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Performance Analysis of Joint Adaptive Modulation and Diversity Combining in TDD-CDMA Systems

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***Abstract* - Adaptive modulation and diversity combining represents the enabling techniques for the future generation of wireless communication. Adaptive modulation is a transmission scheme in digital communications where the transmitter adapts its transmission mode in accordance with the channel. In TDD systems the channel state is known in the transmitter side because of channel reciprocity, hence the adaptive modulation and diversity combining techniques are implemented in TDD-CDMA systems. The combination of TDD and CDMA allows for efficient bandwidth utilization, primarily through uplink/downlink asymmetry and frequency re-use respectively. Both adaptive modulation and diversity combining concepts use some predetermined threshold in their operation. Based on this observation, we naturally combine these two concepts, and develop and analyze Joint Adaptive Modulation and Diversity Combining schemes. The scheme of AMDC (Joint Adaptive Modulation and Diversity combining) is 1.Power efficient AMDC scheme is performed and analyzed in terms of power efficiency and error rate performance in TDD-CDMA systems.**

***Keywords* - TDD-CDMA, AMDC, QAM, BPSK, QPSK, MMS-_GSC, SNR**

I . INTRODUCTION

Future wireless communication systems will provide multimedia services to battery operated portable terminals. These systems must efficiently use the limited bandwidth and power resources to enable high data rate, high reliability transmission over wireless fading channels. Adaptive modulation and diversity combining are two of the most important enabling techniques for future wireless communication systems. Adaptive modulation can achieve high spectral efficiency over wireless channels. The basic idea of the adaptive modulation is to match the modulation parameters such as constellation size to fading channel conditions while maintaining the error rate below the target value. Usually the modulation mode is chosen based on the comparison results of received signal strength with several predetermined thresholds. Diversity combining can improve the reliability of wireless fading channels by appropriately combining differently faded information bearing signals. While adaptive modulation certainly can benefit from diversity combining through the improved channel quality, the design and analysis of these two techniques are usually carried out separately. When the fading conditions are favorable the diversity combining schemes result into a poor use of power resources. In order to save the power we are going to the adaptive combining schemes. One of the more advanced adaptive combining schemes is minimum selection generalized selection combining (MS-GSC). With MS-GSC the receiver combines the lowest number of best branches such that the combines SNR exists the certain predetermined thresholds.

II. SYSTEM MODEL

A. Signal and channel models

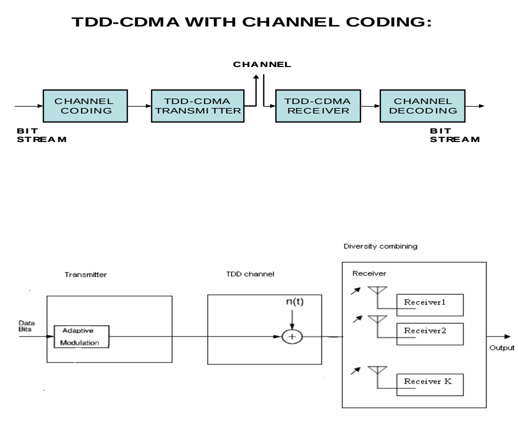

Figure1. joint adaptive modulation and diversity combining

We adopt a discrete time implementation for the proposed AMDC systems. In particulator, short guard periods are periodically inserted into the transmitted signal. During these guard periods, the receiver performs a series of operations, including diversity-path estimations and their comparison with predetermined thresholds, in order to determine the most appropriate diversity-combiner structure and adaptive modulation mode to be used during the subsequent data burst. Once these decisions are made at the receiver, the adaptive modulation mode is fed back to the transmitter via an error free reverse link before the guard period ends. After that, the transmitter and receiver are configured accordingly throughout the subsequent data burst transmission. We assume that there is L diversity branches available at the receiver. These diversity branches may correspond; for example, to L different receive antennas collecting faded replicas of the transmitted signal.

