Wireless Remote Control of Electro-Pneumatic Positioning System

Prof. **Ryszard DINDORF**, PhD.[1], **Piotr WOŚ**, PhD.[1]

[1] Kielce University of Technology, Poland, dindorf@tu.kielce.pl

Abstract: *Constant development of wireless networks increases possibilities of their application in the industry. Popular wireless computer networks WLAN (Wireless Local Area Network) can be used not only for data transfer between computers, but also for remote control of electro-pneumatic positioning systems based on the application running on the mobile computer. In order to examine the practical effect of the application the laboratory stand was built for wireless control of the electro-pneumatic servo drive. For that purpose the microcomputer board was used, whose task was to connect the wireless card, input/output port and the application for the operator. The input/output port for the controller was a selected module for data acquisition equipped with analog inputs and outputs. A wireless card was used for wireless communication with the computer operator. Servo drive was built based on the proportional pressure valve, pneumatic positioner, pneumatic actuator of double-sided action, convertor of linear transfers and measure of linear transfers.*

Keywords*: wireless control, pneumatic systems, servo-drives*

1. Introduction

Pneumatic positioning systems have been developing rapidly in recent years. Some of the many applications of pneumatic positioning are: handling of workpieces (such as clamping, positioning, separating, stacking, rotating), packing, filling, metal-forming, stamping [1]. With advancements in micro-computer and servo-valve technology, pneumatic systems are now being considered for industrial applications that involve a control system for positioning of a workpiece. Development of automation and robotization in manufacturing process stimulates interest in pneumatic systems whose advantages include low manufacturing costs, high dynamics and reliability. Unsatisfactory positioning accuracy of multiaxis pneumatic systems considerably reduces their application in manipulating machines, manipulators and robots. Rapid advance in parallel pneumatic manipulators imposes a lot of demands on controllers of pneumatic servo-drive concerning positioning accuracy, resistance to alternating parameters of state and disturbing signals. The problem of positioning accuracy of electro-pneumatic systems is difficult to solve when no sufficient information on the process of conversion of the compressed gas energy into mechanical energy of pneumatic cylinder is available. Therefore, new control methods based on wireless remote control were introduced.

2. Wireless network

Wireless networks have become more and more popular in the recent years. Owing to constant development they become faster, safer and more reliable. Since it is easy to install wireless communication it is very common among private users and in industry. Computer networks can be used not only to access the Internet, but also in the communication with devices used in the industry. The aim of this paper is to present the possible use of WiFi wireless network in the servomechanism of electro-pneumatic control system. For that purpose we constructed a laboratory test stand of wireless controlled pneumatic positioning and wrote the application for the communication between operator and pneumatic positioning system. The communication between devices via network must be conducted according to strictly defined principles so-called protocols, which are specific for every applied communication. The task is to define such features as the format and structure of sent message, ways of message exchange between network devices, methods of the system information exchange and errors between network devices as well as to establish and finish connections. Protocols don't usually describe how to carry out a determined function so the implementation of a given protocol is independent of specific technology. Successful communication in the network requires sharing of many different protocols. Such connected group of protocols is called the protocol suite, which is often presented as the stack [2]. There are two basic models of the network. TCP/IP (protocol model) and OSI model (reference model) [3]. The reference model and protocol model along with their are layers presented in Figure 1. TCP/IP is regarded as the model of Internet network. It defines four layers, which are responsible for correct communication network. The Network Access Layer is responsible for control of physical devices and media forming the network. Next layers are responsible for determining the best route of packages in the network, communication between different devices in different networks and reading data from the user. While sending data they go from the upper layer to the lowest, but the receipt of data is a reverse process. In the first layer of the TCP/IP model it is possible to distinguish three types of media transmission, connecting devices and providing data transmission: metal cables, fiber-optic and wireless communication. The advantages of cable networks include providing adequate signal power on the entire cable length, protection against external signals effects as well as lack of local regulations and standards concerning the use of frequency band. For wireless networks the advantages of cable networks will be their defects, because without additional legal standards it is possible to use only some frequency bands. The useful signal is susceptible to external interferences and it is hard to ensure the appropriate quality of signal far away from its source. Advantages of wireless networks are undoubtedly easy access to the medium transmission as well as the ease of structure and expansions. [4], [6]. A popular access wireless method is WLAN (Wireless Local Area Network). Frequency range of the radio waves used by the standard doesn't require the concession; therefore it is possible to use this standard without special licenses. Standard 802.11 determines the outline of division bands into channels for the frequency range between 2.4 GHz and 2.483 GHz, where distance between individual channels are 5 MHz and width of channel is 22 MHz. This band does not require licensing and is divided into 11 channels for North America and 13 channels for Europe.

