DBpia

논문 02-27-12B-8 한국통신학회논문지 '02-12 Vol.27 No.12B

차세대 이동 통신 시스템에서 전송 다이버시티가 결합된 적응 변조 및 코딩 기법의 성능

정회원 황 인 태*, 노 상 민*, 나 현 식*, 정 옥 현**, 권 성 태**, 홍 대 식*, 강 창 언*

Performance Analysis of Adaptive Modulation and Coding Combined with Transmit Diversity in Next Generation Mobile Communication Systems

Intae Hwang*, Sangmin Ro*, Hyunshik Na*, Okhyun Jung**, Seongtae Kwon**, Daesik Hong*, Changeon Kang* *Regular Members*

ABSTRACT

In this paper, we combine Adaptive Modulation and Coding (AMC) with Transmit Diversity (TD) to improve the performance of AMC in CDMA systems and verify the throughput gain over AMC. The received Signal to Noise Ratio (SNR) is improved by adopting TD techniques so that a probability of selecting Modulation and Coding Scheme (MCS) level that supports higher data rate is increased. Therefore, higher average throughput can be achieved. In this paper, we consider two TD schemes, Space-Time block coding based Transmit antenna Diversity (STTD) and Selection Transmit Diversity (STD). The results show that higher throughput is achieved by AMC-TD schemes. Compared to the conventional AMC, AMC-STTD scheme shows about 250kbps increase in throughput and AMC-STD with 2 transmit antennas achieves about 420 kbps throughput improvement over the conventional AM at 9dB SNR in flat Rayleigh fading channel.

Ⅰ. Introduction

Adaptive Modulation and Coding (AMC) has drawn much attention due to its ability of the improved throughput performance in wireless communication systems. It adapts coding rate and modulation scheme to channel condition, resulting in an improved throughput over a fixed transmission technique[1]~[3].

Transmit Diversity (TD) reduces the devastating effects from fading channels so that improved signal-to-noise ratio (SNR) is obtained at receiver. AMC system determines its transmission coding rate and modulation scheme based on SNR estimated at a mobile receiver.

It is very important for CDMA systems to obtain higher data transfer rates and maintain low complexity of mobile receiver. Therefore, the combination of TD and AMC, AMC-TD schemes can be considered as countermeasure for this problem. However, until now, investigation on the gain of AMC-TD was insufficient.

In this paper, we combine open-loop and closed-loop TD techniques with AMC. Additionally, we investigate the improved average throughputs of the combined systems based on the simulation results. STTD is chosen as an open-loop TD, and STD is used as a closed-loop TD.

This paper is organized as follows. The TD

* 연세대학교 전기전자공학과 ** LG전자
논문번호 : 020345-0806, 접수일자 : 2002년 8월 6일

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr

schemes are described in Section II. In Section III, structures of the combined systems are shown for AMC-STTD and AMC-STD. In Section IV, the performance of AMC and each combined scheme are investigated by computer simulation. In Section V, Conclusions are drawn.

Ⅱ. Transmit Diversity Schemes

For STTD with 2 transmit antennas, two consecutive symbols are divided into a transmission group, $\{s_0, s_1\}$. For a transmission at time t, s_0 and $-s_1^*$ are transmitted through the first and second transmit antenna, respectively. At time $t+T$, where T is a time duration of a symbol, the first transmit antenna sends s_1 and the second one transmits s_0^*. Power of STTD encoded symbols are normalized by the number of transmit antennas to maintain constant transmission power.

