

# Methodology of Investigation of Control Process by Internet

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## Abstract

The article is devoted to investigation of possibility of objects control in closed-loop by Internet, using real objects and mathematical model of objects, which are implemented in Simulink software or in digital signal processor DS 1104. The article is concentrated on the determination of conditions ensuring correct operation of the closed-loop system controlled by Internet.

The article is provides verification: methodology development, the correctness criterion for proper cooperation between the given control system with reference to the Internet and correctness of the algorithm to check the possibilities of cooperation with the specified set point adjustment system to the Internet.

## 1 Introduction

To examine the control processes by the Internet for as wide a group of objects it is proposed to replace the actual object by the corresponding mathematical models, which are implemented in Matlab / Simulink or on the DS1104 signal processor.

In the real object (for example electric motor together with his control system) prepared to operation/cooperation with Internet usually is difficult to change same parameter, because of manufacturing process restriction. So investigation of properties of such a real object connected to the internet is limited to only chosen and permanently set parameters. Replacing the real object by his mathematical representation we have from practical point of view, free choice for object parameter change.

Additional advantages of Matlab/Simulink and DS 1104 usage is possibility of simulation not only with chosen parameters and free working environments but also it is possible to observe the influence some investigated object parameters of change.

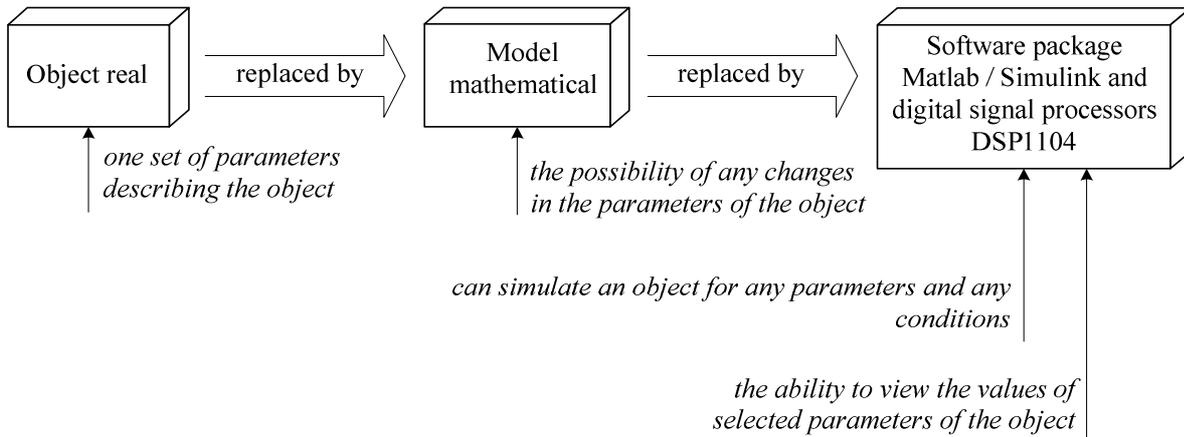


Fig.1. Block diagram showing the replacement of a mathematical model of a real object with an indication of the benefits obtained

## 2 General conception

The real object may be replaced by his mathematical model, which may be implemented in Matlab/Simulink or equivalently on signal processor board DS 1104.

