Single Input Multiple Output (SIMO) Wireless Link with Turbo Coding

M.M.Kamruzzaman*
Information &Communication Engineering
Southwest Jiaotong University,
Chengdu, Sichuan 610031, china
E-mail: kamruzzaman@qq.com

Dr. Mir Mohammad Azad**
Computer Science and Engineering
Shanto Mariam University of Creative
Technology, Dhaka, Bangladesh
E-mail: azadrayhan@gmail.com

***Abstract*— Performance of a wireless link is evaluated with turbo coding in the presence of Rayleigh fading with single transmitting antenna and multiple receiving antenna. QAM modulator is considered with maximum likelihood decoding. Performance results show that there is a significant improvement in required signal to noise ratio (SNR) to achieve a given BER. It is found that the system attains a coding gain of 14.5 dB and 13 dB corresponding to two receiving antenna and four receiving antennas respectively over the corresponding uncoded system. Further, there is an improvement in SNR of 6.5 dB for four receiving antennas over two receiving antennas for the turbo coded system.**

Keywords- Diversity; multipath fading; Rayleigh fading; Turbo coding; Maximal Ratio Combining (MRC); maximum-likelihood detector; multiple antennas.

I. INTRODUCTION

The increasing demand for high data rates in wireless communications due to emerging new technologies makes wireless communications an exciting and challenging field[1-2]. Turbo code is the most exciting and potentially important development in the coding theory which is capable of achieving near Shannon capacity performance [3-5]. Diversity technique can be applied to minimize the effect of fading in a wireless channel. Space time block coding is found to be an effective means to combat fading in a multipath propagation environment [6-7]. In [6-7], it is found that use of two transmit antenna and multiple receive antennas and space time block coding provides remarkable performance improvement. The use of space-time block coding with concatenating turbo product codes is also recently reported .Instead of using STBC, the performance of a wireless link may be improved by applying turbo coding in a SIMO configuration. In this paper, performance analysis of a wireless link with turbo coding in conjunction with multiple receiving antenna diversity is presented for a rayleigh fading channel with single input multiple output (SIMO) configuration. Performance result is presented in terms of bit error rate for multiple receiving antenna diversity schemes. Computer simulation is carried out to evaluate the performance result.

II. SYSTEM MODEL

The block diagram of the system under consideration is shown in Fig.1 and Fig. 2. The data is turbo encoded with frame size 1024, with the following generator matrix with code rate ½ and

$$G(D)=\left[1,\frac{1+D+D^3}{1+D^2+D^3},\ \frac{1+D+D^2+D^3}{1+D^2+D^3}\right]$$

modulated by a 64 QAM modulator before transmission. At the receiving end, signal is received by multiple receiving antennas. The detail block diagram of the combiner is shown in Fig.3.

If the symbol transmitted by transmit antenna is s1, then the signal received by the receiving antennas can be written as:

$$r_1 = h_1 s1 + \eta_1$$

$$r_2 = h_2 s1 + \eta_2$$

$$\vdots$$

$$r_n = h_n s1 + \eta_n$$

Where $h_{1\ldots}h_n$ and $\eta_{1\ldots\ldots}\ \eta_n$ represent the channel coefficients and additive white noise for IF link.

The combiner combines received signals which are then sent to the maximum likelihood detector. If we consider two receiving antennas, then received signal r_0 and r_1 are fed to combiner and then combiner generates the following signal [6]:

$$\tilde{s}_1 = h_1^* r_1 + h_2 r_2^* \qquad (1)$$

for more then two receive antenna then r_0, r_1, r_2, r_3 -------------- r_n

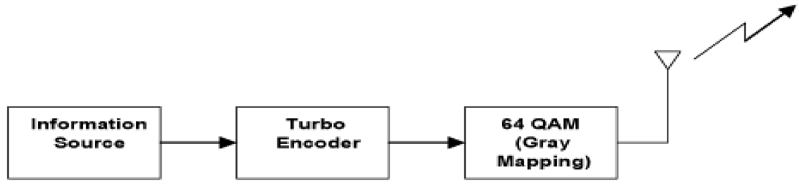

Figure 1. Block diagram of transmitter with turbo encoder and one transmit antenna

