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A Schumann-like resonance on Titan driven by Saturn's magnetosphere possibly revealed by the Huygens Probe

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Abstract

The low-frequency data collected with the antenna of the Permittivity, Wave and Altimetry experiment on board the Huygens Probe that landed on Titan on 14 January 2005 have been thoroughly analyzed considering different possible natural and artificial effects. Although a definite conclusion is still subject to the outcome of complementary inquiries, it results from our analysis that the observations can be explained, for the most part, in term of natural phenomena rather than being artifacts. Extremely-low frequency waves generated in the ionosphere of Titan, driven by the corotating Saturn's frozen plasma flow, are assumed to be the most likely source for the observation of the second eigenmode of a Schumann-like resonance at around 36 Hz in the moon-ionosphere cavity. This particular mode is thought to be enhanced with respect to other harmonics because of the particular location of the landing site with respect to that of the supposed sources. The power budget of the observed wave amplitude seems to be consistent with a rough model of the global current of the wake-ionosphere circuit. Broadband low-frequency noise events which are observed sporadically during the descent are probably due to shot noise on the antenna when the Probe is crossing aerosol clouds, an interpretation supported by post-flight ground tests. Contrary to the situation encountered on Earth, atmospheric lightning does not appear to be the source of a conventional Schumann resonance on Titan.

Keywords: Satellites, atmospheres; Lightning; Saturn, magnetosphere; Titan

1. Introduction

The search for atmospheric lightning activity was one of the main objectives of the electric field measurements performed in the extremely-low and very-low frequency ranges (ELF-VLF) by the Permittivity, Waves and Altimetry (PWA) analyzer (Grard et al., 1995), as a sub-system of the Huygens Atmospheric Structure Instrument (HASI) (Fulchignoni et al., 2002) that landed on Titan on January 14, 2005. It was then hypothesized that different signatures of a significant lightning activity could be detected in the atmosphere by the instrument. Such a major scientific discovery would have strongly supported the importance of atmospheric electricity in the theoretical models that predict the sparking production of complex organic compounds and eventually of pre-biotic molecules (Raulin et al., 1998), as it is thought to have been the case in the primitive Earth's atmosphere.

One electric component of electromagnetic (EM) and, possibly electrostatic (ES) waves was measured with a dipole made of two electrodes Rx1 and Rx2, distant of about 2 m, with the

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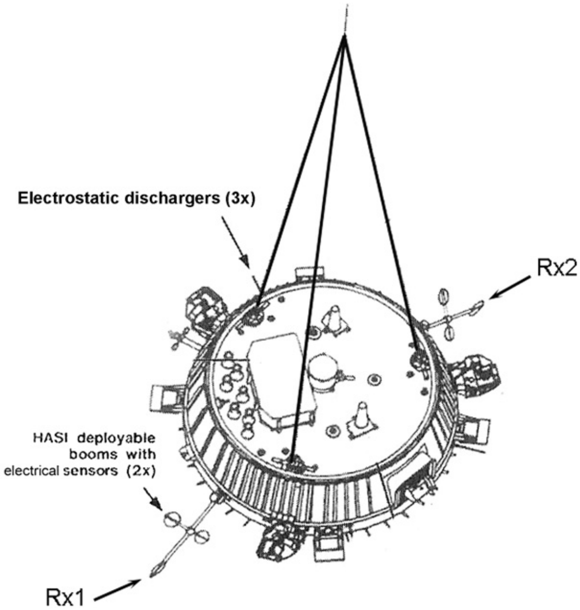

Fig. 1. General view of the Huygens payload and parachute bridles (after Lebreton and Matson, 2002).

Huygens Probe body in between (Fig. 1). Severe constraints imposed by the mission complexity leaded to design such short antenna with the consequence of reducing drastically the sensitivity. This is applicable as well to passive observations of natural waves, as to the active Mutual Impedance (MI) measurement, designed for deriving the local electron conductivity and density (Hamelin et al., 2007). However, in spite of those constraints and of the loss of one telemetry channel between the Probe and the orbiter (Grard et al., 2006), the optimized use of the resources allowed to perform both passive and active measurements throughout the descent from 140 km to landing for 2 h 25 min, and during 32 min at the surface until the end of the transmission session.

