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EFFICIENCY OF PARTLY ERRORS CORRECTION IN ARQ DTS BASED ON TIMER SIGNAL CONSTRUCTION

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ЕФЕКТИВНІСТЬ КОРЕГУВАННЯ ЧАСТИНИ ПОМИЛОК У АДАПТИВНИХ СИСТЕМ ІЗ ВИРІШАЛЬНИМ ЗВОРОТНІМ ЗВ'ЯЗКОМ НА БАЗІ ТАЙМЕРНИХ СИГНАЛЬНИХ КОНСТРУКЦІЙ

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Анотація.: *Розроблено метод передавання на базі систем з вирішальним зворотнім зв'язком та таймерних сигнальних конструкцій з корегуванням частини помилок інтервалу «хорошого» стану рівнянням якості. Визначені граничні умови його використання та ефективність.*

Abstract. *The data transmission method was proposed based on ARQ systems and timer signal construction with error correction by "quality equation" on the "good" interval of the channel. It was defined efficient and boundary conditions of its use .*

Well known, that is important to search and improvement techniques that can ensure the most efficient use of resources, equipment and physical channels [1] under solving the problem of development of data transfer system (DTS).

Top of these methods are occupying the timer signal construction (TSC) [1, 2]. TSC substantially simplifies developing of the telecommunication systems and increases the capacity of real channels [2].

It's Important to mention that it's effective to use automatic repeat-request (ARQ) for reduce redundancy channel coding It's allow to reduce the required redundancy for error correction in real channels [2] almost in two times. There is the line of works [1, 2] that describes performance improving possibility based on using adaptive ARQ and TSC.

However, in most cases the methods based on ARQ and TSC describes only classical binary block coding redundancy compensation and does not take into account the stochastic characteristics and distortion of TSC while it's passing real communication channels.

Real communication channels in most cases can be describes by two states [2]: "good" state (characterized by the state number of modulation points (MP) on the construction period) It's takes T_{trnsm} 0.99 of whole transmission period and can be characterized $P_e \geq 10^{-9} ... 10^{-8}$ error probability (it's means that standard deviation MP with respect to the actual position equals $\sigma \approx 2\%$) and "bad" state (characterized by changed number of MP on the construction period) in the range $T \leq 0,01T_{\text{trnsm}}$ with probability $P_e \to 0,5$.

Let's consider a system based on the timer signal construction that can be described by [2]:

- the specified number i of MP in the code word synthesized on the interval m;
- the number i specified the maximum number of implementations on given interval;
- distance between adjacent MP (τ_c) not less than Nyquist element and can vary discretely on the interval $\Delta(\Delta = \frac{t_0}{S}; s = 2 \div m)$, $\tau_c \geq t_0 + z\Delta \ \ (z \in 1,2,3...)$;
- nonlinearity - the sum of two codeword's doesn't make codeword contained in the alphabet.

Thus, information build into the length of the transmitted signal intervals between TSC and their relative position.

Structure analysis shows that in general alphabet capacity is a^{ms}, so in the case of designs with parameters $i = 3, m = 8, s = 7$ combinations number will be 2^{56}, of which only $\approx 2 \cdot 10^{-10}$ % are allowed[1]:

TSC structure represented in Figure 1.

<table>
<tr><td colspan="7">Interval 1 t_0</td><td colspan="7">Interval 2 t_0</td><td colspan="9">Interval 3 … m t_0</td><td colspan="7">Interval m+1 t_0</td><td colspan="7">Interval 1 t_0</td><td colspan="3"></td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td></td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="20">Effective elements of 1 TSC</td><td colspan="10">Synhronization element</td><td colspan="10" rowspan="2">2 TSC</td></tr>
<tr><td colspan="30">1 TSC</td></tr>
</table>

Figure 1 – TSC example wit parameters s=7, *i*=3, *m*=8.

$$N_{pT} = \frac{[s(m-i)+1]!}{i![s(m-i]!}. \tag{1}$$

However, gain under binary positional coding will be:

$$V = \frac{[s(m-i)+1]!}{2^m i![s(m-i)]!}. \tag{2}$$

The results of calculation by formula (5) with different values of the TCS code words parameters *i* and S are represented in Table 1.

It is clear that reducing energy distance makes code words TSC pain vulnerable to the gain. But, there is the special mechanism that allows to synthesize redundant TSC and correct their distortions – “quality equation” [2] (see Fig. 2. a).

Table 1 – Using TSC benefits with implementation in the time interval $T_c = 8t_0$ and values *i* = 3 and *i* = 4.

