Power-Controlled Multicarrier and Multiuser Detection Techniques in Wireless CDMA Systems

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Abstract: This paper describes power-controlled multi carrier and multiuser detection techniques for Code Division Multiple Access (CDMA) systems. In conventional CDMA systems, a RAKE receiver is employed to overcome wireless channel effect due to frequency selective characteristics of wireless CDMA systems. Alternatively, multi carrier technique can also be used to overcome the effect of frequency selective channel. Conventional CDMA systems also employ single-user detection scheemes, in that interference between users, called the multiple access interference (MAI), is considered as interference which contributes to the statistics of detection variables affecting the quality of detection. Now, multiuser detection method is proposed to mitigate the inter user interference in CDMA systems. In multiuser detections, the MAI component can be eliminated or cancelled by the use of all user's spreading code in the system to be available to each user. Another technique that is commonly employed in CDMA system is power control, to mitigate the effects of near-far and fading channel fluctuations. In this study, the basic concept of multi carrier and multiuser detection technique is described in a simple model and the performance for various number of users is simulated and evaluated. The performance of power-controlled multi-carrier and multiuser detection technique is then evaluated and compared with that of the single-user detection to show a significant improvement.

Keywords: CDMA; detection; multicarrier; mutiuser; power-control, single user.

1. Introduction

Communication systems using spread spectrum techniques have long been used in military communication systems [1]. Later, the spread spectrum technique has also been used for multiple access method in mobile wireless communication systems which is called code division multiple access (CDMA) system. CDMA multiple access technique utilizes the same frequency spectrum by multiple users simultaneously, using spreading code, calledthe chip, which is unique to each user. Implementation of the spread spectrum technique on military communication systems typically uses frequency hoping technique, whereas the cellular system employs direct sequence CDMA (DS-CDMA) technique [2]. The use of DS-CDMA techniques for multiple access applications produces an interesting characteristic because it can provide high and flexible (soft) system capacity. It also can overcome the effects of multipath channel, as well as can perform soft-hand off in mobile cellular system with many cells/sector conFigureuration [3].

In the DS-CDMA system, data symbol to be transmitted is first spread with spreading code (chip sequence) that is unique to each user. The sreading code has a higher rate than the data rate, so that the frequency spectrum will be increased following the spectrum of the chip rate being used. Furthermore, the data symbols that already experiencing a spectrum increase will undergo a modulation process, frequency conversion, amplification, etc. as commonly occurs in signal transmission systems of regular communication system. On the receiver side, each user will generate identical spreading code and synchronization process with that of the transmitted code generated in the transmitter side, so that the data can be detected and recovered.

In conventional CDMA system, RAKE receiver is employed to overcome wireless channel effect due to frequency selective channel characteristics of wireless CDMA systems. In conventional DS-CDMA system detection technique of each user only uses spreading codes assigned to it to detect the data symbol. The detection variable will consist of its data symbols, the inter-user interference (multiple access interference, MAI) as a result of cross-correlation between spreading codes of a different user, and the noise generated by the receiveing device (Gaussian noise). Multi carrier technique is employed to overcome the effect of frequency selective channel characteristic of CDMA systemwhich has a wideband characteristics. Detection techniques using just spreading code dedicated to each user is referred to as single-user detection technique (single-user detection) [4]. Detector performance will be determined by the quality of signal statistics as a detection variable, consisting of data symbols mixed with MAI and noise. The more users are active using the same frequency spectrum simultaneously, the worse the quality of the detected signal, and of course, the worse detection performance will results. Even in the wireless mobile communication system in which communication channels will experience the process of multiple propagation path (multipath), then some users will receive a higher signal power than other users (near-far problem). The near-far problem in CDMA system will lead to the problem that the user located far away from the transmitter station (receiving low power) is ruined over by users who are close to the transmitter location (accepting higher power level). To overcome this problem, tight power control is required [5].

In this study of multi carrier and multiuser detection scheemes, each user has access to all spreading codes designated in the system. However in single-user detection technique, spreading code belong to other users is considered as interference, in multiuser technique, spreading code belong to other users is considered as a useful signal to be used as interference canceller. This technique is referred to as multi-user detection technique [6], since all the signals belong to each user is used to eliminate the multiple access interference, instead of being interference to other users. Of course using spreading code for each user to cancell other user's MAI will improve the signal quality for detection statistics. However, multi-user detection techniques involving all spreading signals to detect the data symbols of each user will increase its computational complexity. Therefore, research in this area is still ongoing at this time, and the objective is now to find the optimum solutions that will trade-off the performance and complexity of multi-user detection techniques [7].

The rest of the paper is organized as follows : Section II describes the wireless channel and signal model of the CDMA system, section III describes the multi carrier CDMA system to overcome the wireless frequency selective channel effect. In section IV, detection technique of CDMA system with single-user detection and multiuser detection techniques are presented. Section V describes the performance evaluation of detection techniques through numerical simulations, and discuss its performance. Section VI presents the power-controll technique to improve the multi carrier and multiuser detection performance. Section VII draws conclusions of this paper.

