Interference Management for DS-CDMA Receiver through Base Station Assignment in Multipath Fading Channels

Mohammad Dosaranian Moghaddam
Department of Electrical Engineering
Qazvin Islamic Azad University
Qazvin, Iran
email: m_dmoghadam@qiau.ac.ir

Hamidreza Bakhshi and Gholamreza Dadashzadeh
Department of Electrical Engineering
Shahed University
Tehran, Iran
emails: bakhshi@shahed.ac.ir, gdadash@itrc.ac.ir

Abstract—**The interference reduction capability of antenna arrays, base station assignment and the power control algorithms have been considered separately as means to increase the capacity in wireless communication networks. In this paper, we propose base station assignment based on minimizing the transmitter power (BSA-MTP) technique in a direct sequence-code division multiple access (DS-CDMA) receiver in the presence of frequency-selective Rayleigh fading. This receiver consists of three stages. In the first stage, with conjugate gradient (CG) adaptive beamforming algorithm, the desired users' signal in an arbitrary path is passed and the inter-path interference is canceled in other paths in each RAKE finger. Also in this stage, the multiple access interference (MAI) from other users is reduced. Thus, the matched filter (MF) can use for the MAI reduction in each RAKE finger in the second stage. Also in the third stage, the output signals from the matched filters are combined according to the conventional maximal ratio combining (MRC) principle and then are fed into the decision circuit of the desired user. The simulation results indicate that BSA-MTP technique can significantly improve the network bit error rate (BER) in comparison with the conventional case.**

Keywords-adaptive beamforming; base station assignment; DS-CDMA; maximal ratio combining; perfect power control.

I. INTRODUCTION

Systems utilizing code-division multiple access (CDMA) are currently being deployed around the country and around the world in response to the ever increasing demand for cellular/personal communications services. Extensive research has been published on the performance analysis of CDMA systems. Fading is among the major factors affecting the performance of such systems. Fading is generally characterized according to its effect over a geographical area. Large-scale fading consists of path loss and shadowing, the latter term referring to fluctuations in the received signal mean power. Large-scale fading is affected by prominent terrain contours between the transmitter and receiver. Small-scale fading is the common reference to the rapid changes in signal amplitude and phase over a small spatial separation. In this work, the combined effect of large- and small-scale fading are considered. The small-scale fading is assumed to be governed by the Rayleigh distribution (Rayleigh fading) [1], [2].

Besides fading, CDMA systems are susceptible to the near-far problem. It is well known that in order to fully exploit the potential advantage of CDMA systems, power control is required to counteract the effects of the near-far problem. The CDMA system capacity (defined as the number of users that can access the system simultaneously) is maximized if each mobile transmitter power level is controlled so that its signal arrives at the base station (BS) with the minimum required signal-to-interference-plus-noise ratio (SINR) [2]-[7]. In this work, we assume perfect power control (PPC) in order to compensate the near-far problem. Accordingly, the received power in base station of all users is fixed.

Also diversity is one effective technique for enhancing the SINR for wireless networks. Diversity exploits the random nature of radio propagation by finding independent (or, at least, highly uncorrelated) signal paths for communication. If one radio path undergoes a deep fade, another independent path may have a strong signal. By having more than one path to select from, the SINR at the receiver can be improved. The diversity scheme can be divided into three methods: 1) the space diversity; 2) the time diversity; 3) the frequency diversity. In these schemes, the same information is first received (or transmitted) at different locations (or time slots/frequency bands). After that, these signals are combined to increase the received SINR. The antenna array is an example of the space diversity, which uses a beamformer to increase the SINR for a particular direction [8]-[10]. In this work, we use conjugate gradient (CG) adaptive beamforming and switched beam (SB) technique for the space diversity.

To improve the performance of cellular systems, base-station assignment technique can be used. In the base station assignment, a number of base stations are potential receivers of a mobile transmitter. Here, the objective is to determine the assignment of users to base stations which minimizes the allocated mobile powers [11]-[14]. In simple mode and in multiple-cell systems, the user is connected to the nearest base station. This way is not optimal in cellular systems under the shadowing and multipath fading channels and can increase the system BER. In this paper, we present base-station assignment based on minimizing the transmitter power (BSA-MTP) for decreasing the BER in all cells.

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The goal of this paper is to extend the works in [15] and [16] by considering multiple-cell system and BSA-MTP technique. In these works, a RAKE receiver in single-cell system was proposed in the presence of frequency-selective Rayleigh fading channel and PPC, and the conventional base station assignment was considered.

