СЕКЦИЯ 1
ТЕОРИЯ КОДИРОВАНИЯ
И ЦИФРОВАЯ ОБРАБОТКА СИГНАЛОВ

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INTERLEAVING BASED ON LINEAR BLOCK CODE

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Abstract. In this paper the methods of transforming one-dimensional linear code into two-dimensional symmetric and asymmetric recursive scattering information code are analyzed. The method has transformed the encoded information sequence into a discrete sequence to combat the burst noisy environment. Channel coding is effective when detecting and correcting single errors are not too long strings and is ineffective for long burst errors caused by interference and fading of the mobile communication channel. However, the interleaving technique can solve the above problem without adding extra redundancy.

Keywords: symmetric and asymmetric method, interleaving technology, channel coding, burst interference.

Introduction

In recent years, there has been an increasing demand for efficient and reliable digital data transmission and storage systems. This demand has been accelerated by the emergence of large-scale, high-speed data networks for the exchange, processing, and storage of digital. A major concern of the designer is the control of errors so that reliable reproduction of data can be obtained.

In digital communication, due to inherent noise characteristics and fading characteristics, there are always different levels of interference and fading during information transmission, resulting in errors in signal transmission. In order to reduce the information error rate and improve the reliability of information transmission, channel coding techniques such as Hamming code, cyclic code and convolutional code for error correction have been invented. However, with the development of technology and the increasing demand for information accuracy, the limitations of these technologies have become increasingly prominent. For example, channel coding is only effective when detecting and correcting single errors and not too long error strings and generates multiple consecutive errors when the channel generates burst interference. Such Hamming codes, cyclic codes, and convolutional codes are not enough.

In this regard, the interleaving technology have been innovated and invented. As a new coding technology, interleaving coding technology is mainly used for memory channels, especially in wireless channels, to correct some bit errors and some burst errors.

A data interlace is often added to the end of the transmitter and a deinterlace is located behind the receiver, and the interleaved code is used to actively modify the channel, and a memorized burst channel is transformed into an independent memoryless channel through the interleaving and deinterleaving channel. Thereby the burst errors of the channel are spread out.

In this way, if some burst errors are occurred， thanks to the existence of the interleaving module, the errors are divided to some individual ones and then it is possible to correct these separated errors and revive the original information by use of the channel coding error correction ability [1].

Interleaving coding principle

The basic structure of the system is presented in Fig. 1.

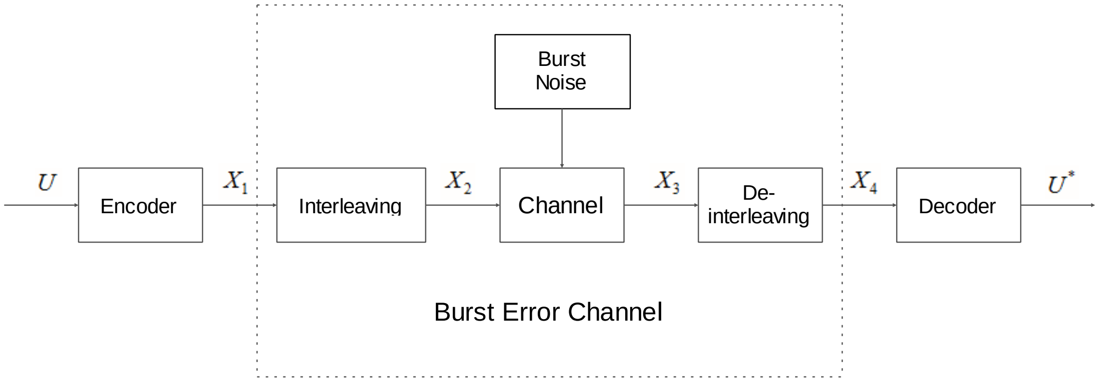

Fig. 1. Interleaved coding principle block diagram

The transmitted information can be represented by symbols. The function of the linear encoder is to encode the message which consists of binary digits string. The main task of the communications system is to convey the information from one point to another without distortion. But the ideal channel without any noise is not exist, the information always exposed to the noise which causes degradation of the signal. The detailed behavior of communication systems in the presence of noise is a lengthy study. The authors are concerned mostly with the interleave and deinterleave block, transmitting the message to the data interleave, adding a de-interleave to the receiving end, using the interleaving method to actively modify the encoded message, and transforming a memorized burst channel into an independent memoryless channel through the interleaving and deinterleaving channel, thereby the burst errors of the channel are spread out. The generation of interleave greatly improves the reliability of information transmission. The channel error correction code is to adapt to the channel, by adding redundancy to high transmission reliability, only suitable for anti-random interference. Different interleaving codes are used for error correction. They transform the channel without adding redundancy, suitable for anti-burst interference [2].

