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Lithospheric resistivity as a damping parameter in Schumann resonances: A chance for planetary exploration?

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Electric resistivity - a parameter not only in transfer functions ...

This community is familiar with electric resistivity as a parameter derived from transfer functions between several components of the electromagnetic field measured at or near surface. It belongs to the fundamentals of electromagnetic depth research that this parameter has a local or regional character and is (of course without ignoring the induction radius / penetration depth) closely connected to the location of the measurement. Here we present a different way to look at electric resistivity as a parameter in geophysics and planetary research.

... but also in damped Schumann Resonances

The electrically conducting lithosphere / hydrosphere as the inner and ionophere as the outer confining sphere form a resonant cavity for electromagnetic waves emitted from electric discharges generated during meteorological thunderstorms. These Schumann resonances [1] reveal themselves on Earth as maxima in the natural electromagnetic spectrum at approximately 7.8 Hz, 15 Hz, 22 Hz, and further multiple frequencies. A realistic derivation of these frequencies for the terrestrial case requires a consideration of the damping properties of the ionosphere whereas the ground may be approximated as perfectly conducting [2]. If damping in the inner confining sphere is taken into account, the ground resistivity becomes a governing parameter in the Schumann resonance problem [3]. Damping shifts the resonant maxima to lower frequencies and amplitudes. Furthermore, the maxima become broader and become asymmetric over frequency [4].

Brine Case: $\sigma_1 = 5\times10^{-10}$S/m, $h_1 = 2.6$ km, $\sigma_2 = 10^{-2}$ S/m
Water Case: $\sigma_1 = 10^{-10}$ S/m, $h_1 = 4.2$ km, $\sigma_2 = 5\times10^{-4}$ S/m

Dry Case: $\sigma_1 = 5\times10^{-10}$ S/m, $h_1 = 10$ km, $\sigma_2 = 10^{-8}$ S/m, $h_2 = 30$ km, $\sigma_3 = 10^{-4}$ S/m

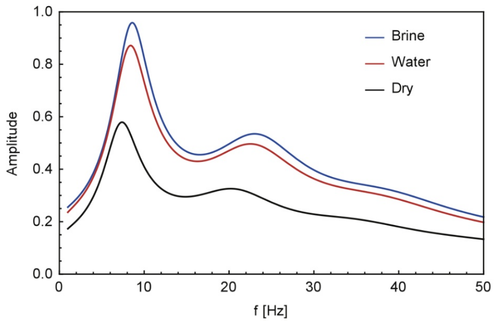
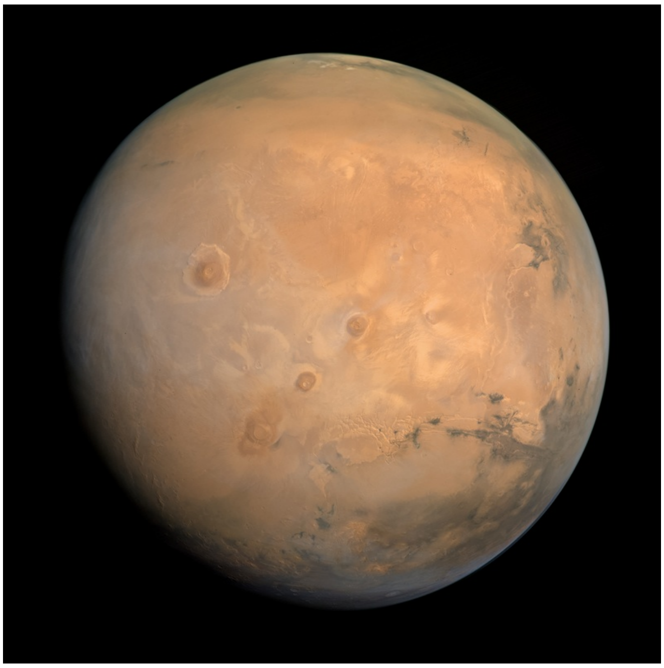
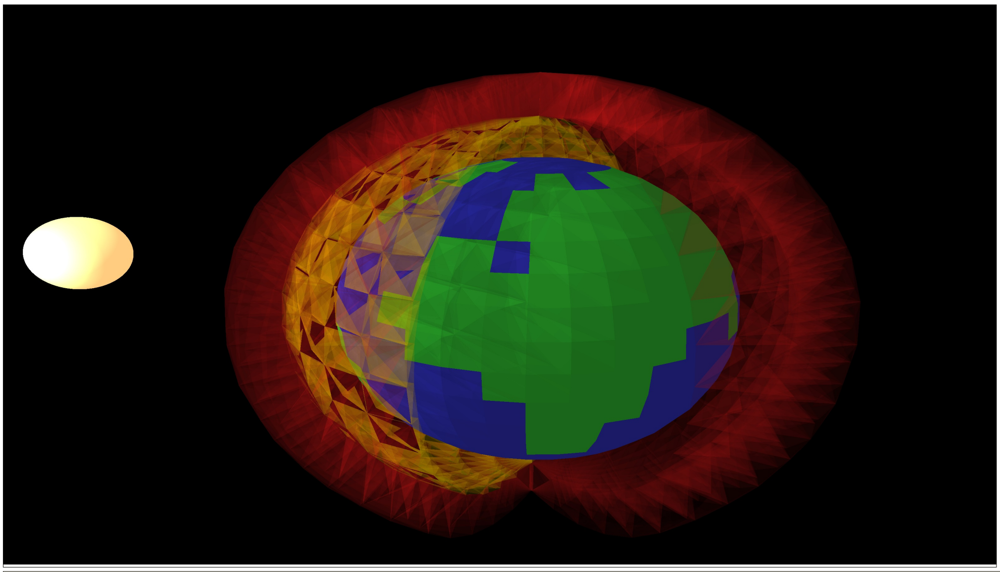


