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Performance of CDMA system using Antenna Arrays with Power Control Error in a Rayleigh Fading

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Abstract:

Antenna arrays have been recognized by most fourth generation CDMA systems proposals as a way to enhance the capacity and system coverage by effectively combating multipath fading and mitigating co-channel interference. The multiple access interference (MAI) problems can be overcome by power control by the process so that the average received power at base station is same for each user.

The paper introduces a new approach to outage probability analysis of prediction maximal ratio combining (MRC) diversity reception in Rayleigh fading channels. The analysis joins several of the most important factors affecting the performance of CDMA systems; including path loss, large-scale fading (shadowing), small-scale fading (Rayleigh fading), and co-channel interference (CCI) as well as for correcting mechanisms such as power control error (compensates for path loss and shadowing), spatial diversity (mitigates against Rayleigh fading), and voice activity gating (reduces CCI).

We show that by controlling the power level of a user at the output of the diversity combiner (MRC) and imposing the condition that a user does not transmit when in a deep fade; the average inter-cell interference level of the system is significantly reduced. As a result of this reduction, we demonstrate analytically that the outage capacity of the system is improved more than linearly with increasing number of antenna elements.

Keywords: CDMA system, maximal ratio combining (MRC), power control error, Rayleigh fading, BER.

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1. Introduction:

Personal communication services (PCSs) or CDMA systems, are being saturated by an ever increasing user demand. In addition to advanced coding and modulation techniques, adaptive antenna arrays at base stations are considered an effective technique to suppress interference and increase the capacity of cellular mobile radio systems [1–6]. Adaptive antenna arrays provide a solution to spatially filter out interfering users by exploiting the user locations. In previous work, antenna arrays have been applied to both time division multiple access (TDMA) and code division multiple access (CDMA) [1,2,4] systems, Was concerned with an antenna array combined with an interference canceller to improve the CDMA system performance. In [2] an adaptive antenna was employed for a mixed cellular system. Antenna arrays for macrocell systems were discussed in [3, 4]. Advanced the study for tutorial on antenna arrays for CDMA systems was presented in [5, 6]. One of the most important issues about employing antenna array processing for interference limited 3G mobile communication systems is the increase in the number of users that can be simultaneously sustained, as well as the gain in the transmitted uplink power, which is very limited. In the CDMA system, the role of power control is to adjust the transmit power for each individual user in order to achieve a certain signal-to-interference ratio (SINR) based on a block-error rate (BLER) target. With the antenna array processing, the desired target SINR can be achieved for the lower transmitted power.

With the use of antenna diversity techniques (MRC), the probability of deep fades at the output of the diversity combiner is significantly reduced. In addition to this, due to the limited transmit power of the mobiles, a user cannot transmit at the power level required by the PC mechanism when in a deep fade. Therefore, it is reasonable to adopt a truncated PC scheme [4] and impose the condition that a user does not transmit when in severe fading conditions. Under these assumptions, the use of fast PC algorithms on the combined output power of a receive antenna array results in a significant reduction of the average transmit power of users, which corresponds to less interference from outer cells (intercell interference).

In most practical CDMA systems, a power control error (PCE) scheme is implemented to keep the power received from the users at a constant level, thereby reducing the near–far problem. These schemes usually compensate for the variations due to path loss and shadowing, but are unable to track the multipath fading. Recently, faster PCE methods that are able to keep track of the multipath fading component in slowly varying channels have been introduced. However, it has been shown that tracking the multipath fading in multi cellular environments results in an increase in the interference level from outer cells due to the occurrences of deep fades, in which case the users transmit at high power levels to compensate for it [3].

Power control loops are designed to compensate for large-scale fading effects, but amplitude variations due to small-scale fading are too rapid to be tracked. Power control circuits, however, have finite accuracy, which implies that CDMA systems are still faced with residual shadowing effects. The signal received at the base station from a power-controlled user can be modeled as governed by the log-normal distribution [4, 5]. The standard deviation of the received signal power is defined as the PCE and is typically of the order of 1,2,3,4 dB. Some advantages of using PC in DS-CDMA system are Overcoming the near-far effect.; Reduce MAI and inter-cell interference.; Maximize the capacity of the overall cellular system.; Decrease the user's power consumption.; Increase the battery life time. The paper is organized as follows. The channel and system model is given in Section 2. The BER Performance analysis power control error in combination with antenna array over Rayleigh fading channel processing is explained in Section 3. Numerical results are given in Section 4 and the conclusions are drawn in Section 5.

2. Channel And System Model:

We consider a BPSK-modulated DS-CDMA system over a multipath fading channel. Assuming K active users (k =1, 2, . . . ,K), the low-pass equivalent signal transmitted by user k is presented as

$$S^k(t) = \sqrt{2p_k}\, b^k(t) g^k(t)\, a(t) \cos[\omega_c t + \varphi^k] \qquad (1)$$

Where a(t) is a pseudo noise (PN) randomization sequence which is common to all the channels in a cell to maintain the CDMA systems, $g^k(t)$ is an orthogonal channelization sequence, and $b^k(t)$ is user k's data waveform. In (1), p_k is the average transmitted power of the k^{th} user, ω_c is the common carrier frequency, and φ^k is the phase angle of the k^{th} modulator to be uniformly distributed in [0, 2π). The orthogonal chip duration T_g and the PN chip interval T_c is related to data N_c = T/T_c. We assume, for simplicity that T_g equals T_c. The complex low pass impulse response of the vector channel associated with the k^{th} user may be written as [3]

$$h_k(\tau) = \sum_{l=0}^{L(k)-1} \beta_l^{(k)} \exp\left(j\varphi_l^{(k)}\right) V\left(\theta_l^{(k)}\right) \delta\left[\tau - \tau_l^{(k)}\right] \qquad (2)$$

