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分段光滑曲线边界波动方程数值模拟研究

王忠仁, 刘瑞, 赵博雄*

吉林大学仪器科学与电气工程学院地球信息探测仪器教育部重点实验室, 长春 130026

Numerical simulation of wave equation with segmented smooth curve boundaries

WANG Zhong-Ren, LIU Rui, ZHAO Bo-Xiong*

Key Lab of Geo-Exploration and Instrumentation, Ministry of Education, College of Instrumentation and Electrical Engineering, Jilin University, Changchun 130026, China

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摘要 矩形网格有限差分法在地震波传播数值模拟方面具有计算速度快的显著优势，但该方法在处理复杂边界问题上存在着效率低的严重缺陷.本文针对分段光滑曲线边界定义了尖点处的一种正则导数，给出了矩形网格情形分段光滑曲线网格边界点法向导数的一种插值计算方法.采用矩形网格有限差分法对复杂边界地球介质模型进行地震波场数值模拟，并采用波场系列快照技术揭示地震波在起伏地表和复杂介质中的传播规律.模拟结果表明：法向导数插值计算方法为矩形网格有限差分法处理复杂边界提供了有效途径，采用波场系列快照技术可以清晰地展现地震波在反射界面的反射和透射规律、在尖点的绕射规律以及在自由表面的直达波和多次反射规律.

关键词 数值模拟, 起伏地表, 复杂地质体, 有限差分法, 分段光滑曲线边界

Abstract: The rectangular grid finite difference method in numerical simulation of seismic wave propagation possesses a significant advantage in fast computation speed. However, in dealing with complex boundaries this method has a serious defect of low efficiency. In this paper, a kind of regular derivative is defined for the cusp on a segmented smooth curve boundaries, and an interpolation method is given for computing normal derivatives at the rectangular grid points on the boundary. The finite difference method based on rectangular grids is used to simulate seismic wave propagation on an earth medium model with complex boundaries, and propagation laws in the relief surface and complex media are revealed using the technique of a series of wave field snapshots. The simulation results show that the normal derivative interpolation method provides an effective tool to deal with complex boundaries for the rectangular grid finite difference method, and the technique of the series of wave field snapshots can clearly reveal the reflection and transmission propagation laws on the reflective interface, the diffraction at a cusp as well as the direct wave and multiple reflection on the free surface.

Keywords Numerical simulation, Relief surface, Complex geological body, Finite difference method, Segmented smooth curve boundary

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About author: 王忠仁，男，1954年生，教授，主要从事地球物理勘探方法与技术研究工作.E-mail：wzr@jlu.edu.cn

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