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Space Time Block Code for High Data Rate Using CD Algebra

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Abstract -Multiple antennas at both Transmitter and receiver end of wireless digital transmission channel may increase the data rate and reliability of the communication. Reliability and high data rate transmission over channels can be achieved by proposed Space Time block code. Determinant and Rank code design has been proposed to enhance the diversity and coding gain. Cyclic Division algebras is a new tool for constructing space time block code, this is non-commutative algebras that naturally yield fully diverse codes. The CDA based construction method usually consists of two steps. First steps are to construct a degree-n cyclic extension over a base field. Second steps are used to find a non-norm algebra integer in base field. Proposed STBC for 4X2, 4X3, 4X4, 8X1 at code rate '3/4' and 16QAM modulation technique are used. This proposed STBC code is compared with Generalized silver code ,silver code ,golden code. Simulation results of symbol error rate for 4 Tx and 8 Tx shows proposed STBC code is good in error performance at offering one dimensional lower decoding complexity by using sphere decoding.

Index Terms— Cyclic algebras; division algebras; full diversity; golden code; silver code; non-vanishing determinant; sphere decoding.

I. INTRODUCTION

Wireless communications has made a tremendous impact on the lifestyle of a human being .It is very difficult to survive without wireless in some form or the other. As compared to fixed wireless systems, today's wireless networks provide high speed mobility for voice as well as data traffic. Complex orthogonal STBC designs [1]-[3]. Which uses maximum likelihood (ML) decoding but not offer a high data rate . but for n t x nr MIMO system , a full rate code can transmit at least min (n t x nr) complex symbols per channels. Spectrum and limitation on the processing power availability in the portable handheld unit of mobile user are the other important constraints in designing wireless systems. Alamouti code for 2 transmit antennas is full rate for 2X1 MIMO system. Those STBC has the full rate which code fully utilize the all freedom of the channel provide.[4].but when we want to increase rate tends to result then increase decoding complexity. But we know that Golden code [5]-[6]proposed for 2 Tx and 2 Rx has full rate . Golden code has the signal constellation size 'M' and the order of complexity must be less than M^4 then decoding complexity $M^{2.5}$ for square QAM. In current research says to increase the high data rate , reduce symbol error rate and decoding complexity. Silver code [7] transmit antennas '2' proposed with low decoding complexity . silver code is also a full rate ,fully diverse and decoding complexity is less than golden code which is M^2 [8]. Silver code has algebric property which yield naturally fully diverse code.

In now days full rate STBC with ML decoding complexity $M^{5.5}$ and Non vanishing determinant property[9]. According to researches , it is not known how one can design full rate STBC for arbitrary T_x and R_x antennas but we also known that maximum mutual information achieve with a STBC is at best equal to ergodic capacity of the channel. But Generalized Silver code proposed a full rate STBCs for 2^a transmits and any receiver antenna with the lowest decoding complexity and minimum self interference among known codes [10].

II. MODELLING OF THE CHANNAL

Single transmitter T_x antenna during a single time slot sends a single signal which can be complex number which can be represented by x, and x Є C. This single signal 'x' travels through the channel. It will suffer distortion which can change the shape of the signal .This can be modeled as multiplication by complex 'h' which is called fad coefficients. But in more condition receiving antenna can pick up the noise .which noise can be modeled by adding complex number 'η 'then received signal can be represented in eq(1)

$$r = h\,x + \eta \qquad (1)$$

Suppose there are 'n_t'transmitting antennas, by using these tx antennas are transmitting simultaneously to 'n_r'=1 receiver antenna. Let us assume that x_j Є C denote the signal sent by jth antenna ($1 \le j \le n_t$) .When n_t Multipliers transmitting antenna

transmitted simultaneously ,each of these antenna contributes to signal detected by the receiver. The received signal r Є C which is the linear combination of those complex noise . this can be modeled by adding the noise , it can be shown by the eq(2)

$$r = h_1\,x_1 + h_2\,x_2 + - - - - - + h_{nt}\,x_{nt} + \eta \qquad (2)$$

in this eq.(2) h_j Є C is fade coefficient b/w transmitting antenna 'j' and receiver antenna 'i' .due to more receiver antenna , each antenna can pick up the noise η. Fade coefficients h_{ij}

($1 \le i \le n_r$) , $1 \le j \le n_t$).when each receiver will pick up the noise then $\eta_1, \eta_2 .... \eta_{nr}$ Є C.

