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On Measuring Instruments for Space Plasma Electron Component Parameters in the Presence of 'Plasma-Body' Potential Difference

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The measuring instruments for space plasma electron component parameters are applied in the study of the surrounding space aboard artificial earth satellites when variable potential is available at the space object (satellite body).

Such instruments are familiar from reference sources as performing experiments with the help of Langmuir cylindric probes [1, 2, 3]. They are composed of a current-voltage converter (TCV), connected with the cylindric probe collector (CSL). In turn the TCV output is connected with the telemetric system (TMS), as well as with sawtooth voltage generator (GSTV). The latter controls the protective electrode of the CSL.

The disadvantage of the described instruments is incomplete measurement of space plasma electron component parameters (only density or electron temperature in restricted range) under relatively high potential of the body with respect to the surrounding environment of plasma. Complete loss of information is to be observed occasionally in such experiments.

I. In order to design instruments for measurement of plasma electron component parameters with CSL so as to obtain complete scientific information on the density and the temperature of the electrons in the direct measurements aboard the spacecraft within a large range of variation of the body-plasma potential difference, it is necessary to satisfy several conditions.

First, it is necessary to incorporate an additional system for automatic control of the variation range of the sweep voltage, applied to the electrodes of the CSL, in dependence on the value of the mentioned potential difference. In general, this system contains a TCV converter, connected with the collector and the protective probe electrode. The TCV output transports the converted and enhanced signal to the TMS, as well as to the system for automatic selection SAC of the translation voltage. One of the outputs of SAC is controlled by the probe protective electrode and the other is connected with the TMS. The other input of the SAC controls the output of the main generator GSTV.

Such a device has positively advantages as compared with systems now in use.

An examplary design of the described instruments is given in Fig. 1 where *1* — is probe (protective electrodes); *2* — potential meter; *3* — DC-, DC voltage converter; *4* — collector of cylindric probe; *5* — second converter of DC-DC voltage; *6* — input (output of amplifier-differentiator); *7* —

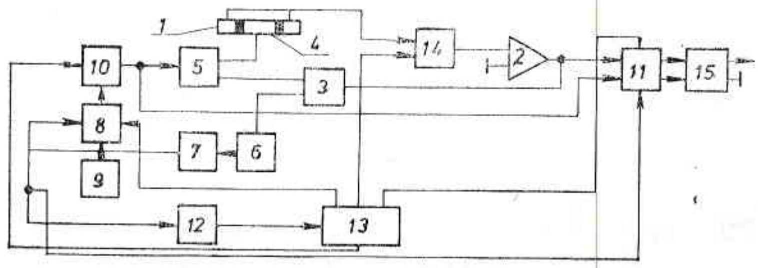

Fig. 1. An example of a block diagram

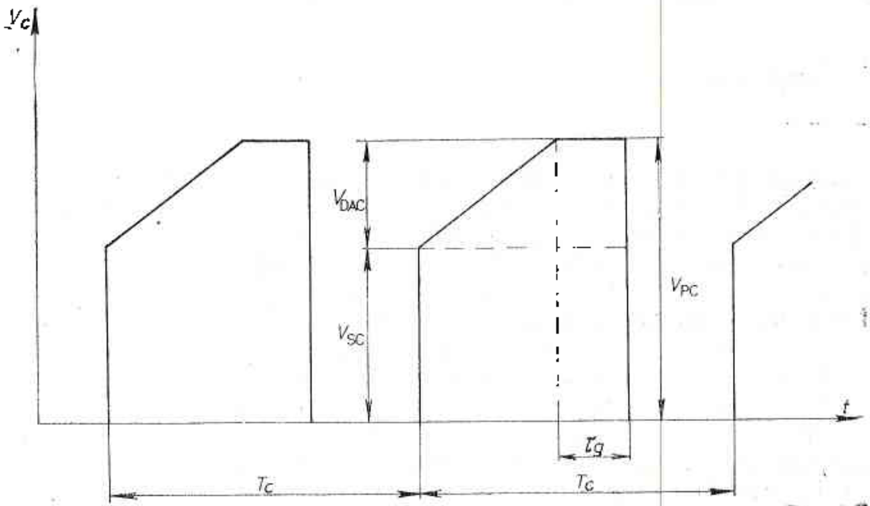

Fig. 2. An example of a time-voltage diagram

peak detector; *8* — first switch; *9* — pulse generator; *10* — digit-to-analog converter; *11* — second switch; *12* — retarding block; *13* — 'measurement sampling' block; *14* — switch; *15* — analog summator.

