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NEURAL NETWORK USE IN CONTROL SYSTEM OF ANTENNA COMPLEX FOR INFORMATION RECEIVE OF EARTH REMOTE SENSING

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Застосування нейронної мережі в системі керування антенним комплексом прийому інформації дистанційного зондування Землі

В статті розглянута структура і алгоритм функціонування системи керування наземної станції прийому інформації дистанційного зондування Землі спеціальної конструкції для забезпечення супроводу низькоорбітальних космічних апаратів. Структура і алгоритм роботи системи керування побудовані на принципах нейромережевих технологій.

Ключові слова: антенна система, дистанційне зондування Землі, система керування, нейронна мережа

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Применение нейронной сети в системе управления антенным комплексом приема информации дистанционного зондирования Земли

В статье рассмотрена структура и алгоритм функционирования системы управления наземной станции приема информации дистанционного зондирования Земли специальной конструкции для обеспечения сопровождения низкоорбитальных космических аппаратов. Структура и алгоритм работы системы управления базируються на принципах нейросетевых технологий.

Ключевые слова: антенная система, дистанционное зондирование земли, система управления, нейронная сеть

A structure and algorithm of functioning of the aerial system for the remote sensing of Earth of the special construction for providing of accompaniment of space vehicles in some range of trajectories of motion is considered in the appendix. The structure and description of work of the control system, built on principle of neural network technology are resulted.

Introduction. The remote sensing of Earth (RSE) by means low orbit satellite vehicles (SV) needs more and more expansion distribution, providing various industries of national economy by informative resources. Tendency to growth of high-band for information reception by means of large aerial systems (AS) at high speeds of accompaniment requires reduction of dynamic errors of accompaniment AS (about units of angular min.) and according to a structure and algorithms the operation of control system with such AS. Existing aerial complexes were developed, as a rule, on the basis of the analogue control systems and a lot of methods of classical management theory used for these systems became insufficient using computing machinery means in control system structure.

Architecture and algorithm. For RSE [1,2] as to the management (fig. 1) object complication of its construction caused by the necessity of avoidance of "dead" areas at accompaniment of SV in the district of zenith through limitation of speed of aiming AS is the feature of the developed aerial system.

Fig. 1. Watching 3-axis AS for RSE

In the aerial system for such aims in the structure of supporting-turning device the entered additional azimuth axis with the angle of slope ≅15° and range of rotation in a horizontal plane as well as at a basic azimuth axis ±170°, that allows to conduct

SV on some trajectories. At the same time there is the necessity of the management AS on three axes and count of co-ordinates from the in-plant 3-axial system in "global" one and vice versa.

Below resulted formulas for transformation of absolute («global») angular coordinates α, β in the «local» co-ordinates AS α1 (corner of turn of the basic azimuth axis E1), α2 (corner of turn of horizontal, or elevation axis E2) and α3 (corner of turn of additional azimuth axis, E3):

$$\alpha 2 = arctg\left(\frac{\cos\gamma\cdot\sin\beta - \sin\gamma\cdot\cos\beta\cdot\cos(\alpha-\alpha 3)}{\sqrt{1-(\cos\gamma\cdot\sin\beta-\cos\beta\cdot\cos(\alpha-\alpha 3)\cdot\sin\gamma)^2}}\right)+\gamma, \qquad (1)$$

$$\alpha 1 = \begin{cases} \alpha_1', \text{при } X_A \geq 0; \\ \alpha_1' + 180^\circ, \text{при } X_A < 0 \text{ и } Z_A \geq 0; \\ \alpha_1' - 180^\circ, \text{при } X_A < 0 \text{ и } Z_A < 0; \end{cases} \qquad (2)$$

where

$$\alpha_1' = \operatorname{arctg}\left(\frac{\cos\beta\cdot\sin(\alpha-\alpha 3)}{\cos\gamma\cdot\cos\beta\cdot\cos(\alpha-\alpha 3)+\sin\gamma\cdot\sin\beta}\right), \qquad (3)$$

$$X_A = \cos\gamma\cdot\cos\alpha 3\cdot\cos\alpha\cdot\cos\beta+\sin\gamma\cdot\sin\beta+\cos\gamma\cdot\sin\alpha 3\cdot\cos\beta\cdot\sin\alpha; \qquad (4)$$

$$Y_A = -\sin\gamma\cdot\cos\alpha 3\cdot\cos\beta\cdot\cos\alpha+\cos\gamma\cdot\sin\beta-\sin\gamma\cdot\sin\alpha 3\cdot\cos\beta\cdot\sin\alpha; \qquad (5)$$

$$Z_A = -\sin\alpha 3\cdot\cos\beta\cdot\cos\alpha+\cos\alpha 3\cdot\cos\beta\cdot\sin\alpha \qquad (6)$$

$\gamma \cong 15^\circ$ it is corner of declination of the axis E1 from the axis E3.

