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Modelling of EISS GPR's electrical and magnetic antennas for ExoMars mission

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Despite several past and present missions to Mars, very little information is available on its subsurface. One of the scientific objectives of the European ExoMars mission (ESA) is to characterize the water / geochemical environment as a function of depth and investigate the planet subsurface to better understand the evolution and habitability of the planet. The electromagnetic survey of subsurface will provide a nondestructive way to probe the subsurface and look for potential deep liquid water reservoirs.

The LATMOS (ex CETP) is currently developing a ground penetrating radar (GPR) called EISS "Electromagnetic Investigation of the Sub Surface", which is a enhanced version of the TAPIR "Terrestrial and Planetary Imaging Radar", developed in the frame of the Netlander mission cancelled in 2004. The GPR main objective is to perform sounding of the sub-surface down to kilometric depth.

EISS is an impulse GPR operating, from the Martian surface, at HF frequencies ($\sim$ 2-4MHz) with a wide bandwidth (100kHz-5MHz). EISS can operate in four modes: impedance measurement, mono and bi-static survey, passive mode. The EISS innovative concept is based on the use of the fixed station (Lander) and mobile rover to conduct subsurface surveys of the area visited by the Rover. The work at HF frequencies, EISS uses a half-wave resistively loaded dipole electrical antenna i.e. two monopoles 35 meters long each to transmit (and also receive in mono-static mode) the signal. The resistive profile of the antenna follows a Wu-King profile which is optimized to transmit the pulse without noticeable distortion and avoid ringing. The two monopoles will be deployed in roughly opposite directions on the surface of Mars. The exact value of the direction of deployment for each monopole will be chosen in order to minimize the contact with the Lander structure, avoid obstacles and the solar panels still ensuring a good coverage of the whole area. In bi-static mode, the signal is received with a small magnetic sensor accommodated on the Rover. As a consequence, since the direction that the rover will follow after its egress will not be know until the Lander is on Mars, it is essential to chose a configuration that will result in a radiation pattern compatible with bi-static measurements whatever the direction of the rover is (within a distance of 1 kilometer). Studies based on electromagnetic simulations have been performed to check the impact of the angle between the two monopoles on the radiation pattern.

Study of EISS performances is ongoing using numerical modeling and experimental verifications. We use numerical simulation (FDTD code), analytical models and data processing algorithms to determine the performances of each operating mode and to prepare data interpretation.

The subsurface survey requires knowledge of the permittivity of the studied sub-surface layers to convert the measured propagation delay into distance. Access to electrical characteristics of ground without return samples and *in situ* analysis is unusual in space missions and aroused great interest. Results will be presented about different ways EISS can provide estimation of the electrical properties of the shallow subsurface. Simulations that highlight the impact of the chosen resistive profile and of the angle between the two deployed monopoles will be shown. The presentation will mainly be focused on the bi-static mode that greatly improves the 3D representation of subsurface structure and on the associated instrumental requirements such as the perfect synchronization of the two part of the instrument. A method to retrieve the direction of arrival for each detected echo will be presented that allows a more accurate sub-surface mapping. Only the three magnetic field components are required to implement it, which makes the EISS configuration particularly interesting. This method is based on the orthogonality between the propagation vector and the polarization plane.