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Synthetic Aperture Orbital Telescope for Earth Remote Sensing Equipment

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One of the main requirements for modern orbiting telescopes is to ensure the maximum resolution of the optical system while maintaining a high level of image contrast. The spatial resolution determines the smallest size of objects that can be distinguished in the image and can be carried out both in panchromatic mode (more accurate) and in multispectral mode. Today, ultra-high-resolution images include images in which objects of 0.3-0.9 m in size are visible [1, 2, 3].

The actual task remains to increase the temporal resolution, which determines the frequency of obtaining images of a specific area on the Earth's surface. The increase in temporal resolution is possible in two directions. The first is the formation of a spacecraft group synchronized in a photograph when working on a specific part of the surface. The second is the increase of the height of the spacecraft orbit, which leads to the increase of its stay time over a specific part of the Earth's surface.

The disadvantages of telescopes located in the GSO (geostationary orbit, 35.786 km above sea level) include the total delay of the transmitted signal of about 2-4 s and the impossibility of observing parts of the Earth’s surface at high latitude (81-90) or significant signal shielding by ground objects already at latitude (from 75°) [4]. To form a high-resolution image with a telescope located in the GSO, the aperture of its main mirror should be about 30-40 m. Making such a mirror and then placing it into the orbit is a difficult task. In classical spacecraft for remote sensing the aperture of the input window of the optical system is about 0.4-1.1 m. An increase in the aperture of the main mirror leads to additional difficulties associated with an increase in its mass, as well as the need to install additional mechanisms for balancing and adjusting. In addition, technological costs associated with the formation of a high-quality reflective surface increase.

Creating systems with a large aperture became possible by splitting the main mirror into segments [5]. According to the theory, in a synthesized aperture telescope, the final image is formed from separate fragments of several mirror modules and is equivalent in quality to a telescope with a solid mirror surface, provided that the images are geographically acceptable and phase synchronized. Today, from a practical point of view the problems of simulating synthetic aperture systems have been successfully solved only for ground-based observatories: the Very Large Telescope of the South European Observatory (VLT ESO); Hopkins multi-mirror telescope (MZT) and mainly for radar systems – Murchison Radio Astronomy Observatory (ASKAP). Orbital telescopes with segmented elements of the main mirror are implemented only in James Webb Space Telescope (JWST). Design options for orbital telescopes with synthetic aperture are currently lacking.

The purpose of the research was to develop a concept and determine possible options for building a high-resolution orbital telescope with a synthesized aperture of the main mirror for a remote sensing satellite located in a geostationary orbit.

The analysis of existing methods for the formation of the synthesized aperture was carried out, their accuracy, cost, and mass-dimensional characteristics were evaluated. A new version of the optical system of synthetic aperture mirror lens is presented and its optimization is performed in the Zemax software package. An estimate of the accuracy of the designed system has been made; a design variant has been developed that includes a transformation mechanism when a telescope is put into near-earth orbit.

It has been established that the use of aperture synthesis technology allows to develop high resolution optical-electronic systems with lower production and operation costs compared with classical methods for forming the surface of the main mirror. In the course of the simulation, the instability of the values of the frequency-contrast characteristic with increasing angle of view was determined, which is important for a low near-earth orbit, and the requirement for positioning elements of the optical system was established.

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