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Performance of a DS-CDMA system in Rayleigh fading channel

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Abstract
Multi-carrier DS-CDMA is considered to be an efficient scheme to minimize multiple access interference by moving the signals ' orthogonality property to the frequency domain. Nevertheless, due to the smaller bandwidth, the multi-carrier approach results in non-selective frequency fading in sub-channels. In this paper we will propose using a soft decision decoding Reed Muller code to recover the corresponding quality loss and compare the resulting system with a single carrier DS-CDMA system.

Keywords: Multiple access interference (MAI), Orthogonality, multipath fading

1. Introduction

Because of its ability to provide greater device efficiency over traditional multiple access technologies, the DS-CDMA technique has been favorably regarded for use in modern mobile cellular networks. Unlike TDMA and FDMA, often bandwidth-limited, a CDMA system's capability is restricted at the level of interference. Any decrease in interference results in an increase in device efficiency directly and linearly. The main form of interference that limits the ability of the CDMA system is multiple access interference caused by nonzero cross correlation between different spreading sequences. Because most sets of spreading codes have cross-correlation properties that are either too complicated to study or very difficult to measure when separate transmissions are not synchronized, a random sequence is usually assumed. Gaussian distribution with variable variance in the case of medium to major processing gains is a good approximation for multiple access interference distribution. One approach to reducing multiple access interference is to use orthogonal spreading sequences and attempt to synchronize the chip-level transmissions. A multi-carrier DS-CDMA scheme is used in this paper to facilitate the process of synchronization and thus reduce interference with multiple access.

2. System Model

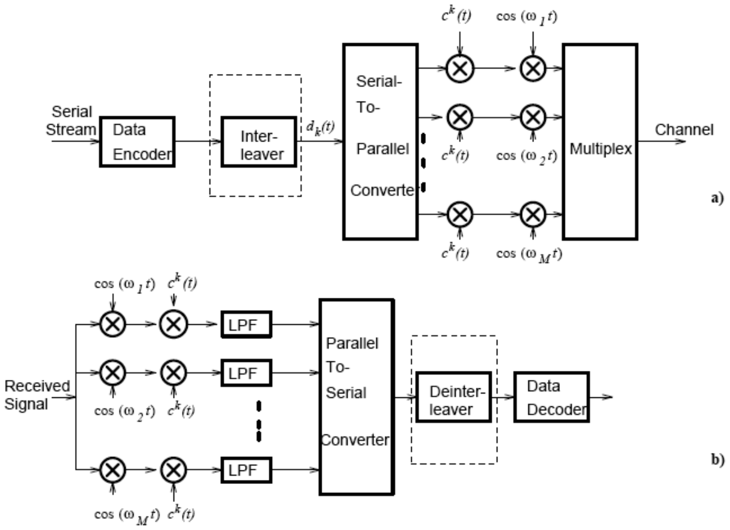

Fig 1: Multi carrier direct sequence spread spectrum system a) T_X and b) R_X

Transmitter Model

The dk (t) data flow of the client at the transmitter is divided into M interleaved streams and extended to a fraction 1/M of the transmission bandwidth W by a spreading series ck (t). The resulting sequences of chips are then used to modulate M carrier.

$$T_c = \frac{1}{W} \times M.$$

They are regularly spread over (0,2Pi).

Channel Model

The channel is modelled for complex impulse response.

$$p_k(t) = \sum_{l=0}^{L} \alpha_{k,l}\delta(t - \zeta_{k,l}) \exp(j\phi_{k,l}),$$

The impulse response of sub channel is,

$$h_{k,m}(t) = \alpha_{k,m}\delta(t - \zeta_k) \exp(j\phi_{k,m}),$$

Receiver Model

There are M branches in the receiver with each detecting the data sub-stream from one sub channel. The output of the low pass filter at the sampling point is,

$$y_{1,m_0}(T) = \pm\frac{\gamma_{1,m_0}T}{2} + I_{m_0} + J_{m_0} + \eta,$$

Soft decision is decoded serially and performed for channel fading.

BER Performance Analysis

The BER is evaluated based on the sequences of orthogonal distribution

$$I_{m_0} = \sum_{k=2}^{K} \frac{\gamma_{k,m_0}}{2} \cos(\theta_{k,m_0})\tau_k \sum_{j=0}^{N-1} \hat{c}_{j-1}^{k} c_j^{1},$$

The similarly distant hypothesis turns out to be valid for orthogonal codes such as the Reed Muller (RM) code used in this scheme. Mean is,

$$\mathcal{E}(\mu_i) = T \sum_{j=1}^{d_{min}} \gamma_{1,m_{1j}}^{2},$$

Variance is

$$V(\mu_i) = 4[V_I + V_J + \sigma_\eta^2] \sum_{j=1}^{d_{min}} \gamma_{1,m_{1j}}^{2}.$$

