Enhancement of CDMA system using Antenna Arrays and Power Control Error in a Multipath Fading Environment

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ABSTRACT

IN wireless direct-sequence code-division multiple access (DS/CDMA) systems, multiple access interference (MAI) and multipath fading are two major channel impairments that degrade system performance. The paper provides a new analytical expression for the outage and bit-error probability (BEP) of CDMA systems. We analyze the uplink outage capacity improvements in CDMA systems using receive antenna array and power control schemes that can track multipath fading. These expressions account for adverse effects such as path loss (L), 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) and spatial diversity (mitigates against Rayleigh fading). In this paper, we analyze the outage capacity improvements that can be achieved by combating these undesired effects through the use of antenna arrays. Employing antenna arrays at the receiver enables signal reception through multiple independent channels. The channel is modeled as slowly varying Nakagami fading with lognormal shadowing and path loss. The use of antenna arrays helps improve the systems performance by increasing channel capacity and spectrum efficiency, extending range coverage, tailoring array shape, steering multiple antennas to track many mobiles, and electronically compensating for the aperture distortion. It also reduces multipath fading, co-channel interference, system complexity and cost, bit-error rate (BER), and outage probability. We show that by controlling the power level of a user at the output of the diversity combiner and imposing the condition that a user does not transmit when in a deep fade; the average intercell 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.

Index Terms: **CDMA system, maximal ratio combining (MRC), power control error, Nakagami-m; Rayleigh fading, BEP.**

1 INTRODUCTION:

System utilizing code-division multiple accesses (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 [1]. 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.

Antenna arrays have been recognized by most third 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 ever-increasing demands for a variety of wideband services such as the high-speed Internet access and high-quality video transmission render the wideband DS-CDMA system the most promising candidate. In CDMA systems, the transmitted signal is attenuated, reflected and refracted by many obstacles along the paths between the transmitter and the receiver. Early propagation experiments [2] indicate the Nakagami-rn distribution is one of the most versatile models to describing the fading statistics. The Nakagami-m distribution includes the Rayleigh distribution as a special case for m=l; it can also well approximate the Ricean fading when m>1 , with one-tone mapping between the fading parameter m and Ricean factor (R_k). An application of antenna arrays has been suggested in recent years for mobile communications systems, to overcome the problems of single-antenna system.

The main problem in CDMA is multiple access interference because all users use the same frequency at the same time and the PN code is not orthogonal. The distance between base stations and mobile station also affects the signal strength received by the base station. Users that were located closer to the base station will be more dominating than the user who is relatively further. This problem can be over-come by power control by the process so that the average received power at base station is same for each user. 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 [1, 2]. The standard deviation of the received signal power is defined as the power control error (PCE) and is typically of the order of 1.5–2.5 dB. While large-scale fading effects are compensated by power control, small-scale fading can be mitigated by space–time diversity provided by an antenna array along with a Rake receiver. Power control to mitigate Rayleigh fading in CDMA system has been studied in [3] and evaluation about CDMA performance using diversity technique is shown in [3]. The purpose of this research is to determine the performance improvement for system when use combined power control and diversity technique on the receiver using 2-branch and 3-branch antenna. The idea is the received signal that experience fading is overcome by diversity technique then power control works to make fading shallower.

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 (intercell interference) due to the occurrences of deep fades, in which case the users transmit at high power levels to compensate for it [4]. The signal received at the base station from a power-controlled user can be modeled as governed by the log-normal distribution [5, 6]. The standard deviation of the received signal power is defined as the power control error (PCE) and is typically of the order of 1- 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 model is given in Section 2. The BER Performance analysis power control error in combination with antenna array over Nakagmi-m 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 MODEL

We consider the reverse link of a coherent DS-CDMA system. There are total K users with identical average transmitted power, P, in a single cell. The interference from the neighbor cells is ignored in this analysis, considering that it is relatively small comparing with intra-cell interference. The transmitted signal for the k^{th} user can be written as:

$$S_k(t) = \sqrt{2P_k} c_k(t) b_k(t) \cos[\omega_c t + \phi_k^0] \quad (1)$$

Where ω_c, is the common carrier frequency, $c_k(t)$, $b_k(t)$ and $\phi_k^0(t)$ denote the k^{th} user's binary spreading sequence, data waveform and carrier phase shift. LetT_c, andT_b be the chip duration and the data bit duration, then $N=T_b/T_c$, is the processing gain of the spread spectrum system.

The general wideband CDMA systems channel is usually represented by a tapped-delay-line model. The equivalent low pass vector channel is described by the time-variant impulse response.

$$h(t;\tau) = \sum_{l=0}^{L_p-1} \delta[\tau - \tau_l] * a_l(t) \quad (2)$$

There are a total of L_p multipath components, and τ_l is the path delay. The l^{th} channel vector, which is itself a linear combination of a large number of path vectors that has approximately the same delay, is defined as:

$$a_l(t) = A(\varphi_l,\theta_l).\alpha_l.e^{j\phi_l(t)} \quad (3)$$

Where $A(\varphi_l,\theta_l)$ represents the array response vector in terms of the azimuthally angle φ_l and elevation angle θ_l. We restrict our interest to the horizontal plane only, i.e. $\theta_l = \pi/2$. While $\alpha_l.e^{j\phi_l(t)}$is fading statistics are characterized.

For a N_a- element uniform linear array with the element spacing d, we have:

$$A(\varphi_l) = [1 \;\; e^{-j2\pi d \sin\phi_l/\lambda} \ldots e^{-j2\pi(N_a-1)d \sin\phi_l/\lambda}]^T \quad (4)$$

-Each path is faded independently, and the fading statistics are characterized by $(\alpha_l.e^{j\phi_l(t)})$. In a Nakagami fading environment, $\{\alpha_l\}_{t=0}^{L_p-1}$ is independent Nakagami-m distributed signal envelope with pdf given in:

$$P(\alpha_l) = \frac{2}{\Gamma(m_l)} \cdot \left(\frac{m_l}{\Omega_l}\right)^{m_l} \cdot \alpha_l^{2m_l-1} \cdot e^{-\frac{m_l\alpha_l^2}{\Omega_l}} \quad (5)$$

Where $\Gamma(.)$ is the Gamma function, $\Omega_l = \overline{\alpha_l^2}$: is the average power on l^{th} path, the phase ϕ_l is unifor-mmly distributed over the range $[0,2\pi)$, and $m_l \geq 0.5$ is the fading parameter. [2] Assuming an exponential multipath intensity profile (MIP) distribution for all users, i.e. $\Omega_l = \Omega_0 e^{-l\delta}$,

