THE SECOND STAGE OF SOLVING PRIORITY SCIENTIFIC PROBLEMS ON PRELIMINARY ADJUSTMENT OF THE RADIO-OPTICAL TELESCOPE ROT-54/2.6

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One of the primary tasks for the successful reboot of the ROT-54/2.6 radio-optical telescope is the alignment and adjustment of the antenna. The initial step in addressing this involves assessing the current state of the telescope's physical, mechanical, and radio engineering parameters. Once these parameters are accurately measured, they must be compared to the data from the ROT-54/2.6 specifications documented over 30 years ago when the telescope antenna was first constructed, to determine the scope of work required for alignment and adjustment. A clear action plan has been established to conduct this work. Currently, practical assessments of the antenna's condition cannot proceed, as the telescope has been transferred to the National Institute of Metrology under the Ministry of Economy of Republic of Armenia, with which certain disagreements remain unresolved. Before implementing the developed action plan, a comprehensive software package was created, enabling a range of measurements to be conducted in a virtual environment with simulated results. This software package includes an accurate three-dimensional model of the radio-optical telescope antenna, along with simulation programs incorporating components that generate random results within a specific range of measurement errors. Through the practical application of this measurement method, the software package will expedite the process of assessing the antenna's condition, allowing for a more precise evaluation of the required alignment and adjustment work.

Keywords: radio-optical telescope, ROT-54/2.6, antenna, alignment methods.

Introduction. The ROT-54/2.6 radio-optical telescope constructed between 1980 and 1987 by a team led by Academician Paris Heruni operated until 2012. Afterwards it was preserved and transferred to the National Institute of Metrology under the Ministry of Economy of Republic of Armenia. Over the years, the radio-telescope has facilitated numerous astronomical measurements, the reception of signals from distant radio sources, and several studies related to the antenna technology [1-4].

It should be noted that during the conservation period, changes in the antenna's physical, mechanical, and radio-technical parameters may have occurred due to various intrinsic and biogenic factors, necessitating precise documentation and as-

sessment. Specifically, one of the support brackets for the east-west axis of the antenna structure failed in 2015 and, instead of being researched and repaired, was simply welded to keep the axis stationary. Consequently, the small reflector of the telescope can only move by rotating around one axis.

The successful reboot of the radio-optical telescope will create opportunities for scientists in Armenia and around the world to study the universe, monitor space debris, ensure communication with distant space, and conduct many other scientific investigations [5].

To reboot the radio-optical telescope, it is necessary to carry out the alignment and adjustment of the antenna. The action plan aimed at accomplishing this work includes a sequence of several complementary steps. These steps include the creation of an accurate three-dimensional model, determination of the precise center of the antenna, and software simulation of the center determination [6].

To verify the precise geometric center of the radio-optical telescope antenna and the alignment of the rotation axis of the small reflector, two methods have been developed by Professor A. Sargsyan [5]. The first of the methods designed for determining the geometric center of the large reflector of the antenna, is presented in an article devoted to addressing the priority scientific tasks of the antenna's alignment [7].

This article is devoted to the technology of applying the second method aimed at determining the center of the sphere and its alignment, as well as the software simulation.

The problem statement and justification of the methodology. To achieve the greatest precision in actions and effective operation, it is advisable to divide the research conducted using the method into clear sequential steps:

- precise determination of the north-south and east-west axes;
- running a metallic invar wire with a diameter length of the circular rigger; marked every 20 *cm*, over the surface of the rigger, perpendicular to these axes;
- running perpendicular wires and measuring their lengths five times for each wire;
- comparing the obtained results with the calculated data.

The first step involves the accurate determination of the north direction with precision to seconds, which will allow to establish the directions for the antenna and position the north-south and east-west axes. For measurements taken during the day, the sole source of light used is the position of the Sun. In nighttime conditions, the position of the Polar Star is used for calculations. Formula (1) is applied for performing calculations based on the position of the Polar Star:

$$H_{pol} = \theta_{sid} - \alpha_{pol} \; ,$$ (1)

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where H_{pol} – star hour angle; θ_{sid} - sidereal time; α_{pol} – right ascension.

