receives Rayleigh fading in the AWGN can be presented as follows[8].

$$P = \int_0^{\infty} p(\gamma)p_e(\gamma)d\gamma \qquad (13)$$

IV. SIMULATION

In this chapter, this study aims to compare and analyze the average error probability of DS-CDMA system. The study set the number of antenna as 9, and assumed that there are 500 users in a single set. For the channel distribution, it applied the Nagakami fading distribution and set the fading index as 1. The code rate was 1/2 and 1/3, and QPSK and OQPSK modulation methods were used. Table 1 display the results of the DS-CDMA system performance analysis applying QPSK and OQPSK modulation methods.

The Normal 1 graph in Figure 4. applied a code rate of 1/2, diversity method, convolutional code, and turbo code. The Normal 2 graph applied a code rate of 1/3, diversity method, convolutional code, and turbo code. The Proposed graph applied the diversity algorithm proposed by this paper to the DS-CDMA system.

Table 1 E_b / N_o of QPSK and OQPSK system

Modulation	Method	Code rate	E_b / N_0
QPSK	normal 1	1/2	$10^{-2.4}$
	normal 2	1/3	$10^{-2.7}$
	proposed	1/3	$10^{-2.9}$
OQPSK	normal 1	1/2	10^{-3}
	normal 2	1/3	$10^{-3.3}$
	proposed	1/3	$10^{-3.5}$

The average error probabilities of Normal 1 and Normal 2 when E_b / N_o is 20 dB are$10^{-2.4}$ and $10^{-2.7}$ respectively and that of the Proposed is $10^{-2.9}$ where it was proven that the performance of the diversity algorithm proposed by this study is superior to the others.

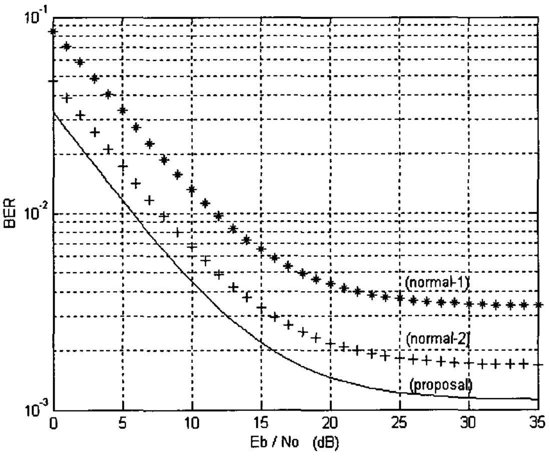

Fig. 4 BER of QPSK system

Figure 5 shows the average error probabilities upon each modulation method. When B_b/N_o is 20 dB, the average error probabilities of Normal 1, Normal 2 and the Proposed were 10^{-3},$10^{-3.3}$ and 10^{-3b} respectively; and it also showed that the diversity algorithm proposed by this study is superior to the others in the OQPSK modulation method.

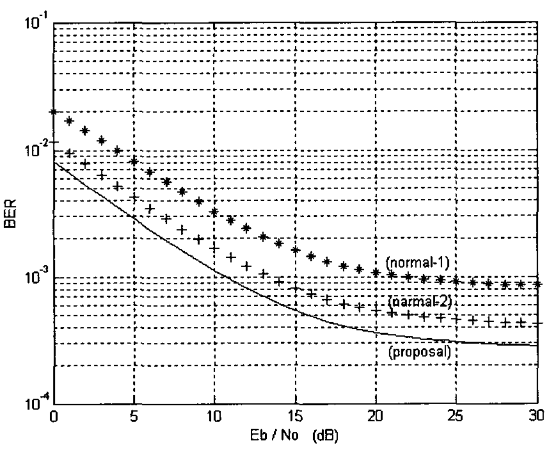

Fig. 5 BER of QPSK system

IV. CONCLUSIONS

This study proposed a new diversity algorithm to reduce the average error probability. In Figure 4., where BER is 10^{-2}, it improved 7dB in the proposed algorithm compared to that in Normal 1, and 5dB was an improvement over that of Normal 2. In Figure 5, where BER is 10^{-2}, it improved 5 dB in the proposed algorithm compared to that of Normal 1, and about 3dB was an improvement over that of Normal 2. Therefore, these proved the superiority of the diversity algorithm proposed by this study. Comparing Figure 4 and Figure 5, the QPSK was 10-2.9 and OQPSK was 10-3.b -- a finding again, that the diversity algorithm proposed in this study is more appropriate to the OQPSK modulation method.

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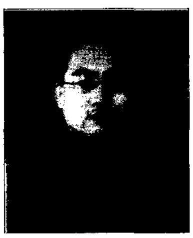

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