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PRELIMINARY RESULTS OF THE DETERMINATION OF THE ORIENTATION OF "INTERKOSMOS-17" AUOS

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16. Abstract

Discussed herein is an algorithm for determining the orientation of the "Interkosmos-17" automatic multipurpose orbital station. Graphs are provided which show variations of the satellite's orientation, relative to a given orientation in an orbital system of coordinates.

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PRELIMINARY RESULTS OF THE DETERMINATION OF THE ORIENTATION OF "INTERKOSMOS-17" AUOS

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An algorithm is set forth for determining the orientation of the "Interkosmos-17" automatic multipurpose orbital station. Given among the results are graphs of the variations of the satellite relative to a given orientation in an orbital system of coordinates. /2*

Until the present, within the scope of the "Interkosmos" program, the determination of the orientation was carried out either for unoriented satellites ("Interkosmos-8, 10, 12", and others), or for artificial earth satellites (satellites of the "Prognoz" series). A characteristic feature of these subjects was the insignificant amount of perturbing moments, as compared with the kinetic energy of movement relative to the center of mass. In this connection, a procedure based on a model of unperturbed movement was successfully utilized during the determination of the orientation. /3

The switch to automatic multipurpose orbital stations (AUOS), which are oriented subjects, does not eliminate the task of determining the orientation, since the accuracy of the orientation proves insufficient for the solution of a series of problems. However, the utilization of a procedure based on a model of unperturbed movement becomes impossible, insofar as the movement of an AUOS, relative to the center of mass, is determined by the perturbing moments evoked by the stabilization system.

Set forth in section 1 is the algorithm used for deter-

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*Numbers in the margin indicate pagination in the foreign text.

mining the actual orientation of the "Interkosmos-17" AUOS.

Given in section 2 are the basic results obtained.

1. The artificial earth satellite "Interkosmos-17" was launched on September 24, 1977, into an orbit which was close to circular, with an altitude $h \approx 500$ km and an inclination $i \sim 83^{\circ}$. /4

Orientation conditions were given in an orbital system of coordinates, with which the major central axes of inertia of the satellite coincide with the Earth-artificial earth satellite direction, perpendicular to the plane of the orbit, and the axis which adds the two previous ones to the orthogonal reference point, respectively.

Mounted on the satellite for monitoring of the orientation were a three-component magnetometer, which measures the vector of directivity of the Earth's magnetic field $\vec{H}$, and a solar sensor, which measures the unit vector of direction towards the Sun $\vec{S}$, with an accuracy of $\sim 1^{\circ}$.

The presence of the simultaneous measurements of the two vectors $\vec{H}$ and $\vec{S}$ makes it possible to make use of the local method of determination of the orientation. However, its use proves ineffective, because of the possibility of shading of nearly half of the orbit, the poor solvability of the problem at intervals where the angle between the vectors $\vec{H}$ and $\vec{S}$ are close to 0 or π, the presence of irregular sections of telemetry of considerable duration, and also because of the insufficient accuracy of the magnetometer.

Therefore, selected for determining the orientation of the "Interkosmos-17" AUOS was a statistical method of determining orientation, which utilizes a model of movement relative to the center of mass [1].

Insofar as the effect of the stabilization system on the movement of the satellite is quite complex, it was not possible to create a dynamic model of movement relative to the center of mass, which would prove to be high-speed, with the necessary accuracy, with realization on a computer.

In this connection, a kinematic model was utilized [2]

$$\theta_k = a_0^k + \sum_{n=1}^{N_k} (a_n^k \cos n\omega t + b_n^k \sin n\omega t), \qquad (1) \qquad k = 1,2,3,$$

where θ_k are the angles which determine the position of the satellite in an orbital system of coordinates (fig. 1), ω is the orbital frequency, and N_k is the number of harmonics. /5

The unknown coefficients a_0^K, a^K, and b^K were determined from the condition

$$a_0^k, a_n^k, b_n^k = \arg\min \Phi, \qquad (2)$$

where

$$\Phi(a_0^k, a_n^k, b_n^k) = \sum_i |\tilde{d}_i - M(\theta_1, \theta_2, \theta_3)\vec{d}_i|^2. \qquad (3)$$

Here, $\vec{d}_i$ is the measured vector in the orbital system of coordinates, $\tilde{d}_i$ is the measured value of that same vector, and M is the matrix of the switch from an orbital system of coordinates to a fixed system.

The desired parameters a_o^K, a_n^K, and b_n^K satisfy the equations

$$\frac{\partial \Phi}{\partial a_0^k, a_n^k, b_n^k} = 0, \quad k = 1,2,3. \qquad (4)$$

Utilized for the solution of system (4) was a modification of Newton's method, proposed in [1].

