Diyala Journal of Engineering Sciences

ISSN 1999-8716
Printed in Iraq

Vol. 10, No. 2, pp. 1-11, June 2017

IMPROVEMENT OF MIMO SYSTEM USING STTC WITH ARTIFICIAL NEURAL NETWORK

Raad H. Thahir [1], Hussien Y. Radhi [2], Ghassan K. Ali [3]
[1] Assistant professor, Electrical Engineering Department, College of Engineering, Al-Mustansiriah University
[2, 3] Computer Engineering Department, College of Engineering, University of Diyala
(Received: 13/2/2014; Accepted: 20/1/2016)

ABSTRACT: - The wide demand for high data rate rapid development in mobile and internet communication system limitation of the radio spectrum and the communication capacity needs cannot be met without a significant increase in communication spectral efficiency make it important to increase the capacity and decrease the Bit Error Rate (BER) of communication channel. In this paper, analysis of the capacity for four types of communication systems are performed, it was found that the MIMO communication system capacity is the best, Space Time Trellis Code (STTC) technique is used to improve the performance of MIMO system by decreasing the BER as well as possible, finally artificial neural network was used at the receiver of with (STTC) to get more suitable results by decreasing the BER of the proposed system.
Keywords: Channel capacity (c) Multiple Input-Multiple Output (MIMO), multipath effect, Bit Error Rate (BER) Space Time Block Code (STBC) Space Time Trellis Code (STTC) and Artificial Neural Network (ANN).

1- INTRODUCTION

MIMO based on the principle of multiple antennas at the transmitter and receiver to send and receive signals. Certain algorithms are used to send out the Data in different paths which are then reassembled after arriving at the receiving antenna [1]. Through propagation mechanisms such as reflection diffraction and scattering objects in the channel create multiple path from the transmitter to the receiver we collectively refer to these objects as scatters the paths are of different lengths and thus the signals arrive at the receiver with different amplitudes and phases [2,3], this is called multipath effect which can limit the operation of any communication system in order to combat the effects of multipath interferences space time coding (STC) can be used with MIMO systems mainly there are two types of (STC) the first type is space time block code (STBC) and the second is space time trellis (STTC).

2- RELATED WORK

In [1] the conventional point-to-point MIMO systems under Nakagami fading, and later extended to the more general distributed MIMO systems was proposed. In [3] different MIMO schemes more specifically receive and transmit diversity are analyzed using MATLAB Simulations and the performance criteria are bit error rates (BER), Cumulative Distribution Function (CDF) and channel capacity. In [4] the fundamental DMA tradeoff achievable by any scheme in uncorrelated Rayleigh block-fading MIMO channels was presented. In [5] MIMO system capacity using the Spatial Channel Model (SCM) was investigated which proposed by standardization bodies (3GPP-3GPP2) for third generation systems. In [6] capacity of different communication system was stated under variable environments. In [7] different antenna selection schemes and the performances are compared in an analytical manner was investigated. In [8] the most important detection techniques for MIMO spatial multiplexing wireless systems, focusing on their performance and computational complexity. In [9] a brief tutorial on artificial neural networks; some of the most commonly used Artificial Neural Network (ANN) models and several applications of it was briefly described. In [10] Artificial Neural Network architecture was investigated.in this paper the capacity under variable environments was investigated and an ANN is used with STTC technique is used to reduce the BER at the receiver.

3- SYSTEM MODEL

For the transmitted signal $\vec{X} = [\vec{X}_1, \vec{X}_2 \dots . \vec{X}_{NT}]$, where NT represent the number of antennas at the transmitter the received signal can be expressed as[2]

$\vec{Y} = \vec{X} * \vec{H} + \vec{N}$ …….. (1)

Where N is the additive white gaussian and H is the impulse response matrix which can be expressed in equation (2)

$$H = \begin{bmatrix} H_{11} & H_{12} & \dots \dots \dots H_{1M} \\ H_{21} & H_{22} & \dots \dots \dots H_{2M} \\ . & . & . \\ H_{N1} & H_{N2} & \dots \dots \dots H_{NM} \end{bmatrix} \dots \dots .. (2)$$

The block diagram of proposed system is given in figure (1).

4- MIMO CHANNEL CAPACITY

The channel capacity plays an important role in the design and analysis of multi-input multi-output (MIMO) communication systems Shannon capacity equation is given [5].

