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DEPLOYMENT SIMULATION AND ANALYSIS OF SPACE MESH ANTENNA

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Abstract. The aim of work is to create a dynamic model of a space antenna with the pantograph structure and study the processes of its deployment using open-source software. The methods of theoretical mechanics, multi-body dynamics, computational mechanics, and computer modeling were used for this research. The object for modeling is a novel mesh antenna, which is designed for mini-satellites. The most significant difference between this antenna and others is the design of the support ring in the form of a pantograph. Using the built model, antenna deployment is simulated for different cases. Values of deployment time and cable tension during the antenna deployment are analyzed.

Keywords: reflector antenna, deployment, multibody dynamics, open-source software, mesh antenna.

Introduction. Antennas of various types are used for space applications [1], such as communication, military intelligence, remote sensing and climate forecasting. Antennas with a large aperture are designed to increase the efficiency of solving such tasks. Due to the fact that space under the fairing of a space rocket is limited, such structures are made deployable. In papers [2, 3], a novel design of mesh antenna was proposed for mini-satellites. Since this structure is very complex, it is crucial to validate its deployment. Modeling of a deployment antenna is not a straightforward task. Unfortunately, specialized commercial software for this task is very expensive and small groups of researchers and startups cannot use them. However, there are free open-source software packages that can help with modeling such complex systems. This work uses such an open-source software package named HotInt.

Antenna design. The antenna model selected for research is described in detail in the article [4]. The transformable supporting pantograph ring is the basis of the antenna design. Two nets are attached to the supporting ring, which are tensioned by ties and form a required shape of the reflector. A reflective mesh is attached to one of the nets. Nets consist of thin strips folded in such a way that they cross each other to form a mesh. The upper and lower nets are connected by screeds, which keep the deflection of the nets that we need unchanged. The supporting ring of the antenna consists of 18 identical sections connected to each other by hinge units. Each section is formed from diagonal and horizontal rods of tubular cross-section. The diagonal rods are connected to each other by hinges, which ensure the rotation of one rod relative to the other. The diagonal rods are also connected to the lower and upper horizontal rods, which are transformable by means of V-folding bar hinges. The sections of the ring are also connected to each other by hinged units at the junctions of the diagonal and horizontal rods.

All diagonal and horizontal rods are made of carbon fiber and hinges and connecting elements are made of aluminum. All net strips and screeds are made of carbon fiber as well.

The antenna is deployed by means of cables passing through a system of pulleys and driven by two electric motors.

Computer model. The main part of the antenna, that is, the deployable support ring, is modeled with the help of script files using Hotint software commands. To create units of the antenna, such as antenna sections, nets stretched between sections, and tension ties between nets, script files are written for each part separately. The code for each part of antenna consists of separate blocks that describe model elements and is created according to the algorithm described in detail in the article [4].

The approach to modeling antenna nets with the help of flexible beam elements leads to a high complexity of calculations. That is why it was chosen to simulate the tension effect created by the nets between the antenna sections using springs. Modeling of tension ties between nets using springs was chosen for the same reasons. Point masses are use at the nodes where net elements intersect with each other and ties are attached to the nets. These elements are adjusted in such a way as to be equal to the mass of the nets and ties. A formula for the cable tension is derived based on the data obtained in previous works and taking into account the geometric characteristics of the structure. This formula is used to select a tension force, which allows the antenna to be opened in a required time.

Conclusion. The antenna model is designed to simulate deployment processes. The model of nets creating a tension force between antenna sections has been created. The shape of the nets is maintained by the tension ties. The deployment of the reflector is modeled using the formula that describe the cable tension. Variations of the antenna parameters over time are analyzed.

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