New Antenna Measurement Technologies Used to RATAN-600 Radio Telescope

V.B.Khaikin[1] , N.N.Bursov[1], D. G.Vikoruk[2], M.Y.Druzinin[2], S.V.Yakovlev[2], V.V.Yakunin[2] , A.V.Kornev[3]

[1]The Special Astrophysical Observatory of Russian Academy of Sciences, St.Petersburg branch, Pulkovskoe shosse 65, St.Petersburg, e-mail:vkhstu@mail.ru

[2]Neva Technology, St. Petersburg, Marinesco st, 6, lit. A, e-mail : sergey.yakovlev@nevatec.ru

[3]JSC "SSTC", St.Petersburg, Promyshlennaya 7, e-mail: zgtluk@rambler.ru

Abstract—**New antenna measurement technologies were investigated at RATAN-600 radio telescope. Their use can improve the antenna efficiency of a radio telescope in an operating mode. Antenna measurements and adjustment were done on a geostationary satellite Turksat 2A/3A at 42°. New fast laser geodesic devices INDOOR GPS and SURPHAZER were tested at RATAN-600 using API TRACKER-3 with an interferometer as a reference tool. Results of tests and antenna measurements are presented.**

***Index Terms*— radio telescope; antenna measurements; adjustment; geostationary satellite; laser geodesy; surface topography;**

I. INTRODUCTION

RATAN-600 is a huge reflector antenna consisting of about 1000 antenna elements currently working up to wavelength of 8 MM. As Far region of the radio telescope at 8 MM wavelength starts from 40000 km distance traditional antenna measurement methods on a remote oscillator can not be properly used. A variable antenna profile allows us to use an Autocollimation method for antenna measurements and adjustment of a main reflector with a ground noise source in the autocollimation focus. In an operating mode a lot of kinematic errors must be taken into account which can not be easily found or updated. Strong cosmic sources do not provide us with high enough S/N ratio to accurately measure a beam pattern with sidelobes in a short CM band not to mention the adjustment that requires their long time tracking. Several attempts were done before to use a signal of geostationary satellites for RATAN-600 adjustment [1,2] but unstable position of a satellite in its orbit considerably complicated antenna measurements and application of their results.

Another important task is to support a reflecting surface of antenna elements and secondary mirrors of a short wave radio telescope at high enough accuracy level that requiring the use of new fast laser geodesic methods which are considered bellow.

II. ANTENNA MEASUREMENTS ON GEOSTATIONARY SATELLITE SIGNAL

Recently we successfully used the geostationary satellite TURKSAT 2A/3A at 36000 km orbit for an adjustment of North sector of RATAN-600. TURKSAT 2A/3A at 42° has elevation about 40 degrees at RATAN-600 and it is located near meridian at our longitude. RATAN-600 elements were successively set in satellite direction to find a signal maximum and correct their coordinates using the suggested automatic algorithm with one reference antenna element and one under test. The adjustment of one antenna element on three coordinates relative to the reference element takes a few minutes. Significant improving the amplitude (more than 30%) and shape of the beam pattern at 2.7 cm was achieved after the adjustment. TURKSAT 2A/3A working in a band of 11.7-12.7 GHz has high enough signal and position stability and gives us a very high S/N ratio. Accuracy of

