ON-ORBIT EXPERIMENTS AND RESEARCH ON MEASURING THE SPACECRAFT CHARGING

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Introduction

Lavochkin Association is one of the leading enterprises in Russia for about forty years, having specialized in the field of design and manufacturing of tools for orbital injection of payloads and automatic vehicles to further study the solar-earth relationships, the Moon, small heavenly bodies and planets of the solar system.

A long-term experience of the Association in the field of space engineering also includes the development of anti-charging protection tools for s/c. This protection is achieved by means of bonding and screening. Originally, two flight experiments on measuring the surface of the s/c charging have been initiated in 2002 and thereafter continued.

The purpose of these experiments is as follows:

- Receiving the data on relationship between s/c charging and operational capability of its systems;
- Obtaining the experimental data about specific parameters of the charging;
- Study of the regularities of the charging process.

Onboard Measurement Equipment.

"Zond-Zaryad" equipment, which is analogous to the one that has been installed on "Mir" station (1), has been used for these experiments. The characteristic feature of this equipment and the experiment in general is the capability to monitor continuously the s/c parameters in orbit. Such capability is reached through the presence of the monitoring equipment that continuously accumulates and stores the information and, then, transmits it to the Earth during communication sessions. The information entry phase is approximately 40 seconds. There is also a capability for data direct transmission into the telemetry system. In this case, the frequency of the sensors inquiry is up to 200 Hz.

The following parameters have been measured:

- electrostatic field;
- Variable electric field;
- Current on a sensor.

The quasistatic electric field is measured by the sensors of vibrational type (electric field frequency modification is up to 10 Hz). The principle of sensors' operation is similar to the one described in (2). The measurement range is approximately:

- ±350 kV/m – in case of direct data transmission into the telemetry system of the s/c;
- ±6 kV/m – in case when the values are entered into sensor's own storage device (the variance in measurement ranges is connected with potential of the memory storage device and limitations to the volume of the information that can be transmitted).

A variable electrostatic field is measured over the frequency range up to 2000 Hz. The amplitude of the variable field is up to 1.5 kV/min. This parameter is recorded only onto the own memory device. It is the maximum value, which occurs during the measurement (period), that is measured in the course of experiment.

The current on a sensor is in the range of ±1.5 nA/sm^2.

Orbit Parameters and S/C Attitude Control Modes.

The s/c for optic-electronic observation "ARCON-1" (international label -2002-037A) has been launched into orbit on July 25, 2003 with the following parameters:

Perigee altitude – 1513.8 km;
Apogee altitude – 1841.7 km;
Obliquity – 63.46º;
Orbit time – 119.89 min.
Later, the orbit of the space craft did not undergo any considerable modifications (3).
The exterior of this s/c is pictured on fig. 1.

