By Using of the Gamma Variates to Analyze the performance of MC-DS-CDMA System over Selective Fading Channels

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ABSTRACT

A new pdf (probability density function) of SNR (signal-to-noise ratio) is proposed such that the complex procedure of traditional method can be abstained. The sum of correlated-gamma variates was considered for evaluating the system performance of MC-DS-CDMA (multi-carrier direct-sequence coded-division multiple-access) system operating in frequency selective fading channels in this paper. The analysis including multiple-user and single-user, are validating the fact that the performance degradation of the MC-DS-CDMA is sensitive to the correlation coefficient between the fading branches.

Key-words: *frequency selective channels, Gamma Varieties, MC-DS-CDMA system, RAKE receiver*

1: INTRODUCTION

The spread-spectrum techniques have been adopted as attractive multiple-access scheme in 3G (third-generation) wireless systems. Generally speaking, multi-carrier DS systems can be categorized into two types: (1) a combination of OFDM (orthogonal frequency division multiplexing) and CDMA, and (2) a parallel transmission-scheme of narrowband DS waveform in the frequency domain [1, 2]. Both aforementioned modulation methods have been dedicated to analysis by combining them with many varieties of assumption. In [3], the researchers, in order to obtain the average BER (bit error rate) performance for an MC-DS-CDMA system, employed three methods to approximate the pdf (probability density function) of the sum of *i.i.d.* (independent identical distribution), the Rayleigh random variable. In [4], the researchers evaluated the system performance of an MC-DS-CDMA system with MRC (maximal ratio combining) over the Rayleigh fading channel. The performance of an MC-CDMA with correlated envelopes was not only analyzed by Q. Shi, and M. Latva-aho [5], but the researchers also presented the effect of the correlated phases. Performance analyses of MC-CDMA and the MC-DS-CDMA systems operating in the presence of correlated Rayleigh fading channels were calculated, by T. Kim, et al [6], and W. Xu, and L. B. Milstein [7], respectively. Recently, the publication cited in [8] evaluated the performance of an MC-DS-CDMA system with partial band interference working in Nakagami-*m* fading channels. The same author in [8], assuming that the MC-CDMA system works in a correlated Nakagami-*m* fading environment, evaluated the average BER performance [9]. L. -L. Yang, and L. Hanzo [10] investigated the spacing between two adjacent subcarriers of the generalized MC-DS-CDMA system over Nakagami-*m* fading channels with the BER performance. Their results given that the best BER for the MC-DS-CDMA system will be obtained after the optimum subcarrier spacing and the orthogonal between the subcarrier can be kept. The characteristics of correlated and independent subcarrier for MC-CDMA system over frequency have been studied in [11], in which the authors evaluated the average BER of an uplink MC-CDMA system with MRC reception, and proposed the relationship between the correlation of the subcarries and the fading parameters.

We aim on the evaluation of the performance of MC-DS-CDMA system which is assumed working over a correlated Nakagami-*m* fading channel in this paper. In section 2 the MC-DS-CDMA system models are defined. Analytical expressions of BER performance for MC-DS-CDMA in correlated Nakagami-*m* channels is derived in section 3. The numerical results from adopting the examples with single and multiple-carrier are presented in section 4. In section 5 there is a brief conclusion was described.

2: SYSTEM MODELS

2.1:TRANSMITTER MODEL

In Fig. 1, the overall bandwidth of a MC-DS-CDMA system with all the subcarrier is given by $BW_M = (1+\mu)/MT_c$, where $0 < \mu \le 1$ is roll-off factor, and T_c is the chip duration. From the points described above, the total bandwidth of the MC-DS-CDMA system of the k-th user can be counted as $BW_T = (1+\mu)/T_c$. The transmitted signal can be written as [7]

$$s_k(t) = \sqrt{2E_c}\sum_{n=-\infty}^{\infty} c_{k,n} d_{k,h} h(t - nMT_c - \tau_k)\sum_{i=1}^{M} \mathrm{Re}\left[e^{j(2\pi f_i t + \theta_{k,i})}\right] \quad (1)$$

