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Performance Analysis of an Adaptive-MCM System with Combining AMC and MIMO Schemes

Changwoo Seo, Insik Cho, Gilsang Yoon, Jeonghwan Lee, Sherlie Portugal, Intae Hwang

***Abstract*— In this paper, we propose an Adaptive Modulation Coding MIMO System (Adaptive-MCM), which results from the combination of two schemes: Adaptive Modulation and Coding (AMC) and Multiple Input Multiple Output (MIMO). A system using AMC improves its throughput and reliability, because the Channel Coding rate and the Modulation scheme are selected according to the channel conditions. We want to probe that if the MIMO scheme also changes adaptively, the resulting system will achieve a higher data rate and error performance. Through computer simulation, we analyze and compare the throughput performance of the Adaptive-MCM with a Non-Adaptive-MCM, which keeps fixed values of modulation, coding rate and MIMO scheme. The results show that the Adaptive-MCM presents a better trade-off between Signal to Noise Ratio (SNR) and throughput; and consequently, a better average data rate.**

***Index Terms*—MIMO, MCM, AMC, SNR.**

I. Introduction

The accelerated increase of the mobile communication users has made indispensable the creation of mobile communication techniques and systems able to provide continuously increasing data rates and reliability. Among the techniques proposed to satisfy those demands we can mention MIMO and AMC. In a limited frequency resource environment, the MIMO scheme increases the channel capacity by using multiple transmit and receive antennas;

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Changwoo Seo is with Chonnam National University, Gwangju 500-757, South Korea (phone: +82-62-530-0654; fax: +82-62-530-0659; e-mail: apples021@naver.com).

Insik Cho is with Chonnam National University, Gwangju 500-757, South Korea (phone: +82-62-530-0654; fax: +82-62-530-0659; e-mail: choiskhy@hanmail.net).

Gilsang Yoon is with Chonnam National University, Gwangju 500-757, South Korea (phone: +82-62-530-0654; fax: +82-62-530-0659; e-mail: luckyface0410@hanmail.net).

Jeonghwan Lee is with Chonnam National University, Gwangju 500-757, South Korea (phone: +82-62-530-0654; fax: +82-62-530-0659; e-mail: ljh8311@gmail.net).

Sherlie Portugal was with Technological University of Panama, Panama. She is now with Chonnam National University, Gwangju 500-757, South Korea (phone: +82-62-530-0654; fax: +82-62-530-0659; e-mail: sherlie.portugal@gmail.com).

Intae Hwang is with Oregon State Uni-versity, OR 97331, USA, on leave from Chonnam National University, Gwangju 500-757, South Korea (phon : +82-62-530-1805; fax: +82-62-530-0659; e-mail: hit@chonnam.ac.kr).