In this work, the performance analysis of direct-sequence (DS)-CDMA system in frequency-selective Rayleigh fading channel has been studied. If the delay spread in a multipath channel is larger than a fraction of a symbol, the delayed components will cause inter-symbol interference (ISI). Adaptive receiver beamforming schemes have been widely used to reduce both co-channel interference (CCI) and ISI and to decrease the bit error rate (BER) by adjusting the beam pattern such that the effective SINR at the output of the beamformer is optimally increased [17].

In this paper a RAKE receiver in DS-CDMA system is analyzed in three stages according to Fig. 1 [15]. In the first stage, this receiver uses conjugate gradient adaptive beamforming (CGBF) to find optimum antenna weights assuming perfect estimation of the channel parameters (direction, delay, and power) for the desired user. The desired user resolvable paths' directions are fed to the CG beamformer to cancel out the CCI from other directions. Also, the RAKE receiver uses conventional demodulation in the second stage and conventional maximal ratio combining (MRC) in the third stage to reduce multiple-access interference (MAI). Reducing the MAI and the CCI will further decrease the system BER.

The organization of the remainder of this paper is as follows. The system model is given in Section II. The RAKE receiver structure is described in Section III. In Section IV, we propose the BSA-MTP technique. Section V presents the SB technique. Finally, simulation results and conclusions are given in Section VI and VII, respectively.

II. SYSTEM MODEL

In this paper, we focus on the uplink communication paths in a DS-CDMA cellular system. L replicas of the signal, due to both some form of diversity reception (for instance antenna diversity) and channel frequency selectivity, are assumed Rayleigh distributed and optimally combined through a RAKE receiver according to Fig.1. Also assume that there are M active base stations in the network, with K_m users connected to mth base station, where $1 \le m \le M$. Also assume that each base station uses an antenna array of S sensors and N weights, where $S = 2N - 1$, to receive signals from all users. Note that in CG adaptation method, unlike other adaptation algorithms, the number of weights is less than the number of sensors. Also, for simplicity we assume a synchronous DS-CDMA scheme and BPSK modulation in order to simplify the analysis of proposed technique. Additionally, in this paper we assume a slow fading channel. Hence, the received signal in the base station q and sensor s from all users can be written as [11], [15], [18]

$$r_{q,s}(t) = \sum_{k} \sqrt{P\Gamma_k(x,y)} \sum_{l=1}^{L} \alpha_{k,m,l} b_{k,m}(t - \tau_{k,m,l}) \times c_{k,m}(t - \tau_{k,m,l}) \exp(-j2\pi sd \sin\theta_{k,m,l} / \lambda) + n(t) \quad (1)$$

where P represents the received signal power of all users within cell q in the presence of perfect power control. Also, $c_{k,m}(t)$ is the pseudo noise (PN) chips of user k in cell m (user k,m) with a chip period of T_c ; $b_{k,m}(t)$ is the information bit sequence of user k,m with a bit period of $T_b = GT_c$ where G is processing gain; $\tau_{k,m,l}$ is the lth path time delay for user k,m ; $\theta_{k,m,l}$ is the direction of arrival (DoA) in the lth path for user k,m ; $\alpha_{k,m,l}$ is the complex Gaussian fading channel coefficient from the lth path of user k,m ; λ is signal wavelength; d is the distance between the antenna elements that for avoid the spatial aliasing should be defined as $d = 0.5\lambda$ and $n(t)$ is an additive white Gaussian noise (AWGN) process with a two-sided power spectral density (PSD) of $N_0/2$. Also in the case of conventional BSA technique, $\Gamma_k(x,y)$ is defined as

$$\Gamma_k(x,y) = \begin{cases} 1 & ; k \in S_{\mathrm{BS}q} \\ \dfrac{\min\limits_{m \in \Theta_k} \left\{ d_{k,m}^{L_\alpha}(x,y) 10^{\xi_{k,m}/10} \right\}}{d_{k,q}^{L_\alpha}(x,y) 10^{\xi_{k,q}/10}} & ; k \in S_o \end{cases} \quad (2)$$

where L_α is path-loss exponent; $d_{k,m}(x,y)$ and $d_{k,q}(x,y)$ are the distance between user k and BS m and BS q , respectively (see Fig. 2); $\xi_{k,m}$ is a random variable modeling the shadowing between user k and BS m ; $S_{\mathrm{BS}q}$ is the set of users that connected to BS q and S_o is the set of users that not connected to BS q [4].

