SUBBAND ADAPTIVE ARRAY FOR MIMO-CDMA SPACE-TIME BLOCK CODED SYSTEM

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ABSTRACT

This paper presents an interference suppression using subband adaptive array for space-time block coding (STBC) code division multiple access (CDMA) under the frequency selective fading (FSF) channel. The proposed scheme utilizes CDMA with STBC and receive array antenna with subband adaptive array (SBAA) processing at receiver. The received signal is converted into the frequency domain before despreading and adaptive processing is done at each subband. A novel construction of SBAA is introduced to process CDMA signal based on STBC. Furthermore, to improve the performance of proposed scheme, we also introduce STBC-SBAA adopting spreading codes cyclic prefix (CP). Simulation results demonstrate improved performance of the proposed system in the case of single and multiusers environment compare to competing relatives.

1. INTRODUCTION

Recently, there are a large number of research papers on use of multiple input multiple output (MIMO) in CDMA transmission [1] to combat multipath fading and provide spatial diversity. Among them, space time spreading (STS) [2] and space time block coding (STBC) [3] are the most efficient method due to its provision of full spatial diversity and simple linear decoder. For multiuser transmissions, STBC can be used in conjunction with receive adaptive beamforming to suppress the co-channel interferences (CCIs) [4, 5].

However, the quality of high-speed data transmission in MIMO-CDMA using SBTC is severely degraded due to frequency selective multipath fading (FSF) channel resulting from the presence of many propagation paths with different time delay. The effect is merely worst in the increased multiple access interference (MAI), which dramatically deteriorates the performance. In [6], a combination of time reversal STBC (TR-STBC) and single carrier block transmission (SCBT) which can effectively deals with FSF through zero padding (ZP) of the blocks. However, the channel state information (CSI) assumed to be known for the equalization process at the receiver. Moreover, the spectral efficiency and, hence the user rate of SCBT CDMA systems is limited by received signal-to-noise ratio (SNR). But, most of the authors assumed their work with the CSI known at receiver side and there are few proposal on this work which do not consider the CSI at all.

In this paper, we propose a novel MIMO-CDMA system using subband adaptive array (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. The proposed scheme utilizes a STBC as transmit diversity and receive antenna with SBAA. At the receiver, a novel construction of SBAA to process CDMA signal based on STBC was introduced. The receive block signal is divided into two groups and adaptive processing is done to equalize and estimate the desired signal. In addition, to improve the performance of STBC-SBAA, spreading code cyclic prefix (CP) [7] was applied in our proposed scheme. A discussion on effects of CP and delay length in STBC-SBAA is also given from theoretical point of view. Simulation results demonstrate the outstanding performance of the proposed transceiver compared to competing alternatives.

2. STBC-SBAA FOR MIMO-CDMA

2.1 STBC-SBAA

The configuration of the proposed STBC-SBAA for MIMO-CDMA system is illustrated in Fig. 1. In this paper we restricted our system for Alamouti's STBC [3] with $M = 2$ and N MIMO-CDMA system. Extension to more general type of STBC is quite straight forward. We assume a FSF channel with the delay length L with time spacing of chip duration T_c, is given as $\mathbf{H}_p(\tau) = \sum_{l=0}^{L-1} H_p^{(l)} \delta(\tau - lT_c)$, where

$$H_p^{(l)} = [\boldsymbol{h}_{1,p}^l \quad \boldsymbol{h}_{2,p}^l] = \begin{bmatrix} h_{11,p}^l & h_{21,p}^l \\ \vdots & \vdots \\ h_{N1,p}^l & h_{N2,p}^l \end{bmatrix}, \quad (1)$$

δ is the Dirac delta function, and $h_{ji,p}^l$ is the channel coefficient with delay l between i-th $(i = 1, \dots, M(=2))$ transmit and j-th $(j = 1, 2, \dots, N)$ receive antenna elements for p-user. In this paper, different from the conventional STBC [3], the STBC-SBAA transmission is carried out in block sequence as shown at the bottom of Fig.1. This operation is to realize an additional multipath diversity gain without sacrificing full spatial diversity.

