Blind Identification of Helical Interleaving of the First Type

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Abstract—**Interleaving is commonly used to guard against burst errors since it provides a form of time diversity in the coded sequence. A novel algorithm for identifying the helical interleaving of the first type is presented based on the linear property of channel coding and the structure characteristic of the helical interleaver. We make use of the basis of parity-check vectors to locate codewords within the interleaved block to estimate the parameters at the output of a binary symmetric channel. Experimental results are run to validate the algorithm.**

Keywords—helical inteleaver; blind recognition; GJETP

I. INTRODUCTION

Several interleaver types are applied in communication systems including the block interleaver, convolutional interleaver, helical interleaver [1]. Traditional strategy for recovering the block interleaver parameters involves applying a Gauss elimination process directly and exhausts all parameter candidates. It was first introduced by Burel and Gautier [2] for noiseless channels and extended to noisy channels by Sicot and Houcke [3]. Tixier et al. [4,5] reconstructed the block interleaver which has no particular structure, as it was chosen randomly among all possible permutations. Liru and Kwok [6] studied the convolutional interleaver by considering the code construction approach. Gan et al. [7] proposed a low complexity algorithm in a non-cooperative context by breaking the estimation process into two steps. Jeonghoon and Dongweon [8] studied the blind reconstruction of a helical scan interleaver which is the helical interleaving of the second type.

A full reconstruction process for blind interleaved data involving non-brute-force parameter identification for the helical interleaver (i.e., we do not exhaust all parameter candidates) is proposed here. We focus on block channel coding and the helical interleaving of the first type. According to the structure of the helical interleaver and the location, we can calculate the parameters directly based on helical interleaver properties by locating the bits belonging to the same codeword on the interleaver block.

This paper is organized as follows. Section II presents the properties of a helical interleaver. In Section III, we develop the principle of blind identification. Experimental results are provided in Section IV. Conclusions are drawn in Section V.

II. PROPERTIES OF HELICAL INTERLEAVER

Helical interleaver of the first type uses an array internally for its computations. It permutes the symbols in the data by placing them in an unlimited-row array in a helical fashion and then outputting rows of the array. Generally, the interleaver partitions S symbols from the input into consecutive groups of W symbols, where W corresponds to the interleaver width and m denotes the number of columns (i.e., $S=W*m$). It then places the kth group in the array along the kth column, starting from row $1+(k-1)*s$, where s denotes the step. Array positions that do not contain input symbols have default values. The received sequence is restored to its original ordering using an inverse process. Helical interleaver of the first type is governed by the rules listed below.

Rules: 1. $S \geq n$, and $S=m \times n$, $m \in N$, where m=2,3,4,… and n is the codeword length. **2.** $m < n$. **3.** $W=n$, each codeword occupies a column of the block. **4.** The starting point of the helical interleaver corresponds to the first bit of some codeword within one interleaver period.

Properties: 1. The minimum interval of contiguous bits after interleaving is m-1. **2.** When $(m-1)*s<n$ and synchronization is completed, each period contains $sum(m-1)*s$ bits of data belonging to the previous period and the same number of bits will be arranged into the next period. These are called *excess bits*. **3.** When $(m-1)*s \geq n$ and synchronization is completed, the delay is $sum(m-1)*s+t*n$ bits, where t is the number of times that bits in the last row of one period did not belong to any codeword involved in this period.

III. ESTIMATION AND RECONSTRUCTION

A. Principle of the approach

Redundant bits in error-correcting code are used to rectify limited random errors in information bits resulting from transmission. The interleaved bit streams still carries the information and check bits. Their linearity is preserved at an interval equal to the corresponding codeword period.

The first task is to find the maximum number of “almost dependent columns” after obtaining the interleaver depth S using conventional rank criteria [5]. We then locate the

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codewords within the interleaved sequence and calculate the parameters using the properties. Once S is gotten, we find the "almost dependent column" in matrix $\boldsymbol{A}$ such that its length is several times larger than the depth. The bits in these "almost dependent columns" are linear combinations of other bits located in the same block. A can be modeled as A= Ã+E where Ã is the error-free matrix and E contains all transmission errors. Define a set of column positions: $\boldsymbol{J}_{\mathrm{j}}^{\tilde{A}} = \{ i_p^j \}, p \in [1, p_j]$. Thus, during one interleaver period, the bits at positions i_p^j are linearly dependent and therefore belong to the same codeword. If $q \in \boldsymbol{J}_1$ and $q \in \boldsymbol{J}_2$, the bits in $\boldsymbol{J}_1$ and $\boldsymbol{J}_2$ are in the same codeword. Merge sets which are associated with each other and collect all. Choose the longest one as the length of the codeword and discard the shorter ones which bring errors. Then a basis of parity-check vectors will be obtained.

B. Synchronization

We select the first bit of the first detected codeword (after confirming its position) as the first bit of the interleaving period (the synchronization bit) based on **Rule** 4.

C. Parameters

According to **Property** 1, the minimum distance between adjacent bits in one codeword is m-1 after interleaving. Calculate this value by using the positions corresponding to one codeword and we can obtain the interleaver width as S/m. The calculation is considered correct thus far if the value is equal to the code length. The step size of the helical interleaver should be considered separately for two cases.

Case 1: When $(m-1)*s<n$, the *excess bits* in the last column are fewer than n (i.e., the bits in the last row of one interleaver period are data bits which exist in detected codewords). We then confirm the number of bits which should have been within one period but were pushed to the next period by a delay.

Case 2: When $(m-1)*s \geqslant n$, the last row of one interleaver period has at least one bit that does not belong to any detected codeword. We thus extend the period until all bits in the last row exist in detected codewords. According to **Property** 3, these bits consists of two parts: the *excess bits* and $t*W$.

IV. EXPERIMENTAL RESULTS

We consider the (7,4) BCH code and a helical interleaver of size S=42 here. Matrix A is constructed from 29056 intercepted bits in F_2. The threshold β is fixed at 0.2.

After obtaining the interleaving period S conventionally using rank criteria, our algorithm is able to identify the data bits corresponding to the same codewords within several periods. From this, we determine the other parameters such as the width, the number of columns, and the step size of the helical interleaver according to the structure properties of the helical interleaver. Fig. 1 depicts probability of detection against channel error probability, for 5, 25 and 40 iterations. From experiment results, we note that the algorithm performances are enhanced by iterations. What's more, marginal utility of detection decreases as the number of iterations increases as the number of iterations increases. As we can see, the global performances of probability of detection with 25 and 40 iterations are very close.

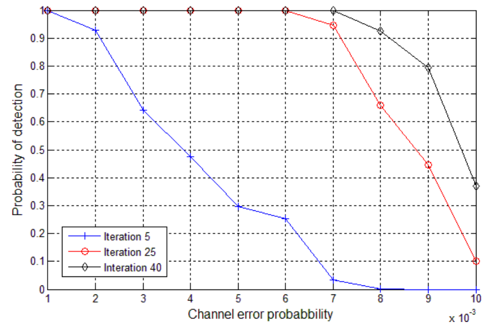

Fig. 1 Probability of detection against P_e

V. CONCLUTION

In this paper, we present a new method to blindly estimate the parameters of a helical interleaver of the first type based on the linear property and structure characteristic of an interleaved stream in a noisy channel. We determine the parameters according to the structure properties of the helical interleaver after synchronization without exhausting all parameter candidates. The probability to detect true parameters proved to be closed to 1 with a P_e<0.07 for C(7,4) with more than 25 iterations.

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