1. Publication Nº	2. Version	3. Date	5. Distribution
INPE-3206-PRE/564		*July, 1984*	☐ Internal ☒ External ☐ Restricted
4. Origin *DGA/DIO*	Program *ELIS*		

6. Key words - selected by the author(s)

LANGMUIR PROBE *FLOATING POTENTIAL*
ELECTRON DENSITY *SPACE POTENTIAL*
PLASMA IRREGULARITY

7. U.D.C.: *523.4-853*

8. Title *INPE-3206-PRE/564*

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10. Nº of pages: *13*

11. Last page: *12*

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14. Abstract/Notes *A new Langmuir Probe payload, to be flown on-board SONDA III and SONDA IV rockets, is being developed at INPE. The major scientific objectives of the experiment are the measurements of electron density and electron temperature, the study of the spectral distribution of electron density irregularities in the day and nighttime ionosphere, and the study of the plasma irregularities in the equatorial electrojet. The payload basically consists of a Langmuir Probe sensor made of stainless steel ogive in shape, situated at the nose-tip of the rocket, and an electronic system to monitor the sensor current and to telemeter it to the ground station. A sweep voltage varying between -1V and +4V is applied to the sensor, and the current collected by it is converted into a varying voltage signal, and is then amplified and telemetered to the ground using an on-board telemetry system. To cover the almost five decades dynamic range of the electron density variation with height, as well as obtain information about the spatial variations in the electron density, the sensor signal is processed through three different channels. The total signal at low gain is transmitted through one of the telemetry channels, while the second channel carries the signal processed at an automatic gain control unit. The signal, after passing through a band pass filter, is transmitted through the third channel. The sensor current and its slope with respect to the sensor voltage, as measured through the first two channels, give information about the electron density and electron temperature respectively, while the third channel contains information about the electron density irregularities.*

15. Remarks *This work was partially supported by the "Fundo Nacional de Desenvolvimento Científico e Tecnológico", under Contract FINEP-537/CT. This work will be presented in the SBPC, 1984.*

A ROCKET-BORNE LANGMUIR PROBE FOR IN-SITU MEASUREMENT OF IONOSPHERIC PLASMA

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ABSTRACT

A new Langmuir Probe payload, to be flown on-board SONDA III and SONDA IV rockets, is being developed at INPE. The major scientific objectives of the experiment are the measurements of electron density and electron temperature, the study of the spectral distribution of electron density irregularities in the day and nighttime ionosphere, and the study of the plasma irregularities in the equatorial electrojet. The payload basically consists of a Langumuir Probe sensor made of stainless steel and ogive in shape, situated at the nose-tip of the rocket, and an electronic system to monitor the sensor current and to telemeter it to the ground station. A sweep voltage varying between -1V and + 4V is applied to the sensor, and the current collected by it is converted into a varying voltage signal, and is then amplified and telemetered to the ground using an on-board telemetry system. To cover the almost five decades dynamic range of the electron density variation with height, as well as to obtain information about the spatial variations in the electron density, the sensor signal is processed through three different channels. The total signal at low gain is transmitted through one of the telemetry channels, while the second channel carries the signal processed at an automatic gain control unit. The signal, after passing through a band pass filter, is transmitted through the third channel. The sensor current and its slope with respect to the sensor voltage, as measured through the first two channels, give information about the electron density and electron temperature respectively, while the third channel contains information about the electron density irregularities.

INTRODUCTION

Laboratory measurements of plasma parameters such as electron and ion densities, electron and ion temperatures, and the spatial distribution of electrons and ions, have been mainly through the use of what are generally known as Langmuir Probes (LP). The LP technique was first applied for ionospheric measurements when Spencer and his co-workers used V_2 rockets for upper atmospheric measurements (Gunnar Hok et al., 1953). Since then various forms of LPs have been used for plasma measurements in the ionosphere (Boggess et al., 1959; Ichimiya et al., 1960; Boyd and Willmore, 1962; Prakash and Subbaraya, 1967; Smith, 1969; Prakash et al., 1968, 1972; Hirao and Oyama, 1970).