Formula (2) is used to calculate the sidereal time:

$$\theta_{sid} = \theta_0 + \frac{\lambda}{15^o} + \frac{T_{UTC}}{1.00273790935} , \tag{2}$$

where θ_0 - is the Greenwich Sidereal Time (GST) at 00:00 UTC; λ - is the longitude of the observation point in degrees; T_{UTC} - is the Universal Coordinated Time of the observation.

The azimuth of the North Star (Polaris) is determined using formula (3):

$$A_{pol} = tan^{-1}(\frac{\sin H_{pol}}{\cos H_{pol}*\sin\varphi - \tan\delta_{pol}*\cos\phi}) , \tag{3}$$

where ϕ - is the latitude of the observation point; δ_{pol} - is the declination of Polaris (89.3^o).
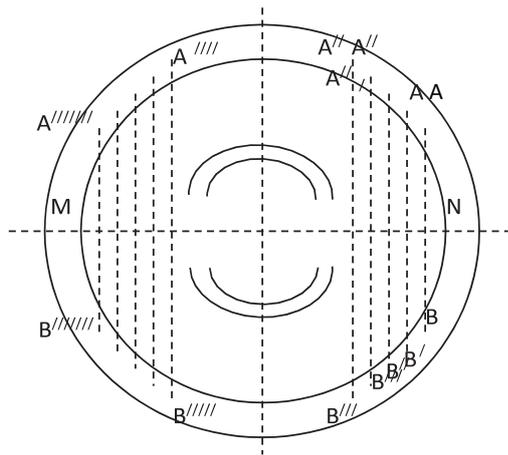

Fig   1   The measurement execution scheme

The precise determination of the geometric north-south axis is carried out after the determination of the north direction. The second step of the research involves running the invar wire along the surface of the circular rigger in the direction of the true north-south axis. The diameter of the wire should not exceed 3 *mm*. The diameter of the circular riggel is 6 *m*, and the installation of wire of the same length is possible thanks to a special opening in the central part of the metallic frame that holds the small reflector, in the north-south direction. In the east-west direction, this opening is absent; therefore, the installation of the wire in this direc-

tion will be carried out in two sections: the wire will be dropped from both sides of the riggel and secured to the metallic frame by wrapping it around one full turn.

When running the invar wire in the east-west direction, it is necessary to check the alignment of the wire with the axes twice, for both sides, since, as a result of passing it around the frame, the field of view is obstructed to the west. Consequently, when passing the wire from the west, it is essential to make the adjustment by observing from the frame toward the west, and on the other side, from the frame toward the east. Prior to running the wire along the axes, a special mark is made at every 0.2 *m* length of the wire. After aligning the wire along the north-south axis, another wire is installed perpendicularly every 20 *cm* along the length of the wire, connecting both sides of the rigel to determine the lengths of segments AB depicted in Fig. 1. The lengths are measured from each end of the rigel to the mark at a distance of 2 meters, taking into account the diameter of the metallic frame carrying the small reflector, data obtained from the passport of the ROT-54/2.6 compiled at the time of the construction of the radio-optical telescope [1]. To carry out the measurements with a theodolite, it is necessary to verify that the angle formed by the wire is exactly 90 degrees. After completing the measurements along the north-south axis, similar measurements are taken with the wire laid out in the east-west direction. Considering the presence of the metallic frame in the central part of the wire-laying path, the last mark on the wire used for measurement is accepted at a distance of 2 *m* from each end.

The results of the study. Measurements are conducted five times for each mark, after which the measurement results are compared with the calculated data, and the root mean square error of these measurements is calculated using formula (4):

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i + y_i^{\wedge})^2 \ ,$$ (4)

where y_i - the actual value; $y_i^{\wedge}$ - the ideal value; n - the number of measurements.

The calculated data presented in the Table are obtained using formula (5):

$$c = 2\sqrt{r^2 - (r - h)^2} \ ,$$ (5)

where c - the length of the chord; r - the radius of the circle; h - the height of segment.