In a multipath channel with L resolvable paths, assuming that constant channel across two consecutive symbols and no interference, the received signals are

$$\begin{aligned} r_0(t) &= \sum_{l=0}^{L-1} h_{0,l}\, c(t-\tau_l)\, s_0 - h_{1,l}\, c(t-\tau_l)\, s_1^* + n_0 \\ r_1(t) &= \sum_{l=0}^{L-1} h_{0,l}\, c(t-\tau_l)\, s_1 + h_{1,l}\, c(t-\tau_l)\, s_0^* + n_1 \end{aligned} \qquad (1)$$

where $r_i(t)$ is the received signal at time $t+iT$, $c(t)$ means a spreading sequence, τ_l indicates delay of l-th path, n_i is a zero mean AWGN with a variance σ^2 at time $t+iT$, and $h_{i,l}$ represents Rayleigh fading channel coefficient between l-th path of transmit antenna i and a receive antenna.

After de-spreading, signals from the l-th finger will be

$$\begin{aligned} r_{0,l} &= \int r_{0(t)}\, c^*(t-\tau_l)\, dt \\ &= h_{0,l}\, s_0 - h_{1,l}\, s_1^* + n_{0,l} \\ r_{1,l} &= \int r_{1(t)}\, c^*(t-\tau_l)\, dt \\ &= h_{0,l}\, s_1 + h_{1,l}\, s_0^* + n_{1,l} \end{aligned} \qquad (2)$$

where $r_{0,l}$, $r_{1,l}$ are the received signals of l-th path at the first and second symbol timing.

A mobile receiver detects transmitted symbols $\tilde{s}_0$, $\tilde{s}_1$ by combining STTD decoded signals from L paths. The estimated symbols can be written as

$$\begin{aligned} \tilde{s}_0 &= \sum_{l=0}^{L-1} h_{0,l}^*\, r_{0,l} + h_{1,l}\, r_{1,l}^* \\ &= \sum_{l=0}^{L-1} (|h_{0,l}|^2 + |h_{1,l}|^2)\, s_0 + \tilde{n}_{0,l} \\ \tilde{s}_1 &= \sum_{l=0}^{L-1} h_{0,l}^*\, r_{1,l} - h_{1,l}\, r_{0,l}^* \\ &= \sum_{l=0}^{L-1} (|h_{0,l}|^2 + |h_{1,l}|^2)\, s_1 + \tilde{n}_{1,l} \end{aligned} \qquad (3)$$

Eq.(3) shows that $2L$ branch diversity can be obtained in multipath channel with L resolvable paths when the multipath interference is perfectly removed.

In STD, assuming no errors or delay problems in feedback, the transmitter chooses the best antenna based on the feedback from a mobile receiver and transmits only on the selected one. The selection of the transmit antenna is based on the feedback from the mobile receiver. Therefore, considering STD with two transmit antennas, the SNR at the rake output will be

$$\gamma = \max\left\{ \sum_{l=0}^{L-1} \gamma_{0,l},\ \sum_{l=0}^{L-1} \gamma_{1,l} \right\} \qquad (4)$$

where $\gamma_{i,l}$ indicates the received SNR from the l-th path of the i-th transmit antenna.

Ⅲ. AMC combined with TD techniques

Fig.1 shows the AMC-STTD structure in CDMA systems. The information bits are encoded by turbo coding and interleaved. After modulation, STTD encoding followed by the Walsh modulation and scrambling process is done A mobile receiver performs de-scrambling, Walsh demodulation, and STTD decoding. From the STTD decoder, channel state information is obtained. The channel state information is used for feedback to Modulation and Coding Scheme (MCS) selector. MCS selector modifies

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr

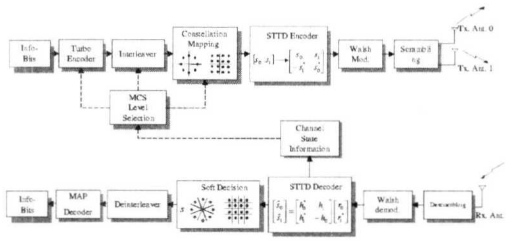


Fig. 1 AMC-STTD structure

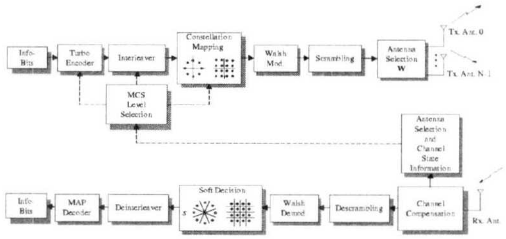


Fig. 2 AMC-STD structure

transmission parameters, coding rates and modulation scheme, based on the received SNR at the mobile receiver. STTD decoded symbols are demodulated, de-interleaved. and information bits are recovered by MAP decoder.