Accordingly, the received signal in the base station q in sensor s for user i,q is given by [15]

$$r'_{i,q,s}(t) = \sum_{l=1}^{L} \sqrt{P} b_{i,q}(t - \tau_{i,q,l}) \, c_{i,q}(t - \tau_{i,q,l}) \times \alpha_{i,q,l} \exp(-j2\pi sd \sin\theta_{i,q,l} / \lambda) + I_{i,q,s}(t) + n(t) \quad (3)$$

where $I_{i,q,s}(t)$ is the interference for user i,q in sensor s and can be shown to be

$$I_{i,q,s}(t) = \sum_{m=1}^{M} \sum_{\substack{k=1 \\ k,m \neq i,q}}^{K_m} \sum_{l=1}^{L} \sqrt{P\Gamma_k(x,y)} b_{k,m}(t - \tau_{k,m,l}) \times c_{k,m}(t - \tau_{k,m,l}) \alpha_{k,m,l} \exp(-j2\pi sd \sin\theta_{k,m,l} / \lambda) \quad (4)$$

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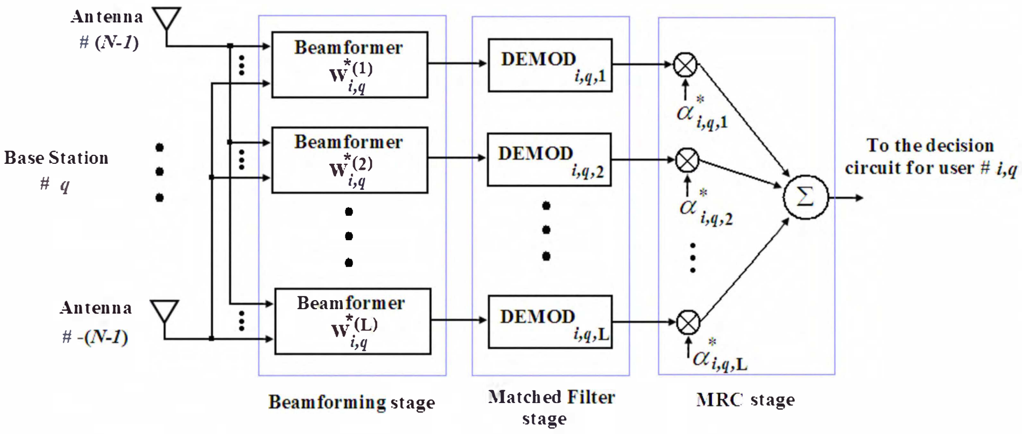

Figure 1. Block diagram of a three-stage RAKE receiver in DS-CDMA system [15].

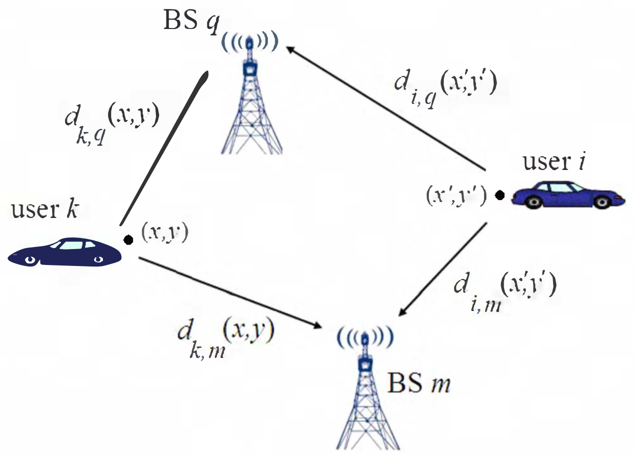

Figure 2. The distance between two pairs of mobile transmitters and base-station receivers [11].

where K_m is the number of users in cell m and M is the number of base stations/cells.

III. RAKE RECEIVER PERFORMANCE ANALYSIS

The RAKE receiver structure in the DS-CDMA system is shown in Fig. 1. The received signal is spatially processed by a CG beamforming circuit, one for each resolvable path (L beamformers). The resultant signal is then passed on to a set of parallel matched filters (MFs), on a finger-by-finger basis. Also, the output signals from the L matched filters are combined according to the conventional MRC principle and then are fed into the decision circuit of the desired user [15].

