Investigation of the Martian Environment by ELF Radio Measurements

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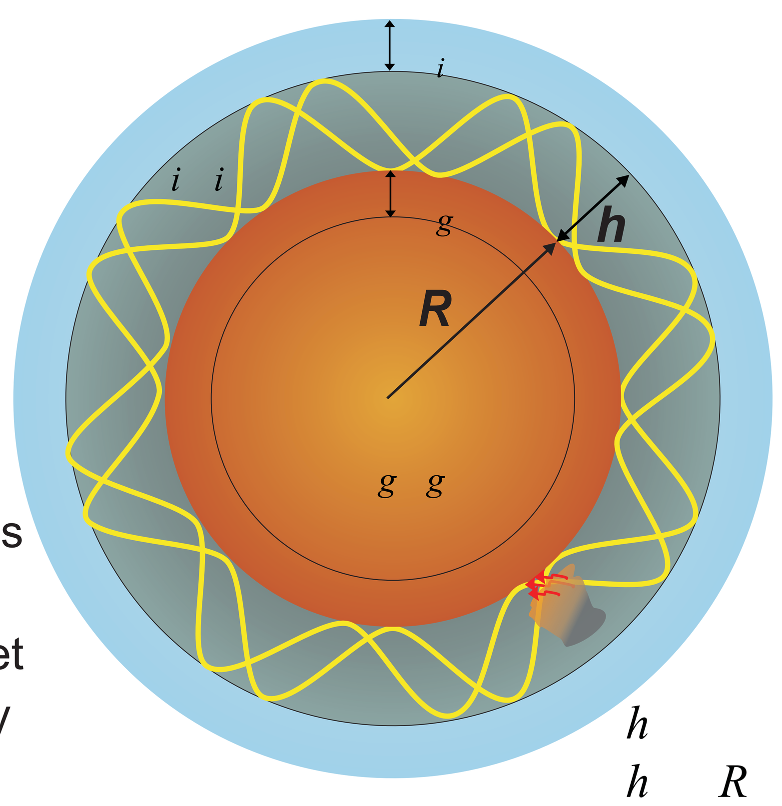
Introduction

We present methodology and instruments which on Mars allow investigation of the environmental aspects, such as the structure of the ionosphere, lightning activity or the planetary subsurface.

The presented methodology is based on the propagation of extremely low frequency (ELF) electromagnetic waves (3Hz - 3kHz). These waves, once generated, propagate around the planet in a waveguide made of two electrically conductive spheres: the planetary surface and the ionosphere.



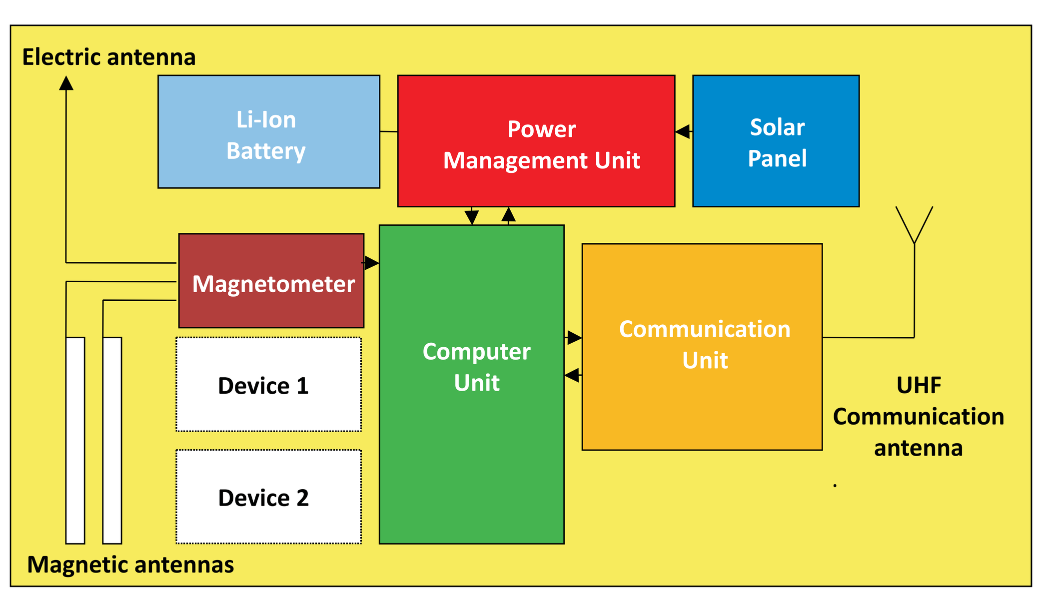
Within the ground-ionosphere waveguide a resonance of ELF waves occurs. It is called Schumann resonance [*Schumann, 1957*], and its parameters are strongly related to the properties of the waveguide.

