ATTITUDE CONTROL AND STABILIZATION SYSTEM FOR THE SCHOOL MICROSATELLITE

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ABSTRACT

Simple magneto-gravitational system (MGS) for the attitude control and stabilization of the School Scientific-Research Micro-Satellite (SSRMS) [1] is described. Using the MGS for the SSRMS is preferable due to several points. First, physical ideas lying in the base of this system are very simple to explain for students. Second, active magnetic stabilization systems are very effective and suitable for small satellites in comparison to active gas microengines because of their ions and gas production around the satellite and as a consequence creation of some interference to the scientific measurements. Third, the MGS can operate with use of power supply during a short time. Some technological characteristics of the MGS are discussed: angular range of the stabilization around the Earth’s-directional axes, precision, electromagnetic compatibility to other service and scientific systems of SSRMS, possible operation of such type of systems together with TV and optical equipment. Some separate exploration was made for the possibility of precise magnetic measurements on the micro-satellite, which is equipped with such system. As a result some processing procedures are described.

1. INTRODUCTION

The purpose of development the active MGS is the decision of the following tasks:

a) Orientation of a longitudinal axis Z of the micro-satellite (MS) along of local vertical with the given accuracy in orbital system of coordinates during all period of active existence MS at the stable or poorly disturbed atmosphere;

b) Study of dynamic characteristics of the experimental MGS in real flight on low orbits in conditions of the disturbed atmosphere and magnetosphere within the active Sun period with the purpose of further use in __ of the orbital stations, integrated in an infrastructure of the International Space Station (ISS);

c) Formation of the information about the functioning and processes of orientation MS for the subsequent transfer on telemetering channels on the Earth.

2. MGS MAIN PARAMETERS

After the decision of the listed tasks MGS should meet the next requirement - the deviation of the longitudinal axis _Z, connected with MS reference system, from the local vertical position should not exceed $(10 - 15)^0$ (in conditions "of the quiet Sun").

The ballistic characteristics of an orbit MS:

- Orbital period (91,3-93,4) min;
- Height of an orbit (380-420) km;

- Inclination of a plane of an orbit to a plane of equator $51,6^0$;
- The maximal time of a shadow on an orbit 36 min.

Initial angular velosities of MS after the launch on all three axes up to $0,3^0$/s, initial deviations from axes of the orbital reference system up to 2^0. MGS should be developed according to the requirements on nondisturbed movement of the MS mass centre, minimization of influences from the attitude control system on electrical and magnetic fields experiments, and also to exclude an opportunity of pollution at the functioning environmental MS of environment.

The basic tasks assigned on MGS, are reduced to stable orientation of the MS in orbital reference system at the low requirements to the dynamic and accuracy characteristics of the MGS.

Systems of orientation are using usualy the next external factors:

a) A gradient of a gravitational field of the Earth (on this basis the systems of gravitational orientation ensuring orientation MS along a local vertical in orbital reference system are constructed);

b) Pressure of residual gas, aerodynamic effects (on this basis the aerodynamic systems of orientations ensuring orientation MS along a vector of the orbital speed are constructed);

c) Solar pressure (on this basis the systems of MS orientation along a direction to the Sun are constructed);

d) A magnetic field of the Earth (on this basis the magnetic systems of orientations ensuring orientation MS along a vector of a geomagnetic field are constructed).

On the basis of use of the listed factors a lot of systems of orientation distinguished from other systems by simplicity (the small nomenclature of instrument structure), reliability, long service life, small or practically absent power supply and small cost are developed.

From attitude control systems using only the external factors, constant orientation MS in orbital reference system or along a local vertical, provide, as above , only gravitational systems. The opportunity of maintenance of such orientation MS during the practically unlimited time in a wide range of heights of orbits also is the basic advantage of gravitational attitude control system. As this orientation MS is most used, the similar type of systems have found in practice the greatest application.

The gravitational systems supply many spacecraft (SC). With use of similar systems the orientation both many perspective commercial and scientific small space vehicles started in last years is provided or which start is planned in a near future, for example such as: "Predvestnik" (Russia), "Sterkh" (Russia), UoSAT (England), PoSAT-1 (Portugal), TumgSAT (Malaysia), TMSAT (Thailand), Tsinghua-1 (China), ESAT (USA), OERSTED (Denmark), SunSAT (Southern Africa), MegSat-0 (Italy), Equator-S (Germany), etc.

