Subband Adaptive Array for Space-Time Block Coded Multirate Multicode MIMO CDMA System

Nordin Bin RAMLI [1], Tetsuki TANIGUCHI [1], and Yoshio KARASAWA [1]
[1]*Advanced Wireless Communication research Center (AWCC),*
The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu-shi, Tokyo 182-8585, JAPAN
Email:nordin@radio3.ee.uec.ac.jp

Abstract

This paper[1] present an interference suppression using subband adaptive array (SBAA) for space-time block coding (STBC) with multiple input multiple output (MIMO) multirate multicode code division multiple access (CDMA) under the frequency selective fading (FSF). The proposed scheme has a flexible configuration which allows base station (BS) to dynamically adapt to multirate transmission requests from mobile stations (MS). At the receiver, the received signal undergoes STBC based subband adaptive array processing at each subband to suppress the intersymbol interference (ISI), multicode interference (MCI) and multiple access interference (MAI) simultaneously. The proposed system is simulated under different channel conditions and is compared against conventional SBAA.

1. Introduction

Future wireless systems such as fourth generation (4G) cellular will need flexibility to provide subscribers with a variety of services such as voice, data, images, and video. Because these services have widely different data rates and traffic profiles, future generation systems will have to accommodate a wide variety of data rates [1]. This has motivated research on multicode CDMA systems which allow variable data rates [2], [3] by allocating multiple codes, and hence varying degrees of capacity to different users. Recently, variable spreading and multicode are two methods which have been adopted in multirate implementation in high data rate (HDR) and flexible data rate communications over wireless channels[4], [5]. The basic concept of multicode CDMA is to split the user data into a number of streams and use parallel orthogonal channel codes to modulate. The introduction of multicode transmission causes several problems, namely multicode interference (MCI). One is the high envelope variation, which results from a linear sum of signal over multicode streams. Beside that, the multicode transmission introduces the intersymbol interference (ISI) caused of different delays of in each users signal in a multipath environment.

On the other hand, in radio communication systems, the quality of HDR transmission is severely degraded due to multipath fading resulting from the presence of many propagation paths with different time delay. In order to achieve a HDR transmission, high quality communications or high capacity communications, countermeasures should be employed to combat these impairments. As a solution, there have been a large number of works on use of multiple antenna (multiple input multiple output (MIMO)) to combat multipath fading and provide spatial diversity. Among them, space time block coding (STBC) [6] is the most efficient method due to its provision of full spatial diversity and simple linear decoder. For multiuser communication systems, STBC can be used in conjunction with receive adaptive beamforming to suppress the co-channel interferences (CCIs)[7]. Besides, STBC have been also proposed to use with DS-CDMA to combat the impairments of multiuser channels[8].

However, in the frequency selective fading (FSF) channel, the transmission using STBC suffers from inter-symbol interferences (ISI) and increased multiple access interference (MAI), which dramatically deteriorates the performance. A CDMA system which utilizes a transmit antenna array at the transmitter and a receive antenna array at the receiver side with tap delay line (TDL)s filters at both side [8] shows a significant performance and capacity improvement in FSF environments. However, when the delay spread is higher and number of user increased, both transmitter and receiver's TDL memory will be longer and the complexity is increased exponentially. Recently, subband adaptive array (SBAA) for STBC (STBC-SBAA) [9] has been proposed, which can reduce the computational complexity through block processing and improve the performance of the system with the helps of cyclic prefix (CP) would be one of the solution to TDL Adaptive Array (TDLAA).

In this paper, we propose a novel multirate multicode MIMO CDMA system using SBAA designed for STBC transmission under FSF channel, assuming channel state information (CSI) is unknown at transceivers, while a pilot signal is available during the training period. Here, we propose a joint equalization scheme which utilizes a STBC as transmit diversity and receive antenna with SBAA. At the receiver, a novel construction of SBAA to process multirate multicode CDMA signal based on STBC is introduced. The receive block signal is divided into two groups and adaptive processing is done in chip-level to equalize and estimate the desired signal. Simulation results demonstrate the effectiveness of STBC-SBAA, especially when the CP is applied.