S	2	3	4	5	6	7	8	9	10
				i =3					
V	1,12	3,19	6,91	12,79	21,31	32,95	48,20	67,56	91,76
$N_{p_s}/N_{p_{s-1}}$		2,85	2,17	1,84	1,66	1,54	1,46	1,4	1,35
				i =4					
V	1,93	7,11	18,92	41,50	79,98	140,46	230,09	356,98	530,24
$N_{p_s}/N_{p_{s-1}}$		3,67	2,66	2,19	1,92	1,75	1,63	1,55	1,48

The experiment was carried out in order to test the TSC error correction method efficiency. The system has been implemented with the basic element $\Delta=0{,}14t_0$ (S=7), $i = 3$ in the range of one byte $T_c=8t_0$. In the synthesis signal designs as coefficients for “quality equation” [2]: A_1=2; A_2=3; A_3=7; A_0=19 has been chosen.

Statistical data transmission of one fragment are:

1.The number of transmitted codewords TSC - 90000

2. The number of distorted codewords on receiving side - 651;

3. The number TSC codewords fixed by “quality equation” - 518 (all of them with one distorted PM, fig 2.b);

4. Standard deviation MP with respect to the actual position equals $\sigma \approx 2\%$.

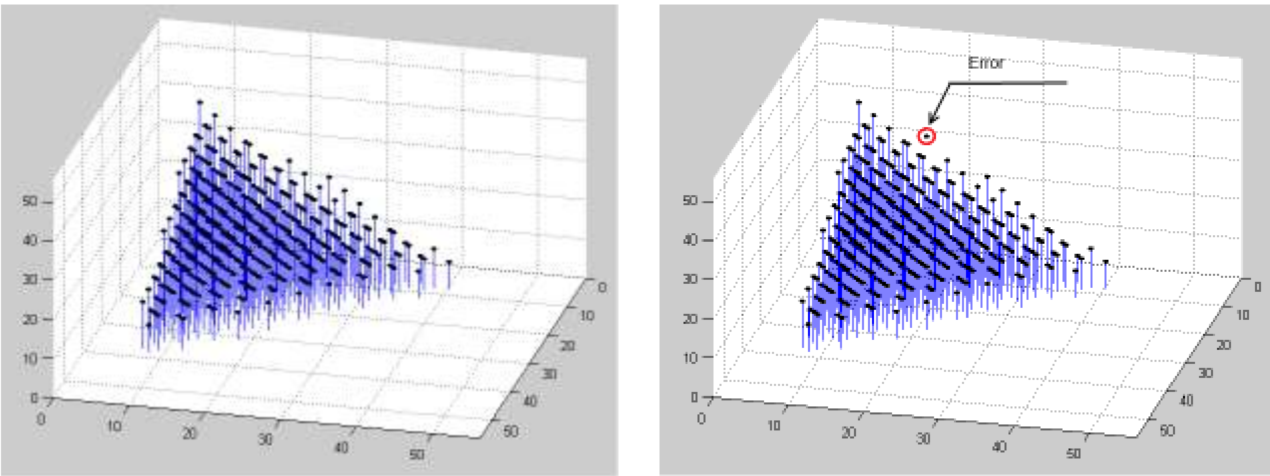
5. Received number distorted codewords with increasing number of PM - 133.

There were changed numbers of PM [3] in all distorted codeword on the range of “bad” state of the channel. The example of such code words are given in Table 2.

All distorted codewords transmitted in the range of "good" state has been founded and corrected. “Quality equation” error vectors are represented in Table 3 (chose coefficients A_1=2; A_2=3; A_3=7; A_0=19). Table 3 shows that some errors vectors are equal in the case of selected coefficient use.

Table 2 – Received TSC with changed number of PM codeword structure

№	Analyze place	Codeword structure
1628 3	On receive side	00000000010000000001000000010010011001000100000000010000000000000
	On transmit side	00000000010000000001000000000000000000000000000000010000000000000
1696 5	On receive side	00000000010000000100110010001000000000000100000000000000000000000
	On transmit side	00000000010000000100000000000000000000000100000000000000000000000



a) redundant TSC selected by using "quality equation"

b) distorted one PM on 1Δ TSC registration

Figure 2 – Codewords correction with using "quality equation"

Table 3 – TSC codewords errors vectors (MP numbers marked as X1 – 1, X2 – 2, X3 – 3 and (C) – "quality equation" syndromes.

