Bulgarian Academy of Sciences. Space Research Institute.
Aerospace Research in Bulgaria. 18. 2003. Sofia

SIMPLE ADAPTIVE METHOD FOR USE OF CYLINDRICAL LANGMUIR PROBE IN A WIDE RANGE OF SATELLITE SKIN POTENTIAL

Bankov L.G., Vassileva A.K.

Space Research Institute – Bulgarian Academy of Sciences

Abstract

Spacecraft charging effects have been studied since the beginning of the first satellite-borne experiments in space. Here, both skin and internal dielectric charging effects are meant. The first high-altitude flights showed that these effects could become of great importance for the proper operation of onboard electronic equipment. In some cases, satellite skin potential could reach relatively high levels, for example at geostationary orbits. Completely new type of problems could appear when large bodies like manned spacecrafts, space stations at docking procedures etc. have to operate for a long period on orbit with high reliability of the onboard equipment for reason of crew safety. Here, we propose very simple equipment for wide range measurements of the satellite skin potential using Langmuire probe in a special operation mode.

INTRODUCTION

The skin potential of the charged body in space depends on the balance of the inflow and outflow currents to its surface. The physical characteristics of the surrounding plasma and the different materials of the surface have considerable input to this balance. Large bodies in space like manned spacecrafts, space stations or large geostationary satellites can form significant potential drops between different parts of their constructions. Very often this could be a problem for onboard electronics and/or other charge-sensitive devices. A simple solution could be a distributed system for skin potential measurement and control sensors spread on the surface of the spacecraft unit. Here, the proposed Langmuir probe for spacecraft skin potential measurements is working close to a zero detection system mode, which simplifies the measuring techniques and onboard electronics.

INSTRUMENTATION

The cylindrical Langmuir probe (**CLP**) is a very extensively used instrument for electron density N_e, electron temperature T_e and satellite skin potential U_{sat} measurements because of its simplicity and relatively high accuracy [1,2,3]. Here, we will discuss the basic aspects of the CLP application for ionospheric plasma diagnostics. I.Langmuir and H.Mott-Smith were the first to postulate plasma probe measuring technique in laboratory plasma in 1924 [4]. Briefly described, plasma probe diagnostics is based on electrometer measurements of the current from the conductive electrode in plasma as a function of the sweep voltage applied to it, which is often called volt-ampere curve. In Fig.1, a sketch of a typical V/A curve (J_{clp} vs U_g) from a cylindrical Langmuir probe operating onboard the satellite is shown. Four important regions could be identified on the volt-ampere curve, denoted by A,B,C,D, accordingly. Region A represents the ion saturation current from CLP at enough negative U_g at which all attracted ions reach the collector surface while the electrons are repelled from it. The relative changes in total ion current with U_g represent the changes in the effective ion collection surface of the probe. In the retardation zone B, the electrons with sufficient energy reach the probe surface. The probe potential at which J_{clp} becomes zero as a superposition of equal electron and ion currents to the probe surface is called floating potential U_{fl}. Near U_{fl} the rapid change in the probe current is a function of the effective retardation U_g for electrons where the Te determines the power of exponent in the theoretical expression of the V/A curve. A large Te value corresponds to a large retardation zone. In a close area of point C, the probe potential becomes positive in respect to the plasma and as a result, the probe current is almost caused by electrons attracted to the probe. This value of the U_g sweep, at which the probe potential becomes zero compared to the undisturbed plasma far from the probe is called satellite skin potential U_{sat}. A large positive potential U_g in the saturation region D causes the probe current to be …….. only by the attracted electrons on the CLP surface. To obtain T_e, N_e and U_{sat} values from the experimental C/V curve, a least square technique could be used to fit the theoretical expression for J_{clp}. It is important to note that large T_e values correspond to a large retardation zone and as a consequence on large U_{sat}-U_{fl} difference. In the Earth's ionosphere $|U_{sat}-U_{fl}|$ does not exceed 0.5÷0.6v. In the case of wide range measurements of the satellite potential U_{sat}, for example, from –200v to +200v, the $|U_{sat}-U_{fl}|$ difference becomes less than 0.5% of the desired range. Therefore, if we measure accurately U_{fl}, this in fact corresponds to a U_{sat} value with less than 0.5% accuracy in the whole targeted (-200v÷200v) dynamic region.

