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Chennel Estimation for Orthogonal Polynomial Based Space-Time Block Coded CDMA 2000 in Multipath Fading Channels

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Abstract: Space-Time Block Coding (STBC) is a promising spatial diversity technique for future wireless communications systems. The combination of STBC and Code Division Multiple Access (CDMA) technology has the potential to increase the users performance in wireless communication networks. Space Time Transmit Diversity (STTD) is the extension of Space-Time Block Coding (STBC) to code division multiple access (CDMA) systems. To date, most discussions of STTD either assumed flat fading or ignored the Inter-Symbol and Multi-Access Interference (ISI and MAI) induced by frequency selective fading. MAI and ISI can pass an unacceptable break down in STTD performance with conventional, interference are limited only by channel estimation. RAKE receiver is used in the CDMA system to gain the multipath diversity. In this study, we combine the new Orthogonal polynomial based on STBC extended with CDMA 2000(STTD), so as to avoid ISI and MAI. Simulation results show that the increased accuracy of the channel estimation schemes significantly improves the Bit Error Rate (BER) performance.

Key words: Direct sequence, code, division, multiple, access, STBC. Inter symbol, interference, multi access interference

INTRODUCTION

Third Generation cellular systems are expected to provide increased throughput, both voice and packet data transmission. To achieve this goal, we must over come the limitations inherent in a wireless channel. One of the biggest hurdles of mobile cellular communications is that of multipath fading, implying that, multiple copies of the transmitted signal are received with varying amounts of attenuation and delay. By employing multiple transmit and receive antennas the information capacity of wireless communication systems increases dramatically by Foschini[1]. An effective approach to increase data rate over wireless channels is to introduce temporal and spatial correlation into signals transmitted from different antennas in order to provide diversity gain and coding gain[2-4]. In[5] Tarokh generalized the Alamouti scheme and constructed space-time block codes from Orthogonal design. The performance of the space-time coded systems over frequency selective multipath channel is discussed by Gong[6]. In[7] Tarokh have proved that the presence of the multiple paths does not decrease the diversity order. Kari Hooli[8] have proposed multiple access interference suppression with linear chip equalizers in WCDMA downlink receivers. In[9], Anja Klein have proposed data detection algorithms specially designed for the downlink of CDMA mobile radio system. Hochwald and Marzetta[10] have proposed a transmitter diversity scheme for wideband CDMA system based on space-time spreading. Mitra[11] proposed, the optimal space-time block codes over narrow band CDMA channel are derived. In[12], Geng have proposed space-Time block Codes in multipath CDMA systems. Dabak[13] have proposed STTD and adopted in wideband CDMA systems as a means of enhancing the downlink capacity. In[14], Nugroho have proposed Space-Time Block Coded for CDMA 2000 with pilot channel estimation. RAKE receiver is used in the CDMA system to gain the multipath diversity. In similar line, utilizing the Orthogonal Polynomials based on STBC in CDMA systems. In this study, investigated improved channel estimation methods in STBC-CDMA (STTD) with RAKE combining.

STBC BASED ON ORTHOGONAL POLYNOMIALS

The essential construction principle of the proposed Orthogonal Polynomial Based Space Time Block

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Code(OPSTBC) [11] is briefed hereunder: The proposed space time block coding is considered around a cartezian coordinate separable, blurring, code operator in which the signal I results in the super position of point source of impulse weighted by the value of the object function f. Expressing the object function f in terms of derivatives of the signal function I relative to the cartezian coordinates and time is very useful for analyzing the signal in order to achieve the diversity. Hence, the initial requirements to analyse the diversity may be stated as follows: Since the diversity can be achieved based on the local properties of the signal, a local code operator is required to be devised such that it is cartezian separable and denoising operator. The two dimensional code function M(x,y) can be considered to be a real valued function for $(x,y) \in X{\times}Y$ where X and Y are ordered subsets of real values. In our case the x is modeled to represent the space and y represents time slot, and consisting of a finite set, which for convenience can be labeled as {0,1,2…,n-1}, the functions M(x,y) reduces to a sequence of functions

$$M(i,t) = u_i(t),\ I=0,1,2,\ldots n-1 \qquad (1)$$

As shown in Eq. 2 the process of space –time block codes analysis can be viewed as the linear two dimensional transform coding defined by code operator, M(x,y) M(i,t) = $u_i(t)$

$$\beta'(\zeta,n)=\int_{x\in X}\int_{y\in Y} M(\zeta,x)M(\eta,y)\,I(x,y)\,dxdy \qquad (2)$$