2. Wireless Channel and CDMA Models
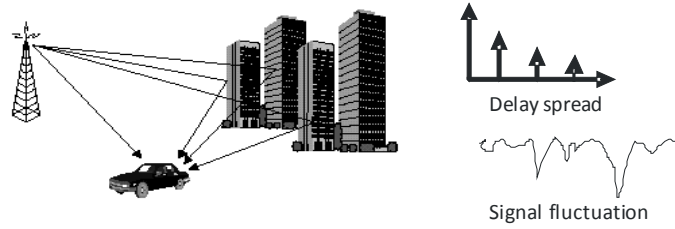*A. Wireless Channel Model*

In a mobile communication system, a signal transmitted through a wireless channel will undergo a complicated propagation process that involves diffraction, multiple reflections, and scattering mechanisms. In most cases, a line-of-sight path (LOS) between the mobile and the base station is hardly in existence due to a very dense propagation environment.

Figure1a shows the near-far distance problem due to location variability of mobile users around the base station. To overcome the near-far problem, an open-loop power control can be used [8]. The open-loop power control is designed to ensure that the received powers from all users are equal in average at the base station. In the open-loop algorithm, the mobile user can compute the required transmit power by using an estimate from the downlink signal (no feedback information is needed). This is because the large-scale propagation loss is reciprocal between uplink and downlink channels. In Figure 1b the signal also experience time spread as

well as amplitude fluctuation due to multipath propagation environment. In order to avoid inter symbol interference due to delay spread effects of the channel, the transmitted signal bandwidth must be kept less than the channel coherence bandwidth, which is inversely proportional to the delay spread. Since in most situation of cellular propagation environment, the channel coherence bandwidth is in the order of ten to hundred kHz, while CDMA systems occupy at least 1.25 MHz of bandwidth, multicarrier system such as Orthogonal Frequency Division Multiplexing (OFDM) or MC-CDMA will need to be employed. In multicarrier system the transmitted signal bandwidth is divided into a number of subcarriers which is then transmitted into the channel. Therefore, despite the fact that the channel is frequency selective for the entire signal bandwidth, for each subcarrier transmission the channel becomes frequency flat.
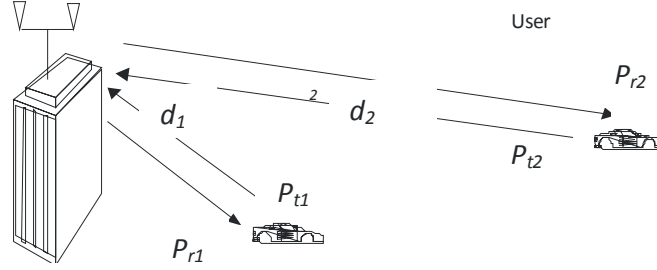
a. Near -far distance problem

b. Multipath fading problem

Figure 1. Wireless Channel Model in Cellular Mobile Communications

A mathematical model to describe the received multipath signal can be determined as follows. Let the transmitted signal be $x(t)$ which can be expressed as

$$x(t) = s(t)e^{j(2\pi f_c t)} ,$$
(1)

where $s(t)$ is the complex baseband signal with bandwidth W, $f_c = c/\lambda$ is the carrier frequency, c is the speed of light, and λ is the wavelength of the radio frequency (RF) signal. The received signal $r(t)$ as the superposition of L multipath components can be expressed as

$$r(t) = \sum_{l=1}^{L} C_l s(t - \tau_l) e^{j2\pi[(f_c + f_D \cos \psi_l)t - f_c \tau_l]} ,$$
(2)

where C_l is the fraction of the l-th path of the incoming signal amplitude, τ_l is the lth path delay, $f_D = v/\lambda$ is the maximum Doppler spread, and ψ_l is the direction of the l-th scatterer with respect to the mobile velocity vector, v. From (2), we can see that the magnitude and phase of $r(t)$ is random variables indicating signal level and phase fluctuation, $f_D \cos \psi_l$ represent the carrier frequency shift due to Doppler frequency, and τ_l represents the time delay of signal

received from the lth path. In this research we consider the channel is frequency flat, so the effect of path delay τ_l is not taken into account. The carrier frequency demodulation is also assumed to be perfect, so the effect of Doppler shift is negligible.