For each receive antenna i Є {1, ……….. n_r }

$$r_i = h_{i1}\,x_1 + h_{i2}\,x_2 + - - - - - + h_{i\,nt}\,x_{nt} + \eta_i \qquad (3)$$

all receiver antenna n_r has a matrix. This can be represented by eq(4). Then we can write in abbreviated form

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$$\vec{r} = H\vec{x} + \vec{\eta} \qquad (4)$$

$$\begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ \vdots \\ r_{nr} \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} & & h_{1\,nt} \\ h_{21} & h_{22} & & h_{2\,nt} \\ & & & \\ h_{nr1} & h_{nr2} & & h_{nr\,nt} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_{nt} \end{pmatrix} + \begin{pmatrix} \eta_1 \\ \eta_2 \\ \vdots \\ \eta_{nr} \end{pmatrix} \qquad (5)$$

III. CYCLIC DIVISION ALGEBRA

Division algebras are ring with identity element and inverse that means each non zero has multiplicative inverse. It is non commutatively of division algebras that gives the unique identity. If we take the example for Quaternion Division Algebras. The canonical example of division algebra is the ring $D = R(e, i, j, k)$ (6)

This can be represented by the e q (6).this is quaternion over the real no. R when 'e' is identity $e^2 = 1$, i , j, k are element that $i^2 = j^2 = k^2 = 1$

$$and\ i.j = j.i = jk, jk = -kj\ \ ki = -ik = j \qquad (7)$$

Division algebra are natural algebraic object by which we can construct full rate space time block. STBC code where difference between any matrix has full rate. Full rate mean code rate of particular code is 1.Representaion of square matrix of element can be constructed by division algebras. This type of representation generated when one consider an element in division algebra as a linear transformation corresponding multiplicative of elements in division algebra by "d" .The matrix representation of complex No shown by consider linear operation

$A: C \rightarrow C$

$$if\ A(U + i\,V) = [a + ib](U + iV) \qquad (8)$$

C is vector Space over 'R' , we can represented by matrix, it represented by following eq(8).

$$A = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \qquad (9)$$

This type of code can be constructed by mapping .

$$[a + i\,b] \rightarrow A$$

$$A = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \qquad (10)$$

This is a ring as long as a $[a + i\,b] \neq 0$, by this property every element in division algebra has inverse gives matrix representing. They give the full rate property.

Cyclic division algebra is mathematical tool to design the space time coding, which give the best way of build a fully diverse space time code. CDA used to increase the throughput of the code by using algebras over number field. The number field is used to encoding of QAM and HEX constellations. Then family algebras is called cyclic algebra which built over number field[11]. When number of transmit Antenna n and n x n space time code word, this type of code words send the n^2 information symbol encoded into signals. Space time coding has the most important property which is the non vanishing determinants. The ring of integer of number of field can be used to build the algebra lattice. By using of the lattice structure can control the transmitted energy when encoding the space time codes

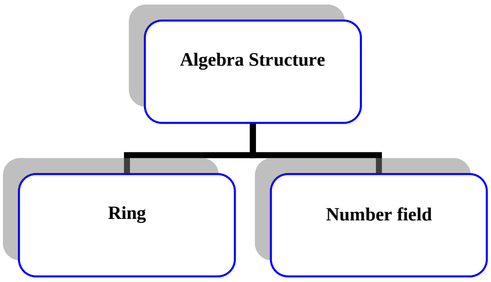

Fig.(1) CD Algebra

In Fig (1). shown the algebra structure of cyclic division algebra .Number field is the set of rational number Q is the direct sum. Equation (13) shows the cyclic algebra [11] , number can check this is field or not. Let element 'i' .when Q is linear combination 'i' the this is Q (i). This is called field extension of Q. This is field extension of Q is called Number field. The procedure of STBC can be used to designed by Cyclic Division Algebra.

