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나까카미-m 페이딩 채널에서 최대비합성과 동이득합성에 관한 연구

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A Study on the MRC and EGC in Nakagami-m Fading Channel

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요 약

MC-CDMA의 전체 시스템 대역폭은 부대역으로 분할되며, 각 부대역은 직접시퀀스확산을 사용하고 각 부대역 신호는 부캐리어 주파수를 사용하여 전송한다. 본 논문에서는 주파수 선택적 나까카미-m 페이딩 채널에서 동이득 합성법과 최대비 합성법을 사용한 MC-CDMA시스템 성능을 분석한다. 본 논문에서 제안된 시스템은 데이터 스트림을 직렬에서 병렬로 변환하여 , 각 병렬 데이터 스트림을 MC-CDMA시스템에 사용한다. 데이터 스트림은 송신기에서 칩 레벨과 심볼 프락션 레벨을 확산시킨다. 본 논문에서는 동 이득 합성과 최대비 합성 두가지 다이버시티 합성법을 비교분석하였다. 동이득 합성법 보다 최대비 합성법을 사용한 시스템 성능이 우월하였다.

Abstract

In multicarrier code division multiple access(MC-CDMA), the total system bandwidth is divided into a number of sub-bands, where each subband may use direct-sequence(DS) spreading and each subband signal is transmitted using a subcarrier frequency. In this paper, the system performance analysis of MC-CDMA using to gain combining(EGC) and maximal ratio combining(MRC) method over frequency selective Nakagami-m fading channel is analyzed. In the proposed system, a data sequence is serial-to-parallel converted, and MC-CDMA is used on each of the parallel data streams. The data streams are spread at both the symbol fraction level and .at the chip level by the transmitter. In this paper, the compare to analysis ,two standard diversity combining techniques, EGC and MRC, The good performance of system using to MRC more than EGC

▸ Keyword : MC-CDMA, Nakagami- $m$fading, EGC, MRC

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Ⅰ. 서 론

RECENTLY, Many wireless access systems based on direct sequence code division multiple access (CDMA)[1][2] have been proposed for next-generation mobile communications to flexibly offer wideband services that cannot be provided by present cellular systems. In multicarrier code division multiple access(MC-CDMA)[3][4][11], the total band width available is divided into a number of subbands, where each subband signal is transmitted with the aid of a sub-carrier. In MC-CDMA systems, serial to parallel(SP) conversion is invoked at the transmitter, in order to decrease the transmitted symbol rate for the sake of mitigating the effects of inter symbol interference(ISI). Frequency diversity in MC-CDMA systems is usually achieved by repeating the transmitted signal in the frequency domain with the aid of several sub-carriers. A combination of MC modulation and CDMA benefits from both techniques. The major advantage of the combination scheme is that it needs a lower symbol rate, since in a multicarrier CDMA system with N carriers, the entire bandwidth of the systems is divided into N sub-bands, and the symbol rate in each subcarrier can be lowed to make it easier for the quasi synchronization of the transmissions. Recently much efforts has been making to study the MC-CDMA system performance based on the more general fading model, i.e., frequency selective Nakagami fading model[5]. However, most of the work made assumption to experience independent flat Nakagami-m fading. The subcarrier independency issue of MC-CDMA was discussed in for frequency selective Rayleigh fading channels. To the authors knowledge, the analysis of performance comparison between the independent and correlated systems based on the Nakagami-$m$fading channel model has not been studied. Bit-error rate(BER) is one of the most important performance measures for communication systems and th BER analysis of various systems has been studied extensively. To analyze the BER performance of MC-CDMA systems, including MC-CDMA[6] and MC-DS-CDMA, the multiple access interference(MAI) is commonly assumed to be Gaussian distributed. Hower, the accuracy of this approach depends on the system configuration, especially on the number of users and their powers. In this paper, our goal is to present an accurate and unified BER analysis of synchronous MC-CDMA over Nakagami-m fading channels using diversity method. Combine method used equal gain combining(EGC)[11]or maximum ratio combining (MRC) are considered. Specifically, for frequency selective fading channels, the difference of the BER obtained from the Rayleigh fading channel and Nakagami-m fading channel can usually be neglected if all subcarriers are independent. Other contributions of this work include that a general Nakagami-m $(m \geq 0.5)$ fading channel model is studied, and both independent and correlated fading models for different subcarries are considered.