Ranges of change of corners	α	-	(0÷360°);
	β	-	(0÷90°);
	α1, α3	-	(0÷±170°);
	α2	-	(0÷120°).

The receipt of its adequate mathematical model is the necessary stage of decision of task of management by the difficult dynamic system that is based, as a rule, on the theoretical and experimental analysis of properties of the system. Calculation of the dynamic parameters of AS, especially with a triaxial turning mechanism, after classic methods related to the row of technical difficulties, in particular by complication of measuring or calculation of such parameters of the real AS, as for example, moments of inertia, change of friction of resistance from the angles of slope and correlation of positions of aerial on different axes, changes of inflexibility of mechanical transmission, influencing of backlashes, instability of descriptions of electrodrives, stochastic influencing of the wind loadings, possible instability of sentineling intervals of discretization and programmatic data processing at transformation of co-ordinates, etc. Such AS is possible to attribute to the class of the nonlinear systems.

With unclear certain parameters the use of algorithm of proportional-integral-differential (PID) regulator with the adaptive tuning PID-coefficients is the effective method of management by dynamic objects:

$$u(t) = K_p \left[\varphi(t) + \frac{1}{T_I} \int_0^T \varphi(t)dt + T_D \frac{d\varphi(t)}{dt} \right] \tag{7}$$

where the $u(t)$ – initial signal of regulator is, K_p is amplification factor in the link of reverse communication;

$\varphi(t)$ it is deviation of angular position from set one;

T_I, T_D – steel of time of integration and differentiation. For the digital discrete control system, law of digital PID regulator is led to the kind comfortable for programmatic realization on microcontroller:

$$u(t) = u(t-1) + K_P(e(t) - e(t-1)) + K_I e(t) + K_D(e(t) - 2e(t-1) + e(t-2)). \tag{8}$$

where $e(t) = r(t) - y(t)$, and $r(t)$, $in(t)$ is the set and initial size of signal for the object control;

K_P, K_I, K_D – PID-coefficients which require the optimum tuning.

However in dynamic processes with in-out parameters, notable non-linearity and hindrances enough it is heavy to provide the optimum tuning of coefficients. There is the row of methods and algorithms of self-tuning of PID-controllers, the results of which in majority are taken to complication of algebraic calculations with introduction of many new parameters of the system

One of alternatives there is creation of case frame on the basis of the use of artificial neuron networks to the classic models and methods (NN). Self-training possibility after certain teaching sequences and algorithms is the important property NN.

The distributed three-contour hierarchical structure identical for every axis is the feature of the offered control system, but with different parameters of adjusting, which are determined by NN, entered in the external contour of management (fig. 2). An internal contour locks oneself in the most frequency regulator which sets tension, current of electrodrive for the local adjusting of turns and which also act in inspector.

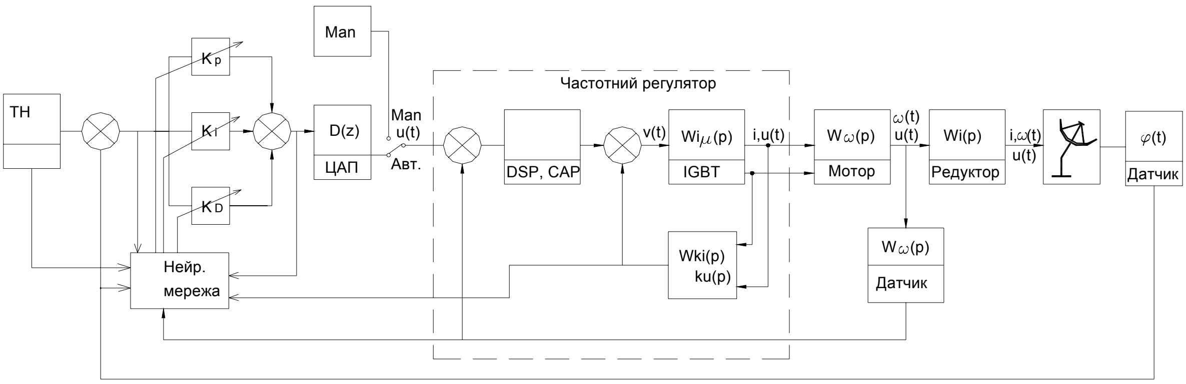

Fig. 2 Structure of control contour AS based neurocontroller

Second there is the contour of adjusting of speed of rotation of the axes AS. An external regulative contour locks oneself according to the angular regulations of the axes AS.