Where Ω_0 is the average signal strength corresponding to the first incoming path, and δ is the rate of average power decay, with δ = 0 corresponding to constant MIP assumption. Define the normalized array spatial correlation matrix as Following:

$$R_s^{(l)} = \int_{\phi_0-\pi}^{\phi_0+\pi} A(\varphi_l).A^H(\varphi_l).P(\varphi)d\varphi \quad (6)$$

Where $P(\varphi)$ represents the angular power spectrum (APS). In the numerical evaluation, we will use spatial correlation derived under truncated Gaussian APS [6], which is the function of antenna spacing, mean angle-of-arrival (AOA) and the angle spread and $A^H(\varphi_l)$ as complex conjugate transpose of a matrix (N_a- element uniform linear array for equation (4)). The equivalent low-pass received signal for asynchronous operation is given in [7] as

$$r(t) = \sum_{k=1}^{K}\sum_{l=0}^{L_p-1} \sqrt{2P_k} c_k(t-(\tau_k + lT_c)) b_k(t-(\tau_k + lT_c)) \,.\, a_{l,k} \cos[\omega_c(t-(\tau_k + lT_c)) + \theta_k^0] + n(t) \quad (7)$$

Where $(\tau_k + lT_c)$ is the l^{th} path delay of the k^{th} user, assumed to be independent identically distributed (i.i.d). random variable uniform in [0, T_b] , $\theta_{l,k} = \theta_k^0 + \phi_{l,k}$ is the overall path phase shift, i.i.d. uniform random variable over [0,2π), and n(t) represents the complex additive white Gaussian noise(AWGN) with the noise terms $N_{I,Q}^K$ and the MAI terms $M_{I,Q}^K$ For zero mean and two-sided spectral density $\eta_0/2$.

The received powers $P_k, k = 1, \ldots, K$, are the result of path loss, shadowing, and imperfect power control error (PCE) and are modeled as i.i.d. random variables with log-normal distribution. If P_k has a log-normal distribution, then the received power expressed in decibels, $\alpha_k = 10\log_{10}P_k$, has a normal distribution with mean m_α and variance σ_α^2. The standard deviation of is the PCE measured in decibels. Since $\alpha_k < m_\alpha$ with probability 0.5, $10^{m_\alpha/10}$ is the median value of P_k [8].

3. BER Performance Analysis over Nakagmi-m Fading Channel:

The BER of coherent DS-CDMA system is derived in [9] with an exponentially decaying power delay profile, and assuming identical fading parameters. The closed form approximation to the BER is accurate for small values of the power decay factors. [9] Extended the analysis to non-identical and non-integer fading parameters along different RAKE paths. The exact BER expression is represented by an infinite-limit integral, with the integrand consisting of nested trigonometric functions. The RAKE receiver with antenna array (referred as 2DRAKE receiver) was initially proposed by Naguib [10] to exploit both

temporal and spatial diversity. The BER and outage probability are derived for M-ary orthogonal modulation and for BPSK [3] in independent Rayleigh fading. In addition, the field test results show that the statistical correlation of fading signals received at different antenna elements exist even if the antenna separation is more than ten wavelengths apart [λ_0]. While it is reasonable and mathematically convenient to assume independent fading along different RAKE paths, the spatial correlation should be taken into account in the 2D-RAKE receiver. In [9,11] ,assuming correlated fading between antennas of a 2D-RAKE receiver, the Signal-to-Noise ratio (SNR) at the output of combiner is approximated by a gamma random variable with the first two moments identical with the exact distribution of SNR, and the average BER has the same form as [11].

Assuming the matched filter is matched to the spreading sequence of the desired user, i.e. the 1st user, and the synchronization is achieved with respect to the initial path arriving at the antenna array(N_a). The decision variable at the output of L_r finger RAKE receiver. Here, we assume perfect channel vector estimation, and MRC combining, i.e. $a_{l,1}$ and employ Gaussian assumption to model multiple access interference, thus the decision variable U is also a Gaussian random variable with the mean

$$\bar{U} = \sqrt{2E_bT}\sum_{l=0}^{L_r-1}\left| a_{l,1}\right|^2 \quad (8)$$

and the variance [2,5]

$$\sigma_u^2 = E_bT\Omega_0\left\{\frac{(2K+1)q(L_p,\delta)-3}{12N} + \frac{\eta_0}{4E_b\Omega_0}\right\}\sum_{l=0}^{L_r-1}\left| a_{l,1}\right|^2 \quad (9)$$

Where $E_b = P\,T$ is the average transmitted energy-per-bit, While N is pros sing gain (PG) and

$$q(L_p,\delta) = \sum_{l=0}^{L_p-1} e^{-l\delta}$$

Where δ is MIP average power decay factor; L_r is the No of resolvable multipath (No of finger RAKE receiver) and L_P is the No of propagation paths arriving at the receiver.

Then the instantaneous SINR at the output of 2D-RAKE receiver is given by:

$$\gamma = \bar{U}/2\sigma_u^2 = (E_b/N_e)\sum_{l=0}^{L_r-1}\left| a_{l,1}\right|^2 \quad (10)$$

Where, $N_e = E_b\Omega_0\{\frac{(2K+1)q(L_p,\delta)-3}{3N} + \frac{\eta_0}{E_b\Omega_0}\}$,is viewed as the equivalent two-sided interference plus

noise power spectral density. The equivalent average SINR per bit corresponding to the first path is expressed as:

$$\bar{\gamma}_e = E_b\Omega_0/N_e = [\frac{(2K+1)q(L_p,\delta)-3}{3N} + \frac{1}{\bar{\gamma}_0}]^{-1}$$

$$\bar{\gamma}_e = [\frac{(2K+1).\sum_{l=0}^{L_p-1} e^{-l\delta} - 3}{3N} + \frac{\eta_0}{E_b.\Omega_0}]^{-1}$$

$$= [\frac{(2K+1).\sum_{l=0}^{L_p-1} e^{-l\delta} - 3}{3N} + \frac{1}{SNR.\Omega_0}]^{-1} \quad (11)$$

