Journal of Theoretical and Applied Information Technology
20th June 2014. Vol. 64 No.2
© 2005 - 2014 JATIT & LLS. All rights reserved·
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

GENETICALLY OPTIMIZED PRECODERS FOR HIGHER TRANSMIT DIVERSITY IN SINGLE USER MIMO

[1]P.SATYANARAYANA, [2] DR.S.SRIGOWRI, [3] DR.B.PRABHAKARARAO
[1]Assoc.Professor, Dept. of ECE, K.L University,Vaddeswaram
[2]Professor, Dept. of ECE , S.R.K Inst. of Technology, Enkepadu ,Vijayawada,
[3]Professor, Dept. of ECE, JNT University Kakinada, Kakinada
INDIA
E-mail: satece@kluniversity.in

ABSTRACT

Wireless communications depends on multiple-input-multiple-output (MIMO) techniques for high data rates. Feedback of channel information can be used in pre-coding to use the strongest channel mode and improve MIMO performance. This paper proposes genetic algorithm to optimize codebook for Alamouti and OSTBC pre-coding technique to enhance the Performance of MIMO system. The Simulation and Result shows that proposed optimized codebook provides improved bit error rate than the conventional rotating codebooks.

Keywords: *MIMO, Alamouti, OSTBC, Genetic Algorithm, Pre-coded Alamouti, Pre-coded OSTBC, CSIT*

1. INTRODUCTION

The primary concern in configuration of wireless communication lies in the domains of spectral efficiency and link reliability [1]. Multiple antennas at transmitter and receiver ends of MIMO technology are capable to cope with these issues in future wireless communication systems. Multiple views of received signals enhance the robustness due to employment of Diverse Multipath Fading algorithm. Spatial diversity improves the channel reliability in pre-defined resources and transmission time but at the expanse of high transmission power [2]. Number of distinct fading channels is the model of several signal paths of broadcasted informative signals.

The STBC transmission technique transmits a couple of copies of data across the predefined array of antennas. Space time coding combines all copies of received signal to extract maximum information from each of them. For performance efficiency the channel-state information of receiver can be shared with the transmitter end (channel side information at transmitter-CSIT). Before signal exploitation the precoding technique exploits CSIT [3]. Theoretically a linear precoder is the best suitable approach for conventional forms of partial CSIT [4] [5] [6]. A linear precoder could be employed as multimode beamformer that would match the signals of transmission and other end channels. For this purpose the transmit signal is split into orthogonal spatial eigenbeams and are assigned with greater power in favor to beams possessing strong channels and lower eigenbeams to low power beams. The design of precoding techniques is the functions of CSIT and performance criteria. The Alamouti STBC scheme [7] employs two transmit antennas regardless of number of receivers to obtain full diversity at full data rates. Alamouti groups the symbol in a single couple. The entries of the codebook matrix are linear combinations of the variables and their conjugates.We propose the codebook matrix optimization in Alamouti by genetic algorithm. In further sections the mathematical model of channel models and system are presented. The proposed method is based on these methods and the tests results (analyzed in MATLAB) are presented in section 3. Lastly we conclude our paper by comparison of techniques.

Yoo Byungwook et al. in [10] studied about the linear precoding techniques in a setup of MIMO systems. The codebook matrix selection was the function of source and relay precoding matrix. The algorithm of authors was above of the open-loop, Alamouti and OSTBC. However the system under study was only a 2 hop system with limited feedback at source and relay nodes.

David J. Love in [11] studied the two way feedback in OSTBCs and formed a matrix under

© 2005 - 2014 JATIT & LLS. All rights reserved·
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

the title 'priori'. The receiver looks for the matrix that is modified by the current channel conditions. The codebook matrix selection algorithm was designed to minimize the symbol error probability. Optimal Selection of codeword was tasked to derive low average distortion codebooks.

A double structure codebook that multiplies two codebooks to obtain final result was proposed by Karol Schober et al. in [12]. The optimization of both the codebooks was executed along with low-complexity code word selection algorithms for codeword with long term and wideband channel properties. However, the best performance of the codebook matrix selection and overall proposed scheme could be seen only at the transmission of eight antennas.