To explain the cyclic algebra let us assume a Galois extension of degree of x, which is Galois group

$$G = Gal\ [L/X] \qquad (11)$$

Equation (11) is cyclic with generator 'G' which take the element .this the on commutative algebra denoted by B

$$B = \{\ \ L/X, g, y\} \qquad (12)$$

$$B = L \oplus eL \oplus \ldots\ldots\ldots\ e^{n-1} \qquad (13)$$

Let 'P' be some symbol that satisfies the relation:-

$$lz = z\sigma(l)\ \forall\ l \in L\ and\ z^n = \gamma \qquad (14$$

$$for\ \ \gamma = \in F^* \qquad (15)$$

Let 'x' is smallest integer for the relative norm . $N_{\frac{L}{x}}(u)$ of some element u in L^*, is in " n".

Maximum subfield L can be constructed by setting eq. (13).

A space time block code 'X' can be associated to D by selecting the set of matrix representing of elements of a finite subset of 'D' .

1. Selection of " non-norm" parameter " γ"
2. Non-vanishing determinant (NVD) property
3. Cyclic extension of some Number.

IV. PROPOSED CDA BASED STBC

$$\begin{bmatrix} S_1 & S_2 & \frac{S_3}{\sqrt{2}} & \frac{S_3}{\sqrt{2}} \\ -S_2^* & S_1^* & \frac{S_3}{\sqrt{2}} & \frac{-S_3}{\sqrt{2}} \\ \frac{S_3^*}{\sqrt{2}} & \frac{S_3^*}{\sqrt{2}} & \frac{(-S_1 - S_1^* + S_2 - S_2^*)}{2} & \frac{(-S_2 - S_2^* + S_1 - S_1^*)}{2} \\ \frac{S_3^*}{\sqrt{2}} & \frac{-S_3^*}{\sqrt{2}} & \frac{(S_2 + S_2^* + S_1 - S_1^*)}{2} & \frac{-(S_1 + S_1^* + S_2 - S_2^*)}{2} \end{bmatrix} \qquad (16)$$

eq. (16) represent Space time block code which can be used to improve the error performance .

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V. DECODING ALGORITHM

At the receiver brute force ML decoder give the best performance which search for matrix X which is minimum over noise power. An ML decoder compute an estimate of Transmitted matrix as

$$\hat{X} = arg\ min \|Y - XX\|^2 \quad (17)$$

But ML decoder has very high complexity in MIMO channels at high data rates.

The sphere decoding algorithm based on sphere radius, which is a parameter of the algorithm, must be chosen to ensure a non vanishing probability of solving the detection problem. To reduce the decoding complexity, this is a new algorithm which is called sphere decoding .The basic principle of SD algorithm is to find the closest constellation point to receive signal with in sphere initial radius.

If at any point found , if distanced b/w centre point and point is less than radius of sphere then radius of sphere is updated to that distance and this process is continued till only one point is left in sphere . This will be the closest point to, received point . if point is not find initial then radius of sphere is incremented and same process is started.

In proposed [12] a closed-form expression for the expected complexity, both for the infinite and finite lattice, which also expressed a wide range of signal-to-noise ratios (SNRs) and numbers of antennas for the expected decoding complexity .In proposed [13], a new family of linear dispersion codes (LDCs), these type of code decoded by fast sphere decoder algorithm in MIMO system. This algorithm reduce the 71-83% and 76-88% reduction for 2times 4 MIMO system , transmitting 64 QAM and 256 QAM symbols block length '4'respectivly .

In proposed [14] SD complexity exponent which represents the exponent of SNR of complexity that can be imposed on SD algorithm while maintaining close to ML performance also provides closed form solution .

Algorithm Step Of Sphere Decoding is given below

Let $M = HG,\quad so\ \ Y = MZ + N$

we perform Gram –Schmidt ortho normalization of column of M (QR Decomposition) . To calculate M=QR, here R is upper triangular matrix with the positive diagonal elements and Q is unitary matrix.

$R = \{\ r_{ij}\ \}$

R is (Equivalents all rij) is a input to algorithm.

