IOP Conf. Series: Materials Science and Engineering **450** (2018) 032009 doi:10.1088/1757-899X/450/3/032009

Basic requirements and principles for the compensation system development

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Abstract. The paper considers the development and logic of disclosure of the transformable antennas of the spacecraft. The key requirements and principles of the compensation weight component are outlined. The necessity to compensate the weight component in the assembly and testing of the design is identified.

1. Introduction
Modern trends in the development of large-size transformable reflectors (LTK) of the spacecraft (SC) cover the extension of the operating frequency range, a decrease in the specific mass and an increase in the overall dimensions of their components. The world practice to date is aimed at increasing the size of LTR spacecraft and their working area up to the diameter of 60 meters. By 2017, there are more than 40 civilian and dual-purpose LTK on orbit. The world leader in the LTK production is Harris Corporation, USA. So in the USA, some space complexes for both civil and special purposes have been developed with a diameter of antenna-feeder systems up to 30 and more meters.

The direction for the development large-size mechanical systems is seen as a priority not only for the USA but also for other countries with a developed space industry. In this field the work is conducted in Europe, Japan, China and India. But due to the technical complexity of the problem, flight samples are available only in the USA and in Japan but not so intensively [1, 2].

It is necessary to study the state of the market and the prospects for large reflectors to explore the concept of antennas. The study of the market situation is shown in Figure 1. This analysis is based on more than a hundred flight reflectors supplemented by estimates for the period of some previous years. This confirms that the growth and complex developments since the 1980s now reach an average of five developments per year. The market prospects for reflectors below 9 meters represent approximately 2/3 of the market needs, with an average estimate of 7-8 developments per year.

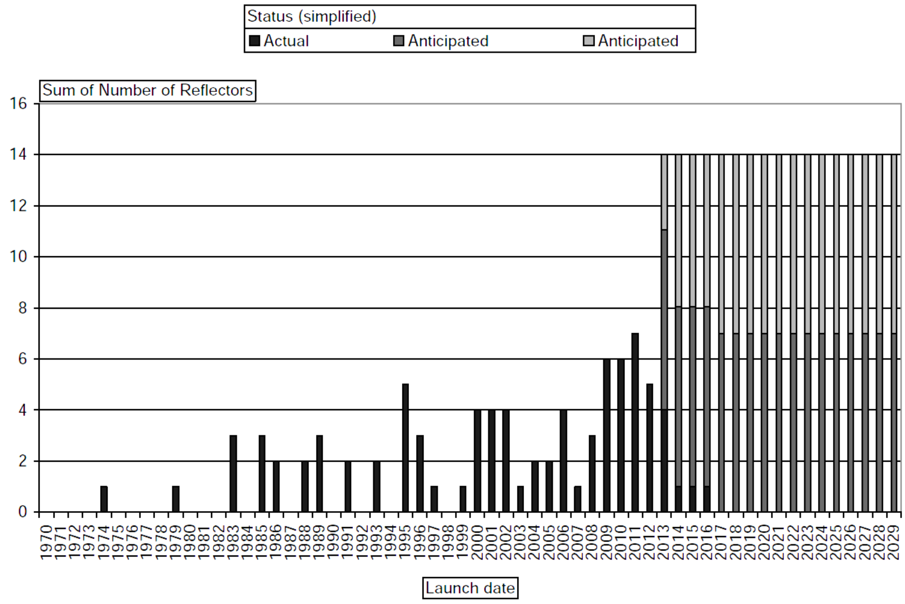

Figure 1. Number of the launched reflectors per year.

According to the information given above, a spacecraft with the LTK have created a new technique in the competitive struggle for a consumer, thus providing market advantages to those countries that own the necessary satellite technologies for broadband multimedia broadcasting.

The analysis of the LTK existing on the world market has shown that, in spite of certain achievements in this field, only a few of them are able to ensure the accuracy of the specified shape and the necessary stiffness of the structure in zero gravity. It is not always possible to achieve their reliable disclosure. The reason is in violation of the technology at any of the following stages:

- manufacture of units and components taking into account resource characteristics of the structure;
- high-precision assembly on the bench complex;
- bench test of LTR.