Feng Li proposed the codebook design and feedback scheme in [13] that attains decoding, low complexity and maximum diversity in data transmission by adjoining array processing and space-time codes. The scheme involved quantized feedback system that attains low complexity decoding for every data to be transmitted along with full diversity in case when the multiple number of users attempt to forward data at same point of time.

Juan Hang in [14] created several channel overlap regions with a unit of codebook to define channel vector in region. The scheduling algorithm was proposed by the author based on alpha-orthogonal channel region sets. The motive of low complexity was achieved with channel vector quantization.

2. ALAMOUTI ALGORITHM

The scheme is simple approach that gains spatial diversity in an antenna couple. The mathematical formulation of scheme is:
Let the sequence of signals under transmission written as:

$$\{x_1, x_2, x_3, \ldots\ldots, x_n\} \quad (1)$$

Where, x_1, x_2 are transmitted in first and second time slots respectively. Further signals follow the same behaviour.

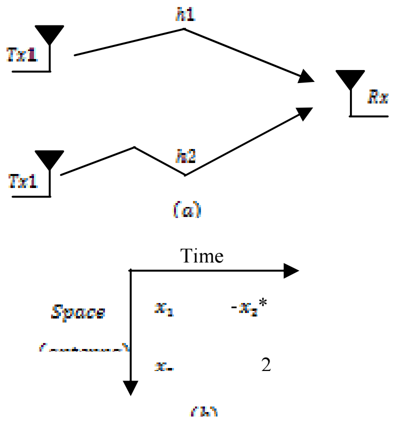

Figure 1: (a) Transmit, (b) Receive Alamouti STBC Coding

The Alamouti Algorithms pairs the signals with two in each. The first couple is of $x_1$and x_2 from antenna-1 and antenna-2 respectively in initial time slot. Second time slot is the couple of $-x_2$* and x_1^* transmitted from antenna-1 and antenna-2 respectively. Hence the third process follows the sequence and transmits x_3 and x_4 from antenna-1 and antenna-2 respectively. This process continues for further signals [15].

3. OSTBC SCHEME

The Alamouti scheme is restricted to the use of only single pair of transmitting antennas. To calculate random number of transmitters the theory related to generalized orthogonal designs was proposed. The equation below is the representation of a condition followed by matrix X that formulates algorithm to construct STBC.

$$A.A^H = p.(\sum_{i=0}^{n}|a_i|^2).I_{M_T} \quad (2)$$

Where,
A^H = Hermitian of A
P = Constant
I_{M_T}= Identity Matrix of square matrix M_T
M_T = Total Transmitting Antennas
n = Total symbols transmitted by a_i per transmission block A.
The generalized theory of orthogonal design is the basic element to code the above equation.

The STBCs orthogonality property aligns all the rows of A orthogonally to each other. We can say that the orthogonal sequence of elements is transmitted from two different antennas for every single transmitting unit. However, the above statement is not feasible in case when the signals

Journal of Theoretical and Applied Information Technology
20th June 2014. Vol. 64 No.2
© 2005 - 2014 JATIT & LLS. All rights reserved
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

are of complex structure [9]. The encoding and decoding scheme is congruent to as described in Alamouti's scheme. The coding matrices can be generated for complex signals by employing orthogonal designs and achieve the rate of broadcasting to be half in case when number of antennas is more than two [16].

$$A_{1/2} = \begin{bmatrix} a_1 & -a_2 & -a_3 & -a_4 & a_1^* & -a_2^* & -a_3^* & -a_4^* \\ a_2 & a_1 & a_4 & -a_3 & a_2^* & a_1^* & a_4^* & -a_3^* \\ a_3 & -a_4 & a_1 & a_2 & a_3^* & -a_4^* & a_1^* & a_2^* \end{bmatrix},$$

$$A_{1/2} = \begin{bmatrix} a_1 & -a_2 & -a_3 & -a_4 & a_1^* & -a_2^* & -a_3^* & -a_4^* \\ a_2 & a_1 & a_4 & -a_3 & a_2^* & a_1^* & a_4^* & -a_3^* \\ a_3 & -a_4 & a_1 & a_2 & a_3^* & -a_4^* & a_1^* & a_2^* \\ a_4 & a_3 & -a_2 & a_1 & a_4^* & a_3^* & -a_2^* & a_1^* \end{bmatrix}$$

It is mandatory for the channel coefficients to hold same value in the period of block consisting symbols A.