The organization of this paper is as follows. The system model and Nakagami-m fading the frequency domain are briefly described in section II. In section III, we present theBER analysis of synchronous MC-CDMA under the assumption of independent fading for different sub-carriers. Both downlink and uplink with EGC or MRC are considered. In Section IV, The BER expressions for both uplink and downlink are derived and compared. Section V concludes this paper.

II. Nakagami-m Fading Channel

2.1.Transmitter

Consider a MC-CDMA system with k users and N sub-carriers. A synchronous uplink is assumed. We will only describe the uplink, but it is straightforward to tailor the presentation to the downlink case. Fig.1

Illustrates the block diagrams of the transmitter and receiver of user k. It should be noted that Fig.1 is shown for illustration purposes only. In practice, MC modulation/demodulation can be implemented by IFFT/FFT algorithms. In addition, if the data rate is high, a serial to parallel converter can be used before the multicarrier modulation. Assume that BPSK modulation and binary spreading sequences($\{c_{k,n}\}_{n=1}^{N}$) for user k are employed. The transmitted signal of user k may be expressed as[7]:

$$s_k(t) = \sum_{u=-\infty}^{\infty}\sum_{n=0}^{N-1}\sqrt{\frac{2p}{N}}b_k(u)pT_b(t-uT_b)c_{k,n}\cos(w_n t+\theta_k) \quad \cdots\; (1)$$

Where $b_k(u)$ represents the uth data substream of user k and $b_k(u)$ is assumed to be a random variable, assuming values of +1 or _1 with equal probability. Furthermore, $C_{k,n}$ is the nth chip of the spreading code assigned to user k, which is also assumed to be a random variable taking values +1 or -1 with equal probability. ω_n: nth the subcarrier frequency, P : power of data bits identical for all users, PT_b: rectangular pulse defined in $[0,T_b]$, T_b : bit duration , θ_k : random carrier phase of user k

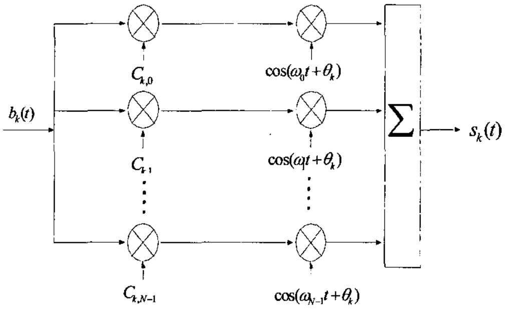

Fig 1. MC-CDMA transmitter of user k

2.2. Channel Model

A slowly varying fading channel, whose parameters are unchanged over one bit duration, is assumed. Since Nakagami-m distribution is a versatile yet relatively simple statistical model and it is well suited to characteristic a radio mobile channel, we use a Nakami-m distributed to represent the amplitude of channel gains. By properly selecting the number of sub-carriers, we assume that signals on each subcarrier experience flat fading. The fading amplitude $\alpha_{k,n}$ is a random variable obeying the Nakagami-m distribution having a PDF given by[8]

$$f_{\alpha_{k,n}}(\gamma) = \frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m \gamma^{2m-1}\exp(-\frac{m}{\Omega}\gamma^2) \quad \cdots\cdots\; (2)$$

