Interpolation Information-Measuring System on the Basis of Television Scanistor

Y.K. Shelkovnikov [1], A.I. Korshunov [2], S.G. Seletkov [3], V.A. Kulikov [4]

[1] Laboratory of information-measuring systems, Institute of Mechanics UB RAS, Izhevsk, Russia
E-mail: evshelk@mail.ru
[2] Kalashnikov Izhevsk State Technical University, Izhevsk, Russia
E-mail: kai@istu.ru
[3] Department of Higher Mathematics, Kalashnikov Izhevsk State Technical University, Izhevsk, Russia
E-mail: s.g.seletkov@mail.ru
[4] Department of Computer Engineering, Kalashnikov Izhevsk State Technical University, Izhevsk, Russia
E-mail: kulik00@istu.ru

Received: 3.12.2015

Abstract. The purpose of the paper is to discuss the issues of improving the accuracy of determining the coordinates of the middle of the light zone of the TV scanistor. The expediency of applying two methods of comparison to this purpose was shown, particularly when the dimensions of the light zone may vary during the measurement. Interpolation information and measuring system with the proposed interpolation method of measuring the time interval was described.

Keywords: TV scanistor, information and measuring system, video signal, measurement accuracy, time interval, interpolation method

INTRODUCTION

A television semiconductor p-n-p structure of scanistor (solid scanistor, discrete multiscan) is a non-vacuum analogue of a television transmitter tube and can be used as a sensor for automatic control of the space-time state of the object [1–3]. Scanistor structures are used in various fields of science and technology for measurement of angular and linear movement, velocity, acceleration, size and relative position of objects [4–7]. It was established that the most appropriate method of scanistor utilization is to use them as the coordinate-sensitive photodetectors for measuring sizes and positions of various light zones. In this case, a coordinate resolution equals to several units or fraction of a micron (i.e., 2 orders of magnitude higher than their television resolution and almost an order of magnitude higher than the actual resolution of the coordinates (size) light zones have and photodiode structures) [8, 9]. The broad functionality of TV scanistor structures, simplicity of design, manufacturing technology and the scheme of formation and allocation of the video signal allow to create simple and reliable scanistor information-measuring systems (SIMS) for instrumentation, process control systems in the field of aerospace, chemical and physical studies, etc. [10]. It was noted that increase of measurement accuracy of coordinates of light streams with the help of SIMS is a relevant task.

BLOCK DIAGRAM OF THE INTERPOLATION SIMS

Figure 1 shows a block diagram of a high-precision interpolation SIMS for coordinate measuring of the middle of the light zones of the scanistor, where TS – television scanistor; FD – frequency divider; CPS – clock pulse source; VC – videosignal converter; SAW – sawtooth-voltage generator; VS – bias voltage source; T_1–T_4 – RS-triggers; DA_1, DA_2 – differentiating amplifiers; LA – limiting amplifier; Sh – shaper of the signals; AND_1–AND_5 – AND gates; OR_1-OR_3 – OR gates; PC_1-PC_5 – pulse counters; TAC_1–TAC_3 – time-to-amplitude converters; ADC_1-ADC_3 – analog-to-digital converters; MCU – microcontroller unit; LCD – liquid-crystal display.

FORMATION OF THE VIDEO SIGNAL IN THE INTERPOLATION SIMS

Scanistor (TS) is a narrow strip of silicon of p-n-p structure and three ohmic contacts, two of which (E_1, E_2) are located on the edges of the emitter region. The strip itself is a photosensitive layer, and simultaneously a voltage divider bias source (see Figure 1). The third contact (K) serves as the contact to the equipotential collector region.

There are such high metrological characteristics of the scanistor due to the fact that the scanning is carried out with the analog method equipotential zero line, which is created and moves along the photodiode structure using the sawtooth generator and emitter bias source (fission) layer. In the output of VC there is forming of a video signal that reflects the light distribution of relief F along the photosensitive surface of the scanistor. Timing diagrams are shown in Figure 2, they explain the work of the interpolation SIMS. A video signal of trapezoidal shape is being formed in the output of VC block during the differentiation of the current of the scanistor (Figure 2c) then is differentiated twice by a DA_1 (Figure 2d) and DA_2 (Figure 2e) to highlight coordinates x_1, x_2 of the edges of the light zone, then the video signal enters through the limiting amplifier LA (Figure 2f) into the shaper of the signals Sh, which generates at its first output video pulse of the beginning of the zone (Figure 2g), and at its second output – video pulse of the end of the zone (Figure 2h). At its third output the shaper generates a video strob, leading and trailing edges of which coincide in time with the video pulses of the start and the end of the zone of scanistor respectively.