In the conventional rocket-borne LP system the sensor is a small section of the nose-tip of the rocket, or a separate electrode projecting outside from a suitable portion of the rocket nose-cone, and is well-insulated from the rocket body. A potential varying around the floating potential of the rocket is applied to the sensor and the current drawn by it from the surrounding plasma is measured. When the probe is at a constant potential, sufficiently positive, the probe current is proportional to the ambient electron density, and the probe current profile is a faithful reproduction of the electron density profile in the medium. By applying a varying potential to the probe, it is possible to obtain the electron temperature from the slope of the probe current-probe voltage characteristic.

A new LP payload to be flown on-board SONDA III and SONDA IV rockets is being developed at INPE and the system details are presented here. The major scientific objectives of the experiment are the measurement of electron density and temperature and the study of the spectral distribution of electron density irregularities.

LANGMUIR PROBE SYSTEM

The present LP system is shown schematically in Figure 1. The sensor electrode is the nose-tip of the rocket electrically insulated from the rocket body. A sweep voltage is applied to the sensor through a high input inpedance amplifier, which converts the varying sensor current into a varying voltage. An additional electrode called the guard electrode is introduced between the sensor and the rocket body. This electrode is in the form of a metallic ring and is kept at the same potential as the sensor, but well-insulated from it. The purpose of this electrode is to render the electric field near the sensor normal to its surface and to reduce the a.c. leakage in the surface and the capacitive effects. In order to get the height profile of the electron density as well as small scale fluctuations in the electron density (a.c. part) and also to accommodate the large dynamic range (~ 5 decades) of the electron density variations, three different subcarrier channels are used. The output of the current to voltage converter amplifier is fed simultaneously to three different amplifiers. One of them is a constant low gain d.c. amplifier which will be useful in the lower regions of the ionosphere where the electron densities are likely to be rather low. The second one is a variable gain d.c. amplifier which can be conveniently used to study the electron density variations with height, to a greater detail. The third amplifier is exclusively meant for the study of the electron density fluctuations, generally known as plasma irregularities.