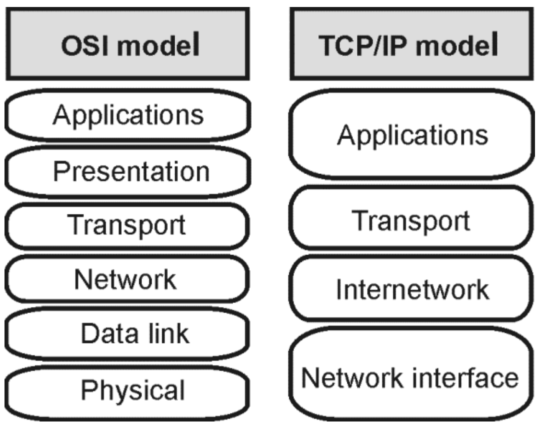

Fig. 1. OSI and TCP/IP models

Network layer is responsible for the exchange of data fragments via network between some determined terminal devices. This layer is responsible for addressing, encapsulation, routing and decapsulation of transmitted data. The most popular protocol used in the network layer is IP protocol (Internet Protocol). Currently it is used in version 4 and in version 6. Moreover, the network layer includes the following protocols: IPX (Internetwork Packet Exchange), Apple Talk or connectionless service CLNS/DECNet network. IP protocol is a connectionless protocol, which makes communication faster and flexible, but also unreliable. The reliable transmission is dependent on layers of the high level in network model. In the IP protocol in version 4 addressing is hierarchical. An IPv4 address consists of a 32-bit number, divided into a host part and a network part. The host part uniquely identifies a given host on a given physical network. The network part identifies the network to which the host is connected. The entire pool of addresses ($2^{32} = 4294967296$) is divided into classes A, B, C, D and E, where classes from A to C are addresses of the unicast type should be allocation for the addressing network devices [2]. Transferring large and constant data bands could make it impossible to make other transmission in the same time because the entire transmission channel is seized. Another problem would be rectifying transmission errors and retransmitting damaged data. Therefore, data are divided into smaller fragments (segmentation), which are transmitted between devices in the network. Such process also allows for many different applications for simultaneous work in the network by placing a part of messages coming from different applications (multiplecsation) in one transmission channel. The tasks of segmentation, merging data and multiplexing communication fall to the transport layer [5]. Depending on requirements concerning data transmission, two basic transmission protocols are distinguished: TCP and UDP. The TCP Protocol is a protocol which guarantees reliable provision of data to the recipient by tracking transmitted data, confirmation of data receipt and repetition of lost data. It is the interconnection protocol, which means that before data is transmitted by the network, the connection is established between the communicating devices. Second protocol which is simpler is UDP. It is faster than TCP, doesn't require confirmations and doesn't provide lost data for the retransmission, and thus doesn’t ensure reliability. Where reliability of the data transmission is required the TCP is applied (database applications, electronic mail, websites). In case of less sensitive data, where applications are tolerant to loss of small amounts of data the UDP protocol is applied (video or voice transmission) [2]. The task of protocols layer is to provide an interface between the user of the network device and network data. In this layer it is possible to distinguish two types of the software: applications and services. Services of the application layer are usually transparent for the user and are responsible for connecting the application with network as well as sending data. The application provides interface for the user as well as initiates the process of data transmission by the network. The application layer like the remaining layers of the network contains protocols of different type defined by standards and data formats. FTP can be an example of the application, service and protocol, which constitutes the interface for user (application), supporting program connections for transmission files (service) and interchange standard of network communications (protocol). Protocols of the application layer define the way of data exchange between applications and services, which are started on devices participating in the communication. They carry it out by determining the type and format of an exchanged message as well as by determining the way in which the message is sent and received.

3. Wireless controller of servo-drives

The wireless controller of pneumatic positioning system was built on the basis of the TCP/IP model (Fig. 2) [7], [8]. The wireless controller contains the ALIX.1D microcomputer board (Fig. 3a). The board is equipped with AMD Geode 500 MHz processor and 256 MB memory RAM. It is powered with 12 V and characterized by small current intensity of 0.4 to 0.5 A. The task of board is to connect wireless card, input/output port and application for the controller. For that purpose operating system Windows XP was installed on the memory card. This system was chosen, because the ALIX.1D system board meets the minimal requirements and there are no major problems with detection of additional devices and drivers installed in it.

