Modeling and optimization of loaded electrical antennas dedicated to deep Martian subsurface sounding by a bistatic HF GPR operating from the surface

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In the frame of the ESA's ExoMars mission, the EISS ground penetrating radar (GPR) has been designed and developed by LATMOS to perform deep soundings of the Martian sub-surface from the surface. EISS was designed to take advantage of the potential for bistatic radar investigations of the Martian subsurface between the fixed station (Lander) and the mobile rover. Using this approach, EISS can be used to characterize the 3-D structure and stratigraphy of the subsurface at depths ranging from 100 m to a few kilometers out to a 1-km radius around the Lander.

EISS is an impulse radar operating at HF frequencies (~ 2-4MHz). EISS can operate in four modes, including: (1) surface impedance, (2 & 3) subsurface monostatic and bistatic, and (4) passive (i.e., atmospheric monitoring) mode. EISS makes use of an electrical dipole antenna made of two 35m resistively loaded monopoles, to transmit (and also receive in mono-static mode) the signal. The resistive profile of each monopole is carefully optimized to transmit the pulse without noticeable distortion and avoid ringing. The two monopoles are deployed on the surface in nearly opposite directions, at an angle which, when EISS is used in bistatic mode, ensures good volume coverage around the Lander. Electromagnetic simulations have been used to optimize the value of this angle based on its impact on the radiation pattern of the two monopoles.

EISS's most innovative capability is its potential for bistatic operation, made possible by the placement of a small magnetic sensor on the ExoMars Rover which can be rotated to measure all 3 components of the propagation vector of the reflected signal transmitted by EISS, whatever the direction and orientation of the Rover. EISS's bi-static performance has been explored using both FDTD simulations and analytical models -- investigations that have yielded important results regarding antenna optimization, the impact of the angle between the two deployed monopoles, and the coupling between the antennas and ground. Finally, a method to retrieve the direction of arrival for each detected echo will be presented that allows the 3-D location and orientation of buried reflecting interfaces.

Nevertheless EISS can also take advantage of the existence of a single stationary platform and perform monostatic soundings of the terrestrial subsurface, estimate the near subsurface properties. Potential applications on Earth are, for example, the search for deep liquid water reservoirs in arid environments or the mapping the bed-rock buried under thick layers of ice. After the last redesign of the original ESA's 2016 ExoMars mission, the whole lander payload was removed; EISS (in its monostatic version) will be also proposed for the ESA EDL (Entry, Descent and Landing) demonstrator (2016) which will maybe provide the next future opportunity for EISS to fly to Mars.