B. CDMA System Model

A baseband signal model of DS-CDMA system with *K*-users that employ shared frequency spectrum is shown in Figure. 2. Signaling interval for each user's data symbol is *T* seconds, and the input data symbols is a sequence of binary symbols {+1, -1}. Spreading codes are unique for each user with a chip rate higher than the rate of the symbol data rate belongs to each user, so each symbol will contain many spreading chips as shown in Figure. 2 (a). In the frequency domain the data symbols for each user before undergoing the process of spreading has a narrow spectrum, and after experiencing the process of spreading will have a wider frequency spectrum, as shown in Figure. 2 (b). DS-CDMA signal of each user is then sent to the communication medium (channel), in that in the mobile wireless system it will be a multi-path channel. In the receiver side, the single-user detection perform the reverse process of spreading (despreading) to recover the data symbols transmitted by each user.
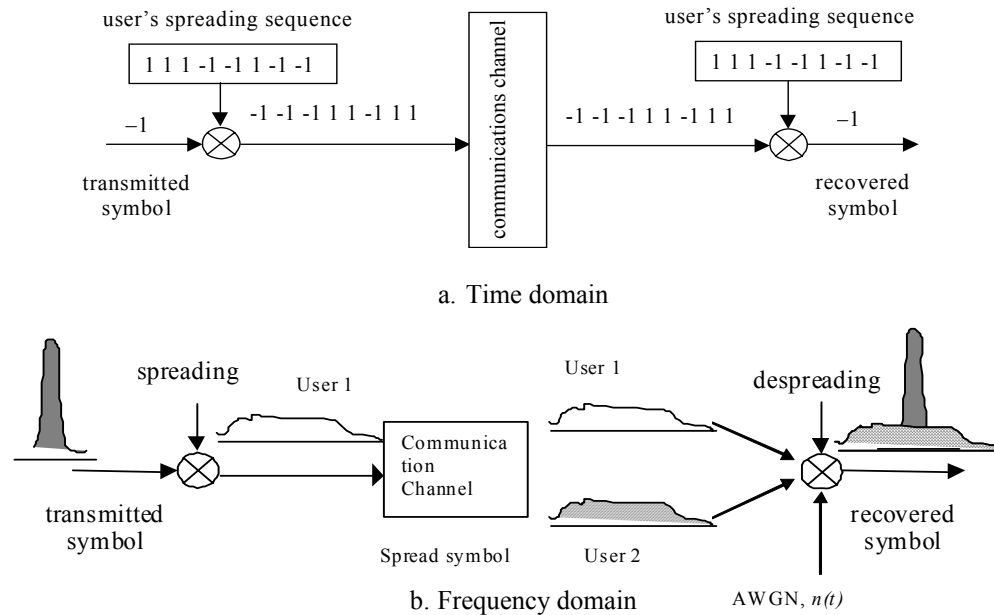

a. Time domain

b. Frequency domain
Figure 2. A baseband signal model of DS-CDMA system [8]

At the symbol signaling interval, the *i*-th input vector for the DS-CDMA system is $x_i = (x_i^1, ..., x_i^k)^T$, with x_i^k is the *i*-th input symbol for the *k*-th user. The *k*-th user ($k = 1, ..., K$) will be allocated spreading code $c_k(t)$ in the time interval [0, *T*] which is normalized to

$$\int_0^T c_k(t)^2 dt = 1 \tag{3}$$

If the *i*-th symbol interval for the *k*-th user has a_i^k channel attenuation and transmission delay of τ_k, then the baseband signal of the *k*-th user using a single path ptropagation is

$$y^k(t) = \sum_{i=0}^{\infty} x_i^k a_i^k c_k(t - iT - \tau_k) \tag{4}$$

The signal received by each user on the detector is the sum of signals from all users plus $n(t)$ as an additive white Gaussian noise noise (AWGN), written as follows:

$$y(t) = \sum_{k=1}^{K} y^k(t) + n(t) \tag{5}$$

which will undergo a filtering process (matched filter) at the receiver to generate statistical variables for detector/decorelator.

3. Multi Carrier CDMA System

In MC-CDMA model shown in Figure. 3 [9] the carrier bandwidth B_u is divided into J subcarriers of bandwidth B_d so that $B_d = B_u/J$ or $B_u = JB_d$. Each of these J subcarrier frequencies is then modulated, summed, and transmitted over the channel.
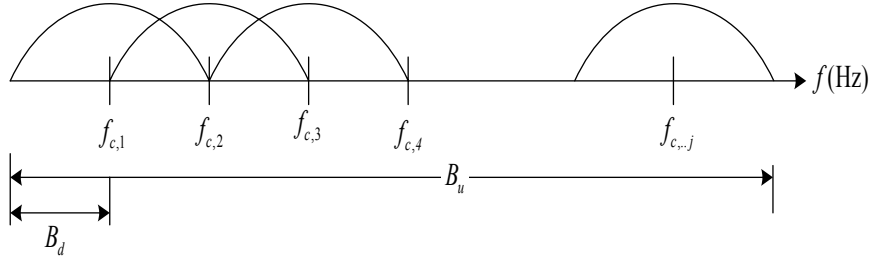