OPERATION OF THE INTERPOLATION SIMS

Measurement of the time coordinate t_x of the middle of the video strobe, corresponding to coordinate x in the middle of the light zone scanistor, carried out consecutively in two stages. At the first stage trigger T_1 forms the measuring impulse of the duration t_{x1}, the gate AND_1 is filled by counting pulses from CPS with the repetition period t_{cp} (Figure 2i).

At the second stage he elapsed time $(t_{x2} - t_{x1}) / 2$ is measured, which equals to half the length of the video strobe that is formed by the shaper Sh, this video strobe is filled with counting pulses from the output of the frequency divider FD with the repetition period $2t_{cp}$ (Figure 2j). The time coordinate t_x is determined in the output of gate OR_1 as the sum N (Figure 2k) of the number of pulses n_1, which are proportional to the interval t_{x1}, and the number of pulses n_2, which are proportional to the interval $(t_{x2} - t_{x1}) / 2$. The sum is calculated by the counter PC_1 and recorded by the microprocessor MCU.

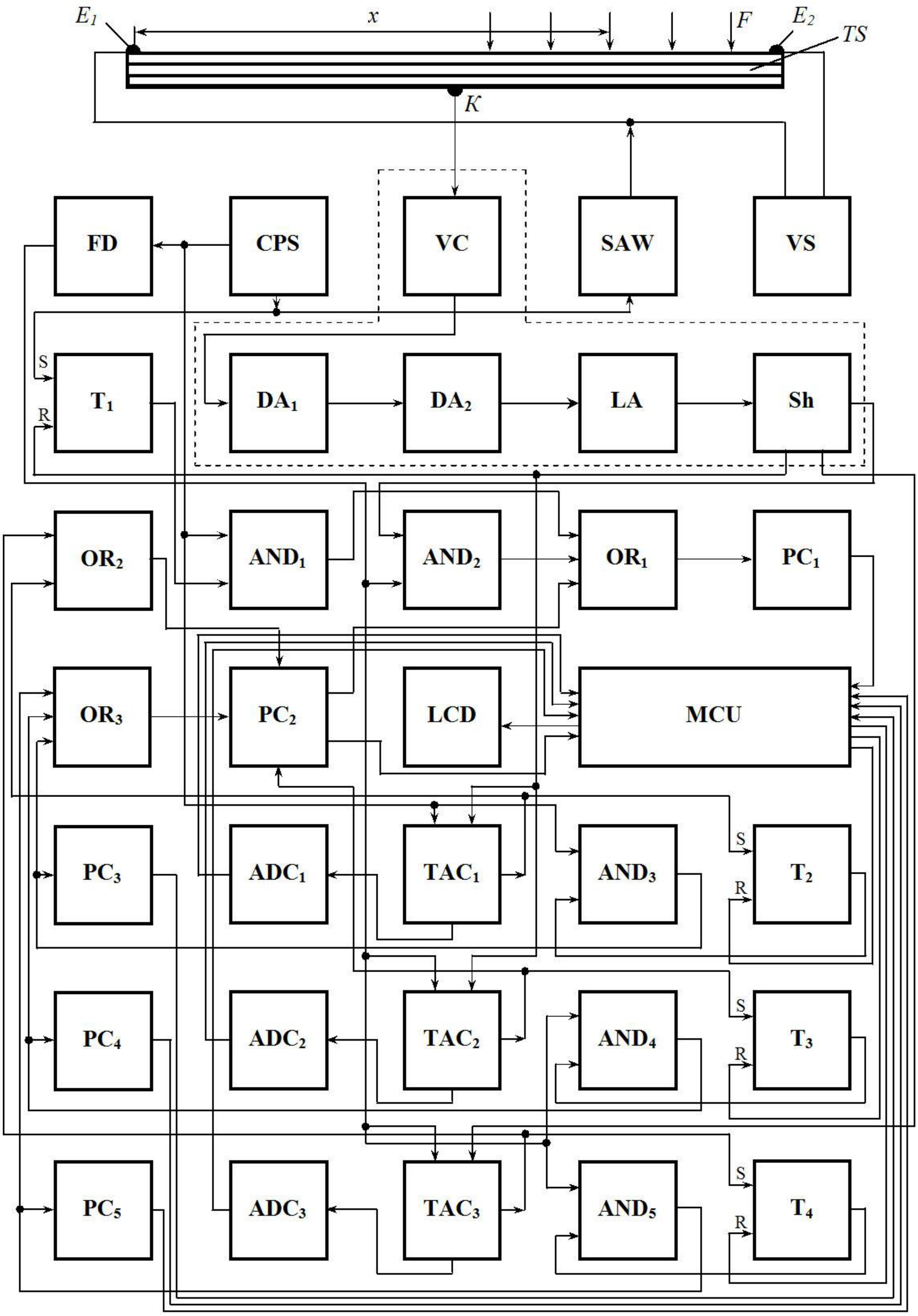

Figure 1. Block diagram of precision interpolation SIMS

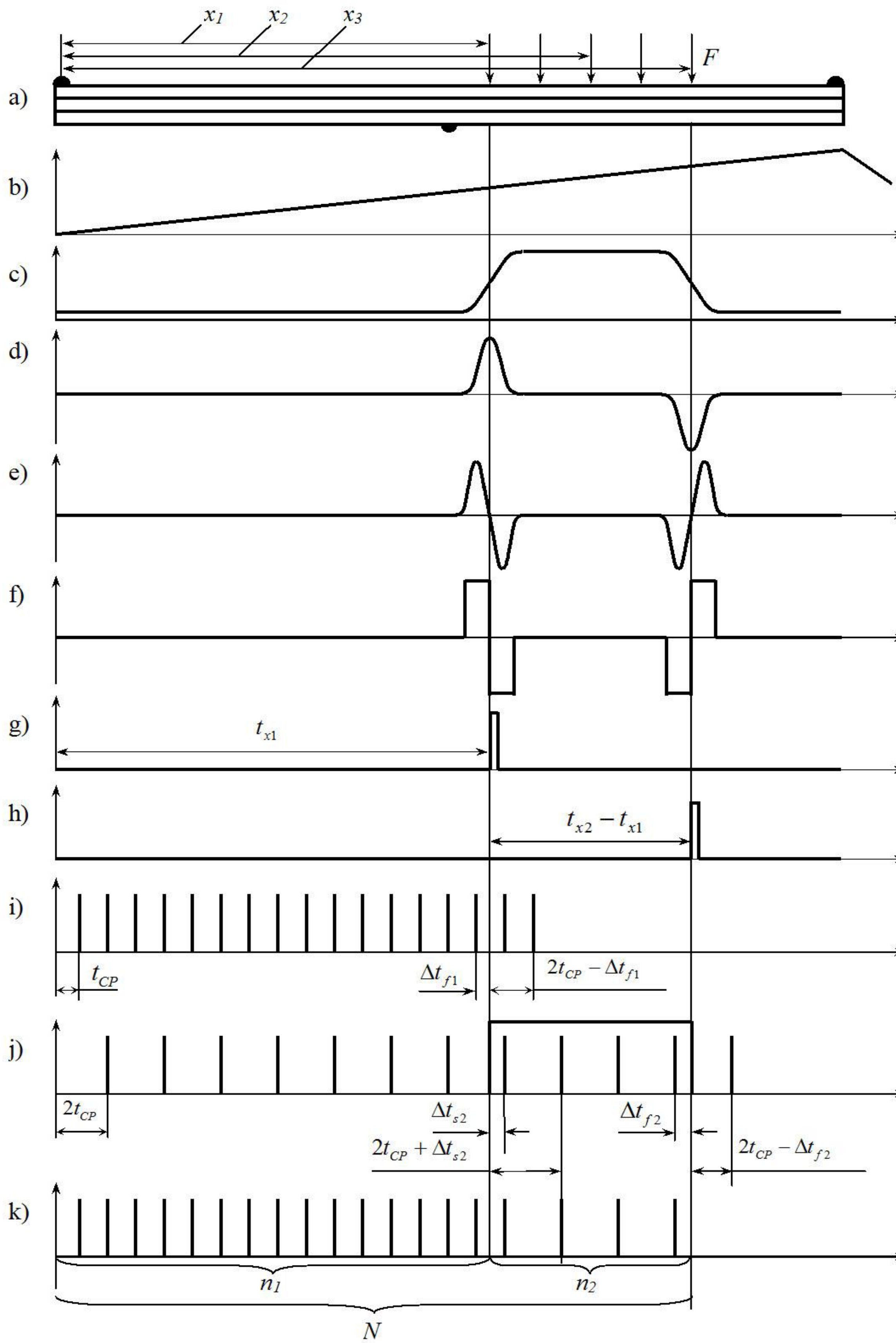

Figure 2. Timing diagrams explaining the operation of the interpolation SIMS

In this SIMS compare error δ_{comp} is appeared from the neglect of the time interval Δt_{f1} (Figure 2i) during the quantization of the interval t_{x1} by counting pulses with a repetition period t_{cp}, and from the neglect of time intervals Δt_{s2}, Δt_{f2} (Figure 2j) during the quantization of the interval $(t_{x2} - t_{x1})$ by counting pulses with a period $2t_{cp}$:

