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OPTIMUM MEDIUM ACCESS TECHNIQUE FOR NEXT GENERATION WIRELESS SYSTEMS

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ABSTRACT

This paper proposes a Multi-Code Multi-Carrier CDMA, best suited for multi-rate services using multi-code schemes and multi-carrier services used for high rate transmission as required for the Universal Telecommunication Mobile Systems (UMTS) Long Term Evolution (LTE). The system performance has been analyzed and evaluated by means of signal-to-noise plus interference ratio and bit error rate under a selective fading channel. The throughput of the system signifies more superior than the conventional CDMA, Multi-Code CDMA and Multi-Carrier CDMA systems. It has been widely adopted due to its high performance rate and low sensitive to impulse noise and multipath channels.

Keywords: *Multi-Code Multi-Carrier CDMA, Universal Telecommunication Mobile Systems, Long Term Evolution, Multiple Access Interference.*

1. INTRODUCTION

In mobile wireless communications, system performance is severely degraded due to rapidly time-variant multipath fading. Traditional communication systems designed for the worst-case channel conditions use a fixed link margin to maintain acceptable performance when the channel quality is poor. The transmitter and the receiver are not optimized for the current channel condition. As a result, there is a need to create new transmission techniques that can efficiently utilize the capacity of the multipath fading channel encountered in mobile communications.

This proposed system provides higher performance, robustness to selective fading channel model and more prominent in handling multiple data rates. The system performance in different fading channel was analyzed in [1] for Multi-Code CDMA and in [4] about Mutli-Carrier CDMA. With a single carrier in a fading channel about Multi-Code Multi-Carrier was investigated in literature. System performance improvement of Mutli-Carrier system using diversity techniques was discussed in [5].

2. SYSTEM MODEL

The proposed MC-MC-CDMA system consists of the multi-code part and the multi-carrier part. The multi-code part converts serial input data into parallel sub streams, spreads each parallel sub stream with orthogonal codes to produce code division multiplexed bits. And, now all the sub streams are summed to produce a super-stream $B_k(t)$ [1]. In the multi-carrier section, the super-stream is Serial-to-Parallel (S/P) converted again, spread with a user specified Pseudo-random Noise (PN) sequence, and modulated with orthogonal carriers. The data $d_k(t) = d_k^i(t) - jd_k^q(t)$ has duration T and symbol rate RM/T, assuming R codes and M carriers, where $d_k^i(t)$ and $d_k^q(t)$ represent the in-phase (I) and quadrature (Q) data symbols respectively, where k subscript denote the k^{th} user. If the system is BPSK modulated, only the in-phase data symbol is present. After S/P conversion and orthogonal code modulation the resulting output is

$$B_k(t) = \sum_{r=1}^{R} d_{kr}(t) a_r(t) \quad \dots (2.1)$$

Where $d_{kr}(t)$ is an input sub stream and a_r is an orthogonal code set for the r^{th} sub stream given by

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$$a_r(t) = \sum_{n=0}^{Na-1} a_r^n P_{T_{N_a}}(t - nT_{N_a}) \ldots \quad (2.2)$$

Where N_a is the code length of the orthogonal codes, T_{N_a} is the chip duration, a_r^n is the n[th] value of a_r, with chip rate $1/T_{Na} = M\,Na/T$. In order to maintain orthogonality, the maximum number of the sub streams is limited to $N_a = \frac{T}{MT_{Na}}$

3. PERFORMANCE ANALYSIS

The analytical framework is formulated and system performance is evaluated by means of signal-to-noise plus interference ratio and bit error rate under a slowly fading channel [1, 2]. In order to calculate the variance of the noise and interference terms, we assume that all terms are zero mean, statistically independent random variables.

We examine the SNIR and the BER performance of MC/MC-CDMA system compared to the conventional CDMA, the Multi-Code CDMA, and the Multi-Carrier CDMA systems.

3.1 SNIR Performance Analysis

Here we assume that all terms are zero mean statistically independent random variables. We find the value of Multipath Interference, Inter-Sub stream Interference, Inter Carrier Interference, Multi-User Interference and AWGN. Total interference and noise variance are obtained. Number of multi path, Number of sub streams, Number of carriers, Number of users, Local mean power and Multipath decay factor are chosen

3.2 BER Performance Analysis

BER of MC-MC-CDMA system with the existing systems was compared. Performance of MC-MC-CDMA is expected to be superior to any other conventional system.

