1-1-2011

Precoded turbo code within 0.1dB of Shannon limit

S Tong
Xidian University, sheng@uow.edu.au

H Zheng
Xidian University

B Bai
Xidian University

Precoded turbo code within 0.1dB of Shannon limit

Abstract

The application of the precoding technique to turbo codes is investigated, resulting in a new class of turbo-like codes named precoded turbo codes. The introduction of a precoder provides a degree of freedom for code optimisation. As a result, an optimised rate-1/2 precoded turbo code with a threshold of 0.28 dB is designed using the EXIT chart.

Keywords

code, within, precoded, 1db, turbo, shannon, limit

Disciplines

Engineering | Science and Technology Studies

Publication Details

S. Tong, H. Zheng & B. Bai, "Precoded turbo code within 0.1dB of Shannon limit," Electronics Letters, vol. 47, (8) pp. 521-522, 2011.

Precoded turbo code within 0.1 dB of Shannon limit

S. Tong, H. Zheng and B. Bai

The application of the precoding technique to turbo codes is investigated, resulting in a new class of turbo-like codes named precoded turbo codes. The introduction of a precoder provides a degree of freedom for code optimisation. As a result, an optimised rate-1/2 precoded turbo code with a threshold of 0.28 dB is designed using the EXIT chart.

Introduction: A precoder is a device located in front of a conventional turbo-like encoder for improving its iterative decoding performance [1]. By using an accumulator as a precoder for RA codes [2], Abbasfar *et al.* proposed a novel class of turbo-like codes named accumulate-repeat-accumulate (ARA) codes [1], which not only exhibit excellent performance but also allow low complexity codec implementations. Inspired by the success of ARA codes, we intend to investigate the effect of the precoding technique on turbo codes [3]. A new coding scheme is obtained by prefixing a precoder to a turbo encoder and hence the name precoded turbo codes. The introduction of a precoder provides a degree of freedom for code optimisation. With the help of the EXIT chart [4], a rate-1/2 precoded turbo code is designed with a threshold of $E_b/N_0 = 0.28$ dB, within 0.1dB of the Shannon limit, which is $E_b/N_0 \simeq 0.19$ dB for rate 1/2 in a binary-input AWGN channel.

Precoded turbo codes: The encoder of a precoded turbo code is shown in Fig. 1, where the serial-to-parallel converter, the parallel-to-serial converter and the two branches in between, i.e. the accumulator and the direct line, constitute the precoder [1]. The ratio of the data bits to be encoded by the accumulator is referred to as the precoding ratio, denoted as α, which is the only parameter to be optimised in this coding scheme. Note that by removing the precoder or equivalently by setting $\alpha = 0$, this coding scheme reduces to the conventional turbo codes.

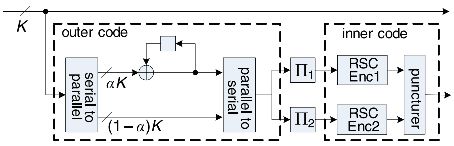

Fig. 1 *Encoder of precoded turbo code*

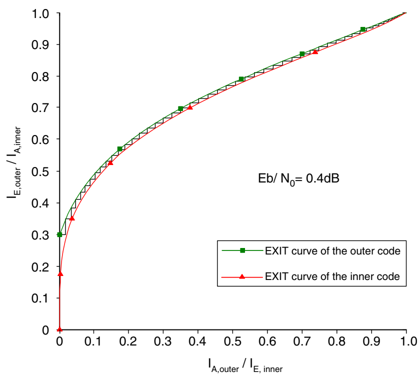

Fig. 2 *EXIT chart of precoded turbo code with $\alpha = 0.42$ and RSC generator (7,5)*

Convergence analysis and precoder optimisation using EXIT chart: For simplicity, we only consider symmetric turbo codes, the two component recursive systematic convolutional (RSC) encoders of which are the same. Following the 'serial to parallel conversion' [5], a precoded turbo code can be viewed as a serially concatenated code. Referring to Fig. 1, the outer code is a mixture of a rate-1/2 repetition code (abbreviated as a Rep2 code) and a serial concatenation of an accumulator and a Rep2 code (abbreviated as an Acc-Rep2 code), while the inner code is a RSC code. Thus, the convergence behaviour of a precoded turbo code can be visualised by drawing EXIT curves for the inner and outer codes (see Fig. 2).