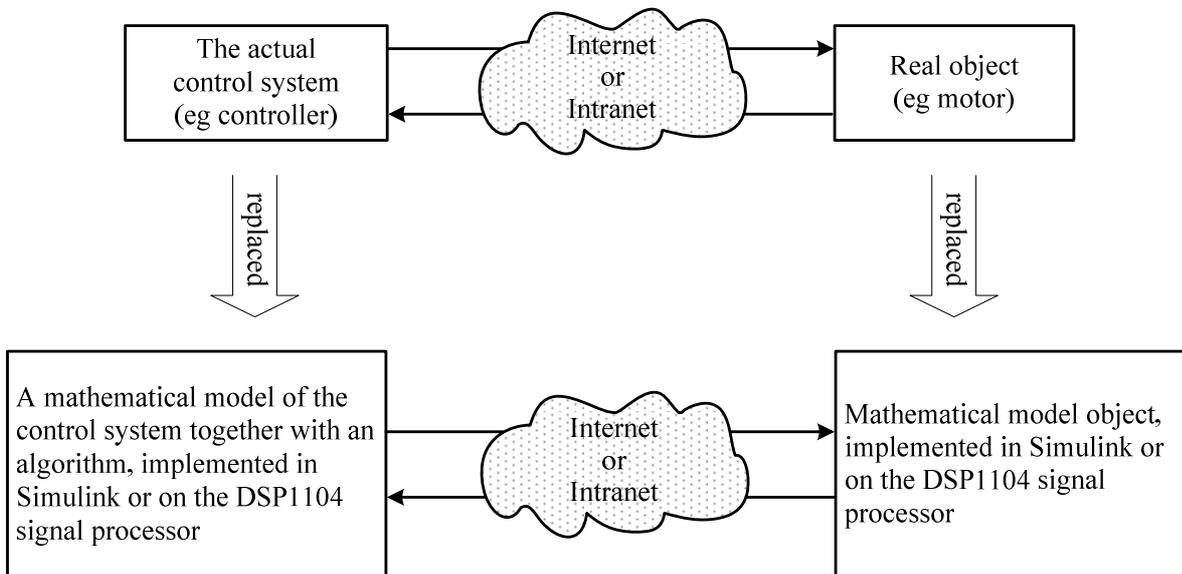


Fig.2. Block diagram showing the general concept of the proposed research methodology

The approach taken is important that the Internet and local network are real and are not replaced by mathematical models. This means that the exchange of packets between the model and object model of the control system is implemented through a real PC network cards (for which simulations are performed), and using TCP / IP.

Environment Matlab / Simulink is a powerful mathematical programs [6], allowing simple implementations developed mathematical models and use the digital signal processors DS1104 cards [3, 4, 5].

Mathematical model, implemented in SIMULINK is converted to program in C++ [7, 8], which lists all state variables of an object, in the following steps of calculation (ie at a specified interval of time). Step calculation is predefined for each simulation, and its minimum value depends on the properties (parameters) of the test system.

### 3 Conditions for implementing the proposed methodology of the study: the first condition and second condition

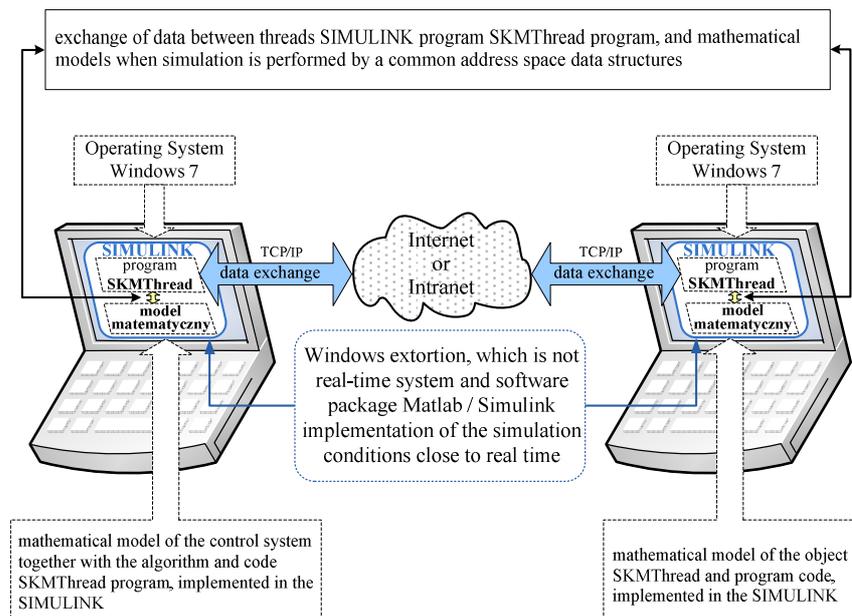
To the above concept could be realized, must be fulfilled two conditions:

The first condition: The conditions of research, conducted with the use of mathematical models, they can not deviate from those studies performed on real objects.

Two methods are proposed for first condition: Method A and Method B:

- Method A (Fig. 3) - use a computer running Windows 7 Professional and the software package Matlab / Simulink, in which work is carried out - the simulation of control system with control algorithm. Conditions for performance of the simulation, close to real time is achieved by the use of the S-function element from the library program SIMULINK, the program code RTBlock [9], written in C++, which forces the system and SIMULINK program, enabling the implementation of the simulation time close to real time. The data exchange between the mathematical models, simulated in SIMULINK on computers connected to the Internet, is accomplished via a multi-threaded program SKMThread.