The structure of AMC-STD is described in Fig.2. The structure of AMC-STD is similar to AMC-STTD case. The difference is that transmit antenna selection part exists and selection information is included in the feedback. The weights W for transmit antenna selection is given by

$$W=\{W_0, W_1, \ldots, W_{N-1}\}, \quad W_i=\begin{cases}1 & \text{if } i=n \\ 0 & otherwise\end{cases} \qquad (5)$$

where W_i is weight of i-th transmit antenna, n is an index of the selected antenna, and N is the number of transmit antennas.

In the AMC schemes combined with TD, multiple channels exist between transmit antennas and receive antennas. The condition of each channel is assumed to be independent.

In AMC-STTD case, the estimated SNR after STTD decoding process is same for each estimated symbol $\tilde{s}_0, \tilde{s}_1$ in Eq.(3). Therefore, the SNR calculated after STTD decoding is used for MCS level selection in AMC. Considering SNR for MCS level selection in AMC-STD case, the received SNR is obtained in the same manner as the single transmit antenna case.

The concept of the estimated SNR for STTD and STD with two transmit antennas is illustrated in Fig.3 and 4. In the combined schemes in Fig.1 and 2, the selection of MCS level is determined based on the SNR in Fig.3 and 4 respectively.

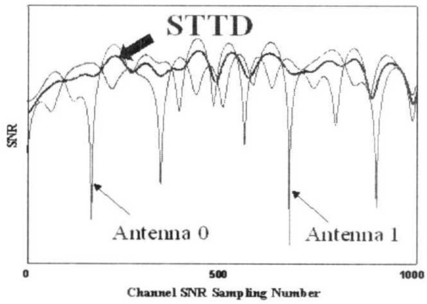


Fig. 3 Received SNR for STTD

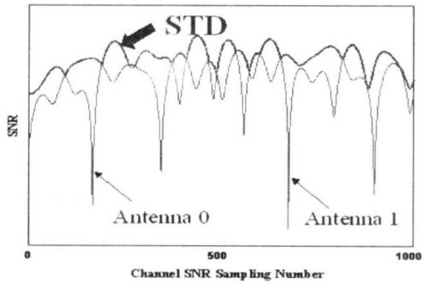


Fig. 4 Received SNR for STD with 2 Tx. antennas

In STTD, the transmission power is normalized by the number of transmit antennas[4]. Therefore, the estimated SNR from STTD decoding can be seen as an averaged SNR. On the other hand, STD with two transmit antennas does not suffer 3dB transmit power penalty that appears in STTD case because it selects only one transmit antenna.

Ⅳ. Simulation Results

The simulation parameters and MCS levels are described in Table 1 and Table 2 respectively. The MCS levels are chosen from HDR(High Data Rate) spec[8]. The threshold setting for MCS level selection is based on the result in Fig.5. It

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr

shows the throughput for each MCS level using a single transmit antenna in AWGN. To obtain the maximum throughput, each threshold is determined at the crossing SNR points of a throughput in Fig.5. Threshold between MCS level 1 and 2 is 3.25dB. For MCS level 2 and 3, 7.25dB is chosen. 9.25dB is the threshold between MCS level 3 and 4.