where E_c is the chip energy, $c_{k,n}$ is the pseudo-random spreading sequence, $d_{k,\lfloor n/N \rfloor} \in \{+1,-1\}$ denotes the data bit of the *k-th* user, where *N* indicates the length of PN-sequence, *h(t)* is the impulse response of the chip wave shaping filter, τ_k is an arbitrary time delay uniformly distributed over $[0, NMT_c]$, $\mathrm{Re}[\cdot]$ denotes the real part, $\theta_{k,i}$ and f_i's, $i = 1,2,...,M$ are a random carrier phase uniformly distributed over $(0, 2\pi]$ and the carrier frequency, respectively.

2.2:RECEIVER MODEL

In Fig. 2. The complex lowpass equivalent impulse response of the *i-th* channel is $\left\{c_i = \xi_i \cdot \delta(t),\ \text{i=1...M}\right\}$, and $\xi_{k,i} = \alpha_{k,i}\exp\left(j\beta_{k,i}\right)$, where $\alpha_{k,i}$ and $\beta_{k,i}$ correspond to represent attuation factor and phase-shift for *i-th* channel of the *k-th* user. The complex equivalent impulse response of the channel is expressed as $c(t) = \sum_{l=0}^{L-1}\alpha_l\delta(t - lT_c)$. The received signal at the receiver is given as [4]

$$r(t) = \sum_{k=1}^{K}\left\{\sqrt{2E_c}\sum_{n=-\infty}^{\infty}d_{k,h}c_{k,n}h(t - nMT_c - \tau_k)\right.$$
$$\left.\times\sum_{i=1}^{M}\alpha_{k,i}\cos(2\pi f_i t + \psi_{k,i})\right\} + N_w(t) + N_J(t) \tag{2}$$

where K denotes the user number, $\psi_{k,i} = \theta_{k,i} + \beta_{k,i}$, $N_w(t)$ is AWGN with a double sided PSD (power spectral density) of $\eta_0/2$, $N_J(t)$ is partial band Gaussian interference with a PSD of $S_{n_J}(f)$, which is written as

$$S_{n_J}(f) = \begin{cases}\dfrac{\eta_J}{2}, & f_J - \dfrac{W_J}{2} \le |f| \le f_J + \dfrac{W_J}{2}\\ 0, & otherwise\end{cases} \tag{3}$$

where f_J and W_J represent the bandwidth of the interference and the center frequency, respectively. Then the interference (Jamming)-to-signal ratio, JSR, is defined as

$$\text{JSR} = \frac{\eta_J W_J}{\frac{E_b}{T}} = (1+\mu)\frac{\eta_J}{E_b}\frac{N}{M} \tag{4}$$

The output from the chip-matched filter in the branch ζ_i is give by [4]

$$\zeta_i = D_{\zeta_i} + MAI_{\zeta_i} + JSR_{\zeta_i} + N_{\zeta_i} \tag{5}$$

where the first term of the last equation denotes the desired signal of the reference case can be written as

$$D_{\zeta_i}(t) = \sqrt{E_c}\alpha_{1,i}\sum_{n=-\infty}^{\infty}d_{1,h}c_{1,n}x(t - nMT_c) \tag{6}$$

the second term in (5) is the interference comes from the other users, when the user number K approximates as Gaussian random variable, and can be determined as

$$MAI_{\zeta_i}(t) = \sum_{k=2}^{K}\left\{\sqrt{E_c}\xi_{k,i}\sum_{n=-\infty}^{\infty}d_{k,h}c_{k,n}\cdot x(t - nMT_c - \tau_k)\right\} \tag{7}$$

where $\xi_{k,i} \equiv \alpha_{k,i}\cos\phi_{k,i}$ and is i.i.d. (identical independent distribution) Gaussian, $\phi_{k,i} = \psi_{k,i} - \psi_{k,1}$. The third term in (5) is the JSR defined in (3), can be represented as

$$JSR_{\zeta_i}(t) = LPF\left[\sqrt{2}n'_{i,j}(t)\cos(2\pi f_i t + \psi_{1,i})\right] \tag{8}$$

