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SUBBAND ADAPTIVE ARRAY FOR SPACE TIME BLOCK CODING

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1 Introduction

Future mobile communications is required to provide data transmission with higher rates and more reliability than current systems. As a solution to this problem, the diversity transmission using Alamouti's space time block coding (STBC)[1] has been adopted in several wireless standard due to its attractive features such as full spatial diversity at full transmission rate. Usually, it requires channel state information (CSI) at the receiver but in [2], whose authors have proposed an adaptive beamforming scheme for Alamouti-type STBC which does not require the explicit CSI for coherent decoding at the receiver. This scheme achieves high performance in a flat fading (FF) channel with co-channel interferences (CCIs), but it cannot applied for the frequency selective fading channel (FSF).
Tapped delay line adaptive array (TDLAA)[4] is well known as a solution for this problem since it utilizes the delayed signals to enhance the desired signal instead of excluding them as interferences. However, this method required a large computional load compared to conventional adaptive array system. In this paper, in order to improve the performance of STBC in multipath frequency selective fading channel, we propose a combined transmission scheme of Alamouti's space-time encoding and subband adaptive array (SBAA) processing. In order to improve the performance of STBC-SBAA, cyclic prefix (CP) is also introduced.

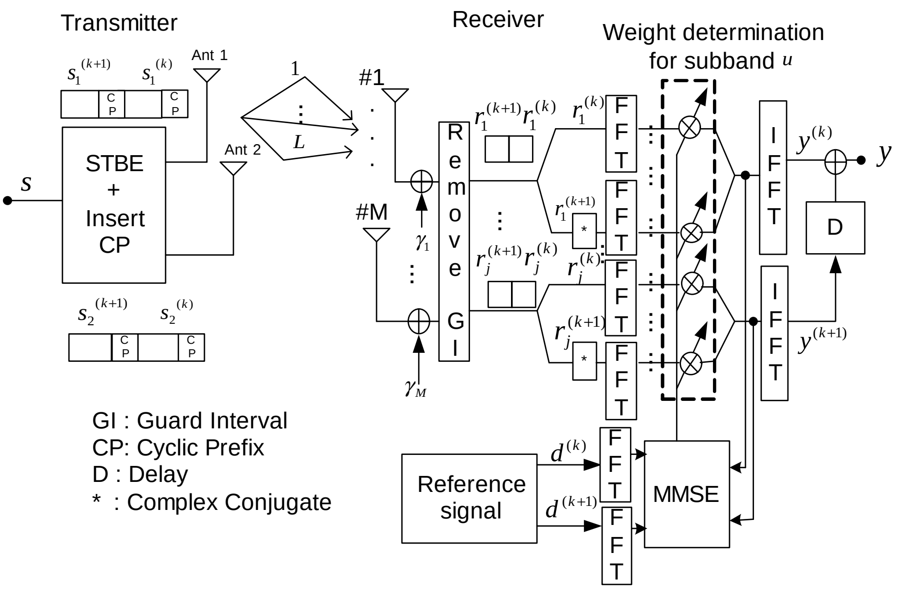

Figure 1: Configuration of STBC-SBAA

2 System Description

The configuration of the proposed scheme is illustrated in Figure 1. Here we consider a system using Alamouti-type STBC[1] with two transmit antennas and M-receive antennas for a single

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user. First, the input signal $\{\boldsymbol{s}^{(k)}, k \in \boldsymbol{Z}\}$, is divided into blocks of length N. The k^{th} block $\boldsymbol{s}^{(k)} = [s^{(k)}, \ldots, s^{(k+(N-1))}]^T$ contains N symbols with the duration of T. At the odd time $k, k = 1, 3, 5, 7, ..$, a pairs of length-N blocks $\boldsymbol{s}_1^{(k)}$ and $\boldsymbol{s}_2^{(k)}$ are transmitted from antenna 1 and 2, respectively. Similarly, at the even time $k+1$, a pairs of length-N blocks $\boldsymbol{s}_1^{(k+1)}$ and $\boldsymbol{s}_2^{(k+1)}$ are transmitted. The transmitted blocks are encoded as follows

$$\boldsymbol{s}_1^{(k+1)} = (-\bar{\boldsymbol{s}}_2^{(k)})^* \quad (1)$$

$$\boldsymbol{s}_2^{(k+1)} = (\bar{\boldsymbol{s}}_1^{(k)})^* \quad (2)$$

Noted that $(-\bar{\boldsymbol{s}}_2^{(k)})^*$ and $(\bar{\boldsymbol{s}}_1^{(k)})^*$ are time reversed and element-by-element complex conjugated version of $\boldsymbol{s}_1^{(k)}$ and $\boldsymbol{s}_2^{(k)}$, respectively [3]. In addition, a CP of length L_{CP} is added to each transmitted block in order to mitigate the inter-symbol-interference (ISI). The transmitted signal from each antenna has been normalized by $\sqrt{2}$ to make the total transmitted power unity.
The received signal of antenna $j(\{1, 2, .., M\})$ at time (k) and $(k+1)$ is given as follows