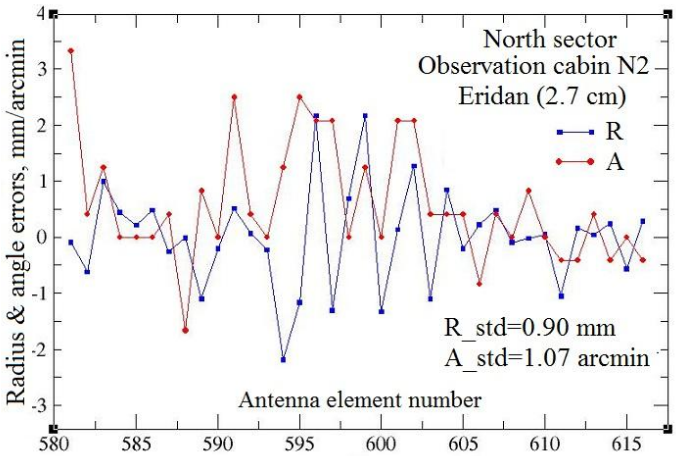

Figure 1. An example of measured kinematic errors on the satellite

antenna measurements was 0.2 mm (RMS) but a future launch of TURKSAT 3A/4A in 20 GHz band should improve measurement accuracy up to 0.1 mm (RMS). Antenna measurements on the satellite signal showed radial kinematic errors in position of antenna elements in an operating mode up to 2 mm while RMS positional error after an Autocollimation adjustment does not exceed 0.2 мм. An example of radial/angle kinematic errors measured on the satellite is shown in Fig.1, radius/angle RMS error is 0.9 mm/1.07 arcmin.

Our measurements have demonstrated a significant progress in achieving antenna accuracy of RATAN-600 main mirror in an operating mode and a real need to use new fast geodesic methods to measure all kinematic errors and take them into account. By this way we can expect a factor 2-3 in the antenna efficiency of the radio telescope in 1 cm - 8 mm band at the satellite altitude if RMS surface error of the antenna elements is maintained at 0.2-0.3 mm.

III. New Fast Laser Devices

Recently we have experienced a new fast geodesic devices SURPHAZER and INDOOR GPS using API TRACKER-3 with an interferometer as a reference device.

A. Application of SURPHAZER at RATAN-600

In October 2012 we scanned one of RATAN-600 secondary mirrors (6x8 m size) in order to determine the accuracy of scanning and time-consuming in real conditions of a large short wave radio telescope.

As a scanning device used SURPHAZER, the laser scanner of the latest generation, allowing to obtain three-dimension coordinates of points with rate 1 million points in one second through each millimeter of a surface at distances up to 10 meters and more in a non-contact mode. The laser scanner SURPHAZER measures the distance to the surface points on the phase difference between the emitted and reflected signal, encoders detect vertical and horizontal angles of the instrument at the time of the radiation pulse. Then the distance and angles of a measured point are converted into X, Y, Z coordinates. Expected RMS measurement accuracy of the device is 0.2-0.3 mm depending on measurement conditions.

Directly, ahead of the beginning of scanning with SURPHAZER, reference scanning was made by a laser tracker API Tracker-3 in a contact mode with a margin error measurements 0,01 - 0,03 mm in these conditions. These measurements gave us RMS surface error of the secondary mirror of 0,3 mm. The same RMS error for the surface was obtained with a laser radar MV-200 by JSC “BUM TECHNO” a few years ago.

By results of scanning with SURPHAZER RMS surface error 0,33 mm was obtained on the same points as with a tracker. Our estimate of own RMS accuracy of the device under test is 0.16 mm which is better than expected. The cartogram of surface deviations coincides with the result of reference scanning. Fig.1. shows an example of scanning the secondary mirror number 1 with SURPHAZER. Surface topography of the secondary mirror number 1 after processing the results of scanning with the optimum shape of the reflecting surface is shown in Fig.2-3, the histogram of night and day surface errors is given in Fig.4. It can be seen that some panels of the secondary mirror have deviations of the optimal form but generally they are well adjusted to each other. Operation of the device during a day allows us to study the thermal deformations of the secondary mirror when sunlight falls on the back structure and associated large-scale variations in the distribution of the amplitude and phase of the field in the main mirror aperture.

The time spent for scanning of the secondary mirror is about 20 minutes, including time necessary for device installation in the operating position. The obtained results demonstrate a real possibility to carry out a quick topography monitoring of large precise focusing surfaces at a short wave radio telescope with the SURPHAZER. One of

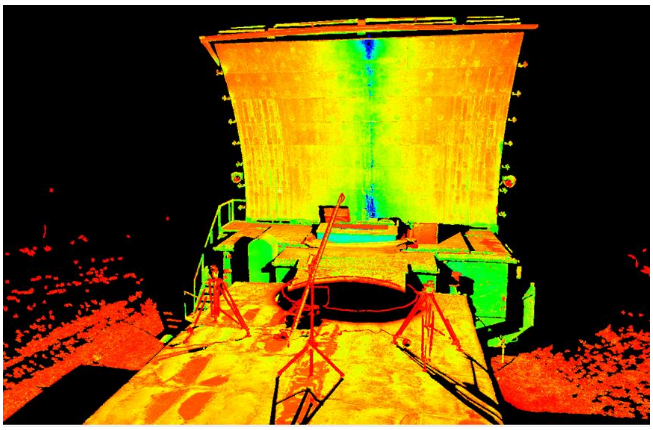

Figure 1. An example of scanning the secondary mirror number 1 with SURPHAZER.

