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W-cyclic method of interleaving of the data for communication systems

Abstract. *A modified cycling interleaver for complex data transformation (W-cyclic method) based on redundant coding is described. Algorithms of interleaving and deinterleaving are considered. A comparative analysis of the efficiency of information transformation on the basis of W-cyclic method is carried out.*

Streszczenie. *Została opisana zmodyfikowana metoda cyklicznego przeplotu danych (metoda W-cyclic), opierająca się na kodowaniu nadmiarowym. Przeanalizowane zostały także algorytmy przeplotu i odwrotnego przeplotu. Dodatkowo została opisana porównywalna analiza efektywności przekształcenia informacji za pomocą metody W-cyclic. (**Metody w-cykliczne przeplotu danych w systemach komunikacji**).*

Keywords: interleaver, reverse interleaving, communication systems, complex transformation of information.
Słowa kluczowe: przeplot, przeplot odwrotny, systemy komunikacyjne, złożona transformacja informacji.

Introduction

Currently communication systems require high speed transmission and transformation of information which ensures the required level of reliability. However, they are exposed to various types of interference: electromagnetic field of meteorological conditions, operating conditions, etc. This leads to errors in data transmission [1]. Research has shown that the errors are self-dependent and have a tendency to clustering. The result is that there is a loss and distortion of information [2].

To avoid errors methods based on a robust information coding are applied. The improvement of the efficiency of coding schemes to neutralize the errors of higher multiplicity can be achieved through the sharing of correcting code and an interleaver, known as a complex transformation of information [3]. The role of the interleaver is to reduce the correlation between adjacent symbols by reversing characters. This allows converting grouping errors to a single one. Efficiency of the interleaver is determined by the the minimum distance of erroneous bits separation.

The most famous interleavers are block, s-random and cyclic interleavers. However, existing methods do not allow interleaving evenly scattered errors of large multiplicity and are characterized by a low minimum distance separation.

Description of cyclic interleaver

The function of the cyclic interleaving is [4]:

(1) $$\pi(i) = i \cdot a \bmod N,$$

where i is the number of the current level; $\pi(i)$ is the location of the informational bit after interleaving, N is the size of the original sequence, $a < \lfloor \sqrt{2 \cdot N} \rfloor$ is the step, that determines the distance between two neighboring bits after interleaving. Besides parameters values of *a* and N must be coprime numbers.

W-cyclic method interleaving

The investigation showed that cyclic interleaver has different properties depending on step values. As shown in Figure 1, with step size a = 31 the cyclic interleaver can spread errors of high multiplicity to the relatively small distance, and with a = he 251 the cyclic interleaver shows excellent results at a low multiplicity of errors, but at a higher multiplicity the depth of errors separation is low.

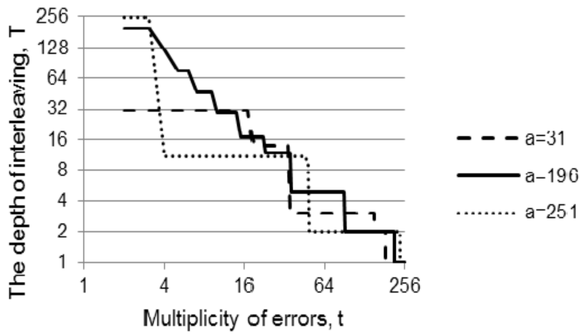

Fig.1. The curves of minimum separation distances of errors for cyclic interleaver with different values of the step at N = 512

Therefore, it is reasonable to improve the cyclic interleaver with the aim of separation at long distances of high and low multiplicity errors (a = 196 for N = 512). It is proposed to use the following function, as a modification of cyclic interleaver:

(2) $$\pi(i) = i \cdot W \bmod (N+1),$$

where W is an integer number, coprime to (N+*1*). It is experimentally established that interleaver separates errors of any multiplicity very well by using step $\lfloor 0.382 \cdot N \rfloor - 2 \le W \le \lfloor 0.382 \cdot N \rfloor + 2$, where 0.382 is Fibonacci ratio.

Test case of w-cyclic interleaver usage

Let us suppose that it is needed to interleave the sequence of bits (N = 512). Firstly, let us determine the value of the step size W. In accordance with inequality $194 \le W \le 198$. Let W = 196 (numbers 196 and 513 are mutually prime), then according to expression 2, we get the new address bits (Tab. 1).