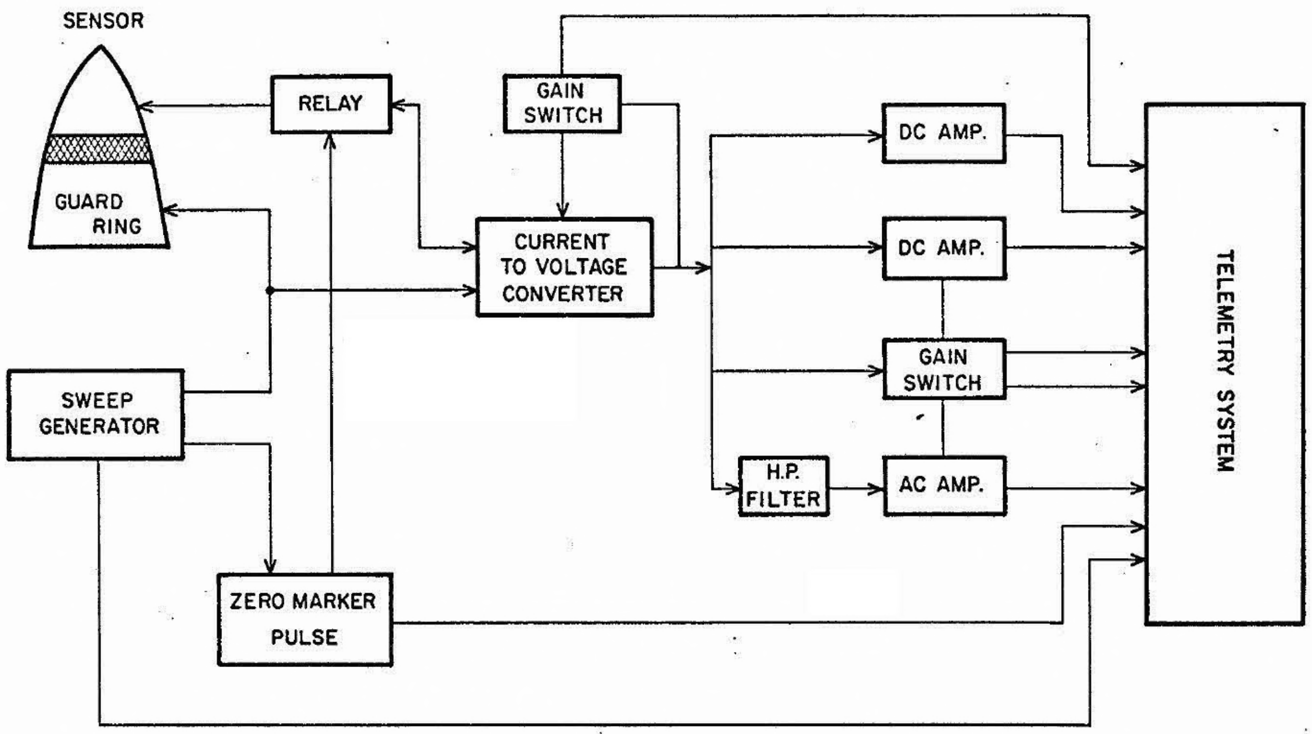

Fig. 1 - Block diagram of the Langmuir Probe System.

PRINCIPLE OF OPERATION

A conducting sphere of surface area A moving with a velocity v_s in a plasma collects both electron and ion currents. The current thus collected depends on the thermal velocity of these particles as well as the velocity of the sphere. In the beginning, though the electron current is much larger than the ion current, due to the large thermal velocity of electrons,this charges the sphere to a negative potential. This negative potential of the sphere rises to a value called the floating potential at which the electron and ion currents become equal. The negative floating potential of the sphere causes the development of an ion-sheath surrounding, the sphere and this modifies the current to the sphere,especially the positive ion current.

Over the height range of 75 to 3000km the ion-sheath thickness has values of a few centimeters and can be neglected for sensors of large diameters (of the order of meters). But increasing the sensor diameter poses another serious problem related to the return path for the current collected by the sensor. To overcome this "current-dumping" problem the surface area of the probing sensor should be made negligibly small compared to the surface area of the parent spacecraft. This puts an upper limit on the size of the senor, at which the ion-sheath effects cannot be neglected. To overcome this problem, one of the practical methods adopted is to apply an additional potential to the probing sensor, with respect to the spacecraft, and sweep this in time from a negative value to a positive value. It can be shown that, for a negative potential V of the sensor, the net current to the sensor is given by the relation:

$$i = enA \left[v_s - \overline{v}_e \exp(-eV/kT_e) \right] \qquad (1)$$

where

e is the electronic charge,
n is the number density of electrons and ions (assumed to be equal),
$\overline{v}_e$ is the thermal velocity of electrons,

T_e is the electron temperature,
k is the Boltzmann's constant, and
A is the surface area of the probing sensor.

For positive values of the sensor potential the net current to the sphere is given by the approximate relation:

$$i = enA\left[v_s \exp(eV/kT_+) - \bar{v}_e (1 - eV/kT_e) \right] \qquad (2)$$

The variation of sensor current i with sensor voltage V (measured with respect to the space plasma) given by equations (1) and (2) in an idealized situation is shown in Figure 2. From the i-V characteristics curve it is possible to determine both the electron density and the electron temperature.