Considering both X and Y to be finite set of values {0,1,2…,n-1} eq. 1 can be written in matrix notation as follows

$$|\beta'_{ij}| = (|M|\otimes|M|)^t\,|I|$$

where the code operator |M| is

$$|M| = \begin{vmatrix} u_0(t_0) & u_1(t_0) & \ldots & u_{n-1}(t_0) \\ u_0(t_1) & u_1(t_1) & \ldots & u_{n-1}(t_1) \\ & \vdots & & \\ u_0(t_{n-1}) & u_t(t_{n-1}) & \ldots & u_{n-1}(t_{n-1}) \end{vmatrix} \qquad (3)$$

$\otimes$ is the outer product $|\beta'_{ij}|$ and |I| are the n^2 matrices arranged in the dictionary sequence. |I| is the signal to be transmitted and $|\beta'_{ij}|$ are the coefficients of transformation. We consider a set of orthogonal polynomials $u_0(t)$, $u_1(t)$,…,$u_{n-1}(t)$ of degrees 0,1,2,…, n-1, respectively. The generating formula for the polynomials is as follows.

$$u_{i+1}(t) = (t-\mu)\,u_i(t) - b_i(n)\,u_{i-1}(t) \text{ for } i \geq 1,$$
$$u_1(t) = t-\mu, \text{ and } u_0(t) = 1, \qquad (4)$$

where

$$b_i(n) = \frac{<u_i,u_i>}{<u_{i-1},u_{i-1}>} = \frac{\sum_{t=1}^{n} u_i^2(t)}{\sum_{t=1}^{n} u_{i-1}^2(t)}$$

and

$$\mu = \frac{1}{n}\sum_{t=1}^{n} t$$

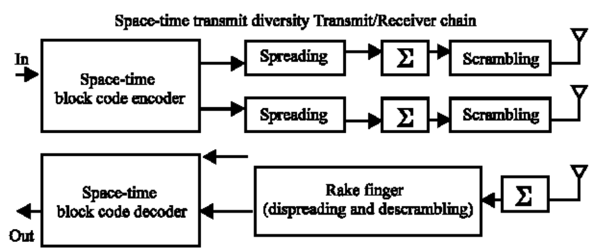
Considering the range of values of t to be t =i , i = 1,2,3,…,n, we get

$$b_i(n) = \frac{i^2(n^2-i^2)}{4(4i^2-1)},\quad \mu = \frac{1}{n}\sum_{t=1}^{n} t = \frac{n+1}{2}$$

We can construct code operators $|M|_s$ of different sizes from the above orthogonal polynomials. The code operator in Eq. 3 that defines linear transformation of signal can be obtained as $|M| \otimes |M|$, where |M| is computed and scaled from Eq. 4 as

$$|M| = \begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix} \qquad (5)$$

SYSTEM MODEL



The synchronous CDMA2000 downlink employing orthogonal polynomial based STBC [M_2]scheme is considered; where

$$|M| = \begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix},$$

from Eq. 5. The base station has two transmit antennas and the mobile has one receive antenna; the distance between transmit antennas is far enough to ensure that the fading channels are not correlated. At the base station, the data stream of the kth user is QPSK modulated. Two QPSK symbols at a time are encoded by the STBC encoder, spread by a unique Walsh code and scrambled by a complex PN long code. Pilot symbols are usually modulated by the first Walsh code.

