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Direct reconstruction of dielectric constant profile from orbital based radar sounder data

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Orbital based high frequency sounding radars are considered as very effective tool to investigate the subsurface structure and lithology of planetary crust. For example, two ongoing missions ESA'a Mars Express and NASA's Mars Reconnaissance Orbiter are carrying synthetic-aperture, orbital sounding radars MARSIS and SHARAD. They work by transmitting a low-frequency radar pulse that is capable of penetrating below the surface, and is reflected by any dielectric discontinuity present in the subsurface. Whereas MARSIS is optimized for deep penetration, having detected echoes down to a depth of 3.7 km over the South Polar Layered Deposits, SHARAD is capable of a tenfold-finer vertical resolution, namely 15 m or less, depending on the dielectric constant of the material being sounded. MARSIS is capable of transmitting at four different bands between 1.3 MHz and 5.5 MHz, with a 1 MHz bandwidth. SHARAD operates at a central frequency of 20 MHz transmitting a 10 Hz bandwidth.

Processing of MARSIS and SHARAD data is made complex by a number of factors. The first is the incomplete characterization of the transfer function of these instruments, due to the impossibility to calibrate their very large antennas on ground. The second is the distortion of the radar signal caused by the Martian ionosphere, blurring and attenuating echoes. The third is the possibility that surface echoes reaching the antenna from off-nadir directions after the nadir surface echo, called "clutter", are interpreted as subsurface reflections. Extraction of the electromagnetic properties of the Martian subsurface from radar echoes, that is data inversion, is thus a complex and difficult problem, but it is an unavoidable step to achieve the scientific objective of the experiments. Although spectacular results have been already published, such as the mapping of the thickness of the South polar layered deposits, rigorous quantitative determination of the dielectric properties of the surface and subsurface remains an elusive goal, except in a few favorable cases.

In this report we present effective and fast numerical procedure for **direct** reconstruction of dielectric constant from radar echoes. This routine assumes one-dimensional plane wave model of wave's propagation, absence of dispersion of dielectric properties of the regolith in MARSIS and SHARAD wavelength range and sharp boundaries between different layers. In case of small signal losses in the material it allows exact reconstruction of the real part of dielectric constant with possibility to distinguish increase or decrease in the value of dielectric constant from layer to layer. This routine is implemented for reconstruction of dielectric constant distribution of modeling crust structure for SHARAD and different MARSIS working bands. Since discovery of buried water deposits is one of the main goals of MARSIS project we considered dry layered model of crust and porous layered model with pores saturated by water. We discuss also the influence of different factors such as surface clutter, losses, dispersion of refraction index and losses on the stability and reliability of the result of reconstruction and implementation of this technique for processing of SHARAD data.