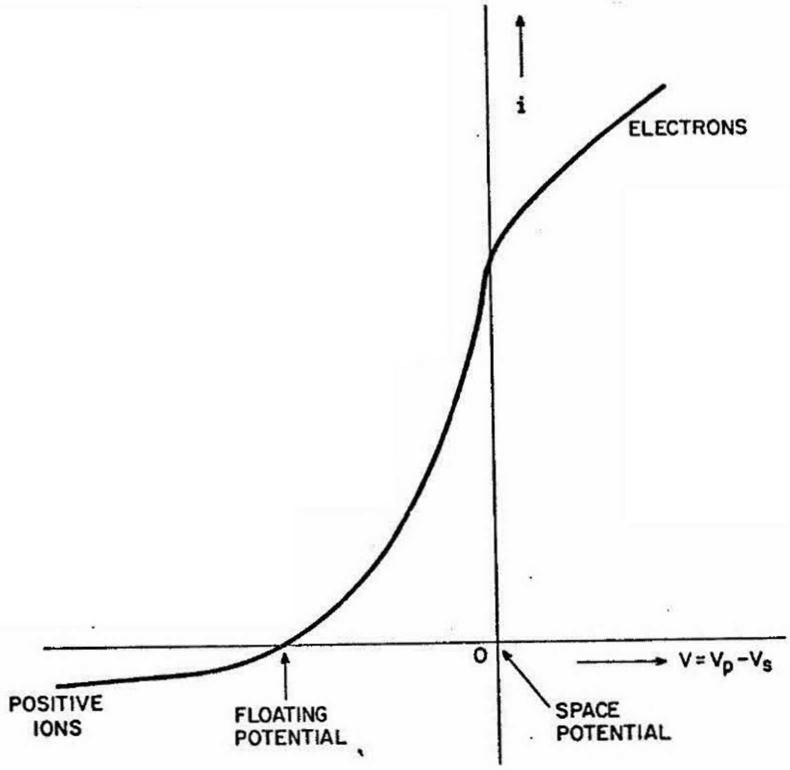

Fig. 2 - Net Current collected by a sensor from the ambient plasma as a function of the relative potential of the sensor V with respect to the space potential V_s (Source: Boyd, 1974).

SENSOR ASSEMBLY AND OPERATION

The sensor assembly is shown schematically in Figure 3. The probing electrode is made of stainless steel, ogive in shape, and has a surface area of about 20cm^2. It is insulated from the "guard ring", by an "insulator ring" made of ceramic glass, which has high thermal resistivity and is a good electrical insulator. The guard electrode is also made of stainless steel and is insulated from the rocket body by the "outer insulator" and from the sensor by the "inner insulator", both made of teflon. The guard-electrode is maintained at the same potential as the sensor to reduce the capacitive effects between the sensor and the guard electrode to a minimum. The pre-amplifier card containing the relay for zero marker also forms a part of the sensor assembly.

