LOWFREQUENCY ELECTRIC FIELD MEASUREMENT PROBES ON BOARD INTERCOSMOS - 24 - AKTIVEN SATELLITE

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On 30 September 1989, from the Plesetsk launching site, the Intercosmos - 24 - AKTIVEN satellite was launched, with the following orbital parameters: apogee 2500 km, perigee 530 km, and orbital inclination 82.2^o. The AKTIVEN Project envisaged measuring the parameters of undisturbed plasma and the characteristics of perturbations in the surrounding plasma caused by the actual impact on it from board of satellite. On board the major satellite, a powerful low-frequency transmitter with major frequency 9.8 kHz was installed, along with a neutral-gas injector: xenone. The spatial-time characteristics of the perturbated area were studied by the satellite-sub-satellite system (including space apparata IK-24 and MAGION-2) whereas the distance between them could be partially controlled. The scientific equipment comprised a complex for measuring low-frequency electric field consisting of the devices: NVK-ONCh, ONCh-2, and ShASh. Six identical probes designed at the Space Research Institute (SRI) of the Bulgarian Academy of Sciences (BAS) acquired the input signal to all devices within the complex. The probes included sensitive elements - spheres with glass-carbon cover interacting with the surrounding plasma, and an input electronic block mounted within the spheres. To provide basis for comparison of the results, the similar electromagnetic wave complex KEM-1 on MAGION-2 satellite was furnished with probes with the same sensitive spherical elements designed and worked out in SRI - BAS.

Introduction

The spherical form of the probes' sensitive elements is used in various devices for measuring electric fields on satellites, rockets, and balloons. A comprehensive theoretical study of the requirements and limitations for their use is provided in [1]. In the same work, the use of probes with carbon cover is thoroughly substantiated. A study of this type of probes operation in measuring the quasi-constant electric fields (DC), and alternating electric fields (AC) is provided in [5-11], whereas a large amount of experimental data for the operation of the satellites Injun-5, OGO-6, GEOS 1, GEOS 2, DE-A, DE-B, S3-3, and ISEE 1 is used. In accordance with the scientific program of the AKTIVEN Space Project, the requirement was set for the electric field to be measured within a wide frequency range: from 5Hz to 25kHz for the satellite, and from 0.01Hz to 100kHz for the sub-satellite. This presented serious requirements to the probes, too - to their surface qualities and to their structure. In the paper, some characteristics of the probes used on board of the Intercosmos 24 - AKTIVEN satellite are discussed.

Measurement Technique and Requirements to the Probes

The devices NVK-ONCh, ONCh-2 and ShASh measured the electric field using the double-probe technique [1]. In this case, the input signal to the electronic blocks is given by expression (1):

$$\Delta U = \frac{\vec{E}'.\vec{d} + (V_1 - V_2) + (WF_1 - WF_2)}{1 + R_1 / R + R_2 / R} \qquad (1)$$

where E is the electric field in satellite coordinate system, d is the distance between the spheres' centers, V_1 is the potential difference between sphere 1 and the surrounding plasma with infinite input impedance, V_2 is the potential difference between sphere 2 and the surrounding plasma with infinite input impedance, WF_1 is the work function for sphere 1, and WF_2 is the work function for sphere 2, R is the input resistance of the preamplifier, and R_i $(i = 1,2)$ is the resistance of the plasma layer surrounding probes 1 and 2. Quantities V_1 and V_2 depend on plasma temperature T and concentration N at the measurement site; they change along the orbit and, generally, are difficult to determine. The targeted accuracy of measurement can be achieved by minimization of expression V_1 - V_2., i.e. by provision of the best possible conditions for location, operation and identity of the probes. For this reason, as sensitive elements, glass-carbon spheres were used featuring maximum symmetry. The probes were located at the far end of the rods projecting in front of the satellite and symmetrical to its velocity vector.