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2. STBC-SBAA FOR MULTIRATE MULTICODE MIMO CDMA SYSTEM

A. Multirate Multicode CDMA Model

In multirate multicode systems [4], [5], the signal of HDR users are decomposed into a number of low data rate (LDR) streams which are often chosen to be the data rate of the user with the lowest rate. These streams are then spread and transmitted by different codes of the same length, thus it can be done in the similar way as in a single code CDMA system. Fig. 1 shows the configuration of transmitter of each user (MS (mobile station)) which supports $v(v = \{1, \ldots, V)$ different data rates correspond to each class of services. Those with the LDR (basic rate) R_1 are called Class 1 users, and the users of class v has its data rate $R_v = vR_1$, where v is an integer. In this system, transmission data of HDR user $\boldsymbol{b}_p[t]$ is decomposed into v streams of $b_{p,v}[t]$. Therefore, vth code stream of p-user is considered transmission data from *effective user* $b_{p,v}[t]$. Thus a *physical user* (p) is said to contain v *effective users*. In order to spread these code stream signals, the subcode concatenation process should be done to create v subcodes from the primary code assigned to user p ($p = \{1, \ldots, P\}$). Since the primary codes assigned to users in CDMA systems are pseudo-random (PN) codes and in effect not orthogonal. The use of this PN codes directly for effective users may cause MCI for a physical user comprised of several effective users, extremely for HDR users. The purpose of the subcode concatenation process is to create v orthogonal subcodes for user (p, v) in which, $c_{p,i}[t] \perp c_{p,l}[t]$ for $i \neq l$. The function of the subcode concatenation block is thus similar to Walsh-Hadamard function. The spread signal for p-th user is given by

$$s_p[t] = \sum_{v=1}^{V} b_{p,v}[t]c_{p,v}[t]. \quad (1)$$

B. STBC-SBAA for Multirate Multicode MIMO CDMA System

In this paper, we shall consider the asynchronous multiuser CDMA system employing STBC at each MS. On the BS, we propose a SBAA based on STBC (STBC-SBAA) to estimate the desired user's signal. Each MS utilizes M transmit antennas and the BS utilizes N receive antennas. The configuration

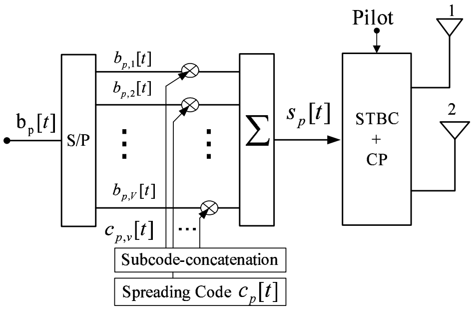

Fig. 1: The transmitter of multirate multicode MIMO CDMA system.

of the proposed transmitter and receiver of STBC-SBAA for MIMO-CDMA system are illustrated in Fig. 1 and Fig. 2, respectively. The conventional SBAA was introduced by Compton [11] and studied further in [3], [9]. In this paper we restricted our system for Alamouti's STBC[6] with $M = 2$. Extension to more general type of STBC, namely with $M > 2$ is quite straight forward.

In this paper, we assume a FSF channel with the total of multipath L with time spacing of chip duration T_c, is given by the next equation.

$$\boldsymbol{H}_p(\tau) = \sum_{l=0}^{L-1} \boldsymbol{H}_p^{(l)} \delta[\tau - lT_c] \quad (2)$$

$$\boldsymbol{H}_p^{(l)} = \begin{bmatrix} h_{11,p}^l & h_{12,p}^l \\ \vdots & \vdots \\ h_{N1,p}^l & h_{N2,p}^l \end{bmatrix}, \quad (3)$$

where, δ is the Dirac delta function, and $h_{ji,p}^l$ is the channel coefficient with delay l between i-th $(i = 1, 2)$ transmit and j-th $(j = 1, \ldots, N)$ receive antenna elements for p-user. In this proposed method, different from the conventional STBC [6], the STBC-SBAA transmission is carried out in block sequence as shown in Fig. 3.

Consider that the spread signal of multirate multicode CDMA signal of each MS is given by (1). The spread signal of each user $s_p^{(k)}[q]$ is then be divided into chip blocks of length Q. The k^{th} chip-block with each element is represented as

