Abstract - This paper presents a spreading method for down-link road to vehicle communication systems, which support broadcast and unicast communication in the same frequency. The proposed system is based on MC/DS-CDMA system, and uses a small spreading factor for broadcast transmission to achieve high data rate and uses a large spreading factor for unicast transmission to reduce the interference among vehicles. In the proposed system, the scrambling code, which is used for reducing the interference among cells under the multi-cell environments, is designed for unicast communication not to affect to the broadcast communication. Moreover, a Space-time block coding (STBC) technique is applied to receive the site diversity gain with keeping orthogonality for broadcast transmission by using the plural access points. The performance of the proposed system is evaluated by computer simulation under additive white Gaussian noise (AWGN) and Rayleigh fading environment.

Keyword - MC/DS-CDMA, OVSF, Scrambling code, STBC

I. INTRODUCTION

Recently, many researches have attracted attention to Intelligent Transportation Systems (ITS) [1]. ITS are designed for securing the safety, improving the comfort, measuring the position of the vehicle, reducing the pollution, mitigating the traffic congestion and so on. Among those demands, road to vehicle communication is considered for an important communication method for realizing ITS. Road to vehicle communication is a system which can communicate the data between access points installed along the road and the vehicles. In this communication system, two types of data are expected to be transmitted; broadcast data and unicast data. The broadcast data are used to broadcast the data of traffic information, map information and so on. On the contrary, the unicast data are used for data communication between individual vehicles.

Usually in the road to vehicle communication systems, broadcast and unicast data are transmitted in a different frequency band using different system [1]. In such system, the frequency utilization efficiency decreases and we have to prepare plural transmitters and receivers for supporting both frequency bands. In recent years, the demands for small terminals and the demands for improving the frequency efficiency become large. To solve above problems, the broadcast and the unicast data transmission in the same frequency band is effective.

Therefore, in this paper, we introduce a system that can transmit the broadcast and the unicast data in the down-link communication for road to vehicle communication in the same frequency band using the same communication method. In addition, a diversity technique is applied to broadcast data, because the same data can be transmitted from all access points. The proposed system is based on Multi-carrier direct sequence code division multiple access (MC/DS-CDMA) systems, and uses a small spreading factor for the broadcast communication to achieve high data rate, and a large spreading factor for the unicast communication to prevent the interference among the signals from the plural access points at the vehicles [2].

The orthogonal variable spreading factors (OVSF) code is well known as a spreading method that can support such different spreading factors [3]. In this method, the signals with different data rate are spread by different spreading factors and combined them in each transmission. In addition, to prevent the interference among the cells under the multi-cell environment, the spread signals can be multiplied by the scrambling code before transmission. However, the signals from other access points are treated as an interference signals even if the transmitted data for broadcast containing the same information and this interference decreases the performance. In order to solve this problem, in the proposed system, the data are spread by two-stage spreading operation for keeping the orthogonality for broadcast data transmitted from different access points with also keeping the orthogonality between the unicast and the broadcast transmission. The proposed method can use the scrambling codes only for the unicast signals without giving any affect for the broadcast signal, because these broadcast data from all access points are synthesized and orthogonalized in the proposed method, in order to improve the performance of the users located around the cell-edge, Space-time block coding (STBC) technique can be applied. We can get the diversity gain for broadcast data by using the site diversity technique using the proposed spreading method [4] [5].

The rest of this paper is organized as follows. Section II deals with the basic concept related to spreading code and site diversity method. Section III describes the proposed systems in detail. Simulation results and discussion are shown in section IV. The paper concludes with some final remarks in section V.

II. RELATED TECHNIQUE

A. Spreading code and Scrambling code

In CDMA cellular systems, the scrambling code is usually multiplied after the operation of the usual spreading to identify
the cell and to decrease the interference among the cells under the multi-cell environment. The usual scrambling code is designed based on a random code or an $M$-sequence. Each chip of the signals after spreading by CDMA modulation is multiplied by the spreading code. In cellular systems, the different scrambling code is assigned to each cell, so that the receiver can demodulate combined signals from all access points by using the assigned scrambling code in each cell. Hence, the interference of the signals from other access points can be reduced.

