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The Retarding Potential Analyzer on AEROS-B

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Abstract. The planar Retarding Potential Analyzer is integrated in the AEROS-B payload to provide electron- and ion temperatures, electron and ion densities of the predominant ion constituents and photoelectron fluxes up to 30 eV. The experiment has two sensor heads. They are mounted on a spinning sunpointed satellite at the shadowed part of the spacecraft. Both sensors measure electrons and ions alternatively. The selection of the sensor of optimal angle of attack is controlled by the spacecraft. The spatial resolution for densities is about 50 km, for the other parameters about 150 km. The estimated accuracy of the derived plasma parameters is $\pm$ 10%. The high sensitivity and dynamic range of the experiment allow measurements of temperatures and densities in the entire altitude range of the satellite. Sensor and electronics are described and some data of the AEROS-A version of the experiment are given as examples.

Key words: Retarding Potential Analyzer — AEROS.

Introduction

The purpose of the planar Retarding Potential Analyzer (RPA) on board of the satellite AEROS-B is to determine the energy distribution of the thermal and suprathermal electrons (and consequently the electron temperature), the ion temperature, the total ion density contributed by the predominant ion species, the ion drift velocity and the vehicle potential of the satellite. The RPA will provide a very significant portion of the total data from the AEROS-B project.

Principle of Measurement

The above mentioned parameters are derived by the measurement of the plasma current intercepted by the sensor and depending on the applied grid voltages. The electrons or ions respectively have to overcome the potential of a retarding grid. Only these particles whose energy is greater than the applied retarding potential can pass this grid and reach the collector where they are measured. By changing the retarding voltage the energy distribution of the plasma constituents can be determined. To separate electrons from ions the collector is biased in such a way that it attracts particles of one sort and repells the other. An additional screen grid suppresses escape of secondary electrons from the collector and shields the capacitive coupling between the retarding grid and the collector.

Experimental Constraints

The spacecraft is of cylindrical shape and is spinstabilized with a spinrate of 10 r.p.m. The spinaxis is along the cylindrical axis and maintained in a sunward pointing direction. This concept is required by the EUV spectrometer.

The planar sensor of the RPA is sensitive to the angle of attack of the particles to be measured. Therefore the mounting position of the sensor on the spacecraft, which is moving through the ionosphere with varying angle of attack, is of great importance.

To achieve a good measuring position the RPA is constructed with two identical sensor units along the same meridian of the spinning spacecraft. One sensor is positioned such that the normal to the entrance aperture makes an angle of 92° with the spin axis while the other makes an angle of 135° (Fig. 1). This placement of the sensors precludes direct sunlight from entering either detector, thereby avoiding the effects of photoemission in the sensor.

The angle that the velocity vector makes with the normal to the entrance aperture of the sensor unit, the angle of attack, depends upon both the position of the spacecraft in its orbit and the position of the sensor with respect to the azimuthal angle of the spin. During each spin cycle the angle of attack sweeps through its minimum value for a given sensor for the particular location of the spacecraft in its orbit. At certain positions of the orbit one sensor is more favorably oriented with respect to the velocity vector than the other and consequently the better positioned sensor is active, the other is in standby position. In this way the minimum angle of attack is always less than 45° in the southern hemisphere and 32° in the northern hemisphere for a given sunsynchroneous 3.00/15.00 hour orbit.

In the spinphase controlled program of the satellite the experiment is triggered by the spacecraft so that the sensor is only measuring during the time of best ram position in each spin cycle; every 6 seconds a new measurement can be achieved. In the special program of the satellite measurements are continuously made during $2^1/_2$ spincycles to analyze interesting effects related with the angle of attack or the position to the magnetic field.

The Instrument

The RPA consists of the main electronic box providing the different sensor voltages, the program and control circuits, and of the sensor including the electrometer and the two sensor heads. Each head is constructed

