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DESIGN OF A THREE-DIMENSIONAL MODEL OF THE ROT-54/2.6 RADIO-OPTICAL TELESCOPE

To define and verify the geometric and radio technical parameters of the ROT-54/2.6 radio-optical telescope antenna, currently, in a preserved state, within a virtual environment, and to virtualize various additional technical tests, a decision has been made to design an accurate three-dimensional model of the antenna using the SOLID WORKS software. This software application enables the calculation of antenna parameters based on input data. Consequently, estimating the work required to revitalize this antenna becomes straightforward, and similar calculations can be performed for other comparable antennas in a virtual environment. This article details the research focused on creating a three-dimensional model of the ROT-54/2.6 radio-optical telescope antenna and the preparation process informed by the research findings. The study has utilized data from the antenna's technical passport recorded during its construction, and actual measurements of several geometric parameters of the preserved antenna structure conducted between 2019 and 2021. The three-dimensional modeling process was executed in the SOLID WORKS software, typically employed for creating mechanical models.

Keywords: antenna, radio-optical telescope, ROT-54/2.6, SOLID WORKS, three-dimensional model.

Introduction. The ROT-54/2.6 radio-optical telescope constructed between 1980 and 1987 (Fig. 1), boasts the world's largest double-reflector spherical antenna. This remarkable instrument has been pivotal in researching this unique type of antenna. Over the years, it has demonstrated its versatility by exploring space, and for future it can be used for facilitating deep space communications and monitoring space debris.

The ROT-54/2.6 antenna's precision allows it to operate at extremely short wavelengths, down to 1 *mm*. Its primary advantages include the highest accuracy of mirror surfaces (50 microns), high gain at the shortest wavelength (approximately 70 *dB* for 1 *mm*), and an exceptionally low level of self-noise (2.7 *K*), indicating its high sensitivity. The antenna's unique optical design prevents diffraction rays from the edges of the reflectors from reaching the focus point, effectively shielding it from the surrounding high temperatures (around 300 *K*). Consequently, the antenna maintains a very low level of self-noise [1-4].

Since 2012, the ROT-54/2.6 radio-optical telescope has remained in a preserved state primarily due to financial constraints. Being in a canned state for a long time has probably led to a deviation of some antenna parameters [5].

To calculate and refine the ideal physical, geometric, and radio technical parameters, it is essential to have access to the ROT-54/2.6 radio-optical telescope's technical passport, which details its complete specifications at the time of construction [6,7]. Additionally, to estimate the scope of work for its configuration, a three-dimensional model of the antenna must be created. This model will allow for virtual measurements and parameter adjustments, effectively simulating the assembly work before its actual implementation and serving as a guiding tool throughout the process. Besides the three-dimensional model, a software is currently being created using the C++ programming language. This software will allow users to provide starting information—which includes geometric and radio engineering aspects—and carry out automated calculations concerning the antenna by applying the known formulas.

Despite the antenna being in a preserved state, experiments were conducted to demonstrate its operability in this condition. These experiments highlighted the need to de-conserve the antenna for use in various space research activities. In particular, recordings of the sky signal around the time of the passage of the Cygnus region were conducted. The first recording was made, and the second one followed 13 days later. Without any direct source identification, this data should allow us to detect the time shift of the pattern between the two dates. Remarkable structures, probably originating from astronomical sources, appear time-shifted between the two epochs of recording.

Problem statement and justification of the methodology. It is evident that the ROT-54/2.6 antenna requires repairs, including lubrication and inspection of its portable mechanisms. It also needs to be equipped with modern digital control systems, restoration of certain services, and comprehensive adjustments. There is a project aimed at revitalizing the ROT-54/2.6, transforming it into a fully operational instrument and establishing the Herouni Space Center (HUSC) on-site.