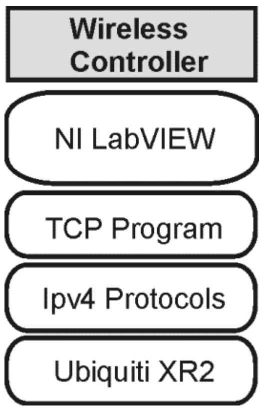

Fig. 2. Wireless controller scheme

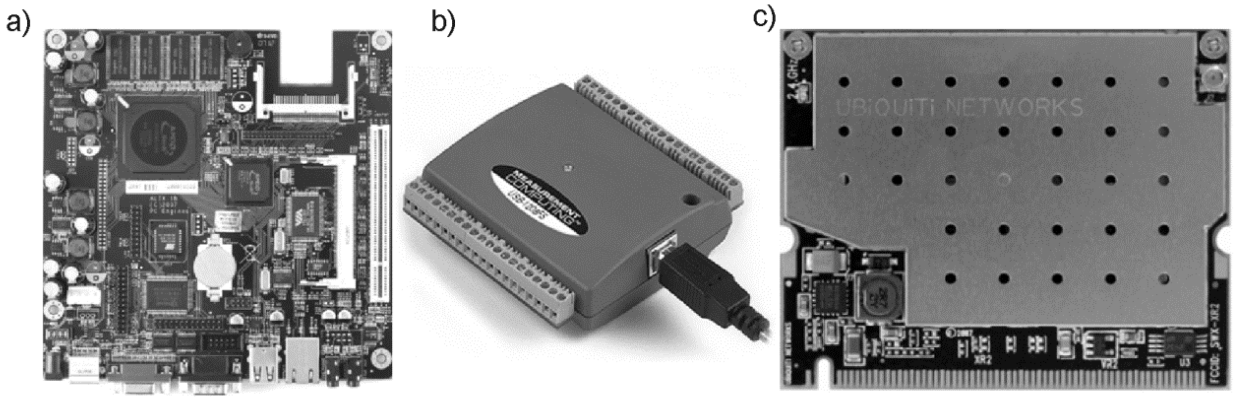

Fig. 3. Elements used for construction of the wireless controller: a) ALIX 1D microcomputer board, b) module of the acquisition data MicroDAQ USB-1208FS, c) wireless card Ubiquiti XR2

As input/output port for the driver was a chosen module for the data acquisition MicroDAQ USB-1208FS (Fig. 3b). This system has 4 analog inputs in the symmetrical system (differential) and 8 - inputs in the asymmetrical system. Inputs have resolution of 12 bits in the symmetrical system or 11 bits in the asymmetrical system. In the asymmetrical system there is a possibility of voltage measurement which is ± 10 V, while in the differential system it is ± 20 V. The module is characterized by sample frequency of up to 50 kS/s while using hardware scanning. For generation of output signals 2 analog outputs are available with resolutions of 12 bits. Output voltage range amounts to 0–4.096 V at maximum load capacity of 15 mA. Analog data are sent with the frequency to 10 kS/s for one channel or 5 kS/s for two channels using the hardware method. This module is connected to the driver board by USB interface. For the communication with operator the Ubiquiti XR2 card is used (Fig. 3c). The card is equipped with MMCX connector which provides a better connection card (pigtail), than the one popular miniPCI cards UFL connectors. The advantages of this card are 802.11b and 802.11g standards, large output power (26 dB) and sensitivity of the receiver to -95 dB. The card is recommended for applications, where the highest reliability and quality of transmission is required. Depending on aerial inside the premises it is possible to obtain the space up to 200 m, however in the open space it is about 50 km. The proper operation of TCP/IP requires that he devices in network be assigned a unique network addresses. For that purpose the pool of addresses IPv4 from class B was divided into subnet consisting of two hosts. The division into smaller subnet was achieved by such a change of the mask that only 2 least significant bits were used for appointing addresses of devices. The output address was network address 172.16.0.0/16. The remaining address in the subnet (172.16.2.3) is a reserved broadcast address. Such addressing increases safety before a "strange device" is connected to the network, since the next address 172.16.2.4/30 is already an address of other subnet,. Consequently the devices will not be able to communicate directly with each other In order to provide the reliability of transmission and due to small amounts of data which are sent by the network TCP was chosen as the transport protocol. For the communication between the driver and the operator two applications were written, one for the controller and the other for the operator. The application of controller performs the role of the service. Its task is to listen attentively and wait for the operator to indicate the connection on a chosen port. When connection is detected the service starts to collect and send data. When operator finishes the connection, the application again turns into the state of listening and waiting. Both programs were written using LabVIEW software (Fig. 4) which allows one to write program with the use protocols like TCP, UDP, Bluetooth or IrDA. The applications capable of sending data via TCP protocol must use blocks to open and close connection for a determined IP address and port, a blocks to listen for incoming connections as well the blocks that record and read data from the TCP connection. In the figure below an example of the client application and server created with the use of LabVIEW is presented. Apart from the basic TCP blocks a loop was applied. Its task was a constant sending of data from the client application and a constant reception of data from the server.