$C = B \, log_2 \, (1 + SNR) \, bps \;\; \dots \dots .. (3)$

Where B is the bandwidth of the channel and SNR is the signal to noise ratio for single input-single output system (SISO) the capacity equation is [8].

$$C = log_2(1 + SNR|h|^2) \, bps/Hz \dots \dots .. (4)$$

Where (h) is the channel impulse response between the transmitter and receiver for MISO system the transmitter diversity is obtained [11].

$$C = log_2(1 + \frac{SNR}{N_T} \sum_{n_t=1}^{N_T} |h_{N_T}|^2) \, bps/Hz \dots \dots .. (5)$$

Whereh_{N_T} is the normalized complex gain of the nth transmitter antenna and N_T is the number of transmit antennas. For SIMO system the reciever diversity is obtained 11].

$$C = log_2(1 + SNR \sum_{n_r=1}^{N_R} |h_{N_R}|^2) \, bps/Hz \dots \dots .. (6)$$

Where h_{N_R} is the normalized complex gain of the nth receiver antenna. According to the channel impulse response matrix MIMO system capacity can be divided into deterministic and random capacity equation of deterministic MIMO channel can be expressed as [6].

$$C = log_2[det \, (I_{N_R} + \frac{SNR}{N_T} \, HH^H)] \, bps/Hz. \dots \dots .. (7)$$

Where det (.) denotes the determinant of a matrix I_{NR} is an N_R *identity matrix and H^H is the complex conjugate transpose of H in addition the capacity of a random MIMO channel is given as[6]

$$C = E[log_2[det \left(I_{N_R} + \frac{SNR}{N_T} \, HH^H\right)]] \, bps/Hz \dots \dots .. (8)$$

Where E (   )denotes the expectation operator for MIMO channel the matrix elements h_{ij} are

$$h_{ij} = 1, i = 1,2, \dots, N_R \, , j = 1,2, \dots, N_T \;\; \dots \dots .. (9$$

The channel capacity combining is given as[8]
$C = log_2(1 + N_R\, N_T SNR) bps/HHz$ ....(10)

While in Non-coherent Combining, the signals transmitted from various antennas are different and all channel entries are equal to (I), there is only one received signal in the equivalent channel. Thus, the capacity is given as [11].

C = log2 (1 + N_R SNR) bps/Hz ....(11)

When the channel has the same number of transmit and receive antennas, $N_T = N_T = N$, and that they are connected by orthogonal parallel sub-channels, so there is no interference between individual sub-channels. By linking each transmitter with the corresponding receiver by a. separate waveguide, or by spreading transmitted signals from the various antennas by orthogonal spreading sequences, the channel matrix is given as [11].

$H = \sqrt{N}\, I_N$ ....(12)

The capacity equation in this case is :

$$C = log_2 \det\left(I_N + SNR\frac{N}{N} I_N\right)$$

$$= log_2 \det(diag[1 + SNR])$$

As a result

$C = log_2\, det(l + SNR\,)^N = Nlog_2 det\,(1 + SNR)$ ....(13)
Where diag(.) Is the diagonal of the matrices.

5- SPACE TIME BLOCK CODE (STBC)

Space—time block coding is a technique used in wireless communication to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data transfer [12]. The encoding and decoding operation is carried out in sets of two modulated symbols. Let us denote X_1 and X_2 the two modulated symbols that enter the space—time encoder. Usually, in systems with only one transmit antenna, these two symbols are transmitted at two consecutive time instances t_1 and t_2.The times t_1 and t_2 are separated by a time duration T. In the Alamouti scheme, during the first time instance, the symbols X_1 and X_2 are transmitted by the first and the second antenna element, respectively. During the w second time instance t_2, the negative of the conjugate of the second symbol, i.e., $-{X_2}^*$, is sent to the first antenna while the conjugate of the first constellation point, i.e., ${X_1}^*$, is transmitted from the second antenna. The block diagram of Alamouti space—time encoder is shown in figure (2) [12,13].
At the transmitter, input information is modulated and coded using STBC technique then it is transmitted from $N_T th$ antennas. There are many types of modulation such as Amplitude Shift Keying (ASK), Phase Shift Keying, PSK, and Frequency Shift Keying, FSK. In this paper (PSK) is employed because it gives a minimum bit error rate [12].For two transmit antennas, the transmitted Signals will be [12,13].

$X^1 = [X_1, -{X_2}^*]$
........(14)
$X^2 = [X_2, {X_1}^*]$

For Rayleigh channel with Additive White Gaussian Noise, one receive antenna, the fading channel coefficients from the first and second transmit antennas to the receive antenna at time

t are denoted by $h_1(t)$ and $h_2(t)$, respectively. Assuming that the fading coefficients are constant across two consecutive symbol transmission periods, they can be expressed as [12].

$$h_1(t) = h_1(t+T) = h_1 = |h_1|e^{j\theta_1}$$
$$h_2(t) = h_2(t+T) = h_2 = |h_2|e^{j\theta_2} \quad \ldots\ldots..(14)$$

Where $|h_i|$ and θ_i $i = 0, 1$, are the amplitude gain and phase shift for the path from transmit antenna i to the receive antenna, and T is the symbol duration. At the receive antenna, the received signals over two consecutive symbol periods, denoted by r_1 and r_2 for time t and $t + T$, respectively, can be expressed as [12,13].

