TWO-DIMENSIONAL CORRECTION OF TELEVISION ANGIOMICROMETER PICTURES

S. P. Gaevoi, A. I. Mazurov,
V. I. Mozheiko, V. M. Khayutin,
and R. S. Sonina

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The effectiveness of two-dimensional correction in television angiomicrometry is examined. Attention is concentrated on correction of wall fronts of microvessels and dynamic unsharpness of blood cells in the microvascular system. It was shown experimentally that a two-dimensional corrector can double the contrast of the walls in pictures of microvessels and can reveal the structure of the blood flow.

KEY WORDS: angiomicrometer; microcirculation; microvessels.

Television angiomicrometers [5, 8] are designed for qualitative assessment and quantitative study of microcirculatory processes. Characteristics of microvessels such as thickness of the wall, external and internal diameters, and the velocity of the blood flow and of single erythrocytes can be subjected to quantitative analysis.

To ensure good quality of the picture of the microvessels and accuracy of measurement of these parameters, the transmitters of the video signal must ensure high performance as regards spatial and temporal resolving powers. As a rule, however, transmitters of the signal of a television angiomicrometer are based on transmitting tubes of the vidicon class that are simple to couple to the microscope and are reliable in work, but have limited spatial and temporal resolving powers, so that methods for their correction are necessary.

Until recently the spatial resolving power has been corrected by means of an aperture corrector through amplification of the high-frequency components of the videosignal spectrum. However, because of the discreteness of image scanning in a television system, by means of this method it has been possible to improve the transmission of small details and boundaries running transversely to the direction of line scanning. Correction of temporal resolving power (inertia) has not been possible at all.

With the development of instruments delaying the videosignal for the duration of a frame on image storing tubes [1, 2], it has become possible to develop simultaneous correctors of spatial and temporal resolving powers of television systems; the corrector used with a transmitting television tube can be used to improve differences in brightness and to increase contrast of small objects, whether stationary or moving in any direction.

One such two-dimensional corrector using a vidicon has been tested for use with a television angiomicrometer (Fig. 1a). The videosignal carrying information about the microstructure examined is led from the transmitting television camera through the recording amplifier to the cathode of the vidicon of the corrector, the target of which is uniformly illuminated. The potential relief is recorded and counted on the target of the vidicon by a defocused electron beam. The recording current flowing through the load on the vidicon has the same frequency spectrum as the signal applied to the cathode of the vidicon. The current flowing through the load during counting of the preaccumulated charge by the same beam has no high-frequency components in its spectrum and is opposite in polarity. During loading of the tube these currents are subtracted, as a result of which the output signal contains only high-frequency components of the spectrum, corresponding to gradations and fine details of the picture. Subsequent summation of this signal with the original signal enables

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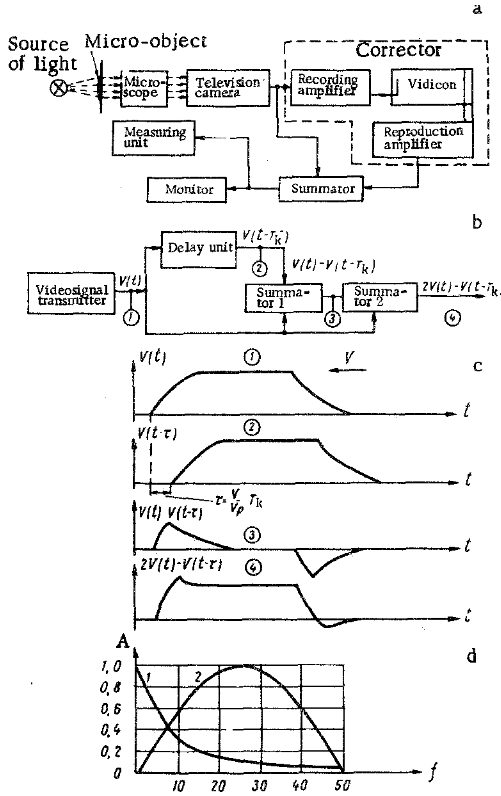

Fig. 1. Functional schemes of television angiomicrometer with two-dimensional corrector (a) and inertia corrector (b), voltage diagrams at control points (1)-(4) of the inertia corrector (c), and contrast-frequency characteristic of television system using vidicon (1) and amplitude-frequency characteristic of corrector (2) (d). Explanation in text.

two-dimensional correction of spatial frequencies contained in the picture to be carried out. The degree of defocusing of the vidicon beam by a change in the current of the focusing coil enables the frequency spectrum of the signal obtained from the corrector to be regulated (Fig. 1b). A detailed analysis of facilities of the corrector during transmission of stationary pictures has been given by Kazantsev [3] and Arp [6], and for that reason only the correction of moving details of the picture will be examined here.