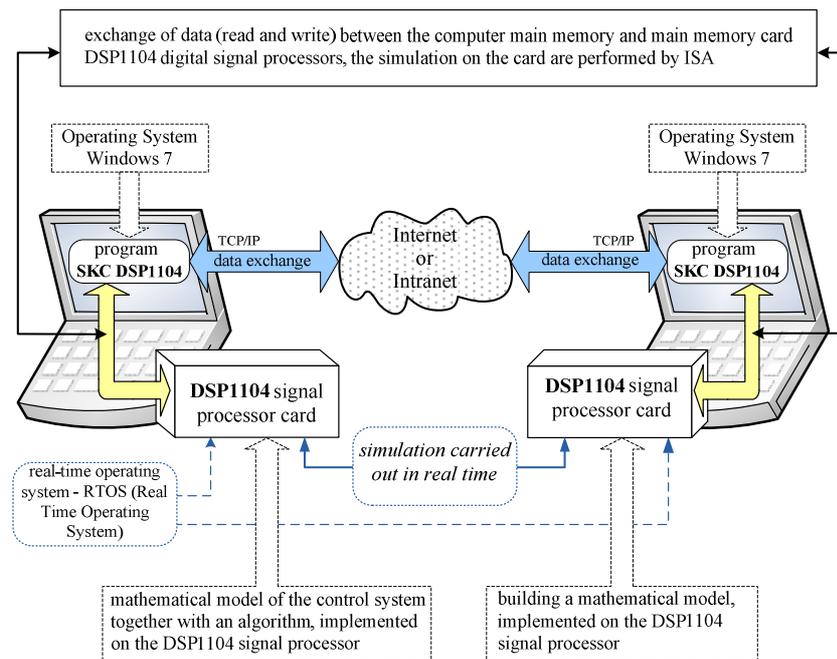
Fig.3. **Method A** – a block diagram showing the use of SIMULINK program and the author's program for implementing the proposed SKMThread research methodology



The disadvantage of this method is that Windows is not real-time system, which requires additional intervention program in the system and SIMULINK program (to ensure the synchronization of computations in such a way that the mathematical model behaves just like a real object), while the existence common address space for the main thread and the thread of the process simulation program implementing the exchange of data over a TCP / IP / Ethernet should be considered an important advantage of this method.

- Method B (Fig. 4) - application card DSP1104 digital signal processors, which is equipped with real-time system [10, 11] - RTOS (called Real Time Operating System).

Fig. 4. **Method B** - a block diagram showing the use of cards DSP1104 digital signal processors and program SKCDSP1104 to implementing the proposed research methodology



On the card is located digital signal processor, which performs all necessary calculations during the simulation, ensuring synchronization of computation so that each second of simulation program to match, to each second of the actual object. The data exchange between mathematical models implemented on the digital signal processors (which is the card is connected to a PC via the ISA bus), is implemented through a network of computers connected to the Internet. The data exchange is performed by the author's multi-threaded program SKCDSP1104.

The data exchange via the Internet takes place through the use of TCP / IP. The advantage of this method is that the signal processor is dedicated to the implementation of real-time simulations, but its drawback is the existence of an additional track data exchange between the mathematical model of the card (the exchange takes place between the ISA bus, a computer network card).

The conclusion on the first condition is:

Both Method A and Method B shall ensure the implementation of real-time simulations. It can be concluded that both methods: Method A and Method B, ensure the respect the first condition ie: the conditions of research conducted with the use of mathematical models did not differ from those of studies carried out on real objects.

An important issue that requires thorough and careful consideration is the effect of additionally introduced, and necessary in the study, author's programs: the program SKMThread in method A and Program B SKCDSP1104 in the method of data transmission times, which binds to the second condition.

Second condition: The proposed research methodology will be correct, if - as a result of additional own program: SKMThread or SKC DSP1104 - transmission times over a local

network will not increase significantly (ie will increase in a negligibly small). In other words, developed programs and SKCDSP1104 SKMThread may be considered useful in the implementation of the proposed research methodology whereupon, if the transmission times of packets transmitted between simulated objects over a local network using TCP / IP and using the proposed copyright the software, do not differ significantly (or - in other words - will vary, but in a negligible way) in relation to the time of transmission of packets between programs operating autonomously (independently) and not benefiting from the program SIMULINK.

