선택적 전송다이버시티를 사용한 개선된 AMC-MIMO 다중화시스템

강 민 구*

Improved AMC-MIMO Multiplexing Systems Using Selection Transmit Diversities

Min-goo Kang*

요 약

본 논문에서는 MIMO 시스템에서 적응 변조 및 부호화 (AMC) 기법의 성능을 향상시키기 위한 방안으로서 기지국과 단말기 간에 선택적 전송 다이버시티를 적용하였다. 이는 전송 다이버시티를 적용하여 수신 단의 신호 대 잡음비(SNR)를 개선함으로써, 보다 높은 전송률을 지원하는 변조 및 부호화 레벨(MCS) 확률을 증가시키고 이에 따른 평균 전송률의 이득을 얻고자 하는 것이다. 전송 다이버시티로는 선택적 전송다이버시티 (STD) 기법을 적한 AMC-MIMO다중전송시스템은 기존 시스템에 비하여 향상된 전송률을 얻을 수 있었다. 특히, 균일한 레일리 페이딩 채널환경에서 4개 안테나로 부터 2개의 안테나를 선택하는 제안된 전송안테나를 사용한 AMC-MIMO는 15dB SNR 성능상태에서 1Mbps 전송률 이득을 보였다.

ABSTRACT

In this paper, Adaptive Modulation and Coding (AMC) is combined with Multiple Input Multiple Output (MIMO) multiplexing to improve the throughput performance of AMC. In addition, a system that adopts Selection Transmit Diversity (STD) in the AMC-MIMO multiplexing system is proposed. The received SNR is improved by adopting STD techniques. And it increases probability of selecting MCS (Modulation and Coding Scheme) level that supports higher data rate. This leads to an increased throughput of the AMC-MIMO system. STD in our simulation selects 2 transmission antennas from 4 antennas and AMC-MIMO multiplexing process operates with the selected antennas. The computer simulation is performed in flat Rayleigh fading channel. The results show that the proposed system achieves a gain of 1Mbps over the AMC-MIMO multiplexing system with the same number of antennas at 15dB SNR.

키워드

Adaptive Modulation and Coding(AMC), Input Multiple Output(MIMO) multiplexing, Selection-Transmit Diversity(STD), MCS(Modulation and Coding Scheme) levels

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*한신대학교 정보통신학과

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1. Introduction

The throughput improvement in the downlink wireless communication systems will be the hot issue in the next generation communication systems. In order to fulfill the need for ultra-high speed service, researches about Multiple Input Multiple Output (MIMO) system have been in progress. The Bell-lab LAyered Space-Time (BLAST) is representative of the MIMO multiplexing scheme [1]. Also, in order to improve throughput performance, together with MIMO multiplexing system, Adaptive Modulation and Coding (AMC) has drawn much attention [2][3].

The AMC scheme adapts coding rate and modulation scheme to channel condition, resulting in improved throughput and guarantees transmission quality.

For this advantage, the High Speed Downlink Packet Access (HSDPA) and 1x-Evolved high-speed Data Only/Data and Voice (1xEV-DO/DV) for high-speed data packet transferring adopts the AMC in the current 3rd wireless communication systems [4][5].

Consequently, the combination of MIMO multiplexing system and AMC could be the solution for improved throughput performance. This paper aims at Transmit Diversity (TD) technique that could be a useful application for improving throughput of AMC-MIMO systems. TD technique brings on a higher SNR and allows a usage of MCS level that supports higher data rate with a satisfactory throughput. In this paper, the performance analysis of the AMC-MIMO system is presented. Moreover, a reformed AMC-MIMO multiplexing system that adopts the STD is proposed.

The reason of the selecting STD from the other TD techniques is as follows.

First, closed-loop TD is considered since the AMC system basically contains feedback information. Second, instead of open-loop TD like Space-Time Block Coding (STBC), higher diversity gain is achievable by using closed-loop TD.

Finally, the feedback information of STD is simpler than that of the other closed-loop TD like Transmit Adaptive Array (TxAA). In the combination of MIMO multiplexing system and AMC, the Vertical BLAST (V-BLAST) is considered for lower complexity [6].

2. Configuration for proposed AMC-MIMO Multiplexing System

The system configuration of the proposed AMC-MIMO multiplexing was shown in this section. In addition, some considerable points for combining AMC-MIMO multiplexing system and STD are discussed.