4. PRECODERS

The structure of Optimum Codebook targets to crest the trough value of Chrodal distance (See fig. 2) for any random channel.

A suboptimal yet practical design is the employment of DFT matrices is presented in mathematical form as:

$$F = \{\delta_{DFT}, \theta\delta_{DFT}, \dots\dots, \delta^{L-1}\delta_{DFT} \quad (3)$$

Initial value of codeword could be extracted from the square matrix N_T with $(k,l)^{th}$ entry defined by $\frac{e^{\frac{j2\pi(k-1)(l-1)}{N_T}}}{\sqrt{N_T}}, k, l = 1,2, \dots, N_T$. Furthermore, θ is given as:

$$\theta = diag\left(\left[e^{j2\pi u_1/N_T}\ e^{j2\pi u_2/N_T} \dots e^{j2\pi u_T/N_T}\right]\right) \quad (4)$$

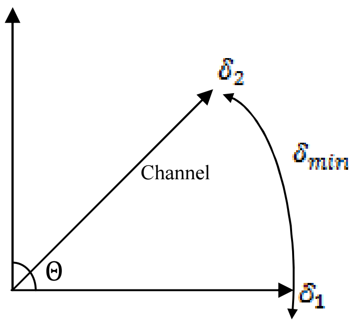

Figure 2: Precoding Matrix and Chordal Distance

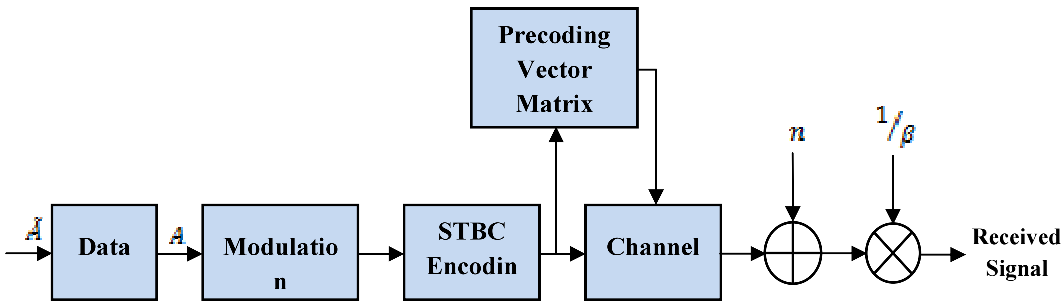

Figure 3: Linear Pre-equalization

With free variables $\{r_i\}_{i=1}^{N_T}$ awaiting for resolution. If δ_{DFT} is initial codeword, rest (L-1) codewords can be calculated by multiplication of δ_{DFT} and $\theta^i, i = 1,2, \dots\dots, L-1$. For calculation of $\{r_i\}_{i=1}^{N_T}$ (Equation 3) chordal distance is required to attain apex value.

$$r = \underset{\{r_1, r_2, \dots, r_{N_T}\}}{\arg\max} \quad \underset{l=1,2,\dots,N-1}{\min} d(\delta_{DFT}, \theta^l\delta_{DFT}) \quad (5)$$

r= rotational vector.

With the help of u codebook can be generated as follows:

$$\delta_i = diag\left(e^{j2\pi.\frac{1}{4}} e^{j2\pi.\frac{8}{4}} e^{j2\pi.\frac{61}{4}} e^{j2\pi.\frac{45}{4}}\right)^{i-1} \delta_{ini} \quad (6)$$

$i = 2, 3, \dots, 64.$

δ_{ini} is adopted from IEEE 802.16E based on number of transmitter antennas and rotational vector value.

© 2005 - 2014 JATIT & LLS. All rights reserved·
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5. SYSTEM MODEL

Of the various approaches that utilize CSI for spatial-multiplexing system, the model of pre-equalization is architected in this paper. we will model the pre-equalization method. Figure 3 illustrates the precoding (Section IV) equivalent pre-equalization at broadcasting end.