2. Based on experience in determining the orientation of a similar subject ("Kosmos-900"), the interval of processing was selected as an orbit in length, and the number of harmonics $N_K = 5$. About 40 orbits were processed. Listed below are the basic results obtained.

1) The procedure works satisfactorily in the majority of orbits. Difficulties occur in orbits where the shading close to (Illegible Line] sections where the angle between the vectors $\vec{H}$ and $\vec{S}$ is close to 0 or π.

2) The error in determination of the actual orientation of the subject does not exceed 2-3° at the ends of the interval of processing, and 1-2° in the remaining portion of the orbit. This error was determined as the accuracy of coupling of the results of processing in adjacent intervals.

The angles $(\vec{H}_{meas}\hat{,} MH_{calculated})$ and $(\vec{S}_{meas}\hat{,} M\vec{S}_{calculated})$ between the measured directions of the vectors $\vec{H}$ and $\vec{S}$, and the calculated directions of the vectors $\vec{H}$ and $\vec{S}$ obtained as a result of statistical processing, do not exceed 1° in the majority of cases, and have a random nature.

3) The nature of the variations of the satellite in the orbital system of coordinates depends substantially on whether the examined orbit is shaded, or is fully illuminated. Shown in figure 2 are the graphs of the variations of the angles of yaw (θ_1), roll (θ_2) and pitch (θ_3) in four consecutive, fully -illuminated orbits. Shown in figures 3, 4 and 5 are the graphs of the variations of those same angles in 14 consecutive orbits with shading. The section of the shadow is noted with the dotted line. The origin of all of the graphs

corresponds to the moment of passage of the ascending angle. The geometric meaning of the angles θ_1, θ_2, and θ_3 is represented in figure 1.

As is evident from the given graphs, the amplitudes of the variations do not exceed 6° in the fully illuminated orbits, whereas in the orbits with shading, the variations in the angle of yaw may reach 20° with variations in roll and pitch within a 7° range.

Thus, in orbits with shading, greater deviations from the given orientation, according to the angle of yaw, are possible. This is evidently explained by the effect of the thermal flexure of the gravitational probe [3].

4) Analysis of the amplitudes at each harmonic for the angle of yaw shows that the fourth harmonic is usually decisive, and the calculation of the fifth harmonic is evidently optimal. /7

Further work with the described procedure will be conducted in the following areas:

a) overcoming of the difficulties for orbits with a great deal of shading;

b) the inclusion of the measurements of a star gauge, which can be installed on the AUOS.

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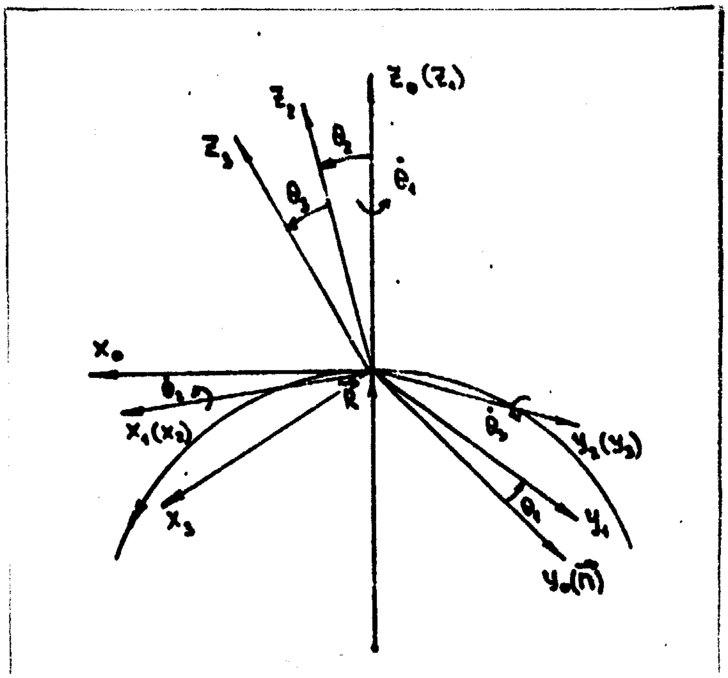


