# A

**Asian Institute of Technology**
**ELECTRONIC DOCUMENTATION FORM**

1. Type
   *Thesis*

2. Title
   BIT-INTERLEAVED CODED MODULATION WITH ITERATIVE DECODING
3. Author
   IQBAL SHAHID
4. Name(s) of Advisor and Committee Members
   Dr. R.M.A.P. Rajatheva (Chairperson)
   DR. Poompat Saengudomlert (Member)
   Assoc. Prof. Tapio J. Erke (Member)

5. School
   SCHOOL OF ENGINEERING AND TECHNOLOGY
6. Field of Study
   TELECOMMUNICATIONS
7. External Examiner *(for Dissertations only)*

8. Expert Comments on the Work and Facility for the Feedback from the Users

9. Abstract of the Work


Bit Interleaved Code Modulation (BICM) was first introduced by Zehavi (**Zehavi**, 1992) to improve the performance of a coded modulation scheme over fading channels. Biglieri (**Biglieri** *et.al*, 1998) then formally introduced the idea along with the complete and detailed performance analysis. In order to cope with the shortcomings of BICM over AWGN channels as compared to conventional Trellis Coded Modulation (TCM) schemes, Li ( **Li** *et al*., 1997) introduced iterative decoding on the receiver side. Space-Time BICM is supposed to improve the performance of conventional Space-Time systems in both AWGN and fading scenarios.

In this thesis, we first discuss the performance of Space-Time BICM over correlated fading channels which is an untouched area until now. We consider both Rayleigh and Rician fading channels and assume symmetrical correlation model. Numerical results are also shown to supplement the theoretical derivations.

As another application of BICM, we discuss BICM with Adaptive Modulation and Coding (AMC) in the physical layer alongwith the effects of queuing in the data link layer. This is a kind of cross-layer analysis where we optimize the packet dropping rate due to queuing and packet loss rate due to non-ideal channel conditions. Numerical results show that the performance of the given systems increase considerably when BICM is applied as compared to the case

without any bit-wise interleaving.

10. Keywords (minimum 5; maximum 10)
    BICM
    AMC
    PERFORMANCE ANALYSIS
    RICIAN FADING CHANNEL
    BER

11. References


1. 3GPP, (2003) High speed downlink packet access: UE radio transmission and reception,3GPP, Tech. Rep. V1.3.0 Release 5. RAN WG4 Meeting 26, Feb.
2. Aalo V. A. (1995), Performance of maximal-ratio diversity systems in a correlated Nakagami fading environment, IEEE Trans. Commun., vol. 43, pp. 23602369, Aug.
3. Alamouti S. M. (1998), ”A simple transmit diversity technique for wireless communications”, IEEE J. Select. Areas Commun., vol. 16, no. 8, pp.1451-1458, Oct.
4. Baro S. , Bauch G. and Hansmann A. (2000), Improved codes for space-time trellis coded modulation,” IEEE Commun. Letters, vol.4, pp. 20-22, Jan.
5. Bertsekas D. and Gallager R., Data Networks, 2nd ed. Upper Saddle River, NJ: Prentice-Hall, 1992.
6. Benedetto S, Divsalar D, Montorsi G, Pollara F. (1997), A soft-input soft-output APP module for iterative decoding of concatenated codes, IEEE Commun. Lett., vol. 1, pp. 2224, Jan.
7. Benedetto S, Biglieri E (1999), *Principles of Digital Transmission with Wireless Applications.* New York: Kluwer.
8. Berrou C., GlavieuxA., and Thitimajshima P. (1993), Near shannon limit errorcorrecting coding and decoding: Turbo codes, in Proceedings of ICC 93, pp. 1064 1070, May.
9. Biglieri E., Caire G., Taricco G. (1996), Traveset J. V., ”Simple Method for evaluating error probabilities”, Electronic Letters, February 1, Vol. 32, No. 3.
10. Brink S. ten (2001), Convergence behaviour of iteratively decoded parallel concatenated codes, IEEE Trans. Commun., vol. 49, no. 10, pp. 1727 1737, Oct.
11. Caire G., Taricco G., Biglieri E. (1998), ”Bit-Interleaved Coded Modulation”, IEEE Transactions on Informaton Theory, Vol. 44, No. 3, May.
12. Chindapol A, Ritcey J. A (2001), ”Design, Analysis and Performance Evaluation for BICM-ID with Square QAM Constellations in Rayleigh Fading Channels”, IEEE Journal on Selected Areas in Communications, Vol. 19, No. 5, May.
13. Divsalar D. and Simon M. K. (1988), The design of trellis coded MPSK for