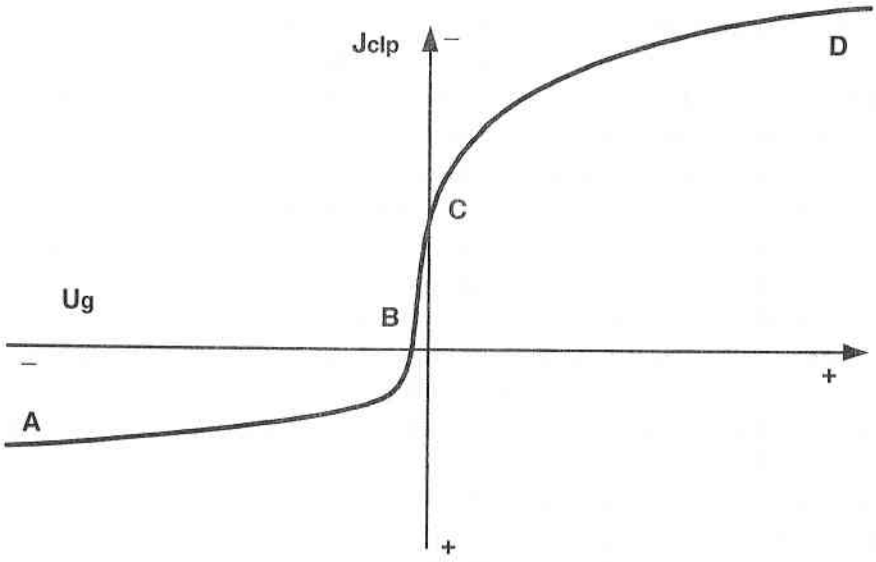

Fig.1

The basic assumption of the measuring technique proposed here is to measure U_{fl} as a zero J_{clp} current level detector with fixed sensitivity current-to-voltage converter. In the beginning of the operation cycle we use a CLP only as a rough zero current detector. In Fig.2, we show the schematic solution of the proposed instrument. CLP output is connected to the input of a current-to-voltage converter (**CVC**) with appropriate sensitivity. The output voltage of the CVC through a zero crossing voltage comparer (**COMP**) provides an opto-isolated logical output signal. This logical signal is used as an up/down switch of the counter (**COUNT**) whose output through a digital-to-analogue converter forms the U_g voltage sweep. The wide dynamic range of U_g is a function of the gain of the voltage amplifier (**AMP**). The high output voltage of the AMP stage is connected to the floating ground of the CVC to provide voltage offset in respect to the plasma. The DC/DC converter and the opto-isolated telemetry buffer output are used to protect onboard electronics. The operation principle of this instrument is quite simple. If the input CLP current passes through zero level at some $U_g=U_{fl}$ the output logical signal from the comparer reverses the counting direction of the counter, gain of the output amplifier stage and starts analog to digital conversion of the ADC block. Every passing through zero level current repeats this process in the downward direction and in fact a current-to-voltage characteristic with a fine voltage sweep from the CLP in a digital form to the TM output. This part of the C/V curve could be successfully processed for N_i, N_e, T_e and U_{sat} [5]. When the bottom level of the counter is reached, logic control changes the gain and output voltage step to search for next $U_g=U_{fl}$ level. To minimize the error caused by the difference between Usat and Ufl some a shift in the zero level adjustment of the comparer can be applied. Time resolution of the method is limited from the clock (**CLK**) frequency and frequency band of the CVC. The input stage of the current-to-voltage converter has to be overload protected. A differential pair of high voltage transistors could be used. The dynamic range of this instrument could be extended by the special HV protected construction of the electronic block. The main objectives of this schematic solution could be realized in some part by a micro-controller unit (counter, DAC, TM output). This will not reduce significantly the used measuring algorithm. In some cases, low integration chips are better protected from the influence of high voltage static discharge, high level radiation etc. Either way, the electronics and CLP could be small enough to be spread at different locations on the surface of large body spacecrafts, space stations etc.

CONCLUSION

In the present paper a simple method of CLP application within a wide range of satellite skin potential values is proposed. This measuring technique could be an effective tool as a part of onboard control and safety systems.