The effect of scrambling code also can be applied to the system based on MC/DS-CDMA. A typical down-link MC/DS-CDMA transmitter is illustrated in Fig. 1. The transmit signals of users $i$ and $j$ are shown in Fig. 2, where $i$ is a user within access point 1, and $j$ is a user within access point 2. The number of users in access points 1 and 2 is defined as $I$ and $J$, respectively.

![Fig. 1. MC/DS-CDMA Transmitter.](image)

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![Fig. 2. The transmit signals of users $i$ and $j$.](image)

Fig. 2. The transmit signals of users $i$ and $j$.

$A_i = \{a_{1i}, a_{2i}, \ldots, a_{Si, SF} \}$ and $A_j = \{a_{1j}, a_{2j}, \ldots, a_{Sj, SF} \}$ are the scrambling codes that allocated to access points 1 and 2, respectively. In this paper, the random code is used for the scrambling code. The spreading code for user separation that is allocated to users $i$ and $j$ are represented as $W_i = \{w_{i1}, w_{i2}, \ldots, w_{iSF} \}$ and $W_j = \{w_{j1}, w_{j2}, \ldots, w_{jSF} \}$, respectively. Here, Walsh-Hadamard sequence is used for orthogonal spreading code [5]. The data of each user are spread by using its own spreading code and these spreading signals are orthogonal spreading code [5]. The data of each user are spread by using its own spreading code and these spreading signals are orthogonal spreading code [5]. The data of each user are spread by using its own spreading code and these spreading signals are orthogonal spreading code [5]. The data of each user are spread by using its own spreading code and these spreading signals are orthogonal spreading code [5].

$\sum_{j=1}^{J} d_{j1} w_{jn}$

(1)

In this equation, the signals of only one subcarrier are shown. $d_{j1}$ represents the data allocated in subcarrier 1 of user $i$. Correspondingly, the multiplied signals in the access point 2 are given by,

$\sum_{j=1}^{J} d_{j2} w_{jn}$

(2)

The signals that are received from two or more access points with different attenuation and fading are combined at the receiver. As a result, the received signals of one subcarrier can be expressed as $r_{ni}$ and demodulated data signal can be expressed as $r_{1i}$, when containing two access points.

$r_{ni} = a_{1i} P_{1ni} + a_{2i} P_{2ni}$

(3)

In this equation, the noise components are not included for simplicity. The channel responses from the access point 1 and the access point 2 are shown by $\alpha_{1i}, \alpha_{2i}$, respectively. At the receiver, the received data are multiplied by the scrambling code that assigned to each access point, and after that the spreading code of user $i$ is multiplied for dispreading operation to obtain data of $i$ the user. The despread signals of user $i$ are shown as,

$s_{ni} = \sum_{k=1}^{SF} a_{ki} w_{kn} \left[ \alpha_{1i} a_{ki} \sum_{j=1}^{J} d_{j1} w_{jn} + \alpha_{2i} a_{ki} \sum_{j=1}^{J} d_{j2} w_{jn} \right]$  

(4)

It can be seen that $J_0$ decreases if the spreading factor (SF) increases. This property can be utilized to reduce the interference from other access points. In case of the transmission of the broadcast data, the small SF is used to get the high data rate communication. However, due to the small SF, the interference of other access points cannot be reduced enough. This multi-cell interference is affected even if all access points send the same information for broadcast data. As a result, in the basic multi-cell CDMA using OVSF, the performance of the users around the cell edge degrades and affects to the total performance. Therefore, the performance improvement of the users around cell edge is importance issue.

**B Site diversity techniques**

As one of the techniques for improving the performance of the users around the cell edge, the site diversity techniques are well known. In these techniques, two or more access points transmit the same data and the diversity gain is obtained at the receiver. In usual broadcast system using CDMA, the same data are transmitted from the plural access points by using the scrambling code assigned in each access point. In this case, since the different scrambling codes are used in different access points, the interference among cells is remained after combining the signals by having conventional site diversity [5]. In order to solve above problem, the STBC site diversity has been proposed in addition to the idea for the way of giving the scrambling code without inter-cell interference at the receiver.

STBC site diversity is a technology that can obtain the diversity gain by assigning the STBC encoding patterns generated by the same data to two or more access points. The plural access points transmit these encoded signals at the same
time to the receiver. Here, we show the example in which two access points transmit the STBC signals for obtaining the STBC site diversity gain. At a given symbol period, two signals are simultaneously transmitted from two access points.