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Table
Calculated chord length data

Height of segment (*m*)	Length of chord (*m*)
0.2 (5.8)	2.15
0.4 (5.6)	2.99
0.6 (5.4)	3.6
0,8 (5 2)	4.08
1 (5)	4.47
1 2 (4 8)	4.8
1.4 (4.6)	5.08
1 6 (4 4)	5.31
1 8 (4.2)	5.5
2 (4)	5.66

After comparing the measurement results with the calculated data and calculating the root mean square error, the next step is to compare the measurement results from the first stage of solving the alignment and adjustment tasks [6]. The simulation created in the first stage represented the determination of the precise geometric center of the large mirror sphere using the measuring base and the theodolite.
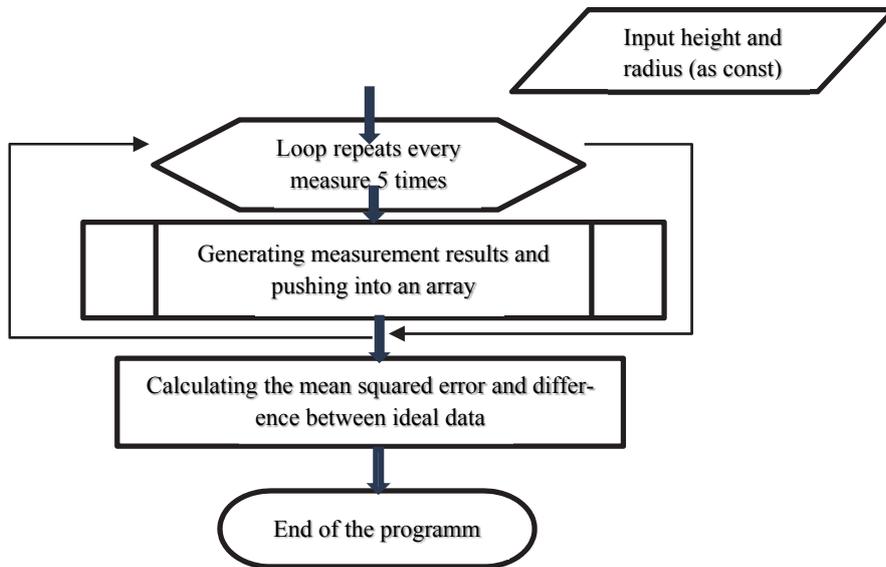
Fig 2   Flowchart of the programm

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The data obtained from the measurement simulation are compared with the simulation data from the second stage, specifically when the measuring base and the theodolite are located on the same side of the ring truss. Along with the angular dimensions of the measuring base, the lengths of the perpendicular wires of the ring truss are additionally calculated, which allows for refining the measurement results obtained by the method of determining the center of the sphere in the first stage [7].

Thus, the next part of the software for the preliminary alignment and adjustment of the ROT-54/2.6 antenna involves verifying the coincidence of the rotation center of the metallic frame carrying the small reflector with the actual geometric center of the large mirror sphere through the generation of simulation data. The computer program uses the Mersenne Twister MT19937 function [8] to generate pseudorandom data within a specified error margin. For the method mentioned in the article, the allowable error probability is set at ±0.125%. The simplified block diagram of the created simulation program is presented in Fig. 2.

Conclusion. The research conducted in this article helped create a more precise plan for the sequence of actions for carrying out measurements in practice. It assisted in predicting the probable errors in measurements. The magnitude of the errors can be input in the simulation as variables, allowing for more flexible calculations in case of any probable deviations. Considering the dependence of the measurement results on the initial data, and the fact that all data used in the software environment are introduced as variables, it becomes possible to improve the measurement methodology and automate the calculations of their results in a virtual environment, establishing a connection between several different measurement outcomes. This completes the assessment of the current state of the radio-optical telescope's antenna and the scope of work directed at its adjustment.