The action of the corrector in the case of moving objects in the field of vision of the angiomicrometer is illustrated by the functional scheme (Fig. 1b) and diagrams (Fig. 1c). The videosignal from the transmitter reaches the delay unit and the two summators simultaneously. In the first summator the delayed signal is subtracted from the transmitter signal, and in the second summator the difference between the videosignals obtained at the output of the first summator is added to the transmitter signal. A signal which has an indistinct leading edge and "tail" at the input of the corrector will be corrected so that the leading edge becomes steeper and the "tail" is reduced. It follows from the above description of the action of the two-dimensional corrector that its vidicon performs the function of delay unit and first summator of correctors of the fronts of moving objects.

Let us now examine the problem of correction of inertia by this method analytically. According to the delay theorum, the spectrum of a function $U(t - T_k)$, depicting a signal $U(t)$ delayed by time (T_k) can be obtained by multiplying the spectrum $S(f)$ of signal $U(t)$ by $\exp(-j2\pi fT_k)$, i.e.,

$$S_{T_k}(f) = S(f) \exp(-j2\pi fT_k). \tag{1}$$

The transmission factor of the delay unit with the first summator has the form:

$$K(f)=\frac{S(f)-S_{T_k}(f)}{S(f)}=1-\exp(-j2\pi f T_k). \quad (2)$$

From equation (2), using the relationships $\exp(-j2\pi fT_k)=\cos 2\pi fT_k - j\sin 2\pi fT_k$ and $1-\cos 2\pi fT_k = 2\sin^2\pi fT_k$, it is easy to obtain the amplitude-frequency characteristic of the system under examination:

$$|K(f)|=2|\sin\pi f T_k|. \quad (3)$$

According to the broadcasting standard of resolution for vidicons $T_k=0.02$ sec [4]. The amplitude-frequency characteristic of the corrector for this case is illustrated in Fig. 1d, which also shows the temporary contrast-frequency characteristic of a television system incorporating a vidicon with effective integration time $\tau=0.05$ sec [7]. As Fig. 1d shows, the corrector has a certain maximum of the frequency characteristic curve at f = 25 Hz. Above 25 Hz the characteristic curve falls to reach a minimum at f = 50 Hz. Considering that the television system of broadcasting standard of resolution is intended for transmission of signals in this region of temporary frequencies, the corrector can be effectively used to reduce inertia of the videosignal transmitters.

The operation of the corrector was tested experimentally on microvessels of the frog depressor mandibulae muscle. Photomicrographs of part of the muscle containing a venule about 80 μ in diameter are illustrated in Fig. 2. The photographs were taken from the screen of the video control apparatus with (Fig. 2b) and without (Fig. 2a) the corrector. The negatives were analyzed by means of a microphotometer. This was done in order to evaluate the efficiency of operation of the two-dimensional corrector objectively when used in conjunction with a television angiomicrometer. The line of photometry is indicated by arrows. The results of photometry are given in Fig. 3.