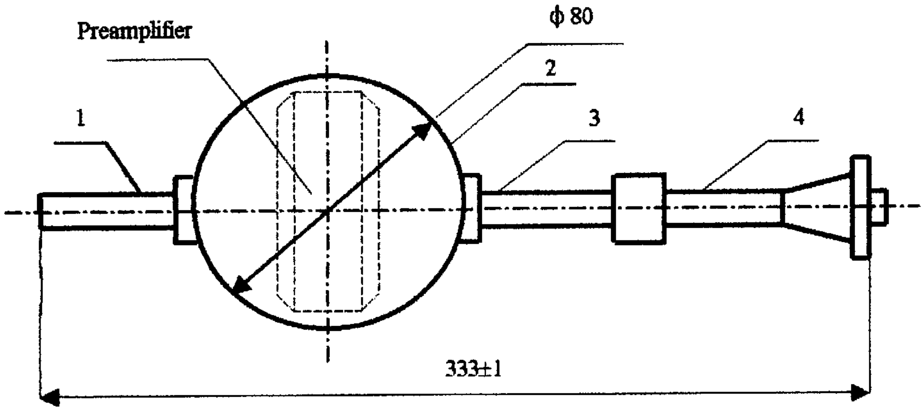

Fig. 1

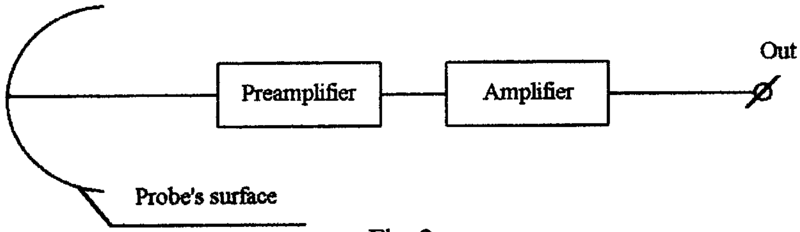

Fig. 2

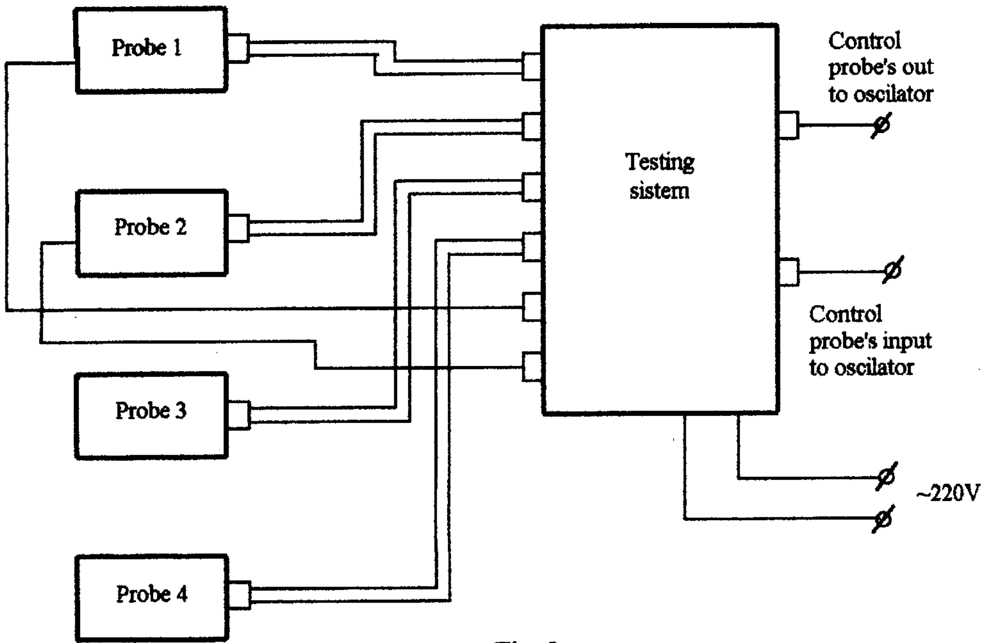

Fig. 3

The outer appearance of the probes is shown in Fig.1 where the notifications are as follows: symmetry axis (1), spherical sensitive element (2), bearing axis (3), antiphotoelectron axis (4), preamplifier (5).

The spherical irregularity of the sensitive elements of the probes influences the value of V thus producing systematic error. For this reason, special measures were taken to maximally reduce spherical irregularity. The results from the performed measurements revealed that spherical irregularity does not exceed 0.04 mm for each sphere.

