International Journal of Engineering Research and General Science Volume 2, Issue 4, June-July, 2014
ISSN 2091-2730

Performance Evaluation of Time Reversed Space Time Block Codes in Nakagami-m Fading Channel

Subhashini Dhiman[1], Surbhi Sharma[1]

[1]Department of Electronics and Communication, Thapar University, Patiala

E-mail Subhashini.dhiman@gmail.com

Abstract— Two transmit and one receive antenna design was presented by Alamouti in [5], where channel coefficients at adjacent time intervals are assumed to be same. When the channel suffers from intersymbol interference (ISI) due to large delay spread, Time Reversal Space Time Block Codes (TR-STBC) achieves better performance [8]. In frequency selective Multiple Input Multiple Output (MIMO) channel environment, loss of 'quasi static' assumption produce the ISI in TR-STBC. In this paper, a low complexity receiver is evaluated to mitigate the effect of intersymbol interference caused due to 'quasi static' assumption in TR-STBC in Nakagami-m fading channel.

Keywords— Space time block codes (STBC), Time Reversal Space Time Block Codes (TR-STBC), Intersymbol interference (ISI), Multiple Input Multiple Output (MIMO),fast fading, Nakagami channel, Orthogonal frequency time division multiplexing (OFDM)

INTRODUCTION

Wireless communications has emerged as one of the fastest growing sectors of the communications industry. Wireless networks widely used today comprise: Wireless Local Area Networks, cellular networks, personal area networks and wireless sensor networks. Use of Wireless communication for data application such as internet and multimedia access is increased. So demand for reliable high-data-rate services is elevated quickly. However, it is hard to achieve reliable wireless transmission due to time varying multipath fading of wireless channel. Also, the range and data rate of wireless networks is limited. To enhance the data rates and the quality, multiple antennas can be used at the receiver to obtain the diversity. By utilizing multiple antennas at transmitter and receiver, significant capacity advantages can be obtained in wireless system. In a Multiple Input Multiple Output (MIMO) system, multiple transmit and receive antennas, can elevate the capacity of the transmission link. This extra capacity can be utilized to enlarge the diversity gain of the system. This results in development of Lucent's "Bell-Labs layered space-time" (BLAST) architecture [1]-[4] and space time block codes (STBCs) [5]–[7] to attain some of this capacity. Space time coding has utilized diversity and coding gains to achieve high data rate transmission. STBC gained popularity because of their capability to provide simple linear processing for maximum likelihood decoding at the receiver.

Time reversal space time block codes (TR STBC)

STBC scheme presented by Alamouti in [5] is a transmit diversity scheme, where two transmit and one receive antenna was used. The scheme was proposed for flat fading channel where the fading is assumed to be constant over two consecutive symbols. But further same scheme approach was applied to the frequency selective channels. Particularly, methods such as time reversal [8], OFDM [9], [10], and single-carrier Frequency domain equalization [11]–[13] have gained attention. But both OFDM and SC-FDE schemes, depends on transmission of cyclic prefix, which makes the channel matrix circulant. This characteristic diagonalizes the matrices by FFT and permits effective equalization in the frequency domain. In contrast, TR-STBC applies the Alamouti's scheme on blocks instead of symbols in the time domain. At the receiver, spatiotemporal matched filter is used for transforming the received signal into block decoding and permits the perfect decoupling between the blocks [8], [13].

TR STBC System model

TR STBC expands transmission of Alamouti's scheme for frequency selective channels. It encodes normally arranged and time reversed blocks of symbols together [8], [14]. The data stream $y(t)$ is divided into two separate streams, $y_1(t)$ and $y_2(t)$. Then these two streams are transmitted from first antenna and second antenna in (alternating) time intervals. At first time interval, $y_1(t)$ is transmitted form antenna 1 and $y_2(t)$ is transmitted from antenna 2. So the corresponding received signal at the transmitter end is

$$r_1(t) = h_{1,t} y_1(t) + h_{2,t} y_2(t) + n_1(t) \quad (1)$$

where $h_{1,t}$ is the channel between transmit antenna 1 and the receive antenna. And $n_1(t)$ is the noise sample at the first time interval.

