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Performance Analysis of Mc Ds-Cdma System Using BPSK Over Correlated And Independent Nakagami-M Fading Channel

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Abstract. This paper deals with simulation of Nakagami-m fading in wireless channels using generalized MC DS-CDMA scheme using binary phase shift keying modulation. The paper proposes for deriving Bit Error Rate (BER) in BPSK MC DS-CDMA system over Nakagami-m fading channels. The numerical results are plotted as BER vs SNR for various values of Nakagami factor m, number of users K, and jamming interference (JSR) using MAT LAB software. The performance analysis for a system using MRC at the receiver was carried out and difference between independent and correlated fading for various values of m was observed. It is observed that the BER of correlated fading is high when compared with the independent fading. There is a decrease in Bit Error Rate for increase in m for MC DS-CDMA. The number of users k, JSR increases as Bit Error Rate increases for MC DS-CDMA. As the Correlation coefficient increases the Bit Error Rate increases for MC DS- CDMA. Effect of fading is more for high correlation coefficients.

Keywords: Nakagami-m fading channel, MC DS-CDMA, MC- CDMA, SC -CDMA, BPSK, MRC diversity technique

1. Introduction

Fading is observed in wireless communication channels [12] due to multi path propagation. The Nakagami-m distribution accurately models the fading effect for short distance communications. This paper deals with the derivation of BER in BPSK- MC DS-CDMA systems[11] over Nakagami-m channel. In the generic form, DS-CDMA access is a spread spectrum technique for simultaneously transmitting a number of signals representing information messages from a multitude of users over a channel employing a common carrier. The method by which the various users share the channel is the assignment of a unique pseudo noise (PN) type code to each user (which accompanies the transmission of information) with orthogonal like properties that allows the composite received signal to be separated into its individual user components, each of which can then be demodulated and decoded. A complete discussion of techniques for accomplishing these functions and their impact on system performance can be found in [1].

2. System Model of MC-DS CDMA

MC DS-CDMA Constitutes a trade off between SC DS-CDMA and MC DS-CDMA, MC DS-CDMA typically requires low chip rate spreading codes than DS-CDMA due to employing multiple sub-carriers. It necessitates a lower number of sub-carriers than MC DS-CDMA due to imposing DS spreading[2] on each sub-carrier signal. MC DS-CDMA requires low rate signal processing than DS-CDMA and has lower worst-case peak to average power than MC DS-CDMA. MC DS-CDMA has highest of freedom in family of CDMA schemes. A MC DS-CDMA exhibit a no of advantageous properties, this technique is employed in wireless communication, irrespective of presence of other techniques [9].

In the following model shown in fig.1, a generalized MC DS-CDMA system with K users and BPSK modulation is assumed. At the receiver, the desired user's signal will be decoded and the other K-1 user will contribute to multi-user interference.

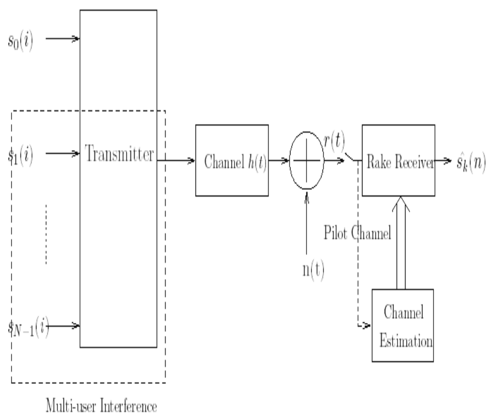

Fig.1 System Model For The Mc Ds-Cdma System

2.1. Transmitter

The block diagram for the transmitter for the kth user is shown in Fig 2.

