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Combined Coding Algorithm of LDPC Codes in Bit-Patterned Media Recording Channels

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Abstract. This paper presents a new coding algorithm of irregular low-density parity-check (LDPC) codes. This algorithm consists of two parts of block codes; parity bits was encoded using the magic square based algorithm (MSBA) which suitable for the short block (less than 500 bits) and the data bits, the rest part of all block codes, was encoded using the random number table. This proposed coding algorithm is called 'Combined Coding Algorithm LDPC codes (CCA-LDPC codes)' which can be used in bit-patterned media recording (BPMR) channels. The performance of the constructed codes was numerically simulated in BPMR channels model. The obtained performance of the proposed codes was compared with the comparable existing codes. The simulation results show that, at a block length of 4110 bit and code rate of 0.9, the proposed CCA-LDPC codes yields better performance than the existing ones, especially at high signal-to-noise ratio scenario.

Introduction

There are many types of error-correcting codes which have being used in the communication and data recording systems. One of the most popular codes and actually used in such systems is LDPC codes. The LDPC codes is a linear block codes defined by a sparse parity check matrix firstly proposed by Gallager [1] where, the parity check matrix used is randomly generated. This code was re-tested by Mackay [2]. The obtained results show that the code performance can be made close to Shannon's limit; therefore, many researchers were interested in LDPC codes. Mackay also pointed out that the decoding complexity of sum product algorithm (SPA) is linear, means that there is a constraint for codes with long block length. Array codes, presented by Blaum et.al [3], are error-correcting codes that have the capability to correct error bursts using an algebraic decoder, but can also be fully incorporated into soft iterative decoding schemes with an algebraic decoder. The symbols for array codes can be very large, making them especially suitable for correcting long bursts of errors.

Prasartkeaw and Choomchuay [4] proposed a new construction algorithm for the short block irregular LDPC codes. A newly developed algorithm, the so-called MSBA, is obtained by applying a magic square theorem as a part of the matrix construction. Simulation results based on AWGN channels show that with the code rate of 0.8 and SNR 5 dB, the BER of 10^{-7} can be obtained whilst the number of decoding iteration is relatively low. Consequently, as research paper [5], they presented the application of a random number table for the parity check matrix construction of irregular LDPC codes. The performance of the constructed codes was also tested in BPMR channels. The obtained performance of the proposed codes was compared with the comparable existing codes. The simulation results show that, at a block length of 4110 bit and code rate of 0.9, the proposed LDPC codes yields better performance than the existing ones.

This study aims at proposing a new algorithm for coding scheme. The proposed algorithm of parity check matrix construction consists of two parts of coding; first, the parity bits was encoded using the MSBA (as presented in [4]) which suitable for the short block and, second, the data bits was encoded using the random number table (as presented in [5]). This structured parity check matrix of LDPC codes can be used in the BPMR channels. The simulation results were compared with the existing results presented in [6].

Magic Square Based Algorithm

A magic square is a square array of the numbers 1, 2, 3, ..., z^2, with the property that the summation of every row, column and both diagonals, is the same number. Since there are z rows and z columns, the summation of all the numbers in the magic square must be $z \times M$, where M is the number that each row, column and diagonal must add up to. In summation notation can be expressed as Eq. 1.

$$\sum_{i=1}^{z^2} i = z \times M \qquad (1)$$

Then solving for M gives $M = [z(z^2+1)]/2$. According to how they are generated, the existing magic squares can be classified into four groups [4]: 1) magic squares associated to the astrological planets, 2) odd order, 3) doubly even order, and 4) singly even order. Among these, the best codes are obtained by using a 6×6 magic square of group 4) [4]. Therefore, the magic square generated using Strachey-method will be used in this current study.

Random Number Table Based Algorithm

Random number tables have been used in statistics for tasks such as selected random samples. Tables of random numbers have the desired properties no matter how chosen from the table: by row, column, diagonal or irregularly. The first such table was published by L.H.C. Tippett in 1927 [5]. To select a random number from the random number, we could choose all required numbers at any point of table every required-digit number. It depends on where you start in the table, and whether we work down or across. Keep going until you have enough different numbers (two-digit for this study) for filling in the sub-matrix as a shifting order. The parity check matrix **H** can be constructed according to the following steps [5].

