Performance Analysis of A Beyond 3G Mobile Communication System in the Presence of Co-channel Interference

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Abstract: - This paper presents a new model for systems beyond 3G of cellular communication techniques. The proposed scheme includes several new techniques: multiple-input multiple-output (MIMO), orthogonal frequency division multiplexing (OFDM), and smart antennas (beamforming). The performance analysis was done in an interference-rich environment, and closed form expression for *SINR* was also determined. The results proved the effectiveness of the proposed system, particularly, in the presence of co-channel interference (CCI).

Key-Words: - Co-channel Interference, Beamforming, Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Code-Division Multiple Access (CDMA), Frequency Selective Channel.

1 Introduction

In presence, Code-Division Multiple Access (CDMA) cellular mobile networks capitalize on the concept of frequency reuse to improve the overall system capacity [1, 2, 3, 4]. The presence of CCI limits CDMA systems that are offered to users. One popular technique used to reduce the effect of CCI is the beamforming (smart antennas) [5]. It exploits the spatial dimension by assigning most of signal energy toward the desired user, thereby, improving the link quality without affecting system capacity.

In general, CDMA signals are affected by the multipath phenomenon of wireless channels, which causes the intersymbol interference (ISI). This issue can be dealt with by using multicarrier (MC)-CDMA instead of single carrier. In MC-CDMA systems, each user benefits from frequency diversity by spreading its signal over independently fading sub-channels, thus enhancing system performance [3].

Wideband communication channels such as MIMO are frequency selective channels. Using MC modulation (MCM) technique as the OFDM turns those channels into a set of frequency nonselective (flat) fading subchannels. Including MIMO technique in cellular systems has many advantages. It increases both capacity and diversity, and reduces fading effects of wireless channels [4].

Co-channel interference in CDMA cellular systems and particularly from neighboring cells is not widely studied. In addition, most studies addressed the CCI in single carrier CDMA systems [6, 7]. The CCI was considered to be the sum of multiple access interference (MAI) and the ISI. Both studies considered uplink slowly varying Rayleigh channels. Other algorithms of CCI cancellation were proposed in [8, 9]. Those two studies considered the CCI from users in the same cell in a MC-CDMA cellular system.

The CCI from neighboring cells was presented in [10]. It was defined as the sum of ISI and MAI in the mother cell and the MAI from neighboring cells. This study considered the worst case where the mobile station (MS) was assumed to be at the center of a triangle formed by three heavily loaded base stations (BSs).

Studying the CCI in the 3G cellular systems is of great interest for many researchers. In [11], the authors analyzed the effect of CCI in three different architectures: microzoning, sectoring, and omni-directional. Other techniques that can be used to reduce the out-of-cell CCI is the multiuser detection [12]. An optimum multiuser detection in the context of the IS-95 downlink was first considered, then, it was developed to a reduced complexity optimum detector. This detector extracts the weak downlink transmissions from strong out-of-cell CCI.

As can be seen, most of the previous work was performed for systems with single transmit and single receive antennas. Also, there was no use for the beamforming technique. In this paper, we present a new scheme for a cellular system. In addition to its compatibility and simplicity, it includes several high advanced techniques. The direct sequence spread spectrum (DSSS) was included to reduce the effect of CCI along with the beamforming technique. In addition, the OFDM modulation technique was used to solve the problem of frequency selectivity of MIMO channels and the ISI and multipath effect on CDMA signals. Another 3G technique is the MIMO which was used to increase system capacity, spatial diversity, and to combat fading.

The reminder of this paper is organized as follows. The next section gives the model of the studied system. Section 3 offers the performance analysis. The simulation results are presented in section 4. Finally, section V states the conclusions.

2 Problem Formulation

2.1 System Model

2.1.1 System Description

Figure 1 shows the studied scenario. The downlink transmission was considered in an omnidirectional CDMA architecture. For simplicity, the CCI from first-tier neighboring cells was only considered. Each user was assigned a pseudo noise (PN) spreading code. Each BS was assumed to have N_T antennas, and each user (MS) N_R antennas.

2.1.2 System Transmitter

The block diagram of system transmit side is shown in figure 2. It gives system transmitter for signal of user *j* at BS0 (mother cell). The transmitter transmits one OFDM symbol at a time. For the *n*th OFDM symbol, the input data stream is multiplied by the spreading code, and the resulted signal is converted to parallel form. The output *N* substreams are modulated by the *N*-point IFFT. Finally, the beamforming operation (shown in figure 3) is performed on the output sequences resulting in MC DS-CDMA signal vector of user *j*. System transmitter of the signal of any user in any interfering cell is similar to that shown in figure 2.