$$s_p^{(k)}[q] = s_p[kQ + q] \quad (4)$$

where $q \in \{0, 1, \ldots, Q-1\}$. The k-th chip block $\boldsymbol{s}_p^{(k)} = [s_p^{(k)}[0], \ldots, s_p^{(k)}[Q-1]]$ contain Q chips. The input chip block signal is encoded by STBC [6], where at odd slot of $2k - 1, (= 1, 3, 5, 7, \ldots)$, a pair of chip blocks $\boldsymbol{s}_p^{(2k-1)}$ and $\boldsymbol{s}_p^{(2k)}$ are transmitted from antenna 1 and 2, respectively. Similarly, at the even time slot of $2k, (= 2, 4, 6, \ldots)$, a pairs of chip block $-\bar{\boldsymbol{s}}_p^{(2k)}$ and $\bar{\boldsymbol{s}}_p^{(2k-1),*}$ are transmitted from antenna 1 and 2, respectively. Note that $\bar{s}_p^{(2k-1),*}[q] = s_p^{(2k-1),*}[Q-q-1]$ and $\bar{s}_p^{(2k),*}[q] = s_p^{(2k),*}[Q-q-1]$ are time-reversed and element by element complex-conjugated version of $s_p^{(2k-1)}[q]$ and $s_p^{(2k)}[q]$, respectively. The operation of time-reversion is for handling the frequency domain processing in the receiver [10]. The transmit signal $s_{p,i}^{(k)}[q]$ at antenna $i \in \{1, 2\}$ of $p-$th user can be shown as below.

$$s_{p,1}^{(2k-1)}[q] = s_p^{(2k-1)}[q], \quad s_{p,1}^{(2k)}[q] = -\bar{s}_p^{(2k),*}[q] \quad (5)$$

$$s_{p,2}^{(2k-1)}[q] = s_p^{(2k)}[q], \quad s_{p,2}^{(2k)}[q] = \bar{s}_p^{(2k-1),*}[q] \quad (6)$$

Then, the CP is applied, i.e., the last L_{CP} chip of each block is copied and pasted at the top of each block as guard interval (GI), to make the total length of $Q + L_{CP}$ as shown in Fig. 3. This operation is for minimizing the effect of ISI and producing multipath gain [9]. It is shown as below for

$v \in \{2k-1, 2k\}$,

$$\grave{\boldsymbol{s}}_{p,1}^{(v)} = [s_{p,1}^{(v)}[Q-1-(L_{CP}-1)], \ldots, s_{p,1}^{(v)}[Q-1], s_{p,1}^{(v)}[0], \ldots, s_{p,1}^{(v)}[(Q-1)]]^T \quad (7)$$

$$\grave{\boldsymbol{s}}_{p,2}^{(v)} = [s_{p,2}^{(v)}[Q-1-(L_{CP}-1)], \ldots, s_{p,2}^{(v)}[Q-1], s_{p,2}^{(v)}[0], \ldots, s_{p,2}^{(v)}[(Q-1)]]^T. \quad (8)$$

After passing through the FSF channel and assuming that CP is chosen to satisfy $L_{CP} \geq L-1$ and after discarding the CP, the receive signals at antenna j for block $v \in \{2k-1, 2k\}$ is given as follows:

$$r_j^{(v)}[q] = \sum_{p=1}^{P}\sum_{l=0}^{L-1}\{h_{j1,p}^{l} s_{p,1}^{(v)}[q-lT_c] + h_{j2,p}^{l} s_{p,2}^{(v)}[q-lT_c]\} + n_j^{(v)}[q] \quad (9)$$

where $n_j^{(v)}[q]$ is the additive white gaussian noise (AWGN) at antenna j, which are assumed to be independent and identically distributed (i.i.d) with mean 0 and variance σ_n^2 at each real dimension. Note that, when the delay spread length is larger than block length ($Q + L_{CP}$), the receive block signal will be shifted to the previous block, .i.e. for $l > q$, $s_{p,i}^{(v)}[q-l] = s_{p,i}^{(v-1)}[Q + L_{CP} + q - l]$. Here, the transmitted power from each antenna is half of its value in the single antenna case, so that the total transmission power is fixed.

At the receiver, as shown in Fig. 2, the chip synchronization is done before the part of *Remove GI*, then the first L_{CP} symbols corresponding to GI are removed from each block. Then, $r_j^{(2k-1)}[q]$ is delayed about QT_c to synchronize with even block data. At the same time, the even blocks are complex-conjugated to be $r_j^{(2k),*}[q]$ to extract the component of $\boldsymbol{s}_p^{(2k-1)}$ and $\boldsymbol{s}_p^{(2k)}$ without conjugation.