The weight matrix $\delta \in \mathbb{C}^{N_T \times N_T}$ represents coefficients of pre-equalizer and thus precoded symbol vector $A \in \mathbb{C}^{N_T \times 1}$ is given by

$$A = \delta \breve{A} \tag{7}$$

Where, $\breve{A}$ is the novel representation vector for transmission.

Zero Forcing (ZF)
If the zero-forcing (ZF) method of equalization is introduced then the weight matrix (for square channel matrix) would be defined as:

$$\delta_{ZF} = \beta Ch^{-1} \tag{8}$$

Here, β is a fixed variable that equalize the constraint of overall broadcasted power and is determined by:

$$\beta = \sqrt{\frac{N_T}{Tr(Ch^{-1}(Ch^{-1})^{Ch})}} \tag{9}$$

For minimization of alteration offered by β at the broadcasting end, the signal received is modified by dividing from β via Automatic Gain Control (AGC) (See Fig. 3). The mathematical interpretation of received signal is:

$$\begin{aligned} y &= \frac{1}{\beta}(Ch\delta_{ZF}\breve{A} + n) \\ &= \frac{1}{\beta}(Ch\beta Ch^{-1}\breve{A} + n) \\ &= \breve{A} + \frac{1}{\beta}n \\ &= \breve{A} + \tilde{n} \end{aligned} \tag{10}$$

The weight matrix δ_{MMSE} in case when MMSE pre-equalization is utilized:

$$\begin{aligned} \delta_{MMSE} &= \beta \times \arg\min E\left\{\left\|\beta^{-1}(Ch\delta\breve{A} + n) - \breve{A}\right\|^2\right\} \\ &= \frac{1}{\beta}(Ch\delta_{MMSE}\breve{A} + n) \end{aligned} \tag{11}$$

β is constant similar to equation 7.

6. GENETIC ALGORITHM BASED PROBLEM SOLUTION

GA is essential to locate multiple local optima and also the global one. For exhaustive researches the GA significantly saves the search time. We optimize GA with precoded Alamouti and precoded OSTBC to elevate the performance parameters and solve formulated problem. The three components of GA address formulate throughput maximization problem.

Coding
Coding is processed by combination of two variables $\delta_{ZF}$and δ_{MMSE}. The real number coding scheme [7] generates the primary chromosome population of CR network model. Coding the variables is source for generation of elementary genes. These genes form operational individuals in evolution stage by linking with each other. The technical term of the above procedure is chromosome.

Fitness Function
Fitness function is crucial for optimization process. The calculation of fitness function is determined by objective functions (9 and 10).

$$Fit(i) = \frac{2\pi(\zeta(i) - \zeta_{min})}{\sum_{j=1}^{C}(\zeta(i) - \zeta_{min})} \tag{12}$$

Where, $Fit(i)$ is the fitness of the j_{th} chromosome, C is the number of chromosomes, $\zeta(i)$ is the objective value of the j_{th}chromosome, and ζ_{min}represents the minimal objective.

Genetic Process
The combination of three steps (selection, crossover and mutation) is called as genetic manipulation.

1) Selection: Upon adopting fitness value by an individual (see section V-A) they are selected from population. The probability for selection of each chromosome is the ratio of total fitness population and of each individual [7].

© 2005 - 2014 JATIT & LLS. All rights reserved·
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$$P_s(i) = \frac{Fit(i)}{\sum_{i=1}^{m} Fit(i)} \quad (13)$$

Here, $P_s(i)$ is selected probability for j_{th} chromosome's fitness.

2) Crossover: In this step, selection of father genes couple and applied crossover operation for data exchange among them. For V_i and V_j as the father genes, the off springs generated will be V_i' and V_j' [8].

$$V_i' = bV_i + (1-b)V_j$$
$$V_j' = (1-b)V_i + bV_j \quad (14)$$

Where, *b* is an arbitrary value in the range 0 and 1.0.