The principle of performance is the following: the protective electrodes of the cylindric Langmuir probe, in fact 'floating' (insulated from the body and the other equipment), are charged to potential V_{SC}, close to the potential of the surrounding plasma V_{PC}. At the initial phase of each measurement cycle one of the inputs of the switch *11* is closed by block *13*, and switches *8* and *14* are open. The collector *4* receives initial potential V_{SC} from the output of the potential meter *2* after conversion into convertor *3*, equal to the potential of the protective electrodes *1*. Through the closed switch *8* at the input of the digit-to-analog converter, pulses from generator *9* are fed in the result of which linearly changing voltage V_{DAC} is generated at the output of converter *10*. This voltage after being converted into converter *5*, is added to the voltage at the output of the first converter *3* and changes the potential of collector 4 [4]. Due to the serial connection of blocks 5, 3, 6 to collector 4, a signal is obtained at the output of amplifier-differentiator 6, which is proportional to the derivative of the collector current i_k in time $\frac{dI_k}{dt}$. Since the variation law of the potential of collector 4 in time is linear, the signal is proportional also to the derivative $\frac{dI_k}{dU_k}$. This performance is interpreted with the following theoretical consideration: the volt-ampere characteristics of the probe are composed by two sectors of different curvature. The potential of the collector in the inflextion point of this curve is identified with the potential of the surrounding plasma. At the moment when this derivative attains its maximum, a signal occurs at the output of the peak detector 7, which opens switch 8 and provides resolution to switch 11. The determined value of the signal from the output of the digit-to-analog converter 10 is summed in the analog summator 15 with the value of the potential difference V_{CK} between the 'floating' electrodes 1 and the body from the output of meter 2. At the output of summator 15 we obtain potential equal to the plasma-body potential difference.

The signal from the first detector 7, after certain delay T_D determined by the retarding block 12, is fed to 'measurement sampling' block 13 which closes switch 11 and repeats the measurement cycles of periodicity T_C.

II. All the things discussed thus far could be summarized and specified, considering the fact that the bulk charge generated as a rule depends on the size of the radius of Debay, and hence, on the measurement height. In addition, the consideration of the error in the measurement is not possible without some other additional probe measurements. The aim of the following analysis is to consider the effect of the bulk charge arround the probe and as a result to decrease the errors in probe applications of space experiments. This problem is resolved as follows (Figs 3 and 4). Fig. 3 illustrates the block diagram of the discussed instrument and Fig. 4 shows the temporal diagrams of the instrument (in particular to the outputs of the two generators of trapezoidal voltage -- blocks 4 and 5).

The principle of performance is the following: each cycle of performance on the diagram contains four characteristic time intervals respectively denoted by t_1, t_2, t_3 and t_4. The ratios $t_1+t_2+t_3<t_4$ and $t_1=t_2\gg t_3$ are valid for them. During t_1 the block controls the logics 7, switches through switch 3 the second end electrode 1 to the collector of probe 2. The cylindric Langmuir probe performs as a unilateral protected probe of length $l=l_{(1)}+l_{(2)}=2l_{(2)}$ in total. The current from the collector (already 1+2) it converted into voltage by current-voltage converter 6, and the latter is fed to integrator 10 through switch 8 and the first (upper) channel of distributor 9 where it is memorized. During the period t_1+t_2 the second end electrode 1 is switched by block 7 through switch 3 to the first end electrode 1 and the probe operates as a bilateral protected Langmuir probe with collector length of l [5]. The current from collector 2 is transformed into voltage by 6 and through second switch 8 and second channel of distributer 9 is fed to the input of integrator 11 where it is memorized. During the interval of $t_1+t_2+t_3$ the generator 5 generates dc voltage of value equal to the maximum accelerating voltage of the linearly decreasing sweep. During t_1+t_2 switches 12 and 13 are closed open. During t_3 switches 12 and 13 are closed and the voltages from the outputs of integrators 10 and 11 are fed to the inputs A and B of summator 14, as channel A has coefficient of convergence "1" and channel B has coefficient of convergence "2". At the output of summator 14 we obtain voltage, proportional to the

current, determined by the availability of the bulk charge in the frontal part of the second end protective electrode *1*.

