Chapter 2
STBC Decoding with ANN in Wireless Communication

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Abstract Diversity techniques can be used to reduce the ill effects of multipath fading observed in wireless channels. Multiple-input-multiple-output (MIMO) technology is a promising application of multiple antennas at both transmitter and receiver to improve communication performance by achieving spatial diversity. The concept of space–time coding has arisen from diversity techniques using smart antennas. With the implementation of data coding and signal processing at both sides of transmitter and receiver, space–time coding now is more effective than traditional diversity techniques. Space–time block codes (STBC) were designed to achieve the maximum diversity order for the given number of transmit and receive antennas subject to the constraint of having a simple linear decoding algorithm. Application of ANNs for STBC decoding is such an area which offers solutions to tackle the intricacies associated with the fluctuations observed in multipath propagation which is always the problem area in wireless communication.

Keywords Multi-input-multi-output (MIMO) system · Space–time block codes (STBC) · Artificial neural network (ANN) · Multipath fading · Rayleigh fading channels · Rician fading channels

2.1 Introduction

During the last decade, in wireless local area networks and cellular mobile systems, the demand for capacity has grown explosively. The need for wireless Internet access and multimedia applications requires an increase in information throughput with

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order of magnitude compared to the data rates made available by today's technology. The use of multiple antennas at both the transmitters and receivers in the system makes this increase in data rate possible. Space–time wireless technology that uses multiple antennas along with appropriate signaling and receiver techniques offers a powerful tool for improving wireless performance. In various wireless networks and cellular mobile standards, some aspects of this technology have already been incorporated. More advanced MIMO techniques are planned for future mobile networks, wireless local area network (LANs), and wide area network (WANs). Here, we discuss the use of STBC codes in MIMO systems implemented using artificial neural network (ANN). The primary reason behind the use of ANN for such a purpose is the fact the ANN is a learning-based system and can use the knowledge acquired for subsequent processing.

2.2 Background

Most work on wireless communications had focused on having an antenna array at only one end of the wireless link, usually at the receiver. Seminal papers by Foschini and Gans [1], Foschini [2], and Telatar [3] enlarged the scope of wireless communication possibilities by showing that when antenna arrays are used at both ends of a link, substantial capacity gains are enabled by the highly scattering environment. Many established communication systems use receive diversity at the base station. For example, global system for mobile communications (GSM) [4] base station typically has two receive antennas. This receive technology is used to improve the quality of the uplink from mobile to base station without adding any cost, size, or power consumption to the mobile [5].

2.2.1 Multi-Input-Multi-Output (MIMO) System

Multiple-input and multiple-output system contains multiple antennas at both transmitter and receiver. Figure 2.1 shows a MIMO system with TxM transmits antennas and RxN receive antennas. The received signal Y can be given by the following matrix equation:

$$Y = Hx + n \tag{2.1}$$

Here, x is the transmitted signal vector, n is the statistically independent complex zero-mean Gaussian random variables with equal variance [6], H is channel between transmitter and receiver which can be represented by matrix $T_{xM} \times R_{xN}$. The channel matrix is formed by h_{MN} which are gain coefficients modeling random phase shifts and channel gains.

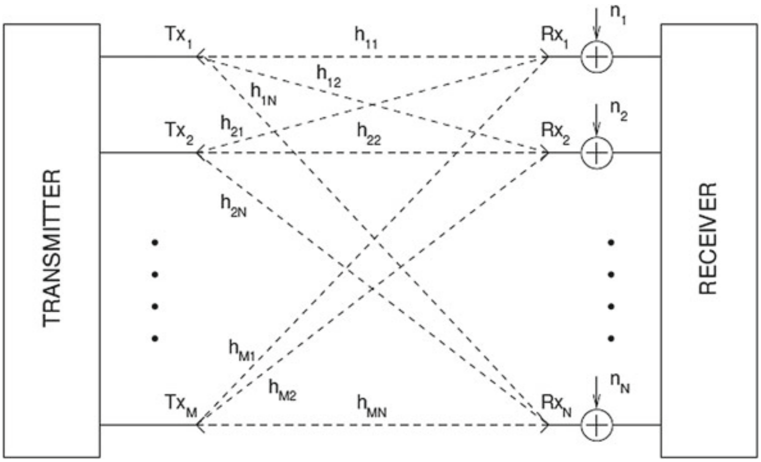

Fig. 2.1 MIMO system model

2.2.2 Statistical Models for Wireless Channels

In wireless communication, the received signal is the combination of many replicas of the original signal impinging on receiver from many different paths. The signals on these different paths can constructively or destructively interfere with each other. This is referred as multipath fading [7, 8].