Where $\Gamma(\cdot)$ is the gamma function, $\Omega = E[(\alpha_{k,n})^2]$ and m is the Nakagami-m fading parameter. For MC-CDMA systems an important issue to consider is the correlation between sub-carriers. This is due to the fact that an MC-CDMA system may be subject to correlated fading for different sub-carriers if the subcarrier spacing is less than the coherence bandwidth of the channel. In this paper, both independent and correlated fading channel models are considered. At the transmitting side, the bit stream with bit duration T_b is serial-to-parallel converted into M parallel streams. The new bit duration on each streams is $T = MT_b$. Each stream feeds S parallel streams such that the same data stream exists on the branches. The S branches carrying the same data stream are denoted as indentical-bit branches, and after modulation, the frequencies carrying the same data stream are denoted as identical-bit carriers. On the identical bit branches the data streams are interleaved such that on two contiguous branches, the replicas of the same bit are separated by an interval. This interleaving is required to achieve time diversity. All data streams are spread by the same PN code of length N and chip duration T_c such that $T = NT_c$. One of MS orthogonal carriers is used for QPSK modulation of each stream. The transmission BW is assumed to be the pass-band null-to-null $BW(2/T_{c1})$, where,

T_{c1} is the PN code ship duration for single carrier case(M=S=1). The total BW ins case of MS carriers is given by[2]:

$$BW = \frac{MS+1}{T_c} \quad \text{(3)}$$

To keep the BW fixed for and selections of $M$and S , the PN code chip T_c. Consequently with $T_c = MT_b/N$, the period N of the PN sequence must be as follows. The matched filter outputs of the identical-bit carriers are de-interleaved and the decision statistics of the same bit are added prior to the threshold device in an MRC. The multipath Nakagami fading channel is assumed. when the maximum delay spread of the channel is T_m, the number of resolvable paths L is given by equation(4).

$$L = \left\lceil \frac{2(L_1-1)}{MS+1} \right\rceil + 1 \quad \text{(4)}$$

2.3 Receiver

All users are assumed to be synchronized throughout this paper. The received signal at the base station is given by[9]:

$$r(t) = \sum_{u=-\infty}^{\infty} \sqrt{\frac{2p}{N}} b_k(u) pT_b(t-uT_b) \sum_{n=0}^{N-1} \alpha_{k,n} c_{k,n} \cos(w_n t + \phi_{k,n}) + \eta(t) \quad \text{(5)}$$

Where

$$\Phi_{k,n} = \Theta_k + \Phi_{k,n}, \quad (n=0,\cdots,N-1)$$

and $\eta(t)$is an additive white Gaussian noise(AWGN) with zero mean and double-side power spectral density $N_o/2$. A coherent correlation receiver with EGC or MRC is employed. Perfect channel estimation for the desired user is as summed. The MC-CDMA receiver considered is based on coherent at correlator detector. As shown in Fig.2, the decision variable $D_u$of the 0th data bit in the uth data substream of the reference user given by:

$$D_u = \sum_{n=0}^{N-1} D_{un} \quad \text{(6)}$$

$$D_{un} = \sum_{v=0}^{N-1} \alpha_{k,n} c_{i,n} \frac{1}{T_b} \int_0^{T_b} r(t) \cos(\omega_n t + \phi_{i,n}) dt \quad \text{(7)}$$

Where $\alpha_{k,n} = 1$ for EGC and $\alpha_{k,n} = \beta_{k,n}$for MRC. Base on the decision variable, D_u $u = 1,2,\cdots,U$, the current data bit of the u th substream is decided to be 0 or 1, depending on whether $D_u$is higher then zero. Finally, the U number of parallel data substreams are parallel to serial converted, in order to output the serial data bits. Let us now analyze the statistics of the decision variable and the achievable BER with the aid of these statistics.