2.1.3 System Receiver

The receiver of user *j* is shown in figure 4. First, the received MC DS-CDMA signal vector is beamformed by the receive beamforming operation (shown in figure 3). Then, the *N* estimated sequences are demodulated by the *N*-point FFT MC demodulator. The resulted components (substreams) are converted to serial form. Finally, the output signal of the P/S converter is multiplied by the spreading code, and the transmitted data is recovered.

3 Problem Solution

3.1 Performance Analysis

The MC DS signal of user *j* transmitted from BS0 can be written as:

$$x_{0,j}(t) = \sqrt{P_j} \sum_{i=-\infty}^{\infty} \sum_{l=0}^{NM-1} a_{0,j}(i) c_{0,j}(l) p(t - iT_b - lT_c) \tag{1}$$

where P_j is the signal power of user *j*, and *N* is the number of chips in one OFDM symbol (# of used subcarriers), and *M* is the number of OFDM symbols used to transmit one data bit, and $a_{0,j}(i)$, $c_{0,j}(l)$ are respectively, the *i*th information bit and the *l*th chip of the spreading code with length *NM*, and $P(t)$ is the chip pulse wave form. It is assumed to be a rectangular pulse and given by:

$$p(t) = \begin{cases} 1 & , \quad 0 \le t \le T_c \\ 0 & , \quad otherwise \end{cases} \tag{2}$$

For the *n*th OFDM symbol, and at the time instant $i = 0$, Equation (1) becomes:

$$x_{0,j}^{(n)}(t)=\sqrt{P_j}\sum_{l=0}^{N-1}a_{0,j}c_{0,j}(l)\,p\left(t-(nN+l)T_c\right) \tag{3}$$

where $0 \le n \le M-1$.

The N output substreams of the S/P converter can be written in vector form as:

$$\underline{\mathbf{u}}_{0,j}^{(n)}=\left[u_{0,j,0}^{(n)},u_{0,j,1}^{(n)},\cdots,u_{0,j,N-1}^{(n)}\right] \tag{4}$$

The output sequences of the IFFT seem to be:

$$\underline{\mathbf{v}}_{0,j}^{(n)}=\underline{\mathbf{u}}_{0,j}^{(n)}\mathbf{W}^H \tag{5}$$

where $\mathbf{W}^H$ is the IFFT matrix with entry $\frac{1}{\sqrt{N}}\exp(j2\pi im/N)$. It is given by:

$$\mathbf{W}^H=\frac{1}{\sqrt{N}}\begin{bmatrix}1 & 1 & \cdots & 1\\ 1 & \exp(j2\pi/N) & \cdots & \exp(j2\pi(N-1)/N)\\ \vdots & \vdots & \ddots & \vdots\\ 1 & \exp(j2\pi(N-1)/N) & \cdots & \exp(j2\pi(N-1)(N-1)/N)\end{bmatrix}_{N\times N} \tag{6}$$

For the kth user in the sth interfering cell, the MC DS-CDMA transmitted signal can be written as:

$$x_{s,k}(t)=\sqrt{P_k}\sum_{l=0}^{N-1}a_{s,k}c_{s,k}(l)\,p\left(t-lT_c\right) \tag{7}$$

where P_k is the signal power of the kth interferer.

The N output substreams of the S/P converter can be written in vector form as:

$$\underline{\mathbf{u}}_{s,k}=\left[u_{s,k,0},u_{s,k,1},\cdots,u_{s,k,N-1}\right] \tag{8}$$

The output sequences of the IFFT seem to be:

$$\underline{\mathbf{v}}_{s,k}=\underline{\mathbf{u}}_{s,k}\mathbf{W}^H \tag{9}$$