A. *Conjugate Gradient Adaptive Beamforming Stage*

It is well known that an array of N weights has $N-1$ degree of freedom for adaptive beamforming [15], [18]. This means that with an array of N weights, one can generates $N-1$ pattern nulls and a beam maximum in desired directions. From (4), it is clear that the number of users is $K_u = \sum_{m=1}^{M} K_m$ and the number of interferes is $LK_u - 1$. To null all of these interferes; one would have to have LK_u weights, which is non practical. So, we focus only on the L paths of the desired user (inter-path interference). Thus, the minimum number of the antenna array weights is L where, typically, L varies from 2 to 6 [15].

In this paper, we use the CG adaptive beamforming algorithm that is used of orthogonal principle. On this basis, a set of vectors $\mathbf{w}_i$ is to select such that they are $\mathbf{A}$-orthogonal, i.e., $\langle \mathbf{Aw}_i, \mathbf{Aw}_j \rangle = 0$ for $i \neq j$.

The optimum weights at time n are obtained by minimizing [15], [16]

$$\left\| \mathbf{x}_{i,q}^{(j)}(n) \right\|^2 = \mathbf{x}_{i,q}^{H(j)}(n)\mathbf{x}_{i,q}^{(j)}(n) \tag{5}$$

where

$$\mathbf{x}_{i,q}^{(j)}(n) = \mathbf{A}_q \mathbf{w}_{i,q}^{(j)}(n) - \mathbf{y}_{i,q}^{(j)} \tag{6}$$

and

$$\mathbf{A}_q = \begin{bmatrix} r_{q,-(N-1)} & \cdots & r_{q,0} \\ . & . & . \\ r_{q,0} & \cdots & r_{q,+(N-1)} \end{bmatrix} \tag{7}$$

is the $N \times N$ signal matrix in the base station q. Also,

$$\mathbf{y}_{i,q}^{(j)} = \left[e^{-j(N-1)\theta_{i,q,j}/2} \ldots 1 \ldots e^{j(N-1)\theta_{i,q,j}/2} \right]^T \tag{8}$$

and

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$$\mathbf{w}_{i,q}^{(j)}(n)=\left[w_{i,q,0}^{(j)}(n)\ \ w_{i,q,1}^{(j)}(n)\ \ \ldots\ \ w_{i,q,N-1}^{(j)}(n)\right]^T \qquad (9)$$

are the excitation and weight vectors ($N\times 1$) for user i,q in the *j*th path, respectively.

It should be mentioned that CG algorithm has two main characteristics [15]:

1- This algorithm can produce a solution of the matrix equation very efficiently and converge in a finite number of iterations (the number of beamformer weights).

2- In CG algorithm, the convergence is guaranteed for any possible condition of the signal matrix, according to (7).

According to the method of CG, the updated value of the weight vector for user i,q in the *j*th path at time $n+1$ is computed by using the simple recursive relation [15], [16]:

$$\mathbf{w}_{i,q}^{(j)}(n+1)=\mathbf{w}_{i,q}^{(j)}(n)+\kappa_{i,q}^{(j)}(n)\boldsymbol{\beta}_{i,q}^{(j)}(n) \qquad (10)$$

where

$$\begin{aligned}
&\kappa_{i,q}^{(j)}(n)=\left\|\mathbf{A}_q^H\mathbf{x}_{i,q}^{(j)}(n)\right\|^2/\left\|\mathbf{A}_q\boldsymbol{\beta}_{i,q}^{(j)}(n)\right\|^2\\
&\mathbf{x}_{i,q}^{(j)}(n+1)=\mathbf{x}_{i,q}^{(j)}(n)+\kappa_{i,q}^{(j)}(n)\boldsymbol{\beta}_{i,q}^{(j)}(n)\\
&\boldsymbol{\beta}_{i,q}^{(j)}(0)=-\mathbf{A}_q^H\mathbf{x}_{i,q}^{(j)}(0)\\
&\boldsymbol{\beta}_{i,q}^{(j)}(n+1)=\mathbf{A}_q^H\mathbf{x}_{i,q}^{(j)}(n+1)+\eta_{i,q}^{(j)}(n)\boldsymbol{\beta}_{i,q}^{(j)}(n)\\
&\eta_{i,q}^{(j)}(n)=\left\|\mathbf{A}_q^H\mathbf{x}_{i,q}^{(j)}(n+1)\right\|^2/\left\|\mathbf{A}_q^H\mathbf{x}_{i,q}^{(j)}(n)\right\|^2.
\end{aligned} \qquad (11)$$