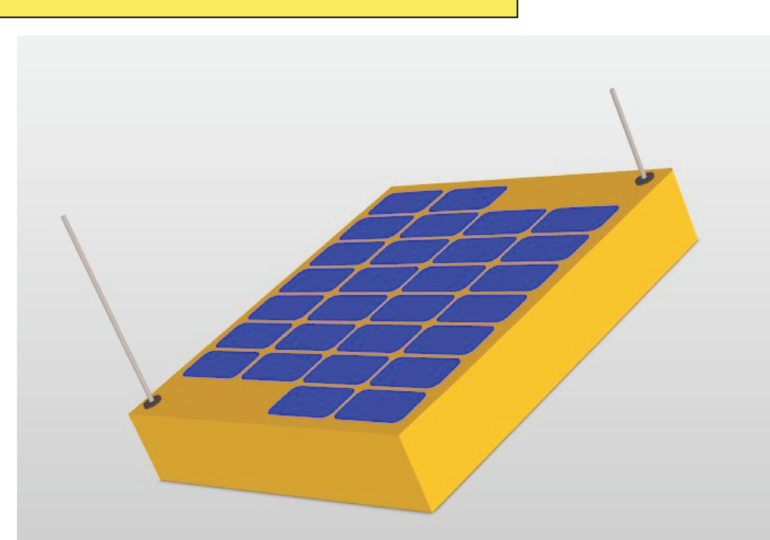
On Mars, as there is no liquid water at the planetary surface, the ground has a low conductivity. In such a situation ELF waves penetrate deep into the planetary subsurface, and as a result, presented methodology can be used as a tool to detect e.g. groundwater reservoirs.

