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Search Methods for Rate 1/N Convolutional Codes used in Concatenated Systems

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Abstract - Different criteria for selection of good convolutional codes have been testet and the interesting conclusion is that the Viterbi bound on BER evaluated at a higher E_b/N_0 value is the best guide when selecting codes for use on low E_b/N_0 channels.

I. Introduction

Conventionally, selection of codes have been based on optimal (i.e. minimal BER) *asymptotic* performance. However, as mentioned by Lee [1] the optimal *asymptotic* performance may not be the goal for practical purposes. Among applications concatenated coding systems with a convolutional code of rate R = 1/N and a Reed-Solomon (RS) outer code carries great weight. For such systems the best inner code with a given rate and constraint length becomes the code which minimizes the required signal-to-noise-ratio E_b/N_0 for a given symbol-error-rate (SER) in the interval $10^{-1} < \text{SER} < 10^{-2}$. In most systems the symbol size J of the RS code is selected such that $8 \leq J \leq 12$.

II. Code Search Tecnique

There are two ways to follow in a search for codes minimizing the SER in the above mentioned interval. One is to use a parameter like the event-error-rate (EER), which can be shown to be closely related to the SER. Another way is to use parameters aimed at minimizing the bit-error-rate (BER) in the interval $5 \cdot 10^{-2} < \text{BER} < 10^{-3}$, since numerous simulations indicate that codes that are good according to the BER criterion are also good according to a SER criterion. To establish efficient search methods we have tested the following parameters:

1). optimum d_f with a minimum number $a(d_f)$ of adversary paths of weight d_f.

2). optimum d_f with a minimum sum $b(d_f)$ of weights of input sequences generating the adversary paths of weight d_f.

3). optimum d_f and an optimum distanceprofile.

4). optimum increase in extended-row-distance function.

5). minimum upper bound on BER for a specific E_b/N_0.

6). minimum upper bound on EER for a specific E_b/N_0.

Many researchers have reported on codes which are optimum according to one of the criteria 1-6 above, but to our knowledge no one have investigated the feasibility of these criteria for selection of codes according to our criterion. We therefore performed a test to judge the different criteria and find the one best suited for a search. For N=4 and M=5 we selected at random 200 codes, calculated the parameters for each criterion and sorted the codes. Each criterion was then judged by comparing the 10 best codes according to that criterion, with the 10 best codes according to computer simulations of SER. If for a certain criterion, a large intersection of "best" codes is found, then that criterion is possibly a good choice when selecting codes which are optimum according to our chosen criterion.

The interesting result is that although Viterbi's union bounds on BER and EER are completely unfit for prediction of the actual error rates in the intervals we selected, then the bounds used for a somewhat higher E_b/N_0 (3.0 dB for N=4, M=5) are by far the *best guides* among the criteria to select codes according to our chosen criterion.

The E_b/N_0 value should in principle be selected as the smallest possible value before the bounds diverge to infinity, and tests with higher E_b/N_0 values (e.g. E_b/N_0=5 dB) result in a smaller intersection of "best" codes. Thus the E_b/N_0 value used to evaluate the bounds should be decreased when we search for longer constraint length codes, but further tests with such codes indicate that it becomes less critical to use the smallest possible E_b/N_0 when the constraint length is increased.

Tests for different values of M indicate that the BER and EER criteria are equally well suited for selecting codes according to our minimum SER criteria (J=8), but since calculating the bound on BER require less computations than calculating the bound on EER it is our suggestion to use BER as selection criterion.

The straight-forward method of calculating Viterbi's union bounds involves the timeconsuming step of finding a large (since we want significant results) number of components of input-weight- or weightspectrum (depending on whether to calculate BER or EER) by an algorithm described by Cedervall and Johannesson [2]. Lee has in [3] given a more direct method of calculating BER (this method can also easily be adapted to calculate EER). Both methods were tested and Lee's method has by far the best performance of the two.

III. Conclusion

Our conclusion is that the best criterion for selecting convolutional codes for use in concatenated systems, is BER evaluated by Lee's method at minimum possible E_b/N_0 for the specific N and M.

Since the ensemble of codes is of size $2^{N(M+1)}$ it is impossible to perform exhaustive searches, even for moderate N and M, and we therefore have to reduce the subsets, but in such a way that the probability of missing (near) optimal codes according to our criterion is very small. Furthermore the subsets must be found in advantage such that only codes in the subsets need to be generated. To do this we used methods similar to what have been done in earlier code searches. Exhaustive computer searches were then carried out in the subsets, and we present a number of new codes, although most of them only marginally better than codes previously known.

References.

[1] Pil Joong Lee, "New short constraint length, rate 1/N convolutional codes which minimize the required SNR for given desired bit error rates.", *IEEE Trans. Commun.*, vol. COM-33, no. 2, February 1985, pp. 171-177.

[2] Mats Cedervall & Rolf Johannesson, "A fast algorithm for computing distance spectrum of convolutional codes", *IEEE Transactions on Information Theory,* Vol. IT-35, No. 6, Nov. 1989, pp. 1146-1159.

[3] Pil Joong Lee, "A very efficient transfer function bounding technique on bit error rate for Viterbi decoded, rate 1/N convolutional codes", *Jet Propul. Lab. Pasadena, CA, TDA Progress Rep. 42-49*, November 1984, pp. 114-123.

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