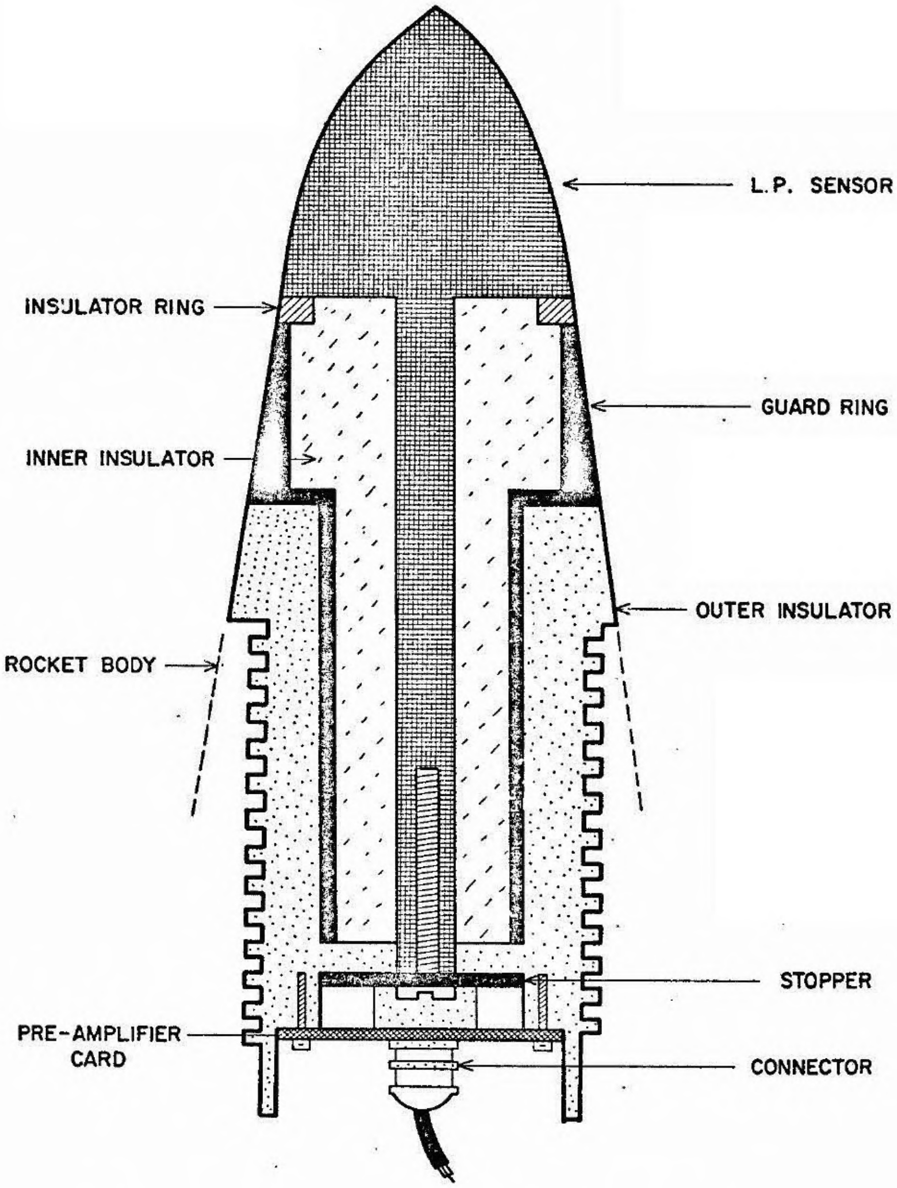

Fig. 3 - - Langmuir probe sensor assembly

A sweep voltage varying between -1V and +4V is applied to the sensor and the guard electrode, through a high input impedance pre-amplifier. For the circuit configuration shown in Figure 4, the leakage currents are reduced to a minimum as the input to the amplifier is directly connected to the sensor. The sensor current has a large dynamic range of about 5 decades and could be as low as a few nano-amperes. The 5 decades of dynamic range in the sensor current is compressed to 3 decades by using a gain switch in the feedback circuit of the pre-amplifier. For an input current varying from 10^{-9} amp, the pre-amplifier output varies from 0.5mV. A low gain d.c. amplifier is used to amplify, this voltage into the range of 0 to 5V, and then is transmitted to the ground station through one of the three telemetry channels. A second d.c. amplifier with three different gain modes is used to get detailed information about the sensor current variations. Gain switching is done depending on the level of the pre-amplifier output. This d.c. amplifier output is telemetered to the ground station through the second telemetry channel. To study the spatial fluctuations in the electron density, corresponding to the time variations in the sensor current, a filter-a.c. amplifier combination is used. The pre-amplifier output is passed through a high pass filter (Figure 5) to remove frequencies below 20Hz, and the a.c signal thus obtained is amplified using the a.c. amplifier operating in three gain modes, and transmitted through the third telemetry channel.