3.3 Comparisons with other Approaches

CDMA's Rate Determination Algorithm (RDA) is designed to select Rate 1 (9.6 kbps) for speech and Rate 1/8 (1.2 kbps) for non-speech. Unfortunately, impairments such as background noise and acoustic echo are often misinterpreted by the RDA as voice, consuming unnecessary network bandwidth [4].When deployed, Ditech's CDMA Capacity solution prevents noise and acoustic echo from entering the RDA, reducing the average forward-link data rate generated by the vocoder by an average of 20% in noisy conditions. The power consumption of a minimum mean square error (MMSE) multi-carrier CDMA receiver implemented in digital hardware is considered in [8]. Simulations using data consistent with typical performance of a multi-carrier CDMA receiver indicate that the block based approach can produce a power reduction of around 50%. The performance enhancement due to such near optimal rate and power adaptation decreases with diversity order with increase in capacity.

In our approach the bit error rate of the system is analytically derived in frequency selective fading, with Gaussian noise and multiple access interference. The results show that the proposed MC-MC-CDMA system clearly outperforms both single-code multi-carrier CDMA (MC-CDMA) and single-carrier multi-code CDMA in a fixed bandwidth allocation. This indicates that MC-MC-CDMA should be seriously considered for next generation cellular systems.

3.3.1 Performance degradation due to multiple access interference

K CDMA transmitters share the same channel. Timing, frequency and phasing of all the users are identical. The mean square of the cross-correlation between the different spreading codes=1/Q where there are Q chips per period T. The SINR seen by the modem includes both the receiver noise and multiple access interference. The degradation depends upon the operating E_b/N_o, the number of users K and the spreading factor Q.

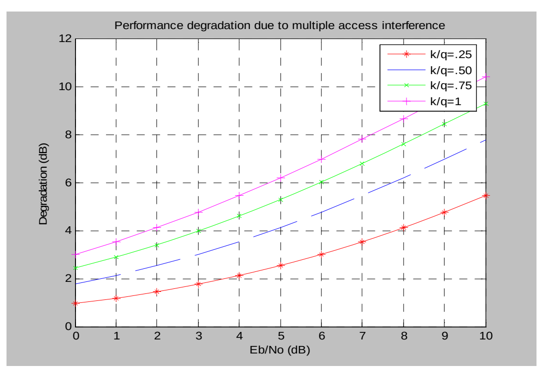

Figure.3.1 Performance degradation due to multiple access interference

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3.3.2 Power control

In conventional systems, transmitters that reuse the same channel are separated such that their mutual interference is sufficiently attenuated. In MC/MC CDMA system, the intent is to reuse the same frequency channel within the same area.
The SINR of the first user is given by

$$SINR = \frac{(E[y])^2}{\sigma_Y^2} \quad \ldots (3.1)$$

$$= \frac{\alpha_1^2 E_b}{N_0 + \frac{1}{Q} E_b \sum_{k=2}^{K} \alpha_k^2} \quad \ldots (3.2)$$

$$= \alpha_1^2 \frac{Eb}{N0} D_g^{'} \quad \ldots (3.3)$$

Where,

$$D_g^{'} = \frac{1}{1 + \frac{K-1}{Q} \frac{\alpha_1^2 E_b}{N_0} \left(\frac{1}{K-1} \sum_{k=2}^{K} \left(\frac{\alpha_k}{\alpha_1} \right)^2 \right)} \quad \ldots (3.4)$$

The term $\alpha_1^2 E_b / N_0$ in Eq. (3.3) is the SNR in the absence of multiple access interference. The factor $D_{g'}$ is the degradation due to multiple access interference. Comparing D_g' with D_g we see that the received energy for the desired signal is now $\alpha_1^2 E_b$ instead of E_b.