where $LPF[\cdot]$ is applied to express the function of LPF, and the last term of (5) indicates the output signal caused by the fact that the AWGN passes to the low pass filter, and which can be expressed as

$$N_{\zeta_i}(t) = LPF\left[\sqrt{2}n'_{w,i}(t)\cos(2\pi f_i t + \psi_i^{(1)})\right] \tag{9}$$

where the terms $n'_{i,j}(t)$ in (8) and $n'_{w,i}(t)$ in (9) results from passing $n_J(t)$ and $n_w(t)$ in (2), respectively, through the *i*-th bandpass filter. The statistics results of the signal at the output of the *i*-th correlator are to be determined as

$$\chi_i = D_{\chi_i} + MAI_{\chi_i} + JSR_{\chi_i} + N_{\chi_i} \tag{10}$$

where each terms shown in last equation is adopted as that of the same results evaluated and shown in [4].

2.3:CORRELATED CHANNELS

Let $\left\{q_i\right\}_{i=1}^{L}$ be a set of L correlated gamma variates parameters with m and Ω_i, respectively, $\left[\text{i.e., } q_i \sim G(m, \Omega_i)\right]$ and let $\{\rho_{ij},\ i, j = 1, 2, ..., L\}$ denotes the correlation coefficient between the branch of q_i and q_j, where $i \ne j$, i.e.

$$\rho_{ij} = \rho_{ji} = \frac{Cov\left(q_i,\ q_j\right)}{\sqrt{Var\left(q_i\right)Var\left(q_j\right)}},\ 0 \le \rho_{ij} \le 1,\quad i, j = 1, 2, ..., L \tag{11}$$

where $Var(\cdot)$ and $Cov(\cdot)$ are the variance and the covariance operators, respectively. The pdf of $\gamma = \sum_{i=1}^{L} q_i$ can be expressed as

$$p_\gamma(\gamma) = \prod_{i=1}^{L}\left(\frac{\lambda_1}{\lambda_i}\right)^m\sum_{k=0}^{\infty}\frac{\delta_k\gamma^{Lm+k-1}e^{-\gamma/\lambda_1}}{\lambda_1^{Lm+k}\Gamma(Lm+k)}U(\gamma) \tag{12}$$

where $\Gamma(\cdot)$ is the gamma function and $U(\cdot)$ is the unit step function. The $\lambda_1 = \min_i\left\{\lambda_i\right\}$, $\left\{\lambda_i\right\}_{i=1}^{L}$ are the eigenvalues of the matrix *A*=*DC*, where the *D* is a $L \times L$ diagonal matrix with the entries $\left\{\Omega_i\right\}_{i=1}^{L}$, and *C* is an $L \times L$ positive definite matrix defined by

$$C = \begin{bmatrix} 1 & \rho_{12}^{1/2} & \cdots & \rho_{1L}^{1/2} \\ \rho_{21}^{1/2} & 1 & \cdots & \rho_{2L}^{1/2} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{L1}^{1/2} & \cdots & \cdots & 1 \end{bmatrix}_{L\times L} \tag{13}$$

where ρ_{ij}, $i, j = 1, 2, ..., L$ were expressed in (11), and the recursive parameter, δ_k, in (12) can be calculated by the formula shown as

$$\begin{cases} \delta_0 = 1 \\ \delta_{k+1} = \dfrac{m}{k+1}\displaystyle\sum_{i=1}^{k+1}\left[\sum_{j=1}^{L}m_j\left(1 - \frac{\lambda_1}{\lambda_j}\right)^i\right]\delta_{k+1-i},\ k = 0,\ 1,\ 2, ... \end{cases} \tag{14}$$

where $\left\{\lambda_i\right\}_{i=1}^{L}$ are the eigenvalues of the matrix *A*=*DC*, and $\lambda_1 = \min\left[\lambda_i\right]$ [12].