Now, the received signal vector at user j in the main cell can be written as:

$$\underline{\mathbf{r}}_j=\underline{\mathbf{s}}_{0,j}\mathbf{H}_{0,j}+\sum_{s=1}^{N_B}\underline{\mathbf{s}}_{s,j}\mathbf{H}_{s,j}+\underline{\mathbf{w}} \tag{10}$$

where $\underline{\mathbf{r}}_j$ is a $1\times N_R$ vector, and N_B is the number interfering cells, and $\underline{\mathbf{s}}_{0,j}$ is the $1\times N_T$ signal vector transmitted from BS0 to user j in the same cell, and $\mathbf{H}_{0,j}$ is the channel matrix representing short term fading from the BS0 to user j, and $\underline{\mathbf{s}}_{s,j}$ is the $1\times N_T$ signal vector transmitted from the sth BS, and $\mathbf{H}_{s,j}$ is the channel matrix representing short term fading from the sth BS to user j, and $\underline{\mathbf{w}}$ is the additive white Gaussian noise vector with zero mean and covariance matrix $\sigma_w^2\mathbf{I}_{N_R}$. The channel matrices are assumed to be slowly varying Rayleigh fading channels. Also, they are assumed to be fixed during the transmission of one OFDM symbol and known at both the transmitter and the receiver.

The channel matrices $\mathbf{H}_{0,j}$, $\mathbf{H}_{s,j}$ can be written as:

$$\mathbf{H}_{0,j}=\begin{bmatrix}h_{0,j,11} & h_{0,j,12} & \cdots & h_{0,j,1N_R}\\ h_{0,j,21} & h_{0,j,22} & \cdots & h_{0,j,2N_R}\\ \vdots & \vdots & \ddots & \vdots\\ h_{0,j,N_T1} & h_{0,j,N_T2} & \cdots & h_{0,j,N_TN_R}\end{bmatrix}_{N_T\times N_R} \tag{11}$$

$$\mathbf{H}_{s,j}=\begin{bmatrix}h_{s,j,11} & h_{s,j,12} & \cdots & h_{s,j,1N_R}\\ h_{s,j,21} & h_{s,j,22} & \cdots & h_{s,j,2N_R}\\ \vdots & \vdots & \ddots & \vdots\\ h_{s,j,N_T1} & h_{s,j,N_T2} & \cdots & h_{s,j,N_TN_R}\end{bmatrix}_{N_T\times N_R} \tag{12}$$

Based on figure 3, each BS sums the signals of users inside its cell and transmits the resulted signal at a time. Assuming K users/cell, the transmitted signal from BS0 can be written as:

$$\begin{aligned}\underline{\mathbf{s}}_{0,j}&=\sum_{k=1}^{K}\underline{\mathbf{s}}_k^{(0,n)}\\ &=\sum_{k=1}^{K}\underline{\mathbf{v}}_{0,k}^{(n)}\mathbf{B}_{0,k}\end{aligned} \tag{13}$$

where $\underline{\mathbf{s}}_k^{(0,n)}$ is the $1\times N_T$ signal vector of the kth user in the main cell (BS0), and $\mathbf{B}_{0,k}$ is the transmit beamforming matrix of that user. It is given by:

$$\mathbf{B}_{0,k} = \begin{bmatrix} b_{0,k,11} & b_{0,k,12} & \cdots & b_{0,k,1N_T} \\ b_{0,k,21} & b_{0,k,22} & \cdots & b_{0,k,2N_T} \\ \vdots & \vdots & \ddots & \vdots \\ b_{0,k,N1} & b_{0,k,N2} & \cdots & b_{0,k,NN_T} \end{bmatrix}_{N \times N_T} \quad (14)$$

Now, Equation (10) can be re-written as:

$$\underline{\mathbf{r}}_j = \sum_{k=1}^{K} \underline{\mathbf{v}}_{0,k}^{(n)} \mathbf{B}_{0,k} \mathbf{H}_{0,j} + \sum_{s=1}^{N_B} \sum_{k=1}^{K} \underline{\mathbf{v}}_{s,k} \mathbf{B}_{s,k} \mathbf{H}_{s,j} + \underline{\mathbf{w}} \quad (15)$$

where $\mathbf{B}_{s,k}$ is the $N \times N_T$ transmit beam-forming matrix of the *k*th user in the *s*th interfering cell. It can be written as:

$$\mathbf{B}_{s,k} = \begin{bmatrix} b_{s,k,11} & b_{s,k,12} & \cdots & b_{s,k,1N_T} \\ b_{s,k,21} & b_{s,k,22} & \cdots & b_{s,k,2N_T} \\ \vdots & \vdots & \ddots & \vdots \\ b_{s,k,N1} & b_{s,k,N2} & \cdots & b_{s,k,NN_T} \end{bmatrix}_{N \times N_T} \quad (16)$$