The length of the bearing and symmetry axes is $L = 2r$ =80mm where r is the sphere's radius. The bearing and symmetry axes are electrically isolated from the collecting surface but their potential is equal to the sphere's potential. This provides for greater symmetry in the distribution of the electric potential in the probe-surrounding plasma. The symmetry axis aims to provide equal shading of the probe's collecting surface with different orientation of the satellite with respect to the sun.

The length of the antiphotoelectron axis is $L = 2r$ =80mm. It is also isolated from the other parts of the probes but its potential is strongly negative, about 10 V. As a result of this, it stops the photoelectrons that have left the satellite' surface, so the useful signal is determined mainly by the parameters of the surrounding plasma.

These structural features were selected to minimize the second term in expression (1) $(WF_1\text{-}WF_2)$.

For the purpose, the spheres' surface was covered by glass-like carbon produced by a technology developed at BAS particularly for electrical field measuring devices [4]. Glass-carbon features uniform work function all over its surface. The measurements of both flat specimen and real probes revealed that this cover provides for a mean quadratic deviation of the work function *WF* less than 0.025 eV. Thus, the third term in expression (1) was minimized.

In the probes used so far for electric field measurement by the IESP device on board the IK-Bulgaria-1300 satellite [2], the preamplifiers were mounted within a box positioned in the end of the bearing axis, at the place where the axis is attached to the rod. The surface of the box was covered by special thermo-protection die providing normal temperature operation regime of preamplifier's (PA) board mounted in it. To improve preamplifiers' characteristics, preamplifiers (PA) of probes BVU.01 of device NVK-ONCh were mounted within the glass-carbon-covered spherical sensitive elements, on their operation surface.

The probes' structure was selected so as to leave enough room to mount the preamplifier within the sphere. This posed certain requirements for the features of the electronic elements used therein, such as operation within a definite temperature regime, consumed power etc. Laboratory measurements were made to evaluate the thermal conditions under which these elements are to operate. The reflection characteristics were studied of graphite specimen covered with glass-carbon produced by the same technology as the one used in working out the probes' spheres. The reflection characteristics of the specimen obtained when they were subjected to radiation of monochromatic light with wavelength from 200 nm to 2500 nm were used for theoretical evaluation of temperature within the sphere. The preamplifier mounted within the sphere had an output of 0.25W. The temperatures obtained (Tmax = 40^{o}C) lie within the allowed temperature range providing for the preamplifier's electronic components normal operation. Another means of overcoming the problem with the amplifier's temperature increase as a result of spheres temperature increase caused by the sun is to make the amplifier's thermal regime practically independent of the sphere's thermal status. This can be achieved by precise processing of the outer surface of the amplifier's box, i.e. by making it shining-smooth.

Probes BVU.01 constitute a part of the device NVK-ONCh. They are intended to measure the low-frequency electric fields by the double probe technique. The structure of probes BVU.01 is illustrated in Fig.1. The length of each probe without the connecting cable is 333±1 mm. Its mass without the cable and protective case does not exceed 0.3 kg. The probes are electrically connected to device NVK-ONCh by a 550 mm long cable and an RS-19 connector. The flow-chart of the electric part of probes BVU.01 is shown in Fig.2. These are preamplifiers (PA) mounted on a round glass-textolite board with near-to-uniform distribution of electronic elements mass on it. The amplifiers preserve their operability with multiple shock 100 g loadings of the three axes. According to the Technical Mission of the device, the amplifiers should operate within the frequency range of 0.1 Hz to 25 kHz. The non-linearity of the amplitude-frequency characteristics of the PA within the range from 5 Hz to 25 kHz should not exceed 0.5 dB and the temperature range within which the PA preserves its characteristics is from -55^{o}C to +125^{o}C. Two versions of PAs were designed: one based on operation amplifiers LH 0042, and another, on LF 156. These amplifiers have a JFET input, input resistance of the order of 10^{12} Ω, low drift of the input signal (3÷5 μV/ ^{o}C), and low noise level of the input signal - about 100 nV/Hz^{½} at frequency 10 Hz. A thorough description of the circuit, its operation and the results from the study of the amplitude-frequency, dynamic, and noise characteristics of six BVU.01 probes with preamplifiers is given in [3].