Consider an uplink multiuser communication system where P mobile users exist, the signal of each user is given by $s_p[k]$, where $p = \{1, 2, \dots, P\}$, $\{k \in \mathbb{Z}\}$. Each user signal is spread by a factor of Q at the given spreading code $\boldsymbol{c}_p$ (chip duration of T_c), to be represented in k^{th} block with each elements of $s_p^{(k)}[q] = s_p[k]c_p[q]$, where $q \in \{0, 1, \dots, Q-1\}$. The k^{th} chip-block $\boldsymbol{s}_p^{(k)} =$

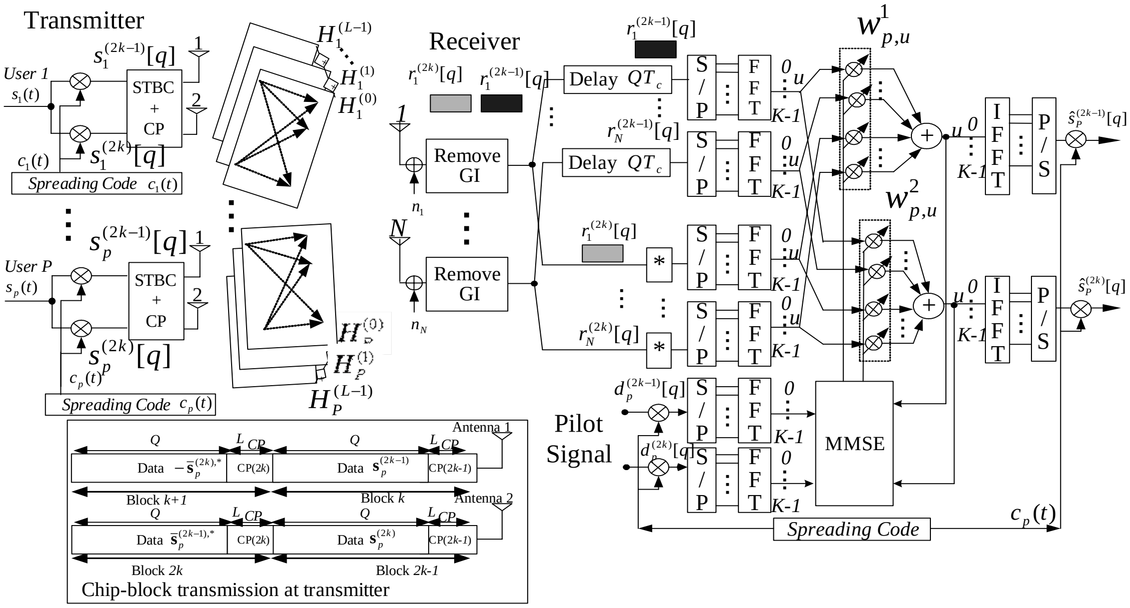

Figure 1: Configuration of STBC-SBAA for MIMO-CDMA

$[s_p(Qk), \ldots, s_p(Qk+(Q-1))]^T$ contain Q chips. The input chip block signal is encoded by space-time block encoder (STBE) [3] to make the transmit signal $s_{p,i}^{(k)}[q]$ at antenna $i \in \{1,2\}$ of $p-$user as below.

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

$$s_{p,2}^{(2k-1)}[q] = s_p^{(2k)}[q], \quad s_{p,2}^{(2k)}[q] = \bar{s}_p^{(2k-1),*}[q] \tag{3}$$

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-reversed is for handling the frequency domain processing in the receiver [8]. 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 at the bottom of Fig. 1. This operation is for minimizing the effect of ISI [7].

