A Space-Borne Retarding Potential Analyser for *In Situ* Measurement of Charged Particle Flux

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A standard technique to measure the flux of charged particles with different energies and masses is to use a Retarding Potential Analyser (RPA). The front end of the experiment is a window that allows the particles of all energies and masses to enter the detector. These particles pass through a set of grids, where the selection of particles in the required mass and energy range is made. Only particles in this certain energy and mass range finally reach the collector electrode. The current collected by the collector electrode is, therefore a direct measure of the number of particles collected by it. By varying the electric potentials applied to the set of grids one can measure the flux of charged particles in different energy ranges. An RPA experiment is being developed in the Aeronomy Laboratory of INPE, to be used for the measurement of the spectral distribution of thermal and suprathermal electron in the energy range of 0 to 32eV, on board rockets and satellites. Basic details of this experiment are presented here. The experiment can be adapted to measure the spectral distribution of negatively or positively charged particles including electrons in other energy ranges.

INTRODUCTION

Charged particles in the ionosphere, with energies distinctly greater than the ambient thermal plasma particles, although represent only a small fraction of the total number of ionised particles, provide a significant means of momentum and energy coupling between ionosphere and magnetosphere. They take part in both large scale and micro-scale processes (see also Pfaff, 1996). The flux of charged particles of cosmic or solar origin also interact with the upper atmosphere of the earth. One of the factors that affect the useful life of a satellite is the intensity of this flux. These particles bombarding on the surface of the sensors or even penetrating into the integrated circuits used in the electronics packages of the experiments on board are known to cause damages to the sensors and the electronic components. In addition to their role in causing damages to the sensor surfaces and the electronic components of space-borne experiment packages, the supra-thermal electrons also play important roles in maintaining the night time ionosphere, in the generation of micro instabilities in the ionospheric plasma and in carrying the effects of magnetic perturbations to the ionospheric plasma. Supra-thermal electron measurements are also needed to understand the charge transfer processes associated with the field-aligned currents in the auroral region, as well as the wave heating created by intense electrostatic oscillations in the auroral and equatorial electrojets and other regions.

A detailed knowledge of the distribution in space and the principal characteristics of these particles are extremely important in designing the space-borne experiments. High-resolution measurements of the spectral and pitch angle distribution of these particles are essential for our understanding of the energy transfer processes occurring in the upper atmosphere and the ionosphere. The measurement of charged particles with energies just greater than that of the ambient thermal plasma, the

so called suprathermal particles, remains one of the most challenging experimental goals that face the space experimentalists today. The suprathermal electrons observed in the daytime ionosphere, for example, carry in the form of kinetic energy, almost one third of the solar energy associated with the UV ionisation process. This energy is eventually transferred to the neutral atmosphere (Hays and Sharp, 1973), yet there are no reliable in situ measurement techniques with which to measure and understand this flux. Some of the frequent problems associated with the accurate and reliable measurement of the energy spectra of suprathermal particles are the following.

1. The plasma sheath that develops around the spacecraft prevents the lowest energy particles from entering the detector or significantly modifies their trajectories.
2. The spacecraft and the magnetic fields associated with it modify the flux of incoming particles in ways other than by sheath effects.
3. Photoelectrons created on the spacecraft and its interiors contaminate the measurements.

One standard technique to measure the integral flux of particles with energies above the ambient thermal level is to use a Retarding Potential Analyser (RPA). RPA is an instrument that measures, when in an ambient plasma, the positive or negative current to a suitably biased collector electrode as a function of the potential applied to a retarding grid. From the measured current-voltage characteristics, it is possible to deduce several parameters of the ambient plasma. In this approach, a set of grids is biased to accept only those ions/electrons with energies above a threshold level. By varying the energy threshold with successively higher values, in principle, one can obtain the differential spectral information. Since the particle velocity distribution depends on the orientation of the sensor aperture with respect to the magnetic field and spacecraft velocity vector, normally multiple detectors are flown (see Carlson and Kelly, 1977). An RPA experiment, a modified and simpler version of a more

sophisticated RPA developed by Somayajulu et al (1986) for measurements on board one of the Indian Aeronomy satellites SROSS-3, is being developed in the Aeronomy Division of INPE will be used to measure the energy distribution of the thermal and suprathermal electrons in space. In the first phase the RPA will be launched on board a rocket and later on board a near-earth orbit satellite.

EXPERIMENTS DETAILS

The RPA being developed at INPE has a planar aperture and is designed to collect electrons through a gridded aperture that is modulated with an applied potential. It is planned to measure the flux of thermal and suprathermal electrons in the energy range of 0 - 32eV. The energy selection will be made using six grids in the form of meshes that form the front end of the RPA detector. The aperture, grids and the collector plate are aligned in parallel planes oriented perpendicular to the main direction of arrival of the particles. The aperture grids G1 and G2 are normally grounded to the instrument housing (and the spacecraft) or maintained at a negative potential of 1V. Maintaining the aperture grids connected to the ground will ensure that the plasma senses an electrically uniform spacecraft interface without any fringe fields around the aperture, while maintaining at a slight negative potential will repel electrons of energy less than a threshold from entering into the detector. The retarding grids G3 and G4 will be modulated by the applied retarding potentials that varies between 0V and - 32V so as to allow electrons in the energy range of 2.5eV to 80eV to be collected by the collector grid. The suppressor grid G5 is maintained at a positive potential to ensure that no thermal ions reach the collector. The grid G6 acts as a shield between the retarding grids and the collector, and is normally maintained at the collector potential. The RPA detector is schematically represented in Figure 1. The detector has a circular aperture of diameter about 60mm. Electrons in the selected energy range that pass through the grids are collected by the positively biased collector and the current caused by these electrons is amplified by the preamplifier unit and later processed electronically for transmission by the on board telemetry system to the ground receiving station.

It should be mentioned here that the RPA details provided here are for a typical experiment and in principle are subject to modifications in mechanical dimensions and electronic details depending on whether the RPA is going to be launched on board a rocket or a satellite as also on the energy range of charged particles to be measured.

As mentioned earlier a retarding potential (for electrons) in the range of 0V to -32V is applied to the grids G3 and G4. The aperture grids G1 and G2 are normally connected to the satellite ground to avoid possible interference with the ambient plasma and a potential of +14V is applied to the collector plate. The potentials of the grids G3 and G4 are varied in a programmed manner so as to maintain the grids at

fixed potentials for short intervals of time (about 16ms, for example) to collect electrons of a particular energy range at a time. A "staircase" sweep generated at the grid voltage generator will do this job. By measuring the current collected by the collector as a function of the retarding potential applied to the grids G3 and G4 one can, not only estimate the number of particles received in a given energy range, but also estimate the electron temperature. In principle, the same experiment can be used to collect electrons in other energy ranges or positive/negative ions of any energy range by properly selecting the potentials of the grids G1 to G6. But the potentials used, except that of the collector, are always retarding ones for the particles that are intended to be collected by the detector.

Figure 1.: Schematic diagram of a Retarding Potential Analyser-RPA

The block diagram of the system electronics is given in Figure 2. The particle current collected by the collector is converted into a varying voltage at the preamplifier and then amplified further at a multiple gain dc amplifier before being converted into digital data at an A/D converter. The gain of the dc amplifier is automatically adjusted depending on the amplitude of the incoming signal so that the dc amplifier output always remains in the 0-5V range. The digital data along with the dc amplifier gain and the grid bias information are stored in the digital buffer from where it is passed on to the on board telemetry system to be transmitted to the ground telemetry receiving station.

Figure 2.: Block Diagram of the RPA System Electronics

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