Where $\bar{\gamma}_0 = (E_b/\eta_0).\Omega_0$ the averaged is received SNR per bit corresponding to the first path. Similarly, $\bar{\gamma}_l = (E_b/N_e).\Omega_l = (E_b/N_e).\Omega_0 e^{-l\delta} = \bar{\gamma}_e.e^{-l\delta}$ is averaged SINR contributed from l^{th} path, Denoting $a_{l,1}^j$ as the j^{th} element of $a_{l,1}$, and defining: $\gamma_l = E_b/N_e.\left| a_{l,1}\right|^2$; and $\gamma_{l,j} = E_b/N_e.\left| a_{l,1}{}^j\right|^2$ as the

-Instantaneous SINR on the I-th RAKE finger, and on the j^{th}, array elements of the l^{th} RAKE finger, respectively, we can rewrite γ as follows, i.e.

$$\gamma = \sum_{l=0}^{L_r-1}\gamma_l = \sum_{l=0}^{L_r-1}\sum_{j=0}^{N_a}\gamma_{l,j} \quad (12)$$

From (12), we can see that the performance improvement comes from two factors: one is the SINR gain, which is proportional to the number of array elements, if signals arriving on antennas are indepen- dent; and the other is the diversity gain, which comes from the space diversity of multiple antennas and path diversity of RAKE fingers. For the general case of correlated received signals on antennas, the characteristic function of γ_l, is given in [12,13] as

$$\emptyset_l(t) = \left| I_{N_a} - jt\,(\overline{\gamma}_l/m_l)R_s^l \right|^{-m_l} \quad (13)$$

The characteristic function of γ is simply;

$$\psi(t) = \prod_{l=0}^{L_r-1} \left| I_{N_a} - jt\,(\overline{\gamma}_l/m_l)R_s^l \right|^{-m_l}$$

$$= \prod_{l=0}^{L_r-1} \left| I_{N_a} - jt\,(\overline{\gamma_e}\, e^{-l\delta}/m_l)R_s^l \right|^{-m_l} \quad (14)$$

The average error probability in the presence of fading is obtained by averaging the conditional error probability over the pdf of γ . The conditional error probability for coherent binary phase-shift-keying (CBPSK) is given by [2, 11, 12], i.e. $P(e/\gamma) = Q(\sqrt{2\gamma})$, where Q(x) is the Gaussian Q-function Using the alternative representation of Q(x) given in [14- 19], $Q(x) = (1/\pi)\int_0^{0.5\pi} \exp(x^2/\sin^2(\theta))\,d\theta;\ \ x \geq 0$;

-The average BER can then be written as:

$$P_e = (1/\pi)\int_0^{\infty}\int_0^{0.5\pi} \exp\left(-\gamma/\sin^2(\theta)\right) P(\gamma)\,d\gamma$$

$$= (1/\pi)\int_0^{0.5\pi} \psi(t)\Big|_{it=\left(-\frac{1}{\sin^2(\theta)}\right)} d\theta$$

$$P_e = (1/\pi)\int_0^{0.5\pi} \prod_{l=0}^{L_r-1} \left| I_{N_a} + jt\left(\overline{\gamma_e}\, e^{-l\delta}/m_l.\ \sin^2(\theta)\right)R_s^l \right|^{-m_l} d\theta \quad (15)$$

The above expression only requires an integral with finite limits, and it is easy and accurate to use numerical integration by setting N_a=2, the average BER for the dual diversity receiver (L) is obtained as:

$$P_2 = (1/\pi)\int_0^{0.5\pi} \prod_{l=0}^{L_r-1} [\{1 + \left(\overline{\gamma_e}/m_l.\sin^2(\theta)\right)\}^2 - \left(\overline{\gamma_e}\, e^{-\delta}/m_l.\sin^2(\theta)\right)^2.\left|\rho_{12}\right|^2]^{-m_l}\, d\theta \quad (16)$$

Where ρ_{12} is the spatial correlation coefficient between two antennas, For $N_a > 2$, the integrand of (15) expressed in terms of spatial correlation becomes cumbersome, the alternative representation of the determinant of matrix is desirable. Since R_s^l is positive definite, it can be easily shown that the following equation holds for any real, positive g

$(g = jt\left(\overline{\gamma_e}\, e^{-l\delta}/m_l.\ \sin^2(\theta)\right))$,

$$\left| I_{N_a} + g.R_s^l \right| = \prod_{l=0}^{L_r-1} 1 + g.\lambda_i \quad (17)$$

Where $(\lambda_i)_{l=1}^{N_a}$, are R_s^l Eigen values therefore, (15) can be rewritten as

$$P_e = (1/\pi)\int_0^{0.5\pi} \prod_{l=0}^{L_r-1}\prod_{l=0}^{N_a}[1 + \overline{(\gamma_e}\, e^{-l\delta}/m_l.\sin^2(\theta)).\lambda_{l,i}]^{-m_l}\, d\theta$$
(18)

For independent antenna branches, i.e. $\lambda_i = 1$, i = 1 ,..., N_a, (18) is simplified to (19). Power control for DS-CDMA reverse link is the single most important system requirement because of the near/far effect. In this case, it is necessary to have a dynamic range for control on the order of 80dB [16, 20].

$$P_{indep}(e) = (1/\pi)\int_0^{0.5\pi} \prod_{l=0}^{L_r-1}\left[1 + \overline{(\gamma_e}\, e^{-l\delta}/m_l.\sin^2(\theta))\right]^{-N_a.m_l} d\theta$$
(19)

For the forward link, no power control is required in a single cell system, since all signals are transmitted together and hence vary together. However in multiple cell systems, interference from neighboring cell sites fades independently from the given cell site and thereby degrades performance. Thus it is necessary to apply power control in this case also, to reduce inter cell interference. Power control error $[e^{0.5(\mu 1.\sigma_m)^2}]$

$$P_{indep}(e) = (1/\pi) * e^{0.5(\mu 1.\sigma_m)^2}\int_0^{0.5\pi} \prod_{l=0}^{L_r-1}[1 + \overline{(\gamma_e}\, e^{-l\delta}/m_l.\sin^2(\theta))]^{-N_a.m_l}\, d\theta \quad (20)$$

4 Numerical Results:

In this section, we present several numerical examples to illustrate the impacts of the operating environment (i.e. the diversity order, the delay spread and angular spread) on the BEP performance improvement with 2D-RAKE receiver in Nakagami-m fading channels. Without loss of generality, the Base Station antenna array is assumed to be a Uniform linear array with identical spacing$d = 0.5\lambda$ between elements, broadside receiving ($\varphi_l = 0$), 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_P, is common to all the users. The effect of L_P, δ and the number of users in the cell, K, on the equivalent SINR is given by (11). The processing gain N, is usually constrained by the available bandwidth and the inform-ation rate. In all the numerical examples that follow, N is kept constant at 128. For notational simplicity, the Nakagami fading parameters used in each plot is given as a vector $\overline{m}_{L_P} = [m_0, m_1, \ldots, m_{L_P-1}]$ of length Lp, corresponding to the L, resolved paths at the receiver. In the case that the fading parameters are identical along all the resolved paths, we simply give that value. The above expression only requires an integral with finite limits, and it is easy and accurate to use numerical integration tools in MathCAD software package to evaluate the results from equation (11) and (20) form.