$$\boldsymbol{r}_j^{(k)} = \frac{1}{\sqrt{2}} \sum_{l=1}^{L} h_{j1}^l \boldsymbol{s}_1^{(k)} + h_{j2}^l \boldsymbol{s}_2^{(k)} + \boldsymbol{\gamma}_j^{(k)} \quad (3)$$

$$\boldsymbol{r}_j^{(k+1)} = \frac{1}{\sqrt{2}} \sum_{l=1}^{L} -h_{j2}^l (\boldsymbol{s}_2^{(k+1)})^* + h_{j2}^l (\boldsymbol{s}_1^{(k+1)})^* + \boldsymbol{\gamma}_j^{(k+1)} \quad (4)$$

where h_{ji}^l is the channel coefficience between transmit antenna $i(\in \{1, 2\})$ and receive antenna j for path $l(\in \{0, 1, 2, .., (L-1)\})$, and h_{ji}^l is constant for the whole k^{th} block and $\boldsymbol{\gamma}_j$ is the Gaussian noise at j-th receive antenna. At the receiver, the guard interval (GI) corresponding to CP will be discarded from each blocks, and the even blocks are conjugated to be $(\boldsymbol{r}_j^{(k+1)})^*$. Then, the samples are transformed using fast fourier transform (FFT) to give subband signals $\{\tilde{\boldsymbol{x}}_u; u = 1, \ldots, K\}$. Then the receive signal is decimated with maximal rate N. The reference signal $\boldsymbol{d}$=$[(\boldsymbol{d}^{(k)})^T, (\boldsymbol{d}^{(k+1)})^T]^T$ is also converted into the frequency domain subbands in the same manner. In the training process, the complex weights in subbands are updated by the error signal. Using the minimum mean square error as the criterion, the optimal weight vector in u-th subband is given by well-known Wiener-Hopf equation,

$$\boldsymbol{w}_u^{(k)} = (\boldsymbol{R}_u)^{-1} \boldsymbol{p}_u^{(k)} \quad (5)$$

$$\boldsymbol{w}_u^{(k+1)} = (\boldsymbol{R}_u)^{-1} \boldsymbol{p}_u^{(k+1)} \quad (6)$$

where $\boldsymbol{R}_u = E[\tilde{\boldsymbol{x}}_u (\tilde{\boldsymbol{x}}_u)^H]$ is covariance matrix and $\boldsymbol{p}_u^{(k)} = E[\tilde{\boldsymbol{x}}_u (\tilde{d}_u^{(k)})^*]$, $\boldsymbol{p}_u^{(k+1)} = E[\tilde{\boldsymbol{x}}_u (\tilde{d}_u^{(k+1)})^*]$ are the correlation vectors of reference and received signal in subbands. Here, $E[.]$, $(.)^*$, and $(.)^H$ are the notations expressing expectation, complex conjugate and Hermitian transpose, respectively.

The subbands signal after weighted by the optimal weight are combined according to each subband and the inverse fast fourier transform (IFFT) is then performed to get output signal $\boldsymbol{y}^{(k)}$ and $\boldsymbol{y}^{(k+1)}$ in time domain. The output signal is expressed as $\boldsymbol{y}$= [$\boldsymbol{y}^{(k)}$,$\boldsymbol{y}^{(k+1)}$].

3 Simulation Results

We investigate the performance of the proposed scheme through computer simulations. In this paper we consider the case of BPSK transmission with 2 transmit antennas and 4 receiver antennas,$i.e$, $M = 4$. Each data block contains 8 symbols, and the number of subbands $K = 8$.

The channel is assumed to be frequency selective Rayleigh fading channel with the maximum delay of L. The channel transfer function used in this simulation is shown as follows

$$\boldsymbol{H}(t) = \sum_{l=0}^{L-1} \eta_l H^{(l)} \delta(t - lT) \tag{7}$$

$$H^{(l)} = \begin{pmatrix} h_{11}^{l} & h_{21}^{l} \\ \ldots\ldots & \ldots\ldots \\ h_{M1}^{l} & h_{M2}^{l} \end{pmatrix} \tag{8}$$