Where $\beta_l^{(k)}$ is the Rayleigh fading strength, $\varphi_l^{(k)}$ is its phase shift, and $\tau_l^{(k)}$ is the propagation delay. The k^{th} user's l^{th} path, antenna array (AA) response vector is expressed as:

$$V\left(\theta_l^{(k)}\right) = \left[1, \exp\left(-j\,2\pi.\, d\cos\theta_l^{(k)}/\lambda\right), \ldots, \exp\left(-j\,2(M-1)\pi.\, d\cos\theta_l^{(k)}/\lambda\right)\right]^T$$

Throughout this paper, we consider that the array geometry, which is the parameter of the antenna aperture gain, is a uniform linear array (ULA) of N_a identical sensors in

Figure 1.a. All signals from MS arrive at the BS AA with mean angle of arrival (AOA) $\theta_l^{(k)}$ which is uniformly distributed in $[0, \pi\ )$ [6].
Assuming Rayleigh fading, the probability density function (pdf) of signal strength associated with The k^{th} user's l^{th} propagation path, l= 0, 1, . . . , $L^{(k)} - 1$,[7] is presented as:

$$p\left(\beta_l^{(k)}\right) = \frac{2\beta_l^{(k)}}{\Omega_l^{(k)}} \exp\left(-\frac{\left(\beta_l^{(k)}\right)^2}{\Omega_l^{(k)}}\right) \tag{3}$$

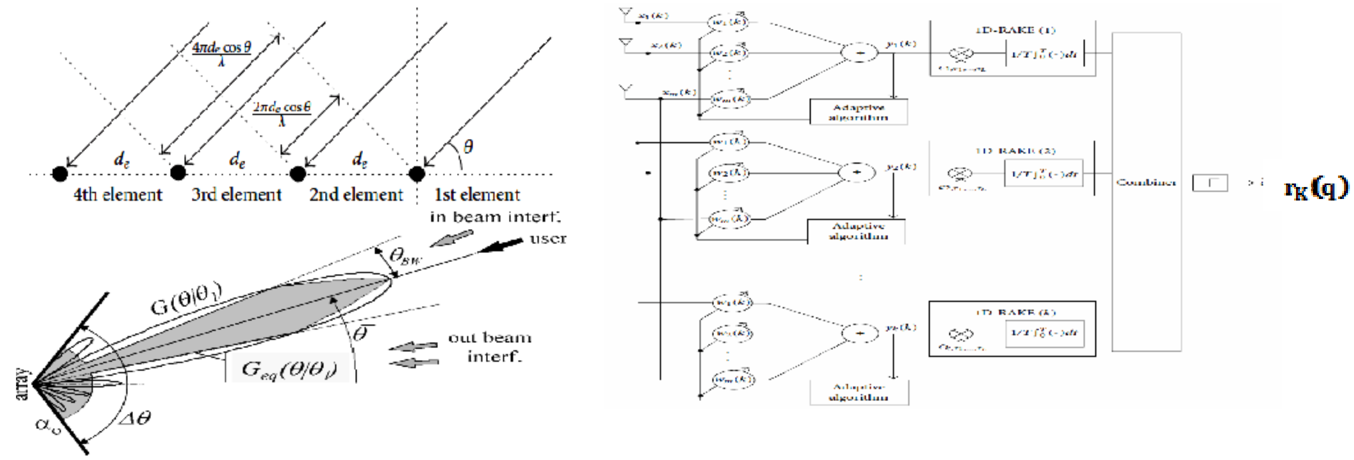
Where $\Omega_l^{(k)}$ is the second moment of $\left(\beta_l^{(k)}\right)$ with $\sum_{l=0}^{\infty}\Omega_l = 1$ and we assume it is related to the second moment of the initial path strength $\Omega_0^{(k)}$ for exponentially decaying MIP as: $\Omega_l^{(k)} = \Omega_0^{(k)} \exp(-l\delta)$, for $0 \le l \le L_P^{(k)} - 1$, $\delta \ge 0$; (4)
Where δ reflects the rate at which the decay of average path strength as a function of path delay occurs. Note that a more realistic profile model may be the exponential MIP.

The receiver is a coherent RAKE receiver with AA in Figure 1.b, where the number of fingers L_r is a variable less than or equal to $L_P^{(k)}$ which is the number of resolvable propagation paths associated with the k^{th} user. Perfect estimates of the channel parameters are assumed. The complex received signal is expressed as

$$r(t) = \sqrt{2P} \sum_{k=1}^{K} \sqrt{\lambda_k} \sum_{l=0}^{L^{(k)}-1} \beta_l^{(k)} V(\theta_l^{(k)}) b^k(t-\tau_l^{(k)}).g^k\left(t-\tau_l^{(k)}\right) a(t-\tau_l^{(k)}) \, Cos[\omega_c (t-\tau_l^{(k)}$$

(5)

Where P is the average received power and $\psi_l^{(k)}$ is the phase of the l^{th} path associated to the k^{th} carrier. λ_k Corresponds to the PCE of the k^{th} user which is a random variable due to imperfect power control [8]. We consider λ_k being lognormal distributed with standard deviation σ_{λ_k} dB. [9, 10] In other words, $\lambda_k = 10^{\left(x/10\right)}$, where the variable x follows a normal distribution. n(t) is an $N_a \times 1$ spatially and temporally white Gaussian noise vector with a zero mean and covariance which is given by E{n(t) n^H(t)} = $\sigma_n^2 I$, where I is the $N_a x N_a$ identity matrix, σ_n^2 is the antenna noise variance with $\eta_0/2$, and the superscript H denotes the Hermitian-transpose operator. One of the weaknesses of RAKE receiver is the complexity when the number of correlators increases. Unlike the goal it raises the power and cost [4, 18,19].
Notation. $(\ast)^H$ $(\cdot)$ H is reserved for the matrix Hermitian



Figure(1.a) A linear equally spaced AA,(b): In-beam/out-beam partitioning of the MAI, (C): CDMA- 2D-RAKE receiver [3].