Fig. 1 shows the average BEP of 2D-RAKE receiver vs SNR for the case that varying number of antennas with N_a= 14,9,16 antennas, total K=100 users, Prossing gain (PG) N=64, in m = 2 Nakagmi fading channel, with maximal 6 resolvable multipaths and MIP decay factor δ =1. It is clear that employing multiple antennas dramatically reduces the irreducible BER for 1D-RAKE receiver. In addition, if RAKE receiver cannot resolve all the multipaths, i.e. $L_r < L_P$, there is a sharp performance degradation. The result shows that for as SNR=10 dB, it is found that BER= 0.13 at single antenna; BER =0.01 at N_a =4; BER =2.46 * 10^{-4}at N_a =9 while BER decrease to =1.624 * 10^{-6} at antenna array (N_a=16); BER decrease so for increase number of antenna, there is a tremendous improvement in the BER depending on the increase number of antenna. At the same other factor. We also see that a high advantage in the system performance was obtained by using antenna array.

Fig. 2 shows the average BEP of 2D-RAKE receiver vs SNR for the case that varying Prossing gain PG=32, 64, 128 with number of antennas N_a= 4 antennas, total K=100 users, in m = 2 Nakagmi fading channel, with maximal 6 resolvable multipaths and MIP decay factor δ =1; PCE=1. there is a sharp performance degradation. The result shows that for as SNR=10 dB, it is found that BER= 0.043 at PG32; BER =0.01 at PG64;

while BER decrease to =1.177 * 10^{-3} at PG128; BER decrease so for increase PG, there is a tremendous improvement in the BER depending on the increase PG. We also see that a high advantage in the system performance was obtained by High Prossing Gain.

Fig. 3 shows the average BEP of 2D-RAKE receiver vs K number of user for the case that varying number of user with N_a= 1,4,9,16 antennas, SNR=10dB, Prossing gain PG=64, in m = 2 Nakagmi fading channel, with maximal 6 resolvable multipaths and MIP decay factor δ =1, PCE=1 . The result shows that for as K=40, it is found that BER= 0.115 at single antenna; BER =6.85 * 10^{-3} at N_a =4; BER =1.014 * 10^{-4} at N_a =9 while BER decrease to =3.475 * 10^{-7} at antenna array N_a=16; BER decrease so for increase number of antenna, there is a tremendous improvement in the BER depending on the increase number of antenna. While BER increase so for increase number of user. We also see that a high advantage in the system performance was obtained by using antenna array.

Fig. 4 shows the average BEP of 2D-RAKE receiver vs SNR for the case that varying Power control error PCE=1,2,3,4 dB with number of antennas N_a= 4 antennas, total K=100 users, PG=64 in m = 2 Nakagmi fading channel, with maximal 6 resolvable multipaths and MIP decay factor δ =1. The result shows that for as SNR=10 dB, it is found that BER= 0.011 at PCE=1dB; BER =0.012 at PCE=2dB; BER =0.014 at PCE=3dB while BER decrease to =0.02 at PCE=4dB; BER increase so for increase PCE, there is a tremendous improvement in the BER depending on the increase PCE. We also see that a high advantage in the system performance was obtained by increase PCE.

Fig. 5 shows the average BEP of 2D-RAKE receiver vs K number of user for the case that varying Power control error PCE=1,2,3,4 dB with number of antennas N_a= 4 antennas, SNR=10 dB , PG=64 in m = 2 Nakagmi fading channel, with maximal 6 resolvable multipaths and MIP decay factor δ =1. The result shows that for as K=40, it is found that BER= 7.15* 10^{-3}at PCE=1dB; BER =7.614 * 10^{-3} at PCE=2dB; BER =8.929 * 10^{-3} at PCE=3dB; while BER increase to =0.013 at PCE=4dB; BER increase so for increase 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.

Fig. 6 shows the average BEP of 2D-RAKE receiver vs SNR for the case that varying m- Nakagmi fading channel, $\overline{m}_6 = [m_0, m_1, \dots, m_{Lp-1}]$ = [0.6,0.75, 1, 2,3,4], with maximal 6 resolvable multipaths; PCE=1 dB with number of antennas N_a= 4 antennas, , PG=64 in and MIP power decay factor δ =1. The result shows that for as SNR=10 dB, it is found that BER= 2.15* 10^{-3}at $m_0 = 0.6$; BER =1.138 * 10^{-3} at $m_2 = 1$; BER =4.322 * 10^{-4} at $m_4 = 3$ while BER decrease to =3.676 * 10^{-6} at $m_4 = 4$; BER increase so for increase m, there is a tremendous improvement in the BER depending on the decrease m. We also see that a high advantage in the system performance was obtained by increase m.

Fig. 7 shows the average BEP of 2D-RAKE receiver vs K No of user for the case that varying m- Nakagmi fading channel, $\overline{m}_6 = [m_0, m_1, \dots, m_{Lp-1}]$ = [0.65,0.85, 1, 2,3,4], with maximal 6 resolvable multipaths; PCE=1 dB with number of antennas N_a= 4 antennas, , PG=64 in and MIP power decay factor δ =1. The result shows that for as K=40 user, it is found that BER= 2.413* 10^{-3}at $m_5 = 0.65$; BER =1.569 * 10^{-3} at $m_4 = 0.85$; BER =4.95 * 10^{-4} at $m_3 = 1$; BER =3.308* 10^{-4} at $m_1 = 3$ while BER decrease to =2.629 * 10^{-4} at $m_0 = 4$; BER decrease so for increase m, there is a tremendous improvement in the BER depending on the decrease m. We also see that a high advantage in the system performance was obtained by decrease m.