2.2.2.1 Rayleigh Fading Channels

In Rayleigh fading [3], no line-of-sight (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.

2.2.2.2 Rician Fading Channels

Wireless channels where a LOS component is present due to absence of high rise structures is modeled by the Rician fading. If a LOS path is present (or one path which dominates the rest), the Gaussian approximation usually preferred needs to be reconsidered.

2.2.2.3 Space–Time Coding (STC)

Space–time coding is used in wireless communication for 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. STC can be divided into three types. First space–time trellis code (STTC) which provides both coding and diversity gain [9]. The second type of STC is space–time turbo codes (STTuC), a combination of space–time coding and turbo coding [10]. The third type is space–time block codes (STBC) which provides diversity gain but not coding gain [10, 11]. So it is less complex than STTC and STTuC.

2.2.2.4 Artificial Neural Network (ANN)

An artificial neural network (ANN) is a parallel distributed processor that acquires knowledge through a learning (training) process. An artificial neuron is a simplistic representation that emulates the signal integration and threshold firing behavior of biological neurons by means of mathematical equations. The advantages of ANN are their nonlinearity, input–output mapping, adaptivity, evidential response, contextual information, fault tolerance, uniformity of analysis and design, neurobiological analogy, and diversity of types and topologies.

2.3 System Model

The proposed system model comprises of the blocks as shown in Fig. 2.2. A signal is generated using 10^6 b. The signal is sent to the modulator where it is modulated with different modulation schemes, then it is encoded with Alamouti STBC encoder and transmitted through the multipath fading channel. After the receiver has received the signal it is decoded in Alamouti decoder and passed to the demodulator and the desired signal is obtained and BER is compared between the transmitted signal and the received signal. The ANN in feedforward form trained with back propagation (BP) algorithm is used to perform the STBC decoding in the MIMO setup.

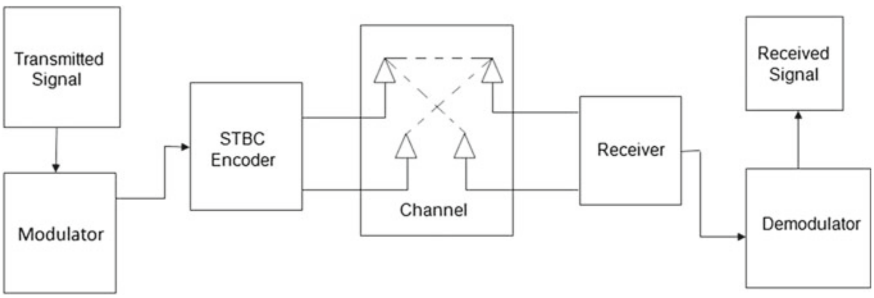

Fig. 2.2 System model

Table 2.1 Parameters used for simulating the Rayleigh channel

Channel type	Rayleigh channel
Input sample period	$1.0000e^{-005}$
Doppler spectrum	$[1 \times 1 Doppler.jakes]$
Max doppler shift	100 Hz
Path delays	$[01.500e^{-005}\ 3.2000e^{-005}]$
Average path gain in dB	$[0\ -3\ -3]$
Path gains	$[0.3814 - 0.1735i - 0.0962 - 0.4042i\ 0.1016 - 0.1244i]$
Channel filter delay	4
Number of sample processes	100

2.3.1 Simulating the Rayleigh Channel

We have simulated a Rayleigh channel having three multipath components. Table 2.1 gives the parameters for simulating the Rayleigh channel.

2.3.2 Comparison Between Three Channels

Figure 2.3 shows BER versus Eb/No performance of the Alamouti scheme with one transmitter and one receiver with coherent BPSK modulation. Here, we can see that BER performance is poor. For -10 dB we get the BER of 10^{-1}, at 0 dB we get $10^{-1.5}$ and at 10 dB the BER is $10^{-2.5}$. Next, we have considered a system of two transmitters and one receiver in Fig. 2.4. Here theoretical and simulated BER performance of BPSK signals in Rayleigh fading channel is observed. We can see that the theoretical and simulated BER is almost the same and BER performance is better than one transmitter and one receiver system. At -10 dB we get BER of 10^{-1}, at 0 dB BER of $10^{-2.5}$ is recorded, and about 10 dB the BER performance is about $10^{-4.5}$.

