Findings from the PP-SESAME experiment on board the Philae/ROSETTA lander on the surface of comet 67P

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Abstract

The Permittivity Probe (PP-SESAME [1]) on-board the Philae Lander of the ROSETTA mission was designed to constrain the complex permittivity of the first 2 meters of the nucleus of comet 67P/Churyumov-Gerasimenko and to monitor its variations with time. Doing so, it is meant to provide unique insight into the composition (and activity if data could have been acquired longer) of the comet. In this paper, we present the analysis of the PP-SESAME measurements acquired during the first science sequence, on November 13, 2014, on the surface of the comet.

1. Introduction

The ROSETTA probe reached its final target last summer: the comet 67P/Churyumov-Gerasimenko. On November 12, 2014, the Philae module landed on the surface of the small body. Among the instruments on board Philae, the Permittivity Probe experiment, which is part of the SESAME package [1], operated both during descent and on the ground. The objective of this experiment is to measure the low frequency complex permittivity, i.e. the dielectric constant and electrical conductivity, of the first two meters of the subsurface of the cometary nucleus. Unfortunately, interferences during the descent and the non-nominal attitude of Philae at the surface made this task more difficult than anticipated. In this paper, we describe the efforts undertaken to understand the data collected by the Permittivity Probe and interpret them in terms of cometary composition.

2. Theory of Mutual Impedance Probes

PP-SESAME is a mutual impedance probe. Its principle is based on the quadrupole array technique which uses a set of transmitters to inject a current in the ground, and measure: i) the magnitude of the induced potential difference ΔV between a pair of receiving electrodes, ii) the magnitude of the injected current I and iii) the phase shift between them [2]. The mutual impedance of the array is the complex ratio $\Delta V/I$ and normalizing it by the mutual impedance in vacuum we can derive both the dielectric constant and the electrical conductivity of the surface down to a depth that is in the order of magnitude of the distance between the receiving electrodes.

3. Determining the complex permittivity with PP-SESAME

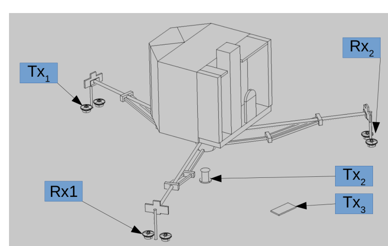

Figure 1: Modelling of PP-SESAME in operation with COMSOL Multiphysics®

PP-SESAME can use 5 electrodes, 3 located on the feet of the Philae lander and 2 mounted with other instruments (see Fig. 1). It operates at very low frequencies, in the range 10 Hz-10 kHz. In practice, in order to derive the complex permittivity from PP-SESAME active measurements, the influence of both the electronic circuit of the instrument and the conducting elements in its close environment (Philae body, harpoons, ice screw...) must be accounted for. The method that allows this has been described before in [3] and [4]. To be applied it requires a good knowledge of the attitude of the Philae lander with respect to the ground.

4. Measurements during descent and on the surface of the comet

During descent PP-SESAME acquired data during four measurement sequences which were mainly devoted to calibration, with the deployed landing gear, away from the Rosetta spacecraft influence and in an environment of known permittivity (i.e. near-vacuum). Unfortunately the measured received potentials during descent were all saturated due to disturbances from another instrument. The transmitted current, however was not and therefore could be measured. On the cometary ground, PP-SESAME performed measurements during four identical sequences, each of them separated by 2 hours, during the night. The amplitude of measured transmitted current on foot $+X$ was very close to that measured during descent indicating no contact with the ground (at least a few cm away) and/or a very low dielectric constant (close to 1). This latter interpretation would be consistent with the high porosity of the nucleus around 80% [5] and the results obtained by the CONSERT radar [6]. The potentials received on feet $+Y$ and $-Y$ were also measured but cannot be used as planned due to many factors. First, the attitude of the lander with regard to the surface is not well known. Second, the measurements were obtained in safe mode before the deployment of two of the transmitting electrodes, therefore PP-SESAME was operating with only 3 electrodes and not in a quadripolar configuration as it should. However, some constraints can be derived from the amplitude of potentials received on the two feet. The potential on $+Y$ is higher than that that on $+Y$ (Fig. 2). This is most probably not an effect of the temperature on the electronics as both feet are at the same temperature at the end of the night and the potential difference is still present. The most likely explanation is the presence of more material around the $+Y$ foot. Accurate simulations of the lander attitude and environment at the surface of the comet, using all available information (camera images, solar panel telemetry...) should confirm this hypothesis and allow us to derive the material electric properties. Furthermore, new laboratory measurements on the electronics of the receiving feet (down to -175°C) have shown that the drop in potential throughout the night (see Fig. 2) can be explained by the effect of temperature on the electronics. We recall that the electrical properties of the surface, and in particular of water ice, are not expected to vary at such low temperature (below -130°C).

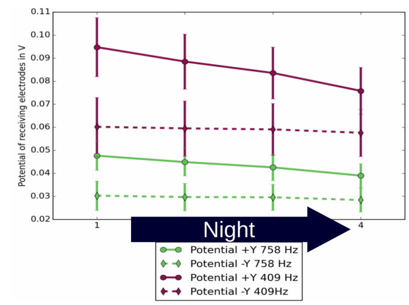

Figure 2: Received potentials on the +Y and -Y feet of the lander as a function of time

5. Summary and Conclusions

In this paper, we present the work done to understand the measurement of the PP-SESAME instrument on the surface of the comet. We will present simulations of the lander and its attitude with respect to the surface and the constraints on the surface properties we are able to derive from these simulations. Future work includes the geo-electrical characterization of materials relevant to the comet's nucleus and analysis of the data collected during a possible long term science sequence.

Acknowledgements

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