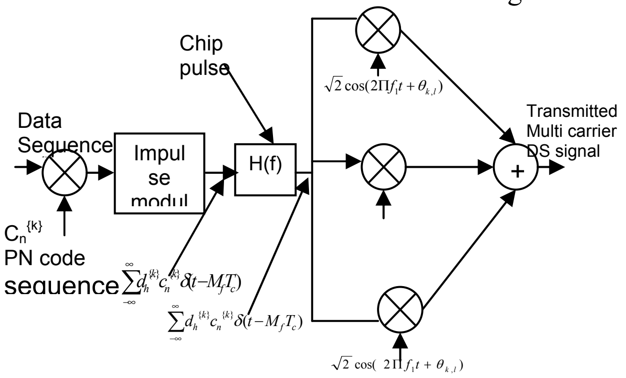

Fig.2 Transmitter For The Kth Uesr

Consider a BPSK multi carrier coherent DS-CDMA system with K$_u$ independent users each transmitting with power P. The users are simultaneously sharing an available bandwidth BW=(1+α)/T$_c$, where T$_c$ is the chip duration of a corresponding single-carrier wideband DS-CDMA system, and α (0 ≤ α ≤ 1) is the roll off factor of the chip wave-shaping Nyquist filter. The available spectrum BW is divided into (not necessarily contiguous) M$_f$ equal bandwidth sub band search of width BW_{Mf} approximately equal to the coherence bandwidth of the channel. Each subband is assigned a carrier which is DS-CDMA modulated with the same user information at the bit rate 1/T$_b$ and chip rate 1/(M$_f$T$_c$) (see Fig. 2). Each user is effectively assigned a specific periodic code sequence of chip elements (+1, -1) and of processing gain per subband PG$'$=PG/M$_f$. We assume deterministic subband PN codes with ideal auto correlation function. The use of band limited (Nyquist shaped spreading) waveforms with wave-shaping filter transfer function denoted by H(f) guarantees that the DS waveforms do not overlap.

2.2. Channel Model

Following the system design and modeling assumptions of kando and well as their bandwidths are chosen so that the separate sub bands fade slowly and no selectively. Under these assumptions, the channel transfer function of the lth subband for the kth user is $\alpha'_{k,l}\exp(j\theta_{k,l})$,where the $\{\alpha'_{k,l}\}_{l=1}^{M_f}$ are the fading amplitude RV's and $\{\theta'_{k,l}\}_{l=1}^{M_f}$ are independent uniformly distributed RV's over [0,2Π].The average fading power of lth subband is denoted by $\Omega_l' = (\alpha_{k,l}')^2$ and is assumed to be independent of k.

2.3. Receive

The receiver consists of a bank of M$_f$ matched filters followed by MRC (see fig 3). Each of the received modulated sub band carriers is first passed through a band pass chip-modulated filter H*(f), then coherently

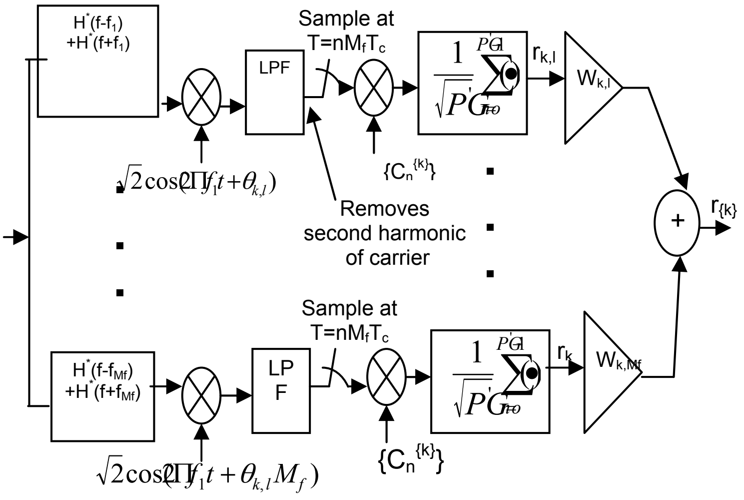

Fig.3 Block Diagram Of Reciever

demodulated, sampled, dispread and summed,all these operations assume that the receiver is correctly phase and time synchronized at every branch. We denote by $X(f)=H(f)H^*(f)=|H(f)|^2$ the overall frequency response of the chip wave shaping Nyquist filter and assume that X(f) is a root-cosine frequency response given by

$$X(f)=\begin{cases}\frac{1}{W}, 0\le|f|\le\frac{W}{2}(1-\alpha)\\ \frac{1}{2W}\left[1-\sin\left(\frac{1}{2\alpha}\left(\frac{2\pi|f|}{W}-\pi\right)\right)\right], \frac{W}{2}(1-\alpha)\le|f|\le\frac{W}{2}(1+\alpha)\\ 0, \frac{W}{2}(1+\alpha)\le|f|\end{cases}$$

