Turbo Equalization for ISI Channels Incorporating Estimation Error Statistics

Markus A. Dangl, Christian Sgraja, Jürgen Lindner
University of Ulm, Dept. of Information Technology
Albert-Einstein-Allee 43, 89081 Ulm, Germany
Email: markus.dangl@e-technik.uni-ulm.de

Abstract

We consider a coded data transmission over an intersymbol interference (ISI) channel with a coherent receiver frontend, where the channel impulse response is unknown at the receiver. Optimum receiver design with respect to minimum bit error rate requires a tree search and performs jointly channel estimation and equalization (and decoding if necessary) [1]. In most cases this type of receiver is impractical due to its tremendous computational complexity. In [2], a maximum a posteriori (MAP) equalizer with an expanded trellis is proposed for joint equalization and channel estimation, whereas equalization and decoding is done separately, e. g. , in an iterative fashion (turbo equalization) [3]. Other approaches extend turbo equalization to iterative channel estimation, equalization, and decoding, in order to reduce computational complexity [4], yet still achieve results close to the optimum receiver. It is known that the statistics of the channel estimation error should be included in the equalizer design, and noticeable gains can be achieved for trellis-based equalization [5]. Unfortunately, these gains are quite small when using linear equalization [5] or decision feedback equalization [6] and are further reduced when applying multi-level modulation. The influence of multi-amplitude symbols on the channel estimation error, leading to estimation error terms with varying power, was studied in a couple of publications, e. g. , in [7], [8], [9]. In [10], an error model for equalizer design was proposed obeying the dependency of the data symbols on the channel estimation error. This approach showed an improved performance.

In our contribution we extend the concept of unbiased minimum variance equalization (UMVE) [11] with soft interference cancellation to turbo block equalization schemes incorporating the estimation error statistics according to the error model used in [10]. The new turbo equalizer is based on linear filtering similar to [12], the main difference between the two equalizers is the additional scaling, resulting in unbiased data estimates. The performance is assessed for block Rayleigh fading channels and separate channel estimation and turbo equalization (using only known symbols for estimation), as well as for iterative (data-based) channel estimation and turbo equalization. Moreover, we show results for an improved version of the LMS channel estimation algorithm [13] when optimizing its step size based on an error analysis described in [14].

References

[1] R. A. Iltis, J. J. Shynk, and K. Giridhar, "Bayesian algorithms for blind equalization using parallel adaptive filtering," *IEEE Trans. Commun.*, vol. 42, no. 2/3/4, pp. 1017–1032, Feb./Mar./Apr. 1994.

[2] L. M. Davis, I. B. Collings, and P. Hoeher, "Joint MAP equalization and channel estimation for frequency-selective and frequency-flat fast-fading channels," *IEEE Trans. Commun.*, vol. 49, no. 12, pp. 2106–2114, Dec. 2001.

[3] C. Douillard, M. Jézéquel, C. Berrou, A. Picart, P. Didier, and A. Glavieux, "Iterative correction of intersymbol interference: Turbo-equalization," *European Trans. Telecomm.*, vol. 6, no. 5, pp. 507–511, Sept./Oct. 1995.

[4] R. Otnes and M. Tüchler, "On iterative equalization, estimation, and decoding," in *Proc. IEEE ICC*, vol. 4, Anchorage/USA, 2003, pp. 2958–2962.

[5] M. Tüchler and M. Mecking, "Equalization for non-ideal channel knowledge," in *Proc. CISS*, Baltimore/USA, Mar. 2003.

[6] C. Sgraja and J. Lindner, "Decision feedback equalization for MC-CDM with channel uncertainty," in *Proc. IEEE ICC*, Paris/France, June 2004, to appear.

[7] A. Aghamohammadi and H. Meyr, "On the error probability of linearly modulated signals on Rayleigh frequency-flat fading channels," *IEEE Trans. Commun.*, vol. 38, no. 11, pp. 1966–1970, Nov. 1990.

[8] C. Sgraja, J. Egle, and J. Lindner, "On pilot-assisted MAP detection in frequency-flat Rayleigh fading channels," in *Proc. IEEE WCNC*, New Orleans/USA, Mar. 2003.

[9] C. Sgraja and J. Lindner, "A lower bound on the symbol error probability of joint channel estimation and detection in OFDM systems," in *Proc. 8th Intern. OFDM-Workshop*, Hamburg/Germany, Sept. 2003.

[10] M. Dangl, C. Sgraja, and J. Lindner, "On unbiased minimum variance equalization with channel estimation uncertainty," in *Proc. CISS*, Princeton/USA, Mar. 2004, pp. 609–614.

[11] A. Bury and J. Lindner, "Block transmission equalizers using constrained minimum variance filters with application to MC-CDM," in *Proc. IEEE ISSSTA*, New Jersey/USA, Sept. 2000, pp. 159–163.

[12] M. Tüchler, R. Koetter, and A. Singer, "Turbo equalization: Principles and new results," *IEEE Trans. Commun.*, vol. 50, no. 5, pp. 754–767, May 2002.

[13] S. Haykin, *Adaptive Filter Theory*, 4th ed. Upper Saddle River, New Jersey: Prentice Hall, 2002.

[14] C. Kuhn, "Iterative Kanalschätzung, Kanalentzerrung und Decodierung für den EDGE-standard," Master's thesis, Technical University of Munich, Institute for Communications Engineering, May 2002, in German language.