Fig. 1

x_0, y_0, z_0—orbital system of coordinates

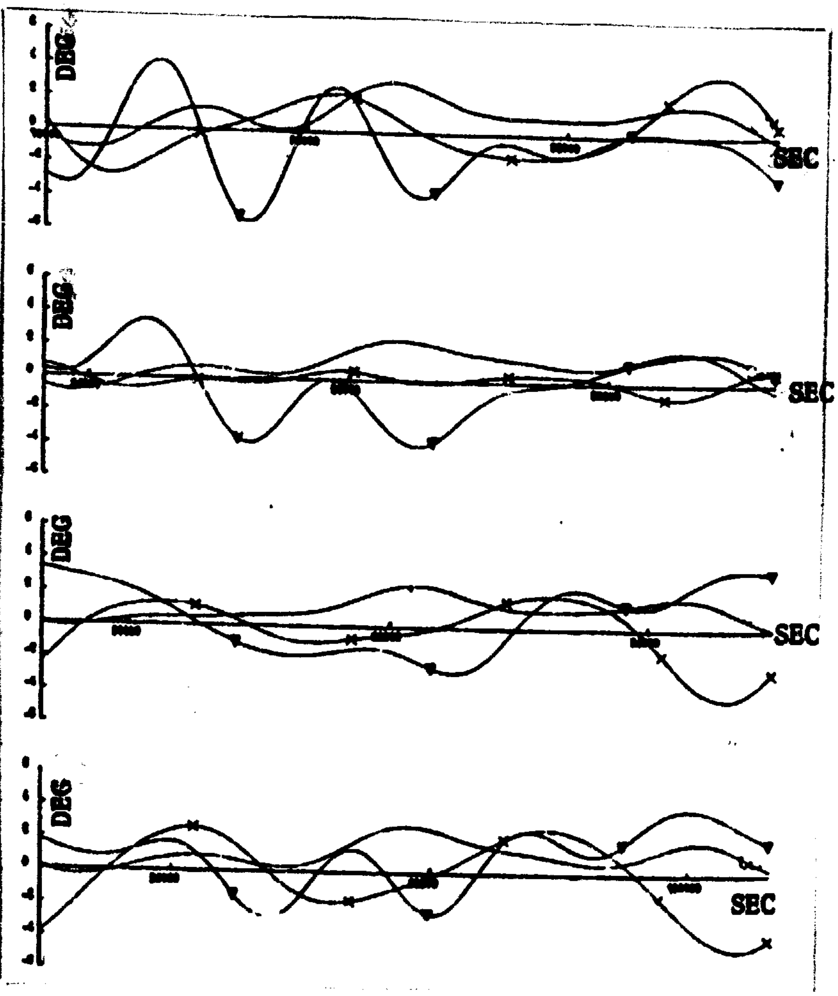
x_3, y_3, z_3—fixed system of coordinates

