

Radar experiments for sounding internal structures of the asteroids using scale-down model

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For the preparation of sounding internal structures of the asteroids in future missions, radar experiments have been performed using a scale-down model. The internal structure of an asteroid tells us its history of accretion, metamorphism, differentiation impacts, disruption, and reassembly. Wilkison et al. (2002) compared several models of formation and internal structure models for 433 Eros. Based on the bulk porosity estimated from the mass and volume, and comparison of the sizes of the boulders and craters on the surface, 25143 Itokawa was suggested to be a rubble pile asteroid (Abe et al., 2006; Fujiwara et al., 2006). Imaging of the asteroid internal structure by radar was proposed in several studies. Simulations of radio wave propagation and internal structure imaging were performed by applying seismic migration technique and suggested that bistatic radar was more effective than monostatic radar (Sava et al., 2015; Grimm et al., 2015). Several simulations of radio wave propagation and radar tomography were also performed based on the concept of a bistatic radar system installed on multiple cube satellites (Pursiainen and Kaasalainen, 2016; Takala, 2016; Sousa et al., 2019). The purpose of this study is to perform the radar experiments of the radar sounding of the asteroid internal structures by using a scale-down model. In the radar experiments, 1m scale-down asteroid model is measured by a bread-board model (BBM) of chirp radar operated in a frequency range from 1 to 3 GHz for demonstration of radar sounding 20-m asteroid in a frequency range from 50 to 150 MHz. In order to obtain reference data for the radar experiment, Finite-Difference Time-Domain (FDTD) simulation was performed. In two dimensional 400'400 grids, the internal permittivity structure of the asteroid model was defined. The permittivity of boulders (rocks) was in a range from 3 to 7 and that of regolith (sand) was 2. In the simulation box, the evolution of the electric field of radar pulse was calculated with changing the locations of transmitter installed on the main orbiter and receiver installed on the sub orbiter. The synthetic echo data can be obtained by sampling the calculated electric field at the receiver on the sub orbiter. In the synthetic radargram, we can find several echo profiles: (1) Diffracted pulses propagating outside of the asteroid, (2) pulses propagating inside of the asteroid, which is severely overlapped with (1) since the bulk permittivity range of the asteroid is ~2, (3) pulses propagating inside the asteroid and reflected at permittivity contrasts in the asteroid, which is not much overlapped with (1) and (2). We, therefore, use the echo profiles (3) for inversion analyses of the internal structures. For the initial trial, we applied Kirchhoff migration to radargram with an assumption of bulk permittivity of 2, and obtain the distribution of the reflectance in the asteroid, which shows good correspondence with the permittivity structure defined in the FDTD simulation.

Keywords: Internal structure of the asteroids, Bistatic radar, radio tomography, Finite-difference Time-domain (FDTD) method, Scale model experiment