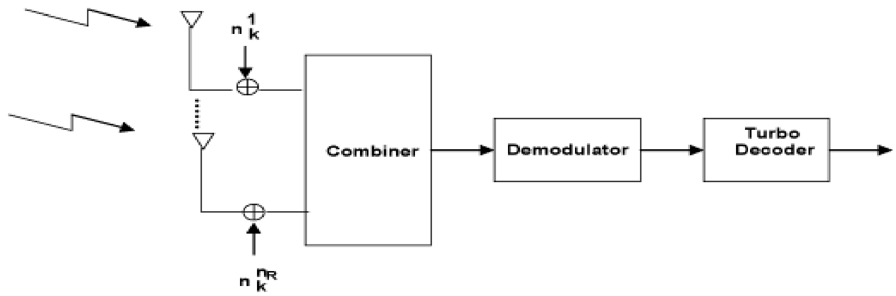

Figure 2. Block diagram of receiver with multiple receiving antennas and turbo decoder.

Fig. 1. : Block diagram of a wireless link with turbo coding and multiple receiving antennas
(a) Transmitter (b) Receiver

received signal are send to combiner and combiner generate the following signals [6]:

$$\tilde{s}_1 = h_1^* r_1 + h_2 r_2^* + h_3^* r_3 + h_4 r_4^* \text{------} h_{n-1}^* r_{n-1} + h_n r_n^* \qquad (2)$$

III. MAXIMUM LIKELIHOOD DECISION RULE

Maximum likelihood decoding of combined signal $\tilde{s}_1$ can be achieved using the decision metric [7]

$$\sum_{i=2,4,6....}^{n} \left(\left| r_{i-1} - h_{i-1} s_1 \right|^2 + \left| r_i - h_i s_1^* \right|^2 \right) \qquad (3)$$

Over all possible values of s1.

We expand the above equation and delete the terms that are independent of the code words and observe that the above minimization is equivalent to minimizing [7]

The above can be rewrite:

$$- \sum_{i=2,4,6......}^{n} \left[r_{i-1} h_{i-1}^* s_1^* + (r_i)^* h_i s_1 \right] + |s_1|^2 \sum_{i=1}^{n} |h_i|^2 \qquad (4)$$

Thus the minimization of **(1)** and in turn is equivalent to minimizing the decision metric [7]

$$\left| \left[\sum_{i=2,4,6......}^{n} \left(r_{i-1} h_{i-1}^* + (r_i)^* h_i \right) \right] - s_1 \right|^2 + \left(-1 + \sum_{i=1}^{n} |h_i|^2 \right) |s_1|^2 \qquad (5)$$

for detecting s1.