Considering several factors, particularly the current inability to perform real measurements due to the mismanagement by CJSC National Authority for Standardization and Metrology, which currently owns the ROT-54/2.6, and the necessity to virtualize various scientific studies as new technologies develop, a decision was made to simulate various parameters of the ROT-54/2.6 radio-optical telescope using an accurate three-dimensional model. Creating a model in the SOLID WORKS software environment allows to conduct various tests in the same software environment, as well as process and analyze the test results using a computer. In order to build the model accurately, it is necessary to coordinate the software environment. In order to ensure greater accuracy of the system of units of measurement provided to the software environment, as well as to avoid additional conversion of actual measurement results, the SOLID WORKS program was switched from the standard IPS system (inches, pounds, seconds) to the MMGS system (millimeters, grams, seconds). The MMGS system is more effective for special cutting, grouping of elements, and building precise inclined planes (such as the plane of the antenna's large reflector)[8].

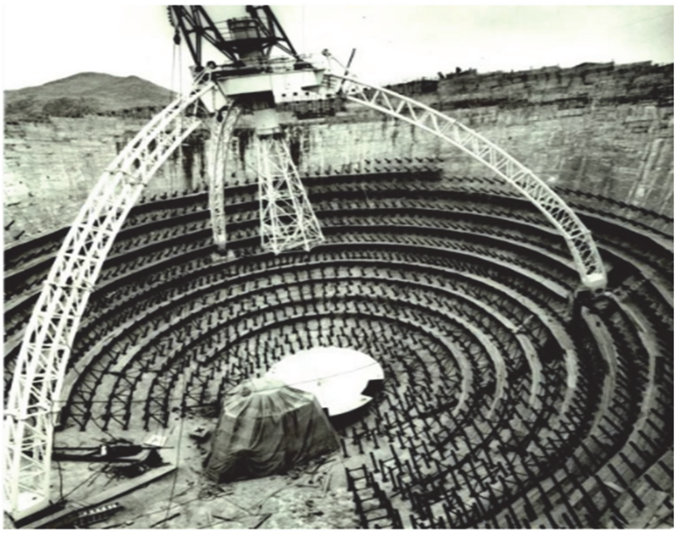

Fig. 1. The manufacturing process of the ROT-54/2□6 radio-optical telescope

Table 1

Panel lines of the surface of antenna's large reflector

Line number	Quantity	Panel form
0	1	Hexagon
1	6	Trapezoid
2	12	Trapezoid
3	12	Trapezoid
4	24	Trapezoid
5	48	Trapezoid
6	48	Trapezoid
7	96	Trapezoid
8	96	Trapezoid
9	96	Trapezoid
10	96	Trapezoid
11-27	192	Trapezoid

Results and analyses. Firstly, in order to manufacture the model, it was necessary to conduct an accurate study and calculation of the design of the radio-optical telescope. The information gathered from actual measurements of the structure conducted from 2019 to 2021 was supplemented by calculations using various archival images during the model's creation. To provide a clear and comprehensible description of the preparation process and the mathematical calculations, a substantial number of photographs from the SOLID WORKS software environment were utilized.

In the initial stage of measurements, the number of panels on the surface of the antenna's large reflector was determined, along with their surface area and arrangement in rows. Subsequently, a table was compiled detailing the rows and panel structures. To accurately construct a three-dimensional model, starting from the upper - first row of the antenna's large reflector panels, the lengths of the circles formed by the rows of panels were calculated by reducing the radius by 1 meter at each step, using the formula (1) to calculate the circumference:

$$l = 2\pi r. \qquad (1)$$

The following relevant results were obtained for each lap.

The calculation of the circle lengths begins at 26.5 meters instead of 27 meters because the height of the panels in each row is 1 meter, while the width of the upper and lower parts of the panel varies. For this reason, half the height of the panel was taken as the average width data. Having the data from Table 2 and using the ratio of this data to the number of panels listed in Table 1 (2), by row, we get the size of panels in each row:

$$W = \frac{l}{Q} = 2\pi r/Q\ , \qquad (2)$$

where W is the average width of each panel of line, l is the length of the circle from Table 2, and Q is the quantity of panels in each line.

