Peak-Shift and Bit Error-Correction with Channel Side Information in Runlength-Limited Sequences*

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Abstract. An error-correcting modulation coding technique is proposed for correcting combinations of multiple peak-shift errors and single bit errors in (d, k)-constrained sequences. The decoding process of the proposed technique uses channel side information in a magnetic recording system. Examples and comparisons are also presented.

1 Introduction

A (d, k) code is well known as a binary modulation or recording code [1], [2], [3], [4], [7], which is applied to input restricted channels, such as magnetic and optical recording systems. (d, k) means that any two consecutive 1’s in the input bit stream are separated by at least d 0’s and by at most k 0’s. During the NRZI (non-return-to-zero-inverse) precoding step that is usually applied to a (d, k) code, the 1’s in the (d, k)-constrained sequences are mapped onto transitions in the corresponding binary channel bit sequences. Then, in the (d, k)-constrained sequences, the minimum separation d and the maximum separation k are imposed in order to reduce intersymbol interference and extract clock control from the received bit stream, respectively. In this paper, we consider error-corrections in (d, k)-constrained sequences.

It has been reported that in magnetic recording channels, most of the errors are right- and left-shift errors, and drop-out and drop-in errors also arise due to various physical reasons [2], [3]. A right-shift error shifts a 1 in right direction; a left-shift error shifts a 1 in left direction; a drop-out error turns a 1 into a 0; a drop-in error turns a 0 into a 1. In this paper, right- and left-shift errors are referred to as peak-shift errors, and drop-out and drop-in errors are called bit errors. In most practical applications, the probability that a 1 is shifted by two

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or more positions is very small. In this paper, we assume that a 1 may be shifted by at most one position.

In a conventional recording system, after data are encoded by an error-correction encoder, a modulation encoder encodes the code sequences into \((d, k)\)-constrained channel sequences, as depicted in Fig. 1. Then, errors in the received sequences are extended by the modulation decoder. Therefore, the error-correction decoder must correct the burst error even if only a single error is in the received sequences. It is desirable that the modulation decoding is performed after the error-correction decoding, as illustrated in Fig. 2. In Fig. 2, an error-correcting modulation encoder encodes modulation code sequences into channel sequences with error-correction capabilities. Such a recording system has been proposed in [1] and [2]. In this paper, we consider an error-correcting modulation coding technique in the recording system as shown in Fig. 2.

![Fig. 1. Block diagram of a conventional recording system](image)

Ferreira and Lin [1], Hilden, Howe, and Weldon [2], Kuznetsov and Vinck [7], and Saitoh, Ohno, and Imai [8] have developed peak-shift error-correcting modulation coding techniques. Ferreira and Lin [1] has also presented bit error-correcting modulation coding techniques. In this paper, we propose an error-correcting modulation coding technique for correcting combinations of multiple peak-shift errors and single bit errors in \((d, k)\)-constrained sequences. The decoding process of the proposed technique uses well known channel side information [1], [5] in a magnetic recording system.

The structure of this paper is as follows: In Sect. 2, a peak-shift error-correction technique is described. Section 3 describes channel side information for determining whether or not a single bit error is in the received sequence.