$$r_1 = h_1x_1 + h_2x_2 + n_1$$
$$r_2 = -h_1X_2^* + h_2X_1^* + n_2 \quad \ldots\ldots..(15)$$

Where n_1 and n_2 are independent complex variables with zero mean and power spectral density $\frac{N_0}{2}$ per dimension, representing additive white Gaussian noise samples at time t and $t + T$, respectively. To detect the received data, there is Z, , I more than one method such as Zero ,forcing (ZF) receiver, minimum mean square error (MMSE) algorithm, and Maximum Likelihood (ML) receiver algorithm. Maximum Likelihood (ML) receiver algorithm gives the smallest BER therefore; ML algorithm is used to find it which calculated as [12].

$$J = |r - HX|^2 \ldots\ldots..(16)$$

Where r is the received signal, X is the transmitted data, and H is the channel matrix response. For 2NT *2NR equation (16) can be rewritten as [12].

$$\left(\begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix} - \begin{matrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{matrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}\right)^2 \ldots\ldots..(17)$$

If the channel fading coefficients, h_1 and h_2, can be perfectly recovered at the receiver, the decoder will use them as the channel state information (CSI). Assuming that all the signals in the modulation constellation are equiprobable, the maximum likelihood decoder chooses a pair of signals$(\dot{x}_1, \dot{x}_2)$ from the signal modulation constellation to minimize the distance metric [8]. Forr a given channel realization hl and h2, the decision statistics it}, $i = l, 2$, is only a function of x_i , $i = l, 2$. Thus, the maximum likelihood-decoding rule (17) can be separated into two rules for x_1 and x_2, given as [12,13].

$$\dot{x}_1 = arg_{\dot{x}_1 \in s}^{min}(|h_1|^2 + |h_2|^2 - 1)|\dot{x}_1|^2 + d^2(\tilde{x}_1, \dot{x}_1)$$
$$\dot{x}_2 = arg_{\dot{x}_2 \in s}^{min}(|h_1|^2 + |h_2|^2 - 1)|\dot{x}_2|^2 + d^2(\tilde{x}_2, \dot{x}_2) \quad \ldots\ldots..(17)$$

6- SPACE TIME TRELLIS CODE (STTC)

Space-Time Trellis Code Possess both diversity and coding gain [12]. The encoder of (STTC) maps binary data to modulation symbols, where a trellis diagram describes the mapping function [8]. The encoder block diagram of the STTC is shown in figure (3), with (m) binary input sequences $c^1, c^2 \ldots\ldots, c^m$is fed into the encoder, which consists of m feed forward shift registers, The K-th input sequence $c^1 = ({c^k}_0, {c^k}_1, {c^k}_2 \ldots\ldots, {c^k}_t,$ $k = 1, 2, \ldots m,$ is passed to the $K - th$ shift register and multiplied by an encoder coefficient set. The multiplier outputs from all shift registers are added module M, giving the encoder output x=(x , x). For 4-state space-time trellis coded QPSK scheme with 2 transmit antennas, the generated sequences are: $g^1 = [(02), (20)]$, $g^1 = [(01), (10)]$

The trellis consist of $2^v = 4$ states, represented by state nodes. The encoder takes $m = 2$ bits as its input at each time. There are $2^v = 4$ branches leaving from each state corresponding to four different input patterns. Each branch is labeled by $\frac{c^1\,c^2}{x_t{}^1\,x_t{}^2}$, where $c^1\,c^2$ are a pair of encoder bits and $x_t{}^1\,x_t{}^2$ are represents two coded $QPSK$ symbols transmitted through antennas 1 and 2, respectively. The row listed next to a state node in figure (4) indicates the branch labels for transitions from that state corresponding to the encoder inputs 00,01,10,11, respectively [12].

7- ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks ANNs are massively parallel computing systems consisting of an extremely large number of simple processors with many interconnections [10]. ANNs are used for engineering purpose, such as patterns recognition, forecasting, and data compression.

8- BACK PROPAGATION ALGORITHM

The back propagation algorithm is used in layered feed-forward ANNs. This means that the artificial neurons are organized in layers, and send their signals “forward”, and then the errors are propagated backwards. The network receives inputs by neurons in the input layer. There may be one or more intermediate hidden layer. The back propagation algorithm uses supervised learning, which means that we provide the algorithm with examples of the inputs and outputs we want the network to computer, and then the error (difference between actual and expected results) is calculated. Figure (5) shows the proposed ANN, The input layer plays the role of distributing the input to all neurons in the first processing layer, where, first hidden layer (layer (1)) contains ten neurons and every input in the input layer is connected to every neuron in layer (1). The output of layer (1) is computed as [10]:

$$O = tansig\,\{(W\{1\}.I) + B\{1\}\} \quad \text{…….(18)}$$

Where O represents the output of layer (1), W{1} represents the weights that connect the input layer with layer (1). B{1} represents the bias values of layer (1) and tansig represents the activation function as mentioned in Equation (2.33) for layer (1).

