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31. เจนวิทย์ สินธุสัคค. การปรับปรุงการหักล้างสัญญาณแทรกสอดแบบผสมโดยใช้เทคนิคการหักล้างบางสวนแบบขนานในช่องสัญญาณที่มีการลดทอนแบบเรลีย์ในระบบการสื่อสารแบบแบ่งแยกด้วยรหัสชนิดไดเรกต์ซีเควนซ์. วิทยานิพนธ์ปริญญาวิศวกรรมศาตรมหาบัณฑิต, ภาควิชาวิศวกรรมไฟฟ้า, คณะวิศวกรรมศาสตร์,จุฬาลงกรณ์มหาวิทยาลัย, 2542

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ภาคผนวก

ผลงานวิจัยของผู้เขียนที่ได้รับการตีพิมพ์แล้ว คือ

Kanchanawat, R., Kunaruttanapruk, S., Khunabut, P., Tansongcharoen, P., and Jitapunkul, S. V-BLAST Technique for Uplink MC-CDMA Systems in Rich Scattering Environment. IEEE Wireless Communications and Networking Conference (WCNC2004) (March 2004)

V-BLAST Technique for Uplink MC-CDMA Systems in Rich Scattering Environment

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Abstract

In this paper, we propose a new approach for MC-CDMA system in rich scattering environment. For our proposed system, an efficient MIMO technique, called as V-BLAST (Vertical Bell Laboratories Layered Space-Time), is applied in order to increase the capacity of uplink Multi-Carrier Code Division Multiple Access (MC-CDMA) system. High speed transmission can be also achieved by using low spreading factor. In this system, different users can use the same spreading code, so system capacity can be increased significantly. Different from, most of V-BLAST related researches which assume the perfect knowledge of channel, we also consider the effect of the practical channel estimation to the system performance. In this paper, we investigate the performance of this system in both rich scattering channel and low scattering channel. We show that this system can be used efficiently in rich scattering environment. In low scattering environment, the performance of this system is too close with original MC-CDMA system. In addition, the result of simulation with estimation error shows that this system is suitable for practical implementation.

Keyword : MIMO, DS-CDMA, MC-CDMA, V-BLAST, ICI

1. Introduction

Multi-carrier code division multiple access (MC-CDMA) is a promising candidate for the 4-th generation mobile communication because it is known for robustness against frequency selective fading. In this technology, each chip of data symbol is spread into several parallel substreams, each substream is then modulated with respective subcarrier.

Recently, multi-input multi-output (MIMO) communication system has also gain much interest [1-3]. Information theory research has shown that the rich scattering wireless channel can achieve enormous spectral efficiency through multiple transmitter and receiver antenna systems. The vertical layered space-time architecture proposed by Lucent Bell Labs [4], known as V-BLAST, is one such system. It splits a single data stream into multiple substreams and transmits these substreams simultaneously, one on each transmit antenna.

The multiuser detection base on BLAST was proposed for DS-CDMA system in flat fading environment [5]. Main objective of this approach is to increase the transmission capacity by re-use the spreading code. The data of users with the same spreading code can be distinguished by using V-BLAST processing. A mobile station is considered as one transmitter antenna, and multiple antennas must be installed at base station.

This paper proposed the hybrid system between MC-CDMA and V-BLAST. We focused on using this system for uplink mobile communication network. With re-use spreading code, system capacity can be increased significantly. Moreover, this system can support high speed transmission because of using low spreading factor code. We investigated the performance of this system by comparing with that of the original MC-CDMA system. In addition, practical conditions, particularly channel estimation and area of implementation, will be taken into consideration.

The paper is organized as follows. We briefly introduce the V-BLAST overview in section 2. Section 3 presents the hybrid system between MC-CDMA system and V-BLAST system . In section 4, simulation results of the hybrid system are shown. Finally, conclusions are given in section 5.