In quality the parameters of authentication for NN the signals of divergence between the entrance sequence **R(t)** (aiming table) and real position AS for every point of table, managing action, from a frequency regulator are used also.

It is known [3] that NN, which consists of three layers and, which has the arbitrary amount of knots in the hidden layer, can approximate some function of material numbers with set to degree exactness. For the decision of tasks of the management AS and authentications of parameters we use simple NN with direct distribution of signal and back distribution of error (fig. 3).

The initial neurons of network with a sigmoid transmission function form the scaled coefficients of PID-regulator K_P^*, K_I^*, K_D^*

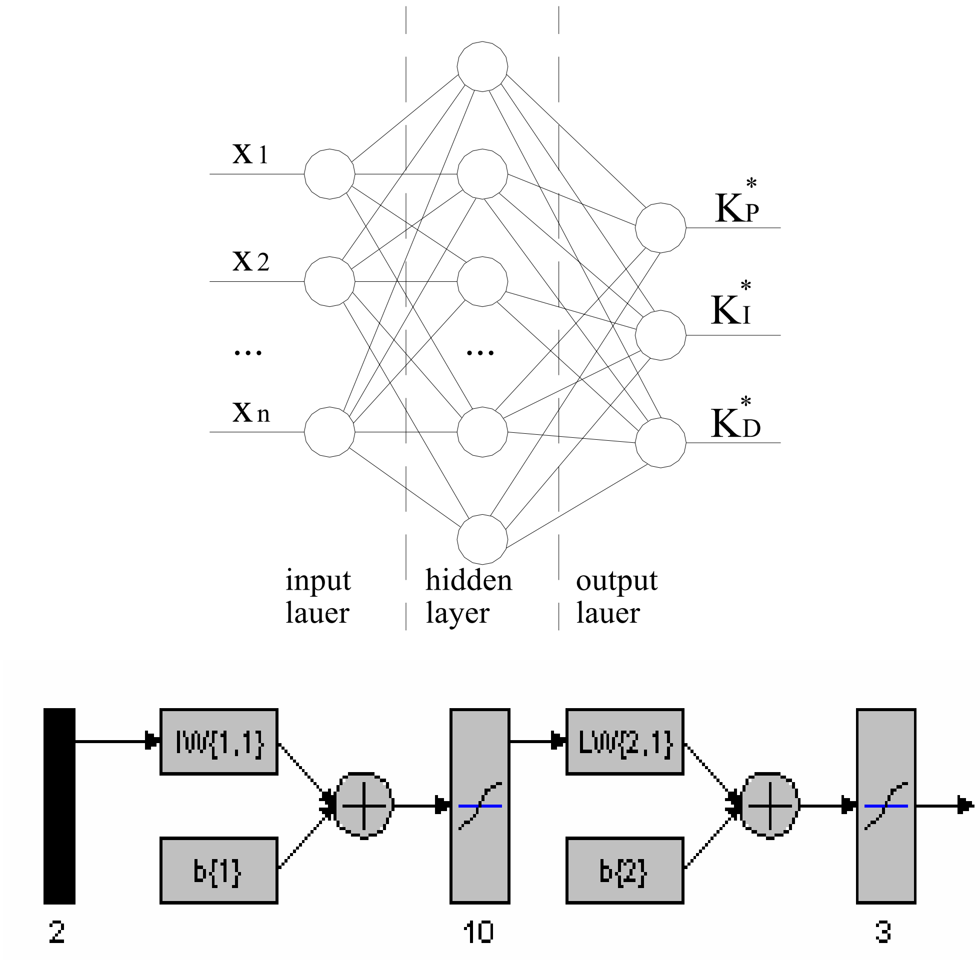

Fig. 3 Structure neural network of controller

We will designate the output of neuron of initial layer through $O(k)$.

$$O(k) = f(net_k),$$

where $net_k = \sum_j w_{kj} O_j + \theta_k$

So as value PID – coefficients is not limited to the range from 0 to 1, after the output of network *O(k)* it is possible to use some coefficient of transmission of ***c***, such, that

$$O(k) = cf(net_k), \quad c > 0. \tag{9}$$

For realization of algorithm of studies of network the quadratic function of the ***E*** error is entered, that is subject to minimization.