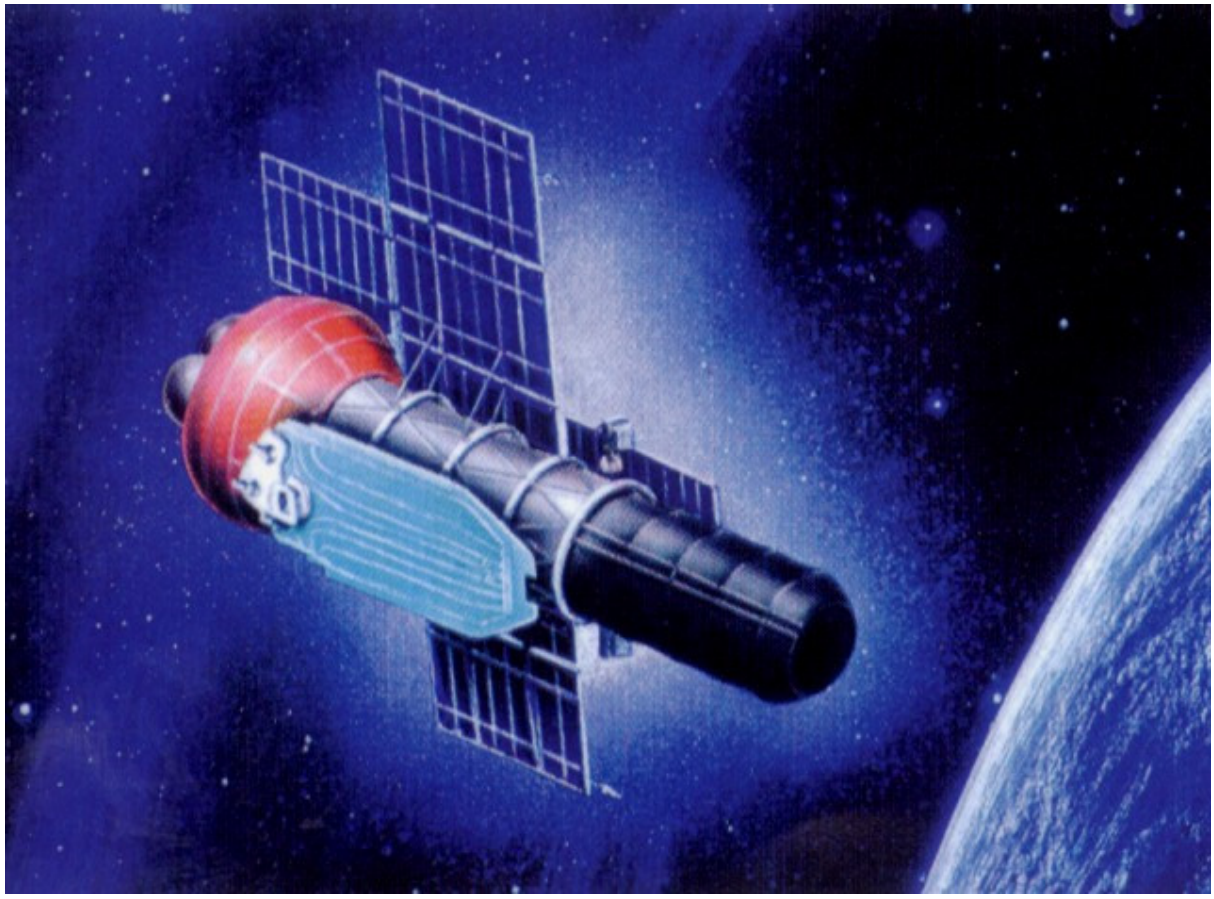


Figure 1.

The s/c "Cosmos - 2393" (international label - 2002-059A) has been launched into orbit on December, 24, 2002 in the interests of the Ministry of Defense of the Russian Federation with the following parameters:

Perigee altitude - 523 km;
Apogee altitude - 39067 km;
Obliquity – 62.83º;
Orbit time – 702.34 min (4)
The exterior of this s/c is pictures on fig. 2.