![STBC site diversity Transmission.](image)

The signal \( s_j \) is transmitted from access point 1 and \(-s^*_{j+1}\) from access point 2. During the next symbol period signal \( s_{j+1} \) is transmitted from access point 1 and \( s^*_{j} \) from access point 2 where \( \ast \) is the complex conjugate operation. The transmit patterns are shown as follows, 

\[
x_1 = \begin{cases} s_j \\ s_{j+1} \end{cases}, \quad x_2 = \begin{cases} -s^*_{j+1} \\ s^*_{j} \end{cases} .
\]  

(5)

The channel responses from access points 1 and 2 at time \( t \) are defined as \( h_1(t) \) and \( h_2(t) \), respectively. If we can assume that the fading is constant across two consecutive symbols, the channel responses can be expressed as,

\[
\begin{align*}
\hat{h}_1(t) &= h_1(t + T) = \alpha_1, \\
\hat{h}_2(t) &= h_2(t + T) = \alpha_2,
\end{align*}
\]

where \( T \) is the symbol duration. Then the received signals can be expressed as,

\[
\begin{align*}
r_j &= r(t) = \alpha_1 s_j - \alpha_2 s^*_{j+1} + n_j, \\
r_{j+1} &= r(t + T) = \alpha_1 s_{j+1} + \alpha_2 s^*_{j} + n_{j+1},
\end{align*}
\]

(7)

where \( r_j \) and \( r_{j+1} \) are the received signals at time \( t \) and time \( t+T \), respectively. \( n_j \) and \( n_{j+1} \) are noise and interference components at the receiver at time \( t \) and time \( t+T \), respectively. At the receiver, each transmission signal is separated by using the following STBC decoding to these received signals.

\[
\begin{align*}
\hat{s}_j &= \alpha_1 r_j + \alpha_2 r^*_{j+1} = (\alpha_1^2 + \alpha_2^2) s_j + \alpha_1 n_j + \alpha_2 n^*_{j+1}, \\
\hat{s}_{j+1} &= \alpha_1 r_{j+1} - \alpha_2 r^*_{j} = (\alpha_1^2 + \alpha_2^2) s_{j+1} + \alpha_1 n_{j+1} - \alpha_2 n^*_{j}.
\end{align*}
\]

(8)

This STBC site diversity technique can be used effectively in broadcast transmission when all the access points transmit the same information.

III. PROPOSED CODE ASSIGNMENT SYSTEMS

In this paper, we apply the STBC site diversity method to the broadcast signals and the normal spreading method to other unicast signals. However, if the conventional spreading method and scrambling method based on the OVSF codes are used, STBC transmission cannot achieve the effective performance. This is because the conventional spreading method cannot combine the STBC signals at the receiver due to the lack of orthogonality of the signals from different access point. Therefore in this paper a novel code assignment method for ITS access points are proposed.

A. Conventional OVSF system (System 1)

First, we explain the conventional OVSF code, which is one of the spreading codes supporting the plural spreading factors. We call this system as “system 1” in this paper. The block diagram of the system 1 is shown in Fig. 4. In OVSF spreading method, the signals with different data rates can be combined without lack of orthogonality by spreading the signals with different spreading gain. In system 1, the broadcast signals are allocated to the short spreading code (code length is assumed to be 4 as an example) and the unicast signals are allocated to the long spreading code (code length is assumed to be 64 as an example). Finally these signals are combined before transmission. After that, the scrambling code is multiplied to decrease the interference among cells. However, due to the scrambling code, the broadcast signals from plural access points cannot achieve the perfect orthogonality at the receiver and it causes the degradation of the performance improvement of the broadcast data even if the site diversity technique is used. Consequently, only unicast data realize the sufficient performance by using OVSF spreading method.

![Conventional OVSF system.](image)

B. Proposed two-stage orthogonal code assignment system (System 2)

In order to solve the problem of system 1, we propose a novel orthogonal code assignment method with two-stage structure supporting orthogonality of common broadcast signals among cells. We call this method as “System 2” in this paper.