$$E = \frac{1}{2}\sum_{k=1}^{N} e^2 \tag{10}$$

For a neuron network we build a teaching rule on the basis of algorithm of the most rapid lowering, in obedience to which the weighing coefficients of initial layer are determined as:

$$\Delta w_{kj}(t+1) = -\eta \frac{\partial E}{\partial w_{kj}} + \alpha \Delta w_{kj}(t), \tag{11}$$

and for the hidden layer

$$\Delta w_{ji}(t+1) = -\eta \frac{\partial E}{\partial w_{ji}} + \alpha \Delta w_{kj} i(t). \tag{12}$$

We will define that

$$\delta_k = \frac{\partial E}{\partial net_k}, \tag{13}$$

using a gradient method, we will get:

$$\frac{\partial E}{\partial w_{kj}} = \frac{\partial E}{\partial net_k}\frac{\partial net_k}{\partial w_{kj}} = \frac{\partial E}{\partial net_k} O_j \tag{14}$$

and

$$\delta_k = \frac{\partial E}{\partial net_k} = \frac{\partial E}{\partial y(t+1)}\frac{\partial y(t+1)}{\partial u(t)}\frac{\partial u(t)}{\partial O(k)}\frac{\partial O(k)}{\partial net_k} \tag{15}$$

but

$$\frac{\partial E}{\partial y(t+1)} = \frac{\partial E}{\partial e(t+1)}\frac{\partial e(t+1)}{\partial e(t+1)} = -(r(t+1) - y(t+1)) = -e(t+1),$$

$$\frac{\partial u(t)}{\partial O(k)} = f'(net_k) = O(k)(1 - O(k)),$$

with the account of that $O(1)=K_P$, $O(2)=K_I$ and $O(3)=K_D$. we will get correlation:

$$\frac{\partial u(t)}{\partial O(k)} = \begin{cases} e(t) - e(t-1) & ;k=1 \\ e(t) & ;k=2 \\ e(t) - 2e(t-1) + e(t-2);k=1 & ;k=1. \end{cases} \tag{16}$$

We will get thus

$$\Delta w_{kj}(t+1) = -\eta \delta_k O_j + \alpha \Delta w_{kj}(t), \tag{17}$$

where

$$\delta_k = e(t+1)\frac{\partial y(t+1)}{\partial u(t)}O(k)(1-O(k))\frac{\partial u(t)}{\partial O(k)}. \qquad (18)$$

For the hidden layer we will get

$$\frac{\partial E}{\partial net_j} = \sum_k \frac{\partial E}{\partial net_k}\frac{\partial net_k}{\partial O_j}\frac{\partial O_j}{\partial net_j}\frac{\partial net_k}{\partial w_{kj}} = \sum_k \delta_k w_{kj} f'(net_j) = -\sum_k \delta_k w_{kj} O_j (1-O_j).$$

η- parameter, that determines speed and firmness of process of studies.

As a result we will get the rule of finding of weighing coefficients for every following step:

$$\Delta w_{ji}(t+1) = -\eta\delta_j O_i + \alpha\Delta w_{ji}(t), \qquad (19)$$

$$\delta_j = \frac{\partial E}{\partial net_j} = \sum_k \delta_k w_{kj} O_j (1-O_j) \qquad (20)$$

Experiment. For the studies of network the trajectories of type different to the test are generated sinusoidal, impulsive function for every axis, and also we use the real trajectories of some SV.

Developed special program of the management AS and visualization of transitional descriptions of the T3SUA.EXE type a «digital oscilloscope» by which is estimated the size of readjusting and time of transitional process at the set coefficients.

On fig. 4 the process of network training is shown for a horizontal axis (elevation) on an impulsive function. By yellow the shown set impulsive trajectory, dark blue is result of working off. Result PID-coefficients that are the NN outputs it is possible to look, or change (“studies with a teacher”) in a separate interface window (fig. 5).