Table 2

Circumferences of the surface of antenna's large reflector for each meter of radius

Radius (*m*)	Length of the circle (*m*)
26.5	166,4995
25.5	160,2165
24.5	153,9335
23,5	147,6505
22,5	141,3675
21,5	135,0845
20,5	128,8015
19,5	122,5185
18,5	116,2355
17,5	109,9525
16,5	103.6695
15,5	97,3865
14,5	91,1035
13,5	84,8205
12,5	78,5375
11,5	72,2545
10,5	65,9715
9,5	59,6885
8,5	53,4055
7,5	47,1225
6,5	40,8395
5,5	34,5565
4,5	28,2735
3,5	21,9905
2,5	15,7075
1,5	9,4245
0,5	3,1415

Table 3

Average width of panels of each line

Line number	Average width of each panel (*m*)
27	0.8671
26	0.8344
25	0.8017
24	0.769
23	0.7362
22	0.7035
21	0.6708
20	0.6381
19	0.6053
18	0.5726
17	0.5399
16	0.5072
15	0.4744
14	0.4417
13	0.409
12	0.3763
11	0.3436
10	0.6217
9	0.5563
8	0.4908
7	0.4254
6	0.72
5	0.589
4	0.9162
3	1.309
2	0.7853
1	0.5236

Using the data from the previous three Tables, the large reflector of the antenna was assembled. The total number of panels on the model, consistent with the actual count, amounted to 3,799.

After constructing the antenna's large reflector (Fig. 2), the next task was to accurately build the tripod. To this end, actual measurements provided the cross-sectional diameters of cylindrical tubes from various sections of the tripod's metal structure. These data are essential for the construction process:

- the diameter of the large iron pipes forming the quadrangle of the tripod legs is 150 *mm*;

• the distance between 2 opposite tubes is 1000 *mm*;
• the diameter of the stepped legs on the legs is 30 *mm*;
• the distance between the legs is 300 *mm*;
• the number for each leg is 95;
• the diameter of large pipes of the tripod legs is 100 *mm*;
• the distance between them is 780 *mm*;
• the number on each leg is 19;
• the absolute value of the slope of the legs is 17204.94 *mm*.

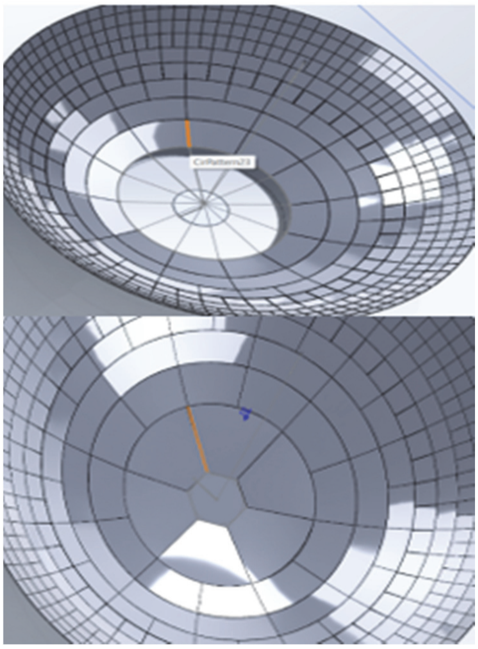

Fig. 2. The process of carrying out the antenna’s large reflector

Once this information as gathered, detailed effort was put into the SOLID WORKS graphics platform to craft the tripod with equal precision. To make the tripod bases, various sections from the antenna's large reflector's panels were cut out, and the exposed portion of the tripod legs started from these areas.

After making the tripod (Fig. 3), the next step is to make a small reflector and an optical telescope (Fig. 4). Here are the data used to create this structure.

• the diameter of the small reflector is 5000 *mm*;

• the length of the small reflector–bearing structure, counting from the central crossbar, is 14,500 *mm*;

• the crossbar diameter is 6000 *mm*;

• the height of the crossbar is 1500 *mm*;

• the diameter of the main rods of the small mirror-bearing structure is 200 *mm*;

• the diameter of the additional rods connecting the main rods of the structure carrying a small mirror is 100 *mm*;

• the height of the supporting structure of the optical telescope is 9850 *mm*;

• the length of the optical telescope body is 5200 *mm*;

• the diameter of the optical telescope is 2600 *mm*;

• the total diameter of the observation deck is 5500 *mm*;

• the height of the fence posts of the observation deck is 1000 *mm*;

• the number of fence posts of the observation deck is 100;

• the diameter of the main rods of the optical telescope 's supporting structure is 200 *mm*;

• the diameter of the additional rods connecting the main rods of the supporting structure of the optical telescope is 100 *mm*.

