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An analysis of Digital Selective Calling system with regard to generating false distress signals within Global Maritime Distress and Safety System

SUMMARY

In this paper a mathematical analysis of the Digital Selective Calling (DSC) system is presented with regard to the occurrence probability of different errors which can cause generation of false distress signals [5,6]. In particular, the kinds of sequences were considered which – in accordance with some ITU recommendations – should indicate „distress", „urgent" and „routine" messages. The DSC system serves within the GMDSS as the only way of sending alert signals by means of terrestial communication [3,4]. However during its use at sea DSC creates many serious problems especially those connected with the false alert signal generation [7]. Presently this problem is being carefully monitored and analyzed under auspices of the International Maritime Organization (IMO) and International Telecommunication Union (ITU).

INTRODUCTION

The basic signal sequence of the DSC system, assumed in [1], is the 10-bit error – detecting code, called Berger's code.

The set of codes of the International Telegraph Alphabet No 5 (ITA No 5) contains $2^7 = 128$ sequences to which specific meanings have been assigned for creating the formats of call sequences [1].

According to [1] and [2], in the code field „Category" transmission of a code with number 112 is assumed to mean „distress", that of number 110 – „urgent" and that of number 123 – „selective calling" of an individual station.

In order to perform an error analysis the following notions and definitions were assumed :

The elementary (binary) error is a false reproduction of one of the code sequence elements. Two kinds of the elementary error can occur :

- of the kind 0→1, i.e. substituting 1 for 0, and
- of the kind 1→0, i.e. substituting 0 for 1.

In the result of the elementary errors another error can occur, which causes that a false signal is received instead of a correct one. There are two kinds of such errors : the transposition error B_t and simultaneous error B_s .

The transposition error B_t occurs in the situtation when the number of elementary errors contained in the information field is even, and a half of them is of the kind 0→1 and the rest of them – of 1→0. Moreover the detection part of the sequence is error-free reproduced.

The simultaneous error B_s occurs in the situation when the elementary errors occur simultaneously in the information and detection parts of the sequence, in such a way that the received sequence is accepted, i.e. the number of zeros in its information part is in compliance with that given in the detection part.

A theoretical analysis of the occurrence probability of the errors is presented below, in which the following notations are assumed :

p_{01} – occurrence probability of an elementary error of the kind 0→1
p_{10} – occurrence probability of an elementary error of the kind 1→0
p – occurrence probability of an elementary error in the case of the symmetrical channel
k – number of zeros in the information part of the code sequence, k = 0,1,...,7
$P(B_t)$ – transposition error occurrence probability
$P(B_s)$ – simultaneous error occurrence probability
P(B) – total error occurrence probability.

The full analysis of the occurence probability of the transposition, simultaneous and total error was performed for the symmetrical channel only, out of the three considered code series (112, 110 and 123), as merely short-wave band radio-communication channels can be considered symmetrical. Hence for the asymmetrical channel the analysis was limited to the transposition error as that of the highest ocurrence probability.

ANALYSIS OF ERROR OCCURRENCE PROCEDURE FOR BERGER'S CODE IN THE CASE OF TRANSMISSION OF THE CODE SEQUENCE 112

Below, the analysis is performed of an error consisting in reception of the code sequence 0000111 | 100, numbered 112 in the case when another code sequence has been sent.

Analysis of error occurrence in the case of the symmetrical channel

At first the transposition error probability for the above given case is calculated. The transposition error probability is given by the formula :

$$P(B_t/112) = 12p^2(1-p)^5 + 18p^4(1-p)^3 + 4p^6(1-p) =$$
$$= 12p^2 - 60p^3 + 138p^4 - 174p^5 + 118p^6 - 34p^7 \quad (1)$$

In Tab.1 and Fig.1. the probability $P(B_t/112)$ in function of the elementary error probability p is presented.