2. V-BLAST Overview

In V-BLAST system, multiple antennas are used at transmitter and receiver. We assume that this system consists of T transmitter antennas and P receiver antennas. The data stream is split into T substreams, and each substream is sent through a different transmitter antenna. The data symbols from all transmitter antennas are transmitted via same bandwidth at same time. It is clear that each receiver antenna must receives the signals from all T transmitter antennas. These signals can be distinguished by difference among channel coefficients.

Therefore, nulling vectors must be used. Property of nulling vector ($\vec{w}$) is shown in (1). That is

$$\vec{w}_i(\vec{H})_j = \begin{cases} 0 & ; i \neq j \\ 1 & ; i = j \end{cases} \tag{1}$$

where $\vec{H}$ is $P \times T$ channel transfer function matrix, and $(\vec{H})_j$ denotes j-th column of $\vec{H}$. h_{ij} is the complex channel coefficient from transmitter j to receiver i.

The satisfy nulling vector $\vec{w}_i$ is i-th row of pseudo inverse matrix of $\vec{H}$. The detection process is shown in (3) and (4).The $P \times 1$ total received signal vector is denoted by $\vec{r}''$. a_i denotes desired signal of i-th user. η is additive white Guassian noise.

$$\vec{r}'' \quad = (\vec{H})_1 a_1 + (\vec{H})_2 a_2 + (\vec{H})_3 a_3 \ldots\ldots\ldots\ldots + \eta \tag{2}$$

$$\vec{w}_1 . \vec{r}'' \; = \vec{w}_1(\vec{H})_1 \vec{a}_1 + \vec{w}_1(\vec{H})_2 \vec{a}_2 + \vec{w}_1(\vec{H})_3 \vec{a}_3 \ldots\ldots\ldots\ldots + \vec{w}_1 \tilde{\eta} \tag{3}$$

From (1)

$$\vec{w}_1 . \vec{r}'' = \vec{a}_1 + \vec{w}_1 \tilde{\eta} \tag{4}$$

Moreover, the original V-BLAST system consists of successive detection and subsequent cancellation of detected signals. Among the undetected symbol, the signal with highest post detection SNR is detected first.

3. Hybrid System between MC-CDMA and V-BLAST

We use the hybrid system over uplink of MC-CDMA system in order to extend capacity and transmission rate. The base station consists of multiple receiver antennas while the multiple transmitter antennas in original V-BLAST are treated as individual mobile station transmitter. In the considered system, we assume that all of K users in system are divided in G group of M users. Every user in one group uses same spreading code, so we use only G different spreading code for all of K users.

The received signal of MC-CDMA system in l-th period at p-th antenna denoted by $r_p[l]$.We use code of which its spreading factor equal to N.

$$r_p[l] = \sum_{k=1}^{K} \sum_{n=1}^{N} a_k[l] h_{k,n,p} c_{k,p}(n) e^{2\pi f_n t} + \eta_l \tag{5}$$

The discrete Fourier transform of the received signal $r_p[l]$ with in one symbol period is $x_p(n)$.

$$x_p(n) = F\left[r_p[l]\right] = \sum_{k=1}^{K} c_{kp}(n) H_{kp}(n) a_k[l] + \eta_l(n) \tag{6}$$

We represent $x_p(n)$ in vector form as the sum of signal of all users and additive white Gaussian noise.

$\eta = [\eta(1), \eta(2) .. \eta(N)]^T$

$$x_p = \begin{bmatrix} x_p(1) \\ \vdots \\ x_p(N) \end{bmatrix} = \begin{bmatrix} \psi_{p11} & \cdots & \psi_{p11} \\ \vdots & \psi_{pnk} & \vdots \\ \psi_{pN} & \cdots & \psi_{pNK} \end{bmatrix} \begin{bmatrix} a_1 \\ \vdots \\ a_k \end{bmatrix} + \begin{bmatrix} \eta_1 \\ \vdots \\ \eta_N \end{bmatrix} = \vec{\psi}\vec{a} + \eta \tag{7}$$

where $$\psi_{pnk} = c_{pk}(n) H_{pk}(n) \tag{8}$$

$H_{pk}(n)$ is channel transfer function of n-th subcarrier of k-th user, and $c_{pk}(n)$ is n-th chip of spreading code of k-th user.