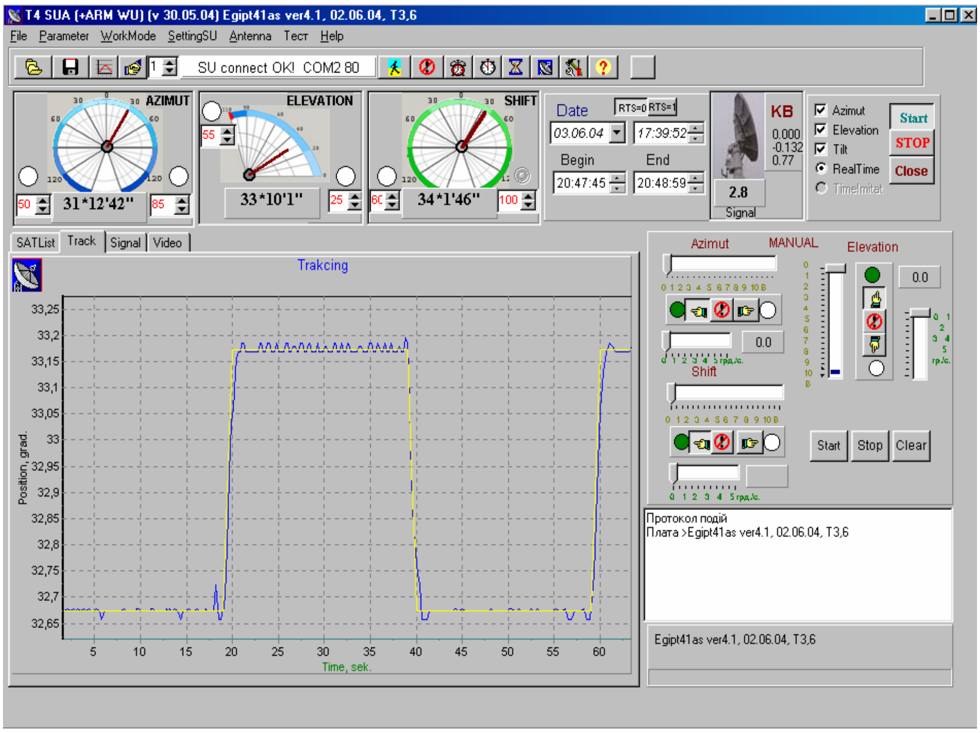

Fig. 4. Impulsive description AS on an axis β

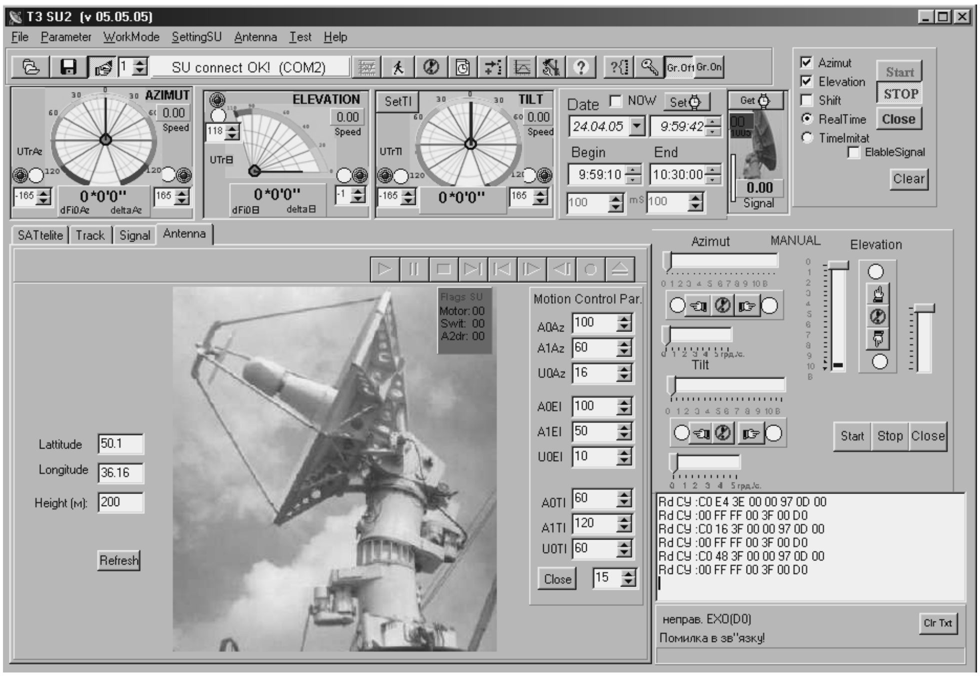

Fig. 5. Menu of the PID- coefficients correction

On fig. 6 working off the special test trajectory is shown with 15 points (by duration 15 seconds) in which speed of accompaniment change from 0 to a 5 degree per second. The error of working off a trajectory does not exceed a 5 angle minutes.