Conditional error probability:

$$p_i(\lambda_s) = \frac{1}{2} erfc\sqrt{\lambda_s},$$

λ_s is defined as

$$\lambda_s = \frac{T^2\Gamma_{1,1}}{8[V_I + V_J + \sigma_\eta^2]}.$$

The average BER system over a long transmission period is calculated. To find the probability of unconditional error pi calculate the PDF which is as follows,

$$f(\lambda_s) = \frac{1}{(d_{min} - 1)!\lambda_b^{d_{min}}} \lambda_s^{d_{min}-1} \exp(-\lambda_s/\lambda_b),$$

Average SNR ratio per sub-channel that is shown as,

$$\lambda_b = \frac{1}{\frac{1}{\mathrm{SIR}} + \frac{2}{\mathrm{SNR}}},$$

SIR is known as the interference ratio of the average signal per sub channel.

The closed form of solution

$$p_i = \left(\frac{1-\nu}{2}\right)^{d_{min}} \sum_{l=0}^{d_{min}-1} \binom{d_{min} - 1 + l}{l} \left(\frac{1+\nu}{2}\right)^{l},$$

$$\nu = \sqrt{\frac{\lambda_b}{1 + \lambda_b}}.$$

Probability for the function is

$$P_e \approx \frac{1}{2} p_s = \frac{N_c - 1}{2} p_i.$$

3. Numerical and Simulation results

The parameter 2n, n+1 is selected for numerical calculation because it provides better probabilities of error control. The drawback is its comparatively low code rate resulting in an expansion of large signal bandwidth. Though, it does not create a problem in the DS system where the available bandwidth for transmission is usually considerably larger than the actual signal bandwidth.

In figure 2 & 3, the MC-DS-CDMA's BER output is compared to a SC-DS-CDMA, which almost entirely balances the performance loss due to multi-path fading. The fig 2 show that the MC-DS -CDMA system does not outclass the SC-DS-CDMA system in the absence of coding, its performance is less delicate to the increasing the number of users. This is due to the fact that MC-DS-CDMA system suppresses the MAI in a much effective manner. The main basis of performance loss is due to flat fading over individual\ sub channel. But, error control coding combats fading very effectively. Figure 3 displays (6,4) RM code gives a considerably large margin to the error probability of an MC-DS-CDMA system than the SC-DS-CDMA system. Throughout the study, a rectangular chip pulse was presumed. For practice, to minimize inter sub channel interference, a band-limited chip pulse is prefarable. Fig 4 shows the performance improvement by using a minimum sinc pulse bandwidth that eliminates inter channel subinte reference. The results above are obtained on the assumption that fadind amplitudes are independent over the sub channels. Fig. 5 shows the output in the other extreme case where path amplitudes are fully correlated. This deteriorates the performance and thereby implementing the interleaving technique. It is assumed that the performance of a functional device should fall between these two extremes. The results of the simulation are shown in fig 2 & 3.

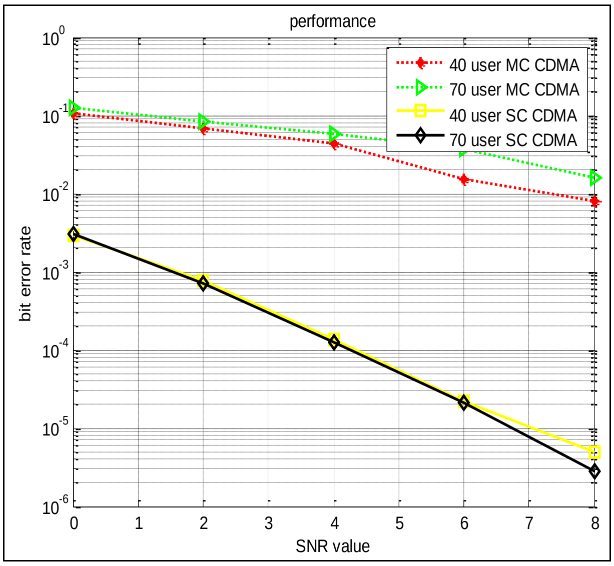

Fig 2: Comparison of performance sensitivities to the variation of the number of users between MC-DS-CDMA and SC-DS-CDMA