C. MMSE Detection

We now present the theoretical model of minimum mean square error (MMSE) multiuser detector for STBC-SBAA. We begin to describe the configuration by attempting to rewrite (9) into the vector form. First we define the transmit signal, receive signal and noise as follows.

$$\breve{\boldsymbol{s}}_p^{(k)}[q] = \left[\; (s_p^{(2k-1)}[q]) \quad (s_p^{(2k)}[q]) \;\right]^T \quad (10)$$

$$\boldsymbol{n}^{(v)}[q] = \left[\; (n_1^{(v)}[q]) \quad (n_2^{(v)}[q]) \quad \ldots \quad (n_N^{(v)}[q]) \;\right]^T \quad (11)$$

$$\boldsymbol{r}^{(v)}[q] = \left[\; (r_1^{(v)}[q]) \quad (r_2^{(v)}[q]) \quad \ldots \quad (r_N^{(v)}[q]) \;\right]^T \quad (12)$$

where $v \in \{2k-1, 2k\}$, and then stack $\boldsymbol{n}^{(v)}[q]$, $\boldsymbol{r}^{v}[q]$ as

$$\breve{\boldsymbol{n}}^{(k)}[q] = \left[\; (\boldsymbol{n}^{(2k-1)}[q])^T \quad (\boldsymbol{n}^{(2k)}[q])^H \;\right]^T \quad (13)$$

$$\breve{\boldsymbol{r}}^{(k)}[q] = \left[\; (\boldsymbol{r}^{(2k-1)}[q])^T \quad (\boldsymbol{r}^{(2k)}[q])^H \;\right]^T \quad (14)$$

For simplicity, we define the FSF channel of (3) as

$$\boldsymbol{h}_{1,p}^{l} = [h_{11,p}^{l}\; h_{21,p}^{l}\; h_{31,p}^{l}\; \ldots\; h_{N1,p}^{l}]^T \quad (15)$$

$$\boldsymbol{h}_{2,p}^{l} = [h_{12,p}^{l}\; h_{22,p}^{l}\; h_{32,p}^{l}\; \ldots\; h_{N2,p}^{l}]^T \quad (16)$$

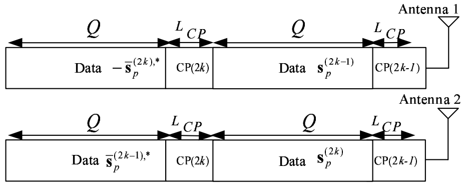

Fig. 3: Block transmission scheme for multirate multicode STBC-SBAA for MIMO-CDMA System.

and then stack them to have

$$\tilde{\boldsymbol{H}}_p^{l} = \begin{bmatrix} \boldsymbol{h}_{1,p}^{l} & -\boldsymbol{h}_{2,p}^{l} \\ \boldsymbol{h}_{2,p}^{l*} & \boldsymbol{h}_{1,p}^{l*} \end{bmatrix}. \quad (17)$$

Using the notations from (10) to (17), we can rewrite the receive signal (9) to be as

$$\breve{\boldsymbol{r}}^{(k)}[q] = \sum_{p=1}^{P}\sum_{l=0}^{L-1} \tilde{\boldsymbol{H}}_p^{l} \breve{\boldsymbol{s}}^{(k)}[q-lT_c] + \breve{\boldsymbol{n}}^{(k)}[q] \quad (18)$$

In this paper, the subband adaptive processing with the most popular linear multiuser method, namely, MMSE is used for detecting transmitted signals from P users. To perform adaptive signal processing in subband, the receive signal $\breve{\boldsymbol{r}}^{(k)}[q]$ is decomposed into subbands using Fast Fourier Transform (FFT). The analysis filter employed in this proposed configuration utilizes *critical sampling*. This operation will result in block processing mode and thus helps to save a great amount of computational load compared with sliding window processing [11], [9]. As shown in Fig. 2, in order to work with STBC, the subband processing is done by referring two consecutive blocks as its input; therefore two groups of optimal weight exist for maximizing the output power of detected signal. Let us define the FFT operation by $\mathcal{F}_{u,q} = e^{-j\frac{2\pi}{Q}uq}$. After taking FFT, we obtain the frequency samples at u-th subband as,

$$\tilde{\boldsymbol{r}}_u^{(k)} = \sum_{q=0}^{Q-1} \mathcal{F}_{u,q} \breve{\boldsymbol{r}}^{(k)}[q] = \sum_{q=0}^{Q-1} \mathcal{F}_{u,q} \sum_{p=1}^{P}\sum_{l=0}^{L-1} \tilde{\boldsymbol{H}}_p^{l} \breve{\boldsymbol{s}}^{(k)}[q-lT_c] + \sum_{q=0}^{Q-1} \mathcal{F}_{u,q} \sum_{q=0}^{Q-1} \breve{\boldsymbol{n}}^{(k)}[q] \quad (19)$$