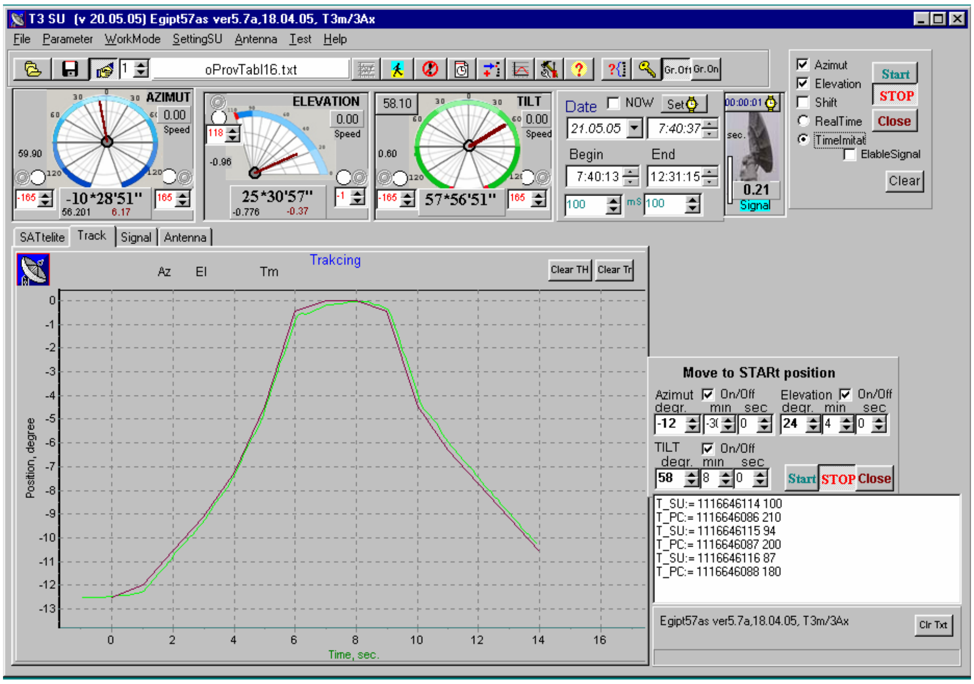

Fig.6. Test trajectory at full pelt accompaniment 5 degree/sec

Change diagram of angular deviation error from the set trajectory on both axes (1-st line-azimuth, 2-nd line-elevation) in angular minutes is shown on a fig. 7.

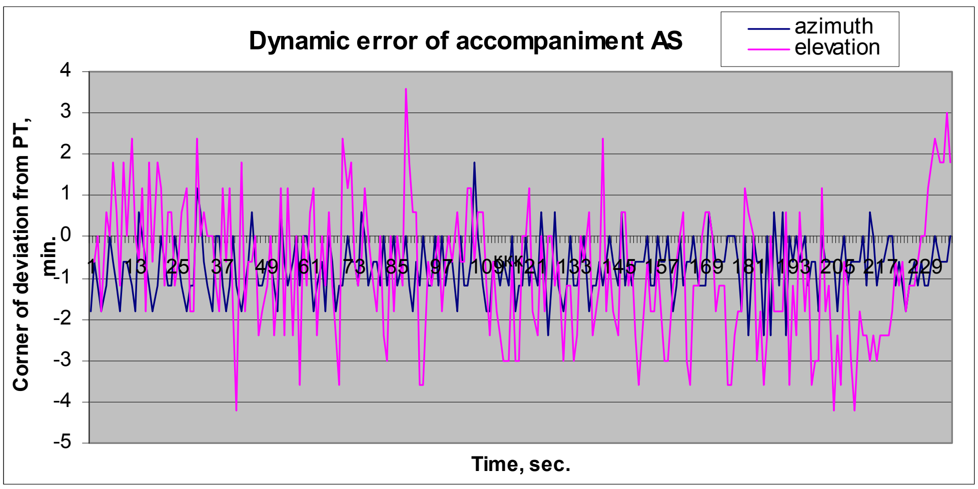

Fig. 7. The change diagram of angular deviation error from real pointing table in angular minutes

Conclusions. Consequently the use of neuron network in a control circuit gives substantial advantage before the traditional control systems, due to that for their realization not necessary exact mathematical model of object control.

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Usage of the neuronic network in the control system of the antenna information reception complex of distance Earth sounding

The structure and function system algorithm of ground station control of information reception of distance Earth sounding with the special construction for supplying with escorting lower orbital spacecrafts are given in the article.

The structure and the direction system algorithm are built on the principles of neuronic-network technologies.

The key words: antenna system, distance Earth sounding, control system, neuronic network.

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