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On the issue of surface contamination of a Langmuir Probe sensor: Demeter ISL results

J.-P. Lebreton (1)

(1) LPC2E (CNRS-Universite d'Orleans), Equipe Plasma Spatiaux, Orleans Cedex 2, France (jean-pierre.lebreton@cnrs-orleans.fr), (2) LESIA (Obs Paris-Meudon) 5 Place Jules Janssen, 92195 Meudon Cedex , France (jean-pierre.lebreton@obspm.fr)

The Langmuir probe is in principle a simple and very versatile space plasma diagnostic instrument for in situ measurements. A classical Langmuir probe uses a single sensor, which may be of different geometry (cylindrical or spherical). The Demeter Langmuir Probe (ISL: Instrument Sonde de Langmuir) comprises two Langmuir Probe sensors. It includes a classical cylindrical sensor (5 cm long, dia 6 mm) and a 4-cm diameter spherical Segmented Langmuir Probe (SLP) whose surface is divided in six 1-cm disk sections. This design provides directionality measurement capability. The sensors are made of titanium and coated with a TiN layer. The CNES Demeter satellite was launched in June 2004 on a 700-km altitude high-inclination orbit. ISL worked flawlessly till the satellite was decommissioned in March 2011. It provided more than 6 years of data. For operational reasons, the science payload was only operated below magnetic latitude 65°. It was switched off twice per orbit when above 65°. A transient behavior of the ISL sensors was systematically observed each time it was turned on at the beginning of each half-orbit segment. This transient behavior is attributed to the fact that the electricalcontact with the plasma is not purely resistive. This is attributed to the presence of a thin insulating layer on the sensor surface, most likely due to contamination. The characterization of the electrical properties of this layer is achieved in two different ways: i) analysis of the recording of a series of I-V curves at different sweep rates using a special mode designed for that purpose; ii) analysis of the transient behaviour of the I-V characteristics recorded at instrument switch ON at the beginning of each half orbit. As independently observed from the comparison between Demeter ISL measurements and ground-based ionospheric radar sounding measurements, (J.-J. Berthelier, private communication, 2011) it is shown that the electron temperature measurements performed by a contaminated Langmuir Probe are significantly higher than the true physical value. In this work, we assume that the layer can be approximated by a parallel RC network which is in series with the non-linear sheath resistance of the sensor immersed in the plasma. The characteristics of the layer are analysed through analytical modeling of its effects on the I-V characteristics and on the transient response of the probe. This work makes use of both in-flight and laboratory data that were recorded prior to launch for calibration purposes. The higher the plasma density the most pronounced the effects of the contamination layer on the plasma measurements if not properly taken into account during the analysis. As it is extremely difficult to guarantee a contamination-free Langmuir probe sensor, in-flight decontamination methods and in-flight characterisation of the electrical properties of the contact properties of the sensor with the plasma are being addressed in this paper.