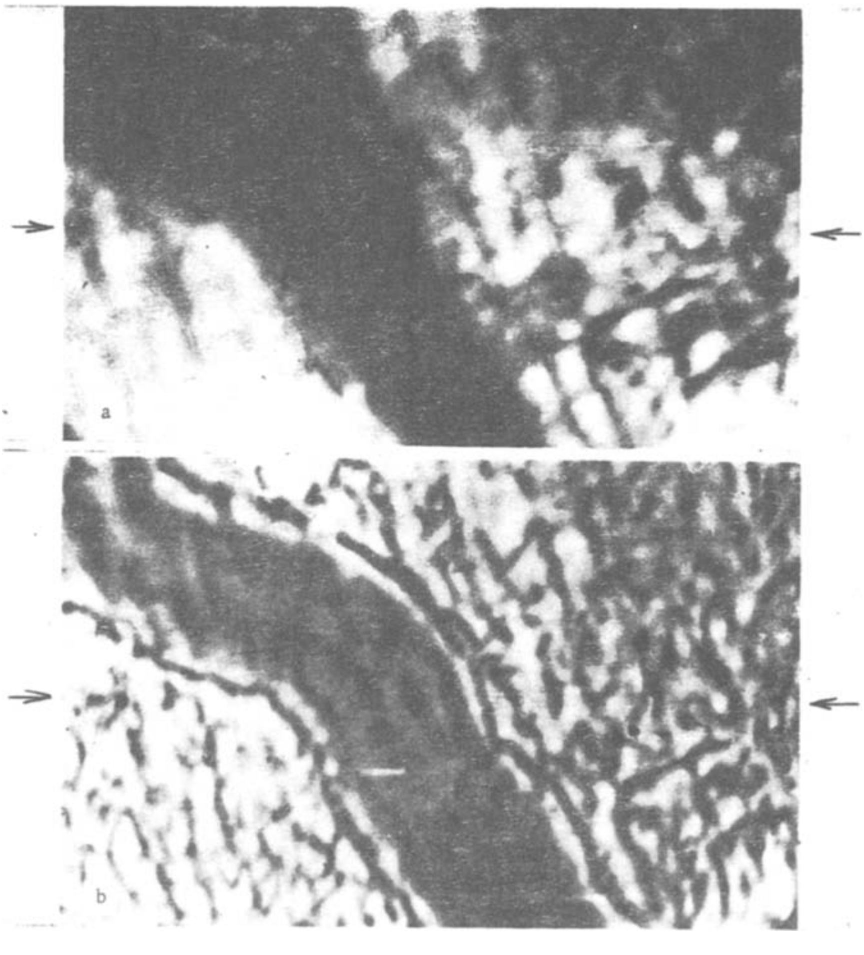

Fig. 2. Photomicrograph of part of the frog depressor mandibulae muscle containing a venule (diameter 80 μ): a) without correction, b) with correction.

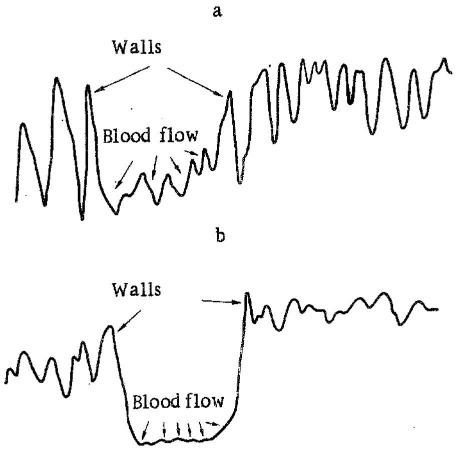

Fig. 3. Densitograms of television picture of frog depressor mandibulae muscle: a) with correction, b) without correction.

It will be clear from Fig. 3 that if the aperture corrector is not working the picture of the blood flow was virtually completely obscured, whereas when the corrector was functioning, individual erythrocytes could be distinguished visually. The part of the curve (Fig. 3b) reflecting the distribution of brightness in the picture of the blood flow, obtained without the corrector, contained hardly any information of the structure of the blood flow. However, this same part of the curve, with the corrector in operation, reflects details in the picture of the blood flow. Consequently, the use of correction considerably reduces inertia of the television transmitter and the structure of the blood flow can be observed visually. Furthermore, the picture of the walls of the microvessels becomes more clearly distinguishable and sharper, as is clear if the pictures of the walls of the venule are compared. The falls in brightness corresponding to the walls of the microvessel were more than doubled by introduction of the two-dimensional corrector (Fig. 3).

Experimental testing of the two-dimensional corrector thus showed that, if used in conjunction with a television angiomicrometer, it increases contrast of the walls in the picture of the microvessels by more than twice and enables the structure of the blood flow to be detected. By increasing the accuracy of measurement of the parameters of microvessels, the use of this device thus enables various problems in practical and experimental medicine to be solved.

LITERATURE CITED

1. S. V. Denbnovetskii and G. F. Semenov, Cathode-Ray Storage Tubes in Information Processing Systems [in Russian], Moscow (1973).
2. O. B. Lur'e et al., Tekh. Kino Telev., No. 9, 47 (1965).
3. G. D. Kazantsev, "Investigation of a two-dimensional filter of higher spatial frequencies incorporating a vidicon," Candidate's Dissertation, Tomsk (1968).
4. Ya. A. Ryftin, The Television System. Theory [in Russian], Moscow (1967).
5. A. M. Chernukh, P. N. Aleksandrov, and O. V. Alekseev, The Microcirculation [in Russian], Moscow (1975).
6. F. Arp. Arch. Elekt. Übertrag., 20, 205 (1966).
7. H. Dümmling, Siemens Forsch. Entwickl.-Ber., 1, 71 (1972).
8. C. A. Widerheilm, J. Appl. Physiol., 18, 1041 (1963).