IMPLEMENTATION OF TAST CODES IN DS-CDMA COMMUNICATION SYSTEM

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ABSTRACT

The fundamental principle of threaded algebraic space-time (TAST) block code and DS-CDMA are retrospectedand their integrationare studied and analyzed. Simulation results show that a substantial improvement in bit error rate (BER)can be achieved in CDMA networks by integratingTAST codes in it.

KEYWORDS: *Space-time Block code, Threaded Algebraic Space-Time (TAST) Block codes, DS-CDMA,*

INTRODUCTION

To meet the dramatically increasing demand for mobile communication systems, more advanced and capable system of communication is required. The idea to have more than one antennas both at transmitter and receiver sides,*i.e*. Multiple-Input Multiple-output (MIMO) strategy has revolutionary solved the problem to have high data rate without augmentation of bandwidth and transmit power. Actually a MIMO system is a strategy to exploit transmit, spatial and receiver diversity to increase the system capacity and data rate[1]. space-timeblock codes (STBC) initially proposed in[2], is a coding tool for MIMO system to efficiently exploits diversity and high reliability. But for more than two transmit antenna scheme, the STBC loses their diversity and code rate. TAST codes can obtain full rate and maximum diversity irrespective of number of transmit/receive antennas and signaling constellations[3].

In[4] the authors have explored the application of STBC codes in DS-CDMA but for more than two transmit antenna, this scheme will lose its diversity and code rate.

In this paper, we review TAST coding technique, and explore its application in DS-CDMA communication system.It is shown that a substantial improvement in BER can be obtained by integratingalgebraic space-time coding technique into a DS-CDMA system. Unlike[4] and[5] our proposed technique retains its diversity and code rate for any number of transmit/receive antenna and signal constellation.

Threaded Algebraic Space Time codes

TAST is a coding technique in which different fully diverse SISO constituent codes γ_i's are transmitted in different threads at different algebraic sub-spaces in such a way that the conglomerate STBC obtains maximum diversity of $N_T N_R$ and the rate equals to N_T[3], where N_T symbolize number of transmit antennas and N_R thenumber of receive antennas.

In this technique of coding, the source information vector is first split into a set of L disjoint component vectors x_i , $i = 1,...L$, $L \leq N_T$ where each vector x_i indicates a sub-space of the TAST code and is called a layer. Each layer x_i undergoes through an independently DAST code[6] with a rotation matrix $\boldsymbol{M}_i$and constituent encoder γi. Different layers are separated by appropriate algebraic number ϕ. Therefore theconglomeratechannel encoder, will comprise of L constituent encoders γ_1, γ_2,... γ_1 operating independently, and there is acorresponding separation ofconglomeratecodeword $\gamma(x)$ into a set of constituent codewords $\gamma_i\ (x_i)$.

A DAST code is achieved by circumvolving an N_T-dimensional information symbol vector $s=[S_1,S_2,...S N_t]_T$ by an $N_T\ x\ N_T$ circumvolution or rotation M in such a way that it maximizes the minimum product distance[6].

$$d_{NT} = \min_{x=M(s-s'),\ s\neq s'} \prod_{i=1}^{N_T} |x_i| \qquad (1)$$

wheres and s' belong to the considered multidimensional constellation. The rotation matrix Mis built on an algebraic number field (θ) with θ being an algebraic number of degree n[7].

Actually, the simultaneous transmission of more than one DAST code in different threads is referred as TAST code, *i.e*.

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$$\gamma i(s_i) = \phi_i x_i = \phi_i M_i s_i \quad (2)$$

where M_i is an N_T x N_T rotation matrix that obtains full diversity as a DAST code, and the number $\phi_i \in$, $i = 1, \ldots, L$, is selected to make it sure that the conglomerate code gets full diversity and maximize the coding gain. We denote the TAST codes by $T_{NT,1..R}$, where the subscript N_T, L, R denote the number of transmit antennas, layers and code rate, respectively.

The algebraic numbers or Diophantine number $\{\phi_1, \ldots, \phi_L\}$ sare selected in such a manner that the efficient separation of different layers at the receiver is assured.