After passing through the FSF channel and discarding the CP (by assuming $L_{CP} \geq L$), the receive signals at antenna $j(\{1,2,\ldots,N\})$ at block $2k-1$ and $2k$ is given as follows:

$$\begin{aligned} r_j^{(2k-1)}[q] &= \frac{1}{\sqrt{2}} \sum_{p=1}^{P} \sum_{l=0}^{L-1} \{h_{j1,p}^l s_{p,1}^{(2k-1)}[q-lT_c] \\ &\quad + h_{j2,p}^l s_{p,2}^{(2k-1)}[q-lT_c]\} + n_j^{(2k-1)}[q] \end{aligned} \tag{4}$$

$$\begin{aligned} r_j^{(2k)}[q] &= \frac{1}{\sqrt{2}} \sum_{p=1}^{P} \sum_{l=0}^{L-1} \{h_{j2,p}^l s_{p,2}^{(2k)}[q-lT_c] \\ &\quad + h_{j1,p}^l s_{p,1}^{(2k)}[q-lT_c]\} + n_j^{(2k)}[q] \end{aligned} \tag{5}$$

where $n^{(2k-1)}[q]$ and $n_j^{(2k)}[q]$ are the additive white gaussian noise (AWGN) with zero mean and covariance σ_n^2 at $2k-1$ and $2k$, respectively. At the receiver, 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.

2.2 MMSE Detection

We now present the theoretical model of minimum mean square error (MMSE) multiuser detector for STBC-SBAA by rewriting (4) and (5) into the vector form. First we define the transmit signal, receive signal and noise as follows.

$$\breve{\boldsymbol{s}}_p^{(k)}[q] = \begin{bmatrix} s_p^{(2k-1)}[q] & s_p^{(2k)}[q] \end{bmatrix}^T \tag{6}$$

$$\boldsymbol{n}^{(2k-1)}[q] = \begin{bmatrix} n_1^{(2k-1)}[q] & n_2^{(2k-1)}[q] & \ldots & n_N^{(2k-1)}[q] \end{bmatrix}^T \tag{7}$$

$$\boldsymbol{n}^{(2k)}[q] = \begin{bmatrix} n_1^{(2k)}[q] & n_2^{(2k)}[q] & \ldots & n_N^{(2k}[q] \end{bmatrix}^T \tag{8}$$

$$\boldsymbol{r}^{(2k-1)}[q] = \begin{bmatrix} r_1^{(2k-1)}[q] & r_2^{(2k-1)}[q] & \ldots & r_N^{(2k-1)}[q] \end{bmatrix}^T \tag{9}$$

$$\boldsymbol{r}^{(2k)}[q] = \begin{bmatrix} r_1^{(2k)}[q] & r_2^{(2k)}[q] & \ldots & r_N^{(2k)}[q] \end{bmatrix}^T \tag{10}$$

and the $\breve{\boldsymbol{n}}^{(k)}$, $\breve{\boldsymbol{r}}^{(k)}$ for $2k-1$ and $2k$ can be stacked as below.

$$\breve{\boldsymbol{n}}^{(k)}[q] = \begin{bmatrix} \boldsymbol{n}^{(2k-1),T}[q] & \boldsymbol{n}^{(2k),H}[q] \end{bmatrix}^T \tag{11}$$

$$\breve{\boldsymbol{r}}^{(k)}[q] = \begin{bmatrix} \boldsymbol{r}^{(2k-1),T}[q] & \boldsymbol{r}^{(2k),H}[q] \end{bmatrix}^T \tag{12}$$

For simplicity, we define the channel of (1) to be as

$$\tilde{\boldsymbol{H}}_p^l = \begin{bmatrix} \boldsymbol{h}_{1,p}^l & \boldsymbol{h}_{2,p}^l \\ \bar{\boldsymbol{h}}_{2,p}^{l*} & -\bar{\boldsymbol{h}}_{1,p}^{l*} \end{bmatrix} \tag{13}$$

Using the notations from (6) to (13), we can rewrite the receive signal (4) and (5) to be as

$$\breve{\boldsymbol{r}}^{(k)}[q] = \sum_{p=1}^{P} \sum_{l=0}^{L-1} \tilde{\boldsymbol{H}}_p^l \breve{\boldsymbol{s}}_p^{(k)}[q - lT_c] + \boldsymbol{n}^{(k)}[q] \tag{14}$$