3: PERFORMANCE ANALYSIS

The conditional mean of χ_i shown in (10), condition upon the channel attenuation factor $\alpha_{1,i}$ are given by

$$E\left[\chi_i \mid \alpha_i, d_{1,h}\right] = E\left\{\chi_i \mid \alpha_{1,i}, \left\{d_{1,h}\right\}\right\}$$
$$= \sqrt{E_c}\alpha_{1,i}\sum_{n'=0}^{N-1}\sum_{n=-\infty}^{\infty}d_{1,h}c_{1,n}c_{1,n'}\cdot x\left[(n'-n)MT_c\right]$$
$$= \pm N\sqrt{E_c}\alpha_{1,i} \tag{15}$$

Note that the $x\left[(n'-n)NT_c\right]=0$ for $n'\neq n$. The conditional variance of χ_i can be represented as

$$\begin{aligned} Var\{\chi_i \mid \alpha_{k,1}\} &\equiv \sigma_i^2 \\ &= Var\left\{MAI_{\chi_i} + JSR_{\chi_i} + N_{\chi_i} \mid \alpha_{1,i}\right\} \\ &= Var\left\{MAI_{\chi_i}\right\} + Var\left\{JSR_{\chi_i}\right\} + Var\left\{N_{\chi_i}\right\} \end{aligned} \quad (16)$$

where the results of each terms shown in (15) can be calculated as given in [4].
All signals at the output of the correlators are combined with the MRC scheme, and the result can be expressed as

$$\chi = \sum_{i=1}^{M} G_i \chi_i \quad (17)$$

where G_i is defined as the channel estimate of the *i-th* branch. In order to maximize the SNR, the channel estimate G_i is defined as the ratio of the desired signal amplitude to the variance of the noise and interferance components in the output, and is written as

$$G_i = \frac{E\{\chi_i \mid \alpha_{1,i}\}}{Var\{\chi_i \mid \alpha_{1,i}\}} \quad (18)$$

By combining (15) with (16), then the SNR, (S/N), at the output of the MRC, can be obtained as

$$\left(\frac{S}{N}\right) = \frac{E^2\{\chi_i \mid \alpha_1\}}{Var\{\chi_i \mid \alpha_1\}} \equiv N^2 E_c \gamma \quad (19)$$

where the reference user (1st user) is considered, and

$$\gamma = \sum_{i=1}^{M} \frac{(\alpha_{1,i})^2}{\sigma_i^2} \equiv \sum_{i=1}^{M} q_i \quad (20)$$

where the fading branch of the reference user $\left\{\alpha_{1,i}, i=1,...,M\right\}$ are modeled as correlated-Nakagami-*m* statistic. Therefore, it can be shown that γ has the Gamma pdf [12], and the pdf of γ is expressed in (12). By using of averaging conditional pdf of SNR as shown in (21) over the pdf of the correlated channel, the BER is approximately determined by

$$P_e^{case} = \int_0^{\infty} \phi(\sqrt{N^2 E_c \gamma_{case}}) f_\gamma(\gamma_{case}) d\gamma_{case} \quad (21)$$

For the differentiable reason of system performance analysis for different cases, include single user and multiple user cases, the γ_{case} in (21) is going to be replaced with the corresponding cases by means of the exact subscript. For example, γ_{mu-sc} represents the SNR of multi-user case with single carrier, while γ_{su-mc} indicates the SNR of single-user case with multi-carrier. Similarly, the means will be employed for the symbol, P_e^{case}, of average BER. The average BER of those cases will be illustrated in the next subsection, respectively. The $\phi(x)$ in (21) is the Gaussian Q-function and defined as

$$\phi(\mathrm{x}) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{j^2}{2}} dt = \frac{2}{\sqrt{\pi}} e^{-x^2} \sum_{j=0}^{\infty} \frac{2^j x^{2j-1}}{(2j-1)!!} \quad (22)$$

3.1:MULTI-USER CASE

3.1.1:MULTI-CARRIER

The autocorrelation function, $R_{I_i}(0)$, which can be obtained from [4] and represented as

$$\begin{aligned} R_{I_i}(0) &= \int_{-\infty}^{\infty} S_{I_i}(f) df \\ &= \frac{(K-1)E_c}{2}\left(1-\frac{\mu}{4}\right) \end{aligned} \quad (23)$$