The high standards are set for LTK. It is also necessary to take into account that LTKs of a spacecraft undergo the action of various loads and temperature fields. First of all, they are high requirements for rigidity, due to the need for antenna orientation and ensuring the accuracy of the working surface of the reflector to LTK [4]. The main problem in the practical use of such antennas is in existing restrictions on the payload dimensions for the launch vehicle launcher installation in their high mass, necessitating the use of heavy-duty satellites and capable of degrading the quality of the communication satellite.

The development of antenna systems with large-size equipment characterized by high reliability of deployment and quality of the working surface, and while having a relatively small mass refers to unique technologies.

2. Formulation of the problem

To understand the logic of LTK disclosure, let's consider its purpose and structure. LTK consists of the following main units:

- conductor frame with deployment mechanism;
- form-building structure;
- network radio reflector.

Figure 2 shows the LTK in its working state. The required accuracy of the radio reflecting surface of the reflector and its conservation under the influence of space factors depends on the design and materials of the power frame. To ensure the required dimensions in the transport position, the power frame has a transformable structure and is brought into working position by means of a mast telescopic mechanism (MTM). The structure of the power frame is an assembly consisting of radially arranged conductor spokes pivotally mounted on the base and having the possibility of rotation relative to the base.

The structure of the conductor spokes involves:

- root link;
- end link;
- hinged link;
- intermediate hinged joint (HJ);
- root HJ.

Heavy frames and guys are between the conductor spokes of the conductor frame. The MTM is fixed to the ground. A telescopic mast is connected to the mechanism for adjusting the shape of the reflector (MASR). Telescopic struts of the conductor spokes are attached to it. A support with radial belts and guys attached to it are installed on the MTM.

The developed LTK are developed for the following purposes:

- selection of optimal design versions to achieve specified technical characteristics;
- development of techniques for manufacturing a metal knitted netting optimized for L- and S-bands;
- development of techniques for manufacturing high-modulus size-stabilized cords for the shape-forming structure of reflectors;
- development of mathematical models used in the development of LTK;
- development of methods for conducting thermal and mechanical tests used in the development of LTK;
- development of measurement techniques and confirmation of the accuracy of the geometry of LTK and their constituent units, both on Earth and in orbit;
- development of testing methods of the equipment for deploying LTK [3,4].

The main principles of the weight component compensation system (WCCS) are formulated on the basis of the design and purpose of the considered LTK:

1. WCCS should provide operation with the LTK in the structure. It includes the following basic structural elements: a spoke (involving a root spoke, an end spoke, a strut, a guy) - 12 pieces; heavy frames – a set; form-building structure - a set; radio-reflecting coils - 1pieces.
2. The cable hangers of the WCCS should be attached to the center of mass: spokes of the root link with hinge elements; spokes of the end link with hinge elements, a strut with hinged elements. In this case, a node must be sufficiently rigid (without changing the geometry and, correspondingly, a center of mass), so that in its own coordinate system a center of mass of the node remains in the same place regardless of its orientation in the gravitational field
3. The amplitude of the weighing force (cable tension) must be independent on the trajectory of the point of suspension of the object.
4. The error in the implementation and maintenance of the weighting force should not be more than 3% of the force necessary to compensate the weight of the movable unit of the reflector in the entire range of opening angles.
5. The WCCS should have a tracking device for changing the angle (in order to ensure the verticality of the cable) and a device for tracking the tension of the cable (to regulate the length of the cable and maintain a constant effort of weighing).
6. The WCCS should continuously measure the readings from the weight and angle sensors, dynamic parameters of acceleration / deceleration, speed of the servo motors, amount of tension of the flexible coupling along the entire path of opening the spokes of the antenna.
7. The estimation of the value of the weighting force with an error of not worse than 0.5H and the actual center of mass of links (linearly) with the error not worse than 1mm.
8. The total uncompensated moment should not be more than ± 1H / m.
9. The value of dynamic jerks:

- spokes of the root link are to be not more than 10% of the weight loss force;
- spokes of end link are to be not more than 10% of the weight loss force;
- strut is to be not more than 10% of the weight loss force.