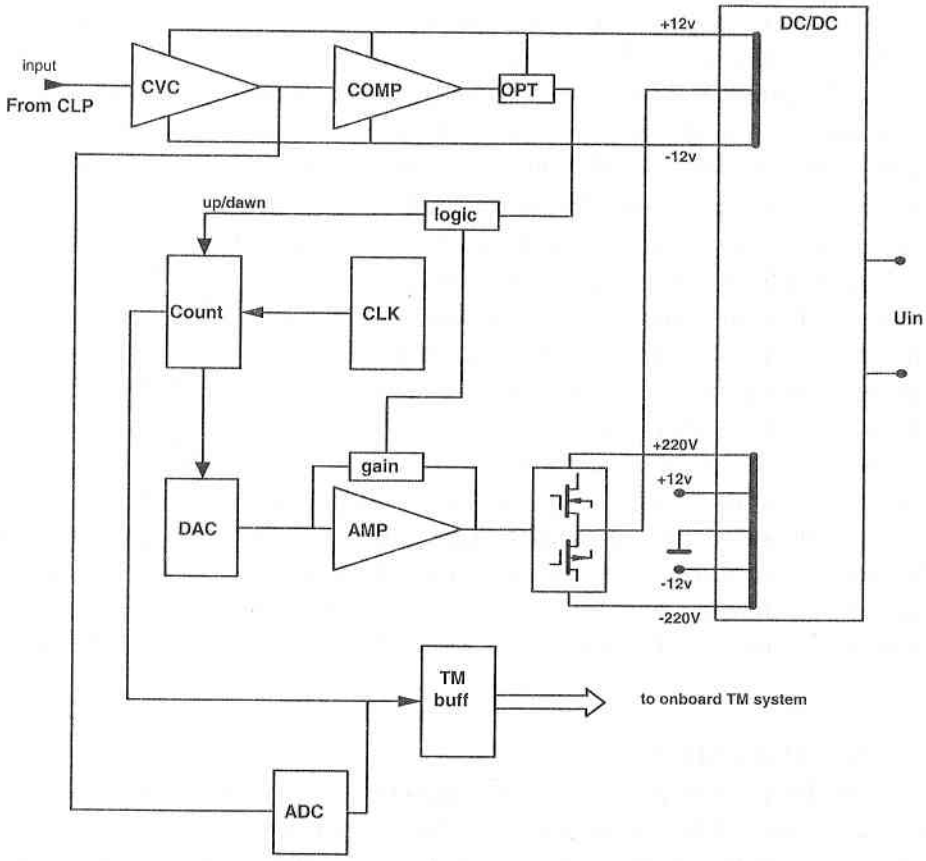

Fig.2

References

1. Brace L.H., R.F. Theis, and A.Dalgarno. The cylindrical electrostatic probes for Atmosphere Explorer-C,D,E , Radio Science,vol.8, 4, p.341, 1973.
2. Krehbiel J.P.et al., The Dynamics Explorer Langmuir probe instrument, Space Science Instrumentation, 5, 4, 493, 1981.
3. Bankov L.G. et al., An instrument for electron density and electron temperature measurements, N36160/reg. N61371/1983.
4. Langmuir I., Mott-Smith H.M., Sdudies of electric discharges in gases at low pressures, General Electrical Review, 27, 616, 1924.
5. Krehbiel J.P. et al., Pioneer Venus orbiter electron temperature probe, IEEE, 18, 1, 49, 1980.

ПРОСТ АДАПТИВЕН МЕТОД ЗА ИЗПОЛЗВАНЕ НА ЦИЛИНДРИЧНА СОНДА НА ЛЕНГМЮР В ШИРОК ДИАПАЗОН НА ИЗМЕНЕНИЕ НА ПОТЕНЦИАЛА НА СПЪТНИКА

Л.Банков и А.Василева

Резюме

Ефектите от зареждане на космическите апарати са били изучавани още с първите спътникови експерименти в космоса. Този проблем се разделя на външен и вътрешен (диелектричен) ефекти на зареждане. Първите високо апогейни полети показват, че тези ефекти биха могли да бъдат от изключителна важност за правилното функциониране на бордовата електроника на спътника. В някои случаи, потенциалът на повърхността на спътника може да достигне относително високи нива, например за геостационарни орбити. Напълно нов тип проблеми могат да се появят, когато големи тела като пилотируеми космически кораби, космически станции по време на процедури за скачване и т.н. трябва да функционират за дълъг период на орбита с висока надеждност на оборудването, гарантиращо безопасността на екипажа. В тази работа ние предлагаме много прост прибор за измерване на потенциала на повърхността на спътника в широк диапазон, като се използва сонда на Ленгмюр, като се използува специфичен режим на работа.