2.1 Transmit and receive structure of the AMC-MIMO multiplexing system

AMC-MIMO multiplexing system needs to estimate the received SNR of each transmission layer. But, in the AMC-MIMO multiplexing system, the received SNR can not be determined at each receive antenna because these signals contain signals from the other transmit antennas. Therefore, the SNR in receiver is achieved after nulling. The calculation of SNR from each transmit antennas can be summarized as following. If the V-BLAST system has M transmit antennas and N receive antennas, MIMO channel will have a $M \times N$ channel response matrix as $\mathbf{H}^{M \times N} = \{h_{ij}\}$, where h_{ij} means the channel response from the i-th transmit antenna to the j-th receive antenna. Then the received signal, $\mathbf{X}_n$ can be written as

$$\mathbf{X}_n = \sqrt{\frac{E_S}{M}}\mathbf{H}\,\mathbf{s}_n + \mathbf{V}_n \tag{1}$$

With AMC-MIMO, the received SNR of signal from each transmission layer needs to be calculated for the MCS level selection.

But the received SNR cannot be directly obtained from Eq.(1). After the nulling process, the SNR becomes visible. The SNR of each transmitted layer is determined as the following equations [7].

$$\tilde{\mathbf{s}}_{\mathbf{n}} = \mathbf{G}\mathbf{X}_{\mathbf{n}} = \sqrt{\frac{E_S}{M}}\mathbf{G}\mathbf{H}\,\mathbf{s}_{\mathbf{n}} + \mathbf{G}\mathbf{V}_{\mathbf{n}} \tag{2}$$

$$\mathbf{G} = \begin{cases} \mathbf{H}^{+} : ZF \\ (\mathbf{H}^{*}\mathbf{H} + N_0 / E_s\mathbf{I}_{\mathbf{M}})^{-1}\mathbf{H}^{*} : MMSE \end{cases} \tag{3}$$

$$ZF : SNR_k = \frac{E_S / MN_0}{[\mathbf{H}^{*}\mathbf{H}]_{kk}^{-1}} \tag{4}$$

$$MMSE : SNR_k = \frac{E_S / MN_0}{[\mathbf{H}^{*}\mathbf{H} + \frac{MN_0}{E_S\mathbf{I}_{\mathbf{M}}}]_{kk}^{-1}} - 1 \tag{5}$$

where N_0 is a noise variance, $\mathbf{G}$ is a nulling matrix, $\mathbf{V}_{\mathbf{n}}$ is a noise vector at each receive antennas, $\mathbf{s}_{\mathbf{n}}$ is a transmitted symbol vector, and $\tilde{\mathbf{s}}_{\mathbf{n}}$ means an estimated symbol vector.

Notation * means a hermitian matrix and $[\square]_{kk}$ represents the element at the kth-row and the kth-column (k=1, 2, M).

The results from Eq.(4) or (5) are used for the selection of MCS level. If channel encoding/decoding, interleaving/deinterleaving and modulation/demodulation schemes are separately applied to each layer, it will contribute to the throughput improvement. But the amount of a feedback information increases and it leads to a reduced uplink capacity. If the same MCS level is used for all transmit antennas, the amount of the feedback information will be decreased comparatively. In this paper, the simulation is performed using the same MCS level for all antennas in consideration of simple feedback informations.

2.2 Combining AMC-MIMO Multiplexing System with Selection Transmit Diversity

The AMC-MIMO multiplexing system attains an improved throughput compared to a conventional AMC system. Moreover, the throughput can be greatly increased by adopting transmit diversity. The Space-Time Block Coding (STBC) or the STD can be one of the many choices.

In the simulation, STD is applied because it achieves higher diversity gain than that of STBC. Fig.1 shows the transmitter and receiver structure of the proposed system.

Fig.2 shows the transmit antenna selection algorithm when STD is applied to AMC-MIMO multiplexing system where M_t is the number of transmit antenna which is possible to select and M is the number of selected transmit antenna for MIMO multiplexing[7].

The SNR of each layer is obtained as a result of nulling. When we select M antennas among M_t candidate antennas for MIMO multiplexing, the possible combination of the antenna selection is ${}_{M_t}\mathbf{C}_M$.

For each possible combination, SNR for each of the M selected transmit antennas can be obtained. The layer that has the minimum SNR in each set of antennas limits the throughput of the system.

Consequently, the selection of the set of antennas aims at the maximization of the minimum SNR. First, SNR values that are the minimum in each combination are compared. The selected set of antennas is one that has the maximum value among the compared SNRs.