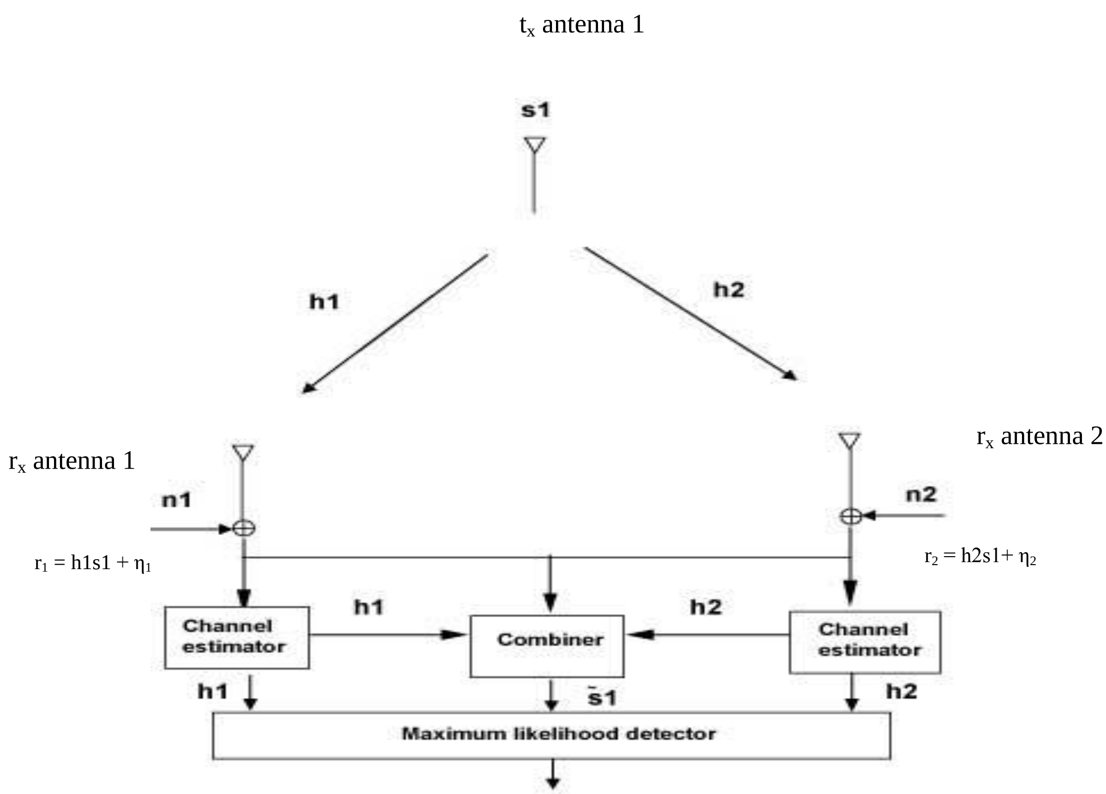

Figure 3. Receive diversity with one transmit antenna and two receive antenna

Output of the combiner is demodulated using a coherent demodulator. Decoding of the turbo coded bits are carried out following the MAP decoding algorithm.

IV. RESULT AND DISCUSSION

Computer simulation is carried out to find the bit error rate (BER) performance of a wireless transmission system with turbo coding with multiple receiving antennas. The results are evaluated for several combinations of t_x and r_x antennas with and without Turbo coding. The plots of BER as a function of SNR (E_s/N_o) are shown in fig.3. It is found that there is a significant improvement in required SNR for achieving a given BER with two receiving antenna compared to four receiving antennas of a turbo coded system. The coding gain is found to be 6.5 dB at BER 10^{-6} of a turbo coded system for two receiving antenna compared to four receiving antennas. There is also significant improvement with turbo code compared to the uncoded system. For two receiving antennas, the coding gain is found to be 14.5 dB and for four receiving antennas, the coding gain is found to be 13 dB at BER 10^{-6} over the uncoded system with same numbers of receiving antenna. Thus the effectiveness of turbo coding is more significant for higher number of receiving antenna.

ACKNOWLEDGMENT

The authors would like to thank anonymous reviewers for helpful comments to improve the presentation of the paper.

REFERENCES

[1] Haowei Bai, Honeywell Aerospace; Mohammed Atiquzzaman, University of Oklahoma “Error Modeling Schemes for Fading channels in wireless Communications: A Survey” IEEE Communications Surveys & Tutorials, 2003

[2] B.Sklar,”Rayleigh Fading Channels in Mobile Digital Communication Systems, part I: Characterization, “IEEE Commun. Mag., vol. 35, no. 9, sept. 1997,pp.136-46.

[3] G. Berrou, A.Glavieuc, and P.Thitmajshima, “Near Shannon limit error-correcting coding: Turbo codes,” in Proc. 1993, Int. Conf. Com., Geneva, Seitzerland, May 1993, pp.1064-1070.

[4] S.Benedetto, D.Divsalar, G.Montorsi, and F.Pollara, “Soft output decoding algorithms in iterative decoding of Turbo codes”, TDA progress report 42-124, February 15, 1996.

[5] Mustafa Eroz, A.Roger Hammons Jr., “On the design of prunable interleavers for Turbo codes,” in Proc. IEEE VTC’99, Houston, TX, May15-19, 1999.