9- SIMULATION AND RESULTS

The purpose of this paper is to analyze the performance of MIMO capacity with Space Time Codes, also the artificial neuron network algorithm was used to decrease the BER as illustrated in simulated results. Figure (6) shows the capacity of difference communication systems. From figure(6), it can be found that the capacity of MIMO system is larger than other system since MIMO capacity is (5.7396 bps/Hz) while SIMO system capacity is (3.4578 bps/Hz) MISO system capacity is (2.8965 bps/Hz) and SISO system capacity is (1.5722 bps/Hz) at SNR =8 dB. In figure (7) the capacity of random system is less than the capacity of deterministic system since the effect of reflection, attenuation and absorption of signals is very small in deterministic as compared with random. In figure(8), the capacity of with and without coding is illustrated which shows that the capacity of MIMO system is not large effected by using coding. Figure (9) shows that the BER can be reduced from the BER for SISO system to small value of BER for MIMO system. Figure (10) illustrates that the BER of proposed system can be decreased by using ANN at the receiver as well as possible.

10- REFERENCES

1- Caijun Zhong “Capacity and Performance Analysis of Advanced Multiple Antenna Communication Systems”, Degree of doctor thesis, Department of Electronic and

Electrical Engineering, University College London, London, United Kingdom, March 2010.

2- Nelson Costa and Simon Haykin, "Multiple- Input,Multiple-Output Channel Models", IEEE, John Wiley & Sons, 2010.

3- Ghulam Abbas, Ebtisam Ahmed, Waqar Aziz, Saqib Saleem, Qamar-ul-Islam, " Performance Enhancement of Multi-Input Multi-Output (MIMO) System with Diversity", International Journal Of Multidisciplinary Sciences and Engineering, Vol. 3, NO. 5, May, 2012

4- Luis G. Ord´o˜nez,1 Daniel P. Palomar,2 and Javier R. Fonollosa1, " On the Diversity, Multiplexing, and Array GainTradeoff in MIMO Channels", IEEE Dept. of Electric and Computer Engineering, Hong Kong University of Science and Technology, June 13 - 18, 2010.

5- Sunil Gautam Panda and Birupaksha Bhattacharjee "Capacity analysis of underwater acoustic MIMO communications", National Institute of Technology, Rourkela,2012

6- Bengt Holter" Capacity of multiple-input multiple-output (MIMO) systems in wireless communications" Department of Telecommunications, Norwegian University of Science and Technology, 15-11-2012.

7- Dominik Seethaler_, Harold Art_es+, and Franz Hlawatsch" Detection Techniques for MIMO Spatial Multiplexing Systems", Accepted for publication in e&i, January 21, 2005.

8- Shuo Pan "Capacity of MIMO Systems for Spatial Channel Model Scenarios", The Australian National University, Canberra, Australia, , June 2006

9- S. P. PREMNATH1, J. R. JENIFER2, C. ARUNACHALAPERUMAL3 "Performance Enhancement Of Mimo Systems Using Antenna Selection Algorithm", ISSN 2250-2459 (Online), An ISO 9001:2008 Certified Journal, Volume 3, Special Issue 1, January 2013.

10- Neha Gupta" ARTIFICIAL NEURAL NETWORK", VSRD International Journal of Computer Science & Information Technology, Vol. 3 No. 5 May 2013.

11- Michail Matthaiou" MIMO Systems in Wireless Networks", 12 April 2011.

12- Branka Vucetic and Jinhong Yuan, "Space-Time Coding", John Wiley & Sons, British Library Cataloguing in Publication Data, 2003.

13- Mohinder Jankiraman, "Space-Time Codes and MIMO Systems", Artech House Boston , London, British Library Cataloguing in Publication Data, 2004