The other, more important, difference is that the denominator D_g' includes the factor

$$\frac{1}{K-1} \sum_{k=2}^{K} \left(\frac{\alpha_k}{\alpha_1} \right)^2 \quad \ldots (3.5)$$

The term in Eq. (3.5) is a multiplier applied to the multiple access interference. If all transmitted signals are received with equal power, then this term is unity. However, if any of the signal strengths is significantly greater than the desired signal (i.e., $\alpha_k >> \alpha_1$), then there will be a significant increase in the multiple access interference. This phenomenon is known as the *near far problem*. That is, signals coming from the transmitters significantly closer to the receiver can cause excessive interference with the desired signal. To illustrate the problem, we plot the degradation in performance with CDMA for K = 2 users in Figure. 3.2. One solution to the near-far problem is *power control*, in which each user's transmitted power is adjusted individually such that the received power $\alpha_k^2 E_b$ is constant and thus independent of K. Power control improves interference management significantly. We plot the degradation in performance with CDMA for the case of K=2 users. The degradation of the first user is plotted against relative power of the second user.

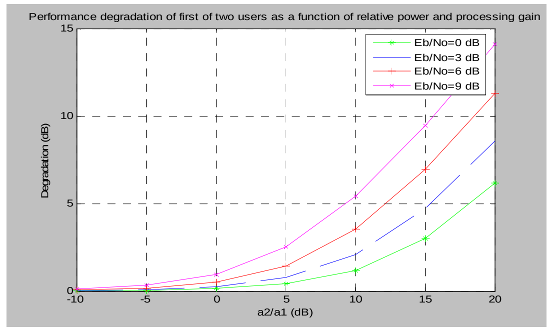

Figure . 3.2 Performance degradation of first of two users as a function of relative power and processing gain.

3.3.3 Degradation due to multiple access interference with & without FEC

We plot the degradation in performance with CDMA for different values of K/Q and is plotted against the loading K/Q for uncoded situation and calculated for different values of E_b/N_0.

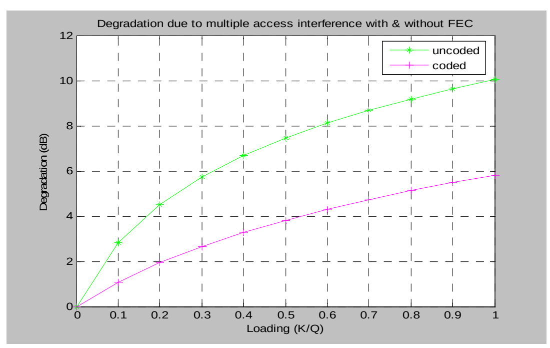

Figure.3.3 Degradation due to multiple access interference with & without FEC

3.3.4 MC-MC CDMA in cellular environment

One of the advantages of CDMA is that interference caused by another CDMA signal appears to be approximately equivalent to additive white Gaussian noise. This property is used advantageously in cellular systems. The multiple

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access interference (MAI) is directly proportional to the channel loading. For a constant SINR, moving from a noise limited system (Io/No=0 dB) to an interference limited system (Io/No=10 dB) increases the channel loading. For a constant SINR, increasing other cell interference reduces the permissible channel loading. Reducing the SINR required by the receiver significantly improves the permissible channel loading.

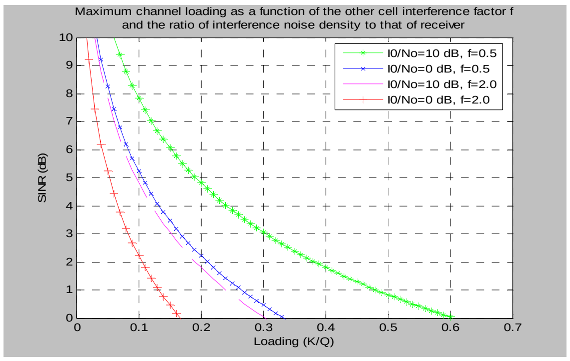

Figure.3.4 Maximum channel loading as a function of the other cell interference factor and the ratio of interference noise density to that of the receiver.

4. RESULTS AND ANALYSIS

For a comparison we assume variables like delay range, bandwidth, power and bit rate to be same for all the systems. In the case of delay range, we used the same channel with the same propagation delay for all systems compared, especially, when interference from several elements are considered.