In system 2, the spreading of unicast data is operated with two-stage structure. In the first stage, the unicast data are spread by a long spreading code that is allocated for unicast users to keep the orthogonality within the cells (code length is assumed to be 16 as for example). The unicast signals of all users are spread and these signals are multiplexed. The multiplexed signals are multiplied by the scrambling code that allocated to the cell. In the second stage, the broadcast signals and the scrambled unicast signals derived in the first stage are spread by short spreading code so as to keep the orthogonality of the broadcast signals and the unicast signals (code length is assumed to be 4 for example). Figure 5 depicts the transmitter of the system 2. Consequently, by using the system 2, the scrambling code is multiplied only to the unicast signals and the orthogonality of the unicast signals within the cell can be kept.
On the other hand, the broadcast signals can be orthogonalized to unicast signals, by using the short orthogonal code at the second stage.

Moreover, if the broadcast signals from all access points use the same spreading code at the second stage, the all broadcast signals are orthogonalized to all unicast signals. If this orthogonality of the broadcast signals can be kept around the all position of the communication area, STBC site diversity can be used without the interference of the broadcast signals among the cells. As a result, by using the proposed two-stage orthogonal code assignment technique, the broadcast signals have an excellent communication performance without degrading the orthogonality of the unicast signals because the scrambling code is not multiplied to the broadcast signals. On the other hand, in the proposed method, the unicast signals also can be transmitted by keeping the orthogonality of the broadcast signals not only its own cell but also other cells. As a result, the unicast signals do not affect the interference of the broadcast signals transmitted from any access points and it can be used for improving the performance of the unicast signals.

IV. SIMULATION RESULT AND DISCUSSION

In this section, the bit error rate (BER) performance of the proposed method with different configurations and parameters is evaluated by computer simulations. We assume that the cell model is three straight cells and the distance of two access points is 2000m. In this simulation, the broadcast signals and the unicast signals are simultaneously transmitted from the same access points with different spreading factor. The BER is derived by changing the distance of access point 2 and receiver, which is shown in Fig. 6. The simulation parameters are shown in Table 1.

A Broadcast Transmission

The original site diversity technique using the characteristic of scrambling code is used for broadcast signals in the system 1. The STBC site diversity is used for broadcast transmission in the system 2. Figure 7 shows the BER performance of the broadcast data with a parameter of the SNR when the distance between access point 2 and the receiver is 200m and 800m. Figure 8 shows the BER performance of the broadcast data with a parameter of the distance between access point 2 and the receiver when SNR is 10dB and 25dB.

In near by areas to the access point, both systems show approximately the same BER performance as shown in Fig. 8. When the user is near to the access point, the signals form the adjacent access point becomes weak. Thus, we cannot get clear diversity gain in the system 2. On the other hand, when the distance between the receiver and the access point is increased, the BER performance of the system 2 is significantly improved due to the site diversity gain without large inter-cell interference. However, the performance of the system 1 is worse than that of the system 2 because the large inter-cell interference occurs with the difference of the scrambling code. Thus, the site diversity gain does not clearly appear. As a result, we can confirm that the system 2 is suitable for broadcast transmission under the simulated straight cell model.

B Unicast Transmission

In the system 2, the unicast data are spread twice by using the two-stage spreading operation. First, the signals are spread by using the long orthogonal spreading code and after that the scrambling code is multiplied. In this case, the spreading gain at the first stage of the system 2 is less than the spreading gain of the system 1. Therefore, some performance degradation is expected in the system 2. On the other hand, in the system 2, the unicast data are not affected by the interference of the broadcast signals form the other access points. These characteristics improve the performance. So, we evaluated the trade off of the performance of the unicast signals by simulation.
Figure 9 shows the BER performance of the unicast signals with parameter of SNR when the distance between the receiver and the access point is 200m and 800m.

Figure 10 shows the BER performance of the unicast signals with a parameter of the distance between access point 2 and the receiver when SNR is 10dB and 25dB. From these figures it can be seen that the both system show approximately the same BER performance.

As a result, we can confirm that the proposed system 2 can achieve the best BER performance for broadcast data and the almost the same performance for unicast data in comparison with the system 1. It can be concluded that the proposed system 2 is suitable for road to vehicle communication system.

V. CONCLUSION

In this paper, we have proposed a novel down-link road to vehicle communication system based on MC/DS-CDMA system that can support the broadcast data and the unicast data at the same frequency. We consider two systems. One is a system based on OVSF code and the other one is a system based on the spreading method based on two-stage spreading structure. The performance of the both system are evaluated by using the computer simulation. From the simulation results, we can confirm that the proposed two-stage spreading method has better performance with supporting both the broadcast data and the unicast data at the same frequency.

REFERENCES