In this paper, the subband adaptive processing with the most popular linear multiuser method, namely, minimum mean square error (MMSE) is used for detecting transmitted signals from each user. To perform adaptive signal processing in subbands, the receive signal $\breve{\boldsymbol{r}}^{(k)}[q]$ is decomposed into subbands using analysis filter. The analysis filter employed in this proposed configuration utilizes *critical sampling*, i.e, the received signal at each array element is decimated with maximum rate Q. This operation will result in block processing mode and thus helps to save a great amount of computational load compared with sliding window processing [7, 9]. As shown in Fig.1, in order to work with STBC, the subband processing is done by referring two consecutive blocks as its input; therefore two group of optimal weight exists for maximizing the output power. Let us define that the Fast Fourier Transform (FFT) operation of $\mathbf{x}$ by $\mathcal{F}(\mathbf{x})$. After taking FFT, equation (14) in u-th subband is given by $(u = \{0, 1, \ldots, K-1\}$($K$:total number of subband.)

$$\tilde{\boldsymbol{r}}_u^{(k)} = \mathcal{F}(\breve{\boldsymbol{r}}^{(k)}[q]) \tag{15}$$

$$= \mathcal{F}(\sum_{p=1}^{P} \sum_{l=0}^{L-1} \tilde{\boldsymbol{H}}_p^l \breve{\boldsymbol{s}}_p^{(k)}[q - lT_c]) + \mathcal{F}(\breve{\boldsymbol{n}}^{(k)}[q]) \tag{16}$$

Assume that the p-user is taken to be desired user while the rest of $P-1$ users are uninterested (undesired) users. The pilot signal of p-user $\boldsymbol{d}_p^{(k)}[q] = [d_p^{(2k-1),T}[q], d_p^{(2k),T}[q]]^T$ is also converted into subband signals in the same manner to be $\tilde{d}_{u,p}^{(2k-1)}$ and $\tilde{d}_{u,p}^{(2k)}$. By using MMSE criterion, the $2K \times 1$ optimal weight vector for estimating $\tilde{\boldsymbol{s}}_p^{(2k-1)}$ and $\tilde{\boldsymbol{s}}_p^{(2k)}$ are derived as follows.

$$\boldsymbol{w}_{p,u}^1 = \arg\min E\{|\tilde{d}_{p,u}^{(2k-1)} - (\boldsymbol{w}_{p,u}^1)^H \tilde{\boldsymbol{r}}_u^{(k)}|^2\} \tag{17}$$

$$\boldsymbol{w}_{p,u}^2 = \arg\min E\{|\tilde{d}_{p,u}^{(2k)} - (\boldsymbol{w}_{p,u}^2)^H \tilde{\boldsymbol{r}}_u^{(k)}|^2\} \tag{18}$$

Here, $\boldsymbol{w}_{p,u}^1$ and $\boldsymbol{w}_{p,u}^2$ are the optimal weight of kth block at each subband of p-user. Satistifying equation (17) and (18) gives us the optimal weight as follows.

$$\boldsymbol{w}_{p,u}^1 = (\boldsymbol{R}_{rr}^u)^{-1} \boldsymbol{v}_{p,u}^{(2k-1)}, \ \boldsymbol{w}_{p,u}^2 = (\boldsymbol{R}_{rr}^u)^{-1} \boldsymbol{v}_{p,u}^{(2k)} \tag{19}$$

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

$$\boldsymbol{v}_{p,u}^{(2k-1)} = E[\tilde{\boldsymbol{r}}_u^{(k)} \tilde{d}_{p,u}^{(2k-1),*}], \ \boldsymbol{v}_{p,u}^{(2k)} = E[\tilde{\boldsymbol{r}}_u^{(k)} \tilde{d}_{p,u}^{(2k),*}] \tag{20}$$

are the correlation vectors of receive signal and reference signal in subband. Here, $E[\cdot]$ denotes the ensemble average operator. The subband signals after weighted by the optimal weight are synthesized through the inverse FFT (IFFT).