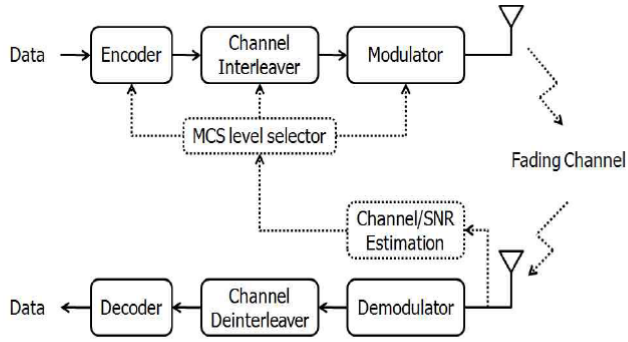

Fig. 1. Structure of an AMC system

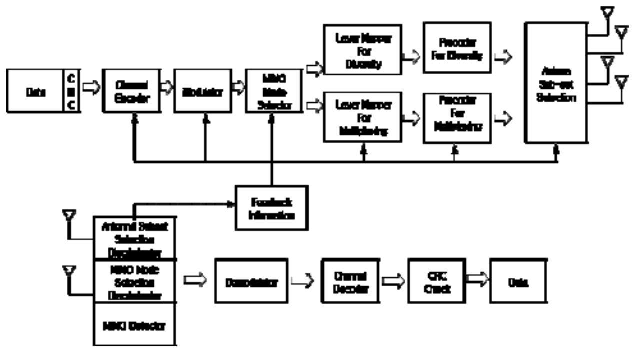

Fig. 2. Structure of the Adaptive-MCM System

thus, providing high quality and transmission rate. MIMO can be divided into two main types: MIMO diversity and MIMO multiplexing. The MIMO diversity scheme [1] [2] has a low data rate compared to MIMO multiplexing; however, unlike layered MIMO [3], which is a type of MIMO multiplexing, MIMO diversity increases the system reliability despite a low SNR. Therefore, there has been a great interest among the researchers in combining these two MIMO schemes in a single system and take advantage of both, the diversity and the multiplexing gain. As for AMC, its adaptation features makes it a research worthy object, especially if a high data rate is among the expected results. Our proposal consists then, in the combination of MIMO and AMC schemes in one single system: Adaptive-MCM. The optimal selection of coding rate, modulation and MIMO scheme result is an improvement of the data rate and system reliability, enhanced by the addition of pre-coding and Antenna Subset-Selection.

The next sections of this paper are organized as follows: Part II describes the structure and characteristics of the proposed Adaptive-MCM System as well as the conventional AMC.

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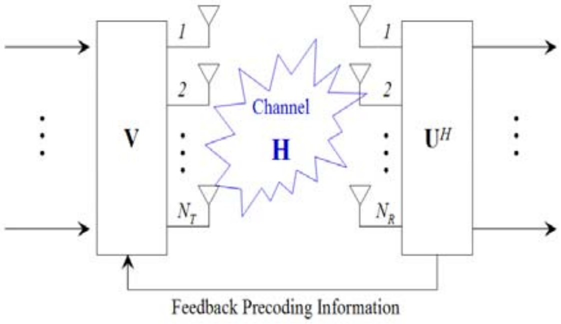

Fig. 3. The concept of SVD scheme

In section III, we explain the characteristics of the each of the schemes that compose the Adaptive-MCM System; following, in chapter IV, by analysis of its performance through computer simulation. And finally, in chapter V, we draw up our conclusions and final comments.

II. STRUCTURES AND CHARACTERISTICS OF THE ADAPTIVE-MCM SYSTEM

In this section, we describe the structure of the Adaptive-MCM system. First, we describe the structure of the conventional AMC System [4] depicted in Fig. 1. At the transmitter, the data is coded, interleaved, modulated and then, transmitted through the channel. Once at the receiver the channel condition is estimated with a SNR criterion [5]; this information is sent back to the transmitter, which decides what Modulation and Coding Scheme (MCS) level to use.

Choosing a MCS level means to select a specific code rate and modulation scheme according to the estimation of the channel conditions. If the channel condition is favourable, a high order of modulation and code rate are used. Otherwise, a low order of modulation and code rate are selected. With the appropriate MCM level, AMC can get an excellent throughput performance and quality for a specific channel condition. Fig. 2 shows the structure of the Adaptive-MCM system. If we compare it to the conventional AMC in Fig. 1, we can see that what makes Adaptive-MCM different is that it uses a combination technique of modulation, channel coding, and MIMO Scheme; the three of them changing adaptively according to the channel condition. The system also includes pre-coding and antenna subset-selection schemes in order to get the optimal performance.

III. CHARACTERISTICS OF THE EACH OF THE SCHEME COMPRISING THE ADAPTIVE-MCM SYSTEM

In this section, we explain characteristics of the each of the scheme comprising the Adaptive-MCM system.

A. Pre-coding scheme

The pre-coding scheme is located at the transmitter. It improves the system performance by using the estimated channel information calculated at the mobile station. There are several techniques used for pre-coding, such as Pre-Zero Forcing (ZF), Pre-Minimum Mean Square Error (MMSE) [6], and Singular Value Decomposition (SVD). The SVD technique, which we use in the Adaptive-MCM System, finds the interference components caused by the channel and eliminates them using singular value decomposition.