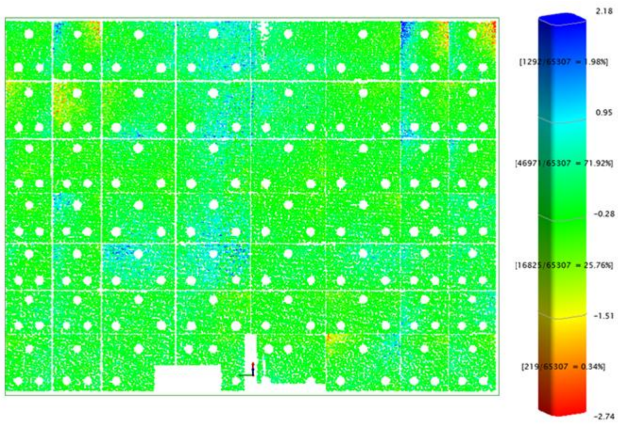

Figure 2. Surface topography of the secondary mirror number 1 in the evening

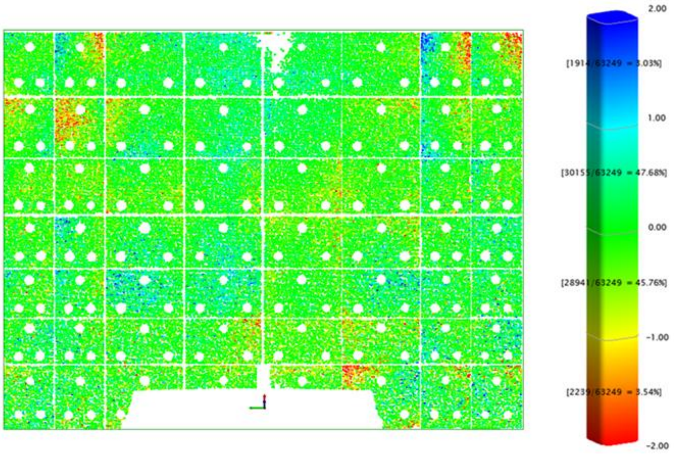

Figure 3. Surface topography o of the secondary mirror number 1 in the day time

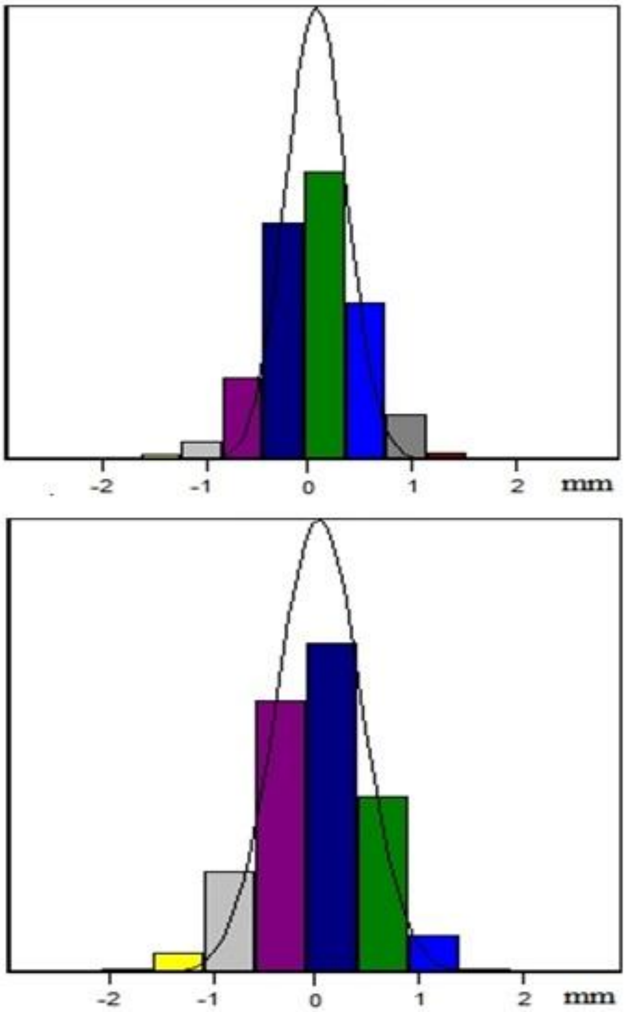

Figure 4. The histogram of night and day surface errors

Figure 5. A transmitter of IndoorGPS

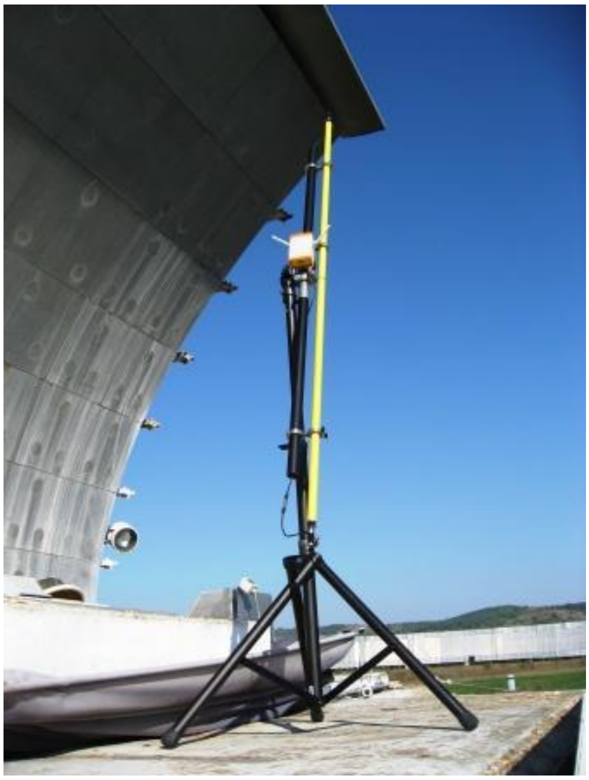

Figure 6. The two-meter calibrating rod of INDOOR GPS

Figure 7. The secondary mirror number 1 during tests of new devices

the most promising applications of the device on the RATAN-600 - control of surface topography errors of antenna elements and their subsequent correction by means of 286 adjustment screws on the surface of an antenna element. In the past, a similar process took a day by a contact method in suitable weather conditions and is performed only rarely [3].

B. Application of INDOOR GPS (I-SPACE) at RATAN-600

The similar experiment on scanning of the same secondary mirror was carried out with the help of a contact system INDOOR GPS (or I-SPACE). Infrared laser transmitters (at least 2) are fixed on a tripod in the space around the object being measured. One transmitter of INDOOR GPS is presented in Fig.4, two tripods with transmitters are seen in Fig.1, others - in Fig 6. Transmitter rotation around the vertical axis of the tripod with rate 40 Hz forms on the surface being measured two moving intersecting planes. Sensors receiving signals from transmitters are installed in surface measuring points. The program then uses the arrival time of the infrared pulses to calculate highly accurate infrared sensor coordinates X, Y, Z. Expected RMS measurement accuracy of the device is 0.1-0.3 mm depending on measurement conditions. Measured RMS surface accuracy of the secondary mirror by this method is 0,36 mm on the same points as with a tracker. Our estimate of own measurement RMS accuracy of the device under test is 0.23 mm which is close to the expected. The cartogram of distribution of deviations coincides with the result obtained by the reference scanning. Test measurement of length of the two-meter calibrating rod (Fig.5) placed in the area of the secondary mirror showed a difference between the reference and measured length of the rod of 0,07 mm.

Scanning of the secondary mirror with INDOOR GPS took about one hour. However INDOOR GPS can measure coordinates of tens points at the same time with rate 40 Hz. This allows us to use INDOOR GPS for determination of kinematic errors of RATAN-600 antenna elements in a dynamic mode.

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