$$\tilde{s}_p^{(2k-1)}[q] = \mathcal{F}^{-1}(\sum_{u=0}^{K-1} \{(\boldsymbol{w}_{p,u}^1)^H \tilde{\boldsymbol{r}}_u^{(k)}\}) \tag{21}$$

$$\tilde{s}_p^{(2k)}[q] = \mathcal{F}^{-1}(\sum_{u=0}^{K-1} \{(\boldsymbol{w}_{p,u}^2)^H \tilde{\boldsymbol{r}}_u^{(k)}\}) \tag{22}$$

After rearrange and combined the IFFT output tap as $\tilde{\boldsymbol{s}}_p^{(k)}[q] = [\tilde{s}_p^{(2k-1)}[q] \ \tilde{s}_p^{(2k)}[q]]$, the desired signal is retreavied by despreading with p-user's spreading codes as $\tilde{s}_p[k] = \sum_{q=0}^{Q-1} \tilde{s}_p^{(k),T}[q] \boldsymbol{c}_p^*[q]$.

3. EFFECTS OF CP IN STBC-SBAA

Now, we consider the effects of CP in STBC-SBAA for MIMO-CDMA. Consider $\boldsymbol{s}_0$ be a vector of the desired signal. Its extended version using CP, denoted by $\boldsymbol{s}_0^{CP}$ and $\boldsymbol{s}_l^{CP}[q]$,$(l = 1, \ldots, L-1)$ is delayed version of $\boldsymbol{s}_0^{CP}[q]$. After the transmission of $\boldsymbol{s}_0^{CP}[q]$, last Q samples referred as $\boldsymbol{s}_{C,l}$ to be the input of STBC-SBAA.

3.1 Case 1:$L \leq L_{CP}$

In this case, the delayed signal $\boldsymbol{s}_{C,l}$ contains all the data in the original though its order was changed. As shown in Fig 2(ii), when the STBC-SBAA input using CP can be represented as $\boldsymbol{s}_{C,l} = [\boldsymbol{s}_{l,1}^T, \boldsymbol{s}_{l,0}^T]^T$. The u-th band component of $\boldsymbol{s}_{C,l}$ is expressed by $\tilde{\boldsymbol{s}}_C^u = \mathcal{F}(\boldsymbol{s}_{C,l})$. While $\tilde{\boldsymbol{s}}_C^u$ is in general different from $\tilde{\boldsymbol{s}}_0^u(=\mathcal{F}(\boldsymbol{s}_0))$ both in amplitude and phase, the DFT of signal with CP is same as $\tilde{\boldsymbol{s}}_0^u$ except the term of linear phase. As the result, if the set of source signal consists of $\tilde{\boldsymbol{s}}_0^u$ and its delayed signal, we have

$$\boldsymbol{s}_C = [\boldsymbol{s}_{C,0}^T, \ldots, \boldsymbol{s}_{C,L-1}^T]^T \tag{23}$$

$$\tilde{\boldsymbol{s}}_C^u = \mathcal{F}(\boldsymbol{s}_C) \tag{24}$$

Therefore the correlation matrix of the received signal of N-received antennas is given by $\boldsymbol{R}_{rr}^u = \mathbf{R}_{C,rr}^u$ as

$$\mathbf{R}_{C,rr}^u = \mathbf{R}_{ss}^u + \mathbf{R}_{C,nn}^u \tag{25}$$

$$\mathbf{R}_{ss}^u = \sum_{p=1}^{P} \sum_{l_1=l_2=0}^{L-1} \mathcal{F}(\boldsymbol{H}_p^{l_1}) \mathbf{R}_{C,ss} \mathcal{F}(\boldsymbol{H}_p^{l_1,H})^H \tag{26}$$