Fig. 8 shows the average BEP of 2D-RAKE receiver vs SNR for the case that varying MIP power decay factor δ = 1,0.8,0.4,0.2 ; m=2 Nakagmi fading channel, with maximal 6 resolvable multipaths; PCE=1 dB with number of antennas N_a= 4 antennas, , PG=64. The result shows that for as SNR=10 dB, it is found that BER= 5.776* 10^{-4}at factor δ = 1; BER =2.272 * 10^{-3} at δ = 0.6 ; BER =2.028 * 10^{-3} at δ = 0.4 while BER decrease to =1.5 * 10^{-3} at δ = 0.2; BER increase so for increase δ, there is a tremendous improvement in the BER depending on the δ. We also see that a high advantage in the system performance was obtained by increase δ.

Fig. 9 shows the average BEP of 2D-RAKE receiver vs K No of user for the case that varying MIP power decay factor δ = 1,0.8,0.4,0.2 ; m=2 Nakagmi fading channel, with maximal 6 resolvable multipaths; Power control error PCE=1 dB with number of antennas N_a= 4 antennas, , PG=64. The result shows that for as K=40 user, it is found that BER= 3.308* 10^{-4}at factor δ = 1; BER =6.373 * 10^{-4} at δ = 0.6 ; BER =1.226 * 10^{-3} at δ = 0.4 while BER decrease to =3.041 * 10^{-3} at δ = 0.2; BER decrease so for increase number of user, there is a tremendous improvement in the BER depending on the decrease K and increase δ. We also see that a high advantage in the system performance was obtained by increaseδ.

Fig. 10 shows the average BEP of 2D-RAKE receiver vs L_p No of multipath MRC for the case that L_r the same No of finger Rake Rx ($L_p = L_r$) and varying number of antennas with N_a= 14,9,16 antennas, total K=100 users, Prossing gain PG=64, in Nakagmi fading channel m = 2 and MIP decay factor δ =1. The result shows that for as SNR=10 dB, it is found that BER= 2.8* 10^{-3}at $L_r = 1$; BER =2.15 * 10^{-4} at $L_r = 3$; BER =2.15 * 10^{-4} at $L_r = 5$;while BER decrease to =7.9 * 10^{-6} at $L_r = 7$; BER decrease so for increase number of antenna, 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.

Fig. 11 shows the average BEP of 2D-RAKE receiver vs L_r No of finger Rake Rx for the case that varying number of antennas with N_a= 14,9,16 antennas, total K=100 users, Prossing gain PG=64, in m = 2 Nakagmi fading channel, with maximal 7 resolvable multipaths and MIP decay factor δ =1. The result shows that for as SNR=10 dB, it is found that BER= 2.8* 10^{-3}at $L_r = 1$; BER =2.15 * 10^{-4} at $L_r = 3$; BER =2.15 * 10^{-4} at $L_r = 5$;while BER decrease to =7.9 * 10^{-6} at $L_r = 7$; BER decrease so for increase number of antenna, 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.

Fig. 12 shows the average BEP of 2D-RAKE receiver vs L_r No of finger Rake Rx for the case that the case that varying m- Nakagmi fading channel, $\overline{m}_6$ =[0.65,0.85,1,2,3,4] with N_a= 4antennas, total K=100 users, Prossing gain PG=64, with maximal 7 resolvable multipaths and MIP decay factor δ =1. The result shows that for as SNR=10 dB, it is found that BER= 2.8* 10^{-3}at $L_r = 1$; BER =2.15 * 10^{-4} at $L_r = 3$; BER =2.15 * 10^{-4}

at $L_r = 5$;while BER decrease to =7.9 * 10^{-6} at $L_r = 7$; BER decrease so for increase number of antenna, 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.

5. CONCLUSION

A simple closed-form expression is derived to evaluate reverse link user capacity for CDMA systems with antenna array, antenna diversity and a Rake receiver in a multipath fading and multicell environment. Both transmit and receive antenna array are assumed in the system and signify cant capacity improvements are observed with an increase of the number of antenna elements. The capacity improvement due to the Rake receiver is also illustrated. The impact of the correlation between antenna groups on reverse link user capacity is analyzed. The relationships between the capacity and various system parameters, including the target SNR, CDMA processing gain, antenna array gain patterns and the number of Rake receiver fingers, number of multipath are reflected in the simple closed-form capacity equation.

-Closed loop power control can improve the BER performance of slow fading channel. However, power control is not perfect due to feedback delay and finite step size which produce residual variation of the SNR (power control error). For higher fading rates PCE becomes inefficient in that the improvement of BER performance by power control error is insignificant. With antenna diversity at the base station, it is found that the performance of power control improves significantly in slow fading channels. Power control is the most important system requirement for CDMA systems. For CDMA system to function effectively, we need to control the power; if power control is not implemented many problems such as the near-far effect will start to dominate and consequently will lower the capacity of the CDMA system. However, when the power control in CDMA systems is applied, it allows users to share resources of the system equally between themselves, leading to increased capacity.

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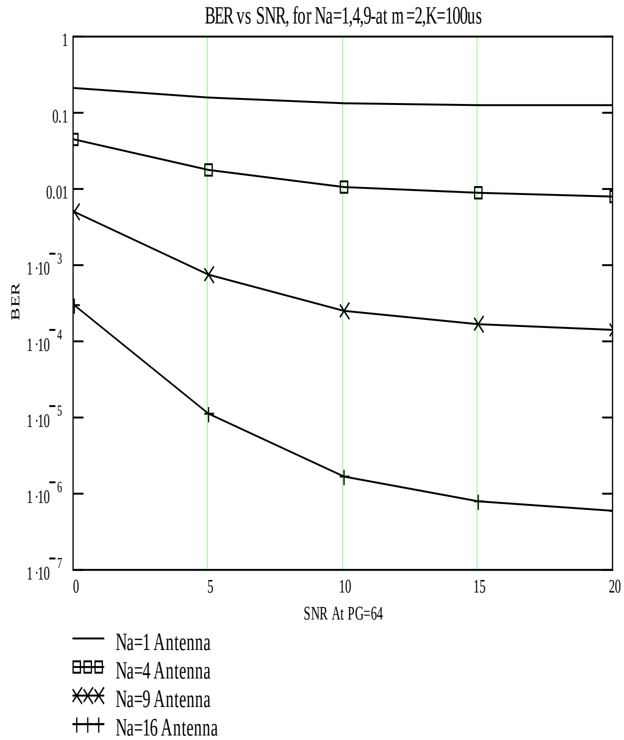

Fig 1. BER vs. SNR (dB) for varying Na=1,4,9,16; K =100 user with 6 paths assuming Nakagmi-m=2 fading Channels respectively.