$\vec{R}$ —direction of Earth-artificial earth satellite

$\vec{h}$ —normal to the plane of the orbit

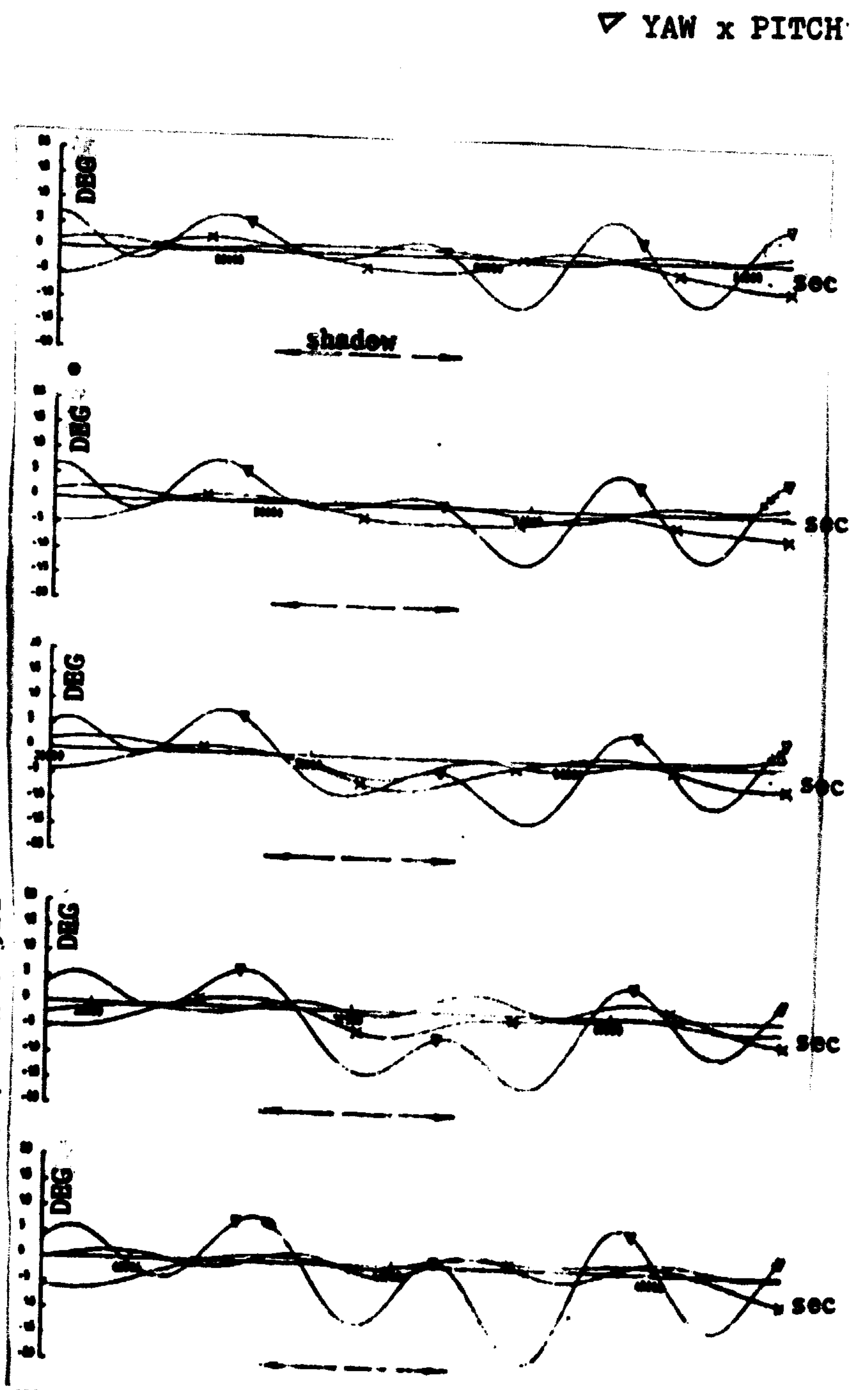
θ_1—yaw, θ_2—list, θ_3—pitch

▽ YAW x PITCH



