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A subsurface instrument to measure electrical soil properties

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Abstract

We propose an in-situ instrument that can determine local soil and subsoil electro-magnetic properties in future planetary missions. The existing laboratory model of the HP^3 Permittivity Probe (PP) is presented. Its ability to detect the electric properties of the local soil as well as structural properties has been already proven in laboratory tests. With relatively modest changes the instruments functionality could be increased to determine the electrical as well as the magnetic properties of the surrounding media.

1. Introduction

The HP^3 Permittivity Probe (PP) was initially intended to be flown onboard the ExoMars Humboldt surface station as part of the HP^3 sensor suite. After the cancellation of the Lander station and postponement of the original ExoMars mission it was decided to continue the sensor development until a laboratory model with a high proto-flight maturity level was achieved.

As a further development of an ESA prototype [1] the HP^3-PP was the first selected permittivity probe which is fully employed on a mole penetrator. With its concept based on a classical Wenner array [2], PP is injecting an alternating electrical field in the investigated medium. Measuring the medium dependent voltage-amplitude and phase differences to the transmitted signal it is able to determine the electrical properties (conductivity, permittivity and dielectric loss) of the sample. Additionally, textural parameters (e.g. stratification and local inhomogeneities) can be derived, as has been proven in laboratory tests. As the existing electronics already provides the basic measurement parameters (amplitude and phase) for measuring electrical properties, it is further possible to increase the functionality of the instrument to determine the magnetic properties of investigated samples for a relatively modest change of the existing PP-electronics.

By combining measurements of electrical and magnetic properties, either as a penetrating or a surface instrument, it would be possible to acquire a vast amount of physical information. Key scientific goals are the detection of small amounts of bound water (permittivity) and Fe-phases (permeability). Such a coupled instrument would be able to gain important information about the surface evolution of planetary objects.

2. The PP-instrument

Initially, PP was planned to be located on a mole cylinder. For this purposes the instrument was designed to be small and lightweight. A picture of the PP electrode foils mounted on one half shell of the cylindrical payload compartment is shown in Fig. 1. Table 1 summarizes the characteristic features of the existing sensor.

Figure 1: One half shell of the HP^3 Permittivity Probe.

For technical reasons and redundancy the payload compartment of the permittivity sensor is split into two half shells, containing the payload and the mole electronics. The PP electronics consist of two redundant electronic boards connected to the electrode foils located around the payload cylinder. Each board is operating one side of the instrument as a vector analyzer. Covering a comparatively broad frequency range (4 – 20,000 Hz) PP already provides the required frequencies for additional measurements of magnetic properties [3]. A magnetic permeability probe could easily be derived by adding a set of coils to the existing electrodes as a separate channel using the same electronics.

The actual measurement error for permittivity and electrical conductivity measurements is less than 10%. This will be reduced to about 5 % after final calibration.

Table 1: Characteristic parameters of the HP^3 Permittivity Probe

parameter	value
working frequency range	4 – 20,000 Hz
mass front end electronics	15 g
mean power consumption	166.1 mW
length	250 mm
Diameter of payload compartment	24 mm
measurement error (uncalibrated)	<10 %

3. Permittivity Probe- Test Results

A large quantity of laboratory measurements testing the functionality and capabilities of the HP^3-PP sensor has been performed. Representatively in Fig. 2 the evaluated permittivity for the Martian soil analogue Salten Skov is plotted as function of the operating frequency. The errors of the permittivity values contain the actual measurement error of the sensor as well as the variation in changing measurement conditions in the laboratory like e.g. ambient humidity and room temperature.

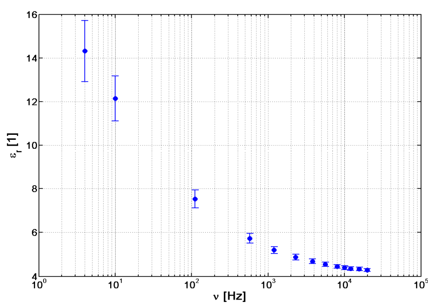

Figure 2. Evaluated permittivity for the Martian soil analogue Salten Skov as a function of frequency.

In the frequency region below 3800 Hz a strong increase in the permittivity is detected, which is an indicator for water deposits in the sample. The mentioned sample was not additionally enriched with water, subsequently only a small amount, originating from the ambient air humidity could be adsorbed. The resulting increase of the permittivity value demonstrates a high sensitivity of the Permittivity Probe to water abundances in the sample. In general, fine grained samples show a high hygroscopic behavior. To increase the accuracy of the evaluated permittivity values careful sample preparation and desiccating processes are essential. Additional theoretical evaluations will provide a clear understanding of the origin of the measured quantities in future.

4. Conclusions

With the HP^3 Permittivity Probe it is possible to determine electrical soil and sub-soil properties with an error <10 %. After the final calibration this error will be reduced to about 5 %. Laboratory measurements demonstrate the high sensitivity of the sensor to water abundances in a sample. The developed PP-electronics already provide the basic components to additionally determine the magnetic properties of the investigated material. Such an instrument could reveal small amounts of bound water (permittivity) and Fe-phases (permeability) and therefore provide important information concerning the surface evolution of planetary objects.

References

[1] Trautner, R. et al.: A new instrument for measuring the low frequency electrical properties of planetary subsurface materials, Proceedings of 37th ESLAB Symposium, ESASP-543, 193-196, 2004.

[2] Wenner, F.: A method of measuring earth resistivity, US Bureau of Standards Bulletin, 12, Sci. paper 259, p 469, 1915.

[3] Bentley, M.S. et al.: In situ multi-frequency measurements of magnetic susceptibility as an indicator of planetary regolith maturity, Planetary and Space Science, 57, Issue 12, 1491-1499, 2009.