where $u = \{0, 1, \ldots, K-1\}$, and K is total number of subband. Since the critical sampling is used in STBC-SBAA, we assume that $K = Q$. In order to generate the receive antenna weights, we utilize the pilot training method. Define the pilot signal of p-user as $d_p[t]$, and after being spread and encoded by STBC, the pilot signal for odd and even blocks are respectively given by $d_p^{(2k-1)}[q]$, and $d_p^{(2k)}[q]$. These pilot signals are also converted into subband signals in the same manner to be $\tilde{d}_{p,u}^{(2k-1)}$ and $\tilde{d}_{p,u}^{(2k)}$. By using MMSE criterion, the $2K \times 1$ optimal weight vector for estimating $\hat{\boldsymbol{s}}_p^{(2k-1)}$ and

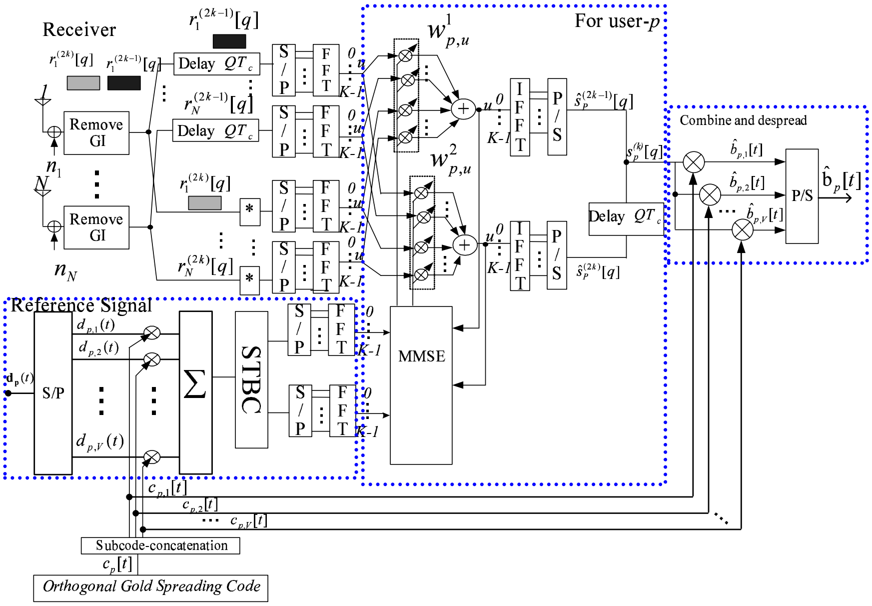

Fig. 2: The receiver of STBC-SBAA for multirate multicode MIMO-CDMA system

$\hat{\boldsymbol{s}}_p^{(2k)}$ are derived as follows.

$$\boldsymbol{w}_{p,u}^1 = \arg\min \ E\{|\tilde{d}_{p,u}^{(2k-1)} - (\boldsymbol{w}_{p,u}^1)^H \tilde{\boldsymbol{r}}_u^{(k)}|^2\} \quad (20)$$
$$\boldsymbol{w}_{p,u}^2 = \arg\min \ E\{|\tilde{d}_{p,u}^{(2k)} - (\boldsymbol{w}_{p,u}^2)^H \tilde{\boldsymbol{r}}_u^{(k)}|^2\} \quad (21)$$

Note that $E[\cdot]$ denotes the ensemble average operator. Here, $\boldsymbol{w}_{p,u}^1$ and $\boldsymbol{w}_{p,u}^2$ are the optimal weight for the odd and even block at each subband of p-user and updated on block-by-block basis. Satisfying equation (20) and (21) gives us the optimal weight vector in u-th subband as follows.