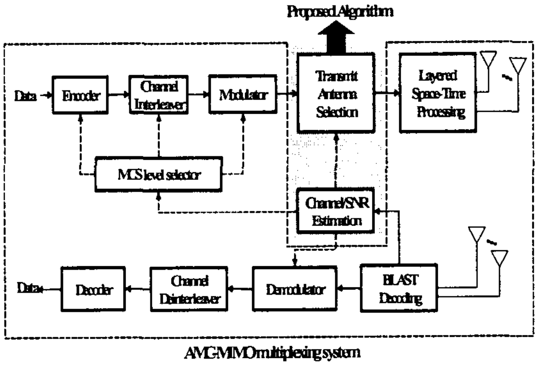

Fig 1.Transceiver structure of the proposed systems

As an example, if there are four antennas and two antennas are used for MIMO multiplexing, six combinations of antennas exist and each combination, the set of antennas, will be composed of two antennas. Then six minimum SNRs from the combinations can be obtained and compared. In the end, one combination that has the maximum value in the compared SNRs is chosen and the antennas of the combination are used for the data transmission.

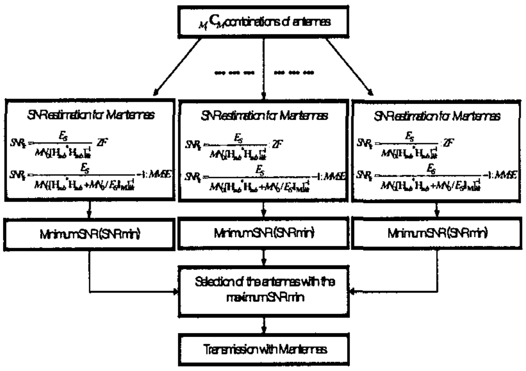

Fig 2. Transmit antenna selection algorithm in MIMO

3. Simulation Results

In this section, simulation results are presented and discussion of the throughput performance of AMC-STD, AMC-MIMO multiplexing system, and the proposed system is made.

3.1 MCS levels and Simulation Parameters

Table 1 show the MCS level selection. As shown in Eq. (6), the throughput has much relation to frame error ratio E_{FER}.

$$P_{Throughput} = (1 - E_{FER}) \times R \tag{6}$$

Data rate of MCS levels is shown in Table 1. In AMC- MIMO multiplexing system, data transmission rate of each MCS level increases proportional to the number of the transmit antennas. There are many references in the selection of the MCS level selection threshold.

In this paper, since the main emphasis is on data transmission rate, the thresholds that maximize throughput are selected.

Accordingly, each MCS level selection threshold is defined as the throughput performance cross point in AWGN environment.

MCS level selection thresholds decided by the cross points are 3.25dB, 7.25dB, 9.25dB.

Table.1 MCS levels

MCS level	Data rate(kbps)	Number of bits per 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

Table.2 Simulation parameters

Bandwidth	1.2288MHz
Slot length	1.67msec
Modulation	QPSK, 8PSK, 16QAM
Code rate	1/2, 2/3
Channel coding	Turbo coding (Number of iterative decoding: 4)
Number of Tx. Antennas	1, 2, 4
Number of path	1
Spreading factor	16
Doppler frequency	50Hz

3.2. Performance of the AMC systems with multiple antennas and the proposed system

Fig.4 shows throughput performance of the MC-MIMO multiplexing system when MMSE nulling is adopted. The AMC-STD systems that select one antenna from 4 candidate antennas, AMC-STD (4Tx), and AMC+STBC (2Tx) are also compared.

The result verifies that maximum throughput is increased by applying MIMO multiplexing to AMC. In the low SNR, approximately under 1dB, the 2X2 AMC-MIMO (2 transmit and 2 receive antennas) multiplexing system shows a poor performance. AMC-STBC scheme hardly gets a considerable diversity gain in the low SNR since STBC just averages the channel gains of two branches.

In contrast, the AMC-STD and 2X4 MMSE AMC-MIMO (2 transmit and 4 receive antennas) cases achieve a considerable throughput improvement under the same SNR region because the diversity gain is obtained. This demonstrates that the closed-loop and receiver diversity techniques make enable AMC-MIMO multiplexing systems to get a considerable throughput, if the SNR is low.

But it is impractical to use receive diversity in the downlink for the limited number of antennas at mobile receiver. Therefore, it is desirable to apply STD technique for AMC-MIMO multiplexing systems to guarantee the stable throughput while the maximum throughput is maintained.

Fig.5 depicts the throughput improvement for the proposed AMC-STD-MIMO multiplexing system. The same experiment environment of Table 1 and 2 is applied. 4-2X2 means the proposed AMC-MIMO multiplexing system that selects 2 transmit antennas from 4 candidate antennas and the number of receive antennas is two. 3-2X2 indicates the proposed system which selects 2 antennas from 3 candidate antennas.