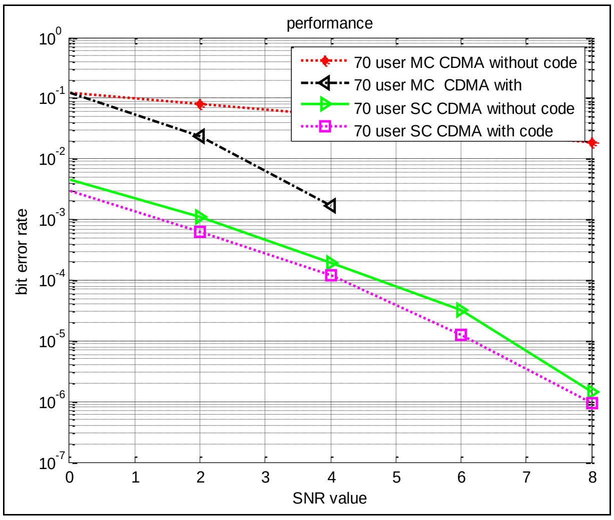

Fig 3: Effect of error control coding on MC-DS-CDMA& SC-DS-CDMA systems

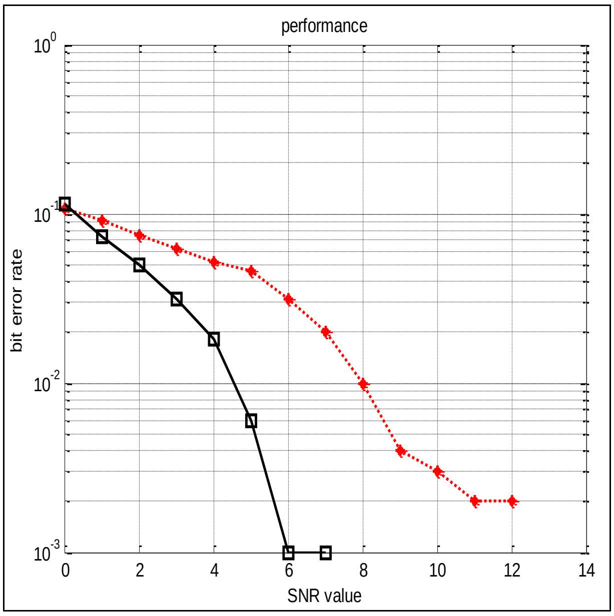

Fig 4: MC-DS-CDMA performance using different pulse shapes

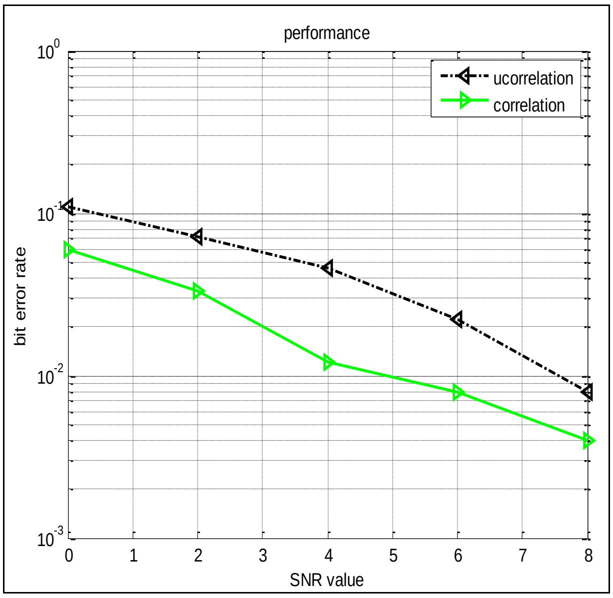

Fig 5: Performance under different fading amplitude correlation assumptions

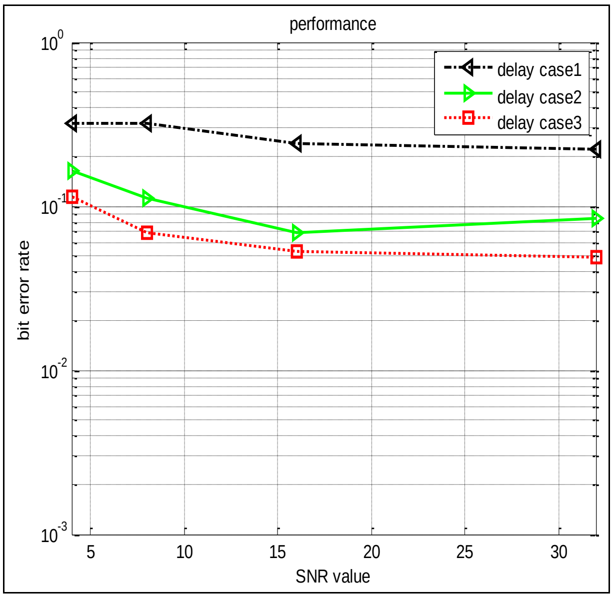

Fig 6: MC-DS-CDMA system performance versus the number of sub-channels

4. Conclusion

Following the discussion above, a variety of assumptions were drawn to act as guidance for developing the process.

- MC-DS-CDMA system quality is less influenced by consumer no. variability than the SC-DS-CDMA model.
- In contrast to the SC-DS-CDMA system where performance is limited by MAI, but the chief deterioration the of the MC-DS-CDMA system is due to multi-path fading error control coding with soft decision decoding.
- Fading amplitudes decorrelation improves performance.
- In comparison to AWGN channels, a greater quantity of sub channels M will not lead to better output with independent fading amplitudes.

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