With $W=1/T'_c=1/(M_fT_c)$ for multicarrier and $W=1/T_c$ for single carrier

3. Performance Analysis

Case 1: No partial band Interference:

The decision variable of k^{th} user may be written as the sum of a desired signal component and two interference/noise components [9]

$$r_k=\sum_{l=1}^{Mf}w_{k,l}r_{k,l}=\pm\sum_{l=1}^{M_f}w_{k,l}\alpha'_{k,l}\sqrt{\frac{E_b}{M_f}}+\sum_{l=1}^{Mf}w_{k,l}(I_{M_l}+N)$$

Gaussian RV with Conditional mean and conditional variance are given by

$$E[r_k\mid\{\alpha'_{k,l}\}_{l=1}^{M_f}]=\pm\left(\sum_{l=1}^{M_f}w_{k,l}\alpha'_{k,l}\right)\sqrt{\frac{E_b}{M_f}}$$

$$\mathrm{var}(r_k\mid\{\alpha'_{k,l}\}_{l=1}^{M_f})=\sum_{l=1}^{M_f}(w_{k,l})^2\frac{N_0}{2}$$

Maximum conditional SNR of single–carrier system is given by $SNR_{\max}(\{\alpha_{k,l}\}_{l=1}^{L})=\frac{E_b}{N_0}\sum_{l=1}^{L}(\alpha_{k,l})^2\left[1+\frac{(K_u-1)\Omega_T}{PG}\left(1-\frac{\alpha}{4}\right)\gamma_l\right]^{-1}$

Case 2: Partial band interference:

Consider the presence of PBI jammer model as a band limited white Gaussian noise with bandwidth $W_J=BW_{Mf}$ is given by

$$S_{n_j}(f)=\begin{cases}\frac{\eta_j}{2}, f_j-\frac{W_j}{2}\le|f|\le f_j+\frac{W_j}{2}\\ 0, elsewhere\end{cases}$$

Where f_j denotes jammer carrier frequency.

The decision variable of K^{th} user may now be written as sum of desired signal component and 3 interference /noise components [9].

$$r_k = \sum_{l=1}^{M_f} w_{k,l} r_{k,l} = \pm\left(\sum_{l=1}^{M_f} w_{k,l} \alpha'_{k,l}\right)\sqrt{\frac{E_b}{M_f}} + \sum_{l=1}^{M_f} w_{k,l}(I_{J_l} + I_{M_l} + N)$$

where I_{jl} is the Gaussian PBI present in l^{th} subband with variance

$$\sigma^2_{J_l} \equiv \frac{N_{J_l}}{2} = \frac{1}{2}\int_{-\infty}^{\infty}[S_{n_j}(f - f_l) + S_{n_j}(f + f_l)]X(f)df$$

The K^{th} user maximum conditional SNR is given by

$$\beta_l = \left[1 + \frac{K_u - 1}{M_f PG}(1 + \frac{\alpha}{4})\overline{\gamma_l}' + \frac{N_{j_l}}{N_0}\right]^{-1}$$

Where $\frac{N_j}{N_0} = \frac{JSR_v \gamma_v}{PG'(1+\alpha)}$ v = 1,2,…..or M_f

Where $JSR_v = n_J W_J/\Omega_v E_b/T_b$ represents the interference (jamming) to SNR in the v^{th} sub bands.