3. BER Performance Analysis over Rayleigh fading channel:

To analytically determine the performance of the CDMA system, we follow the approximation procedure proposed in [5-8]. The approximation proposes to adapt the single antenna performance bounds to array antenna systems by manipulating those terms in the error probability formulas for single antenna receivers that account for the noise and multiple access interference (MAI). The procedure divides the number of interferers into two categories pass band (in-beam) and stop band (out-of-beam) based on whether their direction of arrivals lie inside or outside the beam formed toward the desired user. The attenuation provided by the array antenna to each of the out-of-beam interferes is assumed to be constant. The in-beam interferers are counted as interference while the out-of-beam users increase the additive noise level for the evaluation of the error probability. The main objective of this section is to present a closed form expression for the probability density function (pdf) of signal-to-interference-plus-noise ratio (SINR) for MRC when the desired and interfering signals fade independently with Rayleigh statistics. Also, we deal with the modelling of the other-cell interference to access the performance of an Antenna arrays using the proposed signal enhancement scheme in the multicell interference.

For Frequency-Selective Rayleigh Fading, the SINR at the output of an antenna array following [5] , it can be shown that for a single antenna in Rayleigh fading environment, the noise terms $N_{I,Q}^{K}(t)$ can be modeled as mutually independent zero mean Gaussian random processes with variance: $\sigma_N^2 = N_0/2$; Similarly, the MAI terms $M_{I,Q}^{K}$ can be modelled as a zero mean Gaussian random processes with variance: [14-17]

$$\sigma_M^2 = E_S/3N_c \sum_{k=2}^{K} E\left[(\beta^k)^2\right] = \frac{E_s}{3N_c}(K-1)$$

Where $E_s = E_b.\log_2(M)$ is the symbol energy, E_b is the bit energy, N_c = 64 is the spreading factor and the total path power for each user is normalized to unity. The total variance is a sum of squares of two Gaussian random variables, each with variance [5]:

$$\sigma_T^2 = \sigma_N^2 + \sigma_M^2 = {N_0}/{2} + \left({E_s}/{3N_c}\right).(K-1)$$

Using the SINR and the statistics of the decision variable, it can be shown that the mean bit error probability for a conventional RAKE receiver (i.e. single antenna without beam forming) in Rayleigh fading over L−fold multipath diversity with MRC is given by [2]. We assume that uniform power delay profile is used to characterize the multipath fading channel and that all users have the same average signal power at the receiver due to perfect power control, i.e. Ω1 = Ω2 =…= ΩL = Ω / L_r. The SINR can thus be written as:

$$\gamma = {E_s}/{N_0} = \frac{({E_b}/{N_0})\Omega}{L_r}.\log_2(M)$$

$$SINR_{1D} = \frac{E_s}{2\,\sigma_T^2} = \frac{\gamma\ .N_0}{2\left(\frac{N_0}{2} + \frac{\gamma}{3}\frac{N_0}{N_c}.\ (K-1)\right)} = (3\,\gamma\ N_c)/[3\,N_c + 2\,\gamma\ (K-1)]$$

(6)

Where N_c the spreading is gain, E_s is the symbol energy and N_0 is the noise power spectral density. With K active users, an L_r finger non coherent RAKE combiner; k^{th} transmitting user and the n^{th} element of the N_a.

For Performance Analysis-2D RAKE Receivers, let the modified variances of the noise and MAI be denoted as $\bar{\sigma}_N^2$ and $\bar{\sigma}_M^2$ respectively. We know that the noise at the output of the antenna array is reduced by N times. Hence, $\bar{\sigma}_N^2 = \frac{({N_0}/{2})}{N_a}$; Let H denote the number of in-beam interferers. The number of out-of-beam interferers = K − H − 1. Hence we have:

$$\bar{\sigma}_M^2 = \overbrace{\left\{\alpha_0(K-H-1).\left({E_s}/{3N_c}\right)\right\}}^{\text{out-of-beam}} + \overbrace{\left\{f.H.\left({E_s}/{3N_c}\right)\right\}}^{\text{in-beam}}\ ;$$

Where α_0 is the attenuation factor for out-of-beam interferers and (f =0.75) is a correction factor for In-beam Interferers [9,11, 12] . The modified SINR expression is thus given by:

$SINR_{2D} = {E_s}/{2\bar{\sigma}_T^2}$; The respective self interferences due to the desired users own multipaths and can be modelled as zero mean Gaussian random processes with variance [9],

$$\sigma_I^2 = \frac{E_s}{3N_c}\sum_{l=1}^{L} E\left[\left(\beta_{k,l}\right)^2\right]$$