During t_4, switch *3* switches second end electrode *1* in its capacity of protection (1+1). The current of collector *2* is transformed by *6* into voltage

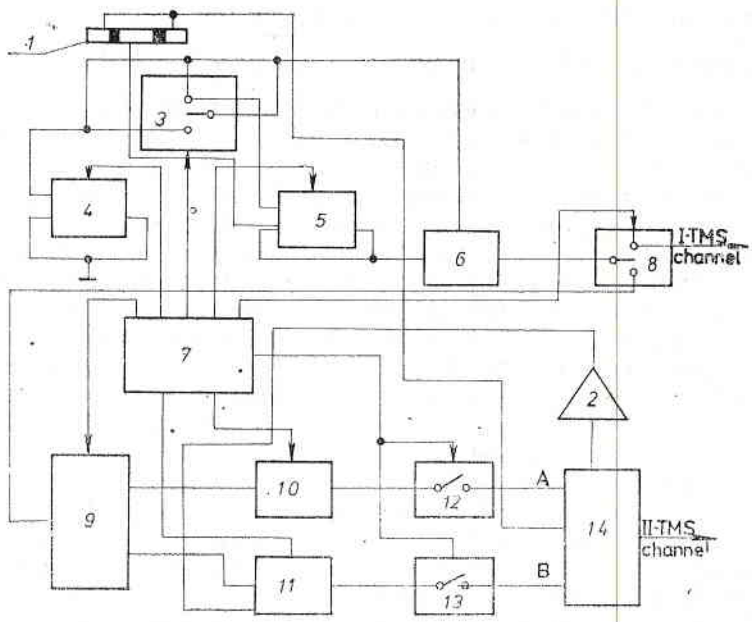

Fig. 3. The actual block diagram of the device

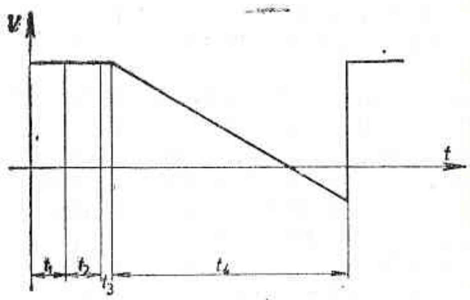

Fig. 4. Temporal diagrams of the instrument

and the latter is fed to the I telemetric channel through switch *8*. During t_4 the second generator operates in linear decreasing sweep mode (Fig. 4).

The output signal obtained in the interval t_4 describes the volt-ampere characteristics of the probe, and the electron density is computed by its slope, through the use of familiar formulae of plasma theory. The signal obtained within interval t_3 is determined by the availability of bulk charge and contains information on the introduced error.

Conclusion

Future attempt will join together the above-mentioned aspects from the minimization, optimization and updating of the probe technique, applying cylindric Langmuir probes in space experiments. It should be mentioned here that in some space experiments in particular the ionospheric-magnetospheric project INTERCOSMOS-BULGARIA-1300 instruments were designed on the basis of the above considerations. They successfully performed and provided abundant information for the fine structuring of the electron plasma component.

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Об устройствах измерения параметров электронной компоненты космической плазмы при наличии разности потенциалов „объект — плазма"

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(Резюме)

Дискутируется ситуация вокруг объекта — носителя научной аппаратуры в реальных условиях. Наличие разности потенциалов „объект — плазма" может привести к ошибочным научным результатам, особенно что касается зондовых методов. В работе сделана попытка описать устройства измерения параметров электронной компоненты плазмы с помощью цилиндрического зонда Лэнгмюра, посредством которых получается полная научная информация о концентрации и температуре электронов при непосредственном измерении с борта КА (в широких пределах изменения разности потенциалов „корпус — плазма"), а также анализировать влияние объемного заряда вокруг зонда и в результате — уменьшить ошибки при применении зонда в космическом эксперименте.