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Numerical Modeling of RadioAstron SRT Temperature Deformations

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Abstract—The results of modeling the thermal deformations of a space radio telescope's reflecting surface are presented in the paper. Calculations were performed for the versions of the most unfavorable telescope illumination by the Sun.

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One of the main factors that influence the accuracy of space radio telescope's (SRT) reflecting surface in orbit are temperature deformations of the structure. At the same time, the surface accuracy should meet very high requirements [1]. However, the size of the mirror in the working state does not allow one to perform ground-based thermal-vacuum tests while monitoring the full volume of deviations in the reflecting surface. The only way to estimate temperature deformations and deviations in the reflecting surface as a whole at the orbital operation stage is numerical modeling.

Calculation Model

We used the finite-element technique in the MSC.Nastran software implementation as the main computational method. The finite-element model includes the models of 27 petals, a central part, a reflector farm, a science payload container, and a transition farm. The total number of components in the model is 49821, the number of items is 47247. The model was developed taking into account the possibility of using it, not only for deformation analysis, but also for thermal analysis. In addition, for higher reliability of the results, the temperature fields were calculated by software for domestic development. This has greatly reduced labor consumption and increased the accuracy of the results. The verification of a calculation model and the adequacy of its real structure is a significant problem. The works on verifying calculation models can be subdivided into three directions. The first direction is associated with formal checks of the model, which are standard in the finite-element modeling.

These checks include the following:

(1) the control of initial data, including characteristics of materials, the cross section, the thickness of components, etc.;

(2) the control of integrity of the grid, the absence of degenerated elements and elements with nonoptimal geometry;

(3) the analysis of parasitic thermal stresses and the frequency of natural oscillations of a free structure, the response at applying unitary loads, etc.

These checks have accompanied works on modeling the strain state at all modeling stages because the calculation model has undergone changes in the course of these works. The second type includes the complex of works associated with the analysis of the effect of initial data (characteristics of materials, boundary conditions, design features) on the response (deflections of a reflecting surface) of the calculation model. In fact, this direction of verification comb the whole experience gained in the course of works on modeling the deformations. The third and most valuable direction of verification is the comparison of numerical modeling results with the results of field tests. These were vibration-dynamic tests of the item 1410 (the SRT model for vibration-dynamic tests), for which good coincidence was obtained between the results of tests and numerical modeling results [2]. Good coincidences were also obtained for the static loading of the same item in the course of works on controlling the accuracy and repeatability of mirror opening. The thermal-vacuum tests of individual petals carried out at the ESTEC test center of the European Space Agency in 1994 and 1998 turned out to be very useful for developing the calculation techniques.

Boundary Conditions

Different versions of temperature fields caused by SRT orientation relative to the Sun were considered to be the boundary conditions for final calculations. Below, we present the results for the two most typical versions, i.e., illumination from the side of the Navigator service module at the angle of 15° to the longitudi-

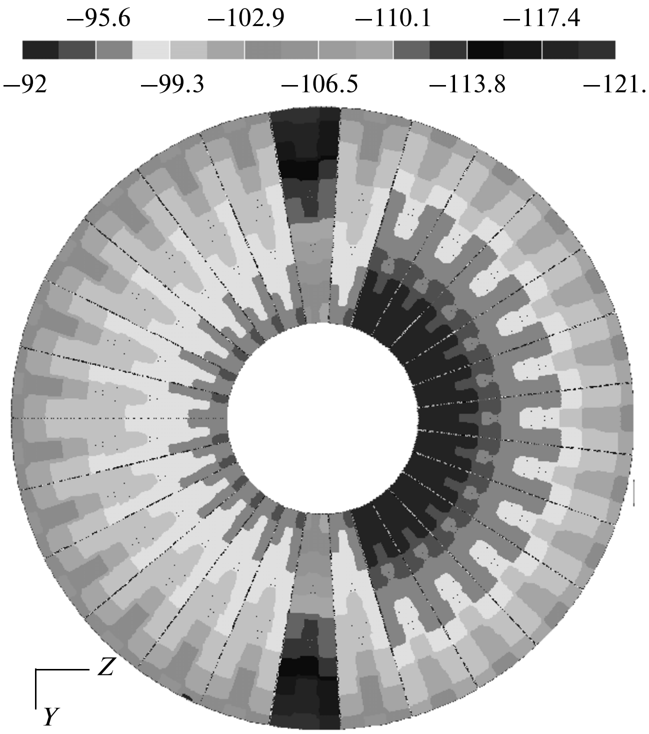

Fig. 1.

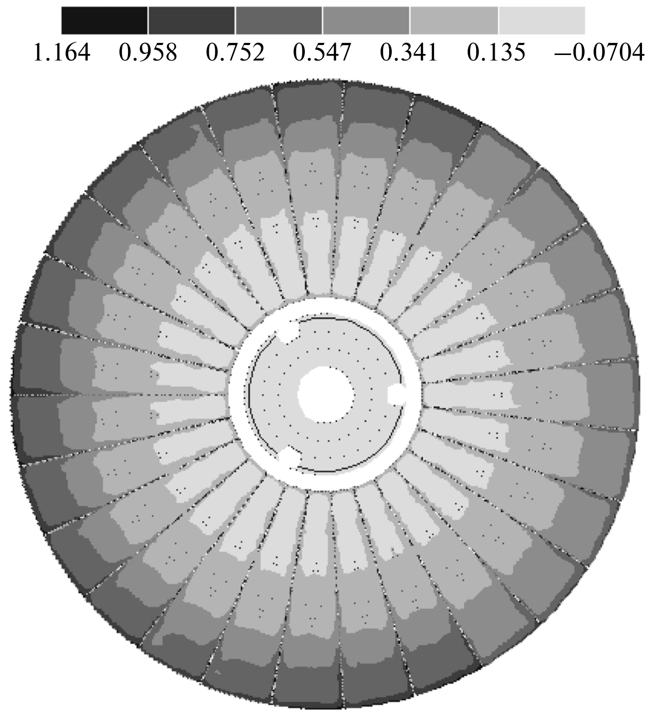

Fig. 2.

nal axis of the spacecraft (SC) (the estimated case X15) and illumination perpendicular to the longitudinal axis of the SC (the estimated case Z0). As an example, Fig. 1 presents the field of temperatures on reflector's petals for the estimated case X15; the most considerable drop of temperatures is observed on two petals shadowed by solar battery panels.

RESULTS

The table presents the results of final modeling of temperature deformations for estimated cases of SC orientation relative to the Sun.

CONCLUSIONS

The deviations in the reflecting surfaces of the SRT are presented for two characteristic cases of temperature fields caused by the orientation of the SC relative to the Sun. The maximum deviations (in addition to temperature deformations), which included manufacturing errors, alignment inaccuracies, opening inaccuracies, and deviations caused by the features of the behavior of composite materials under space conditions, did not exceed 2.0 mm for either version of SRT orientation relative to the Sun.

Table.

Deviations along the normal	Orientation relative to the Sun	
	X15	Z0
Maximum	+1.16 mm	+1.00 mm
Minimum	−0.07 mm	−0.138 mm
Root mean square	0.40 mm	0.29 mm

The RadioAstron project has been carried out by the Astro Space center of the Lebedev Physical Institute of the Russian Academy of Sciences and by the Federal State Unitary Enterprise (FSUE) Lavochkin Association under contract with the Russian Space Agency, jointly with many scientific-technological organizations in Russia and other countries.

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