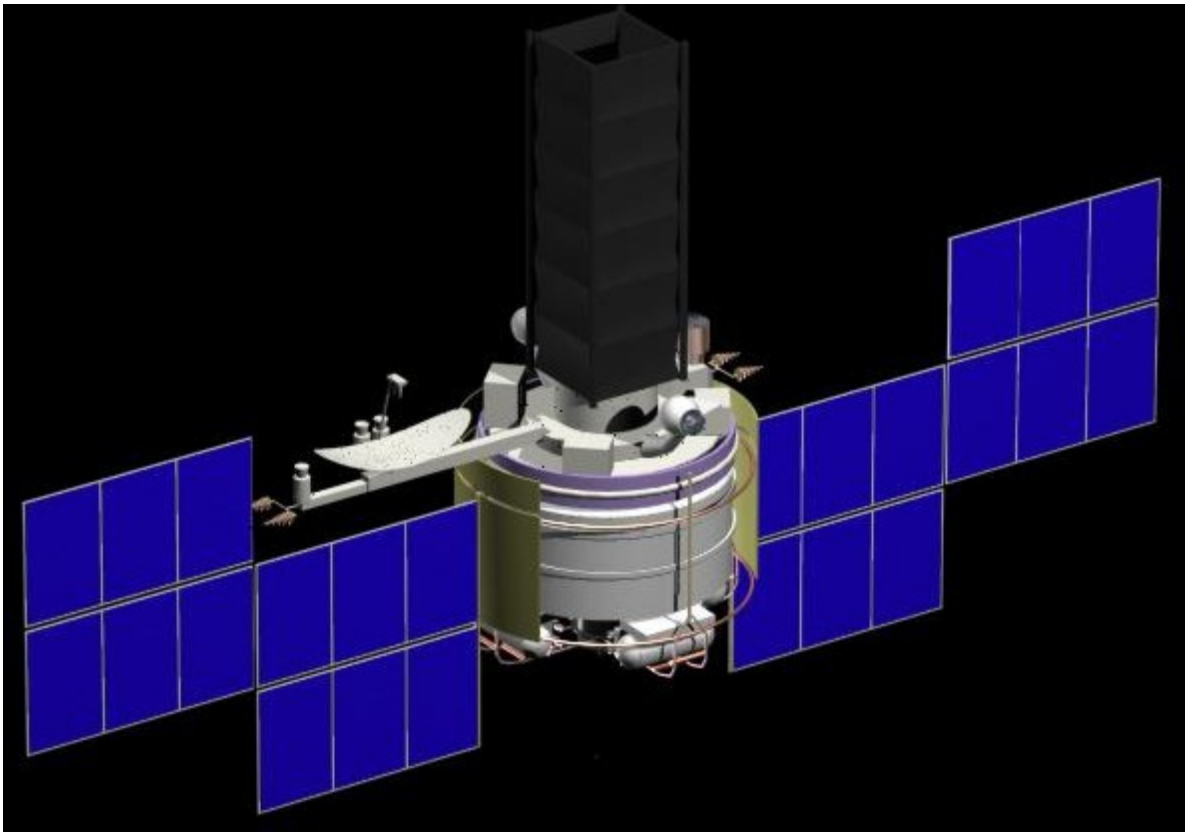


Figure 2.

Installation of the Measuring Equipment on the S/C

The following criteria were considered for selecting of the installation points for the sensors on the surface of the space craft:

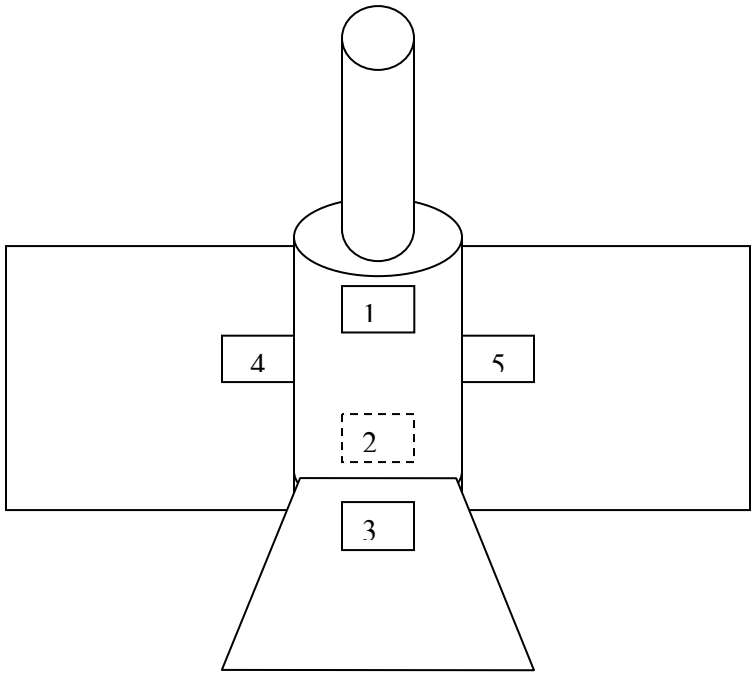
- Lack of small parts of the s/c located near the sensors;
- Sensors should be located at the spots that differ from each other in the view of the exterior factors effecting these placement spots;
- Devices that could be potential subjects to the charging effect should preferably be located near the sensors.