For detection process, the first step of is the despreading of received signal for suppression information of other users who use different spreading code. In addition, the MRC equalization technique is also adopted in this step for MAI suppression. After that, we sum signals from all of receiver antennas for increasing in space diversity. Let Y be the $K \times 1$ complex vector of signal obtained after despreading and MRC equalization. That is

$$\vec{Y}^{(0)} \quad = \sum_{p=1}^{P} \psi^H x_p \; = \; \tilde{R}\vec{a} + \tilde{\eta} \tag{9}$$

$$\tilde{R} \quad = \sum_{p=1}^{P} \psi_p^H \psi_p \tag{10}$$

$\tilde{R}$ is $K \times K$ space-code cross correlation matrix and

$$\tilde{n} \quad = \sum_{p=1}^{P} \psi_p^H n_p \tag{11}$$

where P denotes number of receiver antennas.

In the second step, we evaluate pseudo inverse of $\tilde{R}$. In practical aspect, we can obtain this $\tilde{R}$ matrix form channel estimation process.

$$G_i \quad = \left[\tilde{R}^{(i)}\right]^+ \tag{12}$$

$^+$ denotes Moore-Penrose pseudo inverse operation. Index i indicate the order in iterative process. In this considered system, $\tilde{R}$ is square matrix, so we can use inverse operation instead of pseudo inverse operation for reduction of complexity. In third step, we obtain the k_i-th user who has maximum post detection SNR, defined by

$$k_i \quad = \arg{}_j \min \left\| (G_i)_j \right\|^2 \qquad : j \notin \{k_1 \ldots k_{i-1}\} \tag{13}$$

where $(G_i)_j$ denotes j-th row of G_i matrix. We use the k_i-th row of matrix G_i to be the nulling vector of this user. That is

$$w_{k_i} \; = \; (G_i)_{k_i} \tag{14}$$

The fourth step is the computation of the estimate symbol $\hat{a}_i$

$$z_{k_i} \; = \; w_{k_i} Y^{(i)} \tag{15}$$

$$\hat{a}_{k_i} = \Phi(z_{k_i}) \tag{16}$$

Φ(.) denotes slicing operation which appropriates to modulation technique in use. The fifth step is interference cancellation. We subtract the detected symbol from $\vec{Y}$ vector. That is

$$\vec{Y}^{(i+1)} = \vec{Y}^{(i)} - \left(\tilde{R}^{(i)}\right)^{k_i} \hat{a}_{k_i} \tag{17}$$

where $\left(\tilde{R}^{(i)}\right)^{k_i}$ denotes the k_i-th column of $\tilde{R}^{(i)}$. After that, we obtain matrix $\tilde{R}^{(i+1)}$ by zeroing the k_i-th row and the k_i-th column of $\tilde{R}^{(i)}$, and the step 2th-5th have been repeated continually until the symbols of all users are detected. It should be noted that the performance of this detection process depends on nulling vector w_{k_i} and quantity of noise in $Y^{(i)}$. From (9) and (15)

$$\begin{aligned} z_{k_i} &= w_{k_i} Y^{(i)} = w_{k_i}^{H} (\tilde{R}^{(i)} \bar{a} + \tilde{\eta}) \\ &= a_{k_i} + w_{k_i}^{H} \tilde{\eta} \\ &= a_{k_i} + w_{k_i}^{T} \left(\sum_{p=1}^{P} \psi_p^{H} n_p \right) \end{aligned} \tag{18}$$

Thus, post detection SNR (ρ_{k_i}) can be given by

$$\rho_{k_i} = \frac{\left\langle a_{k_i} \right\rangle^2}{E\left\| \left(\sum_{p=1}^{P} \psi_p^{H} n_p\right) \right\|^2 \left\| w_{k_i} \right\|^2} \tag{19}$$

Hence, we can conclude that the smaller the norm of w_i, the better the performance. This norm depends on the number of receiver antennas, and multipath scattering characteristic of channel. This fact is shown in figure 1.