The BER performance of BPSK modulated signal in AWGN, Rayleigh fading channel, and in MIMO channel is compared. As expected, Fig. 2.5 shows that the BER performance of the BPSK signal with Alamouti STBC with two transmitters and two receivers in Rayleigh fading channel is better than the signal without STBC. Table 2.2 gives the BER comparison of the three channels.

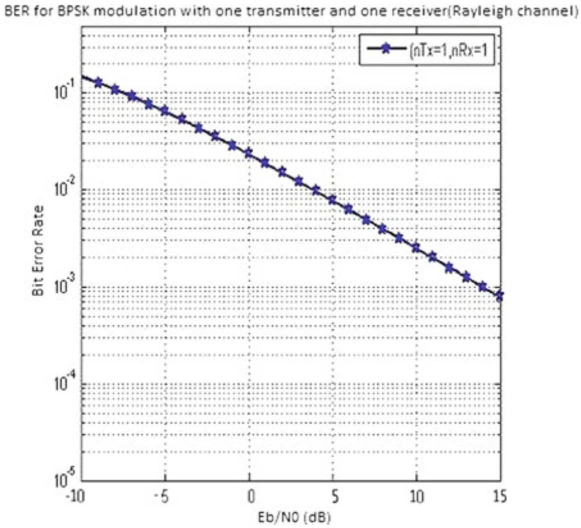

Fig. 2.3 BER for BPSK modulation with one transmitter and one receiver (Rayleigh channel)

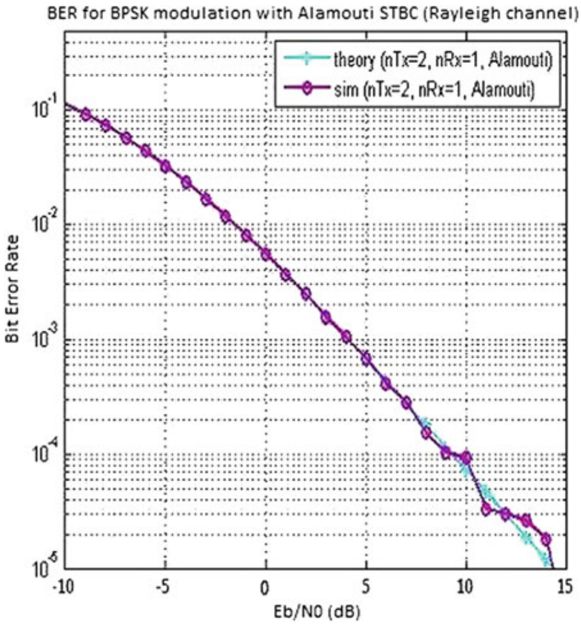

Fig. 2.4 BER of BPSK modulation with Alamouti STBC (Rayleigh channel)

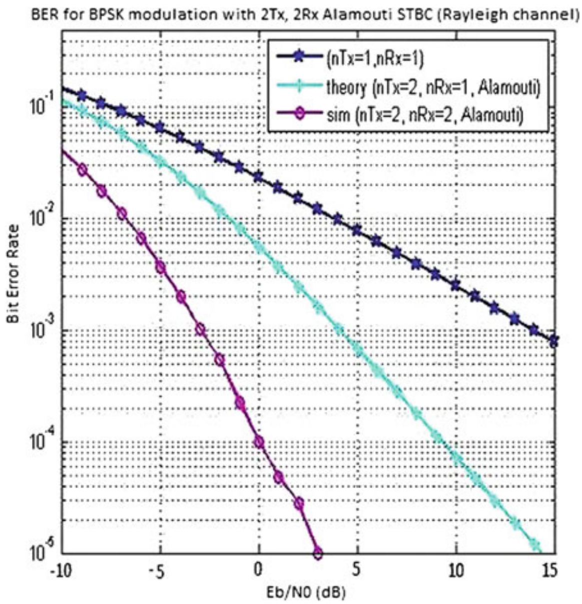

Fig. 2.5 BER of BPSK modulation with 2Tx and 2Rx Alamouti STBC (Rayleigh channel)

Table 2.2 BER performance at AWGN, Rayleigh, and MIMO channel

BER in dB	AWGN channel	Rayleigh channel	MIMO channel
−10	$10^{-0.5}$	$10^{-2.5}$	$10^{-0.9}$
5	10^{-1}	$10^{-0.5}$	$10^{-1.5}$
10	10^{-3}	$10^{-1.5}$	10^{-4}

2.3.3 Application of ANN for STBC Decoding

The ANN can be used for STBC decoding. It can also provide estimation of the channel which may help to mitigate some of the deficiencies of multi-user transmission. In ANN based systems, the multipath fading can be minimized by training the ANN and we can have a system with better bit error rates (BERs).