Fig. 5. The SR spectra for three models of the Martian subsurface: with groundwater of high and low salinity, and without groundwater. All the spectra were normalized to the amplitude of the ideal case.



The case of Mars: Water in the subsurface?

It is believed that Schumann resonances could occur also on Mars (the picture above is taken from Wikipedia). Whereas our neighbour planet possesses a lithosphere and ionosphere structurally similar to the ones of Earth, there obviously are no lightnings connected to clouds. However, some authors assume that electric discharges could be produced in dust devils which do occur on Mars. If Martian Schumann resonances existed, they would be damped in a much higher degree than terrestrial ones, since the Martian ground is believed to be poorly electrically conductive. On the other hand, if there remained subsurface water on Mars, it could increase the ground conductivity dramatically. This would be immediately visible in the damping pattern of Martian Schumann resonances. Due to the global nature of the resonant phenomenon a single point measurement would be sufficient to get an idea about this question crucial for the search of traces of life on Mars [3]. The source of the example to the left-hand side is [3]. Damping shifts the resonant maxima to lower frequencies and amplitudes. Furthermore, the maxima become broader and become asymmetric over frequency [4].



Idea of a project applied for recently

The abovementioned models for the resonant cavity are spherically homogeneous (1D). However, Schumann resonance data are known to reflect temporal and spatial changes in the ionosphere, first of all, the day-night asymmetry [5]. A model approach able to deal with such more complex ionospheric structures has been presented in the literature [6]. A research project applied for recently is dedicated to the fact that the terrestrial inner confining sphere is inhomogeneous in terms of damping too. For source-observer geometries leading to travelling paths mainly over continental lithosphere the assumption of a perfectly conducting ground should not hold, especially for the third frequency mode. It is our aim to provide a model that additionally accounts for the differences in damping by oceans and continents for Schumann resonance data. The picture shows a vision of the complexity of resonant cavity models to be developed in the frame of the project.

References

[1] W. O. Schumann, Über die strahlungslosen Eigenschwingungen einer leitenden Kugel, die von einer Luftschicht und einer Ionosphärenhülle umgeben ist, Zeitschrift für Naturforschung A, vol. 7, pp. 149–154, 1952.
[2] T. Madden and W. Thompson, Low-frequency electromagnetic oscillations of the Earth-ionosphere cavity, Rev. Geophys., vol. 3, no. 2, pp. 211–254, 1965.
[3] Kozakiewicz, Joanna, Andrzej Kulak, Janusz Mlynarczyk (2015), Analytical modeling of Schumann resonance and ELF propagation parameters on Mars with a multi-layered ground, Planetary and Space Science, doi:10.1016/j.pss.2015.05.019.
[4] Kułak, A., Młynarczyk, J., Zięba, S., Micek, S., and Nieckarz, Z. (2006), Studies of ELF propagation in the spherical shell cavity using a field decomposition method based on asymmetry of Schumann resonance curves, J. Geophys. Res., 111, A10304
[5] Sátori G, Neska M, Williams E, and Szendrői J, Signatures of the day-night asymmetry of the Earth-ionosphere cavity in high time resolution Schumann resonance records, Radio Science 42, doi:10.1029, 2007.
[6] Prácser, E., Bozoki, T., Sátori, G., Takatsy, J., Williams, E., & Guha, A. (2020). Two approaches for modeling ELF wave propagation in the earth-ionosphere cavity with day-night asymmetry. IEEE Transactions on Antennas and Propagation, 69(7), 4093-4099

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