The fulfillment of these requirements at installating the sensors should enable to use the data received in the process of measuring both directly – by estimating the relationship between the s/c charging and the malfunctions of the certain airborne systems, and indirectly - by estimating the s/c charging in general (including the use of mathematical modeling).

"ARCON-1" is the s/c operating on LEO and equipped with five sensors, thus measuring all three parameters listed above (part 1). The setting spots of the sensors on the s/c surface are indicated on Scheme 1.

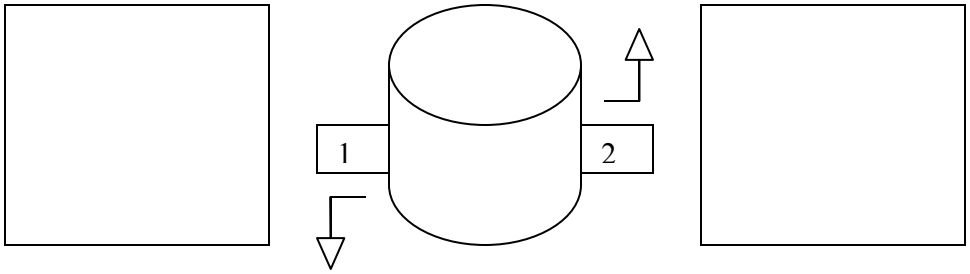
Sensor #2 is placed under the back panel of the solar battery at the distance of about 100 mm from its edge. The axes of sensitivity of all sensors are directed by a normal line from the body of the s/c.

Such placement of the sensors allows measuring the following characteristics of the s/c charging:



Scheme 1

- Difference in charging characteristics of the diametrically opposite panels of the s/c body through indications of sensors #4 and #5 (that is similar to the "Kvant" module of "Mir" station);
- Currents on a sensors from three different directions (sensors #4, #5 and #1);
- Effect of the s/c structural elements on the measured parameters under the condition of equal orientation of the sensors axes (sensors #1 and #3);
- Charging of the solar battery back panel.
- Operating in high-elliptical orbit “Molniya” s/c is equipped with two sensors (setting points for the sensors are indicated on Scheme 2).



Scheme 2

A diametrically opposite placement of sensors allows measuring of specific characteristics of the s/c charging connected with the following factors effects:

- Level of illuminance of the s/c opposite panels;
- Vector of the s/c linear velocity.

Findings

At present, connection between the measured parameters and malfunctions in operation of airborne systems is not detected.

Data was obtained during one year of measurement in LEO and approximately 6 months of measurement experiments in "Molnya" orbit.

As the result of this measurement, we determined the following:

- Regular changes of electrostatic fields has the average range of ±3 kV/m;
- Maximum values of stationary values of electrostatic fields range from -14 kV/m up to 4.3 kV/m for "Cosmos-2393" space craft and from -5.9 kV/m up to 4 kV/m for "ARCON-1" space craft;
- Tension of the electrostatic field measured by sensors located under the solar battery of s/c "ARCON-1" has predominately a positive polarity;
- On "ARCON-1" s/c, the maximum values are observed both on separate sensors and on several sensors simultaneously. These values have equal polarity;
- Variable electric fields are within the limits of 1.5 kV/m (measuring limit of sensors);
- Currents on sensor are ±1.5 nA/sm2 (measuring limit of sensors). For "ARCON-1" space craft, a period of time during which these values were fixed, is, as a rule, no more than tens seconds. For "Cosmos-2393" s/c, this time can reach several hours.

Due to the great volume of data, on analysis of the relationship between measured parameters of the s/c charging and exterior conditions has been performed mostly for "ARCON-1" s/c.