The algorithm is designed for fixed radius below:-

$Algorithm\ (input\ D_0^1\ , y, X_i)$

Step1: Initialization, $set\ i = n, T_n = 0, E_n = 0, dc = D_0^1$ (Current sphere square radius)

Step 2:- $(Bound\ on\ X_i\ ) if\ d_c < T_i\ go\ to\ step\ 4\ else$

$J_i(X_{i+1}^n) = \max\{0, (Y_i^1 - E_i - \sqrt{d_c} - T_i)/r_{ij}\}$

$K_i(X_{i+1}^n) = \max\{Q - 1, (Y_i^1 - E_i - \sqrt{d_c} - T_i)/r_{ij}\}$

$set\ X_i = J_i(X_{i+1}^n) - 1$

Step 3:- $Interval\ of\ natural\ sampling\ \ I_i(X_{i+1}^n, X_i = X_i + 1)$

$if\ X_i < K_i\ (X_{i+1}^n)$

$go\ to\ step\ (5) else\ go\ to\ step\ 4$

Step 4:- (increase i : move on level down) if i= 1 else set i=i+1 and go to step 3 .

Step 5:- (decrease 'i' , move on one level up) if 'i'>1 them Let

$E_{i+1} = \sum_{j=1}^{m} r_{i-1}\ , X_j, T_{i-1} = T_i + |y_i' - E_i - r_{i,i}x_i|^2$

Let i=i+1 and go to step 2.

Step 6:- when a valid point is found , calculate $\vec{d} = |y_i' - E_i - r_{i,i}x_i|^2$

If $\vec{d} < d_c$, then $d_c = \vec{d}$, save $\hat{x} = x$ and update the boundaries.

$F_i(X_{i+1}^m) = \max\{Q - 1, (Y_i^1 - E_i - \sqrt{d_c} - T_i)/r_{ij}\}$

,for all t =1---------------m go to step3

if it terminated in step 4 then increases the initial radius d_c then run it again .

VI. PROPOSED STBC SIMULATIONS

Fig(2) shows the symbol error performance of 4X2 MIMO , which has the code rate 3/4 and modulation techniques16 QAM used for the SNR range 0-14 .Fig (3) shows error performance for the 4X3 MIMO system , is the function of SNR for the range of 0-14 for 16 QAM modulation technique.

.Fig (4) shows error performance for the 4X4 MIMO system , is the function of SNR for the range of 0-14 for 16 QAM modulation technique. Fig (5) shows error performance for the 8X1 MIMO system , is the function of SNR for the range of 0-14 for 16 QAM modulation technique.

Fig.(8) shows Comparison of SER as the function of SNR at each receiver .proposed code has the decoding complexity same as the GS code .To enhance the performance of proposed code for 4X2 multiplied by the $e^{j\,\Pi/4}$ and used the sphere decoding and Table 1. represents proposed code reduce 11% Symbol error performance.

Fig.(6) shows Comparison of SER as the function of SNR at each receiver .proposed code has marginally better symbol error performance than generalized silver code in lower range of SNR. the decoding complexity $M^{6.5}$ than $M^{8.5}$ GS code . To enhance the performance of proposed code for 4X3 multiplied by the D_1 U $e^{j\,\Pi/4}$ D_2 U j D_1 and used the sphere decoding and Table 2. represents proposed code reduce 66% Symbol error performance. Fig.(7) shows Comparison of SER as the function of SNR at each receiver .proposed code has better symbol error performance than GS code in lower range of SNR. The decoding complexity $M^{11.8}$ than $M^{12.5}$ GS code . To enhance the performance of proposed code for 4X4 multiplied by the D_1 U $e^{j\,\Pi/4}$ D_2 U jD_1 U j $e^{j\,\Pi/4}$ D_2 and used the sphere decoding and Table 3. represents proposed code reduce 49% Symbol error performance. D_1 , D_2 are generator matrix and U unitary matrix.

Table 4. represents proposed code reduce 19% Symbol error performance.

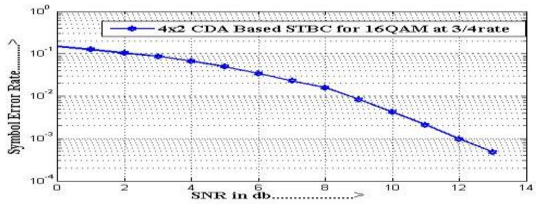

Fig.(2) SER performance of code for 4x2 MIMO System

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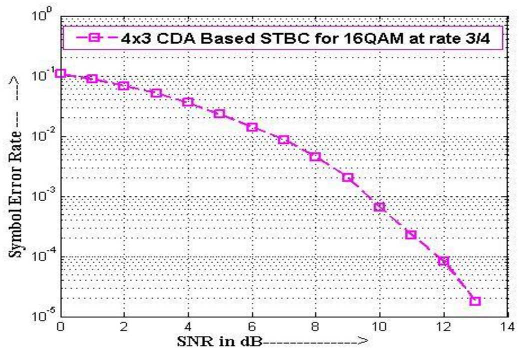