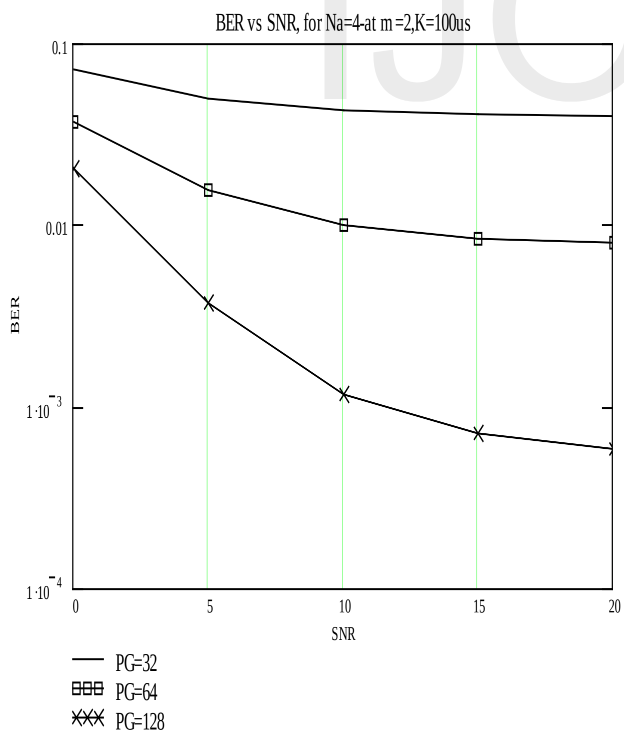

Fig 2. BER vs. SNR (dB) for varying PG= 32,64,128 at Na=4; K =100 user with 6 paths assuming Nakagmi-m =2 fading Channels respectively.

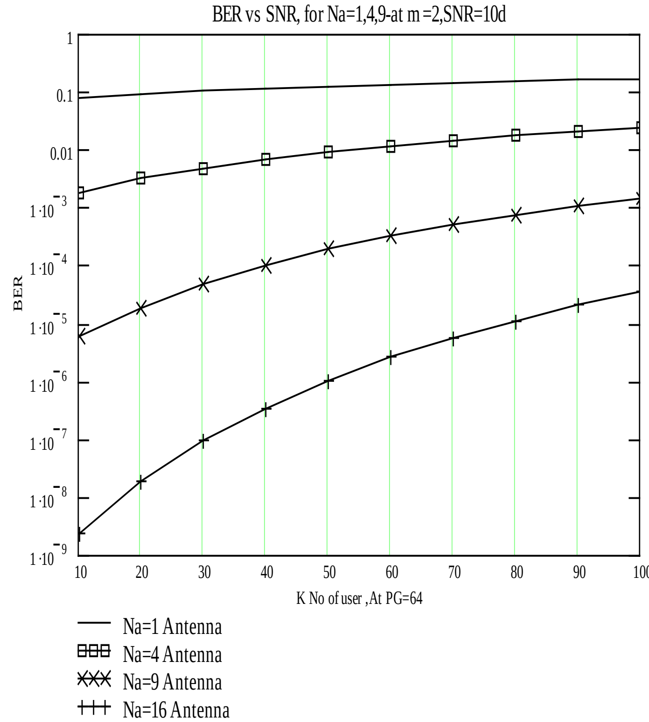

Fig 3. BER vs. K No of user , for *varying* Na=1,4,9,16; SNR =10dB with 6 paths assuming Nakagmi-m=2 Fading Channels respectively.

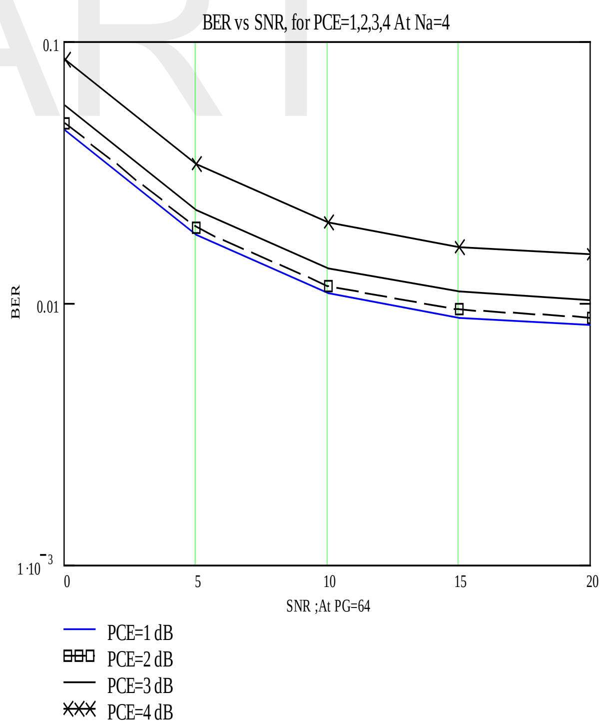

Fig 4. BER vs. SNR (dB) for *varying* PCE =1,2,3,4; Na=4, K =100 user ,PG=64 with 6 paths assuming Nakagmi-m=2 fading Channels respectively.

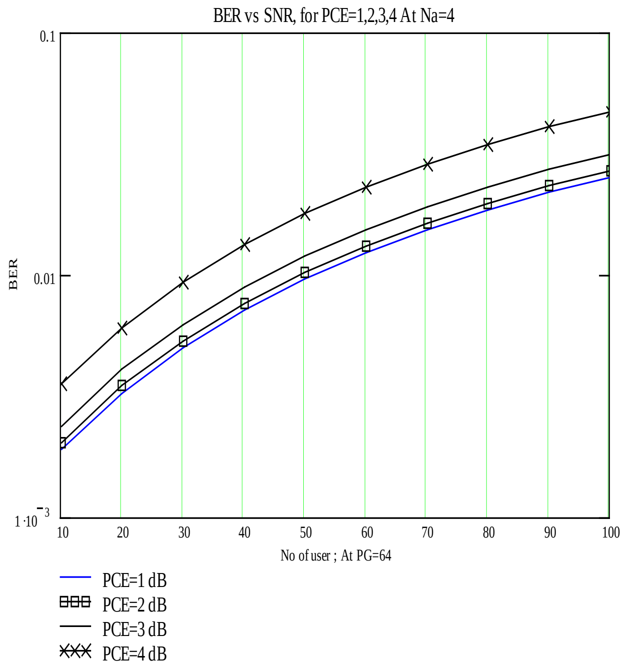

Fig 5. BER vs. K No of user for *varying* PCE =1,2,3,4 dB; Na=4, K =100 user with 6 paths respectively assuming, Nakagmi-m=2 fading Channels.