At the second time interval, $-\overline{y_2}\,{*}(t)$ is transmitted form antenna 1 and $\overline{y_1}\,{*}(t)$ is transmitted from antenna 2. Where (.)* denotes the complex conjugate. And $\overline{(.)}$ represents the time reversed signal. So the received signal is

$$\overline{r_2}(t) = -h_{1,t+1}\overline{y_2}\,{*}(t) + h_{2,t+1}\overline{y_1}\,{*}(t) + \overline{n_2}\,{*}(t) \quad (2)$$

where $n_2(t)$ is the noise sample at the 2nd time interval.

Case 1: Slow fading : For slow fading in time we have, $h_{1,t} = h_{1,t+1}$

So, (2) can be written as $r_2(t) = -\overline{h_{1,t}}\,{*}y_2(t) + \overline{h_{2,t}}\,{*}y_1(t) + n_2(t)$

where $\overline{hi}$ is the time-reversed expression of hi .So we can rewrite following:

$$\begin{pmatrix} r_1(t) \\ r_2(t) \end{pmatrix} = \begin{pmatrix} h_{1,t} & h_{2,t} \\ \overline{h}_{2,t}* & -\overline{h}_{1,t}* \end{pmatrix} \begin{pmatrix} y_1(t) \\ y_2(t) \end{pmatrix} + \begin{pmatrix} n_1(t) \\ n_2(t) \end{pmatrix}, \text{ where } H = \begin{pmatrix} h_{1,t} & h_{2,t} \\ \overline{h}_{2,t}* & -\overline{h}_{1,t}* \end{pmatrix}$$

At the receiver, received signal is multiplied by H^H and a decoupled matched filter output was produced.

So, $z(t) = H^H r(t) = H^H H y(t) + H^H n(t)$

which perfectly decouples the decoding of $y_1(t)$ and $y_2(t)$. Since all off diagonal terms of $H^H H$ are zero, we can obtain

$$H^H H = \begin{bmatrix} h_{1,t}{}^H h_{1,t} + h_{2,t}{}^H h_{2,t} & 0 \\ 0 & h_{1,t}{}^H h_{1,t} + h_{2,t}{}^H h_{2,t} \end{bmatrix} = \begin{bmatrix} J & 0 \\ 0 & J \end{bmatrix}$$

So, the received signal can be written as, $z_1(t) = Jy_1(t) + n_1(t)$ *and* $z_2(t) = Jy_2(t) + n_2(t)$. So $y_1(t)$ and $y_2(t)$ can be separately decoded.

Case 2: Fast fading: In this case, $h_{1k} \neq h_{1k+1}$ and $h_{2k} \neq h_{2k+1}$

So in matrix form it can be written as:

$$\begin{pmatrix} r_1(t) \\ r_2(t) \end{pmatrix} = \begin{bmatrix} h_{1,t} & h_{2,t} \\ \bar{h}_{2,t+1}* & -\bar{h}_{1,t+1}* \end{bmatrix} \begin{pmatrix} y_1(t) \\ y_2(t) \end{pmatrix} + \begin{pmatrix} n_1(t) \\ n_2(t) \end{pmatrix}$$

In this case output of matched filter is:

$$z(t) = H^H r(t)$$

$$= \begin{pmatrix} h_{1,t}{}^H h_{1,t} + h_{2,t+1}{}^H h_{2,t+1} & h_{1,t}{}^H h_{2,t} - h_{2,t+1}{}^H h_{1,t+1} \\ h_{2,t}{}^H h_{1,t} - h_{1,t+1}{}^H h_{2,t+1} & h_{2,t}{}^H h_{2,t} + h_{1,t+1}{}^H h_{1,t+1} \end{pmatrix} \begin{pmatrix} y_1(t) \\ y_2(t) \end{pmatrix} + H^H \begin{pmatrix} n_1(t) \\ n_2(t) \end{pmatrix}$$

which can be written as,

$$= \begin{pmatrix} h_{1,t}{}^H h_{1,t} + h_{2,t+1}{}^H h_{2,t+1} & \varepsilon \\ \varepsilon & h_{2,t}{}^H H_{2,t} + h_{1,t+1}{}^H h_{1,t+1} \end{pmatrix} \begin{pmatrix} y_1(t) \\ y_2(t) \end{pmatrix} + H^H \begin{pmatrix} n_1(t) \\ n_2(t) \end{pmatrix}$$