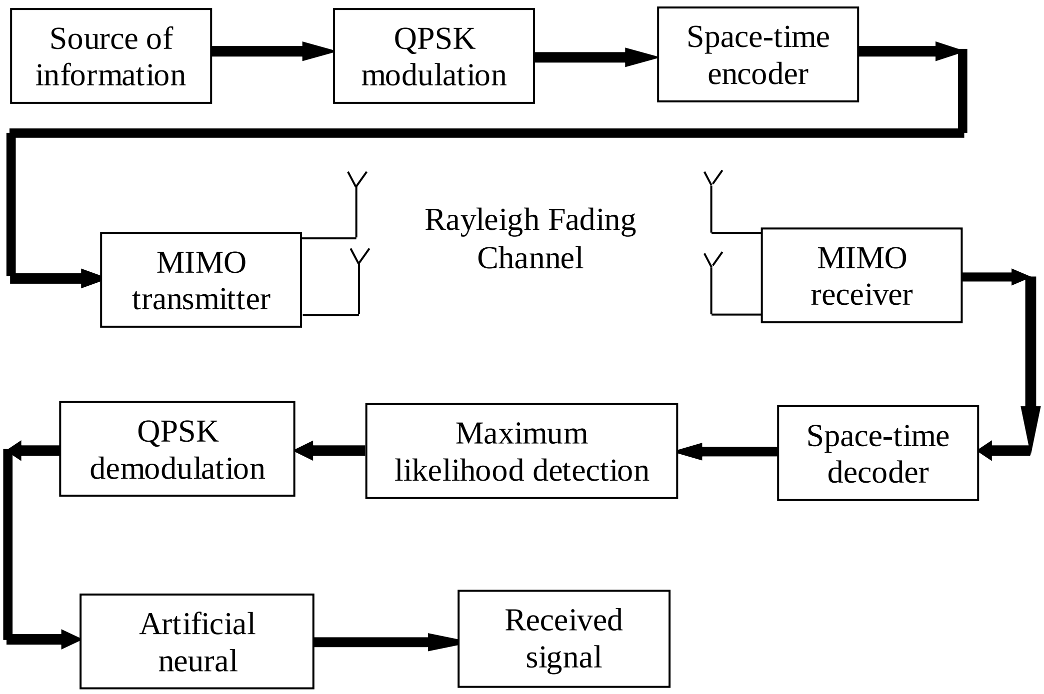

Fig. 1 Proposed Block

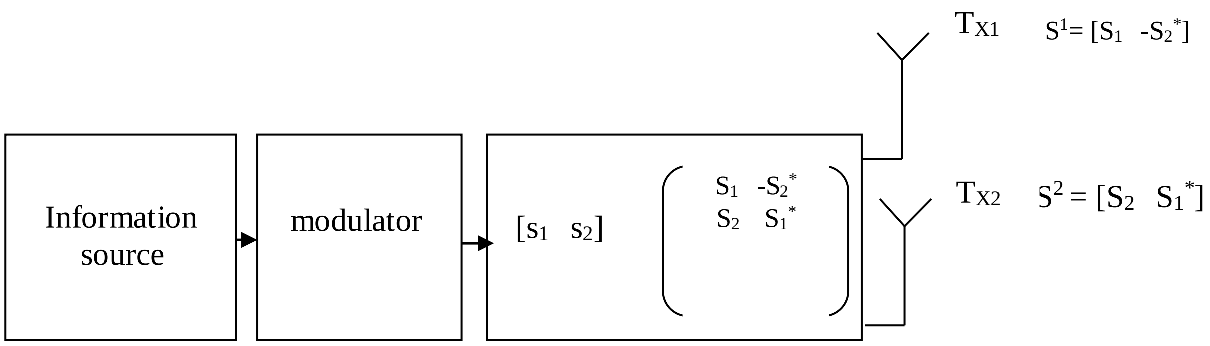

Fig. 2 Alamouti space-time encoder

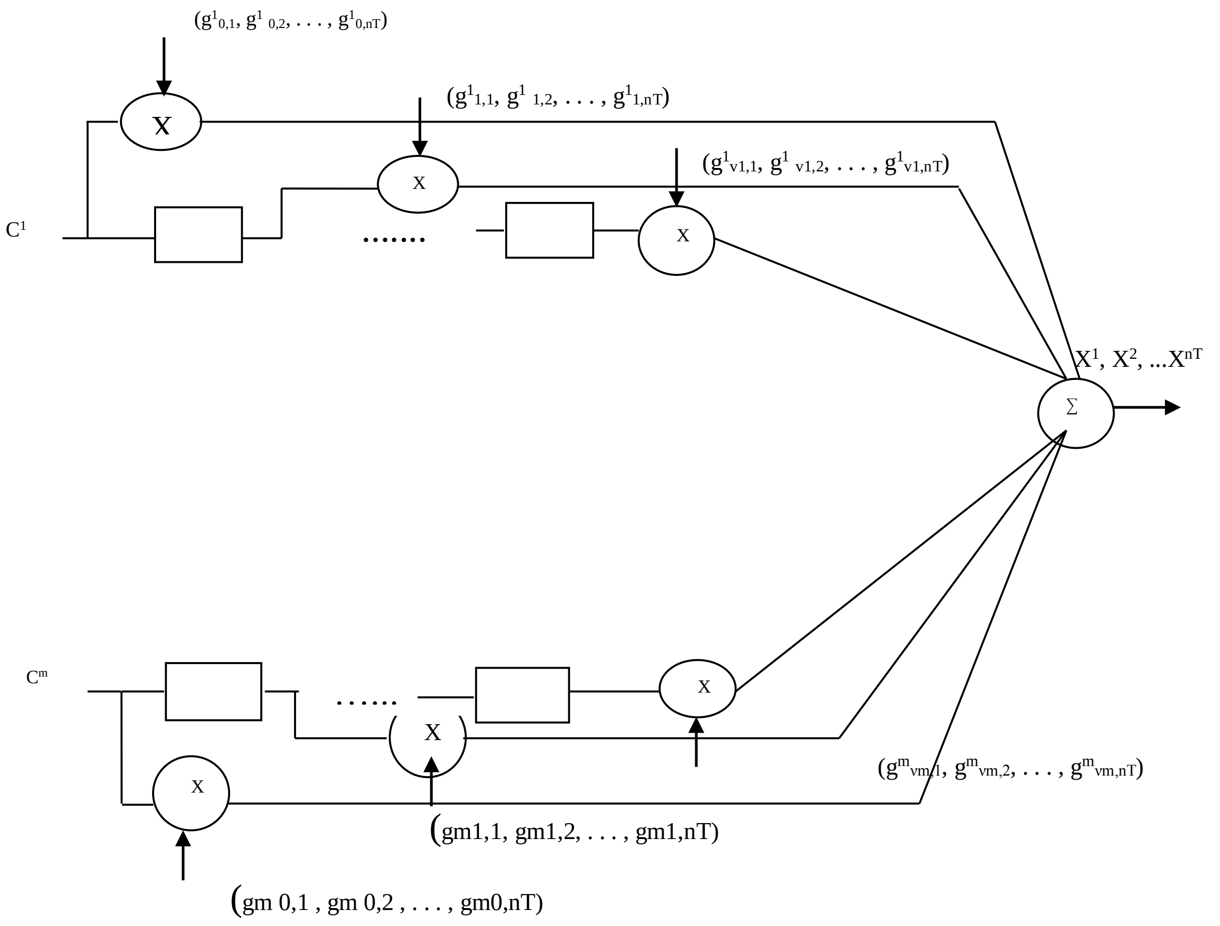

Fig. 3 STTC

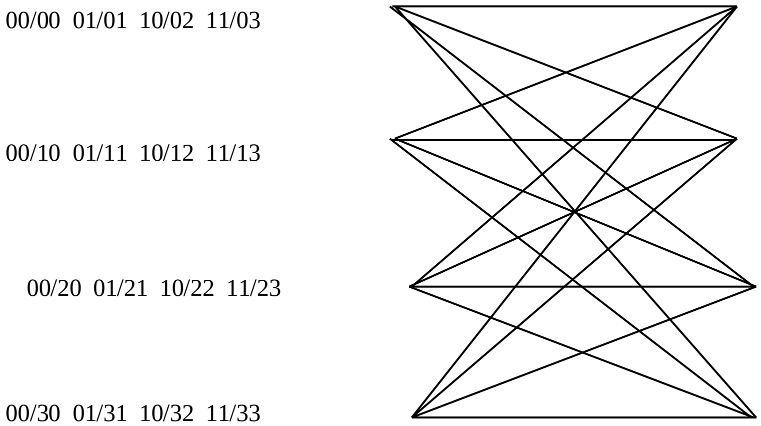