Conclusions

The operability of probes BVU.01 with preamplifier was studied by Control-Measurement Instrumentation (CMI), the connection diagram being shown in Fig.3.

The probes' features were also verified upon the performance of climatic tests (temperature - with temperature ± 80^{o}C; moisture - with relative moisture 93% and temperature +40^{o}Cl; and thermo - vacuum - with temperature ± 80^{o}C and pressure about 10^{-4} Pa), as well as upon the performance of vibro-mechanical tests with single 100 g loading.The device NVK-ONCh with probes BVU.01 operates successfully on board the IK-24-AKTIVEN satellite. The scientific results related therein are published in [13-15].

To illustrate the qualities of probes BVU.01 in Fig.4 are presented results from electric field measurements within the range from 300 Hz to 10400 Hz performed by the filter spectrum analyzer of ONCh-2 device during an active experiment. Active impact is indicated by arrow 2 in the upper left corner of Fig.4. Data refers to orbit No 1930 from 02.03.1990; it is analyzed in [13].

'IC - 24' Orbit 1930 / 02. 03. 1990

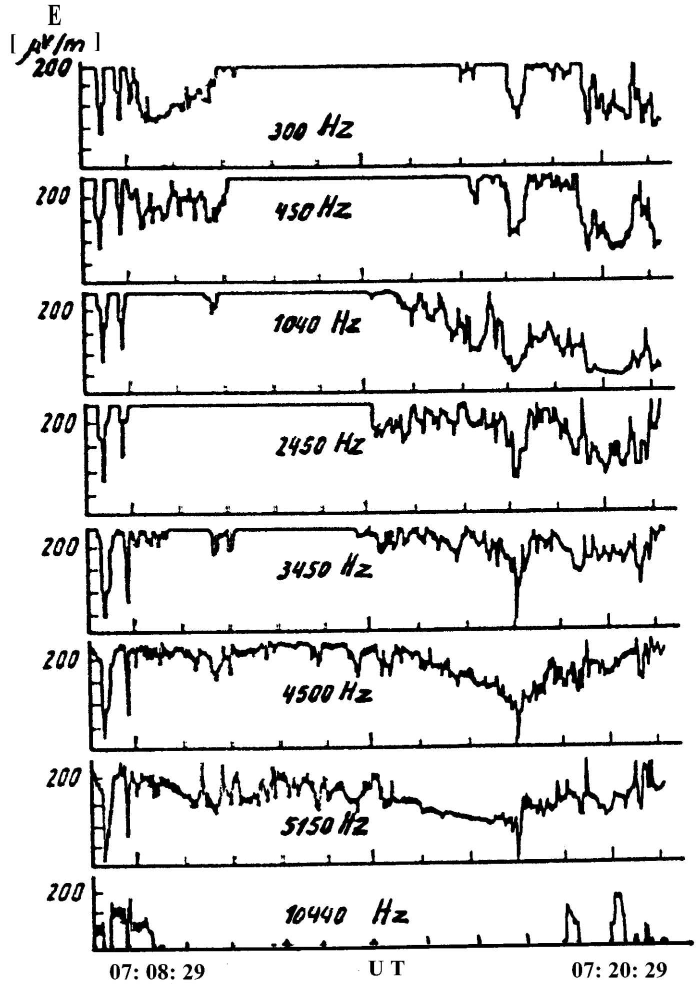

Fig.4

The results may be used as basis for further improvement of the probe complex for measurement of electric field by the double probe technique and its use in future space experiments.

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(A b s t r a c t)

In the paper, the probes used for low frequency electric field measurement on board “Intercosmos-24-AKTIVEN” are presented. The reasons for using amorphous carbon in the structure of the BVU.01 probes are analyzed. Amorphous carbon is a know-how technology of the Space Research Institute at the Bulgarian academy of Sciences. The mechanical structure and flow-chart, as well as the probes connection with the ground-based testing system are drawn. The characteristics of the probe electronic parts are discussed. The results from the actual measurements of the electric field in space plasma during active experiments are shown. Conclusions about reliability tests and probes operation in space are made.