4.1 Simulation Parameters

Number of multipath: 3
Number of substream: 8
Number of users: 13
Bit Rate: 9600

4.2 SNIR Performance Analysis

The SNIR of MC/MC CDMA is compared with other systems for the required parameters. The figure 4.1 illustrates the performance of a MC/MC CDMA system. The system has higher SNIR compared to multi code or multi carrier CDMA systems.

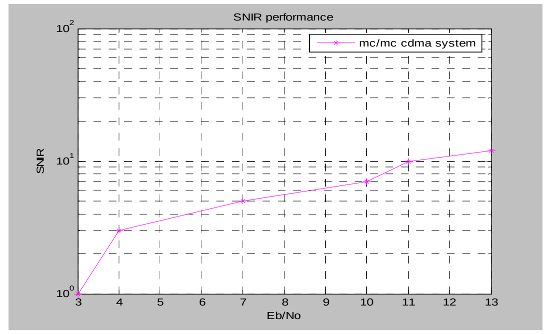

Figure.4.1 SNIR performance ratio for MC-MC CDMA

4.3 BER Performance Analysis for different systems

For a given system, the bit error ratio will be affected by both the data transmission rate and the signal power margin. Comparison of the BER for conventional CDMA, multi carrier CDMA, multi code CDMA and multi-code multi-carrier CDMA system was calculated. The BER is obtained by averaging the conditional probability of error P_e. Figure 4.2 clearly states, MC-MC-CDMA system has the lowest BER performance of all the systems compared and found be superior than the others.

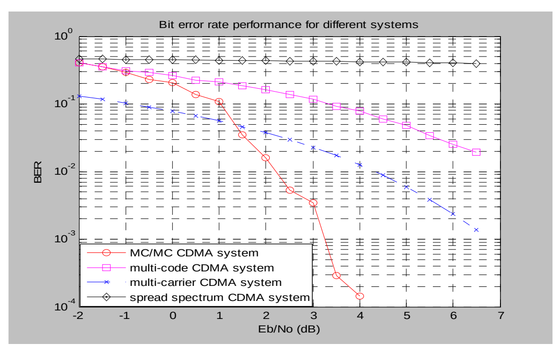

Figure.4.2 Bit error rate performance for different systems

4.4 BER Performance vs. Number of users

The figure 4.3 shows the performance as a function of the number of users. Increasing K decreases E_b/N_o, and increases BER performance. MC/MC CDMA system can be used more effectively by more users compared to the other systems.

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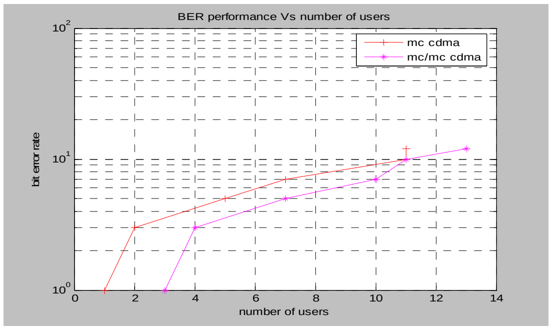

Figure.4.3 BER performance vs. number of users

5. CONCLUSION

We have proposed a novel approach to implement multi-code multi-carrier CDMA system. The analytical frame-work is formulated and system performance was evaluated under a slow fading channel and analyzes was made. The performance is compared to Multi-Carrier CDMA, Multi-Code CDMA and conventional CDMA system. In all performance measure, it was found that the proposed MC/MC CDMA provided superior performance. This access technique illustrates the efficiency, which is expected to get more and more significance in the next generation wireless system. Extensive simulation studies were performed under various cases and from the simulation results we conclude that the performance of MC/MC CDMA system is superior to conventional systems. In addition, this shows that data rate flexibility can be achieved in a multi-carrier CDMA system without any sacrifice in performance. Also we see that the degradation is very less even for large number of users keeping the spreading factor high. FEC coding improves performance over the case without coding by 2.7 dB. Maximum channel loading as a function of the other cell interference factor and the ratio of the interference noise density to that of the receiver was obtained.

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