***Tab.1.** The transposition error probability $P(B_t/112)$) in function of the elementary error probability p in the case of the symmetrical channel*

p	0.01	0.02	0.05	0.07	0.1	0.2	0.3	0.4	0.5	0.6
$P(B_t)$	0.00143	0.0093	0.0233	0.041	0.0722	0.172	0.234	0.259	0.266	0.268

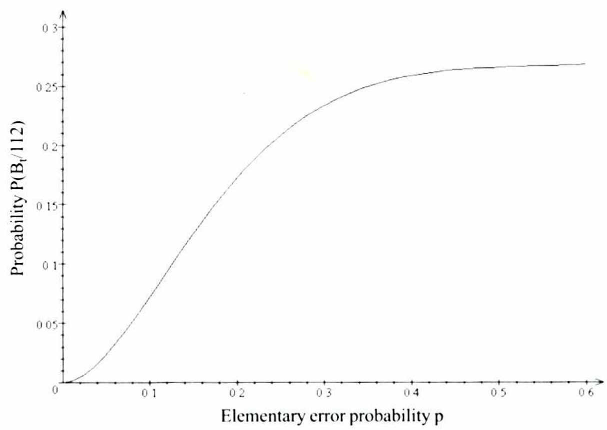

***Fig.1.** The transposition error occurrence probability $P(B_t/112)$ versus the elementary error probability p in the case of the symmetrical channel*

Next, the occurrence probability of the simultaneous error for the case in question is calculated .

Based on the author's calculations [8] the following expression for the simultaneous error probability has been obtained :

$$P(B_s/112) = 17p^6(1-p)^4 + 4p^5(1-p)^5 +$$
$$+ 26p^4(1-p)^6 + 3p^3(1-p)^7 + 3p^2(1-p)^8 \quad (2)$$

In Tab.2 and Fig.2. the calculated probability $P(B_s/112)$ in function of the elementary error probability p is presented.

***Tab.2.** The simultaneous error occurrence probability $P(B_s/112)$ in function of the elementary error probability p in the case of the symmetrical channel*

p	0.01	0.02	0.05	0.07	0.1	0.2	0.3	0.4	0.5	0.6
$P(B_s)$	0.000565	0.00213	0.01115	0.01932	0.03292	0.07165	0.086	0.0794	0.06348	0.047

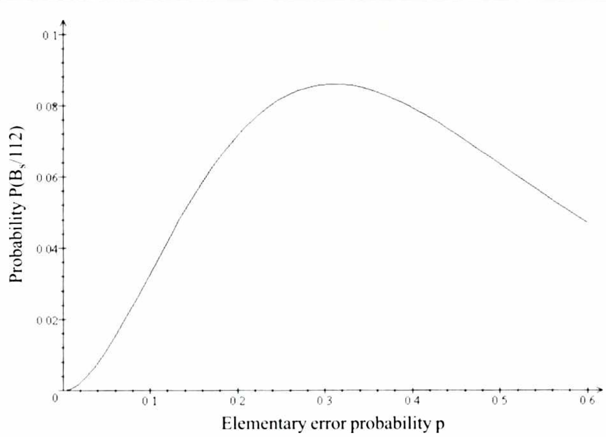

***Fig.2.** The simultaneous error occurrence probability $P(B_s/112)$ versus the elementary error probability p in the case of the symmetrical channel*

As the total error occurrence probability $P(B)$ is the sum of the occurrence probability of the transposition error and that of the simultaneous error the following expression for $P(B)$, after summation of (1) and (2) and transformation of the result, is obtained :

$$P(B/112) = 35p^{10} - 171p^9 + 365p^8 - 488p^7 +$$
$$+ 495p^6 - 405p^5 + 247p^4 - 96p^3 + 18p^2 \quad (3)$$

In Tab.3 and Fig.3. calculation results are shown of the relationship (3) of the total error occurrence probability $P(B/112)$ versus the elementary error probability p.

***Tab.3.** The total error occurrence probability P(B/112) in function of the elementary error probability p in the case of the symmetrical channel*

p	0.01	0.02	0.05	0.07	0.1	0.2	0.3	0.4	0.5	0.6
P(B)	0.001995	0.01143	0.03442	0.06057	0.1051	0.24388	0.319	0.338	0.3291	0.315

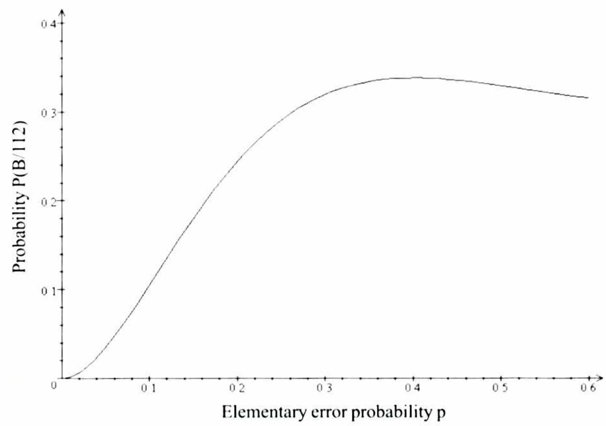

***Fig.3.** The total error occurrence probability P(B/112) versus the elementary error probability p in the case of the symmetrical channel*

Analysis of error occurrence in the case of the asymmetrical channel

As in the above analyzed case the transposition error occurrence probability is calculated at first.