Fig.(3) SER performance of code for 4x3 MIMO System

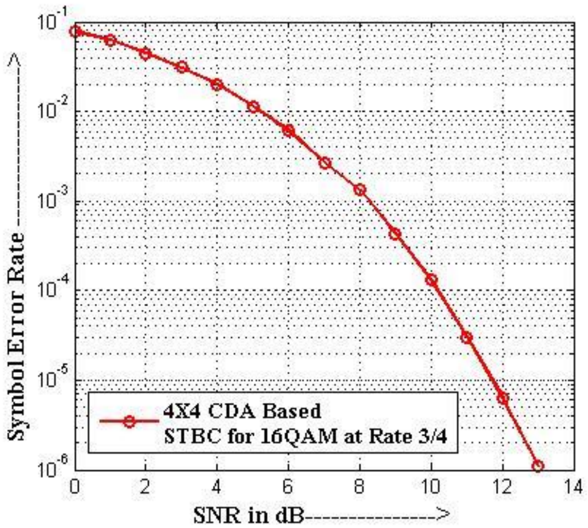


Fig.(4) SER performance of code for 4x4 MIMO System

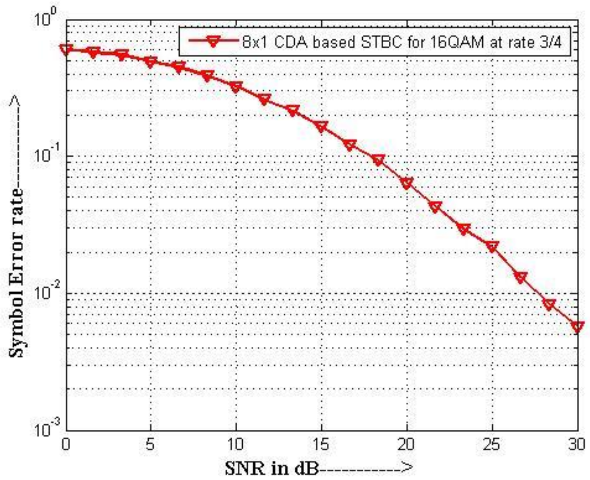


Fig.(5) SER performance of code for 8x1 MIMO System

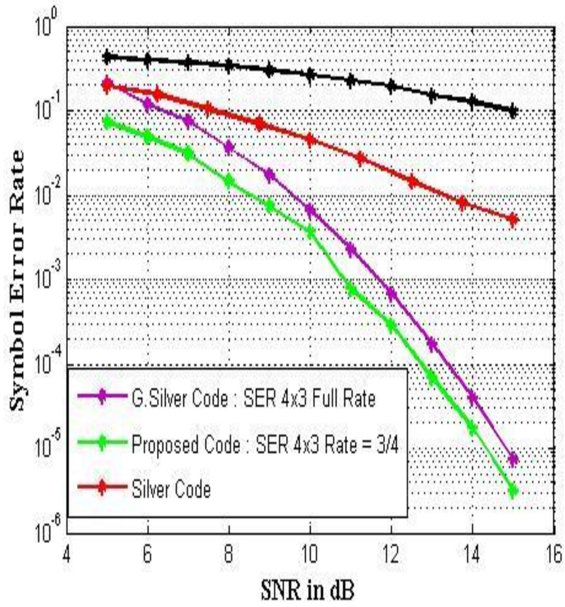
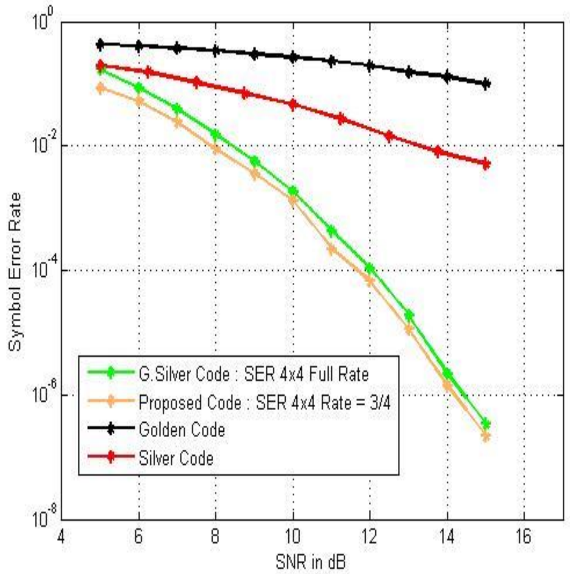


Fig.(6) Comparison of SER of new STBC for 4x3 MIMO System and existing code.



