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Samar Jyoti Saikia

Dept of Electronics and Communication Technology Gauhati University, Guwahati-781014,
samar_saikia@yahoo.com

Kandarpa Kumar Sarma

Department of Electronics and Communication Technology, Gauhati University, Guwahati, Assam-781014,
kandarpaks@gmail.com

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ANN based STBC-MIMO set-up for Wireless Communication

¹Samar Jyoti Saikia, ²Kandarpa Kumar Sarma

Dept of Electronics and Communication Technology
Gauhati University, Guwahati-781014
Email: ¹samar_saikia@yahoo.com, ²kandarpaks@gmail.com

Abstract— Space Time Block Code is a powerful tool for improving performance in wireless communication. Multiple input multiple outputs (MIMO) are a promising application of multiple antennas at both transmitter and receiver to improve communication performance by achieving spatial diversity. MIMO, when used with appropriate STBC coding techniques and proper channel estimation, can achieve huge performance gains in multipath fading wireless links. Our work aims to simulate the space-time coding over worst fading environment and evaluate its performance in terms of BER. An Artificial Neural Network (ANN) can be used to provide an estimate of the channel which help to mitigate some of the deficiencies of multi-user transmission.

Keywords- Rayleigh fading, MIMO, STBC, ANN and BER

INTRODUCTION

Wireless communication undergoes attenuations in most situations due to multipath fading and interferences. Diversity techniques can be used to reliably determine the transmitted signal. MIMO architectures are useful for combined transmit receive diversity [1]. When used in parallel mode of transmission, MIMO systems offer high data rates in a narrow bandwidth. MIMO systems have the potential for increased capacity in rich multipath environments. STBC can be used for generating the MIMO channel by the multiple transmitters and receivers. Alamouti space-time block codes (STBC) is highly dependent on the knowledge of the received signal. Our aim is to reduce the dependency. The proposed schemes derive estimates of the received signal directly from the transmitted signal by using Artificial Neural Network.

I. THEORETICAL BACKGROUND

The wireless channel can be described as a function of time and space. The received signal may be multiple delayed receptions of the transmitted signals due to reflections suffered in buildings, hills, cars and other obstacles, etc. Absence of a line-of-sight (LOS) path and prominence of non-LOS (NLOS) components, varying attenuation, time delay, phase shift etc in each path, constructive and destructive addition of the constituent paths due to multiple phase shifts etc. results in fluctuations in the signal strength.

These factors act together to give rise to a phenomenon referred as multipath fading [2] [3].

A. Rayleigh multipath Fading channels

In Rayleigh fading [3] there is no LOS component is present. It is typically encountered in land mobile channels in urban areas where there are many obstacles which make LOS paths rare. This represents the worst fading case.

The received pass-band signal without noise after transmitted unmodulated carrier signal $\cos(2\pi f_c t)$ can be written as

$$\begin{aligned} x(t) &= \sum_i \alpha_i(t) \left(2\pi f_c t - \tau_i(t) \right) \\ &= \text{Re} \left[\sum_i \alpha_i(t) e^{-j2\pi f_c \tau_i(t)} e^{j2\pi f_c t} \right] \end{aligned}$$

Here Re represent the real part of the quantity within its brackets, $\alpha_i(t)$ is time-varying attenuation factor of the i^{th} propagation delay $\tau_i(t)$ is the time-varying delay and f_c is the carrier frequency.

The equivalent baseband signal can then be expressed as:

$$h(t) = \sum_i \alpha_i(t) e^{-j2\pi f_c \tau_i(t)}$$

When the components of $h(t)$ are independent the probability density function of the amplitude $r = |h| = \gamma$ has Rayleigh pdf:

$$f(r) = \frac{r}{\sigma^2} e^{-\frac{r}{\sigma^2}}$$

where $E\{r^2\} = 2\sigma^2$ and $r \geq 0$.

This is known as Rayleigh fading.

B. Multi-Input-Multi-Output (MIMO)

MIMO technology offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability or diversity. MIMO can also be used to increase capacity which may very linearly with the number of antennas [4].

In MIMO system the received signal y can be given by the following matrix equation:

$$y = Hx + n$$

Here, x is the transmitted signal vector; n is the statistically independent complex zero-mean Gaussian random variables with equal variance [5]. H is channel matrix between transmitter and receiver.

C. Space Time Codes

Space-time code (STC) is a method usually employed into wireless communication systems to improve the reliability of data transmission using multiple antennas [6] [7] [8]. STCs rely on transmitting multiple, redundant copies of a data stream to the receiver in the hope that at least some of them will survive the physical path between transmission and reception in a good state to allow reliable decoding.

STBC acts on a block of data. It provides diversity gain but not coding gain [7] [8]. So the computational complexity of STBC is less. An STBC is usually represented by a matrix. Each row represents a time slot and each column represents one antenna's transmissions over time. The Figure 1 shows a STBC matrix.