Average BER:

The $P_b(E)$ of MC DS-CDMA over the MRC combiner is given by

$$Pb(E) = \frac{1}{\pi}\int_0^{\pi/2}\prod_{l=1}^{M_f} M_{\gamma'}(-\frac{\beta_l}{M_f \sin^2\phi})d\phi$$

Where $M_{\gamma l}'$ denotes the MGF of the l^{th} subband SNR/bit .

$$M_{\gamma' l}(-\frac{\beta_l}{M_f \sin^2\phi}) = (1 + \frac{\beta_l \overline{\gamma_l}'}{mM_f \sin^2\phi})^{-m}$$

$$P_b(E) = \frac{1}{\pi}\int_0^{\pi/2}\prod_{L-0}^{l-1}(\frac{mM_f \sin^2\phi}{\overline{\gamma_l}'\beta_l + mM_f \sin^2\phi})^m d\phi$$

Independent fading across the sub bands: The SNRs of various diversity branches are independent. The average BER is given

$$P_b(E) = \frac{1}{\pi}\int_0^{\pi/2}\prod_{l=1}^{M_f} M'_{\gamma_l}(-\frac{\beta_l}{M_f \sin^2\phi})d\phi$$

Where $M_{\gamma'_t}(s)$ denotes the MGF of the l^{th} –sub band SNR/bit.

Correlated Nakagami-m Fading: The SNRs of various diversity branches depends on one another and the dependency is measured by correlation coefficient. As the correlation coefficient approaches zero, the fading tends to be independent. The average BER is given by

$$P_b(E) = \frac{1}{\pi}\int_0^{\pi/2} M_{\gamma'_t}\left(-\frac{1}{\sin^2\phi}\right)d\phi$$

Where $M_{\gamma'_t}(s)$ is the MGF of the combined output SNR with arbitrary correlated Nakagami-m faded sub bands and can be found as

$$M_{\gamma'_t}(s) = E_{\gamma'_1,\gamma'_2,,,,,,,,,\gamma'_{M_f}}\left[\exp\left(s\sum_{l=1}^{M_f}\frac{\beta_l}{M_f}\gamma'_l\right)\right]$$

$$= \prod_{l=1}^{M_f}\left(1 - \frac{s\beta_l}{mM_f}\right)^{-m}[\det[C_{ij}]_{M_f x M_f}]^{-m}$$

Where

$$C_{ij} = 1, \qquad i = j$$

$$= \sqrt{P_{ij}} \left(1 - \frac{mM_f}{s\beta_j} \right)^{-1}, \qquad \text{otherwise}$$

With P_{ij} fading power correlation coefficient between sub bands i and j

4. Results

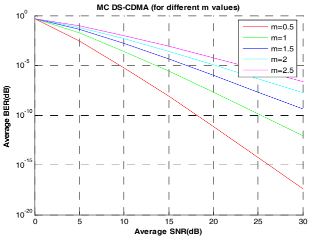

Fig 4. Performance of MC DS-CDMA Using BPSKOver Nakagami-m Channel for Different m Values

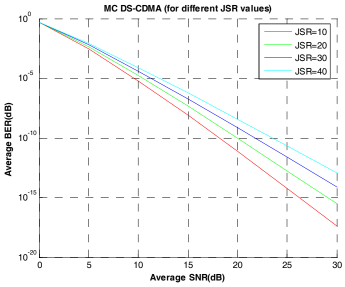

Fig 5.Performance of MC DS-CDMA Using BPSK over Nakagami-m Channel for Different Values of JSR

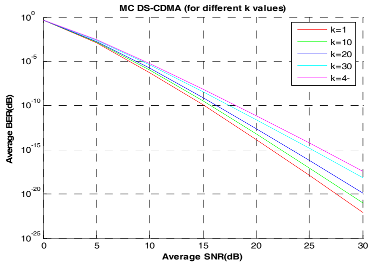

Fig 6. Performance of MC DS-CDMA Using BPSK over Nakagami-m Channel for Different *K* Value

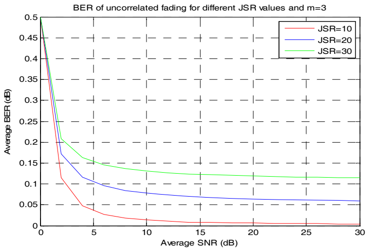

Fig7. Performance of MC DS-CDMA over Nakagami-m Uncorrelated Fading Channel with Different JSR Values

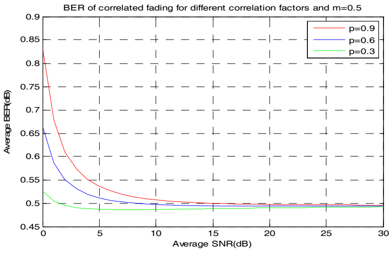

Fig 8. Performance of MC DS-CDMA using BPSK Over Nakagami-m Correlated Fading Using MRC Diversity Technique with Different Correlation Coefficients