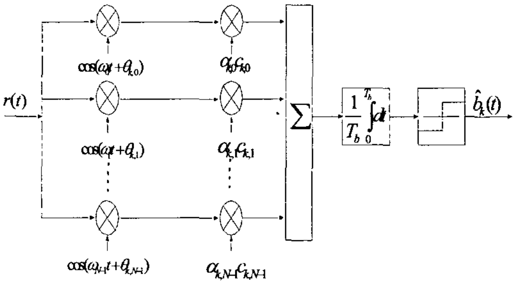

Fig 2. MC-CDMA receiver of user k

III. BER Analysis

3.1 Decision Variable Statistics

If maximal ratio combining is employed for detection by multiplying each subcarrier by a factor $\alpha_{k,n}$ after dispreading the signal of the kth user, the decision variable$D_u$can be expressed as

$$D_u = D + I_{MAI} + I_N \quad \text{(8)}$$

Where D denotes the desired signal term given by(assuming $b_o(0) = +1$). In order to obtain the probability density function(PDF) of the decision variable D_u of (8) for deriving the bit error probability, we approximate the multiuser interference(MUI) by additive Gaussian noise, since it is constituted by the sum of numerous independent random variables. Based on the Gaussian approximation, the decision variable D_u of (8) can be approximated as Gaussian random variable having a mean given by

$$E[D_u] = D \qquad (9)$$

and a variance given by

$$Var\ [D_u] = (K-1)Var\ [I_{MAI}] + Var\ [I_N] \qquad (10)$$

Where $Var[I_N]$ was previously given in the context of (10), while $Var[I_{MAI}]$ is given by

$$Var\ [I_{MAI}] = \frac{E[(\alpha_{k,n})^2]}{3N}\sum_{n=0}^{N-1}\alpha_{k,n}^2 \qquad (11)$$

Upon substituting $Var[I_N]$ and $Var[I_{MAI}]$ of (11) into (10), we obtain the variance of the decision variable D_u ,which is expressed as

$$Var[D_u] = \left[\frac{(K-1)}{3N} + \left(\frac{N_0}{2E[(\alpha_{k,n})^2]E_b}\right)E[(\alpha_{k,n})^2]\right]\sum_{n=0}^{N-1}\alpha_{k,n}^2 \qquad (12)$$

Where $E_b = PT_b$ is the bit energy and E_b/N_o is referred to as the signal to noise ratio(SNR). Having obtained the statistics of the decision variables, be low we derive the BER expression of the MC-CDMA system, when communicating over both AWGN, as well as over frequency selective slow and fast Nakagami-m fading channels.

3.2 Bit Error Rate

With the aid of (9) and (12), the signal to interference plus noise ratio(SINR) for the given channel parameters of $(\alpha_{k,n}^2)$ can be expressed as

$$SINR(\alpha_{k,n}^2) = \frac{E^2[D_u]}{2\,\mathrm{var}[D_u]} \qquad (13)$$

$$= \left[\frac{2(K-1)}{3N} + N_1\left(\frac{N_0}{E[(\alpha_{k,n})^2]E_b}\right)E[(\alpha_{k,n})^2]\right]^{-1}\sum_{n=0}^{N-1}\frac{\alpha_{k,n}^2}{E[(\alpha_{k,n})^2]} \qquad (14)$$

In the context of AWGN channels we have $\alpha_{k,n}^2 = 1$ and correspondingly also $E[(\alpha_{k,n})^2] = 1$. Upon substituting these results into(13), the SINR achievable over AWGN cab be expressed as

$$SINR = \left[\frac{2(K-1)}{3N} + \left(\frac{N_0}{E_b}\right)\right]^{-1} \qquad (15)$$

With the aid of (13) and (14), let us now derive the corresponding BER expressions. In the context of the frequency-selective Nakagami-m fading channels, the BER conditioned on the fading amplitudes $\{\alpha_{k,n}\}$ can be written as

$$P_b = Q\left(\sqrt{2\cdot SINR\ (\{\alpha_{k,n}^2\})}\right) \qquad (16)$$

$$= Q\left(\sqrt{\gamma_C\cdot\sum_{n=0}^{N-1}\alpha_{k,n}^2}\right) \qquad (17)$$

$$\gamma_c = \left[\frac{2(K-1)}{3N} + \left(\frac{N_0}{2E_b}\right)\right]^{-1} \qquad (18)$$