Instruments

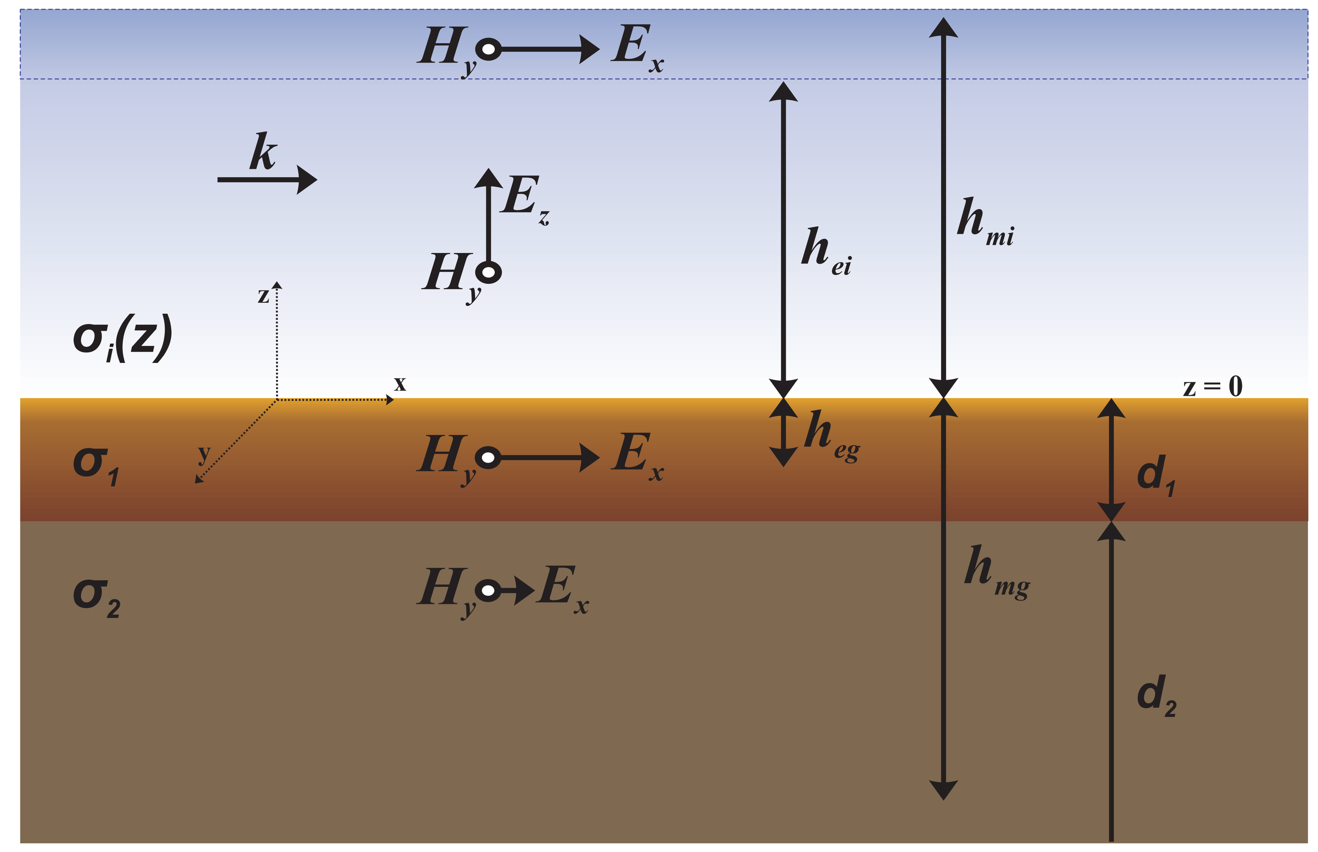
As ELF propagation is of the global nature, one measuring station is enough to perform some basic research. The lightweight measuring equipment consists of a low-power ELF receiver, two magnetic antennas and an electric antenna.

In this study, we propose a fully autonomous station with two ortogonal magnetic antennas and one electric antenna.





- External electronic warm box (EEWB): 850mm x 850mm x 150mm
- Magnetic antennas: 700mm x 10mm, electric antenna: __________
- Internal electronic warm box (IEWB): 645mm x 645mm x 100mm
- Mass: 15 kg
- Room and resources for other scientific equipment: device 1, device2
- Power: 12 W (available:___)



Method

Propagation of ELF waves can be represented in the 2D waveguide formalism [*Kirillov, 1993, 1997*]. There are two parameters associated with ELF waves propagation: electric h_e and magnetic h_m altitude. The first one is responsible for the behavior of the vertical electric component, the second for the horizontal magnetic component. For a TEM wave propagating along the x-axis parallel to the surface (z = 0), these altitudes are given by the vertical electric and magnetic distributions of the field amplitude $E_z(z)$ and $H_y(z)$. The distributions are calculated by solving the Maxwell equations in the medium characterized by some complex conductivity given by: $\bar{\sigma}(z) = \sigma(z) + i2\pi f\varepsilon(z)$. Using this formalism, we have developed a new analytical method to obtain the Schumann resonance parameters of the cavities with the multi-layered ground [*Kulak et al.*, *2013*].

When an ELF wave is propagating from its source to a receiver the environmental properties, such as: electrical conductivity or permittivity of the surface, influence its propagation parameters. Using an analytical approach based on a solution of Maxwell's equations, we can estimate the structure of the subsurface or ionosphere on the basis of measured propagation parameters.

