DEVICES FOR REDUCTION OF CCD DISTORTION UNDER SCAN MODE OBSERVATIONS

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ABSTRACT. Practical experience on application of CCD detectors in a precise astrometry has shown, that one from the essential factors affecting a positional accuracy of an observation of stars in a scanning mode, especially for high declinations, is so-called CCD distorsion caused by the lack of co-incidence of projections of small circles of the celestial orbits on a plane of CCD with straight-line trajectories of moving charges. On the base of performed theoretical analysis of CCD distortion the authors have offered the devices essentially decreasing influence of CCD distortion on a positional accuracy of star observations in the scanning mode.

1. INTRODUCTION

The deterioration of positional accuracy of CCD scan mode observations at increase of declinations because of smearing of the star images owing to CCD - distortion is the well-known fact (Stone et al. 1996). The purpose of the given work consists in search of effective instrumental methods of reduction of influence CCD - distortion on positional accuracy of observations in scan mode.

2. CCD DISTORTION ANALYSIS AND DEVICES FOR REDUCTION OF CCD DISTORTION UNDER SCAN MODE OBSERVATIONS

Theoretical analysis of expressions for estimation of the smearing of the star image in both coordinates because of the CCD distortion taking place under scane mode observations with the MAC (Meridian Axial Circle) shows, that: a) the distortions of the star image in declination and right ascension have different character; b) with accuracy up to the second order terms concerning such small values as an hour angle $t_\circ$ of a star at the moment of a beginning of its electronic tracking, the difference of declinations $\Delta\delta$ of an observable star and projection of

the CCD centre on the celestial sphere and a time interval of scanning ΔT of a star, the size of the smearing in declination does not depend on size $\Delta\delta$ and has parabolic dependence on duration ΔT, that produces asymmetrical distribution of brightness in the image of a star in appropriate coordinate; c) with the above-stated accuracy the size of the smearing in a right ascension is proportional to the electronic scan duration ΔT and to the parameter $\Delta\delta$, but symmetric distribution of brightness in the star image in appropriate coordinate is remained; d) the errors of definition both declination and right ascension increase with the increasing of declinations and are especially great for the nearpole zone. From stated the obvious "tactical" instrumental improvement of the MAC suggests itself, which will supply essential reduction of the scan smearing. The essence of such improvement is that in front of the light-sensitive field of the CCD - matrix in parallel to it the rectangular diaphragm with variable width is established. Width and height of the diaphragm are accordingly guided lengthways and across with respect to the direction of charge transfer in a plane of the CCD-matrix. Width of the diaphragm is adjusted according to the formula: $\Delta l = lcos\delta_\circ$, where Δl is width of the diaphragm, l is width of the light-sensitive field of the CCD - matrix, $\delta_\circ$ - declination of a point in the sky in a plane of a meridian, to which sighting axis of the MAC is directed. In this case the smearing of the star image in declination reaches the maximal value at declination 45° and is equal to zero both for the equator and for the celestial pole, and in right ascension it reaches maximal, but not infinite value at the pole. It is necessary also to emphasize, that the offered design of a meridian telescope provides an opportunity to carry out scan mode observations independently on declination of observable stars down to the celestial pole.

On the base of performed theoretical analysis of the CCD distortion taking place under scan mode observations it follows as well that it is the uniform total smearing of the images of all objects along the circles. The centres of these circles coincide with the beginning of the CCD-matrix coordinate system. This total smearing is characterized by angular velocity, which in one's turn depends on the angular velocity of daily rotation of the Earth and on declination $\delta_\circ$. Basing on this conclusion, the authors offer to supply the meridian telescope with an additional optical element - the Dove prism, which should be mounted in an optical path of the tool in parallel beams and completely block its aperture. The distinctive features of the offered meridian telescope consist in the following. Two collimation objectives and Dove prism are entered into its optical tract. The Dove prism is established with an opportunity of rotation around of an optical axis of a telescope in the bearings, rigidly attached to a pipe, and has the appropriate drive, connected with the personal computer. The angular velocity of rotation of the Dove prism is adjusted according to the formula: $\omega = (1/4)Sin\delta_\circ \times k[rad/sec]$, where k $= 2\pi/(2 \times 24 \times 3600)$ is a constant factor. Its numerical value is small. Use of the Dove prism in a design of the MAC allows essentially to reduce the smearing of the star images in a plane of a CCD-matrix during scan mode observation, namely, to reduce the smearing in declination up to values about 3-rd order terms concerning instrumental parameters $t_\circ$, $\Delta\delta$ and ΔT, and to reduce twice the smearing in right ascension. Accordingly at the expense of instrumental reduction of CCD - distortion offered transit telescope allows essentially raising an accuracy of determination of star coordinates. It is necessary to note, that offered by the authors the improvements of a design of the MAC, namely auxiliary assembly with the Dove prism or assembly of the diaphragm with adjustable width, can be successful applied in a design of anyone meridian telescope, on which the scan mode observations are carried out. The authors have received the patents of Ukraine for the inventions concerning technical improvements, considered in this paper.

3. REFERENCES

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