In the observed time periods, we found the following regularities:

For "ARCON-1" s/c:

- Variable electric fields have major intensity on the irradiated segments of the s/c orbit and are observed at the entrance/exit of the s/c from the shadow of the Earth. In the shadow of the Earth, the intensity of variable electric fields is rather insignificant (fig.3);
- Maximums of the constant electric field fall in the auroral areas of the magnetosphere. In some cases, the values of up to -5.9 kV/m (the measuring limit of the sensors) were observed. During the period of time from May 07, 2003 till May 09, 2003, in all six cases, the maximum values have been registered when the s/c was in auroral areas of the magnetosphere of the Earth. At the same time, the maximum values have not been registered at each and every time when the s/c was located in these areas (fig. 4).
- There is a relationship between the intensity of variable electric fields (frequency of ignition and amplitude) and the attitude control mode of the space craft. Curve 1, depicted on fig.5, reflects the mean value of the variable electric field registered during one orbit by five sensors; Curve 2 reflects an approximate time unit when the s/c changed its orientation.
- In order to estimate the geomagnetic activity, we have used index Kp and index of avroral activity, obtained through analyzing the data received by one of the "POES" s/c. These data have been retrieved from http://www.sec.noaa.gov. Fig.3 and Fig. 4 shows these values for the time period from May 7, 2003 to May 9, 2003. It allows us to draw a conclusion, that these indices do not directly influence the parameters

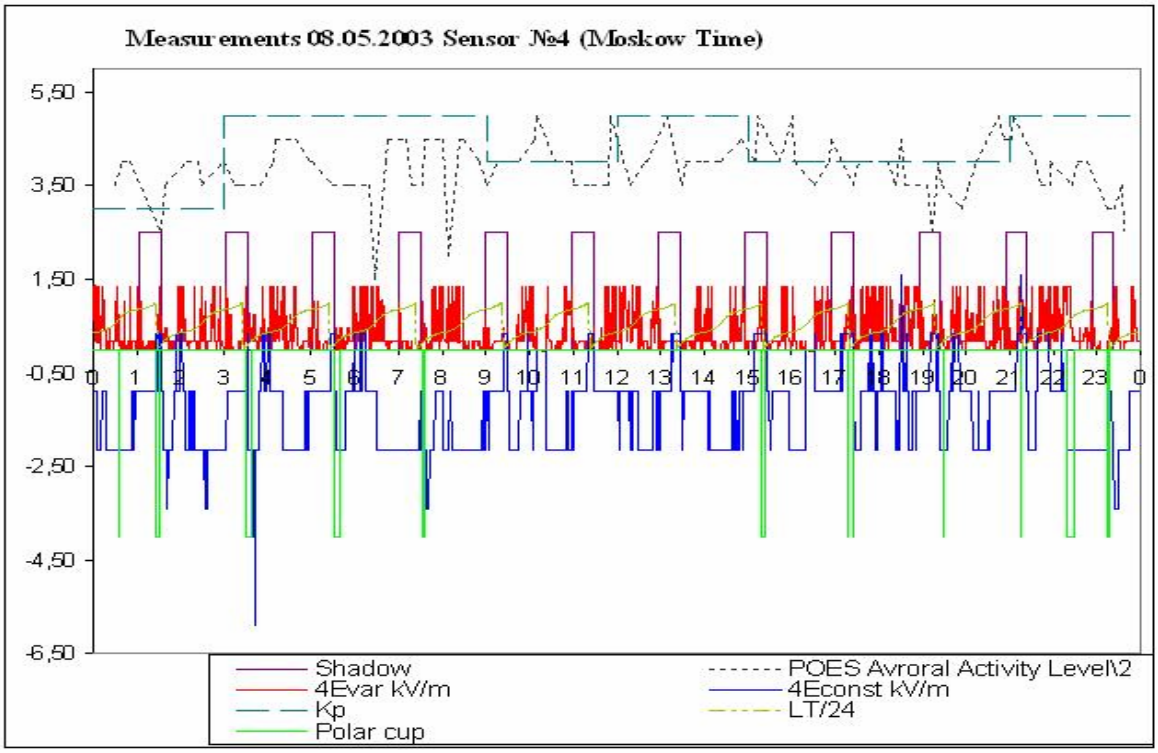


Figure 3.

