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Nonlinear Oscillations of a Deployable SAR-Satellite Antenna*

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1. Introduction

One of the experiments of the European research satellite ERS-1 will be realized by a plane SAR-antenna (SAR=synthetic aperture radar). The large dimensions (length: 10 meters) of the antenna make it necessary the antenna to be folded during the transportation in the launching vehicle. It is therefore split up into five panels which are connected by a deployable truss. Two main demands have to be fulfilled by the folding truss: it has to guarantee the desired kinematical transmission behaviour, and it has to serve — after the deployment — as a supporting structure. Here, a very high accuracy to the stretched position of the antenna is required.

2. Dynamical Model of the Deployable Truss

The deployable truss consists of series connected plane four-bar mechanisms, which are arranged in such a way that two panels each can be unfolded to the left and to the right side (Fig. 1). The resulting multibody system has two degrees of freedom to each side. After splitting the deployment process into separate parts each partial motion has one degree of freedom and

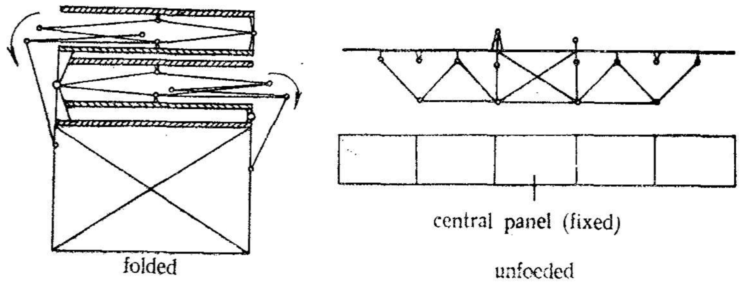

Fig. 1. SAR-antenna with deployable truss

* The SAR-antenna is investigated under contact with the German Aerospace Company Dornier System GmbH.

a separate driving device. In the first partial motion the outer panel is unfolded to the right side. In the second partial motion the outer panel together with the adjacent panel is turned to the left side, ending up in a stretched position with the fixed central panel. The deployment process of the two remaining panels to the right side occurs in a similar way.

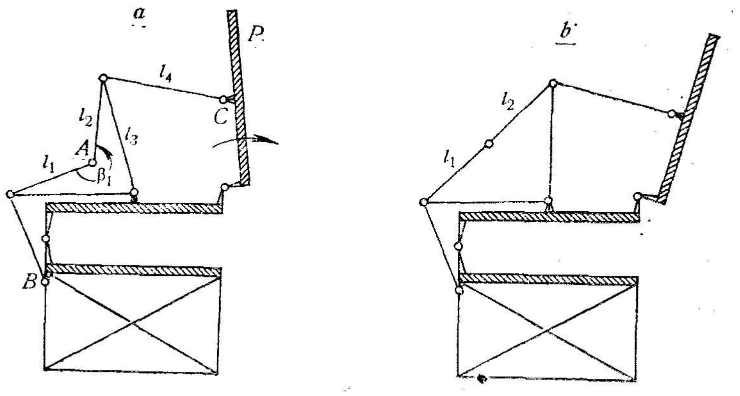

Fig. 2. SAR-antenna — first partial motion

By regarding only the unfolding of the outer panel, it is realized by a mechanism of two series-connected plane four-bar mechanisms. The corresponding multibody system consists of five bodies: the panel P and the rods l_1 to l_4 (Fig. 2a). The unfolding motion is initiated by a passive device in hinge A, resulting in a complicated nonlinear oscillation about the equilibrium position which is given by the stretched position of rods l_1 and l_2 (Fig. 2b). Due to additional dashpots in the system, the oscillation is damped. (During this first partial motion the second degree of freedom of the system is blocked in hinge B.)

As a derivation by hand of the complex equations of motion for the folding truss is very labourous, a computer algorithm has been developed which states the equations of motion automatically. It is based on the four-bar mechanism as a closed transmission element.

3. Nonlinear Oscillation of Unfolding Outer Panel

By using the driving angle β_1 as a generalized coordinate, the equation of motion for the first partial motion has the structure

$$(1) \qquad m(\beta_1)\ddot{\beta}_1 + k(\beta_1)\dot{\beta}_1^2 = q(\beta, \dot{\beta}, t),$$

with $m(\beta_1)$ — generalized mass, $k(\beta_1)\dot{\beta}_1^2$ — centrifugal force, $q(\beta, \dot{\beta}, t)$ — generalized force, including applied forces as well as damping forces.

The results of a real time numerical simulation of Eq. (1) are shown in Fig. 3. Of particular interest is the rapidly decreasing time period of the oscillations and the shocklike increasing angular velocity and acceleration in the neighbourhood of the equilibrium position.

While the changes in the time period are caused by the geometrical properties of the four-bar mechanisms, the peaks in the angular velocity and, in particular, of the angular acceleration have kinematical and dynamical reasons: In the equilibrium position (Fig. 2b) the angular velocities of the panel P and

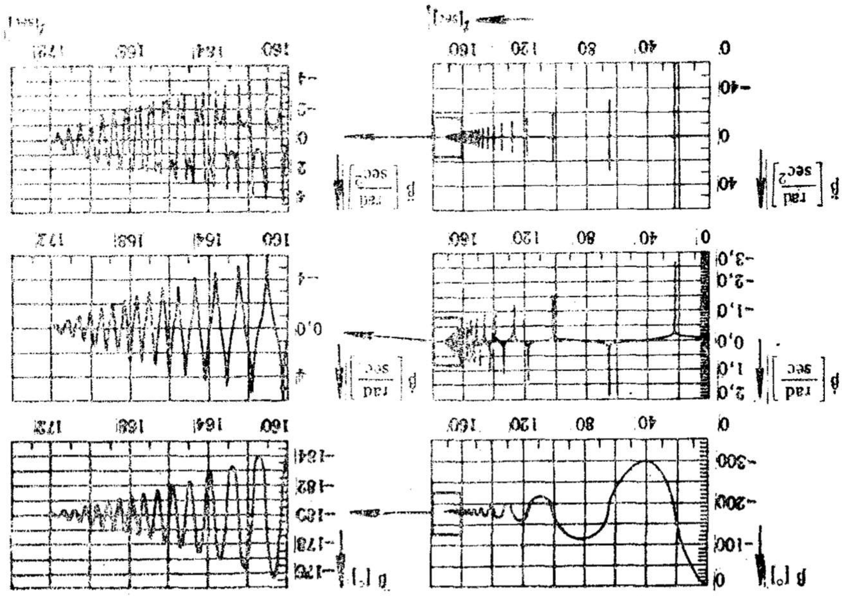

Fig. 3. Real time simulation of first partial motion

the rods l_3, l_4 are zero, due to a change in the direction of motion. So, only the rods l_1, l_2 are moving parts, storing in a small time interval the complete kinetic energy of the system. Hereby, the mass ratio of panel to rod is about 70:1.

Concentrating the mass of panel P in point C and the masses of rods l_1, l_2 in point A, the system can be replaced in the neighbourhood of the equilibrium position by two pendulums for which the kinetic properties can easily be calculated analytically. By small changes in the ratio $l_2:l_3$, where $l_1=l_2$, $l_3=l_4$, and by an additional small mass in the rods, the acceleration peaks can be remarkably reduced.

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