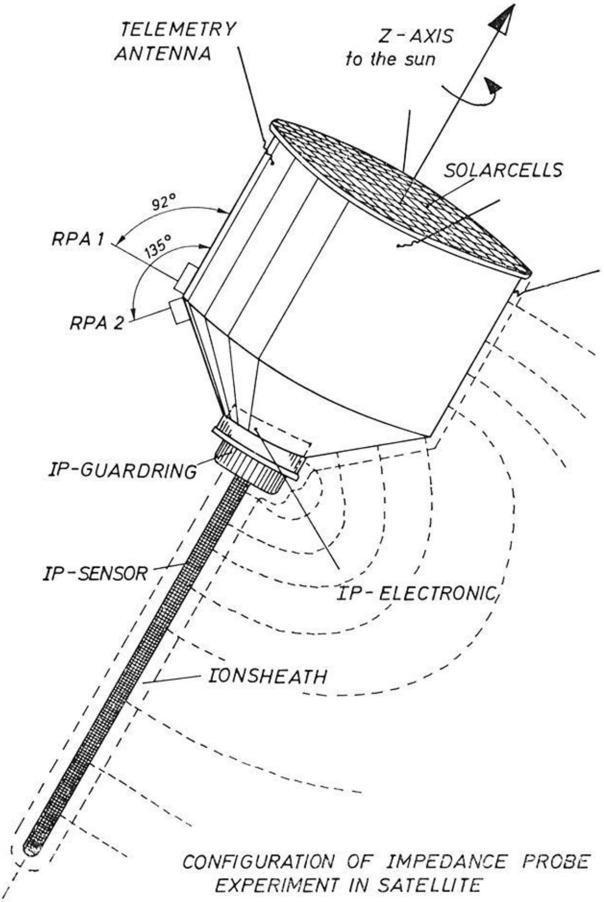

Fig. 1. Mounting position of the two RPA-Sensors on board the satellite AEROS-B

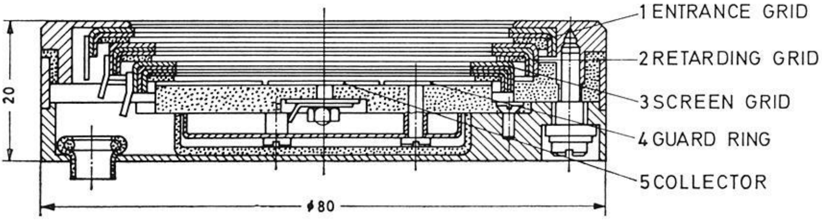

Fig. 2. Configuration of the planar AEROS RPA-Sensor

with a planar entrance grid which covers the entire aperture (Fig. 2). Behind the entrance grid a double retarding grid and a double screening grid are mounted. The remaining electric field penetrating through the holes is reduced by this arrangement of double grids to 0.4 %. This means that the inhomogenity of the retarding potential generated by the geometry of the grids is lower than the work function variation along the surface of the grids. All grids are electrically insulated from each other. The grids are electroformed, having 24 wires per cm with a thickness of 0.001 cm. The measured transparency of the total grid system is 35%. The small collector plate (2 cm^2) which determines the limiting measuring area is surrounded by a guard ring to avoid egde effects. All surfaces of the sensor including the grids are gold-plated to reduce contact potentials to as low a value as possible and thereby minimize the effects from spurious electric fields (Feuerbacher and Fitton, 1972).

Modes of Operation

The RPA is designed to operate in three basic modes with the same sensor by varying the different grid voltages. In the normal program the system is programmed to automatically cycle through the following three modes within 0.83 sec per mode and spin during the minimal angle of attack: electron energy, electron temperature and ion mode. This means that the space resolution is 144 km with exception of the plasma density measured in each mode every 48 km.

In the electron energy mode, El, and the electron temperature mode, E2, the screen grid and the collector are maintained at +17.8 volts and +30.3 volts respectively. As a result, the thermal ions are repelled and do not arrive at the collector. The collector is positive relative to the screen grid so that secondary electrons produced at the surface of the collector can not escape from the collector. In the electron energy mode the retarding grid is stepped from 7.4 volts to —28 volts in 80 steps thereby determing the energy distribution of suprathermal electrons up to about 30 eV. The entrance grid has the same voltage as the retarding grid between 7.4 and 0 V improving, as additional grid, the energy resolution for low energy electrons; then it is set to +12 V during the rest of the scan (analyzing the suprathermal electrons). This is necessary to exclude the ions from the negative retarding grid, where they generate secondary electrons. The yield of electrons depending on the changing retarding voltage is higher at a 20 V grid than the expected suprathermal electron flux (Knudsen and Harris, 1973). A possible distortion of thermal electrons by the relatively high entrance grid voltage can be tolerated since during this mode the purpose is to measure electrons with an energy above 3 eV.