Where $H^H H = \begin{pmatrix} h_{1,t}{}^H h_{1,t} + h_{2,t+1}{}^H h_{2,t+1} & \varepsilon \\ \varepsilon & h_{2,t}{}^H H_{2,t} + h_{1,t+1}{}^H h_{1,t+1} \end{pmatrix}$

As the off-diagonal terms are not zero. So, the received signal cannot be decoupled separately.

Here off diagonal terms i.e. ε represents the interference.

Proposed scheme: To remove the ISI in the fast fading, we propose a low complexity zero forcing receiver.

So, $H^{PZF} = \begin{pmatrix} h_{1,t}* & \bar{h}_{2,t+1} / P_t \\ h_{2,t}* & -\bar{h}_{1,t+1} / P_t \end{pmatrix}$

Where $P_t = \bar{h}_{2,t+1}\bar{h}_{1,t+1}^* / h_{1,t}^* h_{2,t}$

further,

$$H^{PZF}H = \begin{pmatrix} |h_{1,t}|^2 + |\bar{h}_{2,t+1}|^2 / P_t & \varepsilon_1 \\ \varepsilon_2 & |h_{2,t}|^2 + |\bar{h}_{1,t+1}|^2 / P_t \end{pmatrix}$$

where $\varepsilon_1 = h_{1,t}^* h_{2,t} - \bar{h}_{2,t+1}\bar{h}_{1,t+1}^* / P_t$

by substituting the value of P_t in above equation,

$$\varepsilon_1 = 0$$

Also, $\varepsilon_2 = h_{2,t}^* h_{1,t} - \bar{h}_{1,t+1}\bar{h}_{2,t+1}^* / P_t^*$

So, it reduces to zero after substituting the value of P_t^* in above equation.

Hence the off- diagonal terms becomes zero. So ISI is reduced in fast fading environment. But this scheme also reduces the diversity gain.

Therefore, $z(t) = H^{PZF}H\, y(t) + n(t)$

And $\hat{y}(t) = \left(H^{PZF}H\right)^{-1} . z(t)$

Where $\hat{y}(t)$ is the estimated data stream.

So, decoding of $y_1(t)$ and $y_2(t)$ can be done at the receiver.

Simulation results:

Bit error rate performance of TR-STBC for two transmit and one receive antenna is studied. The performance of TR-STBC is evaluated for fast fading in Nakagami-m fading channel for different values of shape factor and compared with the classical zero forcing receiver. Proposed scheme reduces the computational complexity at the receiver. Proposed low complexity receiver gave same results as of classical zero forcing receiver for value of m=1 i.e. for the Rayleigh channel and it gives better performance than classical zero forcing for value of m>1 and its performance degrades for value of m<1.

