DEEP RADAR SOUNDING OF MARTIAN POLAR DEPOSITS: RADIATIVE TRANSFER MODELS.

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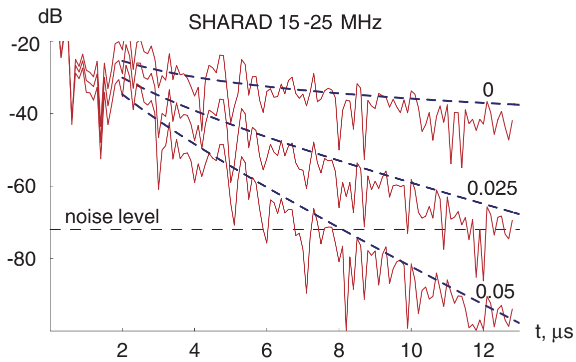
Introduction: Investigation of the internal structure of martian polar caps, being a challenging task during past decades [1], is now going to be solved with the ground penetrating radar (GPR) instruments, both orbital and landed. In the present report the propagation of ultra wide band (UWB) chirp pulse in martian polar ice caps is investigated. The specific nature of the problem is that rather inhomogeneous layered structure of the caps lead to formation of diffuse structure of the radar signal field. Application of coherent radar signal processing techniques fails to resolve individual internal scatterers within the bulk of the polar caps, so that some incoherent interpretation technique should be utilized. In the present work the results of application of radiative transfer theory to the problem of radar sounding of the martian polar deposits.

Electrical model of the caps: we essentially exploit the electrical model of the caps, previously developed in earlier papers. It has been repeatedly argued that the primary constituent of the northern polar cap is water ice. The following observations provide basis for this statement: high water vapor concentrations over the cap during summer [2], low density [3], a thermal inertia [4] and albedo [5] corresponding to dirty water ice. The surface of the southern polar cap does not look like water ice, but there also are evidences that water ice is its major volatile constituent, too [6,7].

There are also numerous observational evidences of layered structure of Martian polar caps [1]. Thickness of individual layers has been estimated to be 14 – 45 m [8] and 80-120 m [9] for northern and southern polar caps, respectively. Recent studies of layered structure of northern polar cap [10] have revealed its more complicated structure, largely consistent with earlier rough estimates. Precipitational and sedimentational models predict that layers of dirty ice are separated from each other by a dusty cover about 1 m thick [3]. Such cover is formed from the layer material due to ice ablation, which occurs periodically according to variations of Martian orbit parameters.

A model of Martian polar caps as a stack of layers of two types, the so-called “icy” and “dusty” layers, has been previously suggested [11]. It has been shown there that only electromagnetic waves at frequencies below 1 MHz can propagate through such a layered medium without significant distortion. Above 1 MHz, there are frequency bands where the medium is opaque. On the other hand, at frequencies below 1 MHz the northern cap is relatively transparent. However, most currently developed and previously proposed radar instruments operate well above 1 MHz.

Radiative transfer model: The basic idea of this part of the study is to apply the non-coherent theory of radiative transfer to the problem of subsurface radar sounding of martian polar layered deposits, which are the random layered media. Within the approach applied in the present paper, the compressed radar pulse is regarded as a short plane wave packet, reflecting from, and penetrating through, the interfaces between layers. It is correct from the mathematical point of view because, for the simulation purposes, the compression of the pulse and wave propagation through medium can be interchanged. Assuming the layered structure of polar caps to have many internal parallel interfaces reflecting the sounding wave, one can consider the limiting case of continuously scattering medium. The theory of radiative transfer is a well developed tool for treating such problems. In recent papers [12,13] this theory has been applied to the considered problem for orbital and landed radar GPR instruments, respectively.



Simulated signals [12] for the northern polar cap are shown in the figure. Solid and dashed lines represent the exact solutions of electromagnetic equations and the asymptotic solutions of the radiative transfer theory. Mean loss tangents of the dust are labeled nearby the curves.

Conclusions: a new approach to the problem of radar sounding of martian polar deposits, based on the radiative transfer theory, has been developed. Numerical simulations, showing validity of the developed approach, have been performed.

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