$$\delta_{comp} = \Delta t_{f1} + \Delta t_{s2} + \Delta t_{f2} \tag{1}$$

The most rational way of accounting Δt_{f1}, Δt_{s2}, Δt_{f2} is to use segments of the interpolation method of measuring of time intervals. This method allows to combine the advantages of the digital and the analog hardware implementations successfully. In the considered SIMS a version of the proposed interpolation meter [11] is implemented. Number of disadvantages inherent in the known devices have been eliminating. In this embodiment, time intervals $(2t_{cp} + \Delta t_s)$, $(2t_{cp} - \Delta t_f)$ are subjected to analog conversion, instead of the segments $0 \div \Delta t_s$, $0 \div \Delta t_f$ as in the known meters, that is way the relative variation range of the converted interval does not exceed 50 % of the maximum value of the interval t_{cp}, which improves linear characteristics of interpolating blocks.

Consider the formation of the error δ_{comp} in measuring the interval $t_x = t_{x1} + (t_{x2} - t_{x1}) / 2$ (Figure 2, i–k):

$$\begin{aligned} t_x &= (t_{cp} \cdot n_1 + 2t_{cp} \cdot n_2) + \delta_{comp} = (t_{cp} \cdot n_1 + \Delta t_{f1}) + [2t_{cp} \cdot (n_2 - 1) + \Delta t_{s2} + \Delta t_{f2}] = \\ &= (t_{cp} \cdot n_1 + 2t_{cp} \cdot n_2) - (2t_{cp} - \Delta t_{f1}) + (2t_{cp} + \Delta t_{s2}) - (2t_{cp} - \Delta t_{f2}); \end{aligned} \tag{2}$$

or

$$\delta_{comp} = -(2t_{cp} - \Delta t_{f1}) + (2t_{cp} + \Delta t_{s2}) - (2t_{cp} - \Delta t_{f2}). \tag{3}$$