The received signal vector after the receive beamforming process seems to be:

$$\underline{\hat{\mathbf{v}}}_{0,j}^{(n)} = \sum_{k=1}^{K} \underline{\mathbf{v}}_{0,k}^{(n)} \mathbf{B}_{0,k} \mathbf{H}_{0,j} \mathbf{A}_{0,j} + \sum_{s=1}^{N_B} \sum_{k=1}^{K} \underline{\mathbf{v}}_{s,k} \mathbf{B}_{s,k} \mathbf{H}_{s,j} \mathbf{A}_{0,j} + \underline{\mathbf{w}} \mathbf{A}_{0,j} \quad (17)$$

where $\mathbf{A}_{0,j}$ is the $N_R \times N$ receive beam-forming matrix at user *j*. It can be written as:

$$\mathbf{A}_{0,j} = \begin{bmatrix} a_{0,j,11} & a_{0,j,12} & \cdots & a_{0,j,1N} \\ a_{0,j,21} & a_{0,j,22} & \cdots & a_{0,j,2N} \\ \vdots & \vdots & \ddots & \vdots \\ a_{0,j,N_R 1} & a_{0,j,N_R 2} & \cdots & a_{0,j,N_R N} \end{bmatrix}_{N_R \times N} \quad (18)$$

After implementing the FFT, Equation (17) becomes:

$$\underline{\hat{\mathbf{u}}}_{0,j}^{(n)} = \sum_{k=1}^{K} \underline{\mathbf{u}}_{0,k}^{(n)} \mathbf{W}^H \mathbf{B}_{0,k} \mathbf{H}_{0,j} \mathbf{A}_{0,j} \mathbf{W} + \sum_{s=1}^{N_B} \sum_{k=1}^{K} \underline{\mathbf{u}}_{s,k} \mathbf{W}^H \mathbf{B}_{s,k} \mathbf{H}_{s,j} \mathbf{A}_{0,j} \mathbf{W} + \underline{\mathbf{w}} \mathbf{A}_{0,j} \mathbf{W} \quad (19)$$

where $\mathbf{W}$ is the $N \times N$ FFT matrix.

Implement the despreading operation, the last Equation becomes:

$$\begin{aligned} \underline{\hat{\mathbf{u}}}_{0,j}^{(n)} \left(\underline{\mathbf{u}}_{0,j}^{(n)}\right)^H &= \underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{B}_{0,j} \mathbf{H}_{0,j} \mathbf{A}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \\ &+ \sum_{\substack{k=1 \\ k \neq j}}^{K} \underline{\mathbf{v}}_{0,k}^{(n)} \mathbf{B}_{0,k} \mathbf{H}_{0,j} \mathbf{A}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \\ &+ \sum_{s=1}^{N_B} \sum_{k=1}^{K} \underline{\mathbf{v}}_{s,k} \mathbf{B}_{s,k} \mathbf{H}_{s,j} \mathbf{A}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \\ &+ \underline{\mathbf{w}} \mathbf{A}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \\ &= Desired\ \ signal + MAI + CCI + Noise \end{aligned} \quad (20)$$

Now, let us define the following matrices:

$$\mathbf{D}_{0,j} = \mathbf{B}_{0,j} \mathbf{H}_{0,j} \mathbf{A}_{0,j} \quad (21)$$

$$\mathbf{D}_{0,k} = \mathbf{B}_{0,k} \mathbf{H}_{0,j} \mathbf{A}_{0,j} \quad (22)$$

$$\mathbf{D}_{s,k} = \mathbf{B}_{s,k} \mathbf{H}_{s,j} \mathbf{A}_{0,j} \quad (23)$$

where each of the previous matrices has dimensions $N \times N$.

Now, Equation (20) seems to be:

$$\begin{aligned} &\Rightarrow \underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{D}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H + \sum_{\substack{k=1 \\ k \neq j}}^{K} \underline{\mathbf{v}}_{0,k}^{(n)} \mathbf{D}_{0,k} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \\ &+ \sum_{s=1}^{N_B} \sum_{k=1}^{K} \underline{\mathbf{v}}_{s,k} \mathbf{D}_{s,k} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H + \underline{\mathbf{w}} \mathbf{A}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \end{aligned} \quad (24)$$