$$\mathbf{R}_{C,nn}^u = \mathbf{R}_{nn}^u = \mathcal{F}(\mathbf{R}_{nn}) \tag{27}$$

where $\mathbf{R}_{C,ss} = E[\boldsymbol{s}_0 \boldsymbol{s}_0^H]$ and $\mathbf{R}_{nn} = E[\boldsymbol{n}\boldsymbol{n}^H] = \boldsymbol{\sigma}_n^2 \mathbf{I}_{2N}$, $\mathbf{I}_N$ is $N \times N$ identity matrix. As a result, the STBC-SBAA of each band acts as superposition of several $\boldsymbol{s}_0$ came from different directions, thanks to the help of CP. Noted that two consecutive block are relatively dependent to each others to maximize its output power of desired signal.

3.2 Case 2:$L \geq L_{CP}$

Different from Case 1, the first $D_l - L_{CP}$, (where D_l :delay length) samples are not recovered even by using CP. As shown in Fig.2(iii), we can represent the

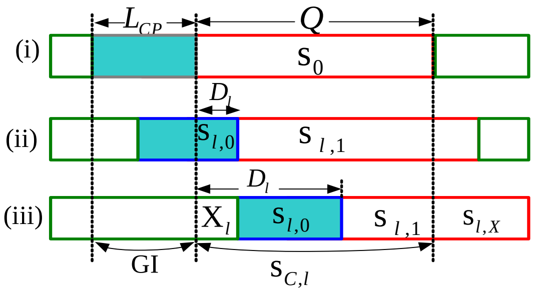

Figure 2: Effects of CP and delay length D_l, in STBC-SBAA when (i)$L = 0$,(ii)$L \leq L_{CP}$,(iii)$L \geq L_{CP}$

input of STBC-SBAA as

$$\begin{aligned} \boldsymbol{s}'_{C,l} &= [\boldsymbol{s}^T_{l,1}, \boldsymbol{s}^T_{l,0}, \boldsymbol{X}^T_{l,X}] && (28)\\ &= \boldsymbol{s}_{C,l} + \triangle \boldsymbol{s}_{C,l} && (29)\\ \boldsymbol{s}_{C,l} &= [\boldsymbol{s}^T_{l,1}, \boldsymbol{s}^T_{l,0}, \boldsymbol{s}^T_{l,X}]^T && (30)\\ \triangle \boldsymbol{s}_{C,l} &= [\mathbf{0}^T_{L_{CP}}, \mathbf{0}^T_{Q-L_{CP}}, \triangle \boldsymbol{s}^T_{l,X}]^T && (31) \end{aligned}$$

where $\triangle \boldsymbol{s}_{l,X}$ is the errors contained in unrecoverable part of $\boldsymbol{s}'_{C,l}$ and it is uncorrelated with $\boldsymbol{s}_0$. Hence, the correlation matrix will be as

$$\mathbf{R}'^{,u}_{C,rr} = \sum_{p=1}^{P} \sum_{l_0=l_1=0}^{L-1} \mathcal{F}(\boldsymbol{H}^{l_0}_p) \mathbf{R}'_{C,ss} \mathcal{F}(\boldsymbol{H}^{l_1,H}_p)^H \quad (32)$$

$$= \sum_{p=1}^{P} \sum_{l_0=l_1=0}^{L-1} \mathcal{F}(\boldsymbol{H}^{l_0}_p)(\mathbf{R}_{ss} + \triangle \mathbf{R}_{ss}) \mathcal{F}(\boldsymbol{H}^{l_1,H}_p)^H \quad (33)$$

where

$$\begin{aligned} \triangle \mathbf{R}_{ss} &= E[\triangle \boldsymbol{s} \triangle \boldsymbol{s}^H] && (34)\\ \triangle \boldsymbol{s} &= [\triangle \boldsymbol{s}^T_0, \triangle \boldsymbol{s}^T_1, \ldots, \triangle \boldsymbol{s}^T_{L-1}] && (35)\\ \triangle \boldsymbol{s}_l &= [\mathbf{0}_{L_{CP}}, \triangle \boldsymbol{s}^T_{l,X}, \mathbf{0}^T_{Q-L_{CP}}]^T && (36) \end{aligned}$$

where, $\mathbf{0}_l$ is the zero matrix. From (33), the term of $\triangle \mathbf{R}_{ss}$ interferes the correlation matrix compared to (26) of previous case. Therefore, it is proved that usage of CP would diagonalizable the correlation matrix, hence maximize the performance of STBC-SBAA (in the sense of $L \leq L_{CP}$).