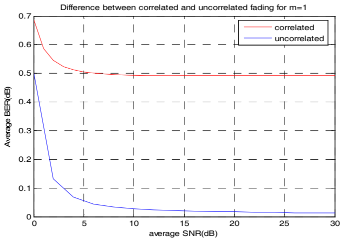

Fig9. Performance of MC DS-CDMA using BPSK over Nakagami-m Correlated and Independent Fading using MRC Diversity Technique with m=1

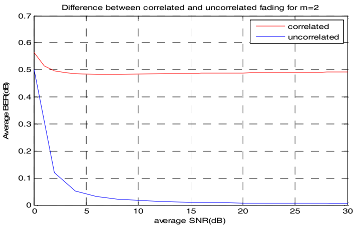

Fig 10. Performance of MC DS-CDMA using BPSK over Nakagami-m Correlated and Independent Fading using MRC Diversity Technique with m=2

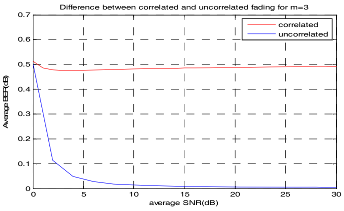

Fig 11. Performance of MC DS-CDMA using BPSK over Nakagami-m Correlated and Independent Fading using MRC Diversity Technique With m=3

Table 1. Average BER of Correlated and Uncorrelated Fading Channels for different values of m for a given SNR

m	Average Bit Error Rate for SNR=5dB		Average Bit Error Rate for SNR=10dB	
	Correlated	Uncorrelated	Correlated	Uncorrelated
1	0.5049	0.05636	0.4933	0.02776
2	0.4843	0.04219	0.4847	0.01665
3	0.4765	0.037405	0.4816	0.01324

5. Conclusions

In this paper, The BER expressions for the generalized MC DS-CDMA scheme using Maximal Ratio Combining on a Nakagami-m fading channel is derived. The system is evaluated over correlated and uncorrelated Nakagami-m channel. Due to the presence of multiple sub-carriers, the analysis of the generalized MC DS-CDMA system is much more complicated than a DS-CDMA system. The performance analysis for the MC DS-CDMA using MRC receiver is carried out and the difference between independent and correlated fading is observed and a comparison is made. Following is a summary of the observations and results that are obtained in this paper.

Fig4. shows the bit error rate of MC DS-CDMA over Nakagami-m fading channel with respect to signal to noise ratio. It is clear from Fig 4. that as the value of m increases bit error rate decreases. Fig.5 shows the bit error rate of MC DS-CDMA increases with increasing JSR (Jamming Interference). Fig.6 shows that as the number of users *k* increases the bit error rate also increases for MC-DS CDMA. Fig.7 show the variation of average BER with average SNR for different values of m and jamming interferences, From this figure it can be observed that as the value of jamming interference ratio is decreasing the average BER is also decreasing for a given value of *m* and SNR.

Fig.8.show the variation of average BER with average SNR for different values of m and correlation coefficients without considering JSR. It can be noticed from these figures that the bit error rate increases as the value of correlation coefficient increases for a given value of m. Further the effect of fading is more for high correlation coefficients.From Fig.9. for Rayleigh fading channel (m=1) average bit error rate remains constant for both correlated and uncorrelated fading for signal to noise ratio greater than 6dB. However for uncorrelated fading the average bit error rate is greatly reduced when compared to correlated fading for almost all the average SNRs.From Fig10. it can be observed for m=2 average bit error rate remains constant for both correlated and uncorrelated fading for signal to noise ratio greater than 8dB. However for uncorrelated fading the average bit error rate is greatly reduced when compared to correlated fading for almost all the average SNRs.From table 4.1 corresponding to the Figs. 9 to 11 one can conclude that for a Nakagami-m fading channel for a given SNR as m value increases, the average bit error rate decreases for both correlated and uncorrelated fading channels.

6. References

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