The onboard processing of the waveform received by the electric dipole was performed with the Fast Fourier Transform technique, within two frequency ranges, namely the so-called "Schumann" ELF band (3–96 Hz, with 3 Hz resolution) and a VLF band from 180 Hz to 11.5 kHz (for detail see Grard et al., 1995). In this paper, we will focus essentially our analysis on the ELF observations since the challenge of the passive measurements was the eventual detection of a Schumann resonance similar to that observed on Earth since the middle of the last century (Schumann, 1952; for a historical review see Besser, 2006). The existence of this phenomenon would be indeed an indirect evidence of a strong lightning activity.

2. Observations

In the ELF range, due to the loss of the second telemetry channel, one got only half of data, i.e., the even spectral lines by steps of 6 Hz, with 3 Hz resolution each, from 6 up to 96 Hz in the first part of the descent (Fig. 2). A pre-programmed mode change occurred at about 61 km, at 1930 s after ignition of the landing sequence, so that the available data until touch-down contain only the even spectral lines by steps of 12 Hz, with 6 Hz resolution (Fig. 3). A similar transition applies to the VLF range (not seen here), which also contains valuable data (Grard et al., 2006), put forward in Section 7 for the interpretation of the ELF noise. The spectrogram obtained during the first phase

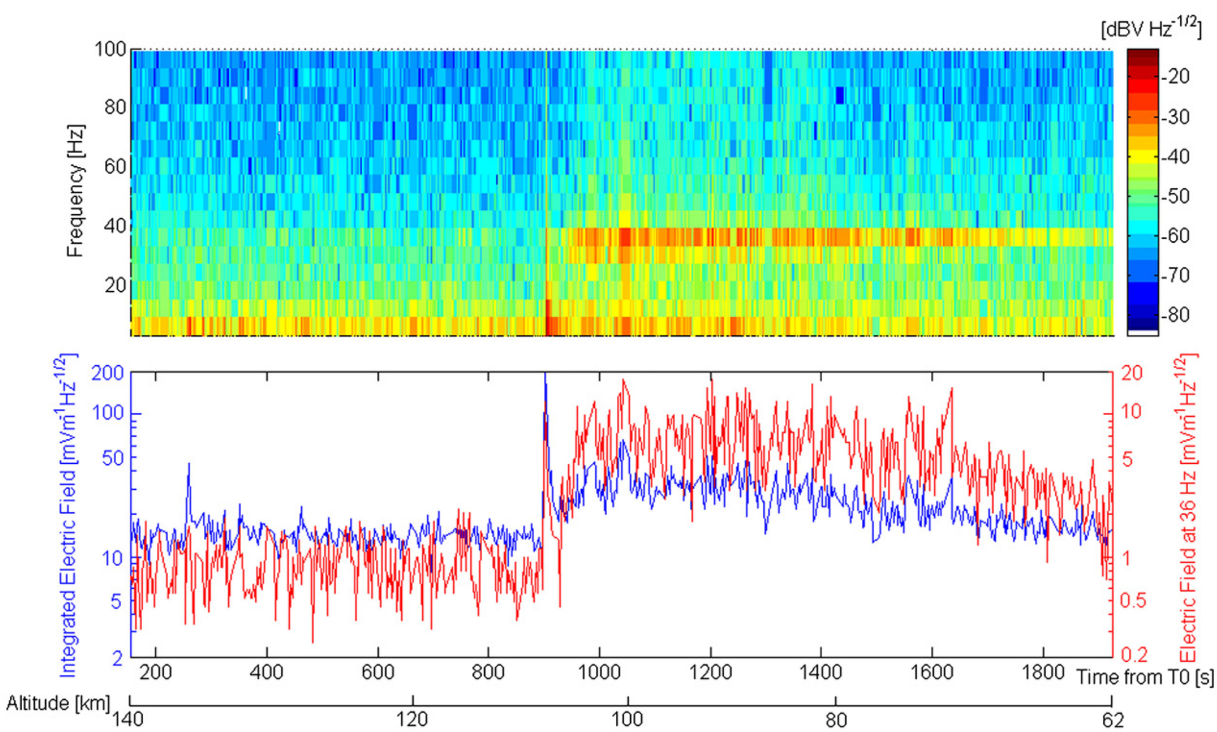

Fig. 2. Spectrogram of the ELF signal received with the electric dipole during the descent in Titan's atmosphere between 140 and 62 km. Top: spectrogram in the bandwidth 6–99 Hz; bottom: integrated field amplitude within the 99 Hz bandwidth (blue) and spectral level of the "36 Hz" line (red).