Modernization of the Subreflector Surface of the RT-32 Radio Telescopes

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Abstract In order to improve the accuracy of VLBI observations in the high-frequency bands, the subreflector surface of the Quasar network RT-32 radio telescopes was upgraded. This paper presents a description of the design, installation, and alignment of new panels. This project was implemented in 2020–2021.

Keywords Radio telescopes, subreflector, photogrammetry

1 Introduction

The reflective antenna system of the RT-32 radio telescopes consists of:

- a main quasi-parabolic mirror (diameter of 32 m, focal distance of 11.4 m) and
- a secondary mirror (subreflector). It has the form of a modified hyperboloid with one plane of symmetry and is not an axisymmetric body.

The subreflector surface is composed of nine panels: eight petals and one central panel. The central panel of the old design was molded out of an aluminum sheet and was attached to the other eight panels. Adjustments of the central panel were not possible. The RMS of the old central panel is about 1 mm, and the entire subreflector RMS is 0.73 mm. In 2013, the central panels on all three subreflectors were replaced with new ones made out of solid aluminum. The new panels were produced by milling and were attached with their own fasteners, which allowed them to be adjusted. As a result, the RMS of the new central panels was approximately 0.13 mm, and for the entire subreflector it became 0.62 mm approximately.

To improve the RMS of the subreflector surface further, it was decided to replace the eight petal panels with more accurate ones. This work was carried out in 2020.

2 The Design of New Panels and its Advantages

The old panels were molded out of an aluminum sheet (2 mm thickness) and fixed to the primary frames with rivets. The primary frame of the panel was made of rivets and interconnected U-shaped aluminum channels. The thickness of the entire panel is 200 mm. The panels are fastened to the subreflector's spatial truss frame with firmly fixed pins. This type of fastening allows adjusting of the position of the panels vertically only. The primary structure of the subreflector is the same as it was, so, the position and number of attachment points remains the same. The panel scheme is also preserved. The new panel consists of several molded aluminum sheets fixed to a primary frame. The primary frame is made of aluminum angle bars with cutouts. A polyurethane sealant is used to connect the primary frame of the panel to the reflective surface sheet. This design of the frame and its attachment allows the shape of the reflective sheet to be completely repeated and avoids stresses in it. The total thickness of each panel is about 100 mm. It is not possible to mount this type of panel on old studs. The fastening height of the old panels is 30–40 mm from the base, and the fastening height of the new ones is 140–150 mm. The increased

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Fig. 1 The old panel and its fasteners.

distance could increase the loads on the studs and lead to the displacement of the panels due to gravity or other factors (wind, snow). Therefore, a new type of fastener was developed. It provides a wide range of panel adjustment and firm fastening. Panels are fixed with an M10 threaded stud (Figure 2, right drawing, position 2) to the bracket (position 4), which is welded to the platform on the spatial truss frame (position 6). Elongated holes for fastening are made in the brackets and panels. They are perpendicular to each other, which allows panels to move in two planes. Adjustment in the third plane (height) is carried out along the threaded stud. The primary structures of the panel and the bracket are not strictly parallel. To compensate for this factor, on the side of the bracket, the stud is fastened with spherical washers. The design of the panel structure and fasteners was carried out jointly with Vertex Antennentechnik GmbH.

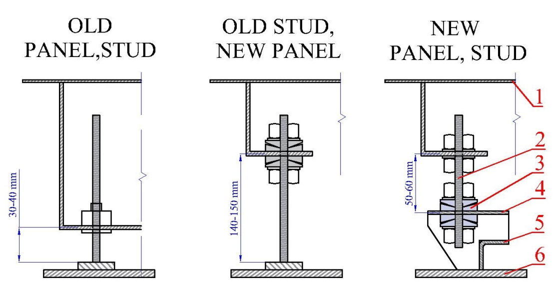

Fig. 2 Panel fixing scheme: 1–panel's surface, 2-–M10 threaded stud, 3—spherical washers, 4—bracket, 5—adapter, 6—platform on the subreflector truss.