In this case the transposition error occurrence probability is given by the following expression :

$$P(B_t/112) = 12p_{01}p_{10}(1-p_{01})^2(1-p_{10})^3 +$$
$$+ 18(p_{01})^2(p_{10})^2(1-p_{01})(1-p_{10})^2 + 4(p_{01})^3(p_{10})^3(1-p_{10}) \quad (4)$$

The relevant calculation results based on the formula (4) are shown in Tab.4 and Fig.4.

***Tab.4.** The transposition error occurrence probability $P(B_t/112)$ in function of the elementary error probabilities p_{01} and p_{10} in the case of the asymmetrical channel*

p_{01} \ p_{10}	0.01	0.03	0.05	0.07	0.1	0.2	0.3	0.4	0.5
0.01	0.0011	0.0033	0.0053	0.0071	0.0094	0.015	0.0172	0.0169	0.0148
0.03	0.0032	0.0093	0.0149	0.0199	0.0268	0.0425	0.0493	0.0488	0.043
0.05	0.0051	0.0146	0.0233	0.0313	0.042	0.0671	0.0782	0.078	0.0694
0.07	0.0066	0.0191	0.0307	0.0413	0.0554	0.0889	0.1042	0.1047	0.0942
0.1	0.0248	0.0398	0.0536	0.0121	0.0722	0.1037	0.1072	0.0935	0.0711
0.2	0.0121	0.0351	0.0565	0.0765	0.1167	0.1722	0.1841	0.1671	0.134
0.3	0.0122	0.0356	0.0576	0.0784	0.1379	0.2104	0.2336	0.1379	0.1879
0.4	0.0103	0.0302	0.0493	0.0675	0.1402	0.2228	0.2589	0.2587	0.232
0.5	0.0075	0.0222	0.0365	0.0506	0.1280	0.2144	0.2630	0.2784	0.2656

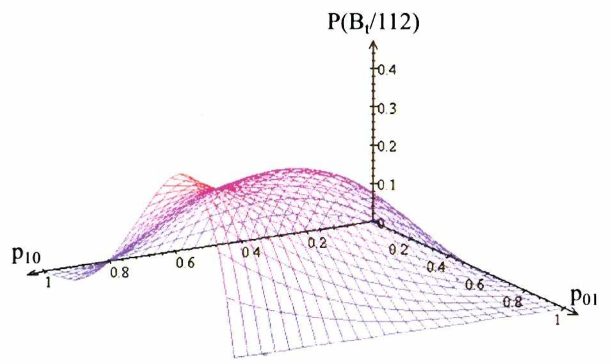

Fig.4. The transposition error occurrence probability $P(B_t/112)$ versus the elementary error probabilities p_{01} and p_{10} in the case of the asymmetrical channel

ANALYSIS OF ERROR OCCURRENCE PROCEDURE FOR BERGER'S CODE IN THE CASE OF TRANSMISSION OF THE CODE SEQUENCE 110

Now, the analysis is performed of an error consisting in reception of the code sequence 0111011 | 010, numbered 110 in the case when another code sequence has been sent.

Analysis of error occurrence in the case of the symmetrical channel

At first the transposition error occurrence probability for the above given case is calculated.

In the case in question the transposition error occurrence probability is given by the following expression :

$$P(B_t/110) = 8p^2(1-p)^5+6p^4(1-p)^3 = \\ = 8p^2 - 40p^3+86p^4 - 98p^5+58p^6 - 14p^7 \qquad (5)$$

The relevant calculation results based on the formula (5) are shown in Tab.5 and Fig.5.

