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Abstract

A Permittivity Probe (PP) instrument is now on board the Philae lander of the ROSETTA mission, en route towards comet Churyumov-Gerasimenko. The objective is to deduce the complex permittivity of the comet after touchdown from mutual impedance measurements between two pairs of transmitting and receiving electrodes. The full set of electrodes, also taking advantage of the instruments APX and MUPUS, will be deployed only some time after landing and then nominal operations will start. However, considering all other elements including the lander body as extra electrodes, it is possible to derive the complex permittivity from early measurements when only the landing feet would be deployed. The geometry is less suited due to symmetry constraints but in-flight calibration of the reduced system can be performed before landing in this configuration.

A numerical model of the instrument on Philae has been developed for simulating both free flight calibrations and first measurements on the comet. We discuss the results with respect to different crude models of cometary material.

1. Introduction

The internal structure and dynamics of comets are poorly known. Their surfaces are exposed to fast spinning variations of illumination as well as deep variations with the distance to the sun. Assessment of complex permittivity variability along the orbit is a valuable approach to investigate comet characteristics at shallow depths, and related sublimation and outgasing phenomena.

The mutual impedance method to measure the complex permittivity of the ground was first introduced by Wenner for geophysical prospection [1], and it was proposed for planetary investigations by Grard using a four-electrode array [2]. On Philae the probe consists of a system of 5 electrodes, 2 receivers and 3 transmitters, and works in principle as a quadrupolar probe utilizing only two receivers and two transmitters at a given time, as shown in Fig. 1. The 3 feet of the lander hold the 2 receivers and one transmitter, whereas the two other transmitters are hosted by the MUPUS and APX sensors. However, the system of electrodes is strongly influenced by the vicinity of the lander body and other grounded items that work as additionnal electrodes.

2. The three feet reduced model

2.1 Model

With two receiving electrodes and only one transmitter the usual quadrupole cannot be formed, except if we consider the return current flowing through the body of the lander and other connecting parts. As this ground electrode is geometrically distributed in the main body and several items as harpoons, it is not possible to consider them small or pin points. The PP electronics allows for measuring either the differential voltage between the two receivers or the voltage with respect to the lander potential; then it is possible to use the lander body and connected parts as an extra electrode.

The quasi-static approximation can be used because the working frequencies are lower than 10 kHz and, for an angular frequency ω, the currents **I** and potentials **V** of the electrodes are linked by the equation:

$$\mathbf{I} = i\omega\,[\mathbf{K}]\,\mathbf{V} \qquad (1)$$

where [**K**] is the electrostatic capacity-influence matrix of the electrode array computed with the finite element technique and a more or less representative geometrical model as shown in Fig. 2. Currents and potentials measured by the instrument are supposed to be well known, and [**K**] holds the information about the permittivity environment.

2.2 Calibration

The free-flight of Philae after release from ROSETTA provides a unique opportunity to perform in-flight calibration of the reduced system in deployed configuration, except for harpoons and ice screws.. However, their influence is small and can be evaluated. As no calibration of PP in fully deployed configuration was possible before flight, the calibration during the release sequence is really necessary, even in the descent configuration. Due to operational constraints, the calibration will be repeated several times during the descent of Philae to the comet, but at the single frequency of 1 kHz.
In-flight calibration provides corrections to the capacity-influence matrix for the case of a vacuum. In the case of a non negligible plasma environment, corrections would be evaluated from the MIP-ROSETTA instrument plasma measurements.

2.3 Simulation

For simulations of the first measurements after landing we assumed H2O ice with various values of porosity. In this model, Philae is assumed to have landed on a flat, homogeneous substrate. On the comet, the permittivity will be deduced by matching the potential measurements with a grid of simulated values computed with the numerical model. It is shown that these first measurements could provide a first estimate of the ground permittivity. Combined with other experiments such as MUPUS that measures the thermal properties, this approach would provide a first characterization of the cometary material.

3. Figures

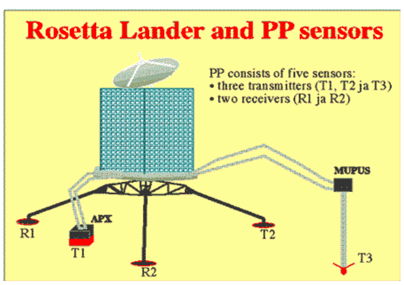

Figure 1: Sketch of the five electrodes used by PP.

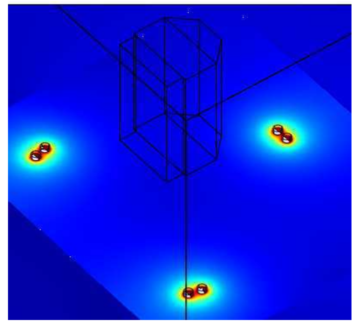

Figure 2: A model for the reduced geometry to calculate the 3D potential distribution.

4. Summary

The success of such early permittivity measurements of the cometary surface is expected if - as foreseen - the medium is not too conductive. On Earth, measurements would be generally difficult, except for low conductivity terrains such as glaciers.

This work defines a strategy for instrument calibration in idealized cases, with a nominal landing on a flat surface. This has to be confirmed by further modelling and laboratory experiments with spare models of the sensors. We also expect that in-flight calibrations of the reduced instrument would improve the data analysis of the nominal functioning with the two standard quadrupolar geometries.

References

[1] Wenner, F.: A method of measuring earth resistivity, US Bureau of Standards Bulletin, Vol. 12, pp. 469-478, 1915.

[2] Grard, R.: A quadrupolar array for measuring the complex permittivity of the ground: application to Earth prospection and planetary exploration, Meas. Sci. Technol. Vol. 1, p. 295, 1990.