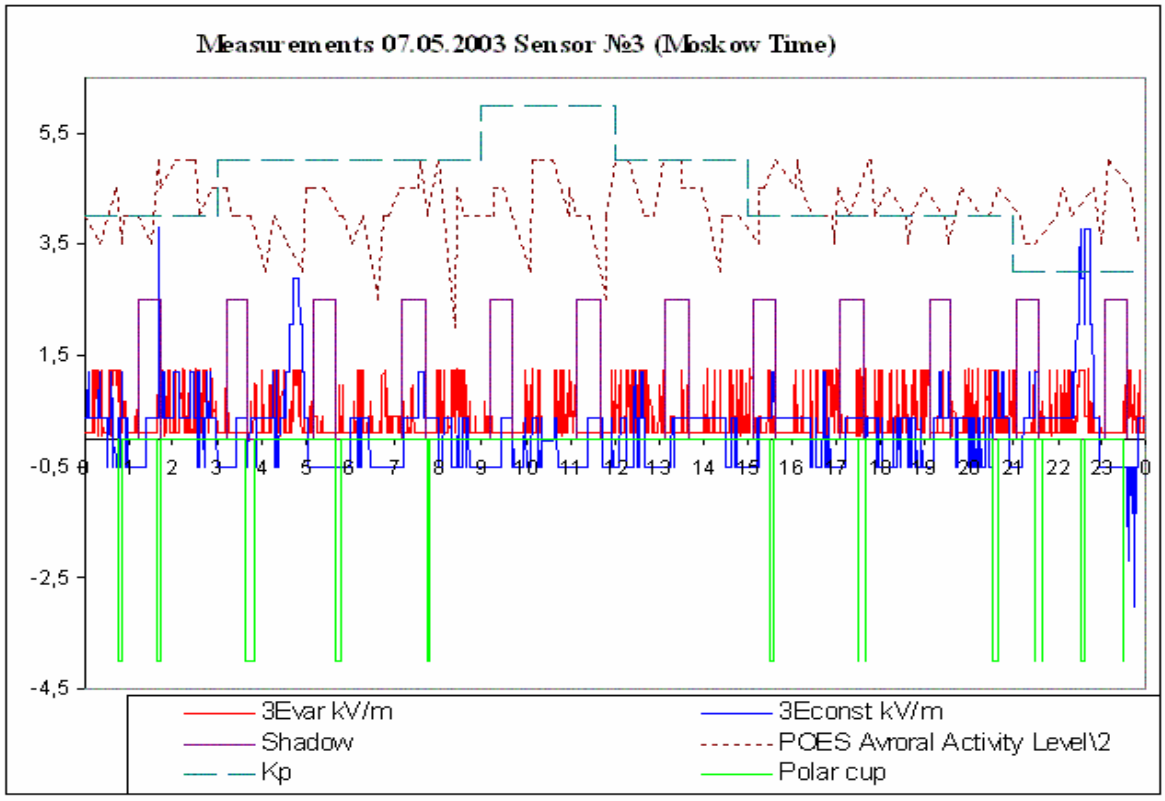


Figure 4.

of the s/c charging. It might be necessary to consider a hypothesis, offered in the paper cited as (2), that there is a time detrusion between the disturbances of the magnetosphere and the s/c charging.

- A sensor that has been covered by the bonding part of the s/c for several weeks did not show any fluctuations of any of the measured parameters during all this time. It proves both that the protective quality of the s/c construction elements is really high and the parameters measured are indeed bound up with the environmental effects.

The very first estimates for the "Cosmos-2393" s/c are as follows:

- There is an essential difference in the values of all three measured parameters, indicated by the sensors that were installed on the irradiated and the shadow panels of the s/c (Fig. 6). In particular, the current on a sensor was about -1.5 nA/sm2 when the sensor was installed on the irradiated panel of the s/c, while the electrostatic field of -3.5 kV/m (a measuring limit of sensors) has been registered by the sensor installed in the shadow panel of the s/c during several consecutive hours;

- There is a relationship between measured parameters of the s/c charging and the s/c position in orbit from perigee to apogee. On Fig. 6, the perigee values are 9.00 and 21.00 and apogee value is 15.00 (Moscow time);
- The maximum value of electrostatic field (-14 kV/m) has been registered in the period of low geomagnetic activity (Kp=3).