The common methods of the interleaving are packet interleaving, convolutional interleaving and random interleaving. The process of the analysis will conduct with the help of the matrix. The information which needed to transmit presented like following:

$$X_1 = (x_0, x_1, x_2, ..., x_{14}, x_{15}). \quad (1)$$

The interleaving memory is written by the column and read by the row.

$$X_1' = \begin{bmatrix} x_0 & x_4 & x_8 & x_{12} \\ x_1 & x_5 & x_9 & x_{13} \\ x_2 & x_6 & x_{10} & x_{14} \\ x_3 & x_7 & x_{11} & x_{15} \end{bmatrix} \quad (2)$$

The output information of the interleaving block which will sent to the channel:

$$X_2 = (x_0, x_4, x_8, x_{12}, x_1, x_5, x_9, x_{13}, x_2, x_6, x_{10}, x_{14}, x_3, x_7, x_{11}, x_{15}). \quad (3)$$

In case, when two burst errors appear, one of them is started from the x_0 and ended in the x_{12} which means there are 4 successive errors, and another one is in the 2 continual position, from x_9 to x_{13}, the error is donated as:

$$X_3 = (x_0', x_4', x_8', x_{12}', x_1, x_5, x, x_{13}, x_2, x_6, x_{10}, x_{14}, x_3, x_7, x_{11}, x_{15}). \quad (4)$$

In the receiver information will saved in another storage after leaving the interleaving modular which is written by row and read by column:

$$X_3' = \begin{bmatrix} x_0' & x_4' & x_8' & x_{12}' \\ x_1 & x_5 & x_9' & x_{13}' \\ x_2 & x_6 & x_{10} & x_{14} \\ x_3 & x_7 & x_{11} & x_{15} \end{bmatrix}. \quad (5)$$

The output of the deinterleaving modular is:

$$X_4 = (x_0', x_1, x_2, x_3, x_4', x_5, x_6, x_7, x_8', x_9', x_{10}, x_{11}, x_{12}', x_{13}', x_{14}, x_{15}). \quad (6)$$

It is obvious that with the help of the interleaving modular, two burst errors, with number of the continual error are 4 and 5 respectively, will change to the random independent error.

Introduction to symmetric and asymmetric interleaving [3,4]

Based on the 2×2 matrics, design the $2^N \times 2^N$ (N-integer) matrics, the interleaved matrices are as presented in Fig. 2.

0	4	8	12
1	5	9	13
2	6	10	14
3	7	11	15

a

0	8	2	10
12	4	14	6
3	11	1	9
15	7	13	5

b

0	4	6	10
8	12	14	2
15	3	9	13
7	11	1	5

c

0	3	6	8
10	12	14	1
4	7	9	11
13	15	2	5

d

Fig. 2. Symmetric and Asymmetry matrices 4×4

The permutation functions on {0,1,2,3} as follows [3]:

$$\begin{aligned} &h_{6i+1}(0)=0, \quad h_{6i+1}(1)=1, \\ &h_{6i+2}(0)=0, \quad h_{6i+2}(1)=2, \\ &h_{6i+3}(0)=0, \quad h_{6i+3}(1)=2, \\ &h_{6i+4}(0)=0, \quad h_{6i+4}(1)=1, \quad h_{6i+1}(2)=2, \quad h_{6i+1}(3)=3; \\ &h_{6i+5}(0)=0, \quad h_{6i+5}(1)=3, \quad h_{6i+2}(2)=1, \quad h_{6i+2}(3)=3; \\ &h_{6i+6}(0)=0, \quad h_{6i+6}(1)=3, \quad h_{6i+3}(2)=3, \quad h_{6i+3}(3)=1; \\ &\qquad\qquad\qquad\qquad\qquad\quad h_{6i+4}(2)=3, \quad h_{6i+4}(3)=2; \\ &\qquad\qquad\qquad\qquad\qquad\quad h_{6i+5}(2)=1, \quad h_{6i+5}(3)=2; \\ &\qquad\qquad\qquad\qquad\qquad\quad h_{6i+6}(2)=2, \quad h_{6i+6}(3)=1; \end{aligned} \quad (7)$$

and $h_i(4k+m)=h_i(m)$ for all nonnegative integers i, k and m.

$$g_{6i+1}(n)=h_5(n),\quad g_{6i+2}(n)=h_3(n),\quad g_{6i+3}(n)=h_1(n);$$
$$g_{6i+4}(n)=h_6(n),\quad g_{6i+5}(n)=h_2(n),\quad g_{6i+6}(n)=h_4(n); \tag{8}$$

for all nonnegative integers i.