To demonstrate the potential of the method we present the relationship between individual environmental properties and propagation parameters.

Results

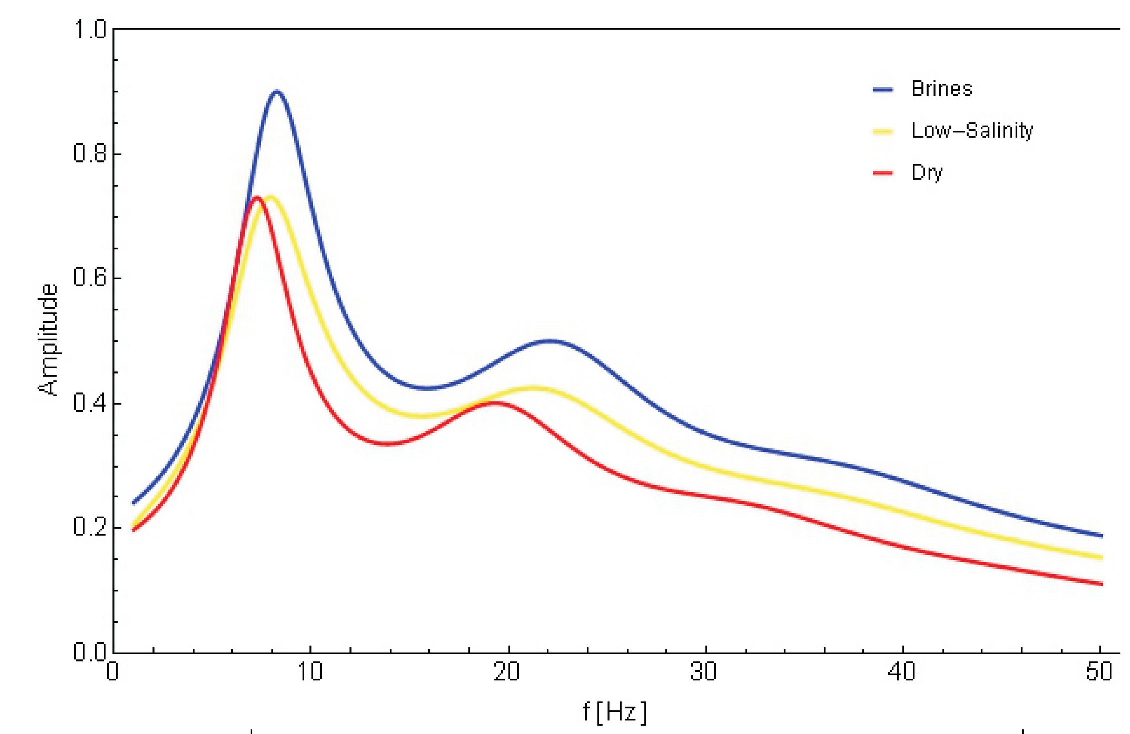
We studied a direct scenario with some hypothetical models of the planetary electromagnetic environment. For these models, we present the ELF pulses propagation and the Schumann resonance spectra.