The encoded symbols of the kth user for two consecutive symbol intervals can be written as

$$\begin{bmatrix} \text{Ant1} & \text{Ant2} \\ dk(0) & -dk^*(e) \\ dk(e) & dk^*(0) \end{bmatrix} \qquad (6)$$

where d(o) and d(e) represent odd and even numbered symbols, and the superscript* denotes complex conjugate. The propagation environment is modelled as time varying and frequency selective. The channel from each transmit antenna to the receiver is assumed to have L resolvable paths with known time delay τ_1 (measured in chip intervals, the first path delay τ_1 is defined as 0). The multi-path delays in both channels are assumed to be equal. We define $h_1(m) = [h_{1,1}(m),...,h_{1,L}(m)]^T$, and $h_2(m) = [h_{2,1}(m),..., h_{2,1}(m)]^t$ as the two multipath channels in symbol period m.

A guard interval is assumed between STBC codewords which can completely remove the ISI between the codewords. Assuming that channels are constant over two symbol periods, the received chip-rate signal vector can be written as

$$r(i) = S(i)D(i)\bar{h}(i) + v(i) \qquad (7)$$

where i is the transmitted codeword block index, v(i) is a zero-mean complex Gaussian noise vector with covariance matrix $N_0 I_{(2n+\delta l)}$, and N is the length of each user's spreading code. In (7), S(i) is defined as

$$S(i) = \left[s_1(i) S_2(i) ......S_k(i) \right] \qquad (8)$$

and $S_k(i)$ is a $(2N + T_l)$ x 2L matrix formed from the kth user's spreading sequence in the ith codeword block;

$$S_k(i) = \left[s_{k,1}(0)....s_{k,L}(0) s_{k,1}(e)....s_{k,L}(e) \right]$$

$$S_{k,1}(0) = \begin{bmatrix} 0_{T1} \\ s_k(0) \\ 0_{N+T_l-T_l} \end{bmatrix}, S_{k,1}(e) = \begin{bmatrix} 0_{N+T1} \\ s_k(e) \\ 0_{T_l-T_l} \end{bmatrix} \qquad (9)$$

where $s_k(o)$ is the N-vector denoting the spreading vector of the kth user in the (2i - 1)th symbol interval; $s_k(e)$ is the kth spreading vector in the 2ith symbol interval. D(i) is defined as

$$D(i) = \left[D_1^T(i)\, D_2^T(i) \dots D_K^T(i) \right]^T; \qquad (10)$$

$$Dk(i) = \begin{bmatrix} d_k(2i-1) & -d_k^*(2i) \\ d_k(2i) & d_k^*(2i-1) \end{bmatrix} \otimes I_L. \qquad (11)$$

where ⊗ denotes the Kronecker product.

$\bar{h}(i)$ represents the multipath fading channels from two transmit antennas, and is defined in terms of h_p (m) as

$$\bar{h}(i) = \begin{bmatrix} h_1(2i-1) \\ h_2(2i-1) \end{bmatrix} \qquad (12)$$

The linear signal model(2) is a new and useful representation of the STTD signal and allows as to derive the following channel estimation algorithms quite easily.

CHANNEL ESTIMATION

Improved pilot channel estimator: Let us assume the spreading codes associated with all users to be known, which is not an impractical assumption[15]. The base station assigns spreading codes to each active user and at each mobile, all users' spreading codes can be provided via an auxiliary channel[15]. In order to estimate the channel in an MAI-free environment, we employ a multi path decor relating filter at the front-end of the estimator. Multiplying r (i) by St (i), which is the Moore-Penrose generalized inverse of S (i), we get

$$\bar{y}(i) = St(i)\, r(i) = D(i)\, \bar{h}(i) + St(i)\, v(i) \qquad (13)$$

The first 2L elements of $\bar{y}$ (i) can be written as

$$\bar{y}_1(i) = D_1(i)\, \bar{h}(i) + \eta(i) \qquad (14)$$

where D_1 (I) contains known pilot symbols and η(i) is the sub-vector formed from the first 2L elements of $S^{\dagger}(i)v$ (I). Therefore η(i) has a covariance matrix R_η equal to the upper left 2L×2L sub matrix of $\sigma_v^2 (S^H(i)\, S(i))^{-1}$.

