The Use of the Ratan-600 Radio Telescope in Astrometry

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The RATAN-600 radio telescope (Kaidanovsky & al. 1972) was designed for solving various problems of astrophysics and radiophysics (Pariisky & al. 1972, Gelfreikh & al. 1972). Because of its high resolving power and large collecting area, this instrument can be used to measure accurate positions of radio sources.

The feed beam of the RATAN-600 extends vertically. This geometrical feature of the receiver determines the main principle of coordinate measurements, which is the recording of the transit time of a radio source across a selected vertical. In the meridian, this radio telescope works as a transit instrument and may be used for right ascension determinations. From combining observations of vertical transits at different azimuths, both declinations and the right ascensions may be determined simultaneously. In this case, the most accurate observations are those made at azimuths symmetrically with respect to the meridian (Pariisky & al. 1972, Fomin and Afanasieva 1980, L'vov 1980).

For the absolute determinations of coordinates, classical astrometry requires that the orientation parameters of the instrument and the local latitude are also independently computed from the observations. Different sectors of the antenna are used when determining positions of radio sources with the RATAN-600. Even with observations it is not possible to ensure the constant orientation of the electrical axis of the system, because the effective aperature of the antenna varies depending on the zenith distances of the radio source observed. For this reason, it is preferable to observe positions differentially with the RATAN-600.

The precision of the differential positional observations at wavelength 2.08 cm at the azimuths $\pm 60^\circ$ may at this time correspond to standard errors of $0\farcs3$ to $0\farcs6$ in declination and $0\farcs5$ in the right ascension for declinations between $+44^\circ$ and -10°. Further south, down to declinations of about -25°, observations at $\pm 30^\circ$ azimuths will result in standard errors of a single declination determination of about 1" (Fomin and Afanasieva 1980). In general, near the equator, the error of declination determinations exceeds that of right ascension by 20% to 40%. Towards the zenith, declinations may be more precisely determined than right ascensions. For example, for a reference source of $+30^\circ$ declination and with a target source between $+24^\circ$ to $+36^\circ$ declination we have, for observations in the

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prime vertical,

$$\sigma_{\Delta\delta} = 0.6\ \sigma_{\Delta\alpha},$$

where $\sigma_{\Delta\alpha}$ and $\alpha_{\Delta\delta}$ are the errors in right ascension and declination, respectively.

In the first approximation, normal refraction has no influence on the accuracy of the position determinatons with the RATAN-600. Moreover, these determinations do not require the use of any angular measuring devices. Therefore, errors originating in, e.g., as division errors, flexure, etc. are eliminated. In this connection the positions observed using the RATAN-600 radio telescope are of special interest for classical astrometry.

The following two astrometric projects are carried out with the RATAN-600:

1) differential position determinations of solar system objects
2) differential position determinations of a large number of faint radio sources

The observations of the inferior planets are those most emphasized among the investigations in the first group. The nearness of these objects to the Sun makes it difficult to determine their positions optically. VLBI, very precise for point sources is inapplicable for a such extended sources as Mercury and Venus. With the RATAN-600, one can achieve a practically uniform distribution of observations of Mercury and Venus on their own orbits, and that of the Earth. The long series of astrometric observations with the RATAN-600, whose precision is comparable to that of optical ones, will contribute significantly to establishing a more accurate theory of the motion of these planets and to the foundation of the dynamical basis of the celestial coordinate system, obtained from the VLBI observations of radio sources.

The first position observations of the inferior planets with the RATAN-600 (Afanasieva & al. 1979) showed that the right ascensions of Mercury relative to the reference sources may be determined with a standard error of about 1" over the ecliptical zone. It was found that Mercury may be observed in the microwave region (λ = 2.08 cm and λ = 3.9 cm) at any point of its orbit.

The investigations of the second project are carried out within the framework of the program in connection with the study of the residual radio emission. In the course of this program, a deep sky survey was carried out in 1980 for the region $4°50' \leq \delta \leq 5°20'$. The observations were performed at λ = 7.7 cm with a resolution of about 1' (Berlin and Pisma 1983). As a result, 38 radio sources were detcted in the region $13^h \leq \alpha \leq 14^h$, $4°50' \leq \delta < 5°20'$. The positions of the faintest sources (flux density about 10 mJy) were determined with standard errors of about 30" in declination and 8" in right ascension, sufficient to identify these objects with the deep sky images.

Among the astrometric investigations carried out by RATAN-600, one should also note the experiment connected with the determination of the selenographic coordinates of the ALSEPs installed on the Moon's surface by American astronauts

(Naugolnoya &. al., 1981). The precision of such determinations corresponds to standard errors of about 1".

For observing faint radio sources, a special "slipping" method may be used: The feed horn moves along the focal line with a speed near that of the radio source image. This results in a significant increase in the signal to noise ratio. A preliminary reduction of the experimental observations of Mercury yielded positive results.

The capabilities of the RATAN-600 as an astrometric device are not yet exhausted. To increase the precision of the position determinations of Mercury and Venus it will be necessary to use a shorter wavelength (λ 1cm) and more sensitive receivers, to find the effects of horizontal refraction and the phase effects on the observations and to develop methods for taking these factors into account. Under these conditions, we might achieve an error of about $0\rlap{.}''1$ for the differential position determinations in both coordinates (Pariisky & al. 1972) with the RATAN-600.

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