Where $\bar{\sigma}_T^2 = \bar{\sigma}_N^2 + \bar{\sigma}_M^2 + \bar{\sigma}_I^2$ is the total variance. Substituting the values and

$$\mathbf{SINR_{2D}} = \frac{\gamma}{\left(\frac{1}{N_a} + \frac{2\gamma}{3N_c} H.f + \frac{2\gamma.\alpha_0}{3N_c}(K - H - 1)\right) + \frac{(L_r - 1)(2\gamma)}{3N_c}}$$

simplifying, we get:
By simplification

$$\mathbf{SINR_{2D}} = \frac{3.N_a.N_c.\gamma}{(3N_c + 2.\gamma.N_a.L_r.H.f + 2\gamma.N_a.L_r.\alpha_0(K - H - 1)) + 2.\gamma.N_a.(L_r -}$$

(7)

Using Equation. (7); assuming uniform distribution of interferers in the sector, we can obtain the average bit error probability of 1-D and 2D-RAKE receiver as the probability of error of the CDMA system for Rayleigh fading channel and N_a antennas. We suppose that there are L_P resolvable paths, the SINR can be derived as

$$\gamma_b = \sum_{l=1}^{L_r} \gamma_l$$

Where $N_0 = \sigma_T^2.4T_b$ and γ_b is the instantaneous SINR at the output of the Antenna Array for 1^{th} path in multipath fading. Since γ_b has agama distribution, with scaling parameter γ_l is statistically independent and shaping parameter L_P multipath signals is mutually independent, [1] pdf of γ_b is given by:

$$F_{\gamma_b}(\gamma_b) = \frac{(\gamma_b)^{L-1}}{\left(\overline{\gamma_b}.K\right)^L (L-1)!} e^{\gamma_b / \overline{\gamma_l}.K}$$

(8)

Where $\overline{\gamma_l}$ is the average SINR per multipath signal per antenna for user; As MAI and SI have Gaussian distribution, the error probability as a function of the γ_b is given by:

$$P_b(\gamma_b) = 0.5\,\mathrm{erfc}\left(\sqrt{\gamma_b}\right) \;;\quad \textbf{Where}\quad \mathrm{erfc}\left(\sqrt{\gamma_b}\right) = \left(\frac{2}{\sqrt{\pi}}\right)\int_0^{\sqrt{\gamma_b}} e^{-x^2}\,dx$$

$$P_b(\gamma_b) = \left(\frac{1}{\sqrt{\pi}}\right)\int_0^{\sqrt{\gamma_b}} e^{-t^2}\,dt \qquad (9)$$

We can easily show that the error probability under the prefect power control is given by

$$P_e = \int_0^{\infty} F_{\gamma_b}(\gamma_b).P_b(\gamma_b)\,d\gamma_b \qquad (10)$$

Using Eqs. (8) And (9) into equation (10) is given by:

$$P_e = \int_0^{\infty} \frac{(\gamma_b)^{L-1}}{(\overline{\gamma_b}.K)^L (L-1)!} e^{\gamma_b / \overline{\gamma_l}.K}.\left(1/\sqrt{\pi}\right)\int_{\sqrt{\gamma_b}}^{\infty} e^{-t^2}\,dt\,d\gamma_b$$

According to [2, 20] we get the integrals and products transform to obtain BER

$$\mathbf{BER} = [0.5(1-\mu)]^{L}\sum_{l=0}^{L-1}[0.5(1+\mu)]^{l}.\frac{(L-1+l)!\,(2L-1)!!}{l!\,(2L-1)!\,2^{L+1}}$$

$$\mathbf{BER} = [0.5(1-\mu)]^{L}.\binom{2L-1}{L}\sum_{l=0}^{L-1}[0.5(1+\mu)]^{l} \qquad (11)$$

Where [µ] is defined as [2] , $\mu = \sqrt{\left(\frac{\bar{\gamma}_1}{1+\bar{\gamma}_1}\right)}$.

If we assume that each user has an identically distributed power control error (PCE), i.e, $E\{\varphi_i\} = E\{\varphi\}$, The error probability under the imperfect power control error $\left[e^{0.5(\mu 1.\sigma_m)^2}\right]$ is given by:

$$\mathbf{BER} = [0.5(1-\mu)]^{L}.\binom{2L-1}{L}.e^{0.5(\mu 1.\sigma_m)^2}\sum_{l=0}^{L-1}[0.5(1+\mu)]^{l} \qquad (12)$$

Where $\mu 1 = {}^{(\ln 10)}/_{10} = 0.23$, σ_m is the slandered deviation of the PCE=1,2,3,4 in dB.

$$\mathbf{BER} = [0.5(1-\mu)]^{L}.\binom{2L-1}{L}.e^{0.5(0.23.\sigma_m)^2}\sum_{l=0}^{L-1}[0.5(1+\mu)]^{l} \qquad (13)$$

In the case of Flat Rayleigh Fading, in man circumstances the channels vary slowly relative to the symbol rate. This channel model is referred to as a flat Rayleigh fading channel. For a flat Rayleigh fading channel (i.e. L=1) under the perfect power control, we then have

$$\mathbf{BER_{l}Flat} = [0.5(1-\mu)] = 0.5(1-\sqrt{((\bar{\gamma}_l/(1+\bar{\gamma}_l)))})$$
(14)