Figure 3. Multicarrier Model

For a Binary Phase Shift Keying (BPSK) modulation with K active users in MC-CDMA, each user k transmits M data symbols d^k_m of symbol duration T_d, where, $d^k_m \in \{+1, -1\}$, $k \in \{1, 2, …, K\}$ is the user number and $m \in \{1, 2, …, M\}$ identifies the symbol interval. The symbol of user k are first sequentially replicated into J parallel branches, then each of these branches are multiplied by a chip of spreading sequence code $\underline{s}^k_m = (s^k_{m,1}, s^k_{m,2}, …, s^k_{m,J})$ where, the chip of spreading code is defined as $s^k_{m,j} \in \{-1/\sqrt{J}, +1/\sqrt{J}\}$ and $j \in \{1,2,…J\}$ identifies the subcarrier index. Here $\underline{s}^k_m$ denotes the spreading code of length J employed by user k at symbol interval m. So in MC-CDMA, each channel symbol d^k_m of user k is spread over j parallel branches by using the user specific spreading sequences $\underline{s}^k_m$, where chip duration T_c is T_d/J. Figure. 4 shows the MC-CDMA for M users
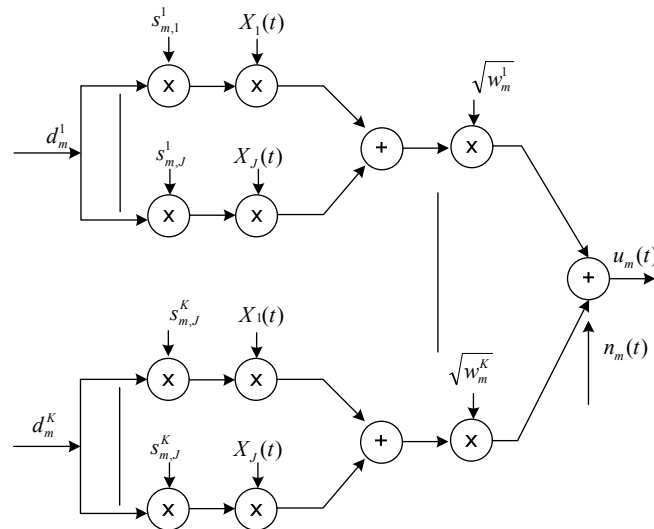

Figure 4. MC-CDMA model for K users

We can derive from Figure. 4 that,

$$s_m^k(t) = p_{T_d}(t) \sum_{j=1}^{J} s_{m,j}^k X_j(t) \tag{6}$$

$$X_j(t) = \frac{1}{\sqrt{J}} cos(2\pi f_c t); j = 1, \dots, J \tag{7}$$

where $1/\sqrt{J}$ is a normalized factor, $X_j(t)$ is the BPSK modulation on subcarrier j and p_{Td} is a unit pulse. The transmitted signal from user k at symbol interval m is then

$$u_m^k(t) = d_m^k s_m^k(t - [m-1]T_d) \tag{8}$$

while the transmission from K users at symbol interval m is

$$u_m(t) = \sum_{k=1}^{K} \sqrt{w_m^k}\, r_m^k(t) + n_m(t) \tag{9}$$

where $n_m(t)$ is the sum of JK uncorrelated AWGN at symbol interval m.

After passing through the channel, at the receiver decision is made to detect the signal, which, for user k is shown in Figure. 5
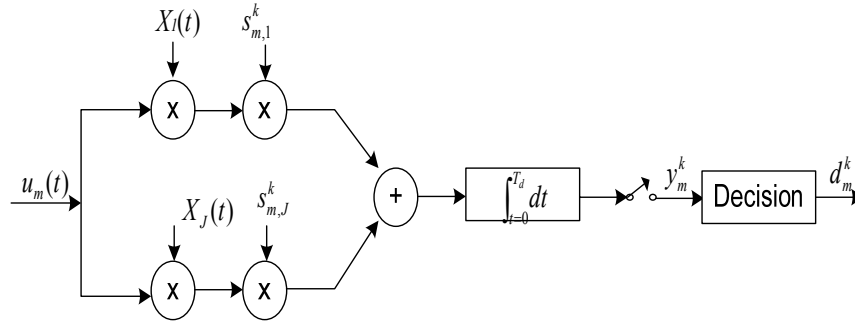

Figure 5. Detection of MC-CDMA for user m.

The detection variable signal at the decision for user k at symbol interval m can be written as

$$y_m^k = \int_t^{mTd} \sum_{j=1}^{J} u_m(t) X_j(t) s_{m,j}^k dt \tag{10}$$

and for the subcarrier j is

$$y_{m,j}^k = \frac{\sqrt{w_m^k T_d}}{\sqrt{J}} d_m^k + \left[\sum_{\substack{q=1 \\ q \neq k}}^{K} \frac{\sqrt{w_m^q T_d}}{\sqrt{J}} d_m^q \rho_{kq} \right] + n_{m,j} \tag{11}$$

where ρ_{kq} is the cross correlation between different users spreading codes. The first term in (11) is the useful term for detection, while the second and third terms are the multiple access interference (MAI) and noise terms, respectively. If the spreading codes are orthogonal the MAI term will vanish. For a large number of subcarrier J, which corresponds to the spreading factor of MC-CDMA system, the subcarrier can be designed to pass through the frequency flat channel, so the inter symbol interference due to delay spread of the channel can be mitigated. However, due to multipath propagation, MC-CDMA system will still experience performance degradation under flat Rayleigh fading condition [10], when non orthogonal code are used due to a non-zero correlation of the spreading codes. To mitigate the effect of Rayleigh channel

fluctuation, power control scheme is required, which is presented in the section that follows the detection technique in CDMA systems.