Fig. 4 Trellis structure for a 4-state space-time coded QPSK with two antennas

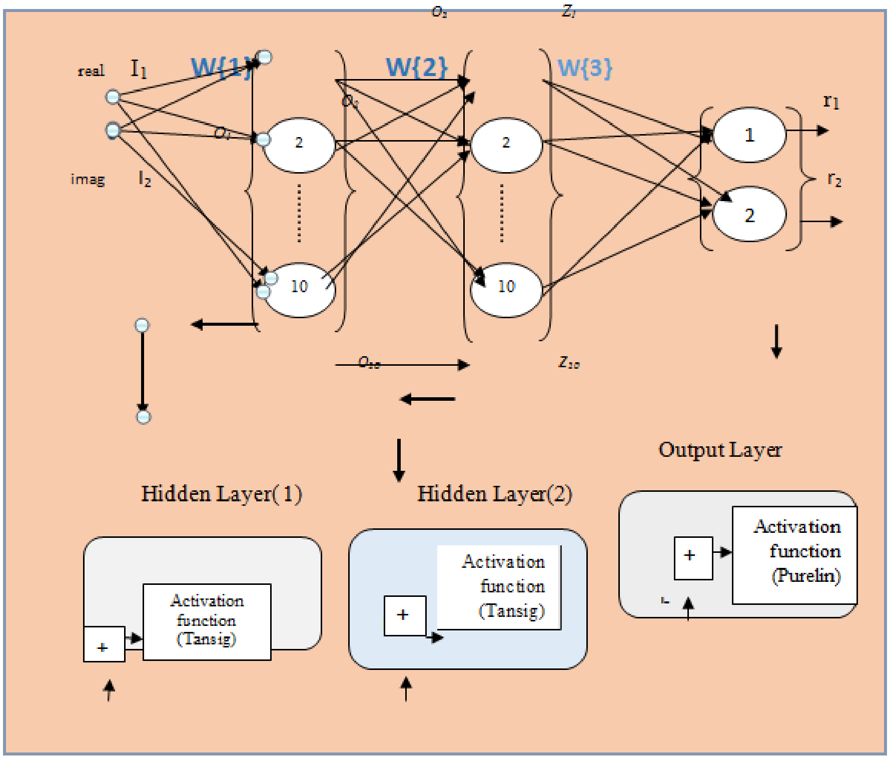

Fig. 5 Trellis structure for a 4-state space-time coded QPSK with two antennas

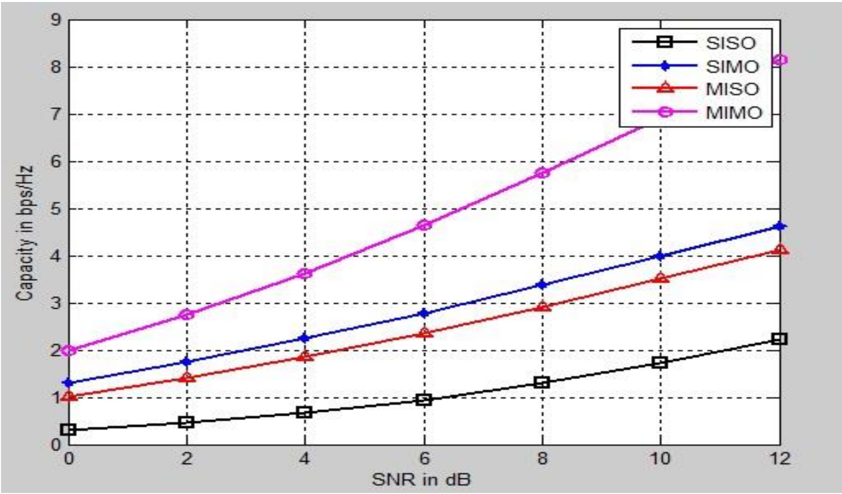