The output signal from the *j*th CG beamformer ($j=1,\ldots,L$) can be written as [15]

$$\begin{aligned}
y_{i,q}^{(j)}(t)=&\sqrt{P}b_{i,q}(t-\tau_{i,q,j})\,c_{i,q}(t-\tau_{i,q,j})\,\alpha_{i,q,j}\\
&+I_{i,q}^{(j)}(t)+n^{(j)}(t)
\end{aligned} \qquad (12)$$

where $n^{(j)}(t)$ is a zero mean Gaussian noise of variance σ_n^2 and $I_{i,q}^{(j)}(t)$, the MAI, is defined as

$$\begin{aligned}
I_{i,q}^{(j)}(t)=&\sum_{m=1}^{M}\sum_{\substack{k=1\\k,m\neq i,q}}^{K_m}\sum_{l=1}^{L}\sqrt{P\Gamma_k(x,y)}\,g_{i,q}^{(j)}(\theta_{k,m,l})\\
&\times\alpha_{k,m,l}\,b_{k,m}(t-\tau_{k,m,l})\,c_{k,m}(t-\tau_{k,m,l})
\end{aligned} \qquad (13)$$

where

$$g_{i,q}^{(j)}(\theta)=\left[e^{-j(N-1)\theta_{i,q,j}/2}\ \ldots 1\ldots\ e^{j(N-1)\theta_{i,q,j}/2}\right]\times\mathbf{w}_{i,q}^{(j)} \qquad (14)$$

is the magnitude response of the *j*th beamformer for user i,q toward the direction of arrival θ and $\mathbf{w}_{i,q}^{(j)}$ is the *j*th beamformer's weight vector for user i,q [15].

B. *Matched Filter Stage*

Using beamforming will only cancel out the inter-path interference for the desired user and will reduce the MAI from the users whose signals arrive at different angles from the desired user signal (out-beam interference). Now, in the second stage of the RAKE receiver, the output signal from the *j*th beamformer is directly passes on to a filter matched to the desired user's signature sequence. The *j*th matched filter output corresponding to the *n*th bit is [15]:

$$z_{i,q}^{(j)}(n)=\sqrt{P}\,b_{i,q}(n)\,\alpha_{i,q,j}+I_{i,q}'^{(j)}(n)+n'^{(j)}(n) \qquad (15)$$

where

$$I_{i,q}'^{(j)}(n)=\frac{1}{T_b}\int_{(n-1)T_b+\tau_{i,q,j}}^{nT_b+\tau_{i,q,j}}I_{i,q}^{(j)}(t)\,c_{i,q}(t-\tau_{i,q,j})dt \qquad (16)$$

and

$$n'^{(j)}(n)=\frac{1}{T_b}\int_{(n-1)T_b+\tau_{i,q,j}}^{nT_b+\tau_{i,q,j}}n^{(j)}(t)\,c_{i,q}(t-\tau_{i,q,j})dt\,. \qquad (17)$$

If we assume that the paths' delays from all users are less than the symbol duration $(\tau_{k,m,l}<T_b)$ for all users' signals on all paths, the *n*th bit MAI at the output of the *j*th beamformer can be expressed as [15]

$$\begin{aligned}
I_{i,q}'^{(j)}(n)=&\sum_{m=1}^{M}\sum_{\substack{k=1\\k,m\neq i,q}}^{K_m}\sum_{l=1}^{L}\sqrt{P\Gamma_k(x,y)}g_{i,q}^{(j)}(\theta_{k,m,l})\\
&\times\alpha_{k,m,l}b_{k,m}(n)R_{i,k}(\tau_{i,q,j}-\tau_{k,m,l})
\end{aligned} \qquad (18)$$

where the autocorrelation function $R_{i,k}(\tau)$ is [1], [15]:

$$R_{i,k}(\tau)=\frac{1}{T_b}\int_{T_b}c_{i,q}(t)c_{k,m}(t+\tau)dt\,. \qquad (19)$$

If all users' delays are multiples of the chip period, then

$$R_{i,k}(\tau)=\frac{1}{G}\sum_{n_1=0}^{G-1}\sum_{n_2=0}^{G-1}c_{i,q}(n_1)c_{k,m}(n_2)R_c(\tau-(n_1-n_2)T_c) \qquad (20)$$

where the autocorrelation function $R_c(\tau)$ is:

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$$R_c(\tau)=\frac{1}{T_b}\int_{T_b} c(t)c(t+\tau)dt \,. \qquad (21)$$

In the case of a maximal-length sequence (m-sequence) and for $0 \le \tau \le T_b$, we have [1]:

$$R_c(\tau)=\begin{cases}1-\frac{|\tau|}{T_c}(1+1/G)\,;|\tau|\le T_c\\ -1/G \qquad ;|\tau|\ge T_c\,.\end{cases} \qquad (22)$$

C. Maximal Ratio Combining Stage

Diversity combining has been considered as an efficient way to combat multipath fading because the combined SINR is increased compared with the SINR of each diversity branch. The optimum combiner is the MRC whose SINR is the sum of the SINR's of each individual diversity branch [1], [19].

After the finger-matched filter, the fingers' signals are combined according to the MRC principle in the third stage of the RAKE receiver. In this paper, we use the conventional MRC that the signal of user i,q in the jth path is combined using multiplying by the complex conjugate of $\alpha_{i,q,j}$.

The SINR in output of the RAKE receiver for user i,q is [15], [19]:

$$\mathrm{SINR}_{i,q}(\alpha)=\sum_{j=1}^{L}\mathrm{SINR}_{i,q}^{(j)}(\alpha) \qquad (23)$$

where

$$\mathrm{SINR}_{i,q}^{(j)}(\alpha)=\frac{P\left|\alpha_{i,q,j}\right|^2}{\mathrm{E}\left(I_{i,q}^{\prime(j)}\right)^2+\mathrm{E}\left(n^{\prime(j)}\right)^2} \qquad (24)$$

is the SINR in output of the RAKE receiver in path j for user i,q .

Also, we can be rewritten the SINR in (24) by (25), that shown at the bottom of the page [15], [20], where $\overline{\Gamma}_k(x,y)=\mathrm{E}(\Gamma_k(x,y))$ and $\overline{\alpha}_{k,m,j}^2=\mathrm{E}\left(\left|\alpha_{k,m,j}\right|^2\right)$.

In order to perform the BER, we assume Gaussian approximation for the probability density function of interference plus noise. The conditional BER for a BPSK modulation is [1], [15]

$$\mathrm{BER}_{i,q}(\alpha)=Q\left(\sqrt{2\times \mathrm{SINR}_{i,q}(\alpha)}\right) \qquad (26)$$

where

$$Q(x)=\frac{1}{\sqrt{2\pi}}\int_x^{\infty}\exp\left(-u^2/2\right)du \,. \qquad (27)$$

IV. BSA-MTP TECHNIQUE

The system capacity might be improved, if the users are allowed to switch to alternative base stations, especially when there are congested areas in the network. Obviously, when uplink performance is of concern, the switching should happen based on the total interferences seen by the base stations [14].

So far, we have considered the power control problem for a number of transmitter-receiver pairs with fixed assignments, which can be used in uplink or downlink in mobile communication systems. In an uplink scenario where base stations are equipped with antenna arrays, the problem of joint power control and beamforming, as well as base-station assignment, naturally arises [11].

In this paper, we modify the BSA-MTP technique to support base station assignment as well. The modified technique can be summarized as follows.

1) Initially by the conventional BSA technique, each mobile connects to its base station, according to (2).
2) Estimate the weight vector for all users with the CG algorithm using (10).
3) Finally, $K_r=\lfloor K_u/M\rfloor$ users that their transmitted power is higher than the other users to be transferred to other base stations according to the following equation, where the function $\lfloor x\rfloor$ returns the integer portion of a number x.

$$\Gamma_k(x,y)=\begin{cases}1 & ;k\in S_{\mathrm{BS}q}\\ \dfrac{\min\limits_{\substack{m\in\Theta_k\\ m\ne q}}\left\{d_{k,m}^{L_\alpha}(x,y)10^{\xi_{k,m}/10}\right\}}{d_{k,q}^{L_\alpha}(x,y)10^{\xi_{k,q}/10}} & ;k\in S_{\overline{\mathrm{BS}q}}\\ \dfrac{\min\limits_{m\in\Theta_k}\left\{d_{k,m}^{L_\alpha}(x,y)10^{\xi_{k,m}/10}\right\}}{d_{k,q}^{L_\alpha}(x,y)10^{\xi_{k,q}/10}} & ;k\in S_o\end{cases} \qquad (28)$$

$$\mathrm{SINR}_{i,q}^{(j)}(\alpha)=\frac{\left|\alpha_{i,q,j}\right|^2}{\sum\limits_{m=1}^{M}\sum\limits_{\substack{k=1\\ k,m\ne i,q}}^{K_m}\overline{\Gamma}_k(x,y)\overline{\alpha}_{k,m,j}^2\sum\limits_{l=1}^{L}\left|g_{i,q}^{(j)}(\theta_{k,m,l})\right|^2R_{i,k}^2\left(\tau_{i,q,j}-\tau_{k,m,l}\right)+\dfrac{0.5}{E_b/N_0}} \qquad (25)$$