Adaptive modulation is a transmission scheme in digital communications where the transmitter adapts its transmission mode in accordance with the channel. Depending on the condition of the channel, the transmitter could be adapting one or more of the following: constellation size, code rate, and power. Adaptive modulation systems invariably require some channel information at the transmitter. This could be acquired in time division duplex systems by assuming the channel from the transmitter to the receiver is approximately the same as the channel from the receiver to the transmitter. Alternatively the channel knowledge can also be directly measured at the receiver, and fed back to the transmitter. Adaptive modulation systems improve rate of transmission, and/or bit error rates, by exploiting the channel information that is present at the transmitter.

Especially over fading channels, which model wireless propagation environments, adaptive modulation systems exhibit great performance enhancement compared to systems that do not exploit channel knowledge at the transmitter.

Modulation techniques used in adaptive modulations are 1.BPSK 2.QPSK 3.QAM. BPSK is the simplest form of PSK. It uses two phases which are separated by 180° and so can also be termed 2-PSK. This modulation is the most robust of all the PSKs since it takes serious distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol (as seen in the figure) and so is unsuitable for high data-rate applications when bandwidth is limited.Binary data is often conveyed with the following signals for binary "0"

$$s_0(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t + \pi) = -\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$

for binary "1"

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$

QPSK- Sometimes known as quaternary or quadriphase PSK or 4-PSK, QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gray coding to minimize the BER — twice the rate of BPSK. Analysis shows that this may be used either to double the data rate compared to a BPSK system while maintaining the bandwidth of the signal or to maintain the data-rate of BPSK but halve the bandwidth needed. Although QPSK can be viewed as a quaternary modulation, it is easier to see it as two independently modulated quadrature carriers. With this interpretation, the even (or odd) bits are used to modulate the in-phase component of the carriers.This yields the four phases $\pi / 4$, $3\pi / 4$, $5\pi / 4$ and $7\pi / 4$ as needed.The implementation of QPSK is more general than that of BPSK and also indicates the implementation of higher-order PSK. Writing the symbols in the constellation diagram in terms of the sine and cosine waves used to transmit them:

$$s_i(t) = \sqrt{\frac{2E_s}{T}}\cos\left(2\pi f_c t + (2i-1)\frac{\pi}{4}\right), i = 1,2,3,4$$

In QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, Since in digital telecommunications the data is usually binary, the number of points in the grid is usually a power of 2 (2,4,8...). Since QAM is usually square, some of these are rare—the most common forms are 16-QAM, 64-QAM, 128-QAM and 256-QAM. The mean energy of the constellation is to remain the same, the points must be closer together and are thus more susceptible to noise and other corruption; this results in a higher bit error rate and so higher-order QAM can deliver more data less reliably than lower-order QAM, for constant mean constellation energy. In general any adaptive modulation scheme can be applied in the proposed AMDC system. we adopt the constant power variable rate uncoded M ary quadrature amplitude modulation (M-QAM)scheme studied in [2].with this adaptive modulation scheme the mode selection is solely based on the fading channel condition. In particular, the SNR range is divided into N+1 regions and the constellation size M=2^n is used during the subsequent data burst if the output SNR of diversity combiner ends up being in the nth region, where n=0,1,2…N. Note that in this case, n bits are carried by each symbol. The region boundaries, denoted by γTn, are determined such that the instantaneous BER for the chosen constellation is below a certain required value, denoted by BER0. it has been shown that the instantaneous BER of 2^n QAM over an additive white

Gaussian noise(AWGN) channel with SNR of γ can be approximately given by

$$BER(\gamma)=(1/5)\exp(-3\gamma/2(2^n-1))$$
$$n=1,2,\ldots N$$

Therefore, it can be shown that the boundary thresholds can be calculated for a target BER value of BER0 as

$$\gamma T_n=-(2/3)\ln(5BER0)\,(2^n-1)$$

Diversity combining schemes

Diversity combining is the best tool in wireless communication systems.In diversity combining several copies of signals are transmitted to the certain number of receivers. The system designers are banking on the fact that the odds are against all of the channels simultaneously experiencing deep fades. By exploiting redundancy, the receiver will generally acquire more "good copies" of the signal than "bad copies."