Fig(7). Comparison of SER of Proposed STBC for 4x4 MIMO System and existing code

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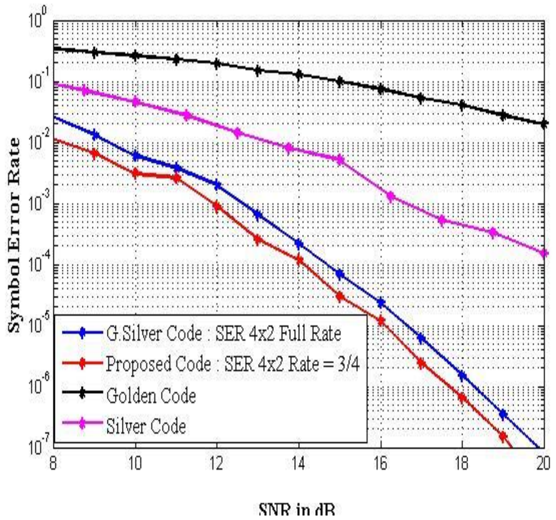
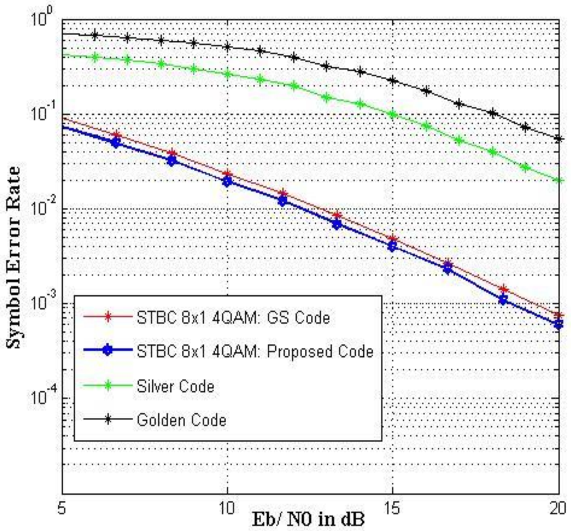


Fig(8). Comparison of SER of new STBC for4x2 MIMO System and existing code.



Fig(9) . Comparison of SER of new STBC for 8X1 MIMO System and existing code

Table 1. SER Comparison of proposed STBC for 4X2 MIMO System with GS code, Golden code , Silver Code

S.No.	Proposed 4x2 STBC , 16 QAM Modulation & SNR range(0-20)in dB at code rate 3/4 (SER=0.135)			
	Code Name	Golden Code	Silver Code	Generalized Silver Code[10]
1	No. of Tx	2	2	4
2	No. of Rx	2	2	2
3	Symbol error rate	0.529	0.395	0.245
4	% of SER from Proposed Code	74%	65%	11%
5	code rate	1	1	1

Table 2. SER Comparison of proposed STBC for 4X3 MIMO System with GS code, Golden code , Silver Code

S.No.	Proposed 4x3 STBC , 16 QAM Modulation & SNR range(5-15)in dB at code rate 3/4 (SER=0.0723)			
	Code Name	Golden Code	Silver Code	Generalized Silver Code[10]
1	No. of Tx	2	2	4
2	No. of Rx	2	2	3
3	Symbol error rate	0.4265	0.1953	0.2133
4	% of SER from Proposed Code	83%	63%	66%
5	code rate	1	1	1

Table 3. SER Comparison of proposed STBC for 4X4 MIMO System with GS code, Golden code, Silver Code

S.No.	Proposed 4x4STBC , 16 QAM Modulation & SNR range(5-17)in dB at code rate 3/4 (SER=0.0858)			
	Code Name	Golden Code	Silver Code	Generalized Silver Code[10]
1	No. of Tx	2	2	4
2	No. of Rx	2	2	4
3	Symbol error rate	0.427	0.195	0.1699
4	% of SER from Proposed Code	80%	56%	49%
5	code rate	1	1	1