Fig .6 Comparison of Capacity for (SISO, MISO, SIMO, MIMO)

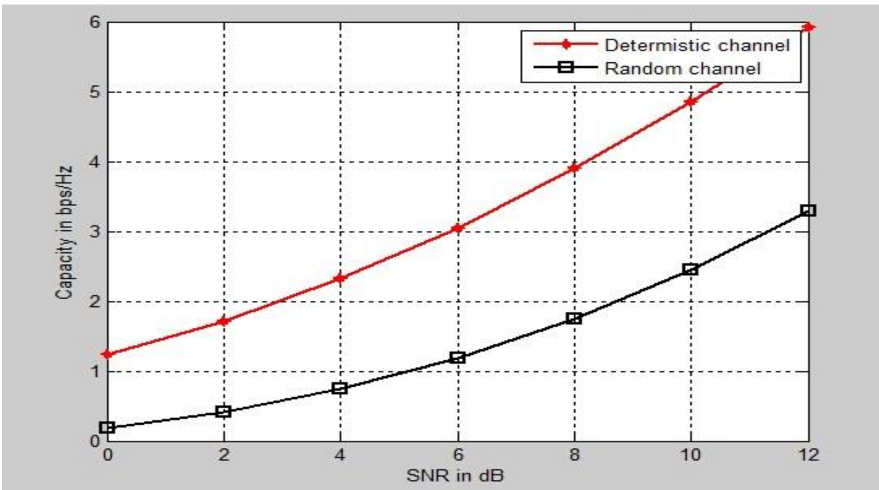

Fig .7 Capacity of 2*2 random and deterministic MIMO systems versus SNR

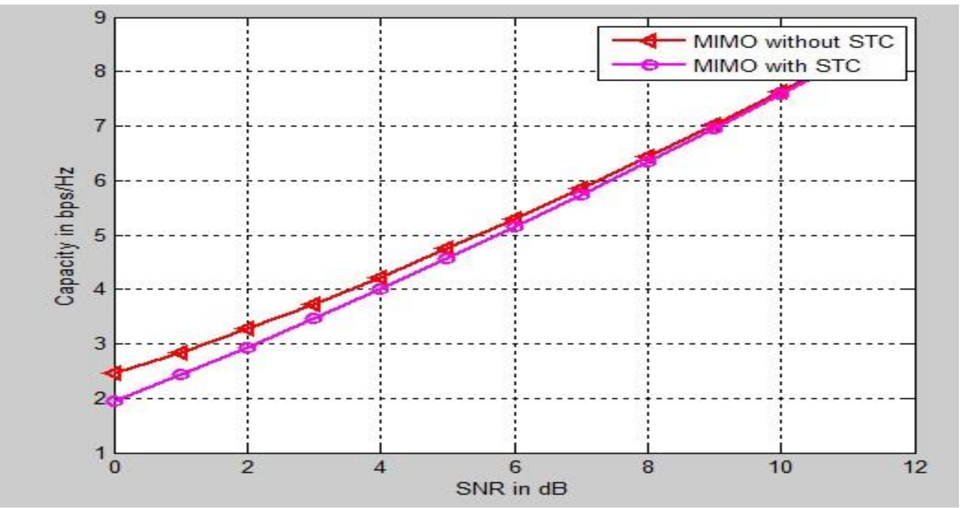

Fig .8 Comparison of Capacity for (SISO, MISO, SIMO, MIMO)