$$\boldsymbol{w}_{p,u}^1 = (\boldsymbol{R}_{rr}^u)^{-1} \boldsymbol{v}_{p,u}^{(2k-1)} \quad (22)$$
$$\boldsymbol{w}_{p,u}^2 = (\boldsymbol{R}_{rr}^u)^{-1} \boldsymbol{v}_{p,u}^{(2k)} \quad (23)$$

where, $\boldsymbol{R}_{rr}^u = E[\tilde{\boldsymbol{r}}_u^{(k)} (\tilde{\boldsymbol{r}}_u^{(k)})^H]$ is the covariance matrix, and

$$\boldsymbol{v}_{p,u}^{(2k-1)} = \mathrm{E}[\tilde{\boldsymbol{r}}_u^{(k)} (\tilde{d}_{p,u}^{(2k-1)})^*] \quad (24)$$
$$\boldsymbol{v}_{p,u}^{(2k)} = \mathrm{E}[\tilde{\boldsymbol{r}}_u^{(k)} (\tilde{d}_{p,u}^{(2k)})^*] \quad (25)$$

are the correlation vectors of receive signal and reference signal in subband. From (22) and (23), the optimal weight of odd and even blocks are calculated using the same correlation matrix for maximizing the power of desired signal at each block. The subband signals after weighted by the optimal weight are synthesized through the inverse FFT (IFFT) can be expressed as below.

$$\hat{s}_p^{(2k-1)}[q] = \sum_{u=0}^{K-1} \mathcal{F}_{u,q}^* (\boldsymbol{w}_{p,u}^1)^H \tilde{\boldsymbol{r}}_u^{(k)} \quad (26)$$
$$\hat{s}_p^{(2k)}[q] = \sum_{u=0}^{K-1} \mathcal{F}_{u,q}^* (\boldsymbol{w}_{p,u}^2)^H \tilde{\boldsymbol{r}}_u^{(k)} \quad (27)$$

After rearrange and combined the IFFT output tap as $\hat{\boldsymbol{s}}_p[kQ+q] = \hat{s}_p^{(k)}[q]$, the desired signal is retrieved by despreading with pth user's subcode concatenation spreading codes to form the V parallel LDR streams. Then, all this streams are to be parallel-to-serial (P/S) to make the estimated HDR streams as,

$$\hat{b}_{p,v}[t] = (\hat{s}_p[t]) * c_{p,v}^*[t] \quad (28)$$
$$\hat{\boldsymbol{b}}_p[t] = [\hat{b}_{p,1}[t] \ldots \hat{b}_{p,v}[t] \ldots \ \hat{b}_{p,V}[t]]^T. \quad (29)$$

TABLE 1: SIMULATION CONDITIONS

Simulation Parameter	Value
STBC Type	Alamouti-STBC $(M = 2)$
Modulation Scheme	Quadrature Phase Shift Keying (QPSK)
Spreading Code	Orthogonal Gold sequence (32 chip)
Subcode concatenation	Walsh-Hadamard Codes (32 chip)
Data length of each block	$Q = 32$ samples
Number of data blocks	5000
Number of trials	100 times
Number of subbands	$K = 32$
Adaptive Algorithm	Sample Matrix Inversion (SMI)
Channel	FSF with exponential power profile, i)$\sigma = T_c, \ L = 10$, ii)$\sigma = 5T_c, \ L = 40$

3. SIMULATION AND RESULTS

A. Simulation Conditions

The simulation conditions are shown in Table 1. We consider the QPSK (Quadrature Phase Shift Keying) data modulation with 3 users with each class per user. The spreading code is normalized such that $c_p^2[t] = 1$, for all t. We always assume the perfect synchronization and transmission power control in the simulation. To examine the efficiency of proposed method in the real radio environment, the FSF channel with discrete exponential power delay profile with normalized delay spread

σ of T_c is applied. The power delay profile is given as below:

$$P_l(\tau) = \frac{1}{\sigma}\sum_{l=0}^{L-1} \exp(-\frac{\tau}{\sigma})\delta(\tau - lT_c) \quad (30)$$

Here, the actual delay length of delay profile is infinite, but L paths of them are used to make the influence of duration clear. To evaluate the efficiency of the proposed system, we compare the STBC-SBAA with 1×2 conventional multirate multicode CDMA with SBAA [3] by plotting the result of the output signal to interference plus noise ratio (SINR) [3], [9], average bit error rate (BER) versus the average energy per bit to noise ratio (E_b/N_0), measured in decibels ([dB]).