The ANN as multilayer perceptron (MLP) is trained using BP algorithm which updates the connecting weights. This adaptive updating of the MLP is continued till the performance goal is met. To train the ANNs, the setup we have used the received signal as the input signal and the transmitted signal is the reference signal or target. Tables 2.3 and 2.4 give the details of ANN setup.

Table 2.3 Details of ANN setup

ANN	MLP
Data set size	Training—10000 Testing—10000
Training type	TRAINGDX
Maximum number of epochs	1500
Variance in training data	50 %

Table 2.4 Performance of ANN

Networks	Data set size	Epochs	Time (s)	MSE
Net 1	10,000	1380	90	10^{-7}
Net 2	10,000	1456	120	10^{-7}
Net 3	10,000	950	80	10^{-7}

2.3.4 Result and Discussion

Here the modulated data is encoded in STBC encoder and sent through the two transmitters. The received data is decoded using ANN-based STBC decoding. The decoded data is demodulated and BER performance is evaluated. The ANN is trained with 10,000 b. The ANN is given a performance goal of around 10^{-3} which is attained after certain number of sessions, though the time taken is around 75 s. Figures 2.6 and 2.7 show the BER values of BPSK and QPSK signal using ANN for STBC decoding in Rayleigh fading channel. The values of the SNR varies from −10 to +20 dB.

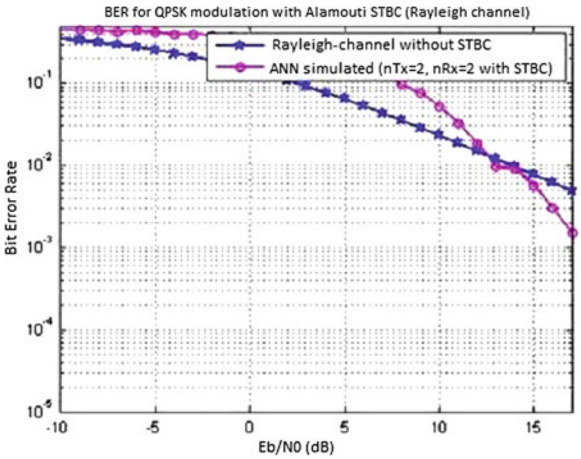

Fig. 2.6 BER plot of QPSK signals in MIMO set-up using STBC code in Rayleigh

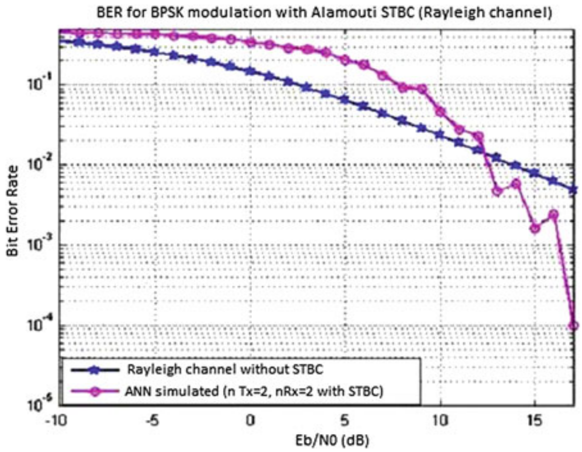

Fig. 2.7 BER plot of BPSK signals in MIMO set-up using STBC code in Rayleigh

2.4 Conclusion

STBC is used to achieve the maximum diversity order for the given number of transmit and receive antennas subject to the constraint of having a simple linear decoding algorithm. One of the viable means of better STBC decoding is the use of soft computing tools like the ANNs. In this work, we have analyzed and simulate the MIMO system with different modulation schemes and STBC in Rayleigh fading channel. We have used ANN for the decoding of STBC coded signal. 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 the design of reception methods of MIMO system.

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