To estimate the error of the comparison δ_{comp} SIMS (Figure 1) has extra equipments: time-to-amplitude converters TAC_1–TAC_3, analog-to-digital converters ADC_1–ADC_3, down counter PC_2, counters PC_3–PC_5, gates AND_3–AND_5, gates OR_2, OR_3, triggers T_2–T_4. The first term of the expression (3) is formed by blocks SIMS as follows. Time-to-amplitude converter TAC_1 is started by the video pulse (Figure 2g) of the beginning of the zone, the end of the conversion cycle is formed at the second counting pulse nearby the video pulse with a repetition period t_{cp} (Figure 2i). At TAC_1 the time slice $(2t_{cp} - \Delta t_{f1})$ is transformed into an amplitude proportional to the length of the segment. For this transformation a condenser with a linear drive charge capacity with a constant current can be used during the duration of this interval. Then the amplitude formed by the analog-digital converter is converted into a code which enters from the output of ADC_1 to the input of MCU for comparing the codes. End of conversion cycle signal on TAC_1 starts trigger T_2, the output voltage of which is supplied one of two inputs of the gate AND_3 and permits passage of countable pulses with the period t_{cp} to the input of counter PC_3 and simultaneously through the gate OR_3 to the information input of down counter PC_2, which is set to subtraction serving mode (to acquire the minus sign before the first term) on its control input through the gate OR_2 with output pulse of end of the conversion cycle TAC_1. Once the code of the counter PC_3 is equal to the code, which is available at the output of ADC_1, MCU generates a signal which sets trigger T_2 in its initial state, as a result the further counting pulses advancing to the counter PC_2, PC_3 stops.

