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Investigations of Titan electric environment and the Titan Electric Environment Package for the TandEM mission

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Abstract

The Permittivity, Wave, and Altimetry (PWA) analyzer, an element of the Huygens Atmospheric Structure Instrument (HASI), investigated the electric environment during the descent of the Huygens Probe through the atmosphere of Titan. The PWA analyzer has measured the electric conductivity profile in the range 40-140 km and identified a conductivity peak related to aerosols and cosmic rays at about 60 km, measured the dielectric properties of the surface and its evolution after landing, and detected an ELF signal that resemble to a natural signature of a Schumann resonance within Titan atmospheric cavity. In this work, we summarize ongoing atmospheric electricity studies and discuss the rationale and architecture of the Titan Electric Environment Package (TEEP) instrument proposed for the Titan and Enceladus Mission (TandEM) mission.

1. Introduction

Before the Cassini-Huygens mission, the electric environment of Titan was largely unknown due to lack of in situ measurements. Atmospheric electricity plays a primordial role in the production of aerosols and soots that contain traces of complex organic, possibly pre-biotic, constituents. The major objective of PWA was the characterization of the electrical state of Titan's environment down to the surface, at altitudes beneath the reach of orbiters, and to study electric features that cannot be resolved with remote sensing or propagation techniques. During the descent of the Huygens Probe, the PWA analyzer measured the electron and ion conductivities, Extremely and Very Low Frequency (ELF-VLF) electromagnetic waves, and acoustic phenomena. After landing, PWA also measured the surface dielectric properties [4], [6-9]. Two deployable booms carried six electrodes to provide a Mutual Impedance Probe (MIP) and two Relaxation Probes (RP). In the passive mode, the MIP receivers worked as a dipole antenna. A pressure sensor mounted on a fixed boom monitors the acoustic atmospheric noise.

2. PWA Results

The Huygens Probe, including HASI and the PWA analyzer provided outstanding, some unexpected findings about the Titan environment, namely atmospheric electricity. Here, we summarize the most relevant results:

⇒ Both MIP and RP identified a conductive layer (~2 nSm^{-1}) peaking at 60-70 km, corresponding to electron and positive ion densities of ~500 and ~2000 cm^{-3}, respectively [7-8];

⇒ The permittivity and conductivity of the surface are ~2 and ~1 nSm^{-1}, respectively [6] (a recent refined analysis provides slightly higher results);

⇒ If present, lightning rate is much smaller than on Earth and possesses different spectral characteristics in the ELF-VLF range [9];

⇒ An ELF signal at ~36 Hz resembling to that of a Schumann resonance was observed during the descent [9] (search for possible artefacts, including at cryogenic temperatures, revealed unsuccessful so far);

⇒ Presently, the most promising generation mechanism to explain the 36 Hz signal involves ion-acoustic turbulence, possibly coupled to the whistler mode, resulting from the interaction of Titan with the magnetosphere of Saturn [1].

3. TEEP Instrument Architecture

The TEEP instrument is an improved version of the PWA analyzer flown onboard Huygens [3][5]. The instrument also takes advantage of developments made for mutual impedance and relaxation probes included in the Rosetta and ExoMars mission payloads [2]. Figure 1 and Table 1 present typical instrument configuration and sensitivity of TEEP-L (lander) and TEEP-B (balloon) options. Under specific configuration and aiming boom alternatives, wiring embedded in the balloon envelope fabric can be used as antennas. Wiring would then provide electric dipole or magnetic loop antennas. To maximize the scientific results, coordinated measurements between TEEP and other instruments, namely magnetic field, optical transients, and sound signals are recommended.

4. Summary and Conclusion

The PWA analyzer provided the first in situ measurements related to Titan atmospheric electricity. Although some hypotheses were confirmed or discarded, unexpected PWA findings considerably changed our perception of the environment of Titan. New questions are raised about the ion chemistry and role of aerosols in the lower atmosphere. If a natural origin of the ELF signal is definitely established, PWA measurements would provide a resourceful approach for the investigation of Titan subsurface, namely the buried ocean predicted by models. The presence of discharging processes, namely lightning, remains nevertheless uncertain. Refined analyses of the Huygens data, ongoing measurements made by Cassini, and a future mission to Titan that includes TEEP, or similar instrumentation, would certainly contribute to answering atmospheric electricity open issues.

Table 1: Measurements sensitivity

Measurement	Range	Comments
Atmospheric conductivity	10^{-14}-10^{-8} Sm^{-1}	Both polarities
Surface conductivity	10^{-13}-10^{-7} Sm^{-1}	-
Surface permittivity	1-10	Resolution ~0.01
Electric fields	DC ELF VLF	Res. (AC/DC) ~100 μVm^{-1} ~50μVm^{-1}Hz$^{-1/2}$

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Figure 1: Instrument indicative design illustrating the TEEP-L (left) and TEEP-B (right) configurations. TEEP-B also includes an option with instrumentation in a guiderope (left).