"Interkosmos-17", Frame 38

Fig. 2



"Interkosmos-17", Frame 311

Fig. 3

▽ YAW x PITCH

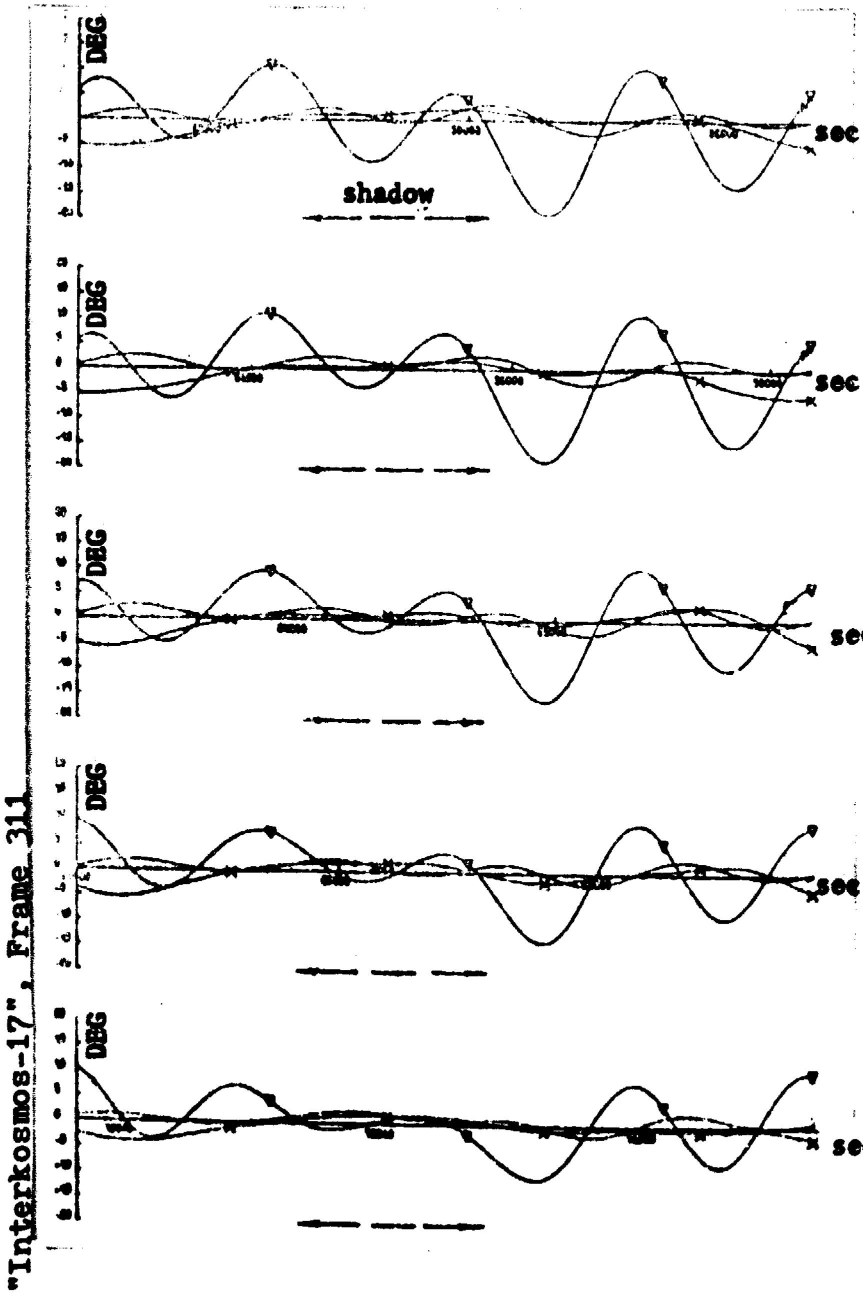
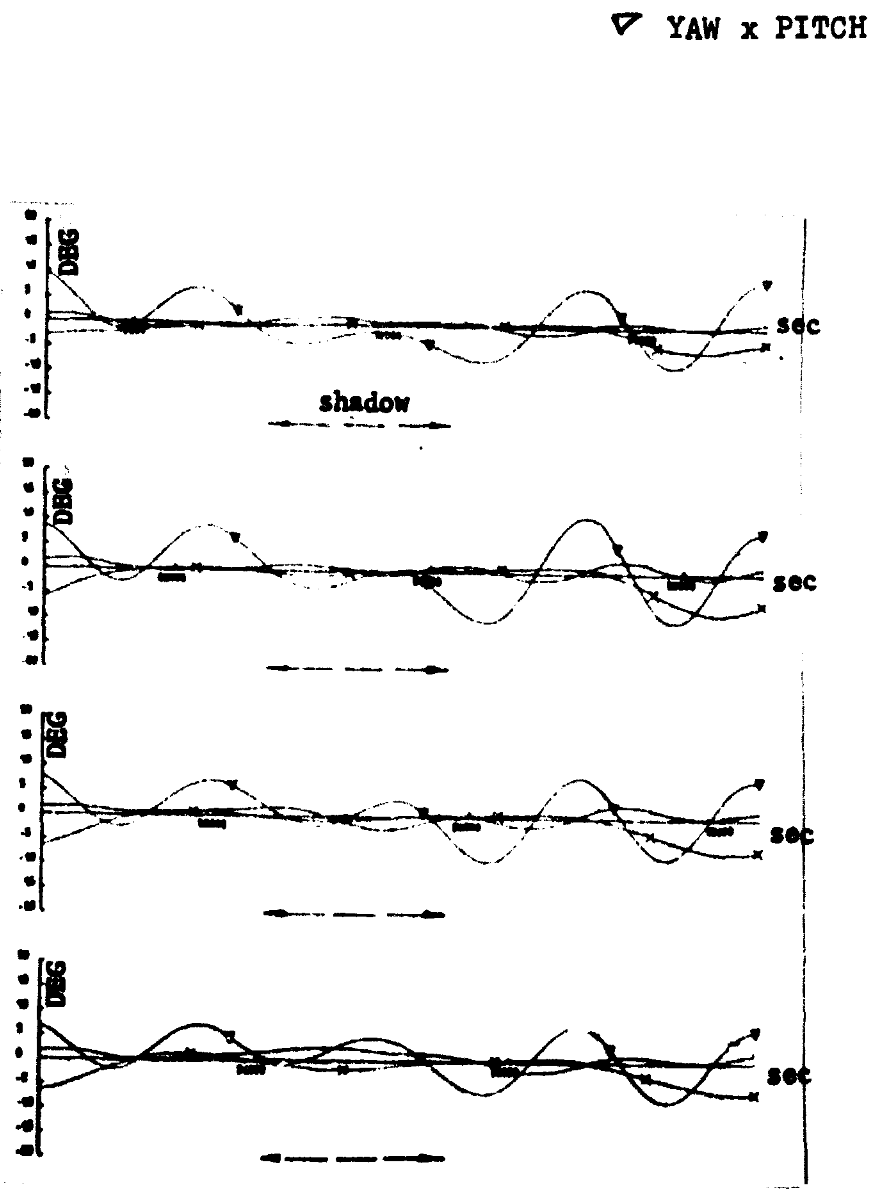


Fig. 4



"Interkosmos-17", Frame 311

Fig. 5