Under the imperfect power control, the error probability is given by:

$$\mathbf{BER_{Flat}} = 0.5(1-\mu)\exp[0.5(0.23.\sigma_m)^2] \qquad (15)$$

4. Numerical Results:

The main objective of this section is to present a closed form expression for the probability density function (pdf) of SINR for 2D-RAKE receiver in Rayleigh fading channels with MRC(eqn. 13;15) when the desired and interfering signals fade independently with Rayleigh statics. Also, we deal with the modelling of the other-cell interference to access the performance of an antenna array using the proposed signal enhancement scheme in the multicell environment. Without loss of generality, the Base Station antenna array is assumed to be a Uniform linear array with identical spacing $\mathbf{d = 0.5\lambda}$ between elements, broadside receiving ($\varphi_1 = 0$), and each path arriving at antenna array with the same angular spread. We assume that the number of propagation paths arriving at the receiver (L), is common to all the users. The effect of $\mathbf{L}, \sigma_m$ and the number of users in the cell (K), on the equivalent SINR is given by equation (6;7). The processing gain ($\mathbf{N_c}$) is usually constrained by the available band width and the information rate. In all the numerical examples that follow ($N_1c = 64, 128$) . It is easy and accurate to use numerical integration tools in MathCAD software package to evaluate the results from equation (13) and (15) form.

Figure 2. Shows the average BER vs K, we study the impact of varying the N_a on the performance of the proposed Scheme. This figures show the results compared the proposed scheme (eqn. 13&15) for 2D Rake receiver with MRC according to N_a =1,4,9 and 16 in case that the N_c is 64 and 128 under the SNR of 10 dB , L=4 and perfect power control environment($\sigma_1 m = 1$) . The analytical results show that proposed scheme has very good BER performance compared to the CDMA systems. The more number of antennas is better performance of the proposed scheme system. BER decrease so for increase number of antenna, increase PG depending type of fading (Frequency-Selective Rayleigh Fading &Flat- Rayleigh Fading) there is a tremendous improvement in the BER depending on the increase number of antenna. We also see that a high advantage in the system performance was obtained by using antenna array.

Figure 3: shows the average BER vs K for the case that varying PCE=1,2,3,4 dB with arrays antennas N_a = 4 antennas, N_c =64 in Rayleigh fading channel, with L= 4 resolvable multipath. Is plotted as a function of the capacity (K) and the PCE value under arrays antenna and varying PCE. We assume that each user has an identically distributed PCE value, i.e., $E\{\varphi_i^2\} = E\{\varphi^2\}$. In the imperfect Power control environment, the analytical results are also shown that of the performance of the proposed scheme is the superior to that of the CDMA systems irrespective of both the PCE value and the processing gain. The BER of the proposed scheme increases according to decreasing in the PEC value for the same capacity. In case of a K=20 users per cell under the processing gain 64, the system BER of the proposed scheme is approximately BER=5.75* 10^{-3} and BER=6.75* 10^{-3} for PCE=2 and 4 dB respectively. BER increase so for decrease PCE, there is a tremendous improvement in the BER depending on the decrease PCE. We also see that a high advantage in the system performance was obtained by decrease PCE.

Figure 4: shows the average BER vs SNR for the case that varying number of antennas N_a = 1,4,9,16 antennas; PCE=1 dB, K=100 users, N_c=64in Rayleigh fading channel, with L=4 resolvable multipath. In the SNR =10dB to obtain a BER=0.2 at single antenna; BER =2.14 * 10^{-5} at N_a =4; BER =7.06 * 10^{-7} at N_a =9 while BER decrease to =1.4 * 10^{-7} at antenna array (N_a=16) for Frequency-selective Rayleigh fading and BER =0.05 at N_a =4 for Flat-Rayleigh fading. The analytical results are shown that the performance of the proposed scheme is much better than that of the CDMA systems irrespective of the processing gain. Especially, more the SNR value and the number of antenna arrays increase, the better the performance of the proposed scheme CDMA system.

Figure5: shows the average BER vs L No of paths for the case that varying number of N_a = 1, 4,9,16 antennas, K=100 user with SNR=10 dB, N_c=64 in Rayleigh fading channel, varying L=1,2,3,4 No of paths. The result shows that for as N_a = 16, it is found

that BER= 0.033 at L=1; BER= 6.352*10^{-3} at L=2; BER =1.004*10^{-3} at L=3; BER =1.481*10^{-4} at L=4. The analytical results are shown that the performance of the proposed scheme is BER decrease so for increase L No of paths at antenna array (N_a=16). While the (L) No of paths = 3; N_a=1 for BER= 0.447; N_a=4 for BER= 0.012; Na=9 for BER= 2.312x10^{-3}; Na=16 for BER =1.004x10^{-3} at PG=64; but also the analytical results BER decrease so for increase L No of paths & increase number of antenna, there is a tremendous improvement in the BER depending on the increase L No of paths. We also see that a high advantage in the system performance was obtained by using L No of paths and antenna array.

Figure 6. Shows the average BER vs SNR (dB) for varying PCE =1,2,3,4dB Comparison between the CDMA systems and the proposed scheme under Rayleigh fading (Frequency-Selective and Flat) channel ; and a single cell environment,: N_a=4, K =100 user with L=4 paths; Processing gain=64.

5. Conclusions:

This paper has presented-outage probability of error assuming 2-Drake receiver with antenna array and presented an efficient performance enhancement scheme for improving the performance of the wiener MRC method- based array Antennas. In a CDMA system, increasing the number of antennas reduces the average users transmit powers linearly since more signals are coherently combined. When a system has a power control (PC) mechanism that is fast enough to track the multipath fading, the diversity offered by increasing the number of antennas also reduces the fluctuations in user transmit powers.