3 Installation of New Panels

In parallel with the development of panels, the installation plan was developed. The dismantling of the entire subreflector assembly was not an option, because that could have led to the strong imbalance of the antenna reflective system. Load from an imbalanced antenna reflective system is transmitted through the elevation drives and the oscillating platform and is able to damage the azimuth bearing. In addition, the process of dismantling the entire subreflector assembly is very laborious and dangerous. As a result, it was decided to replace the panels one by one in the antenna elevation position of 90°. To do this, it was necessary to erect scaffolding around the over-mirror cabin. Scaffolding is needed to provide a comfortable working space of the same area as the subreflector, roughly. Then the final calculation of the entire structure weight was made. The weights of the installation sites, equipment, and workers located on them were taken into account. The result is about two tons. This is much lower than the calculated snow load (about 45 tons). This design is suitable for mounting and has no significant impact on the supporting structures of the radio telescope.

The main load-bearing pillars were arranged in the shape of two octagons. The outer octagon rested on the service platform around the over-mirror cabin, and the inner one (rotated 22.5° relative to the outer one) rested on the edge of the upper platform of the over-mirror cabin. Both octagons were connected by a system of beams. The resulting spatial truss structure was ten meters high and five meters in diameter. All the compo-

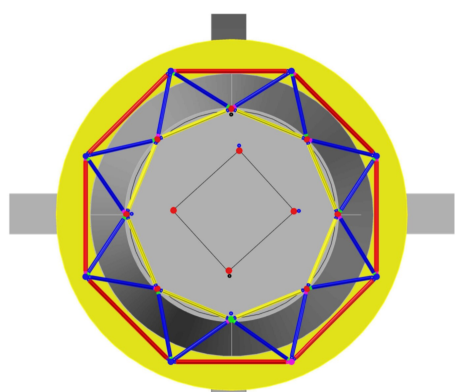

Fig. 3 Scaffolding scheme. Top view: red–outer octagon, yellow–inner octagon, blue-–beams.

nents of the scaffolding assembly were lifted through the hatches inside the over-mirror cabin by electric hoist. But the size of the hatches was insufficient to pass the subreflector panels through them. Hoisting the panels over the edge of the main reflective surface was also not possible. So, it was decided to remove two panels in the fourth row of the main reflective surface. An electric crane was installed above this place, and the panels of the subreflector were lifted through this opening. The replacing of the panels was carried out

Fig. 4 Scaffolding installation process.

step by step. The old panel was removed along with the old studs. Then, an adapter for a new bracket was pre-fixed to the sites. Studs and brackets were attached to the new panel, and after that it was installed in its place. Brackets with studs were installed in the pre-design positions and pre-fixed by welding. Then the panel was removed from the studs, and the final fixation of the adapters and brackets was made. Welds were cleaned and primed. Then, the new panel was returned to its

Fig. 5 Panel replacement process (one panel left to replace).

place, and it was preliminarily adjusted in relation to the neighboring panels. After that, the subreflector was rotated, and the procedure was repeated with the next panel. This method made it possible to install the panels quite accurately and quickly. At the same time, the original shape of the subreflector was preserved quite accurately.

4 Geodetic Control Procedures

Before installing the panels in place, it was necessary to make sure that they meet the characteristics specified in the design documentation and quality certificates. Input control measurements of the new panels were carried out in a closed thermostatic room. The measurements were made with high-precision geodetic equipment (AT-401 Leica absolute tracker) using the contact method. As a result, it was found that the RMS of the new panels' reflective surfaces lies between 0.21 and 0.23 mm, which satisfies the requirements of the technical specifications (to be no more than 0.25 mm).

Then, it was necessary to measure the geometry of the original subreflector surface to understand how the geometry of the reflective surface changed after the upgrade. The measurements were carried out with high-precision geodetic equipment (TDRA 6000 Leica tacheometer) using the step-by-step scanning method, which provides uniform coverage of the entire reflective surface with measuring points. This work was carried out at night when fluctuations in air temperature had not exceeded 2°C.

The successive replacement of the subreflector's panels allows formation of a new reflective surface which closely repeats the geometry of the original one.