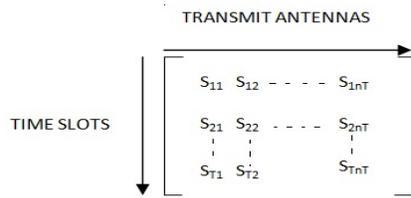


Figure 1: Matrix representation of STBC

In this work, we have used Alamouti space-time block codes and evaluate their performance in Rayleigh fading channels using artificial Neural Network.

D. Alamouti Space Time Block Codes

In Alamouti scheme at the transmitter side, a block of two symbols are taken from the source data and sent to the modulator. After that, Alamouti space-time encoder takes the two modulated symbols. Let us consider s_1 and s_2 at a time and creates encoding matrix H where the symbols s_1 and s_2 are mapped to two transmit antennas in two transmit times as defined in the following

$$H = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1 \end{bmatrix}$$

where the symbol $*$ represents the complex conjugate. The encoders outputs are transmitted in two consecutive transmission periods from the two transmit antennas. In the first transmission period, the signal s_1 is transmitted from antenna one and the signal s_2 are transmitted from antenna two, simultaneously. In the second transmission period, the signal $-s_2^*$ is transmitted from antenna one and the signal s_1^* is transmitted from antenna two.

At the receiver side, when signals are received, they are first combined and then at detector the transmitted signal is recovered.

E. Artificial Neural Network

An Artificial Neural Network (ANN) is a massively parallel distributed processor that acquires knowledge through a learning (training) process. A generic ANN can be defined as a computational system consisting of a set of highly interconnected processing elements, called neurons, which process information as a response to external stimuli.

Two common practices of channel estimation in MIMO systems are blind and non-blind methods. Blind estimation techniques do not require training sequences non-blind estimation where observations are made corresponding to data and pilot are used jointly. Pure training-based schemes can be considered as an advantage when an accurate and reliable MIMO channel needs to be obtained. However, this could also be a disadvantage when bandwidth efficiency is required. This is because pure training-based schemes reduce the bandwidth efficiency considerably due to the use of a long training sequence which is necessarily needed in order to obtain a reliable MIMO channel estimate. An ANN can be used to provide an estimate of the channel which may help to mitigate some of the deficiencies of multi-user transmission. The ANN can be trained to make it robust enough to deal with multiple channel types and formulate a set-up which can be used to investigate if it can lead to an improvement in Bit Error Rate [2].

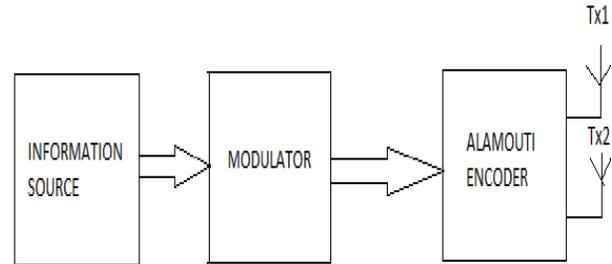


Figure 2: Alamouti space-time encoder diagram.

II. SYSTEM MODEL

The system model comprises of the blocks as shown in Figure 3. The signal is sent to the BPSK modulator then it is encoded with Alamouti STBC Encoder and transmitted through the channel. At the receiver end there is a ANN based channel estimator which will estimate the STBC encoded signal and then decode it and passed to the demodulator and the desired signal is obtained and BER is compared between the transmitted signal and the received signal.

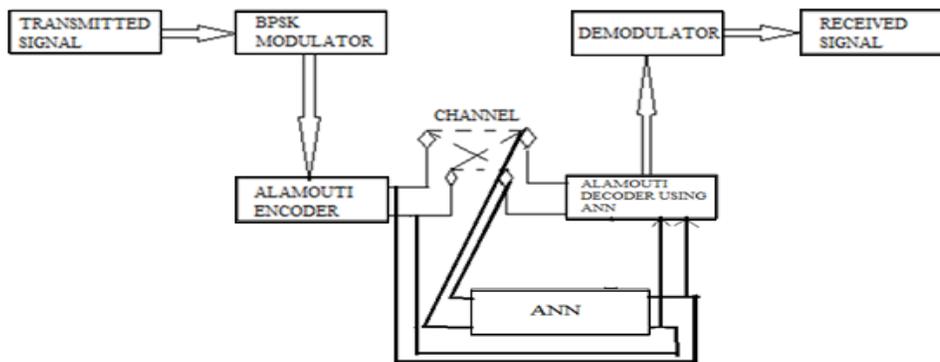


Figure 3: System Model

III. APPLICATION OF ANN FOR CHANNEL ESTIMATION

The application of the artificial neural network (ANN) considers two aspects. The first is the training of the neural network and the second stage is to test the trained ANN under varied condition to check its robustness under a range of channel conditions [2].