4. Detection Technique in MC-CDMA System
A. Single-User Detection

The initial step of signal detection technique is passing the DS-CDMA received signal, $y(t)$ into the filter bank (matched filter) or a row of correlator, which consists of K filters that is matched to the spreading code of each user. Further step is to take samples at the time of $iT + \tau_k$, with $k = 1, ..., K$; and $i = 1,2, ...$. The output of the filter bank or correlator is the statistical variables y_i^k that will generate the input symbol x_i^k based on $y(t)$.

To provide easier explanation, the discussion will begin with modeling of a simple case of two-user DS-CDMA system. Channel attenuation model is assumed to be a real channel to facilitate coherent detection. The practical channel model is of course a complex model, but the extension of the real chanal to the complex channel model can be done easily. For DS-CDMA system using multi user detection, synchronous detection assumption is also used as an initial evaluation model. In CDMA systems with synchronous detection, a simple mathematical model can be presented to be more easily understood. For CDMA synchronous model, output signal $y(t)$ at time intervals $iT \leq t \leq (i + 1)T$ does not depend on the input symbols of other users sent at the time intervals before or after that interval. As a result, the detection time interval t can be done by using the input vector $x_i = (x^1, ... x^K)T$, the attenuation channel of real positive factor of $a^1, a^2, ... a^K$, and AWGN $n(t)$ with a power spectarl density of N_o. The results from sampling of the k-th user after filtering using the preading code for its user is

$$y^k = \int_0^T y(t)c(t)dt = \int_0^T c_k(t)\left[\sum_{j=1}^K c_j(t)a^j x^j + n(t)\right]dt \qquad (12)$$

which will give

$$y^k = a^k x^k + \sum_{j\neq k}^K a^j x^j \int_0^T c_k(t)c_j(t)dt + \int_0^T c_k(t)n(t)dt \qquad (13)$$

On the right hand side of equation (13), the first term is the statistical variables of the desired signal component of user k. The second term is the statistical variables of inter-user interference component or the MAI as a result of the cross-correlation between codes of the k-th user with other users, and the last term is the noise of the k-th user. The influence of the second term on the variable detection is affected by the value of the cross-correlation between spreading codes from each user together with the channel gain represented by factor of a_k, $k = 1, ..., K$.

Detection process using conventional CDMA system that will determine the polarity estimation of transmitted data symbols x_k can be done using

$$\widehat{x}^k = sign(y^k) \qquad (14)$$

where $\hat{x}^k$ is the symbol data obtained from detection process which represents an estimate of x^k.

B. Multiuser Detection

In single-user detection techniques, the statistical detection variables in equation (14) can be described as shown in Figure.2 (b), in which the components of the desired signal for the k-th user is a statistical detection variable as a result of the autocorrelation between the user's own spreding code, indicated by the higher signal level in Figure 2 (b). While the components of interference (MAI) and noise as the result of cross-correlation between the k-th user's spreading code with other spreading codes plus AWGN forms the statistical detection variables having a wider spectrum with lower signallevel. Once this signal is passed into a narrow band

pass filter dedicated to the desired frequency spectrum band, then most of the spectrum of the MAI and the noise will disappeardue to the filtering. The quality of the resulting detection variable is determined by the ratio of the desired signal statistics component to the MAI and noise componets that have been passed through the band pass filter, which is sometimes referred to as the ratio of signal to interference plus noise, expressed as S/(I+N).

If each user is only equipped with a spreading code allocated to them, then of course the cross-correlation between spreading codes will act as interference for each user. However, if all the spreading codes in the whole system is provided to each user, and each user has knowledge of the f power level of other users, then each user will be able to eliminate mutual interference effects of MAI from other users.

To simplify the concept, we see a system with only 2 users, where r is the cross-correlation between the spreading codes of the second user, then we can write

$$r = \int_0^T c_1(t)c_2(t)dt \tag{15}$$

Dalam hal ini, keluaran dari penapis/korelator adalah

$$y^1 = a^1x^1 + ra^2x^2 + n^1 \quad \text{and} \quad y^2 = a^2x^2 + ra^1x^1 + n^2 \tag{16}$$

The MAI component for user 1 and user 2 is respectively ra^2x^2 and ra^1x^1. If it does not exist then CDMA system will be a system with only 1 user with AWGN as noise components, and the bit error rate (BER) for the optimal detector system with one user will be a lower limit for the detector system as follows

$$P_k(e) = Q\left[\sqrt{\frac{(a^k)^2}{N_o}}\right] \tag{17}$$

Where the Q function is defined as

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^\infty exp\left[\frac{-y^2}{2}\right]dy \tag{18}$$

and the detection process is done with the same process as shown in equation (8).