Tab.5. The transposition error occurrence probability $P(B_t/110)$ in function of the elementary error probability p in the case of the symmetrical channel

p	0.01	0.02	0.05	0.07	0.1	0.2	0.3	0.4	0.5	0.6
$P(B_t)$	0.0008	0.0029	0.016	0.027	0.048	0.11	0.138	0.133	0.109	0.079

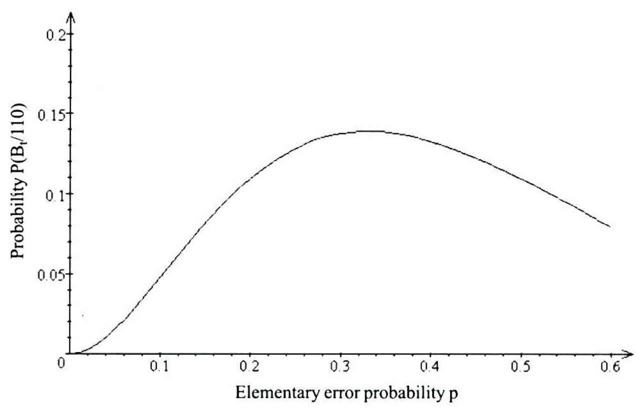

Fig.5. The transposition error occurrence probability $P(B_t/110)$ versus the elementary error probability p in the case of the symmetrical channel

Next, the occurrence probability of the simultaneous error for the case in question is calculated.

Based on the author's calculations [8] the following expression for the simultaneous error occurrence probability has been obtained :

$$P(B_s/110) = 3p^3(1-p)^7+10p^5(1-p)^5+29p^4(1-p)^6 + \\ + 5p^2(1-p)^8+38p^6(1-p)^4+15p^8(1-p)^2+3p^7(1-p)^3+p^{10} \qquad (6)$$

Results of the calculations performed with the use of (6) are presented in Tab.6 and Fig.6.

Tab.6. The simultaneous error occurrence probability P(Bs/110) in function of the elementary error probability p in the case of the symmetrical channel

p	0.01	0.02	0.03	0.04	0.05	0.1	0.2	0.3
$P(B_s)$	0.000464	0.001727	0.003613	0.00598	0.0087	0.02469	0.049	0.067

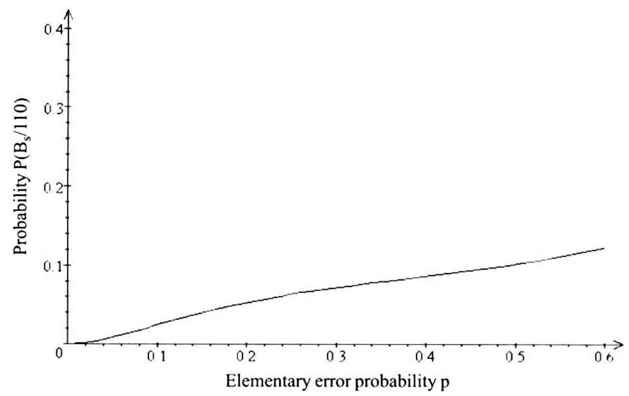

Fig.6. The simultaneous error occurrence probability $P(B_s/110)$ versus the elementary error probability p in the case of the symmetrical channel

The relationship of the total error occurrence probability *P(B/110)* and the elementary error occurrence probability *p* in the case in question is given by the following formula (7) :

$$P(B/110) = 3p^3(1-p)^7+(10p^5+8p^2)(1-p)^5+29p^4(1-p)^6 + \\ + 5p^2(1-p)^8+38p^6(1-p)^4+15p^2(1-p)^2+(6p^4+3p^7)(1-p)^3+p^{10}$$

Results of the calculations performed with the use of (7) are presented in Tab.7 and Fig.7.

Tab.7. The total error occurrence probability P(B/100) in function of the elementary error probability p in the case of the symmetrical channel

p	0.01	0.02	0.05	0.1	0.2	0.3
P(B)	0.0013	0.0046	0.025	0.073	0.159	0.205

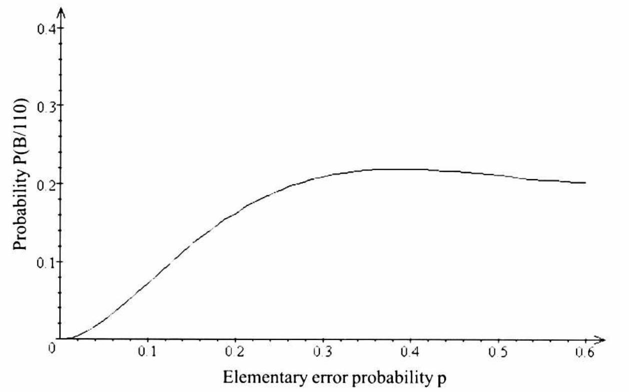

Fig.7. The total error occurrence probability P(B/110) versus the elementary error probability p in the case of the symmetrical channel

Analysis of error occurrence in the case of the asymmetrical channel

In the case in question the transposition error occurrence probability is given by the following expression :

$$P(B_t/110) = 8p_{01}p_{10}(1-p_{01})(1-p_{10})^4 + + 10p_{01}^2p_{10}^2(1-p_{10})^3 \quad (8)$$

In Tab.8 and Fig.8. results of the calculations of $P(B_t/110)$ in function of the elementary error probabilities p_{01} and p_{10}, performed by using (8) are presented.