Here, δ is the Dirac delta function. h_{ji}^{l} is i.i.d with $< |h_{ji}|^2 >= 1$. We also assume that the pilot signal is available in the receiver and sample matrix inversion (SMI) as the adaptive algorithm. The output signal to interference and noise ratio (SINR) has been used to evaluate the performance. The SINR is given by cross-correlation coefficient as follows

$$\rho = \frac{E[\boldsymbol{y}\boldsymbol{d}^*]}{\sqrt{E[|\boldsymbol{y}|^2]E[|\boldsymbol{d}|^2]}} \tag{9}$$

where $\boldsymbol{d}$ is the reference signal in time domain. The output SINR is finally given by

$$\mathrm{SINR} = \frac{|\rho|^2}{1 - |\rho|^2} \tag{10}$$

Here we consider $\eta_0 = \eta_2 = 1, \quad \eta_1 = \eta_3, \ldots = \eta_L = 0$ for FSF and $\eta_0 = 1, \eta_{l \neq 0} = 0$ for FF. Figure 2 to 4 show the simulation results. In Figure 2, we compare the capability of STBC-SBAA with the conventional STBC [2]. It is observed that under FSF, STBC-SBAA can maintain the high output SINR, while output SINR of the conventional STBC scheme degrade. This fact means that the propose scheme with subband processing in the receiver achieves a higher diversity compared to conventional STBC.

Next, in Figure 3, we compare the performance of the propose scheme for the case with and without CP. Here, we used a CP of $L_{CP} = 2$. From the figure, it is seen that the output SINR of STBC-SBAA-CP is comparable to the case of no delay by using CP. Namely, addition of CP can improve the performance of STBC-SBAA.

In Figure 4, we investigate how the delay length affect the output SINR for three different input SNR's,-10[dB], 0[dB] and 10[dB]. The CP length is keep to $L_{CP} = 2$. From the figure, it is noticed that the output SINR is improved when the the delay is shorter than cyclix prefix length, but degraded when the the delayed symbol exceeded the CP prefix length.

4 Conclusion

In this paper, we have proposed a new transmission scheme using space time block coding and subband adaptive array in the receiver with cyclic prefix. In the receiver, the space time equalization is done through the adaptive beamforming. Through computer simulations, it has been verified that the proposed scheme shows better performance than STBC of conventional type and that the proposed scheme is improve by appending CP. In the future, we shall performed the comparison between STBC-SBAA with STBC-TDLAA and generalization of STBC-SBAA.

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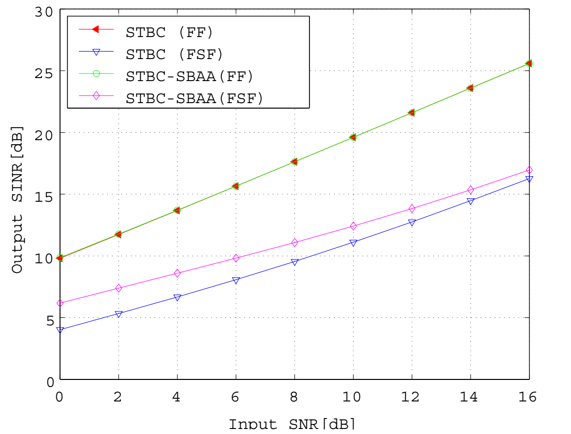

Figure 2: Performance of STBC-SBAA in frequency selective fading

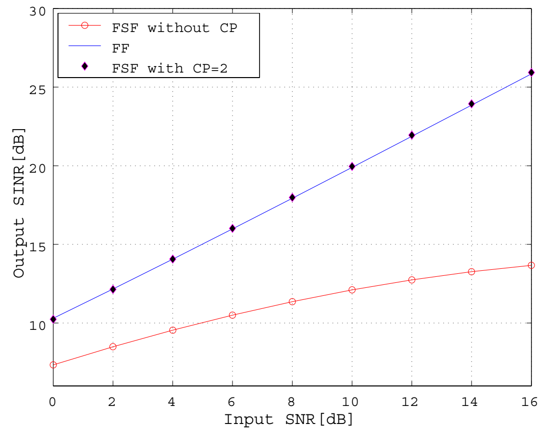

Figure 3: Performance of STBC-SBAA-CP

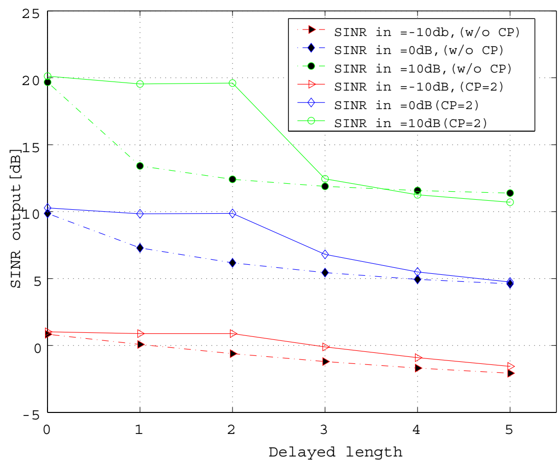

Figure 4: Effect of CP length in STBC-SBAA

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