3) Mutation: Mutation is responsible for the non-zero results in the search of global optimal result probability. The early mature difficulty [7] can be coped with adaptive mutation process [8]. This mutation is suitable against CR networks as SU varies with time. The value of ($\bar{p}_m$) can be found from (14).

$$\bar{p}_m = \begin{cases} p_m \dfrac{Fit_{max} - Fit}{Fit_{max} - Fit_{avg}} & Fit \geq Fit_{avg} \\ p_m & Fit \leq Fit_{avg} \end{cases} \quad (15)$$

Where, Fit_{avg} is the middling value of fitness $Fit_{max}$is the crest value for fitness of population, and *pm* is the mutation probability.

7. GENETICALLY OPTIMIZED PRECODED ALAMOUTI& OSTBC

Consider the single user MIMO system withN_T antennas, thatis$h \in \mathbb{C}^{1\times N_T}$,let $C \in \mathbb{C}^{M\times T}$ refers to the M length space-time codeword given by:

$$C = [c_1 c_2 \ldots \ldots c_T]$$

$$C = \begin{vmatrix} c1 & c2* \\ c2 & c1* \end{vmatrix} \; (for\ Alamouti)$$

In case of signals that are complex in nature, the theoretical model of orthogonal designs are employed for coding matrices in favor to gain half broadcast rate for more than two transmitting antennas.

$$C_{1/2} = \begin{bmatrix} c_1 & -c_2 & -c_3 & -c_4 & c_1^* & -c_2^* & -c_3^* & -c_4^* \\ c_2 & c_1 & c_4 & -c_3 & c_2^* & c_1^* & c_4^* & -c_3^* \\ c_3 & -c_4 & c_1 & c_2 & c_3^* & -c_4^* & c_1^* & c_2^* \\ c_4 & c_3 & -c_2 & c_1 & c_4^* & c_3^* & -c_2^* & c_1^* \end{bmatrix} (for\ ostbc) \quad (16)$$

Where$c_k = [c_{k1} c_{k2} \ldots \ldots c_{kM}]^T$, $k = 1,2, \ldots \ldots, T$ And$M \leq N_T$. The multiplicative index of codeword C and precoding matrix $\delta \in \mathbb{C}^{N_T\times M}$ extracted from codebook $F = \{\delta_1, \delta_2, \delta_3 \ldots, \delta_L\}$is employed for OSTBC precoded systems. The motive is the selection of suitable codeword for improvement of complete system performance in terms of channel capacity and detection of error. If the N_T channels are static for T, received value of signal $y \in \mathbb{C}^{1\times T}$ is defined by:

$$y = \sqrt{\frac{E_X}{N_T}} h \delta_{ge} C + n \quad (17)$$

In above equation the length of each vector is $M \leq N_T$. The probability of codeword error can be derived as follows: For a given channel h and precoding matrix $\delta_{ge}$is obtained from genetic algorithm.

The subsequent measure is utilized for the codebook design:

$$E\left\{\min_{W\in F}\left(\|Ch\delta_{opt}\|_F^2 - \|Ch\delta\|_F^2\right)\right\} \quad (18)$$

Here, for random channel Ch, δ_{opt} (equation 15) is calculated from Eq. 16.

8. RESULTS AND SIMULATIONS

Following are the simulation parameters considered for evaluation of system model.

Channel bandwidth-5MHz.
No of Frames transmitted:10000
No of Packets transmitted:100000
Modulation: BPSK, QPSK, 8PSK, 16PSK.
Codebook Size: 64

The system model has been tested with basic MIMO Alamouti with 2* 2 antenna, OSTBC(with half rate) rate and transmit diversity is evaluated under different modulation technique. To enhance the diversity further ZF and MMSE equalizer is implemented along with existing Alamouti system. The observed results shows MMSE system yields better BER result

© 2005 - 2014 JATIT & LLS. All rights reserved·
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

then ZF system model. Considering the Precoders concepts further precoders (Rotational, IEEE 802.16E) with full channel state information is implemented and it optimized with genetic algorithm. Fig 4 shows the Alamouti algorithm implemented with MMSE equalizer for different modulation technique. Fig 5 shows the Alamouti algorithm implemented with ZF equalizer for different modulation technique. Fig 6 shows the comparative analysis of Alamouti, Precoded Alamouti and genetically optimized precoded system, the observation shows at 20 db SNR the result of genetically optimized precoder yields 40 % Better BER then traditional Alamouti system. Fig 7 and Fig 8 shows the performance of OSTBC system with or without precoders with ZF and MMSE equalizer. Fig 9 shows the optimized precoders BER is10-6 in 10 SNR db. It is fairly enough to say better than normal precoders and OSTBC system.