A TAST code $T_{Nr,1..R}$ carved from rotation matrix M_{NT}, and the QAM constellation mapped from □[i'], (□ denotes ring of rational integers) and the Diophantine numbers

$$\{\phi = 1, \phi_2 = \phi^{1/Nt}, \ldots, \phi_L = \phi^{(L-1)1Nt}\} \quad (3)$$

obtainsfull diversity if $\phi = e^{i\lambda}$ and $\lambda \neq 0$ is analgebraic number (*i.e.*, ϕ is transcendental)[7].

Example 1

$$\begin{bmatrix} x_1 & 0 \\ 0 & x_1 \end{bmatrix} \oplus \begin{bmatrix} 0 & x_2 \\ x_2 & 0 \end{bmatrix} \Rightarrow \begin{bmatrix} x_1 & x_2 \\ x_2 & x_1 \end{bmatrix} \quad (4)$$

Full diversity Full diversity Not full diversity

One can see that the first two codeword matrices are fully diverse but when they are combined the resultant codeword matrix loses its maximum diversity. If we separate the two threads by a Diophantine approximation as

$$\begin{bmatrix} x_1 & \theta x_2 \\ \theta x_2 & x_1 \end{bmatrix} \quad (5)$$

then (5) will be fully diverse if $\{1, \theta^2\}$are algebraically independent over the set containing x_1, x_2.

Example 2

For construction of TASTBC for $N_T = 2$ transmit and more than one receive antenna N_R, we have $L = 2$

$$\begin{bmatrix} \phi_1 x_{11} & \phi_2 x_{22} \\ \phi_2 x_{21} & \phi_1 x_{12} \end{bmatrix} \quad (6)$$

where x_{11} and x_{12} belong to the first thread, and x_{21} and x_{22} to second thread, and

$$x_1 = \begin{bmatrix} x_{11} \\ x_{12} \end{bmatrix} = \boldsymbol{M}_2 \begin{bmatrix} s_{11} \\ s_{12} \end{bmatrix} \quad (7)$$

and

$$x_2 = \begin{bmatrix} x_{21} \\ x_{22} \end{bmatrix} = \boldsymbol{M}_2 \begin{bmatrix} s_{21} \\ s_{22} \end{bmatrix} \quad (8)$$

and $S_{11}, \ldots S_{22}$ belongs to the constellation considered. The appropriate selection of $\boldsymbol{M}_2$ and are the ϕ_i basic design parameters in construction of TASTBC. A good choice of $\boldsymbol{M}_2$ for complex symbols is the following matrix from[7].

$$\boldsymbol{M}_2 = \frac{1}{2}\begin{bmatrix} 1 & e^{j\pi/4} \\ 1 & -e^{j\pi/4} \end{bmatrix} \quad (9)$$

By choosing $\phi_1 = 1$ and $\phi_2 = \phi^{1/2}$, we can pick up the best parameter ϕ to maximize the coding gain. In this case, the coding gain distance is

$$CGD = \min\left|(x_{11} - x'_{11})(x_{12} - x'_{12}) - \phi(x_{21} - x'_{21})(x_{22} - x'_{22})\right| \quad (10)$$

For QPSK, the optimal choice is $\phi = e^{i\pi/6}$. Sphere decoding is used for decoding the transmitted symbols.

DS-CDMA

Unlike TDMA and FDMA, in CDMA all users simultaneously transmit at the same time and frequency. As each user exploits the entire available frequency spectrum that is why CDMA is referred as spread sprectrum communications. Direct-Sequence Code Division Multiple Acess (DS-CDMA) is one of the several techniques of spread sprectrum communications. In DS-CDMA the data signal of each user is multiplied by a distinct code sequence. The composite code comprising of user data and PN sequence is called as chip code and the ratio between them is known as spread factor. In receiver side, the composite signal is once again multiplied by the same code to remove the redundant data and to recover the source code. This operation is shown in Figure 1.

