3.5 - SMALL SPATIAL BUOY - NANOSATELLITE - ON INTERNATIONAL SPACE STATION FOR ENVIRONMENT INVESTIGATION

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Abstract - A set of active experiments onboard MIR and STS-3 experiments onboard Space Shuttle showed the existence of local wakes and turbulence, sometimes provoked as plasma heating and luminescence etc. Active processes onboard MIR, because of non-homogeneous surface conductivity, created local anomalous charges and high EM noises. Also, it is important to find the places and spaces along international space station (ISS) with minimal noise/charge level for installation of scientific equipment. To fulfill these goals the automatic mini-buoys or nano-satellites will be designed, having full autonomy and short-distance telemetry. Both fixed to the ISS surface, free floating and tethered operation modes will be foreseen.

Besides this, when such a satellite is floating freely near the ISS it could give valuable information on the meridional currents flowing in the equatorial ionosphere earlier detected only at dusk time by MAGSAT satellite in 1979-80.

1.Introduction - The ISS is planned to be designed and manufactured by a wide international community. It certainly will be still more important to take into account the influence of electromagnetic situation around the station on its electronic, biological and mechanical systems. Until now, the reaction of non-conductive and semi-conductive surfaces of different constructional materials upon space particles bombardment in the presence of sharply non-homogeneous electric and magnetic fields and currents is not clear.

Besides technological goals, there is very important to monitor electric and magnetic fields in the ionosphere for solving of a set of scientific and applied problems. It will be an important observation point for space weather study and forecast.

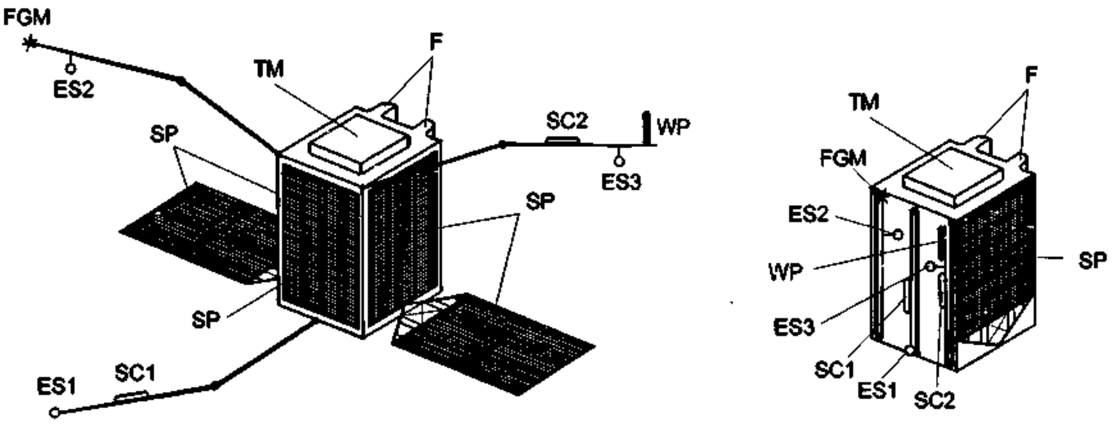
It is necessary to mention that the developed at early stages of space investigations, conception of unique solitary experiments on spacecrafts launched in determined regions of near-earth space is now practically settled - no new results for fundamental physics development can be expected. The qualitative progress in our understanding of space processes could be obtained mainly with the help of regular study both in space and on the Earth during long period, at least of about one cycle of solar activity (11 years). The realization of the proposed project will make considerable input to such a study. Using the opportunity of ISS crew periodical coming out of Station, the search of both places-indicators of anomalous behavior and places with minimal level of interferences for monitoring system installation could be executed.

2. Realization Methodology and Approach - The realization of the electromagnetic monitoring in the ISS environment needs both the development of methodology of observation and the design of corresponding experimental equipment.

The methodology of electric and magnetic measurements aboard spacecrafts was developed intensely at early stages of space investigations [1-3], also with input of the author of the present paper [4-6]. But, some theoretical problems connected with super-large bodies interaction with space plasma, charges and noises estimation, influence of active experiments still wait their investigation.

As a result of preliminary study and taking into account new possibilities of manned spacecraft a new conception of ISS equipment by space buoys or nano-satellites is proposed. This conception includes the development of super-small (about 10 kg) fully autonomous measuring systems each of which will have following facilities (Fig.1):

- flux-gate magnetometer (FGM);
- search-coil magnetometers (SC);
- wave probe (WP);
- electric sensors (ES);
- autonomous power supply (solar panels (SP) and inner long-term battery);
- short-range telemetry (TM);
- manually deployed booms;
- one-side fixator (F).



a) Deployed b) Stowed

Fig.1. Nanosatellite sketch

In the stowed position such nano-satellite (NS) will take very few place (Fig.1,b) and could be easily delivered to ISS as piggy-back cargo. Then the ISS crew will go outside, the NS using special fixator F can be placed at any convenient place on the ISS surface. Its booms will be manually deployed and side SP properly oriented by the operator. Then the NS operation can be controlled from inside ISS control station using short-range TM. A set of such NS along and across the ISS will give spatial structure of ISS electromagnetic environment and will allow to find proper places for its monitoring. For this the NS have to be as cheap as possible and convenient in use. An optimistic estimation of both price and weight of NS is based on already existing achievements, both in the structure construction and scientific payload.