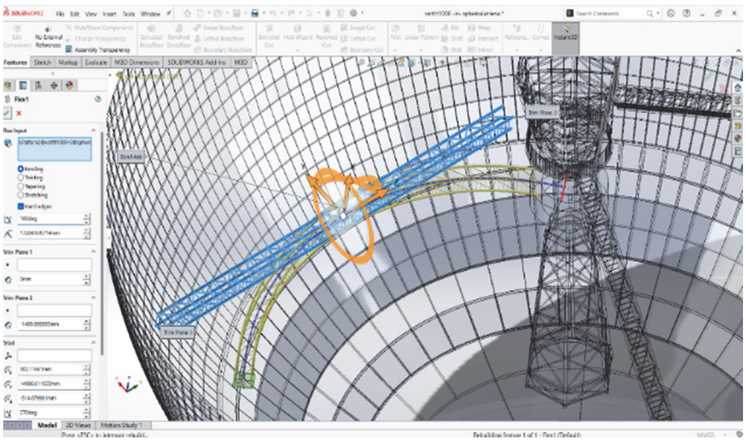

Fig. 3. The process of making tripod legs

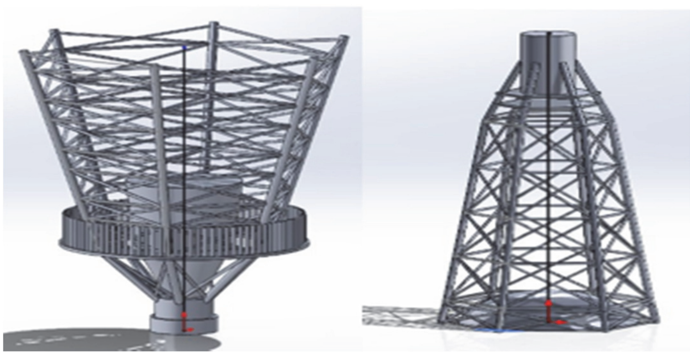

Fig. 4. The process of making a supporting structure of optical telescope and small reflector

Conclusion. The process of preparing a three-dimensional model of the ROT-54/2.6 radio-optical telescope have necessitated numerous additional measurements (Fig.5). The extensive data collection have revealed valuable information about the antenna's structure, which can serve as a supplementary addition to the telescope's technical passport. The process of building the three-dimensional model has also provided extensive experience in the physical aspects of designing and assembling similar antennas.

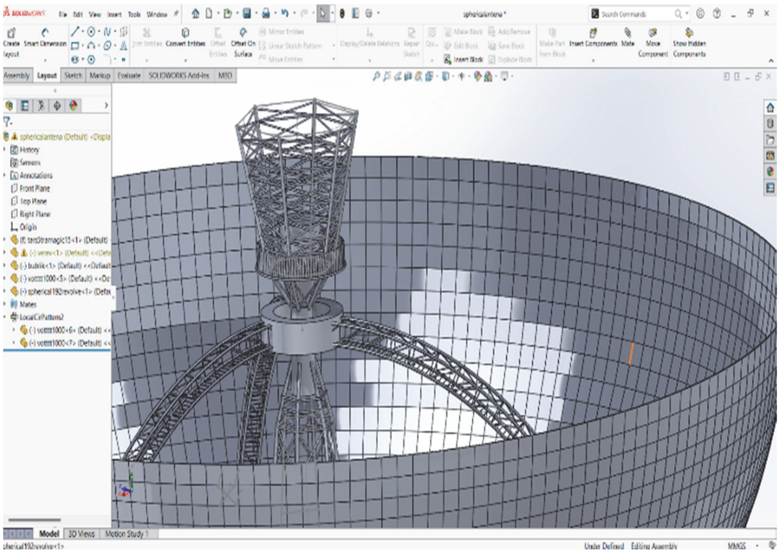

Fig. 5. The final view of ROT-54/2.6 three-dimensional model

Once created, the three-dimensional model will be utilized for remote, virtual execution of various physical and radio engineering measurements. This will significantly contribute to the process of configuring and integrating the antenna.