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where $S_{\overline{\mathrm{BS}q}}$ is the set of users that are in cell q but not connected to BS q [4].

It should be mentioned that the technique for users that are present in the border of cells, the BER can be effectively reduced.

V. SWITCHED-BEAM TECHNIQUE

One simple alternative to the fully adaptive antenna is the switched-beam architecture in which the best beam is chosen from a number of fixed steered beams. Switched-beam systems are technologically the simplest and can be implemented by using a number of fixed, independent, or directional antennas [21]. We list the SB technique conditions for this paper as follows.

1) According to Fig. 3, beams coverage angle is 30° and overlap between consecutive beams is 20°. Thus each base station has 36 beams.
2) According to Fig. 4, each user can be use one beam for its each path to communicate with a base station at any time.

VI. SIMULATION RESULTS

We consider $M = 4$ base stations for a four-cell CDMA system on a 2×2 grid as Fig. 5. We assume a uniform linear array of S omni-directional antennas in each base-station with antenna spacing $d = \lambda/2$. Also, we assume BPSK m-sequence code spreading with processing gain $G = 64$; the input data rate $T_b = 9.6$ Kbps; the number of antenna weights $N = 3$; the number of antenna sensors $S = 5$; frequency-selective fading channel with $L = 2$ resolvable propagation paths; variance of the complex Gaussian fading channel coefficient $\sigma_\alpha^2 = 4\,\mathrm{dB}$; path-loss component $L_\alpha = 4$; variance of the log-normal shadow fading $\sigma_\xi^2 = 8\,\mathrm{dB}$; resolution $R = 1$; initial value for weight vectors in the CG algorithm $\mathbf{w}(0) = \mathbf{0}$. It also is assumed that the distribution of users in all cells is uniform.

Fig. 6 shows the average BER versus the signal-to-noise ratio (SNR) for different receivers (one, two and three-stage receivers), $K_u = 32$ active users, and the PPC case. It should be mentioned that in this simulation, $K_r = 8$ users can to be transferred to other base stations with the BSA-MTP technique. It is clear that, in MF only receiver (one-stage receiver) and in the case of the conventional BSA technique, we still have the error floor at high SNR. Using CGBF and MRC receiver (two-stage RAKE receiver) or CGBF, MF, and MRC receiver (the three-stage RAKE receiver as Fig. 1) has a better performance than using MF only. Also we observe that using the BAS-MTP technique in SB, MF, and MRC receiver, the average BER is lower than other cases. For example, at a SNR of 20dB, the average BER is 0.007 for the three-stage RAKE receiver (CGBF method in the first stage) with the conventional BSA technique, while for SB technique or CGBF method in the first stage and for the BSA-MTP technique, the average BER is 0.0004 and 0.0017, respectively. Hence, it can be seen that the average BER in the SB technique is less than the CGBF method, because in SB technique the MAI is lower than CGBF method. Also, it is clear that the MAI is not removed totally and the performance is still worse than the single user per cell bound.

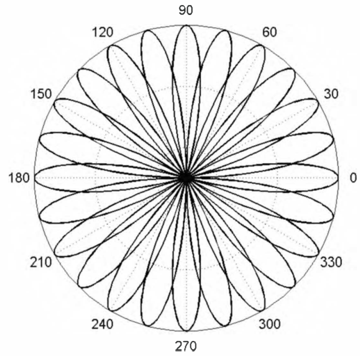

Figure 3. 36 beams in each base station with switched-beam technique.