From Q successive observations $\bar{y}_1$ (j), j = i – Q + 1, …, i. assuming that $\bar{h}$ (j) is constant over the time span of the observations, the ML estimate of $\bar{h}$ (i) is

$$\bar{h}(i) = \left(\sum_{j=i-Q+1}^{i} R_{\eta}^{-1}(j) D_1^H(j) D_1(j) \right)^{-1} \sum_{j=i-Q+1}^{i} R_{\eta}^{-1}(j) D_1^H(j) \bar{y}_1(j) \quad (15)$$

Recalling that we are only using a $(2N + \tau_L)$- chip window and ignoring interference from symbols outside the ith code-word, it is clear that (14) is approximate and not all interference is removed by the decorrelating operation. Expanding the window used in obtaining r (i) will improve performance at the p rice of increased complexity. However, our simulations show that even with the two-symbol window, substantial performance gains can be obtained.

Decision-based iterative channel estimator: In this section, we make use of the vector signal model (2) to derive a simple decision-directed channel estimation scheme that can be iterated any number of time to obtain successively improved performance.

De-spreading the observed signal r(i) with S (i), we have

$$\begin{aligned} y(i) &= SH(i)\, r(i) \\ &= D(i)\, \bar{h}(i) + \bar{z}(i) \end{aligned} \quad (16)$$

where $\bar{z}(i)$ represents MAI, ISI and additive Gaussian noise. y (i) comprises 2L signals from each user:

$$y(i) = \left[y_1^T(i)\ y_2^T(i) \ldots y_{K1}^T(i) \right]^T \quad (17)$$

where $y_k(i) = S_{kk}^H(i)\, r(i) \in C^{2L}$. The first L elements of y_k (i) correspond to the "o" symbol while the second L elements match the"e" symbol, defined earlier. In order to perform Alamouti-style decoding, we partition y_k (i) into 2 length-L sub-vectors, i.e.

$$y_k(i) = \begin{bmatrix} y_{k,o}(i) \\ * \\ yk,o\ (i) \end{bmatrix} \quad (18)$$

and then conjugate the 'e" vector to obtain

$$\tilde{y}_k(i) = \begin{bmatrix} y_{k,o}(i) \\ * \\ yk,o\ (i) \end{bmatrix} \quad (19)$$

and

$$\tilde{y}(i) = \left[y_1^T(i), \ldots, \tilde{y}_{K1}^T(i) \right]^T$$

Now we, have

$$\tilde{y}(i) = \tilde{H}(i) + \tilde{z}(i)^T \quad (20)$$

were $\tilde{z}(i)$ is essentially identical to $\tilde{z}(i)$ except that half its elements are complex conjugates for their counterparts in $\tilde{z}(i)$ and $\tilde{H}$ (i) is]

$$\tilde{H}(i) = I_K \otimes \tilde{H}(i), \quad (21)$$

where

$$\tilde{H}(i) = \begin{bmatrix} h_1(2i-1) & h_2(2i-1) \\ * & * \\ h_2(2i-1) & h_1(2i-1) \end{bmatrix} \quad (22)$$

and

$$d(i) = [d_1(2i-1), d_1(2i), \ldots, d_K(2i-1), d_K(2i)]^T. \quad (23)$$

Because of the orthogonal nature of the our OSTBC, $\breve{H}^H(I)\ \breve{H}(i) = \| \bar{h}(i) \|^2 I$ and hence

$$\hat{d}(i) = \tilde{H}^H(i)\, \tilde{y}(i) \quad (24)$$

$$= \| \bar{h}(i) \|^2\ d(i) + n(i) \quad (25)$$

where n(i) represents filtered noise, ISI and MAI. Clearly, if ISI and MAI were not present, $\hat{d}(i)$ will be the ML estimate of d (I); with ISI and MAI, this method of detection constitutes a conventional, matched-filter approach and is interference limited.