CDMA systems becomes one of potential candidates for the physical layer of 4G mobile systems with the aim of improving cell capacity communication in addition to its efficient application in the 3rd generation. In this paper, the bit error rate (BER) performance of a CDMA system over a frequency selective multipath Rayleigh fading channel was performed. The BER performance also degrade, if we increase the number of users We have also seen that the BER performance degrade, if the number of interfering cells increase, but BER performance will increase, if we increase the Processing gain, the BER performance will also increase, if we increase the number of fingers in Rake Receiver (Lr), More over its found that BER performance will increase, if we increase the No of antenna arrays.

Finally it’s concluded PCE with antenna diversity at the base station improves system performance significantly in fast/Flat Rayleigh fading channels. For an uncontrolled single antenna, this would require 4.2 dB higher $\frac{E_b}{I_0}$.

References:

[1] A. J. Viterbi, "*CDMA: Principles of Spread Spectrum Communications*", Reading, MA: Addison-Wesley, 1995.

[2] j.G. Proakis, *"Digital communications"*, 3rd. New York, McGraw-Hill, pp 824, 1995.

[3]] S. Ariyavisitakul and L. F. Chang, *"Signal and interference statistics of a CDMA system with feedback power control"* IEEE Trans. Commun., vol. 41, no. 11, pp. 1626–1634, Nov. 1993.

[4] G. S. Biradar, S. N.Merchant, and U. B. Desai, *"Chip equalized adaptive rake receiver for DS-CDMA UWB systems"*, IETE Journal of Research, vol. 56, no. 2, pp. 94–101, 2010.

[5] W. Ye and A. M. Haimovich, *"Outage probability of cellular CDMA systems with space diversity, Rayleigh fading and power control error*", IEEE commun.Lett.,vol.2,no.8,pp.220 –222, Aug. 1998.

[6] P. Kumar et. Al.,*"BER Analysis to Increase Capacity of A Cellular System Using SDMA Over a Multipath Rayleigh Fading Channel"*, IJCSE. Vol. 02, No. 04,PP 1196-1200, 2010.

[7] Yong-Seok Kim, ela "*A Combined Antenna Arrays and Reverse-Link Synchronous DS-CDMA System over Frequency-Selective Fading Channels with Power Control Error"* , EURASIP Journal on Applied Signal Processing 28, PP.1299–1307, January 2004.

[8] W.Ye and A.M.Haimovich, "*Performance of cellular CDMA with cell site antenna arrays Rayleigh fading and power control error*", IEEE Trans.Communications,vol.48, no.7, pp. 1151–1159, 2000.

[9] Salman D.,el ta, *"Analysis of the Error Performance of Adaptive Array Antennas for CDMA with Noncoherent M-ary Orthogonal Modulation in Nakagami Fading"*, IEEE Communications Letters, VOL. 9, NO.2,PP 148-150, FEBRUARY 2005

[10] T.S.Rappaport, *"Wireless Communications: Principles and Practice"*, Prentice-Hall PTR, NJ, 2002.

[11] Saunders, S.;"*Antennas and Propagation for Wireless Communication Systems*", Wiley, 2000.

[12] S.C. Yang, *"3G CDMA2000 Wireless System Engineering"*, Artech House, USA. 2004.

[13] R. Kawitkar, *"Issues in deploying smart Antennas in Mobile Radio Networks"*, Proceeding World Academy of Science, Engineering and Technology, vol 31, 2008.

[14] L.C.Godara, Ed., *"Handbook of Antennas in Wireless Communications"*, CRC Press, 2002.

[15] A. F. Naguib and A. Paulraj, "*Performance of wireless CDMA with Mary orthogonal modulation and cell site antenna arrays*" IEEE J. Select. Areas Commun., vol. 14, pp. 1770–1783, Dec. 1996.

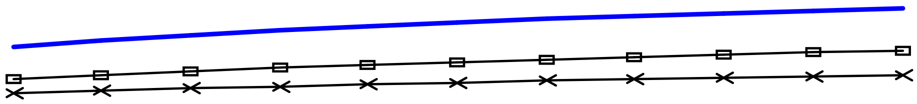
[16] H.Elesawy, A.Fouda,W.Swelam, I.Hafez,"Coverage and Capacity Enhancement in CDMA systems using Antenna array over in Ricean Fading Channels",IJOART International Journal of Advancements in Research & Technology,Volume4,Issue5,PP1524-1530,may-2013.

[17] Kurniawan, A. and B. Maruddani, *"Performance evaluation of the combined power control and antenna diversity in CDMA systems"*, Proceeding ICEEI 2007, Bandung, Indonesia, June 2007.

[18] W. C. Y. Lee, "Wireless and Cellular Telecommunications", McGraw-Hill, 3rd edition, 2006.

[19] D.Manolakis,V.Ingle,andS.Kogon, "Statistical and Adaptive Signal Processing",McGraw-Hill,2005.

[20] I. S. Gradshteyn and I. M. Ryzhik, "Table of integrals, series, and products", CA: Academic Press, San Diego, 7th Edition, 2007.