Tab.8. *The transposition error occurrence probability $P(B_t/110)$ in function of the elementary error probabilities p_{01} and p_{10} in the case of the asymmetrical channel*

p_{01} \ p_{10}	0.01	0.03	0.05	0.07	0.1	0.2	0.3	0.4	0.5
0.01	0.0008	0.0021	0.0032	0.0042	0.0052	0.0065	0.0057	0.0041	0.0025
0.03	0.0022	0.0062	0.0095	0.0122	0.0153	0.0192	0.0169	0.0123	0.0074
0.05	0.0036	0.0101	0.0155	0.0199	0.025	0.0314	0.0278	0.0202	0.0123
0.07	0.005	0.0139	0.0213	0.0274	0.0344	0.0433	0.0384	0.028	0.0172
0.1	0.0069	0.0192	0.0294	0.0379	0.0477	0.0602	0.0537	0.0394	0.0243
0.2	0.0123	0.0342	0.0526	0.068	0.0857	0.1098	0.0996	0.0747	0.0475
0.3	0.0162	0.0451	0.0696	0.0901	0.1141	0.1487	0.1377	0.1058	0.0694
0.4	0.0185	0.0518	0.0803	0.1043	0.1329	0.177	0.1679	0.1327	0.09
0.5	0.0194	0.0544	0.0847	0.1106	0.1422	0.1946	0.1904	0.1555	0.1094

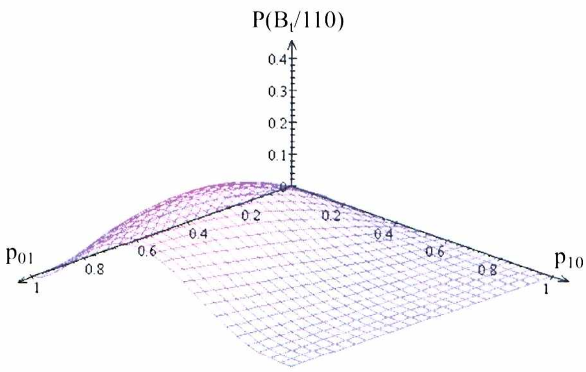

Fig.8. *The transposition error occurrence probability $P(B_t/110)$ versus the elementary error probabilities p_{01} and p_{10} in the case of the asymmetrical channel*

ANALYSIS OF ERROR OCCURRENCE PROCEDURE FOR BERGER'S CODE IN THE CASE OF TRANSMISSION OF THE CODE SEQUENCE 123

Below, the analysis is given of an error consisting in reception of the code sequence 1101111 | 001, numbered 123 in the case when another code sequence has been sent.

Analysis of error occurrence in the case of the symmetrical channel

At first the transposition error occurrence probability for the above given case is calculated.

In this case the transposition error occurrence probability is given by the following expression :

$$P(B_t/123) = 6p^2(1-p)^5 \quad (9)$$

In Tab.9 and Fig.9. results of the calculations of $P(B_t/123)$ in function of the elementary error probability p by using (9) are presented.

Tab.9. *The transposition error occurrence probability $P(B_t/123)$ in function of the elementary error probability p in the case of the symmetrical channel*

p	0.01	0.02	0.05	0.07	0.1	0.2	0.3	0.4	0.5
$P(B_t)$	0.000571	0.00217	0.0116	0.0204	0.035	0.078	0.0908	0.075	0.0469

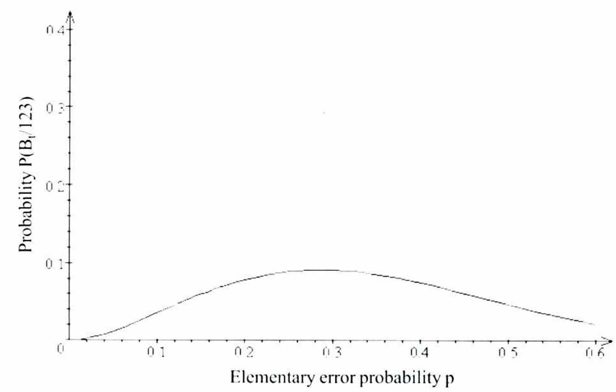

Fig.9. *The transposition error occurrence probability $P(B_t/123)$ versus the elementary error probability p in the case of the symmetrical channel*

Next, the occurrence probability of the simultaneous error for the case in question is calculated.