B. Results

Firstly, in order to examine the interferences cancellation capability of the proposed scheme, we consider the cumulative probability distribution of Output SINR. Here, we set the input E_b/N_0=10[dB] and 3 users are occupied in the system where each user is holding different data rates (class) of Class 1, Class 2, and Class 3, respectively. Note that, data rate for Class $1 <$ Class $2 <$ Class 3. From Fig. 4(a), for $\sigma = T_c$, the STBC-SBAA shows a better cancellation capability compared to conventional SBAA both at Class 1 and Class 3, respectively. Taking the median of cumulative probability($= 0.5$), it is shown that STBC-SBAA without CP has about 1[dB] gain against SBAA, and about 3[dB] when CP is applied. However, the SINR of both STBC-SBAA and SBAA degraded for Class 3 users, due to the average power of each bit allocated is smaller compared Class 1.

On the other hand, from Fig. 4(b) at $\sigma = 5T_c$, it is also observed that the proposed scheme shows a better interference cancellation capability both at Class 1 and Class 3 users. At the median value, Output SINR of STBC-SBAA has 2[dB] gain compared to SBAA, and 4[dB] gain when CP is applied for the both Class 1 and Class 3 users. Therefore, the cancellation capability of STBC-SBAA becomes clearer in the propagation channel with the bigger delay spread. Furthermore, from both figures, it is also observed that the STBC-SBAA adopting CP of $L_{CP} = 10T_c$ achieves a higher SINR, thanks to the help of CP which can absorb the multipath delay signal arrived within GI. We can conclude that, the STBC-SBAA simultaneously eliminates ISI and MAI, thus maintain a higher Output SINR.

Next, we simulate the proposed scheme for the case of the 3 classes (3 users) in the FSF channel with $\sigma = T_c$ and $\sigma = 5T_c$. The input E_b/N_0 is changing at $0 \sim 16$[dB]. The results of BER and Output SINR are depicted in Fig.5 and 6 for $\sigma = T_c$ and $\sigma = 5T_c$, respectively. From these figures, it is shown that the performance degradation of STBC-SBAA and conventional SBAA, due to increasing number of data stream V, is obvious. Here, in the case of Class 1 user which has only one code stream, both BER and Output SINR of STBC-SBAA shows a significant performance compared to SBAA. On the other hand, for Class 3 user which have a three code streams are assume to have 3 different users in the same channel resulting both performance of STBC-SBAA and SBAA are degraded and saturated compare to the case of Class 1 user as the E_b/N_0 increased. However, STBC-SBAA (with and without CP) shows a small degradation. Throughout these figures, it is clear that STBC-SBAA interference cancellation technique can separate interferer without sacrificing performance.

Furthermore, as shown in Fig 5 and 6, the use of the longer CP in the FSF channel with smaller delay spread does not bring additional benefits to STBC-SBAA since the multipath delayed signal arrived within the GI with a smaller compared the length of GI, to be accumulated into the preceding wave only. Here, we suggest that $L_{CP} = 0$ should be chosen for the transmission of STBC-SBAA in the FSF channel with small delay spread, thus enhance the transmission efficiency. Moreover, it is seen that from the slope of BER in Fig 5(a) and Fig 6(a), each user has achieved the same diversity order which mean, STBC-SBAA can accomodate LDR and HDR users with the same diversity gain.

4. Conclusions

We have proposed a novel multirate multicode MIMO CDMA system using SBAA designed for STBC transmission under FSF channel, assuming CSI is unknown at transceivers, while a pilot signal is available during the training period. The proposed scheme has a flexible configuration which allows BS to dynamically adapt to multirate transmission requests from MS. This scheme utilizes a STBC as transmit diversity and receive antenna with SBAA to process the multirate multicode CDMA signal. At the receiver, a novel construction of SBAA to process CDMA signal based on STBC is introduced. Simulation results demonstrate that the proposed scheme can suppress the ISI, MCI and MAI simultaneously.