Where $Q(x)$ is the Gaussian Q function. The unconditional BER of the MC-CDMA systems communicating over frequency selective Nakagami-m

fading channels, can be obtained by average(16) with respect to the PDF with the aid of (2). Hence we obtain the following BER expression[10].

$$P_b = \left[\frac{\left(1-\sqrt{\frac{\gamma_C}{1+\gamma_C}}\right)}{2}\right]^N \sum_{n=0}^{N-1}\binom{N-1+n}{n}\left[\frac{\left(1+\sqrt{\frac{\gamma_C}{1+\gamma_C}}\right)}{2}\right]^n \quad \cdots (19)$$

IV. Simulation

The uplink BER results of MC-CDMA with EGC and MRC in Nakagami-m fading are displayed in Fig.3 and Fig.4 Similar to the downlink case, the fading parameter m influences the BER performance significantly, especially when the number of user is small. Also, we can see that the fading parameter m affects the BER performance more apparently for MRC than for EGC. Clearly, the BER performance changes considerably with the fading severity parameter m. Compared with EGC and MRC appears to be more sensitive the change of m.

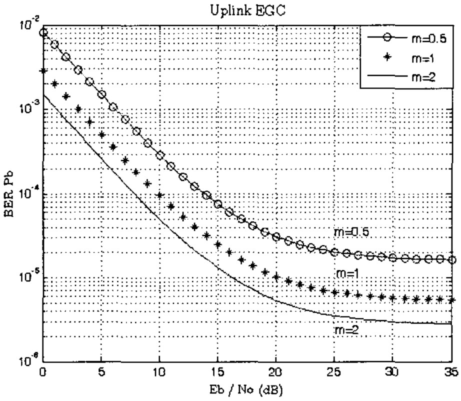

Fig 3. BER of EGC

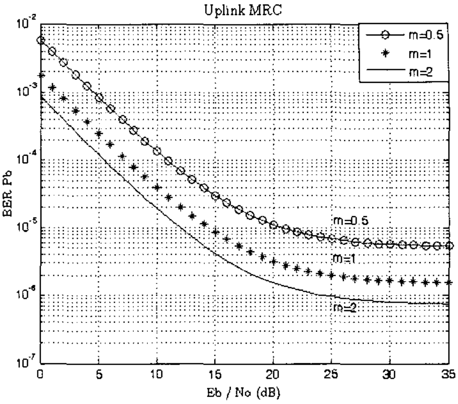

Fig 4. BER of MRC

Table 1. Comparison of MRC of EGC

	MRC	EGC
m=0.5	$10^{-5.3}$	$10^{-4.8}$
m=1	$10^{-5.9}$	$10^{-5.2}$
m=2	10^{-6}	$10^{-5.5}$

V. Conclusion

The average bit error probability of a uplink, downlink synchronous MC-CDMA system with MRC and EGC reception was investigated base on the frequency selective Nakagami-m fading channel model. Both downlink and synchronous uplink, independent fading and correlated fading were considered. When independent fading for different sub-carries is assumed, it was found that MRC performs better than EGC in the uplink and downlink. We showed the BER of the independent subcarrier system with varying fading parameter$m$ are very close to that of the independent subcarrier system experiencing Nakagami-m fading, especially when the number of multipath L is large. As expected, the Gaussian approximation is generally not accurate enough, especially when the number of users is small. However, for the case of MC-CDMA with MRC in the synchronous uplink, the Gaussian approximation gives good accuracy. Compared to MC-CDMA with MRC, MC-CDMA with EGC appears to be more sensitive to the charge of the fading parameter m in both the downlink and synchronous uplink

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