

On the dielectric properties of Mars analogue material

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Abstract

The dielectric properties of the Martian surface and subsurface determine the measurement data acquired through GPR and potential low frequency instruments within future space missions. Since currently no ground truth data for the Martian surface exists we have performed broadband frequency measurements (1 Hz - 20 MHz) on various Martian soil analogue materials to enhance the scientific data interpretation within this field of interest. Especially on Mars the dielectric properties are affected by contributions from various iron oxides. Consequently we included several iron oxides into our study. Moreover the influence of increasing volume fractions of iron oxides to the measured effective dielectric bulk properties has been studied.

1. Introduction

GPR instruments are a very powerful tool for determining the sub-surface stratigraphy of their target body. Currently two GPR instruments (MARSIS, SHARAD) are orbiting around Mars. With the Exo-Mars Rover instrument WISDOM one GPR will even be operating on the Martian surface in the near future. The data acquisition and interpretation of those instruments as well as potential low frequency probes in future is strongly affected by the local surface dielectric properties, which are yet poorly known [1]. The depth of signal penetration as well as the local reaction to the external signal depends on the bulk dielectric properties. Again the physical (bulk-density, temperature) and chemical properties (material chemistry) of the bulk constituents determinate those. Thus in general the local electromagnetic properties like permittivity ϵ_r and permeability μ are effective values, described by the contributing bulk constituents. To define and vice versa interpret these effective values, for permittivity $\epsilon_{r,eff}$ various mathematically based as well as empirical models exist [2]. Most relevant for our study is the well-known effective permittivity approach by

Lichtnecker-Rother

$$\epsilon_{r,eff}^\gamma = \sum_i f_i \epsilon_{r,i}^\gamma \quad \gamma \in [-1, 1] \quad (1)$$

with $\epsilon_{r,eff}$ as bulk permittivity, f_i as volume fraction and $\epsilon_{r,i}$ the permittivity value of the i^{th} contributing material.

2. Materials and Method

The most common Mars soil analogue material JSC-Mars 1A, often cited as close spectral analogue to the bright regions of Mars [3], as well as Salten Skov from Danemark, material from Mojave desert and Dover Sand were taken for this study. To test the contributions from intrinsic bulk physical properties, the dielectric characteristics of mechanical analogue materials from DLR-Bremen (ISIL) and NASA (MSS-D) have been characterised additionally. Since the electromagnetic properties of surface and sub-surface materials especially on Mars are strongly influenced by iron oxide, various oxides have been included into this study too.

The dielectric properties have been determined with a high accuracy impedance spectrometer series "Alpha-A" from Novocontrol Technologies. This instrument works as a vector analyser determining real and imaginary part of permittivity ϵ_r^* and conductivity σ^* of the samples under test.

To avoid contributions from moisture within the material, each sample has been dried at least twice at 373 K until less than 1mg/60s loss in mass was reached. The measurement was then performed under vacuum conditions with ambient pressure $<10^{-3}$ mbar.

3. Results

The determination of the dielectric properties for several Martian analogues and iron oxides has been performed for a broad excitation frequency range. A selection of the results obtained is listed in tab. 1. As shown most samples provide real part permittivities $2 < \epsilon_r' < 4$. This is in general agreement to previous studies [4, 5]. Figure 1 shows the obtained real part per-

Table 1: Listed are the real part permittivity values ϵ'_r for selected analogue materials and iron oxides for several excitation frequencies ν at RT and ambient atmosphere of $< 10^{-3}$ mbar. In brackets the uncertainties in the last decimal are listed.

ν [Hz]	4	3.8k	50k	10M
JSC Mars 1A	3.15(4)	2.61(3)	2.52(3)	2.47(3)
Salten Skov	2.65(3)	2.33(3)	2.26(3)	2.23(3)
Mojave sand	3.07(4)	2.68(3)	2.63(3)	2.62(3)
hematite	5.67(6)	4.44(5)	4.18(5)	4.16(5)
goethite	2.72(3)	1.91(2)	1.67(2)	1.66(2)

mittivity data (ϵ'_r) for various Mars analogue materials, including the soil analogues ISIL (DLR) and MSS-D (NASA) beside those listed in tab. 1. A compari-

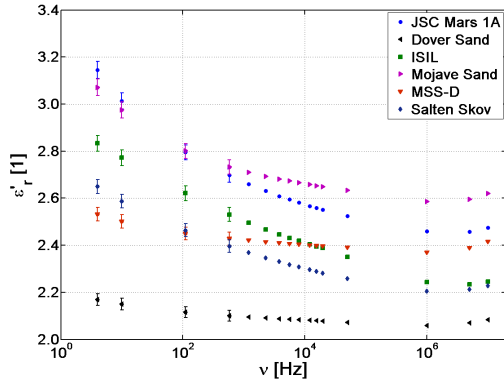


Figure 1: The obtained real part ϵ'_r -values for various Mars analogue materials, including the soil analogues ISIL (DLR) and MSS-D (NASA) beside those listed in tab. 1

son of the effective permittivity model (1) to the data obtained for the JSC Mars 1A sample with increasing volume fractions of various iron oxides has been drawn. The general approach (1) reduces to the linear Maxwell-Garnett formalism in the vast frequency range of our study. This comparable easy approach is able to present the effective permittivity data and vice versa. Thus by knowing the contributing material permittivities, the Maxwell-Garnett model deduces the real volume fraction of the iron oxides. For our data this model yields to the real iron oxide volume fraction within the host material JSC Mars 1A with a relative uncertainty less than 5 % for most of the selected frequencies.

4. Summary and Conclusions

Several Martian soil analogue materials as well as various iron oxides have been characterised in their dielectric properties for a broadband frequency range of 1 Hz - 20 MHz. As a general result the real part permittivity of the analogue materials is between 2 and 4, which is in good agreement with previous studies.

The influence of iron oxides to the bulk properties of a JSC Mars 1A sample have been studied. In an effective permittivity approach, the contributing volume fractions of analogue and iron oxide are described well by the linear Maxwell-Garnett model.

Moreover for our study this formalism leads to the real volume fraction of the contributing bulk constituents with a relative uncertainty less than 5 %.

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