The SVD do not have to consider the transmission power, because it multiplies transmitter and receiver by an orthogonal matrix; in addition, SVD is simple; thus, reduces the system complexity. Fig. 3 shows the concept of SVD; V is a weighted vector which is created using feedback information, and U is a vector used to recover the original signal.

B. Antenna subset-selection

In order to improve transmit reliability, the system selects 2 transmit antennas out of four; the selected antennas have the most favorable channel conditions. To know the channel condition for each of the four transmits antennas, the receiver returns channel information to the transmitter. This method is similar to AMC; therefore, if we apply AMC, antenna subset-selection can be easily implemented. Among the several methods for estimating the channel in antenna subset-selection, we decided to work with the minimum SNR [7], since this method is known for having the best performance.

C. MIMO scheme

As mentioned in the previous section III.B, even though the system has 4 transmit antennas, we selected 2 out of the 4 through antenna subset-selection. At the receiver we also use 2 receive antennas. For example, if the estimated channel condition is not favorable, MIMO diversity (2 transmit antennas) is used, since the space-time encoding of two consecutive symbols improves the transmit reliability. Otherwise, layered MIMO is selected in order to increase the transmission rate.

Fig. 4 shows an example of getting transmit diversity gain by using Space Time Transmit Diversity (STTD) or Space Time Block Code (STBC); there is a decrease of the SNR variance at the receiver. For this reason, the ability to have low or high SNR value relatively decreases; and even when one channel fall into null, the received SNR is stabilized to an average. The layered MIMO scheme, unlike STTD, achieves high data rates by transmitting independent sub-streams of data from each transmit antenna. In addition, layered MIMO reduces the system complexity because it allows the using of SVD, which is easy to implement compared with the complex Maximum Likelihood (ML) decoder that STTD uses.

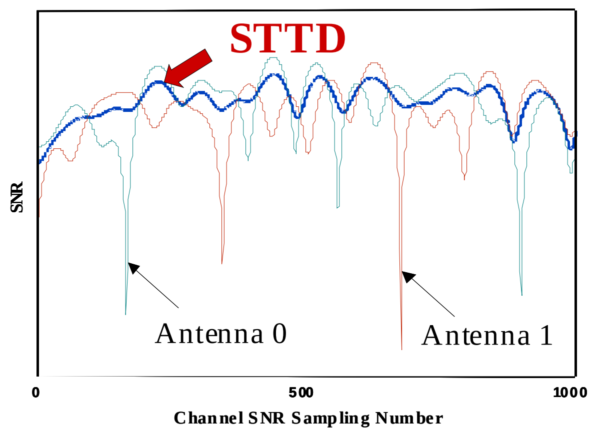

Fig. 4. The concept of diversity gain by STTD scheme

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TABLE 1. MCM-SCHMEME LEVELS

MCM level	MIMO scheme	Code rate	Modulat-aion	Through-put
1	STBC 4x2	1/3	QPSK	160 Kbps
2	Layered 4x2	1/3	QPSK	320 Kbps
3	Layered 4x2	1/2	QPSK	480 Kbps
4	Layered 4x2	1/3	16QAM	640 Kbps
5	Layered 4x2	1/2	16QAM	960 Kbps
6	Layered 4x2	1/2	64QAM	1440 Kbps

TABLE 2. SIMULATION PARAMETERS

Parameter	Value
The number of symbols per sub-frame	480
sub-frame duration	2 ms
channel	Rayleigh Flat Fading
Noise	AWGN
Spreading Factor	16
MIMO scheme	STBC 2x2 Lyered MIMO 2x2
Channel coding	Turbo coding(1/2, 1/3)
Modulation	QPSK, 16QAM, 64QAM
Signal detection scheme	ML(STTD), SVD(Layered)
Antenna Subset Selection	SNRmin