Table 1. The indices of input and output elements for N = 512 bits

i	1	2	3	...	511	512
π	196	392	75	...	121	317

Thus, the first bit of the original sequence is repositioned in place of 196th bit of the interleaved sequence, the second bit is repositioned to 392th place, etc.

Figure 2 shows the output bit position depending on the input one. The figure shows that the interleaver elements are uniformly distributed.

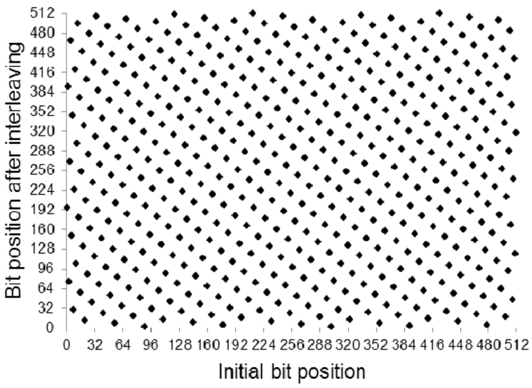

Fig.2. Dependence of the output bit position from input one

Comparative analysis

To analyze the efficiency of the conversion information based on the W-cycle interleaving the calculations of the minimum distance separation of erroneous bits for message size 512 bits were carried out (Tab. 2).

Table 2. Minimum distance separation bit errors at N = 512 bits

Multiplicity of errors	block interleaver	s-random interleaver	cyclic interleaver	w-cyclic interleaver
2	14	22	31	196
3	14	22	31	121
…	...	...	...	...
23	14	1	15	12
…	...	...	...	...
34	14	1	1	12
…	...	...	...	...
40	1	1	1	5
…	...	...	...	...
212	1	1	1	2
213	1	1	1	1

According to the data, given in Table 2, it can be noted, that the minimum distance separation of erroneous bits in the W-cyclic interleaving method for certain lengths of the block is higher than in the other interleavers.

To compare the performance of W-cycle and other known methods it is reasonable to obtain a dependence of the minimum distance separation of errors on their multiplicity (Fig. 3).

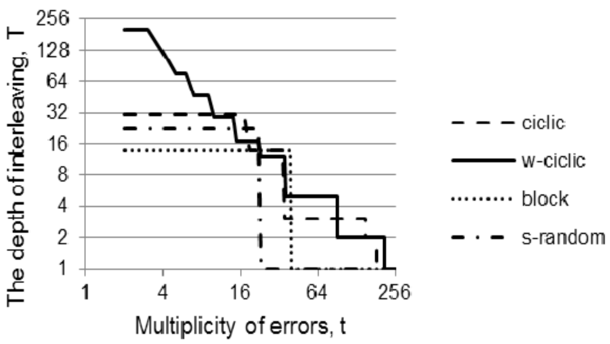

Fig.3. The curves of minimum separation distances of errors for cyclic, w-cyclic, block and s-random interleavers with different values of the step at N = 512

Figure 3 shows that w-cyclic interleaver separates at large distance both errors of low ratio and high multiplicity.

Reverse interleaving

To restore the original sequence of bits after transmission deinterleaver is used. Its function is:

$$\pi'(i) = \pi(i) \cdot W' \bmod (N+1), \tag{3}$$

where $\pi'(i)$ is the location of the bits after deinterleave, W' is the value of a backward interleaver step, an integer value is chosen from the ratio 4:

$$W' = \frac{m \cdot (N+1) + 1}{W}, \tag{4}$$

where *m* is an integer in the interval $0 \le m \le N-1$.

Let's consider the reverse interleaving in the abovementioned example. One ought to find the integer *m* which would ensure, according to (4), the value of the deinterleaving step to be integer (m = 115, W' = 301).

Thus we obtain the bits addresses given in Tab. 3.

Table 3. The indices of input and output elements for N = 512 bits

$\pi(i)$	196	392	75	...	121	317
$\pi'(i)$	1	2	3	...	511	512

Thus, according to the table 3, the original sequence of bits is recovering.

Conclusions

The known methods of interleaving such as cyclic, block and S-random ones are described. A new W-cyclic interleaver method is proposed as a result of improvements in the cyclic interleaving. It ensures good separation of errors of any multiplicity.

A comparative analysis of proposed method with other known methods of interleaving is carried out. It is found, that the minimum distance separation of erroneous bits in the W-cyclic interleaving method for certain lengths of the block is higher than in the other interleavers.

The algorithm of interleaving and deinterleaving based on W-cycling method is considered for message of 512 bits.

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