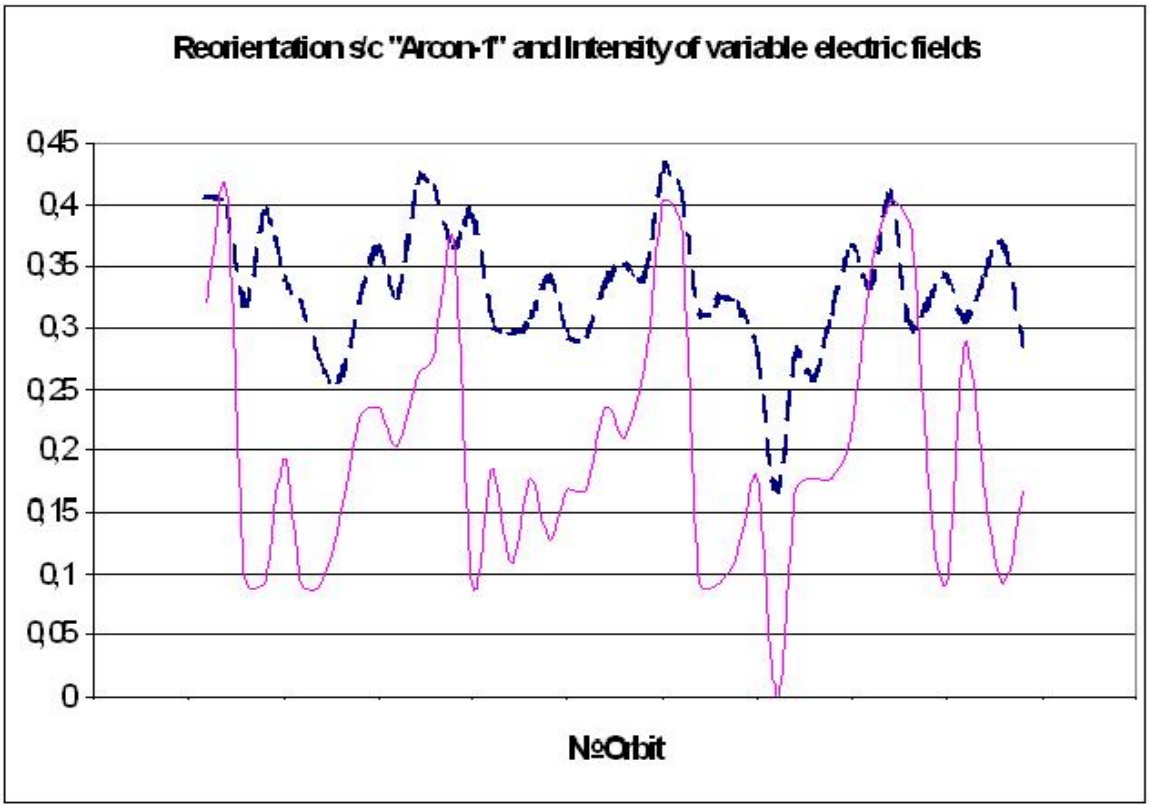


Figure 5.