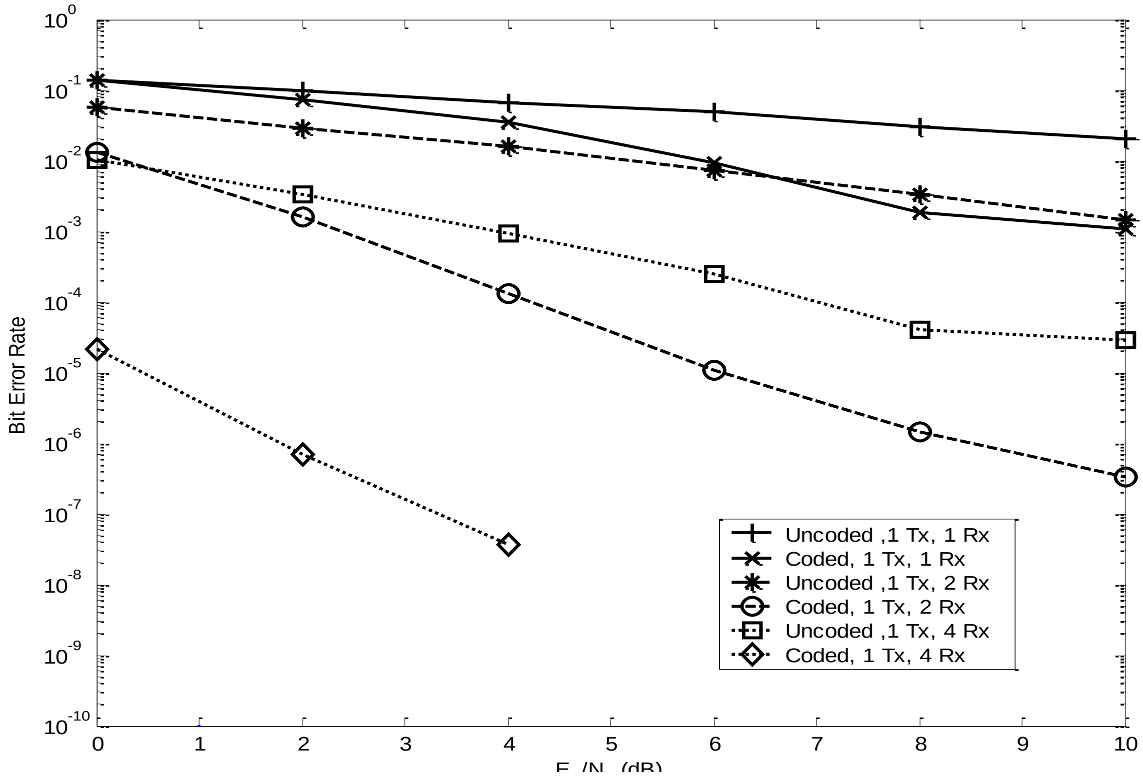

Figure 4. Plots of BER versus E_s/N_o for a wireless system with and without turbo codifferent number of receiving antennas.

[6] S.M. Alamouti, "A simple transmit diversity scheme for wireless communications", IEEE J. Select.Areas Commun., vol. 16, no. 8, pp. 1451–1458, Oct. 1998.

[7] Vahid Tarokh, Hamid Jafarkhani, and A. Robert Calderbank, "Space–time block coding for wireless communications: performance results", IEEE J. Select. Areas Commun., vol. 17, pp. 451–460, Mar. 1999.

