Inversion of Dielectric Constant of Mars South Polar Region Using the MARSIS Data

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Abstract

Radar sounder technology had been applied to Mars explorations, such as MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) in 2003 and SHARAD (SHAllow RADar) in 2005. China is also planning to launch the Mars program in the future. To investigate the radar echoes from Mars layered media, we have developed numerical simulation of radar range echoes at 1-50 MHz from Mars rough surface/subsurface model. Furthermore, we developed the parameter inversions of Mars layered media. As an example to validate these approaches, we collect 34 orbits MARSIS data to invert the dielectric constant of surface regolith around the region of Mars south pole. The result well shows the SPLD (south polar layered deposits) with water ice and high dielectric constant of other places.

1. Introduction

In extra-planetary exploration, the high frequency (HF) radar sounder has been employed to measure the echoes from layered media for information retrieval of layers physical structures, e.g. the European MARSIS [1] (multi-band (0.1~5.5MHz) and the NASA's MRO (Mars Reconnaissance Orbiter) SHARAD (20MHz) [2]. China is also planning to launch the Mars program in the future. Main purpose is that the HF radar waves can penetrate into the deep regolith and reach the interfaces of the layered media. A key issue is how to invert the dielectric properties of the Mars layered media [3-5]. However, the radar echoes from layered media, i.e. Mars cratered rough surface/subsurface has not been well investigated. It leaves too many uncertainties to quantitative inversions.

To investigate the radar echoes from Mars layered media, we have developed numerical simulation of radar range echoes at 1-50 MHz from Mars rough surface/subsurface model [6]. Furthermore, we developed the parameter inversions of Mars layered media [7]. As an example to validate these approaches, we collect 34 orbits MARSIS data to invert the dielectric constant of surface regolith around the region of Mars south pole. It is a first step to apply the modeling/simulation to invert real MARSIS data. The result well shows the SPLD (south polar layered deposits) with water ice and high dielectric constant of other places.

2. From Simulation to Parameter Inversion

Applying the electromagnetic integral equation under the Kirchhoff approximation, the scattering fields can be expressed [7]

$$\mathbf{E}_s(\mathbf{r}) = -ik\iint_S E_0(\mathbf{r}')\mathbf{F}(\mathbf{r}',\alpha,\beta)\frac{e^{ikL}}{4\pi L}\mathrm{d}s' \tag{1}$$

where **F** is a function related with surface roughness and polarized reflection coefficients, and E_0 is the incident field [7]. In nadir direction (0° incidence) and isotropic rough surface with zero slope, the surface reflection coefficient R_0 can be moved out from the KA integral. It can simply lead the received echo power as $P_r = \Theta \cdot R_{01}^2$, where Θ is a function related with surface roughness. Thus, the simulated echoes based on rough surface model can now be applied to inversion of ε_1', as the simulated power $\widetilde{P}_{\mathrm{sim}}$ with a proposed $\widetilde{\varepsilon}_1'$ can iteratively approaches the real measurement P_{real} at the same location.

$$\frac{P_{\mathrm{real}}(\varepsilon_1')}{P_{\mathrm{sim}}(\widetilde{\varepsilon}_1')} = \frac{R_0^2(\varepsilon_1')}{R_0^2(\widetilde{\varepsilon}_1')} \tag{2}$$

Assuming that the imaginary part is much less than the real part of dielectric constant. Then, solving $R_0^2(\varepsilon_1)$ of

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Eq. (2), the real part of dielectric constant ε_1' is inverted as

$$\varepsilon_1' = \left(\frac{1+|R_0(\varepsilon_1')|}{1-|R_0(\varepsilon_1')|} \right)^2 \tag{3}$$

3. Result and Discussion

Using Mars Orbiter Laser Altimeter (MOLA) DEM, we numerically simulate the radar echoes around the Mars south polar region, and specifically choose the largest power of each frame as the surface nadir echo. Due to fast moving of the satellite, the radar position might be changing even during one frame. We apply a boxcar filter to map the surface echoes, i.e. the final simulated echo power is the average of simulated powers over the area of 18 km×18 km. The simulated echo power is presented in Fig. 1.