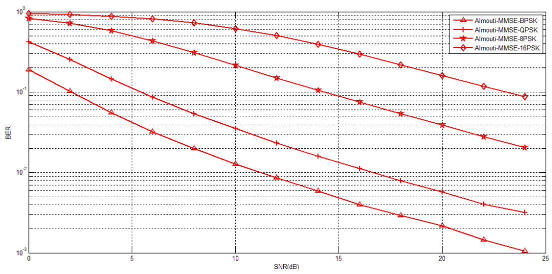

Figure 4: Alamouti With MMSE Under Different Modulation Technique.

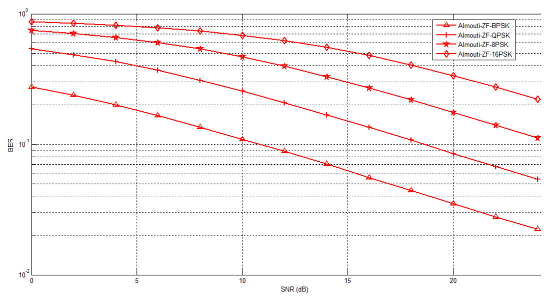

Figure 5: Alamouti With ZF Under Different Modulation Technique.

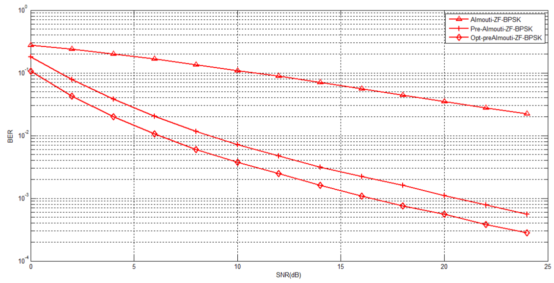

Figure 6: Alamouti With ZF With Precoded System And Genetically Optimized Precoders.

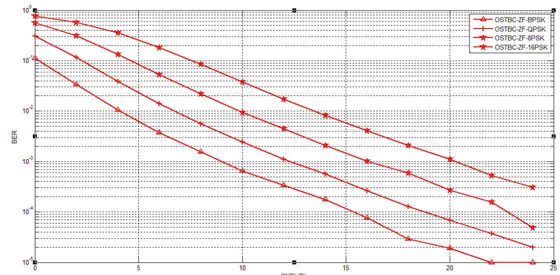

Figure 7: Ostbcwith ZF Under Different Modulation Technique.

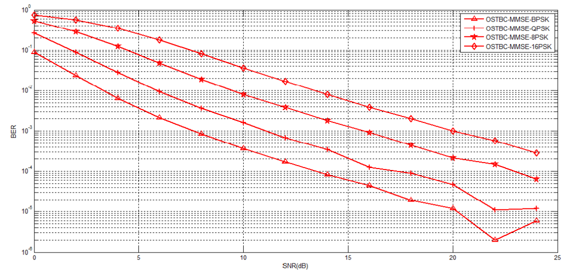

Figure 8: Ostbcwith MMSE Under Different Modulation Technique.

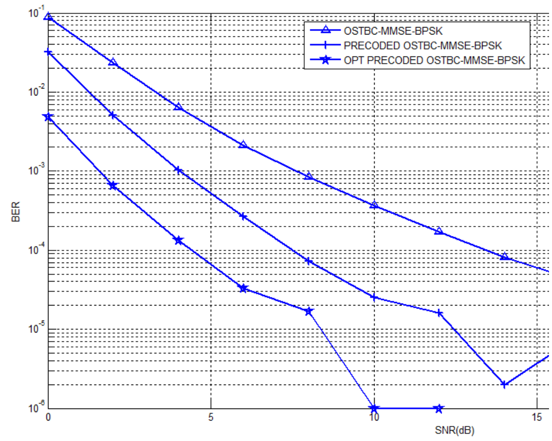

Figure 9: OSTBC With MMSE With Precoded System And Genetically Optimized Precoders.