With the EXIT chart the code design problem is reduced to a curve-fitting problem [6]. Note that a Rep2 code and an Acc-Rep2 code are both of rate-1/2, while their EXIT curves are of different shapes. Thus, by adjusting α, the EXIT curve of the outer code can be shaped to match that of the inner code and improved thresholds can be obtained. This implies that the introduction of the precoder provides a degree of freedom for code optimisation. This optimisation problem is one-dimensional and can be solved in a direct way. We tried several turbo codes and obtained different amounts of improvements. The best rate-1/2 code obtained is the one with $\alpha = 0.42$ and a RSC generator of (7, 5), which exhibits a threshold of $E_b/N_0 = 0.28$ dB. However, the original turbo code has a threshold of $E_b/N_0 = 0.69$ dB (see Table IV [4]). Fig. 2 shows an EXIT chart of this precoded turbo code at $E_b/N_0 =$ 0.4dB. The decoding trajectory is also shown in Fig. 2, which is generated by a simulation of a length-10^6 precode turbo code iteratively decoded as a serially concatenated code. Note that the code can also be decoded in a turbo decoding fashion, resulting in a faster convergence rate.

Simulation results: The BER performance of turbo and precoded turbo codes with a RSC generator (7, 5) are compared in Fig. 3. To evaluate a BER of 10^{-5} for the length-10^6 precoded turbo and turbo codes, 10^8 data bits have been simulated. The performance of the length-10^6 codes is close to the predicted thresholds, respectively, which validates the EXIT chart analysis.

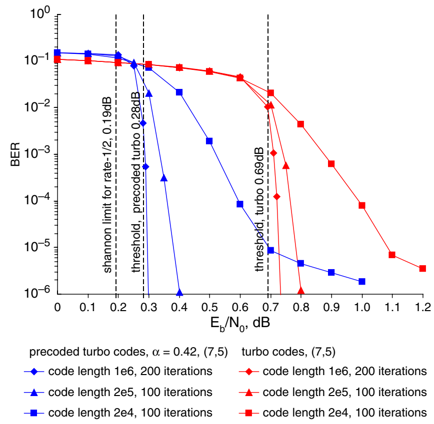

Fig. 3 *BER performance comparison of precoded turbo codes and turbo codes*

We note a rate-1/2 coding scheme by ten Brink with a slightly better threshold of $E_b/N_0 = 0.27$ dB [7], which is a serial concatenation of an outer rate-1/2 repetition code and an inner rate-1, 8-state RSC code. Compared to ten Brink's scheme, the proposed code is a systematic one and has a lower decoding complexity owing to the employment of only 2- and 4-state RSC codes.

Conclusion: In an attempt to apply the precoding technique to turbo codes, we constructed a rate-1/2 precoded turbo with a threshold of 0.28dB within 0.1dB of the Shannon limit. For future works, we may consider using other codes as precoders, and the application of the precoding technique to other coding schemes.

Acknowledgments: This work was supported by NSFC (61001130 and 60972046), the Fundamental Research Funds for the Central Universities (JY10000901017 and K50510010006), and the 973 Program (2010CB328300).

15 March 2011
doi: 10.1049/el.2011.0722
One or more of the Figures in this Letter are available in colour online.

S. Tong and B. Bai (*State Key Laboratory of Integrated Service Networks, Xidian University, Xi'an 710071, People's Republic of China*)

E-mail: ts_xd@163.com

H. Zheng (*Department of Telecommunication, Xi'an Institute of Posts and Telecommunications, Xi'an 710121, People's Republic of China*)

References

1 Abbasfar, A., Divsalar, D., and Yao, K.: 'Accumulate-repeat-accumulate codes', *IEEE Trans. Commun.*, 2007, **55**, (4), pp. 692–702

2 Divsalar, D., Jin, H., and McEliece, R.: 'Coding theorems for turbo-like codes'. Proc. Allerton Conf., Monticello, IL, USA, 1998, pp. 201–210

3 Berrou, C., Glavieux, A., and Thitimajshima, P.: 'Near Shannon limit error-correcting coding and decoding: turbo codes'. Proc. Int. Conf. Communications, Geneva, Switzerland, May 1993, pp. 1064–1070

4 ten Brink, S.: 'Convergence behavior of iteratively decoded parallel concatenated codes', *IEEE Trans. Commun.*, 2001, **49**, (10), pp. 1727–1737

5 Huettinger, S., ten Brink, S., and Huber, J.: 'Turbo-code representation of RA codes and DRS codes for reduced decoding complexity'. Proc. Conf. Information Sciences and Systems, Baltimore, MD, USA, 2001, pp. 118–123

6 Ashikhim, A., Kramer, G., and ten Brink, S.: 'Extrinsic information transfer functions: model and erasure channel properties', *IEEE Trans. Inf. Theory*, 2004, **50**, (11), pp. 2657–2673

7 ten Brink, S.: 'Rate one-half code for approaching the Shannon limit by 0.1 dB', *Electron. Lett.*, 2000, **36**, (15), pp. 1293–1294