#### 4 The test bench for checking the condition of the second implementation of the proposed research methodology

The aim of this study was to determine and compare the packet transmission delay times in the local network through experiments in which "a program running in client mode" and "program running in server mode" were handled from a running simulation program SIMULINK, as well as experiments in the programs running in the modes (Client, Server) supported DSP1104 signal processor card. The results of measurements of packet delay times, obtained during the experiments carried out by the concept, compared with results obtained by experiments in which programs running in client mode and server operate autonomously, and thus only an operating system (measured in the reference system).

Measurements were performed on the test, whose block diagram is shown in Fig.5. The position was made up of two computers with the same hardware configuration and software.

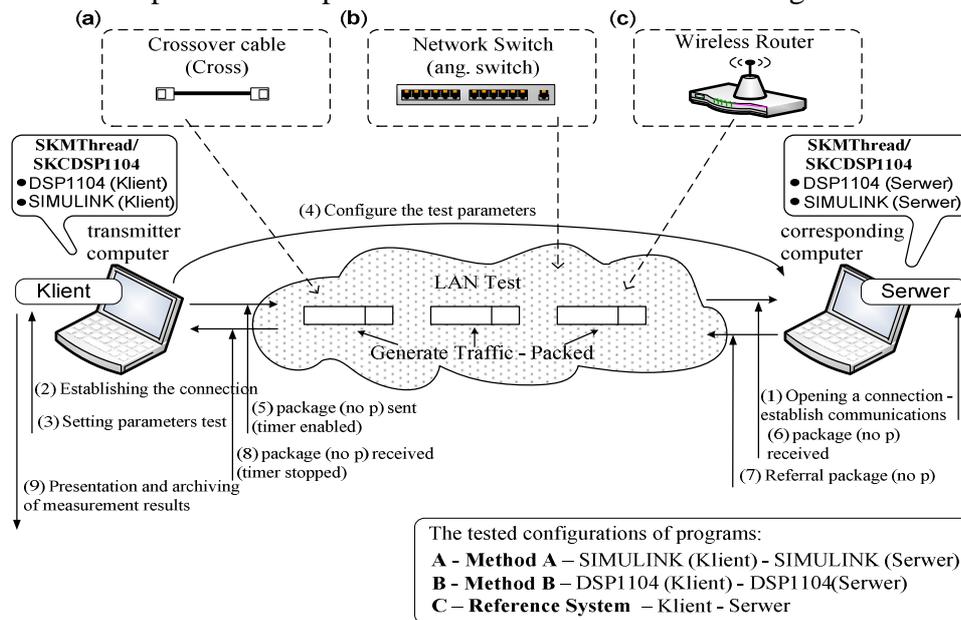


Fig. 5. The test to measure time delays in packet transmission network with the configuration links with: (a) - crossover cable (called a cross cable), (b) - the network switch (called a switch), (c) - Wireless Router

The position has been prepared to carry out experiments for three configurations, a local area network, built with:

- (a) - the network cable crossover (called a cross cable)
- (b) - Switch network (called a switch), TP-Link
- (c) - Wireless Router Linksys

Research is focused on the possibility of using two programs, SKMThread and SKCDSP1104 that can operate in one of two modes: Client or Server (so it is possible to exchange data on a TCP / IP / Ethernet).

## **5 Description of experiments conducted to verify the second condition**

For each configuration, local area network link, made a series of experiments in which measured the packet delay times, for the following combinations of software configuration:

- A - Method A - SIMULINK (Client) - SIMULINK (Server)
- B - Method B - DSP1104 (Client) - DSP1104 (Server)
- C - Frame of reference - Client - Server.

The study was conducted for the following transmission parameters:

- The frequency of sending packets:  $p_1 = 1$ ,  $p_2 = 10$ ,  $p_3 = 100$ ,  $p_4 = 1000$  [ms]
- Packet size: 64 [B]
- The used protocol: TCP / IP.

To measure the transmission time delay measurement method is selected in both directions (round-trip delay). Measured transmission time is the time that takes packets travel from source to destination point, then back to a point source.

The program of research and experimental position was developed to carry out measurements of packet delay times for 36 combinations of setup position (resulting from the existence of 3 configuration programs, 3 configuration, local area network connection, and 4 packet rate). In order to unequivocally assign a set of values - the position and frequency configurations packet, uses the following indices and symbols:

- $i \in \{A, B, C\}$  – a software configuration,,
- $j \in \{a, b, c\}$  – a local area network configuration,
- $k \in \{p_1, p_2, p_3, p_4\}$  – the frequency of sending packets (the time interval between successive packets sent).