Step 1. Define the designed parameters of J, K and L to be an integer greater than 3, where {J, K} ≤ L. All values must satisfy the following condition:

$$(J \times K) - K - \lambda \leq L, \lambda = 5, 9, 14, \ldots \qquad (2)$$

Step 2. Place two-digit random number in the structured parity check matrix **H**. These two-digit random numbers will be used as a shifting order of circulant matrix of L×L.

BPMR Channel

A typical discrete-time BPMR channel model is illustrated in Fig. 1, where we assume only two adjacent tracks cause most of the ITI. Therefore, the read-back signal can be expressed as

$$y_k = \sum_i \sum_m h_{i,m} u_{k-i,m} + n_k \tag{3}$$

where $u_{k,0}$, $u_{k,-1}$, and $u_{k,1} \in \{\pm 1\}$ represent an independent and identically distributed (*i.i.d.*) binary input bit sequences in the main track and the two adjacent tracks, respectively, $h_{i,m}$'s are the 2D channel response coefficients, and n_k is AWGN with zero mean and variance σ^2. Without the track mis-registration, we consider a discrete-time 3-by-3 symmetric channel response matrix of the form

$$H = \begin{bmatrix} h_{0,-1} & h_{1,-1} & h_{2,-1} \\ h_{0,0} & h_{1,0} & h_{2,0} \\ h_{0,1} & h_{1,1} & h_{2,1} \end{bmatrix} = \begin{bmatrix} 0.0347 & 0.2297 & 0.0347 \\ 0.1277 & 1 & 0.1277 \\ 0.0347 & 0.2297 & 0.0347 \end{bmatrix} \tag{4}$$

which is for a magnetic medium with SUL [7, 8]. Therefore, the sequence y_k is sent to a turbo equalizer, which iteratively exchanges soft information between the proposed two-dimensional (2D) SOVA equalizer and the LPDC decoder implemented based on the message passing algorithm with 3 internal iterations.

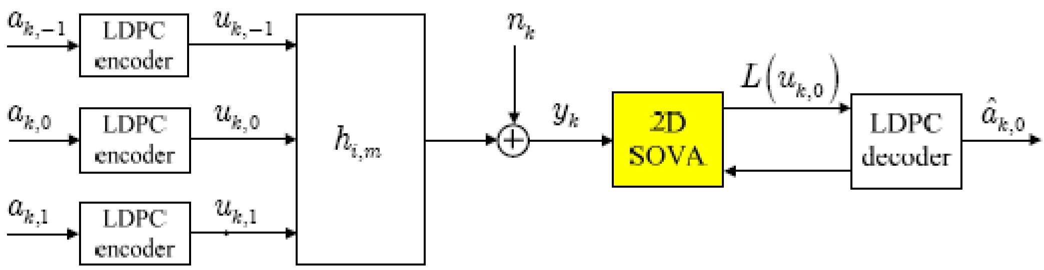

Fig. 1. A typical discrete-time BPMR channel model.

To perform maximum-likelihood (ML) equalization via the 2D SOVA, we propose to use a similar technique that was employed in the so-called bidirectional SOVA [9] to compute the LLR of the bit $u_{k,0}$, i.e., $L(u_{k,0})$. For this 3-by-3 channel matrix, the trellis of this 2D SOVA will have 36 states. For each state at time k, there are 6 outgoing branches to 6 different states at time $k + 1$.

Combined Coding Algorithm

The coding scheme of this study is a combined method between the methods presented in [4] (referred to as MSBA) and [5] (referred to as TRN). The codeword, as shown in Fig. 2, can be encoded-decoded using the flow chart shown in Fig. 3.

Fig. 2. Codeword.