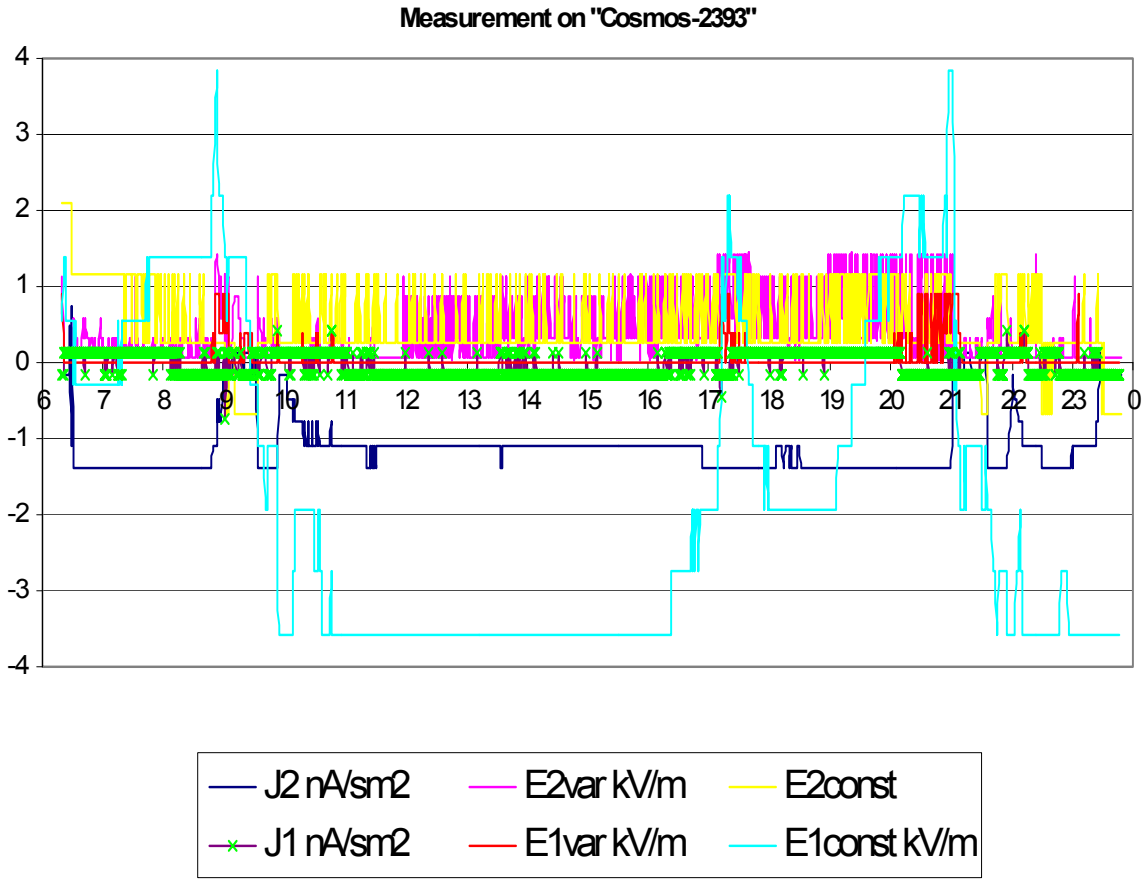


Figure 6.

Conclusion

In general, the experimental data obtained at the present stage of research corresponds with the basic theoretical knowledge about the s/c charging in the Earth orbit. In particular, it is true for the orbit with an altitude of 1500-1800 km and an obliquity of 63º:

- S/c absolute and differential charging up to potential values of several kV is observed;
- Intensity of variable electric fields is influenced by the s/c rotation (the difference is roughly two times) and by the illuminance level of the s/c surface;
- Maximum values of electrostatic field (up to-5.9 κB) are observed in the auroral areas of Earth magnetosphere.

Lack of connection between parameters of the s/c charging and the malfunctions of airborne systems that is currently observed, most likely, indicates the effectiveness of today's anti-charging protection measures.

In order to obtain more statistically reliable experimental data and discover new regularities in s/c charging, we will continue our analysis of the available and new information.

Lavochkin Association is open for cooperation with all organizations interested in any aspects ofthe s/c charging problem (i.e. simulation, protect, ground tests, flight experiments, etc.). Thus, Lavochkin Association has great capabilities to conduct flight experiments of different degrees of complexity and develop and manufacture special experimental s/c that can use the equipment provided by the customer.

References

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