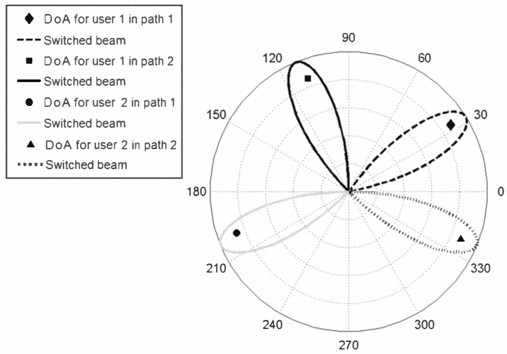

Figure 4. Select of beam for two users in two paths with the SB technique.

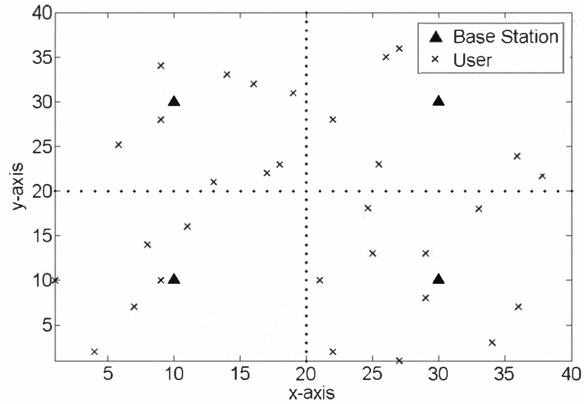

Figure 5. Location plot of base stations and users in four cells.

Fig. 7 shows the average BER versus the number of active users (K_u) for different receivers in the case of the PPC and $\mathrm{SNR} = 10\mathrm{dB}$ as Fig. 6. At a BER of 0.01, the three-stage RAKE receiver (CGBF method in the first stage) with the BSA-MTP technique support $K_u = 52$ users, while for the conventional BSA technique support $K_u = 30$ users. Also at a BER of 0.001, the three-stage RAKE receiver for

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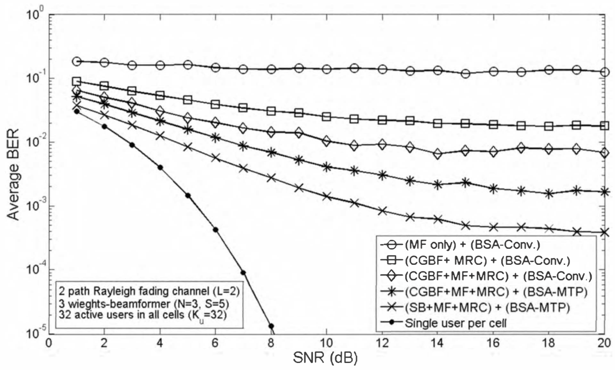

Figure 6. Average BER of all users versus the SNR for the PPC case and $K_u = 32$.

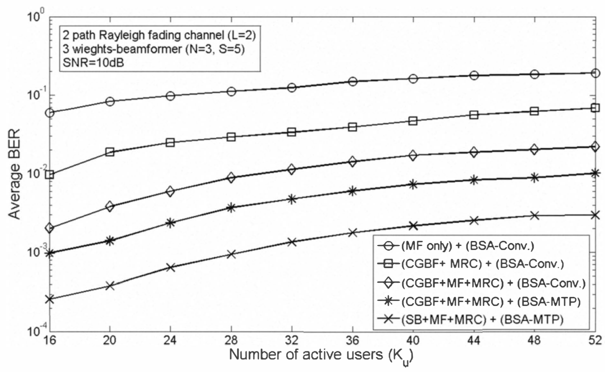

Figure 7. Average BER for all users versus the number of active users (K_u) for the PPC case and SNR $= 10\text{dB}$.

the SB technique or CGBF method in the first stage and for the BSA-MTP technique support $K_u = 29$ users and $K_u = 16$ users, respectively. Also it can be seen that the three-stage RAKE receiver can achieve lower BER than the other receivers. It should be mentioned that increasing the number of active users (K_u), will increase the number of users that can to be transferred to other base stations (K_r) in BSA-MTP technique.

VII. CONCLUSION

In this paper, we studied the RAKE receiver performance of multiple-cell DS-CDMA system with the space diversity processing, Rayleigh frequency-selective channel model, perfect power control, and base station assignment. This receiver consists of CG adaptive beamforming, matched filter, and MRC in three stages.

Accordingly, we proposed BSA-MTP technique to reduce the CCI and the MAI. It has been shown that, by using antenna arrays at the base stations, the proposed technique will decrease the average BER of the system to support a significantly larger number of users. It has also been observed that the average BER in the SB technique is less than the CGBF algorithm.

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