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Analysis of the Decoder's Operation at Correcting Single Errors Using the Triple Code

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The article deals with the singularities of the triple code application at transmission of digital information; shows the possibility of anti-jam protection of the triple code using methods developed for the binary code, in particular, methods of encryption based on the generator matrix and generator polynoms; and shows that methods of syndrome decoding are applicable for channel decoding.

Key words: Communication channels, Encryption, triple polynom.

The problem of reproduction and development of devices with the logic of interpretation of the concept of information for PC computations in the triple numerical system or by means of computing devices with triple memorizing elements occurred in the early 1970s. The prospects of devices using triple logics were doubted based on the assumption that information should be represented in the binary logic and the binary numerical system only. Developing the determined (non-probabilistic) combinatory approach of A.N. Kolmogorov to the quantitative representation of information[1] in this task, we come to another conclusion-the variants of integration of a message in the binary logic and the binary numerical system are reproduced by the results of similar integration in the triple logic and the triple numerical system. At that, the more general triple coding allows representing the formation of information representations more accurately and fully, as unlike the binary coding, it excludes the rounding errors and provides for independent selection of the code value for the case of equivalent alternatives.

The methodology of formation of digit position anti-jam in the triple code

The issues of jam-proof coding are urgent for the contemporary media of data transmission in telecommunication systems[4-13].

Let us find the syndromes of the errors. The type "1" errors: S_1=101; S_2=011; S_3=110; S_4=111; S_5=100; S_6=010; S_7=001.

The type "2" errors: S_8=202; S_9=022; S_{10}=220; S_{11}=222; S_{12}=200; S_{13}=020; S_{14}=002.

We will make a type "1" error in the third digit position and a type "2" error in the fifth position.

2	1	2*	0	2	0	0
0	0	1	0	0	0	0
2	1	0	0	2	0	0

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2	1	2	0	2*	0	0
0	0	0	0	2	0	0
2	1	2	0	1	0	0

The obtained messages are multiplied by the matrix $\mathbf{H}^T$.

$$S = |2100200| \times \begin{vmatrix} 101 \\ 011 \\ 110 \\ 111 \\ 100 \\ 010 \\ 001 \end{vmatrix} = (1,1,0)$$

is the syndrome of the type "1" error in the third digit position " S_3.

$$S = |2120100| \times \begin{vmatrix} 101 \\ 011 \\ 110 \\ 111 \\ 100 \\ 010 \\ 001 \end{vmatrix} = (2,0,0)$$

is the syndrome of the type "2" error in the fifth digit position " S_{12}.

Correction of the type "1" error in the third digit position of the received message and the type "2" error in the fifth position.

_2	1	0	0	2	0	0
0	0	1	0	0	0	0
2	1	2	0	2	0	0

$$\begin{array}{ccccccc} \_2 & 1 & 2 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 0 & 0 \\ \hline 2 & 1 & 2 & 0 & 2 & 0 & 0 \end{array}$$

Let us consider the jam-proof coding using a generator polynom.

We start with the example for the same code (4). The generator polynom $g(x)=x^3+x+1$. The procedures of division are carried out using operations of field GF(3). The information message of type $m(x)=a_3x^3+a_2x^2+a_1x^1+a_0x^0$, in which the ratios a_i belong to the set (0,1,2), is multiplied by x^3. Then, the polynomial $a_3x^6+a_2x^5+a_1x^4+a_0x^3$ is divided by the primitive (indivisible) polynomial $g(x)$.

Example. $m(x)=1x^3+2x^2+2x^1+1$.

$$\begin{array}{l|l} x^6+2\cdot x^5+2\cdot x^4+x^3+0\cdot x^2+0\cdot x+0 & x^3+0\cdot x^2+x+1 \\ \cline{2-2} x^6+0\cdot x^5+1\cdot x^4+1\cdot x^3 & x^3+2\cdot x^2+x+1 \end{array}$$

$$\overline{2\cdot x^5+1\cdot x^4+0\cdot x^3+0\cdot x^2}$$

$$2\cdot x^5+0\cdot x^4+2\cdot x^3+2\cdot x^2$$

$$\overline{x^4+1\cdot x^3+1\cdot x^2+0\cdot x}$$

$$x^4+0\cdot x^3+1\cdot x^2+1\cdot x$$

$$\overline{1\cdot x^3+0\cdot x^2+2\cdot x+0}$$

$$1\cdot x^3+0\cdot x^2+1\cdot x+1$$

$0+1\cdot x+2$ " excess R.

By analogy with the coding method that uses the generator matrix, we obtain check symbols for the equality $R + P = 0$, where R is the division excess, is the vector of the check symbols R = (012), = (021).

Thus, we find the message code $U(x)$= $x^6+2\cdot x^5+2\cdot x^4+x^3+2\cdot x+1$.

The operations of division are easier to perform by representing the codes in the forms of ratios in the respective positions of digits $m = (a_3, a_2, a_1, a_0)$. From the example $m(x) = 1221$.

After the operation of multiplication by x^3 (the three-digit shift to the left) $m(x)\cdot x^3 = 1221000$. The generator polynom $q(x) = 1011$. The process of division. The check digit positions appear from the condition $R + P = 0$ ($P = 021$).

$$\begin{array}{l|l} 1221000 & 1011 \\ \cline{2-2} \underline{1011} & 1211 \end{array}$$

2100

2022

1110

<u>1011</u>

1020

<u>1011</u>

012- “ excess *R*.

Check of correctness of coding by syndrome *S*.

1221.021	1011
<u>1011</u>	1211

2100

<u>2022</u>

1112

<u>1011</u>

1011

<u>1011</u>

000- “ syndrome *S*.

For each generator polynom, we find syndromes of the type “1” and “2” errors. For the code (7.4) and the polynom $q(x)$ = 1011, 14 values of errors syndromes are provided in Table 1.

Table 1. Syndromes of errors for the triple polynom 1011

Errors “1”	Errors “2”
S_{11}=121	S_{21}=212
S_{12}=211	S_{22}=122
S_{13}=220	S_{23}=110
S_{14}=022	S_{24}=011
S_{15}=100	S_{25}=200
S_{16}=010	S_{26}=020
S_{17}=001	S_{27}=002

The fact draws our attention that syndromes of errors in one digit position are reverse by (mod3), i.e. $S_{1j}+S_{2j}=0$.

The correcting capacity of the code is much higher with the base 3 than it is with the base 2.

For example, for the code (7,4), the binary code corrects 7 single errors, at that the set of codes of syndromes $2^{n-m}=2^3$ is used in full. Similar estimations of the triple code show that 14 single errors are corrected. At that, the set of syndrome codes $2^{n-m}=3^3$ is used partially and 12 (27"15) syndrome codes can be used for correction of some double errors.

As the block size of the code (n, m) increases, the anti-jam properties of the triple code increase in geometric sequence if compared to the binary code.

The properties of the qualitative growth of anti-jam of the codes with larger base (2^d, where $d = 2, 3, 4,\ldots$) are implemented in the Reed–Solomon codes [3]. Development of analogs of the Reed-Solomon codes for bases 3^d produces effect that is even more impressive. The corrective capacity of the triple code in channel codecs is substantially higher than the one of the binary code for the same blocks (n, m) [14].

CONCLUSIONS

The specific feature of the triple code is the change of the algorithm of digit positions anti-jam formation. For channel decoding of the triple code, the methods of syndrome decoding are applicable.

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