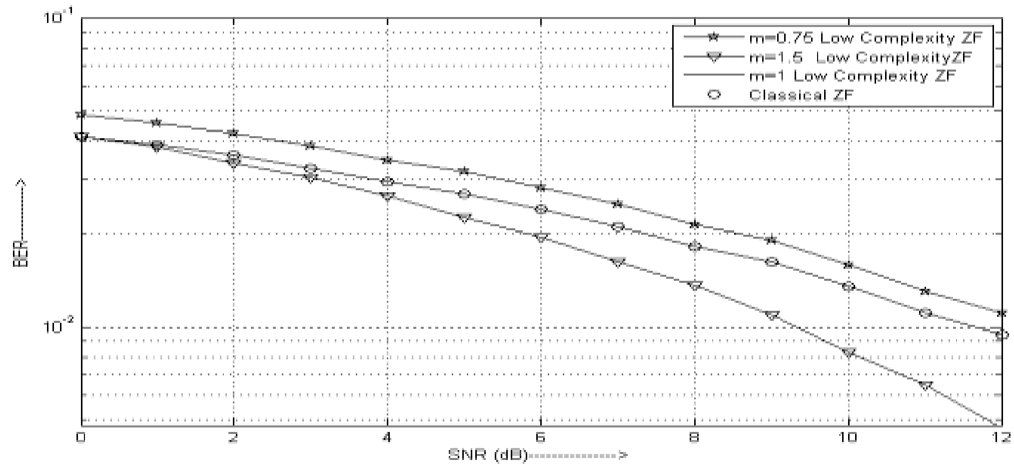

Figure1: Time reversal STBC performance for different fading channel.

CONCLUSION

The high speed mobile environment results in fast fading channel in the wireless communication. The proposed scheme mitigates the effect of interference in the fast fading environment and reduces the computational complexity at the receiver. Performance of proposed low complexity receiver is identical to that of classical zero forcing receiver for value of shape factor m=1.

REFERENCES:

[1] G. J. Foschini and M. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," *Wirel. Pers. Commun.*, vol. 6, no. 3, pp. 311–335, Mar. 1998.
[2] I. E. Telatar, *Capacity of Multi-Antenna Gaussian Channels*, Jun. 1995. AT&T Bell Labs Intern. Rep.
[3] I. E. Telatar, "Capacity of multi-antenna Gaussian channels," *Eur. Trans. Telecommun.*, vol. 10, no. 6, pp. 585–595, Nov./Dec. 1999.
[4] G. J. Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multi element antennas," Bell Labs Tech. J., vol. 1, no. 2, pp. 41–59, Autumn 1996.
[5] S. M. Alamouti, "A simple transmit diversity technique for wireless communications," IEEE J. Sel. Areas Commun., vol. 16, no. 8, pp. 1451–1458,Oct. 1998.
[6] V. Tarokh, H. Jafarkhani, and A. R. Calderbank, "Space-time block coding for wireless communications: Performance results," IEEE J. Sel. Areas Commun., vol. 17, no. 3, pp. 451–460, Mar. 1999.
[7] V. Tarokh, H. Jafarkhani, and A. R. Calderbank, "Space-time block codes from orthogonal designs," IEEE Trans. Inf. Theory, vol. 45, no. 5, pp. 1456–1467, Jul. 1999.
[8] E. Lindskog and A. Paulraj, "A transmit diversity scheme for channels with interference," in Proc. IEEE ICC, New Orleans, LA, Jun. 2000, vol. 1, pp. 307–311.
[9] Z. Liu, G. Giannakis, A. Scaglione, and S. Barbarossa, "Decoding and equalization of unknown multipath channels based on block precoding and transmit-antenna diversity," in Proc. 33rd Asilomar Conf. Signals, Syst., Comput., Oct. 1999, vol. 2, pp. 1557–1561.
[10] H. Bolcskei and A. J. Paulraj, "Space-frequency coded broadband OFDM systems," in Proc. IEEE WCNC, Chicago, IL, Sep. 2000, pp. 1–6.
[11] N. Al-Dhahir, "Single-carrier frequency-domain equalization for space-time block-coded transmissions over frequency-selective fading channels," IEEE Commun. Lett., vol. 5, no. 7, pp. 304–306, Jul. 2000.
[12] S. Zhou and G. Giannakis, "Single-carrier space-time block-coded transmissions over frequency-selective fading channels," IEEE Trans. Inf. Theory, vol. 49, no. 1, pp. 164–179, Jan. 2003.
[13] N. Al-Dhahir, "Overview and comparison of equalization schemes for space time coded signals with application to EDGE," IEEE Trans. Signal Process., vol. 50, no. 10, pp. 2477–2488, Oct. 2002.
[14] S. Geirhofer, L. Tong, and A. Scaglione, "Time-reversal space-time coding for doubly-selective channels," in Proc. IEEE WCNC, Las Vegas, NV, 2006, pp. 1638–1643