The NS structure is planned to be designed as miniaturized copy of micro-satellite structure [7]. It will be still simplified because neither orientation system nor automatic booms deployment system are needed. Preliminary estimation of total weight of all service structure in such conditions gives about 6 kg including 3 two-sections booms of total length about 1 m each and lithium battery.

The scientific payload composed from FGM sensor, 3 ES, 2 SC, 1 WP and electronics also is expected to be enough light and low powered. The sensors weight estimation together with their sensitivities based on present state of development is given in Table 1.

The electronics is supposed to have the weight about 2 kg and power consumption about 2 W.

Table 1. Scientific Payload Proposed for ENVIRONMENT project

1	Device	Measurement	Weight
1.	Wave probe WZ	Electric current density **J**: Frequency range 0.1 Hz ... 40 kHz, Noise 10^{-12} A/cm^{2}Hz$^{1/2}$ Magnetic field **B**: Frequency range 0.1 Hz ... 40 kHz Noise 10^{-13} T/Hz$^{1/2}$ Electric potential φ: Frequency range 0.1 Hz ... 40 kHz Noise 10^{-6} V/Hz$^{1/2}$	240 gr
2.	Electric probe ES	Electric field **E**: Frequency range 0.1 Hz ... 200 kHz Noise 10^{-6} V/Hz$^{1/2}$	120 gr
3.	Flux-gate magnetometer FGM	Frequency range DC - 20 Hz Noise 10^{-11} T	36 gr
4.	Search-coil magnetometer SC	Frequency range 10 Hz...200 kHz Noise 10^{-14} T/Hz$^{1/2}$	110 gr

The short-range TM can be developed using the principles of already existing systems. The simplest realization can be based on cellular phone technology.

All this makes the possibility of small low-price NS creation very optimistic. For the following steps it is planned to complement NS by star imager [8] and use them in tethered or free floating around ISS versions. Then, the detailed structure of ISS electromagnetic environment can be constructed and monitored. By this, the tiny and low-noise NS will allow to realize full sensitivity of scientific instrumentation what is extremely important for the detailed study of microscale formations in ionosphere.

Using star imager, a «puppet-on-the-string» conception easily can be realized. Having permanently exact knowledge of the NS orientation with the error less than 5seconds of the arc by all three components [8], an Euler transformation can be used in order to reduce data collected in the arbitrary oriented NS frame to the reference frame. It is known that any rotation in three-dimensional space can be presented as the rotation L at angle δ around fixed axis $\bar{m}_0$ passing through the beginning of the frame [9]:

$$L\,\bar{r} = \bar{r}' = \bar{r}\cos\delta + \bar{m}_0(\bar{m}_0\,\bar{r})(1-\cos\delta) + [\bar{m}_0\,\bar{r}]\sin\delta, \qquad (1)$$

where L is rotation operator, $\bar{m}_0$ - rotation axis ort, $\bar{r}$, $\bar{r}'$ -- initial and final vector positions. Using standard substitution [9]:

$$m = \bar{m}_0 \mathrm{tg}(0{,}5\delta), \qquad (2)$$

where $\bar{m}_0 = \bar{m}|\bar{m}|^{-1}$ it is possible to rewrite (1) in the form:

$$L\,\bar{r} = \bar{r}' = (1+|m|^2)^{-1}\{\bar{r}(1-|m|^2) + 2\,\bar{m}(\bar{m}\,\bar{r}) + 2[\bar{m}\,\bar{r}]\} \qquad (3)$$

This rotation can be expanded in terms of two rotations with mutually orthogonal vectors $\bar{m}_1$ and $\bar{m}_2$ (Fig. 2) and can be presented with the help of Euler angles φ, ψ, θ. It is easy to show that having simultaneously the measurements of three components of any physical vector in the x, y, z randomly turned frame, we can always calculate the components of this vector in the x^1, y^1, z^1 reference frame.

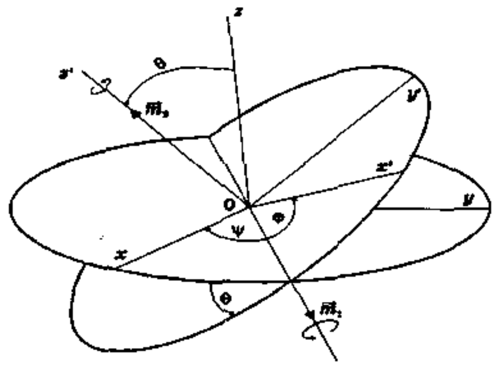


Fig.2. Euler transformation

3. Conclusion - The nanosatellites development stimulates further progress in the space study. First, NS are much cheaper both in the construction and launch. Second, they allow to create a pattern-type space structure, though for some fixed time, able to solve one of the most challenging tasks: to study small-scale effects and wave-particle interactions, to separatee spatial and temporal fluctuations and to realize very low sensitivity threshold of physical sensors. The new investigation strategy could be realized. First, it is the launch of one basic satellite with as much as necessary piggy-back autonomous NS. Then the NS following given procedure will be separated one by one or all together forming a swarm of free-floating subsatellites gradually moving away from the basic satellite. Each NS, having a star imager, realizes «lost-in-the-space» conception and will not need an orientation system. A short-range telemetry of the type of cellular phone will allow first to transmit all collected data to the basic satellite and then to the Earth. Further when a world communication system (like Global Star) will be deployed a direct telemetry to the Earth could be realized.

4. References

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