SIMULATION OF RADAR SOUNDER ECHOES AND INVERSION OF LUNAR SUBSURFACE. Y. Q. Jin, Key Lab of Wave Scattering and Remote Sensing Information, Fudan University, Shanghai 200433, China, Email: yqjin@fudan.edu.cn.

Introduction: Numerical simulation of radar sounder echoes from Moon cratered surface and subsurface, and inversion of the lunar subsurface, e.g. layering thickness and dielectric properties, are developed. Subsurface detection is utilized based on the nadir echoes time delay and intensity difference from the media interfaces. According to Moon surface feature, the cratered topography is numerically generated, and the triangulated network is employed to make digital elevations of the whole surface. Based on the Kirchhoff approximation of rough surface scattering and the ray tracing of geometric optics, radar range echoes at 5~50 MHz from lunar layering structure is numerically simulated. Then, inversions of the regolith layer thickness and dielectric permittivities are designed.

Scattering from Layered Media: Scattering from layering media is derived using the Stratton-Chu integral formula in the KA method [1-4].

In numerical calculation, the surface is divided into discrete meshes. The surface topography at each node of the grid with given mesh dimension (resolution of original DEM) are created.

Summing up all scattering fields from those meshes, whose ranges fall in the range bin r_n (the n-th range bin), the total scattered field received from the lunar surface (sur) $\mathbf{E}_{\rm sur}(r_n)$ and subsurface (sub) $\mathbf{E}_{\rm sub}(r_n)$ received by a radar sounder is then

$$\mathbf{E}(r_n) = \mathbf{E}_{\rm sur}(r_n) + \mathbf{E}_{\rm sub}(r_n) \quad (1)$$

To make enough range resolution and transmitted energy, linear frequency modulation (LFM) pulse is usually employed as the transmission signal [4,5].

Simulations of Radar Range Echoes: Based on statistics of Moon craters, a DEM of a Moon cratered surface is simulated using a Monte-Carlo method.

We selected a bandwidth of 5~50 MHz to design the most feasible frequency for probing lunar subsurface with good resolution and penetration depth.

In simulation of 5, 20 and 50 MHz, the whole scene is 35×25 km^2. Due to computation limitation, the illumination area for the 50 MHz case is reduced. A flat subsurface is assumed to be at 200 m depth.

Simulations of radar range echoes at 5, 20 and 50 MHz are presented for two cases of basalt ε_1=7.1(1+i0.015) and water-ice ε_1=3.15(1+i0.005). It can be seen from comparison between the cases of basalt and water-ice that due to the complex dielectric constant of basalt being larger than that of water-ice, attenuation through the basalt layer is larger.

Also, due to the different dielectric constants of basalt and water-ice in the layer 1, radar ranges for the cases of basalt and water-ice look different because of range change with $1/\sqrt{\varepsilon_1}$.

As frequency increases from 5 MHz to 50 MHz, the echoes from the top surface become stronger and those from the subsurface become much weaker through attenuation. At 50MHz, scattering and reflection from ranges larger than the subsurface almost cannot be seen.

As a real example, a lunar area of the crater taking from the DTM (digital topography model) data is given.

Suppose that the radar at the altitude 100 km is flying across a flat subsurface located at -1850 m. Thus, along the flight, a cross profile shows the layer thickness from 26 m to 486 m. The images of radar range echoes at 5, 20 and 50MHz are simulated for basalt ε_1 and water-ice ε_1, respectively.

This simulation program provides a tool for analysis of radar echoes, and inversions of the layer structures, such as the layer thickness and dielectric properties of the media [6,7].

Inversion of Layer Thickness: The layer thickness d_1, and dielectric properties of two media, ε_1, ε_2, from radar range echoes image are inverted.

Let the radar power I_0 be incident upon the top surface. Then, the radar range echo from top surface can be measured. Comparing this echo with the reflected echo from plat surface based on scattering theory of rough surface, the real part of ε_1 can be first determined. Then, the radar range can be used to determine the layer depth d_1. In radar ecoes, two neighboring locations, S and S′, are specifically chosen, and the height difference between these two locations has been the known δ. The subsurface underlying below these locations is assumed as flat. Comparing these two echoes, the imaginary part of ε_1 and ε_2 can be inverted.

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