fading channels: Performance criteria, IEEE Trans. Commun., vol. 36, pp. 10041011, Sept.
14. Foschini G. J. (1996), ”Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas,” Bell Labs Technol. J., vol. 1, no. 2, pp. 41-59, Aug.
15. Hermosilla C. and Szczecinski L. (2005), Performance evaluation of linear turboreceivers using analytical extrinsic information transfer functions, EURASIP Journal on Applied Signal Processing, pp. 892905, May.
16. Hong Z. and Hughes B. L. (2001), Robust space-time trellis codes based on bitinterleaved coded modulation, in Proc. CISS01, pp. 665670, March.
17. Huang Y., Ritcey J. A (2004), ”Tight BER Bounds for Iteratively Decoded Bit-
18. Interleaved Space-Time Coded Modulation”, IEEE Communication Letters, Vol. 6, No. 3, March.
19. Li X., Chindapol A, Ritcey J. A. (2002), ”Bit-Interleaved Coded Modulation with
20. Iterative Decoding and 8PSK Signalling”, IEEE Transactions on communications, Vol. 50, No. 8, Aug.
21. Li X. , Ritcey J. A. (1997), ”Bit-Interleaved Coded Modulation with Iterative Decoding”, IEEE Communications Letters, Vol. 1, No. 6, Nov.
22. Li X. , Ritcey J. A. (1999), ”Trellis-Coded Modulation with Bit Interleaving and
23. Iterative Decoding”, IEEE Journal on Selected Areas in Communications, Vol. 17, NO. 4, April.
24. Liu Q., Zhou S. , Giannakis G. B. (2005), ”Queuing with Adaptive Modulation and Coding Over Wireless Links: Cross-Layer Analysis and Design”, IEEE Transactions on Wireless Communications, Vol. 4, No. 3, May.
25. Martinez A. , Fabregas A. G. i, Caire G. (2006), ” Error Probability Analysis of Bit-Interleaved Coded Modulation”, IEEE Transactions on Information Theory, Vol 52, No. 1, Jan.
26. Massey J. L. (1974), Coding and modulation in digital communications, in Proc. Of International Zurich Seminar on digital communications, March.
27. Niu H., Ritcey J. A. (2005), ”Pilot-Symbol-Assisted LDPC Coded BICM Over Correlated Rayleigh Fading Channels”, IEEE Transactions on Wireless Communications, Vol. 4, No. 5, September.
28. Polpraset C., Ritcey J. A. (2005), ”Effect of Imperfect CSI on Iteratively Decoded BICM over Nakagami fading channels.”, IEEE.
29. Robertson P. and Worz T. (1998), Bandwidth-efficient turbo trellis-coded modulation using punctured component code, IEEE J. Select. Areas in Commun., vol. 16, pp. 206218, Feb.
30. Salam A. Zummo, Ping-Cheng Yeh, Wayne E. Stark (2006), ”Error Probability of Bit-Interleaved Coded Modulation in Wireless Environments”, IEEE Transactions on Vehicular Technology,Vol. 55, No. 2, March.

31. Salam A. Zummo, Ping-Cheng Yeh, Wayne E. Stark (2006), ”Performance Analysis of Bit-Interleaved Space-Time (BI-ST) Coded Systems Over Wireless Channels”, IEEE Communication Society .
32. Schreckenbach F, Gortz N, Hagenauer J, Bauch G, Optimization of symbol mapping for bit-interleaved coded modulation with iterative decoding, IEEE Commun. Lett., vol. 7, pp. 593595, Dec. 2003.
33. Sethuraman V., Hajek B. (2006), ”Comments on ”Bit-Interleaved Coded Modulation””, IEEE Transactions on Informaton Theory, Vol. 52, No. 4, April.
34. Shiu H. K. , Y. H. Chang, T. C. Hou, and C. S.Wu (2001) , Performance analysis of TCP over wireless link with dedicated buffers and link level error control, in Proc. Int. Conf. Commun., vol. 10, Amsterdam, Netherlands, Jun.Jul. , pp. 32113216.
35. Siwamogsatham S. and Fitz M. P. (2000), Robust space-time coding for correlated Rayleigh fading channels”, in Proc. 38th Annual Allerton Conf. on Communication, Control, and Computing, Oct. , Monticello, Illinois, USA.
36. Tarokh V, Seshadri N, Calderbank A. R (1998),”Space-time codes for high data rate wireless communication: performance criterion and code construction”, IEEE Trans. Inform. Theory, vol. 44, no. 2, pp. 744-765, Mar.
37. Tee J. K. S, Taylor D. P. (2002), ”A Generalised Performance Bounding Technique for Bit-Interleaved Coded Modulation Systems in the Rayleigh fading channel.”, IEEE.
38. Tran N. H, Nguyen H. H, Le-Ngoc T. (2006), ”Performance of BICM-ID with Signal Space Diversity”, IEEE Transactions on Wireess Communications, paper accepted March 12.
39. Ungerboeck G. (1982), Channel coding with multilevel/phase signals, IEEE Trans. Inform. Theory, vol. IT-28, pp. 5567, Jan .
40. Yeh P. C., Zummo S. A., Stark W. E. (2006), ”Error Probability of Bit-Interleaved Coded Modulation in Wireless Environments”, IEEE Transactions on Vehicular Technology, Vol. 55 No. 2, March.
41. Zehavi E. (1992), ”8-PSK trellis codes for a Rayleigh channel”, IEEE Trans. Commun., vol. 40, pp. 873-884, May

42. Type of Project (Sponsored/Non-Sponsored), if applicable

43. Specific Agreement involved in the Sponsorship Agreement, if applicable

The requested details above have to be submitted in a single PDF file to the library at **edf@ait.ac.th**.