In the example with only 2 user when user-1 has a much higher power than user-2, the MAI component of the user-2, ra^1x^1 will be very high and will greatly degrade the performance of the detector for user-2. However, if detection for user 1 with greater power, $\hat{x}^1$ is executed first before the detection of the user-2 who have a lower power, then it will be a reliable detection of the detector for the user-2's perspective2. Therefore, the detection result can be used as the subtractor (deduction) against the MAI component for user-2, so that the process for the user-2 can be done as follows

$$\hat{x}^2 = sign(y^2 - ra^1x^1) = sign(a^2x^2 + ra^1(x^1 - \hat{x}^1) + n^2) \tag{19}$$

If detection for user-1 gives the correct result, then the MAI component can be subtracted from the variable detection of user-2, so variable statistics on user-2 contains only the statistical component of the desired user-1 and AWGN noise. For the number of users more than 2, subtraction process is continued until all the users signal apart from one being detected disappear. Issues that need to be considered in this process of multiuser detection is the knowledge of power levels and the spreading code of each user, which will be processed sequentially from the user with the highest power levels to the lowest one.

5. Numerical Simulation and Results

To see the bit error rate performance (BER) of multi carrier and multiuser detection technique, the MC-CDMA system is simulated using the parameters as follows : the number of users $K = \{2, 5, 8, 10\}$, the number of spreading chips per symbol 64. AWGN is set 10 dB below the signal level. The first simulation was performed using the single detection (single-user detection) and the performance of the detector is shown in BER as a function of the ratio of energy-per-bit to the spectral density of interference plus noise (E_b/I_o). The next simulation is done with the same number of users using multiuser detection technique. The result is shown in Figure. 6.
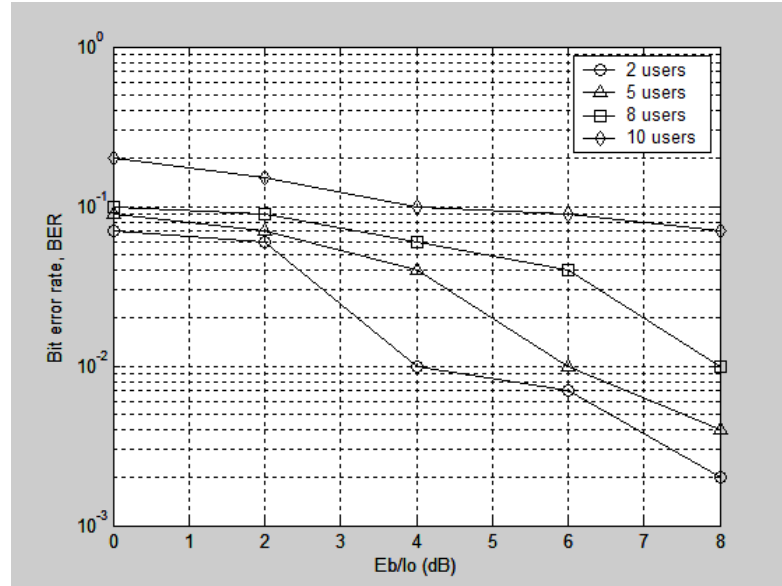
a. Single user detection
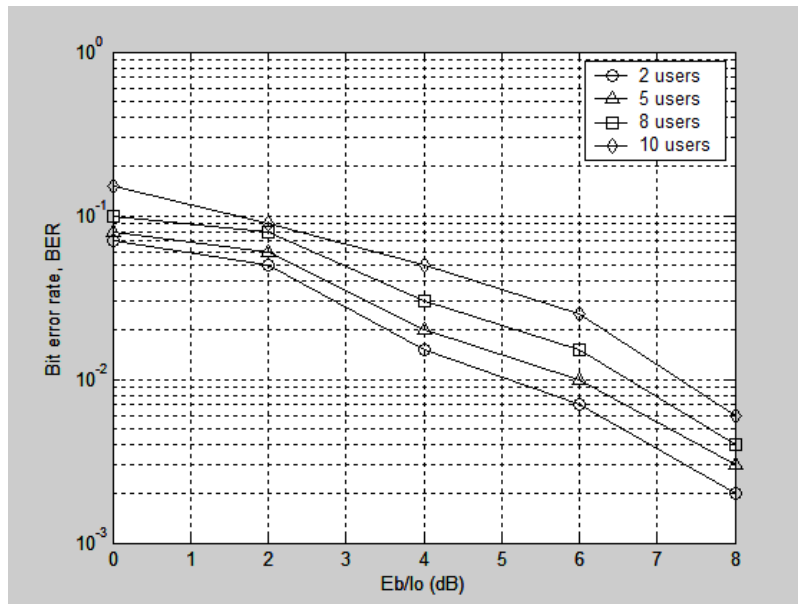
b. Multiuser detection

Figure 6. BER performance of MC-CDMA system.