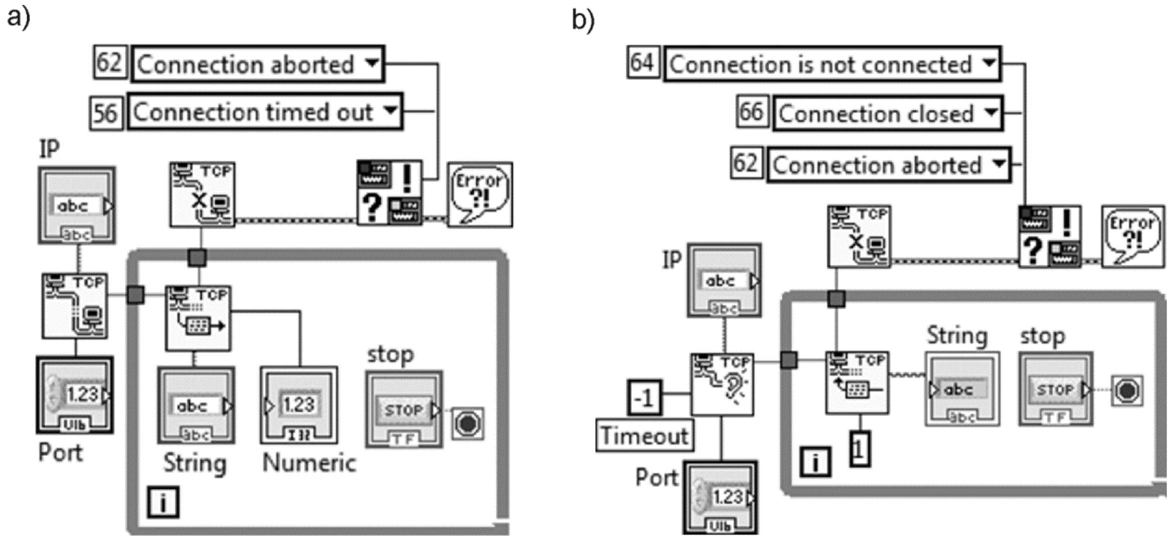

Fig. 4. NI LabVIEW software: a) client application, b) server application

A laboratory test stand of the wireless controlled pneumatic positioning systems and a panel controller view of the wireless communication are presented in Figure 5. Proportional pressure valve SMC of VEP3141 type controls the outlet pressure steplessly according to current [9]. The task of proportional valve pressure is to ensure a set pressure proportional to the value of control voltage on its output. It is possible control the valve in order to obtain on it the output pressure between 5 kPa and 0.15 MPa, at maximum working pressure 1 MPa. It is characterized by flow control of pressure and response time of 0.05 s. Proportional pressure valve is connected to the pneumatic positioner responsible for establishing an appropriate actuator position on the pressure base controlled by the valve. The positioner of the A705 type is designed to cooperate with a 2-side pneumatic-piston-type actuator in the systems of automatic adjustment of the industrial processes in the chemical, foodstuff, energetic industry, etc. [10]. The pneumatic positioner of A 705 type is designed to increase useful force of actuator ensuring precise actuator mandrel positions. Its mechanism of maneuverable tensing ensures fast and accurate setting of the piston actuator, proportional to the value of control signal. Pneumatic positioner can be controlled by the input pressure signal of about 20-100 kPa, at the supply pressure of 0.25-1 MPa. The displacement measurement LVDT of PLx200 type (in the range of 1-200 mm) converting linear displacement of cylinder piston to voltage ± 10 V [11].

