Small Satellites for Earth Observation

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AN ION DRIFT MONITOR FOR EARTH OBSERVATIONS FROM A SMALL SATELLITE

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ABSTRACT
An innovative light weight (700 g) Ion Drift Monitor (IDM) with the capability to measure the full vector of ion drift in the Earth's ionospheric plasma has been developed for use aboard spinning micro-satellites. To determine the full vector of arriving flux, it is necessary to sample at two mutually perpendicular angles of ion arrival with respect to the spacecraft velocity vector. These measurements are used to derive two components of the ambient thermal ion drift velocity which, when combined with the third component (the ram component Vdx), allow the total drift velocity to be determined. To increase the accuracy of the Vdx measurements and make them independent of ion composition, a simple electron sensor for measuring floating potential (FP) and effective electron temperature (Te) is incorporated in the hardware. Four Pi coverage is achievable using two oppositely directed units, each having a mass and power requirement of 700 g and 1.4 W. The data can address numerous open questions concerning ionospheric physics.

1. INTRODUCTION

An instrument (MARIPROBE) developed at the Space Research Institute in Moscow to provide the first global measurements of the near Martian cold plasma during the Mars-96 mission (official manufacturer Space Technology Ireland, Ltd.), was later adapted to study the cold terrestrial ionospheric plasma and flown aboard the ACTIVNY and APEX satellites. This device (TERRIPROBE) consisted of three sub-units, namely (a) a Cold Plasma Meter (CPM); (b) a Spherical Ion Probe (SIP) and (c) an electronic block. CPM was made up of several sensors, including a Drift Meter (DM), which measured two components of ionospheric plasma drift - thereby providing monitoring of electric fields in the polar ionosphere.

The purpose of the present paper is to describe an Ion Drift Monitor (IDM) based on the heritage of the above mentioned instruments but having the capability to measure the full ion drift velocity vector aboard spinning micro-satellites. This instrumental advance depends on the use of innovative technologies (see Section 7). IDM can either act as a 'stand alone' instrument or be flown to complement the ionospheric measurements of 'classical' ion energy spectrometers and electron probes.

2. ION DRIFT MONITOR (IDM)

To determine the full vector of arriving flux of ionospheric ions (Vd), it is necessary to sample at two mutually perpendicular angles of arrival of the flux with respect to the spacecraft velocity vector (Vs). These measurements are used to derive two components of the ambient thermal ion drift velocity which, when combined with the third component (the ram component Vdx), yield the total drift velocity.

IDM has been specially designed to make measurements (see Section 3) of thermal ions arriving at two mutually perpendicular angles at a typical micro-satellite. The capability, on such a vehicle, to also measure the ram component is typically constrained by lack of spacecraft resources. Therefore, to increase the accuracy of the complementary Vdx measurements and render them independent of ion composition (see Section 3), a simple electron sensor to provide determinations of floating potential (FP) and effective electron temperature (Te) is included in the IDM hardware.

3. IDM MEASUREMENTS

The following measurements can be implemented with the IDM instrument

0 Full vector of plasma drift vector (Vd), up to 12 km/s once per spacecraft revolution

0 Ion density, once per spacecraft revolution (Ni from 10 to 5 x 10^6 cm^{-3})

0 Effective Electron Temperature (up to 10 times /s)

0 Ion Temperature Ti ((300 K.......10,000K) once per spacecraft revolution

0 Spacecraft body potential Fs, up to 10 times/s

There are two operational modes.

In **Nominal Mode** (NM), measurements at two mutually perpendicular angles of arrival of the flux with respect to the spacecraft rotation axis are made. From these measurements, two mutually perpendicular angles are derived, namely the vertical angle (pitch) in the orbital plane, and the horizontal angle (yaw) perpendicular to the orbital plane direciton.

In **Energy Analysis Mode** (EA), V-I curves of the Retarding Potential analyser (RPA) are measured. The value of Vdx is uniquely determined if ions of two different masses are present (assuming that they have the same drift velocity) in the ambient plasma. To cover the case of a single ion plasma, independent measurements of the spacecraft potential (Fs) are provided. Fs can then be determined to an accuracy of better than 0.1 V from Floating Potential and effective electron temperature measurements.

4. IDM CONFIGURATION

IDM is contained within a single mechanical housing, see Fig. 1., on the outer surface of which the following sensors are mounted (a) two Retarding Potential Analyzers (RPAs); (b) one Floating Potential Sensor (FPS). The two RPAs are positioned such that their fields of view are in one plane, parallel to the rotation axis of the spacecraft. This allows the angle of elevation of incoming ion flux to be determined (in a spherical co-ordinate system with the polar axis parallel to the rotation axis). The second angle (azimuth) is determined from the phase of rotation (marked by a major maximum in one or two RPAs). Thus, IDM determines the Vd vector once per spacecraft rotation. The electron sensor uses a flat differential noise compensated electrode system and its support electronics are contained within the same (sensor) unit.