From Figure. 6 (a) and (b), it can be seen that the multi carrier and multi-user detection results in better performance than that of single user detection technique. Single user detection technique is strongly influenced by the number of users, while the multiuser detection technique is not because inter user interference (MAI) has been eliminated. However, as we can see in Figure. 6 (b) that performance decreases when the number of user increases from 2 to 10. This is because of the fact that despite multiuser detection is performed sequentially from higher power level to lower power level of user to obtain a more reliable detection, inter user interference has not been completely eliminated. In a perfect multiuser detection, any number of user in CDMA system would theoretically result in the performance of one-user CDMA system, because all inter user interfrence would completely be removed.

The concept of interference removal in a CDMA system using multi-user detection techniques is driven by the motivation that the desired signal component in the CDMA system can be separated from the inter-user interference and noise components. When the spreading codes of each user is known bu every other users in the system, it can be used to eliminate the multi user interference. An issue that arises in multiuser detection using sequential interference removal is on measuring and sorting the users power level from the ower level, in order to obtain a relable step-by-step detection process. In the next section we will show the power controlled multiuser detection technique, to eliminate the need of sequential detection. In a power controlled multiuser detection, all user power level is controlled to produce the same power level for all users when their signals arrive at the detector input.

6. Power Controlled Multiuser Detection

To equalize the power level of all users in multiuser detection techniques of a DS-CDMA system, power control technique can be used. In practical CDMA system power controll has been implemented, so therefore no extra effort is needed to implement power controlled multiuser detection. Hower, in this study we need to evaluate the performance improvement of multiuser detection when it is implemented in a power controlled system environment.

The power control algorithm proceeds as follows as shown in Figure. 7 [11]-[12]. First, the SIR for each user, γ_{est} is estimated at the basestation for the ith time slot. Then the estimated SNR $\gamma_{est}(i)$ is compared with the target SIR γ_t to produce the error signal $e(i)$. The error signal $e(i)$ is then quantised using a binary representation, so it can be transmitted via the downlink channel to the mobile station. The quantised form of error signal is called the PCC bits, which can be implemented using a PCM realisation of mode q, where q is the number of PCC bits required in each power control interval. The PCC bits are transmitted to a mobile station via the downlink channel and are subject to transmission error. The feedback loop delay represents the transmission delay of CDMA signal and processing of the PCC bits. The PCC bits error is represented as a multiplicative disturbance on the PCC bits, while feedback delay is represented by a delay operator of DT_p in the loop as shown in Figure. 7.

After the PCC bits are received by a mobile station, the mobile station computes the required power adjustment, $\Delta p \otimes PCC$. The step size Δp is preset at 1 or 2 dB, while the PCC is either ± 1 in a fixed-step algorithm or any integer between $-q$ and $+q$ in variable-step algorithms. The integrator over one power control interval, T_p is used to increment the transmit-power level from the previous level as shown as

$$p(i+1) = p(i) - \Delta p \cdot e(i-D)_q \tag{20}$$

where $e(i-D)_q$ is shown in (21) for variable step algorithm or $e(i-D)_q \in \{-1, +1\}$ for fixed-step algorithm, $p(i)$ is the transmit power at the ith power control interval, D is the feedback delay, and Δp is the power-update step size.

In the fixed-step algorithm, the PCC contains only a single bit to minimise the signalling bandwidth. This algorithm can be considered as the PCM scheme with mode $q = 1$. The PCC bit can be expressed as
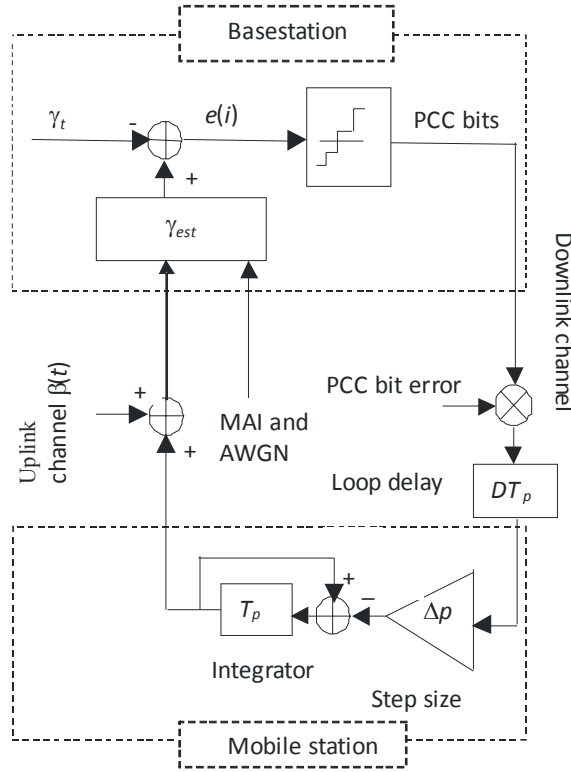
Figure 7. CDMA Power Control Model