## **6 The aggregate description of the delays on the local network while checking the second condition, and their conditions**

A single experiment for a given experimental setup position (i, j, k) was to measure the transmission delay time for the 5000 packages that were sent at regular intervals and at  $k \in \{p_1, p_2, p_3, p_4\}$ . As a result of a single experiment obtained a set of 5000 values of time delays in transmission, on the basis of which the characteristic values determined in accordance with dependencies:

- the minimum amount of time packet transmission delay, determined by dependence:

$$\tau_{\min}^{(i,j,k)} = \min \left\{ \tau_p^{(i,j,k)} \right\}_{p=1 \dots N_p} \quad (1)$$

- maximum transmission delay time value of the package, determined by the formula:

$$\tau_{\max}^{(i,j,k)} = \max \left\{ \tau_p^{(i,j,k)} \right\}_{p=1 \dots N_p} \quad (2)$$

- average packet transmission delay time, determined by dependence:

$$\tau_{av} = \frac{\sum_{p=1}^{N=100} \tau_p^{(i,j,k)}}{N_p} \quad (3)$$

Variation from the set  $N_p$  time delay measurements  $\tau_1, \tau_2, \tau_3, \dots, N_p$  of the arithmetic mean  $\tau_{av}$  for a given experimental setup position (i, j, k):

$$\tau_{\sigma_p^2}^{(i,j,k)} = \frac{(\tau_1^{(i,j,k)} - \tau_{avr}^{(i,j,k)})^2 + (\tau_2^{(i,j,k)} - \tau_{avr}^{(i,j,k)})^2 + \dots + (\tau_{N_p}^{(i,j,k)} - \tau_{avr}^{(i,j,k)})^2}{N_p} \quad (4)$$

The standard deviation for a set of values of packet delay times, determined from a single experiment is the square root of variations:

$$\tau_{\sigma_p}^{(i,j,k)} = \sqrt{\tau_{\sigma_p^2}^{(i,j,k)}} \quad (5)$$

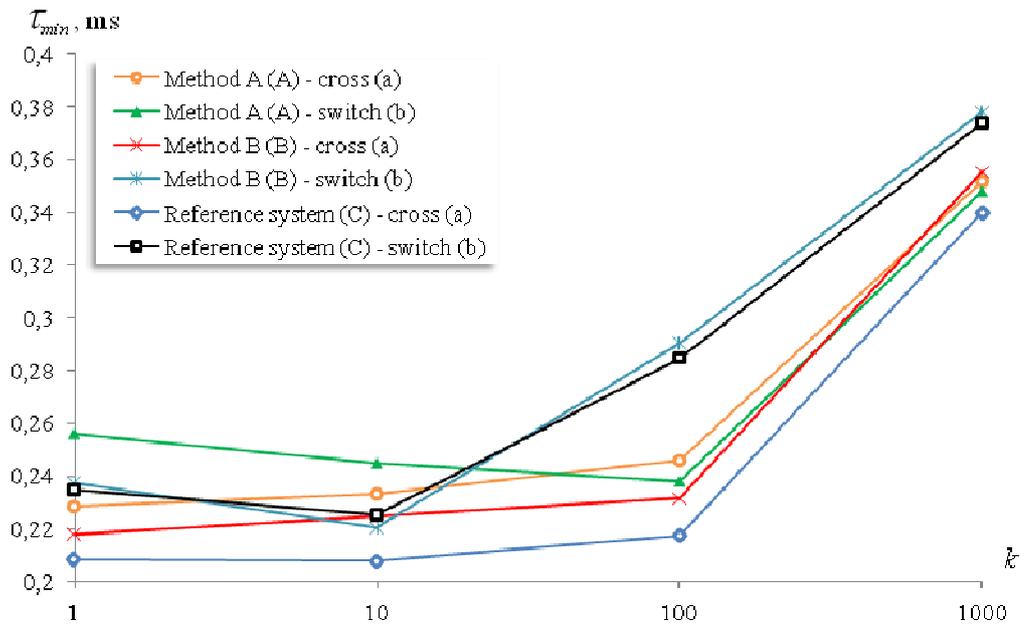


Fig. 6. Comparison of minimum values of packet transmission delay times in the local network (Intranet) for different: configuration programs ( $i = A, B, C$ ) a local area network configuration - crossover cable and network switch ( $j = a, b$ ) and for varying the frequency of sending packets ( $k$ )