Table 1. Simulation parameters

Bandwidth	1.2288 MHz
Slot length	1.67msec
Channel	Flat Rayleigh fading channel
	2path Rayleigh fading channel
Modulation	QPSK, 8PSK, 16QAM
Channel Coding	Turbo Coding (1/2 or 2/3 rate)
Number of Tx. antennas	1, 2, 4
Spreading factor	16
Doppler frequency	50 Hz

Table 2. MCS levels

MCS level	Data rate (kbps)	Bits/frame	Code rate	Modulation
1	614.4	1024	1/3	QPSK
2	1228.8	2048	2/3	QPSK
3	1843.2	3072	2/3	8PSK
4	2457.6	4096	2/3	16QAM

Fig.6 shows a throughput in flat Rayleigh fading channel. Compared to AMC, AMC-STTD achieves about 250kbps increase in throughput at 9dB SNR. AMC-STD with two transmit antennas improves to 420 kbps at 9dB SNR. At a low SNR below -1dB, the throughput of AMC-STTD is almost same as that of AMC. While AMC-STD transmits on a single antenna without reduction of transmit power, the penalty in transmit power exists in AMC-STTD. With 2 transmit antennas, STTD suffers 3dB transmit power penalty that does not occur in STD using two transmit antennas.

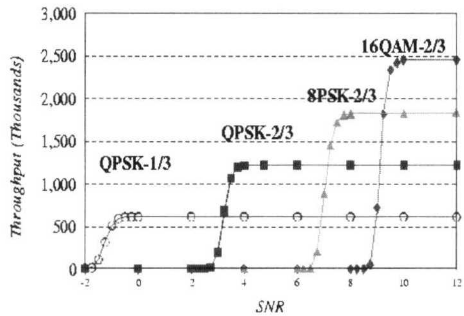


Fig. 5 Throughput of each MCS level in AWGN

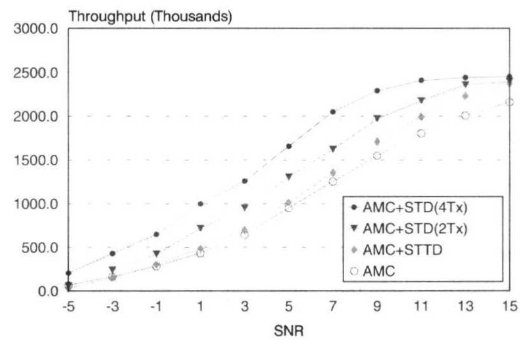


Fig. 6 Throughput in flat Rayleigh fading channel

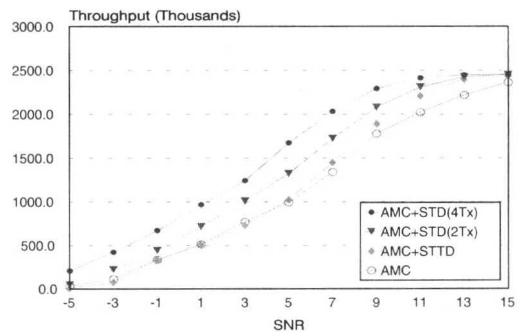


Fig. 7 Throughput in 2path Rayleigh fading channel

For the power penalty of AMC-STTD, AMC-STD obtains higher throughput at a low SNR compared to AMC-STTD. The throughput of AMC-STD with 4 transmit antennas is increased about 700 kbps compared to that of AMC at 9dB SNR. In this case, the improvement of a throughput is increased for higher selection diversity order of 4.

The throughput in 2 path Rayleigh fading channel is presented in Fig.7. To observe the diversity effect in multipath, the interference from

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr

the other path is assumed to be eliminated completely. The signals from multipath obtain effect of increased diversity. As a result, receiving signals from each path, all schemes in Fig.7 show improved performance. In addition, it is shown that the gap in the throughput between AMC and combined scheme is reduced compared to Fig.6. For example, comparing Fig.7 with Fig.6, the performance of AMC in 2 path fading channel is shown to be similar to that of AMC-STTD in the flat fading channel. Moreover, the gap between AMC-STTD and AMC is reduced to 100 kbps at 9dB SNR.