The *SINR* performance measure is given by:

$$SINR = \frac{\mathrm{E}\left[\underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{D}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{D}_{0,j}^H \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \right]}{\left\{ \begin{aligned} &\sum_{\substack{k=1 \\ k \neq j}}^{K} \mathrm{E}\left[\underline{\mathbf{v}}_{0,k}^{(n)} \mathbf{D}_{0,k} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{D}_{0,k}^H \left(\underline{\mathbf{v}}_{0,k}^{(n)}\right)^H \right] \\ &+ \sum_{s=1}^{N_B} \sum_{k=1}^{K} \mathrm{E}\left[\underline{\mathbf{v}}_{s,k} \mathbf{D}_{s,k} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{D}_{s,k}^H \left(\underline{\mathbf{v}}_{s,k}\right)^H \right] \\ &+ \mathrm{E}\left[\underline{\mathbf{w}} \mathbf{A}_{0,j} \left(\underline{\mathbf{v}}_{0,j}^{(n)}\right)^H \underline{\mathbf{v}}_{0,j}^{(n)} \mathbf{A}_{0,j}^H \underline{\mathbf{w}}^H \right] \end{aligned} \right\}} \quad (25)$$

After simplifying the numerator and each part of the denominator in last Equation, the *SINR* is found to be:

$$SINR = \frac{\sigma^2_{h_{0,j}} \underline{\mathbf{v}}^{(n)}_{0,j} \mathbf{A}^H_{0,j} \sum_{i=1}^{N}\sum_{m=1}^{N} v^{(n)}_{0,j,i} \left(v^{(n)}_{0,j,m}\right)^* diag\left(\sum_{g=1}^{N_T} b^*_{0,j,mg} b_{0,j,ig}\right)_{N_R\times N_R} \mathbf{A}_{0,j}\left(\underline{\mathbf{v}}^{(n)}_{0,j}\right)^H}{\left\{\begin{array}{l} \sigma^2_{h_{0,j}} \underline{\mathbf{v}}^{(n)}_{0,j} \mathbf{A}^H_{0,j} \sum_{\substack{k=1\\k\neq j}}^{K}\sum_{i=1}^{N}\sum_{m=1}^{N} v^{(n)}_{0,k,i}\left(v^{(n)}_{0,k,m}\right)^* diag\left(\sum_{g=1}^{N_T} b^*_{0,k,mg} b_{0,k,ig}\right)_{N_R\times N_R} \mathbf{A}_{0,j}\left(\underline{\mathbf{v}}^{(n)}_{0,j}\right)^H \\ +\underline{\mathbf{v}}^{(n)}_{0,j}\mathbf{A}^H_{0,j}\sum_{s=1}^{N_B}\sigma^2_{h_{s,j}}\sum_{k=1}^{K}\sum_{i=1}^{N}\sum_{m=1}^{N} v_{s,k,i} v^*_{s,k,m}\, diag\left(\sum_{g=1}^{N_T} b^*_{s,k,mg} b_{s,k,ig}\right)_{N_R\times N_R} \mathbf{A}_{0,j}\left(\underline{\mathbf{v}}^{(n)}_{0,j}\right)^H \\ +\sigma^2_w \underline{\mathbf{v}}^{(n)}_{0,j}\sum_{i=1}^{N_R} \underline{\mathbf{a}}^H_{0,j,i}\underline{\mathbf{a}}_{0,j,i}\left(\underline{\mathbf{v}}^{(n)}_{0,j}\right)^H \end{array}\right\}} \quad (26)$$

where $\sigma^2_{h_{0,j}}$ is the variance of channel gains of the desired user channel, and $v^{(n)}_{0,j,i}$, $\left(v^{(n)}_{0,j,m}\right)^*$ are respectively, the *i*th element and complex conjugate of the *m*th element in the vector $\underline{\mathbf{v}}^{(n)}_{0,j}$, and $b^*_{0,j,mg}$, $b_{0,j,ig}$ are respectively, the complex conjugate of the *mg*th element and the *ig*th element in the matrix $\mathbf{B}_{0,j}$, and $v^{(n)}_{0,k,i}$, $\left(v^{(n)}_{0,k,m}\right)^*$ are respectively, the *i*th element and the complex conjugate of the *m*th element in the vector $\underline{\mathbf{v}}^{(n)}_{0,k}$, and $b^*_{0,k,mg}$, $b_{0,k,ig}$ are respectively, the complex conjugate of the *mg*th element and the *ig*th element in the matrix $\mathbf{B}_{0,k}$ of the *k*th user in the main cell, and $\sigma^2_{h_{s,j}}$ is the variance of channel gains of the channel between the *s*th BS and the desired user (user *j*) in the main cell, and $v_{s,k,i}$, $v^*_{s,k,m}$ are respectively, the *i*th element and complex conjugate of the *m*th element in the vector $\underline{\mathbf{v}}_{s,k}$, and $b^*_{s,k,mg}$, $b_{s,k,ig}$ are respectively, the complex conjugate of the *mg*th element and the *ig*th element in the matrix $\mathbf{B}_{s,k}$ of the *k*th user in the *s*th interfering cell, and σ^2_w is the variance of the noise vector gains, and finally, $a_{0,j,i}$, $a^H_{0,j,i}$ are the *i*th row of the matrix $\mathbf{A}_{0,j}$ and its Hermitian.