A secondary aim of this mode is to find automatically the approximate potential of the satellite relative to the ambient plasma. If the current decreasse more than 1:36 relative to the first measured value of the scan, the corresponding retarding voltage is roughly the plasma potential. A simple calculation shows that the order of magnitude 1:36 makes sure that the corresponding voltage is not far away from the plasma potential taking into account the possible ionospheric conditions and the applied grid voltage. The exact value of 36 is caused by the electronics. The so determined voltage is stored as a "reference voltage" for the electron temperature- and ion mode.

It is very important to relate the retarding voltage to the plasma potential and not to the satellite potential. In some earlier satellite missions the charge was strongly negative and has prevented useful measurements.

In the electron temperature mode the entrance grid and the double retarding grid are connected and have the same potential during the whole scan. These 3 grids produce a very uniform retarding field and give for the very sensitive measurement of thermal electrons a high energy resolution.

The retarding and entrance grids are stepped from 2.1 volts to —2.9 volts relative to the reference voltage, compensating automatically the spacecraft charge. The step height of the retarding voltage is variable. As long as the current decrease is small the step height is 160 mV. If the current has decreased to more than 1/6 of the first value of the scan the step height is reduced to 40 mV during the following 32 steps and continues then with 160 mV.

A typical example of the characteristic current versus voltage curve for the electron temperature mode is given in Fig. 3. In this figure the actual data points measured by the RPA of AEROS-A are shown, where the log of the electrometer output is plotted against the retarding potential measured from the reference level as described above. The solid curve plotted through the data points in the steep slope portion of the curve is the least square fit to the data points. The different parameters of the electrons, such as temperature, density and satellite charge, are obtained by the least square technique.

In the ion mode the entrance grid is grounded. The retarding grid is swept from 0 to 13.1 V relative to the reference voltage. The step height changes from 60 mV during the first 32 steps to 180 mV during the following 32 steps and to 420 mV during the last 14 steps. This voltage program gives a good current resolution including also such measurements where the angle of attack is not near zero but within 45° degrees. The screen grid is biased with —28 V equal to the highest retarding voltage in the electron energy mode. From the measured electron flux in this mode an eventually necessary correction of the ion data by the suprathermal electron flux

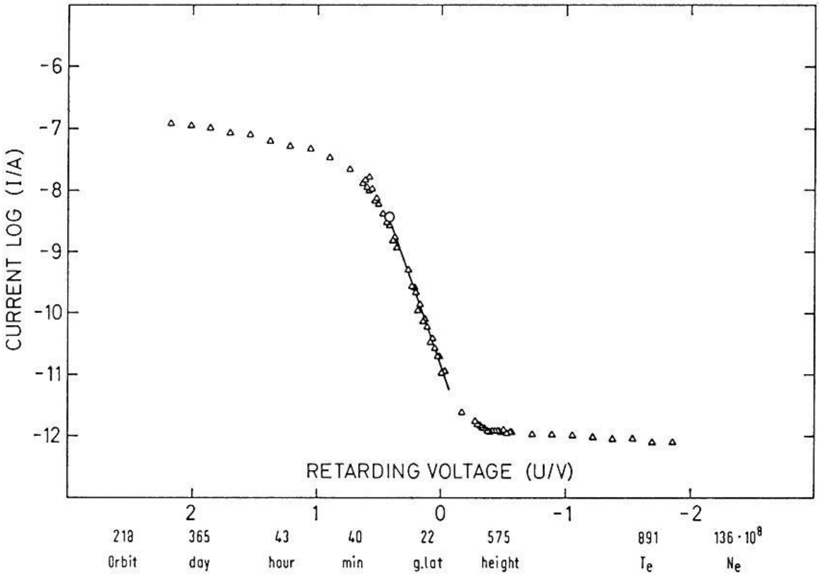

Fig. 3. Current-voltage characteristic in the electrontemperature mode. The straight line is the fitted linear decrease in semilogarithmic plot from which the electron temperature is determined. The circle sign defines the knee point for the calculation of the electron density

above 28 V can be made. The collector and guard ring have a voltage of —16 V. It is positive relative to the screen grid to suppress secondary electrons generated on the collector.

During one scan the azimuth of the spacecraft spins through an angle of approximately +27°. As a consequence the measured ion current, depending strongly on the ram position, permits us to determine the angle of attack in the azimuthal plane of the satellite. A differential measurement between the current of sensor 1 and sensor 2 allows also the determination of the angle of attack perpendicular to the azimuthal plane. This differential measurement will be done during the first 4 data points of each scan.