4. SIMULATION AND RESULTS

In this paper, we consider a Binary Phase Shift Keying (BPSK) modulation transmission with $M = 2$ transmit and $N = 2$ receiver antennas. Each block contains $Q = 31$ chips and Gold spreading codes with $K = 31$ chip length are used. To examine the efficiency of proposed method in the real radio environment, the FSF channel with exponential power profile (delay spread $\sigma = T_c \sim 5T_c$) is applied. The power delay profile is given by

$$P_l(\tau) = \frac{1}{\sigma} \sum_{l=0}^{L-1} \exp(-\frac{\tau}{\sigma}) \delta(\tau - lT_c) \quad (37)$$

Here, the actual length of delay profile is infinite, but L path of them are used to make the influence of duration clear. The received signal is corrupted by a complex AWGN process. Pilot signal is available in the receiver while a perfect synchronization achieved at the receiver were assumed. Sample matrix inversion (SMI) is used as the adaptive algorithm. To evaluate the efficiency of the proposed system, we compare the STBC-SBAA with STBC-Adaptive Beamforming (STBC-ABF) [4] for MIMO-CDMA system. We plot the result of the output signal to interference plus noise ratio (SINR) [4] versus the average SNRs, measured in decibels (dB).

4.1 Results

In order to examine the interferences cancellation capability in FSF, we evaluate the proposed scheme in FSF with $\sigma = T_c$ when input SNR is changing at $0 \sim 12$[dB] for a single user (ISI only) and five users (ISI+MAI). In Fig. 3, in the case of single user, STBC-SBAA shows a significant performance compared to STBC-ABF. When the system is loaded with five users, the performance of STBC-SBAA and STBC-ABF are degraded compare to the cases of single user due to MAI. However STBC-SBAA shows a small degradation, which proved that the proposed scheme also works in multiuser environments. In some cases, the use of CP would not work well in STBC-SBAA since the propagation delay becomes larger than GI. It is noted that when the CP is employed and fully worked, the SINR is maximized to the upper bound of theoretical limit which is given by [7]

$$\mathrm{SINR}[dB] = 10 \log_{10}(N) + 10 \log_{10}(K) + \mathrm{SNR}. \quad (38)$$

Next, we compare the performance of the proposed scheme in FSF with different delay spread in multiuser environments. Here, we consider two cases of $\sigma = T_c$ and $5T_c$ for five users. As depicted in Fig. 4, STBC-SBAA shows an improvement in SINR, linearly increased as SNR increased. When $\sigma = 5T_c$, STBC-SBAA still can achieved a better performance compared to STBC-ABF. It is also clearly observed that the SINR of STBC-SBAA improves very much in multipath rich FSF channel, thus the effectiveness of the proposed scheme is verified. Focusing on the MAI cancellation capability, we simulate the proposed system for three type of input SNR:=$\{-10,\ 0,\ 10$[dB]$\}$ in different delay spread which varies from $\sigma = T_c$ to $\sigma = 5T_c$. The number of user is put to 5 users. The result is depicted in Fig. 5 which shows that the performance of STBC-SBAA and STBC-ABF degraded when the σ increased due to the existence of ISI and MAI. However, STBC-SBAA shows a better performance compared to STBC-ABF for the entire input SNR. A close observation on Fig. 5 also shows that the STBC-SBAA improve very much at the higher SNR, since the average power of combined multipath signal is bigger than MAI, therefore the ability of STBC-SBAA to mitigate MAI is higher.