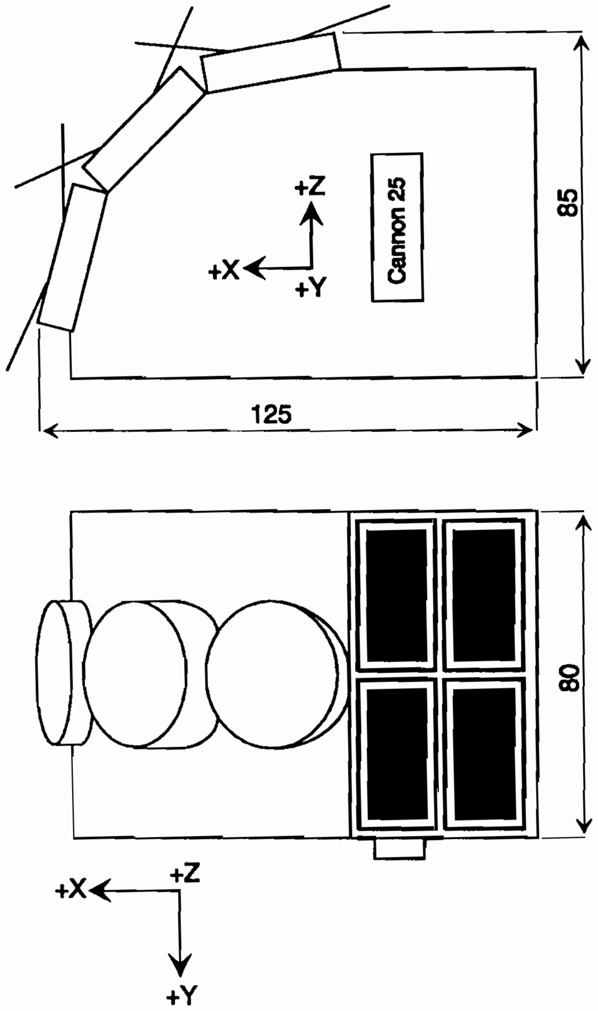

Figure 1. : IDM Experiment - Mechanical Configuration

5. ELECTRONICS

The IDM electronics consist of the following functional elements

DCAU;	Two highly sensitive DC amplifiers which provide a range of DC current measurements from 2×10^{-12} A to 2×10^{-7} A.
SGU;	Sweep generator of analyzing voltage.
LU;	Logic unit (selection of maximum current for Energy Analysis Mode to decrease TM requirements).
DSIU;	Output signal isolation for TM.
PU;	Power unit generating secondary voltages for supplying the sensors and electronic circuits and to receive functional commands.
CB;	Connector board with 3 cannon type connectors (primary power and functional commands, TM and Test connectors).

6. RESOURCE REQUIREMENTS

The toital mass required to accomodate the instrument in the configuration described in Section 4, is 700 g and the corresponding power consumption is 1.4 W. Ion drift measurements are associatively made in slightly more than one hemisphere (slightly more than 2*pi space angle) around the +Z axis of spacecraft rotation when the incoming ion flux is inside this angle. Due to the inherent dependence on spacecraft orientation, different parts of a particular orbit will typically be sampled as time progresses. To obtain effectively 4 pi coverage, a second sensor unit should be mounted on the opposite side of the spacecraft and oriented in the opposing direction (-Z). The additional mass/power resources required to achieve such all sky coverage are 0.7 kg/1.4 W.

Four functional commands, namely FC1-Experiment ON; FC2-Experiment OFF; FC3-EA Mode ON and FC4 -EA Mode OFF are required for each device. Table 1 summarizes the telemetry output from each IDM.

Table 1 ; Telemetry output from IDM

Mode	No. of Channels	Sampling Rate	Bit Rate
Nominal	5 Analog 1 thermistor	4-8 per second	200-400 bps
EA Mode	5 Analog 2 Analog 1 thermistor	4-8 per second 100 per second	200-400 bps 2000 bps

7. INNOVATIVE TECHNOLOY

Innovative techniques used to measure the full vector of ion drift include (i) utilization of a micro-minature RPA developed at IKI which can be flown on a micro-satellite while maintaining the characteristics of a 'large' RPA; (ii) development of IDM technology for a spinning micro-satellite having minimal onboard resources. The accuracy of the achievable drift direction measurements (angles of ion arrival are measured with an accuracy of up to 1-2 degrees), are higher than those made hitherto in space, since the angles of arrival are detemined from relative measurements and are thus not influenced by various errors related to the electronics.

8. APPLICATIONS

The data can address numerous open questions concerning ionospheric behaviour, including the detailed way in which the Equatorial Ionization Anomaly (EIA) is influenced, under different ambient conditions related to seasonal variations and to the phase of solar activity, by the meridional thermospheric wind.

9. CONCLUSIONS

An instrument with the capability to provide state of the art ion drift measurements in the Earth's ionospheric plasma has been developed, using innovative technology, for use aboard spinning micro-satellites.

END