With a curve fitting technique the different ion parameters such as temperature, predominant constituents, density, and drift velocity can be derived (Knudsen, 1966). In Fig. 4 an example of a measured ion curve is shown from AEROS-A. The triangles represent the actual data and the curve is the optimal fit to the data.

By telecommand it is possible to set a constant retarding voltage in each mode. This gives a further possibility to evaluate the angle of attack resulting from the increasing and decreasing current depending on the spin angle. In addition, the relation between the spin angle and the ion and electron current can be directly studied to improve the data evaluation.

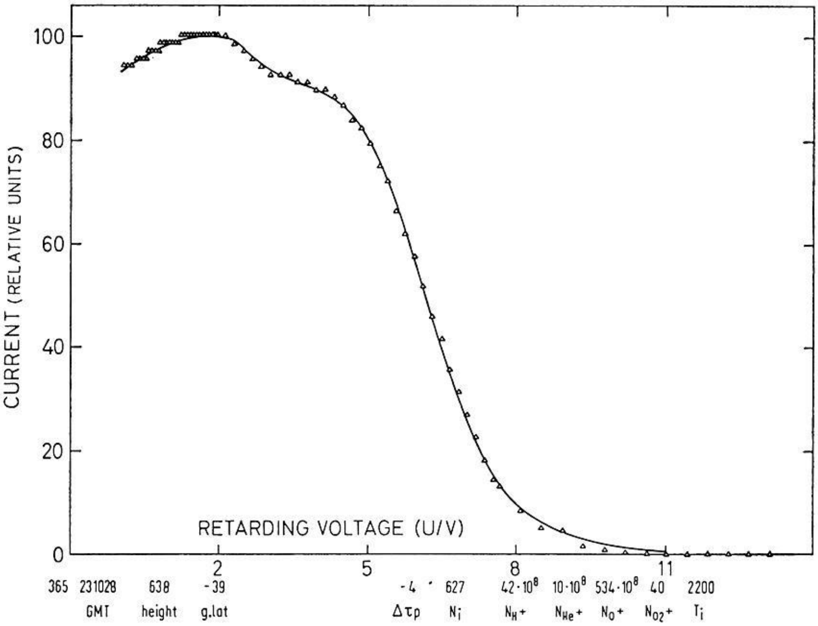

Fig. 4. Current-voltage-characteristic in the ion-mode. The triangles are the measured points. The fitted curve is computed under variation of the following parameters: 4 partial densities, ion temperature, vehicle potential, angle of attack (τ_p). $\Delta\tau_p$ means the difference between the velocity vector of the spacecraft and the computed minimum angle of attack

Electronics

The currents are measured by a linear automatic range-changing electrometer from $6 \cdot 10^{-6}$ amps to $4 \cdot 10^{-12}$ amps full scale with a noise level of about $5 \cdot 10^{-13}$ amps. The bit resolution on the most sensivtive range is $3 \cdot 10^{-14}$ amps.

An inflight calibration of the experiment is automatically switched on every orbit. The electrometer is checked by 8 highly constant currents. All the sensor voltages together with some housekeeping values are linked and the essential functions of the experiment are tested. The error limits of the measurements depending on the tolerances of the electronics can be estimated with less than 5%. The overall accuracy for the derived plasma parameters is expected from the experience of AEROS-A to be better than 10% under normal conditions. The dynamic range of the experiment covers all possible values of the ionosphere within the spacecraft orbit between 200 km and 1000 km during day and night. The total weight of sensor and electronics is 2,5 kg. The electrical power consumption is 2.1 watts.

The experiment RPA on board the satellite AEROS-B is principally identical to that of AEROS-A. Some changes in the retarding voltages and in the measuring sequence were undertaken to improve the data of AEROS-B experiment (Dumbs *et al.*).

Figs. 3 and 4, which show measured data from AEROS-A, illustrate that the total experiments is working highly satisfactorily and is able to provide data of high quality (Dumbs *et al.*, 1974; Spenner *et al.*, 1974). Therefore it was not necessary to make essential changes of the experiment between AEROS-A and AEROS-B, especially in view of strong limitations on costs, time and technical constraints of the spacecraft.

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Note Added in Proof. The satellite AEROS-B was successfully launched on July 16, 1974, and since July 20 complete RPA data are transmitted with high quality.