Table 4. SER Comparison of proposed STBC for 8X1 MIMO System with GS code, Golden code , Silver Code

S.No.	Proposed 8x1STBC , 16 QAM Modulation & SNR range(0-30)in dB at code rate 3/4 (SER=0.2229)			
	Code Name	Golden Code	Silver Code	Generalized Silver Code[10]

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1	No. of Tx	2	2	8
2	No. of Rx	2	2	1
3	Symbol error rate	0.714	0.529	0.2753
4	% of SER from Proposed Code	68%	57%	19%
5	code rate	1	1	1

VII. CONCLUSION & FUTURE SCOPE

Proposed STBC is analyzed for 4times2, 4times 3,4times 4 and for 8times1using CDA algebra with sphere decoding. We also presented cyclic division based algebra, based on Number field and division, which is used to increase the data rate and improve the error performance. Proposed code designed and simulated using Mat Lab 7.10(R2010a). 3G cellular operating in 2GHz, which provide the data rate at least 384 kbps for mobile and 2Mbps for indoor applications. 4G system yield 20-40Mbps. The Future scope of this proposed code approaches towards 4G for achieving high data rate with increased efficiency using MIMO systems.

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REFERENCES

1. V. Tarókh, H. Jafarkhani, and A. R. Calderbank, "Space-time block codes from orthogonal designs," IEEE Transaction Information Theory, vol. 45, no. 5, pp. no.1456–1467, July 1999.
2. "Correction to 'Space-time block codes from orthogonal designs," IEEE Transaction Information Theory, vol. 46, no. 1, pp. no.314, January 2000.
3. O. Tirkkonen and A. Hottinen, "Square-matrix embeddable space-time block codes for complex signal constellations," IEEE Transaction in Information Theory, vol. 48, no. 2, pp. no. 384–395, February 2002.
4. Siavash M. Alamouti "A Simple Transmit Diversity Technique for Wireless Communication" ,IEEE Journal on Select Areas in Communications, Vol. 16, no. 8, pp.no.1451-1458 ,October 1998
5. K. P. Srinath and B. S. Rajan, "Low ML-decoding complexity, largecoding gain, full-rate, full-diversity STBCs for 2x2 and 4x2MIMO systems," IEEE J. Select. Topics Signal Processing., vol. 3, no. 6, pp.no. 916–927, December 2009.
6. M. O. Sinnokrot and J. Barry, "Fast maximum-likelihood decoding of the golden code," IEEE Wireless Communication., vol. 9, no. 1, pp. no. 26–31, January 2010.
7. C. Hollanti, J. Lahtonen, K. Ranto, R. Vehkalahti, and E. Viterbo, "On the algebraic structure of the silver code: A 2x2 perfect space-time code with non-vanishing determinant," in Processing of IEEE Information Theory Workshop, Porto, Portugal, May 2008.
8. O. Tirkkonen and R. Kashaev, "Combined information and Performance optimization of linear MIMO modulations," in Processing ISIT 2002.
9. Z. A. Khan and B. S. Rajan, "Single symbol maximum likelihood decodable linear STBCs," IEEE Transaction Information. Theory, vol. 52, no. 5, pp.no.2062–2091, May 2006.
10. Srinath, K.P and Ranjan , " Generalized Silver Code" , IEEE Transaction on Information Theory,vol.57,pp.no.6134-6147, September 2011.
11. F. Oggier, J.-C. Belfiore and E. Viterbo" Foundations and Trends in Communications and Information Theory" Vol. 4, No. 1 pp. no 1–95. 2007.
12. J. Jalden and B. Ottersten, "On the Complexity of Sphere Decoding in Digital Communications," IEEE Transaction Signal Processing, vol. 53, no. 4, pp. no. 1474-1484, April 2005
13. Dia ,XG " A new family of linear Dispersion codes for fast sphere Decoding ", Canadian conference on Electrical and Computer Engineering , pp. no. 314-317,May 2009 .
14. Jalden , J. , Elia P," The complexity of sphere decoding perfect codes under a vanishing gap to ML performance ", IEEE information symposium on information theory ,pp. no. 2836-2840 , 2011

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