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ՌՕԴ-54/2. 6 ՌԱԴԻՈՕՊՏԻԿԱԿԱՆ ԴԻՏԱԿԻ ՆԱԽՆԱԿԱՆ ՀԱՄԱԼԱՐՄԱՆ ԱՌԱՋՆԱՀԵՐԹ ԽՆԴԻՐՆԵՐԻ ԼՈՒԾՄԱՆ ԵՐԿՐՈՐԴ ՓՈՒԼԸ

Ն.Հ. Համբարձումյան

ՌՕԴ-54/2. 6 ռադիոօպտիկական դիտակի հաջող վերագործարկմանն ուղղված առաջնային խնդիրներից են անտենայի համալարումը և կարգաբերումը: Այդ խնդրի լուծման առաջին քայլը ռադիոօպտիկական դիտակի ներկայիս վիճակի՝ դրա ֆիզիկական, մեխանիկական և ռադիոտեխնիկական պարամետրերի գնահատումն է: Նշված պարամետրերի ճշգրիտ արժեքների ստացումից հետո դրանք անհրաժեշտ է համեմատել ռադիոօպտիկական դիտակի անտենայի կառուցման պահին՝ ավելի քան 30 տարի առաջ, կազմված անձնագրի տվյալների հետ, գնահատելու համար համալարման ու կարգաբերման աշխատանքների ծավալը: Այդ աշխատանքի իրականացման համար մշակել է հստակ գործողությունների պլան: Ներկա դրությամբ անտենայի վիճակի գնահատման գործնական աշխատանքների կատարումն անհնար է, քանի որ ռադիոօպտիկական դիտակը հանձնված է ի պահ ՀՀ Էկոնոմիկայի նախարարության Չափագիտության ազգային ինստիտուտին, որի հետ առկա են մի շարք տարաձայնություններ: Մինչ մշակված գործողությունների պլանի իրագործումը՝ ստեղծվել է համալիր ծրագրային փաթեթ, որը հնարավորություն է տալիս վիրտուալ միջավայրում կատարել մի շարք չափումներ՝ դրանց արդյունքների սիմուլացմամբ: Ծրագրային փաթեթը ներառում է ռադիոօպտիկական դիտակի անտենայի ճշգրիտ եռաչափ մոդելի պատրաստում, իսկ չափումների սիմուլացման համար գրվել են սիմուլյացիոն համակարգչային ծրագրեր՝ չափումների սխալանքի որոշակի միջակայքով պատահական արդյունք գեներացնող կոմպոնենտներով: Չափման այս մեթոդի գործնական կիրառման դեպքում ծրագրային համալիր փաթեթը կարագացնի անտենայի վիճակի գնահատման գործընթացը՝ հնարավորություն տալով ավելի մեծ ճշգրտությամբ գնահատելու համալարմանը և կարգաբերմանն ուղղված աշխատանքների ծավալը:

Առանցքային բառեր. ռադիոօպտիկական դիտակ, ՌՕԴ-54/2 . 6, անտենա, համալարման մեթոդներ:

ВТОРОЙ ЭТАП РЕШЕНИЯ ПРИОРИТЕТНЫХ НАУЧНЫХ ЗАДАЧ ПРЕДВАРИТЕЛЬНОЙ ЮСТИРОВКИ РАДИООПТИЧЕСКОГО ТЕЛЕСКОПА РОТ-54/2.6

Н.А. Амбарцумян

Первостепенной задачей успешного перезапуска радиооптического телескопа РОТ-54/2.6 является юстировка и настройка антенны. Первым шагом в решении этой проблемы является оценка текущего состояния радиооптического телескопа, его физических, механических и радиотехнических параметров. После получения точных значений указанных параметров необходимо сравнить их с данными паспорта, составленного более 30 лет назад, в момент строительства антенны, чтобы оценить объем работ по юстировке и настройке. Для выполнения этой работы был разработан четкий план действий. На данный момент практическое выполнение оценочных работ состояния антенны невозможно, поскольку радиооптический телескоп передан на хранение Национальному институту метрологии Министерства экономики Республики Армения, с которым имеется ряд разногласий. В ожидании реализации разработанного плана действий был создан комплексный программный пакет, который позволяет в виртуальной среде выполнять ряд измерений с их симуляцией. Програм-мный пакет включает в себя подготовку точной трехмерной модели антенны радиооптического телескопа, а для симуляции измерений были написаны компьютерные программы, генерирующие случайные результаты с определенными диапазонами погрешностей измерений. При практическом применении этого метода измерений программный комплекс ускорит процесс оценки состояния антенны, предоставляя возможность более точно оценить объем работ, направленных на юстировку и настройку.

Ключевые слова: радиооптический телескоп, РОТ-54/2.6, антенна, методы юстировки.