X1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0
X2	0	0	1	1	1	-1	-1	-1	0	0	0	1	1	1	-1	-1	-1	0	0	0	1	1	1	-1	-1	-1	0
X3	0	1	-1	0	1	-1	0	1	-1	0	1	-1	0	1	-1	0	1	-1	0	1	-1	0	1	-1	0	1	-1
C	0	7	15	3	10	11	18	6	14	2	9	17	5	12	7	14	2	10	17	5	13	1	8	9	16	4	12

Thus, the next TSC codeword error correction methods for "good" state of the channel can be proposed :

a) One Δ one MP distortion correction;

b) One Δ one, two or three MP distortion detection and than ARQ on reverse channel;

c) One Δ one, two or three MP distortion correction and than ARQ on reverse channel in the case of mad distortion ;

Let's calculate the errors probability in the TSC codewords on range of "good" state of the channel and in the case of step by step increasing of parameter S:

- One Δ one MP distortion probability:

$$P_{11.} = P\ (1) P\ (0) P\ (0) \tag{3}$$

- One Δ two MP distortion probability:

$$P_{12.} = P\ (1) P\ (1) P\ (0) \tag{4}$$

- One Δ three MP distortion probability:

$$P_{13.} = P\ (1) P\ (1) P\ (1) \tag{5}$$

where, for normal distribution of MP:

$$P(1) = 2(\Phi(1,5\Delta/\sigma) - \Phi(0,5\Delta/\sigma)),$$
$$P(0) = 2\Phi(\Delta/2\sigma); \tag{6}$$

where

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_0^x e^{-\frac{z^2}{2}} dz \tag{7}$$

Calculation results are represents in Tab. 4 and Fig. 3

Table 4 – Codewords TSC false receiving probability in the "good" state of the channel, in the case when $\sigma \approx 2\%$, *I*=3 and different values of the parameter S.

S	7	8	9	10	11	12	13
			i = 3				
$P_{11.}$	0,000355	0,001772	0,005413	0,012113	0,021993	0,034502	0,048698
$P_{12.}$	1,26E-07	3,16E-06	2,98E-05	0,000152	0,000519	0,001334	0,002805
$P_{13.}$	4,48E-11	5,62E-09	1,64E-07	1,92E-06	1,22E-05	5,16E-05	0,000162

Analyzing the data represented in Tab. 4, Fig. 3 and the conditions under which the probability of undetected errors (measured by value $P_{13.}$) should be in a range $10^{-7}...10^{-5}$ makes it possible to determine the boundaries value of the *S = 11* for the mentioned before conditions.

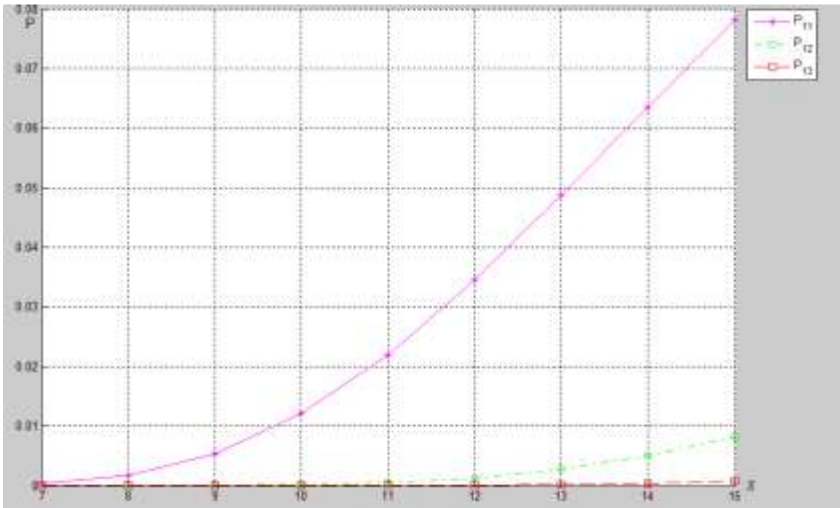


Figure 3 – Codewords TSC false receiving probability in the "good" state of the channel, in the case when $\sigma \approx 2\%$, *i* = 3 and different values of the parameter S.

Let's determine coefficient that's allow to check efficiency of use b) and c) proposed method's under binary redundancy codes. It's can be determined with using TSC parameters $m=8, i=3, A_0=19$ (taking into account that "quality equation" decrease combinations number in A_0 times), formula (2) and decrease transmitting speed on ARQ (in "good" and "bad" state of the channel, where $P_{mpc} = 1,44 \cdot 10^{-3}$):

$$R_{TSC-BIN} = \frac{[s(m-i)+1]!}{A_0 2^m i![s(m-i)]!} \cdot (\frac{R_c}{R_b} - 1), \tag{8}$$

where

$$R_b = (1 - P_{11.} - P_{12.} - P_{13} - P_{mpc})$$
$$R_c = (1 - P_{12.} - P_{mpc}) \tag{9}$$

$R_{TSC-BIN}$ calculation result show that it's equals to 0,238 in the $m=8, i=3, A_0=19$ TSC parameters case. It's justify efficiency of the method c) under proposed variants.

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