RAMS: A Miniature Ram Angle and Magnetic Field Sensor for Picosat Attitude Estimation

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Abstract

The popular and well-established concepts for satellite attitude sensing, including Earth horizon sensing, Sun sensing, geomagnetic field sensing, and star sensing have had almost no new revolutionary additions in decades. In this paper we introduce a new attitude sensing concept and prototype miniature sensor called RAMS (Ram Angle and Magnetic Field Sensor). This novel instrument directly measures the in-situ 2-axis ram direction of a LO satellite by collecting the incoming thermospheric flow field through a wide field of view aperture entrance, counting the neutral molecules in a thermicus chamber, adjusting the kinetic energy of the charged molecules in an electric field, and measuring the impingement location in two coordinate axes on a quad detector. Coupled with its own built-in magnetometer, RAMS provides an estimate of the satellite’s 3-axis attitude relative to the local orbit frame regardless of roll angle or sunlight conditions as long as the ram direction is within the field of regard of the entrance aperture. If available, an external Sun sensor can be utilized in place of the magnetometer during daylight conditions. As a big product of interest to the space weather community, the sensor also provides an estimate of the in-situ cross track wind and density of the thermospheric neutrals.

RAMS is a small magnetometer combined with a quad collector geometry with incidence axis aligned to a rigid satellite reference to obtain the centroid of the neutral and ion flux distributions with respect to the satellite velocity. The total neutrals and the incident ions give the neutral and ion densities.

The vast majority of LEO satellites are Earth-pointing with a forward-looking nose. Motivation

Sat-5 star camera. The popular and well-established concepts for satellite attitude sensing, including Earth horizon sensing, Sun sensing, and the total wind vector

The RAMS apeture has an area, a, of 0.008 cm². The beam half width (w), which provides a measure of temperature, follows from:

where V is the spacecraft velocity and qe is 1.6E-19 C

The ion source ionization efficiency (ξ) is unknown:

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Total neutral density, n, is obtained from the current of

Ion enter a ram-pointing aperture subtend a cone half-angle of less than 10 degrees at the quad-collector. Which corresponds to a fictitious V', (red vector in diagram) with an error directly proportional to the magnitude of W,

Ion source sensitivity ~0.1 mA adjustable electron beam.

The total velocity vector V is defined here as the ram direction, and it is entirely due to the wind vector W and the satellite velocity V_s.

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