IV. SIMULATION RESULTS

Table 1 shows the combination of the adaptive parameters for each MCM level; and table 2 contains the rest of simulation parameters, which are based on HSDPA and 3G LTE standards. In Fig. 5 we can observe the throughput performance for a Non-Adaptive-MCM system corresponding to each MCM level in Table 1. For MCM level 1, the combination parameters are: STBC 4x2, turbo code 1/3 and QPSK modulation; the maximum throughput is 160kbps with a starting point at SNR equal to -9dB. This means that a system that uses a fixed MCM-scheme level of 1, can achieves a maximum Throughput of 160 kbps within a relatively low SNR range; nonetheless, if we compare it with the other systems using different fixed MCM levels, 160 kbps results in the lowest maximum throughput among all the systems. The highest maximum throughput among all systems is achieved using the fixed MCM level 6.

Nevertheless, there is a price to pay since the SNR necessary to guarantee such a maximum throughput is the highest among all the systems; about 5dB. Therefore, if a system uses a fixed MCM level 6, it must guarantee sufficient SNR in order for it to operate properly. On the other hand, the throughput performance of the Adaptive-MCM System, shown in fig. 6, increases gradually because the MIMO scheme, the channel coding, and the modulation scheme change with the increase of the SNR. This improvement in the trade-off between SNR and throughput leads to a better average data rate.

V. CONCLUSION

In this paper, we proposed a system that combines AMC and MIMO schemes. While conventional AMC system changes only the coding rate and modulation, the proposed Adaptive MCM System also selects the MIMO scheme (diversity, multiplexing) according to channel condition.

Furthermore, by applying pre-coding and antenna subset-selection we not only produce optimal performance but also increase the data rate. In case of Non-Adaptive-MCM, the simulation results show that even thought, this system secures enough SNR, and its maximum throughput is limited. As for the Adaptive-MCM system, the simulation shows an overall average data rate increase, and a maximum throughput of 1440kbps that can be achieved because the schemes corresponding to the MCM levels are assigned dynamically.

This probes that the Adaptive-MCM System increases the average data rate by improving the trade-off between SNR and throughput.

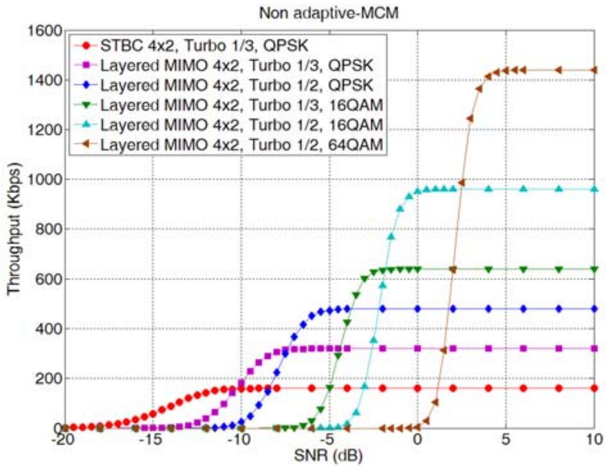

Fig. 5. Throughput of each combined MCM-scheme level for the Non Adaptive-MCM scheme

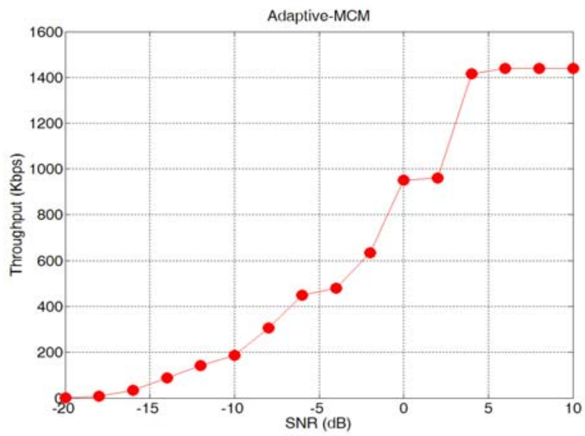

Fig. 6. Throughput of each combined MCM-scheme level for the Adaptive-MCM scheme

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