The second and the third terms of the expression (3) are formed by units of the SIMS in a similar manner, wherein for forming the second term conversion cycle TAC_2 is redefined by the video pulse of the beginning of the zone, and the end of the cycle – by the second neighboring pulse after the counting pulse with the repetition period $2t_{cp}$; to form the third term of conversion cycle TAC_3 is redefined by the video pulse of the end of the zone and the first neighboring pulse after it with the repetition period $2t_{cp}$ (Figure 2j).

The total number of M output pulse of down counter PC_2, is proportional to the sum of unaccounted time segments Δt_{f1}, Δt_{s2}, Δt_{f2}, defines the figure in the junior (secondary) discharge of the LCD and, as a consequence – increase in the accuracy of interpolating the SIMS. Since the value of the total time period may exceed counting pulses repetition period t_{cp} – for transmission transfer pulses from the counter PC_2 to PC_1 serves gate OR_1.

CONCLUSION

Thus, the work of precision interpolation system based on the principle of using two methods of comparison for measuring the time position in the middle of the light zone scanistor. First, to measure the time interval from the start of the survey of scanistor to a time coordinate of the start of the light zone as the first measure applies counting pulses repetition period. Then, doubled counting pulses repetition period during is used to measure the time interval corresponding to half the width of the light zone. The principle implemented in the SIMS, two-coordinate measuring midpoints of both broad and narrow light bands is universal, that is especially important when the dimensions of these zones may vary during the measurement. In the proposed interpolation SIMS the compare error of neglect of fixed time periods. The error is formed during the quantization of the time intervals with counting pulses. To this purpose, the proposed interpolation method of measuring time intervals is used.

REFERENCES

1. B.G. Podlaskin, E.G. Guk, "Position-Sensitive photodetector-multiscan," Measurement Techniques, pp. 31–34, Aug. 2008.
2. Y.K. Shelkovnikov, Y.I. Evseev, Russia Patent No. 974122 (15 November1982).
3. A.M. Lipanov, Y.K. Shelkovnikov, N.I. Osipov, S.R. Kiznertsev, Russia Patent No. 2348900 (10 March 2009).
4. A.M. Lipanov, Y.K. Shelkovnikov, N.I. Osipov, A.V. Aliev, "Noise-free scanistor meter for the angular movements of the objects," Intelligent Systems in Manufacturing (journal), No. 2, pp. 106–112, 2012.
5. Y.K. Shelkovnikov, "Precision Information and Measuring System Based on Television Scanistor," Intelligent Systems in Manufacturing (journal), No. 1, pp. 244–249.
6. Y.K. Shelkovnikov, "Improving the Stability and Linearity of a Coordinate Characteristic of Scanistor Information and Measuring Systems," Intelligent Systems in Manufacturing (journal), No. 1, pp. 251–255, 2011.
7. A.M. Lipanov, Y.K Shelkovnikov., N.I. Osipov, "Usage of discrete-one-piece structure of multiscanner in electrooptical measuring device,"Sensors & Systems, No. 2, pp. 46–49, 2003.
8. A.M. Lipanov, Y.K. Shelkovnikov, N.I. Osipov, "The analysis of multiscanner with amplitude-modulated light rays," Sensors & Systems, No. 10, pp. 12–16, 2003.
9. Y.K. Shelkovnikov, "Extraction of signal from multiscanner with modulation of deploys voltage," Polzunovsky vestnik, No. 2, pp. 107–112.
10. A.M. Lipanov, Y.K. Shelkovnikov, Theoretical science and technique of TV scanistor structures manufacturing, Yekaterinburg: Ural division of RAN, 2005.
11. V.A. Potekhin, Y.K. Shelkovnikov, Russia Patent No. 1302236 (22 Mach 1987).