Simulation & performance Analysis of Space Time Block Code

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***Abstract*—Multipath fading has a very strong detrimental effect on wireless communication systems. To combat against the fading, variety of diversity techniques had been propose. Previously, multipath fading in multiple antennas wireless systems was mostly dealt with by time diversity, frequency diversity and receive antenna diversity. The first Space-Time Code was introduced by Tarokh et al. from AT&T research lab [1] to provide transmit diversity in wireless fading channels by employ multiple transmit antennas. One example of Space-Time code is Space-Time block Code (STBC). Probably the most outstanding and simple STBC is Alamouti's Code [2]. In this paper I have simulated space time block code and compared performance with various modulation techniques.**

I. Introduction

The fundamental problem which makes reliable wireless communication extremely difficult is time-varying multipath fading. It is this problem which makes transmission over a wireless channel a challenge when compared to fiber, coaxial cable, line-of-sight microwave or even satellite transmissions. In recent literature, variety diversity schemes are proposed to mitigate the multipath fading channel. To name a few, time diversity, frequency diversity and receive antenna diversity. Time interleaving, probably together with error correction coding, can provide diversity improvement. The same holds true for frequency domain. In spread spectrum, intension frequency offset could also provide diversity improvement. However, time interleaving results in large delays when the channel's fading rate is slow. On the other hand, spread spectrum techniques are ineffective when the coherence bandwidth of the channel is larger than the spreading bandwidth. Probably the most widely employ technique is receive antenna diversity. To use multiple antennas at the receiver and performing combining and switching in order to improve the quality of the received signal. The major disadvantage of this technique comes from the fact that it increases complexity in terms of cost, size and power of the remote unit. Therefore, for commercial reasons, transmit diversity schemes are very attractive with their promising feature such as: high data rate across both up-link and down-link between base station and remote units and increase space diversity by adding more base stations.

One main type of Space-Time code is Space-Time block code (STBC). STBC operated on a block of input symbols, producing a code matrix which columns represent different antennas (Space) and rows represent time. By comparing a single block code transmits from single

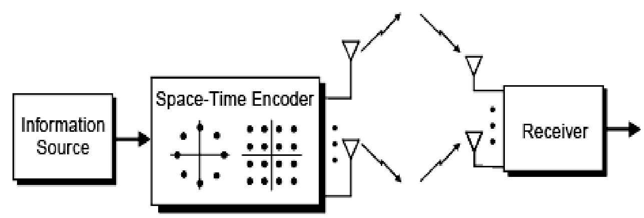


Fig. 1: System Block Diagram

Antenna, space-time block code generally does not provide coding gain. A major feature of STBC is that it provides full diversity and very simple decoding scheme.

II. MIMO System Model

Consider a Multiple Input Multiple Output (MIMO) radio mobile communication system as depicted above where the transmitter radio station equipped with transmit antennas and the receiver side has receive antennas. At each time slot (or time instant)t, signals, d_t^i, i=1,2,…,L_t are transmitted simultaneously from the transmit antennas. The channel is flat-fading and the path gain from transmit antenna i to receive antenna j is denoted by $h_{i,j}$. The path gains are modeled as samples of independent complex Gaussian random variables with variance 0.5 per real dimension. Assume that signals received at different antennas experience independent fading. For Quasi-static fading, the path gains are assumed relative constant over a frame length and varied from one frame to other.At time instant t, the signal r_t^j, received at antenna j is given by

$$r_t^j = \sum_{i=1}^{L_t} h_{j,i} d_t^i + n_t^j ,$$

Where the noise samples are i.i.d. zero mean complex Gaussian with variance

$$\sigma^2 = \frac{1}{(2E_s / N_0)} = \frac{1}{(2 \cdot SNR)}$$

per dimension. The average energy of the symbols transmitted from each antenna is normalized to one, so that the average power of the received signal at each receive antenna is L_t.

Another observation from the diagram is that at each particular time slot, the Space-Time Encoder maps the data symbols into a codeword that actually transmits out at the antennas. In matrix representation, we have

$$R = \begin{bmatrix} r_1 \\ \cdot \\ \cdot \\ \cdot \\ r_{L_t} \end{bmatrix} = HD + N,$$

Where R is the received symbol vector, H is the scattering function with dimension $L_r \times L_t$, D is the data symbol vector and N is the AWGN vector. H could be represents as,

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdot & \cdot & \cdot & h_{1K} \\ h_{21} & h_{22} & \cdot & \cdot & \cdot & h_{2K} \\ \cdot & \cdot & & & & \\ \cdot & & \cdot & & & \\ \cdot & & & \cdot & & \\ h_{M1} & h_{M2} & & & & h_{MK} \end{bmatrix}.$$

Note, D records all the data symbols and could be represents as

$$D = \begin{bmatrix} d_t^{1} \\ d^{2}_t \\ \cdot \\ \cdot \\ \cdot \\ d_t^{L_t} \end{bmatrix}.$$

It is assumed that Channel State Information (CSI) is not known to the receiver; hence channel estimation is required for decoding at the Maximum Likelihood (ML) decoder.