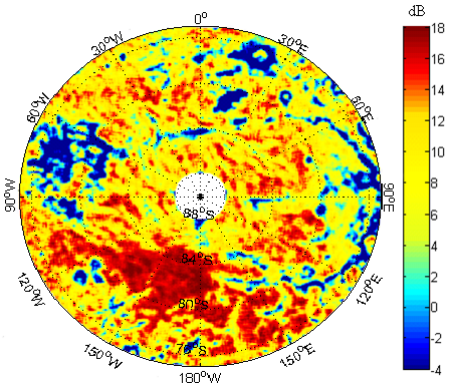

Fig. 1 Simulated surface echo power around the Mars south polar region.

We collect 34 orbits MARSIS data around Mars south polar region, as shown in Fig. 2. Because the MARSIS image data is only normalized for public, we have to choose a reference region around (82°S,180°W) as a known region. This region is flatter than other regions, and is known as covered with Mars South Polar Layered Deposits (SPLD) with the dielectric constant ~3.15. Then, the normalized coefficient can be determined to all other MARSIS data.

Using inversion of Eqs. (2,3), the inverted dielectric constants of the surface regions covered by 34 orbits are presented in Fig. 3.

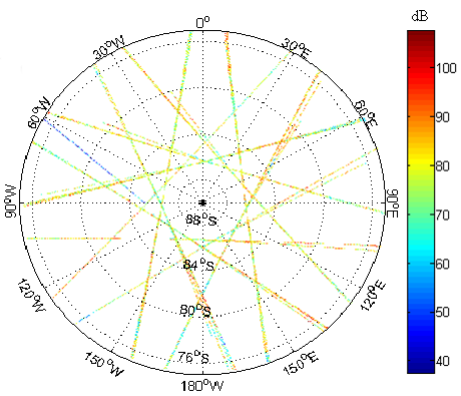

Fig. 2. 34 orbits MARSIS data

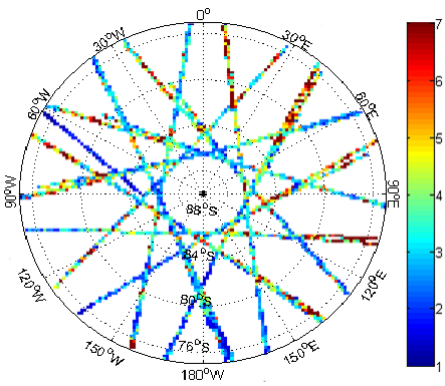

Fig. 3. Inverted dielectric constant

Fig. 4 shows inverted dielectric constant of SPLD, most of them are around 2~4. It was known that the average dielectric constant of SPLD is 2.8, little less than pure water 3.15. This inversion is most likely due to mixture of water ice and CO_2 ice in SPLD [8].

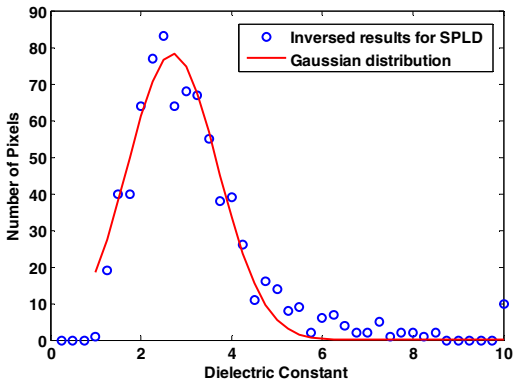

Fig. 4 Inverted surface dielectric constants of SPLD

4. Conclusion and Future Work

In this paper, we presented the inversion of Mars surface dielectric constants over Mars south polar region from the MARSIS image data, based on our simulation works. It validates our simulation/inversion approach, and lays a basis for other parameters inversions based on radar range echoes from cratered rough surface/subsurface model.

5. References

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