Thus, the conditional SNR, γ_{mu-mc}, of the multiple user case with multi-carrier at the output of the receiver can be determined from (19), which is written as

$$\gamma_{mu-mc} = \left\{\frac{K-1}{2MN}\left(1-\frac{\mu}{4}\right) + \frac{\eta_0}{2MNE_c}\right\}^{-1} \frac{1}{M} \sum_{i=1}^{M} (\alpha_{1,i})^2 \quad (24)$$

where *N* representes the chip number per symbol for the multi-carrier case, and $\eta_0/2$ is a double-sided PSD of the AWGN. For the purpose of calculating the system BER formula for this case, P_e^{mu-mc}, by substituting (24) into (21), and it can be obtained as

$$P_e^{mu-mc} = \sqrt{\frac{2}{\pi^{1/2}}} \sum_{j=0}^{\infty} \frac{2^{j/2}\left(\left\{\frac{K-1}{2MN}\left(1-\frac{\mu}{4}\right) + \frac{\eta_0}{2MNE_C}\right\}^{-1} \frac{1}{M}\right)^{j-1/2}}{\sqrt{(2j-1)!!}}$$

$$\times \prod_{i=1}^{L} \left(\frac{\lambda_1}{\lambda_i}\right)^m \sum_{k=0}^{\infty} \frac{\delta_k}{\lambda_1^{Lm+k}\Gamma(Lm+k)} U(\gamma)$$

$$\times \frac{\Gamma(j-1/2+Lm+k)}{\left(1+\left\{\frac{K-1}{2MN}\left(1-\frac{\mu}{4}\right)+\frac{\eta_0}{2MNE_C}\right\}^{-1}\frac{1}{\lambda_1 M}\right)^{(j-1/2+Lm+k)}} \quad (25)$$

where δ_k is defined in (14), $U(\gamma)$ is the unit step function, and $MNE_c = N_1 E_{c1} = E_b$, where N_1 and E_{c1} are length and energy of the spread code, respectively, E_b denotes the bit energy, and $(2n+1)!! = 1\cdot 3\ldots(2n+1)$.

3.1.2:SINGLE-CARRIER

Similarly, the conditional SNR, γ_{mu-sc}, of a single-carrier RAKE receiver, can be determined as

$$\gamma_{mu-sc} = \left\{\frac{K-1}{2N_1}\left(1-\frac{\mu}{4}\right) + \frac{\eta_0}{2N_1 E_{c1}}\right\}^{-1} \sum_{i=1}^{M} \left(\alpha_i^{(1)}\right)^2 \quad (26)$$

where the symbol of the length and the chip energy of the spreading sequence are replaced with the symbols N_1, and E_{c1}, respectively. The system BER, P_e^{mu-sc}, of this case can be obtained as

$$P_e^{mu-mc} = \frac{\sqrt{2}}{\pi} \sum_{j=0}^{\infty} \frac{2^{j/2}\left(\left\{\frac{K-1}{2N_1}\left(1-\frac{\mu}{4}\right) + \frac{\eta_0}{2N_1 E_{c1}}\right\}^{-1}\right)^{j-1/2}}{\sqrt{(2j-1)!!}}$$

$$\times \prod_{i=1}^{L} \left(\frac{\lambda_1}{\lambda_i}\right)^m \sum_{k=0}^{\infty} \frac{\delta_k}{\lambda_1^{Lm+k}\Gamma(Lm+k)} U(\gamma)$$

$$\times \frac{\Gamma(j-1/2+Lm+k)}{\left(1+\left\{\lambda_1\left[\frac{K-1}{2N_1}\left(1-\frac{\mu}{4}\right)+\frac{\eta_0}{2N_1 E_{c1}}\right]\right\}^{-1}\right)^{(j-1/2+Lm+k)}} \quad (27)$$