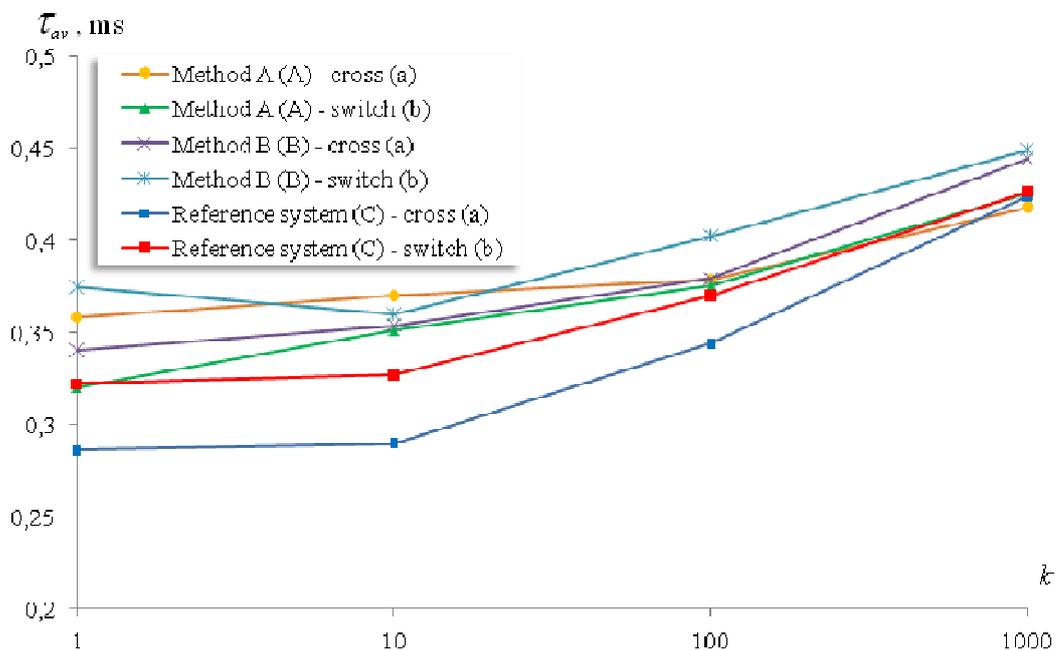


Fig. 7. Comparison of average values of packet transmission delay times in the local network (Intranet) for different: configuration programs ( $i = A, B, C$ ) a local area network configuration - crossover cable and network switch ( $j = a, b$ ) and for varying the frequency of sending packets ( $k$ )