Fig.8 through 11 show the MCS selection probability for AMC, AMC-STTD, AMC-STD with 2 antennas, and AMC-STD with 4 antennas in flat Rayleigh fading channel respectively. For overall results, MCS level 3, 8PSK and 2/3 code rate, has a low probability of selection compared to other MCS levels. The curves of AMC-STD with 4 transmit antennas are moved to the top left corner. Curves moved to the left side mean

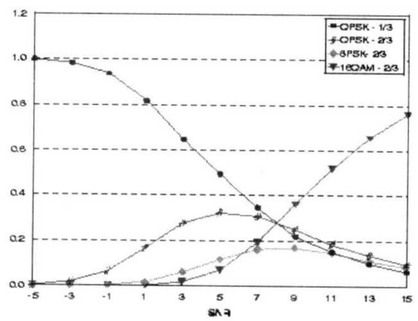


Fig. 8 MCS selection probability of AMC

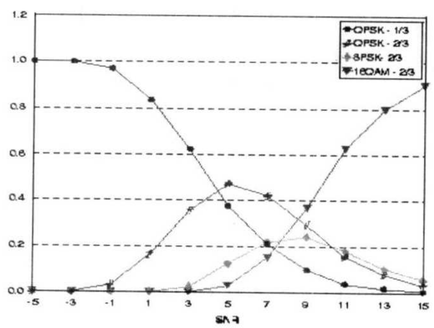


Fig. 9 MCS selection probability of AMC-STTD

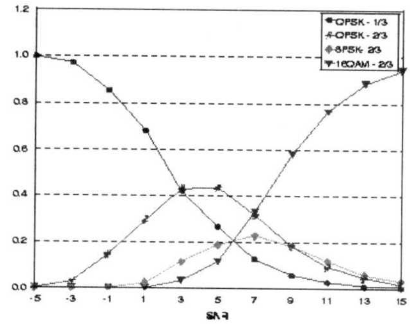


Fig. 10 MCS selection probability of AMC-STD with 2 Tx. antennas

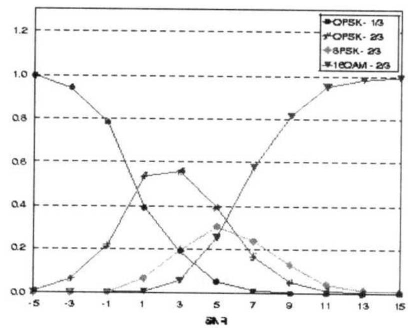


Fig. 11 MCS selection probability of AMC-STD with 4 Tx. antennas

that MCS level with higher data transfer rate is more likely to be selected so that the average throughput increases at given SNR. Therefore, we can see that the characteristics of MCS selection probability match the results in Fig.6.

V. Conclusion

We have investigated the performance of AMC, AMC-STTD, and AMC-STD with 2 or 4 transmit antennas. Using the diversity gain, the effectiveness of received SNR is improved so that the probability of selecting MCS level with higher data transfer rate is increased. As a result, the average throughput increases at given SNR. It is shown that AMC-STD with two antennas provides higher throughput than AMC-STTD. However, AMC-STTD suffers 3dB transmission power penalty. In multipath environment, assuming no interference from other paths, the diversity effect due to signals from various paths gives better

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr

performance. In a realistic case, where multipath interference exists, the throughput performance will be inferior than the flat fading case. Hence, research on the mitigation of multipath interference needs to be considered to utilize diversity effect sufficiently and obtain higher data transfer rate.

Reference

[1] Paul Bender, Peter Black, Mattew Grob, Roberto Padovani, Nagabhushana Sindhushayana, and Andrew Viterbi, "CDMA/HDR : A Bandwidth-Efficient High-speed Wireless Data Service for Nomadic Users", *IEEE Comm. Magazine*, pp.70-77, July, 2000.