Based on [8] the following expression for the simultaneous error occurrence probability has been obtained :

$$P(B_s/123) = 20p^3(1-p)^7+51p^5(1-p)^5+15p^6(1-p)^4 + + p^2(1-p)^8+20p^8(1-p)^2+17p^7(1-p)^3+p^{10} \quad (10)$$

In Tab.10 and Fig.10. results of the calculations of $P(B_s/123)$ in function of the elementary error probability p by using (10) are presented.

Tab.10. *The simultaneous error occurrence probability $P(B_s/123)$ in function of the elementary error probability p in the case of the symmetrical channel*

p	0.01	0.02	0.03	0.04	0.05	0.1	0.2
$P(B_s)$	0.000099	0.000389	0.0008587	0.001493	0.002276	0.00782	0.075

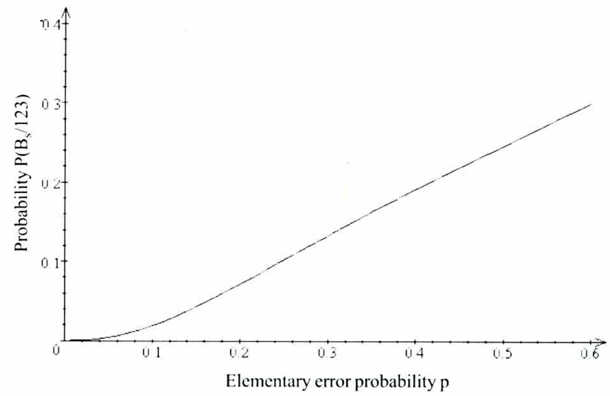

Fig.10. *The simultaneous error occurrence probability $P(B_s/123)$ versus the elementary error probability p in the case of the symmetrical channel*

The relationship of the total error occurrence probability $P(B/123)$ and the elementary error occurrence probability p in the case in question is given by the following formula :

$$P(B/123) = 20p^3(1-p)^7+(51p^5+6p^2)(1-p)^5+15p^6(1-p)^4 + + p^2(1-p)^8+20p^8(1-p)^2+17p^7(1-p)^3+p^{10} \quad (11)$$

Results of the calculations performed with the use of (11) are presented in Tab.11 and Fig.11.

Tab.11. The total error occurrence probability P(B/123) in function of the elemetary error probability p in the case of the symmetrical channel

p	0.01	0.02	0.05	0.1
P(B)	0.00067	0.00256	0.0139	0.044

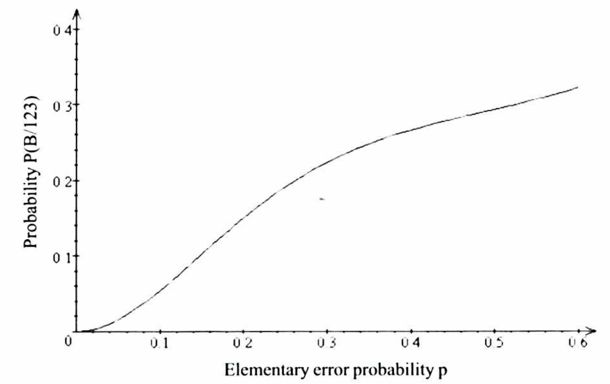

Fig.11. The total error occurrence probability P(B/123) versus the elementary error probability p in the case of the symmetrical channel

Analysis of error occurrence in the case of the asymmetrical channel

The transposition error occurrence probability calculated for the above given case is described by the following expression :

$$P(B_t/123) = 6p_{01}p_{10}(1-p_{10})^5 \qquad (12)$$

In Tab.12 and Fig.12. results of the calculations of $P(B_t/123)$ in function of the elementary error probabilities p_{01} and p_{10}, performed by using (12) are presented.