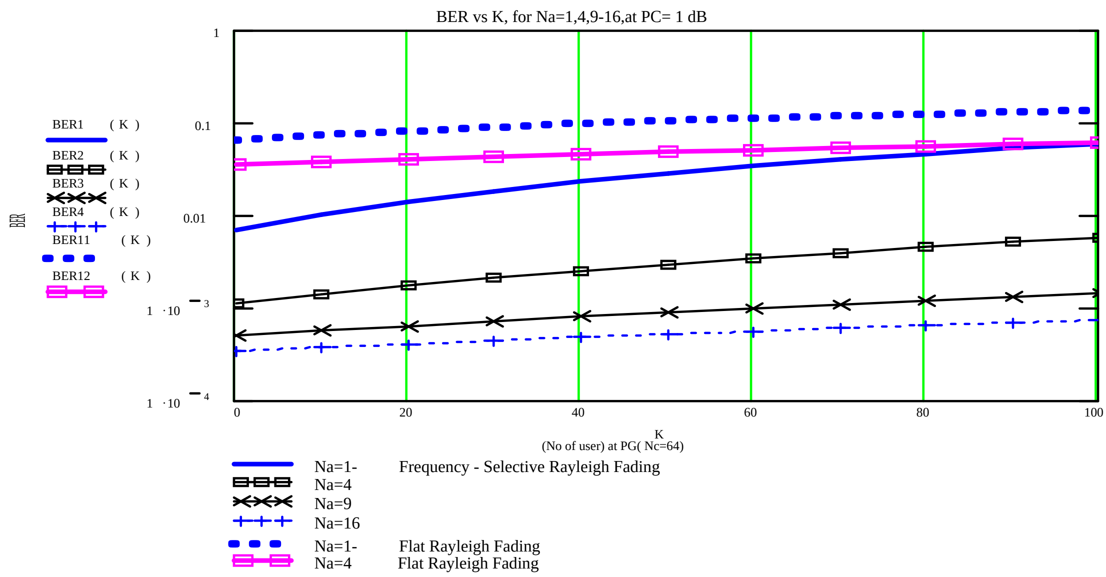


Figure (2): BER vs. K, for varying N_a ; SNR =10dB; N_c =64; proposed scheme under the Frequency - Selective Rayleigh fading& Flat-Rayleigh fading.

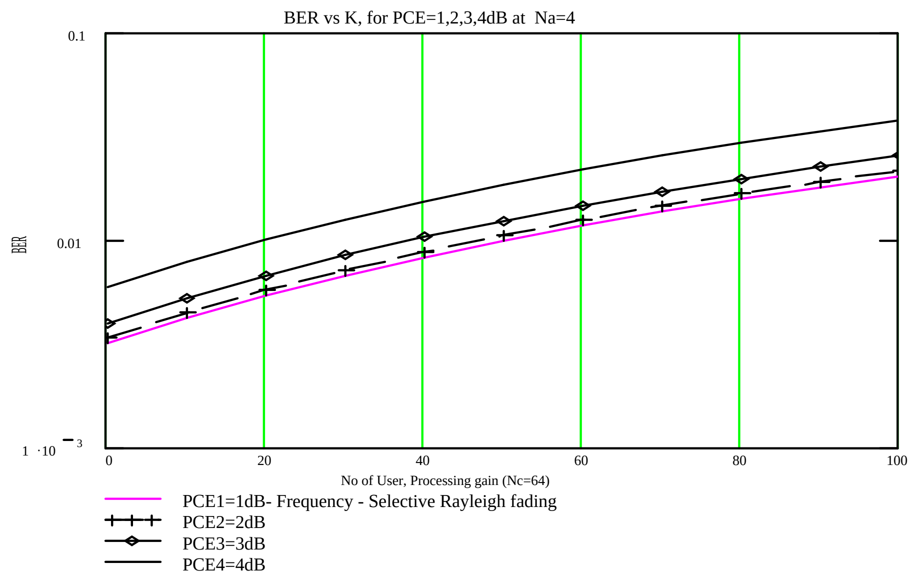


Figure (3): BER vs. K for *varying* PCE =1, 2, 3, 4 dB; Na=4, L=4 paths respectively assuming, Rayleigh fading Channels.

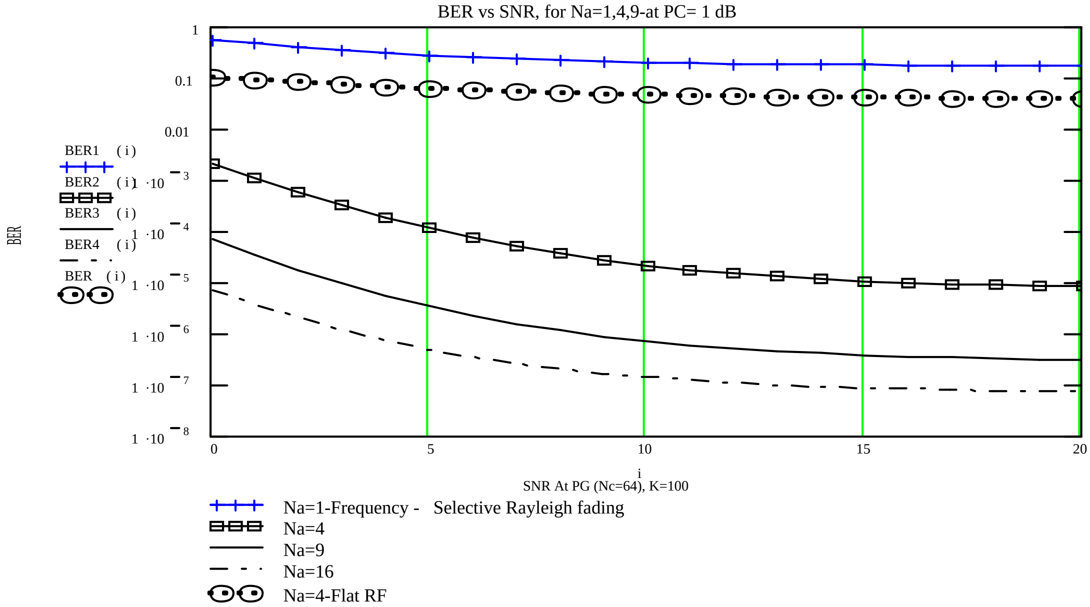


Figure (4): BER vs SNR (dB) for Comparison between the CDMA systems and the proposed scheme under the Frequency - Selective Rayleigh fading and Flat- Rayleigh fading, -PCE =1 dB; Na=(1,4,9,16), K =100 user with L=4 paths, N_c =64.

