EPSC Abstracts
Vol. 9, EPSC2014-453, 2014
European Planetary Science Congress 2014

Measuring the permittivity of the surface of the Churyumov-Gerasimenko nucleus: the PP-SESAME experiment on board the Philae/ROSETTA lander

A. Lethuillier (1), A. Le Gall (1), M. Hamelin (1), V. Ciarletti (1), S. Caujolle-Bert (1), W. Schmidt (2) and R. Grard (3)
(1) LATMOS-IPSL, Université de Versailles Saint Quentin, Guyancourt, France, (anthony.lethuillier@latmos.ipsl.fr) (2) Finnish Meteorological Institute, Helsinki, Finland, (3) ESA/ESTEC-RSSD, Noordwijk, The Netherlands

Abstract

The Permittivity Probe (PP-SESAME) on-board the Philae Lander of the ROSETTA mission will determine the complex permittivity of the surface of the Churyumov-Gerasimenko nucleus and monitor its variations with time. Doing so, it will provide unique insight into the composition and activity of the comet. In this paper, we present the method we have developed to analyze PP-SESAME active measurements. This method will be tested in May 2014 with a replica of the instrument in the giant ice cave system of Dachstein, in Austria.

1. Introduction

The ROSETTA probe will reach later this year its target : the comet Churyumov-Gerasimenko. Among the instruments on board the lander, Philae, the Permittivity Probe experiment, which is part of the SESAME package (Surface Electric Sounding and Acoustic Monitoring Experiment [1]), will measure the low frequency complex permittivity (i.e. dielectric constant ϵ_r and electrical conductivity σ) of the first 2 meters of the subsurface of the cometary nucleus. At frequencies below 10 kHz, the electrical signature of the matter is especially sensitive to the presence of water ice and its temperature behavior. It will thus allow to determine the water ice content in the near-surface and to monitor its diurnal and orbital variations. Doing so, PP-SESAME will provide essential insight on the activity and evolution of the comet nucleus.

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 transmitter 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 deduce both the dielectric constant and the electrical conductivity of the surface down to a depth that is of the order of the distance between the receiving electrodes.

3. In Practice : Determining the complex permittivity with PP-SESAME

PP-SESAME can use 5 electrodes located on the feet of the Philae lander or mounted with other instruments (see Fig. 1). It operates at very low frequencies, in the range 10 Hz-10 kHz.

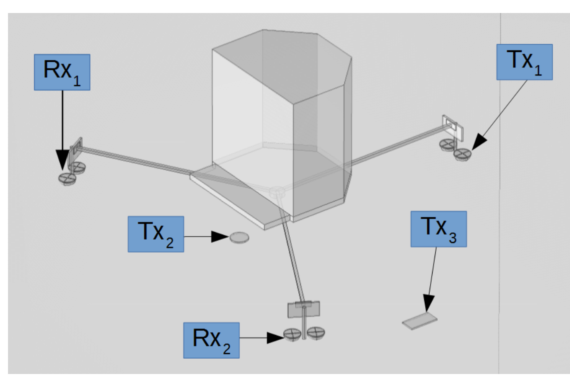

Figure 1: Modeling of PP-SESAME in operation with COMSOL Multiphysics®

During the Descent phase of the lander, PP-SESAME will perform active measurements with the deployed Landing Gear. These measurements are crucial for the calibration of the data that will be acquired on the nucleus surface with different combinations of electrodes. 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. This can be done using the capacity-influence matrix method. The received voltage V can be expressed as:

$$V_r = [K]^{-1}\frac{I}{j\omega} \quad (1)$$

where K is the capacity-influence matrix which can be decomposed as follows:

$$K = K_{elec} + K_{env} \quad (2)$$

K_{elec} can be determined by an accurate characterization of the electronic circuit of PP-SESAME.
K_{env} depends on the complex permittivity of the medium (ϵ_r and σ) and can be determined by modeling.

Figure 2 shows how the mutual impedance measured on the ground and normalized with respect to vacuum is expected to vary as a function of ϵ_r and σ. It also illustrates the difference between the PP-SESAME measurements and the ideal case with four isolated electrodes. Such charts will be used to infer the complex permittivity of the ground from PP-SESAME data.

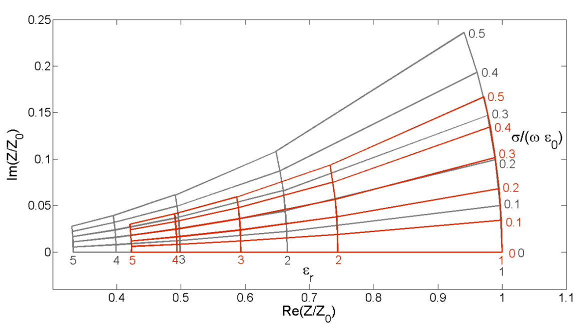

Figure 2: Charts relating the complex ratio $Z/Z0$ (to be measured) to the real and imaginary parts of the complex permittivity of the ground for an idealized mutual impedance probe (in grey) and accounting for PP-SESAME environment (in red).

4. Measurements made with the replica of Philae

In absence of spare model of the PP-SESAME, a replica of the instrument was recently built in LATMOS (Laboratoire Atmosphères, Milieux, Observations Spatiales), France. This replica will soon (in May 2014) be tested in the frame of a field campaign in the giant ice cave system of Dachstein, Austria. The Dachstein caves formed 10 million years ago. At that time there were probably completely filled with water. Today, their ground is covered with a thick layer of ice (several meters thick), which temperature is rather constant throughout the year. This measurement campaign is a unique opportunity to test the capacity influence matrix method (described in section 3) in a natural icy environment.

5. Summary and Conclusions

In this paper, we present the work done to prepare the scientific return of the PP-SESAME experiment on board the Philae Lander of the ROSETTA mission. In particular, we have developed a method to correct the measurements from the contamination of the close environment of the electrodes. Next steps include the geo-electrical characterization of materials relevant to comet nucleus at PP-SESAME frequencies and the analysis of the data which should arrive in November.

Acknowledgments

This project is supported by the Région Ile-de-France (DIM-ACAV program) and the French Spatial Agency CNES.

References

[1] Seidensticker, K.J. and al. : SESAME - An Experiment of the Rosetta Lander Philae: Objectives and General Design, Space Science Reviews, Vol. 128, pp. 301-337, 2007.

[2] Grard, R. and Tabbagh, A. : A mobile four-electrode array and its application to the electrical survey of planetary grounds at shallow depths, Journal of Geophysical Research: Solid Earth, Vol. 96, pp. 4117–4123, 1991.