Let U be the number of down-link users, and be the TAST matrix for user u, $u = 1, 2, \ldots, U$, at the $i$thblock time (the time interval used for simultaneous transmission of$U$ space-time matrices). By considering $N_R$spreading sequences to spread the $N_R$columns of (simultaneous transmission of$N_R$columns) for each user and by considering different spreading sequences for different users (to transmit the TAST codeof all of the users simultaneously), we geta new modulation scheme, *i.e*TAST-CDMA. At the *j*th time sample of the *i*th time block, the transmitted signal is

$$x_i(j) = \sum_{u=1}^{u} C_{i,u} h_{NT}, N_R d_u(j) \quad , j = 1,2,\ldots J \qquad (11)$$

where$J$ denotes PN sequences' length, and $\{d_u(j) \in C^{NRx1}, = 1,2, \ldots,j\}$ is the $N_R$unit-energy spreading sequences for the *u*th user.. is the channel matrix from transmit antenna to receive antenna .

When the code $T_{Nr,1\ldots R}$ is used over a quasi-static channel, the received signal can be expressed as:

$$X = C_{i,u} H_{T\ NT,1\ldots.R} + N$$

$$= \sum_{l=1}^{L} \sum_{u}^{U} C_{i,u} H_l \phi_l diag(S_{l1}, \ldots. S_{lNT}) + N \qquad (12)$$

where $C_{i,u}$ is uth user at the ith time block, $H1, I =, L$ is the N_R x N_T channel matrix as seen by thread L_t. Let x ≅ vec (X^T) which puts the matrix X^T in one column by stacking its columns one after other and let

$$H_l = (diag\ (hl1)\ldots., diag(h_{lNR}))^T \qquad (13)$$

where is the kth row of the matrix . Let , it follows from TAST code structure that

$$x = \sum_{l=1}^{L} \sum_{u}^{u} c_{i,u} H_l \phi_{N_T}^{l-1} M_{il} + N \qquad (14)$$

INTEGRATION OF TAST INTO CDMA CHANNEL

In this section, the applications and performance of a multiuser DS-CDMA communication system encapsulated with TAST system is analyzed. We consider two cases, i.e. (i) a system with two transmit antennas and two receiver antennas(ii) one receiver antenna and two antennas at base station. The purpose of these two set up is to analyze the performance of uplink and downlink channels separately. The network configuration for case (i) and (ii) has been illustrated in Figure 2 and3, respectively For simulation, first we map the source information of each user into QAM symbolsand then these symbols aregiven toTAST encoder. Theoutput data of TAST encoder are spread by a PN sequence having appropriate length. For our simulation we have taken a sequence having a length of 15. The spread signals of different usersare put together by CDMA channel and then transmitted through antenna A_1 and A_2 simultaneously.

To decorrelate the received signal, a matched filter (MF) is used at each unit. The output of MF is then regurgitated into the TAST decoder. The TASTdecoder decodes the received signals in a manner as described in earlier section.

