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Recent Advances in Ionospheric Modeling for Mars Exploration using Ground Penetrating Radars

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Orbiting ground penetrating radars (GPRs) as the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) and the Shallow Radar (SHARAD) currently operating on Mars need a fine ionospheric correction in order to deliver products useful for geological investigations. Ionosphere influence can be assessed using a new approach based on the finite-difference time-domain (FDTD) method. The proposed work aims to underline the errors introduced by a not perfect knowledge of the ionosphere electron density profile on the transmitted chirp signal. Such effect has a great impact on the data inversion process that aims to estimate the permittivity of the subsurface detected interfaces. Data inversion is accomplished by evaluating, via a two channels approach, quantities related to crust attenuation, surface/subsurface geometry and power scattered by the detected interfaces. The final product delivered after SAR processing is highly dependent on the ionosphere compensation.

Ionosphere phase related distortions have been theoretically modelled using the Chapman density function. They introduce an S/N and a side lobe level (SLL) degradation after matched filtering along with a delay and a pulse shape distortion. Since several data acquired over smooth surfaces do not present a pulse shape verifying the backscattering models introduced for MARSIS and SHARAD and based on Kirchhoff approximation it is important to provide a different approach for the ionosphere compensation in order to obtain more reliable products. Not perfectly compensated data would provide erroneous power levels and a wrong geometric interpretation jeopardizing the entire data inversion process.

The finite-difference time-domain (FDTD) method can be used to study the propagation of a MARSIS/SHARAD chirp signal into a plasma modelled according to a desired electron density profile adding a new important benefit to the simulation methods available to understand GPR signals in this context. A 1D-FDTD code is enough to model both plasma and collision frequencies. Using the simulator some recently proposed Martian multi-peak electron density profiles similar to Chapman's one have been synthetized. The Chapman model is then used during matched filtering, as on MARSIS/SHARAD data, to compensate the distortions introduced by the ionosphere underlining the eventual presence of uncompensated residuals quantified in terms of S/N loss, SLL degradation and pulse shape distortion. Such work will be highly useful to produce new ionosphere compensation schemes providing more reliable data to be employed in the data inversion procedure.