The gravitational attitude control system , despite of its advantage in a part of an opportunity of maintenance by rather simple means orientation SC in orbital system of coordinates, has essential lack. This lack is connected to conservatism of a gravitational field of the Earth. In the absence of external or internal dispersion of energy the size of amplitude of fluctuations SC concerning a situation of balance does not vary with time and, hence, the accuracy of orientation is determined by the entry conditions, and at presence of the large revolting moments, for example from resistance of an atmosphere, because of small gravitational moments the transition of the SC to unguided chaotic rotation is probable. Some additional passive or active damping elements are used for dispersion of energy of SC fluctuations. First in comparison with second differ by complete absence power supply, but provide or worse dynamic and accuracy of the characteristic of gravitational system , or havy and are difficult in a design. A magnetic forcing system with electromagnets can be applied as active damping element. The electromagnets in comparison with others active damping elements, for example fluid dampers, have the most simple design, and, hence, high reliability. The results of preliminary study have shown that for damping of the SC fluctuations (for the first SSRMS – Russian-Australian “Kolibri-2000” [2]) the electromagnets with the magnetic moment of the order (0,1 - 0,2) Am^2

are required. Such devices, as shows experience of designing of electromagnets, can be designed with low level power supply (no more than 0,4 W).
For reduction or exception of influence of electromagnets on the scientific equipment the electromagnets can be designed as coils without cores. Such electromagnets have not the residual magnetic moment. Besides in MGS the mode of operations with the switched off electromagnets can be stipulated during some limited time.
Thus, as shows the analysis of possible(probable) architecture “Kolibri-2000” MGS, it should have the following instrument structure:

- Flux-gate magnetometr (FGM);
- Electromagnetic devices (EMD);
- The gravitational device (GD);
- The block of management (DWP).

3. MGS MODES OF OPERATION

For solving of the attitude control tasks, assigned to system, it should operate in the following modes:

- Mode of orbital orientation with damping (D-on);
- Mode of orbital orientation without damping (D-off);

The logic of functioning MGS can be described as follows. At the moment of a beginning GD development and MS separation from the ISS in the onboard equipment MS the switching of circuits of a feed DWP is made. After switching circuits of a feed in EMD is included D-on. From this moment, DWP in an independent mode on magnetometer signals with according to the given algorithms of management makes formations of signals of management EMD. The signals of management as voltage move on windings EMD, than the creation dampimg of the mechanical moments,decreasing angular fluctuations MS of a rather local vertical is provided. The mechanical moments focusing MS a rather local vertical, are created at the expense of interaction MS with a gravitational field of the Earth. At joint action focusing and damping of the moments on termination transients the given accuracy of orientation MS of a rather local vertical is provided (Figure 1). If necessary exceptions of influence EMD on the scientific equipment with DWP a feed is removed by switching-off in the onboard equipment of its trunks of a feed from a source of an onboard feed. If a feed with DWP is removed at a presence MS in oriented and damped position, this situation before MS revolution will be supported during 5-6 orbits (Figure 2). Such mode of functioning MGS is D-off mode. At the subsequent connection DWP to the onboard power supply the logic of functioning MGS is similar above described.

4. MGS DEVICES

4.1. Flux-gate magnetometer (FGM).

The FGM is intended for measurement two (on axes __ and __ of MS) orthogonal component of a vector of an induction of a magnetic field of the Earth (EMF) and distribution of signals proportional, measured components.
The FGM has the following basic characteristics:
a). range of measurement by everyone components (+/- 64000 nT);
b). output on everyone a component linear, analog, unipolar.

4.2. The gravitational device (GD).

The GD is intended for creation the distribution of inertia ensuring orientation MS in orbital reference system.
The GD has the following basic characteristics:

a). length of a gravitational boom 2 m;
b). time of boom disclosing near 3 s;
c). weight of a terminal cargo of 1,68 kg;
d). total weight of 2 kg;
e). condition of operation - open space.

4.3. The electromagnetic device (EMD).

The EMD is intended for formation of the magnetic moments, which, cooperating with EMF, create the dynamic managing moments concerning axes of system of coordinates connected with MS.
Structurally EMD is designed as the wires coil. EMD are established inside DWP. EMD has the following basic characteristics:
a). maximal magnetic moment (0,2 $A.m^2$);
b). maximal consumed capacity, no more than 0,4 W;
c). condition of operation - open space.