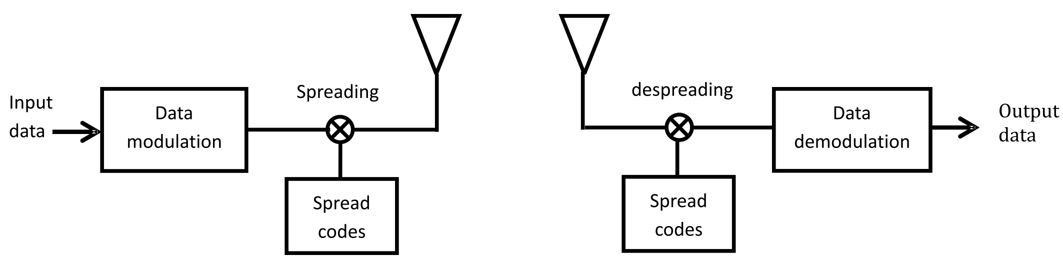

Figure 1, A simple DS-CDMA channel

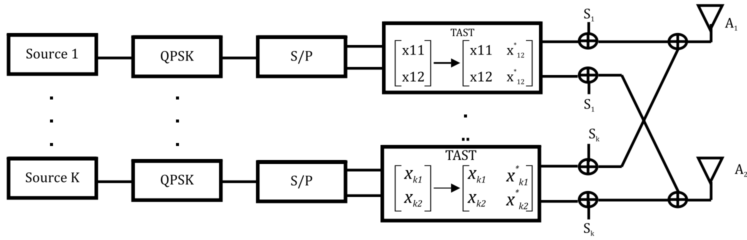

Figure 2. Uplink TAST CDMA transmitter with two transmit antenna

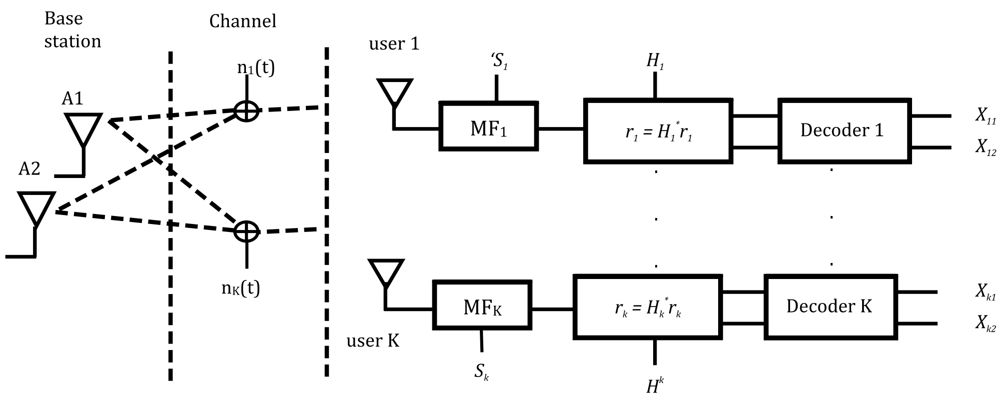

Figure 3. Downlink TAST CDMA receiver with one antenna

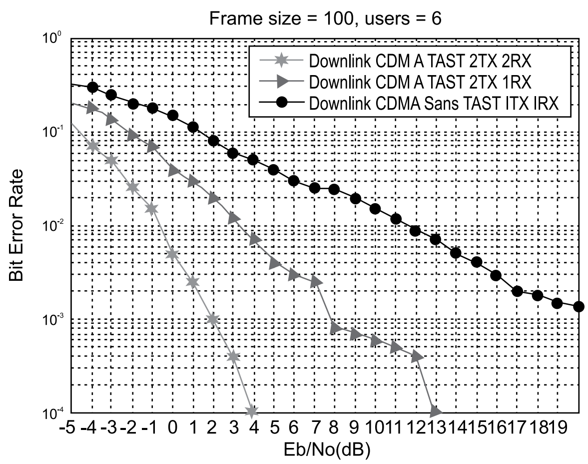

Figure 4. Performance analyses of DS-CDMA downlink channel with and without TAST code

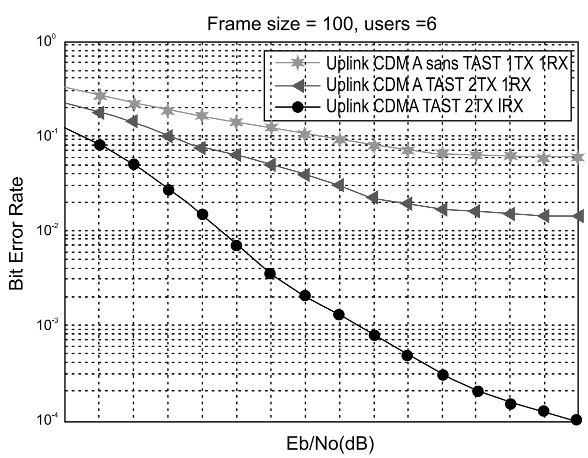

Figure 5. Performance analyses of DS-CDMA uplink channel with and without TAST codes

For simulation, we assumed that the channels are invariant over the frame length and varies independently from frame to frame. The channel impulse responses were modeled as independent complex Gaussian stochastic variables considering a variance of 0.5. The length of frames are taken as 100 and the number of users is taken as 6.

The bit error rate (BER) performance both for downlink and uplink channels are shown in Figure 4 and 5, respectively. The transmitter and receiver

parameters both for downlink and uplink channels are almost same. From the simulation results, we can see from fig 4, that at a BER of 16 dB and 12 dB performance amelioration can be achieved by incorporating CDMA into TAST code having two and one receiving antenna, respectively

CONCLUSION

The potential application of TAST codes in DS-CDMA was explored and it was found that a DS-CDMA system achieve substantial improvement in BER if employed over space time coding system. The simulation was performed over two different set up having two and one receive antenna. A system with two receive antenna get a better performance of 16 dB at a BER of 104.

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