The received signal is given by

$$y = Hx + n$$

Here we have evaluated the channel using,

$$H = y/x$$

In training the neural network we have assumed that the AWGN 'n' is known or can be ignored. While the training the ANN the received signal y is given as input and the transmitted signal x is given as output so that we can estimate the channel properly.

The ANN is a three layered network with one input, one hidden and one output layer. The weights of the network are updated by using back propagation algorithm. Training a neural network by back-propagation involves three stages: the feed-forward of the input training pattern, the back propagation of the associated error and adjustment of the weights.

IV. EXPERIMENTAL DETAILS AND RESULTS

The distortions generated due to multipath propagation and related fading can be reduced using multiple antennas at both transmitter and receiver sides. In this work we have randomly generated data of length 10^5 bits. Then we have design a BPSK and DBPSK modulator. The data generated is then modulated using the two modulators. Now the modulated data is encoded in an Alamouti STBC encoder and send through the two transmitters. The two receivers receive the data and

the channel is estimated using ANN. We have used three networks, two networks for channel estimation and the remaining is for STBC decoding. Now the decoded data is demodulated and BER performance is recorded.

Table I: Details of ANN set up

ANN	MLP
Data Set Size	Training:10000 Testing:10000
Training Type	TRAINIDX
Maximum No. of Epochs	5000
Variance in Training Data	50%

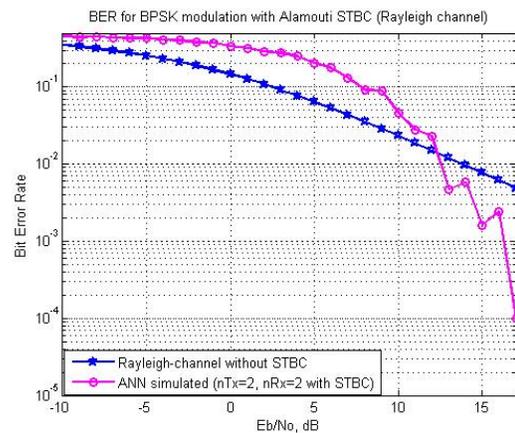


Figure 4: Plot of BER of BPSK signals in MIMO set-up using STBC code in fading channels using ANN.

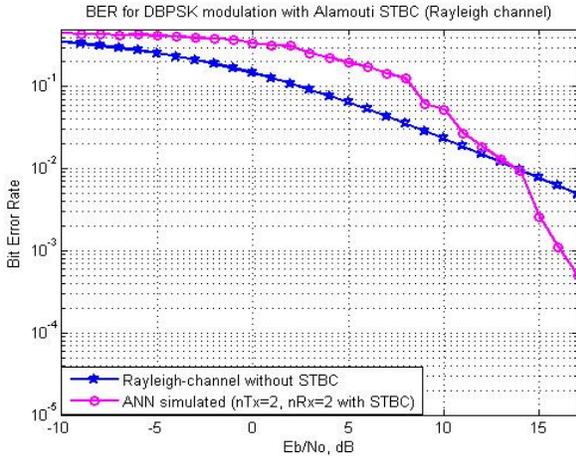


Figure 5: Plot of BER of DBPSK signals in MIMO set-up using STBC code in fading channels using ANN.

The Rayleigh faded channel is created by following the Clarke-Gans model. The ANN is trained with 10000 bits. With these bits during training the ANN shows 100% accuracy when validated with the same set during training.

The ANN gives a performance goal of around 10^{-3} which is attained within a time of around 75 seconds. This time, however, varies with the data size and decreases with smaller blocks of data. Figures 4 and 5 show the BER performance of the BPSK and DBPSK signal with Alamouti STBC in Rayleigh fading channel. It is found that the performance with STBC is better than the signal without STBC.

Table II: Performance of ANN set up

Networks	Data Set Size	Epochs	Time in secs	MSE
Net1	10000	1380	90	10^{-7}
Net2	10000	1456	120	10^{-6}
Net3	10000	950	80	10^{-7}

Table III: BER values generated by a trained ANN for a Rayleigh multipath fading channel

SL No	SNR in dB	BER value
1	5	1.02×10^{-1}
2	12	0.8×10^{-3}

3	15	0.04×10^{-4}
4	20	0.001×10^{-5}

The sample size considered for training includes Rayleigh multipath fading channel model generated using AWGN of values in the range ± 8 dB. The testing includes a range of signal conditions with SNR values ranging from -10 to 10 dB.

V. CONCLUSION

In this work we have analyzed and simulate the MIMO system with Alamouti STBC in Rayleigh fading channel and estimate the channel using ANN. The application of ANN in Rayleigh fading channel can improve the performance in a wireless communication system. The performance derived makes the approach a reliable means for study and analysis of design of reception methods of MIMO system.

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