The detector we just described is implement as L Alamouti decoders (one for each path delay) followed by maximum ratio combining for each data channel. We call this receiver a generalized STTD Rake receiver. It requires channel estimates, which are initially supplied using the conventional channel estimator or limited channel estimator.. To improve on the initial estimates, we feedback the data decisions to a second stage of channel estimation, which can in turn be used for improving data estimates, and so on.

From the signal model (2), the ML estimate of $\bar{h}$ (i) (now that we have symbol decision on all of D(i), not just the pilots) is

$$\bar{h}(i) = \frac{1}{Q} \sum_{j=i\,Q+1}^{i} (\hat{X}^H(j)\hat{X}(j))^{-1}\,\hat{X}^H(j)r(j) \qquad (26)$$

where

$$\hat{X}(j) = S(j)\,\hat{D}(j), \qquad (27)$$

and $\hat{D}(j)$ is defined using (5) with estimated data symbols and true pilot symbols.

It practice, the Bit Error Rate (BER) is sufficiently small, especially in high SNR, so the decision based approach will eliminate MAI and ISI effectively. The simulation shows that the decision based iterative channel estimation can provide significant performance in the bit error rate.

RESULTS

In this study, we present simulation results for STBC-CDMA2000 in multipath fading. The base station employs two transmit antennas and one receive antenna. We evaluate the performance of the different channel estimation schemes. The channel estimation process is performed by walsh code [G = 64] and the scrambling process is performed by random long code with repition period equal to frame duration. We use the number of

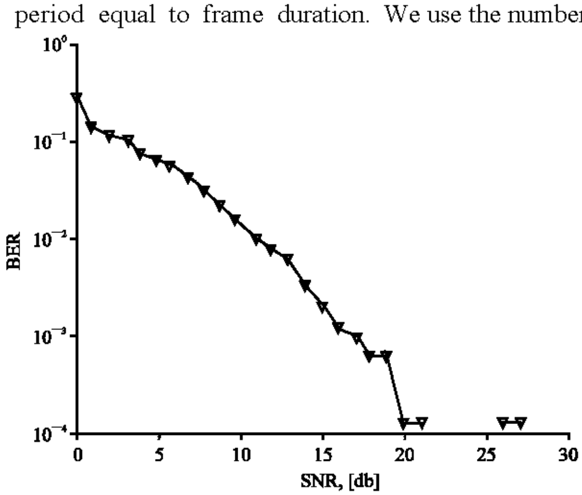


Fig. 1: BER for STTD decision based channel estimation (SNR From 0 to 30)

symbols to be 1000,with SNR ranging from 0 to 30 dB. For the modulation type QPSK, the bit error rate is obtained by thee proposed STTD with rake receiver. Figure 1 shows the performance of STTD decision based channel estimation. Figure 2 shows the STTD de-correlated based channel estimation. From the simulation results the OSTBC extended with CDMA2000 (STTD) scheme significantly improves the bit error rate performance and to avoid ISI and MAI.

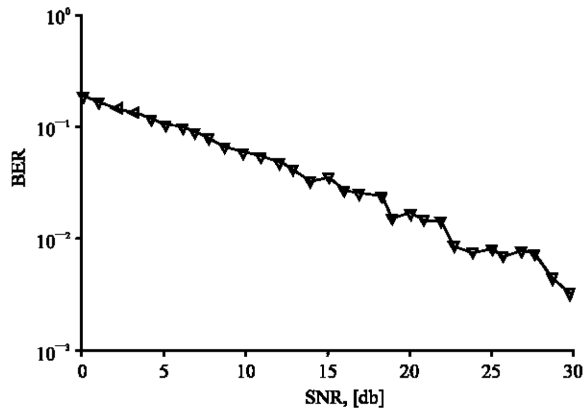


Fig. 4: BER for STTD de-correlated based channel estimation.SNR From 0 to 30)

CONCLUSION

In this study we have proposed a new OSTBC with CDMA system in frequency-selective fading channels. The present method denoted OSTBC-CDMA2000 (STTD) is based on channel estimation. This technique is used to avoid inter symbol interference and multi access interference with improving OSTBC-CDMA. The simulation results demonstrates the additional gain guaranteed by channel estimation in the multi-path diversity.

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