Tab.12. The transposition error occurrence probability $P(B_t/123)$ in function of the elementary error probabilities p_{01} and p_{10} in the case of the asymmetrical channel

p_{01} \ p_{10}	0.01	0.03	0.05	0.07	0.1	0.2	0.3	0.4	0.5
0.01	0.0006	0.0015	0.0023	0.0029	0.0035	0.0039	0.0030	0.0019	0.00094
0.03	0.0017	0.0046	0.007	0.0088	0.0106	0.0118	0.0091	0.0056	0.0028
0.05	0.0028	0.0077	0.0116	0.0146	0.0177	0.0197	0.0151	0.0093	0.0047
0.07	0.004	0.0108	0.0162	0.0204	0.0248	0.0275	0.0212	0.0131	0.0066
0.1	0.0057	0.0154	0.0232	0.0292	0.0354	0.0393	0.0302	0.0187	0.0094
0.2	0.0114	0.0309	0.0464	0.0584	0.0709	0.0786	0.0605	0.0373	0.0187
0.3	0.0171	0.0464	0.0696	0.0876	0.1063	0.118	0.0907	0.056	0.0281
0.4	0.0228	0.0618	0.0928	0.1169	0.1417	0.1573	0.121	0.0747	0.0375
0.5	0.0285	0.0773	0.1161	0.1461	0.1771	0.1966	0.1513	0.0933	0.0469

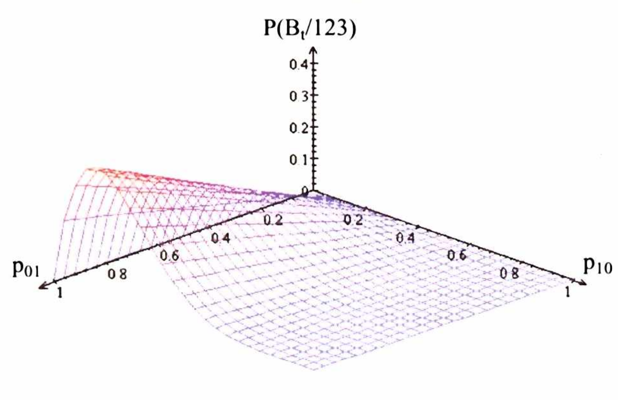

Fig.12. The transposition error occurrence probability $P(B_t/123)$ versus the elementary error probabilities p_{01} and p_{10} in the case of the asymmetrical channel

COMPARISONS

In Fig.13. the transposition error occurrence probabilities for three considered code sequences in function of the elementary error occurrence probability *p* are compared, and - in Fig.14. - the same probability functions at small values of the elementary error probability *p*, contained within the range $0<p<0.1$.

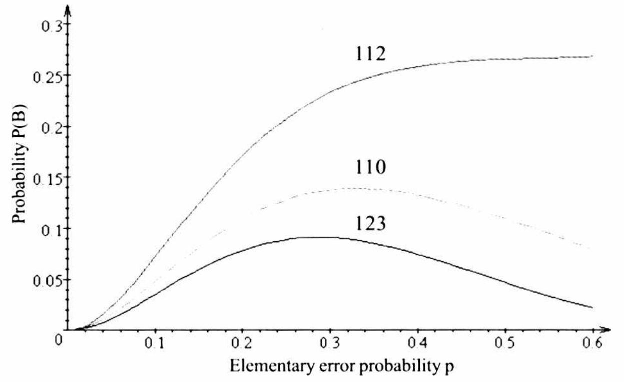

Fig.13. The transposition error occurrence probabilities P(B) for three considered code sequences : 112, 110 and 123 in function of the elementary error occurrence probability p

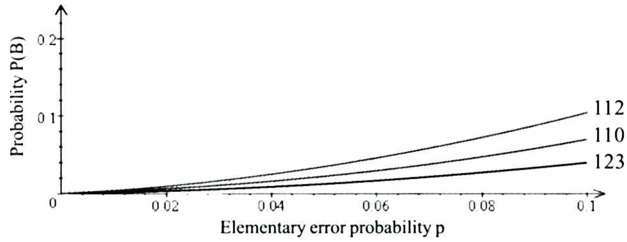

Fig.14. The total error occurrence probabilities P(B) for three considered code sequences : 112, 110 and 123 in function of the elementary error occurrence probability p contained within the range $0<p<0.1$

CONCLUSIONS

- Out of the selected Berger's code sequences the total error occurrence probability, at small values of the elementary error probability *p*, is the greatest for the code sequence 112 to which the meaning „distress" is assigned. The fact deals with all code sequences of the kind „three zeros and four ones" and those of the kind „four zeros and three ones" in the case of both symmetrical and asymmetrical channels (Fig.13 and 14).
- From the analysis performed in this work it can be stated that the code sequence of the smallest value of the total error occurrence probability, should be applied to the „distress" signal coding when attributing the codes to the particular kinds of calling.
- Out of the three considered code sequences the code sequence 123 is of the smallest value of the total error occurrence probability at the values of the elementary (binary) error probability *p*, smaller than 0.1.