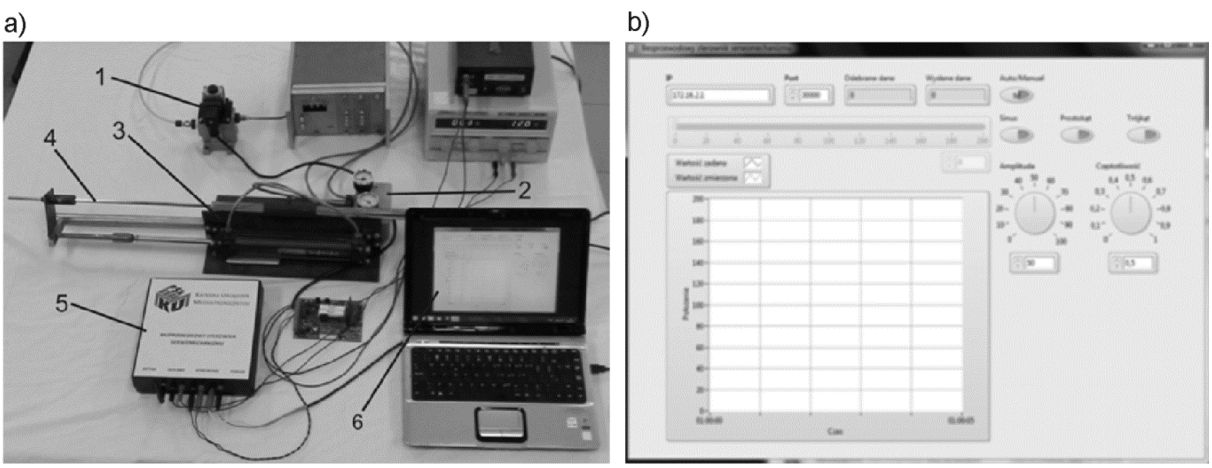

Fig. 5. Laboratory test stand: a) wireless controlled pneumatic positioning systems: 1 – proportional pressure valve SMC VEP3141, 2 – pneumatic positioner type A705, 3 – pneumatic actuator, 4 – displacement measurement LVDT of PTx200,PTx200, 5 – controller to MPL102 type , 6 – driver of the wireless communication, b) computer panel of the controller

4. Results of experimental tests

The experimental tests of electro-pneumatic systems were conducted mainly to check the operation of the designed wireless controller for positioning of pneumatic actuator at various load mass [7], [8]. A transpose control and follow-up control of pneumatic positioning system was carried out. Some graphs showing position tracking of pneumatic actuator are presented in Figures 6-8.