$$f(n,a)=[g_{a+1}(n)+\sum_{b=1}^{a}h_{a-b+1}([\frac{n}{4^b}])](\mathrm{mod}\,4). \tag{9}$$

Where $[\bullet]$ is the floor function ($[x]$ is the greatest integer less than or equal to x), and define

$$r(n,a)=\left\{\begin{matrix}0,\ \text{if}\ f(n,a)\in\{0,1\}\\ 1,\ \text{if}\ f(n,a)\in\{2,3\}\end{matrix}\right\};$$
$$c(n,a)=\left\{\begin{matrix}0,\ \text{if}\ f(n,a)\in\{0,2\}\\ 1,\ \text{if}\ f(n,a)\in\{1,3\}\end{matrix}\right\}. \tag{10}$$

Then the integer n is located at vector (i,j), where

$$i=\sum_{a=0}^{N-1}2^{N-a-1}r(n,a)\quad j=\sum_{a=0}^{N-1}2^{N-a-1}c(n,a). \tag{11}$$

This ordering is more easily understood with an example. Considered the integer 14 in the second array of Fig. 2. The formulas above, with $N=2$, give

$$f(14,0)=g_1(14)=h_5(2)=1$$
$$f(14,1)=g_2(14)+h_1(3)=h_3(2)+h_1(3)=3+3=2(\mathrm{mod}\,4).$$

Thus by (11) the row index for 14 is:

$$2^1\cdot 0+2^0\cdot 1=1$$

and the column index is:

$$2^1\cdot 1+2^0\cdot 0=2.$$

Using the way of table *b, c, d* symmetric and asymmetry matrices 4×4 interleaving, assumed that the position of continuous error occurs is the same as (5), the degree of error dispersion after interleaving can be seen.

$$X'_{1(b)}=\begin{bmatrix}x'_0 & x'_8 & x'_2 & x'_{10}\\ x_{12} & x_4 & x'_{14} & x'_6\\ x_3 & x_{11} & x_1 & x_9\\ x_{15} & x_7 & x_{13} & x_5\end{bmatrix}; \tag{12}$$

$$X_{4(b)}=(x'_0,\, x_1,\, x'_2,\, x_3,\, x_4,\, x_5,\, x'_6,\, x_7,\, x'_8,\, x_9,\, x'_{10},\, x_{11},\, x_{12},\, x_{13},\, x'_{14},\, x_{15}); \tag{13}$$

$$X'_{1(c)}=\begin{bmatrix}x'_0 & x'_4 & x'_6 & x'_{10}\\ x_8 & x_{12} & x'_{14} & x'_2\\ x_{15} & x_3 & x_9 & x_{13}\\ x_7 & x_{11} & x_1 & x_5\end{bmatrix}; \tag{14}$$

$$X_{4(c)}=(x'_0,\, x_1,\, x'_2,\, x_3,\, x'_4,\, x_5,\, x'_6,\, x_7,\, x_8,\, x_9,\, x'_{10},\, x_{11},\, x_{12},\, x_{13},\, x'_{14},\, x_{15}); \tag{15}$$

$$X'_{1(d)} = \begin{bmatrix} x'_0 & x'_3 & x'_6 & x'_8 \\ x_{10} & x_{12} & x'_{14} & x'_1 \\ x_4 & x_7 & x_9 & x_{11} \\ x_{13} & x_{15} & x_2 & x_5 \end{bmatrix}; \quad (16)$$

$$X_{4(d)} = (x'_0,\, x'_1,\, x_2,\, x'_3,\, x_4,\, x_5,\, x'_6,\, x_7,\, x'_8,\, x_9,\, x_{10},\, x_{11},\, x_{12},\, x_{13},\, x'_{14},\, x_{15}). \quad (17)$$

The comparation of these interleaving methods are presented in the table.

Performance comparison of Interleaving methods

Continuous error bit	The number of possible errors	Number of errors that cannot be discrete			
		a	*b*	*c*	*d*
2	15	0	0	0	0
3	14	0	0	2	0
4	13	0	1	3	0
5	12	12	1	4	0
6	11	11	3	6	0
7	10	10	4	6	0
8	9	8	7	6	8

It can be seen from the above table that the *d* method has an ideal performance when faced the continuous errors which is less than 7. However, there is not exist one method which have enough ability to deal with the continued errors which are eight and above.

Conclusion

In this paper, the methods of transforming one-dimensional linear code into two-dimensional symmetric and asymmetric recursive scattering information code were analyzed. The method has transformed the encoded information sequence into a discrete sequence to combat the burst noisy environment. The experiment results indicate that the new method has a good performance.

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