[2] Andrea J. Goldsmith, Soon-Ghee Chua, "Variable-Rate Variable-Power MQAM for Fading Channels", *IEEE Trans. Comm.*, Vol.45, pp.1218-1230, Octorber, 1997.

[3] Andrea J. Goldsmith, Soon-Ghee Chua, "Adaptive Coded Modulation for Fading Channels", *IEEE Trans. Comm.*, Vol.46, pp.595-602, May, 1998.

[4] S. M. Alamouti, "A simple transmit diversity technique for wireless communications", *IEEE J. Sel. Areas in Comm.*, Vol.16, pp.1451-1458, October, 1998.

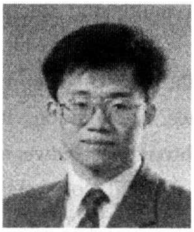
[5] Naguib, A.F, Seshadri, N., calderbank, A.R., "Increasing data rate over wireless channels", *IEEE Sig. Proc. Magazine*, Vol.17, pp.76-92, May, 2000.

[6] Magnus Sandell, "Analytical analysis of transmit diversity in WCDMA on fading multipath channels", *PIMRC'99*, Vol.2, pp.946-950, September, 1999.

[7] Pieter van Rooyen, Michiel Lotter, and Danie van Wyk, *"Space-Time Processing for CDMA Mobile Communications"*, Kluwer Academic Publishers, 2000.

[8] 3GPP2 C.P9010, "Draft baseline text for the physical layer portion of the 1X EV specification,", pp. 9-78, August 2000.

황 인 태(Intae Hwang) 정회원

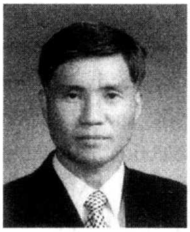


1990년 2월: 전남대학교 전자공학과 졸업
1992년 8월: 연세대학교 전자공학과 석사
1999년 9월~현재: 연세대학교 전기전자공학과 박사과정
1992년 8월~현재: LG전자 책임 연구원

노 상 민(Sangmin Ro) 정회원

한국통신학회 논문지 제 27권 제 4B호 참조

나 현 식(Hyunshik Na) 정회원

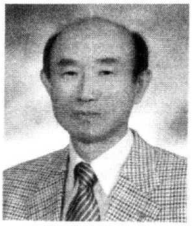


1979년 2월: 연세대학교 전자공학과 졸업
1983년 8월: 연세대학교 전자공학과 석사
1995년 9월~현재: 연세대학교 전기전자공학과 박사과정
1983년 7월~1989년 8월: 서울 산업대학교 강사
1984년 1월~1990년 2월: 금성소프트웨어 연구소 연구실장
1990년 3월~2001년 8월: 호남대학교 정보통신학과 교수

정 옥 현(Okhyun Jung) 정회원

1982년 2월: 서강대학교 전자공학과 졸업
1985년 2월: 서강대학교 전자공학과 석사
1996년 8월: 서강대학교 전자공학과 박사
1985년 1월~현재: LG전자 책임연구원

권 성 태(Seongtae Kwon) 정회원



1974년 2월: 연세대학교 기계공학과 졸업
1991년 3월: LG전자 가전연구소 임원
1992년 10월: LG전자 영상미디어 연구소 연구위원
1998년 7월: LG 반도체 중앙미디어 연구소 부소장
2001년 1월: LG정보통신 CDMA 단말 연구소장
2001년 1월~현재: LG전자 차세대단말 연구소장

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr

홍 대 식(Daesik Hong) 정회원
한국통신학회 논문지 제 21권 제 8호 참조

강 창 언(Changeon Kang) 정회원
한국통신학회 논문지 제 23권 제 2호 참조

Copyright (C) 2003 NuriMedia Co., Ltd.
www.dbpia.co.kr