III. POWER-EFFICIENT AMDC SCHEME

AMDC scheme is to minimize the processing power consumption of the diversity combiner, i.e to minimize the average number of combined/active diversity paths during the data burst reception. Once this primary objective is met, this scheme tries to afford the largest possible spectral efficiency while meeting the required target BER.Based on these objectives, the diversity combiner will perform just enough combining operations such that at least the lowest adaptive modulation mode,i.e binary phase shift keying (M=2), will exhibit an instantaneous BER smaller than the predetermined target value. In particular, the receiver tries to increase the output SNR τ above the threshold for BPSK, i.e $\gamma T1$, by performing MS-GSC diversity. After estimating and ranking the L available diversity paths, the combiner first checks if SNR of the strongest signal from just the strongest path. If not the combiner checks the combined SNR of the first two strongest paths. If not combine SNR of the first three strongest paths. This process is continued until either the combined SNRs become greater than $\gamma T1$ or all L available paths have been combined. In the first case, the receiver starts to determine the modulation mode to be selected by checking in which interval the resulting output SNR falls. In particular the receiver sequentially compares the output SNR with respect to the thresholds, $\gamma T1$, $\gamma T2\ldots$ γTN, whenever the receiver finds that the output SNR is smaller than $\gamma Tn+1$ but greater than γTn, it selects the modulation mode n for the subsequent data burst and feeds back that particular modulation mode to the transmitter. If the combined SNR of all L available branches is still below $\gamma T1$, the receiver may ask the transmitter to either transmit using the lowest modulation mode in violation of the target instantaneous BER requirement, or buffer the data and wait until the next guard period for more favorable channel conditions. The average spectral efficiency of an adaptive modulation system can be calculated as

$$\eta=\sum nP_n$$

P_n is the probability that the nth constellation is used. The average BER for adaptive modulation system can be calculated as

$BER=(1/\eta)\sum_{BERn}$, Where BER_n is the average error rate for constellation n.

IV. SIMULATION RESULTS

PARAMETERS USED:

Modulations Used : BPSK,QPSK,QAM

Diversity combining : Selection combining

SNR Level : 1 to 10 db

No. of Users Taken : 4 and 7

No. of Symbols Taken : 378

Length of PN Sequence : 7

Channel Used : Fading channel

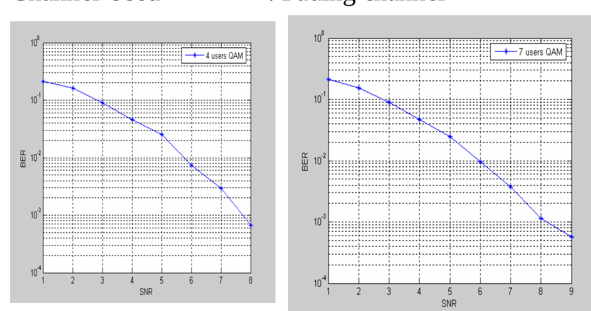

Figure2: 4, 7 users QAM modulation

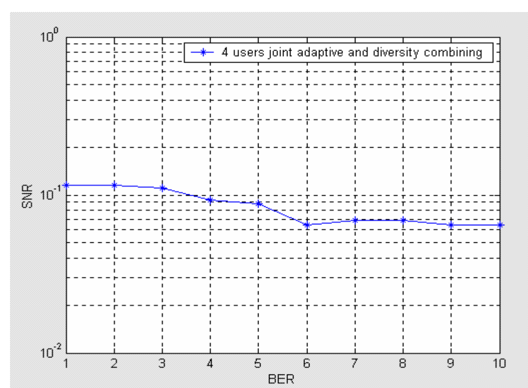

Figure3:4 users joint Adaptive modulation and diversity combining

The maximal-ratio combining (MRC) scheme is investigated in detail. Other diversity combining schemes, such as selection combining (SC) and equal gain combining (EGC) are outperformed by MRC in the case of coherent communications. First, the case of