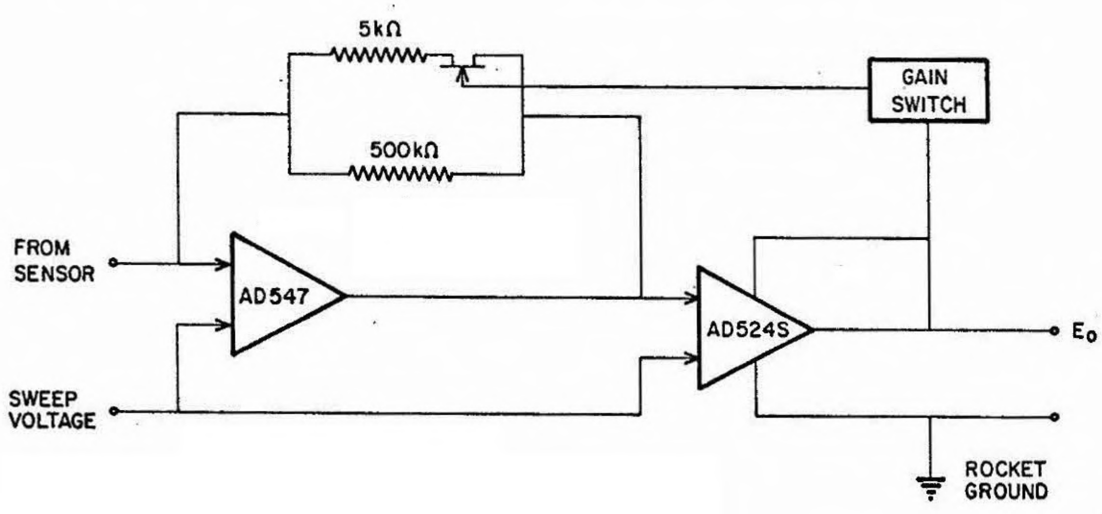

Fig. 4 - Application of sweep voltage to the LP sensor, through the pre-amplifier.

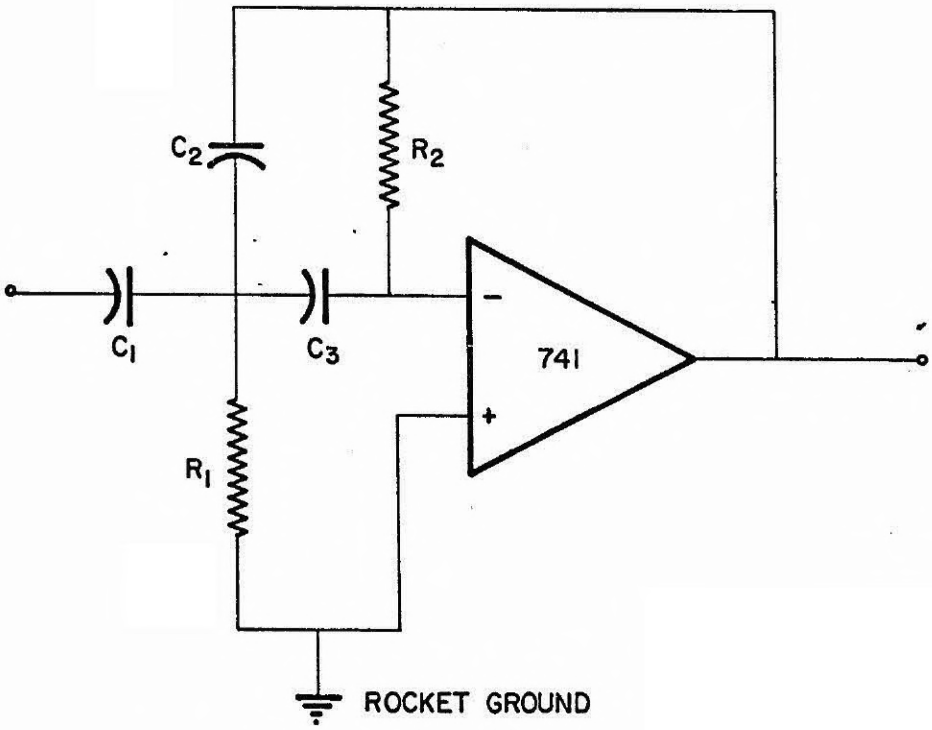

Fig. 5 - Active high pass filter.

Along with the amplifier outputs, the gain information is also transmitted to the ground station. Using a mechanical relay and an FET switch, once in every sweep of the sensor potential the sensor is cut off from the amplifier input, and a calibration mark is obtained in the output of the amplifiers.

RETRIEVAL OF DATA

In addition to the experiment data channels, time marker pulses and the x and z magnetic sensor outputs are also transmitted to the ground station. For the interpretation of the LP data, the rocket position as a function of time (rocket trajectory) is also essential.

For a preliminary analysis, the experiment data is read manually from paper charts. Information about the altitude of the rocket and hence of the LP sensor could be obtained from the magnetic sensor data. For detailed analysis of the LP data, the data signals recorded on analog magnetic tapes are digitised and recorded on computer compatible tapes in a convenient format, using an interface.

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