地球物理学报 » 2009, Vol. 52 » Issue (4) :966-975 doi:10.3969/j.issn.0001-5733.2009.04.013
地球动力学★地震学★地磁学

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引用本文(Citation):
王帮兵;田钢;孙波;崔祥斌.南极冰盖内部结构特性研究——基于三维各向异性电磁波时域有限差分方法. 地球物理学报, 2009,52(4): 966-975,doi: 10.3969/j.issn.0001-5733.2009.04.013

WANG Bang-Bing;TIAN Gang;SUN Bo;CUI Xiang-Bin.The study of the COF feature in the Antarctic ice sheet based on 3-D anisotropy FDTD method.Chinese J.Geophys. (in Chinese),2009,52(4): 966-975,doi: 10.3969/j.issn.0001-5733.2009.04.013

南极冰盖内部结构特性研究——基于三维各向异性电磁波时域有限差分方法

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The study of the COF feature in the Antarctic ice sheet based on 3-D anisotropy FDTD method

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摘要 冰雷达技术已成为目前探测南极冰盖内部结构的主要技术手段.近年发展起来的多极化雷达技术可根据不同方向雷达反射功率的变化推断冰盖内部冰晶组构特征和变化规律，进而推断冰盖内部应力应变历史，这对于理解冰流机制和动力过程以及解释冰盖过去、现在和未来的变化规律具有非常重要的作用.本文从Maxwell方程出发，推导出适于介电常数各向异性的三维电磁波时域有限差分方程，进而建立模型模拟各向异性介质的响应输出及其时空分布特征.模拟结果表明：(1) 电磁波在各向异性介质中传播时，波前面为椭圆形，长轴位于介电常数小的主轴方向；(2) 横向各向异性介质反射波振幅在水平面内具有180° 的变化周期.通过对现场常用三种天线装置类型模拟对比分析发现，不同天线类型各向异性层底界面反射波存在“时差”现象，并且时差大小和正负与上下层介电常数差异以及同层各向异性差异有关.在模拟计算的基础上，作者讨论了由于介电常数各向异性导致的“时间延迟”和水平面内振幅“周期性变化”的原因.模拟结果和结论对于南极冰盖冰雷达数据处理和解释工作具有指导意义.

关键词 各向异性, 电磁波时域有限差分, 南极冰盖, 冰雷达

Abstract: The application of RES technology is the most important method for the study of inner structure on Antarctic ice sheet. The multi-polarization radar method developed in recent years can deduce the feature and changing rule of COF in the ice sheet according to the variation of the reflecting power in different orientation, and determine the history of stain and stress in the ice sheet further. It′s important to understand the flow mechanism and dynamic course and explain the changing law of the ice sheet in the past, present and future. This paper deduced the 3D FDTD equations which was derived from Maxwell equation and adapted to permittivity anisotropy medium. Then we simulated the response and spatio-temporal distributing feature. The simulating results showed that: (1) The wave front is ellipsoid and it′s long axis lie in the axis of minimum permittivity while the radar wave propagating in the anisotropy medium. (2) The amplitude of the reflecting wave propagating in the traverse anisotropy medium have an 180 angle cycle in horizon plane. The author found the delay and periodical amplitude variation from the bottom of anisotropy layer between different antenna type, and the delay and periodical amplitude variation is relate to the permittivity difference between the different direction of anisotropy layer and between the adjacent layer. Then the author discussed the reason of the delay and periodical amplitude variation because of permittivity anisotropy. The results and conclusions help to instruct the data processing and interpretation from the Antarctic RES exploration.

Keywords Anisotropy, FDTD, Antarctic ice sheet, Radio echo sounding

Received 2008-01-03;

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http://118.145.16.227/geophy/CN/10.3969/j.issn.0001-5733.2009.04.013 或 http://118.145.16.227/geophy/CN/Y2009/V52/I4/966