Also, we have used the following assumptions in deriving Equation (26): uncorrelated entries for both the desired user channel matrix $\mathbf{H}_{0,j}$ and the channel matrices of the interfering cells $\mathbf{H}_{s,j}$, also, we have assumed equal variances of channel gains between the transmit antennas and each receive antenna. In addition, we have assumed uncorrelated entries for the noise vector $\underline{\mathbf{w}}$.

3.2 Simulation Results

We have assumed the following parameters in simulating the system given in Equation (26): $N=8$, $M=4$, $\sigma^2_{h_{0,j}}=0.9$, $\sigma^2_{h_{s,j}}=0.02$, $E_u=1$, $E_b=ME_u=4$, $SNR=E_b/N_o = 2/\sigma^2_w$. Where E_u, E_b represent the amount of energy in the OFDM symbol vector $\underline{\mathbf{u}}^{(n)}_{0,j}$ and in the data bit, respectively. The beamforming matrices were chosen to be complex and optimized numerically to get the max. values of $SINR$. Note that the number of users in the main cell was kept at the value 6 when the following curves were generated.

Many scenarios have been made in order to analyze performance of the proposed system. Figures 5, 6 show and demonstrate the effectiveness of spread spectrum technique in enhancing system performance. Figure 7 states the effect of the interferers on system performance. Several curves were generated to study the effect of spatial diversity on system behavior. The effect of spatial diversity at the transmit side is shown in figure 8. Figure 9 states the effect of receive diversity on system behavior. The effect of changing both transmit and receive diversities is shown in figure 10. Figure 11 shows the effect of power distribution of system interferers, where α is the control parameter that represents the ratio of the interferer power to the desired user power. The effect of channel fading is shown in figure 12, where $\sigma^2_{h_{0,j}}$ is the control parameter.

4 Conclusion

In this paper, we have presented a new scheme for a beyond 3G cellular system. As can be seen, the system is simple in construction and involves simple operations. The combination of several advanced and new techniques makes our system a strong candidate to be used in the 4G cellular applications.

Based on the simulation results, the proposed system has proved its effectiveness in reducing the effect of CCI through using both the SS and beamforming techniques. Also, the results have shown the effect of including MIMO technique in the system. One can see that increasing either the spatial transmit or receive diversity or both of them enhances system performance. Another important result is that MIMO scheme acts better than both single-input multiple-output (SIMO) and multiple-input single-output (MISO) schemes. Individual curve was assigned to show the effect of power distribution of system interferers on system behavior. The curve has shown that whenever the ratio of the interferer power to desired user power increases, system performance becomes more degraded. Finally, the last curve states the effect of fading of desired user channel on system behavior.

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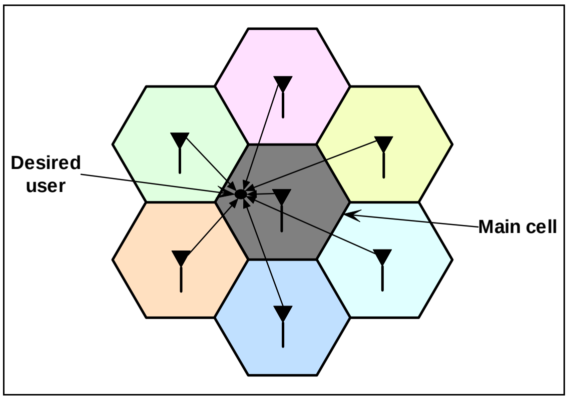

Fig.1: Virtual scheme for the studied scenario.

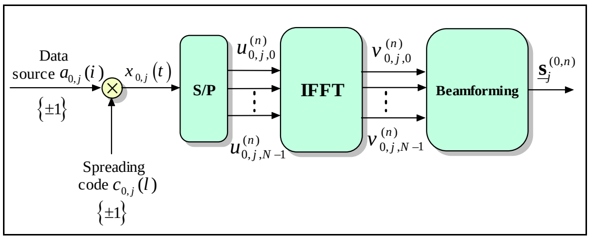

Fig.2: The transmitter of the signal of user *j* at the BS0.