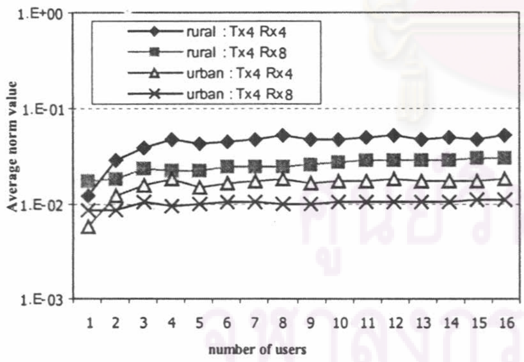

Figure 1. norm effect in different environment

From figure 1, as the number of receiver antenna increases, the average norm value decreases significantly. Furthermore, the average norm value in urban area is smaller than the average norm value in rural area. Thus, the urban area with rich multipath scattering has more capacities than the rural area through using V-BLAST processing architecture.

4. Simulation Result

In this section, we evaluate our proposed hybrid system for different environment. We also consider the effect of estimation error. So, we obtain simulation result of real uplink channel estimation which use time-repeated code (described in [6]). In this simulation, we use channel model described in COST207 standard [7]. We simulate in two frequency selective fading environment. They are typical urban area which is rich scattering area, and rural area which is low scattering area. We assume slow fading channel, so fading is constant over time interval of a symbol. We divide a total of 16 users into 4 groups of 4 users, and use carrier frequency at 20 GHz with QPSK modulation scheme. The main parameters are: spreading factor N=16, number of receiver antennas P=4 , maximum doppler frequency (f max) =370 Hz, frame length 1000 symbols, and chip interval T_c= 0.2 μsec. In addition, we provide cyclic prefix that has sufficient length for intercarrier interference (ICI) suppression.

We first evaluate the performance of the hybrid system in comparison with the original MC-CDMA system. For the hybrid system, the spreading factor (N) and the number of users in the same group (M) are 16 and 2 respectively; meanwhile, we use spreading factor (N) equal to 32 in the original MC-CDMA. Therefore, these two systems have same capacity or can support maximum 32 users. In original MC-CDMA system, we use MMSE (minimum mean square error) receiver [8], of which its complexity is high, for comparison with the hybrid system. Figure 2 shows the average bit error rate (BER) at difference SNR values, for both systems. These systems are simulated in urban area and rural area. In the hybrid system, the performance in urban area is better than the performance in rural area due to the norm effect (described in section 3). In original MC-CDMA system, however, the rural area performance surpasses the urban area performance because of frequency selective fading effect. When we compare between these two systems, it can be seen that the hybrid system outperforms the original MC-CDMA system in urban environment. In rural environment, the performance of the hybrid system is too close with original MC-CDMA system. However, the hybrid system is also useful in rural area environment because using low spreading factor can increase transmission rate considerably.

In figure 3,we consider about estimation error effect on the system performance. We simulate in rich scattering area (urban area), and use the time-repeated code channel estimation for uplink network: no user use same spreading code in pilot period. In table 1, as the frame length increase, the average mean square error (MSE) of estimation increase. When we use frame length equal to 500 (low error of estimation), the system performance are quite good. Next, we increase the frame length ;as a result, estimation error increase considerably (0.02-0.05).

However, we can see that the hybrid system still has suitable performance. At SNR = 10, the hybrid system can tolerate up to 3-10% of channel estimation errors with a acceptable degradation to the performance. Consequently, this result confirms that the hybrid system is suitable for practical implementation.