[8] Yinggang Du Kam Tai Chan "Enhanced space-time block coded systems by concatenating turbo product codes" Communications Letters, IEEE, Volume: 8, Issue: 6 On page(s): 388 – 390 June 2004

[9] Vahid Tarokh and Hamid Jafarkhani, "A Differential Detection Scheme forTransmit Diversity," IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 18, NO. 7, JULY 2000

[10] Zhuo Che_n□, Branka Vucetic□, Jinhong Yuan□_, and Ka Leong Lo, "Analysis of Transmit Antenna Selection/Maximal-Ratio Combining in Rayleigh Fading," IEEE Channels Issue Date : 29 June-4 July 2003 On page(s): 94 [Information Theory, 2003. Proceedings. IEEE International Symposium on]

[11] Rodrigues, M.R.D. ; Chatzgeorgiou, I. ; Wassell, I.J. ; Carrasco, R.,"On the Performance of Turbo Codes in Quasi-Static Fading Channels," IEEE Issue Date : 4-9 Sept. 2005 On page(s): 622 – 626 [Information Theory, 2005. ISIT 2005. Proceedings. International Symposium on]

[12] Yi Hong, Jinhong Yuan, Zhuo Chen and Branka Vucetic,"Space–Time Turbo Trellis Codes for Two,Three, and Four Transmit Antennas" IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 53, NO. 2, MARCH 2004

[13] Hicham Bouzekri and Scott L. Miller, "An Upper Bound on Turbo Codes Performance Over Quasi-Static Fading Channels," IEEE COMMUNICATIONS LETTERS, VOL. 7, NO. 7, JULY 2003

[14] Vivek Gulati and Krishna R. Narayanan, "Concatenated Codes for Fading Channels Based on Recursive Space–Time Trellis Codes ," IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 2, NO. 1, JANUARY 2003

[15] Vahid Tarokh, Nambi Seshadri and A. R. Calderbank, "Space–Time Codes for High Data Rate Wireless Communication:Performance Criterion and Code Construction," IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. 44, NO. 2, MARCH 1998

[16] Gerhard Bauch and Naofal Al-Dhahir,"Reduced-Complexity Space–Time Turbo-Equalization for Frequency-Selective MIMO Channels, " IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 1, NO. 4, OCTOBER 2002

[17] Hyundong Shin and Jae Hong Lee, "Channel Reliability Estimation for Turbo Decoding in Rayleigh Fading Channels With Imperfect Channel Estimates," IEEE COMMUNICATIONS LETTERS, VOL. 6, NO. 11, NOVEMBER 2002

[18] Caijun Zhong and Shi Jin," Capacity Bounds for MIMO Nakagami-Fading Channels," IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 57, NO. 9, SEPTEMBER 2009

[19] Che Lin, Vasanthan Raghavan, and Venugopal V. Veeravalli, "To Code or Not to Code Across Time: Space-Time Coding with Feedback," IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 26, NO. 8, OCTOBER 2008

[20] Naveen Mysore and Jan Bajcsy, "BER Bounding Techniques for Selected Turbo Coded MIMO Systems in Rayleigh Fading," IEEE Publication Year: 2010 , Page(s): 1 – 6 [Information Sciences and Systems(CISS), 2010 44th Annual Conference on]

[21] Khoirul Anwar and Tadashi Matsumoto, "MIMO Spatial Turbo Coding with Iterative Equalization," IEEE Issue Date : 23-24 Feb. 2010 On page(s): 428 - 433 [Smart Antennas (WSA), 2010 International ITG Workshop on]

AUTHORS PROFILE

* **M. M. Kamruzzaman**, Received B.E. degree from Bangalore University, India and M.S. degree from United International University, Bangladesh in Computer Science and Engineering and now Studying PhD in the department of Information & communication Engineering at Southwest Jiaotong University, Chengdu, Sichuan 610031, china. Before doing PhD he was working as faculty of Presidency University, Dhaka, Bangladesh. His areas of interest include modern coding theory, Turbo coding, Space Time Coding and wireless communications

** **Dr. Mir Mohammad Azad**, Received Bachelor of Computer Application (BCA) Degree from Bangalore University, Karnataka, India, Masters of Computer Application (MCA) Degree from Bharath Institute of Higher Education and Research Deemed University (Presently Bharath University), Tamilnadu India. Received PhD in Computer Science from Golden State University. Presently Working as an Assistant Professor and Departmental Head of Computer Science and Engineering, Shanto Mariam University of Creative Technology, Dhaka, Bangladesh. His areas of interest include Networking and Wireless communications.

.