3.1.3:MULTI-CARRIER AND PBI

The conditional SNR, $\gamma_{mu-mc-PBI}$, of a multi-carrier with PBI can be determined from (19) and expressed as

$$\gamma_{mu-mc-PBI}=\left\{\frac{K-1}{2MN}\left(1-\frac{\mu}{4}\right)+\frac{\eta_0}{2MNE_c}+\frac{\eta_J}{2MNE_c}\right\}^{-1}\sum_{i=1}^{M}\left(\alpha_{1,i}\right)^2\Big/M \quad (28)$$

where η_J represents the JSR defined in (4). By using of the same steps as that of the derived results shown in (31), and the system BER under this assumption, $P_e^{mu-mc-PBI}$, can be determined as

$$P_e^{mu-mc-PBI}=\frac{\sqrt{2}}{\pi}\sum_{j=0}^{\infty}\frac{2^{j/2}\left(\left\{\frac{K-1}{2MN}\left(1-\frac{\mu}{4}\right)+\frac{\eta_0}{2MNE_C}+\frac{\eta_J}{2MNE_C}\right\}^{-1}\frac{1}{M}\right)^{j-1/2}}{\sqrt{(2j-1)!!}}$$
$$\times\prod_{i=1}^{L}\left(\frac{\lambda_1}{\lambda_i}\right)^m\sum_{k=0}^{\infty}\frac{\delta_k}{\lambda_1^{Lm+k}\Gamma(Lm+k)}U(\gamma)$$
$$\times\frac{\Gamma(j-1/2+Lm+k)}{\left(1+\left\{\frac{K-1}{2MN}\left(1-\frac{\mu}{4}\right)+\frac{\eta_0}{2MNE_C}+\frac{\eta_J}{2MNE_c}\right\}^{-1}\frac{1}{\lambda_1 M}\right)^{(j-1/2+Lm+k)}} \quad (29)$$

3.2: SINGLE-USER CASE

3.2.1:MULTI-CARRIER

The conditional SNR, γ_{su-mc}, becomes as

$$\gamma_{su-mc}=N^2E_c\sum_{i=1}^{M}\frac{(\alpha_{1,i})^2}{\sigma_i^2}=\frac{2NE_c}{\eta_0}\sum_{i=1}^{M}(\alpha_{1,i})^2 \quad (30)$$

The system BER, P_e^{su-mc}, for single-user and multi-carrier case as

$$P_e^{su-mc}=\frac{\sqrt{2}}{\pi}\sum_{j=0}^{\infty}\frac{2^{j/2}\left(1+\frac{2NE_c}{\lambda_1\eta_0}\right)^{j-1/2}}{\sqrt{(2j-1)!!}}$$
$$\times\prod_{i=1}^{L}\left(\frac{\lambda_1}{\lambda_i}\right)^m\sum_{k=0}^{\infty}\frac{\delta_kU(\gamma)}{\lambda_1^{Lm+k}\Gamma(Lm+k)}\frac{\Gamma(j-1/2+Lm+k)}{\left(1+\frac{2NE_c}{\lambda_1\eta_0}\right)^{(j-1/2+Lm+k)}} \quad (31)$$

3.2.2：SINGLE-CARRIER

Similarly, the conditional SNR of a single-carrier RAKE receiver, γ_{su-sc}, is given as

$$\gamma_{su-sc}=\frac{2N_1^2E_{c1}}{\eta_0}\sum_{i=i}^{L}(\hat{\alpha}_{1,i})^2 \quad (32)$$

where L is the number of resolvable paths of the channels. Note that the parameter has been set as $MNE_c=N_1E_{c1}=E_b$ in the last equation. Thus the average BER, P_e^{su-sc}, of single-user and single-carrier can be determined as

$$P_e^{su-sc}=\sqrt{\frac{2}{\pi^{1/2}}}\sum_{j=0}^{\infty}\frac{2^{j/2}\left(\frac{2N_1^2E_{c1}}{\eta_0}\right)^{j-1/2}}{\sqrt{(2j-1)!!}}$$
$$\times\prod_{i=1}^{L}\left(\frac{\lambda_1}{\lambda_i}\right)^m\sum_{k=0}^{\infty}\frac{\delta_kU(\gamma)}{\lambda_1^{Lm+k}\Gamma(Lm+k)}\frac{\Gamma(j-1/2+Lm+k)}{\left(1+\frac{2NE_c}{\lambda_1\eta_0}\right)^{(j-1/2+Lm+k)}} \quad (33)$$