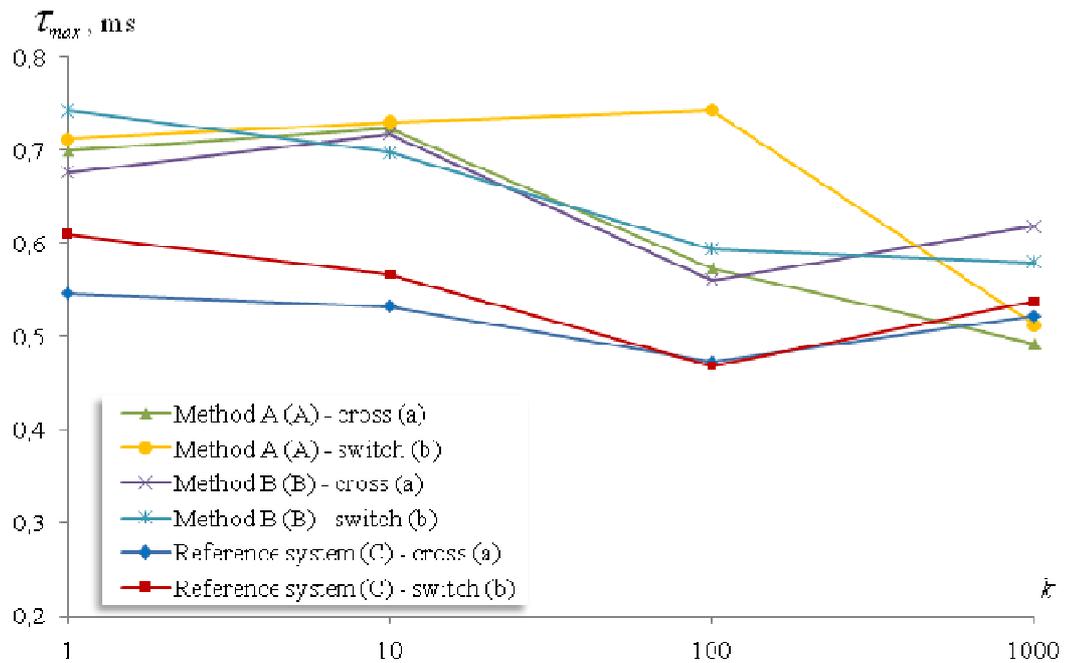


Fig. 8. Comparison of the maximum values of packet transmission delay times in the local network (Intranet) for different: konfiguracji programów ( $i = A, B, C$ ); configuration programs ( $i = A, B, C$ ) a local area network configuration - crossover cable and network switch ( $j = a, b$ ) and for varying the frequency of sending packets ( $k$ )

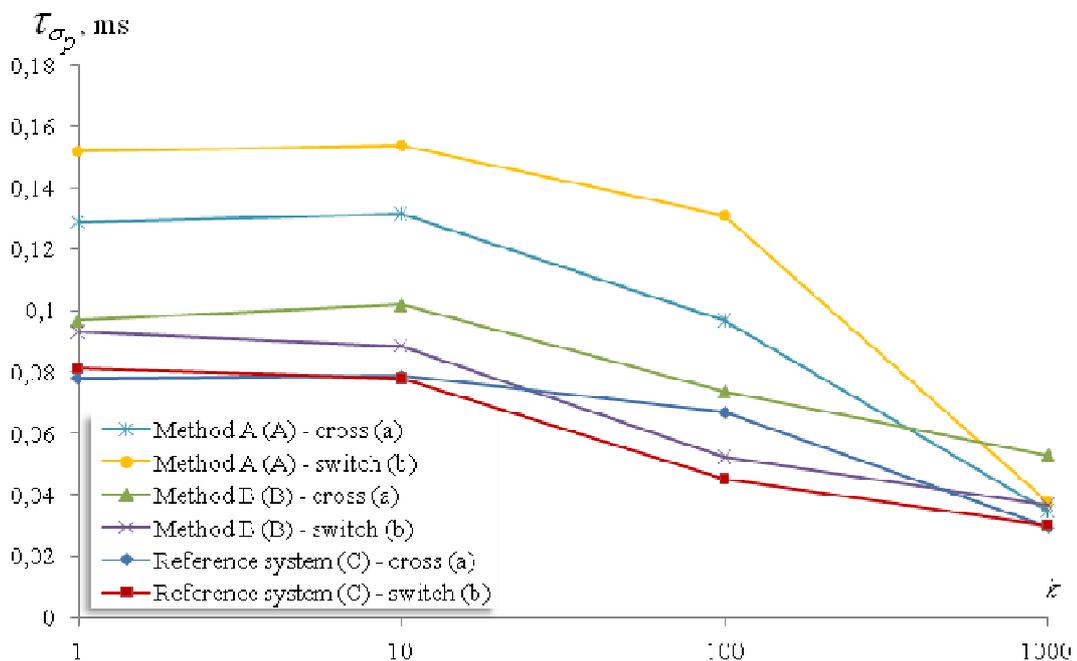


Fig. 9. Comparison of standard deviations from the designated times (Intranet) for different: konfiguracji programów ( $i = A, B, C$ ) a local area network configuration - crossover cable and network switch ( $j = a, b$ ) and for varying the frequency of sending packets ( $k$ )

## 7 Conclusion

Based on the results, compiled in the above figures (Fig. 6 ÷ Fig. 9) can be stated that the second condition, associated with the proposed methodology is met, both for the proposed concept - Method A, as well as for the proposed concept - Method B. Transmission times over a local network do not increase significantly as a result of additional software - exchanging data via TCP / IP / Ethernet:

- a) from the running simulation model implemented in SIMULINK, for Method A - SKMThread program,
- b) the exchange of data (read and write) between the computer's main memory and main memory card DSP1104 digital signal processors by the ISA, the Simulation tab, for Method B - SKCDSP1104 program.

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