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ՌՕԴ-54/2.6 ՌԱԴԻՈՕՊՏԻԿԱԿԱՆ ԴԻՏԱԿԻ ԵՌԱՉԱՓ ՄՈԴԵԼԻ ՍՏԵՂԾՈՒՄԸ

Հաշվի առնելով, որ ՌՕԴ-54/2.6 ռադիոօպտիկական դիտակը գտնվում է կոնսերվացված վիճակում, դրա վերագործարկման, վիրտուալ միջավայրում երկրաչափական և ռադիոտեխնիկական պարամետրերի հաշվարկի կատարման, ինչպես նաև տարբեր լրացուցիչ տեխնիկական փորձարկումների վիրտուալացման նպատակով որոշվել է ստեղծել անտենայի ճշգրիտ եռաչափ մոդել SOLID WORKS ծրագրային միջավայրում: Նույն նպատակով ստեղծվում է ծրագրային համալիր՝ հավելվածի տեսքով, որը թույլ է տալիս հաշվարկել անտենայի պարամետրերը՝ կախված մուտքային տվյալներից: Այս աշխատանքների արդյունքում բավականին հեշտ կլինի գնահատել ՌՕԴ-54/2.6 ռադիոօպտիկական դիտակի վերագործարկման աշխատանքների ծավալը, իսկ նմանատիպ այլ անտենաների դեպքում հնարավոր կլինի վիրտուալ միջավայրում կատարել բազմաթիվ հաշվարկներ: Հոդվածում նկարագրված են ուսումնասիրություններ, որոնք ուղղված են ՌՕԴ-54/2.6 ռադիոօպտիկական դիտակի անտենայի եռաչափ մոդելի ստեղծման գործընթացին' կախված տարբեր պարամետրերի չափումներից ստացված տվյալներից և մի շարք հետազոտությունների արդյունքներից: Հետազոտությունն իրականացվել է անտենայի կառուցման ժամանակ կազմված տեխնիկական անձնագրի տվյալների և 2019-2021 թվականներին անտենայի կոնսերվացված վիճակում իրականացված մի շարք երկրաչափական պարամետրերի իրական չափումների արդյունքների հիման վրա: Եռաչափ մոդելի ստեղծման գործընթացն իրականացվել է SOLID WORKS ծրագրային միջավայրում, որն օգտագործվում է մեխանիկական մոդելների ստեղծման դեպքում :

Առանցքային բառեր. անտենա, ռադիոօպտիկական դիտակ, ՌՕԴ-54/2.6, SOLID WORKS, եռաչափ մոդել:

А.С. САРГСЯН, Н.А. АМБАРЦУМЯН, Л.М. МАРГАРЯН

СОЗДАНИЕ ТРЕХМЕРНОЙ МОДЕЛИ РАДИООПТИЧЕСКОГО ТЕЛЕСКОПА РОТ-54/2.6

В настоящее время для расчета геометрических и радиотехнических параметров антенны радиооптического телескопа РОТ-54/2.6, находящегося в законсервированном состоянии, а также для виртуализации различных дополнительных технических испытаний было решено создать точную трехмерную модель антенны в программной среде SOLID WORKS. С этой целью создается программный комплекс в виде приложения, который позволяет рассчитать параметры антенны в зависимости от входных данных. В результате этих работ будет довольно легко оценить объем работ по восстановлению этой антенны, а в случае других аналогичных антенн можно будет выполнить множество расчетов в виртуальной среде. В статье описаны исследования, направленные на создание трехмерной модели антенны радиооптического телескопа РОТ-54/2.6, и сам процесс подготовки в зависимости от результатов исследования. Исследование проводилось на основе данных из технического паспорта антенны, зафиксированных при ее строении, и результатов фактических измерений нескольких геометрических параметров конструкции антенны в законсервированном состоянии, проведенных в 2019-2021 годах. Процесс создания трехмерной модели выполнялся в программной среде SOLID WORKS, используемой для создания механических моделей.

Ключевые слова: антенна, радиооптический телескоп, РОТ-54/2.6, SOLID WORKS, трехмерная модель.