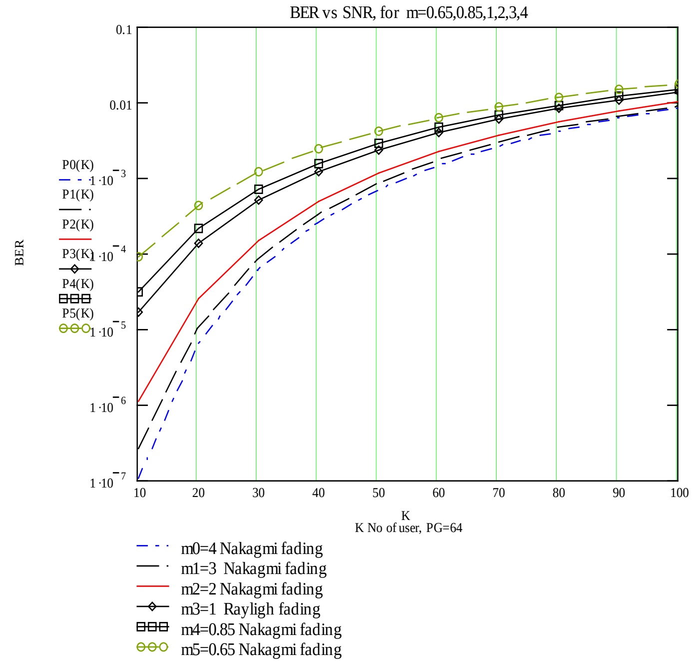

Fig 7. BER vs K No of user , for *varying* Nakagmi- fading Channels $\overline{m}_6$ = 0.65,0.85,1,2,3,4 respectively; at PCE =1 dB; Na=4,, K =100 user with 6 paths assuming, PG=64.

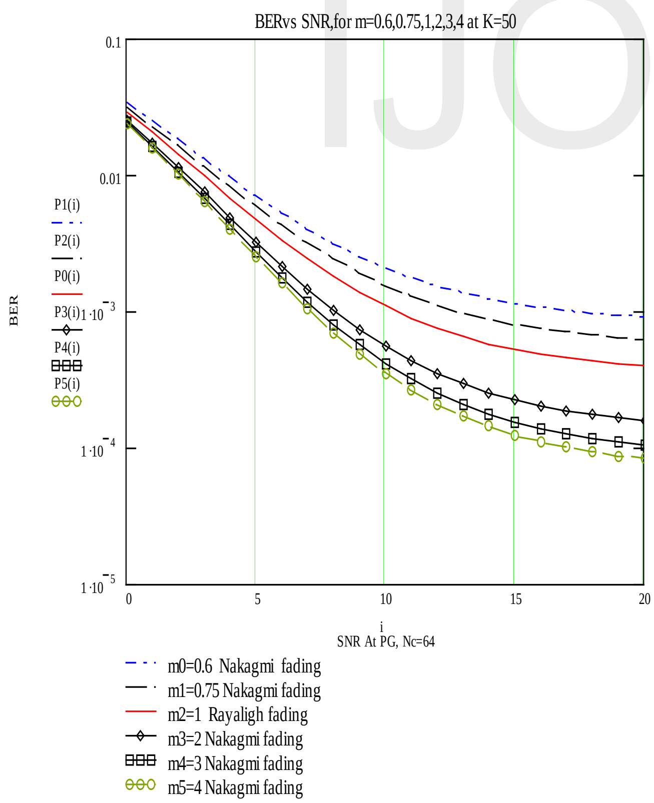

Fig 6. BER vs SNR for *varying* Nakagmi- fading Channels $\overline{m}_6 =$ 0.6,0.75,1,2,3,4 respectively; at PCE =1 dB; Na =4, K =50 user with 6 paths assuming, PG=64.

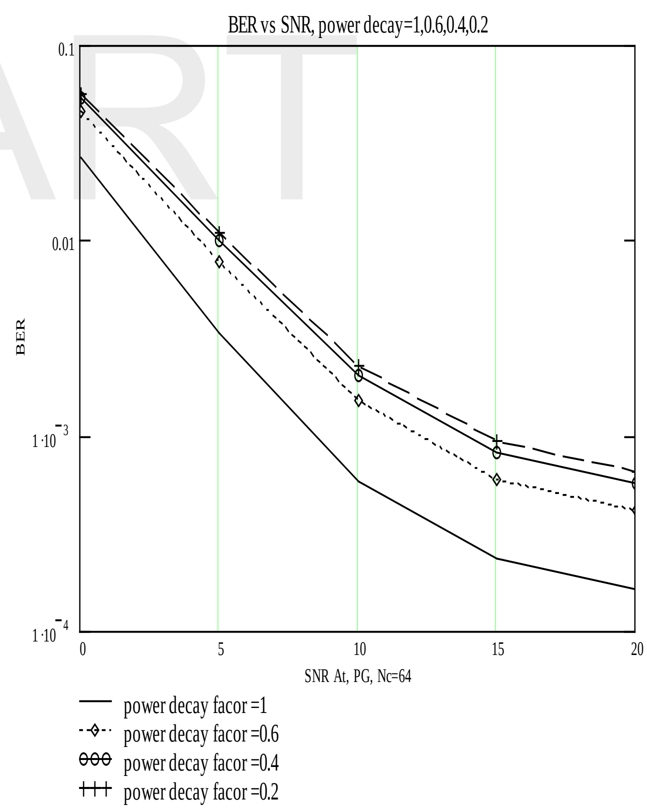

Fig 8. BER vs SNR for varying MIP power decay factor δ = 1,0.6,0.4,0.2 respectively; at PCE =1 dB; Na=4, K =50 User with 6 paths assuming, Nakagmi- m=2 fading Channels.