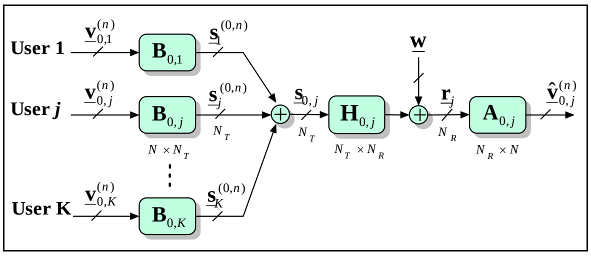

Fig.3: Beamforming process at both BS0 and user *j* in the main cell.

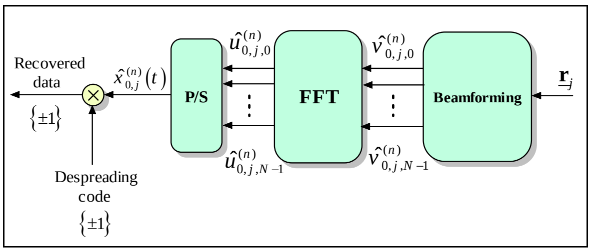

Fig.4: The receiver of MC DS-CDMA signal at user *j*.

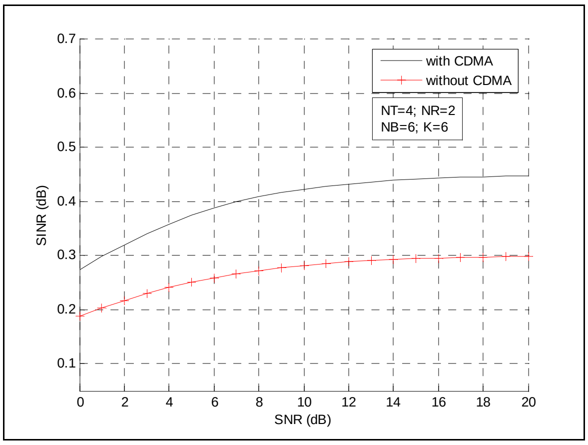

Fig.5: System performance ($SINR$ vs. SNR) with and without CDMA technique.

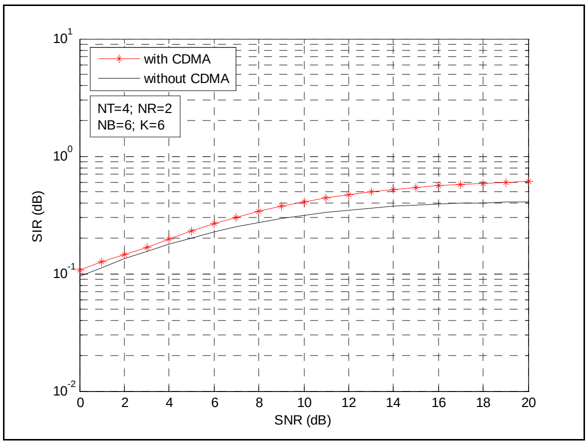

Fig. 6: System performance (SIR vs. SNR) with and without CDMA technique.

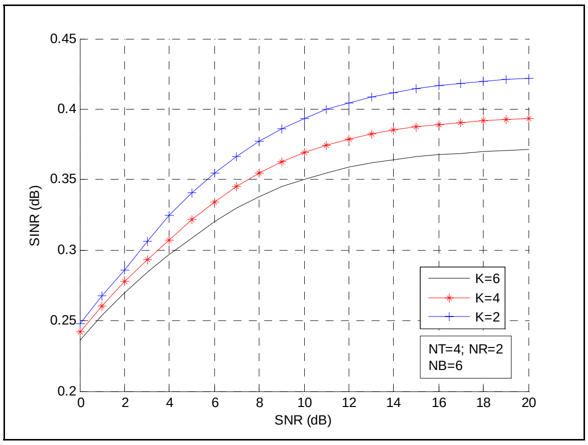

Fig.7: System performance ($SINR$ vs. SNR) when K as the control parameter.