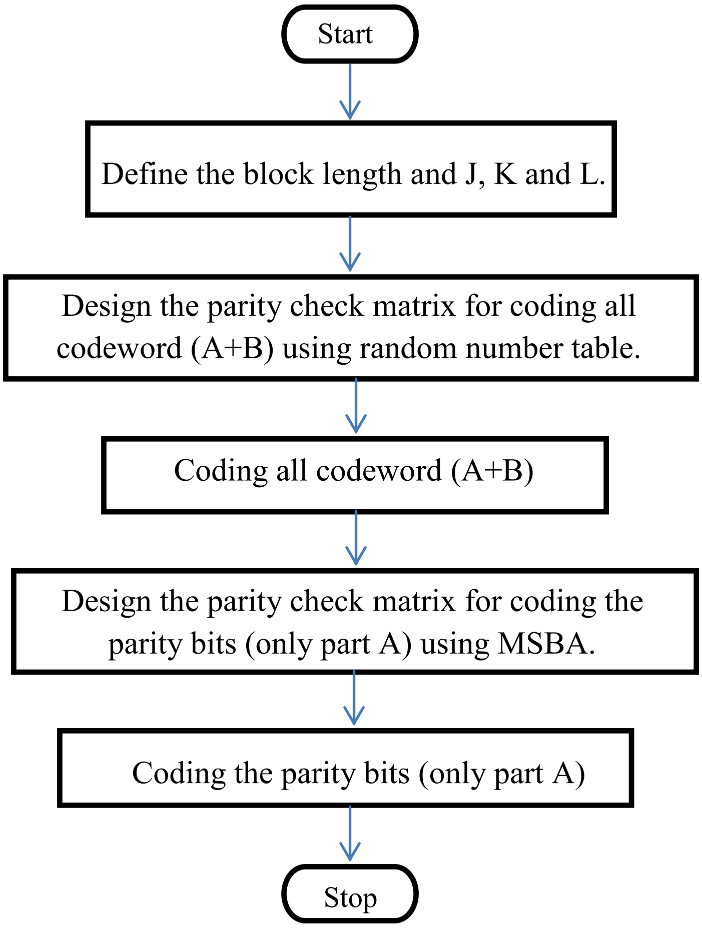

Fig. 3. Steps of the combined coding algorithm.

Simulation Results

The performance of the proposed codes was figured out via the simulation model and the obtained results were compared with the comparable earlier works, where their parity check matrices were generated based on random number table (denoted as TRN) [5] and based on Random Gallager Codes (referred to as MacKay) [6]. The parameters used in our simulation are: $J = 3$, $K = 30$, and $L = 137$ such that all codes will have the same block length of 4110 bits, the parity bits of $J\times L = 411$, the message bits of $K\times L = 3699$ and the code rate of $R = 1 - J/K = 0.9$.

Conclusions

The coding algorithm for LDPC codes was proposed using a combined method between the MSBA and TRN algorithms and the performance of the codes using this coding scheme was tested in BPMR channels. At a block length of 4110 bit and a code rate of 0.9, the proposed codes yield slightly better performance than the comparable earlier codes. It can be concluded that the second task for parity bits coding does not substantially effect on the codes performance, with its higher complexity of coding scheme, but slightly outperform.

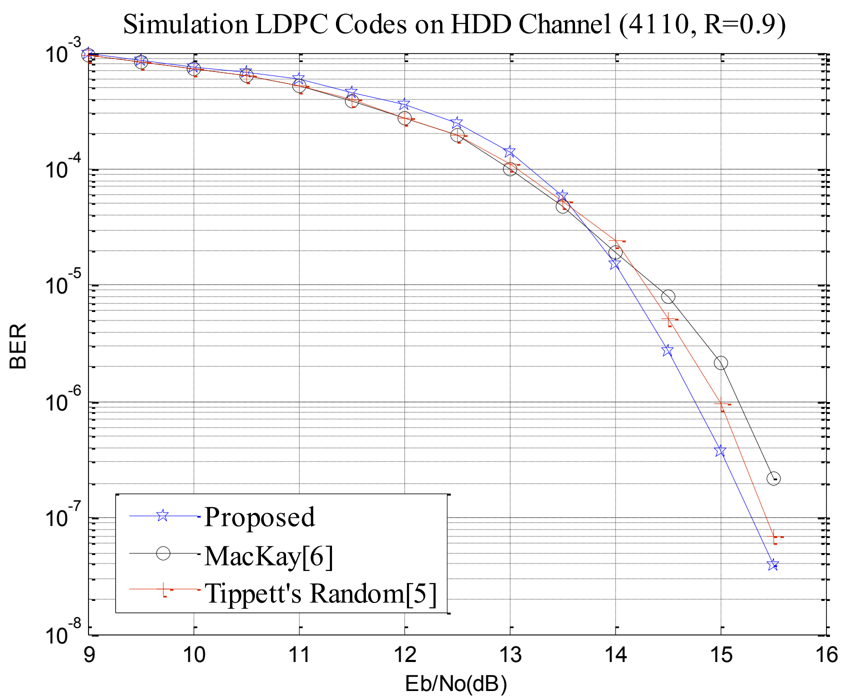

Fig. 4. BER performance comparison.

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