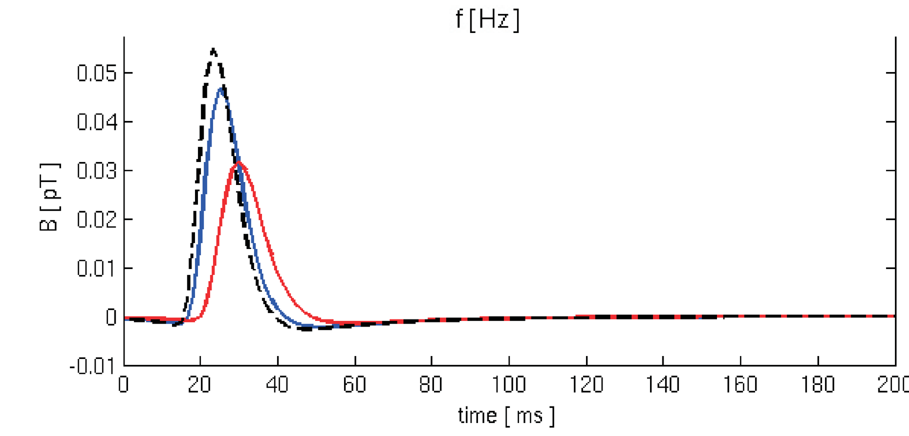
In this theoretical approach, we assume double-layered models of the Martian subsurface [*Kozakiewicz et al*]. In these models, the upper layer has a very low conductivity ($\sigma_1 = 10^{-7}$ S/m). For the lower layer we propose three models: two with water reservoirs and one without them. In the models with aquifers, the thickness of the upper layer is only $h_1 = 10$ km, and the conductivity of the lower layer is $\sigma_2 = 10^{-2}$ S/m (a case with brines) or $\sigma_2 = 10^{-4}$ S/m (a case with low-salinity aquifers). In the model without water reservoirs (a dry case), the low conductive layer is 40 km deep, and the conductivity of the lower layer is $\sigma_2 = 10^{-2}$ S/m. To illustrate the influence of the ground on ELF propagation, we also consider the model with a perfectly conducting ground.

To calculate the propagation of ELF pulses, we assume that the source of an ELF wave has the form of the delta function and an amplitude of 1 C · km.

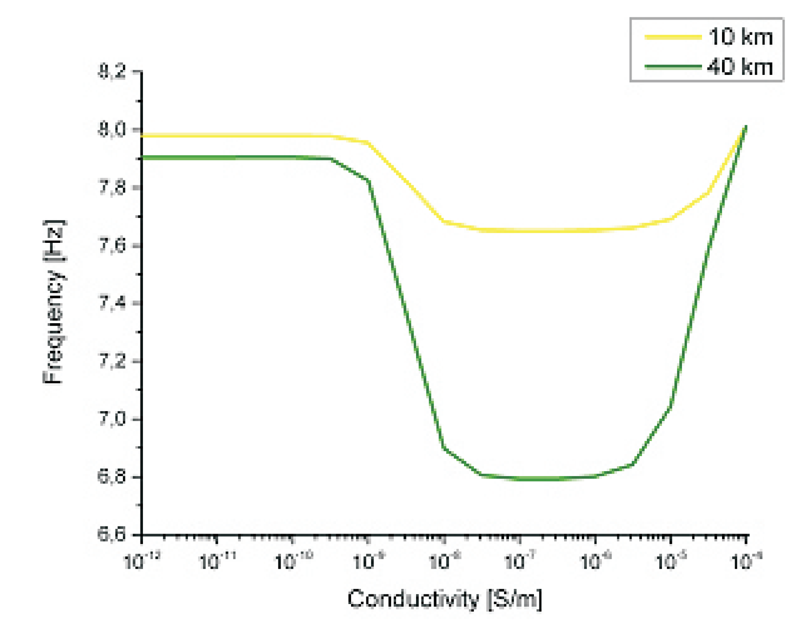
In our work, we used the atmospheric conductivity profiles calculated by *Pechony and Price* [*2004*].

The Schumann resonance spectra and the waveforms of the ELF pulses for the models are shown below.





Examples of the relationship between the conductivity of the upper layer and the first mode frequency of Schumann resonance are shown for two thickness of the upper layer. The second layer conductivity is $\sigma_2 = 10^{-4}$ S/m.



Conclusions

- **The developed equipment and methodology can be used to measured properties of the subsurface, atmosphere and intensity of electrical discharges on Mars.**
- **The presence of aquifers increase significantly the Schumann resonance frequencies and amplitudes.**
- **Finite conductivity of the ground have a significant impact on the delay and the amplitude of the observed waveforms.**
- **The presented fully analytical model is computationally efficient and can be very useful to find inverse solutions.**
- **Data acquired by the ELF receiver will explicitly prove the existence of lightning activity on Mars.**
- **Our method can be applied also to other objects in the Solar System which have electromagnetic cavities.**

References

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