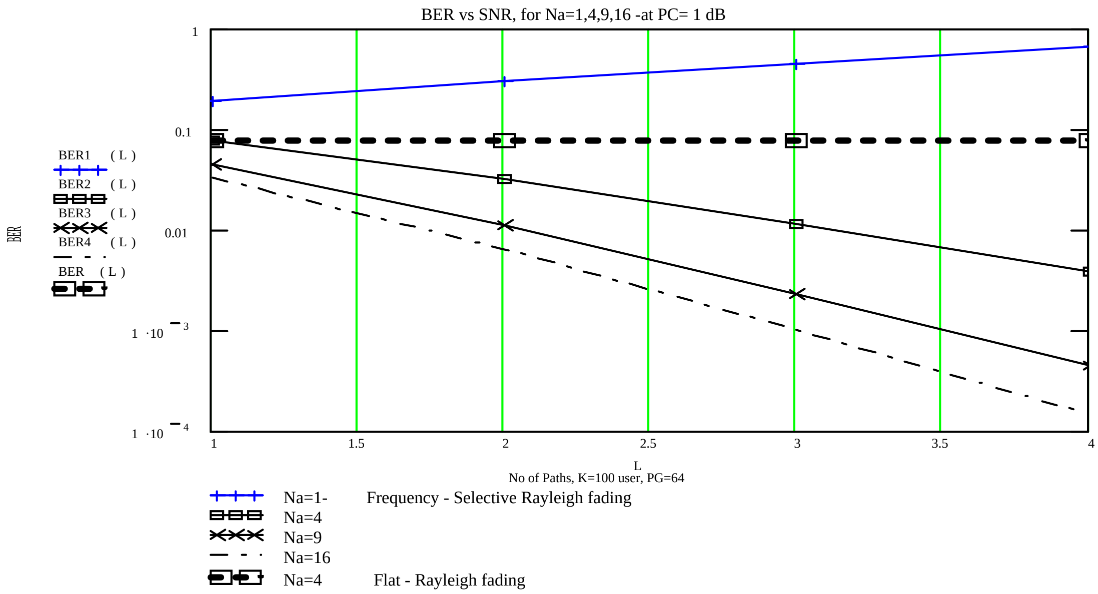


Figure (5): BER vs. L Nº of Multi-paths, for varying Na=1,4,9,16; SNR =10dB with K=100 user assuming Frequency- Selective Rayleigh fading and Flat- Rayleigh fading, the PCE =1dB; and N_c =64 respectively.

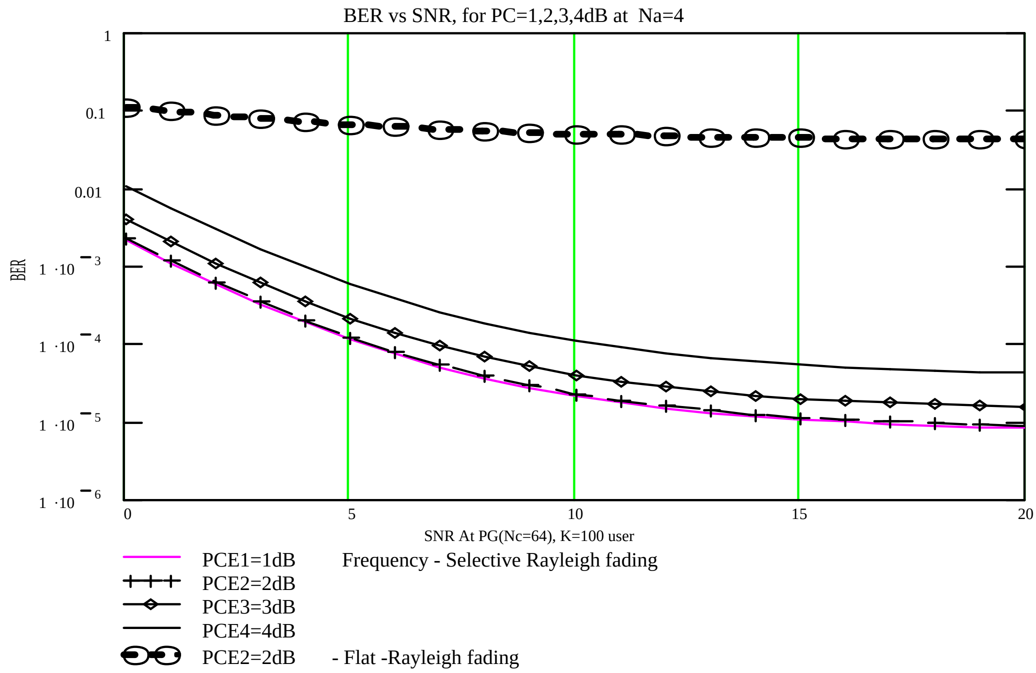


Figure (6): BER vs SNR (dB) for varying the PCE =1,2,3,4 dB Comparison under the Frequency - Selective Rayleigh fading and Flat- Rayleigh fading,; Na=4, K =100 user with 6 paths and N_c =64 respectively.