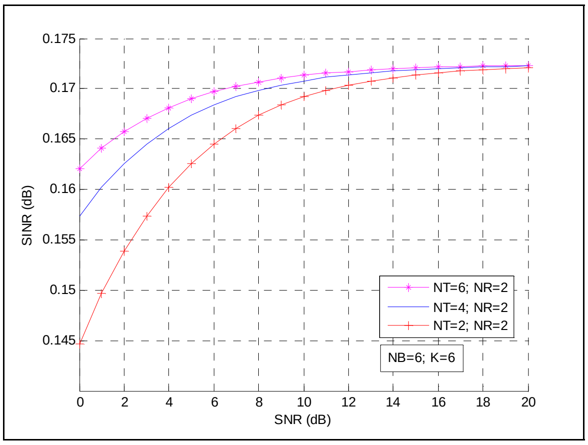

Fig. 8: System performance ($SINR$ vs. SNR) when N_T as the control parameter.

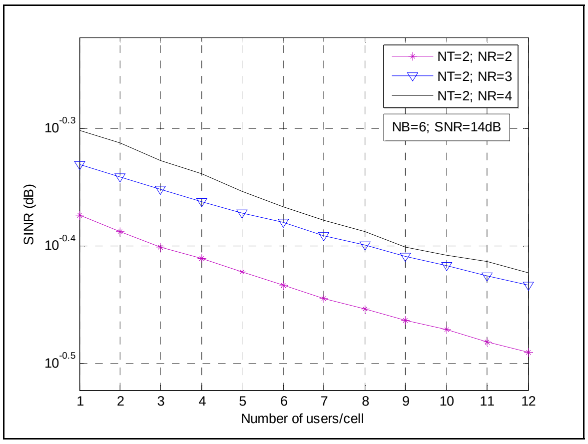

Fig.9: System performance ($SINR$ vs. K) when N_R as the control parameter.

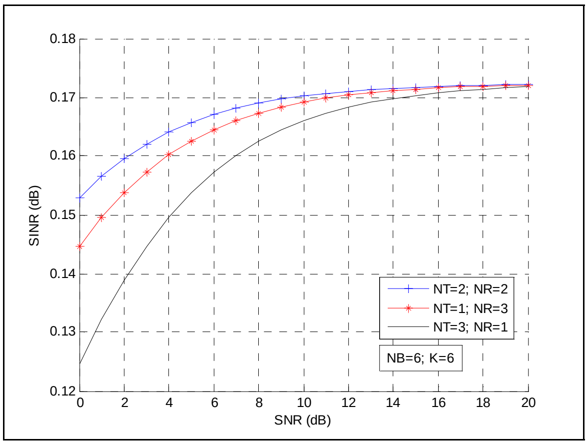

Fig.10: System performance ($SINR$ vs. SNR) for SIMO, MIMO, and MISO schemes.

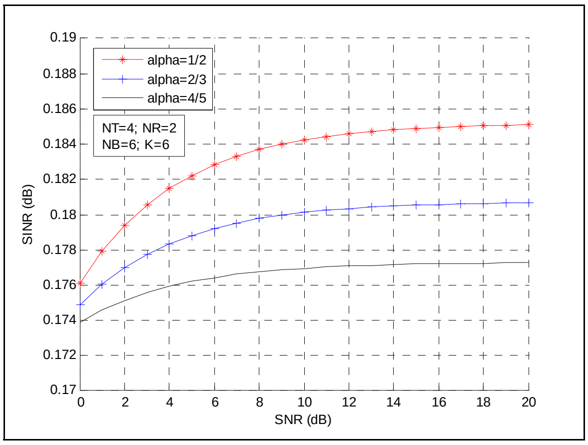

Fig.11: System performance ($SINR$ vs. SNR) when α as the control parameter.

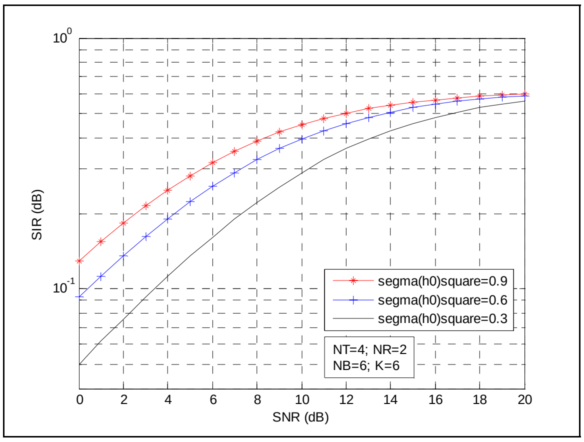

Fig.12: System performance (SIR vs. SNR) when $\sigma^2_{h_{0,j}}$ as the control parameter.