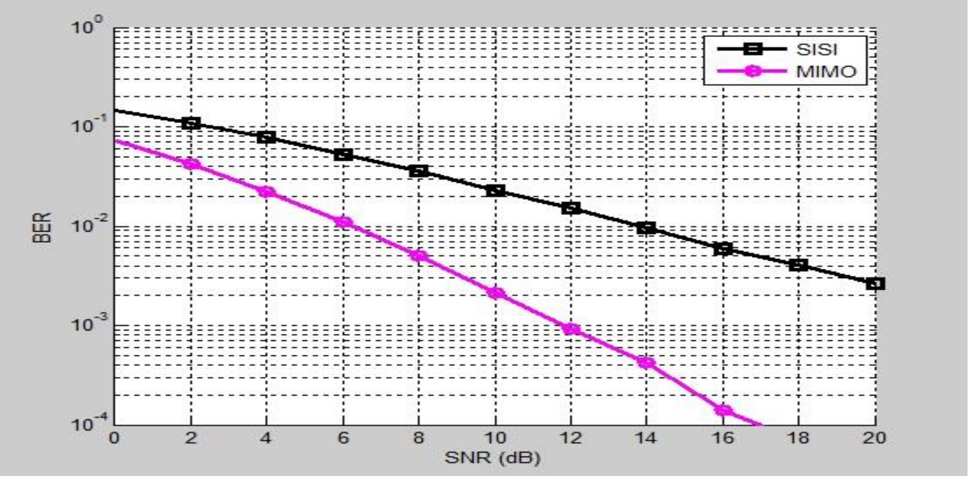

Fig.9 BER Versus SNR for (SISO, MIMO) systems

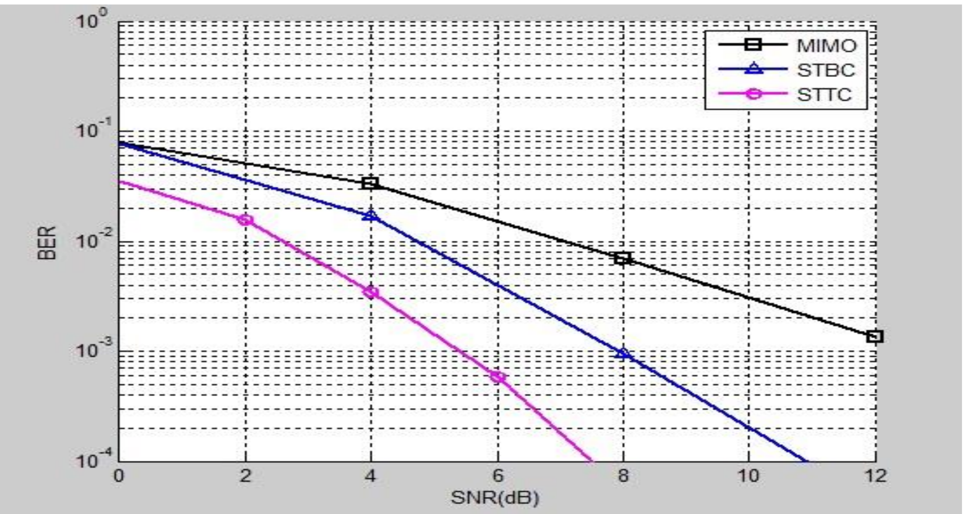

Fig.10 BER versus SNR for 2*2 MIMO with and without STC

تحسين نظام متعدد المداخل متعدد المخارج المشفر باستخدام الشبكة العصبية الاصطناعية

رعد حمدان ظاهر[1] ,حسين يوسف راضي[2] وغسان خزعل علي[3]
[1] أ.م. قسم الهندسة الكهربائية, كلية الهندسة, الجامعة المستنصرية
[2,3] م.م. قسم هندسة الحاسوب / كلية الهندسة /جامعة ديالى

الخلاصة:

الحاجة لمعادلات عالية لنقل البيانات, التطور السريع في أجهزة الاتصالات المحمولة ونظم اتصالات الانترنيت ومحدودية الطيف الراديوي, حثت الباحثين لإيجاد تقنية خاصة لزيادة الاتصال وتقليل نسبة الخطأ في البيانات المستلمة في هذه الورقة تم تحسين سعة القناة الناقلة للمعلومات باستخدام بإستخدام تشفير (STC) وجد أن سعة القناة لنظام متعدد المداخل متعدد المخارج هو الافضل بين بقية أنظمة الاتصالات الاخرى وقد وجد أيضاً انه نسبة الخطأ في المعلومات المستلمة يمكن تقليلها الى أقل ما يمكن باستخدام الشبكات العصبية الاصطناعية