3.2.3:MULTI-CARRIER WITH PBI

When the effect of PBI is considered, the conditional SNR, $\gamma_{su-mc-PBI}$, of multi-carrier and single- user case can be written as

$$\gamma_{su-mc-PBI}=\left(\frac{2MNE_c}{\eta_0}+\frac{2MNE_c}{\eta_J}\right)\frac{1}{M}\sum_{i=1}^{M}\left(\alpha_{1,i}\right)^2 \quad (34)$$

The system BER , $P_e^{su-mc-PBI}$, is also can be determined by the same procedures of the last case, and obtained as

$$P_e^{su-mc-PBI}=\sqrt{\frac{2}{\pi^{1/2}}}\sum_{j=0}^{\infty}\frac{2^{j/2}\left(\left(\frac{2MNE_c}{\eta_0}+\frac{2MNE_c}{\eta_J}\right)\frac{1}{M}\right)^{j-1/2}}{\sqrt{(2j-1)!!}}$$
$$\times\prod_{i=1}^{L}\left(\frac{\lambda_1}{\lambda_i}\right)^m\sum_{k=0}^{\infty}\frac{\delta_kU(\gamma)}{\lambda_1^{Lm+k}\Gamma(Lm+k)}$$
$$\times\frac{\Gamma(j-1/2+Lm+k)}{\left(1+\left(\frac{2MNE_c}{\eta_0}+\frac{2MNE_c}{\eta_J}\right)^{-1}\frac{1}{\lambda_1M}\right)^{(j-1/2+Lm+k)}} \quad (35)$$

4: NUMBERICAL RESULTS

The results of E_b/N_0 versus BER for multi-user and multi-carrier case were considered in Fig. 3, in which the parameter of user number is assigned to $K=50$ and $K=120$, and assuming that the different values of correlation coefficients $\rho=0.16$, $\rho=0.25$, $\rho=0.36$ and $\rho=0.49$, which were suggested in the research paper [12]. It is known that the system performance will become much better when the values of the correlation coefficient are decrease. By setting the length of the spreading sequence is *N=128*, and the same user number are that utilized in Fig. 3, the plots of SNR versus BER with different fading figure, *m=2*, and *5*, illustrated in Fig. 4. It is reasonable to say the fact that the much more of the fading figure, *m* value, in Nakagami-*m* statistic distribution, the better of the system performance from Fig. 4. The results from different effect of PBI (Jimming- to-signal ratio, JSR) are presented in Fig. 5 to Fig. 8. In Fig. 5 the BER versus E_b/N_0 curves for multi-carrier case with different JSR values are presented. It is shown that the performance will become inferior when the JSR is increase gradually, that is, the best one of the performance is the curve $JSR=0dB$ appeared in Fig. 5. The results from the same conditions considered in Fig. 6 is also adopted in Fig. 6 just with different number of subcarrier, $N=128$. The affect of the different subcarrier number can be understood from Fig. 5 and Fig. 6. The PBI is caused from the distinct carrier can be clearly known in this comparison, in which the performance for single-carrier system is always better than that of multi-carrier system.

5: CONCLUSION

In this paper the system performance of an MC-DS-CDMA system working in correlated fading channel were evaluated with the approximate expressions. The pdf of SNR at the output or Rake (MRC) receiver for different cases combination with multi-user and single-user cases were determined, meanwhile, the sum of Gamma variates is applied in the procedures to calculate the system BER performance. It is worthy to note that the performance of MC-DS-CDMA system definitely obtain much deterioration with the lager correlation coefficients obviously than other parameters.