M independent fading channels is considered. The output signal-to- noise ratio (SNR) expression is derived, and an expression for the bit error rate (BER) is determined. Simulations of the channels are performed and the results are compared to the theoretical BER. Then, the case of M correlated fading channels is considered, and an analysis that is similar to the case of independent fading is performed.

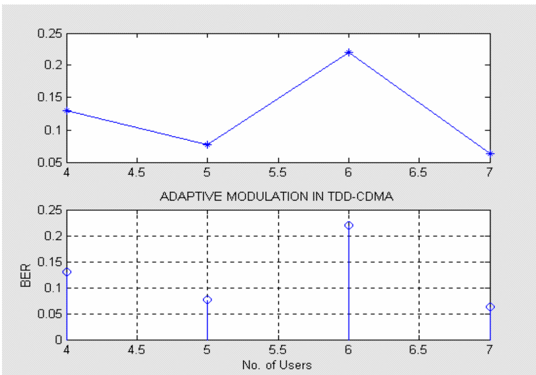

Figure 4:Adaptive Modulation for various users

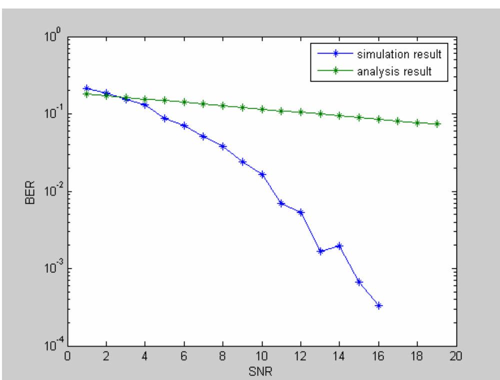

Figure5 : 4 users power efficient AMDC

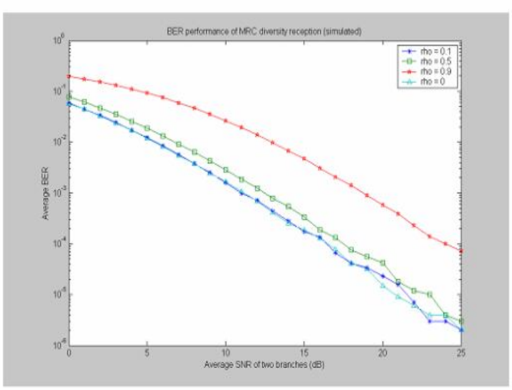

Figure 6:BER performance of MRC diversity receptions

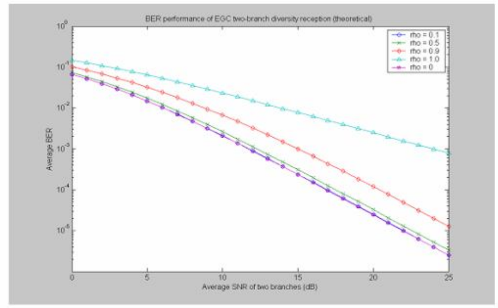

Figure7: Correlated fading for EGC diversity receptions

V. CONCLUSION

Adaptive Modulation in CDMA is used to increase the data rate and to reduce the ISI in higher data rate. In this project, the Adaptive modulation based BPSK,QPSK,QAM systems applied to a Time Division Duplex (TDD)-CDMA and joint Adaptive modulation and Diversity combining(AMDC) is also applied in TDD-CDMA .The BER and SNR performance of all these digital modulation techniques for 4,5,6 and 7 users in TDD-CDMA and AMDC in TDD-CDMA were compared and results were verified using MATLAB.

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