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Simulation of radar sounder echo from lunar surface layer and detection of lunar subsurface structure

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Lunar subsurface feature reserves the history information of lunar geology. Knowledge of lunar subsurface features can provide rich information about physical status, conformation, origin and evolution of the Moon. High frequency (HF) radio wave can penetrate several kilometres into lunar subsurface and therefore may disclosure the subsurface geological features of the Moon.

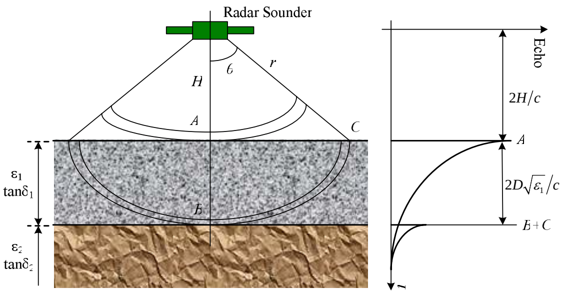

Figure 1. Principle for radar sounder detection of lunar subsurface layer.

In lunar exploration, spaceborne high frequency (HF) radar sounder is an effective tool for investigation of lunar subsurface structure in lunar exploration [1] [2]. The primary strategy for radar sounder detection of subsurface structure is through the time delay and intensity difference of the lunar surface and subsurface nadir echoes (Figure 1). It is important to fully understand electromagnetic wave propagation, scattering and attenuation through the lunar media in order to retrieve information of lunar layering structure from the weak subsurface nadir echoes, which in general is interfered by strong off-nadir surface clutters at the same time. Based on Kirchhoff approximation (KA) of rough surface scattering and ray tracing of geometric optics, an effective simulation approach of radar echo from lunar layering structure is developed. According to the lunar surface feature, the topography of mare and highland surface is generated numerically (Figure 2), and the triangulated network is applied to making digital elevation of lunar surface [3]. Then scattering from the lunar surface and subsurface are numerically calculated using KA approach [4] [5]. Radar echoes of mare regions and radar images of highland regions are numerically simulated (Figure 3). The simulation results show:

(1). The lower the altitude of radar orbit, the easier to distinguish the subsurface echo.

(2). Broadening the bandwidth of the transmission pulse of radar sounder can enhance the range resolution. However, increment of bandwidth requires the increase of the centre frequency of radar sounder, which will reduce the penetration depth of radar wave in lunar subsurface layer. Therefore, selection of bandwidth for radar sounder should be a compromise between the range resolution and penetration depth.

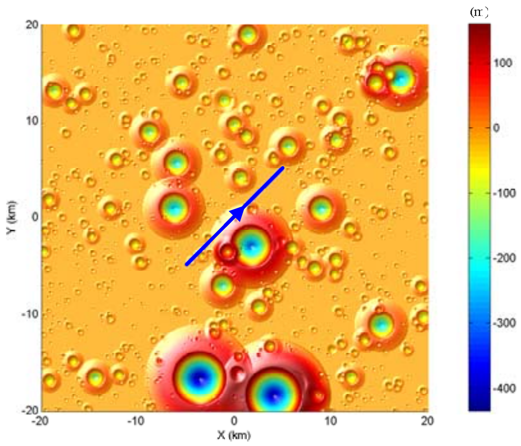

Figure 2. A cratered lunar surface with 1000 craters.

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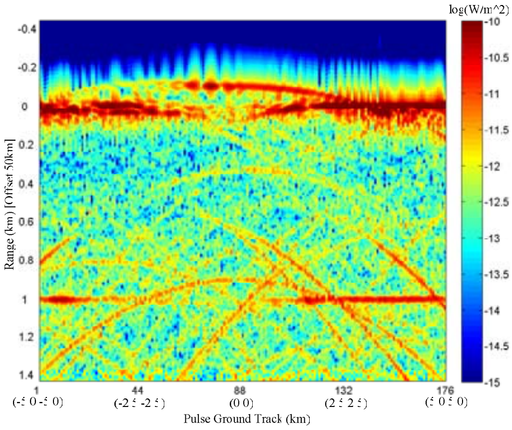

Figure 3. Radar sounder echo of a cratered lunar surface with 1000 craters.

(3). The $FeO+TiO_2$ abundance in lunar surface layer can affect the detection of subsurface echo.

(4). The flat subsurface in radar image looks like a straight line, the subsurface roughness can enhance the subsurface off-nadir echo and reduce the subsurface nadir echo (Figure 3).

(5). In radar image along range direction, radar echoes from larger crater look like circular arcs. As the crater density increases, the subsurface echo is hard to be distinguished due to the interference by surface off-nadir echo. The real data of lunar surface digital elevation model (DEM) will help to analysis the origin of the echo, such as from the crater or the subsurface, and estimate the thickness of lunar subsurface layer and its dielectric constant.

Finally, based on the coherent and incoherent property of nadir echo and off-nadir echo, radar subsurface echo from mare subsurface can be detected by multiple observations and average approach. Over the cratered highland surface, synthetic aperture radar (SAR) technique along range direction is proved to be an effective approach to reduce the surface clutter in order to detect the subsurface structure.

The simulation approach of radar sounder echoes and images in this paper can help to analysis the real observation result of radar sounder, and the same approach can also be applied into Martian subsurface exploration.

Acknowledgments

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