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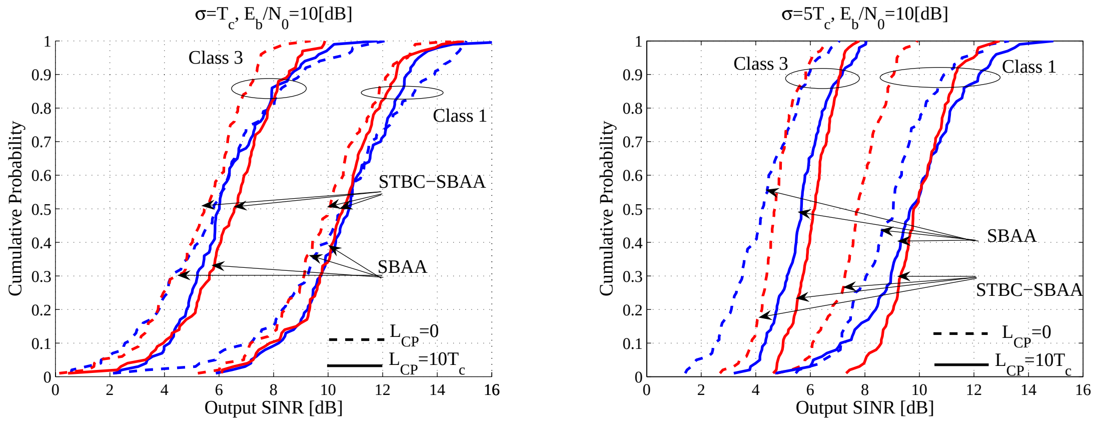
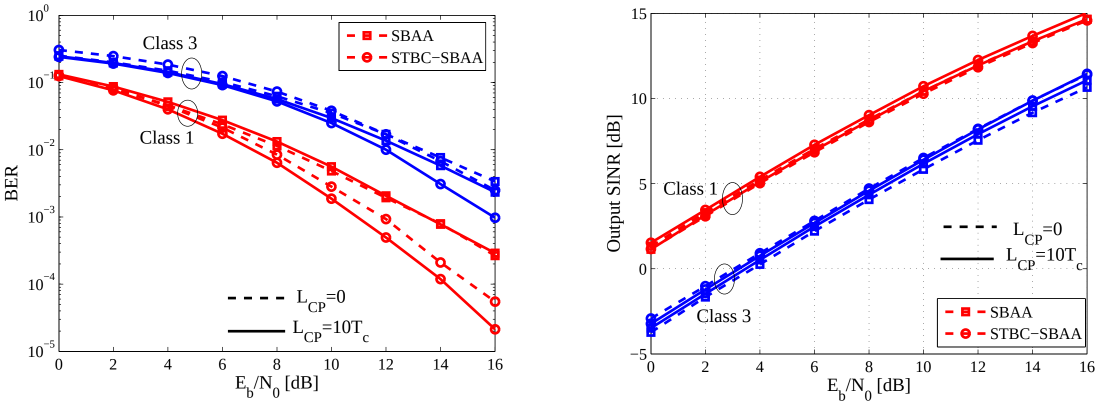


(a) $\sigma = T_c$

(b) $\sigma = 5T_c$

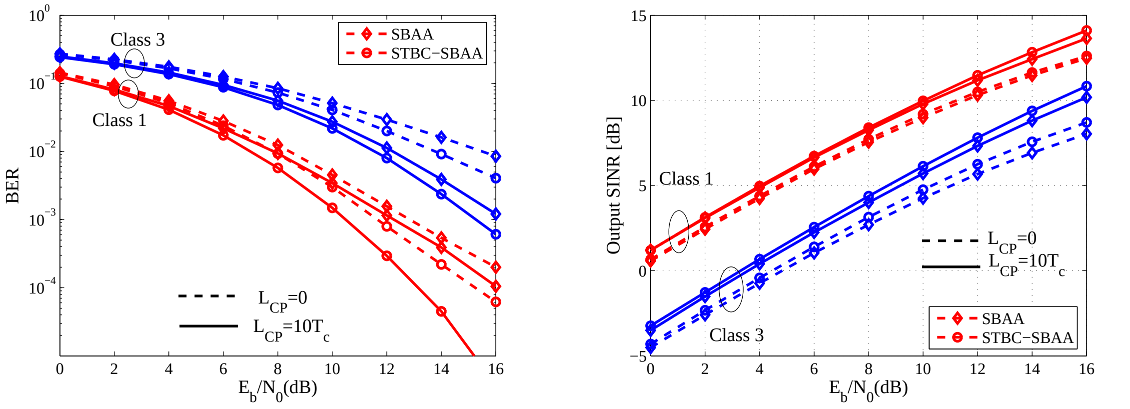
Fig. 4: CDF of Output SINR for 2×2 MIMO CDMA with STBC-SBAA in FSF channel with $\sigma = T_c$ and $\sigma = 5T_c$.



(a) BER

(b) Output SINR

Fig. 5: BER and Output SINR performance of multirate multicode MIMO CDMA with STBC-SBAA in FSF with $\sigma = T_c$.



(a) BER

(b) Output SINR

Fig. 6: BER and Output SINR performance of multirate multicode MIMO CDMA with STBC-SBAA in FSF with $\sigma = 5T_c$.