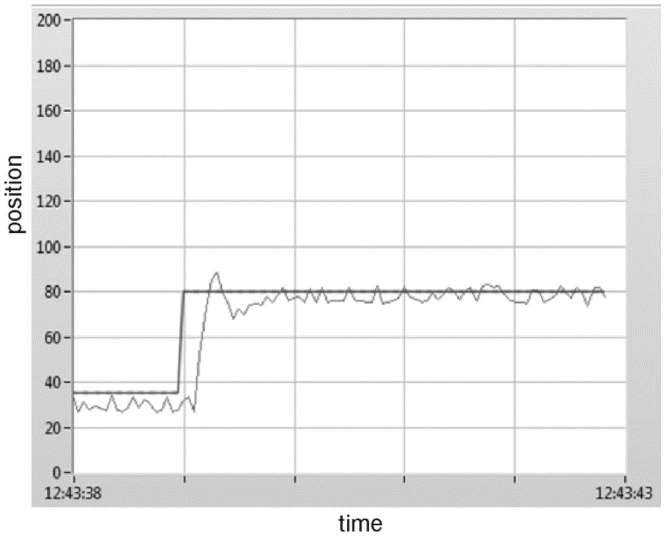

Fig. 6. Position tracking of pneumatic actuator for a step input

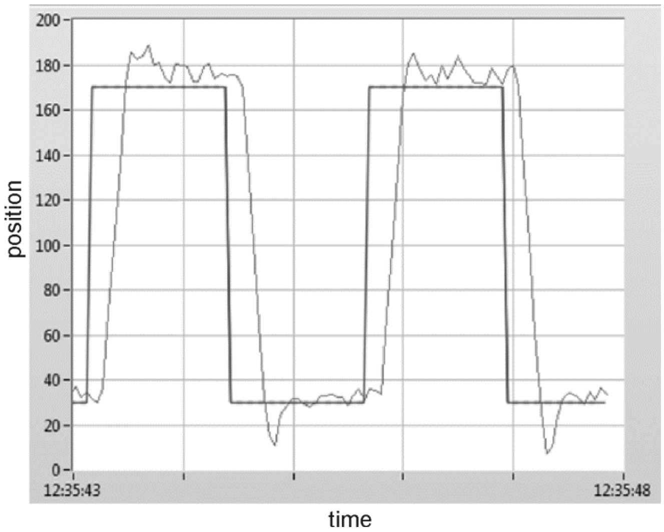

Fig. 7. Position tracking of pneumatic actuator for a rectangular pulse input

From the analysis of above graphs it results that there is a delay between the value of a set signal and actuator position. As the driver performs only the role of control system the delay isn't significant in the process of regulation. Pneumatic positioner is responsible for the regulation process. Small values of delay occur in the process of manual control, but larger delays appear in automatic control, where changes of the control signal are faster. The reason of such delays may be transport protocol, which due to quality transmission assurance imposes delays. The next stage in control of the pneumatic positioning system involves change from TCP to UDP in order to check, whether the simpler transports will also impose delays in the data transmission. In spite of the fact that he studied controller causes delays between the control and read signal, which disqualifies it as the adjuster, it can be used for simple control of the servo drive in systems that do not require high precision and in places dangerous to operator of the servomechanism.

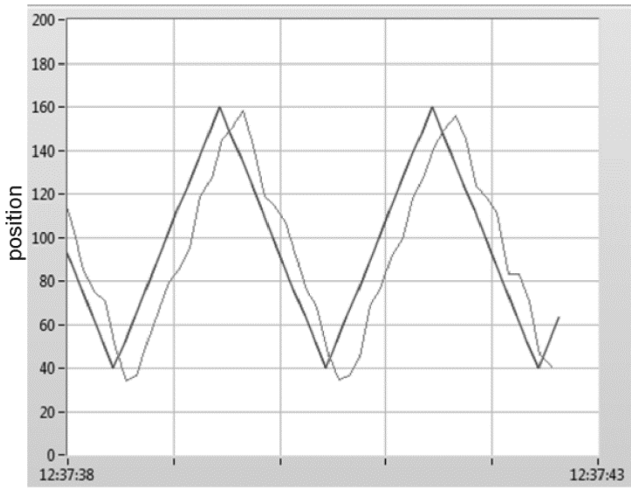

Fig. 8. Position tracking of pneumatic actuator for a triangular pulse input

5. Conclusions

The development of computer networks, particularly wireless networks increases their efficiency and safety, which makes them useful in industry. Wireless communication in spite of its limitations, such as susceptibility to disruptions or delays in transmission can be used where cable networks cannot be applied. Wireless control can significantly improve security of the operator and reduce the costs of the network infrastructure. The simulations conducted in the laboratory confirm that it is possible to use the wireless computer network WiFi for communication of the operator with the remote device without obstacles. Moreover, it should be noted that after the replacement of the software it is relatively easy to adopt the controller to other tasks.

References

[1] G. Prede, D. Schulz, „Servopneumatics". Festo GmbH, Denkendorf 2002;
[2] M. Dye, R. McDonals, A. Rufi, "Network Fundamentals", CCNA Exploration Companion Guide, Cisco Press, Indianapolis, Indiana, 2008;
[3] W. Lewis, "LAN Switching and Wireless", CCNA Exploration Companion Guide, Cisco Press, Indianapolis, Indiana, 2008;
[4] D. Meyer, „TCP/IP versus OSI", IEEE Potentials, 1990, Vol. 9, Issue 1, pp. 16–19;
[5] W. Charfi, M. Masmoudi, F. Derbel "A layered model for wireless sensor networks", SSD'2009 - Systems, Signals and Devices, 6th International Multi-Conference, pp.1-5;
[6] B. Mindang, "Core Technology and Analysis of 802.11N", ICEICE'2011 - International Conference on Electric Information and Control Engineering IEEE, 2011, pp. 978-982;
[7] S. Mazur, R. Dindorf, P. Woś, "Wireless control of the electro-pneumatic servo drive", Information Systems Architecture and Technology. System Analysis Approach to the Design, Control and Decision Support. Wrocław 2012, pp. 231-240;
[8] S. Mazur, R. Dindorf, P. Woś, „System komunikacji bezprzewodowej w sterowaniu serwonapędów elektropneumatycznych", Pneumatyka, nr 2, 2012, pp. 46-51;
[9] SMC Electro Pnuematic Proportional Valve series VEP;
[10] Technical product documentation of the positioner Type A706, CONTROLMATICA ZAP-PNEFAL Sp. o.o. Ostrow Wlkp., Poland;
[11] Peltron http://www.peltron.pl/przetworniki_przemieszczen1-ang.html