4.2 Effect of L_{CP} in STBC-SBAA

In this paper, we use CP length of L_{CP} chips out of the Q chips, which will give a CP power penalty of $Q/(L_{CP} + Q)$. For example, even if $Q = 31$, $L_{CP} = 10$, the degradation in the efficiency is 1.2[dB]. If the larger

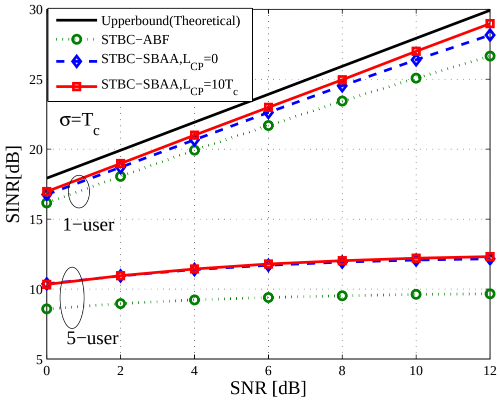

Figure 3: Performance of SINR for 2×2 MIMO STBC-SBAA with single and five active users in FSF channel at $\sigma = T_c$.

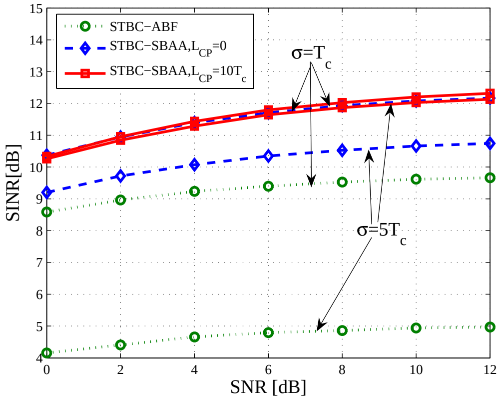

Figure 4: Performance of SINR for 2×2 MIMO STBC-SBAA with five users at FSF with $\sigma = T_c$ and $\sigma = 5T_c$.

gain than the above degradation is obtained, we can say that the proposed scheme is effective. The use of longer CP could mitigate the multipath signal and improve the SINR. But, the use of longer CP will bring a reduction of transmission rate. As the delay spread increased, the channel changes significantly even within one block, which violates the quasi-static assumption. In this case, shorter data blocks have to be used for the better algorithm tracking. However, using smaller data blocks results in increased system overhead due to CP attached to each block. Therefore, choosing of the CP length and data block length is important in order to mitigate the multipath signal and improve the performance of the proposed scheme.

5. CONCLUSIONS

In this paper, for high reliability multiuser transmission under FSF, we have proposed a novel MIMO-CDMA system utilizing SBAA in the receiver. A novel construction of SBAA is introduced to process CDMA signal based on STBC before despreading. In addition, spreading code CP is introduced to improve the performance of STBC-SBAA. Through the computer simulations, it is verified the STBC-SBAA achieves a good SINR compared to STBC-ABF with less complexity both in single and multiusers environment. We proved that the proposed scheme can achieve a significant performance by exploiting the effects of transmit diversity and subband adaptive array.

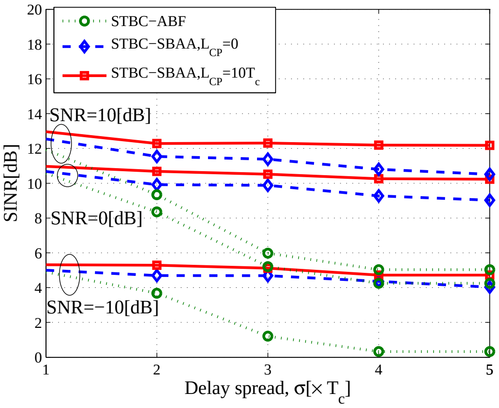

Figure 5: Average SINR for five users 2×2 MIMO-CDMA STBC-SBAA as a function of delay spread, σ.

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