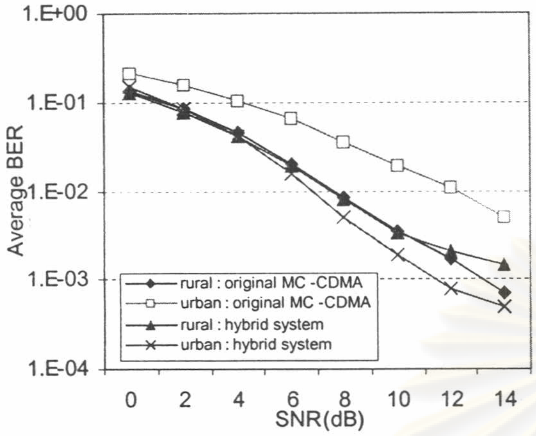

Figure 2. Comparison of performance for the hybrid system with MC-CDMA system

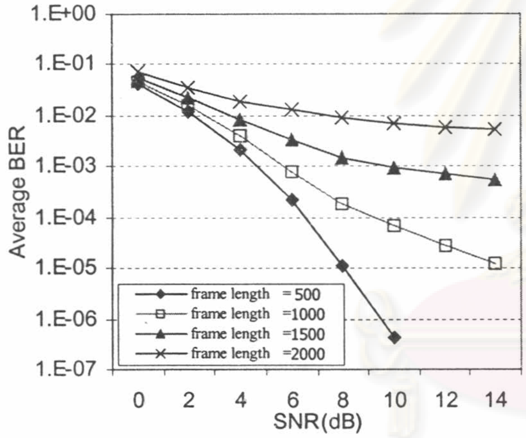

Figure 3. Estimation error effect on performance of the hybrid system

5. Conclusions

In this paper, we proposed to use V-BLAST technique with MC-CDMA in order to improve its performance. This system can achieve frequency diversity to combat against frequency selective fading, and has high system capacity by re-use spreading code. Our results show that this system outperforms the original MC-CDMA system in urban environment. Moreover, we can use this hybrid system for increase in transmission rate due to using low spreading factor. In addition, this system has the good performance when we simulate with real channel estimation in up link mobile communication system.

Table 1. The average MSE of time-repeated code channel estimation

Frame length		500	1000	1500	2000
MSE	SNR = 5	0.089	0.112	0.145	0.199
	SNR =10	0.035	0.057	0.091	0.144

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7. References

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ประวัติผู้เขียนวิทยานิพนธ์

นาย รัฐพล กาญจนวัฒน์ เกิดวันที่ 18 มิถุนายน พ.ศ. 2523 ที่กรุงเทพมหานคร เข้ารับการศึกษาในหลักสูตรวิศวกรรมศาสตรบัณฑิต จุฬาลงกรณ์มหาวิทยาลัย ในปีการศึกษา 2540 สำเร็จการศึกษาปริญญาตรีวิศวกรรมศาสตรบัณฑิต สาขาวิศวกรรมไฟฟ้าจากจุฬาลงกรณ์มหาวิทยาลัย ในปีการศึกษา 2543 และเข้าศึกษาต่อในหลักสูตรวิศวกรรมศาสตรมหาบัณฑิต สาขาวิศวกรรมไฟฟ้า ที่จุฬาลงกรณ์มหาวิทยาลัย ในปีการศึกษา 2544 ซึ่งในระหว่างการศึกษาระดับมหาบัณฑิตนี้ไดรับเงินทุนอุดหนุนการวิจัยจากโครงการเสริมสร้างความเชื่อมโยงระหว่างภาควิชาวิศวกรรมไฟฟ้าและภาคเอกชนทางด้านการวิจัยและพัฒนา (Cooperative Project between Department of Electrical Engineering and Private sector for Research and Development)