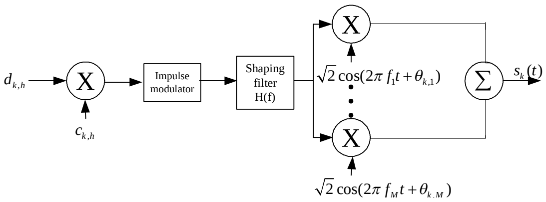

Fig 1. The transmitter block diagram of an MC-DS-CDMA system

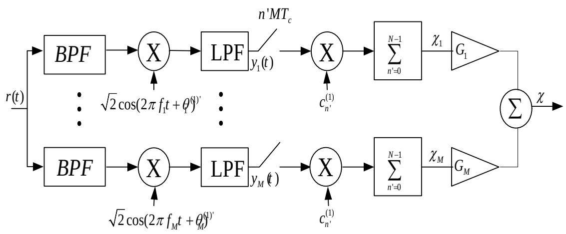

Fig 2. The receiver block diagram of a reference user

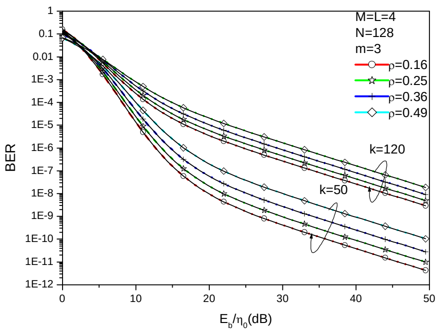

Fig. 3. BER versus SNR with different user numbers

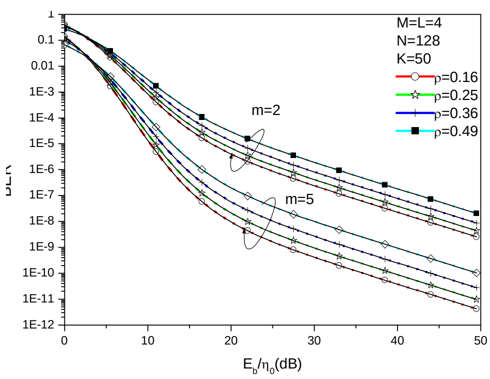

Fig. 4. BER versus SNR with different fading parameters

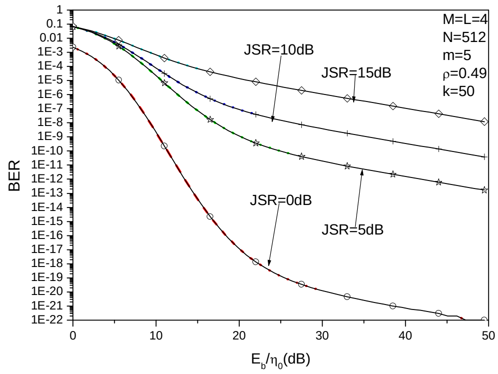

Fig. 5. BER versus SNR with different JSR values

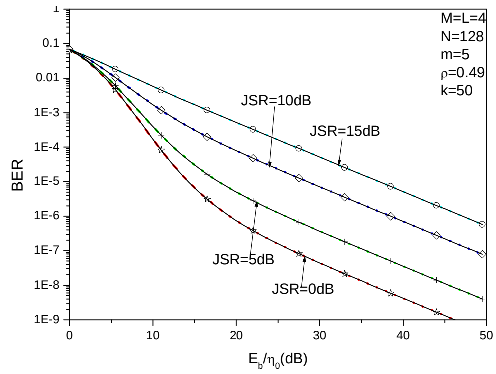

Fig. 6. BER versus SNR with different JSR values

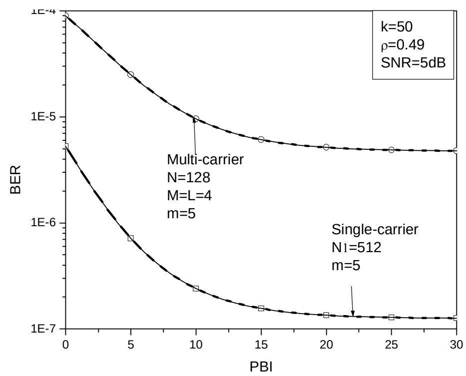

Fig. 7. BER versus PBI for multi-carrier and single-carrier case

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