The result shows the proposed system achieves better throughput performance than the AMC-MIMO multiplexing system in the total SNR range. In case of applying the MMSE nulling method, the proposed achieves the gain of 4.5dB SNR compared to the AMC-MIMO multiplexing system at 3Mbps throughput.

2X4 MMSE AMC-MIMO multiplexing system obtains the receiver diversity gain.

Accordingly, 2X4 MMSE AMC-MIMO multiplexing system can be seen as an upper bound of the other schemes in the simulation. The result demonstrates that the performance of the proposed scheme approaches that of 2X4 MMSE AMC-MIMO multiplexing system up to 2dB for the same throughput.

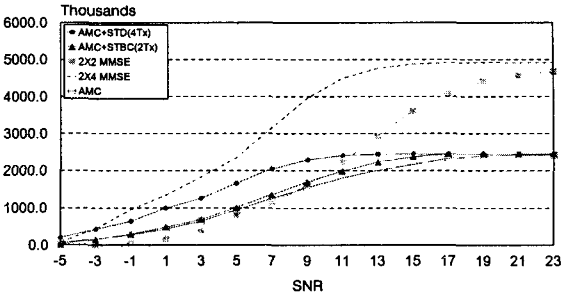

Fig 4. Throughputs (kbps) of AMC-MIMO multiplexing and AMC-TD systems

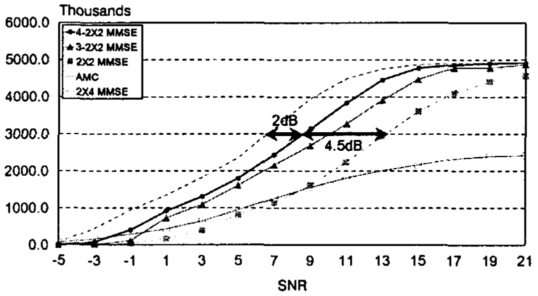

Fig 5.Throughputs (kbps) of proposed systems

4. Conclusion

In this paper, the AMC-MIMO multiplexing system is implemented and its performance is shown from the computer simulations.

The results prove that the AMC-MIMO multiplexing system contributes to the throughput enhancement. On the other hand, it hardly improves the performance in a low SNR range. To mitigate this problem, the AMC-STD-MIMO multiplexing system is proposed.

The improvement of the received SNR by STD allows the AMC-MIMO multiplexing system to select MCS level that supports higher data rate. Moreover, STD makes the error probability lower in the relatively low SNR and ultimately the throughput performance of system is improved.

From simulation results, it is shown that the proposed system provided the maximum throughput improvement and stable throughput increase in the whole SNR range.

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References

[1] G.J. Foschini, "Layered Space-Time Architecture for Wireless Communication in a Fading Environment When Using Multi-Element Antennas," Bell Labs Technical Journal, Autumn 1996.

[2] A. J. Coldsmith, and S.G. Chua, "Variable-Rate Variable-Power MQAM for Fading Channels," IEEE Trans. on Comm., Vol.45, No.10, pp.1218-1230, October 1997.

[3] A. J. Goldsmith, and S.G. Chua, "Adaptive Coded Modulation for Fading Channels," IEEE Trans. on Comm,, Vol.46, No.5, pp.595-602, May 1998.

[4] P. Bender, P. Black, M. Grob, R. Padovani, N. Sindhushayana, and A. Viterbi, Qualcomm, Incorporated, "CDMA/HDR : A Bandwidth -Efficient High-Speed Wireless Data Service for Nomadic Users," IEEE Comm. Magazine, pp.70-77, July 2000.

[5] 3GPP2 C.P9010, "Draft baseline text for the physical layer portion of the 1X EV specification,", pp.9-78, August 2000.

[6] A. Bhargave; R.J.P. de Figueiredo, T. Eltoft, "A Detection Algorithm for the V-BLAST System," GLOBECOM '01. IEEE, Vol.1 , pp. 494 -498, November 2001.

저자소개

강 민 구 (Min-goo Kang)

1982년~1986년 : 연세대학교 전자공학과(공학사)
1987년~1989년 : 연세대학교 전자공학과(공학석사)
1989년~1994년 : 연세대학교 전자공학과(공학박사)
1985년~1987년 : 삼성전자 통신연구소 연구원
1997년~1998년 : 오사카대학 통신공학과 Post Doc.
1994년~2000년 : 호남대학교 정보통신공학부 조교수
2000년~현 재 : 한신대학교 정보통신학과 부교수
※관심분야 : 차세대 이동통신시스템, Wireless LAN