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A DIELECTRIC CONSTANT DETECTION METHOD FOR ITERATIVE OPTIMIZATION COMBINED WITH INTERNAL IMAGING QUALITY OF SMALL CELESTIAL BODIES

Abstract

With the development of deep space exploration technology, human comprehension of celestial bodies has been continuously enriched. Accurate detection of the composition and internal structure of small celestial bodies is required in scientific exploration and research tasks such as revealing the evolution of the solar system, assessing space resources, and defending against asteroid impacts; this puts forward higher requirements for the accuracy of dielectric constant detection methods. Investigating small bodies within the solar system presents unique challenges for deep space missions: their traditional circumnavigation detection accuracy is limited, and sample retrieval faces great difficulties in engineering implementation due to weak gravity and complex surface environments. This study focuses on accurately determining the dielectric constant of minor celestial bodies by proposing a novel inversion method based on SAR image focusing quality. To begin with, the radar echo data is acquired from a scaled laboratory model of a small celestial body. Subsequently, an assumed dielectric constant is incorporated into the high-precision time-domain Back-Projection (BP) imaging algorithm. The quality of the resulting image is quantitatively evaluated using a sharpness metric based on the proportion of high-frequency energy in its 2D Fourier spectrum. According to the imaging results, an iterative optimization is carried out to find the dielectric constant value that maximizes the image sharpness, which is determined to be the accurate estimate for the small body model. Compared with traditional remote sensing methods, this iterative optimization combined with imaging quality can improve the accuracy of the dielectric constant estimation by decoupling it from other physical parameters like surface roughness. Experimental data from our scaled model reveal that the proposed method can reach a high level of precision in dielectric constant detection. The application of high-precision dielectric properties allows for detection results that more faithfully represent the internal composition of asteroids. This improved representation is instrumental in identifying the plentiful resources hidden within, including metal minerals and water ice, thus delivering vital information for the future exploration and exploitation of extraterrestrial resources.