© 2005 - 2014 JATIT & LLS. All rights reserved·
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

9. CONCLUSION

MIMO Wireless system uses antenna arrays at both transmitter and receiver end to provide communication link with diversity and capacity. We have presented an optimal precoder for Alamouti and OSTBC precoding using Genetic algorithm with an objective of minimum bit error rate. Results is showing that BER for MIMO system is less with optimized precoder that rotating precoder. This idea also can be used with multiuser MIMO system to improve performance.

REFERENCES:

[1] Helmut Bolcskei, "Principles of MIMO-OFDM Wireless Systems" *Communication Technology Laboratory*, Swiss Federal Institute of Technology (ETH). Sternwartstrasse 7, CH-8092 Zurich.

[2] Aditya .Kurve, "Multi-user MIMO systems: Thefuture in the making". 0278-6648/09/$26.00 © 2009 IEEE.

[3] Mai Vu and Arogyaswami Paulraj, "MIMO Wireless Linear Precoding" *IEEE SIGNAL PROCESSING MAGAZINE*. SEPTEMBER 2007 1053-5888/07/2007IEEE.

[4] C. Shannon, "Channels with side information at the transmitter," *IBM J. Res. Develop*., vol. 2, no. 4, pp. 289–293, Oct. 1958.

[5] G. Caire and S.S. Shamai, "On the capacity of some channels with channel state information," *IEEE Trans. Inform. Theory*, vol. 45, no. 6, pp. 2007–2019, Sept. 1999.

[6] M. Skoglund and G. Jöngren, "On the capacity of a multiple-antenna communication link with channel side information," *IEEE J. Select. Areas Commun*., vol. 21, no. 3, pp. 395–405, Apr. 2003.

[7] D. E. Goldberg, "Generic Algorithms in Search, Optimization, and Machine Learning". *Reading, MA*: Addison-Wesley, 1989.

[8] X. Hu, Y. Tang, and J. Cai, "Optimal]approximation of Head-related Transfor Function based on adaptive genetic algorithm," in *Proc. Int. Conf. Neural Netw. Signal Process*. Jun. 2008, pp. 129–132.

[9] A. Mezghani, M. Joham, R. Hunger, W. Utschick, "Transceiver Design for Multi-User MIMO Systems". *Proc. 7th International ITG Conference*, Source and Channel Coding (ITG SCC'06), January, 2006.

[10] Yoo Byungwook, Ha Lee Kyu, Kim Hyundo and Lee Chungyong, "Linear Precoding Techniques for 2-Hop MIMO Replaying" *23 International Conference on Circuit Systems,* Computers and Communications (ITC-CSCC 2008)

[11] David J. Love, Robert W. Heath, "Limited Feedback Unitary Precoding for Orthogonal Space-Time Block Codes" *IEEE TRANSACTIONS ON SIGNAL PROCESSING,* VOL. 53, NO. 1, JANUARY 2005

[12] Karol Schober, Tommi Koivisto and Risto Wichman, "MIMO Adaptive Codebook for Closely Spaced Antenna Arrays" *19th European Signal Processing Conference* (EUSIPCO 2011), Barcelona, Spain, August 29 - September 2, 2011

[13] Feng Li, Space-Time Processing for Multi-User Multi-Antenna Z Channels with Quantized Feedback*" IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC),* ISSN: 2250-3501 Vol. 2, No. 1, 2012

[14] Juan Hang, Yuanfeng Zhang and Feng She, "Low Complexity Multi-user Scheduling with Quantization" *2010 3rd International Conference on Computer and Electrical Engineering (ICCEE 2010)* IPCSIT vol. 53 (2012) © (2012) IACSIT Press, Singapore DOI: 10.7763/IPCSIT.2012.V53.No.2.100

[15] Kun Fang, Geert Leusand Luca Rugini, "Alamouti Space-Time Coded OFDM Systems in Time- and Frequency-Selective Channels" http://cobalt.et.tudelft.nl/~leus/papers/globecom06.pdf

[16] Chee Wei Tan, A. Robert Calderbank, "Multiuser Detection of Alamouti Signals" *IEEE Transactions ON Communications*, VOL. 57, NO. 7, JULY 2009