Appraised by Wiesław Sieńko, Assoc,Prof.,D.Sc.

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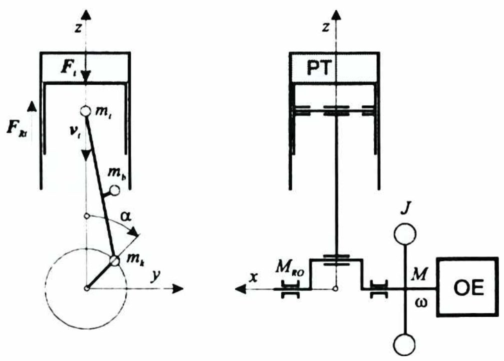
Conference

MODES GDAŃSK 2001

On 8 June 2001 the Scientific Conference on :

Modelling of power systems based on combustion engines

was organized by the Department of Combustion Engines and Compressors, Mechanical Faculty, Technical University of Gdańsk, with the aim of celebrating 70th birthday anniversary of Prof. Marian Cichy and his almost 50-year scientific activity devoted to control problems of the combustion engines, dynamics of co-operation of the engines and energy consumers, engine research automation and development of research instruments. Prof. Cichy developed many important research stands. For several years he has focused his interest on computer-aided modelling methods of physical and energy systems.



After the solemn part of the conference the scientific part of it took place during which 6 papers were presented :

- *Power parameters of SI engines by using the bond graph formalism* – by Prof. M. Cichy, Technical University of Gdańsk
- *Graph and mechanics* – by Prof. J. Wojnarowski, Silesian Technical University
- *On some simulation investigations of hybrid drives* by A. Szumanowski, Warszawa University of Technology
- *SEDT research test for assessment of emission of toxic compounds from SI engine* – by Prof. J. Merkisz, Technical University of Poznań
- *Main modelling problems of the emission of environment ally noxious substances from combustion engines* – by Assist.Prof. Z. Chopek, Warszawa University of Technology
- *Problems of SI engine diagnostics : Rotational speed as a diagnostic parameter* – by Assoc. Prof. A. Piętak, Military Technical Academy, Warszawa.

FOREIGN *conference*

CAMS 2001

On 16-22 July 2001 the International Conference of IFAC on :

Control Applications in Marine Systems

was held in Glasgow, Scotland.

A group of Polish scientific workers from 4 universities took part in it and presented the following papers :

- *The analysis of a ship fuzzy domain in a restricted area* (Z. Pietrzykowski – Szczecin Maritime University)
- *Methods of optimal ship routing for weather perturbations* (K. Stawicki and Roman Śmierzchalski – Gdynia Maritime Academy)
- *A positional Game model of safe ship control process* (J. Lisowski – Gdynia Maritime Academy)
- *Marine engine room monitoring and control system for simulating real processes on a ship* (R. Śmierzchalski – Gdynia Maritime Academy)
- *Predictive control and dynamic path planning of an autonomous underwater vehicle* (R. Śmierzchalski – Gdynia Maritime Academy, M. Kwiesielewicz and M. Szymański – Technical University of Gdańsk, R. Sutton – University of Plymouth)
- *On a ship track – keeping controller with roll damping capability* (Dorota Łozowicka and A. Łozowicki – Technical University of Szczecin, A. Tiano – University of Pavia)
- *Classification and detection of changes in the hydro acoustic signals* (M. Szpilewski – University of Białystok, E. Shpilewski – Lithuanian Academy of Science)
- *A neural detection of the watched target in ARPA systems* (A. Stateczny – Szczecin Maritime University)
- *Genetic method of optimization of evacuation ways in cases in fire growth at ferryboat* (Dorota Łozowicka and Piotr Nikończuk – Technical University of Szczecin)
- *Simulation model of the shiphandling training boat „Blue Lady"* (W.Gierusz – Gdynia Maritime Academy)
- *On-line trajectory planning in collision situations at sea by evolutionary computation-experiments* (R. Śmierzchalski – Gdynia Maritime Academy)
- *Algorithms for the ship trajectory planning and its tracking in the collision avoidance process* (Z. Zwierzewicz – Szczecin Maritime University).