For the final formation of the required geometry, the panels were adjusted. To do this, deviations of the actual form from the theoretical model were determined. Based on the obtained measurement results, recommendations were prepared for panel position corrections. After the panels were adjusted, the measurement of the reflective surface was again performed. If, according to the measurement results, the obtained surface shape did not correspond to the specified accuracy, then the cycle of the above steps was repeated. Thus, after three to five stages of adjustment, the best RMS value was achieved. During the next year after the completion of the panel replacement, control measurements were made by the photogrammetric method. The measurements were carried out with high-precision geodetic equipment (Aicon DPA Industrial coordinate mea-

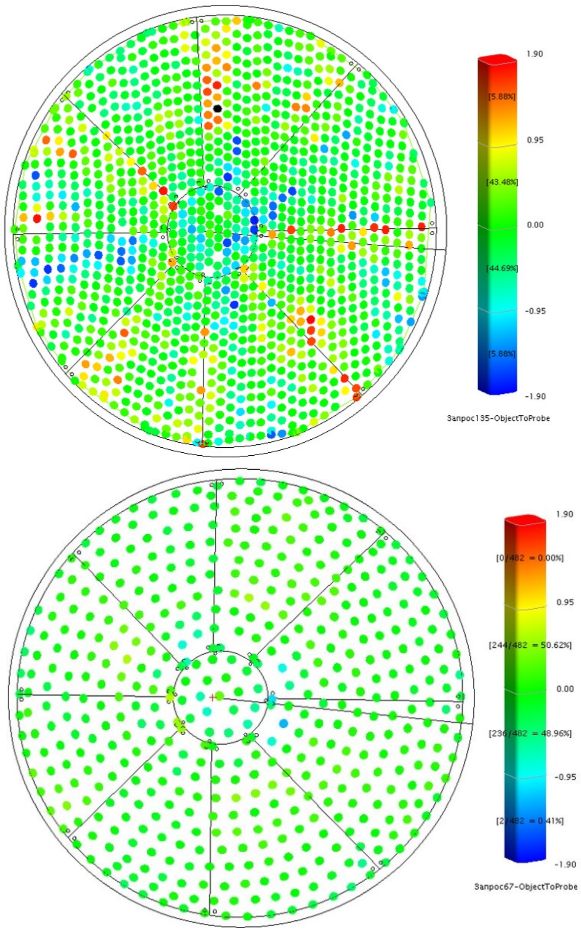

Fig. 6 Cartograms of deviations from the theoretical model before (top) and after (bottom) modernization on the example of a subreflector at the Badary observatory.

suring system). This method combines the advantages of the contact method (measurement accuracy) and the step-by-step scanning method (speed of obtaining the result).

As before, these works were carried out at night, when the fluctuations in air temperature did not exceed 2°C.

Table 1 RMS subreflector surface before and after modernization.

Observatory	Before 2	After 3	Improvement
Svetloe	0,61 mm	0,34 mm	1,79
Zelenchuk	0,63 mm	0,38 mm	1,66
Badary	0,61 mm	0,31 mm	1,97

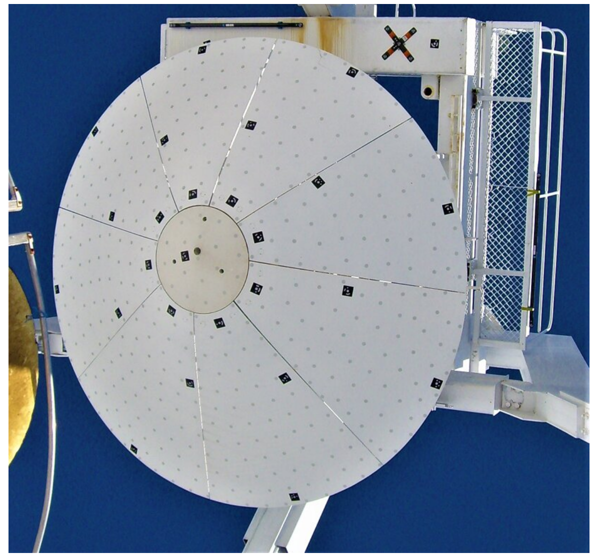

Fig. 7 New panels with photogrammetric marks.

5 Conclusions

As a result of the work carried out on its modernization, it was possible to almost double the geometric parameters of the RT-32 subreflector surface in all observatories of the IAA RAS. During the design and preparation of these works, complex engineering tasks were set and successfully solved. Among other things, with the development of more advanced geodetic control systems, it becomes possible to more accurately control the spatial position of the panels of the secondary and primary parts of the RT-32 reflective system.