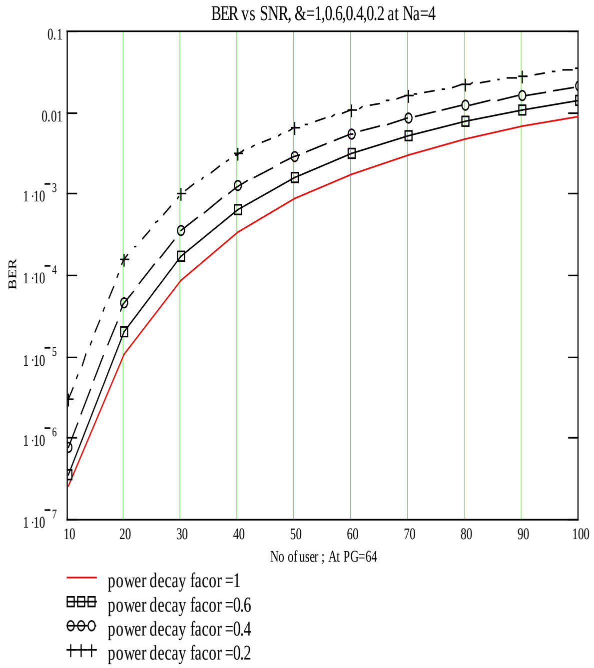

Fig 9. BER vs K No of user for varying MIP Power decay factor δ = 1,0.8,0.4,0.2 respectively; at PCE =1 dB; Na=4, K =100 User with 6 paths assuming, Nakagmi- m=2 fading Channels.

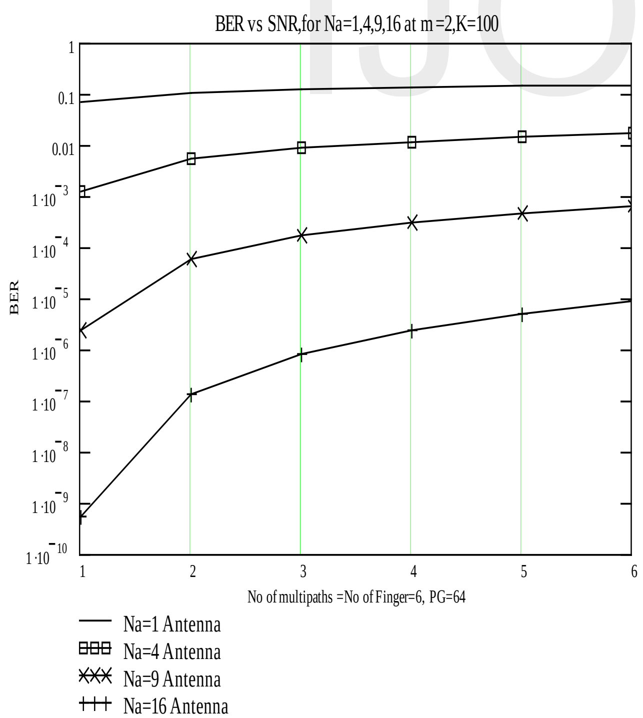

Fig 10. BER vs. L No of multipath for *the same No of Finger Rx ,varying* Na=1,4,9,16 respectively; at PCE =1 dB; δ = 1, K =100 User with 6 paths assuming, Nakagmi- m=2 fading Channels.

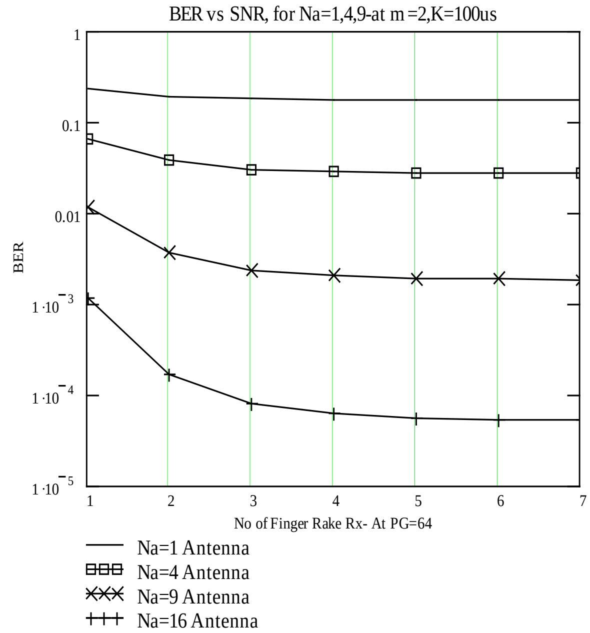

Fig 11. BER vs Lr No of Finger Rake Rx for varying Na=1,4,9,16 respectively; at PCE =1 dB; δ = 1, K =100 User with 6 paths assuming, Nakagmi- m=2 fading Channels.

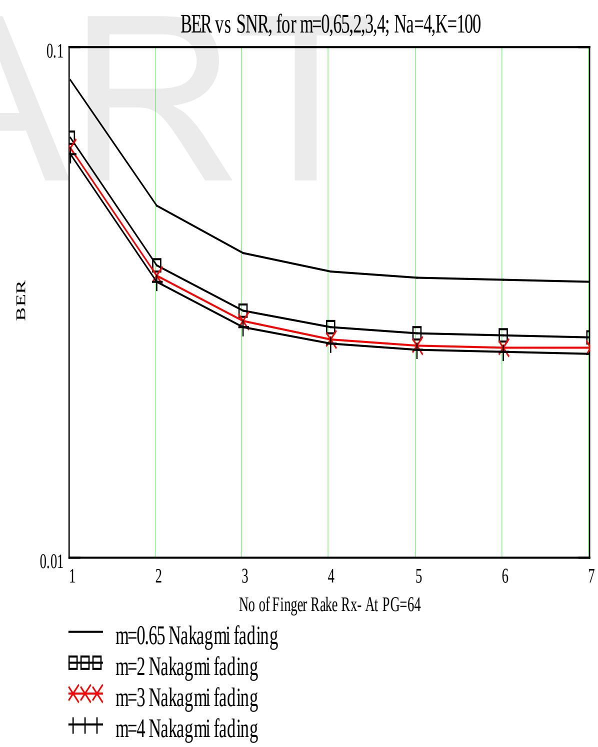

Fig 12. BER vs Lr No of Finger Rake Rx for varying Nakagmi- fading Channels $\overline{m}_6$ = 0.6,0.75,1,2,3,4 respectively; at PCE =1 dB; δ = 1, K =100 User with 4 Antenna.