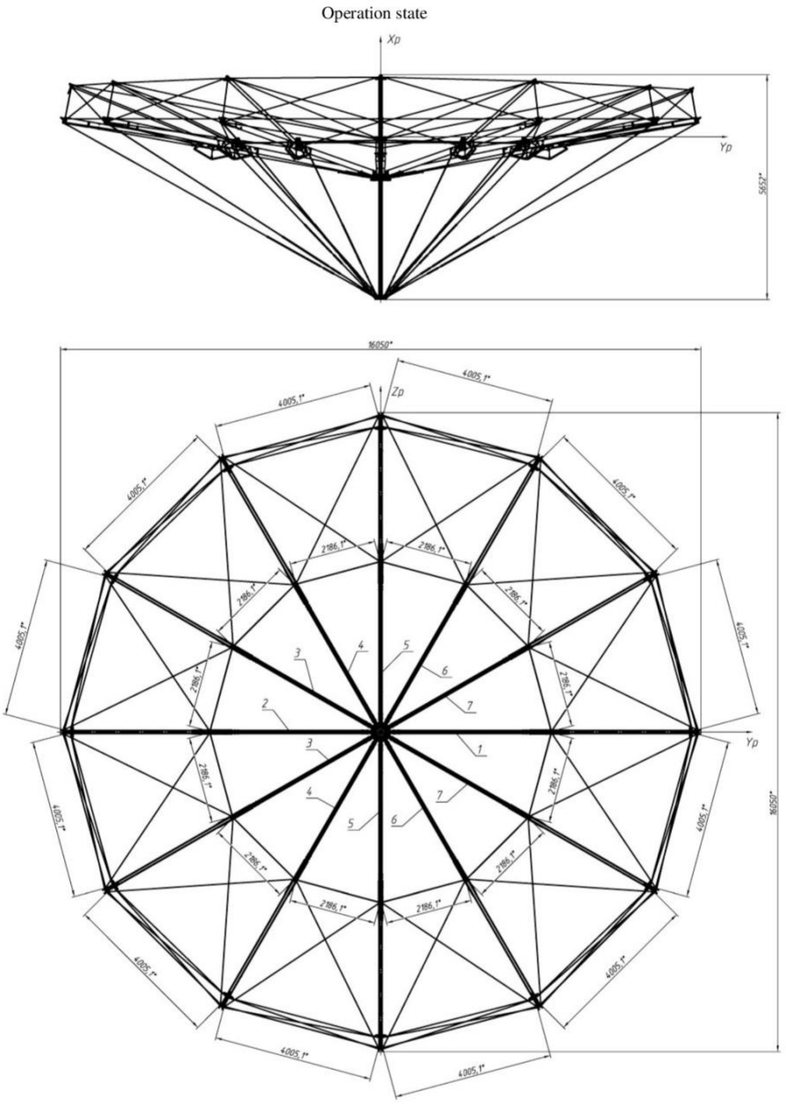

Figure 2. LTK in the operation state.

10. WCCS should be able to operate without the necessary information about the design of the object of depreciation, since its formalization and input is labor-consuming, and, as a rule, unreliable. Complex control algorithms are difficult for debugging and analysis.
11. Shock less switching to the reserve (without introducing disturbance in the controlled process) is obligatory.
12. Time lag for torque, transmitted power and other dynamic characteristics of the system loading is not more than 0.018 seconds.
13. Reliability of the whole system (level of integrated safety SIL1) is considered.
14. SCADA-system with the ability to integrate queries fully for managing and exchanging data on a single platform.

3. Conclusion

Taking into account the requirements considered above, the need for the development of technology, metrological support, specialized technological equipment, i.e. high-precision active automated multi-channel WCCS is revealed. It is possible to achieve this range of WCCS reaction by introducing a monitoring system with constant measurement of the readings from the weight and angle sensors. The use of active WCCS increases significantly the speed of the system, its sensitivity and accuracy. Also the WCCS at large dimensions of unweighed structure can be applied and simultaneous moving of several points of the force application relative to each other can be fulfilled [5].

Therefore, the development of WCCS for ground-based testing of the LTK of a spacecraft is an urgent problem.

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