III. Space Time Block Code

A practical yet straightforward STBC is Alamouti's code, which he proposed in 1998. Alamouti's code translates receiver diversity into transmitter diversity by simple processing acrosstwo transmit antennas at the transmitter side.

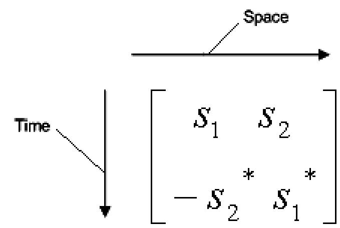


Fig. 2: Alamouti's Two Antenna Transmit Diversity Scheme

At a given time slots, two signal symbols are simultaneously transmitted from the two antennas, namely d_0 from transmit antenna 0 and d_1 from transmit antenna 1. In the consecutive time slot,-d_1^* is transmitted from antenna 0 and d_0 is transmitted from antenna 1. Without loss of generality, $h_0(t)$ denote channel coefficient from transmit antenna 0 to receive antenna at time instant t and $h_0(t+T)$ denote channel coefficient from transmit antenna 0 to receive antenna at next time instant t+T; similarly, let *h1(t)* denote channel coefficient from transmit antenna 1. If we assume that fading is not constant across two consecutive symbols, we can write

$$h_0(t) \neq h_0(t+T)$$
$$h_1(t) \neq h_1(t+T)$$

Where T is the symbol period. The receive signals are

$$r_o = r(t) = h_o(t)d_o + h_1(t)d_1 + n_o$$
$$r_1 = r(t+T) = -h_o(t+T)d_1^* + h_1(t+T)d_0^* + n_1$$

where r_0 and r_1 are the received signals at time t_0 and t_1.The combiner which is shown in Fig. 2 is known as Maximum Ratio Receive Combining (MRRC). It combines the received signals as follows:

$$\hat{d}_0 = [h_0(t+T)r_0^* + h_1^*(t)r_1]^*$$
$$\hat{d}_1 = [h_1(t+T)r_0^* - h_0^*(t)r_1]^*$$

Upon simplifying the above expression for $\hat{d}_0$ and $\hat{d}_1$ which is the output of the MRRC combiner, we arrive at the following two equations,

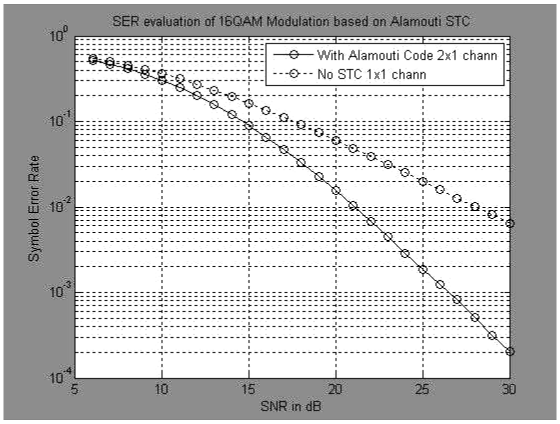
$$\hat{d}_0 = [h_0(t)h_0^*(t+T) + h_1(t)h_1^*(t+T)]d_0 + h_0^*(t+T)n_0 + h_1(t)n_1^*$$
$$\hat{d}_1 = [h_0(t)h_0^*(t+T) + h_1(t)h_1^*(t+T)]d_1 + h_1^*(t+T)n_0 - h_0(t)n_0^*$$

the above results are sent to maximum likelihood detector, which minimize the following decision metric for over all possible values of d_0 and d_1.

$$|r_0 - h_0(t)d_0 - h_1(t)d_1|^2 + |r_1 + h_0(t+T)d_1^* - h_1(t+T)d_1^*|^2$$

The above ML decoder have different decision rule for different complex constellation scheme that was used.

IV. SIMULATION RESULT



Space time block codes are simulated in MATLAB for 16-QAM modulation technique. The above figure shows improvement in BER for given signal to noise ratio with STBC.

V. CONCLUSION

Alamouti's code is simple and elegant in the sense that in transform receive diversity to transmit diversity. It requires no feedback from the receiver to transmitter. Since redundancy is applied in space across multiple antennas, it has no bandwidth expansion.

REFERENCES

[1] V. Tarokh, N. Seshadri, and A.R. Calderbank, "Space-time codes for high data rates wireless communications: Performance criterion and code construction," IEEE Trans. Inform. Theory, vol. 44, pp. 744-765, 1998.

[2] S.M. Alamouti, "Simple transmit diversity technique for wireless communications," IEEE Journal on Select Areas in Communications, vol. 16, pp. 1451-1458, 1998.

[3] Hamid Zafarkhani, "Space Time Coding" – Springer