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Refining the analysis of PWA-HASI/Huygens to constrain Titan's surface electrical properties

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Abstract

Almost 10 years ago, the Huygens probe successfully landed on the surface of Titan, Saturn's biggest moon. The Permittivity, Waves and Altimetry (PWA-HASI) instrument onboard then investigated during 32 min the electrical properties at very low frequencies of the top meters of the surface. Preliminary results reported a relative dielectric constant of ~2 and a low electric conductivity. Since then, much has been learnt on the position of the Huygens probe after landing and on the surface characteristics of Titan. Here we describe the refined analysis of the PWA-HASI data and discuss composition scenarios.

1. Introduction

Mutual impedance probes (MIP) were introduced in geophysics for measuring soil conductivity and later proposed by [1] for studying planetary surfaces. MIP use a set of transmitters to inject a current in the ground and measure the magnitude of the induced potential difference ΔV between a pair of receiving electrodes, the magnitude of the injected current I and the phase shift between them. The mutual impedance of the array is the complex ratio ΔV/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 electrodes (a few meters).

The scientific payload carried by the Huygens probe included a mutual impedance probe: the Permittivity, Waves and Altimetry (PWA) analyser [2], a sub-unit of the Huygens Atmospheric Structure Instrument HASI [3].

PWA-HASI was made of four ring electrodes (one receiving and one transmitting dipoles) mounted on the arms of the Huygens probe. It operated during 32 min after landing at five very low frequencies: 45, 90, 360 and 1440, 5760 Hz.

In this paper we describe the approach we have developed in order to accurately derive from PWA data the electrical properties of the shallow surface of the Huygens landing site. The same approach can be adopted for the analysis of the PP-SESAME/Philae/ROSETTA data that are to be acquired at the surface of the comet Churyumov-Gerasimenko nucleus later this year (see Lethuillier et al., this meeting).

2. Refining PWA-HASI data analysis

Preliminary analysis of PWA-HASI surface measurements reported a relative dielectric constant ε_r of ~2 and an electric conductivity σ of 4 10^{-10} Sm^{-1} [4,5]. However, this analysis did not account for: i) the electronic circuit, ii) the effect on the measurements of the vicinity of conducting elements (in particular the Huygens body) and iii) the position of the electrodes with respect to the ground. Moreover, no error bar was provided.

Since [4,5], an accurate characterization of the electronic circuit of PWA was conducted. Numerical simulations have also been run to account for the influence of the electrode environment using the commercial software COMSOL Multiphysics®. Lastly, different configurations of measurement (electrodes in contact with the ground or not…) were tested.

Doing so we were able to produce charts relating the real and imaginary parts of the complex permittivity of the ground to the actual measurements of PWA-HASI. These charts can then be used to derive from the data Titan surface electrical properties as illustrated in Fig. 1.

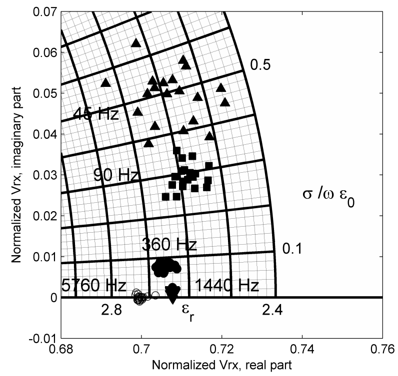

Figure 1: Chart relating the complex ΔV normalized with respect to vacuum (measured by PWA-HASI) to the real and imaginary parts of the complex permittivity of the ground.

3. Constraining the Huygens landing site composition

The refined analysis of the PWA data point to a higher dielectric constant than first estimated in [4,5]. This value must be compared to the known dielectric constant of materials relevant to Titan composition, in particular to that of water ice or tholins, at PWA low frequencies.

The low frequency electrical properties of water ice is relatively well known at 90 K (Titan surface temperature) [e.g. 6] and we also had access to unpublished geo-electrical characterization of tholins (organic matter). We will discuss PWA-HASI results in light of these laboratory measurements.

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