$$
e(i-D)_q = \begin{cases}
2^{q-1}-1, & \textbf{index} < -2^{q-1}+1/2 \\
2^{q-1}-2, & -2^{q-1}+1/2 \le \textbf{index} < -2^{q-1}+3/2 \\
\cdot & \cdot \\
\cdot & \cdot \\
0, & -1/2 \le \textbf{index} < 1/2 \\
\cdot & \cdot \\
\cdot & \cdot \\
-(2^{q-1}-2), & 2^{q-1}-3/2 \le \textbf{index} < 2^{q-1}-1/2 \\
-(2^{q-1}-1), & \textbf{index} \ge 2^{q-1}-1/2
\end{cases}
\tag{21}
$$

$$
\textbf{PCC bit} = sign\,[e(i-D)_{q=1}] = \begin{cases}
+1 & e(i-D) < 0 \\
-1 & e(i-D) \ge 0
\end{cases}
\tag{22}
$$

In the fixed-step algorithm, if the estimated SIR, γ_{est} is less than the target SIR, γ_t, the PCC bit -1 is sent to the mobile to increase its transmit power by Δp dB. If γ_{est} is higher than γ_t, the PCC bit +1 is sent to the mobile to decrease its transmit power by Δp dB. This scheme can be implemented in practice using a delta modulation (DM) type realization [13]. With only one PCC bit, the mobile can only increment by a fixed step size Δp to either increase or decrease its transmit power. However in practice, this method is more attractive than the variable-step method because with only 1 PCC bit for each power-control interval, the power control signaling bandwidth on the downlink channel is minimized. This is the main reason why most

existing schemes of closed-loop power control employ a fixed step algorithm [13]. In this research, we assume error-free PCC bits and negligible loop delay.

To see the performance of power controlled multiuser detection, we repeat our simulation parameter described in section V, but now we use power control algorithm to produce the same power level of each user prior to multiuser detection process. The results is shown in Figure. 8
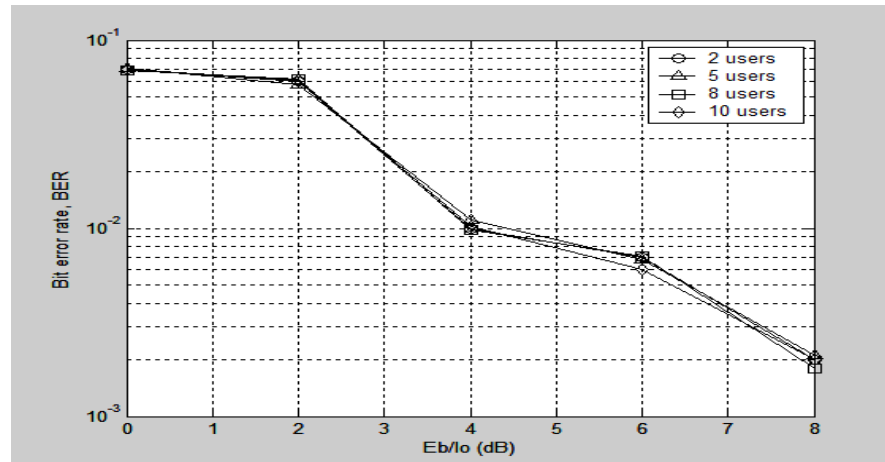

Figure 8. BER performace of power-controlled multi carrier and multiuser CDMA systems

We can see from Figure. 8 that the BER performance of power-controlled multi carrier and multiuser detection of CDMA system for 5, 8, and 10 users CDMA system approaches the performance of 2-user system. This can be explained that when each user has an equal power level prior to the detection process, the step-by-step detection algorithm is more reliable and leads to detection error reduction. In addition, the power-controlled multiuser detection using sequential step-by-step detection algorithm does not require sorting process of power level for each user to execute the detection, and thus simplifies the algorithm.

7. Conclusions

The theoretical foundation of multi carrier and multiuser detection techniques have been described using a simple synchronous model of DS-CDMA system. Multi carrier technique is employed to eliminate the use of RAKE receiver scheeme; while multiuser detection is used to remove the inter user interference due to multiple access interference from other users. The simulation results show that the performance of multi carrier and multiuser detection is much better than the single user detection technique, in that for the number of users more than 2, the multiuser detection outperforms the single user detection method. However, multi carrier CDMA technique cannot overcome the effect of flat rayleigh channel effect due to fading channel fluctation. Power control technique is needed to overcome the effect of Rayleigh channel fluctuation. In multi user detection, the need of ordering the user power level to obtain a reliable detection can also be eliminated by power control technique. The performance of power-controlled multi carrier and multiuser detection can further be improved by implementing power control algorithm prior to multiuser detection.

8. Acknowledgements

9. Reference

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