EPSC Abstracts
Vol. 6, EPSC-DPS2011-1749, 2011
EPSC-DPS Joint Meeting 2011

Measuring the Permittivity on Mars: The Permittivity Sensor of the HP^3 Instrument.

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Abstract

We report on the development and first results from a bore-hole permittivity probe to be used on the surface of Mars.

A permittivity probe covering the frequency range of 4 – 20 000 Hz with a 1 Hz resolution was developed as part of the HP^3 instrument.

The sensor approach follows the classical concept of a Wenner array [1] of equally spaced electrodes wrapped around the outer envelope of the HP^3 payload compartment, where an electrical field is projected into the adjacent material. With the two receiver electrodes this field is measured back and compared with the output signal. From amplitude and gain changes the electrical properties of the ambient material can be inferred.

For calibration, measurements were performed with three different environmental stable polymers, namely polyethylene (PE), polymethyl methacrylate (PMMA) and polytetrafluoroethylene (PTFE). We also used assorted Martian analogue materials

As reference values for the sample permittivity data gained from a high precision impedance spectrometer were used.

In comparison to common literature values and the reference samples, an accuracy of better than 5% can be achieved with the calibrated sensor breadboard for frequency ranges > 1 kHz.

1. Introduction

The Heat Flow and Physical Properties Package HP^3 is designed to penetrate the Martian regolith down to a depth of 5m. During penetration and at the maximum depth it will measure the thermal gradient, the thermal conductivity and also the permittivity of the adjacent material [2]

At the front of the instrument is a self penetrating hammering mechanism a so-called Mole which is dragging the payload compartment behind it. Within this payload compartment the front-end-electronics of the hammering mechanism and the permittivity probe is located. It contains also the thermal sensors for the heat flow probe and on the outside the transmitting and receiving electrodes of the permittivity probe. A tilt sensor is providing attitude information during the penetration process. A tether which itself contains thermal sensors is connecting the mole to the support system on the surface.

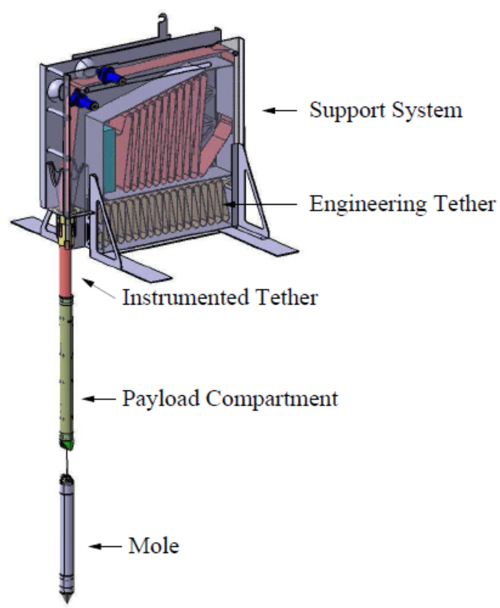

Figure 1: The HP3 instrument schematics.

2. Instrument description

Since the original concept was the deployment of the sensor on a mole penetrator the whole instrument had to be small and lightweight. The overall length of the instrument was 250mm and a maximum outer diameter of 24mm.

Inside the payload compartment two redundant electronic boards operating each one side instruments. The whole concept is representing a vector analyser returning already the phase and amplitude with respect to the output signal. Thus we can achieve a high accuracy and a frequency resolution of 1 Hz in a range of 4 – 20000Hz.

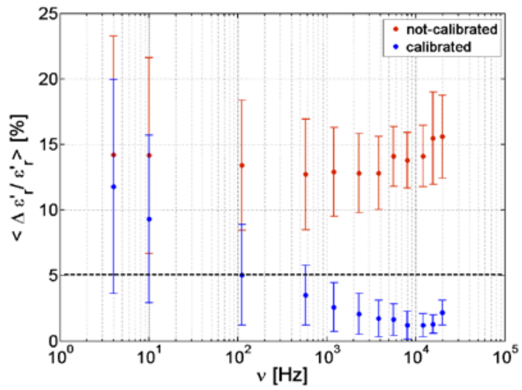

Figure 2: Relative error of the real part ε'_r combined over several sample materials (PE, PMMA, Al2O3, dielectric oil). It demonstrates that on average the error for any measurement is better than 5% for frequencies >1 kHz.

A comparison of the measured permittivity (real part) ε'_r with values from a reference device and/or literature values shows that for frequencies above we can after calibration easily achieve a relative error of less than 5% (Fig: 2). For the range below 1 kHz the error is increasing due to the stronger influence of residual water components within the sample material and a systematic 1/f error dependence of the sampling electronics.

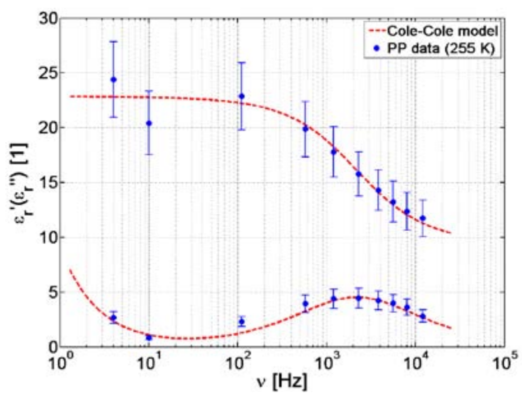

Figure 3: Comparison of measured permittivity values with a relaxation model. [3]

Also the comparison of permittivity values acquired at room temperature in atmospheric pressure with an empirical relaxation model [3] shows a good agreement (Fig. 3).

3. Summary

The measurements we have made so far demonstrate that we can measure the electrical permittivity and conductivity of artificial and natural materials with our instrument approach.

The accuracy of the measurements is well within the requirements for field measurements and given the opportunity of an actual mission we think that we could provide valuable scientific information on the surface and subsurface environment.

References

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