4.4. The block of management (DWP).

DWP represents the electronic device intended for realization of algorithms of management MGS and formation according to them of signals of management EMD. The disclosing of a gravitational bar GD and FGM inclusion is provided with means of the equipment MS.

5. CONCLUSION.

The non-profit Inter-Region Public Organisation "Union of specialists and youth for scientific-technological creation in space technology - Micro-Satellite" (IRPO "MICRO-SATELLITE", micro@iki.rssi.ru) designs and creates SSRMS. It involves the youth of Russia and other countries (learning schools and other educational institutions) in learning and assimilation of modern technologies in the field of research and use of Near Earth Space. The IRPO activity is based on the realisation of concrete projects on building, launching into orbit and then operating micro-satellites equipped with various scientific devices that allow the youth to carry out scientific research work and to introduce them to the procedures of fundamental scientific work. In essence, such micro-satellites are built using modern technologies and are capable of carrying-out a few of the scientific missions normally performed by larger and much more expensive space vehicles.

6. REFERENCES

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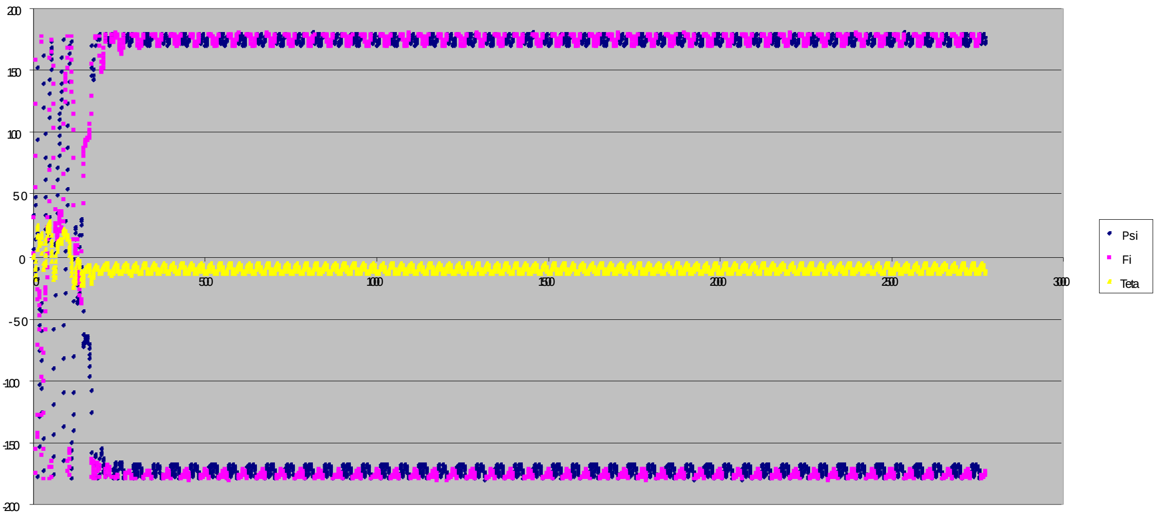

Figure 1. Psi – yaw, Fi – roll, Teta – pitch.

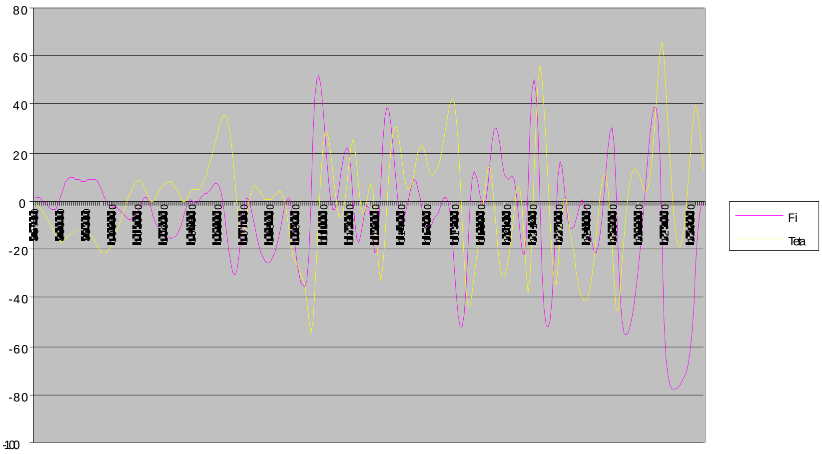

Figure 2. Fi – roll, Teta – pitch.